Integrated sustainability assessment framework

CHPM2030 Deliverable D5.1

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CHPM2030

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Author contact
János Szanyi
University of Szeged
13 Dugonics Square, H 6720 Szeged
Hungary
Email: szanyi@iif. u-szeged.hu

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University of Miskolc
H-3515 Miskolc-Egyetemváros
Hungary
Email: foldshe@uni-miskolc.hu

CHPM2030 DELIVERABLE 5.1

INTEGRATED SUSTAINABILITY ASSESSMENT FRAMEWORK

Summary:
This document considers economical, social and environmental aspects of the proposed CHPM technology. Policy and ethical related issues will be discussed in a seprate work. The structure of the proposed framework was inspired by those industry standard documents that were conceived to ensure the sustainable operation of this specific field of industrial activity.

Authors:
János Szanyi, University of Szeged
Tamás Medgyes, University of Szeged
Balázs Kóbor, University of Szeged
Máté Osvald, University of Szeged
Günter Tiess, MinPol GmbH
Vojtěch Wertich, MinPol GmbH
Lari Tiewsoh, MinPol GmbH

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Executive summary

The anticipated scientific breakthroughs and the successful implementation of the research and development work during CHPM2030 does not translate the proposed methodology into a turnkey solution that is ready to be deployed. For this reason, a series of assessments (e.g. economic, environmental social) will be conducted with the aim of not only understanding and forecasting the probable impacts of the CHPM2030 technology but these studies are expected to help revealing a series of potentially limiting factors that might have fundamental sustainability effects on the proposed technology solutions.

This integrated sustainability assessment framework considers economical, social and environmental aspects of the proposed CHPM technology. Policy and ethical related issues are going to be discussed in a seprate work. The structure of this proposed framework was inspired by those industry standard documents (such as Hydropower Sustainaiblity Assessment Protocol, or the recently released first draft version of the Geothermal Sustainability Assessment Protocol) that were conceived to ensure the sustainable operation of that specific field of industrial activity. The final sustainability framework report will incorporate the results and outputs of all the tasks within the corresponding work package (Tasks 5.2-5.6), with the ability to highlight the complex interconnections of the issues at stake.

This document highlights all those aspects that will be taken into consideration to develop the relevant reports for each sub-task.

The assessment of **economic sustainability** is going to be based on an integrated analysis of statistics, related economic studies and publications that not only enable a complementary synthesis of the current energy markets, trends and prices, but evaluates the potential of the proposed CHPM technology compared to conventional, non-renewable energy sources, other renewable energy options, conventional hydrothermal plants and already operating EGS plants. The resulting economic sustainability report along with the decision support tool for economic feasibility assessment will not only detail the constraints of the currently available energy solutions making it possible to understand the challenges that the CHPM research and innovation efforts need to tackle but it will outline new market opportunities for this new set of technology solutions.

The economic feasibility of the proposed CHPM technology can be estimated using any form of discounted cash flow method (such as Net Present Value, Cost and Benefit Analysis). The base parameters that models will generally take into account are: financial parameters (price of capital, interest rates, equity rate of return), the output of the whole system (thermal drawdown rate, well flow rate, number of production and injection wells), investment costs (site exploration, drilling and re-drilling, reservoir simulation and surface plant facilities) and finally operating and maintenance costs. In addition to these base parameters the improved model will include parameters related to the extraction of metals, additional exploration and capital costs and the price and performance parameters of innovative technologies of metal extraction.

In addition to the analysis of a series of economic models (such as LEAP, GETEM, CREST, SAM), a novel approach will also be presented, that will not only allow the definition of levelized cost of energy (LCOE), investment and operation costs of EGS plants, but also provide estimates on metal production and the definition of the Net Present Value of a CHPM investment. The economic feasibility model

developed for CHPM is foreseen to allow the economic analysis of different types of ultra-deep deposits, while being flexible enough to enable the analysis of different metal extraction scenarios, too.

One key output of the proposed methodology will be the "Self Assessment Tool" (SAT), allowing investors, companies, authorities and communities to analyse their own data, avoiding any potential confidentiality issue, which could often be the case in the mining and geothermal energy sectors. Work under this task will include the professional analysis of the adaptability of present models, the economic modelling work, IT programming of the model, testing and application of the model, analysis of the data produced by the model, and deploying the SAT.

The proposed **social impact assessment framework** will consider the impact of CHPM2030 on the key social development factors, social licence to operate (SLO), regional and local social and economic development, health and safety of workforces and communities, skills development, etc. It will detail the necessary steps required to obtain, secure and maintain a social licence for the proposed CHPM scheme. To achieve this goal, the framework will discuss the necessary steps to: (a) demonstrate to a diversity of stakeholders that minerals extraction is essential for meeting society's needs and can be undertaken without causing long term environmental harm; (b) provide assurance to individuals and communities who are potentially exposed to adverse social and economic impacts from resource projects that these concerns will be recognised and addressed in a timely way; and (c) demonstrate that communities in the vicinity of the proposed developments, and regions can benefit from short, medium and long-term.

The objective of the **Environmental Impact Assessment** on the one hand is to develop an EIA methodology framework, in which the environmental impacts of the proposed CHPM technology line can be evaluated in an objective manner. This means that the environmental impact assessment must consider the hybrid nature of the technology, in which the environmental performance of the two main components (mining and energy generation) should be evaluated in comparison to the conventional ways of producing equal quantities of raw materials and energy, and the environmental footprint should be evaluated cumulatively. On the other hand, to utilise the framework to i.) monitor and evaluate the actual environmental impacts as they arise during the implementation of WP1-WP4 and ii) to develop a methodology with recommendations as to how an EIA should be carried out for a future CHPM facility.

The major environmental issues that are associated with CHPM are ground-water contamination, induced seismicity and noise during drilling and reservoir engineering processes. The investigation of the environmental effects of geothermal fluid losses as well as the afterlife of chemicals and additives used during the process, such as nanoparticles forms also a substantial segment of the EIA work. Altogether the different metals mobilisation pathways will be comparatively evaluated in terms of environmental impacts and risks. This Task will closely follow up the laboratory experiments carried out in WP2, using output data and results for the subsequent modelling of environmental impacts.

Ultimately, the comparison the expected environmental impacts of CHPM technology will be made with conventional mining and conventional EGS. Overall evaluation and recommendations including monitoring suggestions shall also be described.

1 Introduction

It is of general knowledge that the energy usage worldwide is increasing. It has been predicted that the global energy consumption will increase by over one-third by 2035 and the fossil fuels are still dominating the global energy mix (IEA, 2012), but the use of alternatives such as geothermal energy is set to increase, since the world has only finite supply of fossil fuels. Furthermore, in order to combat climate change and fulfil international agreements, low carbon energy sources such as geothermal energy are now being tapped on a larger scale. In 2008, geothermal energy represented around 0.1% of the global primary energy supply, but estimates predict that it could fulfil around 3% of global electricity demand, as well as 5% of global heating demand by 2050 (IPCC, 2012).

While energy is needed for economic growth and sustainable development, energy development also has economic, environmental and social impacts. To have a better understanding about these impacts of a project, a tedious, in depth process should be performed to reveal not only the obvious results of a development but to shed light on more subtle correlations too.

Sustainability assessment is a means of showing the progress of development projects towards or away from sustainability. Sustainability assessments are used for diverse types of projects, including energy developments (Shortall, 2015). Like any other energy source, geothermal energy developments can result in positive as well as negative socio-economic and environmental impacts (UNDP, 2002). For example, geothermal projects can result in socio-economic benefits particularly in developing countries and rural communities by improving infrastructure, or stimulating local economies. They can also act as a reliable source of base-load power for a region's energy system. However, certain issues need to be addressed as many geothermal energy developments result in negative social or environmental impacts (Shortall et al 2015). By adding the subsequent mining aspect of the CHPM2030 concept (combining the highly controversial underground in-situ leaching process (used e.g. in uranium mining) and the EGS approach with a currently unconvincing performance and cost/benefit ratio) it becomes evident that the complexity of the potential environmental, social and economic impacts will increase by at least a factor. Even though some technology components of the proposed concept are available today, some of them have still not advanced from proving the idea viable in a controlled environment, on laboratory scale. The combinations of these solutions carry a great deal of uncertainty in many areas, including the sustainability of the proposed technology concept. Activities within this WP5 will focus on integrating the existing knowledge in terms of environmental, economic and social impacts of those technologies that are currently available and are incorporated in the CHPM2030 concept. In addition, it will make an attempt to forecast the potential impacts that may root in the final configuration of the CHPM2030 technology solution to form a solid basis for future relevant research and iterations in this aspect.

Various assessment tools and frameworks, many of which involve the use of sustainability indicators, exist from the national level to the local level.

Such indicators must provide a holistic view of sustainability and thereby include all sustainability dimensions in order to avoid such examples of unsustainable management of geothermal resources that are presented at the Hellisheidi geothermal power plant in Iceland and the Wairakei power plant in New Zealand. The impacts of geothermal energy developments have significant implications for

sustainable development, and require specific monitoring tools to ensure the impacts are managed in a sustainable manner. Currently there is no standard methodology in place to assess individual geothermal projects using energy indicators for sustainable development (Pinter et.al, 2005).

In addition to that, while routine environmental monitoring is carried out by various agencies nationally, no specific requirements to monitor the environmental, social and economic impacts of geothermal projects are currently specified in legislation for the sustainable management of geothermal projects.

Furthermore, as well as indicators, sustainability criteria or goals are also important for sustainability measurement. Such criteria and indicators should not be rigid but take account of the local context as well as changes in opinions over time (Lim, Yang, 2009). To ensure this, broad stakeholder engagement is an essential part of the indicator development process (Fraser et al, 2006).

The wide variety of available sustainability assessment frameworks in existence today highlights the ambiguity surrounding the meaning of sustainability for different industries, user groups, cultures and regions or organizations. Given the unique issues associated with geothermal energy projects, a specialized assessment tool is essential to ensure that geothermal projects will be properly guided into following best practices and result in positive impacts in all sustainability dimensions: environmental, social and economic.

Even though there are a few different protocols to be used by different players of the energy sector, they are rather inadequate when applied to geothermal initiatives. One example is the *HSAP* (International Hydropower Association Sustainability Assessment Protocol), which is a methodology used to measure the performance of a hydropower project across more than twenty environmental, social, technical and economic topics (Wikipedia). In addition, it assesses various strategic and managerial aspects of the proposed or operational hydropower projects without the use of any indicators (HSAP, 2006). Then there is the *Gold Standard Foundation* that provides a rather general sustainability assessment framework for new renewable energy or end-use efficiency improvement projects. The downside of this latter framework is that it is not specifically tailored to geothermal projects, thus they are not suitable to be used to carry out geothermal assessments, since they do not deal with all the unique sustainability issues associated with geothermal development projects (The Gold Standard Foundation, 2012).

Various renewable energy associations have attempted to improve sustainability assessment for their kind of energy projects without introducing any indicators. The World Wind Energy Association has developed the *Sustainability and Due Diligence Guidelines*, for the assessment of new wind projects (WWEA, 2015), similar to those developed by the International Hydropower Association in their Sustainability Assessment Protocol. These guidelines neither cover the operation stage of a wind energy project nor provide a set of comprehensive indicators. The *WWF Sustainability Standards for Bioenergy* does not provide any indicators either, but does highlight sustainability issues in bioenergy and offers recommendations for its sustainable use (WWF, 2005). UN-Energy has also published a report with a similar focus entitled *Sustainable Bioenergy: A Framework for Decision-Makers (UN-Energy, 2007)*.

At the same time there are several indicator frameworks around to measure sustainable development in the context of energy developments. In 2005 the International Atomic Energy Agency (IAEA) in collaboration with several other bodies published guidelines and methodologies for a set of energy indicators for sustainable development (EISDs), emphasizing national self-examination (International Atomic Energy Agency (IAEA, 2005). The EISDs were created to provide policy-makers with information about their country´s energy sustainability. They are intended to provide an overall picture of the effects of energy use on human health, society and the environment and thus help in making decisions relating to choices of energy sources, fuels and energy policies and plans.

It is clear, that due to their unique characteristics, geothermal projects (large or small scale) cannot really fit into the existing frameworks adequately, thus a customized framework for assessing their sustainability is required. Understanding this need, a consortium gathering the most significant geothermal players of Iceland (eg: Orkustofnun, Landsvirkjun, Orkuveita Reykjavikur) had recently developed the so called *Geothermal Sustainability Assessment Protocol* (GSAP), a sustainability assessment framework for (deep) geothermal development and operation to be used in future geothermal initiatives globally, assessing the viability and sustainability of the proposed concepts. WP5 of the CHPM2030 concept will heavily rely on the structure of this recently released first iteration of GSAP, benefiting from its strictly geothermal focused approach.

The GSAP adapted the internationally recognized and fully tested HSAP to geothermal plants with some tailor-made modifications (such as introducing relevant indicators) enabling the production of a sustainability profile for a geothermal project through the assessment of performance within important sustainability topics. As a modified, and in some sense improved version of the HSAP, the GSAP not only facilitates the sustainability assessment needs of future geothermal projects, but also assesses the strategic basis for a proposed geothermal project including demonstrated need, options assessment and conformity with regional and national policies and plans.

One of the fundamental notions behind such a framework is that the Protocol must be widely applicable and it should be applied in a collaborative way, to ensure the best availability of information and points of view. Similarly to the development and evaluation of a hydropower project, larger scale geothermal programs also tend to involve many actors with different roles and responsibilities. Furthermore, it is recognized that both development and operation may involve public entities, private companies or combined partnerships, and responsibilities may change as the project progresses through its life cycle (Shortall, Davidsdottir, Axelsson, 2015).

The conceptual approach of CHPM2030 currently associated with rather low TRLs, requires the adoption of only the very first stage (Early Stage) of this GSAP protocol, that follows the logic and structure of the HSAP. Later stages (such as Preparation, Implementation and Operation) will come into play as the concept and the related technology solutions emerge, hence they are out of the scope of this particular sustainability assessment to be developed in WP5.

