European Technology and Innovation Platform on Renewable Heating and Cooling

Contents

Executive Summary 4

Glossary 5

INTRODUCTION 6

CHAPTER 1 - Vision 9

Section 1.01 State of the Art 9

Section 1.02 Market trends 10

Section 1.03 Technology Outlook 10

CHAPTER 2 – Technological Targets and Indicators 12

Section 1.04 Key Performance Indicators 12

KPI 2014-2020 12

Technological targets 2020-2030 12

Non-technical targets 2020-2030 16

Section 1.05 SET Plan targets 16

SET Plan Action 1&2 on Deep Geothermal 17

SET-Plan Action 5 on Energy Efficiency Solutions for Buildings: 17

SET-Plan ACTION n°6 - on "Continue efforts to make EU industry less energy intensive and more competitive" 19

Section 1.06 Potential Cost Reduction 21

CHAPTER 3 – Research Priorities 23

A. Production and Resource Management 23

Overview and focus areas 23

Research topics 25

TOPIC A.1 -Deep boreholes for the use of medium depth low-medium temperature geothermal resources 25

TOPIC A.2 - Resource management in dense installation environments 26

TOPIC A.3 - DEEP SUBSURFACE CHARACTERIZATION METHODS INTEGRATION 27

TOPIC A.4 - MINIMIZING THE OPERATION COSTS OF THE REINJECTION .... **Error! Bookmark not defined.**

TOPIC A.5 – HIGH-TEMPERATURE UTES SYSTEMS 29

TOPIC A.6 - CHPM technology, exploitation tests of the metal fraction 30

TOPIC A.7 - Cost efficient closed loop technology solutions 30

TOPIC A.7b - TECHNICAL DEVELOPMENT AND CLOSED LOOP TECHNOLOGY SOLUTIONS – WELL COMPLETION AND DESIGN STRATEGIES + BOREHOLE HEAT EXCHANGERS... **Error! Bookmark not defined.**

TOPIC A.8 – Thermoactive Geostructures 32

TOPIC A.9 - HEATING AND COOLING TECHNOLOGIES AND INTEGRATION WITH POTENTIAL DEPTH AND TEMPERATURE SOLUTIONS .... **Error! Bookmark not defined.**

TOPIC A.10 - INNOVATIVE TOOLS OF HANDLING EXTREMELY POLLUTED GEOTHERMAL BRINES, INCLUDING UTES........ **Error! Bookmark not defined.**

B. System Integration 34

Overview and focus areas 34

Research Topics........ 34

TOPIC B.1 – CITY-BUILDING-SUBSURFACE CO-SIMULATION MODELS (HYBRID MODELS) 34

TOPIC B.2 – SYSTEM INTEGRATION OF GEOTHERMAL AND OTHER RENEWABLE TECHNOLOGIES 35

~~TOPIC B.3 - STORE THEN PRODUCE THE WASTE HEAT WITH UNDERGROUND HEAT STORAGE IN A BIOENERGY OR SOLAR POWER PLANT~~ 36

TOPIC B.4: DEEP CLOSED BOREHOLE HEAT EXCHANGER INTEGRATION AS LARGE SCALE BTES FOR HEATING AND COOLING APPLICATION IN DISTRICT HEATING AND LARGE-SCALE INDUSTRIAL PROCESSES........ 37

TOPIC B.5: INNOVATIVE HEAT ENERGY OPTIMIZATION IN OPERATING BALNEOLOGICAL SYSTEMS SUPPLIED WITH THERMAL WATER 38

TOPIC B.6 - ENERGY SYSTEM INTEGRATION AND DELIVERY........ 39

Implementation 40

C. Non-technical 41

Overview and focus areas 41

Research Topics........ 43

TOPIC C.1 – ENVIRONMENTAL LEGISLATION AND DRILLING REGULATIONS........ 43

TOPIC C.2 - GSHP INTEGRATION AND CONTRIBUTION TO LEED, BREAM AND BIM DESIGN SYSTEMS AND BUILDING CERTIFICATION 44

TOPIC C.3 - HWG DEMAND SIDE INTEGRATION – DEVELOPMENT OF MODELS FOR INTEGRATION OF GEOTHERMAL TO HWG TARGETS........ 45

TOPIC C.4 – GEOTHERMAL RESOURCE MAPPING & STASTICAL DATA COLLECTION 46

TOPIC C.5 - SOCIAL ACCEPTANCE OF GEOTHERMAL SYSTEMS........ 48

TOPIC C.6 - CURRENT AND FUTURE HEATING AND COOLING DEMANDS IN EUROPE........ **Error! Bookmark not defined.**

TOPIC C.7 - QUALITY CONTROL FOR GROUND COUPLING TECHNOLOGIES **(Guus)** .... **Error! Bookmark not defined.**

TOPIC C.8 - SUBSURFACE UNCERTAINTY ASSESSMENT AND RISK MITIGATION........................... 49

CHAPTER 4 - Implementation Plan 51

Budget overview .... **Error! Bookmark not defined.**

Financing geothermal H&C .... **Error! Bookmark not defined.**

Funding Instruments .... **Error! Bookmark not defined.**

Executive Summary

Geothermal heating and cooling have the characteristics required to play a crucial role in our future fully decarbonized energy system: it is clean, providing affordable energy for the economy and the people, and allowing for the competitiveness of European industry.

Geothermal is a renewable energy source, which is local, manageable and flexible. It should be integrated to smart power, heat and cooling grids, thus both reduces costs for society (including system costs, such as infrastructure and storage facilities, as well as externalities, such as greenhouse gas emissions) and improves local security of supply.

Geothermal will be a key energy source both in smart cities and smart rural communities, in addition to supplying energy for industry, services and agricultural sectors. This is thanks to its ability to supply both Heating and Cooling (H&C) and Hot Water, as well as solutions for smart thermal and electricity grids via underground thermal energy storage (UTES).

Research and Innovation are two of the cornerstones for the further development of H&C geothermal technologies and their market uptake. A new generation of geothermal systems and technologies, the improvement of existing technologies for new applications and markets, novel applications to be demonstrated, standardised and combined in hybrid systems, and the promotion of pre-existing technologies will all contribute to an accelerated deployment of geothermal in the EU in the context of the 2030 milestones.

Chapter 1 introduces the vision for geothermal H&C systems and the missions set.

Chapter 2 presents the targets and the expected performance set, along with Key Performance Indicators (KPI).

As regards the research priorities in Chapter C, three main aspects are considered: the identification of R&I actions, which ought to be developed as a priority, the objectives of the research actions, and finally, its targets and measurable performance indicators. An Implementation plan present these objectives with the timeframe of Research and Innovation (R&I) actions.

Finally, Chapter D addresses the funding of these research and innovation activities for geothermal H&C. A key message here is that it is not only necessary to strengthen R&I private investments and increase the public funding budget for R&I projects at European, national and regional levels.

A strengthening of the market deployment policy and knowledge sharing for geothermal H&C are also required.

Glossary

Strategic Research and Innovation Agenda 2019 (SRIA)

2014 Geothermal Strategic Research Agenda (SRA)

shallow geothermal assisted by heat pump (GSHP)

Research, Development and Innovation (RD&I)

geothermal district heating systems (geoDH)

Gigawatts thermal (GWth) - kilowatts thermal (kWth))

Borehole Heat Exchanger (BHE)

underground thermal energy storage (UTES)

renewable energy sources (RES)

domestic hot water (DHW)

INTRODUCTION

This Strategic Research and Innovation Agenda 2019 (SRIA) constitutes an update and blending text of the previous 2014 Geothermal Strategic Research Agenda (SRA) and subsequent Geothermal Implementation Roadmap. It intends to define and reorder the new research topics to answer current and future challenges of the energy sector in Europe, but also to bring them into a quantifiable timescale and dimension in terms of required funding.

Since the first SRA and Roadmaps were released, the geothermal sector in Europe has experienced a sustained growth to reach a capacity of nowadays close to 25 Gigawatts thermal (GWth) installed including more than 2 Million shallow geothermal assisted by heat pump (GSHP) units in Europe. The regional coverage has also grown and nowadays GSHPs are seen in all European countries in a higher or lesser extent. In terms of the overall installation rate, around 100,000 units/y were sold across Europe in the last five years. This value is still far below the 150,000 units/y envisioned in the geothermal roadmap for 2020, and is too low in view of the number of new buildings appearing in cities. However, there has been a significant increase in the number of large systems (systems larger than 50 kilowatts thermal (kWth)).

In parallel, the deep geothermal heat production sector has also grown were many new geothermal district heating areas, and innovative applications in the industry, are contributing to a swift decarbonization of the heating and cooling sectors in their respective regions. With more than 300 geothermal district heating systems (geoDH) in operation, Europe is the global leader in geoDH.

One further positive sign is that research and innovation in geothermal is thriving in Europe, with many ongoing research projects and new funding structures. The European industry also leads the way on innovation, and many new products could be exported.

In correspondence, there has been a substantial increase in the funding for Research, Development and Innovation (RD&I) with over € 300 million spent from European-level co-funding between 2014 and 2018. These funds were invested in a large range of technologies, many of them identified in our previous SRA document. Extrapolating this figure, the sector is not far from reaching the full amount of R&D money expected from public support at European level within the period of Horizon 2020 (2014-2020): around € 400 million.

Horizon 2020 (H2020) is the main EU Research and Innovation programme, with nearly €80 billion of funding made available over 7 years (2014 to 2020). As a matter of fact, EU R&I funding allocated to geothermal energy during the Horizon 2020 European program amounted to around € 250 million by the end of 2018. This sum was divided between an EU contribution of € 160 million and a private sector contribution of € 85 million. In total, 36 projects have been co-funded by public money from H2020 calls on RES&EE and Industrial leadership, as well as from SME-instruments, INTERREG and ERASMUS+.

This joined public-private effort has led to tangible successes whilst encouraging research results in terms of new deployment areas, system efficiencies, new materials, new faster & cheaper drilling methods and reduction of costs have been obtained (see in this regard Deliverable 1.3: Third report on the status of the implementation of the five roadmaps[1], where an extensive analysis is carried out about how different European and national/regional programs and projects have contributed to these achievements).

However, additional efforts are needed, and our aim is to identify and quantify the specific needs required for the further development of geothermal applications to efficiently heat (and cool) buildings, districts and industries, while at the same time improving thermal storage capacity. Research and innovation needs are depicted in chapter 3 presenting the research needs, and the chapter 1 with the Vision is presenting where these applications will be developed.

As shown in several projects, despite promising improvements in costs and efficiencies, shallow geothermal and deep geothermal heating/cooling technologies still have significant room for improvements, thanks to the impressive flexibility of these systems. Swift integration and digitalization are still a pending goal. Despite the extensive mapping effort in different projects, a comprehensive and homogenized EU wide geothermal potential map along with other tools to remove administrative and legal barriers are still items in the to-do list. Other, less explored, applications such as the high temperature underground thermal energy storage (UTES) systems offer the possibility to store in the subsurface industrial excess heat. This technology is especially suitable in regions having a seasonal peak in heating demand, which is usually supplied by fossil fuels. Furthermore, the possibilities of integrating geothermal with the building and city-wide civil structures, have only be tackled tentatively and would need increased determination to unleash its real potential. Alongside, deep geothermal heat, with its excellent connectivity to industrial, commercial and district heating systems is also an area were research of new surface and sub-surface technologies, integration, digitalization and site-specific customization are required to raise the technology maturity level in new development areas.

