Philippe DUMAS
Luca ANGELINO
EGEC
Place du Champ de Mars
1050 Brussels, Belgium
e-mail: p.dumas@egec.org, l.angelino@egec.org

Technika Poszukiwań Geologicznych
Geotermia, Zrównoważony Rozwój nr 2/2015

GEOELEC: DEVELOP GEOTHERMAL ELECTRICITY IN EUROPE

ABSTRACT

The objective of the Geoelec project was to convince decision-makers about the potential of geothermal electricity in Europe, to stimulate banks and investors in financing geothermal power installations, and finally to attract key potential investors such as oil and gas companies and electrical utilities to invest in geothermal power.

The action plan that was developed for the removal of non-technical barriers will result in geothermal electricity drawing the attention of policy makers and industry, giving geothermal power the high profile it has in other parts of the world, and persuade capital ventures and other companies to seek to benefit from investing in the technology.

This project also aimed at effectively showing the potential contribution of geothermal electricity in all EU-28 countries, with a short and mid-term perspective. A strategy to reach these objectives was elaborated by describing the technical, financial, legal, social and environmental issues, and presenting concrete solutions. Notably special attention was paid to training new professionals in the sector and on the future job creation.

KEYWORDS

Geothermal electricity, potential, finance, regulations, training

* * *

INTRODUCTION

Geothermal power generation has its roots in Europe, where the first test in 1904 and the real beginning of power generation in 1913 took place, both at the Larderello dry steam field in Italy. Since then, the development of geothermal technology has been continuous and the

total installed capacity currently amounts to 2 GW_e, generating approximately 12 TWh of electric power every year. For a decade, thanks to the optimisation of the new binary system technology, geothermal electricity can be produced using lower temperatures than previously. Moreover, with Enhanced Geothermal Systems (EGS), a breakthrough technology proven since 2007, geothermal can in theory be produced anywhere in Europe.

The main benefits of geothermal power plants are provision of baseload and flexible renewable energy, diversification of the energy mix, and protection against volatile and rising electricity prices. Using geothermal resources can provide economic development opportunities for countries in the form of taxes, royalties, technology export and jobs.

The potential of geothermal energy is recognised by some EU Member States in their National Renewable Energy Action Plans (NREAPs). However, the actual potential is significantly larger. In order to increase awareness, Geoelec – an IEE project co-financed by the EU and running between 2010 and 2013 assessed and presented for the first time the economic potential in Europe in 2020, 2030 and 2050. The figures are quite impressive, showing the large potential of geothermal and the important role it can play in the future electricity mix.

Although geothermal energy has provided commercial base-load electricity around the world for more than a century, it is often ignored in national and European projections of energy supply. This could be a result of the widespread perception that the total geothermal resource is often associated with identified high-grade, hydrothermal systems that are too few and too limited in their distribution in Europe to make a long-term, major impact at a European or national level.

This perception has led to undervaluing the long-term potential of geothermal energy by missing an opportunity to develop technologies for sustainable heat extraction from large volumes of accessible hot rock anywhere in Europe. In fact, many attributes of geothermal energy, namely its widespread distribution, availability 24 hours per day all year round, base-load ability without the need for storage, small footprint, and practically zero greenhouse gas emissions, are desirable for reaching a sustainable energy future for the EU. This has been recently understood by decision makers in other parts of the world, where new geothermal prospects under development will result in doubling global installed geothermal power generation capacity in the next years.

The objective of Geoelec project was to convince decision-makers about the potential of geothermal electricity in Europe, to stimulate banks and investors in financing geothermal power installations and finally to attract key potential investors such as oil and gas companies and electrical utilities to invest in the geothermal power.

1. PROSPECTS FOR GEOTHERMAL ELECTRICITY IN EUROPE

This work became even more crucial after the publication of the 27 National Renewable Energy Action Plans (NREAPs) of EU Member States. Indeed, many countries showed their lack of knowledge about their deep geothermal potential. Geoelec proposed studying the

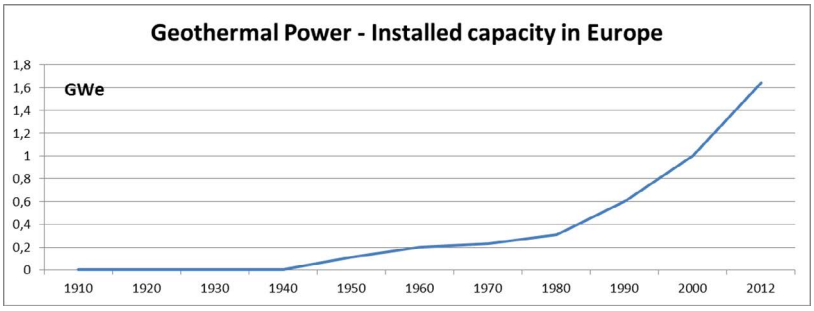

Fig. 1. Geothermal power: installed capacity in Europe, 1913–2013 [in GWe]

Rys. 1. Elektrownie geotermalne: moc zainstalowana w Europie, 1913–2013 [GWe]

potential to produce geothermal electricity in each of the 28 Member States plus Norway, Iceland, Norway, and Turkey.

