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GEOENVI Project: Tackling the Environmental Concerns for Deploying Geothermal Energy in Europe

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ABSTRACT

Deep geothermal has a great potential for development in many European countries. However, the advantages of using geothermal resources for power production and H&C (Heating and Cooling) are not widely known. Recently, deep geothermal energy production in some regions is confronted with a negative perception, particularly in terms of environmental performance, which could seriously hamper its market uptake. Thus, dealing properly with both the evaluation and effective communication of environmental issues is a prerequisite to the deployment of the deep geothermal resources.

The concept of Life Cycle Analysis (LCA) allows assessment and comparison of the environmental impacts of different energy production technologies over their life cycle stages – from extraction of raw materials to production, transport, use and end-of-life. In the framework of the H2020 programme, the GEOENVI project, started in November 2018 for 30 months, aims at engaging with both decision-makers and geothermal market actors, to adopt recommendations on environmental regulations and to harmonize, simplify and promote the implementation of a LCA methodology by geothermal stakeholders. A sub-objective is to map environmental risks and impacts as well as mitigation measures and to make these results available through a public database. Once available, these data will be useful to better deal with impacts and risks. This will make it possible to better communicate on environmental issues, helping to reduce obstacles to sustainable development of this important renewable energy.

The objective of this paper is to present the overall content of the project, and to give insights into first results, notably concerning the online database.

1. INTRODUCTION

Geothermal energy is one of the most promising renewable energy sources for producing electricity and H&C. Geothermal energy will be a key component of the future European energy systems, which the ETIP DG Vision of the Future for deep geothermal notably highlights. Results from past projects assessing its potential (GEODH and GEOELEC projects) show that geothermal energy could supply more than 10 % of EU energy consumption by 2050. Its main advantage is the possibility to offer a wide range of applications in the field of both electricity and H&C with the advantages of being non-intermittent, flexible and dispatchable. Besides it is not dependent on weather-related constraints.

However, the advantages of using geothermal resources for power production and H&C are not widely known. Recently, deep geothermal energy production in some regions has been confronted with a negative perception, and with special attention from local decision-makers, in terms of environmental performance, which could seriously hamper its market uptake.

Some recent incidents, or events, in geothermal energy production such as those in Staufen (DE) where seven geothermal borehole heat exchangers in 2010 created structural damage to buildings as a function of four different geological parameters: artesian groundwater, two interacting karst formations, strong tectonization, and a swellable anhydrite formation, in Basel (CH) where well drilled in 2006 induced micro-seismicity, in St Gallen (CH) in 2013 a gas kick and subsequent work-over operation caused a seismic event , in Lochwiller (FR) where in 2008 a shallow geothermal project created structural damage to buildings as a function of drilling in artesian groundwater, or local concerns such as in Monte Amiata (IT) about non-condensable gas, provoked a debate on the use of geothermal energy especially about induced micro-seismicity, stimulation, non-condensable (NCG) and greenhouse (GHG) gas emissions, ground deformation, etc.

Among the possible environmental impacts, we can list the followings:

- Surface-visual effects (land use, landscape, flora and fauna);

- Physical effects (induced seismicity: micro-seismicity related to all the operational phases of the exploitation, including reservoir connection and fluid reinjection into the reservoir; subsidence; geological hazards; groundwater resource depletion; natural radioactivity)

- Acoustic effects (noise during drilling, construction and management);

- Thermal effects (release of steam in the air, ground heating and cooling for fluid withdrawal or injection).

- Emissions to air (gaseous emissions into the atmosphere, non-condensable gases, pollution and emissions), some of which fall in the "natural emission" category in that they occur regardless of geothermal project development;

- Emissions to water (re-injection of fluids, disposal of liquid)

- Solid waste.

Media reports focus more on disadvantages than benefits, which for instance include electricity, heat and cold at low price, conservation of fossil fuel resources, help to other renewable of intermittent type (wind, solar…), reduced emissions to the environment (with correct solutions and management). However, there is a growing environmental and societal consciousness and a related fear about explorations into the earth's crust. As a result, decision makers and potential investors have concerns about possible environmental impacts and risks involved in implementing geothermal projects, and social resistance often results in practical obstacles - such as significant slowdowns – to the deployment of the deep geothermal resources.

The GEOENVI project aims at analysing and proposing solutions and tools for addressing concerns and highlighting benefits for the geothermal market uptake focusing on the environmental impacts. Power (mainly) and heat production from geothermal resources may have an impact on any environmental matrix (air, water, ground, ecosystems) but solutions exist in term of prevention and mitigation of impacts.

