Environmental impact assessment framework

CHPM2030 Deliverable D5.5

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CHPM2030

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CHPM2030 DELIVERABLE D5.5

ENVIRONMENTAL IMPACT ASSESSMENT FRAMEWORK

Summary:

The ultimate objective of this current document is to provide a comprehensive guideline for the future adopters of the CHPM concept to deliver a well structured and detailed Environmental Impact Assessment that meets the relevant standards and legislative framework of the hosting country, where the project is going to be developed.

Our goal was to compile a rather general approach with some specific details corresponding to the applied technologies, instead of coming up with a made-up site and specifying all aspects accordingly. By doing so we believe that we granted the future EIA practitioners the flexibility to adjust this approach to their corresponding project.

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1 Executive summary

The Executive Summary of an EIA provides decision-makers and the public with a concise presentation of the most significant issues contained in the body of an EIA. The Executive Summary is critical because an EIA may be several hundred pages long and decision-makers may read the Executive Summary only. Since project proponents may understand this, material from the body of the EIA that describes serious environmental and social impacts may be softened or omitted entirely from the Executive Summary. Statements in the Executive Summary that are favourable to the project proponent must be carefully compared with related material in the body of the EIA. (Environmental Law Alliance Worldwide, 2010)

A model structure for the executive summary may follow the framework below:

- DESCRIPTION OF PROJECT
- SIGNIFICANCE OF PROJECT IMPACTS
- STUDY OF ALTERNATIVES
- ENVIRONMENTAL DESIGN CRITERIA AND BEST AVAILABLE TECHNOLOGIES
- DESCRIPTION OF PHYSICAL, BIOLOGICAL, AND CULTURAL ENVIRONMENT
    - Atmosphere
    - Lithosphere
    - Hydrosphere
    - Biosphere
    - Social Sphere
- ENVIRONMENTAL IMPACTS, MITIGATION AND OFFSET MEASURES
    - Exploration and Construction
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- CUMULATIVE AND TRANSBOUNDARY IMPACTS
    - Climate Change
    - Land Acquisition and Resettlement
- ENVIRONMENTAL AND SOCIAL MANAGEMENT SYSTEM
    - Monitoring and Reporting

2 Project description

This is one of the most important sections of the EIA. It needs to describeevery aspect of the proposed project in sufficient detail to enable people to understand the project's true environmental and social impacts. It may include a wide array of relevant details such as:

- project location,
- mineral rights and mineral lease agreements,
- tribute agreements, mining authorizations,
- land ownership,
- surrounding localities and towns, infrastructure,
- presence of servitude, land tenure and use,
- use of adjacent land, river catchment,
- mineral deposits, and estimated reserves,
- mining methods (heat and ore alike),
- production strategy
- planned output and
- projected life of the CHPM operation.

2.1 Brief regional description

The proponent is required to accurately delimit and illustrate the area of interest by

- A topographical map showing the location of the area with relation to neighbouring properties and regions
- A certified land status schedule obtained from the relevant authority, together with a legal description
- A detailed map, plan, drawing or aerial photograph of the application area showing topography, water courses, physical features, vegetation, land use, rights of way and any special features
- A series of photographs showing the application area from several representative viewpoints.

2.2 Overview/About the Project

The proposed CHPM (Combined Heat Power and Metal) development initiative needs to be described in detail, including all steps from the beginning to the end of the project and with special attention to its Enhanced Gethermal System (EGS) and In-situ Leaching (ISL) components. Descriptions of the major phases of exploration, pilot testing, commercial operation, groundwater restoration, waste remediation, site remediation and decommissioning, post decommissioning, and associated social-economic activities with supporting written procedures, maps, data, and time lines are essential for full characterization of the project.

In preparing this information, it is important to recognize that a key element of an environmentally sound CHPM project is an understanding that each phase of the project is equally important and must be conducted in an environmentally responsible manner. As such, waste management and pollution prevention are important aspects of each phase. To aid in the design of management of environmental safeguards, it is recommended that waste management be emphasized for each working phase, and that these individual programmes be integrated into an overall waste management programme (or phase) for the life time of the project (LOP) (Environmental Law Alliance Worldwide, 2010).

2.2.1 Justification / Purpose and Need for the Proposed Action

This section of the document always has to be project and location specific, however the following generic statements on energy security and various societal benefits related to the economic impact of such development may support and reinforce the initial reasoning behind the proposed CHPM plant. In other words, the proposedy CHPM plant development has to be credibly justified in the EIA. The paragraphs below are to serve some generic ideas for project developers highlighting the potential advantages of such a facility.

In the coming decades, the European energy market will face major challenges to become less dependent of imported fossil fuels, to enhance its stability and to reduce the environmental impact of its energy supply. This may apply to several other countries outside the EU, too. Deep geothermal energy is regarded as a key technology for the globe, as it can guarantee a base load of both heat and power, with minimal emissions compared to their conventional fossil counter parts. (EGEC, 2009) In addition, securing the supply of critical raw materials, in particular metals also become a hot topic as certain streams are monopolised by a few countries or the surface environmental toll of extracting them is unacceptable and unfeasible.

In the CHPM technology vision the metal-bearing geological formation will be manipulated in a way that the co-production of energy and metals will be possible, and may be optimised according to the market demands at any given moment in the future.

2.3 Proposed Technology

The CHPM approach is a novel idea that comprises variations of currently available cutting-edge industrial practices with highly innovative concepts that are being developed and tested within the frame of the current project. For this reason, it is mandatory to describe the individual components of the process in detail to prevent misinformation and to demonstrate that it brings great value while posing relatively low risks that in addition are easy to mitigate.

The conceptual backbone of the CHPM facility will be a suitable mineral deposit of high economic value located at great depths, where the ambient rock temperature allows for the development of an Enhanced Geothermal System (EGS) which will be manipulated using

novel geo-engineering approaches for maximum power output and the mobilisation of valuable metals. The methods to be developed will target individual mineral formations taking advantage of their specific structural and geochemical features, utilising a combination of experimental solutions for metal mobilisation and subsequent recovery.

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 a CHPM facility the main emphasis is on energy, and metals are considered by-products (recovered from the brine by electrochemical processes) that are expected to support the economic feasibility of heat and power generation over an extended period in an integrated system.

The sustained metal recovery proposed for the CHPM cycle represents a novel approach in EGS engineering, as it can lower the parasitic load of the geothermal heat and power plant over time by reducing the energy needed to circulate the geothermal fluid.

In addition, a novel technology, that is currently in the lab-research phase will be deployed to further improve the power generation potential of the CHPM facility by tapping into the inherent characteristics of the geothermal brines. Chemical energy is stored in the brine as in the form of dissolved salts. Using a process called ‘reverse electrodialysis’ this energy can be harnessed. Reverse electrodialysis (RE) has been earlier tested at pilot scale for fresh water, sea water and concentrated brine applications. Extracting salt gradient power (SGP) from geothermal brines is a new concept, first investigated within the frame of the CHPM 2030 project.

The specific characteristics of a geothermal brine that first come to mind when envisaging application of ‘reverse electrodialysis’ are the temperature and the composition of the brine. The temperature can create extra leverage in to extracting the energy and is generally considered a ‘free win’. Geothermal brines -especially ultradeep ones- are rich in dissolved species, such as gases, metals and salts. General rules are that the depth of the brine is determining the salt content and on specific locations also the metal content. High salt content favours high energy output from the SGP-RE (salt gradient power - reverse electrodialysis).

Geothermal brines may be used as ‘fuel’ in the salt gradient power generator producing a surplus of energy on top of the energy produced through the binary cycle of the EGS. To do so, the geothermal brine should be contacted with a low salinity water source, e.g., surface water, treated waste water, shallow ground water.

But which low salinity source to use? That depends mainly on the concentration of the brine. If the geothermal brine is saturated with NaCl (~350 g/L) seawater (35 g/L) could easily be used and deliver promising results. However, even for the ultradeep brines of Soultz (France) and Balmatt (Belgium) the concentration doesn’t exceed 210 g/L (Sanjuan et al., 2010). In that case it would be advisable to use low salinity fresh water sources, e.g., as shallow ground water, treated waste water, river water. As a rule of thumb, one should maintain a ratio of around 10 between the HIGH and LOW salinity sources. This will create a minimal stack potential to operate the SGP-RE in an economically feasible way.

The rationale behind exploiting the chemical potential of the geothermal brine consists of the following elements:

- Deep geothermal brines exhibit often very high concentrations of salts. Higher concentration indicates more chemical energy is stored in the brine
- The inherently high temperatures of the geothermal brines make them more suitable for electricity production via reverse electrodialysis
- The technology can be easily integrated in the closed loop of the EGS. Although there is no direct contact between the brine and the low salinity source, salts are transferred to the low salinity source. Moreover, water transport also occurs as a result of osmotic and electroosmotic transport (VITO, 2018).

2.3.1 Main Project Components

Exploration: Drilling-type, drilling mud, water used, borehole abandonment, noise, spill prevention.

Pilot testing and Commercial operation: Construction; Drilling-type, drilling mud, core, water used; Well completion (casing, cementing, screening, mechanical integrity testing,.); Pipelines (setting surface or subsurface, leak monitoring,.); Tanks; Ponds (settling, evaporation,.); Airborne emissions; Liquid disposal (wells, land application, surface discharge,.); Solids disposal (radioactive, non-radioactive); Central processing plant (tankage, pipelines, materials, control and management system); Training and safety; Transportation; Topsoil protection / preservation; Services; Noise.

Decommissioning:

- **Environment remediation:** Plugging and abandoning wells; Conducting radiological surveys of facilities, process equipment, and materials to evaluate the potential for exposure during decommissioning; Buildings decommissioning; Ponds decommissioning, Road reclamation, Backfilling and recontouring disturbed areas; Revegetating disturbed areas.
- **Groundwater remediation:** Leaching solution treatment, volumes, type of treatment, pore volumes, water consumption, discharge volumes, quantity and quality, expected limits for the end, well decommissioning, materials used,.

2.4 Project alternatives

The Project Description should also analyse alternative ways to undertake the project and identify the least environmentally-damaging practical alternative.

- Alternative siting of the CHPM facility:

The location of key facilities should be discussed. The location of these facilities should be chosen to protect public safety and minimize impact on critical resources, such as surface waters, groundwater, or ecologically important wildlife habitat.

• The no-action alternative

An EIA is not complete without a comparative analysis of the environmental and social impacts of the 'no-action' alternative (a future in which the proposed project does not take place). The laws and regulations of many countries explicitly require that an EIA contain a separate assessment of the 'no-action' alternative.

An assessment of the environmental and social impacts in future, when the proposed project should not be realised, is important to understanding what benefits might be lost.. Certain benefits may only come to light when the 'no-action' alternative (Environmental Law Alliance Worldwide, 2010) is discussed.

2.5 Participants:

Depending on the hosting country's EIA system, responsibility for producing an EIA will be assigned to one of two parties involved: (1) the government agency or ministry, or (2) the project proponent. The proponent is that legal entity, which is proposing the establishment of a new project. The proponent will usually make the applications for whatever approvals are required, perform the environmental field work, produce the environmental impact statement, conduct a public information programme, defend the project in any hearings that may be required, respond to any requirements placed on the project by the process, and initiate the actual project after the necessary approvals are received.If EIA laws permit, either party may opt to hire a consultant to prepare the EIA or handle specific portions of the EIA process, such as public participation or technical studies.

Some EIA laws recognize the inherent conflict of interest produced when a development company or other project proponent hires a consultant to prepare an EIA. These laws usually require consultants to be registered with the government and/or professionally accredited in EIA preparation. In some instances, a consultant may be required to file a statement disclosing any financial or other interest in the outcome of the project (Environmental Law Alliance Worldwide, 2010).

Members of the **public** in the proposed development may have legitimate concerns about the nature and impacts of the project. Their concerns should be identified and addressed. It is rare that a project be proposed in an area with no public interest. Often the reverse is true, when the public expresses interest towards the investment, particularly in case of a novel concept such as CHPM with no really previous track record of operation.

Public input should be sought early in the project, preferably when the guidelines for the Environmental Impact Statement (EIS) are being developed. This will ensure that questions that are important to the public are being addressed. Public comment of the EIS should be solicited and, if public hearings are held, public participation should be permitted. However, this public input should be limited to issues which have been identified in the terms of reference. The assessment body should be prepared to explain to the members of the public

why particularly issues are not open for discussion (usually because they have been covered elsewhere).
The proponent is well advised to have a **public information programme** while keeping the public informed about the project by the means of non-technical executive summaries. The use of audio and video tapes in local languages may be of assistance in communicating with local residents who may not be fluent in the business and technical language used in their country (IAEA, 2005).

The third participant in environmental assessment is the **authority** which will judge the acceptability of the project and, if deemed acceptable, will issue the appropriate approvals permits or licenses for the operation, inspects it during the operation and approves decommissioning. The licensing process may involve several stages, and an environmental assessment is a frequent requirement of the approval process. Depending upon the location of a proposed project, more than one level of government may have an interest in the development. For greater efficiency, most countries combine these interests into a single process.

If all the interested parties have the opportunity for input into the environmental assessment, then there is a high probability that the environmental assessment process will be successful. In addition to identifying potential environmental impacts and specifying appropriate mitigative measures, the environmental impact statement must also incorporate plans for the final decommissioning and rehabilitation of the site. (IAEA, 2005).

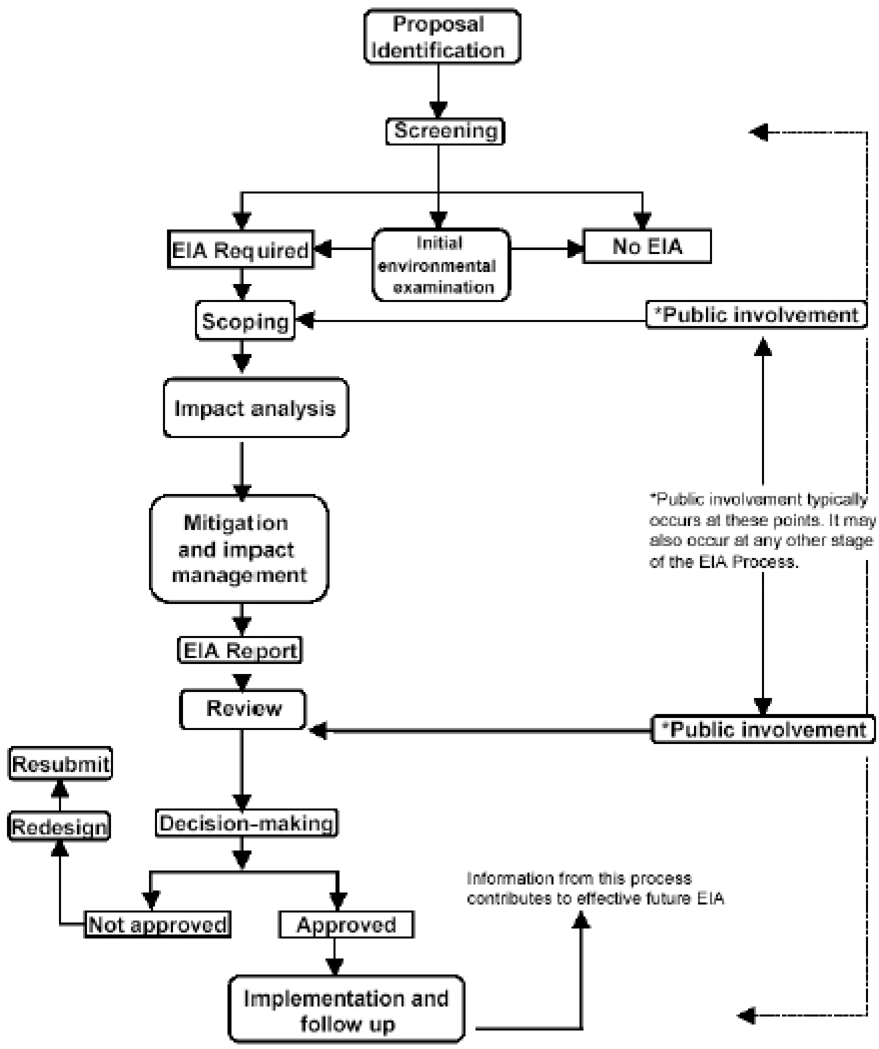

Figure 1: Generalized EIA process flow-chart (Ogola, 2007)

3 Screening

The EIA process kicks off with project screening (European Commission 2009a). The screening process determines whether a project warrants preparation of an EIA. The threshold requirements for an EIA vary from country to country – some national laws provide a list of the types of activities or projects that will require an EIA, others require an EIA for any project that may have a significant impact on the environment or for projects that exceed a certain monetary value. In some cases, particularly if the possible impacts of a project are not known (e.g., in case of a CHPM facility), a preliminary environmental assessment will be prepared to determine whether the project warrants an EIA. (Environmental Law Alliance Worldwide, 2010)

An EIA is usually necessary only when a proposed activity is likely to cause a “significant” adverse impact. The EU’s EIA Directive (Directive (2014/52/EU) defines **‘project’** as: *‘the execution of construction works or of other installations or schemes, other interventions in the natural surroundings and landscape including those involving the extraction of mineral resources.’* The Directive adopts two approaches to screen projects, Annex I and II. Projects listed in Annex I are those that have significant effects on the environment and which, as a rule, should be subject to a systematic assessment (Article 4(1) of the EIA Directive).

> The EIA Directive
> The EIA Directive requires Member States to ensure that projects likely to have significant effects on the environment because of their nature, size or location are subject to an assessment of their environmental effects. This assessment should take place before development consent is given, i.e. before the authority/ies decide(s) that the developer can go ahead with the project. The Directive harmonises EIA principles by introducing minimum requirements, in particular for the types of projects that should be assessed, the main obligations of developers, the assessment’s content and provisions on the participation of competent authorities and the public. (EC, 2013)

Projects listed in Annex II may not necessarily have significant effects on the environment.Thus they are not automatically subjected to an environmental impact assessment, but they should be assessed on a case-by-case basis or according to thresholds and/or criteria (for example size), location (sensitive ecological areas in particular) and potential impact (surface affected, duration), where Member States consider that they are likely to have significant effects on the environment (Article 4(2) of the EIA Directive).

At the same time all projects listed in Annex I are subject to EIA, thus developing an EIA is a legal obligation to the project owner. CHPM related activities currently fall under **Annex II (2) Extractive Industry 2b Underground mining**; and **2d Deep drillings**, in particular: **(i) geothermal drilling**; (European Commission, 2015)
In addition, projects which are subject to an EIA and planned in the same area or which are contingent upon one another may be assessed jointly, e.g., geothermal power stations and the adjacent power lines (Albertsson, 2010). Guidance on screening is available on the European Commission’s homepage [http://ec.europa.eu/environment/eia/eia-support.htm]. It is specifically designed to guide you step-by-step through the screening process.

Outside the EU, especially in the developing countries the classification follows similar principles but with a slightly different approach distinguishing three distinct categories, as highlighted in the corresponding World Bank operation manual (Good practices: Environmental Assessment Operational Policy OP 4.01 Annex C: Environmental Management Plan):
Category A: If the project likely to have significant environmental impacts that are sensitive, diverse or unprecedented. These impacts may affect an area broader than the communities benefiting from infrastructure investments.
Category B: If the projects potential adverse environmental impacts on human populations or environmentally important areas are less adverse than those of Category A projects. These

impacts are site-specific; few if any of them are irreversible; and in most cases mitigation measures can be designed more readily than for Category A projects.

Category C: If the project is likely to have minimal or no adverse environmental impacts. Once the project is assessed and determined as Category C, no further action would be required. Some examples of Category C projects include: Education (i.e. capacity-building,., not including school construction) Family planning (World Bank 1999).

The main outcome of screening will be a classification of the project according to its environmental sensitivity. This will determine whether an EIA is needed and to what detail.