This SRIA on Geothermal heating and cooling identifies a path forward, developing high performance, cost-effective and sustainable shallow and deep geothermal technologies that can expand the production of heating and cooling while reinforcing EU industrial capacity and leadership in the sector. It continues the work of the 2019 Technology Roadmap on Deep

[1] from the European Commission study from the tender on "Support to key activities of the European Technology Platform on Renewable Heating and Cooling", PP-2041/2014

Geothermal published by the ETIP on Deep Geothermal (ETIP-DG), which launched the 2030 objectives and the related Implementation Plan. The mission, goals and actions described here for 2030 and the future date of 2050 build upon the Vision and the Strategic Research and Innovation Agenda for Deep Geothermal (SRIA).

This document is also complementary to the one provided by the Implementation Working Groups on Deep Geothermal and Energy efficiency (buildings and industry) active within the Strategic Energy Technology Plan.

All these challenges require an update of our research agenda to synchronize them with our current needs and to amplify the synergies with other renewable energy sources (RES) technologies, a scope of increased importance. This is the aim of the current document, which shall set the basis of a further successful development of the geothermal sector in Europe and worldwide, in its aspiration to make a more substantial contribution to the sustainability of our energy sectors and our Society.

The SRIA is intended for policy makers, funding institutions, manufacturers and energy market actors, research institutions and other stakeholders.

CHAPTER 1 - Vision

Section 1.01 State of the Art

Currently, geothermal energy has an installed capacity of about 24,3 GWth for heating and cooling in the European Union. Geothermal energy is used for domestic hot water (DHW) and heating and cooling of individual, collective, public and tertiary buildings, including both small (5-30 kW, mainly residential), medium (30-500 kW, mainly commercial) and large schemes (> 500 kW), as well as for district heating in smart thermal grids. The type of buildings using geothermal energy ranges from residential houses to any type of utility buildings as well as greenhouses, aquaculture, agricultural and industrial processes, and to numerous spas and swimming pools. New and innovative applications of geothermal energy have been developed, and some of those have already been demonstrated, such as geo-cooling, melting snow or ice, and sea water desalination. Other applications, such as the use of geostructural concepts (through piles, slabs or other building structures), the safe extension of the energetic use of aquifer thermal energy storage (ATES) systems or the use of deeper boreholes coupled to heat pumps have led to further innovations in the last years, with promising perspectives. Geo-cooling offers a very promising clean solutions of passive cooling, to answer the ever-increasing cooling need in refurbishment of buildings.

Existing housing infrastructure represents a considerable share of the low temperature h&c demand that can be efficiently and sustainably supplied by geothermal heat pumps and geothermal district heating systems. High temperature, CO_2 based, geothermal heat pumps have also been developed in the last years that are suitable to refurbish old buildings without the need to replace existing high temperature distributions systems. Compact drilling solutions are also under investigation, that reduce space requirements for borehole installations. New materials and designs of heat exchangers have also produced promising results to reduce costs and to increase efficiency, but here further work is needed. Furthermore, geothermal district heating will be increasingly targeted at *existing* buildings and old inner cities in dense urban areas. At the same time, the concept of UTES is attracting an increasing interest from industries, research institutions and public authorities. It is expected to gain acceptance and market uptake as it will provide a solution to partially replace the use of fossil fuels and to reduce the costs of heat storage. It will deliver the combination of geothermal energy with underground storage which will constitute a powerful tool in the context of sector coupling. The increased volatility of coupled heat & electricity networks requires thermal storage to amplify the use of local RES heat. Geothermal energy combined with small thermal grids systems is offering one of the most effective option for this market, both in terms of carbon footprint and economics. Newer houses with low heating demand can best be utilised with ground source heat pumps.

Deep geothermal has been developed until now with the primary objective of power production. However, deep geothermal reservoirs can provide heat resources for a large variety of applications providing flexibility in being integrated to existing energy systems and delivering heat for h&c applications at different temperature ranges. Nonetheless, the complexity of the subsurface characterizations, coupled to the high capital investment and to the lack of clear regulatory frameworks are challenges. Moreover, the need to de-risk deep geothermal heat project is a major barrier, to reduce the uncertainties and make deep geothermal heat profitable for operators at the European level.

Section 1.02 Market trends

Marketwise, geothermal heating and cooling (H&C) is a growing sector in the European Union, with sustained growth rates in installed capacity all over Europe. However, uses and trends vary significantly according to national markets and the resource in question, while farther development is often hindered by unsuitable policy, regulatory and financial frameworks.

The shallow geothermal market is the largest segment of the geothermal sector by far and is slowly but steadily increasing across Europe. Sweden, Germany, France, and Switzerland have the highest number of geothermal heat pumps, accounting for 69% of the total installed capacity. However, though some markets are undergoing a rapid acceleration in their use of shallow geothermal energy (Netherlands, Estonia, Finland…), there are others, such as France, which are seeing a dramatic slowdown in the penetration of this technology, driven by the collapse of the market as a result of several factors, one of which is a negative policy change.

On the other hand, the use of deep geothermal for heating and cooling is also present in many parts of Europe, reflecting the broad availability of the resource. Iceland is by far the largest market for deep geothermal heating and cooling use, with a total installed capacity of 2,172 MWth in 2018, followed by Turkey and France. In addition, over the past decade countries like Germany Hungary and The Netherlands, have been steadily building up their geothermal heating and cooling industry while new countries are showing a strong interest in developing deep geothermal heating and cooling projects. Poland appears strongly committed to ramping up its use of geothermal energy, with 20 planned or ongoing projects. Greece (17 projects), Switzerland (13 projects) and Denmark (10 projects) are also looking to increase their use of geothermal energy.

Section 1.03 Technology Outlook

Overall, building on the current state of play and positive trends, significant developments are expected in the uptake of geothermal technologies for heating and cooling in the coming decades, thanks mainly through the introduction and consolidation of shallow geothermal systems, and the increased growth of deep geothermal systems for heating and cooling.

Geothermal heat pumps will be firmly established in the markets of all EU countries, with fair competition with other sources (end of fossil fuel subsidies, carbon pricing, etc.) the right heat market conditions. A continuous growth is expected in each member state. These shallow geothermal systems assisted with heat pump will be combined to deeper geothermal resources for establishing smart thermal grids. It will supply heat and cold integrated into energy systems for buildings, combined with other renewable systems in heat networks. **Multi-commodity networks** (buildings and industrial processes) will be developed too. **Underground thermal energy storage (UTES)** will be made for seasonal storage, with perspectives on the development of low and high temperature (>25°C) systems. Furthermore, the well-established, low temperature heat pump supported applications, energy produced from low temperature air source, water source and solar thermal energy will be stored underground and used for heating and cooling purposes. These systems will become an important provider for heating and cooling for individual houses, industry and utility buildings, but also with **district heating and cooling**.

Geothermal h&c will be further developed notably for agri-food applications (heating greenhouses, food processing, fish farms, etc.). New applications for pre-heating in high-temperature industrial processes will begin to be installed. The breakthrough technology **enhanced geothermal systems (EGS),** will experience a strong development in Europe, contributing in electricity production and combined heating/cooling with **cogeneration installations.** These installations will allow development of new district heating systems for urban areas and high temperature (>150°C) heat supply for industrial process heat.

Ultimately, thanks to the continued technological development, in 2050 Geothermal Heating and Cooling systems are expected to be available and economic everywhere in Europe, for all h&c applications.

CHAPTER 2 – Technological Targets and Indicators

To successfully achieve the full potential of the geothermal heating and cooling, as described in the Vision above, several key challenges have been identified.

Section 1.04 Key Performance Indicators

KPI 2014-2020

The KPIs decided in 2014 have been further clarified in a first revised version in 2018

(i) Deep geothermal:

It should be noticed that part of these KPIs have been taken by the SET Plan - Declaration of Intent on Strategic Targets in the context of an Initiative for Global Leadership in Deep Geothermal Energy, endorsed at the Steering Group meeting of 14th September 2016. These targets are added to the KPIs set in 2014 or replacing the KPI in the case of deep drilling. Topics related to geothermal electricity only are not considered here.

(ii) Shallow geothermal:

During the Geothermal Technology Workshops on shallow geothermal organized by the Geothermal panel of the RHC-ETIP during 2017, a discussion was launched on the review of the KPIs 2014. One main conclusion was that they tend to be too general and redundant when looking at the technological trends in the shallow geothermal sector. Some KPIs were more qualitative than quantitative.

A first decision was to ask the Steering Committee (SC) to come with a new set of KPIs. The new KPIs were finally adopted by the SC in April 2018.

Another decision taken was to ask H2020 project partners to improve their reporting from projects, especially when completed, by detailing the SPF number at the start and at the end of the achieved project.

Technological targets 2020-2030

For the SRIA 2019, the objective is to bring an updated value for the KPI value with both a qualitative and quantitative assessments. Firstly, the KPIs are further clarified in this revised version 2019. Moreover, it makes sense to perform a qualitative assessment, which led notably to a revision of the KPIs on both shallow and deep geothermal.

- Deep geothermal:

Agreed strategic targets in deep geothermal energy are as follows:

1. **Increase reservoir performance** resulting in power demand of reservoir pumps to below 10% of gross energy generation and in sustainable yield predicted for at least 30 years by 2030;
2. **Improve the overall conversion efficiency**, including bottoming cycle, of geothermal installations at different thermodynamic conditions by 10% in 2030 and 20% in 2050;
3. **Reduce production costs** of geothermal energy (including from unconventional resources, EGS, and/or from hybrid solutions which couple geothermal with other renewable energy sources) below 10 €ct/kWh$_e$ for electricity and 5 €ct/kWh$_{th}$ for heat by 2025;
4. **Reduce the exploration costs** by 25% in 2025, and by 50% in 2050 compared to 2015;
5. **Reduce the unit cost of drilling** (€/MWh) by 15% in 2020, 30% in 2030 and by 50% in 2050 compared to 2015;
6. **Demonstrate the technical and economic feasibility** of responding to commands from a grid operator, at any time, to increase or decrease output ramp up and down from 60% - 110% of nominal power.

- Shallow geothermal:

The revision of the KPIs on shallow geothermal with especially the settings of figures for each KPI are:

General KPIs on shallow geothermal		
Topic	**Version 2019**	
The ability to reliably design, build, operate and control geothermal heating and cooling with ground source heat pump (GSHP) and groundwater heat pump (GWHP) systems for districts and individual buildings with improved economic returns, in order to be able to use the year-round potential of geothermal energy for sustainable heat and cold supply.		
Accurate characterization of the subsurface to quantify the geothermal energy potential, reduce the uncertainty and mitigate the risk associated to prospection, exploration and production phases, ensuring along term and sustainable use of these systems		
The integration of geothermal heat and cold into the existing and future energy systems in combination with other RES to increment their penetration, enlarge the use of renewable energy sources and thus and contribute phasing out fossil fuels for energy supply		
To fully utilise the potential of geothermal energy in supporting a decarbonised h&c, a strong technology-specific regulatory and “level playing field” measures will also be required, especially in District Heating and energy intensive areas.		