1.1. Resource assessment

The first exercise was to present the available geological information in the different Member States. The long-term success of geothermal energy technologies depends upon a detailed characterisation of geothermal energy resources Europe-wide, including:

— an assessment of high temperature resource potential to fully leverage new low-temperature and EGS areas,
— development of a geothermal resource classification system for use in determining site potential,
— development of a data system to make resource data available to experts and professionals of the geothermal sector.

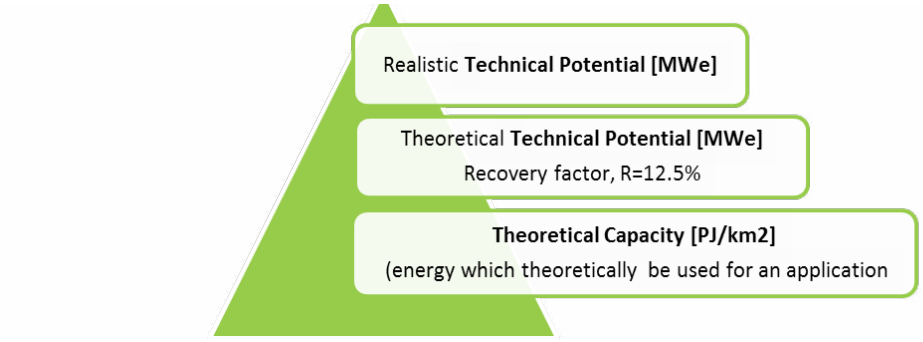

Fig. 2. Schematic workflow of different geothermal potential from theoretical capacity to realistic technical potential

Rys. 2. Schemat przedstawiający różne kategorie potencjału geotermalnego – od teoretycznego do realnego technicznego

This collection of information about geothermal resource assessment in Europe – estimating the magnitude and distribution of the EU Geothermal power/EGS resource, aims at the completion of the EC "Atlas of Geothermal Resources in Europe" published in 2002. This Atlas presents the geothermal resource (hydrothermal) up to 2 Km depths. The Geoelec project used this data, extrapolated, and completed it. The objective was to use all the existing maps and data in order to estimate the magnitude and distribution of hydrothermal and for the first time EGS resources at 0–5 Km depth all over Europe.

1.2. Electricity demand and grid infrastructures

Having collected data to present the geothermal potential, Geoelec studied the electricity demand and the grid access for geothermal in order to evaluate the potential contribution to the future electricity supply.

Recommendations as well as technical justifications are made for the inclusion of geothermal power in existing networks. Like other generating technologies that are integrated into the electricity grid, the basic principles of balancing, backing up, and aggregating apply to geothermal power as well. But geothermal electricity plants have the advantage of more than 90% availability, so it provides the 'base load' but also flexibility.

No matter how hot the resource nor how close it is to the surface, the developer must be able to connect to the electric grid at a point where there is sufficient available capacity to sell the electricity. The ability to negotiate a Power Purchase Agreement with a local/regional/national utility having a respectable credit rating will also enable the developer to gain access to financing on more favourable terms.

1.3. Forecasts and prospects

Based on potential power supply from the resource assessment, grid constraints, and the match to power and heat demand, forecasts on the geothermal power production are made.

Today information utilised in locating and estimating the geothermal resource and potential is spread out in different ministries, universities, national institutes, oil & gas companies and various private entities. The location of the necessary data is furthermore not standardised in the different countries. A barrier to the development is not knowing where to get the information and the time spent in collecting it. Geoelec gives a comprehensive overview of the existing information with some interpretation to further aid the first step in the development, the choice of location.

The geological potential (heat in place) has been translated to an economical potential, using a Levelised Cost of Energy (LCoE) value of less than 150 €/MWh for the 2030 scenario and less than 100 €/MWh for the 2050 scenario:

— The production of geothermal electricity in the EU in 2013 is 6 TWh.

— The NREAPs forecast a production in the EU-28 of ca. 11 TWh in 2020.

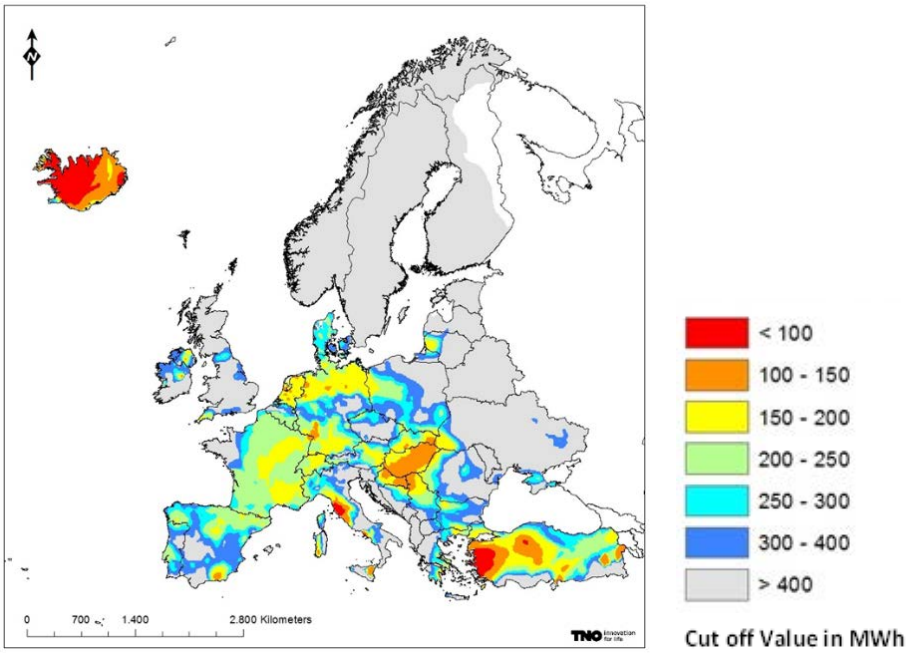

Fig. 3. Geothermal electricity economical potential using a LCoE value of less than 150 €/MWh

