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Methodological sequence applied for Mexican Geothermal Program of Inter-American Development Bank

[1]Alfonso Aragón-Aguilar, [1]Georgina Izquierdo-Montalvo,[1]Candy Cornejo, [1]Abel Hernández, [1]Ignacio Martínez, [1]Joaquín Torres, [1]Carlos Jiménez, [1]Ramón, Torres

[1]Instituto Nacional de Electricidad y Energías Limpias; Reforma 113, Col. Palmira, Cuernavaca Morelos, México, CP 62490.
aaragon@ineel.mx

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ABSTRACT

Focusing in the goal to overcome the lack of geothermal projects development in Mexico during the past two decades the Inter-American Development Bank (IDB) designed the Program of Risk Transfer and Financing for Geothermal Energy. The objective is to isolate the drilling risk during the geothermal projects development. Besides IDB, participates the Clean Technologies Fund (CTF) along with interaction of Mexican Government Institutions: Ministry of Energy (SENER), Nacional Financiera (Mexican development bank NAFIN) and the National Institute of Electricity and Clean Energies (INEEL). This program will be applied in Mexican projects to promote continuity of geothermal exploration in Mexico. Moreover, it includes financing for private investors for field development until construction in permissioned or concession areas is completed. INEEL acts as the technological arm of IDB and has leaded the two main lines of it: Drilling bidding process and Call for field developers. The bidding process for drillers was focused in select those that offer the lowest prices for drilling geothermal wells up to 3500 meters depth and most senior experience. Process also included a detailed analysis of items such as technical and administrative related with drilling activities of geothermal wells: drilling rig capacity, power, accessories availability, tubular goods, professional and technical staff experience, financial stability, administrative reliable. Those, are some of the items considered in drillers evaluation besides their costs offered. The call for field developers was focused to those having permissioned or concessioner zones by SENER. INEEL designed an evaluation pattern for them which considers: Geoscientific studies, drilling wells program, Complete design of the project considering National development plan, applications to develop economically nearby communities, environmental protection, business experience and its professional and technical staff skills. In this paper is shown a methodology to carry out an integral project that supports selection of geothermal well drillers with low costs in theirs offers and investor developers which show high successful possibilities in their permissioned or licensed fields. Also it includes our findings related to drilling price ranges as function to depth compared worldwide.

1. INTRODUCTION

Geothermal development in Mexico started since 1957 with exploratory studies at the Pathe zone of Hidalgo state concluding its stage with drilling of six Wells with depths ranging between 400 and 800 m. The objective of this Project was demostration that geothermal energy is useful for electric generation under this way one of the Wells with geothermal characteristics was selected for be used with an electric power plant. The used well shown successful results with 380 KWe of electric generation and accomplished the demonstrative objective that geothermal steam energy is available for moving a turbine for electric generation (Delgado and Juárez, 2014). Taking into account this technical support started regional and detailed exploratory studies in different zones with thermal manifestations along the country.

La Comisión Federal de Electricidad (CFE) is the operator and owner of the geothermal fields is charged of generation and distribution of electricity along México. So, CFE developed studies regional and of detailed of geothermal zone neighboring, to “Cerro Prieto” Volcano in the called “Mexicali” valley. Exploratory drilling in this zone started in 1968 and was supported with successful results in Wells, whose characteristics allowed developing production tests obtaining indicative measurements of enough capacity for electric generation with a formalized project. The first two electric generation units (37.5 MWe, each one) of Cerro Prieto geothermal field (CPGF) started up since 1973. So, according to results of exploration geosciences studies and of reservoir engineering supplied by drilled wells was taken decision for gradual field expansion, until achieve 720 MWe of installed capacity. At present CPGF continues in exploitation stage even though the majority of its zones have achieved maturity stage.