Environmental impact assessment is always a prerequisite to the authorization of a geothermal plant. However, this sometimes results in biased perspective as the assessment is performed according to different methods depending on the countries and regional regulations and usually only considers partial life cycle stages. Thus, the results are not comparable to other renewable energy sources. When there are several energy production options to generate energy in the area (with and without renewable energy), it is not always possible to objectively compare by this regulatory approach their environmental impacts and clearly identify the most suitable one. The same challenge also emerges when policy makers need to frame a subsidy, incentive, or develop implementation strategies.

Many of these challenges can be tackled with the application of Life Cycle Analysis (LCA), which is a powerful approach for the calculation of a wide range of environmental indicators. The results of a LCA allow analysis and comparison of the environmental impacts of different energy production technologies over their life cycle stages – from extraction of raw materials to production, transport, use, and end-of-life. Standards such as ISO 14040 (Environmental management—life cycle assessment—principles and framework) and ISO 14044 (Environmental management - Life Cycle Assessment - Requirements and guidelines) will contribute to ensure the robustness of the methodology. Assessing and managing the life cycle of processes provides the opportunity to accelerate the transition towards sustainable production. LCA can be used in decision making to generate information which helps to prioritize sustainable development. Information from LCA can be used to support decision making in both public and private sectors. Environmental assessments based on Life Cycle Assessment (LCA) have been performed over the last years for a quite large selection of geothermal installations (Eberle et al., 2017; Tomasini-Montenegro et al., 2017). However, these applications have mainly focused on climate change concerns and the investigation of additional impact indicators would be necessary to get an enhanced comprehensive panorama for environmental footprint of geothermal systems with notably a better handling of air emissions concerns (Parisi et al., 2019), noise and induced seismicity (Lacirignola, Blanc, 2013).

The overall objective of the GEOENVI project is to make sure that deep geothermal energy can play its role in Europe's future energy supply in a sustainable way. It aims at creating a robust strategy to answer environmental concerns (both impacts and risks):

- by providing an online public database to present clear and objective data concerning environmental issues,

- by setting an adapted methodology for assessing environment impacts and by implementing it on some case studies,

- by proposing recommendations on environmental regulations to the decision-makers and finally

- by communicating properly on environmental concerns with the general public.

2. COMPOSITION OF THE CONSORTIUM AND METHODOLOGY

The GEOENVI project (www.geoenvi.eu) is a project funded by the Horizon 2020 funding programme, under the grant agreement n° 818242. It gathers 16 partners from 6 different countries (Belgium, France, Italy, Iceland, Hungary and Turkey). GEOENVI started in November 2018 and will be on-going until April 2021.

GEOENVI

Figure 1: GEOENVI project Logo

2.1 Composition of the consortium

The project is coordinated by the European Geothermal Energy Council. Partners are national associations, national research institutes and operators: European Geothermal Energy Council (Belgium), Rete Geotermica (Italia), Enel Green Power (Italia), Consorzio perlo sviluppo delle aree geotermiche (Italia), Consorzio interuniversitario per lo sviluppo dei sistemi a grande interfase (Italia), Consiglio nazionale delle ricerche (Italia), Bureau de recherches géologiques et minières (France), ES-Geothermie (France), Association pour la recherche et le développement des méthodes et processus industriels ARMINES (France), Islenskar orkurannsoknir (Iceland), Georg-Rannsoknarklasi I jardhita (Iceland), Orkustofnun (Iceland), Vlaamse instelling voor technologisch onderzoek VITO (Belgium), Jeotermal elektrick santral yatirimcilari dernegi JESDER (Turkey), Dokuz Eylul Universitesi (Turkey), Mining and geological survey of Hungary (Hungary).

2.2 Methodology

The first step of the project is to map environmental impacts and risks, and to make knowledge available in a public database. The database is designed to enable efficient research, for instance depending on geography, geology, project characteristics, etc. In addition, information will be provided on mitigation measures and on regulations. This work will facilitate a common understanding of environmental risks and impacts within partners of the project, and will be a rich source of information for all stakeholders and for the public. Then, harmonized guidelines will be develop to conduct LCA studies and environmental impact assessment, using feedback and data from various European case studies. The engagement with decision-makers is an important part of the project, in order to promote recommendations for environmental regulations in the target countries. Harmonized guidelines to conduct life cycle assessment approaches and environmental impact methodologies will be promoted within the market actors in the target countries. Finally, a European dissemination of the results will enable a wide adoption and implementation of the project results.