Rys. 3. Ekonomiczny potencjał geotermalny do produkcji energii elektrycznej określony za pomocą LCoE o wartości mniej niż 150 €/MW

— The total European geothermal electricity potential in 2030 is 174 TWh.
— The economic potential grows to more than 4000 TWh in 2050.

2. FINANCING GEOTHERMAL POWER PLANTS

The development of geothermal electricity needs a large amount of money. Some public incentives schemes like the feed-in tariff in Germany are a great support for this development but it will not be enough. Banks, capital ventures and other public or private financial companies will be key actors. Geoelec needed to convince them to become more involved in Geothermal power by presenting the project financing options for geothermal electricity and improving knowledge among venture capital and financial institutions concerning the benefits from investing geothermal power.

2.1. Project financing

One task consisted of modelling the work cycle and an estimation of the capital investment for the geothermal power plant unit of conventional, binary and in Enhanced Geothermal System in sample projects.

Geoelec described market demands (investors and banks) for project financing and how projects are generally financed. A basic financial model was created for investors and banks to evaluate geothermal electricity projects and to estimate costs for geothermal power-supplied electricity. The modelling is based on sample projects with a description of the financing through the development phases: site identification / pre-feasibility –surface exploration / feasibility – drilling exploration / resource development / plant construction / operating and maintenance.

Newly created software allows relevant parties to conduct a financial pre-feasibility study. The objective is to build a proper but simple financial project model (based on excel) as a guideline for investors, although this is not a substitute to detailed project evaluation. The software provides a basic project evaluation based on IRR (internal rate of revenue) and NPV (net present value). Thus, given their capital costs (WACC – weighted average cost of capital), project initiators and investors can judge upon economic feasibility. To achieve this, the model provides an input sheet for all relevant geological, technical, economic and financial project parameters resulting in an integrated financial modelling of project cash-flows, profit and loss statements as well as balance sheets.

2.2. Geothermal risk insurance

One of the most important financial barriers to develop geothermal power projects is the risk associated with the first drilling. Indeed, the financial obstacles to the development of geothermal energy remain:

— The success of such projects mainly depends on the properties of the geothermal resource that directly impact the exploitation costs, but are only known at the end of drilling work.
— Traditional insurance policies do not offer any specific solutions for this type of risk in view of its very specific nature and because the fairly small number of operations involved does not provide a sufficient statistical basis.
— Moreover, financial organisations refuse to invest unless the public or private operator gives a formal guarantee.

In the absence of coverage against geological and mining risks, any failure of a drilling operation would require to repay the taxpayers of the city or the tenants of subsidised housing concerned. Officials considered this as an unacceptable constraint. This was the main barrier preventing the development of geothermal energy.

Geoelec aimat creating a system of risk guarantees to facilitate the development of geothermal energy.

The proposed system is based on two complementary mechanisms:

— a short-term procedure (STR), based on the socialisation of risks and to guarantees the result of the first well drilled. The STR covers geological risk in the event of total or partial failure of the first drilling operation. STR insurance is used to secure the project's profitability in spite of the geological model's uncertainties;

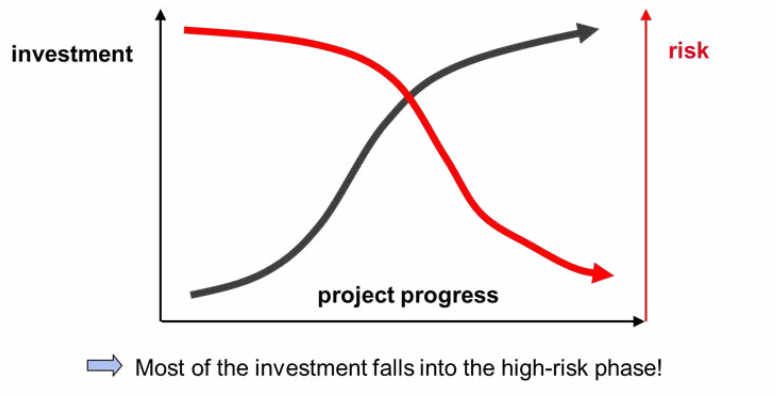

Fig. 4. Risk and cumulative investment during the project progress

Rys. 4. Ryzyko i skumulowane inwestycje w czasie postępu projektu

— long-term procedure: Begin at the starting-up of the facilities and guarantee the sustainability of the resource and the risk of total or partial depletion during 15 years of operation. Long term risk (LTR) insurance principles: After the doublet setting, the geothermal characteristics are known, but their long term behaviour are unknown, as well as long term chemistry effects on wells and reservoir. LTR insurance is used for securing long term profitable exploitation, covering the risks of drilling exploitability's degradation.