The Early Stage assessment tool is a preliminary screening tool to assess the strategic environment from which proposals for geothermal projects emerge. It identifies project risks and opportunities at an early stage in order to identify the challenges and management responses to proceed with a more detailed project investigation. The Early Stage assessment tool may also be usable for other broader

purposes, such as the identification of opportunities to improve the sustainability context of geothermal investments.

The Early Stage assessment tool differs from the other three assessment tools in that it is an assessment guide but not a scoring protocol. This is because there is not a clearly formulated project at this stage, nor a strong basis of information from which to derive sustainability scores. A further difference is that early investigations about potential project possibilities are often of a confidential nature, especially in the case in which developers have not yet decided whether to invest in more detailed studies, or where there is a highly competitive context of a liberalised energy market. As long as no public announcement about project intentions has been made, this Early Stage assessment tool offers a means to encourage better early stage analysis and identification of knowledge gaps. As soon as detailed technical, environmental, social and financial feasibility studies are undertaken, often under a strict governmental process, the use of the Preparation assessment tool will be appropriate (HSAP, 2006).

Work within this WP5 will focus on the most basic, yet the most important aspects of sustainability evaluation by addressing the topics of environmental, economic and social impacts that are associated with a geothermal investment of such a scale and complexity. These aspects will be developed as individual tasks, with corresponding deliverables. This document is to guide the reader through the basic concepts and intentions that will be taken into consideration while progressing with these studies.

It must be noted that even though it follows the principles of the mature HSAP, the GSAP is a relatively new protocol and is still in the process of fine tuning. Its goals and indicators were developed using an iterative process for thematic indicator development (Davidsdottir et al, 2007), with the intention of carrying out further iterations in several different countries. One iteration consists of four steps:

- choosing sustainability goals (e.g.: renewability, environmental management, dissemination of knowledge etc)
- choosing sustainability indicators guided by stakeholder input
  - **environmental** indicators: visibility (landscape), Tons of GHG emissions resulting from geothermal operations, Air quality in the surrounds of the geothermal power plant (GPP), Water quality, soil erosion, induced seismicity)
  - **social indictors:** ownership of the resource**,** average income levels in project affected communities, percentage of community residents that must be relocated due to the energy project
  - **economic indicators** (direct and indirect local job creation over the lifetime of the project Utilisation efficiency for the GPP, Estimated productive lifetime of the geothermal resource, project internal rate of return, real estate value in the area) indicators
- calculating the indicators in a trial assessment of an operational geothermal project and
- evaluating the indicators for suitability (Shortall, Davidsdottir, Axelsson, 2015).

The purpose of the iterative approach is to allow the progressive refinement of the indicators following each iteration. Currently there have been only a single site assessed in Iceland (Theistareykir Power Plant), as the very first iteration of the approach. The assessment consists in a detailed review of 17 different topics relating to the preparations for the Plant, which are designed to provide an overview of how well the plant and its operations conform to international criteria on sustainable development (Landsvirkjun, 2017). Additional sites in Kenya and in New Zealand being considered to confirm and - if needed - to adjust the findings of this very first step, that could be summarised as follows (Shortall et al, 2015):

- any geothermal energy project will face unique sustainability challenges, due to the differing environmental and socio-economic setting in which it is found (sustainability goals and indicators are not uniform)
- qualitative information has to be supplied alongside the reported indicators in order to provide the end user with site specific information.
- to have an associated stakeholder input process that runs simultaneously with a sustainability assessment to ensure that the indicators reflect the evolving nature of sustainable development. Such stakeholder inclusion methods should be culturally appropriate and agreed to by all parties before they are implemented (Meadows, 1998).

Interestingly, environmental and economic indicators were regarded as more relevant than social or institutional indicators in this first iteration of the GSAP in Iceland. Shifting of importance of these indicators might be experienced at a different location that differs from Iceland in terms of socio-economics, cultural background or environmental consciousness in general. The Theistareykir Power Plant survey revealed that the priority sustainability goals for stakeholders were related to renewability, water resource usage and environmental management. The top five indicator choices were related to resource reserve capacity, utilization efficiency, estimated productive lifetime of the geothermal resource and air and water quality (Shortall, Davidsdottir, Axelsson, 2015).

Whilst developing a sustainability assessment framework for geothermal energy projects, the goals and most important sustainability issues measured by the indicators were chosen to reflect the subjective opinions of the group of stakeholders, even though precise, analytical techniques may be used to calculate the indicators once they are chosen. The very act of choosing sustainability goals and indicators can be an adaptive learning process for all parties involved (Reed, Fraser, Dougill, 2006).

In addition to the already mentioned sustainability aspects and frameworks that support these initiatives another important facet of geothermal research must be addressed. As geothermal energy started to claim an ever-increasing share in the global energy mix, key stakeholders (investors, regulators, governments, consumers, and the industry majors) voiced their need for a common assessment and comparison framework; a platform that provides a solid foundation for a comprehensive overview of current and future energy sustainability scenarios at project, company, country, region or world level. For this reason, the joint efforts of the United Nations Economic Commission for Europe (ECE) and the International Geothermal Association (IGA) developed a set of specifications and guidelines to extend the application of the United Nations Framework

Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) to geothermal energy. With no globally agreed geothermal standards, guidelines or codes existing prior to the development of the "*Specifications for the application of the UNFC-2009 to Geothermal Energy Resources*" (ECE/ENERGY/2016/5), document, it is now hoped that the inclusion of geothermal energy within UNFC-2009 will facilitate the improvement of global communication in the geothermal sector as part of the larger energy sector (UN-ESC, 2016).

In the highlights of all this, not only a potential project level cooperation with the developers of the GSAP aiming at contributing to the further development of this framework is envisaged, but some development aspects of the CHPM2030 concept will be guided by this extended UNFC-2009 framework. This could ultimately lead to expanding the current, still draft GSAP framework with certain novel aspects that are for example incorporated in the CHPM2030 project, and further potential iterations of the UNFC-2009 may also benefit from the project's findings. Such a collaborative work may lead to the development of a more flexible and inclusive final framework tailored to fit the needs of various geothermal projects. This approach ultimately has the potential to remain open-ended to accommodate future advancements in the field, like the conceptual leap in in-situ underground mining on the wake of EGS development. From the commercial attractiveness point of view of the CHPM2030 concept such collaboration is vital, since the current version of the already cited ECE/ENERGY/2016/5 document currently is very specific about what is considered as the Geothermal Energy Product. Now it is only heat and electricity, while other products, such as inorganic materials (e.g. silica, lithium, manganese, zinc, sulphur), gases or water extracted from the Geothermal Energy Source in the same extraction process do not qualify as Geothermal Energy Products. Since subsequent ore production adjacent to EGS development is the very core of the CHPM2030 project such discrepancies needs to be resolved to allow the inclusion of such developments under the umbrella provided by this recent UNFC-2009 framework for a more simplified assessment methodology (e.g introducing relevant reference points for each additional product stream).

2 Baseline economics for energy and mineral raw materials

2.1 Introduction – framework for Task and Deliverable 5.2

Task and Deliverable 5.2 will be focusing on methodology of economic feasibility of proposed CHPM (Combined Heat, Power and Metal extraction) energy infrastructure – modelling and assessing of economic feasibility by its own will be part of Task and Deliverable 5.3.

The term "energy infrastructure" is used, because the proposed CHPM technology is a plant generating power (electricity) and heat in the first place. Question, whereas the heat (Brown et al., 2012) can be primary commercial product only in the case of some co-located infrastructure (even fossil fuel power plant), which could use the waste (excess) heat. And if possible extraction of valuable metals (currently not considered as Geothermal Energy Product (UN-ESC, 2016)) can be economically viable by itself is a matter of special natural features (boreholes targeted into suitable mineral deposit) and unique extractive-technology infrastructure.

Or these "other products" can be understand "just as economic advantage", helping with faster redemption of very high capital (initial) cost and reducing considerable operating costs of CHPM plant. According Brown et al. (2012) about two-thirds of the principal investment cost will be consumed to develope pressure simulated HDR (hot-dry-rock) reservoir, especially completing and drilling of deep wells (up to 4000 meters1). They are assuming cost for completing of three 4000 meters deep boreholes of about $28 million. Comparable deep boreholes are used in oil industry, where capital costs per one onshore well fell in range $4.9 – $8.3 million (U.S. Energy Information Administration, 2016).

As any other infrastructure project is aiming to be self-sufficient, effective or in the best case fully economic and gainful, also proposed CHPM technology (power plant) needs to be evaluate through economic analyses, such is for example economic impact analysis, cost-benefit study or feasibility and location study linked to social/environmental impact assessment. Only such complex sets of evaluation can prove effectiveness of the proposed innovative technology. Or the analysis can show, where are the weaknesses and problematic issues, which needs to be overcome to achieve (economical/financial) sustainability of CHPM power plant and fixed such energy infrastructure to the energy market among other economic power plants using different sources for generation of electricity.

Problematic part in the economic assessment of CHPM plant will be the fact, that there is no such a plant already built, to compare it or use historic data. What we know at the moment, there is a none commercial private EGS (Enhanced Geothermal System – similarity with proposed CHPM infrastructure) plant, which wouldn't be financially supported by government to be operating or even to be developed in the first place (Olasolo et al., 2016). Such information suggest serious issues in commercial economic feasibility of the EGS (and future CHPM) energy infrastructure.

Some comparisons (limited, milder leaching agents) for metal extraction, planned for CHPM, are possible to see in mining technology of in situ leaching (ISL) or in situ recovery (ISR), which is common

[1] Discussed depth for proposed CHPM technology to achieve suitable rock temperature, internal project discussion.

extractive method in e.g. uranium mining, where 48% of world mined uranium in 2015 was from ISL operations (World Nuclear Association, 2017). In any way, metal extraction connected with power and heat generation, is very innovative concept with untested feasibility.

For economic assessment of CHPM plant (or Enhanced Geothermal System (EGS) plant or any other planned infrastructure) is needed a set of parameters of the proposed infrastructure, allowing to create economic and business models. Some of the parameters, e.g. depth of boreholes/underground heat exchanger, flow rate, temperature (set of critical parameters for single elements of CHPM) are already discussed and set as a result from previous work packages of the project. More parameters are necessary for economic modelling, among others there should be some agreement on e.g. proposed thermal and electrical power or quantity and type of metals extracted. Essential parameters, framework and methodology for economic modelling will be discussed during Task and Deliverable 5.2 builidng on the already defined parameters of ”project lifetime”, “economic limit”, “contract period”, “projects with multiple energy products” and “intermittent or variable extraction” as they are defined in the “Specifications for the application of the United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009) to Geothermal Energy Resources” framework document.

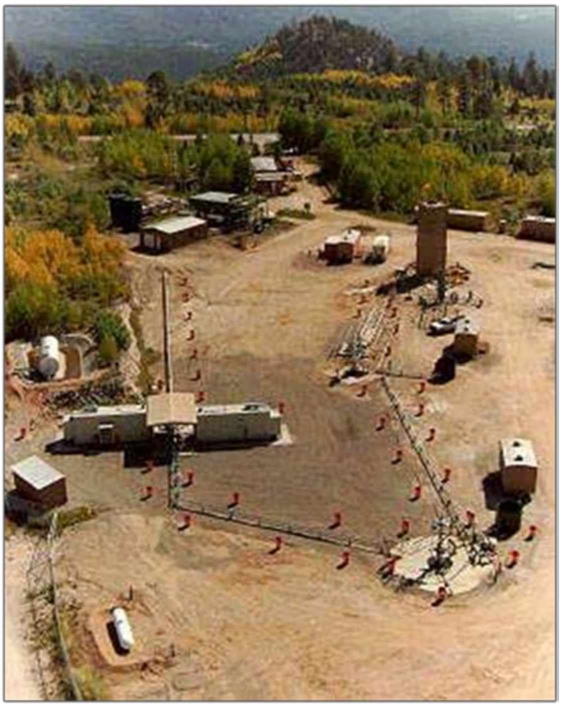


Fig. 1: The first EGS plant at Fenton Hill as result of Geothermal Energy Program at Los Alamos (Los Alamos National Laboratory, 2011).

The idea of setting several scenarios for CHPM plant, coming from suggestions of Advisory Board at the last 4th Consortium Meeting (Brussels, 11th – 14th September 2017), considering different technological parameters, possible also bound geographically to certain area (project study areas, e.g. Portugal / Iberian Pyrite Belt), looks as appropriate approach. Such approach can make easier to set the parameters not only for economic modelling, but also for considering specific metals/minerals, environmental, social aspects and to “prepare land” for road mapping and pilots.

2.2 Comparison of proposed CHPM plant with operating EGS projects

Deliverable 5.2 will include also the list of operating EGS plants, their economic information and collected data will be used for purposes of creation methodology and framework for economic modelling of proposed CHPM plant.

Power and heat production of proposed CHPM infrastructure is in most of the aspects similar (or even identic) with so called EGS plants, EGS mean Enhanced Geothermal System or Engineering Geothermal System e.g. (Breede et al., 2013). Original concept, from which comes out other EGS projects and proposed CHPM technology, was HDR (Hot-Dry-Rock) Geothermal Energy Program at Los Alamos in New Mexico, USA (Fig. 1), patented in 1974 (Potter, Robinson and Smith, 1974). There

is a very well compiled list of EGS plants/projects in already cited article (Breede et al., 2013), which was gathering information about both already operating and developing EGS projects up to year 2013. The list will be updated from newer sources including both public available data, scientific papers or corporate studies.