GEOENVI looks into harmonizing existing regulations with a LCA methodology by analyzing environmental impacts of geothermal plants in different geological settings throughout their lifetime. Simplified models which are suitable for pre-determined geothermal categorization are under development, thus enabling a less complex LCA assessment, with an acceptable degree of uncertainty. All stakeholders, such as decision makers, public institutions, and economic actors are involved in the development. This will allow in the future to integrate LCA assessment in the construction and implementation of regulations. Though leaving flexibility to adapt to the energy profile of different countries, and allowing an objective benchmarking with respect to other renewable energy technologies, the proposed approach will establish correct rules for the environmental costing of the two main outputs (electricity and heat) depending on the plant arrangement and on the general context. Collateral benefits to the project are the familiarization of life cycle thinking to a larger population, which in turn will bring its own socio-economic gain.

2.3 Management plan

GEOENVI is a 30 months project starting from November 1, 2018. The Kick-off meeting took place in Brussels on November 8-9, 2018. The project will consist of 7 work packages: WP1 is management, WP6 is dissemination, WP7 is focused on ethics and the others will be technical work packages where the knowledge required will be developed. Management plan of GEOENVI project and work package leader is presented in Figure 2.

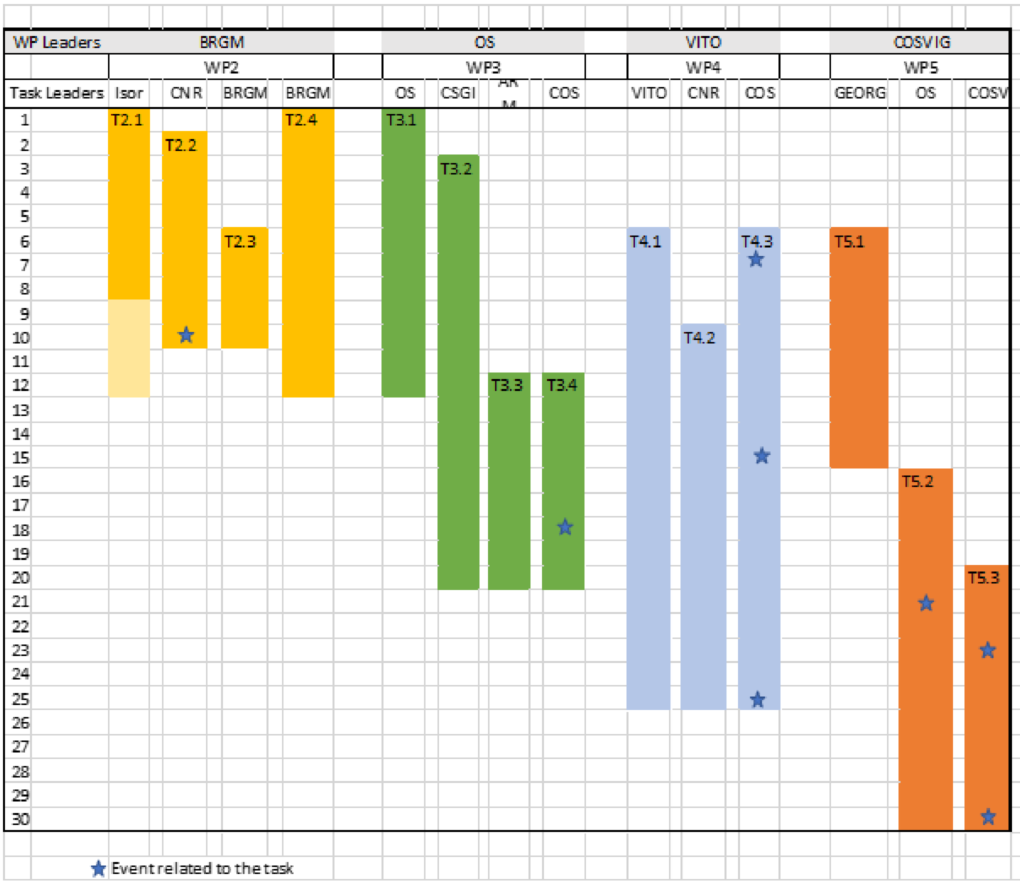

Figure 2: Management plan of GEOENVI project

3. CONTEXT

The deep geothermal potential is rather large as highlighted by GEODH and GEOELEC projects. 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 in Italy. Since then, a growing interest has been observed in the last five years (2012-2017), after nearly a decade of only small development in capacity in the deep geothermal sector both for electricity and for heat supply (mainly district heating). The development of geothermal technologies has been slow but steady, reaching today 127 geothermal power plants in operation, with a capacity of 3 GWe in 2016, and 300 geothermal district heating systems in operation with a capacity of 5.1 GWth in 2018. Globally, the installed power capacity reached 14 GWe and was about 70 GWth in 2017. The level of penetration of deep geothermal is currently limited because of both socio-economic and market conditions. One of the reasons of this trend is that the role of deep geothermal technologies is not sufficiently taken into consideration today in energy policies. In consequence, the conditions are not optimal for an acceleration of market uptake in the next years. This is in part due to the risk related to the community acceptance of geothermal projects (related to the potential environmental impacts of development, which this project aims to address), and the economics of geothermal projects which embed a significant degree of financial risk, as well as long project lead time, which may hinder the competitiveness of this renewable energy technology compared to some alternatives.

However, current market conditions do not allow this development; many non-technical barriers still need to be removed. Besides, a new generation of geothermal technologies is also needed for answering the challenges of the next decade for the European energy system.

If Europe wants the energy transition to be successful, we have to think about an optimal scenario in terms of costs and affordability for customers and citizens. Geothermal will then be a key enabler, a local and stable source of renewable energy, and its role could be crucial in the future energy system.

