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Geothermal **Energy**

SETIS

Contents

Editorial

By Philippe Dumas
Secretary General
European Geothermal Energy Council (EGEC)

Geothermal energy can play a crucial role in our future energy mix: providing affordable decarbonised energy for society and giving European industry a competitive edge.

Geothermal heating & cooling can supply energy at both low and high temperatures and for different requirements (e.g. heating and cooling: from less than 10 kWth to a tenth of a MWth). It can also provide electricity and heat at different loads (base load and flexible). Geothermal is a renewable energy source which is local, manageable, flexible, and improves security of supply. It should be integrated in a systemic regional approach, which reduces costs for society and improves industrial competitiveness.

Geothermal will be a key energy source both in smart cities and in smart rural communities, being able to supply both heating and cooling, and electricity, as well as solutions for smart thermal and electricity grids via underground thermal storage.

Currently, geothermal energy sources provide more than 46,520 GWh per year for heating and cooling in the European Union, to which geothermal heat pump systems contribute the largest share. However, the potential is huge. Geothermal can be used virtually anywhere in residential and tertiary sectors, but also in industrial processes requiring temperatures in the range of up 200-250°C. Following current trends, in the European Union (EU-28), the contribution in 2020 will amount to around 40 GWth installed, corresponding to production of about 116,300 GWh.

The total installed capacity for geothermal power in the EU now amounts to around 1 GWe, producing some 5.56 TWh of electric power yearly. Combined Heat and Power (CHP) plants are marginal, with less than 1 GWth capacity for heating, but the development of Enhanced Geothermal Systems (EGS) will provide further opportunities for CHP systems.

The technological challenges for an accelerated deployment of geothermal energy across Europe are to develop:

- innovative solutions especially for refurbishing existing buildings, but also for zero and plus energy buildings, with systems that are easier to install and more efficient at low temperature for both heating & cooling than current solutions;
- low-temperature geothermal District Heating (DH) systems for dense urban areas;
- competitive heating & cooling solutions, allowing for the decarbonisation of industry;
- EGS technology. Deployment will make this technology competitive and keep production costs for electricity from geothermal resources low, by decreasing the installation and operation cost of power plants, by increasing the longevity of installations, and by optimising efficiency and power output; and to
- include geothermal power in grid-optimisation schemes, and use its advantages as a base load, flexible, sizable, controllable, and local resource.

The R&D&I support dedicated to geothermal energy in the EU is negligible compared to other energy technologies. In 2012, geothermal only received EUR 70 million, compared to EUR 14.7 billion for solar PV and EUR 6.6 billion for nuclear. Geothermal cannot live up to its promises without adequate support. EGEC therefore calls for the swift rebalancing of support across all energy technologies.

MAY 2015

SET-Plan update

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The European Strategic Energy Technology Plan (SET-Plan) aims to transform the way we produce and use energy in the EU with the goal of achieving EU leadership in the development of technological solutions capable of delivering 2020 and 2050 energy and climate targets.
The EU supports geothermal energy through its Framework Programme for Research and Innovation and other mechanisms, and by creating the legislative and policy framework for geothermal energy to flourish. The following is a chronological overview of some of the actions taken to promote geothermal energy in the EU, in addition to a more general look at recent actions in support of the SET-Plan.

Geothermal Energy

- The European Geothermal Energy Council (EGEC)[1] was founded in 1998 as an international non-profit association in Brussels. It represents the geothermal sector in Europe. The Council currently has more than 120 members from 28 European countries: private companies, national associations, consultants, research centres, geological surveys and other public authorities. EGEC is a member of the International Geothermal Association (IGA).
- The European Heat Pump Association (EHPA)[2] was set up in 2000. Its members comprise heat pump and component manufacturers, research institutes, universities, testing labs and energy agencies. Its key goal is to promote awareness and proper deployment of heat pump technology in the European market place for residential, commercial and industrial applications.
- On 1 July 2004, the European Economic and Social Committee decided to draw up an opinion on the use of geothermal energy (2005/C 221/05)[3]. This opinion supplements earlier Committee opinions on energy and research policy. It describes the development and use of geothermal energy as an energy source which, given the extent of reserves, meets the criterion of sustainability and does not contribute to global warming through CO_2 emissions. The opinion includes a brief overview and evaluation of development and use of geothermal energy at the time, its potential, and the problems connected with launching it commercially.
- The European Technology Platform on Renewable Heating and Cooling (RHC-Platform)[4] was created in 2008 at the initiative of the European Commission to bring together over 600 industry and research stakeholders representing all renewable energy technologies for heating and cooling. The Platform's mission is to provide a framework for stakeholders to define and implement a strategy to increase the use of renewable energy sources for heating and cooling, and to foster the growth and competitiveness of the relevant industries.
- In its 2009 Directive on the on the promotion of the use of energy from renewable sources (RES Directive, 2009/28/EC)[5], the European Commission called on Member States to take steps to develop district heating infrastructure to accommodate the development of heating and cooling production from large biomass, solar and geothermal facilities.
- The EERA Geothermal Joint Programme[6] was launched in June 2010 to conduct the research needed to support enhancing geothermal energy production from already identified and utilized resources and to explore large scale new untapped deep-seated hydrothermal systems. Other research goals include making Engineered Geothermal Systems (EGS) ready for large-scale deployment and accessing "high potential" resources such as supercritical fluids and magmatic systems.
- In April 2012, the RHC-Platform published its Strategic Research Priorities for Geothermal Technology[7]. This was followed, in April

2013, by a Strategic Research and Innovation Agenda (SRIA)[8], which identifies the research and innovation activities and investments needed to make RHC technologies cost-competitive in all market segments (residential, non-residential, and industrial) in the short (2020) and medium term (2030). The Platform published a Geothermal Technology Roadmap[9] in March 2014.

- The Geothermal ERA-NET[10] was started on 1 May 2012 for a period of four years, to support geothermal research in Europe. The ERA-Net aims to increase cooperation between energy agencies and ministries in Europe, with a view to opening up national research programmes and infrastructures and developing joint activities. The Geothermal ERA-NET is different from other conventional research projects in the sense that the grant is provided to promote cooperation and the coordination research plans in the countries involved, rather than for direct research. The Geothermal ERA-NET is the first step towards coordinated geothermal research in the EU.
- The first European Geothermal Innovation Award[11] was handed out in 2014. Designed as an opportunity for industry peers to acknowledge excellence, and for the most exciting ideas to be widely publicised, the European Geothermal Innovation Award is a seal of excellence applied to the most intelligent and important ideas in research and industry which will play a key role in the future development of geothermal energy.
- In February 2015, the Joint Research Centre published its 2014 Geothermal Energy Status Report[12]. This is the first edition of an annual report with which the JRC's Institute for Energy and Transport wants to contribute to the general knowledge about the geothermal energy sector, its technology and economics. The report aims to present the overall state of the geothermal industry in Europe. It investigates the technological situation of geothermal technologies, in addition to policies related to geothermal energy and the status of the geothermal market status, both in Europe and globally.

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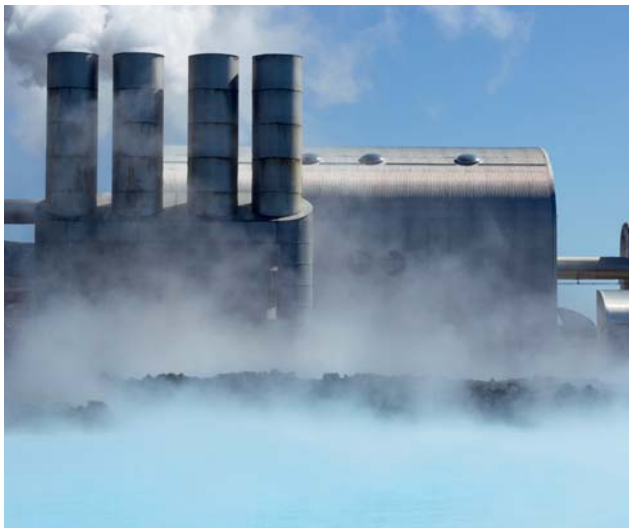
General SET-Plan related news and activities from JRC/SETIS

- The Joint Research Centre published its Energy Technology Reference Indicator projections for 2010-2050[13] in December 2014. The ETRI 2014 report provides independent and up-to-date cost and performance characteristics of the present and future European energy technology portfolio. It covers the time period 2010-2050. This version focuses on electricity generation technologies, but it also includes electrical transmission grids, electricity storage systems, geothermal power production and heat pumps.



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- The Joint Research Centre published A review of factors affecting environmental and economic life-cycle performance for electrically-driven heat-pumps[14] in December 2014. This report presents a review of life-cycle cost studies involving heat pump systems. It presents an overview of the main factors characterising life-cycle cost methodologies for heat pump systems and identifies which factors have the greatest impact on the results. It also suggests methodological improvements to be employed in order to make life-cycle cost analyses more robust.
- On 27 January 2015, the Joint Research Centre hosted a round-table discussion in Brussels on Scientific Support to Europe's Photovoltaic Manufacturing Industry[15]. The roundtable brought together experts from the photovoltaic manufacturing industry, representatives from European institutions and Member States and stakeholders from industry, as well as financing bodies. The discussion explored the possible role of the European Commission in supporting the recovery of the European photovoltaic industry and retaining Europe's prominent place in research. At the same time, participants discussed possibilities of financing photovoltaic industry projects, including through Smart Specialisation Strategies.
- The MatISSE Support to the development of joint research actions between national programmes on advanced nuclear materials[16] vision report from the European Energy Research Alliance (EERA) Joint Programme on Nuclear Materials (JPNM) was published in January 2015 through the JRC. This report presents the vision of the JPNM with respect to the need for nuclear energy as part of a resilient Energy Union with a forward-looking climate change policy; the key role of materials for the development of future sustainable reactor systems; the grand challenges for nuclear materials that need to be addressed; and the establishment of an integrated European nuclear materials research programme.
- The 2014 Ocean Energy Status Report[17] recently published by the JRC addresses the need of monitoring the evolution of the ocean energy technology, industry and market in Europe, with an eye at its global development. It aims to portray the state-of-play of the sector, key achievements, and mechanisms that have been put in place to overcome documented gaps and barriers in the sector towards commercialisation.