Specific KPIs on shallow geothermal		
Topic	**Version 2019**	
Reducing installation and operating costs	**Decrease the energy input** for operating the geothermal heat pump system **by 10% in 2020 and 25% in 2030** (from 2014 value: 44.6 MWh/year electric, for a geothermal system capacity of 50 kW_{th} in a new building, supplying heating at T = 35°C during 2200 h per year and cooling at T = 7°C during 1200 h, in western Europe climate conditions, use a $SPF_{heating}$ of 4)	
	Reduce costs for operating the geothermal heat pump system, leading up to **20% costs reduction of the O&M in 2020, and 30 % in 2030** (from 2014 value: 9430 € per year, for a geothermal system capacity of 50 kW_{th} in a new building, supplying heating at T = 35°C during 2200 h per year and cooling at T = 7°C during 1200 h, in western Europe climate conditions), assumed with stable energy prices (or statistically levelled).	
	Reduce investment costs for a geothermal heat pump system, leading up to **20% costs reduction in 2020, and 30 % in 2030** (from 2014 value: 68'000 €, i.e. 1360 €/kW, for a geothermal system capacity of 50 kW_{th} in a new building, supplying heating at T = 35°C during 2200 h per year and cooling at T = 7°C during 1200 h, in western Europe climate conditions)	
Improve efficiency	**Increase value of Seasonal Performance Factor in the order of 4.5 for 2020 and 5 for 2030** (from 2014 value: $SPF_{heating}$ average of 4, for a geothermal system capacity of up to 50 kW_{th},	

	supplying heating and DHW at T = 35°C, in western Europe climate conditions)	
	Increase value of Seasonal Performance Factor in the order of 5 for 2020 and 5.5 for 2025 (from 2014 value: $SPF_{heating}$ average of 4.5, for a geothermal system capacity of 50-100 kW_{th}, supplying heating at T = 35°C, in western Europe climate conditions)	
	Increase value of Seasonal COP ($SCOP_{cooling}$) in the order of 5 for 2020 and 5.5 for 2025 (from 2014 value: $SCOP_{cooling}$ average of 4.5, for a geothermal system capacity of up to 100 kW_{th}, an active HP supplying cooling at T = 7°C, in western Europe climate conditions)	
	Free cooling: **Increase value of Seasonal COP ($SCOP_{cooling}$) in the order of 22 for 2020 and 25 for 2025** (from 2014 value: $SCOP_{cooling}$ average of 20, for a geothermal system capacity of up to 100 kW_{th}, free-cooling supplying cooling at T = 18°C, in western Europe climate conditions)	
Increase of efficiency by at least 25% through better overall system design and operation	**Improve the overall efficiency of shallow geothermal installations by at least 10% in 2020 and 25% in 2030;** compared to 2014 (see KPI on Seasonal Performance Factors for numbers)	
A **Hellström-efficiency** (a measure of the impact of borehole thermal resistance) of about 80% in 2020	**Increase** the overall impact of a reduced borehole thermal resistance, the **Hellström-efficiency**, from below 60% (in the nineties) to about 75% (2014) in state-of-the-art installations, to more than **80% in 2020 and 85% in 2030.**	

Non-technical targets 2020-2030

The development of geothermal energy resources for heating and cooling application requires a clear regulatory system that facilitates the installation of these systems and a level playing field with other technologies. These conditions remain very diverse across Europe in the context of building integration and underground resource management, with increased regulations in some Member States and none in others. These fragmented conditions are also observed in the development of clear standards for the assessment, design, installation and operation of systems. In order to allow geothermal to play a key role in European and local decarbonisation strategies and facilitate the integration of the technology into 'hybrid energy systems' such as those considered for cities, urban areas, in district heating and in the inclusion of restructures, a common approach to regulation and the implementation of best practices is required.

Improve awareness of technology, create skills and ensure quality	**Increase number of installations in the EU per year to 150,000 units/y in 2020, to more than 200,000 in 2025,** compared to 100,000 units in 2014.	
	Percentage of the number of new installations compared to the number of new buildings at the city levels.	
	Percentage of the number of total installations compared to total buildings at the city levels	

Section 1.05 SET Plan targets

These strategic targets and goals were considered during the preparation of the Geothermal H&C SRIA and served as a foundation for the definition of the main targets for technological and non-technological progress.

SET Plan Action 1&2 on Deep Geothermal

the SET-Plan stakeholders from the European geothermal sector came together in 2016 to agree to six ambitious targets (T) and two transversal goals (G) with respect to efficiency, system integration, cost reduction, transparency and societal inclusion:

- T1: Increase reservoir performance [including underground heat storage], reducing the power demand of reservoir pumps to below 10% of gross energy generation and achieving a predicted 30-year or greater sustainable yield by 2030
- T2: Improve the overall conversion efficiency, including the bottoming cycle, of geothermal installations at different thermodynamic conditions by 10% by 2030 and 20% by 2050
- T3: Reduce the production costs of geothermal energy (including from unconventional resources, EGS, and/or from hybrid solutions which couple geothermal with other renewable energy sources) to below €0.10/kWhe for electricity and €0.05/kWhth for heat by 2030
- T4: Reduce exploration costs by 25% in 2025 and by 50% in 2050 compared to 2015
- T5: Reduce the unit cost of drilling (€/MWh) by 15% in 2020, 30% in 2030 and by 50% in 2050 compared to 2015
- T6: Demonstrate the technical and economic feasibility of responding at any time to commands from a grid operator to increase or decrease output ramp up and down from 60% to 110% of nominal power
- G1: Develop transparent and harmonised methods and instruments for technical and financial risk management
- G2: Pursue increased social acceptability and mitigation of unsolicited side effects (induced seismicity, emissions into the environment).

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

This Implementation plan is divided in two sub-groups:

5.1: New Technologies and Materials for Buildings

5.2: Heating and Cooling Technologies for Buildings

Indicators listed below are based on the agreed specific targets of the dedicated SET-Plan Declaration of Intent of the EC and on the proposed monitoring mechanisms:

Activity	**Indicator**
AF 5.1 – 1: New Materials for Buildings	• Number of new sustainable materials • Monitoring of the market price

AF 5.1 – 2: Prefabricated active modules for façades and roofs or Key Enabling Technologies for active building skins	• Monitoring of the market price • Monitoring of the energy savings, including locally generated energy • Impact on inhabitants
AF 5.1 – 3: Digital planning and operational optimization	• Patents, market entries of new metering technologies
AF 5.1 – 4: Living labs - Energy technologies and solutions for decarbonized European quarters and Cities	• Number of living lab concepts that will be realised after competition/ project

Activity	Indicator
AF 5.2 – 1: Cost-efficient, intelligent, flexible heat pumps and heat pumps for high temperatures	• Cost of heat pumps compared to 2015 market price • Efficiency of heat pumps • Number of projects launched on prefabricated, flexible, high temperature and/or fully-integrated 'plug in and play' hybrid/multisource heat pump systems and integrated compact heating/cooling plants • Number of implemented demonstrators from launched projects
AF 5.2 – 2: Multi-source District Heating integrating renewable an recovered heat sources, higher temperature District Cooling and optimization of building heating system, to minimize the temperature levels in district heating networks	• Amount of renewable heat compared to 2015 • Number of 4th generation DHC networks • Cost of DHC substations for residential buildings compared to 2015
AF 5.2 – 3: Cost reduction and increase in efficiency of micro CHP/CCHP	• Cost of hybrid Micro CHP/ CCHP equipment and installation compared to 2015 market price • Energy efficiency of hybrid Micro CHP/ CCHP compared to 2015 level

AF 5.2 – 4: Compact thermal energy storage materials, components and systems	• Number of new products and materials • Storage density at the system level (including pumps, valves, pipes, short term buffers) • Total available storage capacity of compact storages compared to total storage capacity

SET-Plan ACTION n°6 - on "Continue efforts to make EU industry less energy intensive and more competitive"

The Implementation Plan – Endorsed 27/09/2017 , decided to focus on two sectors: Iron & Steel and Chemicals & Pharmaceuticals. For the two identified sectors, we have classified their sector specific technologies according to their maturity and economic viability:

a) the existing technologies which have been demonstrated but are not (yet) economically viable, i.e. with payback period longer than 3 years[2]

b) the emerging technologies, which still need to be validated in pilot or demonstration plants

Priorities[3] 1 and 2	R&I Targets	Indicators
1. Sector specific R&I: Increasing the energy efficiency of our most energy consuming industries by **increasing the cost effectiveness of not yet economically viable technologies** (TRL>=7) through technological development, while striving to reduce GHG emissions proportionally	By 2030, at least 1/3 of the technical potential energy savings related to sector-specific technologies, identified for Iron & Steel and Chemical & Pharmaceutical, become economically viable (Payback <= 3 years)	Progress of the cost effectiveness of the identified technologies; cumulated energy saving potential of technologies reaching economic viability. Two sets of Assumptions: • Fixed energy prices & production volume • Actual energy prices & production volume

[2] Stakeholders agreed a payback of 3years (not 2) is more realistic (vs energy prices) and still a reasonable economic threshold

[3] There is no ranking among the five priorities. They are numbered for easy reference.

2. Sector specific R&I: Increasing the energy efficiency of our most energy consuming industries by **progressing emerging technologies** (TRL 4 to 6), while striving to reduce GHG emissions proportionally	By 2030, 1/3 of the currently promising emerging technologies are successfully demonstrated at large scale (TRL>=8)	R&I Maturity progress (lab, pilot, large scale demonstration)

The primary energy savings potential and GHG emissions reductions potential are calculated assuming the developed/demonstrated technologies are fully deployed across the EU28.

Priorities 3 to 5	**R&I Targets (baseline 2015)**	**Indicators**
3.Cross-cutting R&I: maximising the **recovery of industrial excess heat/cold** in a cost efficient manner	By 2025, develop and demonstrate (to TRL 8) cost effective excess heat/cold recovery solutions (e.g. heat exchangers, upgrade to higher temperature, storage, distribution, heat-to-power, heat-to-cold, power-to-heat)	Evolution of solutions maturity (TRL), of their cost effectiveness and energy efficiency performance with reference to Best Available Techniques (BAT) (Industrial Emissions Directive)
4. Cross-cutting R&I: maximising the energy efficiency of cross-sector **industrial components** in a cost efficient manner	By 2025, develop and demonstrate (to TRL 8) industrial components whose losses are reduced by 15% (e.g. boilers, dryers, pumps, compressors, fans, conveyors … all of which systems typically contain motors and drives)	Evolution of solutions maturity (TRL), of their cost effectiveness and energy efficiency performance with reference to BAT / Progress of minimum energy performance standards
5.Cross-cutting R&I: Improving **system integration, optimal design, intelligent and flexible**	By 2025, develop and demonstrate solutions enabling small and large,	% of specific energy savings (J/unit of product or J/goods produced in

operation, including industrial symbiosis, to increase energy and resource efficiency while striving to reduce GHG emissions	industries to reduce their energy consumption by 20% while striving to reduce GHG emissions proportionally	industrial park) achieved by at least 10 projects in at least 5 industrial sectors

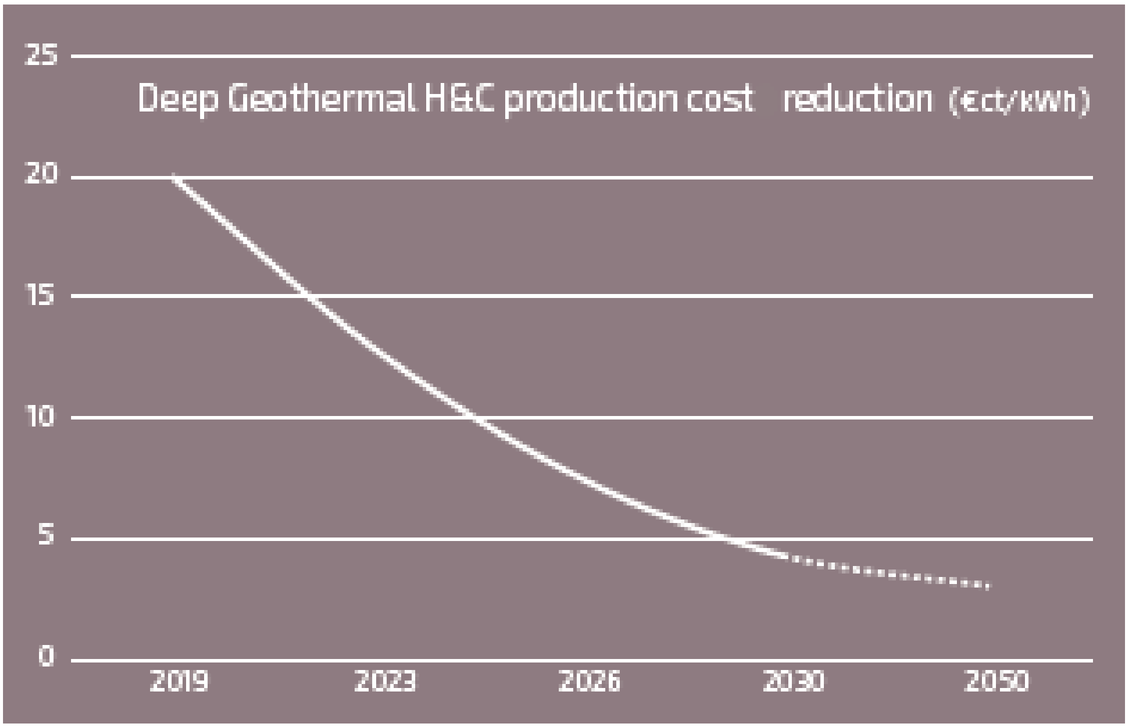
Section 1.06 Potential Cost Reduction

The competitiveness of the geothermal H&C sector must be consolidated by first developing a fair basis of cost comparison between energy sources which goes beyond a limited Levelized Costs of Energy (LCoE) approach, taking into account actual system costs and external factors. For externalities, a carbon pricing for the whole heat sector must be set urgently all over Europe, and a stop to fossil fuel subsidies.