More than 300 geothermal district heating systems (DH) projects are now operating. There are also more than 200 power projects currently under development or investigation, which means that the number of plants operating in Europe could double in the near future. Yet, the geothermal power market is not developing as quickly as expected. Experience from past projects shows that there are several reasons for this.

In particular, non-technical barriers still need to be removed and thereby there is an urgent need to increase awareness of its advantages especially among decision makers, civil society and investors. Environmental concerns are one of the important barriers for deep geothermal market development. Geothermal should be a safe, reliable, and environmentally benign renewable energy source. However, all man-made activities have somehow an impact on nature, including the construction of a deep geothermal plant. Being aware of the impact means that they can be managed. The environmental impact of all infrastructure projects should be rightly considered, and environmental regulations are important tools for the development of geothermal. Such a sustainable development of the geothermal sector would facilitate public acceptance.

Policy and regulation are keys to the growth of renewable energy and it is necessary to understand the impact in the future to be able to come up with favorable provisions for renewable energy production technologies that have the lowest negative environmental impact. LCA (Life Cycle Analysis) has emerged as an approach to quantify and account for environmental impacts (McManus et al, 2015). Originally focused on accounting for current or past impacts in existing projects, LCA is becoming forward-looking to assess future impacts of a more consequential nature. LCA is a valuable tool to help formulate policies and to help taking decisions in creating environmental regulation (Grisel and Osset, 2004). Information from LCA is useful to draft different policy instruments that concern economic actors and consumers, such as label, standard, taxation, incentives, subsidy, etc. It also helps to establish the prices of energy that reflects the cost of the associated environmental damages (Bicalho, 2014). One example of adoption of LCA exists in the EU renewable energy directive (EU 2009) to determine sustainability criteria for biofuel and bio liquids production. This directive defines the requirement of greenhouse gas emission savings from the use of biofuels and bioliquids and, at the same time, the detailed rules and guidelines on how to quantify their CO2 emissions during the life cycle. While it is necessary to have a clear identification of environmental impacts from renewable energy sources, the downside is often found in the execution side as primary data is either unavailable or too time consuming to gather (Hetherington et al. 2014). This falls on the burden of the practitioners or the reporters who use the guidelines for compliance and study. Therefore, database and software packages are the most accessible solution for the practitioner.

With the rapid uptake of renewable energy sources in the European electricity sector, economic performance was the core focus, with the pursuit of rapid cost decrease, in particular looking at metrics such as Levelised Cost of Electricity which exclude many externalities. Plant operators often do not share data about costs of operation and maintenance, nor there is yet substantial experience on plant decommissioning (a heavy burden for PV – modules and batteries – with a recycling scenario not yet defined on a wide market perspective).

In general, the regulatory framework appears to not be primarily focused on the consideration of environmental costs, as these are usually not reflected in the cost of energy, in particular for fossil fuels.