Integrated Roadmap and Action Plan

In the context of the process towards the Integrated Roadmap and Action Plan, organisations (universities, research institutes, companies, public institutions and associations) involved in research and innovation activities in the energy field are invited to register in the European energy R&I landscape database[18], which aims at facilitating partnerships and collaboration across Europe. Registration is open to stakeholders from the EU and H2020 associated countries. Organisations will be able to indicate their area of activity according to the energy system challenges and themes, as identified in the SET-Plan process towards an Integrated Roadmap and Action Plan[19]. The database will be publicly available on the SETIS website[20].

- The next SET-Plan Steering Group meeting has been scheduled on 6 May 2015 in Brussels.

1. http://www.egec.org/
2. http://www.ehpa.org/
3. http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2005.221.01.0022.01.ENG
4. http://www.rhc-platform.org/
5. http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32009L0028
6. http://www.eera-set.eu/eera-joint-programmes-jps/15-eera-joint-programmes/geothermal/
7. http://www.rhc-platform.org/fileadmin/Publications/Geothermal_SRA.pdf
8. http://www.rhc-platform.org/fileadmin/user_upload/members/Downloads/RHC_SRA_epo_final_lowres.pdf
9. http://www.rhc-platform.org/fileadmin/Publications/Geothermal_Roadmap-WEB.pdf
10. http://www.geothermaleranet.is/about-geothermal-era-net/
11. http://egec.info/events/egia/
12. https://setis.ec.europa.eu/publications/jrc-setis-reports/2014-jrc-geothermal-energy-status-report
13. https://setis.ec.europa.eu/publications/jrc-setis-reports/etri-2014
14. https://setis.ec.europa.eu/publications/jrc-setis-reports/review-of-factors-affecting-environmental-and-economic-life-cycle
15. https://ec.europa.eu/jrc/en/event/conference/europe-photovoltaic-manufacturing-industry-scientific-support
16. https://setis.ec.europa.eu/publications/jrc-setis-reports/eera-jpnm-vision-report
17. https://setis.ec.europa.eu/publications/jrc-setis-reports/2014-jrc-ocean-energy-status-report
18. https://setis.ec.europa.eu/set-plan-process/integrated-roadmap-and-action-plan/register-european-ri-energy-landscape-database
19. https://setis.ec.europa.eu/system/files/Towards%20an%20Integrated%20Roadmap_0.pdf
20. https://setis.ec.europa.eu/set-plan-process/integrated-roadmap-and-action-plan/search-european-ri-landscape-database

SETIS TALKS TO:

Thomas Nowak

European Heat Pump Association Secretary General

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EHPA advocates for heat pumps to be acknowledged as a technology that is key to achieving Europe's climate and energy goals. How significant a contribution can heat pumps make to the achievement of these goals?

T.N.: "Heat pump technology uses renewable energy to provide heating, hot water and cooling. The use of heat pumps replaces non-renewable/fossil energy sources and thus reduces the related emissions. The technology can be applied across Europe both for residential and commercial buildings. Heat pumps can also provide process heat for industrial applications.

In addition, heat pumps can greatly improve the energy efficiency of existing buildings and processes by making use of waste energy. While in this case the energy used is not considered renewable, the advantages in terms of GHG emission reduction and energy savings remain. In cities, heat pumps can be a source of energy for individual buildings and for district energy systems.

More heat pumps mean a lower demand for traditional energy sources, fewer emissions and a larger intake of renewable energy. Since heat pumps are developed, manufactured and installed in Europe, an increased market share will have a positive impact on jobs.

As heat pumps use abundant local energy sources, they contribute to the security of supply and affordability of energy.

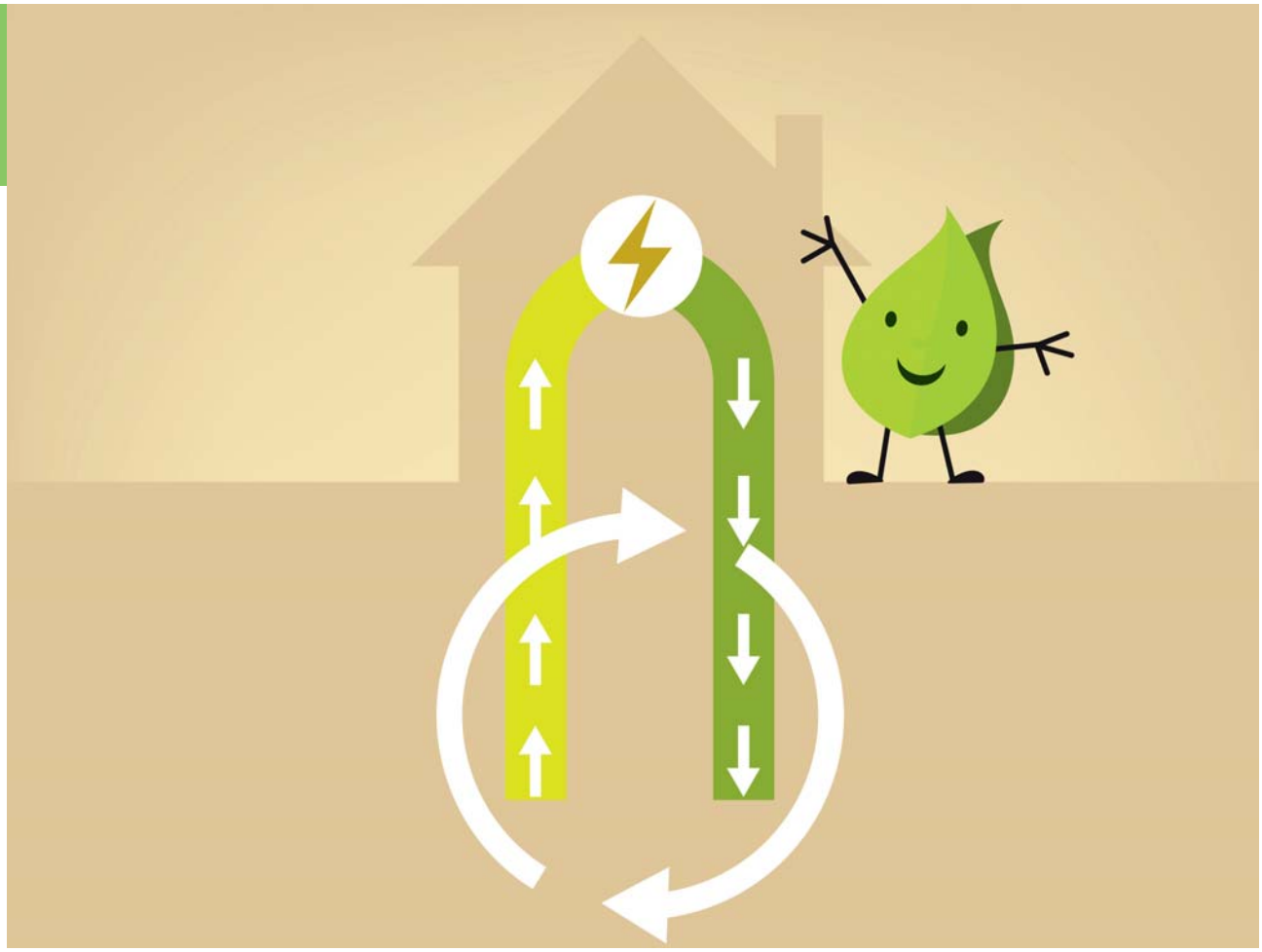
In my opinion, the technology does more than just contribute to the 2020/2030 climate and energy targets: heat pumps contribute to a sustainable European energy system."

How do the different heat pump technologies work and which technology has the greatest potential on the European market?

T.N.: "The basic principle of heat pumps is the refrigeration cycle. A refrigerant is exposed to an energy source, it evaporates and slightly cools down the temperature of the source. The refrigerant gas is then compressed and its temperature increases. The energetic level of the heated gas is transferred to the heating system - the gas cools down, is expanded and becomes a liquid again. The circle can continue indefinitely.

The biggest potential for this technology at the moment is the use of air source heat pumps in the new build sector; this is also the segment that has the largest market share. Recent advancements in technology have also opened up the renovation sector.

A similarly large contribution can be expected from the use of large geothermal or hydrothermal heat pumps applied in industrial applications, quite often providing heating and cooling in parallel. The same type of system is used in large district heating systems, for example in Paris, Stockholm and Helsinki."



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Increased public awareness of heat pumps will be needed if the technology is to reach its full market potential. How can public awareness be improved and what role will EHPA play in this process?

T.N.: “Public awareness can be raised by leading by example. Europe's buildings need to be renovated, 3% of all government-owned buildings should undergo renovation every year. A focus on heat pumps will provide a good example, proving that the technology is reliable. Since heat pump investments are often difficult due to the short-term investment focus of the average consumer, governments could take a leading role in arguing for a life-cycle costing perspective and putting words into action in buildings that are owned and operated by public bodies.

EHPA is providing information to stakeholders on the European level, but is also facilitating the dissemination of information across Europe. We work closely with our members - both on the manufacturing and on the association's side to make best practice heat pump examples more widely known.”

What benefits can an individual consumer anticipate from installing a residential heat pump?

T.N.: “A decision for a heat pump is a decision for more energy independence and an environmentally friendly heating solution. In combination with green electricity, an electric compression heat pump provides 100% renewable energy for heating, cooling and hot water. Thermally driven heat pumps are the best available technology to use fossil fuels for heating and hybrid systems provide the same benefit.

In combination with PV, small scale wind or hydroelectricity, a heat pump becomes the centrepiece of a local energy system that gains the maximum possible benefit from local electricity and can store surplus supply in the hydraulic tank or in the building core itself.

So the consumer receives a reliable, future-proof system with low operating costs.”

Are heat pumps also cheaper solutions than comparable fossil fuel based systems?

T.N.: “The answer depends on where the consumer lives, on the price of electricity (mainly influenced by the way electricity is taxed) and the amount of incentives paid by various bodies.