2.3. Geothermal deep drilling market

Drilling represents from 30% to 50% of the cost of a hydrothermal geothermal electricity project and more than half of the total cost of Enhanced Geothermal Systems (EGS). The Geoelec' report on geothermal drilling' aimed to present proposals to overcome this thirds substantial financial barrier.

Research and Development (R&D) can improve geothermal drilling technologies in order to reduce its costs, but the main challenge today is to improve market conditions for deep geothermal drilling.

However, the deep geothermal drilling market has still not been thoroughly assessed. For instance, access to available geothermal drilling cost data is very limited. Moreover, the interaction between project developers and drilling contractors could be improved.

In order to stimulate both the market and the competition Geoelec provided the following:

— information on drilling costs in some EU countries,
— a European database listing drilling companies in order to pave the way for a dynamic and regularly updated tool to be published online,
— a best practice geothermal drilling handbook for project developers.

2.4. Boost investment in the geothermal sector

The contribution of the geothermal sector for the future renewable energy mix in 2030 will need large investment. The Geoelec project evaluated the investments needed to finance, and the economic consequences of, the strategy developed in the prospective study.

The advancement of geothermal energy will require the involvement of the private sector. Developers and investors are essential for the advancement of all renewable energy Developers need to know their financing options while investors need to have basic knowledge of and confidence in emerging technologies. In addition, a mutual understanding between developers and investors is essential. This is especially true for geothermal energy since this technology requires high up-front investments.

The geoelec guide presents notably:

— New strategies for raising capital in today's turbulent financial climate.
— Understanding what today's investors are looking for in a geothermal investment prospect.
— The emerging role of private equity companies in geothermal investment.
— Assessing the current volume of deals and the outlook for 2010 and beyond.
— Project finance for large-scale geothermal development.
— New alternative financial instruments for geothermal exploration.

3. REGULATORY, SOCIAL AND ENVIRONMENTAL CONDITIONS

Geothermal developers overtly abhor opaque, complex and lengthy licensing procedures. Deficient licensing rules can undoubtedly cramp investment in the geothermal electricity sector in Europe. Licensing rules for geothermal projects are no exception to the European diversity. They may be significantly different from one country to another and have uneven degrees of achievement all over Europe.

No matter the diversity and progress of the national geothermal licensing rules in Europe, they all remain to be perfected if geothermal electricity developers are to be guaranteed legal certainty. In order to kick-start development geothermal electricity deserves at European stage, policy makers should remain aware of the need to further tighten national regulations so as to provide effective, reasoned and pragmatic licensing rules for geothermal. In this respect, the Geoelec project here provides some yardsticks and recommendations for such effective and pragmatic geothermal licensing to be enforced.

3.1. Overview of the geothermal regulatory framework in Europe

By reviewing the geothermal regulatory frameworks in Europe, the main areas of legal problems and legal barriers can be defined. Regulations refer to the licensing process for exploration, drilling and mining and the environmental issues.

The legal issue over terminology has been solved by the Directive on Renewable energy sources (2009/28/EC), with a binding definition of Geothermal Energy in Article 2, which is defined as energy stored in the form of heat beneath the surface of solid earth. On the subject of terminology, it should be underlined that 'exploitation' might not be the best word for a renewable energy such as geothermal; the energy extraction should be seen more as a 'use' or 'development' of the resource.

One area of legal problems and regulatory barriers concerns resource ownership and protection definition. Regarding the ownership of the resources, two different situations can be found within the European countries where plants are operational: a) by adoption of mining law or mineral resources law mentioning that the State/the crown gives a concession to project developer for exploiting the resource. It is a good option if licensing is regulated properly but it creates difficulties if it is included in water legislation; b) the underground resource ownership is given to the owner of the surface. It creates difficult situation in larger project where multiple owners are concerned, and for deep geothermal projects this is very time consuming.

In juvenile markets there are no specifications about ownership. Traditionally, a first come – first served approach is in place; with the exception of states where a priority is given by law to a specific resources: water, energy etc.

Licenses allow the protection of an area and to avoid competitors using the same underground resources. Moreover, a licensing regime defines the frame for dispute solutions: the mining authorities and the responsible court of justice. However, licensing regulations can be another barrier to the development, due to their lengthy and complex procedures.

With state ownership, the following items are crucial for geothermal development:

— who can apply for a license (non-discriminatory process),
— one- or two-step-process (exploration, exploitation),
— time period for which a license can be obtained, possible prolongations,
— royalties (based upon what parameter? Fixed or as a percentage of production?),
— time for obtaining a license.

Typically, exploration permission is firstly given for a period (4–6 years) and for a specific area. Afterwards an exploitation authorisation is attributed for 30 years or more, with in each case possibility of extension.

The length period of the permits should be enough long to allow for exploration and proper production, but should prevent speculations and fake exploratory projects.

The protection of the resource against other uses/users is crucial. No licenses should be given for other uses/users that would jeopardise the resource; and certain distance (or other protection) must be kept for other uses.