4. TARGET COUNTRIES AND CASE STUDIES

The GEOENVI project focuses on six key countries with different deep geothermal potential (figure 2), markets maturity, and geological settings: France, Italy, Belgium, Iceland, Turkey and Hungary. These countries were selected because they have a potential for deep geothermal and there are plants already operating or under development.

The selected countries also present different and complementary geological settings, as well as profiles of environmental concerns. By collecting information in these countries, knowledge gained in experienced markets can be made accessible and transferred to stakeholders in less developed markets all over Europe.

Several case studies have been selected to be treated in the project: they are located in Iceland (Hellisheiðigeothermal power plant), France (Soultz-sous-Forêts and Rittershoffen geothermal power and heat plants), Italy (Bagnore 3&4 geothermal power plants located in Amiata), Turkey (Kizildere plant, Sinem-Deniz-Kerem plants, Dora-2 and Babadere Tuzla plants), Belgium (Balmatt geothermal plant) and Hungary (Szeged district heating system).

This mix of case studies allows us to combine projects at different phases of development, with differences about the most important environmental impacts and concerns, in the stakeholders involved, and in the different geothermal technologies applied and geological situation.

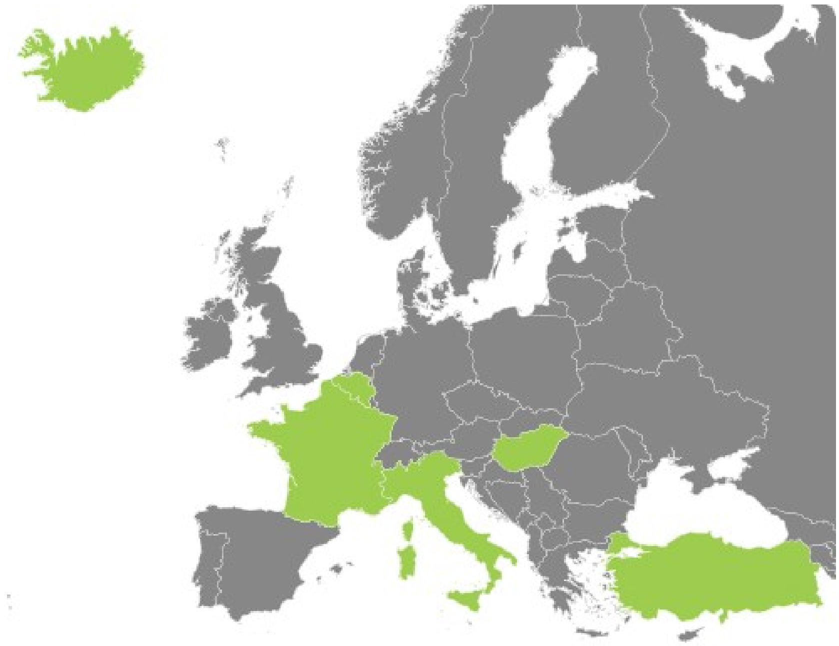

Figure 2: Six target countries (France, Italy, Belgium, Iceland, Turkey, Hungary)

5. MAP ENVIRONMENTAL IMPACTS AND RISKS

A first objective is to elaborate a public database to diffuse information and quantified data concerning the different environmental impacts and risks. This will be a comprehensive database that regroups environmental concerns for every geological and technological contexts.

This requires the elaboration of a common categorisation of risk and impacts, distinguishing consequences (e.g. the effect on environmental targets, for instance “health deterioration”), impacting phenomena (for instance “seismicity”) and causes (origin of the phenomenon, for instance “hydraulic stimulation”). The link between these three levels will be highlighted (Figure 3). Some environmental concerns may constitute an impact (something that occurs for sure) or a risk (an unexpected event that may occur, with a probability), but the boundary may sometimes be tricky. As far as possible, GEOENVI tries to propose a clear view of these issues. The project will also identify the “influencing contexts”, that may favour or inhibit the occurrence or the intensity of the different environmental issues (for instance the fact that stimulation may increase induced seismicity or the fact that in some geological contexts radioactivity is non-existent). These favouring situations could be geographical, geological, technological, etc. For each impact/risk, monitoring measures as well as prevention and mitigation solutions will be proposed in terms of best available technologies. The objective is indeed to give transparent information, but also to go forward with the reduction of risk and impacts. Information concerning the perception of risks and impacts will also be presented in the online database. This work requires an important literature review, already in progress.

In addition to this kind of “wiki-database”, a “sites database” will be elaborated, with description of specific-sites characteristics, and with information on specific environmental issues (Environmental Impact Assessment, Risk Analysis, Life Cycle Analysis, incidents with environmental consequences).