In many countries, investment in heat pumps not only provides environmental benefits, but is also economically viable. In those countries where this is not the case, heat pump investment suffers from high electricity prices vs. the (artificially) low cost of fossil fuels. It is generally believed that the cost of electricity will go down in the future and that the cost of fossils will rise again - both will benefit the economic case for heat pumps.”

What is the current size of the heat pump market in Europe and how do you see the market developing in the medium and long-term perspectives?

T.N.: “In 2013, 771,151 heat pumps were sold, leading to a total stock of 6.7 million units in Europe. The strongest growth is in the segment for sanitary hot water as well as air-water and air-air units. Over the past two years, a turnaround in sales was observable. Many national markets have turned from decline to growth. With the introduction of a number of positive legislative acts, from local schemes to the European level, I am convinced that the heat pump market is poised for growth. New technology developments, like more efficient air source compression heat pumps, hybrid heat pumps mainly combining heat pumps with small gas boilers and thermally driven heat pumps, are closing black spots on the heat pump application map.

The technology is increasingly ready to cover most of Europe's energy needs. Additional RD&D funding efforts will speed up this development.”

What are the main challenges facing the market and what support is needed at a policy level to meet these challenges?

T.N.: “The main challenges are socio-economic rather than technical. If stakeholders understand that the technology is mature, reliable and applicable, they can start factoring it into their planning processes. This applies to the individual user as much as to the industrial or administrative procurement manager. Possibly the biggest challenge is connected to up-skilling the work force. The use of heat pumps in buildings requires planners, architects, designers and installers to understand the interaction between a building envelope and heating technology. While many individuals have this knowledge, its wider distribution to all related actors is still a challenge that needs to be tackled through education and training programs.”

What are the main research needs that should be addressed for heat pumps, and is this research being sufficiently funded in Europe?

T.N.: “Heat pumps are a mature technology that can still be improved. Major advancements are expected from research on the development of products ready for the mass market - this includes more compact units and an optimisation of total cost of ownership.

In light of more renewables in the electric grid, heat pumps must be developed into a bridging technology between electricity and heat. Control units that can evaluate and integrate weather data and user behaviour lead to more efficient systems - both at the local level but also at the level of the grid. Heat pump systems will provide load shifting potential to electric grids, serving as thermal batteries. Research on the proof of concept of this function in smart homes and smart cities and its impact on the business case of the different stakeholders is necessary. New materials, optimised production, installation and maintenance as well as the integration of information technology into heat pumps and systems could be addressed in the calls of the EU's Horizon 2020 program, but also in national and regional R&D schemes.

Reviewing past funding rounds in FP6 and FP7 leads to the conclusion that the support given to heat pump technology does not match its potential. To speak plainly: increasing and stabilising the amount of heat pump funding over the coming years, will help the European citizen, European industry and Europe as a whole.”

Thomas Nowak

Thomas Nowak has more than 15 years of experience in the field of renewable energy. Currently, he is responsible for the management and development of the Brussels-based European Heat Pump Association (EHPA), an industry lobby group with more than 110 members. He is also a board member of the EU Renewable Heating and Cooling Platform and a contributor to scientific publications including the IEA energy technology perspectives and the REN21 Renewables Global Status Report.
Thomas holds a degree in business administration from the University of Paderborn, Germany.

SETIS FEATURE ARTICLE

GROUND-MED
- demonstrating the next generation of geothermal heat pumps

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GROUND-MED (Advanced ground source heat pump systems for heating and cooling in a Mediterranean climate) is a project financed under the European Union's Seventh Framework Programme (FP7) that aims to verify the sustainability of heat pump technology for heating and cooling of buildings in a Mediterranean climate and to demonstrate the next generation of geothermal heat pump (GSHP) systems for heating and cooling.

The six-year project, which started in 2009 with a budget of approximately EUR 7.25 million, was implemented by a consortium of 24 organisations from EU Member States at 8 demonstration sites in Southern Europe . The consortium includes a wide diversity of GSHP actors, such as research and educational institutes, heat pump manufacturers, and national and European industrial associations.

The scope of the GROUND-MED project was to develop, demonstrate and monitor advanced ground source heat pump (GSHP) systems with a seasonal performance factor (SPF) higher than 5.0 (the average for GSHP currently installed in the EU is 3.5). The project, which was completed on 31 December 2014, comprised 25% research and 75% demonstration and dissemination activities and examined GSHP as an integrated system comprising a borehole heat exchanger (BHE) field, a water/water heat pump and an indoor heating/cooling system, with the objective of maximising the energy efficiency of the overall system.

While previous projects focused on improving the coefficient of performance (COP), with the GROUND-MED project the focus of technological development was on the SPF of the heat pump, which means that the capacity control of the heat pump played an important role. Different options were considered, including inverter-controlled compressors and tandem compressors. An additional gain in SPF was achieved by maintaining the heat exchangers in counter flow operation during both heating and cooling modes.

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Other system components were also considered, with a view to developing advanced fan-coil units with power consumption reduced by a factor of 4, improved air handling units with low primary energy use, as well as advanced heat storage nodules, which allow intraday storage of heat and cold at optimum temperatures for maximum energy efficiency. Further energy efficiency improvements were achieved by selecting water circulating pumps from among the energy class-A brands available from European manufacturers.

Special attention was also paid to the GSHP control system, with a view to regulating the temperature of both the BHE field and the water supply to the indoor system. This was done in order to force the system to operate with the lowest possible temperature difference (ΔT) across the heat pump, resulting in the maximum possible SPF. This was achieved by adjusting the water temperature proportionally to the heating or cooling load. In terms of heat pump efficiency, this operating temperature adjustment results in the COP improving from 4.5 to 5.9, which is equivalent to an SPF increase from 4.5 to 5.75. This, in turn, results in 20% less electricity consumption by the heat pump.

Last but not least, as the project targets regions with a Mediterranean climate, cooling is of extreme importance. This poses additional challenges for BHE design and sizing and sets high standards for the heat pump efficiency. While poorly designed GSHP systems can still operate fairly well in heating mode, albeit at the expense of energy efficiency, only the best heat pumps in terms of COP coupled to state-of-the-art BHEs can provide reliable and cost effective operation in cooling mode.

The GSHP technology developed within the framework of the project was applied in buildings at the eight demonstration sites, where advanced GSHP systems for heating and cooling were constructed. For technology evaluation purposes, four different SPF values were calculated considering electricity consumption at: the compressor; the compressor and external circulation pump; the compressor and both external and internal circulation pumps; and the compressor, all pumps, fan-coils and air handling units.

Technology tested as part of the GROUND-MED project includes new prototypes which have been integrated into the eight GSHP systems demonstrated and monitored at the sites. These include three heat pump prototypes from the Austrian manufacturer OCHSNER WP, which are advanced in terms their energy efficiency. The project also demonstrated two advanced heat pump prototypes from the Italian manufacturer HIREF, one with tandem compressors and another with an inverter compressor. The improved performance of these various prototypes resulted in energy savings of 35%.

Also demonstrated, and also producing energy savings of 35%, were three advanced heat pump prototypes from the French manufacturer CIAT with Eurovent class-A energy efficiency levels. Their main features of these pumps are their tandem compressors and water reversibility via four three-way valves. CIAT also provided an improved cold storage system, optimised for better efficiency, in addition to new advanced fan-coil unit prototypes. The latter are characterized by their low-temperature operation and by their extremely low electricity consumption (80% electricity savings).

The effective demonstration of these technologies was the first step towards their large scale market penetration. Successful implementation of the GROUND-MED project will result in increased support for these renewable energy technologies through EU and national funding programs, allowing them to effectively contribute to the EU's 20/20/20 targets. The economic benefits of this research and demonstration work will be felt in the long term, when the technology and solutions developed through the project are replicated throughout the EU and international heating and cooling markets.

For more information:

http://www.groundmed.eu/

1. Septèmes -les-Vallons, France; Oradea, Romania; Coimbra, Portugal; Benedikt, Slovenia; Valencia and Barcelona, Spain; Padova, Italy; and Athens, Greece.
2. This is defined as the ratio of useful energy delivered by a heat pump to the electricity consumed over a season.

SETIS FEATURE ARTICLE

ReGeoCities

- promoting shallow geothermal as a resource for Europe's cities

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Geothermal energy is defined as heat from the earth. In practical terms, geothermal resources are thermal energy reservoirs that can be exploited at costs competitive with other forms of energy and are classified according to their reservoir fluid temperatures into low-, medium- and high-enthalpy fields. The very shallow geothermal energy within the first 10 meters below the Earth's surface is mainly influenced by solar energy input rather than by heat from the Earth's core.

While in the public understanding it is mainly the energy contained in deep aquifers that comes to mind when thinking of geothermal energy resources, the fact is that even the temperatures found at very shallow depths may be used to extract and store heat. Consequently, the heat resource offered by shallow geothermal energy (SGE) can be used as an efficient source of heating and cooling (H&C) for residential, commercial and industrial buildings. SGE systems are more efficient than traditional oil & gas-fuelled H&C systems, and therefore offer significant potential for the decarbonisation of the heating sector. While there is a consistent legal definition for geothermal energy generally in various European countries, few have a detailed legal definition for SGE. In fact, agreeing specific definitions for shallow geothermal resources is one of the key recommendations arising from the ReGeoCities project, launched in 2012 with the support of the Intelligent Energy Europe programme. Nevertheless, it can be said that SGE in Europe always refers to depths of less than 500 meters, and even less in several countries.

In terms of the number of installations, installed capacity and energy produced, SGE is the largest geothermal energy sector in Europe. In some regions, such as Iceland for example, hot water or steam

may be piped directly into radiators. However, the most widespread technology by means of which Europe taps into its geothermal resource is the ground source heat pump (GSHP). Ground source heat pumps convert the low-temperature shallow geothermal energy, which is available almost everywhere, into thermal energy at a higher temperature which can then be used for space and/or water heating. These systems usually involve circulating an antifreeze solution inside a closed coil to exchange heat with the heat source/sink through a ground heat exchanger. While in the United States water-to-air systems are the most popular technology, in Europe water-to-water systems are more common. The ground collector of a GSHP mainly takes the form of horizontal loops or vertical loops made of polyethylene or polypropylene tubes. A third possibility uses so-called geostructures, where the loops are installed in the foundation piles of a building. However, horizontal loops are the most common system, as these offer the lowest costs.