The public entities involved to cover geological, water, energy aspects can be numerous: Mining authorities (national, regional), environmental agencies, local authorities etc. Each step can be time consuming.

Regulatory barriers can also result in cost barriers: These financial burdens include:

— cost for legal fees, license fees,

— cost for royalties: in particular problematic if fixed and not related to production (!),
— cost for environmental studies, public hearings, etc.

Taxes for the exploration permit (x EUR/km² of annual lease), for the mining lease and for the electrical production should neither be too high, and so preventing any investigation, nor too low and so creating speculation on permits.

The acquisition of geological data can also be a barrier when the data purchase is too expensive and when confidentiality blocks the communication of the data. In the case of publicly funded projects, data protection is rather short but for private developers the confidentiality can remain for several years, with copy to the geological surveys.

Another main area of legal problems and regulatory barriers is environmental regulation. The list of barriers resulting from environmental regulations can be rather long. There will, of course, be cases where environmental issues make a project impossible. However, this is limited to few cases and should be known as early in the project as possible. The rules protecting the environment in geothermal regulatory frameworks cover principally water protection, control of emissions, impact assessment and landscape assessment.

Groundwater protection is usually regulated in the different countries by water laws, but not always specific needs of geothermal projects are contemplated. For example pressure issues, soil protection as well as a protocol on micro-seismicity and surface issues. Regarding the protection of waters, Article 11 of Directive 2000/60/EC (Water Framework Directive) gives Member States the option to authorise the reinjection into the same aquifer of water used for geothermal purposes. It is therefore within the competence of the national governments to decide whether reinjection of the geothermal fluids is possible or required.

Regarding emissions, all geothermal plants have to meet various national and local environmental standards and regulations, although emissions are not routinely measured below a certain threshold, and emissions from geothermal plants typically fall below this threshold. The pollution control regulations provided for EGS systems are no major obstacles for permit granting. Only noise limits may be of relevance, with regard to the cementation of the pipes and the hydraulic test work.

A major burden for geothermal projects is the environmental impact assessment (EIA). The National Planning Authority is responsible for monitoring the implementation and management of the EIA and has the power to decide which projects require an EIA. Since the contractor has the costs of implementation of an EIA, clear guidelines, which establish the conditions for EIA should be established.

3.2. Environmental issues

Geothermal is fully recognised to be a safe, reliable, environmentally benign renewable energy source. However, all man-kind activities have somehow an impact on nature, including the construction of a geothermal power plant. Geoelec analysed the impacts to be considered in each of the phases of a geothermal project and put forward clear recommendations about possible mitigation measures. The Table below summarises the result of this work.

— small footprint that leaves little permanent scarring,
— normal construction site disturbance and waste,
— buildings, cooling towers and pipelines create minimal visual impact,
— reinjection of geothermal fluid into the aquifer of origin does not contaminate groundwater,
— hydraulic stimulation uses 99% water, harmless chemicals and no proppants, following environmental rules,
— induced micro-seismicity can occur due to re-injection but is monitored and can be controlled.

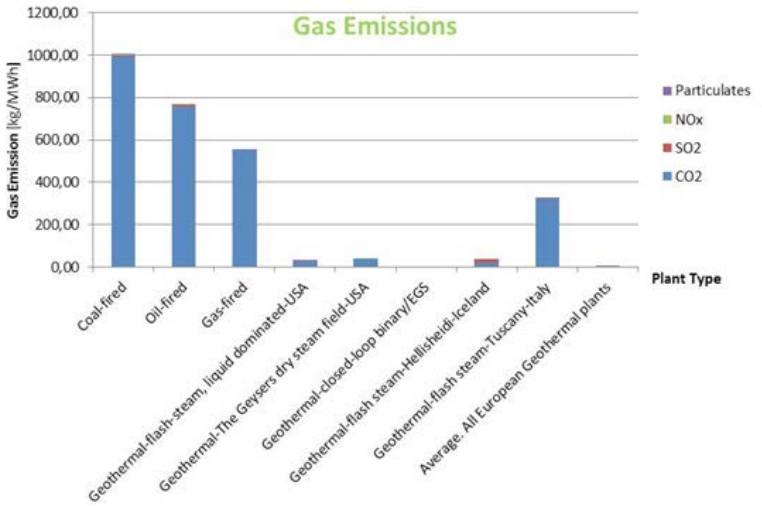

Fig. 5. Emissions from geothermal technologies compared to fossil fuels

Rys. 5. Porównanie emisji gazów z technologii geotermalnych i paliw kopalnych

4. EDUCATION AND EMPLOYMENT IN THE GEOTHERMAL SECTOR

Geoelec aimed to quantify the potential for jobscreation in the geothermal sector and has presented the direct / indirect employment today, with a methodological approach for employment quantification.

The geothermal sector is already suffering from a lack of skilled workers. Geoelec makes proposals on education, mobility and dissemination of information, as an action plan to raise this barrier. Several professionals take part in the process of building a geothermal power plant. In describing the job profiles, Geoelec makes proposals for each situation. Training geothermal power staff notably on EGS is an important issue today. The present situation shows that:

— the limited available higher education specialisations related to geothermal energy exploration, exploitation and utilisation, is inadequate to supply the highly skilled

personnel needed in the geothermal power industry, as important geothermal topics are not presented in existing graduate courses;

— basic training on geothermal technologies is rarely available in EU member states;

— the same applies to post-graduate specialisation in geothermal energy, as most geothermal courses around the world have stopped or reduced activity due to lack of financial support.