3.1 Project feasibility

Initial Environmental Examination or Evaluation (IEE)

IEE is carried out to determine whether potentially adverse environmental effects are significant or whether mitigation measures can be adopted to reduce or eliminate these adverse effects. The IEE contains a brief statement of key environmental issues, based on readily available information, and is used in the early (pre-feasibility) phase of project planning. The IEE also suggests whether in-depth studies are needed. When an IEE can provide a definite solution to environmental problems, an EIA is not necessary. IEE also requires expert advice and technical input from environmental specialists so that potential environmental problems can be clearly defined. (Ogola, 2007)

3.2 Feasibility study

After a potential CHPM site has been identified, it is essential to conduct a feasibility study to determine whether the deposit can be developed economically. The feasibility study entails definition of the heat and byproduct ore reserves and design of a method for recovering them. The capital, operating, and decommissioning costs must be estimated and compared with the projected revenue generated by the sale of the products. To properly conduct this assessment, it is important to do a preliminary environmental baseline study and to estimate the potential impact of the project on the local environment. Coupled with this is the need to examine the regulatory requirements that may be imposed upon the development.

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 like that required for an environmental impact statement, but at a lesser level of detail. From an environmental perspective, the feasibility study needs only to consider those issues that could have serious economic impacts on the project. (IAEA, 2005)

The feasibility study deals with the assessment of only geology related parameters. Thesedefine whether the proposed project can deliver the anticipated results and thus being worth a more complex feasibility study or EIA later. These factors can be considered constant during a future operation, with significant self-recovery potential (e.g., rejuvenation of a heat-depleted deep rock volume over time), hence their current discussion as project feasibility limitations rather than elements of an environmental baseline study.

Several data are needed to calculate temperature at depth. The heat flow (Q) map is the starting point for the calculations. The thermal conductivity (K) and the geothermal gradient ($\partial T/\partial z$) complete the trio of quantities directly involved (Roy et al., 1972).

3.2.1 Heat flow

Heat flow is the movement of heat (energy) from the interior of Earth to the surface. The source of most heat comes from the cooling of the Earth's core and the radioactive heat generation in the upper 20 to 40 km of the Earth's crust. Heat flow is higher in areas with either high radioactivity or where the Earth's crust is thinner. Additionally, there are areas with heat flow 'anomalies' that have higher than average crustal heat flow without a clearly identified tectonic or radioactive explanation, usually related to fluid flow. Heat flow is calculated using the rock thermal conductivity multiplied by the temperature gradient. The standard units are mW/m2 = milli Watts per meter squared. (www.smu.edu)

Tectonic and radioactive components of heat flow

The heat flow at the surface is composed of two main components that may, of course, be perturbed by local effects, i.e., the heat generated by radioactive elements in the crust and the tectonic component of heat flow that comes from the interior of the Earth (referred to here as the mantle heat flow). The radioactive component varies from 0 to more than 100 mW/m^2, with a typical value of about 25 mW/m^2. The characteristic depth of the radioelements (U, Th, and K) in the crust averages about 10 km (Roy et al., 1972), so that most of the variation in heat flow from radioactivity is above that depth. This component can be large and is locally variable, and, thus, there can be areas of high heat flow even in areas that are considered stable continent.

3.2.2 Geothermal gradient

Geothermal gradient is the rate of change in temperature with depth. Away from active tectonic areas, temperature gradient s about 25–30 °C/km at crustal depths. The temperature gradient of Earth at the measurement site is determined from collecting the temperature in a well at specific depths. Often gradient units are either °C/km. If the temperature measurements are taken after the well is no longer impacted from the drilling fluid, it is

considered at equilibrium. These values are of the highest quality and include a series of data points to assist in understanding the changes in the geology/structure of Earth.

3.2.3 Thermal conductivity

Thermal conductivity of rocks is determined from core samples, specimens or cuttings using a device that measures the amount of heat the sample can transfer. Thermal conductivity units are typically in W/mK = Watts per meter Kelvin. Thermal conductivity of rocks (minerals) will change as the temperature increases.

3.2.4 Sediment thickness

Much of the thermal energy resides in "basement" rocks below the sedimentary section. Because basement is usually defined as volumes of metamorphic or igneous rocks, the composition and lithology of "basement" is extremely variable. The basement lithology below the sedimentary cover, where present, is as complicated as the surface exposures. Quantification of the most favourable rock composition and structure for EGS development remains to be done withing the framework of a specialised study. Most of the experimental EGS sites have been in granite (in a strict geologic sense), because of the expected homogeneity of the rock type. In fact, there may be situations where layered rocks might be equally or more favourable because the orientations of fractures might be easier to predict, and the rock types may be more extensively fractured. From a more practical point of view, the lithology also affects the heat flow in the form of its radioactive content and the resulting heat flow. Areas of high radioactivity will have higher heat flow and so may have higher temperatures, all other factors being similar.

Some of the EGS resource resides in the sedimentary section, however. In general, as depth and temperature increase, the permeability and porosity of the rocks decrease. So, at depths of 3+ km and temperatures of 150+°C, the sedimentary rocks are similar to their volcanic or metamorphic counterparts in their permeability and porosity.

3.2.5 Ground surface temperature

Ground surface temperature represents the lowest value of the average heat rejection temperature possible for any energy conversion scheme. The value may originate from measurements of temperature in shallow groundwater wells (Gass, 1982). These temperatures can be used to calculate maximum attainable temperature differences, which can then be used to calculate the thermal energy content (not fully expoitable) of a rock volume for the target area (difference of the rock temperature at depth and the average surface temperature).

3.3 Climate change considerations and adaptation

Climate change refers to shifts that can be attributed directly or indirectly to human activity that alter the composition of the global atmosphere, and which are in addition to natural climate variability observed over comparable time periods (IPCC, 2001). Recently the probability of human influence in climate change has been raised by the IPCC (2013) from 90-95 to 95-100 per cent. Even though the Kyoto Protocol, The Copenhagen Accord, and most recently the Paris Agreement (Article 2) ambitiously declared its goal to keep global warming to “well below 2°C above pre-industrial levels”, specific means to implement and **achieve such mitigation targets seem to be less of a concern for global discussion** (Christopher 2008)

Climate change plays an important role in affecting and altering the course of human development. It has generated significant and irreversible impacts on human survival and development since the early 1990s. To respond to climate change, the past decades saw a great deal of efforts and actions that have been taken to mitigate or adapt to climate change worldwide. Up until today, no effective and efficient techniques have been developed to directly quantify the influences of climate change on human development, but only rough estimations and qualitative descriptions of these effects (Byer &, Yeomans 2007).

As it was asserted by the Organization for Economic Cooperation and Development (OECD), the climate change response should be effectively integrated into development activities, and the EIA process provides an appropriate entry point for the integration of climate change mitigation and adaptation into plans and projects. (OECD, 2006) Traditionally, the core of EIA is to evaluate the impacts on the environment resulting from policy, planning and program/project (PPPs). The impacts on PPPs resulting from the environmental change are rarely assessed [OECD, 2008], but in the face of climate change, EIA and strategic environmental assessment (SEA) are expected to translate global or national mitigation and adaptation targets to project and plan levels of decision-making. (Qi, 2018) This resonates with the earlier findings of IPCC, that highlights interactions of climate change with other environmental stresses to translate global or national reduction targets to plan and project levels of decision-making through SEA and EIA, which have been widely used to address traditional environmental concerns. (IPCC 2001)

By nature, however, EIA is probably not suitable as a primary mean to tackle climate change. Although the EIA procedures could be used to mainly ensure future plans and projects not to significantly increase greenhouse gas (GHG) emissions or to better adapt to climate change, more comprehensive strategies are needed to deal with existing emission sources and climate sensitive sectors and projects. (Christopher 2008)
Though there are many uncertainties regarding climate change, the reduction of GHG emissions and enhancement of the capability for climate change adaptation have become the

common aims worldwide for responding to climate change. Hence, the potential impacts of PPPs (e.g., increased GHG emissions), on climate change should be assessed during EIA implementation, as well as the potential influences of climate change (eg extreme weather events) on PPPs (Chang,Wu, 2013) However, there are a number of basic approaches that have the potential to better address climate change uncertainties in EIA, such as scenario analysis, sensitivity analysis and probabilistic analysis (Byer, Yeomans; 2007)
Canada for example has developed several checklists for EIA practitioners to identify possible concerns in relevance to both GHG emissions and climate sensitivity. The EU Guidelines also highlight the importance of incorporating climate change into environmental assessment “at an early stage (screening and scoping)”, but the screening process is only suggested to integrate climate change issues “where appropriate” (European Commission, 2013). Main climate change concerns are listed to help EIA practitioners develop questions to be asked in the screening process (European Commission, 2013), but no clear criteria or thresholds are provided, meaning that every case is different and the checklist should be tailored in practice That is because it is difficult to attribute climate change impacts to any single action and the idea that climate change is just one of the factors to be weighed against others in the EIA processes (Christopher, 2008).

Furthermore, proper identification and evaluation of climate change parameters rely on advanced climate change methodologies, technologies and information, which could be very challenging in practice, especially in developing countries. Moreover, it should be noted that the Canadian and EU Guidelines focus on integrated assessment at the level of specific projects (Qi, 2018)
Annex III(1)(f) of the Directive 2014/52/EU introduces climate change adaptation as a screening criterion for the EU member states, but mitigation is not explicitly considered as a factor for screening. Therefore, all EU member states are now subject to a compulsory obligation to consistently consider climate change with other environmental concerns at the project level.

A Way forward

After more than 30 years of practice, EIA has become the guarantee to ensure that comprehensive considerations of economic, social and environmental development are well integrated into the decision-making process (Wu et.al, 2011). With the broadening of environmental management, the content of EIA is continuously enriching and expanding, such as from pollutants concentration control to total emission control, from end-of-pipe treatment to cleaner production and circular economy, and from project EIA to regional environmental assessment (REA) and SEA. During the transformation and progress of environmental protection work, EIA has become an effective means for optimising economic growth while environmental protection is implemented, because of the flexibility, openness, scientific validity and practicability of EIA (Chang, Wu, 2013).

Following this train of thought it is clear, that standard EIA approaches need to evolve to become an effective tool for integrating climate change considerations (CCCs) into comprehensive decision making. Moreover, the reality of climate change provides EIA with an opportunity to re-evaluate and reaffirm the assessment process, such as assessment procedures, assessment implementation, and integration of CCCs into decision-making process, and mitigation and monitoring measures. (Burdge 2008)
Despite, climate change considerations (CCCs) have been required to be included in environmental impact assessment since the 1990s, these guidelines are not uniformly applied on a global scale, and the developed countries seem to be bound by them more than the developing regions. (Byer, Yeomans; 2007). Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities. Adaptation needs and actions are sector- and climate change impacts-specific. Such actions could be highly relevant for developments and projects for which EIAs are developed. (IPCC 2001)

The key step to assess the potential adaptation needs and identify adaptation actions is to understand the potential climate change impacts on the planned project and the project area. This is critical, as the impacts of climate change are different for various locations. Furthermore, not all impacts are important for the planned project. However, responding to climate change adaptation is not just a stand-alone activity presented in the form of specific climate change adaptation strategies and plans.

3.3.1 Potential Obstacles for mainstreaming climate change into the EIA procedures

Institutional barriers

The mainstreaming approach indicates that "actors whose main tasks are not directly concerned with mitigation of, or adaptation to, climate change also work to attain these goals" (European Commission, 2015). The introduction of climate change discourse is therefore expected to promote cooperation among government sectors.

Furthermore, there are no rules regulated in according with climate change adaptation, due to the historical background while these laws were instituted. Moreover, there are no comprehensive institutional schemes for laws to found principles, organisations, mechanisms and integration systems for responding to climate change. Therefore, the implementation of the integration of CCCs into EIA is heavily restricted.

Challenges on technology and resources

Climate change entails a degree of scientific uncertainty that is unaccustomed to the existing environmental regulatory mechanisms. Disputes concerning methodologies, parameters, models and technologies applied for integrated assessment have been highlighted by past empirical research (Agrawala et al., 2011). This is one of the main reasons for most EU countries not to evaluate climate change impacts via the EIA procedures before the revision of the EIA Directive in 2014 (European Commission, 2009b). Nowadays, challenges are still highlighted due to the long-term and cumulative nature of impacts, complexity of cause–effect relationship and scientific uncertainty (European Commission, 2013).

Most of the developing countries (where EIA procedures are even in place) currently fail short of a strong scientific background to support consistent climate change assessment on a frequent basis. The availability and reliability of necessary information also affect the accuracy of integrated assessment. The above obstacles are particularly challenging for less developed regions. Furthermore, they also lack practical experience in systematically integrating CCCs into EIAs.

Unfortunately, these areas have been targeted by many controversial development projects and plans. A lack of necessary financial and human resources and unbalanced distribution of limited resources further aggravate the prospect for integrated consideration. Climate change assessment via the EIA procedures entails additional work compared to traditional EIA or SEA (Agrawala et al., 2011).

Due to the immaturity of EIA service market, existing institutional barriers and unbalanced regional development, one can safely predict that the provision of necessary resources is likely to be insufficient in the developing world.

Malfunction of the environmental impact assessment procedures

The track record of the EIA procedures in the developing world is far from reassuring, even absent the complications generated by climate change. It is therefore concerned that

mainstreaming climate change into the EIA procedures could be too much to ask for an overstretched, malfunctioned system.

With increasing pressure from climate change and growing momentum on mainstreaming, all countries with an EIA regulation in effect now face a stark dilemma regarding how to bridge between distant (NB: not so distant any more (IPCC, 2018)) global aspirations and domestic decisions. The mainstreaming proponents argue that climate change can be addressed at smaller scales via the EIA procedures. A holistic consideration of climate change and other environmental protection goals is ideal for dealing with potential synergies and trade-offs (Qi, 2018)

4 Scoping and Preparation of a Terms of Reference

The aim of EIA is not to carry out exhaustive studies on all environmental impacts for all projects.

Scoping provides a mechanism for EIA to consider the total environment then identify from all the potential impacts what ones are likely to be the more significant requiring more detailed consideration. In other words, the scoping process determines the "*content and extent of the matters to be covered in the EIA report*" (European Commission, 2009a).

This step ensures that you do not spend extra time and money on providing information that the relevant authority does not need, while still providing enough information to consider your application. In other words, scoping is used to identify the key issues of concern at an early stage in the planning process (Ahmed & Sammy, 1987).

Scoping of the assessment also includes:

- the selection of Valued Environmental Components (VEC) (and, if required, key indicators for the VEC) and the rationale for its selection;
- influence of consultation and engagement on the scoping of the VEC;
- selection of the environmental effect(s);
- description of measurable parameters;
- description of temporal, spatial, administrative, and technical boundaries; and
- identification of thresholds that are used to determine the significance of environmental effects. (Sission, 2015)

The results of scoping will determine the scope, depth and terms of reference to be addressed within the Environmental statement. Scoping is primarily done to 1) Identify concerns and issues for consideration in an EIA; 2) Enable those responsible for an EIA study to properly brief the study team on the alternatives and on impacts to be considered at different levels of analysis; 3) Determine the assessment methods to be used; and to 4) Provide an opportunity for public involvement in determining the factors to be assessed, and facilitate early agreement on contentious issues. The most important output of the scoping process is the Terms of Reference. (Ogola, 2007)

Terms of Reference (ToR) is a document produced by the authority conducting the EIA study. It is formed during Scoping- the second stage in the EIA process (**Figure** 1). The key aspect during the scoping process is to ensure the environmental impact assessment beingat the appropriate level of detail, corresponding with the scale and significance of the proposed

A clear definition of the scope of the various studies to be carried out at formulation stage is necessary to ensure complementarities and to avoid overlap between the EIA and other studies (e.g. *'general' formulation study, financial and economic analysis*). Close coordination is therefore required in the preparation of the different ToR for these studies if they are not prepared by the same team. (EC:DG-ICD, 2016)

activity. Scoping will ensure that the critical issues are fully addressed (DoE-My, 2010).
Therefore, the ToR is to identify key issues and further outline the environmental data collections that are required, determine the assessment techniques to be used and identify the appropriate methodologies for impact prediction and assessment (Albertsson et al, 2010). Thus, this procedure (namely: to prepare a ToR) is a vital stage in the detailed EIA procedure and (also in number of other studies that will be incorporated in the different steps of the formulation phase).
For this reason, all the stakeholders are invited to submit their concerns regarding the project during a public hearing organized by the EIA committee, which is followed by discussions and deliberations (Eco-Intelligent, 2016). The EIA process for geothermal projects 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 early stages of each project, different views emerge which can be discussed and resolved before the project is fully developed (Albertsson et al, 2010).

The ToR sets out what is expected of a practitioner or a consultant when carrying out an EIA. It highlights the points *that need to be covered* (the ToR itself does not elaborate on these points unless required) during the EIA study. There are no universal formats for this scoping document, which will be suitable for every study. However, there are general rules (listed below), which should be observed when preparing ToR for the EIA. This scoping study should ensure that the consultants focus on the major issues and the most serious likely impacts. The opportunities for enhancing any positive benefits from the project should also be highlighted in the ToR (Ogola 2007).

- The ToR should commence with a brief description of the program or project. This should include a plan of the area that will be affected either indirectly or directly. The institutions that are involved in the proposal should also be mentioned
- An overview of the local environment should follow the general description. This may include socio-economic information, land use, land tenure, water use in the area and any aspect of the flora and fauna. If other studies have been completed a list of available reports should be given.
- In addition, a brief description should be given of the most important institutions, including those responsible for the EIA, the project executing agency and future managers (www.fao.org).
- The study should ensure that the consultants or practitioners focus on the major issues and the most serious likely impacts identified during scoping e.g. air emission, waste water discharge. The opportunities for enhancing any positive benefits from the project should also be highlighted. This component of ToR is usually submitted to the designated authority for scrutiny and approval.

- The ToR should contain explicit references to which safeguard policies may be relevant and which legal requirements should be applied.
- An ideal ToR gives an indication of the team considered necessary for the study and a team leader identified. Depending on the scope of the study this may be multi-disciplinary. However, as the team should not be rigidly imposed on the consultant.
- If international experts are doing the EIA, it is important to make provision for local capacity building and technology transfer in the ToR. Apart from enabling in-country expertise to be built up, this will promote more involvement and understanding of the issues raised by the study. As most EIA studies are of relatively short duration, this is probably best achieved through the attachment of project proponent to the consultants during the study or an insistence on the use of local staff personnel for some of the tasks.
- The expected date of commencement and time limit should be given and consultants program of work must be within the given time limit. In most cases scoping can be done in one to three months using checklists or other techniques assuming adequate data is readily available. Up to 12 months is needed for a full EIA for a medium or large-scale project although this could be longer if the project is complex or considerable primary data must be collected or field measurement undertaken (FAO).
- The budget limit should be given in the ToR. The type of experts, and whether foreign or local, and the duration of their inputs will usually be the deciding cost factors although a large field survey or measurement program with laboratory analysis could significantly increase costs. Any assistance to be provided by the Client to reduce costs should be clearly stated in the ToR.
- Consultant payments proposal should be made and tied to specific milestones
- Reporting requirements should be clearly stated and should comply with local or international reporting guidelines. An annex giving a draft table of contents for the final report (the Environmental Impact Statement) is helpful as this will standardize presentation and ensure all aspects are covered by the consultants. The format of EIS must be clear and the number of copies in soft and hard must be stated.
- Above all, the ToR should also make provision for the consultants to improve the terms of reference and thus the quality of EIA. (Ogola, 2007)

In some instances, views will be subjective, and the consultants should give an indication of the degree of risk or confidence and the assumptions on which conclusions have been drawn. In most cases the output required will be a report examining the existing environment, the impacts of the proposed project on the environment and the effects of the environment on the project, both positive and negative, the mitigating measures to be taken and any actions needed (FAO).