Along Méxican territory has been located more than 4000 surface thermal manifestations, with the characteristic that the majority of them, are encountered along neovolcanic belt. Using data of preliminary geochemical exploration (geothermometry, chemical indices) were chosen those zones with better conditions for starting regional and detailed exploratory studies The results of exploratory campaigns were used for takin decisions on the start of drilling exploratory wells in zones of: "Ixtlán de los hervores" and "Los Azufres" in Michoacán state; "La Primavera" now called, as "Cerritos Colorados" and "La Soledad" in Jalisco state; "Los Humeros" and "Las Derrumbadas" in Puebla state; "Las tres vírgenes" in Baja California Sur state.

The drilled Wells those resulting with possibilities for geothermal exploitation, were those located in “Los Azufres”, “La Primavera”, “Los Humeros” and “Las Tres Vírgenes”. In these four fields were carried out corresponding pre feasibility and feasibility studies in order to define the construction of geothermal power plant and its capacity.

In this way, gradually were constructed in the mentioned fields (excepting "La Primavera") electric power plants. Therefore, besides electric generation from CPGF (1973), were incorporated to national electric generation, that of "Los Azufres" since 1982; "Los Humeros" since 1992; and "Las Tres Vírgenes" in 2001. A map of surface thermal manifestations along Mexican territory and geothermal fields in operation to date is shown in Figure 1.

Figure 1. Surface thermal manifestations along Mexican territory and geothermal fields under operation (modified from Iglesias et al. 2012).

These four fields are operated by CFE which is the owner, nevertheless there is another geothermal field operated by private investor. This field is called "Domo de San Pedro", granted by "Secretaria de Energía" (SENER) to private investor, producing to date 35.5 MWe.

A geothermal project involves two big stages related intrinsically: Field exploration and its exploitation (IGA, 2013). Each one of them implies specific activities which also are considered as stages helping in its successful, however exploitation stage is strongly dependent of the exploration (GEOELEC, 2013; Geothermal Energy Association, 2014). The two main stages of a geothermal project and activities which integrate it, are shown in scheme of Figure 2.

The appropriate application of each one of stages of a geothermal project until to achieve the power plant startup, guarantees the investment recovery. Even though the stages of the process for geothermal fields development has been shown by OLADE (1980, 1994) and IGA (2018), CFE has applied the methodology since the first field (CP). The stages sequence of a geothermal project process (Gudmundsson, 2016) is shown in Figure 3, which are as follows ESMAP's Geothermal Handbook (2012): 1) Preliminary reconnaissance (regional exploration); 2) Detailed exploration; 3) Drilling exploratory; 4) Review, information analysis and Project planning (Feasibility study); 5) Field development (drilling of producer wells and feasibility study); 6) Design and power plant construction; 7) Commercial generation startup; 8) Operation and maintenance of the project (the overall field, the power plant and the wells).

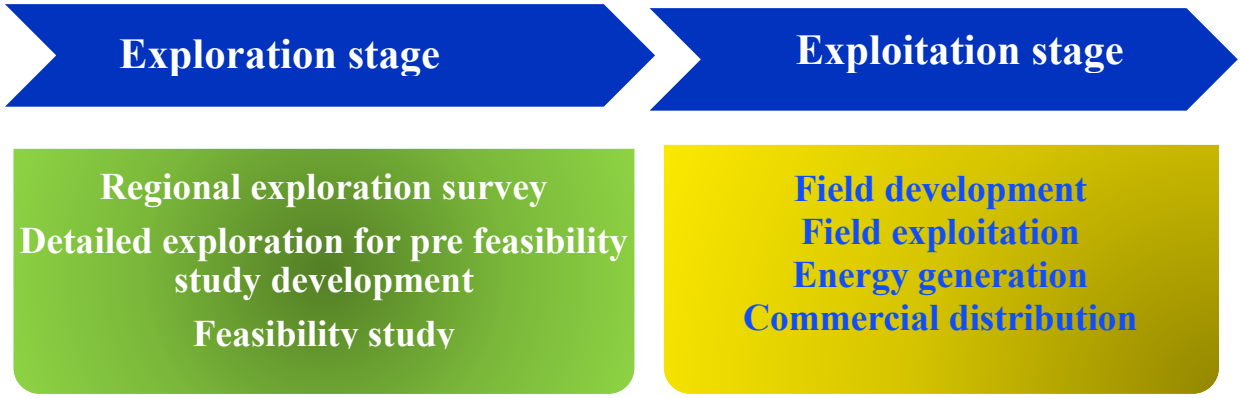

Figure 2. Activities of the two big stages which compose an integral geothermal project, highlighting that exploration success is the fundament for maintaining its continuity.