As geothermal power projects need specialists in many fields of geology and engineering, on-the-job in-company training is still absolutely necessary. The closest fields in terms of available technical expertise are the oil, gas and coal sectors, but even these workers need to be re-qualified in order to operate in the geothermal sector, where technology has to cater for the high temperatures and the chemistry of the fluids concerned.

So geothermal training is expected to grow together with the growing of the geothermal sector.

4.1. Employment survey

The expected acceleration in the development of geothermal energy utilisation and the demand from industry show the present need for a fast increase in highly qualified specialists. Indeed the geothermal energy sector is growing world-wide and there is an increasing demand of geothermal experts. It could lead rapidly to a lack of specialists in many fields of expertise. The complexity of geothermal technology requires a wide range of experts on different levels of skills, multidisciplinary expertise and good interaction of the several disciplines.

Whilst basic training in geothermal exploration, exploitation and utilisation is available in most of the European countries, but these courses are inadequate to supply the high skilled workforce needed in the geothermal sector by 2020 and 2030.

There is a limited number of geothermal training courses in higher education, and only few specific university degree programmes are available. Moreover, professorships in geothermal energy are not sufficient in Europe.

The geothermal sector is therefore already suffering from a lack of skilled workers. For this reason, the Geoelec project put forward some proposals on education, mobility, and dissemination of information in an action plan to overcome this barrier.

In 2013, there were 2,500–3,000 jobs directly related to geothermal electricity in the EU-28. Geothermal energy jobs can be broken down into different types, from engineers, drillers and workers in equipment factories to project managers. Geothermal power also generates indirect jobs, for example with suppliers of raw materials and induced jobs. The estimated total number of geothermal power jobs in 2013 is 10,000 jobs.

The geothermal energy sector builds upon various segments, essential for the core functions of the industry, i.e. resource exploration and geothermal energy production. These segments involve equipment suppliers, service providers (e.g. technical/ financial/legal consul-

tants), or final energy off-takers (consumers). Another key segment for the development of the geothermal industry is underlying research and development as well as relating training and educational activities.

Geothermal development is closely intertwined with other activities such as governmental services (e.g. for obtaining exploration permits), regulatory affairs (upon which market regulation hinges) etc. There are also industries that are related to geothermal in that they employ similar technologies or specialists with identical core skills. With sectors such as mining, oil &gas, carbon capture and storage, the geothermal industry could engage in cooperation and technology crossover. Also, the geothermal sector (being on the rise) could attract workers or subcontractors from related sectors in decline, e.g. the mining sector in Europe.

4.2. Training activities

a) Enhancement the education and training process, since multidisciplinary expertise and the interaction of several disciplines are necessary.

Enhancement of the educational and training process is the factor that can have the largest effect on the long-term needs regarding certain job specialties and skills. Ensuring the existence of necessary skills in the sector requires action at all levels of education and training, meaning technical and scientific education, training and continuous learning. In order to achieve proper education reforms, cooperation between companies, universities, polytechnic schools, training organisations, employment agencies, and certification institutions is needed.

Educational programmes often cover basic skills, while they are not able to meet more specialised requirements. Developing the content of a course may require time, effort and expertise, factors that can limit the educational institutes. This may result in an unattractive educational or training programme. This is why there must be cooperation, so that governments and geothermal power companies assist education suppliers to develop appropriate educational programs. Also, this cooperation will contribute to ensure a frequent refreshing of the content of educational and training programs, so that the skills and knowledge of graduates are always up to date.

Financial support of both students and educational institutes is also a factor that can assist the whole process. In case the difficulty is in attracting young people, rather than the willingness of the industry to train them, then financial measures should aim more at students. Financial incentives can be provided through covering the training cost of the students and by subsidising educational and training programs.

b) Create networks for geothermal energy education and training involving industrial platforms, Universities and Research Centres developing a workforce for future geothermal development.

Cooperation between education and training institutes and companies is necessary, so that the number of graduates fits the requirements of the labour market, while students are

provided with the appropriate skills and knowledge. Linkage between universities and companies can also create a network which may allow a faster and more efficient treatment of the needs that are generated.

The skill and workforce gap issue must be recognised and addressed, not individually, but comprehensively by all countries. International and intergovernmental organisations should work in order to promote cooperation between countries. This may include cooperation and measures to increase the mobility between educational and training suppliers, researchers and apprentices which are involved in the education and training process and in the development procedures of standards regarding skill qualifications in different countries.

Education and training programs targeting on the sector should focus on skills that can be transferred between different fields. Employment in the development, manufacture and installation can be unstable, even if attempts are made to obtain an approximate smooth transition. In occupations associated with operation and maintenance, there may also be periods where the intention to recruit new trained workers will be limited. Education and training programs should therefore be developed around a core specialty which will be suitable for a wider range of sectors.