According to the Eurobserv'ER[1] heat pump barometer, geothermal heat pump sales in 2012 amounted to about 100,000 units, down slightly from about 108,000 units in 2011. In both years brine-water systems accounted for the vast majority of sales. Largely thanks to these sales figures, and the increased efficiency of existing heat pumps, geothermal production is exceeding targets set in National Renewable Energy Action Plans (NREAPs). In 2012, shallow geothermal heat production, mainly through the use of ground source heat pumps (GSHP), exceeded the NREAP target by 40% (JRC 2015[2]).

Recent innovations in shallow geothermal technology include the addition of underground thermal energy storage (UTES). UTES technologies include aquifer thermal energy storage (ATES) and borehole thermal energy storage (BTES). ATES systems utilise aquifers to store low-grade thermal energy such as solar heat during off-peak periods. This energy is used to heat or cool water, which is then injected into an aquifer for storage. BTES systems are designed in such a way that heat is built up in and extracted from a cylindrical volume of soil or rock. In both systems, the underground temperature is changed by injecting heat or cold which can then be retrieved for later use. Solar thermal collectors can also be added to GSHP systems. These can be added directly to the GSHP's ground loop to increase the efficiency of the system while reducing the demand for land area (JRC 2015).

Among the recommendations made in the Geothermal Regulation Framework[3], published in 2009 with the support of Intelligent Energy Europe, an emphasis was placed on the need for streamlined administrative procedures for geothermal licensing. In recognition of this requirement, the ReGeoCities project set the streamlining of administrative barriers as one of its main aims. The project, which is working to integrate SGE at a local and regional level, is focused on supporting European cities in reaching their Sustainable Energy Action Plans (SEAPS) and the 2020 climate and energy goals by examining and promoting best practices and an intelligent regulatory framework.

With a view to achieving these aims, the project consortium conducted an Analysis of the Market for Shallow Geothermal Energy, which found that after tremendous market development in some European countries until about 2009, economic factors resulted in a decrease in annual new installations over the past few years. In addition to economic factors, the report also found that overregulation in some countries resulted in increased costs and time. To evaluate the extent of this problem, the project carried out an overview of the current legislative framework in Europe. This resulting report, which was created using 11 national reports produced by the ReGeoCities partner countries, presents reliable and up to date information about the market conditions and barriers for SGE.

The ReGeoCities also conducted an analysis of best practices in the partner countries and, based on this, identified a list of key measures to provide the required basis for the development of the shallow geothermal sector at national, regional and municipal level. Many of these key measures address shortcomings in the legislative and regulatory framework, and include the development of adequate legislative and regulatory instruments for the management and deployment of SGE systems and, as already mentioned, agreeing specific definitions for shallow geothermal resources in the context of existing legislation and regulations. The project's Best Practice Analysis Report[4] also recommends the development of a simplified permitting and application system for small domestic installations, along with specific regulatory procedures for larger and more complex SGE systems.

One barrier to the development of SGE systems, mentioned by almost all the ReGeoCities partner countries, is a lack of knowledge about technologies and support incentives and a lack of information on the potential for installing GSHP systems, including the low dissemination of data from running operations. By addressing these information gaps, the ReGeoCities project is supporting European cities in their efforts to integrate geothermal into their energy mixes and promoting geothermal energy as a viable source of heating and cooling for the European market.

For more information:

http://regeocities.eu/

1. http://www.energies-renouvelables.org/observ-er/stat_baro/observ/baro218_en.pdf
2. https://setis.ec.europa.eu/system/files/2014%20JRC%20Geothermal%20Energy%20Status%20Report.pdf
3. http://ec.europa.eu/energy/intelligent/projects/sites/iee-projects/files/projects/documents/gtr-h_final_gtr_h_framework.pdf
4. http://regeocities.eu/wp-content/uploads/2014/06/D3-1-Best-Practice-Analysis-Report.pdf

Technology, market and economic aspects of geothermal energy in Europe

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A recent report[1] by the Joint Research Centre, the European Commission's in-house science service, analyses the geothermal energy sector in the EU and assesses the status of technology, ongoing developments, related policies and markets [Sigfusson and Uihlein 2015]. This article presents some key findings from the report.

Geothermal energy is a renewable source of energy that can provide constant power and heat. Geothermal resources have been used by mankind in some form for thousands of years. Depending on the temperature of the resource, it may be used for power production, supply of heat or a combination of both. Geothermal energy is derived from the thermal energy generated and stored in the interior of the earth. This energy is accessible, as groundwater transfers the heat from rocks to the surface either through boreholes or natural cracks and faults.

The geographical distribution of heat within the Earth's crust is highly variable. The highest heat gradients are observed in areas associated with active tectonic plate boundaries and volcanism. The geologic potential (heat in place) for geothermal power in Europe and the world is very large and exceeds the current electricity demand in many countries. However, only a small portion of the heat in place can be realistically extracted due to technical and economic barriers.

The geothermal sector relies on diverse technologies that need to be adapted to the resource depth and temperature as well as to water availability at any given location. So far, no general consensus has been agreed on how to classify geothermal heat sources and production. The JRC report followed the classification which has been adopted by Eurostat and national statistics offices: power generation; direct use; and ground source heat pumps.

The three types of geothermal energy use differ in terms of available resources; while heat from shallow depths is available almost everywhere, hydrothermal resources are limited in Europe (Table 1). The technologies applied in the different sectors are of variable maturity and may therefore need different forms of public financial support to reach the state needed for further commercial deployment. For all three types, research, development & demonstration (RD&D) should focus on developments that allow cost reductions and increases in efficiency (e.g. drilling costs and design optimisations).

Table 1. Overview of technology status, current RD&D focus and development areas

	Power generation	Direct use	Ground source heat pumps
Resource	Limited size of hydrothermal resources, large scale deployment requires engineered geothermal systems (EGS)	Widespread resource available at economic drilling depths	Heat from shallow depths, available almost everywhere
Technology status	Proven technology (dry, flash, binary), pilot projects (EGS)	Proven technology, use of conventional equipment	Proven technology
Main RD&D focus	Lowering costs for drilling and heat exchangers	Improved economics of direct use projects	Further increase efficiency and reduce costs
Development areas	• Cost reduction of injection and production wells • Increase efficiency (improve heat transfer, mechanical efficiencies) • Scaling-up of EGS demonstrations • Control deep-rooted fractures (exceeding 5 km) in order to create a large area for heat transfer and ensure sufficient mass flow between wells and minimise the risk of induced seismicity	• Extend lifetime of doublet design projects by drilling a third production well (triplet system) • Smaller systems with shallower resources, used in combination with large heat pump systems • Low-medium temperature resources used in combined heat and power applications (binary cycle and subsequent direct use)	• Ease of maintenance and repair • Improve control systems • More efficient working fluids • Increased efficiency of auxiliaries (e.g. pumps, fans) • Improve ground collectors (e.g. optimisation of design, grouting material) • New antifreeze fluids (environment, thermal characteristics)
Recommendations	Demonstrate EGS technology under different geological conditions (proof of concept)	Integration of old buildings being refurbished into district heating networks (short term) Integrated local/regional approaches (reduce cost, increase security of supply)	Optimise all components of borehole heat exchangers (especially pipe materials & thermal transfer fluids

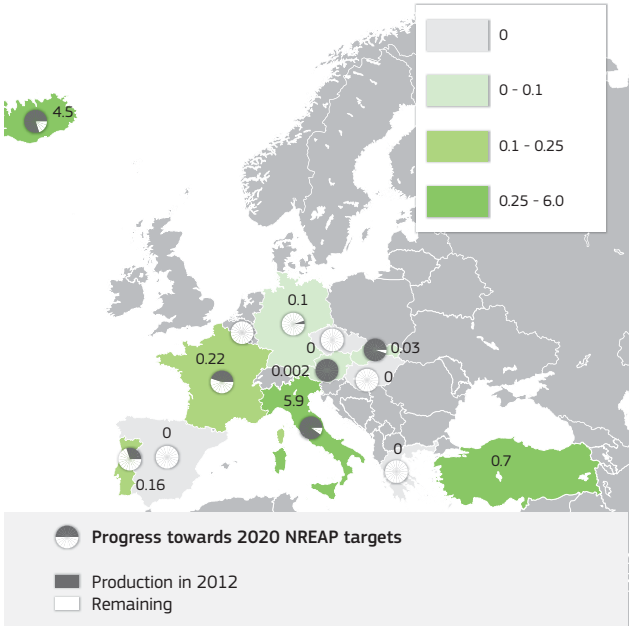
In general, the leading markets for geothermal energy are America, Europe and Asia. On the global and European geothermal energy market, the installed capacity of ground source heat pumps is greatest (about 33.1 GW), followed by direct use (about 15.3 GW) and power generation (about 10.7 GW). Some countries have significant shares for ground source heat pumps (GSHP) while in others power generation dominates. The highest total installed capacity of geothermal energy is in the United States, followed by China, and Sweden. The top 10 countries account for about 75% of total installed capacity worldwide.

The installed GSHP capacity in the EU has reached about 14.9 GW with the main markets being Sweden, Germany, France, and Austria. The number of installed units increased by about 6% in 2011-2012. The EU GSHP market has been shrinking in recent years because the market is very much dependent on the new building market. As the construction sector continues to shrink and fewer houses are being built, fewer GSHP units are sold [Observ'ER 2013]. However, the market is expected to recover over the next few years.

The installed capacity for direct use of geothermal energy for heat in the European Union was about 3.0 GW in 2012, with the highest direct use in Italy, Hungary, and France. Direct use increased by almost 25% between 2011 and 2012. However, an improved methodology to calculate direct use was introduced between 2011 and 2012, which leads to higher capacity, especially for therapeutic baths in Italy. The main direct uses in the EU are heating networks (about 50%) and therapeutic baths (about 20%). Geothermal district heating currently accounts for about 0.5 % of the total district heating market [Euroheat 2014].