For example, a new paper dealing with economic analysis of EGS (Olasolo et al., 2016) contains also a mention, that at 2nd May 2013 Australian company Geodynamics opened the first private commercial EGS plant. But if we looked more detailed on the particular project, we learn that Geodynamics Ltd., quoted on Australian Security Exchange (ASX:GDY), started in May 2013 with power generation from their 3 boreholes 1 MWe Habanero Pilot Plant located in Copper Basin, Australia (Richter, 2013), but even there was the state government fund in the amount of $32.75 million (ARENA, 2015). And what is even worse information considering this first private commercial EGS plant, is announcement about changing company name (Geodynamics to ReNu Energy) and focus to solar, battery storage and hybrid energy system. CEO of the company explained the closing of the project: "The technology worked but unfortunately the cost of implementing the technology and the cost of delivering the electricity that was produced to a market was just greater than the revenue stream that we could create," (Vorrath, 2016).

The EGS projects will be summarized also in tables (content, information more columns will be added according available data, also e.g. ongoing Horizon 2020 project DESTRESS (DESTRESS, 2016)).

Table 1: Example of basic data about new Pohang EGS plant in South Korea

Pohang EGS plant, South Korea, planned start in 2017 / early 2018, data source (Shine, 2017)				
Governmental Funds	Private Funds	Host rock	Depth / Temperature	Power capacity
$16.4 million	$22 million	Non-volcanic	4,348 / 180°C	1.2 MW

2.3 Potential of CHPM technology in comparison with other energy sources

Another part of the Task and Deliverable 5.2 will be dealing with position of proposed CHPM plant in the energy market and its comparison with other renewable, non-renewable (conventional) energy sources. Maps and descriptions displaying bellow (Fig. 2a-c) showing share of different energy sources in the World.

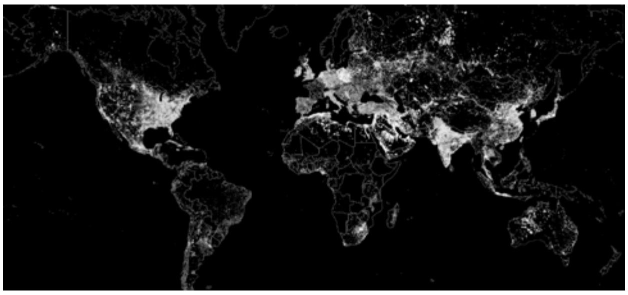


Fig. 2a: Eletricity source: Fossil Fuels (Desjardins, 2017)

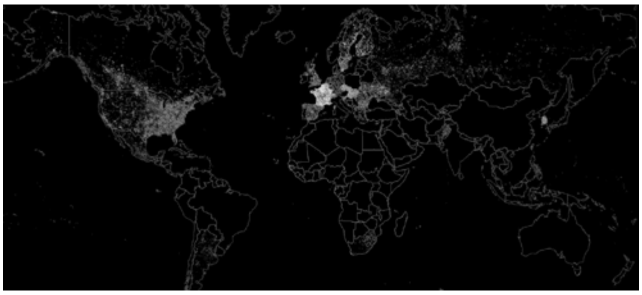


Fig. 2b: Eletricity source: Nuclear (Desjardins, 2017)

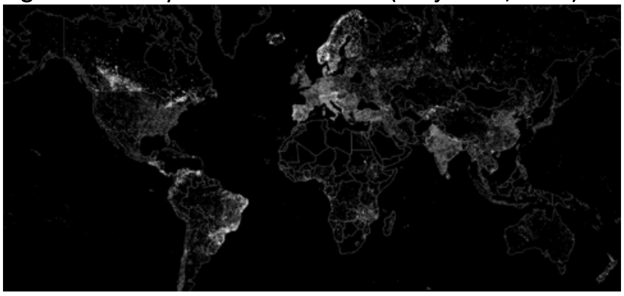


Fig. 2c: Eletricity source: Renewables (Desjardins, 2017)

As you can see at top-left map, fossil fuels (or combustible fuels) are still dominant source for world electricity generation, significantly over half of the world annual electricity generation. Nuclear electricity source is bound more geographically, and takes about 10% of world annual electricity generation. Renewable sources contribution is slightly over 20% and hydro has still leading position (Desjardins, 2017).

Even the fossil (combustible) fuels has still dominated position in the world (Fig. 2a), EU-28 perspective and trends looks differently (Fig. 3).

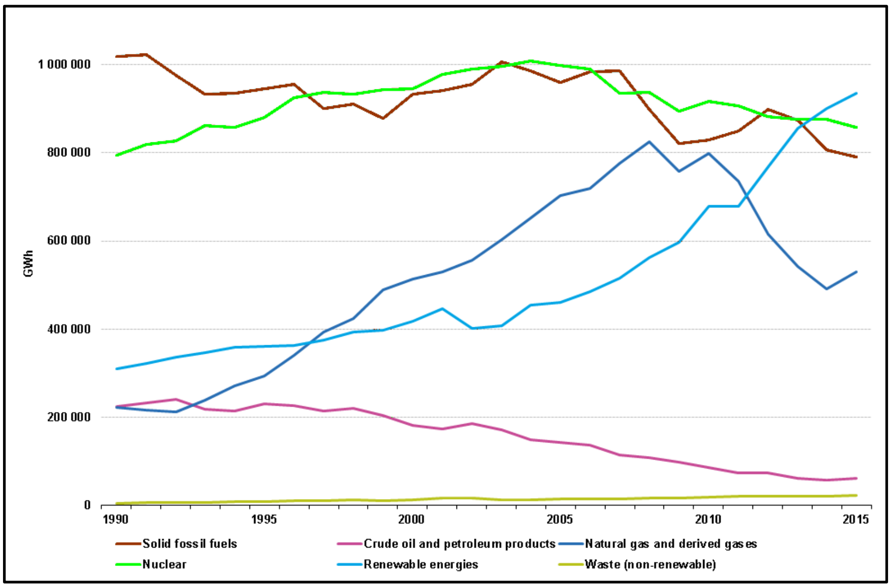


Fig. 3 Gross electricity production by fuel, GWh, EU-28, 1990-2015
(edited after Eurostat, 2017)

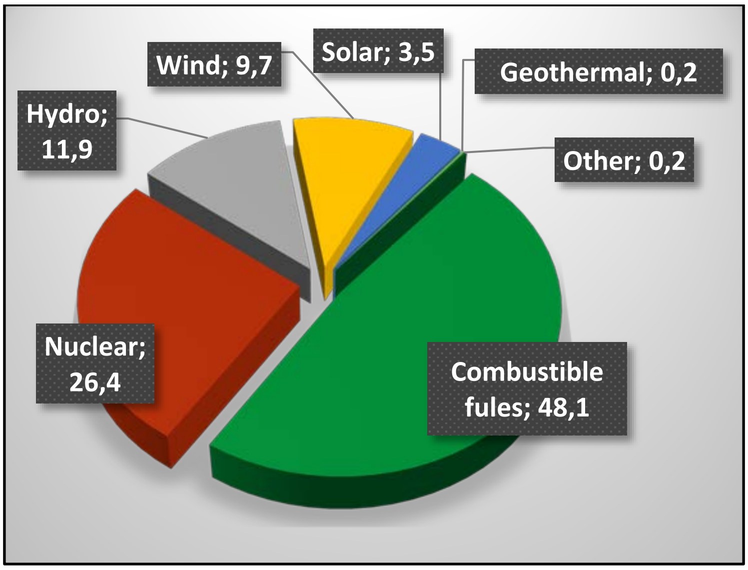


Fig. 4: Net electricity generation, EU-28, 2015, in % of total, based on GWh (edited after Eurostat, 2017)

Solid fossil fuels, natural gas and oil have slowed downward trend. Nuclear is experiencing similar trend as fossil, fed probably by Fukushima accident in 2011. On the other hand, the renewable sources are showing step grow. Although share of geothermal electricity generation in the EU-28 (Fig. 4) is only 0.2% (and these are conventional hydrothermal plants), the trend is supporting the alternative renewable energy sources. Such atmosphere suggesting a good environment (even in searching for funding) for innovative approaches, such as EGS (and possible future CHPM) plants.

Despite about 40 years long history of EGS plants (as something like "predecessor" of proposed CHPM), the technology and cost-effectivity (especially high initial costs and in most cases not-so-high electrical/thermal capacity, Fig. 5) aren't so far mature enough to be fully competitive with commercial (conventional power plants). But, if the concept of co-extraction of valuable metals from same wells used for power and heat generation would be successful and (again) cost-effective (cost comparison with conventional mining and mining methods will be another part of Task and Deliverable 5.2), it can help continuously reducing the operation costs of CHPM facility, then the effectivity and competitivity of CHPM infrastructure would have chance to grow.

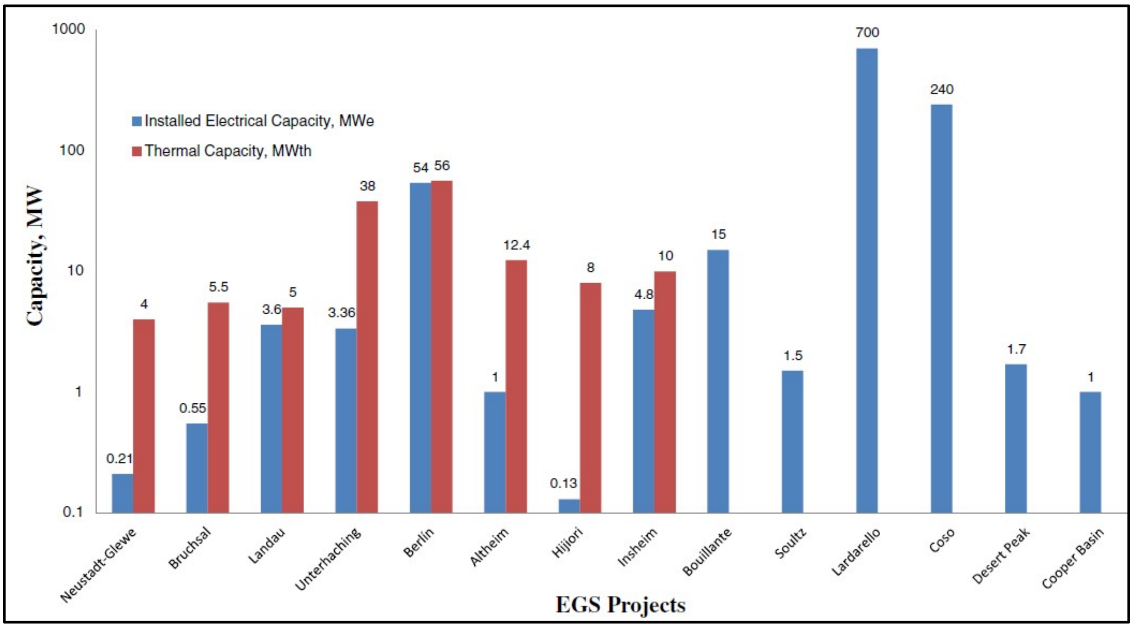


Fig. 5: EGS projects based on their electrical (MWe) and thermal (MWth) capacity (Breede et al., 2013)

3 Decision support for economic feasibility assessment

As for Task and Deliverable 5.3, The economic studies and models of proposed CHPM2030 technology will need to go beyond the usual framework of geothermal feasibility studies. The concept of “coextraction “of valuable metals alongside energy production will require the re-definition of criteria for economic feasibility assessment of such type of investments. Task 5.3 is to develop a methodology for carrying out feasibility studies for CHMP2030 keeping in mind all the complexities which come with coextraction of valuable metals by studying existing economic models for geothermal projects and developing a “Self Assessment Tool (SAT)”, which will allow investors, decision makers and companies to analyse the potential for CHMP sites using their own (probably confidential) data.

Beside developing of SAT, deliverable 5.3 will summarize presently used economic models and software tools for energy industry sector.

3.1 Presently used economic models

Long-range Energy Alternatives Planning system (LEAP): LEAP is a software tool which is used for energy policy analysis and climate change mitigation assessment which was developed at the Stockholm Environment Institute (Heap, 2012; Fig. 6). It is a scenario based modelling tool, which can be used to track energy consumption, production and resource extraction from all sectors of an economy. The power of LEAP is from its flexibility to include all types of energy (conventional and renewable) and its built-in capabilities to model climate change assessment with the use its Technology and Environmental Database (TED). TED describes the technical characteristics, costs and

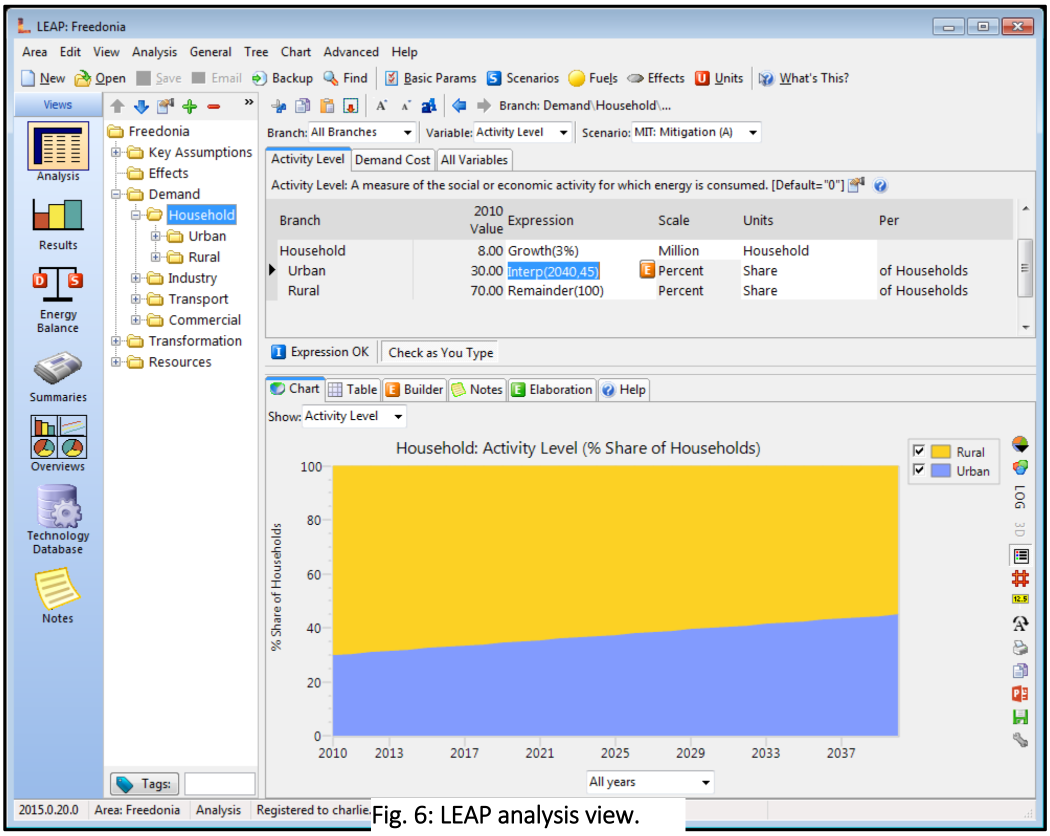


Fig. 6: LEAP analysis view.

environmental loadings of a range of energy technologies. Many studies (Emodi et al.,2017; Nojedehi et al., 2016; Kuldna et al., 2015), which used LEAP, took advantage of TED to deliver articles on lowering the environmental impact of future energy systems (as one of their objectives).