It should be noted that geothermal projects have low systems costs and negligible externalities, which means that the LCoE accounts for almost the full costs for the project.

This potential cost reduction for deep geothermal is linked to the third strategic target of the SET-Plan Declaration. The target is set at a maximum production cost of 6 €ct/kWh for heat by 2023, and 5 €ct/kWh for heat by 2026. These cost targets apply to all types of deep geothermal projects, including EGS and super-hot geothermal systems (> 350°C).

The selling price for heat in existing geothermal district heating systems is usually around 60 €/MWh, and within a range of 20 to 80 €/MWh. The price depends on the local geothermal situation, socio-economic conditions and pricing policies. In addition, district heating networks account for a significant share of the total costs for a geothermal district heating system.



Example of a figure from ETIP-DG Roadmap to illustrate a general costs reduction

CHAPTER 3 – Research Priorities

The selection of topics has been established via a stakeholder consultation process in September 2019 which prioritised goals and further needs for action. This document is complementary to the one provided by the ETIP-DG and by the Implementation Working Groups active within the Strategic Energy Technology Plan (on Deep Geothermal, on Energy Efficiency…), as it ranks short to medium term challenges and actions, tracks long-term strategy, and offers a description of topics and goals, providing performance indicators.

The Research Agenda is intended for policy makers, funding institutions, manufacturers and energy market actors, research institutions and other stakeholders.

A. Production and Resource Management

Overview and focus areas

Geothermal heating and cooling cover a wide range of applications, temperatures and resource & deployment technologies. Each of them with its own specific characteristics in terms of heat production, potential and short/long term management of the heat resource. The basic description of these techniques contained in the 2012 "Geothermal Strategic Research Agenda"[4] is still fully valid and particularly relevant in this regard are chapters 3 and 4, to which the reader is kindly referred.

In view of the evolution of the European R&I framework in connection to geothermal technologies in the last year, the Geothermal Panel decided to merge geothermal production technologies into one main Geothermal Production and Resource Management technologies chapter, formerly subdivided into "shallow" and "deep" geothermal technologies subsections. The reason is the increased difficulty to establish rigid boundaries between both types of system: instead, we see a number of applications in which heat pumps are connected to increasingly deeper boreholes (currently up to 500 m), Underground Storage systems using higher temperatures, shallow and deep geothermal systems flexibly combined in certain District Heating systems and many more "cross domain" applications that do not fit well into previous rigid characterization.

It is technology that enables us to use resources in ways that could not be accessed before and we now tend to see Geothermal Production and Resource Management as and unified area with different specific domains that are partly overlapping and rapidly moving within a

[4] https://www.egec.org/rhc-platform-geothermal-panel/

continuum set of resources, technologies and solutions. It is nevertheless still useful to look at the specific barriers and challenges that are present in each of these domains

Shallow geothermal applications, - see chapter 3 of the SRA for and extensive description of the different types of GSHP systems – generally known as Ground Source Heat Pump (GSHP) and Groundwater Heat pump (GWHP) systems are the most widespread type of geothermal technology across Europe. The main interest of these technologies lies in its extreme flexibility. It can be used anywhere, regardless of ground conditions, allows production of heat and cool with unparalleled efficiency and may be combined or hybridized with any available heat source, from ambient heat to solar. This is the reason why GSHP are continuously growing in the EU at an average rate of 3% in the last 20 years and can be now found everywhere in Europe. Another appealing feature of GSHP is its full compatibility with the ongoing trend to blend heat and cooling with the electric grid ("sector coupling electricity, transport and H&C sectors"), as the primary energy source of heat pumps is electricity.

Despite of its potential GSHP are however, still a niche application in many countries were competing technologies based on cheap fuel or gas burners plus the comparatively higher cost of electricity act as a real barrier against a more generalized adoption by the market.

In the past years, extensive Research Actions following the recommendations contained in the Geothermal Roadmap were undertaken in order to improve the situation. Just to mention a few: high temperature CO_2 heat pumps have been developed to make GSHP suitable for retrofit of historical buildings, cheaper and faster drilling technologies have been produced, plastic materials and grouting with improved thermal characteristics and new hybrid air/ground source heat pumps were created. These promising technologies are now in its development phase (some of the projects having quite low TRLs) and require a continued effort to fully impact the market.

In other areas linked to GSHP systems such as the use of geo-structures and urban infrastructures, a wide effort was undertaken to fully characterize its technology readiness level, potential and needed actions (we can refer to COST action GABI[5] in this domain). One of the many lessons from GABI was the need to cross bridges between building design and geothermal/geo-structural engineering to be able to grasp the full potential of heat/cold harvesting by means of our building and even larger structures (tunnels and even districts itself). This requires not only a full new set of standards but also extensive demonstration and dissemination.

[5] https://www.foundationgeotherm.org/

There are many other areas, such as the use of groundwater as an energy source in open-loop systems and Aquifer Thermal Energy Storage (ATES) systems, where technology is being developed, but still full market penetration throughout Europe is missing.

The label "deep" has been traditionally applied to geothermal heating and cooling (low and medium temperature/enthalpy) produced by extracting the heat from ground and groundwater at depths and temperatures standing within 500 m - 5000 m and 25°C - 150°C, respectively. These also termed as "direct applications" are found in agriculture (horticulture, drying, crop processing), aquaculture, industrial processes and balneology, but also increasingly in the district heating sector and can supply energy to combined heat and \ power (CHP) plants and drive absorption cooling heat pumps thus providing cold to a heating/cooling grid. A clear crosslink between geothermal power heat and electricity production is the use of the residual heat released by a geothermal power (flash or binary) plant can be used as a (downstream, cascading) a source for a geothermal district heating/cooling system.

Research topics

TOPIC A.1 -Deep boreholes for the use of medium depth low-medium temperature geothermal resources
Objective The main objective would be to develop **new generation medium depth (up to 500 m) geothermal heat exchanger solutions** to utilize the unexploited geothermal resources associated to low-medium temperature geothermal source (30 to 150°C). This topic's strategy is based on filling the current technological gap between shallow (low temperature, limited capacity) and deep geothermal (high economic & technical risks) by reliably reaching depths where thermal level and gradients can be exploited at sufficiently economic rates, thus enabling new opportunities for EU renewable energy production. Another objective concerns drilling deeper with linear costs and not exponential ones.
Current Status Several ground coupling technologies exist: drilling methodologies heat exchanger types, designs and materials, heat pumps. A large range of applications of these systems (e.g. different types of subsurface conditions and different types of buildings/user profiles) makes ground coupling technologies challenging. There is still a room for improvement for both the whole system and the different components. This can either be achieved by developing/using A) new drilling technologies or materials adapted for specific conditions to improve performance or reduce costs or B) developing new ground coupling concepts.

Key Actions
A.1.1 - **Development of new concepts and materials for the next generation of underground heat exchangers** for an efficient use of low-medium enthalpy unexploited geothermal energy; **A.1.2 - Further development of underground heat exchangers concepts** in geothermal systems to reduce their material and/or installation/operating costs **A.1.3** - **Development of cost-efficient solutions to increase the conductivity and thermal capacity of the underground** in the vicinity of borehole heat exchangers with environmentally acceptable and stable solutions
Type of Action (Research/Innovation/Demonstration or TRL) TRL 3-4 / 4-6
Key Performance Indicators % reduction in the unit cost of drilling (€/MWh), % improvement of overall conversion efficiency of geothermal installations at different thermodynamic conditions, % reduction of production costs of geothermal energy (€ct/kWhth), decrease (%) of n. of boreholes per kW energy produced, Well-head temperature, flow rate, power of the geothermal system

TOPIC A.2 - Resource management in dense installation environments
Objective Identify design **methods and organizational concepts that result in the most effective and sustainable use of subsurface space by UTES, ATES and BTES systems in dense urban areas**. Evaluation of the interaction between other urban uses of the subsurface (e.g. subways, underground utilities, buildings), including structural foundation elements of buildings, tunnels, slabs etc., with potential geothermal heating, cooling, and sinks or storage opportunities;
Current Status Geothermal energy systems concentrate and cumulate in urban areas where many old and some new buildings stand side by side. The temperature distribution around the wells/boreholes of these systems depend on subsurface conditions and the energy demand profiles of the associated buildings. Uncertainties inherent to future weather conditions, to climate and use of the building, lead to uncertainties in their energy demand and causes its associated use of subsurface space to vary and hard to predict. At the same time, the spreading of heat in the subsurface is invisible and difficult and expensive to monitor. To deal with these uncertainties and possible interaction ATES and BTES systems are over-dimensioned and kept at a large mutual distance to prevent negative interaction between them. Also, little attention is paid to operational aspects such as variation in energy demand between and over the years, which results in both suboptimal use of the subsurface

and in reduced thermal efficiency. These different aspects cause under-utilization of potential GHG savings with UTES systems. Therefore, both the design and organization of UTES need to be improved to safeguard optimal and adequate use of the subsurface.
Key Actions **A.2.1 - Optimal utilization of geothermal resources** and thermal energy storage in urban settings; Subsurface underground models for a sustainable geothermal use in cities; **A.2.2 -** Studying the **impact of subsurface urban heat islands (SUHI)** on the potential of shallow geothermal energy use in cities; **A.2.3 - Best practices strategies** for subsurface land-use plans in European cities. Well/borehole placement strategies **A.2.4 - Mutual interaction between systems, effect on efficiency of storage, and energy performance.**
Type of Action (Research/Innovation/Demonstration or TRL) TRL 6-9
Key Performance Indicators Adoption level of UTES in cities, percentage of subsurface space utilized for shallow geothermal.

TOPIC A.3 - Deep subsurface characterization methods integration
Objective **Reduce the uncertainty of subsurface characterization** by the acquisition of high-resolution data. **Reduce the costs of exploration by combining different methods** which can be applied for target identification and future monitoring operations
Current Status Deep geothermal for heat production is only locally established in Europe (i.e. Munich area, Paris basin) but its potential is large and projects from feasibility studies to drilling and resource assessment are ongoing in some counties but need to further in terms of subsurface characterization, adaptation of regulatory framework and improvement of the economic and social viability.