5. MASTERPLAN TO PROMOTE GEOTHERMAL

The Geoelec team aimed to use the project results to convince notably policy-makers to support the development of geothermal power. Communication was crucial as the main objective was to increase awareness about geothermal power.

5.1. Action plan

Based on the project results, the GEOELEC consortium suggested the following action plan to develop geothermal electricity in Europe:

Create conditions to increase awareness about the advantages of this technology and its potential. National Committees on Geothermal promoting the technology to decision-makers and engaging the civil society to favour social acceptance should be established.

The potential of geothermal energy is recognised by some EU Member States in their National Renewable Energy Action Plans (NREAPs). However, the actual potential is significantly larger. In order to increase awareness, Geoelec has assessed and presented for the first time the economic potential in Europe in 2020, 2030 and 2050. The figures show the large potential of geothermal and the important role it can play in the future electricity mix.

The Geoelec project paved the way for the creation of national Geothermal committees across the EU.

Such committee should be established in each EU-28 Member State with the objective of increasing awareness about geothermal and to ensure public acceptance of the geothermal projects. This initiative builds on the French experience, where such a Committee has alre-

ady been established in July 2010. There, the Energy Ministry launched a 'Comité National de la géothermie' to propose actions and recommendations for a geothermal development in France. It is composed of 35 members from 5 different sectors: State level, Local authorities, NGOs, Employers, and Workers. The first results of the Comité National de la géothermie in France can be presented through 3 key actions:

— Simplifying administrative procedure and quality.
— Training professionals.
— Disseminating information.

Contribute to the economic competitiveness of Europe by providing affordable electricity. In order to progress along the learning curve and deploy at large-scale a reliable renewable technology, a European EGS flagship programme should be launched, including new demonstration plants and test laboratories. It should also look at new technologies, methods and concepts.

EGS is a technology for accessing the heat in hot but impermeable basement rock. Once fully developed, it will provide a major increase in the geothermal resource base, both for heat and electric power. In spite of its potential and although the basic concepts have been developed already in the 1980s EGS has not matured yet into a ready-to-implement technology.

An EGS Flagship program in the EU should be launched for making this technology competitive by the end of the decade. Ultimately, this will establish EGS as a technology applicable almost everywhere for both heat and power production.

At each stage of the EGS development, proven methodologies can be applied and bottlenecks identified. From this state-of-the-art assessment, priorities encompassing five main areas have been defined for medium to long term research. The expected outcome will be geothermal energy in a form that can be widely deployed and competitively priced, underpinned with reduced capital, operational and maintenance costs. Swift progress (and continuous improvement) will be pooled with coordinated international R&D efforts, with a view to successful demonstration and implementation.

— Establish network of complementary 5–10 European EGS test laboratories.
— Develop Demonstration sites in different geological settings and upscale size of the power plants.
— Launch Training and education programs for new geothermal professionals specialized in EGS.
— Ensure Public acceptance on micro-seismicity, stimulation, environmental impact, emissions.
— Towards grid flexibility: Flexible and base load electricity production from EGS plants, with test on dispatchability, to develop regional flexible electricity systems.

Establish the economic and financial conditions for geothermal development: a European Geothermal Risk Insurance Fund (EGRIF) is an innovative option tailored to the specificities of geothermal to mitigate the cost of the geological risk and is a complementary tool to operational support, still needed to compensate for the long-standing lack of a level-playing field.

Financing a geothermal project includes two crucial elements in the initial phase of the project development: a high capital investment for drilling wells which can take up to 70% of the total project costs, and an insurance scheme to cover the geological risks.

As pre-drill assessment of geothermal performance is subject to major uncertainty and EGSis in an embryonic development phase, the risk profile is high compared to alternative sources of renewable energy. In order to face these challenges the following financial incentives are required to facilitate growth of geothermal energy in Europe:

— Support schemes are crucial tools of public policy for geothermal to compensate for market failures and to allow the technology to progress along its learning curve;
— Innovative financing mechanisms should be adapted to the specificities of geothermal technologies and according to the level of maturity of markets and technologies;
— The EGRIF is seen as an appealing public support measure for overcoming the geological risk;
— While designing a support scheme, policy-makers should seek a holistic approach, which exceeds the LCoE and includes system costs and all externalities. As an alternative, there is the chance to offer a bonus to geothermal energy for the benefits it provides to the overall electricity system, balancing the grid.
— Enhance the education and training process, since multidisciplinary expertise and interaction of several disciplines are necessary. Create Networks for Geothermal Energy Education and Training involving industrial platforms, Universities and Research Centres developing a workforce for future geothermal development.

The acceleration in the development of geothermal energy utilisation and the increasing demand of skilled workforce from industry show the present need for a fast increase in highly qualified technicians, engineers and specialists. This transition requires the modification in the existing curricula in different fields of geothermal energy such as basic research in geothermics, reservoir, drilling, material, power plant, utilisation, economics and legal aspects:

— Enhancement of the educational and training process is the factor that can have the largest effect on the long-term needs regarding certain job specialities and skills. Ensuring the existence of necessary skills in the sector requires action at all levels of education and training, meaning technical and scientific education, training and continuous learning. In order to achieve the proper education reforms, cooperation between all organisations involved is required;
— Cooperation between education and training institutes and companies is also necessary to create a network allowing for a faster and more efficient satisfaction of the needs generated in the labour market, while students are provided with the appropriate skills and knowledge.
— Contribute to the development of the local economy. Create local jobs and establish a geothermal industry in Europe which will be able, by 2030, to employ more than 100,000 people (exploration, drilling, construction and manufacturing).