The main “Analysis View” is a hierarchical tree, which displays the main data structure for the analysis. It allows the user to create data structures and scenarios and to enter all the data describing both historical data as well as forward-looking scenarios. In the analysis view, the flow of energy resources (extraction to consumption) starts from bottom and works its way to the top. This can be seen from the resources tab and the demand tab. The view (Fig. 6) shows the basic data structure for an energy system in an economy which involves consumption (demand), production (transformation) and raw materials (resources).

Geothermal Electric Technology Model (GETEM): GETEM is an excel based tool (Fig. 7) developed by National Renewable Energy Laboratory, U.S. Department of Energy. It is used to estimate the Levelized Cost of Electricity for definable geothermal scenarios (Geothermal Electricity Technology Evaluation Model). The tool can be downloaded from their website (URL link)

The most updated version of the tool is still in the beta phase of testing and has not been rigorously checked or validated (as per the disclaimer in the excel file). This tool, as the name suggests, is geothermal specific and, as such, cannot be used for other energy systems (compared to other tools).

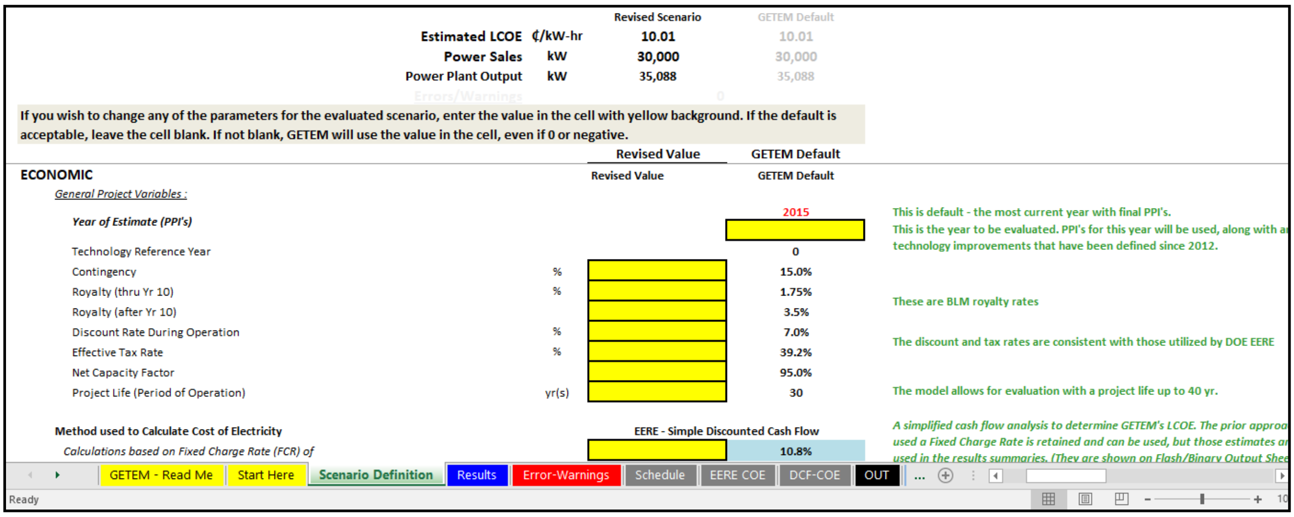
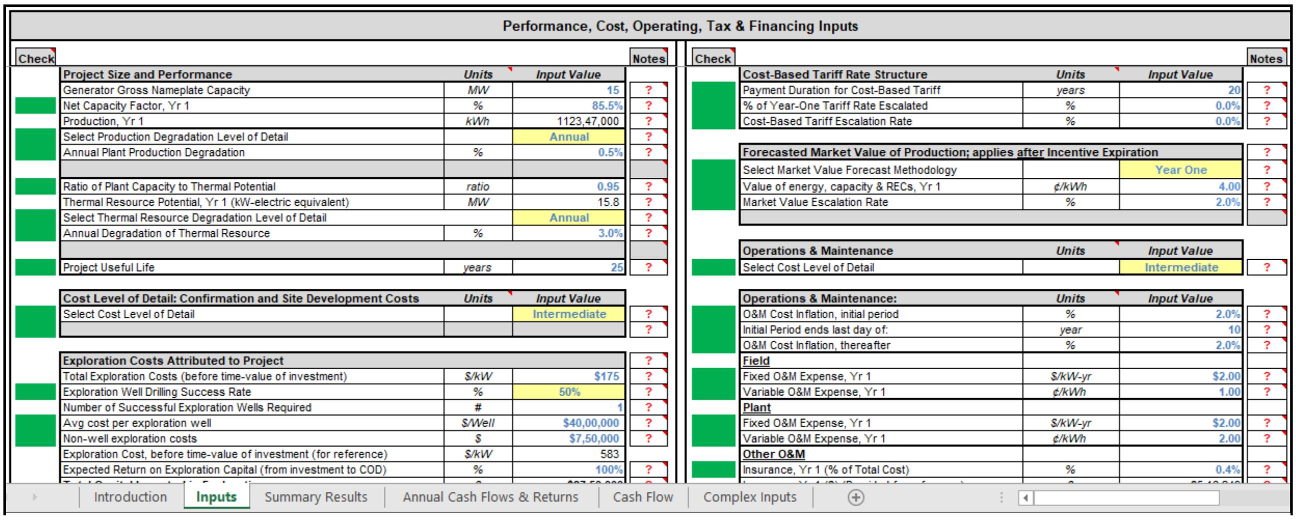


Fig. 7: Scenario editor in GETEM.

The tool is very detailed for geothermal systems and has default values for most of the parameters (in case we do not have data) and is focused on the economic analysis of the geothermal facility. The scheduling tab divides the project into various stages ranging from exploration to plant construction and start-up. This tool was used to analyse the risk for the Geothermal Technology Program of the U.S. Department of Energy (McVeigh et al., 2007)

Cost of Renewable Energy Spreadsheet Tool (CREST): CREST is another excel tool developed by National Renewable Energy Laboratory, U.S. Department of Energy (Fig. 8). It is a cash flow model, which can allow policy and decision makers to assess economic viability, design incentives and impact of renewable energy systems in an economy. The tool is available for different renewable projects including geothermal energy as separate excel files and is available from the website: https://financere.nrel.gov/finance/content/crest-cost-energy-models.

Unlike GETEM tool, which distinguishes between a hydrothermal reservoir and EGS reservoir, CREST does not make any such distinction. It is intended for researchers who want quick preliminary results without going too much into the details of the project.



Performance, Cost, Operating, Tax & Financing Inputs

Project Size and Performance	Units	Input Value
Generator Gross Nameplate Capacity	MW	15
Net Capacity Factor, Yr 1	%	85.5%
Production, Yr 1	kWh	1123,47,000
Select Production Degradation Level of Detail		Annual
Annual Plant Production Degradation	%	0.5%
Ratio of Plant Capacity to Thermal Potential	ratio	0.95
Thermal Resource Potential, Yr 1 (kW-electric equivalent)	MW	15.8
Select Thermal Resource Degradation Level of Detail		Annual
Annual Degradation of Thermal Resource	%	3.0%
Project Useful Life	years	25

Cost Level of Detail: Confirmation and Site Development Costs	Units	Input Value
Select Cost Level of Detail		Intermediate

Exploration Costs Attributed to Project	Units	Input Value
Total Exploration Costs (before time-value of investment)	$/kW	$175
Exploration Well Drilling Success Rate	%	50%
Number of Successful Exploration Wells Required	#	1
Avg cost per exploration well	$/Well	$40,00,000
Non-well exploration costs	$	$7,50,000
Exploration Cost, before time-value of investment (for reference)	$/kW	583
Expected Return on Exploration Capital (from investment to COD)	%	100%

Cost-Based Tariff Rate Structure	Units	Input Value
Payment Duration for Cost-Based Tariff	years	20
% of Year-One Tariff Rate Escalated	%	0.0%
Cost-Based Tariff Escalation Rate	%	0.0%

Forecasted Market Value of Production; applies after Incentive Expiration		
Select Market Value Forecast Methodology		Year One
Value of energy, capacity & RECs, Yr 1	¢/kWh	4.00
Market Value Escalation Rate	%	2.0%

Operations & Maintenance	Units	Input Value
Select Cost Level of Detail		Intermediate

Operations & Maintenance:	Units	Input Value
O&M Cost Inflation, initial period	%	2.0%
Initial Period ends last day of:	year	10
O&M Cost Inflation, thereafter	%	2.0%
Field		
Fixed O&M Expense, Yr 1	$/kW-yr	$2.00
Variable O&M Expense, Yr 1	¢/kWh	1.00
Plant		
Fixed O&M Expense, Yr 1	$/kW-yr	$2.00
Variable O&M Expense, Yr 1	¢/kWh	2.00
Other O&M		
Insurance, Yr 1 (% of Total Cost)	%	0.4%

Introduction | Inputs | Summary Results | Annual Cash Flows & Returns | Cash Flow | Complex Inputs

Fig. 8: Input page in GETEM.

System Advisor Model (SAM): SAM is a performance and financial model developed by National Renewable Energy Laboratory, U.S. Department of Energy. It is designed to facilitate decision and policy makers who are involved in the renewable energy industry. Unlike the other models, SAM is more detailed and require more inputs from the user side to generate results. The other models could be used to generate preliminary results and accordingly researchers can use SAM tool to perform more detailed analysis. The tool supports a variety of renewable energy projects including geothermal projects.

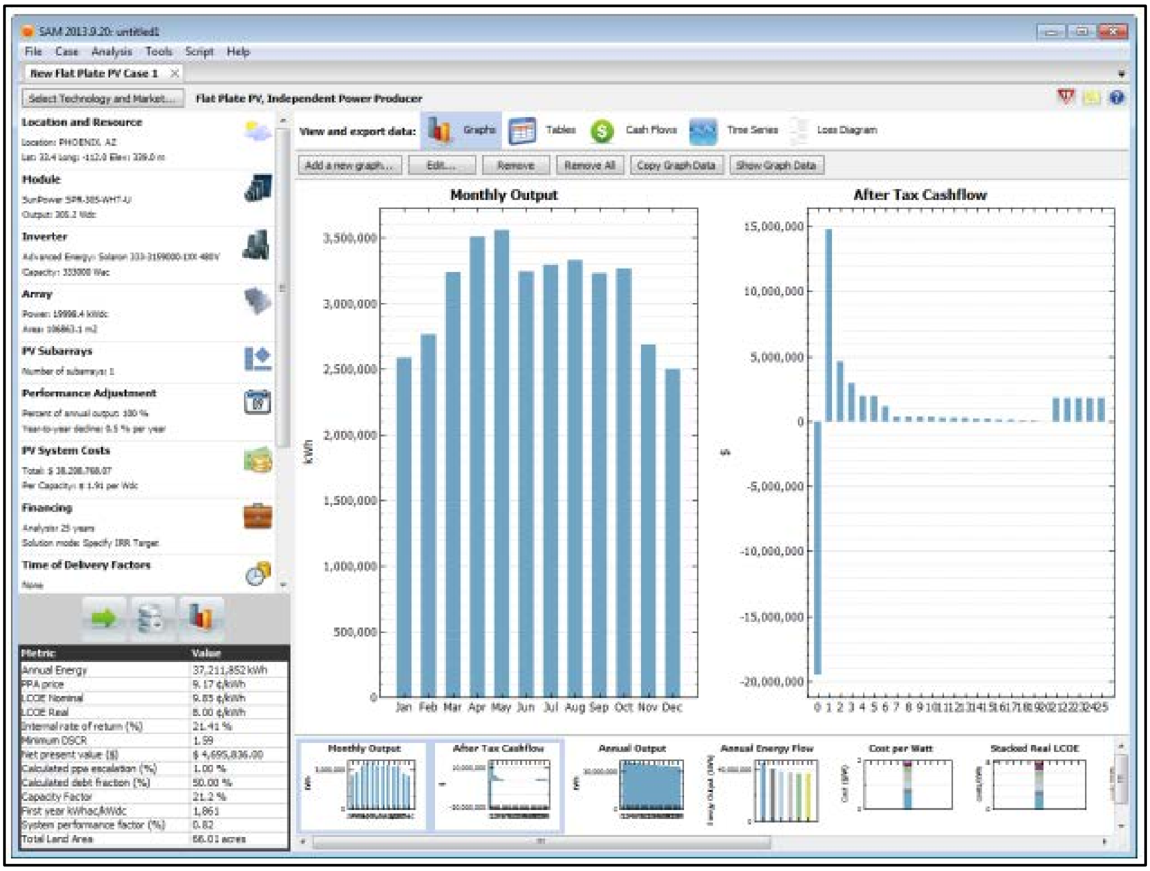


Fig. 9: The SAM main window showing monthly electricity generation and the annual cash flow

3.2 Self-Assessment Tool (SAT)

The Self-Assessment Tool will be based on System Dynamics. This tool can investigate and model complex dynamic problems in terms of stocks (the accumulation of things), flows (the motion of things) and feedback loops at any level of aggregation. According to the goals of task 5.3, the self-assessment tool will allow the definition of levelized cost of energy (LCOE), investment costs, operations costs and provide estimates on the metal production of the EGS facility. The aspect of metal production in CHPM gives an extra dimension in the model, which is not handled in the other models mentioned. Depending on the size of the CHPM facility, the metal production may or may not influence the local or global price of the metals produced. This presents a challenge to model future metal prices from not only conventional mining and recycling sources of the metals but also from CHPM facilities. The answer to all these questions/goals is the objective of the Self-Assessment Tool which is being developed.