The requirements stated in the TOR will determine the length of time needed for the study, the geographical boundary of the EIA, its cost and the type of expertise required. Baseline data collection, if needed, can be time consuming and will have a major impact on the cost and time needed for the study. If considerable data exists the EIA may be possible without further primary data collection. If data are scarce, time must be allowed for field measurement and analysis. (FAO)

Selection of Alternatives

In the scoping stage also selection of alternatives are considered. Analysis of alternatives is done to establish the preferred or most environmentally sound, financially feasible and benign option for achieving project objectives. This includes alternative sites or location, technology, commodity and process which are based on collecting data and information from various possible sources.

The World Bank directives require systematic comparison of proposed investment design in terms of site, technology, processes in terms of their impacts and feasibility of their mitigation, capital, recurrent costs, suitability under local conditions and institutional, training and monitoring requirements (World Bank 1999). For each alternative, the environmental cost should be quantified to the extent possible and economic values attached where feasible. The developer considers both environment and economic criteria while choosing the alternatives. So far as environmental consideration is concerned there are two types of alternative- No Action Alternative and In Action Alternative. No action alternative refers to environmental considerations if the project did not go ahead. It takes more careful discussion and thinking while in action alternatives are positive indicators for the project. (Kalita 2016)

5 Administrative, Legal and Policy framework

Environmental Impact Assessment (EIA) can broadly be defined as a study of the effects of a proposed project, plan or program on the environment. The legal, methodological and procedural foundations of EIA were established in 1970 by the enactment of the National Environmental Policy Act (NEPA) in the USA. This was the first time that EIA became the official tool to be used to protect the environment. Later on, the United Nations Conference on the Environment in Stockholm in 1972 and subsequent conventions further developed and formalized EIA.

By the mid-1990s all developed countries had set up their own environmental laws whereas most of the developing countries were still in the phase of adopting the. (Lee 1995).
The past more than two decades have seen a significant level of dedication towards establishing and defining environmental legislation in the countries of the developing world. On one hand this evolution can be fuelled by increased environmental consciousness but the process had been incentivised by those multilateral and bilateral financial institutions that required such policies in place and practice prior engaging in funding projects in those countries.
At the international level, lending banks and bilateral aid agencies have EIA procedures that apply to borrowing and recipient countries. Most developing counties have also embraced and are in the process of formalizing EIA through legislation. (Ogola, 2007)

5.1 International Conventions

EIA takes place within the legal, policy and institutional frameworks established by individual countries and international agencies. The various processes are regulated by several Multilateral Environmental Agreements to which the host country is a party on an international level such as

1987: Montreal Protocol (on Substances that Deplete the Ozone Layer):
1991: Convention on Environmental Impact Assessment in a Trans-boundary Context (Espoo, Finland) put EIA in a trans-boundary context.
1992: The Rio Declaration called for use of EIA as a national decision making instrument to be used in assessing whether proposed activities are likely to have significant adverse impact on the environment. (Ogola, 2007)
1992: The **Convention on Biological Diversity** (**CBD**)
1992: United Nations Framework Convention on Climate Change (**UNFCCC**)
1997: **Kyoto Protocol**

1998: Aarhus Convention covers the decisions at the level of projects and plans, programs and policies and by extension, applies to EIA and SEA.
2001: Doha Ministerial Declaration encourages countries to share expertise and experience with members wishing to perform environmental reviews at the national level (Ogola, 2007)
2016: Paris Climate Agreement charts a new course in the global climate effort (UNFCCC).

Beyond these overarching international agreements there are many more specific international environmental conventions, agreements or treaties. Most of them may have been ratified by the hosting country of the planned CHPM development and thus become incorporated as part of the national laws and legislations. It is essential that the corresponding international and national legal framework against the EIA will be developed.
The following list is to indicate what additional and specific legislative framework is potentially needed to be assessed when setting up the framework for a CHPM project. These examples are from EIAs delivered within the legislative framework of Kenya and Indonesia covering additional international conventions, agreement and treaties on the environmental, health and safety aspects, that have formed the basis of corresponding local law by having them ratified (INO, 2017).

- **ASEAN Agreement on the Conservation of Nature and Natural Resources**:
- **African Convention on the Conservation of Natural Resources**
- **Convention Concerning the Protection of the World Cultural and Natural Heritage**
- **Convention on the Conservation of Migratory Species of Wild Animals**,
- **Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal**
- **Stockholm Convention on Persistent Organic Pollutants** (Tullow, 2012).

5.2 Multilateral and bilateral financial institutions environmental safeguards

Multilateral and bilateral lenders included EIA requirements in their project eligibility criteria (OECD, 1996). Investment banks like African Development Bank (AfDB), Asian Development Bank (ADB), European Bank for Reconstruction and Development (EBRD), European Investment Bank (EIB), Japanese Bank for International Cooperation (JBIC), World Bank (WB) have environmental safeguards to ensure that financing of projects is not only based on the precautionary principle, preventative action rather than curative treatment but sustainable development (WBCSD,2005).

Although their operational policies and requirements vary in certain respects, the development banks follow a relatively standard procedure for the preparation and approval of an EIA report. Borrowing countries are responsible for the preparation of the EIA, and this requirement possibly more than any other has influenced the introduction and development of EIA in many developing countries (Ogola, 2007)

5.3 Specific, relevant national level and EIA regulations

A country's legal system and its political, administrative, and cultural context play an important role in shaping that country's EIA system, and account for differences in EIA systems among countries. As a result, the use of EIA as a tool varies among countries from its consideration as an administrative process that helps incorporate environmental and social concerns of different stakeholders into the decision-making of authorities.

The overall goal is to integrate environmental concerns into the national planning and management processes and provide guidelines for environmentally sustainable development. The primary objectives to successfully achieve this may include:

- conserving and managing the natural resources (air, water, land, flora, and fauna).
- promoting environmental conservation regarding soil fertility, soil conservation, biodiversity, and fostering afforestation activities;
- protecting water catchment areas;
- enhancing public awareness and appreciation of the essential linkages between development and environment;
- initiating and encouraging well-coordinated programmes of environmental education and training at all levels of society;
- involving NGOs, private sector, and local communities in the management of natural resources and their living environment;
- supporting a coordinated approach to policy formulation on environmental matters;
- ensuring development policies, programmes, and projects to take environmental considerations into account;
- ensuring that an acceptable environmental impact assessment report is undertaken for all public and private projects and programmes;
- developing and enforcing environmental standards;
- enhancing, reviewing, harmonizing, implementing, and enforcing laws for the management, sustainable utilization, and conservation of the natural resources;
- providing economic and financial incentives for sustainable utilisation, conservation, and management of natural resources;
- applying market forces, taxation, and other economic instruments including incentives and sanctions to protect the environment and influence attitudes and behaviour towards the environment;
- ensuring adherence to the polluter pays principle; and
- developing adequate national laws regarding liability and compensation for the victims of pollution and other environmental damage. (Tullow, 2012),

National legislation may also include a statutory requirement for an EIA to be done in a prescribed manner for specific development activities and projects. The statutory requirement to carry out an EIA for specific projects will, for example, require registered experts to carry out the study, the authority with the help of lead agencies and technical committees to review the EIA and approve the project.
Other national legal requirements that govern the use and protection of resources like water, fisheries, forests, wildlife, public health must be identified and complied with during an EIA. (Ogola, 2007)

5.4 EIA in Developed vs developing countries

Doberstein (2004) introduced two models of EIA: a „technical model‟ and a „planning model‟, as two extremes of a continuum with systems of most countries exhibiting a mixture of these.
EIA systems vary in terms of how technical the EIA process is perceived to be, from those where it is seen as a technical process left to technical experts, to systems where the EIA process is seen as more participatory with respect to public involvement.
Countries vary widely in the extent to which EIA relies on public participation, ranging from countries where opening the decision-making process to citizen involvement is one of the main purposes of EIA, to countries where public participation and involvement in the EIA process are not required by EIA regulations and rarely practiced. Most countries fall in between, with regulations that require public involvement at various stages of the EIA process (at screening, scoping, EA preparation, and before and after government decisions). Similarly, disclosure of EIA varies between countries where disclosure of EIA is mandatory, to countries where there is no legal requirement for disclosure of EIA, or where there are legal requirements that are not applied in practice.
Doberstein further notes that most developing countries start with a form of EIA that most closely matches the technical model characterized by a focus on the project level, with weak public participation and reliance on quantitative measurement rather than qualitative perceptions (World Bank)

In the developed countries, the environmental impact of any type of power project is subject to many forms of regulation. For example, in the US the following laws and regulations must be considered before any geothermal development project can be brought to fruition (Kagel et al., 2005):

- Clean Air Act
- National Environmental Policy Act
- National Pollutant Discharge Elimination System Permitting Program
- Safe Drinking Water Act
- Resource Conservation and Recovery Act
- Toxic Substance Control Act

- Noise Control Act
- Endangered Species Act
- Archaeological Resources Protection Act
- Hazardous Waste and Materials Regulations
- Occupational Health and Safety Act
- Indian Religious Freedom Act.

Similar regulatory framework exists in the EU (e.g., EIA Directive) and on the level of individual member states too, as well as in Canada, Australia and New Zealand.
Thus, it is highly unlikely that any geothermal power plant will be a threat to the environment anywhere in the developed world, given the comprehensive spectrum of regulations that must be satisfied (Tester et al. 2006).

In contrast, until recently, EIA as a new concept was not readily understood and accepted as a tool in developing countries. It was considered just another bureaucratic stumbling block in the path of development. Also, it was conceived as a sinister means by which industrialized nations intend to keep developing countries from breaking the vicious cycle of poverty. Furthermore, the experts in the developing countries were foreigners who were viewed as agents of colonization. The need for EIAs has become increasingly important and is now a statutory requirement in many developing countries (Ogola, 2007).
Historically, the choice of new projects was primarily based on one criterion: economic viability. Today, a second and a third criteria, environmental and social impact, have become a strong yardstick, hence the triple bottom-line approach (economic, environmental and social) to project viability (Modak & Biswas, 1999).

Though potentially not as comprehensive as this previous list of applicable regulations, the developing countries have also started to formulate their own policy and legal framework to be able to effectively deal with such development scenarios as early as on the EIA level.

One key task during the scoping phase of delivering an EIA in any CHPM project is being familiar with the applicable national legislative framework and finding the way through the maze of relevant regulations affecting those areas the proposed project may have an impact upon. The following list collects the areas and disciplines you need to check whether your proposed project activities comply with:

- Screening of Key laws related to safety, health, and environment and relevant for the proposed project covering the following areas and disciplines: Land and Water Conservation, Geothermal, Land Procurement for Development for Public Interest, Cultural Preservation, Health, Protection and Management of the Environment, Waste Management, Energy, Forestry, Employment, Biodiversity and Ecosystem Conservation, Occupational Safety:

- **Regulations related to environmental permitting**
- **Regulations related to the protection of the atmosphere** (Air Pollution Control, Stationary Emission Standard, Noise Level Standard, Vibration Level Standard, Ambient Odor Regulations related to the protection of the hydrosphere (Water Quality Management and Waste Pollution Control, Water Quality Criteria, Drinking Water Quality Standard, Groundwater Quality Related to Health, Water Resources Utilization Permit, Requirements of Wastewater Injections, Wastewater Quality Standards (for Geothermal Power plant Business and/or Activity),
- **Regulations related to the protection of the biosphere:** Guidelines on Forest Reclamation, Forest Fire Control, Guidelines on Borrow-Use of Forest Area
- **Regulations related to waste management:** Management of Domestic Waste and Similar Type to Domestic Waste, Guidelines for Waste Management
- **Regulations related to Hazardous Waste and Material**: Guidelines to Prepare Hazardous Waste Documents, Hazardous and Toxic Waste Management, Hazardous Waste Storage and Collection, Labelling of Hazardous and Toxic Waste, processing hazardous waste, Storage, Treatment and Disposal of Hazardous Waste, Hazardous Waste Utilization, Hazardous Material Management, Supervision, Control, and Safety of Commercial Explosive (INO, 2017)

5.5 Institutional framework

EIA institutional systems also vary from country-to-country and they reflect different types of governances. In some countries, either the Ministry of Environment or a designated authority or Planning Agency administers EIA. It is the project developers' responsibility to familiarise himself with the hosting country's institutional framework.

Environmental issues also involve many disciplines and many government bodies with general environmental and resource management laws. Data will therefore have to be collected and collated from a wide range of various levels of government authorities and parastatals where applicable (Ogola, 2007).

5.6 Local/national development strategy/Guidelines

General and sector-specific International Finance Corporation (IFC) Environment, Health and Safety (EHS) Guidelines of 2007 (IFC EHS Guidelines) as main GIIP reference.

The Environmental, Health, and Safety (EHS) Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP) and are referred to in the World Bank's Environmental and Social Framework and in International Finance Corporation's (IFC) Performance Standards.

When one or more members of the World Bank Group are involved in a project, these EHS Guidelines are applied as required by their respective policies and standards. These General

EHS Guidelines are designed to be used together with the relevant Industry Sector EHS Guidelines which provide guidance to users on EHS issues in specific industry sectors. For complex projects, use of multiple industry-sector guidelines may be necessary.

The EHS Guidelines contain the performance levels and measures that are generally considered to be achievable in new facilities by existing technology at reasonable costs. The applicability of the EHS Guidelines should be tailored to the hazards and risks established for each project based on the results of an environmental assessment in which site-specific variables, such as host country context, assimilative capacity of the environment, and other project factors, are considered.
The applicability of specific technical recommendations should be based on the professional opinion of qualified and experienced persons. When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures than those provided in these EHS Guidelines are appropriate, in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment (IFC, 2007).

Project developers will have to consult with the EHS Guidelines for the following specific industry sectors that are relevant from a CHPM development:

- Geothermal power generation
- Mining

IFC Environmental and Social Performance Standards (IFC PS) 2012

The Performance Standards are directed towards clients, providing guidance on how to identify risks and impacts, and are designed to help avoid, mitigate, and manage risks and impacts as a way of doing business in a sustainable way, including stakeholder engagement and disclosure obligations of the client in relation to project-level activities (IFC, 2012).

Various Safeguard Policy Statements issued by relevant multi- and bilateral lenders

A CHPM facility also needs to fit into specific local/regional or national development strategies to bring maximum positive impact to the hosting country/community. Therefore, it is essential to have screened the corresponding development plans and overall strategies applicable to the area the future plant is expected to be commissioned.

6 Methodology

Any proposal must include an understanding of the Terms of Reference and a description of the general approach to the whole EIA. This approach has to be in accordance with the ToR, highlighting the proposed methodology for:

- the engagement of stakeholders;
- the proposed approaches for the definition of the environmental baseline; and
- the proposed methodologies for impact identification and evaluation (including the description of specific tools proposed) (EC:DG-ICD, 2016).

Stakeholder involvement is an important part of the EIA development process. During the scoping stage the practitioner must decide on what approach to take in terms of proactive stakeholder interaction to get 'buy in' to the EIA process and the subsequent decisions made on their behalf; and the form that this should take. It is important that the appropriate stakeholders are identified and engaged with from the start of the EIA process, to inform them of the draft plan and that they have opportunities to comment on the plan. When stakeholders understand the issues and processes involved, they feel encouraged and able to participate further in the consultation process, resulting in wider ownership and integration of sustainable, management solutions.

There is no universally appropriate way to undertake the consultation on the draft EIA. It is a decision for the Client Steering Group to balance the likely costs and benefits of the various approaches. Methods of stakeholder engagement include:

- **Invitation Letters:** Useful in early stages of consultation to provide information regarding the process and disseminate instructions on how to respond/get involved.
- **Questionnaires and Surveys:** Structured way of obtaining basic information which can be easily analysed statistically. Able to reach a large number of people, they are convenient, economic and thus a good starting point. They need to be well structured and ensure that the questions are not preconceived and they do not lead to any particularly favoured directions..
- **Exhibitions and Road Shows:** Useful way of presenting basic information and options to the public, especially local communities. Able to reach large numbers of people if well advertised. Allows face to face feedback ~~of information~~.
- **Public Meetings:** Enable presentation of basic information to the general public. Allow large numbers of people to be involved in some limited discussion. Need to be carefully managed to ensure all views are heard. Cheaper than exhibitions and road shows.
- **Use of the full range of the media:** Engages interested parties and the wider population, through television, newspapers and radio. Useful at reaching those who may be more difficult to involve otherwise. Internet, websites, online questionnaires, chat rooms and notice boards have become increasingly popular ways of providing information and seeking feedback. Media can be used throughout process.

- **Structured Interviews:** Useful for obtaining specific information and attitudes from wider stakeholders in the early stages of the EIA.
- **Semi-Structured Interviews:** Useful in exploring more complex issues from key stakeholders later in the EIA process. The more open questions together with some structure allow a compromise between a thorough exploration of the issues and ease of analysis of responses.
- **Forums:** Flexible in terms of representation, size, outcome and timing. Allows open discussion.
- **Focus Groups:** Involves small groups (6-12) of people, which are asked questions by an experienced facilitator. Allows facilitator to probe emerging issues. It is resource intensive and may be more appropriately used later in the process.
- **Advisory Committee:** Representative group of stakeholders, which can meet regularly throughout the EIA process to provide advice.
- **Workshop:** Structured group discussions designed to solve problems and identify ways forward. Useful in bringing different groups of experts together and require experienced facilitators as well as careful explanation to the attendees.
- **Round Table Discussions:** Facilitated debates between groups with different views with the aim of reaching consensus. Useful for engaging specialist interest and single-issue groups (North Solent 2018).

The EIA will particularly focus on specific environmental components (potentially called valued environmental components or VECs) that are defined as broad components of the biophysical and human environments that, if altered by the Project, would be of concern to regulatory agencies, resource managers, scientists, stakeholders, and/or the general publicare. VECs are typically selected for assessment on the basis of: a) regulatory issues, guidelines, and requirements; b) consultation with regulatory agencies, the public, stakeholder groups; c) field reconnaissance; and d) the professional judgment of the Study Team.
Such environmental data is essential to understanding the environment especially for any potential development. The environmental data will provide a baseline, guide the design of the project, allow assessment of impacts, validate the proposed mitigation and demonstrate compliance during project implementation (Sission, 2015).

For example, in case of a model CHPM project the following parameters could be assessed within the frame of a baseline assessment study (without being limited to only these VECs): Atmospheric Environment; Acoustic Environment; Water Resources; Terrestrial Environment (soils, flora and fauna); Public Health and Safety; Labour and Economy; Community Services and Infrastructure.

Several sources can be used to complete the data collection which is required for each project. General information, including technical data, usually gathered through meeting key personnel from the concerned local/regional or national authorities.
At an early stage of project development desktop studies or desk reviews to screen the available reports are essential as a source of information that could support the impact assessment study especially regarding some of the project's surroundings' description including topography, climate, (Khanke, 2015)
In addition to meeting key personnel from the authorities, further data might be needed to collect through observatory field visits to consolidate the understanding of the environmental, biophysical and geological setting. The field studies also enable cross checking of the data compiled during the desktop study. Moreover, social impacts can be assessed through public discourse and interaction during these site visits.

Optionally, the rationale for the selection of each VEC can be described. A brief summary of the regulatory setting, ecological, and socioeconomic context of each VEC, and the influence of consultation or engagement on the assessment (as applicable) can be also described. The goal is to describe the issues and concerns that arose through legislation, regulatory decision-making, or consultation and engagement activities that influenced the scope of the environmental assessment described in the EIA Report and led to identification of the environmental effects that will be assessed.
The environmental assessment methods address both Project-related and cumulative environmental effects. Project-related environmental effects are changes to the biophysical or human environment that will be caused by a project or activity arising solely as a result of the proposed principal works and activities, as defined by the scope of the Project and as described in the Project Description. Cumulative environmental effects are changes to the biophysical or human environment that are caused by an action associated with the Project, in combination with other past, present or reasonably foreseeable future projects or activities that have been or will be carried out (Sission, 2015).

The consultants should provide an indication of the methodology they plan to use to identify and then assess the risks, constraints and opportunities linked to the biophysical environment in which the project will operate, including the availability or scarcity of natural resources (soils, water, energy, materials), increasing climate variability, and (to the extent they can be predicted) the projected effects of climate change (EC:DG-ICD, 2016).
The applied methodologies or combination of methodologies show a great deal of variety allowing the practitioners to select the most suitable one for the project at hand. 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, 2013).