Key Actions
A.3.1 - High resolution exploration and monitoring methods. Several geophysical methods can be employed and combined in a first instance during exploration and in a second time as time-lapse monitoring during production to reduce the subsurface uncertainty in terms of target identification and characterization (i.e. vertical and horizontal extent, saturation, lithological heterogeneities, compartmentalization) and geologic risk (i.e. hydrocarbon accumulations). **A.3.2 - Reservoir characterization.** Sedimentary and crystalline reservoir can be suitable targets for deep heat production. Their long-term sustainable performances are strongly controlled by favourable conditions in terms of porosity and permeability which conditions can be defined by petrophysics, study on surface analogues to predict subsurface conditions, mineralogical and petrographic characterizations, fracture characterization based on borehole images and 3D modelling, geomechanical characterization and production tests, tracer tests and development of environmentally friendly tracers. **A.3.3 - Machine learning applied to reservoir characterization during exploration and production;** increasing interest is being directed towards big data, thanks to the increasing amount of data that can be collected rapidly and over time which can be integrated to produce 3D integrated static model and to improve the data interpretation process by i.e. automatic fault detection, data-driven seismic facies interpretation, automatic lithology classification using geophysical logs. **A.3.4** – **Thermal-Hydraulic-Mechanical-Chemical (THMC) Modelling** - THMC models have the goal to produce predictive simulations of underground fluid flow, heat transport, geomechanics, and chemical reactions to estimate the efficiency, feasibility, and safety of a project. TH simulations focus on (a) assessing thermo-hydrological challenges to heat storage in the complex subsurface and (b) on quantifying overall thermal efficiency using plausible-yet-simplified realizations of the underground heterogeneity as well as pre-existing hydrological conditions. **A.3.5** – **Minimizing the operation costs of the reinjection -** Reinjection into fractured reservoir is not very challenging. The caves of the formation are generally able to swallow up the brine. However, in case of sandstone reservoirs 100% reinjection often requires high pressure and large quantity of electric energy on injection pumps. The energy, material and human power costs of the reinjection are strongly depending on project planning and also on regular and state dependent maintenance.
Type of Action (Research/Innovation/Demonstration or TRL) TRL 5-6 to 8

Key Performance Indicators

Cost and exploration time optimization

TOPIC A.4 – Development of a new generation of high-temperature UTES systems

Objective

Develop technologies for successful application of storage and recovery of heat in aquifers, for large scale seasonal buffering of heat. Scope: >>40˚C, because at higher temperatures density and water quality issues start to complicate things.

Current Status

In the built environment there are many sources of heat >>40°C. large scale storage facilities would allow for utilisation of this heat for sustainable heating purposes. The subsurface is only technical and financial option for such storage facilities.

A limited amount of HT-UTES systems have been made and hardly any of them operate efficiently / successfully. Depending on the characteristics of the subsurface conditions and temperature level of the heat to be stored either A) development is needed for water treatment and materials and pumps for wells or B) fundamental knowledge development on distribution of heat due to buoyancy flow, impact on groundwater quality and possibilities to monitor and control these heat flows.

Key Actions

A.4.1 - Subsurface characterization of suitable formations (mainly for HT-ATES), identification of potential.

- in RT 5/10?

A.4.2 - Impact / water quality effects / water treatment

- coupled temperature water quality changes, desorption of heavy metals
- cheap-efficient water treatment to prevent clogging

A.4.3 - Optimization of recovery efficiency

- Integration with district heat network
- Deep understanding of buoyancy,
- Optimization with well types / well placement

A.5.4 PCM enhanced borehole heat exchanger UTES applications for DH systems

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

TRL: 4-8 (depending on the type of storage)

Key Performance Indicators

utilized waste/surplus heat, replacement of fossil fuel, recovery efficiency, €/recoverd GJ, District heating network efficiency improvement, >20% Financial risk reduction (Risk of Success) look at cirve rischio finanziario Sistema convenzionale (T-Q), % phase out fossil fuels

TOPIC A.5 - CHPM technology, exploitation tests of the metal fraction

Objective

The goal is to optimize the production of geothermal energy together with minerals extraction. It includes launching the first demonstration CHPM project(s) and evaluating the technical conformance of the technology and the technical opportunities.

Current Status

The recently finished CHPM2030 Project delivered proof of concept for the technological and economic feasibility of mobilisation of metals from ultra-deep mineral deposits using a combination of geo-engineering techniques to enhance the interconnected fracture systems within the orebody. The Project also developed a roadmap in support of the pilot implementation of such system before 2025, and the full-scale commercial implementation before 2030.

Key Actions

A.5.1. Select demonstration sites and production technology
A.5.2. Set up a project financial model
A.5.3. Launch the first demonstration project(s)

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

TRL: 3 to 5

Key Performance Indicators

- Financial support demand
- Produced metal or metals
- Cost of production

TOPIC A.6 - Cost efficient closed loop technology solutions

Objective

Continuing previous research, despite improvements due to research, still there is room for improvements in several areas. A lot can be expected from further reducing manual work in drilling and installation, by automation and robotics. R&D in specific shallow geothermal drilling technology is also required to further reduce the impact on the surroundings (e.g. sensitive clays, groundwater), to provide techniques to control borehole deviation, etc. The efficiency of heat exchange with the geological strata can be increased by R&D for optimization of components such as borehole heat exchangers (design, pipe material, grouting material), well completion materials, compressors, pumps. One more concern is about the identification/development of an environmentally benign, low viscosity antifreeze ("thermal transfer fluid") fluid for closed loop GSHP systems in order to have thermal characteristics that are equal to, or better than, mono-ethylene glycol.

Current Status

In the past years, several R&D projects have dealt with the production of improved piping materials (GEOCOND), optimized drilling solutions (CHEAPs, GEOTECH) and other of the issues of concern. Progress has been made also in the formulation of grouting with optimized features in terms of pumping stability and the inclusion of Shape Stable PCM additives to enhance the capacity of the system to capture heat. Another interesting area of research is the robotization and automatization of the drilling process, nowadays a still cumbersome operation which is one of the key factors for the high relative cost of the technology. Though the machine and drilling technology has improved with the inclusion of concepts such as the coaxial penetrometer developed in CHEAPs, the automatization of the process in order to enhance safety and reduce labour costs hasn't yet been in the focus.

This promising line of research must be continued to bring these concepts into close to market conditions. Plastic materials with very interesting properties could also be deployed in higher temperature and deeper borehole ambient, allowing a substantial cost reduction for the operation. Even higher thermal conductivities could be reached with the inclusion of nano additives. PCM materials together with grouting can have also a range of applications, also in the domain of District Heating Systems, but an upscale of current experiences is necessary.

Key Actions

A.6.1 Enhanced plastic piping materials for BHEs in shallow and deeper shallow applications - The outcomes of projects like GEOCOND, CHEAP-GSHP or GEOTECH have shown the potential of improvements in critical aspects of GSHP technologies and materials. New plastic materials for larger depth applications or including additional features, like data transmission and monitoring. Advanced grouting concepts to enhance the surrounding soil or improved grouting mixtures can still offer a range of improvement in terms of system efficiency & ease of installation.

A.6.2 Development of fully robotized/automatized drilling solutions for shallow and deeper borehole applications. Drilling is still a major cost and safety factor and safety. Robotization and the use of IA driven drilling systems could enhance speed, safety and cost of operation substantially.

A.6.3 Development of very shallow closed loop GSHP systems - In many suburban or rural settings there are less spatial restrictions on the installation of closed loop systems. In combination with the development of more energy efficient housing with an increased annual energy balance between heating and cooling, shallow closed loop systems (indicative interval between 5 – 50 m depth) are of interest. These systems can be stand alone or integrated in to a district system, preferably with a strategy for optimization and communication with the required electrical input used for running the systems. Shallow systems will allow local contractors to move in to the shallow geothermal market without the risk of drilling to greater depth (failure, environmental, investment etc.) **A 6.4 Improved and eco-friendly antifreeze** - The objective is to produce with long term stability - at least as good as mono-ethylene glycol; and preferably derived from a sustainable source. Such antifreeze could contribute to system efficiency by reducing power demand of circulation pumps, and to acceptance with authorities by imposing no threat to the groundwater.
Type of Action (Research/Innovation/Demonstration or TRL) TRL 5-9
Key Performance Indicators Reduction in the unit cost of drilling (€/MWh), % improvement of overall conversion efficiency of geothermal installations at different thermodynamic conditions, % reduction of production costs of geothermal energy (€ct/kWhth), decrease (%) of n. of boreholes per kW energy produced, %reduction in time for the competition of a standard borehole of 100m, %increase in the thermal capacity of a unit volume of grout with PCM

TOPIC A.7 – Geo-structures
Objective "Thermoactive geo-structures" consists in the integration of geothermal heat exchangers into subsurface infrastructure elements that interface with the ground. Geo-structures such as energy piles, diaphragm walls, tunnels, and geosynthetic-reinforced retaining walls can utilize the ground for heating and cooling of structures, storage of heat, or dissipation of waste heat. This is particularly attractive because of the inherent cost saving involved in combining a required structural element with the harvesting of geothermal energy. Similar to conventional ground-source heat exchangers, they can be used as pathways to extract heat in the winter and inject heat in the summer, albeit while taking advantage of the construction process, providing a sustainable approach to transfer thermal energy to and from the ground for a lower installation cost than traditional borehole-type geothermal heat exchangers. However, it also presents new challenges for the broader geotechnical engineering profession, in terms of technical issues associated with soil-structure interaction; thermal effects on surrounding soils, as well as construction and

organizational issues. Furthermore, the widespread application of this sustainable technology is currently hindered by the large heterogeneity in the development, designing methods and regulatory framework in European countries.

Current Status

Thermoactive geostructures are rapidly spreading all around Europe and are increasingly employed for heating and cooling of building in urban environment. Two main Platforms must be mentioned in this point, the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) launched the Technical Committee TC308 on "Energy Geotechnics" and the European Network of researchers and engineers interested in the challenges of thermoactive geostructures, under the figure of a Cost Action (Action **TU1405 – "European Network for Shallow Geothermal Energy Applications in Buildings and Infrastructures - GABI").** Based on multidisciplinary approaches dealing with geothermal energy such as energy efficiency, geological and geotechnical engineering, this heterogeneous group, active between 2015 and 2019, gathered professionals from 26 countries to ensure an inclusive and open platform for scientific discussion and sharing knowledge and experiences, with the aim of defining European best practice rules for geothermal applications, promote public awareness and confidence in this technique, and foster advancement in knowledge through international collaboration, especially in those countries with less experience.

Key Actions

A.8.1.- Ground investigation methods around thermoactive geo-structures and Energy Performance Assesment - One of the cornerstones to address is to search, analyse and compare all the ground and laboratory tests as well as the analytical, numerical and constitutive models existing for the evaluation/modelling/forecasting of soil thermal properties. The main problems concern the scale effect (from micro to macro), the saturation conditions, the spatial scatter of soil properties and the sampling effects. This Key Action is the most interdisciplinary, as it requires consideration of the ground response, as well as all factors affecting the building/infrastructure energy performance. It is also of paramount importance to identify those scenarios where an optimal relation between the building's demands and ground capacities can be established, taking into account state of the art solutions and costs, in order to facilitate the large scale deployment of thermoactive geostructures.