3.2.1 System Dynamics background:

The field of System Dynamics was first developed by J. Forrestor in his book "Industrial Dynamics" (Forrestor, 1961). It was applicable for a wide range of applications ranging from management of research and development, urban stagnation and decay, commodity cycles, and the dynamics of growth in a finite world. Because of its broad scope, its name has been changed to System Dynamics.

There are six different elements in any system dynamics models and it is presented in Table 2 along with their descriptions. Important current simulation environments include Vensim (Ventana Systems, www.vensim.com), STELLA and iThink (isee Systems, www.iseesystems.com), PowerSim (www.powersim.com), and AnyLogic North America, LLC. (AnyLogic, www.anylogic.com).

Table 2: The basic elements of system dynamics. (Adapted from Sterman, 2000).

Name	Description
Stocks	A stock can be visualized as a bath tub where the water flows from a valve. If only one valve is open, water will keep accumulating in the stock. Thus, stocks can be said to be accumulations.
Flows	There are two kinds of flows: inflows and outflows. Inflows flow into a stock while outflows flow out of them. A flow may be both an inflow and outflow if it flows from one stock to another. Otherwise on of the ends will act be a source or a sink.
Causal loops	Causal loops indicate an information flow between elements. They might have a positive or negative polarity. A positive causal loop indicates that the target variable increases while in a negative loop the target variable balances itself.
Sinks/Sources	Sink and sources are the end “boundaries” of the system. They represent stocks which are outside of the constructed model.
Valve	Valve is the flow regulator.
Variables	Variables relate to causal loops. Causal links relate the variables and the polarity indicates how the dependent variable changes due to changes in the independent variable.

3.2.2 Vensim modelling environment:

Vensim has a graphical modelling environment, which allows the user to insert all the system dynamics elements and conceptualizes, documents, simulates, analyses, and optimizes models of dynamic systems (Ventana Systems, 2006). The main view of Vensim is shown in Fig 10.

The main elements are: Variables (default representation is a borderless text); Levels (default representation is a box with text); Arrows which connect variables and levels to each other forming causal links; Rates (double line arrows), which regulate the flow into and out of a level variable. All

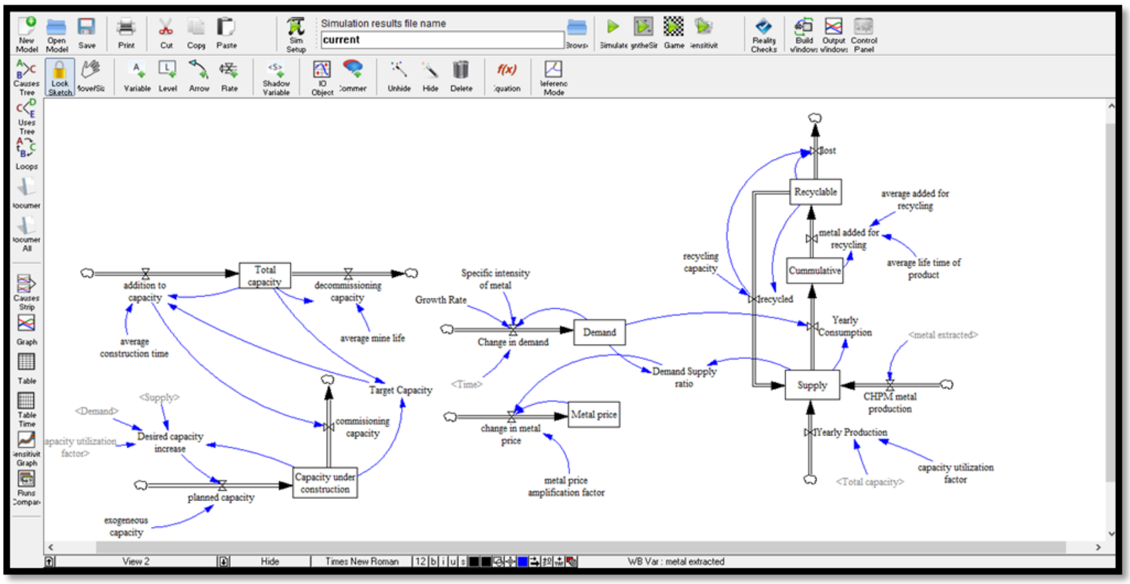


Fig. 10: Vensim modelling environment (source: MinPol)

these elements can be manipulated using an equation editor and the other functions within Vensim are for setting up the model, several user interface options and displaying results of simulations.

3.2.3 Preliminary CHMP model and results in Vensim:

The current CHMP model in Vensim is divided in two modules: one for world production of metal (Fig 10) and another for CHMP facility for electricity and metal production (Fig 11). World production module was made to simulate future prices. System dynamics is an important tool in this process because of its ability to integrate lags into the modules. These lags are important (in modelling) because in the mining industry, the time required to open new production facilities might take many years. Price is a function of demand/supply ratio. Demand is forecasted using macro-economic variables (GDP) while supply was calculated from the accumulation of production coming from mines, recycling and the previous year's stock.

The model demonstrates the commissioning of two CHMP facilities in around 2030 (100 MW) and 2040 (80 MW) along with the construction delay (assumed to be 4 years). Size of the CHMP facility is taken to be a function of investment (in US$) while other external factors such as inflation, economic growth rates, energy prices, etc are taken from historical data. Making the size of the CHMP facility as a function of investment will also allow us to use this data to perform cash flow analysis at a later stage. The example output for the current model for electricity capacity and metal production are shown in Fig 12 and Fig 13. Using system dynamics allows us to integrate metal production and electricity production from CHMP facilities using one modelling package. This reduces the issue of time spent trying to communicate between different models to handle the complex issues raising from such a project.

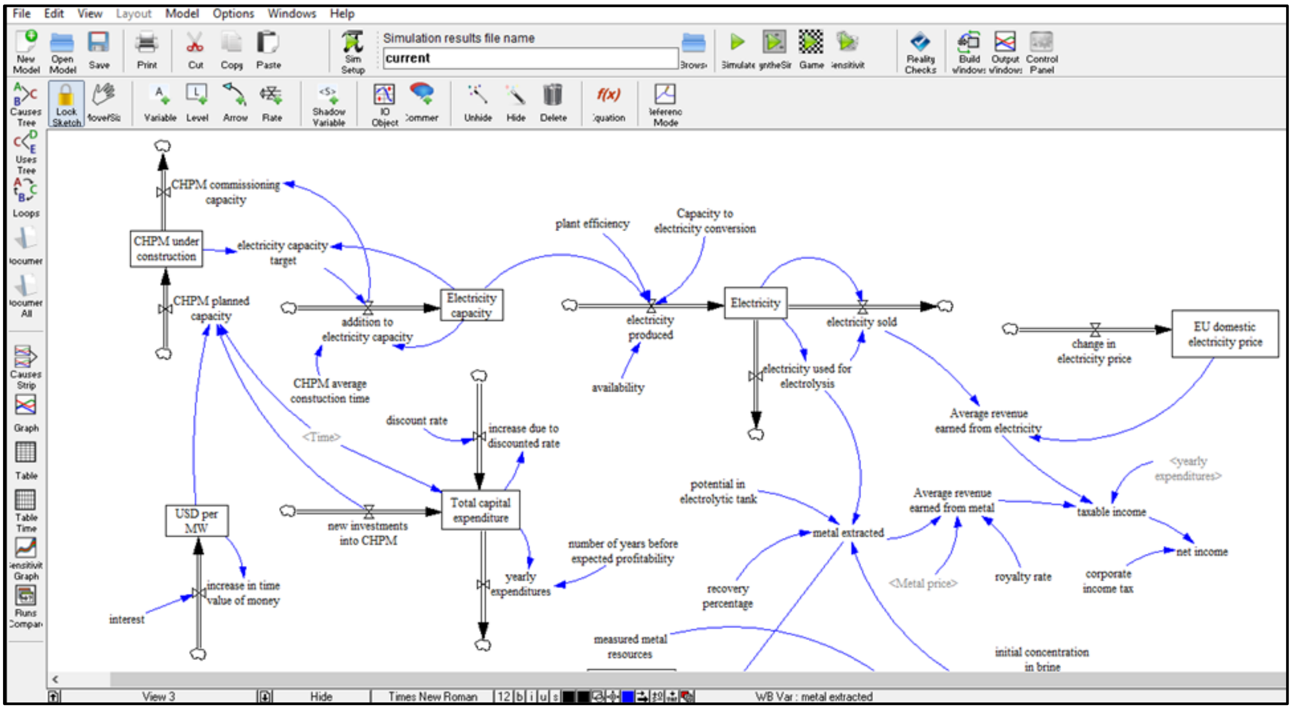


Fig. 11: CHPM model in Vensim (source: MinPol)

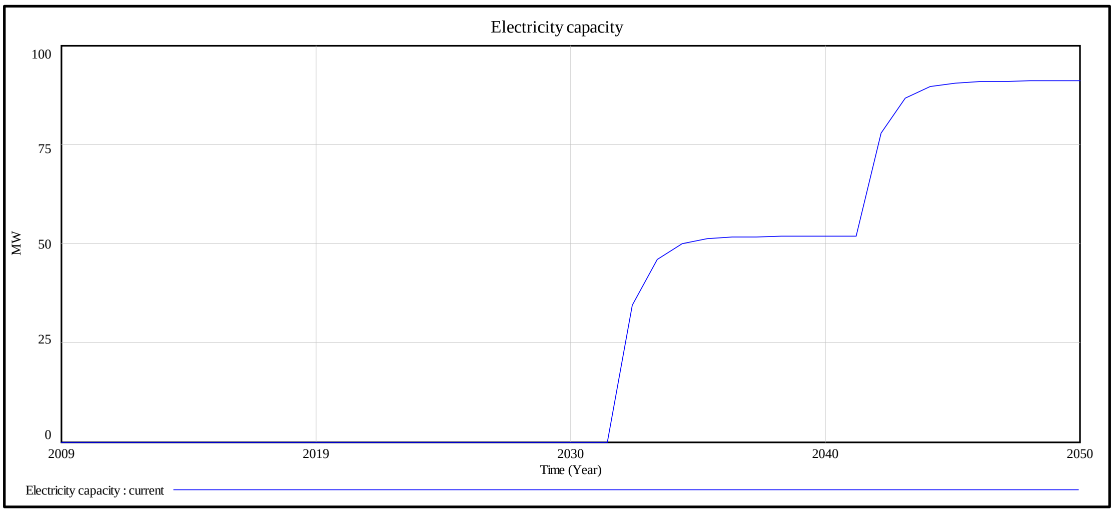


Fig. 12: Example of setting up two CHMP facilities showing the construction delay (source: MinPol)

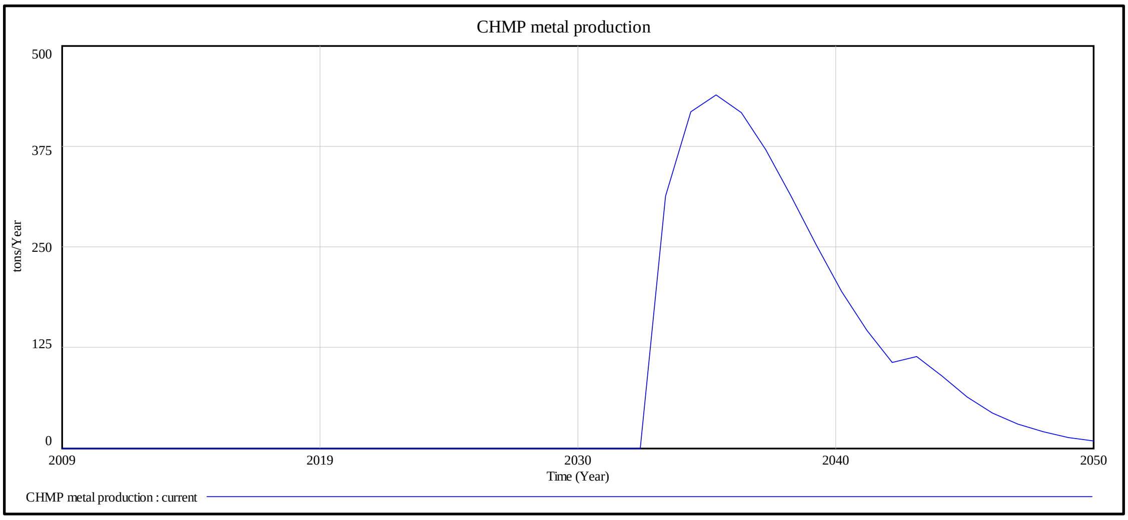


Fig. 13: Example of metal production from the two CHMP facilities (source: MinPol)

4 Social Impact Assessment

The increasing impact of R&I on society and the increasing pace of technological advancements call for a reflection on the impacts of these transformations on society. The EU, and notably the European Commission, has been a driving force behind the development of impact assessment practices, by incorporating the need for responsible R&I in its framework programmes (SATORI).