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)., This process has to follow the ALARA concept to keep environmental degradation *as low as reasonably achievable* with technical, economic, and social factors being taken into consideration. At the same time the investigation of impacts should 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).

Some of the most commonly used tools to assess potential impacts and to identify underlying relations between various elements are listed below.

Checklists – Checklists are standard lists of the types of impacts associated with a particular type of project. Checklists methods are primarily for organizing information or ensuring that no potential impact is overlooked. They comprise list questions on features the project and environments impact. They are generic in nature and are used as aids in assessment.

Matrices - Matrix methods identify interactions between various project actions and environmental parameters and components. They incorporate a list of project activities with a checklist of environmental components that might be affected by these activities. A matrix of potential interactions is produced by combining these two lists (placing one on the vertical axis and the other on the horizontal axis). They should preferably cover both the construction and the operation phases of the project, because sometimes, the former causes greater impacts than the latter. However, matrices also have their disadvantages: they do not explicitly represent spatial or temporal considerations, and they do not adequately address synergistic impacts.

Networks – these are cause-effect flow diagrams used to help in tracing the web relationships that exist between different activities associated with action and environmental system with which they interact. They are also important in identifying direct and cumulative impacts. They are more complex and need expertise for their effective use.

Consultations – with decision-makers, affected communities, environmental interest groups to ensure that all potential impacts are detected. However, there is a risk when excessive consultation might be responsible for some unjustifiable impacts to be included in the ToR (Ogola, 2007).

Once the main environmental and climate-related risks, constraints and opportunities associated with the project have been identified, it is essential to determine which of them are 'significant' and may thus require a change in project design or the adoption of specific adaptation measures. To achieve this goal, it is suggested to characterise and evaluate risks, constraints and opportunities against the following criteria:

- **Relevance**: are the identified risks, constraints and opportunities somehow relevant to the problems the project aims to address and to its objectives?

- **Effectiveness**: can the identified risks, constraints and opportunities positively influence the achievement of project results and objectives, or on the contrary jeopardise it?
- **Efficiency** (i.e. 'value for money' or 'value for resources'): can the identified risks, constraints and opportunities contribute to the production of outputs and results at a 'low' or 'reasonable' cost in terms of resource use, or on the contrary lead to a disappointing 'ratio' between outputs/results produced and resources employed?
- **Sustainability**: can the identified risks, constraints and opportunities promote, or on the contrary prevent, the sustainable production of project benefits over the project's planned lifetime, from a financial, economic, environmental and social point of view?
- **Impact**: can the identified risks, constraints and opportunities contribute to the generation of positive, or on the contrary negative, overall developmental impacts of the project on the wider society in which it operates (EC:DG-ICD, 2016)?

7 Environmental and social baseline / Description of Project Surroundings

The section of an EIA that details existing conditions (often called the 'environmental baseline') demonstrates whether the project proponent truly understands the environmental and social conditions that the proposed project may change (not necessarily in a negative way) or disturb.

The term "baseline" refers to the collection of background information on the biophysical, social and economic settings in proposed project area. Normally, information is obtained from secondary sources or the acquisition of new information through field samplings, interviews, surveys and consultations with the public. The task of collecting baseline data starts right from the period of project inception; however, most of this task may be undertaken during scoping and actual EIA.

Baseline data is collected for two main purposes:

1) To provide a description of the current status and trends of environmental factors (e.g., air pollutant concentrations) of the host area against which predicted changes can be compared and evaluated in terms of significance, and
2) To provide means of detecting actual change by monitoring once a project has been initiated or when finished.

Only baseline data needed to assist prediction of the impacts contained in the ToR and scoping report should be collected (Ogola, 2007).

Baseline data collection requirements are normally specific to a particular project site and may be specified by the governing regulatory agency with input from affected third parties. Before proceeding with the detailed environmental studies needed to assess the impacts of the project, it is important to discuss the proposed project with the applicable regulatory agencies and with local residents. In some jurisdictions there is a specific requirement to determine the concerns of local residents and address these concerns in the environmental assessment (IAEA, 1997).

Baseline studies characterize and document the existing environmental conditions prior to development. These environmental elements that have a likelihood of being affected by the proposed project are in the focus of data collection.

The first section of the environmental assessment should include a description of the project location 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. Descriptions of climate, surface water hydrology, hydrogeology, soil, water and air quality, and natural radiological conditions are required in the baseline document. Any rare or endangered animal or plant species in the area of the project must be identified. A description of factors such as land use, agriculture, livestock, wildlife harvesting, fishing, tourism, is also an integral part of the document (IAEA, 2005). If the EIA does not include details about existing surface water quality, air quality, and the abundance and distribution of

threatened and endangered species, then it simply is not possible for the project proponent to formulate accurate predictions about how the project would impact water quality, air quality, and threatened and endangered species (Environmental Law Alliance Worldwide, 2010).

Finally, a description of the socio-economic situation in potentially impacted areas and the nature of inhabitants livelihood and culture rounds out the description of baseline conditions. The level of investigation of each of these issues is dependent on the size and type of the proposed project (IAEA, 2005).

The section of an EIA that describes the environmental baseline occasionally might contain some potentially misleading information. For example, it is in the interest of the project proponents to describe environmental conditions as already degraded or impaired (so that further deterioration of the local conditions wouldn't be that much off from the ideal state), or to minimize the extent to which local communities inhabit and make use of the project area. If the environmental baseline contains claims that the environment is already degraded or uninhabited, then those claims should be questioned and evidence to the contrary provided. However this environmental baseline is not to be confused with the pristine natural background, and the proposed project area could be already in a relatively poor state eg in case of a brownfield investment where the environemtal baseline will describe a number of issues. (Environmental Law Alliance Worldwide, 2010).

The baseline data collection may be comprised of the following activities:

- Desktop studies on the biophysical and socio-economic conditions and issues in the proposed project area;
- Review of the regulatory framework and institutional arrangements for projects of such nature;
- Detailed environmental assessment;
- Community/stakeholderspublic consultations and sensitization;
- Impact identification and development of mitigation measures; and
- Development of an Environmental Management Plan (EMP) including costs estimates and responsibility assignment.

Prior to the field studies, a desktop study might be neccesary to review the available reports, and to design plans and maps in order to compile relevant biophysical and socio-economic information of the project area. Then a series of field studies may commence (detailed environmental and social impact assessment, public consultations and community sensitization, and development of mitigation measures and environmental management plan). The field studies also enable cross checking of the data compiled during the desktop study (Tullow, 2012).

7.1 Site location

The site location and layout for the proposed operations need to be described using maps that show the relationship between the site and local water bodies (rivers and lakes), geographical features (highlands, forests), transportation links (roads, rails, waterways), political subdivisions, population centres (cities), historical and archaeological features and non-applicant property (farms, settlements)

7.2 Terrain, topography

7.3 Geology

A detailed characterization of the geological environment is essential to any type of mining activity. Description of the **regional geology** based on referenced information helps establish a geologic context for an operation. The **geology in the project area** (site geology) can be described using corelogs and geologic cross-sections based on geophysical logs and field investigation. The geology and mineralogy of the rocks at the project site must be adequatly assessed. Such analyses include the determination of rock type, alteration, primary and secondary mineralogy, the availability of acid-producing and - neutralizing and metal-leaching minerals. An Enhanced Geothermal System operation normally would not need such a detailed assessment, but the proposed leaching methodology to extract metals as a byproduct requires protocols that are normally relevant to in-site leaching and underground mining projects (Maest et al., 2005). The production zone and confining zones need to be identified on the cross-sections. Detailing the **Stratigraphic Setting** of the project area help to identify those formations and structures that may contribute with a higher probability to potentially unwanted geology related occurences, such as induced seismicity, land subsidence. It is also necessary to include in this section the „**reservoir**”, that will be specifically stimulated to host the fracature mesh of the proposed EGS system for the CHPM facility.

7.3.1 Radiological background

Background radiological characteristics

Evaluation of radiological background of the site should be made before operations start, including measurements of radioactive elements (daughter products of uranium, thorium, radium) occurring in soil, air and surface and groundwater that could be affected by the proposed operations.

Background non-radiological characteristics

Information on site specific non-radiological characteristics (various metals and other toxic substances in surface water and groundwater, atmospheric pollutants and dust) needs to be collected, particularly those that are related to expected site-related effluents.

Other regional sources for these same indicators also need to also be documented (IAEA, 2005).

7.3.2 Seismicity

In the past and also in some recent cases EGS operations proved that they have the potential to induce tremors or even earthquakes in the magnitude of human detection. For this reason a detailed and thorough baseline study has to be made about the natural patterns of seismic activities in the immediate and larger vicinity of the proposed facility. The natural activity has to be adequatley accounted for local/regional scale tectonic movements or other structures. A geotechnical evaluation could not only reveal and identify potential geological hazards within the proposed Project Area, but their probability and frequency could be discussed. The severity of seismicity-related issues show strong correlation with the local terrain and topography. At a morphologicaly detailed area debris flows, landslides, surface soil cracking, seismic vibrations and rock falls may occur while at a planar area such danger is not present.

7.4 Soils

Soil baseline studies are based on three major sources of information: desk study, fieldwork, and laboratory analysis. Baseline studies should include soil survey maps, tables documenting the levels of chemical components, analytical methods, literature review, soil sampling, and the results of laboratory analysis. Maps should be accompanied by explanatory information, with information on local geology, vegetation, and land use.

Soil sampling information should comprise a reasonable number of sampling points representative of the mining concession area. Samples must include each horizon encountered in soil profiles. The maximum depth to which a soil profile is dug is usually one meter. In general, samples are taken systematically using a sampling grid, but random sampling or sampling particular areas of interest may be appropriate. The layout and number of samples required can vary, but the number of samples should be representative of the project area.

Laboratory analysis should provide information about soil composition, soil strength (resistance to crushing), mineral content, and pH. Some measure of water content, organic content, soil texture, particle size, and bulk density should also be included. Soil chemistry is important in mining projects because problems with naturally occurring toxic elements are a real possibility. Baseline soil quality analyses should include measurements of these common parameters: pH, cation exchange capacity (CEC; the total number of cations absorbed on soil colloids gives some indication of potential fertility), soil nutrient status: K, Ca, Mg, N, P; potentially toxic elements (PTE): Pb, Cu, Zn, Cd, Hg, Cr (Environmental Law Alliance Worldwide, 2010).

7.5 Climate

The following information should be included in the description of the existing climate at the proposed project site obtained either from desktop studies or nearby meteorological stations:

precipitation annual average, form, seasonal peaks and lows), evaporation, climate type, seasonal/long-term climatic variability, dominant wind directions and speed, typical storm events, temperature (annual average, seasonal peaks and lows) for locations at or close to the proposed project location (Maest et al. 2005).
Rainfall patterns including magnitude and seasonal variability of rainfall must be considered. Extremes of climate (droughts, floods, cyclones) should also be discussed with particular reference to water management at the proposal site (QEPA, 2001).

7.6 Air Quality

Air quality conditions are critical for evaluation of the potential distribution of air pollutants and their effects in a project area ~~in the area~~. Air pollutants can travel long distances, so baseline air quality information should be considered in relation to meteorological conditions, wind patterns, geological formations, and anything else that might influence the distribution of air pollutants.
Baseline air quality data should:

- Identify air basin
- Describe local climate and topography
- Identify national and local air quality standards
- Describe historical air quality trends
- Describe air quality of the proposed mining area and/or air basin
- Identify sensitive receptors
- Describe the exact location of air monitoring and/or sampling stations

Baseline air quality analyses should include measurements of these common parameters:

- Particulate matter (PM10 and PM2.5)
- Carbon monoxide (CO)
- Nitrogen oxides (NO_x)
- Lead (Pb), cadmium (Cd), arsenic (As), mercury (Hg)
- Total Suspended Solids (TSS)
- Sulfur dioxide (SO_2)

Baseline air quality information should be supported by methodological and analytical data. In other words, the EIA must include a clear description of the air sampling methods, and number and exact location of sampling points. These should be representative of the project's area of influence. Frequently, this information is included in tables and figures and the laboratory reports are included as annexes. Results of air water quality data must be compared to existing air quality standards or international guidelines (Environmental Law Alliance Worldwide, 2010).

7.7 Surface and Ground Water Resources (Hydrology/Hydrogeology)

Surface hydrology:

Surface water quality and quantity will need to be characterized where use, quality and quantity could be affected by the project operations. Mapping the contributing drainage area to the project area will establish the acreage involved and help identify groundwater/surface water interactions that need to be discussed (IAEA, 2005).

Characterizing existing surface water quality provides detailed information on the location, distribution, quantity, and quality of all water resources that could be affected by a project.. The data and analysis should have a reasonable level of detail, to help to understand the hydrological conditions in the planned project area.

Baseline studies about water quality should consider the local and regional uses of water (domestic, industrial, urban, agricultural, recreational, others) and assess water quality as part of the ecosystem (in relation to the life of plant and animal communities). Water quality studies should be compared to water standards and other legal guidelines for each water use. The quantity of available water resource to be used must reflect several aspects such as watershed distribution, hydrological processes, and the availability for different water uses at local and regional levels.

Surface water quality data should be supported by methodological and analytical data. In other words, an EIA must include a clear description of water sampling methods, and the number and exact location of sampling points. These should be representative of the area of influence of a project and of all the surface water resources that would be affected by a project. Also, water quality data should include the results of laboratory analysis. This information is presented in tables and figures in an EIA and the laboratory reports are included as annexes.

As mentioned, surface water quality data must be compared to existing water quality standards, according to the uses categorized in national laws or international guidelines (Environmental Law Alliance Worldwide, 2010).

Hydrogeology:

Groundwater resources are very complex systems. Depending on the area, groundwater can be located at low depth with strong interaction with surface waters, or deep with much less or no interaction with surface water. Groundwater can also have different uses, such as agricultural, human consumption, and industrial. An EIA should include the following basic information about groundwater resources:

- Depth of the groundwater level under different seasonal conditions
- Geology and properties of aquifers, thicknesses, and their hydraulic conductivity ranges
- Groundwater flow directions
- Locations/flows of springs and seeps
- Groundwater discharge locations in streams
- Groundwater uses

Regional groundwater quality needs to be defined for the project area based on groundwater quality data collected for a sufficient length of time to identify any important spatial and time variant properties of the potentially affected and surrounding aquifers, to show the pre-operations hydro-geochemistry of the area, and to identify existing or anticipated impacts of adjacent human activities (e.g. mines) on the groundwater quality within the area. In addition, consideration should also be given to the requirements of any existing beneficial users of the aquifer concerned.

Pump tests are also necessary to define aquifer properties. The purpose of the testing is to define aquifer properties within the affected area, especially hydrologic boundary conditions, layering effects, directional permeability, and the vertical confinement of the production zone. Transmissivity data of sufficient detail is necessary to confidently identify axes of directional transmissivities in the production zone.

Documentation of groundwater use within the area that may be affected by the CHPM operation is essential in order to identify competing interests for groundwater allocation. Parameters to be considered are: hydraulic conductivity, transmissivity, storage coefficient, total porosity, effective porosity, aquifer thickness, piezometric surface, hydraulic gradient, permeability (IAEA, 2005).

7.8 Terrestrial Environment (habitats, flora and fauna) / Biodiversity

Wildlife comprises all living things that are undomesticated. This includes plants, animals (vertebrates, birds, fish), and other organisms (invertebrates). Baseline information about wildlife must include a list of wildlife species within the project area and interactions between species. An EIA should include a description of the region, species maps, relationships, population densities, and species distribution. All endemic flora and fauna in the project area that have a special conservation status – for example, listed by the International Union for Conservation of Nature (IUCN) or by national legislation as a threatened or endangered species – should be surveyed for their distribution and abundance in the project area (Environmental Law Alliance Worldwide 2010).

Collection of baseline information for the terrestrial environment including floral and faunal components in the project area is to be based on field observations and supported by literature review. Considerations should include inventories of habitat types and species (including local names, where provided); vegetation cover, classes, and dominance levels; presence of rare and endangered species; presence of ecological reserves, and any critical ecosystem components. In addition, assessment needs to be done to determine whether the area has experienced any known loss of habitat or biodiversity decline, and whether the proposed activity would have any adverse effect on the existing ecosystems, flora, and fauna. Field guide books may become handy in helping to confirm identified species.

Habitats and animal encounters of interest should be recorded, and photographs of species of mammals, birds, reptiles, amphibians, and arthropods present at the time of observation to be taken (Tullow, 2012).

7.9 Land use

This section aims to assess and describe in detail the actual utilisation of the area the proposed project is planned to be delivered upon. Whether it is an industrial, agricultural or residential area or it includes historical or natural heritage site(s) or an otherwise protected area, these factors may induce socio-economic issues and has to be properly addressed.

7.10 Visual Aesthetics

The surface footprint of the proposed CHPM facility is rather small (unlike solar power plants) similarly to geothermal power plants and the technology does not require tall structures, (e.g. in the case of windfarms) thus this baseline can even be neglected, unless local regulation specifically asks for it.

7.11 Noise and Vibrations

Noise level measurements made at different periods of time (day and night), at the projected site of the CHPM facility and nearby habitations will help identify those that may be affected by the project. Identifying sources of significant noise levels will help in preparation of noise mitigation plans.

7.12 Socio-Economics baseline

The socio-economic environment is defined as all activities, and social and economic processes, that could be influenced directly or indirectly by the proposed activity. In most cases (unless the operation is planned to be at a remote location), there is a defined socio-economic environment that will be affected. The community impact assessment is of particular importance. The range of topics (scope) and level of detail can be highly variable.
The section of an EIA that includes the socio-economic baseline data should explain how the scope of the analysis was defined and how the study area was delineated. The section should include information about:

- Location of the local population in relation to the proposed project area
- Population size, age composition, growth
- Economic activities, employment, income (inventory of present economic environment without the project)
- Quality of life
- Housing quality and quantity (this is particularly important if people are to be relocated)
- Community organizations, representative institutions, neighborhood cohesion (usually measured with surveys and interviews)
- Public safety (police, fire)
- Education (average level, access, public and/or private)
- Health services

- Recreation (public, private)
- Existence of local development or well-being plans
- Access to public services and sanitation
- Maps with location and quantity of farmlands
- Maps with existing land-use patterns
- Attitudes towards the project (Environmental Law Alliance Worldwide, 2010)

8 Scoping of environmental and social risks and impacts

8.1 Area of Influence

The area of influence is the project area that will contain the project components specified in the project description as well as transportation routes to/from the project location. The baseline environmental and social setting describes in detail the area of influence, including receptors.

8.2 Scoping Methodology

An EIA requires primary and secondary data. Primary data are obtained from direct observations and field measurements, laboratory analyses, questionnaires and in-depth interviews. Secondary data (e.g. spatial management map, administration map, topographical map, land use map, statistical data, or rainfall data) are obtained from a variety of sources such as published environmental studies, government institutions and the internet. Collected data, which is mainly baseline information, enables the analysis of interactions between the project and host environment (Figure 2).

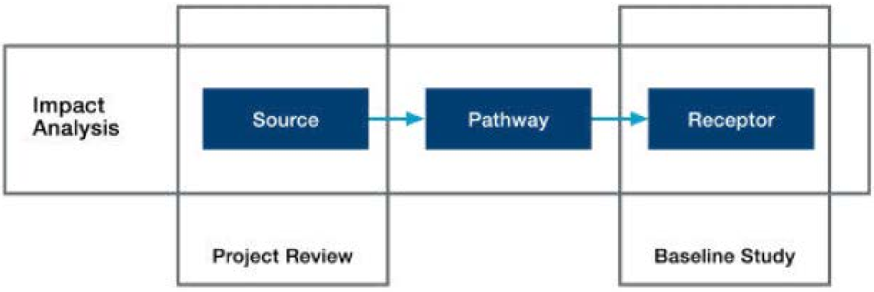

Figure 2: Interactions between the project and host environment (INO, 2018)

Screening occurs in three stages:

Stage 1: Identifying Potential Impacts. The outcome of this stage is a listing of all potential environmental and social impacts associated with the project. In this first step, the impact itself (the magnitude) is determined (predicted).