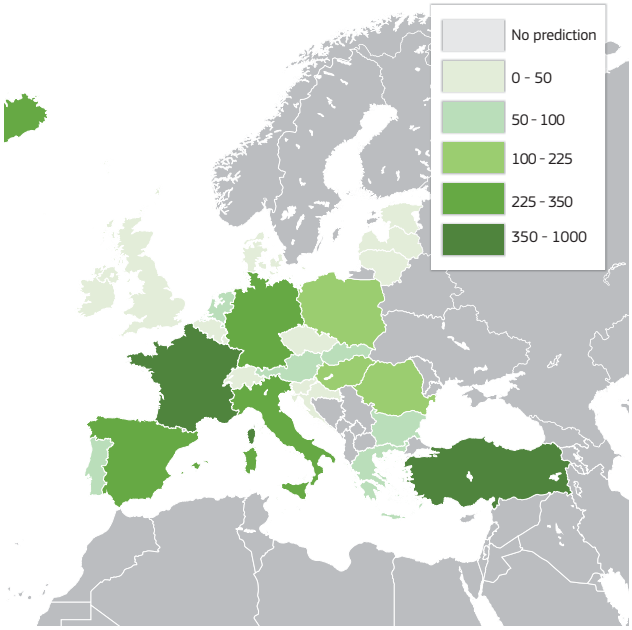
The installed capacity of the 51 power plants in operation in the EU is about 0.95 GW. In 2013, new plants were added in Germany (16 MW), Italy (1 MW), and Romania. Production of electricity in the EU reached about 5.4 TWh in 2012 [Eurostat 2014] and electricity production from geothermal energy in the EU has been relatively stable over the past ten years. In 2012, geothermal energy provided about 0.2% of the total final electricity demand (about 2800 TWh) and 0.9 % of the electricity generated by renewable sources (about 660 TWh) in the EU.

Power production in 2012 (TWh)



Source: EGEC 2013, Eurostat 2014

Potential power production in 2050 (TWh)



Based on data from van Wees et al 2013

The geothermal industry is small with few companies active in the supply chain. The activities in the power and direct use sectors range from exploration, drilling and engineering, to construction and plant operation. One strategy pursued is vertical integration. Most of the integrated companies play a major role in the geothermal sector of a certain region or country and are now aiming to expand their footprint globally. Other companies in the geothermal sector offer highly specialised services such as drilling, geothermal engineering, or act as suppliers of specific plant components.

The European GSHP market has developed from a market with many small local companies to a market dominated by major heating and air-conditioning manufacturers. The manufacturers' countries of origin very much mirror the main GSHP markets, with many big producers coming from Germany and Sweden. Asian manufacturers, which have been focussing on air/air heat pumps and air conditioning in the past, are now more active on the European GSHP market.

There are several EU directives affecting the geothermal sector, the most important one being Directive 2009/28/EC on the promotion of the use of energy from renewable sources adopted on 23 April 2009 [EU 2009]. This Directive introduces National Renewable Energy Action Plans (NREAP) that each Member State must adopt. These lay out how the Member State will achieve the mandatory 20% of energy from renewables target by 2020. NREAP include the use of geothermal for power production as well as heating and cooling and 19 Member States have adopted one or more geothermal categories into their NREAP.

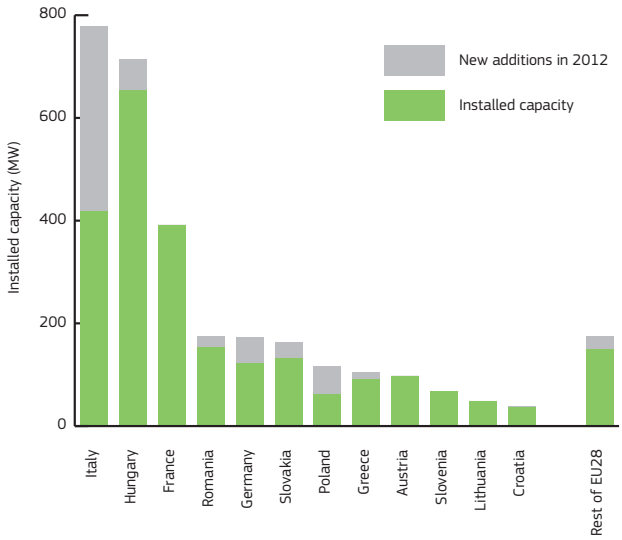
In 2012, the installation of geothermal power plants and heat production from GSHP exceeded EU NREAP targets for the year (Table 1). However the results fell slightly short of EU targets for direct heat production. The JRC analysis shows that the situation varies by country and for each type of geothermal energy. Some countries have already reached their 2020 targets (especially for GSHP), while others have yet to reach their 2012 targets and some have yet to initiate geothermal power production, even though they have set targets.

Table 2. Geothermal power capacity and heat production in the EU-28 in 2012 and NREAP targets in 2012 and 2020

Type	Unit	2012 reported values[1]	2012 targets	2020 targets
Shallow geothermal (mainly GSHP)	Heat production (GWth)	27080	18946	49340
Direct use	Heat production (GWth)	9404	10440	30589
Power generation	Installed capacity (MWe)	876	787	1612

1. Source: [Antics et al. 2013]

Installed direct use capacity in the EU and new additions in 2012 according to country



Source: [EGEC 2013]

For power generation, the 2020 NREAP targets are far below the projected economic potential of 2050 [van Wees et al 2013]. Currently Italy (2.6 %), Iceland (1.4 %) and Portugal (0.25 %) are the only countries where power production is above 0.1% of projected 2050 economic potential. Only 12 countries have included geothermal power production in their 2020 NREAPs. However, although geothermal power production is currently not economically feasible in many Member States, in the long term, geothermal power production may be considered a viable option provided technological bottlenecks are overcome and EGS technology is proven to be commercially successful.

Currently, the market share of geothermal energy in Europe is still small. Large scale deployment of geothermal power production requires the demonstration of successful EGS projects and a reduction of drilling costs. The most important market push instrument for geothermal power production would be the implementation of a European geothermal risk insurance to ease investments in geothermal electricity projects.

The future deployment of shallow geothermal energy and direct-use resources for district heating is very much linked to the recovery of the building sector. During refurbishment, heating and cooling systems of existing buildings should be integrated into district heating and developers of new buildings and infrastructures should be made aware of the flexibility and benefits of geothermal resources.

For more information and references:

https://setis.ec.europa.eu/publications/jrc-setis-reports/2014-jrc-geothermal-energy-status-report

1. https://setis.ec.europa.eu/publications/jrc-setis-reports/2014-jrc-geothermal-energy-status-report

Bergur Sigfusson - Scientific Officer, DG JRC, EC

Bergur Sigfusson is a Scientific/Technical Project Officer at the Joint Research Centre of the European Commission. His main interests are the socio-economic and techno-economic assessment of geothermal energy. He also works on reservoir simulations of Engineered Geothermal Systems. Bergur holds a PhD in Soil Science from the University of Aberdeen.

Andreas Uihlein - Scientific Officer, DG JRC, EC

Andreas Uihlein is a Scientific/Technical Project Officer at the Joint Research Centre of the European Commission. His main interests are the socio-economic and techno-economic assessment of emerging renewable energy technologies, in particular geothermal and ocean energy. He also coordinates the Joint Research Centre's activities related to the NER 300 programme. Andreas holds a PhD in Engineering from the Technical University of Darmstadt.

SETIS FEATURE ARTICLE

GEOCOM - increasing the visibility of geothermal energy

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Central-Eastern European countries have exceptional geothermal resources, which are either unexploited due to a lack of technological know-how, or their utilisation is being conducted in an unsustainable manner. To address this technological shortfall, the Geothermal Communities (GEOCOM) project was launched in 2010 with the aim of demonstrating best available technologies in the use of geothermal energy combined with innovative energy-efficiency measures and to increase the visibility of direct heat applications of geothermal energy throughout Europe.

GEOCOM is a project of the CONCERTO initiative, co-funded by the European Commission as part of its Seventh Framework Programme (FP7). The project, with a total budget of EUR 11.5 million of which the EU is contributing over EUR 3.5 million, showcases a wide array of research and demonstration components to ensure not only first-hand experience for the communities involved, but also to provide the international scientific community with valuable results related to currently-pressing geothermal issues, such as reinjection of heat-depleted brines into sedimentary reservoirs and trans-boundary utilisation of geothermal aquifers.

The main objective of the project, which initially ran until the end of 2014 but has been extended until December 2015, is to implement pilot-scale demonstration of geothermal energy utilisation at three demo-sites in Morahalom (Hungary), Galanta (Slovakia) and Montieri (Italy). The demonstration activities include the development of a geothermal district heating system, the integration of geothermal heating with other renewable energy sources (RES) and the execution of energy efficiency measures such as complementary retrofitting actions on selected buildings. The broad geographical coverage of the sites enables the project to implement different technologies based on local needs while at the same time increasing the replication potential of the project's deliverables. One of the key elements of the project is the efficient dissemination of information and training activities, aimed both at raising public awareness about RES use and at helping to transfer the project's technology and approach to other communities in the region and beyond. All the demonstration actions of the project are supported by socio-economic research, which runs in parallel, in order to monitor public acceptance of these interventions and public opinion about geothermal energy in general.

"By achieving these key demonstration and scientific objectives GEOCOM will contribute towards de-carbonising the energy system in a sustainable way, using cost-effective and resource-efficient technology solutions that are fully in line with the objectives of the Strategic Energy Technology Plan and of related energy legislation and energy policies designed to deliver the 2020 targets," GEOCOM Coordinator István Pári told SETIS.

The project's three demonstration sites have their own distinct geological features and socio-economic conditions. A feature of the thermal waters in the Morahalom region (and, more broadly, in the south of Hungary) is their rather high inherent dissolved gas content (average 520 l/m^3 with 87% CH4). In other words, for every 2 m^3 of thermal water produced there is an average of 1 m^3 of methane which was previously released to the atmosphere. As part of the GEOCOM project, two small-scale combined heat and power (CHP) engines were installed at each of the production well sites to utilise the separated gas content of the produced fluid, which amounts to roughly 90 m^3 CH4/year.