Environmental impact assessment (EIA) and social impact assessment (SIA) studies have most often been carried out in relation to a well-defined initiative. In many cases, these projects incorporate major infrastructure developments (dams, mines, oil and gas drilling, factories, ports, airports, pipelines, power plants, electricity transmission corridors, roads, railway lines and other infrastructure including large-scale agriculture, forestry and aquaculture projects) affecting both the environment and the population on various scales (local/regional). This current CHPM2030 project does not seek to deliver a pilot plant by the end of the initiative, thus a site specific and precise assessment on its potential impact on the environment and the social fabric cannot be adequately performed for the many inherent variables the placing of such a pilot plant carries. In addition, as it was already mentioned earlier in relation to the first iteration of the GSAP in Iceland, environmental and economic concerns outweighed the potential social impacts in that specific survey. Obviously, this does not mean that further iterations at various locations/countries will bring about the same results. Still, given the conceptual stage of the CHPM2030 idea and the more exact nature and methodology of an environmental impact assessment combined with rather location-independent features, the proposed sustainability framework will put more emphasis on the corresponding EIA over the SIA. At the same time, close cooperation is foreseen with the upcoming iterations of the draft GSAP with special focus on their findings covering the various and mostly location-dependent social impacts of a major scale geothermal investment.

The proposed studies dedicated to the Environmental Impact Assessment (D5.5) and the Social Impact Assessment (D5.4) of the CHPM technology will address those latest trends, aspects and guidelines that are considered essential in future development projects to be viable from other than economic perspectives. The resulting framework documents will contribute to carry out the pre-feasibility and feasibility studies as well as the social impact assessment studies usually required by the various international donor agencies (WB, IFC, EIB EBRD etc) that fund such investments, while meeting certain mandatory social performance standards (such as UN Principles for responsible investment (PRI, 2016), World Bank safeguard policies (WB, 2017), and various industry standards and code of conduct) prior any consent, identifying those environmental and social issues, considerations and potential barriers that may influence the location, size, output and performance of a future pilot CHPM plant.

4.1 Fundamental concepts of SIA

Social Impact Assessment is now conceived as being the process of identifying, analysing and managing the intended and unintended social consequences of project development both positive and negative of planned interventions (policies, programs, plans projects) and any social change processes invoked by those interventions (Vanclay, 2002). Although SIA is still used as an impact

prediction mechanism and decision-making tool in regulatory processes to consider the social impacts in advance of a permitting or licensing decision, equally important is the role of SIA in contributing to the ongoing management of social issues throughout the whole project development cycle, from conception to post-closure (Vanclay, Esteves, Aucamp, Franks, 2015). Altogether the primary purpose of SIA is to bring about more sustainable and equitable bio-physical and human environment. The SIA needs to be process oriented to ensure that social issues are included in the project design, planning, and implementation, as well as ensuring that development is acceptable, equitable, and sustainable (Branch, Ross, 1997).

A key difference between SIA and EIA is the increasing focus in SIA on enhancing the benefits of projects to impacted communities. Although the need to ensure that the negative impacts are identified and effectively mitigated remains, also of value is revising projects and ancillary activities to ensure greater benefits to communities. This is necessary for the project to earn its 'social licence to operate' (Boutilier, 2014), one of the key background concepts relevant to SIA, which is not only the need to meet more than just the regulatory requirements, but the need to consider the expectations of a wide range of stakeholders, including international NGOs and local communities as well. Failing to address these issues such projects risks being subject to strikes, protests, blockades, sabotage, legal action and the financial consequences of those actions (Joyce, Thomson, 2000).

It is also necessary because attempting to minimise harm (the traditional approach in SIA) does not ensure that the project will be considered acceptable by local stakeholders, or that a project does not actually cause significant harm. Treating communities with respect is important to earn a social licence to operate. To achieve this, meaningful, transparent and ongoing community engagement practices are essential from the earliest stages of any intervention to build trust and respect. A key concept is trust. If the past experience of a community with projects (their impact history) is bad, new projects will be regarded very sceptically, even if they are in fact beneficial and best practice.

Some other key background concepts relevant to SIA are:

- Free, Prior and Informed Consent (FPIC) (Buxton, Wilson, 2013)
- Human rights due diligence (ICMM, 2012)
- Non-technical risks (aka social risks)
- Sustainable Livelihoods (Scoones, 1998)
- Shared value

These concepts will be duly introduced and discussed in relation to a model CHPM development project within the frame of D5.4

One of the most significant step in the 40+ year evolution of social impact assessment practices is the realisation that SIA is an umbrella or overarching framework that encompasses all human impacts including aesthetic (landscape analysis), archaeological and heritage, community, cultural, demographic, development, economic and fiscal, gender, health, indigenous rights, infrastructure, institutional, political (human rights, governance, democratisation etc.), poverty-related, psychological, resource issues (access and ownership of resources), the impacts of tourism and other impacts on societies (Vanclay, 2002), thus it is a process of management, not a product (Esteves,

Franks, Vanclay, 2012). The various stages of project development, starting as early as preliminary planning and lasting beyond commissioning can cause many kinds of social impacts. From early stages, there typically is speculation about the project that can affect property prices, and can lead either to an exodus of people, or conversely to the influx of people. Projects can create opportunities and benefits for people, but at the same time they can also create harmful effects, too. Good management is needed to ensure that the benefits of projects are maximised, and the negative impacts are avoided or minimised on an ongoing basis during the life of the project. SIA is a process that can greatly assist in ensuring the achievement of benefits and the avoidance of harm.

4.2 What is SIA all about?

Social impacts include all the issues associated with a planned intervention (i.e. a project) that affect or concern people, whether directly (health, aesthetic, economic impacts) or indirectly (demographic, cultural, political impacts). Specifically, a social impact is considered to be something that is experienced or felt in either a perceptual (cognitive) or a corporeal (bodily, physical) sense, at any level (individual, household, workplace, society). In addition, various dimensions are associated with such impacts such as their certainty, frequency or severity as well as their chronicity, locality or susceptibility to the community.

Because 'social impact' is conceived as being anything linked to a project that affects or concerns any impacted stakeholder group, almost anything can potentially be a social impact so long as it is valued by or important to a specific group of people. SIA therefore should address everything that is relevant to people and how they live. This means that SIA cannot start with a checklist of potential impacts. The likely-to-be significant social impacts will vary from place to place, from project to project, and the weighting assigned to each social impact will vary from community to community and between different groups within a given community. Since the factors to be considered in a SIA study should be determined in conjunction with input from the community, it might at first be regarded that there is little utility in having a well-developed list of social impacts to consider (Vanclay, 2002).

Instead, the SIA must identify the social impacts from an awareness of the project and an understanding of how the project will affect what is important to the project's stakeholders.

Social impacts are changes to one or more of the following:

- people's way of life
- their culture;
- their community; (Armour, 1990)
- their political systems;
- their environment – the quality of the air and water people use; the availability and quality of the food they eat; the level of hazard or risk, dust and noise they are exposed to; the adequacy of sanitation, their physical safety, and their access to and control over resources;
- their health and wellbeing – health is a state of complete physical, mental, social and spiritual wellbeing and not merely the absence of disease or infirmity;
- their personal and property rights – particularly whether people are economically affected, or experience personal disadvantage which may include a violation of their civil liberties;

• their fears and aspirations – their perceptions about their safety, their fears about the future of their community, and their aspirations for their future and the future of their children (Vanclay, 2003). Usually the biggest social impact is fear and anxiety associated with the given project.

While SIA is sometimes described as being a social form of environmental impact assessment, there are many differences. For example, the environmental impacts tend only to occur when the first sod of soil is turned, whereas social impacts can happen the moment there is a rumour that something might happen. Rumour leads to speculation and speculative behaviour. In some situations, e.g. a socially-undesirable factory or other locally-unwanted land use, rumour may also promulgate and amplify people's fears and anxieties, whether or not the rumour has any foundation, and whether or not the project actually eventuates. Fear and anxiety, like all perceived impacts, are real social impacts that people experience, and they should not be dismissed, but should be managed effectively (Petkova et al, 2009)

Since social impacts are rarely singular cause-effect relationships with complex patterns of intersecting impact pathways like health, wellbeing and social outcomes are always multi-factorial, the novel, unprecedented CHPM concept and the model development of such a project is naturally expected to raise stakeholder concerns in the field of the environment, health and well-being, property rights and will potentially address some of the fears and aspirations in an indirect way. For this reason, D5.4 will put emphasis on this particular fields of potential social impacts of a future development scenario.

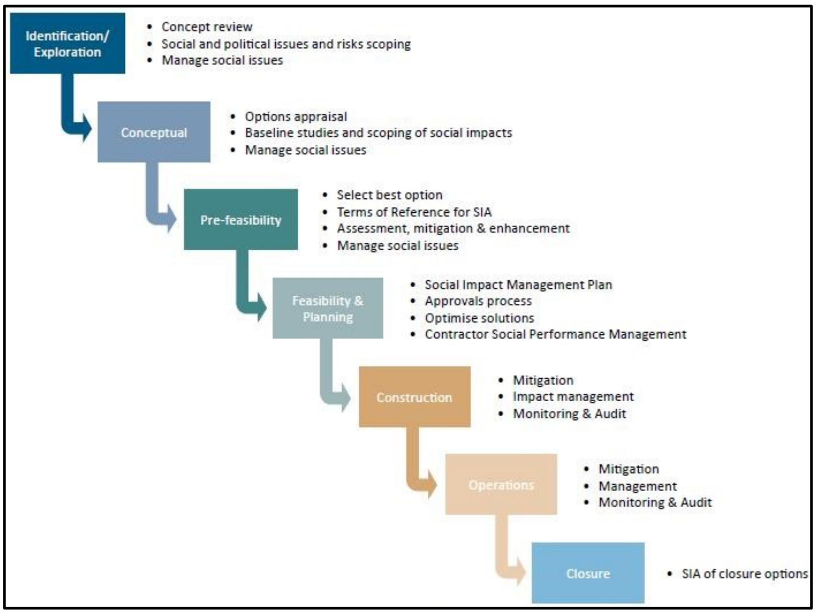


Figure 14: Typical project cycle from SIA perspective

SIA is also the process of managing the social issues of projects. Even though CHPM2030 will address only the potential social impact of the so called "Early Stage", it is essential to have an overlook of the future steps of the project progression. SIA adjusts to the varying social concerns and issues at different points in the project cycle. It is fairly safe to say that almost all projects, almost always cause almost all impacts. Therefore, having ongoing monitoring and adaptive management in place is much more important than just predicting impacts upfront using various checklists, that may even be hard to adapt to the actual project at hand.

Figure 14 (Vanclay, Esteves, Aucamp, Franks, 2015) depicts a typical project cycle and identifies the potential role for SIA at each phase. The crucial point is that at each project phase, there is a role for

SIA. While the project cycle is usually depicted as a linear process, the reality is not so straight forward. Projects do not necessarily transition smoothly from phase to phase, and may become stalled at a certain phase, or may be sent back to earlier stage

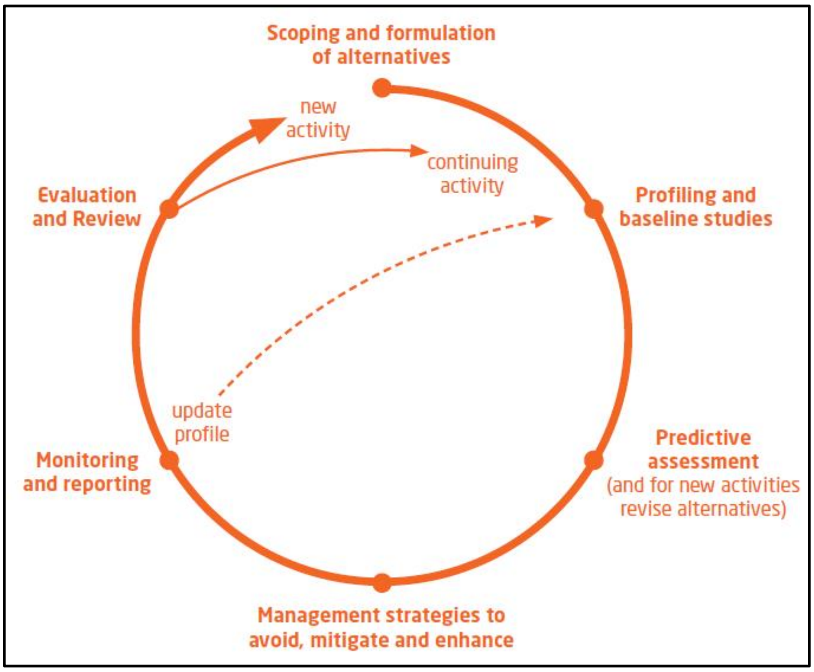


Figure 15: The phases of social impact assessment within an iterative adaptive management process (Franks, 2012)

In terms of social engagement, the old paradigms (DAD ('decide, announce, defend')) are replaced by new participatory philosophies often refered to as MUM ('meet, understand, modify') or POP ('public owns project'). This approach better reflects one of the core principle of SIA, which emphasises that „people have a right to be involved in the decision making about the planned interventions that will affect their lives" (André, Enserink, Connor, Croal, 2006).

Earlier often happened that the SIA was incorporated into the environmental assessment, and thus some major areas with significant social impact were inadequately addressed. Also, quite commonly certain social issues were mentioned in such plans that had hardly any relevance from the affected community's perspective, but the checklist-approach required those field to be covered.

4.3 SIA for CHPM2030

Based on all these principles, D5.4 will analyse SIA reports of previous similar energy infrastructure projects and infrastructural investments in the range of the proposed scale of the model CHPM plant and will formulate its own aspects delivering a model Social Impact Assessment that covers all potential fields that need to be addressed throughout the life-cycle of a model plan that eventually will be implemented in a real-life scenario.