Stage 2: Evaluating Potential Impacts. The outcome of this stage is a screening and prioritization of impacts as significant and non-significant. The key elements for evaluating

environmental impact significance are level of public concern, professional and scientific judgment, disturbance/disruption of ecosystems and degree of negative impact on social values and quality of life.

Stage 3: Detailed Evaluation Hypothetical Significant Impacts. This requires in-depth assessment which is conducted in the subsequent impact assessment.

The purpose of impact evaluation is to assign relative significance to the predicted impacts associated with the project and then to determine the priority in which impacts are to be avoided, mitigated or compensated. This ranking is obtained from the perceived importance of the impacts to the environment and to the human constituencies concerned with the assessment. Impact evaluation also provides a means of comparing various development options and of communicating evaluation results to the public and to decision makers. A wide variety of analytical methods and models is available to aid in this evaluation. A central challenge is to select one or more methods that are best suited to particular project type and possible environmental disturbances. The criteria employed within the method of choice should emphasize the following four factors: ecology, social, environmental standards, and statistical significance (IAEA, 2005).

8.3 Method for Impact Identification and Evaluation

The project needs to be screened against various aspects of the following parameters, for the exploration, construction, operations and decommissioning stages:

- Natural Resources (air, water, land, biodiversity)
- Waste (hazardous and non-hazardous)
- Natural Hazards
- Noise and Light
- Demography, Economy, Social, and Cultural Resources (including livelihoods, customs, housing, welfare)
- Public Health (including facilities, medical staff, sanitation)
- Public Services (transportation, public infrastructure, utilities and services)
- Aesthetics and Reputation

When assessing direct and indirect impacts, the following are considered:

- Number of people affected from planned activities;
- Area affected;
- Intensity and duration of impact;
- Other environmental components affected;
- Nature of cumulative impacts;
- Reversibility of impacts; and
- Other criteria in accordance with sciences and technology.

While proposed development may have a large impact in terms of magnitude, the effects may not significantly affect the environment as a whole. A variety of methods help to determine whether a project activity produces significant impacts or non-significant impacts. This process involves input and analysis from environmental and social experts from inside and outside of PT SERD, as well as engineers and others that understand the technical aspects of the project. The team considers detailed project activities, consultations with people directly or indirectly affected by the project as well experience and lessons learned from similar projects.

The outcome of an impact evaluation in Stage 2 also results in a refined set of important impacts, i.e. the Hypothetical Significant Impacts. During the impact assessment, these impacts are evaluated and studied (INO, 2017).

Figure 3: Methods and Tools for identifying and evaluating impacts (INO, 2017)

Several techniques can be used in predicting the impacts. The choices should be appropriate to the circumstances. The following approaches can be tailored and scaled for use in any step in the impact evaluation, though the more complex and costly methods are used only in the actual impact assessment stage.

Risk assessment: process involves the establishment of context, identification of risks, evaluation of risks and the treatment of risks. Throughout this process there is a requirement to monitor and review and to communicate and consult. The risk assessment process may utilize a risk matrix for the qualitative evaluation of impacts (risks).

Each potential impact is assessed in the matrix and a rating of High, Moderate or Low risk assigned. Impacts identified as having a high risk require mitigation, those found to have a moderate risk can be mitigated utilizing the As Low As Reasonably Practicable Principle (ALARA), with additional efforts to reduce risks to be pursued on a cost vs benefit basis. Impacts identified as having a low risk are considered tolerable and no mitigation measures are normally undertaken.

Another conventional method is to determine importance weighting. This involves a structured approach for assessing importance of each identified impact area. In completing this process, it is important to include all key stakeholders to ensure an accurate assessment is obtained. Clearly defined criteria allow the assignment of significance in a rational way through the process, and provide a measure of consistency necessary for the comparison of alternatives and serve as a documentation of the values and beliefs on which judgments are based. In order to compare different project alternatives the relative value of each type of impact must be assigned (Sadar, 1995).

	CRITICAL	MAJOR	MODERATE	MINOR	NEGLIGIBLE
	ENVIRONMENTAL EFFECTS				
OCCURRENCE OVER FACILITY LIFE	Very serious effects with impairment of ecosystem function. Long term, widespread effects on significant environment	Serious effects with some impairment of ecosystem function. Relatively widespread medium-long term impacts.	Moderate effects but not affecting ecosystem function. Moderate short-medium term widespread impacts	Minor effects. Minor short-medium term damage to small area of limited significance.	No lasting effect. Low-level impacts. Limited damage to minimal area of low significance.
SEVERAL 1 mth – 1 yr	HIGH	HIGH	HIGH	HIGH	MARGINAL
LIKELY 1 – 10 yrs	HIGH	HIGH	HIGH	MARGINAL	MARGINAL
POSSIBLE 10 - 100 yrs	HIGH	HIGH	MARGINAL	MARGINAL	LOW
UNLIKELY 100 - 1000 yrs	HIGH	MARGINAL	MARGINAL	LOW	LOW
VERY UNLIKELY 1000 – 10 000 yrs	MARGINAL	MARGINAL	LOW	LOW	LOW
REMOTE 10 000 – 100 000 yrs	MARGINAL	LOW	LOW	LOW	LOW
IMPROBABLE > 100 000 yrs	LOW	LOW	LOW	LOW	LOW

HIGH	UNACCEPTABLE RISK. RISK REDUCTION MEASURES REQUIRED
MARGINAL	MARGINAL RISK. RISK REDUCTION MEASURES CONSIDERED. ALARA PRINCIPLE APPLIES
LOW	TOLERABLE RISK. RISK REDUCTION NOT NORMALLY UNDERTAKEN

Figure 4: Qualitative risk assessment matrix (Standards AU)

Mathematical Modeling: Standard mathematical models, either analytical or numerical, are used to predict the magnitude of impacts: Gaussian Models to predict dispersion of dust and gaseous pollutants in the ambient air; Mixing Zone Models for water quality parameters; mathematic formulas to determine Importance Value Index (IVI), diversity index, similarity index for terrestrial and aquatic biota; as well as mathematical models to predict socioeconomic and transportation aspects.

Overlay Mapping: Overlay mapping, preferably done by Geographic Information Systems (GIS), assists in identifying the geographic extent of impacts and can assist in identifying where cumulative impacts and impact interactions may occur. Overlay mapping is best suited for identifying physical/chemical impacts and their geographical extent. Overlay mapping involves preparing maps or layers of information which are then superimposed on one another. Overlay mapping can provide a composite picture of the baseline environment, identifying sensitive areas or resources. Overlay mapping helps to illustrate the influences of past, present and future activities on a project or receiving environment.

Threshold Analysis: The boundary of significant impact distribution can be determined using threshold analysis. Threshold analysis is based on the assumption that thresholds exist in most ecological systems, specifying limits in an environmental medium (predominantly, but not limited to air and water) that must not be exceeded, or levels of environmental quality that must be maintained. Thresholds may be expressed in terms of goals or targets, standards and guidelines, carrying capacity, or limits of acceptable change, each term reflecting different combinations of scientific data and societal values.

Analogy Method: Prediction by analogy is where environmental impacts are predicted by direct comparison or extrapolation from similar activities at existing industries. Conclusions may be adjusted to accommodate different conditions at the site of the proposed activity. The analogy between an existing activity and a new project depends on the extent to which both activities and both sites are similar. Predictions based on comparable experiences are always preferred to estimates with no basis of direct observations.

Professional Judgment: Professional judgment always forms an intrinsic part of environmental assessment. No matter what method is applied for identifying and evaluating impacts, it is not possible to conduct an environmental assessment without relying on expert opinions. Many impacts cannot be adequately predicted by numerical methods or by analogy. Such impacts can be judged by experienced professionals who have been involved in similar studies (INO, 2018).

8.4 Method for Determining Significance of Impacts

Assessment of the level of significance requires consideration of the likelihood and magnitude of the environmental effect; its geographical scale and duration in relation to the sensitivity of the key receptors and resources are also considered. Criteria for assessing the significance of impacts stem from the following key elements:

The **magnitude** (including nature, scale and duration) of the change to the natural environment (for example, loss or damage to habitats or an increase in noise), is expressed in quantitative terms wherever practicable.

The **nature** of the impact receptor, may be *physical, biological*, or *human*. If the receptor is physical (for example a water body) its quality, sensitivity to change and importance are considered. In case the receptor is biological, its importance (for example its local, regional, national or international importance) and its sensitivity to impact are considered. For a human receptor, the sensitivity of the community or wider societal group is considered along with its ability to adapt to and manage the effects of the impact.

The **likelihood** (probability) that the identified impact will occur is estimated based upon experience and/or evidence that such an outcome has previously occurred.

The **significance** of impacts is then devised from a combination of the sensitivity of the receptor, the magnitude of impact and the likelihood of occurrence (INO, 2017).

Key factors for establishing impact significance are:

- Level of public concern,
- Scientific and professional judgment,
- Disturbance/disruption of the environment, and
- Degree of negative impact on social values and quality of life (IAEA, 2005).

A series of matrices at each stage of a project can be an effective way of presenting information. A matrix is a grid-like table for identifying the interaction between project activities (displayed on one axis) and environmental characteristics (displayed on the other axis). Environment-activity interactions can be noted in the appropriate cells or intersecting points in the grid. Matrices organize and quantify the interactions between human activities and resources of concern. Once numerical data is obtained, matrices combine values for the magnitude and significance or importance in individual cells to evaluate multiple actions on individual resources, ecosystems, and human communities.

Matrices have values for “magnitude” and “significance.” Magnitude refers to the extension or scale while significance is related to the importance of potential consequences of a previewed impact. Commonly, matrices represent magnitude and significance on a scale of 1-10, with 10 representing the highest value.

Each matrix can be used to compare options rated against select criteria. The greatest drawback of matrices is that they can only effectively illustrate primary impacts. Sometimes an EIA complements matrices with tables, checklists, or network diagrams to illustrate higher-

order impacts and to indicate how impacts are inter-related (Environmental Law Alliance Worldwide, 2010).

8.5 Impact Mitigation Hierarchy

In impact assessment, avoidance of impacts is the preferred option. The next best options in order of preference are: minimization, restoration/remediation and compensation or offset. Where identified risks and impacts cannot be avoided, a management plan is prepared containing mitigation measures to ensure the project will operate in compliance with applicable laws and regulations and meet the requirements.

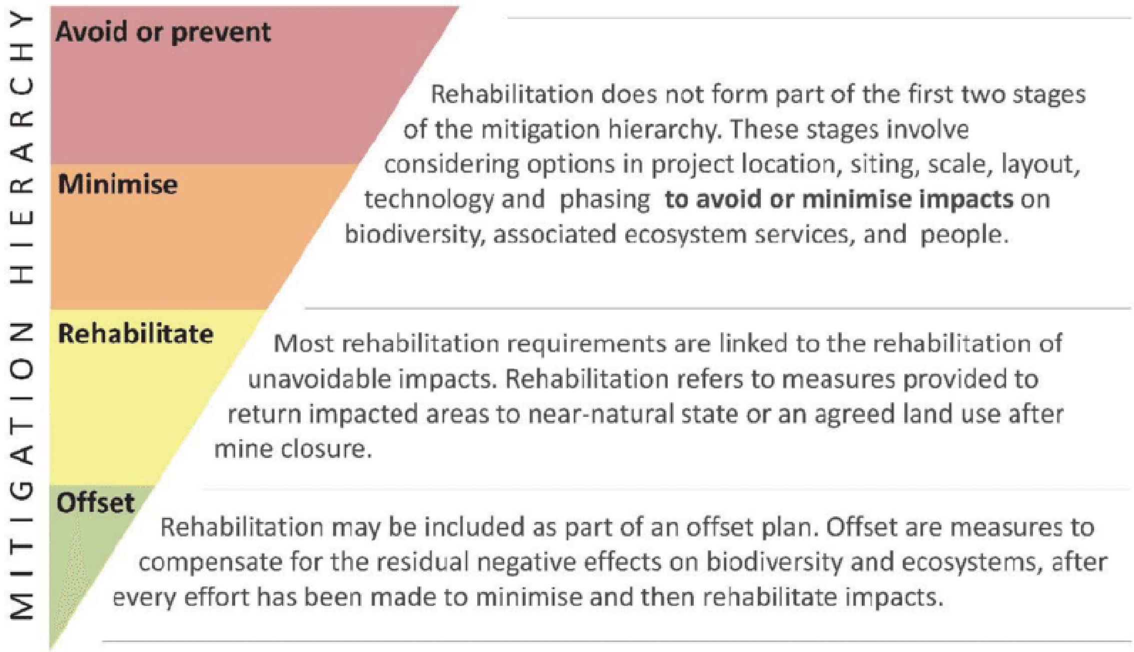

Figure 5: The Impact Mitigation Hierarchy (DEA et al., 2013)

9 Environmental aspects and impacts identification for the individual elements comprising the CHPM approach

Geothermal energy is generally accepted as being an environmentally benign energy source, particularly when compared to fossil fuel energy sources. Geothermal developments in the last 40 years, however, have shown that it is not completely free of impacts on the environment. These impacts are becoming of increasing concern, and to an extent which may now be limiting development. History shows that hiding or ignoring such problems can be counterproductive to the development of an industry because it may lead to a loss of confidence in that industry by the public as well as by regulatory, and financial sectors. If the aim is to further the use of geothermal energy, then all possible environmental effects should be clearly identified, and countermeasures devised and adopted to avoid or minimize their impact (Hunt, 2001).
Geothermal utilization can cause surface disturbances, physical effects due to fluid withdrawal, noise, thermal effects and emission of chemicals as well as affecting the communities concerned socially and economically (Ármannsson and Kristmannsdóttir, 1992).
All geothermal fields contain heated fluids trapped beneath the earth, but temperature and chemical characteristics of the geothermal resource can vary significantly. When these resources are extracted for geothermal generation, the environment of an area can be affected (Baba, 2003).

In general, environmental impact of geothermal facilities may be divided into the following main categories:

- *Surface disturbances,* such as those caused during the plant construction, possibly affecting flora, fauna and surface water (access roads, pipe and power lines, plant and associated land use).
- *Physical effects*, for example, the effect of fluid withdrawal on natural manifestations, land subsidence, induced seismicity, visual effects (buildings, cooling towers, surface pipelines, power transmission lines)
- *Noise*, such as equipment noise during drilling, construction and operation.
- *Thermal pollution*, such as due to hot liquid and steam release on the surface.
- *Chemical pollution*, due to disposal of liquid and solid waste, gaseous emission to the atmosphere, natural radioactivity.
- *Protection*, such as ecological protection (fauna and flora).

The main activities causing environmental impact of geothermal facilities are:

- Building of access roads and drilling pads
- Well drilling and well stimulation
- Well repairs, possible additional well drilling and well testing
- Laying of pipelines, electric power transformation and transmission lines
- Plant construction and equipment installation

- Power plant commissioning and operation
- Decommissioning of facilities (GEOELEC, 2013)

9.1 Potential Environmental Impacts from Deep Geothermal Development

9.1.1 Fluid composition

It is a key driver behind two major environmental aspects of geothermal development, gaseous emissions and water pollution potential in addition to the economic aspect of equipment corrosion.

Gaseous emissions

Gaseous emissions result from the discharge of noncondensable gases (NCGs) that are carried in the source stream to the power plant. In high-temperature geothermal fields, power generation using a standard steam-cycle plant may result in the release of non-condensable gases and fine solid particles into the atmosphere (Webster, 1995). Gas concentration and composition covers a wide range, but the predominant gases are carbon dioxide (CO_2), and hydrogen sulphide (H_2S). Species such as methane, hydrogen, sulfur dioxide, and ammonia as well as other components (e.g. mercury, arsenic, boron) are often encountered in low concentrations and some of them may cause serious environmental problems (Li, 2004). It is expected that for most EGS installations, there will be lower amounts of dissolved gases than are commonly found in hydrothermal fluids. Consequently, impacts would be low and may not even require active treatment and control.
CO_2 occurs in all geothermal fluids but it is most prevalent in fields where the reservoir contains sedimentary rocks, and particularly these with limestones. In an acidic region, CO_2 can accelerate the uniform corrosion of carbon steels. The pH of geothermal fluids and process steam is largely controlled by CO_2 (Conover et al., 1980).

Emissions are managed through process design. In steam and flash plants, naturally occurring NCGs in the production fluid must be removed to avoid the buildup of pressure in the condenser and the resultant loss in power from the steam turbine. The vent stream of NCGs can be chemically treated and/or scrubbed to remove H_2S, or the NCGs can be recompressed and injected back into the subsurface with the spent liquid stream from the power plant. Both of these solutions require extra power input, thereby increasing the parasitic load and reducing the plant output and efficiency. Binary plants avoid this problem because such plants only recover heat from the source fluid stream by means of a secondary working fluid stream. The source geofluid stream is reinjected without releasing any of the noncondensables.

The selection of a particular H_2S cleanup process will depend on the specific amounts of contaminants in the geofluid stream and on the established gaseous emissions standards at the plant site.

Local or country specific standards for the emission of CO_2 have to be taken into consideration. . However, geothermal steam and flash plants emit much less CO_2 on an electrical generation basis (per megawatthour) than fossil fueled power plants, and binary plants emit essentially none. The concentrations of regulated pollutants – nitrogen oxide (NO_x) and sulfur dioxide (SO_2) – in the gaseous discharge streams from geothermal steam and flash plants are extremely minute (Tester et al, 2006).

Water pollution

Liquid streams from well drilling, stimulation, and production may contain a variety of dissolved solids, especially for high temperature reservoirs (>230°C). The amount of dissolved solids increases significantly with temperature. The main potential pollutants in the liquid effluent are: hydrogen sulphide (H_2S), arsenic (As), boron (B), mercury (Hg), and other trace metals (e.g. lead (Pb) and cadmium (Cd)) (Ármannsson and Kristmannsdóttir, 1992). Most high-temperature geothermal bore waters include high concentrations of at least one of the following toxic chemicals: Li, B, As, H_2S, Hg, and sometimes NH_3. Arsenic is preferentially retained (>99 %) by the water phase in steam/water separation, and the measured levels of arsenic in geothermal steam are usually less than 40 µg/kg, but the arsenic concentrations in geothermal waters may present a disposal problem (Ellis, 1978).

The waters with greatest pollution potential are those with very high temperatures and/or high salinities. As pointed out by Ellis (1978), the concentrations of potentially toxic metals tend to rise in proportion to the square of the water salinity so that associated brines pose a metal contamination problem even greater than expected from their salinity.

Some of these metals and compounds can contaminate surface or ground waters and also harm local vegetation. Liquid streams may enter the environment through surface runoff or through breaks in the well casing. Surface runoff is controlled by directing fluids to impermeable holding ponds and by injection of all waste streams deep underground. To guard against fluids leaking into shallow freshwater aquifers, well casings are designed with multiple strings to provide redundant barriers between the inside of the well and the adjacent formation. Nevertheless, it is important to monitor wells during drilling and subsequent operation, so that any leakage through casing failures can be rapidly detected and managed.

In principle, 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. Of course, a catastrophic failure of a surface pipeline could lead to contamination of a limited area until isolation valves are activated and seal off the affected pipeline (Tester et al., 2006).

Corrosion

In utilization of geothermal water, corrosion of installations is a potential problem. Excessive concentration of ions such as Cl^-, SO_4^{2-}, Fe^{2+}, F^- and H_2S can be harmful to production equipment. For example, the chloride ion causes breakdown of passive films that provide protection to substrate metals and often results in pitting corrosion. Chlorides also form relatively stable complex ions or coordination compounds that may cause accelerated corrosion. Sulphate is the primary ion in some geothermal fluids. It is not, however, as aggressive as chloride. Oxygen present in low concentrations in geothermal fluids can be neglected. However, the intrusion of oxygen into hot geothermal fluids will lead to greatly accelerated corrosion. The combination of oxygen and chloride is especially harmful and may lead to catastrophic failures if there is a danger of stress corrosion cracking. In the design of geothermal comprehensive utilization systems, the composition of geothermal water must therefore be taken into account (Li, 2004).