The work is currently ongoing, and the database should be available at the end of 2019. It will be public, dedicated notably to all stakeholders of deep geothermal projects and translated in the six languages of the project. A public report will also be prepared.

Finally, in order to broaden the common understanding of environmental aspects of deep geothermal energy, the environmental impacts and risks will be compared to other renewable energies (and other fields, whenever considered of relevance). This aims at understanding which environmental concerns are common to other renewable energies and how they are managed within these projects. Focus will be on comparison of harmonized life cycle analysis, raw materials needs, land use and energy return on investment among other.

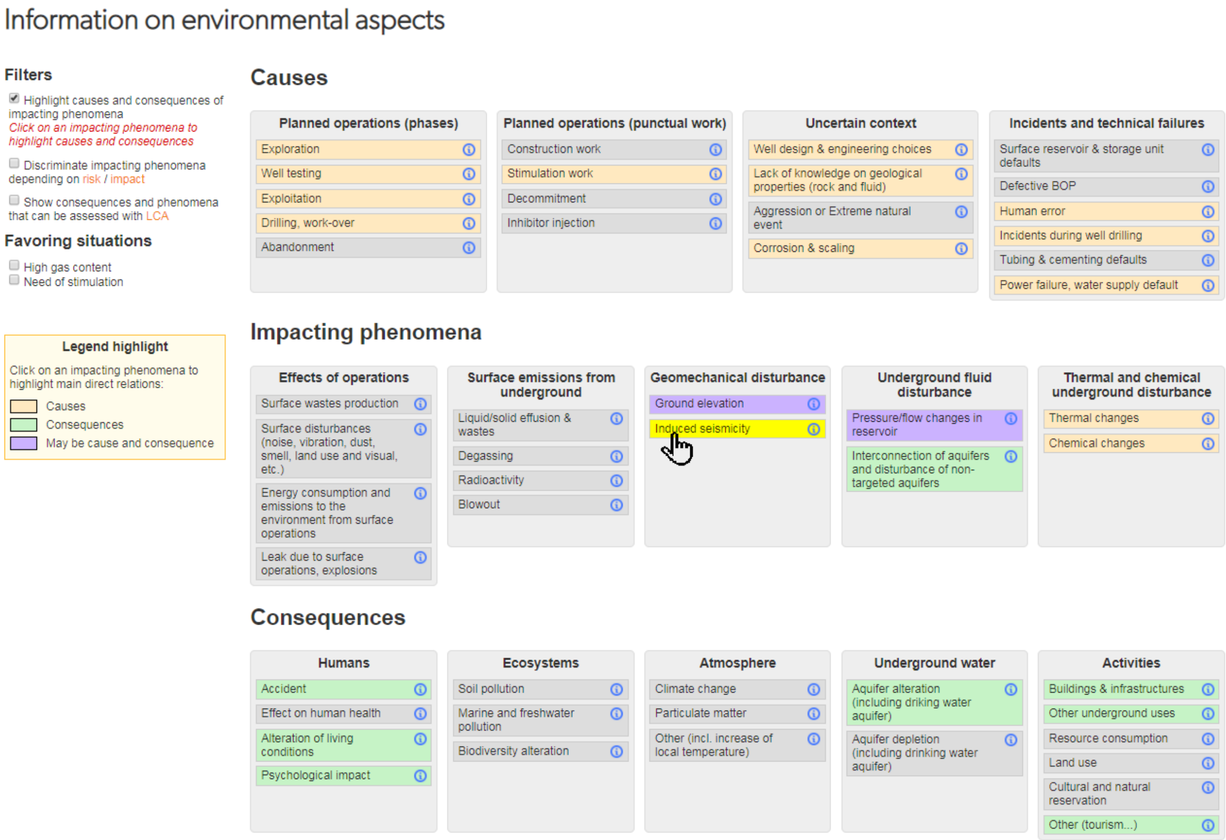

Figure 3: the database highlighting the cause and consequences of induced seismicity.