The content and logic of the proposed model SIA will follow the structure below.

- Introduction
- Project summary

- Methodology: statement about the overall design of the SIA, what methods were used, what community engagement processes were used, and how ethical issues were considered and addressed
- Applicable legal framework and standards: discussion of the legal framework(s) and applicable legislation, regulations and guidelines that apply to the particular case
- Community profile and social baseline: summary of key characteristics and key stakeholder groups
- Scoping report: A statement of all potential social impacts considered in the assessment phase. Scoping can be defined as the process of identifying the main issues of concern as well as determining the interested and affected parties for a particular planned intervention. It is a preliminary process that produces an interim list of issues to be considered that are later properly assessed.
- Prioritize listing of key social impacts: listing of the residual impacts with a discussion of how different stakeholders are affected
- Summary of mitigation and management measures: listing of mitigation and other management measures to address social issues
- Monitoring plan and contingency plan: defining the details of monitoring: what, how, how often will be monitored and who will be responsible
- Benefit statement: summarising the likely project benefits to the local communities
- Ongoing community engagement strategy and grievance mechanisms
- Governance arrangements (Vanclay, Esteves, Aucamp, Franks, 2015)

Due to the model nature of the document that ultimately lacks the site/project specific information and constraints, some of these chapters will not be sufficiently elaborated, however their presence in the list indicate that in case of an actual project, they will also be taken into consideration when delivering a mandatory SIA study.

5 Environmental Impact Assessment Framework

Today, the environmental aspects of geothermal development are receiving increasing attention with a shift in attitude towards the world's natural resources. For example, geothermal electricity generation is projected to increase threefold by 2035 in the US. (USDOE 2011a). Also, with the widely spread resources, geothermal energy is a resource, which can noteworthy contribute to the future energy provision in Europe, too. However, a contribution to a sustainable heat and electricity provision is only reasonable if its use does not result in disadvantages for the environment compared to given alternatives. This must be true for the environmental impacts connected with the whole life cycle (i. e. life cycle assessment (LCA) regarding construction, operation and deconstruction and including the respective pre-chains) but also for the effects on the natural environment, which are primarily site specific and regional (ENGINE, 2008).

Along with these realisations, the public and governments have also become increasingly sensitive to environmental impacts from various industrial activities globally (IAEA, 1997) With significant potential growth opportunities for geothermal technologies, it is thus important to understand their material, energy, and water requirements and potential environmental impacts (Clark, Sullivan, Harto, Jeongwoo, Wang, 2012).Although the impacts of geothermal development projects are often positive, different types of geothermal fields and geothermal development have varying impacts that need to be adequately assessed prior starting any investment projects.

Environmental Impact Assessment (EIA) is the tool most widely used in environmental management and its objective is to determine the potential environmental, social and health effects of a proposed development in order to provide decision-makers with an account of the implications of a proposed course of action before a decision is made. It is also an aid to decision-making and to the minimization or elimination of environmental impacts at an early planning stage. For geothermal energy, which currently plays an important part as a clean energy supply, a well-prepared EIA can significantly minimize or eliminate the environmental impacts at an early planning stage (Li, 2004).

Approaching EIA from a different angle it gives you a process with a primary aim to ensure that the likely significant environmental effects of certain projects are identified and assessed before a decision is made on whether a proposal should be allowed to proceed. This means that the most environmentally favourable option, or at least the environmentally acceptable option, can be identified at an early stage and projects can then be designed to avoid or minimise environmental effects (Li, 2004). In other words, during the EIA process environmental factors are integrated into project planning and decision making. An environmental impact assessment is comprised of an examination of the local environment around a proposed project, an examination of the proposed project itself, and a prediction of the potential impacts of the project on the physical, biological and socio-economic environment, with the objective to judge the acceptability of the project and control those impacts to acceptable levels, while maintaining the viability of the project. (IAEA, 1997).

Since they contain all information related to the physical, biological, chemical and economic condition of the areas where industrial projects are proposed or planned, they present invaluable guidance and a well-defined framework for the planning and implementation of environmental mitigation as well as environmental restoration after the project is over, thus they promote development that is

sustainable and optimizes resource use and management opportunities (IAEA, 1999). They further yield relevant data on the socioeconomic impacts of a project.

In addition, the EIA is intended to provide information to interested individuals or groups that may be impacted by a proposed development, and to provide a forum for public consultation and informed comment on a proposed project (IAEA, 2005) and it forms a uniform basis for negotiations between the developer, public interest groups and the planning regulator.

The past decades have seen a rapid growth in environmental legislation with increasing requirements for environmental assessment. This evolution of environmental assessment is still an ongoing process resulting (IAEA, 2005) that most countries now have some sort of environmental assessment processes, that obviously have been defined differently in those countries with a different name and some slightly different meaning (Roberts, 1991). In fact, it appears that no two countries have defined it in exactly the same way.

Since 1969 (the first EIA system established), such systems have been set up worldwide and become a powerful environmental safeguard in the project planning process.

The US, New Zealand, China, Germany, El Salvador, Iceland, Indonesia, Italy, Japan, Kenya, New Zealand, Philippines, Turkey are only a few of those countries with relevant regulations that require an environmental analysis of a proposed geothermal project, as well as specific regulations that define the quantities of pollutants that may be emitted to the atmosphere or discharged to land and water (Baba, 2003).

Not only the number of different types of EIAs can vary from country to country but the applied methodologies or combination of methodologies, too. These could include interaction matrixes, networks, weighting-scaling (or -ranking or -rating) checklists, multicriteria/multiattribute decision analysis (MCDA/MADA), input-output analysis, life cycle assessment (LCA), AHP or fuzzy AHP, fuzzy sets approaches, Rapid Impact Assessment Matrix (RIAM), and data envelopment analysis (DEA).

The purpose of incorporating EIA approaches has been described as subjecting a proposed action to an examination of what the possible environmental impacts of that action would be and to find ways to mitigate any negative long-term impacts (Namin, Ghafari,Dianati, 2013), following the ALARA concept to keep environmental degradation **a**s **l**ow **a**s **r**easonably **a**chievable with technical, economic, and social factors being taken into consideration, while the investigation of impacts consider both the short and the long-term and include all phases of the project (i.e. construction, mining, remediation, decommissioning and post decommissioning) (IAEA, 2005).

Unlike some other types of large scale energy projects, the utilization of geothermal energy is dynamic in nature Due to the dynamic nature of the geothermal resource itself, where the information is being gathered and processed continuously during the time of utilization, since developers cannot at an early stage of development give decisive information on the scope of a given project, exact location of facilities and geothermal fluid extraction rate. The best example to the conduct of such a process is Iceland, home to many geothermal-related innovations (policy and technology alike). The information gathering involves consultation with public agencies, local and governmental authorities, Non-Governmental Organizations (NGO's) and other stakeholders. By

consulting with bodies involved in the EIA process at the preliminary stages of each project, different views emerge, which can be discussed and resolved before the project is fully developed.

In geothermal projects the Environment Agency, the National Energy Authority, local authorities, local Health Inspectorates, NGO's and the Icelandic travel industry are considered as necessary consultation bodies. The National Planning Agency however plays a key role in the overall EIA process and should be consulted on regular basis (Albertson et al, 2010).

Ideally, The EIA process evaluates the learning and experience gained from exploration and harnessing which can be of immense value for research and development units, schools, educative tourism and the geothermal industry worldwide. The concept of EIA has already created some vital benefits such as broad consultation and created new guidelines for the development of geothermal projects. It is important for all actors in the EIA process to learn from the experience gained from preceding steps and to improve the EIA process in general for geothermal projects, especially how to discuss and assess the uncertainty that is involved with all such projects and the complicated and diverse scientific data that the EIA decision is based on (Albertson et al, 2010). Such approach is especially important in the case of CHPM2030 where some of the technologies have not been tested under real-life scenarios before, thus knowledge sharing is going to be a key facet of an improved EIA procedure that has the potential to handle novel scenarios such as the CHPM2030 concept.

5.1 Environmental impacts of EGS projects

There are several potential environmental impacts from any geothermal power development. Also, there are certain impacts that must be considered and managed with even higher scrutiny if an EGS to be developed as a larger part of a more environmentally sound, sustainable energy portfolio for the future. Most of the potentially important environmental impacts of geothermal power plant development are associated with ground water use and contamination, and with related concerns about land subsidence and induced seismicity as a result of water injection and production into and out of a fractured reservoir formation. Issues of air pollution, noise, safety, and land use also merit consideration (Tester et al, 2006).

Gaseous emissions: for most EGS installations, there will be lower amounts of dissolved gases than are commonly found in hydrothermal fluids. Consequently, impacts would be lower and may not even require active treatment and control. CO2 and H2S emissions are managed through process design. Carbon dioxide, which is usually the major constituent of geothermal gas, and methane have been causing concern because of their role as greenhouse gases. However, the carbon dioxide emission from geothermal plants is negligible compared to that of fossil fuel plant and therefore any energy production by fossil fuels that can be replaced by geothermal energy is environmentally desirable. Carbon dioxide and methane from geothermal applications is a negligible source. Minor gases that cause concern, i.e. Hg, NH3 and B have not been found in dangerous concentrations in most of the geothermal plants in the world. Hydrogen Sulphide gas emission has the potential to cause the greatest concern due to its unpleasant smell and toxicity even at moderate concentrations (Kubo, 2003).

Water pollution: EGS operations are subject to the same possibility for subsurface contamination through casing defects, but there is little chance for surface contamination during plant operation because all the produced fluid is reinjected.

Solids emissions: There is practically no chance for contamination of surface facilities or the surrounding area by the discharge of solids *per se* from the geofluid. Precautions, however, would need to be in place should the EGS circulating fluid require chemical treatment to remove dissolved solids, which could be toxic and subject to regulated disposal and could plug pathways in the reservoir. In addition, combining EGS with in-situ leaching these aspects must be addressed adequately and convincingly during the preliminary design phase.

Noise pollution: During normal operations of a geothermal power plant, noise levels are in the 71 to 83 decibel range at a distance of 900 m (DiPippo, 2005). Noise levels drop rapidly with distance from the source, so that if a plant is sited within a large geothermal reservoir area, boundary noise should not be objectionable.

Land use: The footprint of the power plant, cooling towers, and auxiliary buildings and substation is relatively modest. Holding ponds for temporary discharges (during drilling or well stimulation) can be sizeable but represent only a small fraction of the total well field. EGS plants require much less land area per MW installed or per MWh delivered compared to fossil fuelled, nuclear or solar power plants. The practice of directionally drilling multiple wells from a few well pads will keep the land use to a minimum.

Land subsidence: If geothermal fluid production rates are much greater than recharge rates, the formation may experience consolidation, which will manifest itself as a lowering of the surface elevation, i.e., this may lead to surface subsidence. Since the reservoir is kept under pressure continuously, and the amount of fluid in the formation is maintained essentially constant during the operation of the plant, the usual mechanism causing subsidence in hydrothermal systems is absent and, therefore, subsidence impacts are not expected for EGS systems.

Induced seismicity: Induced seismicity, though a very relevant issue, can be mitigated, if not overcome, using modern geoscientific methods to thoroughly characterize potential reservoir target areas before drilling and stimulation begin. Continuous monitoring of micro-seismic noise will serve not only as a vital tool for estimating the extent of the reservoir, but also as a warning system to alert scientists and engineers of the possible onset of a significant seismic event. Experience to date suggests that an appropriate infrastructure needs to be set up to inform local residents about the program prior to the implementation of an EGS project. Planning needs to include a system, where local residents are briefed on the project and are encouraged to contact a specified person on the program whose duties include answering questions and dealing responsively and sympathetically to any concerns of the local residents. Regular public meetings and arranged visits to the site from schools and interested parties are a way of enhancing acceptance of the program by local residents (Tester et al, 2006).

Water use: for well drilling, reservoir stimulation, and circulation and cooling water for heat rejection.

Thermal pollution the surface originates on one hand from the waste-heat contained in the wastewaters and on the other hand in the steam. The discharge of hot liquids and steam release on the surface has the potential of triggering undesired consequences by interfering with the natural habitat and ecosystem.

Chemical impact: Geothermal development produces significant amounts of solid waste; therefore suitable disposal methods need to be found. Because of the heavy metals particularly arsenic, which are contained in geothermal waters, these solid wastes are often classified as hazardous waste. During drilling, wastes are produced in the form of drilling muds, petroleum products from lubricants, fuels and cement wastes. Drilling muds are either lost through circulation in the well or end up in the drilling sumps as solid waste for disposal. Since a lot of fuel and lubricants are used when drilling a single well, storage and transport of these products should follow sound environmental practice. The principal solid wastes are cooling tower sludges, which may contain mercury. The waste brine from the power station that contains traces of solid wastes (heavy metals) is safely disposed to the infiltration pond avoiding any spills, but the plan is to reinject all this wastewater into one of the wells. The other major solid waste is construction debris and normal maintenance debris (Kubo, 2003).

Despite this extensive list, current and near term geothermal energy technologies generally present much lower overall environmental impact than do conventional fossil fuelled and nuclear power plants. For example, the power plant is located above the geothermal energy resource eliminating the need (a) to physically mine the energy source (the "fuel") in the conventional sense and, in the process, to disturb the Earth's surface, and (b) to process the fuel and then use additional energy to transport the fuel over great distances while incurring additional environmental impacts. Furthermore, the geothermal energy conversion equipment is relatively compact, making the overall footprint of the entire system small. With geothermal energy, there are no atmospheric discharges of nitrogen oxides or particulate matter, and no need to dispose of radioactive waste materials (Tester et al, 2006).