In 2013, there were 2500–3000 jobs directly related to geothermal electricity in the EU-28, while the estimated total number amounts to 10,000 jobs.

Additionally, based on the projects under development and under investigation, more than 100,000 people should be employed in the sector.

Over the last few years little new installed capacity has caused a concentration of jobs mainly in O&M, traditionally requiring only a few workers. The development of a significant number of new projects will trigger a real boom in labour-intensive activities such as exploration, drilling, construction and manufacturing.

The potential of the geothermal power industry can be achieved only through the attraction, retention and renewal of the workforce. Companies and organisations need to team up to universities and research centres to shape and have access to the highly skilled workforce they need.

— Absorb workforce of declining industries: several opportunities exist in the geothermal sector for employing workers from sectors in decline such as the coal sector. Professions concerned are in geosciences, drilling and thermal power plants sectors. Regional and national governments should make use of EU funds available to facilitate the requalification of workers from declining industries and ought to align, to the largest extent possible, their active labour policies to energy and industrial strategies.
— Promote mobility of workers in Europe: the knowledge and expertise on deep geothermal is concentrated today. There is the need to create conditions for more cooperation and exchange between juvenile and more mature markets.
— Launch international cooperation especially on EGS: the EGS flagship programme could integrate an international dimension to exchange experiences and technologies and exploring export opportunities of the European know-how on EGS.

5.2. Promote the creation of National Geothermal Committees

One dissemination activity focused on the promotion Across the EU to create National Geothermal Committees. Such a Committee has already been created in France in July 2010. The Energy Ministry launched a ‘Comité National de la géothermie’ to propose actions and recommendations for a geothermal development in France. They should be constituted by representatives from different public and private sectors: State level, Local authorities, NGOs, Employers, Workers, etc.

During the Geoelec project, a proposal was made to several Energy Ministries and National Energy Agencies for the creation of such a Committee.

CONCLUSIONS

Based on the results of the project, the following recommendations are put forward:

— Create conditions to increase awareness about the advantages of this technology and its potential. National Committees on Geothermal promoting the technology to decision-makers and engaging the civil society to favour social acceptance should be established.

— Contribute to the economic competitiveness of Europe by providing affordable electricity. In order to progress along the learning curve and deploy at large-scale a reliable renewable technology, a European EGS flagship programme should be launched, including new demonstration plants and test laboratories: it should also look at new technologies, methods and concepts.
— Establish the economic and financial conditions for geothermal development: a European Geothermal Risk Insurance Fund (EGRIF) is an innovative option tailored to the specificities of geothermal to mitigate the cost of the geological risk and is a complementary tool to operational support, still needed to compensate for the long-standing lack of a level-playing field.
— Enhance the education and training process, since multidisciplinary expertise and interaction of several disciplines are necessary. Create Networks for Geothermal Energy Education and Training involving industrial platforms, Universities and Research Centres developing a workforce for future geothermal development.
— Contribute to the development of the local economy. Create local jobs and establish a geothermal industry in Europe which will be able, by 2030, to employ more than 100,000 people (exploration, drilling, construction and manufacturing).

REFERENCES

European Union, Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC (Text with EEA relevance), Official Journal L 140, 5/6/2009, p.16.

European Union, Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy, Official Journal L 327, 22/12/2000 p. 1–73.

Geoelec, Geoelec Final Report, 2013, available at www.goelec.eu.

GEOELEC: ROZWÓJ GEOTERMALNEJ ENERGII ELEKTRYCZNEJ W EUROPIE

STRESZCZENIE

Celem projektu Geolec było przekonanie decydentów o potencjale energii geotermalnej do produkcji energii elektrycznej w Europie, zachęcenie inwestorów i banków do finansowania geotermalnych instalacji elektrycznych, a także przyciągnięcie kluczowych potencjalnych inwestorów, takich jak firmy naftowe i gazowe oraz

przedsiębiorców z sektora energii elektrycznej do inwestowania w jej wytwarzanie przy zastosowaniu zasobów geotermalnych.

Plan działania, który został opracowany w celu usuwania barier nie-technicznych ma zwrócić uwagę decydentów i przemysłu na potencjał geotermalnej energii elektrycznej, dając jej wysokie znaczenie, podobnie jak w innych rejonach świata, zachęcić do inwestowania w tę technologię. Projekt miał również na celu pokazać potencjalny wkład energii geotermalnej w produkcję energii elektrycznej we wszystkich 28 krajach UE w perspektywie krótko- i średniookresowej. Opracowano strategię dla osiągnięcia tych celów, opisano aspekty techniczne, finansowe, prawne, społeczne i środowiskowe oraz przedstawiono konkretne rozwiązania. W szczególności uwaga została zwrócona na szkolenia nowych specjalistów w branży i tworzenie przyszłych nowych miejsc pracy.

SŁOWA KLUCZOWE

Energia geotermalna, energia elektryczna, potencjał, finanse, regulacje prawne, szkolenia