6. HARMONIZATION OF ENVIRONMENTAL IMPACTS ASSESSMENT METHODOLOGY ENVIRONMENTAL IMPACTS AND RISKS

When it comes to renewable energy, there are complexities in integrating LCA into regulations. LCA standards described in ISO 14040 are open for interpretation. The methods of assessment between studies differ considerably in their system boundaries, co-product and waste definitions and methods of allocation of environmental impacts. Therefore some guidelines have to be established in order to achieve more homogenized results which will, in turn, allow a fair competition between renewable energy market actors. Furthermore, this integration equally demands LCA to be implemented in broader context, in a more practical way, and without adding too much burden to either the policy / decision makers or the practitioners. This is where LCA needs to be simplified. However, developing LCA towards this direction will risk enlarging the uncertainty factors. In the geothermal sector, one needs to be even more cautious with different geological characteristics between geothermal sites. This factor adds variance on top of the different technologies available to extract from deep geothermal energy and convert it to electricity. This is one of the challenges of the GEOENVI project as it covers several countries with different geological characteristics and employing various geothermal technologies. GEOENVI looks into harmonizing existing regulations with LCA methodology by analysing environmental impacts of geothermal plants in different geological settings throughout their lifetime. Simplified models which are suitable for pre-determined geothermal categorization are going to be developed with an acceptable degree of uncertainty. All stakeholders, such as decision makers, public institutions, and economic actors are going to be involved in the development. This will allow LCA assessment to be more integrated in the construction and implementation of regulations. The collateral benefits to the project are the familiarization of life cycle thinking to a larger population, which in turns will bring its own socio-economic gain.

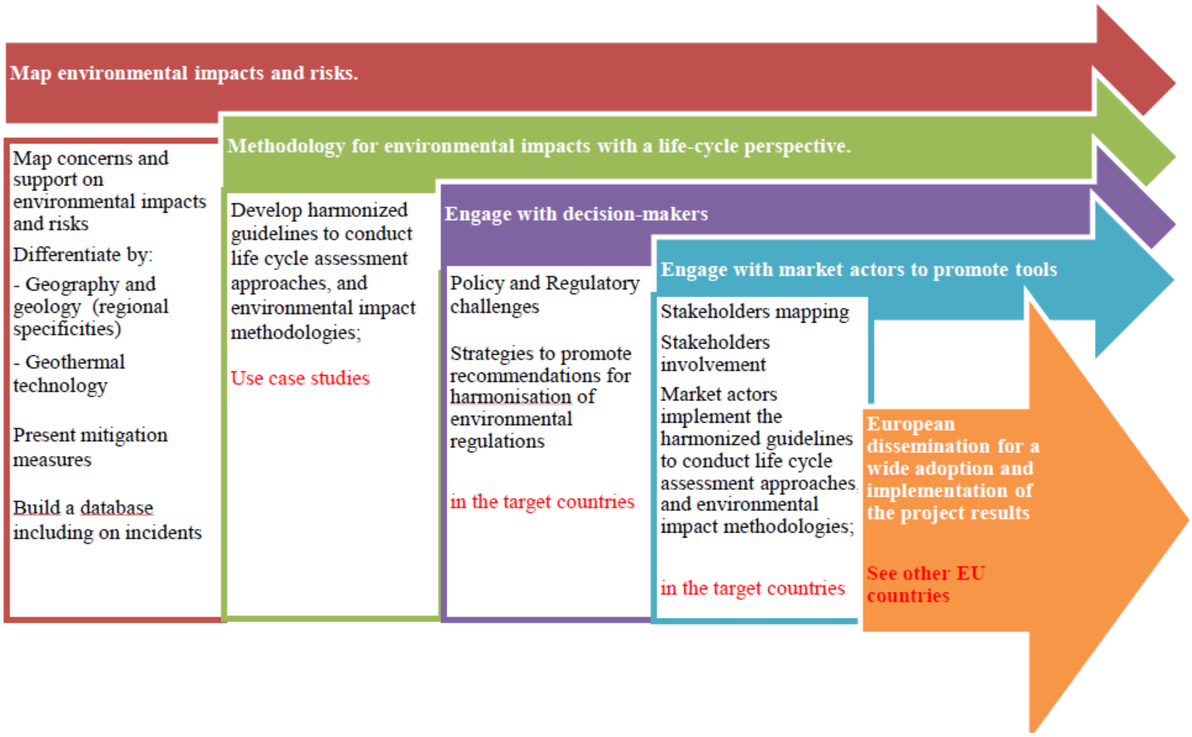

Figure 4. Summary of the GEOENVI Methodology.

The technical experts present in the consortium ensure the quality of the work. They are from public environmental and regulatory authorities, project developers, and scientific institutes. In each country, one partner or associated partner has been selected to represent each key sector: regulators, industry, science. An advisory board is created for these associated partners.