At the Hungarian site, monitoring has supported the initial idea that the achieved savings would become more and more significant as the project progresses and the individual investment components begin to complement each other. For example, three buildings were connected to the geothermal cascade system in 2010, which immediately resulted in a reduction in the natural gas use projected for the year. However, the major breakthrough came in 2011, when the total amount of natural gas used for heating at the three locations fell by almost 90%. Additional savings were achieved by retrofitting the buildings: by improving the thermal qualities of the building envelope the amount of gas needed fell even further - to only 1.1% of the initial value from 5 years earlier.

Meanwhile, near the Slovakian site in Galanta, local real-estate development initiatives called for a sustainable and green energy supply. This demand resulted in the partial refurbishment and extension of a 30+ year-old district heating system within the framework of the project. The new buildings are supplied with geothermal district heating and year-round domestic hot water, offsetting approximately 237,000 m^3 natural gas consumption and 440t CO_2 emissions annually. The Galanta site, which also focused on improving the energy efficiency of residential estates using geothermal heat, saw its annual heat demand fall by 40%. Furthermore, a total of five new estates were connected to the city's existing geothermal heating network in 2012, to take advantage of the surplus heat resulting from the retrofitting efforts.

The project activities at the Italian site in Montieri involve the whole community and aim at achieving three distinct outcomes. First of all, the project involves building a brand new and highly-efficient district heating system (6.26 MW) to utilize high-enthalpy geothermal steam from the site's Montieri-4 well. To ensure that the maximum benefit is received from this heat, the project will also see a number of selected public buildings being retrofitted. Finally, an 8.5 kW solar PV system is being deployed as part of an integrated RES system.

The GEOCOM project also integrates a number of cities as project partners (from Serbia, Romania, Poland and FYROM). These cities either have existing geothermal systems that require technological upgrades, or they would like to implement new systems from scratch with the help of the project partners. The replication potential of the GEOCOM actions is clear, and can be quantified by looking at the number of small-scale private initiatives launched in the neighbourhood of the project sites over the past four years. These initiatives have been driven by building owners wishing to take advantage of the results yielded by the project and to improve the energy efficiency of similar buildings which did not participate in GEOCOM. Energy savings generated by these additional side-projects will release supply on the side of the heating provider, encouraging it to sign up more consumers of renewable energy.

Even though the GEOCOM project is now set to run for another year, the major investment components have already been carried out and are in place. The project's unique approach, focusing on the direct heat applications of geothermal resources, demonstrates that even low-medium enthalpy geothermal systems, which are much more abundant than their high-temperature counterparts, can be harnessed effectively using state-of-the-art technology and adequate planning. It is expected that the local actions in each of the participating countries will be adopted by neighbouring communities in the future. The goal of the project is to disseminate the knowledge and technological solutions proven at the demonstration sites among a target group of municipalities and decision-makers with the ultimate aim of reinforcing direct geothermal heat applications and systems throughout Europe.

For more information:

http://www.geothermalcommunities.eu

SETIS FEATURE ARTICLE

Preparing the way for geothermal DH&C

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Geothermal district heating involves the use of geothermal energy to provide heating to residential, commercial and industrial buildings through a heat distribution network. The first regions in Europe to install geothermal district heating systems were those with the best hydrothermal potential. However, technological advancements and the development of new systems have resulted in an ever increasing number of regions developing geothermal technology for heating and cooling.

There are currently around 250 geothermal district heating plants (including cogeneration systems) in Europe, with a total installed capacity of some 4.5 GWth. The plants in operation in 2012-13 produced approximately 13 terawatt-hours thermal per year (TWh th/y) for heating. Of the 250-plant total, 162 geothermal DH plants, with a total installed capacity of 1.1 GWth, are located in the EU-28. These plants produced 4256 GWh of thermal power in 2012 (GeoDH)[1]. In the broader European context, the main players are Iceland, which accounts for about 50% of the total installed capacity (2.2 GWth), followed by Turkey with about 20% (0.8 GWth) (JRC/EGEC 2013a)[2]. The 2014 Geothermal Energy Status Report[2] published by the Joint Research Centre, the European Commission's in-house science service, found geothermal district heating to be the geothermal sector with the most dynamic development. As a consequence, installed capacity is expected to grow - particularly in Germany, France, and Hungary. Meanwhile, Hungary and Italy have seen some major new capacity additions. A district heating plant was opened in Miskolc, Hungary in 2013 which may reach a capacity of 60 to 70 MWth; while in Italy the 6 MWth Monteverdi Marittimo district heating plant was inaugurated in the same year (JRC 2015/ REN21 2014)[2].

While these countries are the front-runners it should be stressed that, in light of technological advancements in the sector, geothermal DH systems can be installed in all European countries. In confirmation of this, there have been new entrants to the geothermal DH market recently, with capacity installed in the Netherlands, Spain and the UK, and nearly all countries in Europe are expected to have geothermal DH systems by 2020. One of the key findings of the JRC's Geothermal Energy Status Report was that geothermal direct use and ground source heat pumps (GSHP) for heating and cooling are

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best integrated into regional systems, in order to reduce costs and increase security of supply. The report also stressed that, if geothermal energy is to realise its potential to reduce CO_2 emissions in the heating and cooling sector, then the construction industry will need to become more aware of the flexibility that this technology offers.

In addition to flexibility, the other main benefits offered by geothermal heating and cooling are its provision of local baseload renewable energy, the diversification of the energy mix, and the protection it offers against volatile fossil fuels prices. These benefits were promoted by the GeoDH project, which ran from the start of April 2012 to the end of September 2014. With an overall budget of EUR 1.015 million, of which EUR 760,920 was provided by the European Union under the Intelligent Energy Europe programme, the project's goal was to encourage the wider uptake of geothermal energy in Europe. The overarching aim of the project was to accelerate the penetration of geothermal district heating in European Member States. With this in mind, GeoDH specifically aimed to remove regulatory and financial barriers to the uptake of geothermal technologies and simplify procedures for operators and policy makers. With respect to financial barriers, a specific goal of the project was to develop innovative financial models for geothermal DH to help overcome constraints hampering the funding of capital-intensive geothermal projects. Finally, with a view to addressing skills shortages in the sector, the project aimed to train technicians and decision-makers at regional and local authorities in order to provide the technical background necessary to approve and support projects.

The GeoDH consortium worked with countries with juvenile, transitional and mature markets and covered 14 countries in total, with the eventual aim that the project's activities would be replicated in all EU Member States. Policy and decision makers at national and local levels were the main focus of the activities, aimed at promoting a legislative and regulatory framework that was fit-for-purpose, and simplifying procedures at local level. The project also targeted banks, potential investors and other market players in an effort to stimulate investment in the sector. An effort was made to involve a second group of stakeholders - those who stand to benefit from better market conditions and who are interested in the tools provided by the project. These include national and local suppliers, designers and installers of district heating and cooling systems; district heating operators and DH associations; owners and tenants of large buildings; and educational and training institutions. These will also be active during the dissemination phase in order to reach as many stakeholders as possible across the EU.

GeoDH has resulted in increased awareness about the potential applications and benefits of DH&C with geothermal energy, with a set of recommendations for removing barriers and improving regulatory frameworks. The project has also fostered a better understanding of the related technologies, costs and financing and has facilitated the transfer of best practices to national and local authorities. One tool that aided this effort is a database of some of the geothermal district heating projects in Europe, which allows other potential users to understand how these systems work in practice. By providing solutions for developing geothermal DH in the EU, the GeoDH project has assisted Member States in implementing and completing their NREAPs on deep geothermal for heating and cooling.

For more information:

http://geodh.eu/about-geothermal-district-heating/

https://setis.ec.europa.eu/publications/jrc-setis-reports/2014-jrc-geothermal-energy-status-report

1. http://geodh.eu/wp-content/uploads/2012/07/GeoDH-Report-2014_web.pdf
2. https://setis.ec.europa.eu/publications/jrc-setis-reports/2014-jrc-geothermal-energy-status-report

Past Research and Innovation in the Seventh Framework Programme

Krafla, Iceland © Ásgeir Eggertsson

EGS, Enhanced Geothermal Systems, represent an opportunity for Europe to increase the number of viable geothermal sources for the production of electricity and/or heat, and build on the positive results obtained by the Soultz-sous-Forêts FP6 (Framework Programme 6) project. Under the Framework Programme 7 (FP7) two important projects were funded to tackle the main challenges that deep geothermal projects, and in particular EGS, face: mitigation of induced seismicity and reduction of project risks.

During operation of a geothermal plant water warms up while it circulates through the fractures of a reservoir. Seismicity is or might be induced during the so called "stimulation" phase, when water is injected at high pressure into a wellbore in order to open or widen fractures in the hot rock and create or improve a geothermal reservoir. Induced seismicity represents an important EGS technical issue that triggers public concerns and limits the public acceptance of geothermal energy.

Geothermal energy projects require high initial investments, mostly during the drilling phase. In case a well is not successful, i.e. the pre-conditions for exploration, as determined during the planning and design, are not met then the capital loss is large. As a result of such financial risks, the number of newly initiated geothermal projects, in particular of EGS projects, is therefore limited. In order to reduce the risk of these projects it is necessary to improve the way in which geothermal resources are assessed and to introduce new, or a combination of, methodologies.

To respond to these two challenges FP7 funded two projects. The project GEISER (Geothermal Engineering Integrating Mitigation of Induced Seismicity in Reservoirs) focused on investigating and mitigating seismicity induced during hydraulic stimulation. While under the project IMAGE (Integrated Method Advanced Geothermal Exploration Understanding Processes Properties Improve Techniques Integrate Predictive Model) a reliable science-based exploration and assessment method is being developed to reduce the risks of failures of geothermal projects. Most of the FP7 budget for geothermal energy was devoted to these two projects whereas a third area funded was heat pumps.