A.8.2.- Thermoactive structure design - This KA deals with the development of design methods for thermoactive geostructures according to Eurocodes. Currently, no common design methodology exists to assess the performance of thermoactive geostructures. Three major points must be considered for the design of thermoactive geostructures: the thermal axial displacements which can induce settlement or heave of the overlying structures, the complementary stresses in compression or tension due to the constrained movements of

the surrounding soil and the shear stresses mobilized at the soil–structure interface, which control the mobilized resistance in the ground. Furthermore, this work requires the construction of a database of the different research tests performed on thermoactive geostructures and existing monitored installations. Benchmark studies should be conducted by using different national practices in order to identify the main calculation approaches compatible with Eurocodes.
Type of Action (Research/Innovation/Demonstration or TRL) TRL 6 to 9
Key Performance Indicators Number of Thermo-active geostructure installations, Number of dissemination events, training courses, manuals Guidelines, Best practices documents, Standards.

B. System Integration

Overview and focus areas

There is a growing interest in the geothermal resources available at shallow depth beneath cities. However, until now there exists no general procedure for quantifying the low-temperature geothermal potential in urban ground and groundwater or how to integrate shallow and also deep geothermal systems into existing and future renewable energy systems. A premise of integrating geothermal energy use in both urban management plans and modern concepts of underground space management is understanding its potential and the best way for integration. Hence, the following key research topics are outlined, which address an optimal system integration of geothermal systems in urban and also rural areas throughout Europe.

Research Topics

TOPIC B.1 – CITY-BUILDING-SUBSURFACE CO-SIMULATION MODELS (HYBRID MODELS)
Objective The objective of the present research topic to improve and develop simulation tools, which are able to address urban planning with building simulations tools and finally also to integrate subsurface simulation tools such as heat transport models of aquifers or other subsurface planning tools for example for GSHP systems. Hence, the key objective is to develop hybrid models that overcome their typical boundaries and are finally able to simulate the energy planning in integrated way including the city, city districts, individual building and the subsurface.

Current Status Currently, no integrated simulations tools exist yet. Typically, cities, city quarters and individual buildings are simulated without considering the subsurface in great detail or including subsurface heterogeneities such as hydraulic and/or thermal conductivities. The design of the subsurface such as borehole heat exchangers (BHE) and subsurface installations such as building equipment (e.g. heat pumps) are usually planned rather independently.
Key Actions **B.1.1 -** Optimizing the performance of geothermal systems by the integration of subsurface models into building energy models; **B.1.2 -** Creating synergies between different subsurface users responding to dynamic demand patterns of the built environment; **B.1.3 -** Development of straightforward co-simulation tools for HVAC and geothermal consultancies; **B.1.4 -** Combined (hybrid) models for all available renewable energies including geothermal systems.
Type of Action (Research/Innovation/Demonstration or TRL) TRL: 4-6
Key Performance Indicators Integration of geothermal systems in urban management and development plans. Increasing the application of geothermal systems in newly developed city districts and energetically refurbished buildings and districts.

TOPIC B.2 – SYSTEM INTEGRATION OF GEOTHERMAL AND OTHER RENEWABLE TECHNOLOGIES
Objective The key objective is the combined existing and newly developed geothermal technologies with other renewable technologies on the city and district level. Thus, for example, the electricity demand for the heat and circulation pumps is covered by renewable energies such as wind, solar and also deep geothermal systems.
Current Status Until now geothermal system are typically individually design without considering other renewable energy systems. Furthermore, shallow geothermal systems usually operate individual buildings or small district heating systems. Hence, large district heating and cooling systems that intregrate other renewable energies do not exits yet.

Key Actions **B.2.1 -** Optimal utilization of geothermal resources and thermal energy storage in urban settings; **B.2.2 -** Evaluation of the interaction between other urban uses of the subsurface (e.g. subways, underground utilities, buildings) with potential geothermal heating, cooling, and energy storage opportunities; **B.2.3 -** Studying the impact of subsurface urban heat islands (SUHI) on the potential of shallow geothermal energy use in cities; **B.2.4 -** Subsurface underground models for a sustainable geothermal use in cities; **B.2.5. -** Integration of geothermal applications in legally binding land-use plans; **B.2.6. -** Best practices strategies for subsurface land-use plans in European cities.
Type of Action (Research/Innovation/Demonstration or TRL) TRL: 6-8
Key Performance Indicators Monitoring programmes of groundwater temperatures and energy fluxes in European cities; Evaluations of the geothermal potential in European cities, energy costs and CO_2 emission savings in case geothermal systems are employed in European cities;

~~TOPIC B.3 – STORE THEN PRODUCE THE WASTE HEAT WITH UNDERGROUND HEAT STORAGE IN A BIOENERGY OR SOLAR POWER PLANT~~
Objective Increase the energy efficiency with geo-bio or geo-solar hybrid project. Inter-seasonal heat management with underground heat storage. Store the summer waste heat and produce it in winter by the underground heat storage system.
Current Status All the elements of this technology exist. Bio or solar power plants have their annual resource dynamics. If the heat demand is different the produced waste heat should store then reproduce. To create this hybrid system is risky yet, therefore a research project is needed to demonstrate the eligibility of this technology.
Key Actions **B.3.1.** Determine the site, the heat storage formation and the technical parameters

B.3.2. Prepare the financial model **B.3.3.** Implement the demonstration technology system and launch the heat storage
Type of Action (Research/Innovation/Demonstration or TRL) TRL: 5 – 7
Key Performance Indicators ➢ Stored and produced heat temperature ➢ Stored heat capacity ➢ Cost of the Underground Geothermal System

TOPIC B.4: DEEP CLOSED BOREHOLE HEAT EXCHANGER INTEGRATION AS LARGE SCALE BTES FOR HEATING AND COOLING APPLICATION IN DISTRICT HEATING AND LARGE-SCALE INDUSTRIAL PROCESSES

Objective

The exploitation of geothermal energy from intermediate depths (between 500m and 1500m) has the potential to offer an efficient energy source in heating and cooling applications as well as storage for underground processes. The use of deep closed loop heat exchangers offers the opportunity to develop a solution with lower implementation risks and with greater design flexibility in the integration of ground energy storage in complex systems. The objective of the topic is to focus on the technical aspects including drilling methodologies, borehole completions strategies and the development of suitable deep coaxial heat exchanger technologies and the integration of these with source temperature requirements for specific technologies (high temperature heat pumps, absorption/adsorption chiller and industrial processes). Non-technical consideration including economic models for different technology solutions to facilitate their market and the promotion of the environmental benefits compared to other open loop systems need also to be considered.

Current Status

The development of deep closed loop heat exchangers remains limited with applications mostly in large scale applications where the development of new innovative closed loop probes based on shallow geothermal system U-tube design and facilitate installation of up to 600m. Very few deeper closed loop boreholes (some to depths of 2.5km) have been developed at present where higher temperatures and depths are achieved to demonstrate efficient energy extraction. Significant technological improvements are required to increase the performance and allow for these systems to be market ready. The economic aspects relating to the completion and operation of these systems require further investiation.

Key Actions

- B.4.1 Closed System design Model based on load profile requirements – this needs to differ from conventional closed loop design and take account of operational parameters
- B.4.2 Efficient deep borehole drilling– reduced footprint required for deeper boreholes at greater depths (>500m)

- B.4.3 well design completion strategies in line with permitting and environmental regulations
- B.4.4 innovation in deep heat exchanger design
- B.4.3 Closed system integration design in complex energy systems (DHN, industrial process, integration with other technologies)
- B.4.4 Financial Model development including CAPEX and OPEX for different technology solutions and markets (heating, cooling, industrial processes).

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

Key Performance Indicators

- CAPEX cost vs energy produced
- No. of system uptake in large commercial/industrial applications
- No of increased cooling related applications

TOPIC B.5: INNOVATIVE HEAT ENERGY OPTIMIZATION IN OPERATING BALNEOLOGICAL SYSTEMS SUPPLIED WITH THERMAL WATER

Objective
Development of such complex solutions, which are appropriate for increase the efficiency of use in case of secondary utilization of effluent thermal water's heat-energy. Moreover, beside spa complexes the region's services providers and citizens should also benefit from the solutions, i.e. they can support the appearance of new, related activities and industries (e.g. horticulture, further space heating etc.)

Current Status
The thermal spas in Europe have traditions of thousand years, but the conscious energetic utilization of the produced thermal heat started only a few decades ago, moreover it hasn't started everywhere. There are examples for the secondary utilization of effluent thermal water's heat-energy in the case of bathes and spas operating with thermal water. However, these solutions are not sufficient to the proper usage efficiency of the available source of energy. There are only partial solutions so far.

Key Actions

B.5.1 – Analysis of the current energy loss;

B.5.2 – Create a menu of technical solutions for increase the energy efficiency

B.5.3 – Demonstrate the technical feasibility and financial profitability of the different solutions
.

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

TRL: 6-7 to 9

Key Performance Indicators

- Saved heat energy
- Number of cascade steps
- Cost of operation
- Cost effectivity

TOPIC B.6 - ENERGY SYSTEM INTEGRATION AND DELIVERY

Objective

Optimization of the different parts in surface system. Create a standardized design including well heads, piping, active and passive corrosion protection, heat exchangers, filters and water handling, as well as telecommunication systems and remote control. Determine the weak points in different site types, sizes and brine types. Determine the weak points in the implementation of new projects. Develop these weak points in order to achieve the optimal implementation and operation costs, as well as sustainable and reliable operation.

Distinct system design improvement is needed in order to achieve lower implementation and operation costs. Operation and maintenance are two different cost types. Moreover, maintenance consists of three different sub-cost types. Their reduction is aimed in this design.

Current Status

Lots of development have been performed related to the surface technology in deep geothermal sites. They were mainly practical solutions or they belonged to other complex researches. The technological solutions are mostly available in the separate parts of the surface technology. The unification and standardization seems to be the way to the further development.

Key Actions

B.6.1 - Planning and realization the geothermal part of source-to-sink district heating network;

B.6.2 - Material for piping and heat exchangers to improve the lifetime and prevent scaling and corrosion;

B.6.3 - Fluid management in terms of complex chemistry and presence of hydrocarbon

B.6.4 - Energy system modelling to definition the site-specific contribution of deep geothermal heat in complex energy systems mix and district heating networks (connected to RT1 and WG2);

B.6.5 - Integrate deep geothermal heat to food production and process;

B.6.6 - Development of demonstration projects.

Type of Action (Research/Innovation/Demonstration or TRL) TRL: 5-6 to 9
Key Performance Indicators Cost reduction for maintenance operation and performance optimization Cost reduction in project implementation

Implementation

C. Non-technical

Overview and focus areas

The development of geothermal energy resources in heating and cooling applications has provided a considerable number of innovations in the past decades. Significant innovations in the context of ground heat exchanger design including materials as well as drilling and the installation methodologies used in conjunction with these has contributed to the growth of the sector the 'state of the art' in the context of 'shallow geothermal' systems different sub-surface environments and in ever increasing building integration and industrial strategies

The previous sections of this SRIA document have outlined significant innovations in the context of new ground heat exchange technologies where significant improvements in design, the use of materials and the installation of shallow geothermal systems, in particular closed loop technologies used in more complex deployment environments including densely populated urban areas. The SRIA highlights the integration of ground heat exchangers in the built environment through the use of geostructures to deliver new ways of delivering low carbon heating and cooling solutions to buildings and outlines a new development areas for the sector.

The exploitation of 'deeper' geothermal resources has also been conventionally associated with direct heat uses where higher temperatures are considered. The SRIA further push the boundaries in terms of utilisation strategies and depths of installation for conventional systems. The use of intermediate depths (between 500 and 1500m) and of temperatures typically between those delivered through GHSPs and direct heat uses, is specifically targeted in the context of deep energy storage, specific industrial process applications and for cooling, where a crossover of shallow and deep geothermal technologies are proposed. These have the potential to deliver innovations drilling and well completion as well as new resource use and management strategies of the underground to deliver both heating and cooling to complex or multi-end user energy scenarios through district heating and in the fabric of energy planning in cities.