In addition to all these reasonably well defined environmental effects, there is certain degree of uncertainty regarding the imposed impact caused by harnessing of the geothermal reservoir on geothermal ecosystems and geothermal activity on the surface. The dynamic nature of the resource makes it even harder to identify human induces effects. During the EIA process the ecosystems and the geothermal surface activity are usually identified and in the EIS it is stated that there may be some risk of negative impacts caused by the project. In the recent projects, the developer is made fully accountable for this possible, indirect impact. (Albertson et al, 2010).

5.2 In-situ leaching / in-situ recovery

The present project aims to create a proof of concept of the technical and economic feasibility at laboratory scale for new routes to valorise critical metals from such high-performance geothermal systems. Experiences gained during In-Situ Leaching (ISL) production methods will be considered, with the main difference that in ISL emphasis is on fast metal production, where strong chemicals are used and the associated environmental consequences can be substantial. In CHPM2030 the main emphasis is on energy, and metals are considered to be by-products that are expected to support the

economic feasibility of heat and power generation over an extended period of time in an integrated system.

Regardless of the intensity of the proposed metal-production, environmental aspects of the ISL mining technique must to be addressed within the EIA of the CHPM2030 approach.

Mining is an inherently destructive industry, and the mining effects of even a single operation can have a severe impact on the environment and the wildlife that lives nearby. For this, it is important that an assessment should be done of the potential impacts of a mining operation and that the development proceed in such a manner as to keep environmental degradation as low as reasonably achievable (IAEA, 1997). As we have seen before in EGS development, each phase of mining is associated with different sets of environmental impacts, that has to be assesses individually and in context as well.

In situ leach (ISL) mining is defined as the leaching of ore (gold, copper, uranium) from a host rock by chemical solutions and the recovery of targeted ore at the surface. ISL extraction is conducted by injecting a suitable leach solution into the ore zone below the water table; oxidizing, complexing, and mobilizing the target ore; recovering the pregnant solutions through production wells; and, finally, pumping the metal bearing solution to the surface for further processing.

ISL involves extracting the ore mineral from the deposit, with minimal disturbance of the existing natural conditions of the earth's subsurface and surface. In contrast to underground and open pit mining, there are no rock dumps and tailings storage facilities, no dewatering of aquifers, and much smaller volumes of mining and hydrometallurgical effluents that could contaminate the surface, air and water supply sources. Therefore, the impact of ISL on the environment is much less than for other mining methods as long as projects are properly planned, operated and closed using best practices (IAEA, 2005).

The advantages of ISL extraction of ores relative to conventional open pit or underground mining include:

- Lower capital and operating costs, (Only roads, diamond drill holes, processing plants and evaporation ponds need to be created),
- Shorter lead times for mine development,
- Smaller infrastructure, ground disturbance and materials handling requirements than conventional mining methods,
- Much smaller workforce required,
- More flexible mine planning and quicker ramp-up in response to market improvements,
- Inherently safer working environment, ISL reduces the exposure of workers to conventional industrial and radiological risks, relative to underground mines and to a lesser degree open cut mines,
- Limited environmental impacts (no waste rock, no tailings, no ore dust or direct ore exposure, lower consumption of water,

- Economic recovery of lower grade ores (increases resource utilization). Low-grade orebodies, which are sub-economic by conventional techniques, may be mineable by ISL methods (Kay, 1998),
- The time taken for full restoration is up to about 20 years depending upon the leachate (acid or alkaline) used; examples have shown that the chemical and mechanical conditions in the treated aquifers return to near pre-mine conditions in fifteen to twenty years (Underhill, 1998).

ISL is not, however, without potential environmental consequences, particularly its potential impact on groundwater.

- Lower recovery factor of in-place reserves,
- Applicability limited to specific types of ore deposits (the potential alignment of such a deposit with the conditions that make an EGS plant viable is rather low),
- The risk of spreading of leaching liquid outside of the uranium deposit, involving subsequent groundwater contamination, (Such concerns are less critical where saline groundwater is involved, or other contaminants such as radionuclides exceed quality standards.),
- The unpredictable impact of the leaching liquid on the rock of the deposit, (Any loss of treated water from the ISL system represents both an economic cost to the mine (through lost treatment chemicals, ore or both), in addition to an environmental risk),
- The impossibility of restoring natural groundwater conditions after completion of the leaching operations. (WISE-URANIUM project).

While it is generally recognized that the in-situ leach mining technology has environmental and safety advantages as compared to conventional mining and milling, it is also accepted that ISL projects should not be started without considering the potential environmental consequences. Environmental planning is frequently taken into consideration through some type of environmental assessment. This must be completed before a project is authorized to proceed with development. The evaluation is usually done by conducting an environmental impact assessment and producing an environmental impact statement (IAEA, 2005).

5.3 Model environmental assessment process

Completing an environmental impact assessment is an important part of planning. The impact of each project is evaluated in the context of the pre-existing environment and regulatory and licensing requirements. An impact on the environment is any change in the biophysical and/or social environment caused by or directly related to a former, on-going or proposed activity.

As a first step, all the Environmental Criteria for EGS Project Feasibility must be assessed and addressed appropriately to understand whether the planned project is feasible. In determining the feasibility of an EGS project at a particular location, there are a number of technical criteria that carry direct or indirect environmental implications:

- Electricity and/or heat demand in the region
- Proximity to transmission and distribution infrastructure
- Volume and surface expression of a high quality EGS reservoir

- Reservoir life and replacement wells
- Circulating fluid chemistry
- Flash vs. binary technology
- Cost/installed MWe and cost/MWh delivered to a local or regional market
- Load-following vs. baseload capability
- Plant reliability and safety.

Furthermore, as with any energy supply system, there are additional environmental criteria that need to be considered before moving forward with a commercial EGS project. These include:

- Geologic formations that are not prone to large seismic events, devastating landslides, or excessive subsidence
- Compatible land use
- Drinking water and aquatic life protection
- Air quality standards
- Noise standards
- GHG emissions/MWh
- Solid waste disposal standards
- Reuse of spent fluid and waste heat
- Acceptable local effects of heat rejection
- Compliance with all applicable federal, state, and local laws. It is imperative to identify and understand all the laws and regulations that play a role before any geothermal development project can be brought to fruition. If a comprehensive spectrum of regulations is available, that must be satisfied for the project even to commence, yet to be successfully delivered, it is highly unlikely that any geothermal power plant will be a threat to the environment.

All of these will influence the acceptability and the cost of a project, and, ultimately, whether or not a project will go forward (Tester et al, 2006).

To properly conduct a feasibility assessment, it is important to do a preliminary environmental baseline study and to estimate the potential impacts of the project on the local environment. Mitigation of undesirable environmental impacts and stringent regulatory requirements could significantly affect the economics of a project. It is important to assess these factors before proceeding too far with the development. The environmental information needed for the feasibility study is similar to that required for an environmental impact statement, but at a lower level of detail. From an environmental perspective, the feasibility study need only consider those issues which could have serious economic impact on the project.

The level of effort and detail spent in collecting baseline information and identifying potential impacts should be related to the planned activities. Investigation of significant impacts must consider the short and long term, and each phase of the project (i.e., construction, operation, decommissioning and post decommissioning). Detailed planning during each phase of the project can help reduce impacts to the environment.

To develop a baseline-environment study the data collection should be focused on those environmental elements that have a likelihood of being affected by the proposed project. The environmental baseline document should start with the project location described on a national, regional and local basis with increasingly more detailed maps. The regional and local geology and geography lead into a description of the local terrestrial habitat. Climate, surface water hydrology, hydrogeology, water and air quality, and natural radiological conditions should be described. Following the description of the physical environment, the biological environment should be described. This will include primary producers, herbivores, omnivores and carnivores. Any rare or endangered species in the area of the project should be identified. After describing the biophysical environment, resource use should be described. This should encompass land use, agriculture, livestock, wildlife harvesting, fishing, tourism, etc. Finally, the socio-economic environment should be described, indicating the inhabitants of the area and the nature of their livelihood and culture (IAEA, 1997).

Thus, baseline environmental information includes:

- Site location; Meteorology; Geology
- Surface hydrology
- Hydrogeology (subsurface hydrology) / Aquifer properties (Hydraulic conductivity, Transmissivity, Storage coefficient, Total porosity, Effective porosity, Aquifer thickness, Piezometric surface, Hydraulic gradient, Permeability
- Abandoned drill holes
- Flora and Fauna
- Soil/subsoil
- Other environmental features: These include environmental site characterization information that does not clearly fall into any of the above subsections. These typically will be site specific, and may be used by the applicant to mitigate unfavourable conditions, or to provide additional information in support of the description of the proposed facility (IAEA, 2005).

If the gathered data do not fully support the project concept then either alternative means of development needs to be considered or if the feasibility study identifies key issues (economic, environmental or social) then the no action alternative should be followed.

In case of a positive decision regarding the progress of the project the following are guidelines that need to be kept in mind in preparing the EIS:

- Justification of practices. No practice should be authorized unless the practice produces sufficient benefit to the affected individuals or to society to offset the radiation or other harm that it might cause; that is: unless the practice is justified, considering social, economic and other relevant factors.

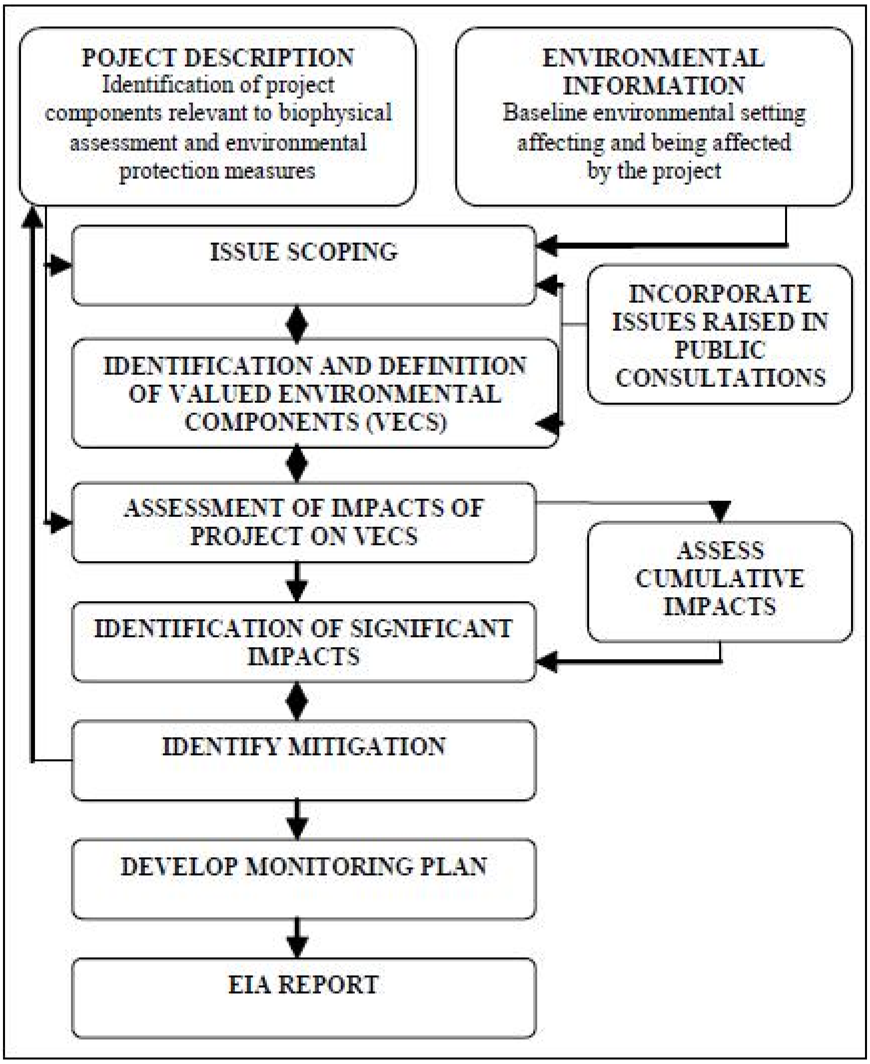


Figure 16: Typical Environmental Assessment Process (Bell, 2003)

- Limitation of effluents. Effluents shall be restricted so that the total impact caused by the possible combination of effluents and exposures from authorized practices, does not exceed any effluent limit specified in accepted environmental and medical standards.
- Optimization of protection and safety. Protection and safety shall be optimized in order that the magnitude of permitted effluents, the number of people affected and the likelihood of incurring effluent events are kept as low as reasonably achievable, (ALARA), economic and social factors being considered, within the restriction that effluents to environment delivered by the source are subject to effluent constraints (IAEA, 1989).

6 Conclusions

This present framework discusses those economic, social and environmental aspects that have the potential to affect the long-term sustainability of the CHPM2030 methodology. It also summarises those relevant concepts, methodologies and subsequent activities and that will be carried out and followed to maximise the output of all the research and development work by granting them a safe passage to large-scale and real-world implementation by addressing the multi-faceted issue of project sustainability.

The novel approach of CHPM2030 ventures to previously uncharted territories when it comes to energy production and mineral extraction within the frame of a single project. There are standard procedures to address individual components of such an initiative in terms of environmental, social or economic assessment. However, to understand the potential impacts of combining and EGS operation with an ISL mining program it takes a lot more than to combine the pros and cons of these two ventures. Carefull and detailed planning is essential to identify those risks and medium-long-term impacts that has the potential either to benefit the local socio-economic setting while leaving a minor environmental footprint or wreack havoc on the neighbouring population, the regional economy or the local environment.

The document provides a guideline for the individual sub-tasks, suggesting a possible route to compile the first draft of the necessary framework documents, that could be further developed as the current technology is going to get taken up on an ever alrger scale.

As it was mentioned before close cooperation is anticipated between the CHPM2030 project and the developers of the Geothermal Sustainability Assessment Protocol. Their iterative approach provides the project wonderful opportunity to join forces with them in developing a GSAP, that covers not only the needs of standard geothermal development but the needs of those initiatives that go beyond the current state of the art.

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