Mitigation of Induced Seismicity

The GEISER project started in January 2010 and lasted 3.5 years. It was implemented by a consortium of 13 participants and it addressed all aspects of scientific, technological and social issues related to seismicity associated with the development of EGS projects. Researchers studied the data collected during stimulation at different European and non-European sites in different bedrock types (sedimentary and granitic). During the course of the project a better understanding of the key parameters that control induced seismicity in response to an injection was developed.

The achieved results and the project main activities are published in the Project Final Report available in the CORDIS database[1]. The project developed a comprehensive probabilistic framework for the assessment of seismic hazards and risks, and it produced guidelines for safe and reliable EGS operations. It produced an advanced "traffic light system" to be utilized during all phases of a geothermal project (Figure 1). This system is a dynamic tool that is reliable if rock physics data and seismic data, with models updated from real-time monitoring, are available. The system allows adjustments during operation activated by the monitoring information that is fed into it.

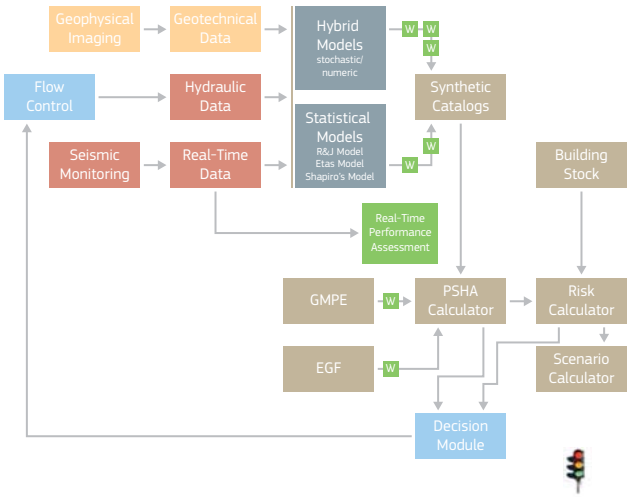

Figure 1: Advanced Traffic Light System.
Legend: W = weighting; GMPE = ground motion prediction equation; EGF = empirical green's function; PSHA = probabilistic seismic hazard assessment (figure taken from GEISER Project Final Report, project coordinator Dr. Ernst Huenges, GFZ).

The GEISER research results and guidelines produced, among other things, strategies for EGS operations with induced seismicity and they are an important step forward to help unlock the potential of geothermal energy in Europe.

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Imagining Geothermal Reservoirs to Reduce Risks

IMAGE is a large 4-year project that started at the end of 2013. The EC contribution is over EUR 10 million and the consortium includes 20 participants from industries, research institutions and universities. As summarized in the project website "the objective is to develop new methods to scrutinise and appraise geothermal systems in such a way that exploration wells can be sited with greater accuracy than before, thereby maximizing the success rate and reducing the cost of drilling associated with geothermal projects. In addition, such precision wells would reduce any potential environmental impact."[2]

The research covers both magmatic and basement/sedimentary geological conditions to which the developed interdisciplinary approach and research methods will be applied. The participation of industrial partners and the number of test sites that is to be used during the different phases of the project positions IMAGE very close to industrial applications and make it instrumental in lowering the risks of geothermal projects.

Research in the geothermal field in Horizon2020

With long-term goals in mind, it is therefore now essential to maintain momentum and funding in this sector. Within the Horizon 2020 programme, the EU aims to go the extra mile in supporting research and development. With a view to promoting a clean low-carbon European economy, catalysing the growth of the geothermal energy sector was foreseen under the first H2020 Work Programme of 2014-2015. For this, the focus of the Work Programme is on developing and demonstrating next generation technologies for renewable electricity and heating and cooling. For both deep and geothermal energy the challenge was to reduce drilling costs as they represent a significant share of the total costs of geothermal installations. The Work Programme also addresses the need to increase the number of geothermal plants in Europe and as a natural continuation of the previous work programmes it includes a call on EGS testing in different geological environments. The call deadline is in May 2015.

The next Work Programme 2016-2017 foresees addressing further research and innovation needs in the geothermal field. In particular, for both shallow and deep geothermal energy, there is room for improvement of components and systems, as well as prolonging the life cycle of facilities to lower the cost of energy as much as possible and to increase the contribution of geothermal energy, particularly heating and cooling, to the energy mix. In addition, public acceptance considerations of technologies have to be addressed.

For more information:

http://ec.europa.eu/research/energy/eu/index_en.cfm?pg=research-geothermal-support

http://www.image-fp7.eu/Pages/default.aspx

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1. http://cordis.europa.eu/result/rcn/143609_en.html
2. http://www.image-fp7.eu/beginners/Pages/presentation.aspx

Susanna Galloni - Research Programme Officer, DG RTD, EC

Susanna Galloni is a Research Programme Officer in the Renewable Energy Sources Unit of the Directorate-General for Research and Innovation of the European Commission. She is responsible for research and innovation policy activities and for the management of research projects in the area of geothermal and wind energy. Susanna holds a Master of Engineering degree in Civil and Environmental Engineering from the Massachusetts Institute of Technology.

SETIS FEATURE ARTICLE

The promise of continuous clean energy beneath our feet

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In 2010, after more than 20 years of research, development and testing, an experimental 2.1 MW geothermal power plant in Soultz-sous-Forêts, 50 km north of Strasbourg (France), became the first Enhanced Geothermal Systems (EGS) plant to be connected to the electricity grid. Rather than relying on naturally occurring steam produced by underground volcanic activity, EGS injects cold water from the surface into hot rocks deep underground. The heated water (at about 200°C) is then pumped back to the surface and used to drive turbines. The advantage of EGS, if it can become commercially viable, is that sites with subsurface layers of hot rock, like the granite beneath Soultz-sous-Forêts, are much more common across the globe than the volcanic regions traditionally associated with geothermal power production. However, the energy is much more difficult to harness, not least because of the costly deep drilling technology involved.

The attractiveness of more widely available geothermal energy, however, motivated a decision in 1987 to develop a pilot EGS plant on the site of former oil wells in Soultz-sous-Forêts, in the Upper Rhine Valley, where the geological conditions were right. A public-private consortium was set up, under the umbrella name of Géothermie Soultz, with industrial partners including French and German utilities (EDF, Electricité de Strasbourg, EnBW and Pfalzwerke), the chemical multinational, Evonik and German geothermal specialists, Bestec. Several public research centres are also part of the project, including the French National Centre for Scientific Research (CNRS) and the Geological Survey (BRGM). Public funding has come from the European Commission, under its Framework 6 and 7 programmes, the French environment and energy agency, ADEME, the German project management agency, PTJ and the German Federal Environment Ministry.

The idea of tapping into the Earth's natural geothermal energy to produce electricity is not new. The oldest geothermal plant, in Larderello (Northern Italy), first produced electricity – enough to power five light bulbs – as long ago as 1904. However, this site still relied on the availability of hot fluids relatively near to the surface. EGS, initially known as HDR (hot dry rock) geothermal energy, however, exploits the natural heat in layers of sedimentary rock over 3 000 metres below the surface. First developed in the Los Alamos National Laboratory (USA) in the 1970s, the principle involves injecting water from the surface, thus dispensing with the need for a local reservoir of groundwater to produce the steam needed to power electricity turbines.

The first challenge to develop EGS is to locate suitable subsurface rock formations. For the European pilot project, these were already known to exist in disused oil wells at Soultz-sous-Forêts. There also appeared to be an underground adjacent source of salty water, which would facilitate the production of steam. After drilling to shallow depths (2 km) in the 1990s and confirming the temperature gradient, three boreholes were finally drilled to about 5 000 metres, tapping into rock at the required 200°C. A central well is used to inject water from the surface – the underground brine source not being sufficient to power the turbines – and two adjacent collector wells, 700 metres apart in the rock, are used to pump the heated water back to the surface.

For EGS to work, though, the permeability of the naturally impervious granite has to be increased, by opening existing fractures and creating new ones. This is carried out either with hydraulic (using pressurised water) or chemical stimulation – both 'fracking' techniques borrowed from the oil and gas industries. It has proven essential to understand and monitor the network of fissures created, both to maximise the flow of water from the injection well to the collector wells and to manage the risk of triggering seismic activity.

A prototype commercial EGS being developed in Basel (Switzerland), at the same time as the Soultz project, was abruptly halted in 2006 when hydraulic stimulation triggered a 3.5 magnitude earthquake, causing damage to buildings. This innovative plant was situated in an industrial zone within the city and had been designed to be part of 'green' energy complex also incorporating a waste recycling plant. After this event, hydraulic stimulation at Soultz was abandoned in favour of chemical stimulation, using hydrochloric and organic acids.

At Soultz, once the hot water has been pumped to the surface, it is fed into an organic Rankine cycle process in a binary power unit to produce electricity. Isobutane is used as the working fluid rather than water, because of its lower boiling point. The cooled water can then be re-injected into the underground wells in a closed loop, to be reheated and pumped back to the surface. Of the 2.1 MW the plant produces, 1.5 MW of electricity is available to be fed into the grid, while the remainder is used to run the plant itself.

Now that the Soultz plant has been producing electricity continuously for almost five years, new research is being carried out to improve on existing techniques and develop new innovations. One measure of how much new ground has already been covered during the development of the Soultz project is the scientific output it has produced – some 40 PhDs and over 200 scientific publications. Now, attention is turning to the use of supercritical CO_2 as a heat transfer fluid, rather than water. CO_2 is potentially more efficient, with greater power output, reduced loss from pumping and cooling, and the added possibility of carbon sequestration. Another avenue being explored is to inject air into abandoned oil and gas reservoirs and exploiting the very high temperatures produced by in-situ combustion.

Following the success of the Soultz-sous-Forêts demonstration project, new partners are now being invited to invest. Meanwhile, utility companies and industrial partners are now exploring the feasibility of developing other, similar sites in Europe, including mainland France, Germany, the Czech Republic and the UK, while EGS projects are well advanced in Australia, Japan, and the USA. The French authorities have already awarded permits to carry out exploratory drilling at 20 sites in France, mostly in the former volcanic regions of Auvergne and Ardèche. Meanwhile, planning permission has recently been granted to develop a 3–4 MW EGS power plant at the Eden Project in Cornwall (UK). The energy produced would be sufficient to run the Eden project itself and to provide power and heat for around 4 000 homes nearby. And, the 100 year-old Larderello site in Tuscany has continued to evolve, incorporating new EGS technologies, making Italy one of the world leaders in geothermal heat and power production.