9.1.2 Solids emissions

In the classical approach of an EGS facility there is practically no chance for contamination of surface facilities or the surrounding area by the discharge of solids *per se* from the geofluid. The only conceivable situation would be an accident associated with a fluid treatment or minerals recovery system that somehow failed in a catastrophic manner and spewed removed solids onto the area. Since the CHPM technology seeks exactly such a scenario, where dissolved metals could be accumulated from the geothermal brine its essential to list such impact among the most adverse ones. Even though currently there are no functioning mineral recovery facilities of this type at any geothermal plant – although one was piloted for a short time near the Salton Sea in southern California – recent and future advances in the coreresponding and relevant fields of technology may yield viable solutions to associate any such facility with an EGS plant in the near-mid future. But even without such a facility in place and operating, precautions and relevant mitigation protocols need to be in place, for example to remove dissolved solids by chemical treatment from the circulating fluid. These solid particles could potentially be toxic and subject to regulated disposal and also could plug pathways in the reservoir.

9.1.3 Noise pollution

Noise from geothermal operations is typical of many industrial activities (DiPippo, 1991). The highest noise levels are usually produced during the well drilling, stimulation, and testing phases when noise levels ranging from about 80 to 115 decibels (dBA) may occur at the plant fence boundary. 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 if a plant is located within a large geothermal reservoir area, boundary noise should not be objectionable. If necessary, noise levels could be reduced further by the addition of mufflers or other soundproofing means but at added cost. For comparison, congested urban areas typically have noise levels of about 70 to 85 decibels, and noise levels next to a major freeway are around 90 decibels. A jet plane just after takeoff produces noise levels of about 120 to 130 decibels.

During normal operations, there are three main sources of noise: the transformer, the power house, and the cooling tower. Because the latter is a relatively tall structure and the noise emanates from the fans that are located at the top, these can be the primary source of noise during routine operation. Aircooled condensers employ numerous cells, each fitted with a fan, and are worse from a noise perspective than water cooling towers, which are smaller and use far fewer cells for a given plant rating.

Because EGS plants will likely be located in regions where water may be in short supply, they may require aircooling, and proper attention may be needed to muffle the sound from their aircooled condensers (Tester et al., 2006).

9.1.4 Land use

Land footprints for hydrothermal power plants vary considerably by site because the properties of the geothermal reservoir fluid, the amount of power capacity, the type of energy conversion system, the type of cooling system, the arrangement of wells and piping systems, and the substation and auxiliary building needs and the best options for waste stream discharge (usually reinjection) are highly site specific.

Typically, the power plant is built at or near the geothermal reservoir because long transmission lines degrade the pressure and temperature of the geofluid. Although well fields can cover a considerable area, typically 5 to 10 km^2 or more, the well pads themselves only cover about 2% of the area. A drill site is usually between 200 and 2500 m^2 in area (Ármannsson and Kristmannsdóttir, 1992). With directional drilling techniques, multiple wells can be drilled from a single pad to minimize the total wellhead area (Tester et al., 2006).

Gathering pipelines are usually mounted on stanchions, so that most of the area could be used for farming, pasture, or other compatible 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.

The Geysers, one of the largest geothermal plant in the world, has a capacity of approximately 1517 megawatts and the area of the plant is approximately 78 square kilometers, which translates to approximately 13 acres per megawatt. Like the Geysers, many geothermal sites are located in remote and sensitive ecological areas, so project developers must take this into account in their planning processes (UCS). For example, the construction of road access to

drill sites can involve destruction of forest and vegetation which, particularly in tropical areas with high rainfall (Indonesia, the Philippines), can result in erosion (Hunt, 2001).

9.1.5 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, and may lead to surface subsidence.

Most of EGS geothermal developments, however, are likely to be in granitic type rock formations at great depth, which may contain some waterfilled fractures within the local stress regime at this depth. After a geothermal well is drilled, the reservoir is stimulated by pumping highpressure water down the well to open up existing fractures (joints) and keep them open by relying on the rough surface of the fractures. Because 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 (Tester et al., 2006).

9.1.6 Induced seismicity

One of the few disparate environmental aspects related explicitly to the EGS installations is induced seismicity.

Induced seismicity in normal hydrothermal settings has not been a problem because the injection of waste fluids does not require very high pressures. However, the situation in the case of many petrothermal EGS reservoirs will be different and requires serious attention. Induced seismicity continues to be under active researchers' review and evaluation worldwide (Tester et al., 2006).

Induced seismicity has occurred in the development and production of several conventional fractured geothermal resources (typically deeper than 1 km) EGS especially. Prior to EGS activities, the Project Owner will need to implement the Protocol for Induced Seismicity Associated with Geothermal Systems, which includes the following steps:

Stimulation

To create an EGS but also to improve the productivity or the lifetime of high and medium enthalpy hydrothermal systems, stimulation techniques are needed. The objective is to extract as much mass flow: geothermal brine as possible by using stimulation techniques characterized by water injection under pressure. Contrary to hydraulic fracking for shale gas, where the goal is to produce new fractures (in sedimentary rock: shale, with low porosity/permeability and clay minerals; at a depth of: 1000-3000 m); geothermal stimulation aims at the reactivation of naturally occurring fractures in rocks like granite, in order to engineer a reservoir with high permeability and low clay mineral content at 3000-5000 m depth.

To re-open faults through dilatant shearing of natural fractures, injection is made at low pressure= 25-200 bars.2

Stimulation of EGS is looking at increasing the permeability and at creating a loop. Moderated quantity of water is used and it is reinjected in any case. So EGS do not produce wastewater by-products.

Hydraulic stimulation is typically done with water (at 99%) and chemicals, but no proppants. Being at 5 km depth, the risk of groundwater contamination is none. No geothermal installations have had such experience. Wells casing is crucial for respecting environmental rules and ensuring economic feasibility of the project without brine/temperature leakage. The integrity of geothermal wells is crucial (GEOELEC, 2013).

- Evaluation of applicable laws and governing regulations
- Establish a microseismic monitoring network
- Establish a traffic light system

The collection of baseline data at the selected site prior to the onset of drilling is useful in separating natural from induced events. Additionally, it is prudent to instrument the site for any unexpected natural or induced felt microseismic events. A procedure also needs to be in effect to assess any effects on the public and local infrastructure. Lastly, sound geological and tectonic investigations must be carried out prior to the selection of the site to avoid the inadvertent lubrication of a major fault that could cause a significant seismic event (Tester et al., 2006).

A microseismic array (MSS) will need to be designed by seismologists and installed as part of operations. In most cases a permit has to be secured for installation of this network. The network should surround the target well while one network station is located close to the injection well. A minimum of 4 stations is required to detect and localize seismic events in 3D. Initially, seismometers should only be installed at permitted surface locations and in existing well bores. Data should be downloaded manually and periodically from each site to provide input to the assessment of natural seismic hazards, discussed below.
Prior to stimulation, the MSS is to be modified to include telemetry and real-time data monitoring, and may be modified with the drilling of additional bore holes with seismometers installed downhole.

- Assessment of natural seismic hazard potential
- Assessment of induced seismicity potential

Assessment of natural seismic hazards and induced seismicity potentials need to be conducted by an independent consultant approved by authorities, prior to any stimulation activities. Natural seismic hazard potential can be assessed by reviewing the seismic history available from permanent local and regional seismometer installations and from data collected from the installed monitoring seismometers.

Stimulation techniques may cause induced seismicity that may be sufficiently intense to be felt on the surface. Although induced seismicity can be used as a monitoring tool to understand the effectiveness of EGS operations and shed light on the mechanics of the reservoir, there is some risk that, particularly in seismically quiet areas, operation of an EGS reservoir under pressure for sustained periods may trigger a felt earthquake (Sowiżdżał et al., 2017).
The importance of understanding induced seismicity and to have relevant and effective protocols in place to mitigate subsequent issues as well as maintaining public trust towards

such operations is demonstrated the best by a quite recent event that happened in South Korea in November 15, 2017.

The moment magnitude (Mw) 5.4 **Pohang earthquake**, the most damaging event in South Korea since instrumental seismic observation began in 1905, occurred beneath the Pohang geothermal power plant in 2017. Geological and geophysical data suggest that the Pohang earthquake was induced by fluid from an enhanced geothermal system (EGS) site, which was injected directly into a near-critically stressed subsurface fault zone. The magnitude of the mainshock makes it the largest and most damaging earthquake ever to have been associated with an EGS, making it a potential "**game changer**" for the geothermal industry worldwide (Grigoli et al., 2018).

The temporal relationship between seismicity and fluid injection, the spatial relationship between the hypocenters and the EGS site, and the lack of seismicity in the area before the EGS was established all suggest that the Pohang earthquake was induced. Furthermore, the immediate response of seismicity to fluid injection and the locations of the foreshocks and mainshock at the bottom of the injection well suggest that fluid was injected directly into a fault zone.

Many interlocking lines of evidence indicate that the Pohang earthquake was "almost certainly induced" in Frohlich et al.'s system of assessment (Frohlich et al., 2016). Using McGarr's (McGarr, 2014) equation for the relationship between the maximum magnitude and the total volume of injected fluid, to conlude that about 4.7 × 106 m3 of injected fluid would be required to induce an Mw 5.4 earthquake, which is more than 810 times the fluid volume injected at the Pohang EGS site. The permeability structure of fault zones is highly heterogeneous, and patches or layers of clay-rich gouge within the fault core act as barriers to fluid flow (Caine et al., 1996). The pore pressure thus can locally reach a critical value for earthquake nucleation after a relatively small volume of fluid is injected, depending on fault zone structure. The results imply that if fluid is injected directly into a near-critically stressed fault, it can induce a larger earthquake than current theory predicts. Detailed investigation of the geological, geochemical, and geophysical properties of the Pohang EGS site should improve our understanding of earthquake-inducing processes (Kim et al., 2018).

In the highlights of all these seismology related issues it is common and proper practice to improve social acceptance for such operations by:

- Establishing a dialogue with regional authority
- Educating stakeholders on the procedures and the unlikely adverse effects
- Interacting with stakeholders

A public relations and outreach program should be established, intended to educate and inform authorities and other interested stakeholders, and to respond to stakeholder concerns.

It is also a good practice, in most cases required by authorities, to implement an official Procedure for Evaluating Damage.

Procedures for responding to reports of induced seismicity and evaluation of property damage should be included in a Stimulation Plan issued during planning of the project.

If water injection pressure is properly controlled injection can be stopped in time before any impact occurs (GEOELEC, 2013).

9.1.7 Water use

Geothermal projects, in general, require access to water during several stages of development and operation. Water use can be managed in most cases to minimize environmental impacts. Various aspects of water use in EGS projects are described below.

It is expected that in most advanced EGS applications, surface water will be needed to both stimulate and operate the reservoir (i.e., the underground heat exchanger) and produce the circulation patterns needed. The quantity of hydrothermal fluids naturally contained in the formation is likely to be very limited, particularly in formations with low natural permeability and porosity. In some EGS resource areas, water treatment will be needed to ensure sufficient quality for reinjection and reuse or to remove potentially hazardous contaminants that might be dissolved or suspended in the circulating geofluid or cooling water. It is necessary to coordinate water use during field development with other local water demands for agricultural or other purposes.

In principle, EGS systems may be approximated as “closed-loop” systems whereby energy is extracted from the hot fluid produced by production wells (namely, a heat exchanger for binary plants) and cooled fluid is reinjected through injection wells. However, the circulation system is not exactly closed because water is lost to the formation; this lost water must be compensated by surface water supplies.

Cooling water is generally used for condensation of the plant working fluid. The waste heat can be dissipated to the atmosphere through cooling towers if makeup water is available. Water from a nearby river or other water supply can also serve as a heat sink. There are opportunities for recovering heat from these waste fluids (and possibly from the brine stream) in associated activities such as fish farms or greenhouses (Tester et al., 2006).

9.1.8 Disturbance of natural hydrothermal manifestations

EGS projects will generally be sited in non-hydrothermal areas and will not have the opportunity to interfere with natural hydrothermal manifestations, such as geysers, hot springs, mud pots. For EGS facilities sited at the margins of existing hydrothermal plants where manifestations might be present, reservoir simulations should be performed to gauge the possible effects on those surface thermal features of drilling new wells and operating the EGS plant. However, because there is no “drawdown” in the traditional sense of an existing

water table for an EGS system, it is unlikely that normal operations will have a significant effect on them (Tester et al., 2006).

9.1.9 Disturbance of wildlife habitat, vegetation, and scenic vistas

It is undeniable that any power generation facility constructed where none previously existed will alter the view of the landscape. Urban plants, while objectionable to many for other reasons, do not stand out as abruptly as a plant in a flat agricultural region or one on the flank of a volcano. Many geothermal plants are in these types of areas, but with care and creativity can be designed to blend into the surroundings. Avoiding locations of particular natural beauty is also important, whether or not the land is nationally or locally protected. EGS developments will be no different than conventional hydrothermal plant developments, in that the design of the facility must comply with all local siting requirements.
The development of a geothermal field can involve the removal of trees and other vegetation to facilitate the installation of the power house, substation, well pads, piping, emergency holding ponds. However, once a geothermal plant is built, reforestation and plantings can restore the area to a semblance of its original natural appearance, and can serve to mask the presence of buildings and other structures (Tester et al. 2006).

Once the drilling/well repair activity is finished usually only a small pump house and the injection pipeline remains. Where possible, the injection pipeline can be lead in the ground, so the subsurface pipeline will not have visual impact. When situated in rocky landscape or where the pipeline cannot be lead in the ground due to other reasons there will be visual impact.
The surface mounted injection pipeline is typically mounted slightly elevated (~20 cm) above the surface and where roads have to be crossed the pipe is placed inside a suitable culvert. The visual impact can be minimized by making the pipeline follow the contour of the land which it crosses, using colors for the aluminum sheathing that blends in well with the surroundings and ensure a low profile where small hills have to be crossed.

Most power plants house its envisaged equipment, at least electrical and control equipment and in most cases also the turbine. For example, heat exchangers can in suitable climate be situated outside of the power plant housing. There is also a tower either air cooled or water cooled to cool the working fluid and a substation for connection to the electrical grid situated nearby the rest of the power plant equipment. The other equipment involved in geothermal utilization (constructions) is associated with well enclosures and pipelines.
Visual impact of various buildings and equipment can be minimized through careful layout of the power plant buildings and landscaping once the construction phase is over. Applying good architectural principles in the design and layout of the power plant facility is also important in order to ensure that it falls in with the surroundings in the best possible way (GEOELEC, 2013).

With regard to the construction of an EGS facility, it can be expected that similar impacts will take place on the land surface and result in a facility having a central power plant with a network of aboveground pipelines connecing the power station to a set of production and injection wells. However, the land can be at least partially restored to its natural condition through the same reclamation techniques practiced at hydrothermal plants (Tester et al. 2006).

9.1.10 Thermal pollution

Although thermal pollution is currently not a specifically regulated quantity, it does represent an environmental impact for all power plants that rely on a heat source for their motive force. Heat rejection from geothermal plants is higher per unit of electricity production than for fossil fuel plants or nuclear plants, because the temperature of the geothermal stream that supplies the input thermal energy is much lower for geothermal power plants. Considering only thermal discharges at the plant site, a geothermal plant is two to three times worse than a nuclear power plant with respect to thermal pollution, and the size of the waste heat rejection system for a 100 MW geothermal plant will be about the same as for a 500 MW gas turbine combined cycle (DiPippo, 1991). Therefore, cooling towers or aircooled condensers are much larger than those in conventional power plants of the same electric power rating. The power conversion systems for EGS plants will be subject to the same laws of thermodynamics as other geothermal plants, but if higher temperature fluids can be generated, this waste heat problem will be proportionally mitigated (Tester, 2006).
Though reservoir characteristics in terms of pressure and temperature may differ from site to site, most EGS plants produce steam. Steam is much more mobile than water. The generation and movement of steam can increase ground temperatures so that vegetation becomes stressed or killed. If excess heat enters the environment via geothermal steam, it may affect cloud formation and even cause changes in the local weather. Where wastewater is piped into a stream, a river, a lake or even local groundwater, it may seriously affect the biota in the local environment and eventually the whole ecological system (Ármannsson and Kristmannsdóttir, 1992).

In all aspects, with the exception of possible effects caused by induced seismicity, geothermal plants are the most environmentally benign means of generating baseload electricity. Overall, EGS plants would have comparable impact to hydrothermal binary plants operating with closedloop circulation. The only potential area of concern, induced seismicity (which is somewhat unique to EGS), 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 microseismic 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. On balance, considering all

the technologies available for generating large amounts of electric power and their associated environmental impacts, EGS is clearly the best choice.

9.2 Potential environmental impacts from subsequent underground mining operations

In situ mining technology can be both an economic and environmentally acceptable method for extracting various valuable metals from deep ore bodies. Because of the lower capital and operating costs associated with in situ mining, and because of the minimal environmental impact of this mining technique, In-Situ Leaching (ISL) is widely popular and accepted on a global scale to tap relevant resources.

The advantages of ISL extraction of metals relative to conventional mining include:

- Lower capital and operating costs,
- Shorter lead times for mine development,
- Much smaller workforce required,
- More flexible mine planning and quicker ramp-up in response to market improvements,
- Inherently safer working environment,
- 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).

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

- Lower recovery factor of in-place reserves.
- Risk of groundwater contamination.
- Applicability limited to specific types of mineral deposits.

Once the baseline information on the ecological, cultural, air, land and water resources has been collected, and the corresponding mining plan established, it is possible to identify the probable environmental impacts. Concurrently, impacts to the local social structure and economy are estimated. 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, mining, decommissioning and post decommissioning). Ecological risk assessment is a useful tool for evaluating the importance of various factors to the environmental assessment. This process identifies potential undesirable ecological impacts,

estimates the probability of their occurrence and evaluates the ecological consequences of such impacts.
The nature of the ore body and waste rock, and the planned mining method can have a major influence on the severity of the impacts to the environment. In some situations it may be necessary to modify the mining method to reduce the probable impacts to the environment to an acceptable level. Detailed planning during each phase of the mining project can help reduce impacts to the environment (IAEA, 1997).

In ISL extraction the primary source of potential contamination is the acidic leaching solution. The low pH of the fluid results in the dissolution of various metals contained within the host rock. The combination of low pH and elevated concentrations of metals as well as radionuclides creates a risk to surface waters and soil (from spills) and a separate risk to adjacent groundwaters (IAEA, 2005).

Acid mine drainage is considered one of mining's most serious threats to water resources. A mine with acid mine drainage has the potential for long-term devastating impacts on rivers, streams and aquatic life. Acid mine drainage dissolves toxic metals, such as copper, aluminum, cadmium, arsenic, lead and mercury, from the surrounding rock. Even in very small amounts, metals can be toxic to humans and wildlife. Carried in water, the metals can travel far, contaminating streams and groundwater for great distances. Acid mine drainage is particularly harmful because it can continue indefinitely causing damage long after mining has ended (Environmental Law Alliance Worldwide, 2010).

Materials and activities, with potential for environmental impacts include:

- Chemical components from ISL process (acids, bases, oxidants, radioactive components, heavy metals, other metals),
- Lixiviants,
- Other chemical stocks (oil, fuel),
- Top soil disturbances,
- Yellowcake, liquid wastes, solid wastes, scrap materials
- Excavations,
- Others (eg. noise)

Sources for such materials and activities to impact the environment include:

- Operating well casing (subsurface), pipelines (surface), well heads (in combination with the EGS facility)
- Process vessels, storage tanks
- Pump seals an ponds (air, soil),
- Yellowcake packaging and drying system,
- Disposal well casing leaks,

- Ancillary equipment (electrical transformers, air compressors, machinery, tools, transport vehicles). (IAEA, 2005)

Despite all these potential hazards, ISL has evolved to the point where it has been demonstrated to be a controllable, safe, and environmentally benign method of mining certain minerals (such as uranium or other metals) that should operate under strict environmental controls.