Based on the selected case studies covering both flash and binary operating geothermal power plants and geothermal heating and cooling projects, as well as Combined Heat and Power (CHP) projects, GEOENVI will build harmonized guidelines for environmental impacts assessment. These guidelines will integrate life cycle assessment approaches tailored to geothermal installations to be further adopted at the European and possibly at the international level. Detailed LCA studies will be performed by experts on these selected case studies. These LCA studies will be examined to design reference parameterized models.

As a second stage the interest of LCA alternatives will be investigated with stakeholders, using simplified models dedicated to non-LCA experts. A simplified model generated for GEOENVI cases will serve as an example to pave the way towards this new type of tools. A protocol to generate such types of simplified tools will be provided. Both objectives aim at enlarging the dissemination of knowledge on environmental issues linked with geothermal installations by providing stakeholders with relevant tools and harmonized methodologies.

One key issue is evaluating the environmental costs for different products, such as heat and electricity, which are produced by geothermal plants. The proportion of the two productive outputs is widely different depending on the specific site and technology employed. The problem is common to other systems providing CHP: in this light, GEOENVI will take advantage of existing regulations (Directive 2004/8/CE) introducing a common reduction to the Primary Energy Saving (PES). Moreover, the value of heat as a product is heavily associated to its exergy content and to the use of material streams to produce it: an exergy-environmental approach based on LCA evaluation of the environmental costs will be applied. The required detailed Life Cycle Inventory (LCI) will be reverse-engineered from global LCI in order to allow application of this methodology also to the Simplified Life Cycle Analysis.

GEOENVI will report its first data early 2020 about greenhouse gas emissions (g/kWh) based on production, and based on LCA studies. It will also provide data about emissions in H2S and Hg. The application of mitigation measures such as applying AMIS will also be assessed about its effects on reducing H_2S and Hg emissions.

7. ENGAGE DECISION-MAKERS AND MARKET ACTORS

GEOENVI aims at engaging with both decision-makers and geothermal market actors, to adopt recommendations on regulations and to see the LCA methodology implemented by geothermal stakeholders. The engagement with stakeholders includes sharing of knowledge by adopting an open and FAIR (findable, accessible, interoperable, reusable) data approach. The aim is to contribute to the development of a calm, transparent and trustworthy climate to discuss environmental concerns, thus favouring a solid deployment of future projects. The relevant geothermal market actors in the countries will be listed, since they represent parties that affect or are affected by geothermal activities and their mapping will be carried out to identify their entity and relationship with geothermal energy and projects. The objective is indeed to see market actors adopting the GEOENVI toolkit (methods and models) for environmental impact assessments and on life cycle assessment approaches. It is essential to engage strong interactions with strategic groups, including political decision makers, project developers, investors, the general public, and local communities, in order to address environmental impacts. Indeed, it is responsibility also of decision and policy makers to ensure that the growth of renewable energy is in line with sustainability. Several workshops with stakeholders and GEOENVI partners are planned along the project in the six targeted countries and first workshops will be in autumn 2019.

As a result, the environmental risks and impacts of geothermal energy projects shall be reduced while maximizing the benefits derived from the project to local communities. A monitoring tool will be developed to measure how these objectives have been achieved.

In order to engage with decision-makers, the best strategy to harmonize and empower the existing environmental regulations, adapting life cycle thinking is also engaging the relevant national and local authorities (e.g. environment ministries, mining authorities) in order to facilitate the change. At this point, other relevant countries outside the consortium that have strong activity in geothermal energy (Germany, the Netherlands, etc.) are going to be included in the scope. Decision makers such as energy or environmental ministries, mining authorities, public funding, and local authorities are going to be mapped. Furthermore, for an efficient engagement, it is important to set some prioritization strategy by analysing relevant existing regulations, and identifying the owners of the regulations, their level of influence or authority and their openness to changes in the countries of the consortium. By having them identified, engagement efforts could be focused to the ones having higher influence to the success of changes implementation.

8. CONCLUSION

By creating a database of environmental impacts and risks and analyzing their mitigation measures, GEOENVI will facilitate the harmonization of environmental impacts assessment methodology. The life cycle approach is expected to be very favourable in quantifying the possible negative environmental issues, and in order to allow comparisons with other renewables. The adoption of the outcoming recommendations of the GEOENVI project by decision-makers and market actors will support the increase of geothermal energy in the future energy mix, first in the target countries of the project, and then in all Europe.

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