The technical topics proposed in this SRIA are more focussed on an end-use approach and a consideration of the wider energy system in which geothermal technologies may be applied. Integration of geothermal energy in such a way, brings new challenges in the context of addressing the non-technical barriers including regulatory and legislative issues, but more importantly the public acceptance of geothermal as a technology and its inclusion in ever increasing local community led energy initiatives and planning strategies.

Regulatory and legislative conditions for geothermal resources in Member States vary greatly, with the implementation of these more developed as a function of the maturity of the market. These conditions are often focussed on environmental and underground protection and are clearly defined in terms of the application of shallow and deep geothermal regulatory systems where these regulatory conditions are implemented. The inclusion of hybrid solutions such as those proposed in this SRIA is less clear and requires further development. The implementation of deep closed loop geothermal systems for the purpose of energy storage or for use in direct applications are an example of this. The integration of these geothermal innovations into wider and more complex energy systems such as those being discussed as part of the Horizontal Working Groups that include city wide developments, though district heating and industrial processes, demonstrates the need for new demand-led response of different renewable technologies when their integration and design and operational level is required. Geothermal plays a key role at delivering energy storage options to achieve this.

The resource assessment and operational data compilation from geothermal energy systems represents another non-technical barrier to the development of the sector. The complex nature of the underground and the use with the different energy exchange technologies used in geothermal prevents clear harmonised, measurable and quantifiable assessment of exploitable resources to demonstrate the contribution geothermal technologies can make to heating and cooling to key stakeholders. The importance of these data in geothermal mapping and operational resource management strategies are demonstrated in some areas of Europe as critical to the sustainable development of the sector but are much less developed in emerging markets. Geothermal resource mapping and system data integration represent a critical tool in informing key stakeholders in the context of energy planning and in the potential for integration in building energy performance compared to other renewable technologies. The introduction of geothermal technology innovations for energy storage, the use of geostructures in the built environment, represent an additional requirement for improving the quantification of the geothermal energy potential at local level.

Public acceptance and knowledge sharing in the development of projects has greatly improved in the last decade with significant work implemented in the context of specific issues related to the implementation of projects including in the context of microseismicity and in the ground subsidence with the implementation of improved communication and stakeholder engagement strategies. The role of community stakeholders and of key policy makers is continuously highlighted as the energy transition to a low carbon energy sector has significantly increased the role that local communities have. Further work in the context of deep geothermal projects and particularly the implementation of large scale shallow geothermal project (BTES/ATES) requires new models for community engagement. Increased awareness and engagement with policy makers, government department representatives and professional groups needs to be further addressed to further facilitate market penetration of geothermal technologies.

Research Topics

TOPIC C.1 – ENVIRONMENTAL LEGISLATION AND DRILLING REGULATIONS
Objective The objective of the topic is to align GHE technology and Drilling innovations (closed loop & hybrid collectors, new material and compounds, new drilling and installation methodologies) with environmental/legislation and drilling regulations by demonstrating applicability across different legislative frameworks. The regulatory and licensing/permitting processes for these new technologies and geothermal energy systems (including cooling, energy storage) coupled with medium temperature and 'intermediate depth systems' needs to be assessed and demonstrated as not representing a barrier to development. The deployment of the innovative geothermal technologies should also be considered in the context of the wider energy system and where ground coupling technologies constitute an integral part of the building infrastructure (geostructures). In the context of building regulations, the application of both existing and new innovative geothermal technologies needs to be considered in context of the implementation of nZEB in renovation and historical buildings where current regulations are likely to increase the contribution of renewable technologies as part of refurbishment measures.
Current Status The legislative and regulatory environment governing the deployment of geothermal energy systems is varied across many jurisdictions and mostly better defined for the current 'state of the art systems' (shallow and deep). In more mature markets a higher level of legislation and regulation is observed with a varying degree of applicability of these in less developed markets. The differentiation between shallow and deep resources generally implies the application of very different legislative and regulatory procedures. Recent technological developments that consider the use of geothermal resources from intermediate depths below the defined 'shallow geothermal depth' defined in the regulations and above that of conventional deeper system exploiting higher temperatures are subject to unclear regulatory and permitting processes. The same is true when ground heat exchange technologies such as restructures are considered.
Key Actions • C1.1 Best practice regulatory implementation strategies for geothermal as key enabling technology in hybrid scenarios • C.1.2 Guidelines and recommendations for the design, completion and specification of geostructures • C. 1.3 CEN/ISO standard working ground recommendations for new ground heat exchange technologies and drilling and completion strategies to cover all new intermediate depth energy exchange technologies, cooling and geostructures and standing column wells • C.1.4 Regulatory guidance in relation to energy storage and contract structures in the implementation of complex energy systems and hybrid solutions. • C.1.5- Regulatory guidance in relation with the use of Energy Geostructures - It is mandatory to prepare a draft version of a guideline concerning the design of thermo-active geostructures, taking into account: structural and geotechnical design under the Eurocode

and European Standards, necessary input data influencing the design, additional thermally-induced actions and uncertainties caused by them. This Key Action must be performed considering CEN activities associated with standardization and harmonization of design rules across Europe.
Type of Action (Research/Innovation/Demonstration or TRL) TRL 5/7 to 9
Key Performance Indicators • Adoption of new ground heat exchange technologies (materials, design, methodologies) in existing EN and ISO standards • Regulations to cover 'intermediate depth systems' (below current shallow geothermal state of the art') • Best international practice standards on the design and completion of geostructures

TOPIC C.2 - GSHP INTEGRATION AND CONTRIBUTION TO LEED, BREAM AND BIM DESIGN SYSTEMS AND BUILDING CERTIFICATION

Objective

The implementation of the EPBD requires Member States to implement strategies with increased energy efficiency and increased uptake of renewable energy technologies in both new buildings and deep retrofit scenarios. The design of these and the implementation of nZEB standards are becoming more critical as part of this process. In the non-domestic sector the implementation of designs achieving international energy and performance certification systems such as, BRE Environmental Assessment Method (BREAM), Leadership in Energy and Environmental Design (LEED) and other national certification schemes are more and more common. The use of building specific energy systems is demonstrated to provide advantages in the certification scoring schemes in specific higher categories. The objective of the topic is develop new streamlined integration strategies in nZEB buildings certification for both shallow geothermal (the current state of the art) and new solutions including energy storage, cooling and deep geothermal systems when developed either on site or as part of district heating/cooling networks. These integration strategies can be considered in the context in different climatic conditions and supported by specific new design tools and certification protocols.

Current Status

The feasibility design and subsequent certification of these schemes using geothermal systems through either on-site energy generation or through 'local' schemes area not easily defined leaving designers a more limited range for implementing geothermal systems over other technologies. The number of certified buildings in schemes of this kind using geothermal systems are mostly limited to the use of ground source technologies (the state of the art) with generation being mostly achieved on site. This is reflected in shallow geothermal systems integrated in very

large scale renovations and new build buildings achieving only the higher certifications levels and less common in the lower certification categories. Less common are the use of geothermal in complex buildings and in markets where geothermal is less mature to the detriment of air source heat pumps and other renewable technologies.
Key Actions • C.2.1 Improved design and post-construction tools and strategies for geothermal system integration options to include energy storage, cooling and district energy as part of a complex energy system • C.2.2 Increase awareness in the potential for geothermal integration in lower certification rankings (historical/heritage buildings) in energy and environmental classes • C.2.3 Improved LCA assessment methodologies for geothermal systems • C.2.4 Integration of geothermal to other renewables to increase system efficiency and reduce CO_2 emissions
Type of Action (Research/Innovation/Demonstration or TRL) TRL 7 to 9
Key Performance Indicators • Increased uptake of geothermal in certification scheme buildings • Improved credit/point system for energy and environmental categories for geothermal systems • Increased operational energy efficiency from geothermal systems in post-construction assessment

TOPIC C.3 – Horizontal Working Group DEMAND SIDE INTEGRATION – DEVELOPMENT OF MODELS FOR INTEGRATION OF GEOTHERMAL TO HWG TARGETS
Objective The integration of geothermal energy in complex energy systems such as those considered in horizontal working groups (DHN, cities, industrial) requires integrated strategies where geothermal technologies can be demonstrated as delivering key aspects of the entire energy system. The integration strategies need to be considered in context of the current market ready shallow geothermal and deep geothermal technologies and their abilities to deliver base load energy as well as storage options. Innovations in energy exchange methods (BTES, GeoStructures and deep heat exchangers) can be integrated into complex industrial processes and in the design of energy systems at city scale. Innovative deployment models and strategies targeted at policy makers, system designers and planners to demonstrate these integration strategies are required.
Current Status Integration of geothermal energy into complex industrial processes and in particular in cities is very much developed either on a case by case basis or as part of energy planning in more mature

markets. Synergies developed with other technologies in the form of energy storage or as base load energy delivery are often building or system dependent.
Key Actions • C.4.1 Models and operational strategies for geothermal energy storage in complex systems (increased system reliability, integration with other technologies) • C.4.2 Sector specific integration strategies in industrial sectors to demonstrate base load energy and storage options • C 4.3 Innovative geoenergy exchange systems in cities and the built environment including geostructures - Rationalization and planning in large cities is becoming more and more necessary, considering the potential interferences being created by different systems and specially when considering additionally the use of thermoactive geostructures operating in adjacent areas. Guidelines to help in better locating the thermoactive geostructures are required. Integrating the emerging needs and exploiting new opportunities can allow to maximise benefits for the communities of future smart cities.
Type of Action (Research/Innovation/Demonstration or TRL) TRL 6-7 to 9
Key Performance Indicators • Increased Base load energy (heating or cooling) delivered through geothermal in DHNs; • 25-30% increase in geothermal energy applied to industrial processes (direct use or storage) based on process temperature profile models; • Increased integration of geothermal in complex energy systems with other renewable technologies.

TOPIC C.4 – GEOTHERMAL RESOURCE MAPPING & STASTICAL DATA COLLECTION
Objective Resource mapping comprises a key aspect for the integration of geothermal resources in energy planning and policy making and in assessing contributions to heating and cooling strategies as part of national climate action plans. A consistent geothermal resource mapping approach is required to assess the potential of delivering geothermal heating and cooling solutions using shallow geothermal closed loop ground heat exchangers, open loop and aquifer based systems and energy storage. Harmonised methodologies allowing comparable contributions from the above systems to quantified at national and EU levels are required. Resource quantification methodologies need to consider varying geological conditions (the shallower unconsolidated subsurface as well as deeper hard rock conditions), the hydrogeological conditions and aquifer characteristics in the context of energy delivery and system performance as well as in resource and environmental

management for both shallow geothermal and deeper applications. Any resource mapping linked to implementation methodologies including drilling potential and ground exchange technology (including any possible innovations and the use of geostructures) need to be considered in the context of applicable local legislation and regulations. The reporting and data collection used for the assessment of geothermal resource availability in the context of existing operating systems and their performance needs to be also harmonised. In the case shallow geothermal systems the calculations of system efficiencies at the operational stage should be similar in all Member States. Data collection and reporting methodologies should also be harmonised in the context of accounting for cooling contributions. A harmonised approach would allow a common assessment of potential resources available to designers and better inform policy maker in energy planning
Current Status Geothermal resource mapping is implemented in many EU Member States with varying degrees of quantification. In many cases resource mapping is provided as a guidance or screening tool of available resources based on existing available datasets. In some cases these are simply limited to estimates of potential implementation solutions (resource/collector potential, subsurface temperature maps etc), in other cases (generally limited to more mature market areas) a more in depth approach is adopted where existing system operational data and regulatory/legislative restrictions relating to underground uses are considered as part of produced maps. There are currently no set criteria in the context of dataset requirements and methodologies for resource mapping in different jurisdictions. This results in several resource assessment datasets that are not comparable at EU level and that inhibit detailed and harmonised energy planning and policy decisions. The lack of harmonised approach in the context of data gathering from existing and planned installations further accentuates this problem.
Key Actions **C.4.1 –** Harmonised geothermal system data recording parameter to cover resource assessment, installation and operation **C.4.2 -** Open loop mapping parameters and the harmonisation of these and reporting across the EU including aquifer characterisation and linking to resource assessment and potential for exploitation (shallow and deep). ; **C.4.3 -** Closed Loop mapping potential and methodologies – similar to above this would allow a common understanding of technical resources available and the potential for actual exploitation. **C.4.4** – geothermal resource mapping and alignment with local energy demand to match resource and demand areas and facilitate energy planning **C.4.5** – Promotion and dissemination strategies of geothermal resources to policy makers, sustainable energy communities, end users and professionals in energy system design based on end use and potential applications. **C.4.6** Harmonised statistical data collection methodologies and calculation/quantification of components, including cooling, to further allow the geothermal contributions to be accounted for (based on RES Directive calculation with SPF_{H2})