10 Assessment of anticipated environmental and social risks and impacts

Table 1 summarizes the impacts for a number of various activities related to a model CHPM initiative regarding their positive or negative perception. Table 2 presents a template where the magnitude, frequency, likelihood and consequence of each impact can be developed. Please note that table is not an exhaustive list of impacts and site specific conditions may apply in further developing this model list.

Table 1: Impacts for selected activities related to a model CHPM initiative. Source: INO, 2017 (NEG is for negative impact, POS is for positive impact)

Environmental and social impacts	Activity stage								
	Expl.	Construction			Operations				Decommissioning
	Well drilling	Land preparation / Mobilisation	Well Drilling / Plant Facilities	Transmission / Pipeline / Road	Well drilling	Power Generation	Transmission / Pipeline / Road	In-situ leaching	
PHYSICAL-CHEMICAL									
H2S Emissions	NEG		NEG		NEG	NEG			
GHG						NEG			
Heavy metal emissions	NEG		NEG		NEG			NEG	
Dust		NEG	NEG	NEG			NEG		NEG
Noise		NEG	NEG		NEG	NEG			NEG
Erosion and sedimentation/ water quality, increased run-off rate	NEG	NEG	NEG	NEG	NEG				NEG
Ground- and surface water usage		NEG	NEG		NEG	NEG		NEG	
Induced seismicity	NEG		NEG						
Solid and liquid waste		NEG	NEG	NEG	NEG	NEG		NEG	NEG
Hazardous waste		NEG	NEG	NEG				NEG	NEG
BIODIVERSITY									
Flora	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG
Fauna	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG
Invasive species	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG

SOCIAL & CULTURAL									
Employment opportunities	POS	POS	POS	POS	POS	POS	POS	POS	POS
Workforce impacts on communities disease, cultural, drain on local resources.		NEG	NEG	NEG					NEG
Business opportunities	POS	POS	POS	POS	POS	POS	POS	POS	POS
Cultural heritage		NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG
Land acquisition / Economic displacement	NEG	NEG							
Community concern	POS/ NEG	POS/ NEG	POS/ NEG	POS/ NEG	POS/ NEG	POS/ NEG	POS/ NEG	POS/ NEG	POS/ NEG
Indigenous people	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG
Community Health, Safety and Security-			NEG	NEG	NEG	NEG	NEG	NEG	NEG
Traffic and Transportation		NEG	NEG	NEG					NEG
WORKFORCE									
Occupational safety and health (OSH)	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG
Compliance with labor legislation	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG
GENERAL									
Cumulative and Transboundary Impacts – Influx		NEG	NEG	NEG	NEG	NEG	NEG	NEG	NEG
Loss of Opportunity (Business, Employment)- construction and decommissioning		NEG	NEG	NEG					NEG

Table 2. Detailed assessment of the various impacts related to the various stages of development

Actvity	Type of Impact	Magnitude	Frequency / Duration	Likelyhood	Consequence (+/-)
EXPLORATION PHASE					
Drilling deep (3+ km) geothermal wells	On-site storage of specialised materials and equipment	Medium	Temporary	Definite	Negative
	Contamination of surface/ground water due to spills and propagation of chemical elements	Medium / Significant	Temporary / Long-term	Medium / High	Negative
	Noise pollution	Significant	Temporary	High	Negative
	Unsustainable water use	Minimal / Medium	Temporary	Low/ Medium	Negative
Hydraulic stimulation of the reservoir	Surface felt seismic events, tremors, low magnitude earthquakes	Minimal / Medium / Significant	SIngle event occurences	Low/ Medium / High	Negative
CONSTRUCTION PHASE					
Site preparation	Earthworks may have an impact on the native topography	Minimal / Medium	Permanent	Medium	Negative
	Dust emissions generated from earthworks due to loading and unloading materials on site	Minimal	Only during construction	Medium	Negative
General use of vehicles and machinery	Spills or leaks of fuels, lubricants or chemicals from machinery and vehicles may contaminate groundwater	Significant	Long-term / Permanent	Low	Negative
	Source of noise	Medium	Only during construction	High	Negative
Construction of the reinjection pipeline	Generation of excavation material to be disposed of	Medium	Only during construction	High	Negative
	Potential worker	Significant	Only during	Low/	Negative

	accidents		construction	Medium	
Land use around the facility	Deterioration of landscape that exists at the proposed site	Minimal / Medium	Long-term/ Permanent	Low	Negative
Fugitive emissions					

10.1 Long-Term / Cumulative Effects

Cumulative impacts are defined by the International Association of Impact Assessment as those that result from combined, incremental impacts of an action in a particular place and time. According to the U.S. EPA:
"*Cumulative impacts result when the effects of an action are added to or interact with other effects in a particular place and within a particular time. It is the combination of these effects, and any resulting environmental degradation, that should be the focus of cumulative impact analysis. While impacts can be differentiated by direct, indirect, and cumulative, the concept of cumulative impacts takes into account all disturbances since cumulative impacts result in the compounding of the effects of all actions over time. Thus, the cumulative impacts of an action can be viewed as the total effects on a resource, ecosystem, or human community of that action and all other activities affecting that resource no matter what entity (federal, non-federal, or private) is taking the actions.*" (US-EPA, 1999)

There is no standard method to assess cumulative impacts, but given their importance, national guidelines for EIAs should require the assessment of cumulative impacts. According to the U.S. EPA: "*The assessment of cumulative impacts is not substantially different from the assessment of direct or indirect impacts. The same types of considerations are made to determine the environmental consequences of the alternatives for direct, indirect, or cumulative impacts. One possible difference is that cumulative impact assessment entails a more extensive and broader review of possible effects. Reviewers should recognize that while no "cookbook" approach to cumulative impacts analysis exists, a general approach is described in the CEQ handbook. As with the review of direct or indirect impacts, EPA review of cumulative impacts analysis is most effective if done early in the process, especially in the scoping phase.*"(US-EPA, 1999)

One possible difference is that the cumulative impact assessment entails a more extensive and broader review of possible effects. As mentioned, it is necessary to review the legal requirements of including cumulative impacts. It is expected that large-scale mining projects consider cumulative impacts as a significant issue in an EIA. The U.S. EPA states, "The analysis should be commensurate with the potential impacts, resource affected, project scale and other factors."(Environmental Law Alliance Worldwide, 2010)

Key issues include:

- Does the EIA address short and longterm environmental and social effects caused by more than one source?
- Does the EIA assess the possible effects on the human environment that may be impacted by other productive activities in the area (e.g., the presence of a smelter)?
- Are the significance and magnitude of impacts on water, air, and soil evaluated based on one pollution source at a time?
- Is any particular resource (soil, water, air) especially vulnerable to incremental effects of pollutants?
- How is the geographic area identified? Does it include the resources potentially affected by the project?

10.2 Impacts of related or connected actions

Some EIA laws require an assessment of connected actions, such as railways for transporting ore, pipelines for heat transport or transmission lines to power distribution hubs. There is controversy over the fragmentation of EIAs and whether they should include related or connected actions. Ideally, an EIA for a large-scale EGS/CHPM project would assess connected actions and their potential impacts on the project (Environmental Law Alliance Worldwide, 2010).

11 Environmental Considerations During Implementation (ESMP)

Mitigation and monitoring measures for potentially significant impacts are detailed in the Environmental and Social Management Plan (ESMP). The ESMP designates responsible authorities and identifies relevant project documents that support execution of the ESMP. This model ESMP addresses the msot important issues, but is far from complete and project specific impacts and their corresponding information are to be included upon developing this document.

Phase I:

Exploration

(including: building of access roads and drilling pads, well drilling and well stimulation, well repairs, possible additional well drilling and well testing).

Impact	Potential Receptors	Mitigating Measures	Monitoring Measures and Frequency	Responsible Authority	Cost estimate / Fund sources	Performance Indicators	Relevant Project Document
Land Acquisition	Land owners and occupants of project areas	• Carry out land acquisition and compensation that is compliant with laws and regulations and acceptable to the affected parties. • Take into account the aspirations of land owners and government	• Dissemination of acquisition plans, per Stakeholder Engagement Plan • Awareness-raising of Grievance Mechanism, per Stakeholder Engagement Plan	• External Relation Manager • Project Manager	Internal staff costs only	Has not caused conflicts in the community	• Land Acquisition Process • Stakeholder Engagement Plan • Grievance Mechanism
Liquid and liquid carried pollutant release		• To select only contractor(s) that have good environmental record. • Special approved waste ponds (slurry ponds and other liquid waste disposal facilities) of the required capacity and approved design are constructed on or close to the activity site, only non-polluting drilling fluid additives will be used and care taken to minimize all unnecessary releases					
Noise and vibration,	Workers, nearby community	• Inform affected communities of current project activities (that produce noise) • Establish safe exclusion zone for high noise level prior to any activity • Noise generated equipment i.e. electricity	• Conduct noise monitoring every 6 months at wellpads during exploration • 6-monthly review of management measures to confirm their successful	HSE Manager Construction Manager Drilling Contractors	Project cost	Noise level meets the national standards day and night	

		generator shall be covered with casing or place inside noise-proof room • Install silencer on noise sources • To apply hearing protections. Noise barriers will need to be erected if residential areas are being affected.	implementation and, where necessary, make continual improvement to improve effectiveness • Regular equipment maintenance			alike	
Induced seismicity and seismic hazards	Nearby communities	• Prior to EGS activities, the Project Owner will need to implement the Protocol for Induced Seismicity Associated with Geothermal Systems. • implement an official Procedure for Evaluating Damage	Procedures for responding to reports of induced seismicity and evaluation of property damage should be included in a **Stimulation Plan** issued during planning of the project				**Stimulation Plan**
Solid Non-Hazardous Waste (drilling mud and cuttings, domestic)	• Soil • Surface water • Ground water	• Follow Waste Management Plan • Conduct waste management training to relevant workers • Implement 3Rs initiative • Segregate waste to its characteristics • Send recyclable waste to recycling facility • Reuse drilling mud as much as possible. Dispose excess mud in the mud disposal • Drilling cuttings are collected in temporary drilling cuttingstorage or, once dried and reuse such as for constructionand road material or disposed in drilling cutting disposal • Dispose solid non-hazardous waste to Temporary Solid Waste Storage (TPS)	• Inspection to waste management facility • 6-monthly review of management measures to confirm their successful implementation and, where necessary, make continual improvement to improve effectiveness • Annual review training records to confirm those handling waste are receiving requisite training	HSE Manager	Internal staff cost only	Complied with waste management policy of the company	Waste Management Plan
Hazardou waste	• Soil • Surface • Ground water	• Hazardous waste management to be in compliance with government regulations • Follow Waste Management Plan • Conduct awareness training to relevant workers • Install secondary containment around flammable and dangerous waste materials storage as needed	• Prepare hazardous waste manifest • Prepare routine and submit it to relevant agencies • 6-monthly review of management measures to confirm their successful implementation and, where necessary, make continual improvement to improve effectiveness	HSE Manager	Internal Staff Cost only	Complied with regulations on hazardous waste management	Waste Management Plan
Surface water usage	affected nearby communities	• Comply the local requirements for water extraction • Install flow meter to record daily intake • Intake volume not to exceede allowable limit	• Prepare implementation report to relevant agencies • Regularly monitor the implementation of permit requirements	• HSE Manager • External Relations Manager • Project Manager • Drilling Manager • Drilling	Project cost with dedicated budget	No complaints from the community regarding water availability and quality	• Water Use Permit

				Contractor			
Water quality	affected nearby communities surface water	• Comply with the ambient surface water applicable regulation • No land clearing will be conducted beyond the approved plan • Control surface water runoff by employing engineered drainage systems • Construct trenches to divert storm water and build catch trap at the downstream before entering water body • Remove sediment in regular interval to the trenches and catch trap • Compact the open area and spread gravel to reduce erosion ▪ Planting trees perpendicular to water flow or parallel to the contour and/or in open areas that are prone to erosion • Revegetation of wellpad areas and other exposed surfaces follows Restoration Plan. • During drilling, use high density polyethylene (HDPE) lined mud ponds to protect shallow groundwater • Install steel surface casing pipe in all wells to protect groundwater • Reinject of drilling water and brine instead of discharge to the environment	• Ambient surface water monitoring at the nearby communities every 6 months during exploration • Inspection to the erosion and sedimentation control • 6-monthly review of management measures to confirm their successful implementation and, where necessary, make continual improvement to improve effectiveness • Revegetation schedule in accordance with Project Plan	• HSE Manager • Project Manager • Drilling Manager • Drilling Contractor	Project cost with dedicated budget	No complaints from the community regarding water availability and quality	• Water Management Plan • Schedule of Environmental Compliance Norms (Standards for surface water quality) • Revegetation Plan
Wastewater	surface water groundwater	• Wastewater is reinjected to the well • Build collection pond for water and mud lined with impermeable HDPE material • Reuse wastewater from drilling activity as much as possible, and/or reinjected to the injection well • Produced water (i.e. brine) is temporarily collected in the pond and reinjected to injection well • Domestic sewage will be treated with septic tank	• Integrity inspection to the ponds • Wastewater monitoring at the water and mud pond every 6 months • 6-monthly review of management measures to confirm their successful implementation and, where necessary, make continual improvement to improve effectiveness	HSE Manager	Internal staff cost only	Wastewater quality meets the standards.	
surface release of geothermal fluid,		• To avoid ecologically sensitive areas where possible. • Short-term and/or emergency liquid releases will have to be accommodated in a special, water tight holding tank or a holding pond					
surface disturbance and visual impact		• To avoid ecologically sensitive areas where possible. • Plant buildings should be located close to the production wells and the pipeline from the wells to the plant should be as short as possible to cause minimal visual impact					

		• Wellheads to be enclosed in a small building of a design that falls well in with the surroundings • Drilling of many (e.g. 2-4) deviated wells from the same pad					
Invasive Species	Flora	• Revegetation using local species only • Monitor and respond to invasive alien species on Project site and vicinity	5-year review of revegetation plans and practices, including monitor the presence of invasive species	• HSE Manager • Project Manager	Internal Staff cost only	No invasive species encountered during routine monitoring	Biodiversity Action Plan
Host Community Concerns	affected nearby settlements	• Execution of the following: • Stakeholder Engagement Plan • Community Development/CSR Plan • Grievance Mechanism	• 6-monthly review management measures to ensure they are being effectively executed; undertake continual improvement if necessary. • Monthly review of Grievance Mechanism log to determine if there are legitimate issues that should be given priority in resolving.	External Relations Manager	Internal Staff cost only	No negative perception of the company; No valid grievance recorded.	• Stakeholder Engagement Plan • Community Development Plan • Grievance Mechanism

Phase II:

CHPM plant construction and equipment installation

(including: Laying of pipelines, electric power transformation and transmission lines)

During construction, the amount of extraneous land disturbed for roads and material storage areas can be reduced through careful planning. Construction contractors must be briefed to minimize disturbance to land, vegetation and wildlife, and their performance in this area must be closely monitored. They must also be instructed to report encountering any cultural resource and, if encountered, to stop construction activities until the situation can be properly investigated. The contractor must dispose of any waste and trash that is generated during construction in an approved manner.

Impact	Potential Receptors	Mitigating Measures	Monitoring Measures and Frequency	Responsible Authority	Cost estimate / Fund sources	Performance Indicators	Relevant Project Document
Economic displacement (if neccesary)	Land owners	• Implementation of skill development and livelihood improvement program. This shall be developed based on the skills profile and training needs assessment by the community/skill development consultant. • Preparation and implementation of a Grievance Mechanism that includes • logs of the grievance received and the actions	6-monthly review management measures to ensure they are being effectively executed; undertake continual improvement if necessary.	External Relations Manager	Internal Staff costs only	No valid complaints from the host communities	• Land Acquisition Process • Land Acquisition and Livelihood Impact Monitoring

		taken to address the grievances. • As part of recruitment strategy, prioritized employment opportunities to affected persons, especially vulnerable households. • Prepare annual Livelihood Impact Monitoring Report.					Report • Stakeholder Engagement Plan • Grievance Mechanism
Surface disturbance,		land is unlikely to be recoverable in its original form on decommissioning of the plant					
Dust	workers affected communities	• Dust concentration is in compliance with applicable regulation • Converting roads to hard surfaces and frequently watering dirt roads during dry season • Water road during dry season • Limit the speed of vehicles (maximum speed of 20 km/hour) • Regular vehicle maintenance • Install signs for Safety, Occupational Health, and Environment in accordance with the SOP • Provide dust maskes for workers	• Inspecting construction activities to confirm use of water to minimize dust. • Ambient air quality monitoring for TSP concentrations at residential area adjacent to access roads • Inspection of roads to determine effectiveness of dust controls and undertake improvements. • Spot checking vehicle speeds • 6- monthly review of management measures to confirm their successful implementation and, where necessary, make continual improvement to improve effectiveness • 6-monthly review management measures to ensure they are being effectively executed; undertake continual improvement if necessary.	• HSE Manager • Project Manager	• Review measures internal staff only. • Air quality monitoring with fixed annual budget	Air quality meets the country specific standards	
Noise	workers affected communities	• Noise level at residential area adjacent to access road shall be in compliance with applicable regulations • Inform affected communities of current project activities (that produce noise) • Establish safe exclusion zone for high noise level prior to any activity • Wear proper hearing protection equipment for workers work near noise sources • Schedule major mobilization activities at night time to minimize congestion and disturbance at residential areas	• Ambient air quality monitoring for noise level at residential area adjacent to access road • 6-monthly review of management measures to confirm their successful implementation and, where necessary, make continual improvement to improve effectiveness • Spot checking on vehicle speeds on roads	HSE Manager Construction Manager	• Mgmt review measures internal staff costs only. • Noise survey, internal staff costs only.	Noise level meets the national standard:	• Schedule of Environmental Compliance Norms (Standards for Noise) • Occupational Safety, Health and Environmental Plan • • Stakeholder

		• Restrict vehicle speed limit at 20 km/hour. • Provide traffic marshalls during mobilization to ensure compliance to noise standards at night time (45 dB). • Establish vehicle safe distance on roads • Regular vehicle maintenance • Noise generated equipment i.e. electricity generator to be covered with casing or place inside noise-proof room • Install silencer on noise sources • Regular equipment maintenance • The typical construction noise is temporary and its general level does not exceed 80 dB					Engagement Plan • • Grievance Mechanism
Surface Water Usage	affected communities	• Provide water storage structure (e.g. lined pond) so that there will be ample supply during peak demand (i.e. Drilling operations) • Collect and reuse drilling water to reduce consumption of fresh water • Developed a detailed Water Balance for the Construction Phase and Operation Phase • Install water catchment pond within the natural drainage system which will serve as impoundment of rainwater and silt traps.	• Prepare implementation report to relevant agencies • Regularly monitor the implementation of permit requirements	• HSE Manager • External Relations Manager • Project Manager	• Compliance monitoring and Water Quality testing with fixed annual budget	• No complaints from the community regarding water availability and quality • No violation of Water Extraction Permit	Water Use Permit
Water quality	affected communities surface water	• Surface runoff shall be in compliance with relevant regulations • No land clearing conducted beyond the approved plan • Control surface water runoff by employing engineered drainage systems • Construct trenches to divert storm water and build catch trap at the downstream before entering water body • Pave access road with gravel • Compact the open area and spread gravel to reduce erosion • Remove sediment in regular interval to the trenches and catch trap • Erosion control • Planting trees perpendicular to water flow or parallel to the contour and/or in open areas that are prone to erosion • Revegetation of wellpad areas and other exposed surfaces follows Rehabilitation Plan.Compact the open area and spread gravel to reduce erosion	• Ambient surface water monitoring at the nearby communities in every 6 months during construction • Inspection to the erosion and sedimentation control • 6-monthly review of management measures to confirm their successful implementation and, where necessary, make continual improvement to improve effectiveness • Routine monitoring of pond water levels • Revegetation schedule in accordance with Project Plan	• HSE Manager • Project Manager	Compliance monitoring and Water Quality testing with fixed annual budget	• No complaints from the community regarding water availability and quality • No violation of Water Quality Standard	Revegetation Plan