The main issue for EGS in Europe now is to demonstrate its long-term sustainability and to attract investors. The up-front costs of exploration, drilling and stimulation are still dissuasive, given that the technology may still be 10 to 15 years from maturity and that an EGS project can take up to 7 years to develop, from start to finish, with as much as five years for exploration, test drilling and field development before the plant itself is constructed. But, if these obstacles can be overcome, EGS has the potential to open up a largely untapped source of continuous, base-load electricity for millions of users, without the intermittency issues and storage requirements of solar and wind.

For more information:

http://ec.europa.eu/research/energy/eu/index_en.cfm?pg=research-geothermal-support

SETIS FEATURE ARTICLE

Ultra-deep drilling turns a corner

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In theory, constant, base-load electricity could be available 24 hours a day, 7 days a week, with near-zero carbon emissions, almost anywhere in the world. This is because there is hot rock beneath our feet, no matter where we are. Unfortunately, because of the thermal gradient in most parts of the world, the layers of rock that are hot enough to be exploited to produce electricity are only found at depths of over 5 kilometres (see article in this issue on Enhanced Geothermal Systems). And supercritical water (SCW), an equally abundant geothermal source, with temperatures of over 374°C, is usually found at depths of over 10 km and at pressures of up to 1000 bar. Drilling to these depths and in such extreme conditions tests the limits of currently available technology and, above all, becomes prohibitively expensive. But revolutionary ultra-deep drilling technologies, such as high-pressure water jets combined with electric-discharge plasma, could be set to change this.

The most widespread geothermal deep drilling technology is the rotary drill, which has been in use since the introduction of the tri-cone rotary bit in 1909. Diesel-electric drilling rigs are used to create boreholes protected by steel casings. These are arranged one inside the other as drilling proceeds, leading to a progressive tapering, which limits the final size of the borehole. Typically, the cost of deploying this technology rises exponentially with depth. Indeed, drilling can represent more than half the cost of developing Enhanced Geothermal Systems (EGS).

Despite a number of improvements, such as the polycrystalline diamond compact (PDC) bits developed in the 1970s, the search is on for radically different, breakthrough technologies to lower these costs substantially, and to allow drilling to depths of 10 km, to exploit the geothermal energy potential of supercritical water. This is steam that has become so dense that its liquid water and steam phases merge into a single fluid. At present, drilling for supercritical geothermal resources is only feasible where there are unusually high geothermal gradients, such as in Iceland, where supercriticality occurs at a depth of about 4 – 5 km.

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As many as 20 new ultra-deep drilling technologies are currently being explored, such as plasma-jet rock cutting, the use of high-energy laser beams to disintegrate the rock by melting it (thermal spallation) and electrical discharge. But none of these has so far proven to be effective in the severe conditions found at depths of 10 km[1].

One of the reasons for the exponentially rising costs of using rotary bit technology for deep drilling is the need to replace worn-out drill bits. This involves withdrawing the 'string' - the interconnected drilling rods - bringing it to the surface, dismantling and then reassembling it. The deeper the well, the longer this process takes. The more interesting new developments are technologies where there is no drill bit and no direct contact with the rock.

One promising technology, which could be the breakthrough that the industry is looking for, is a variant of hydrothermal spallation drilling, where a jet of supercritical water is directed at rock at the bottom of a water-filled borehole (which is usually the case beyond depths of 6 km). Because the rock is a poor conductor of heat, only the upper layer is heated rapidly, eventually leading it to fracture into small fragments. In this case the corrosive nature of SCW, which is usually a handicap to conventional drilling techniques, is turned to good use, by aiding the disintegration process.

Along similar lines, with the help of a EUR 2.4 million grant from the EU Structural Fund, a Slovakian engineering company, GA Drilling (formerly Geothermal Anywhere) has developed a pulsed-plasma and ultra-sound cutting tool, known as Plasmabit, which is attached to the head of a long, coiled tube. As the cutting tool is fed down the borehole, the plasma and the ultra-sound pulses break up and disperse the rock without direct contact. Water is then pumped down the tubing and rises back up the borehole, enabling buoyancy to be used to bring capsules of drilled disintegrated rock to the surface.

Because there is no direct contact with the rock, there is no bit to wear out. GA Drilling claims that, by using its technology, the cost of drilling will only increase linearly with depth, instead of exponentially, thus drastically reducing the costs of ultra-deep drilling. Also, because of other new technology the company has developed, the inevitable tapering of the borehole with depth, found with conventional rotary bit systems, no longer applies, leading to the possibility of boreholes with a constant diameter from surface to rock.

The technology has passed its proof of concept stage and is now ready to be tested at moderate depths. GA Drilling has recently teamed up in a strategic partnership with UK geothermal engineering company EGS Energy, to use its contactless plasma drilling technology for a proposed enhanced geothermal systems initiative at the Eden Project in Cornwall (UK), which involves drilling two boreholes to a depth of about 4.5 km. Cornwall was also the location for Europe's first deep geothermal research and development facility, the Hot Dry Rocks project, at Rosemanowes between 1976 and 1991.

For more information:

http://www.geoelec.eu/wp-content/uploads/2011/09/D-3.3-GEOELEC-report-on-drilling.pdf

1. http://www.geothermal-energy.org/pdf/IGAstandard/ISS/2009Slovakia/VIII.5.Kocis.pdf

SETIS TALKS TO:

Ernst Huenges

EERA Geothermal Joint Programme Coordinator

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What are the main geothermal energy technologies, and which of these technologies has the greatest potential on the European market?

E.H.: “Geothermal energy technologies depend on the specific geological setting. We have hot water bearing horizons in many parts of Europe. We call them hydrothermal reservoirs. In addition, the ground all across Europe has increasing temperature with depths. The horizons which do not bear water are called petrothermal systems. A general technology to economically exploit these reservoirs is to follow the so called concept of Enhanced (or Engineered) Geothermal Systems (EGS). The EGS concept includes artificial improvement of the hydraulic performance of a reservoir with the goal of using it as a source for the economic supply of heat or electric energy. The enhancement challenge involves the use of several non-conventional methods for exploring, developing and exploiting geothermal resources that are not considered economically viable with the use of conventional methods.”

What is the current contribution of geothermal to the EU energy mix and how is this share expected to change in the medium to long term?

E.H.: “The current contribution is still very small compared to the huge existing potential. In the medium term a significant increase in geothermal heat supply can be expected, with a significant increase in geothermal power production in the long term. In the past we observed an increase in capacity of one order of magnitude in 20 years. With investment in research and development we have the chance to accelerate the deployment of geothermal technologies. However, it is important to note that a project with deep drill holes takes several years to implement and therefore the learning curve cannot be as steep as with other technologies, such as solar and wind, for example.”

What technical obstacles currently hinder the scaling up of geothermal energy? What are the research priorities to overcome these obstacles?

E.H.: “There are still research challenges that need to be addressed in geothermal exploration and reservoir engineering and also in the monitoring and reliable operation of geothermal plants. Let’s take reservoir engineering, for example: if we succeed in increasing the productivity per well, then we can achieve a significant reduction in the specific costs of energy supply.”

Is there potential to enhance geothermal output from resources that have already been identified / utilised? How does current research support this?

E.H.: “We have to invest further in EGS-technologies, because this enables the access to most of the European geothermal reservoirs. We learn most from operational projects. Therefore, increased investment in demonstrating the new methods would help a lot. We need several demonstration sites and each site requires investment in the order of EUR 10-30 million. Once we have these demonstrators in Europe, companies will be able to follow best practise and prepare for an extended market penetration. In addition, Europe will be able to retain its current technological lead in geothermal research.”

Is the existing energy infrastructure ready to accommodate an increase in geothermal energy? How can the energy system be adapted to ensure that geothermal reaches its full potential?

E.H.: “There are no special requirements to accommodate electricity from geothermal plants into the grid. However, adapting district heating to low temperature would significantly increase the demand potential for geothermal heat, similar to solar heat. Nowadays, district heating systems are usually fired with fossil fuel, allowing temperatures above 100 or 130 °C. For these temperatures we would have to drill much deeper than necessary because only temperatures of about 60 °C are required for heating purposes. To take advantage of lower temperatures, we need heat transfer stations with larger areas in order to get the same amount of heat to the customer.”

How does geothermal compare with other technologies in terms of levelised cost of electricity (LCOE)? Is there a cost target that the sector is aiming to achieve?

E.H.: “The LCOE of geothermal power depends on the site and specifically on the geological setting. For example, you don’t need to drill as deeply for geothermal energy in volcanic areas as in other regions. The LCOE of geothermal heat depends more on the size of the plant. Above a threshold of scale geothermal plants become competitive with any other source of heat supply.”

Is enough being done to increase awareness among decision makers and the public regarding geothermal energy? What other non-technical barriers exist and what needs to be done to overcome them? What role does the SET-Plan play in this process?

E.H.: “We are seeing a significant improvement in the visibility of the geothermal option within the context of the future environmentally friendly energy mix. The SET-Plan and the involvement of industry are crucial for a broader deployment of geothermal plants. As with almost all new technologies, there is a public debate about the environmental risks associated with geothermal energy production. Dialog with the public requires the participation of all actors in the geothermal chain, with the provision of fundamental explanations of all the processes involved and a clear assessment of the risks. Political support is needed in setting the right framework conditions, for example in the mining regulatory process, and in the form of incentives to accelerate market penetration.”

Professor Ernst Huenges

Professor Ernst Huenges holds degrees in physics and geology. He is head of the International Centre for Geothermal Research at the Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences in Germany and lecturer on geothermal energy systems at the Technical University of Berlin. His research focuses on safe and efficient geothermal technologies to make geothermal a reliable component of the future energy mix.

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