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

Key Performance Indicators

- Adoption of common resource assessment strategies
- Increased share of identified deployable geothermal technology across the EU
- Increased geothermal integration in energy policy in emerging and less mature markets.
- Harmonised SPF reporting structure for geothermal heat pumps

TOPIC C.5 - SOCIAL ACCEPTANCE OF GEOTHERMAL SYSTEMS

Objective
The objective of the topic is to assess and improve the opinions of local communities regarding the potential and real exploitation of geothermal energy and to develop new methodologies for improving the social acceptance of geothermal energy in local communities. The topic covers both deep and large-scale shallow systems where different technical aspects can be addressed (seismicity, groundwater induced subsidence, drilling, thermal behaviour of the ground etc) as well as the socio-economic impacts to local communities. The proposed actions aim to increase acceptance at local community level in order to decrease risk perception levels and through the implementation of common best practice strategies to achieve this

Current Status

The social acceptance status of shallow geothermal systems remains varied and based on the level of development of the technology. Recent studies have demonstrated that overall a lack of knowledge amongst local communities and policy makers in emerging markets is one of the main aspects relating to the lack of uptake. This lack of technology awareness is coupled with the poor knowledge of regulatory framework restrict that restrict the deployment of geothermal resources. This is true in case of emerging markets, in the development of deep geothermal energy systems and in the use of large scale closed loop shallow geothermal systems in housing developments with multiple adjacent users and interactions.

Key Actions

C.5.1 - Develop procedures acceptable for local legislation (municipal or regional level) for both strands of shallow and deep systems;

C.5.2 - Develop implementation procedures/guidelines to provide long term assurance to the end users.

C.5.3 – Best practice public engagement strategies for policy makers and members of local communities and sustainable energy communities (SEC) on shallow and deep geothermal project development.

Type of Action (Research/Innovation/Demonstration or TRL) TRL 6-7 to 9
Key Performance Indicators • Increased community acceptance of geothermal systems (sustainable energy communities) • Decrease in environmental risk perception • Adoption of geothermal public acceptance strategies.

TOPIC C.8 - SUBSURFACE UNCERTAINTY ASSESSMENT AND RISK MITIGATION **(Attila)**
Objective Create the unified European Geothermal Risk Insurance System (EGRIS). EGRIS should operate on market basis, with a minimal EU or Member States support.
Current Status It is a very old intention of the European geothermal sector to have a unified EGRIS. Currently there is a few national risk insurance schemes and some experience in private risk insurance contracts. A research is under implementation. GeoRisk Project is going to create further national, perhaps international schemes. However, these schemes require significant financial support from EU member states. At an early date the European Geothermal community will be well prepared to create EGRIS that is able to operate sustainably with minimal support or fully market base.
Key Actions **C.8.1.** Analysis in all related EU Member States to map legal barriers **C.8.2.** Setup an EGRIS administration that is able to involve the Member States and Projects with different natural, environmental, financial and legal background **C.8.3.** Launching the Scheme with demonstration projects
Type of Action (Research/Innovation/Demonstration or TRL) TRL 6 – 8-9

Key Performance Indicators

- Number of involved member states and projects
- Number of legal barriers removed
- Sustainability of the EGRIS; rate of the financial support required for the 10 years operation

CHAPTER 4 - Implementation Plan

Budget overview

The implementation of the Roadmap relies on various resources according to the research & innovation priorities and the specific needs of the technologies. Several mechanisms for supporting developments in geothermal heating and cooling exist at European and national level. These mechanisms address different project stages and stem from different sources.

The innovation cycle is similar for all technologies as reflected by the TRL scale: from basic research through to development, demonstration, deployment, and commercial market uptake. During these phases public funding for continuing industry-led research, development, and deployment is needed. It is crucial to invest in new renewable technologies and to improve existing ones through RD&I.

[funding figures]

Financing geothermal H&C

Geothermal energy projects are characterised by a high investment cost, notably resulting from the cost of drilling. This makes the deployment of geothermal energy systems more challenging because such projects are often in direct competition with other heating and cooling technologies – often fossil fuels – that have a much less investment intensive cost structure. At the household level, and for local communities or even businesses, the cost structure of geothermal projects – whether shallow or deep – represents a major hurdle to clear, as the availability of capital of heating and cooling investments is not always guaranteed.

The financing of geothermal energy projects for heating and cooling, if it entails similar challenges linked with the cost of capital, for small scale projects and large-scale ones, it also corresponds to vast differences in solutions and specific issues according to the type of project. Financing small scale systems supposes different financial constraints than financing large scale ones. The risk profile of project development is also quite different.

For shallow geothermal, there are two major business models, although in either case, there is a direct link between the investment and the owner of a building or a facility that will benefit from the heating and cooling. In general, the business model will be directly linked to the consumer and her demand profile.

Different needs typically correspond to the use of different types of heat pump systems. Conversely, certain technologies are not suitable in every situation.

- Very small systems are used either to produce domestic hot water or as air conditioning (AC) for cooling. While investment cost is low, they also tend to have lower efficiency.
- Small systems are used at the individual home scale, covering heating, cooling and domestic hot water needs. These systems can utilise either ambient energy or geothermal.
- Medium size systems are used in larger buildings (e.g. blocks of flats, office buildings etc.).
- Large heat pump systems with capacity rated in the MW range are usually intended to meet the needs of industrial installations for process heat, or for district heating.

Large scale shallow geothermal systems are mainly used by large buildings but can also be developed for district heating networks. When used in a large building, such as a shopping mall or an office building, these systems tend to be integrated in the design of new buildings and therefore the business model is directly linked to that of the building itself, the choice of a geothermal system is often the result of a cost-benefit analysis against other technologies – although the investment may be incentivized by a public subsidy such as a tax break.

For individual systems, which are usually either for the use of a small business (SME) or a household, the business model is different, and more in line with the small-scale construction business.

In either case, while current financing models are fairly straightforward, there are many prospects for innovation, with the ESCO model being an interesting prospect. Indeed, geothermal heating and cooling systems can be part of the integrated approach of an ESCO in maximizing energy savings and renewable energy penetration. Moreover, when considering an integrated approach, such systems have the benefit to also provide geothermal space cooling which is often not considered when considering against "heating only" alternative technologies.

In large scale geothermal heating and cooling project, especially deep geothermal projects, the geological risk is a key factor to contend with. Beyond exploration, the bankability of a geothermal project is threatened by this geological risk. The geological risk includes: - The short-term risk of not finding an economically sustainable geothermal resource after drilling; - The long-term risk of the geothermal resource naturally depleting rendering its exploitation economically unprofitable. Until the first borehole has been drilled into the geothermal reservoir, developers cannot be sure about the exact parameters (temperature and flow rate) of the planned geothermal electricity or heating and cooling project.

Large geothermal energy projects are indeed challenging to finance and require specific schemes. Among the specific constraints embedded in the development of new geothermal projects, the geological risk and the very capital-intensive structure of project financing constitute a challenge, which can slow down the deployment of new geothermal capacity. Moreover, considerable diversity in the quality of geothermal resources and the level of market maturity creates widely varying conditions for geothermal project developers. In order to fund geothermal projects, it is therefore necessary to lay out the right financing scheme for the right project.

Accelerated deployment for large scale geothermal geothermal heating and cooling requires investments that cannot solely rely on public funds. Hence, the engagement of the private sector is crucial. However, financial barriers to developing geothermal power projects in Europe persist and need to be overcome through public support from the outset of geothermal development. The establishment of a favourable framework is also required in order to ensure security for large investments in geothermal.

The Implementation Working Group on Deep Geothermal of the SET-Plan – whose priorities are particularly relevant for large geothermal heating and cooling projects – has forecast an investment budget of around € 936 million to execute its Implementation Plan, largely by 2023:

- € 456 million from industry (49% of the total)

- € 342 million from national R&I programmes (36.5 % of the total)
- € 138 million from European programmes (14.5 % of the total)

Funding Instruments

Grant-based financing is a staple of public support for geothermal heating and cooling projects, notably when it comes to supporting innovative technologies, demonstration projects which carry more risk to investors.

Private . However, grants are usually designed to decrease the cost of capital – which increases with the risk. This is intrinsically the case when part of the project is funded for "free". The fact that grants can come in at the early stages of the project to provide funding for project development or high-risk stages of the project (such as drilling an exploratory well for a geothermal project) can provide benefits in terms of cost of capital that far outweigh the actual size of the grant.

Nevertheless, while R&I grant-based funding is vital to early-stage technological development, it still lacks the scale needed to help demonstrations and pilot projects in energy progress beyond the financial "valley of death" and towards commercialisation and industrial roll-out.

By way of response to such a crucial issue, instruments such as the NER300 – soon to be substituted by the new Innovation Fund – do provide a much-needed boost to the demonstration of innovative geothermal energy technologies in Europe, plugging the gap between R&I funding and revenue support instruments such as Member States' renewable energy support schemes.

Industry experience still suggests that there is room for improvement however; the NER300, for example, did not fully tackle some of the essential challenges faced by innovative and capital-intensive technologies, such as a lack of upfront funding. Revenue support provides long-term market visibility, yet it does not address the risks of early-stage technologies. There is a lack of clarity over who bears the risk should a project fail.

Recommendations

Based on the analysis of the case studies examined as well as the existing framework for financing geothermal demonstration projects, ETIP-DG proposes the following recommendations, also illustrated in figure 8:

1. The European Commission should maintain a focus on grants as an essential delivery mechanism for the demonstration of innovative renewable technologies at scale. Grants are unparalleled in allowing the development of innovation along the whole value chain of the project. In the case of geothermal it is important not only to demonstrate the feasibility of a given technology, but also for the workforce to acquire valuable skills and experience that can then prove beneficial in projects with greater share of private financing or different types of instruments.

2. Upfront, de-risked, non-conditional finance. For grants, a milestone system could be used to maintain incentives for efficient device/project development, though 80% of the pay-outs should

remain upfront in order to de-risk the finance provided, while a maximum 20% of the funding should be dependent upon performance (energy production or GHG emissions reduction).

3. Blending finance is another potentially valuable instrument to scale innovation more widely than with grants. Combining traditional grants with hybrid financing, like non-interest bearing instrument, and, possibly, grants and loans will bring more funding opportunities for innovative technologies. The resource risk*8*, the long lead times for project development and the high capital intensity of geothermal project development are significant barriers to financing geothermal energy projects. Grants can incentivise geothermal energy development in potentially high risk activities and for R&D activities. Hybrid financing provides new opportunities with the ability to shift funding from grant to