		• Build biopores at some appropriate locations • Establish Buffer zone adjacent to the water body					
Visual impact		• Plant buildings should be located close to the production wells and the pipeline from the wells to the plant should be as short as possible to cause minimal visual impact • Injection pipeline can be lead in the ground • Subsurface pipeline follow the contour of the land which it crosses • Visual impact of various buildings and equipment can be minimized through careful layout of the power plant buildings and landscaping once the construction phase is over					
Disposal of waste		• Contractors involved in the construction and equipment installation should be provided with a storage area for their equipment • Contractort to be made responsible by contract to observe environmental rules of conduct specified by the plant owner and clean up their own waste when their work is done					HSE management program for the development
Damage to wildlife or habitat	Fauna Flora	Unacceptable impact. Examine alternatives to proposal especially if the area is sensitive or a breeding area					
Biodiversity	Fauna Flora	• For pipelines, use thermally insulated pipelines and installabove-ground to allow terrestrial animals to pass. • Undertake erosion prevention and soil stabilization to maintain stability of the pipeline. • Collaboration with stakeholders to protect the landscape, Socialization with the community on protected species awereness • Minimize open land areas without vegetation; • Open new land areas in stages and in accordance with approved project schedule and activity planning • Relocate and conserve protected flora found around the project site; • Revegetate using local plants that adjust local soil types and climatic conditions on bare areas; • Revegetate using plant species that are a source of food for animals; • Prohibit hunting and poaching of wildlife and removal of protected flora; • Install banners informing the prohibitions of	• 6-monthly review of management measures to confirm their successful implementation and, where necessary, make continual improvement to improve effectiveness • Monitor threatened species and the presence of endangered species on project site (at least every 3 years)	• HSE Manager • Project Manager • External Relations Manager • Security Manager	• Management training, consultations with fixed annual budget. • Habitat restoration with dedicated budget per land unit (ha)	• Land clearing in accordance with the project requirements • All land area restored at the end of construction; • No of employees and workers reached in awareness training program • Established and implemented Community Conservation Management Plan	• Critical Habitat Assessment • Biodiversity Action Plan • Environmental Management and Monitoring Plans

		hunting/poaching and removal of protected flora; • Build nursery for revegetation and rehabilitation;					
Fragmentation and isolation of Natural Habitat (due to the construction of the reinjection pipeline)	Terrestrial Fauna and Wildlife	• Wildlife movement across pipeline can be facilitated by either above-pipeline crossings, or under-pipeline crossings. • Under pipeline crossings are preferred. All opportunities for underpipeline crossings must be incorporated into the pipeline design. The placement of pipeline crossing shall consider wildlife habitat corridors and attempt to maintain movement corridor for the full of diversity of species expected to occur. Data sources such as wildlife monitoring, vegetation/topographical maps, and LIDAR may inform these decisions and influence crossing location. • Over-pipe crossings shall only be used when under-pipe crossings are not feasible or logistically possible. Ancillary use of over-pipe crossings for vehicle is prohibited.	• Ensure that the reinjection pipeline design is fully compliant with the requirements. • Close supervision of the pipeline • Construction from start to finish.	Project Manager	Internal staff cost only	100% compliance with pipeline design	
Spills or leaks of fuels, lubricants or chemicals from machiner		Spill control measures should be implemented to prevent spills from infiltrating into the groundwater table.					
Invasive species	Fauna	• Revegetation using only local species • Monitor and respond to invasive alien species on Project site and vicinity	5-year review of revegetation plans and practices, including monitor the presence of invasive species	• HSE Manager • Project Manager • Contractor	• Internal staff costs. • Cost of external review	No invasive species encountered during routine monitoring	Biodiversity Action Plan
Traffic and Transportation	affected nearby communities	• Mobilization of equipment and materials to occur at night • Operating transportation impacts are not significant. • Where contractors are used, this requirement is to be written into the contract.	Observation of equipment mobilization to assure that it occurs within specified hours.	• Project Manager • Contractor	Internal staff costs.	No valid trafficrelated complaint/ no traffic accident	Traffic and Transportation Plan
Workforce Impacts on Communities-Disease, Cultural, Drain on Local Resources.	affected nearby communities	• Implement Public Health Awareness Raising Plan to address hygiene and sanitation and other community health issues. • Conduct cultural awareness training for construction workforce. • Monitor local resource impacts; address gaps and problems as needed.			Internal Staff Costs only.	• No complaint from the communities • No spread of new diseases	Public Health Awareness Raising Plan
Host	affected	Execution of the following:	• 6-monthly review management	External	Internal Staff	No negative	• Stakeholder

Community Concerns	nearby settlements	• Stakeholder Engagement Plan • Community Development/CSR Plan • Grievance Mechanism	measures to ensure they are being effectively executed; undertake continual improvement if necessary. • Monthly review of Grievance Mechanism log to determine if there are legitimate issues that should be given priority in resolving.	Relations Manager	cost only	perception of the company; No valid grievance recorded.	Engagement Plan • Community Development Plan • Grievance Mechanism

Phase III:
CHPM plant commissioning and operation

Impact	Potential Receptors	Mitigating Measures	Monitoring Measures and Frequency	Responsible Authority	Cost estimate / Fund sources	Performance Indicators	Relevant Project Document
Emission and injection of geothermal fluids		Thermodynamic scaling control could be applied instead of inhibitor chemicals					HSE management program
Gaseous emissions		Information and good public relations Specific abatement equipment, may be added to the plant to capture and treat chemicals, and to re-inject them together with the rest of the fluid					
H2S Emission	• Humans • Fauna	• H2S emission in compliance with applicable standards. H2S monitoring at each well, power plant and various points on pipeline network is undertaken to ensure the H2S exposure limit is not exceeded. • Comply with SE SHE Policy and Manual, including training and applicable procedures related to H2S concentrations, such as use of personal H2S monitors. • Select the optimum well location that minimizes and avoids adverse impacts and establish safe exclusion zone according to the SOP • Install alarm system which will set off at concentration >20ppm • Caustic soda injection to capture H2S inside the production pipe	• Routine H2S monitoring at each well and other points within the facility to ensure the H2S exposure limit is not exceeded. • Conduct ambient air monitoring at 500 – 1000m radius inside wellpads vicinity every 6 months • 6-monthly review of management measures to confirm their successful implementation and, where necessary, make continual improvement to improve effectiveness 6-monthly review management	HSE Manager	• Review measures internal staff only. • Air Quality monitoring with dedicated annual budget	• Air quality meets the national standards (eg. H2S <35mg/Nm3; odor level <28 µg/Nm3)	• H2S measurement records • H2S SOP

		• community Health, Safety and Security: Socialization related to H2S communication and emergency procedure (odor).	measures to ensure they are being effectively executed; undertake continual improvement if necessary. • Annual review of training records of occupational HSE procedures and incident records to assess pattern and make improvement				
GHG Emissions	Climate Change	Based on steam production and analysis of NCG, carry out GHG inventory and post results on the project website	Annual GHG inventory records	HSE Manager	Included in costs	Air quality meets the standards	GHG Inventory
Noise	workers affected communities	• Noise level at residential area adjacent to access road shall be in compliance with applicable regulations • Inform affected communities of current project activities (that produce noise) • Wear proper hearing protection equipment for workers work near noise sources • Establish safety exclusion zone at noise sources • Regular equipment maintenance	• Ambient air quality monitoring for noise level at residential area adjacent to access road • 6-monthly review of management measures to confirm their successful implementation and, where necessary, make continual improvement to improve effectiveness • Spot checking on vehicle speeds on roads	HSE Manager	• review measures internal staff costs only. • Noise survey,.	Noise level meets the national standard:	• Schedule of Environmental Compliance Norms • Occupational Safety, Health and Environmental Plan • Stakeholder Engagement Plan • Grievance Mechanism
Surface Water Usage	affected communities	• Comply the relevant legal requirements • Install flow meter to record daily intake • Intake volume not exceeding allowable limit	• Prepare implementation report to relevant agencies • Regularly monitor the implementation of permit requirements	• HSE Manager • External Relations Manager	• Compliance monitoring and Water Quality testing with fixed annual budget	• No complaints from the community regarding water availability and quality	Water Use Permit
Wastewater	surface water groundwater workers affected nearby communities	• Implement the requirements set forth in the wastewater injection permit • At the separator station, produced water (brine) is separated from steam. Brine is collected temporarily in an impermeable pond and reinjected back to reservoir through dedicated brine injection well • Condensate from the condenser unit is temporarily collected in an impermeable pond and reinjected back to reservoir through dedicated condensate injection well	• Integrity inspection to the facility • Wastewater monitoring at the water and mud pond every 6 months • 6-monthly review of management measures to confirm their successful implementation and, where necessary, make continual improvement to improve effectiveness	HSE Manager	Internal staff cost only	Wastewater quality meets the standards.	

		• No discharge of brine and condensate to surface water • Wastewater from production and injection wells acid treatment is injected to reservoir through injection wells					
Biodiversity	• Fauna • Flora	• Collaboration with stakeholders to protect the landscape • Socialization with the community on protected species awareness • Minimize open land areas without vegetation; • Open new land areas in stages and in accordance with approved project schedule and activity planning • Relocate and conserve protected flora found around the project site; • Revegetate using local plants that adjust local soil types and climatic conditions on bare areas; • Revegetate using plant species that are a source of food for animals; • Prohibit hunting and poaching of wildlife and removal of protected flora; • Install banners informing the prohibitions of hunting/poaching and removal of protected flora; • Build nursery for revegetation and rehabilitation;	• 6-monthly review of management measures to confirm their successful implementation and, where necessary, make continual improvement to improve effectiveness • Monitor threatened species and the presence of endangered species on project site (at least every 3 years)	• HSE Manager • Project Manager • External Relations Manager • Security Manager	Management, training/awareness, monitoring withd edicated annual budget	• Land clearing in accordance with the project's requirement; No incidence of hunting or poaching of wildlife. • Flora: presence of protected species, pioneer species, and invasive species either native or alien. • Fauna: presence, abundance and distribution of species with important conservation status and endemic species as a basis for habitat and population management. • No of employees and workers reached in awareness training program	• Critical Habitat Assessment • Biodiversity Action Plan • Environmental Management and Monitoring Plans
Invasive Species	Flora	• Revegetation using only local species • Monitor and respond to invasive alien species on Project site and vicinity • The linear nature of the structures in such a project and their spatial arrangement raises the risk that invasion can occur and a risk assessment and mechanism for initiating an appropriate response needs to be	5-year review of revegetation plans and practices, including presence of invasive species	HSE Manager	Internal staff costs	No invasive species encountered duringroutine monitoring	

		addressed in the Biodiversity Action Plan.					
Community Health, Safety and Security	affected communities	• Implement relevant Health Safety, and Environment (HSE) policies and procedures, including security. • Carry out site management practices such as the provision of fencing around mud ponds and road signage to drive HSE objectives. • Implement Public Health Awareness Raising Plan to address hygiene and sanitation and other community health issues. • Implement ERP, ensuring that it includes contact names and phone numbers and community aspects such as communication routes in the event of an emergency—including disclosure to local government to ensure the implementation is a coordinated effort. • Increase public awareness of HSE issues by providing information directly and indirectly through campaigns.	Annual review of management measures to confirm their successful implementation and, where necessary, make continual improvement to improve effectiveness	HSE Manager	• Internal Staff Costs only.	No increases in diseases, no change in disease pattern	• Community Health and Safety (CCHS) Plan • Emergency Response Plan
Encroachment and other cumulative and Trans boundary Impacts	• Flora • Fauna • Affected communiti es	• Monitor the perimeter area around the site at least annually to gauge encroachment and settlement trends. If negative trends are deemed to have been caused by the project take remedial action. • Assess whether project is causing transboundary impacts at least every 5-year; address identified impacts. • Leverage Biodiversity Action Plan and Community Development Plan to prevent encroachment • Implement Stakeholder Engagement Plan and Grievance Mechanism; document feedback.	Annual review of management measures to confirm their successful implementation and, where necessary, make continual improvement to improve effectiveness	• External Relations Manager • HSE Manager	Internal Staff Costs only.	All encroachment attempts prevented.	• Biodiversity Action Plan • Stakeholder Engagement Plan • Community Development Plan

Phase IV:
Decommisiioning of facilities, site rehabilitaion and reclamation

A major aspect of the environmental assessment process is the development of the decommissioning and final reclamation plan, including the reclamation of all land, air and water resources that are projected to be adversely affected by the operation. The decommissioning plan should be based on factors including the mine/reservoir plan, the baseline environmental information, the long-term mechanical, geotechnical and geochemical stability of the site.

In this model CHPM facility decommissioning is expected to be 30+ years after operation begins; however, the project may continue beyond that timeframe if commercial and resource conditions permit. Therefore, this impact is to be addressed in detail towards the end of the project’s operational life.

The management strategies to address expected impacts are as follows:

- Proactively socialize the decommissioning to build awareness and encourage employees, the supply chain and other beneficiaries of the project to prepare and diversify.
- Preparation of a retrenchment plan for the workers that includes appropriate compensation. Some workers will likely be redeployed to other similar projects.
- Undertake revegetation and minor earthworks to restore surface drainage and minimize sedimentation and soil erosion.
- Where possible, develop beneficial uses of project infrastructure.
- For infrastructure that is dismantled, seek beneficial use of the materials inside or outside the project area; where this is not possible, dispose the materials in lined landfills (INO, 2017).

In addition to that, individual assessments could be developed for each identified impact, including the following information (2 examples)

Example I

NATURE	Change in drainage patterns	Status	
IMPACT SOURCE(S)	• Clearing of natural vegetation • Construction of a pilot CHPM facility and corresponding structures • Obstruction of natural drainage lines		
AFFECTED STAKEHOLDERS	• Conservationists; • People with biodiversity interests; • International community involved in species conservation andprotection; • Existing landowners		
MAGNITUDE	Extent	**Local**	
	Intensity	**Medium**	
	Duration	**Long term**	
	Reversibility	**Reversible**	
	Probability	**Likely**	
SIGNIFICANCE	Without mitigation	**Medium / High**	M-H
	With mitigation	**Low / Medium**	L-M
CONFIDENCE	**High**		

Source of the impact: Construction of the pilot CHPM facility: on-site complex, roads network, pipelines, transmission station, metal processing facility.

Description of the impact: The construction of the on-site complex, access roads may cross over several minor and major drainage lines or streams. These crossings will more than likely alter the drainage pattern (or at least theflow of water) in a localised area. Should drainage patterns alter significantly, the resulting consequence would be a change in the vegetation structure and community.

Significance: The significance of the impact is expected to be of a medium to high negative significance without mitigation, this due to the high probability that drainage lines will be impacted on. With mitigation the significance of the impact can decrease to a low- medium negative.

Mitigation measures: Extreme caution should be exercised to maintain construction activities within the declared footprint/ construction areas. Should drainage lines or streams be impacted on in any way, care should be taken to rehabilitate the area to ensure the restoration of natural drainage patterns. Where roads cross drainage lines, culverts and drains must be put in place to ensure that the natural flow of water is maintained. These culverts must be inspected regularly for silting and be cleared of all silt and debris.

Example II

NATURE	Noise and dust pollution during constructio		Status	
IMPACT SOURCE(S)	• Earthworks • Removal of vegetative cover • Increase in traffic on gravel roads			
AFFECTED STAKEHOLDERS	• Adjacent landowners			
MAGNITUDE	Extent	**Site**		
	Intensity	**High**		
	Duration	**Short-Medium term**		
	Reversibilit y	**Reversible**		
	Probability	**Definite**		
SIGNIFICANCE	Without mitigation	**High**		H

	With mitigation	**Medium**	M
CONFIDENCE	**Low-Medium**		

Source of the impact: Social impacts relating to the physical environment relates to exposure to dust, noise, risk, odour, vibration, artificial light.

Description of the impact: During the construction phase, there will be a decrease in the quality of the physical environment. Noise levels and traffic will increase as result of the construction activities. The impact that the construction phase might have on the adjacent landowners should also be considered.

Significance: The cumulative impact upon the quality of the living environment will be moderate, due to the fact that the impacts on noise, dust and traffic are considerable given the current surroundings. However, if mitigation measures are applied, the impacts will be lessened to medium and medium to low significance.

Mitigation measures: Construction times should be negotiated with the immediate and surrounding landowners. Ensure that construction vehicles move in convoy to try and minimise the amount of traffic on the road – rather have one larger convoy moving through, than a number of individual trucks using the road separately.

Template for further identified impacts

NATURE			Status
IMPACT SOURCE(S)	• •		
AFFECTED STAKEHOLDERS	• • •		
MAGNITUDE	Extent	Footprint / Site / Local / Regional	
	Intensity	Low / Medium / High	
	Duration	Temporary / Permanent or Short / Medium / Long term	
	Reversibility	Irreversible / Reversible / Not-applicable	
	Probability	Likely / Possible / Unlikely / Remote / Improbable	
SIGNIFICANCE	Without mitigation	Negligible / Minor / Moderate / Major / Critical OR Low / Medium / High	
	With mitigation	Negligible / Minor / Moderate / Major / Critical OR Low / Medium / High	
CONFIDENCE	Low / Marginal / High		

12 Conclusion

The International Association for Impact Assessment (IAIA, 1999) and other institutions and organisations have developed guiding principles for EIA/IA. The principles listed below are a selection of some of the documented ones.

Participative: The process should provide appropriate opportunities to inform and involve the interested and affected publics and incorporate their input in decision-making.
Transparent: Assessment process, outcomes & decisions should be open and accessible.
Certainty: The process and timing of the assessment should be agreed in advanced and followed by all participants.
Accountable: The decision-makers and project proponents are responsible to all parties for their action and decisions under the assessment process.
Credible: Assessment is undertaken with professionalism and objectivity.
Cost-effectiveness: The assessment process and its outcomes will ensure environmental protection at the least cost to the society.
Practical - the process should result practical outputs, which can be implemented by proponent.
Relevant - the process should focus information that is relevant for development planning and decision-making.
Focused - the process should concentrate on significant environmental effects and key issues that need to be taken into account in making decisions.
Interdisciplinary - the process should ensure that the appropriate techniques and experts in the relevant disciplines are employed, including use of traditional knowledge as relevant.
Integrated - the process should address the interrelationships of social, economic and biophysical aspects.

There are many instruments that ultimately inform the EIA process. For example, strategic environmental assessment extends the application of environmental assessment from projects to policies, plans, and programs, and assesses environmental aspects considering their inter-linkages with social and economic factors. Risk assessment may also feed health-issue considerations into the EIA process for projects requiring thorough examination of risks to human health, and could either proceed separately of EIA or be integrated within the EIA process (Demidova and Cherp 2005).

Despite these risks and limitations, EIA remains a useful tool for two reasons. First, it does drive developers of new projects to take environmental impacts and risks into account (partially internalizing the cost). Second, it allows or may allow governments and society to analyze projects in depth. Yet this is an expensive process with regard to both inputs and time. Even when studies are of excellent quality, the process may reach wrong conclusions because EIA takes the project's effects into account but seldom are cumulative effects considered. Hence, it is important to apply EIA selectively, but also apply it in conjunction with other tools that take cumulative effects into consideration (WORLD BANK: Getting to Green).

EIA certainly has a crucial role to play in addressing environmental issues surrounding project development, especially power plant projects. The integration of environmental risks into industrial planning is the most important tool in achieving sustainable development. Environmental protection and economic development must thus be dealt with in an integrated manner. EIA process is necessary in providing an anticipatory and preventive mechanisms for environmental monitoring and protection.. The need for capacity building for quality EIA is especially needed in developing countries. As a good routine, environmental impact assessment has become an integral part of project planningand it is continually being improved by legislation and technical actions (Ogola, 2007).

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