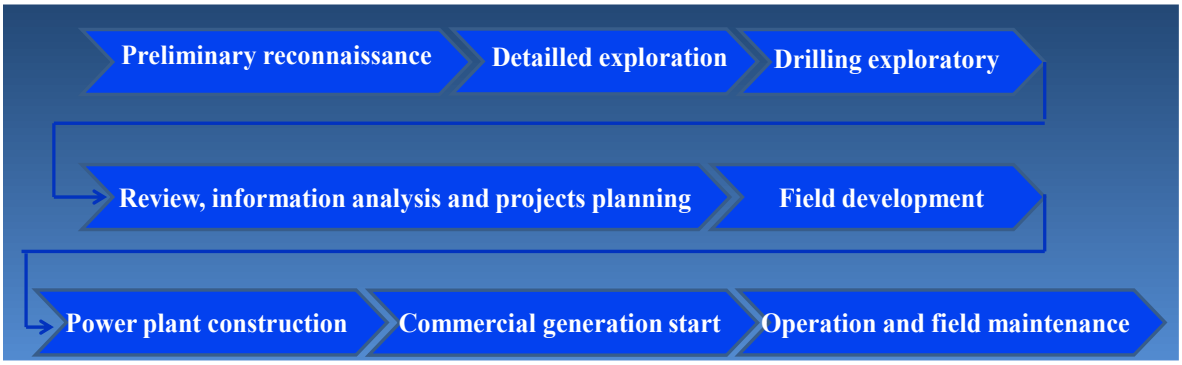

Figure 3. Schematic diagram of the process shown by OLADE (1980, 1994), ESMAP (2012) and IGA (2013), with addition of the operation and field management stage.

2. BACKGROUND

Although is followed a right methodology, in first stages of geothermal projects prevails uncertainties for wells location selecting. Besides, it is main taking into account that geothermal project maturation until startup power plant operation for electric generation utilizes between six to nine years (Eliasson et al., 2011). Obviously all stages supported by existence of a zone with geothermal potential. From economic analysis of investment that must be applied, it results that exploration stages need only a 5 % of project total cost. However, must be taking into account that in the first three stages decisions are taken on the project viability, as for zone selection and location of the first exploratory wells be drilled. A graphical scheme of investment in relation to project risks along its different stages is shown in Figure 4.

It is widely known that, although, the results of geochemical, geologic and geophysical studies guarantee certainty for defining the zone and wells location be explored, the only one way for confirming it is through of drilling a well (Mwangi, 2007; Mercado et al., 2008). Due to well drilling cost represents high investment, also at this stage prevails high risk, until the results of this well eliminate uncertainties. These possible results (successful or failure) must be considered by investor-developer of the field in order to maintain a back for investment at least five exploratory wells. Ordinarily, the recommended strategy is if the first exploratory well does not is successful, must be necessary looking for the second alternative suggested by detailed exploration studies. According to followed strategy in petroleum and geothermal fields, a zone with exploitation possibilities is defined, with results of at least between three and five wells.

If the first well or any of these exploratory, shows result successful, the strategy recommends continuing with area of this zone development, for ensuring positive results in next drilled Wells. If any of the drilled exploratory wells does not have successful results, then the zone is discarded as for exploitation through geothermal conventional techniques and must be to looking for another way of heat recovery. Under this assumption, the Inter-American Development Bank (IDB) offers to México the absorption of the associated risks with the exploratory drilling. This initiative is based on the investor developer would have permissions or concessions over a geothermal zone given by "Secretaria de Energía" (SENER) with possibilities of storing geothermal energy. The investor-developer must show geoscience studies which support presence of a geothermal reservoir in his zone.

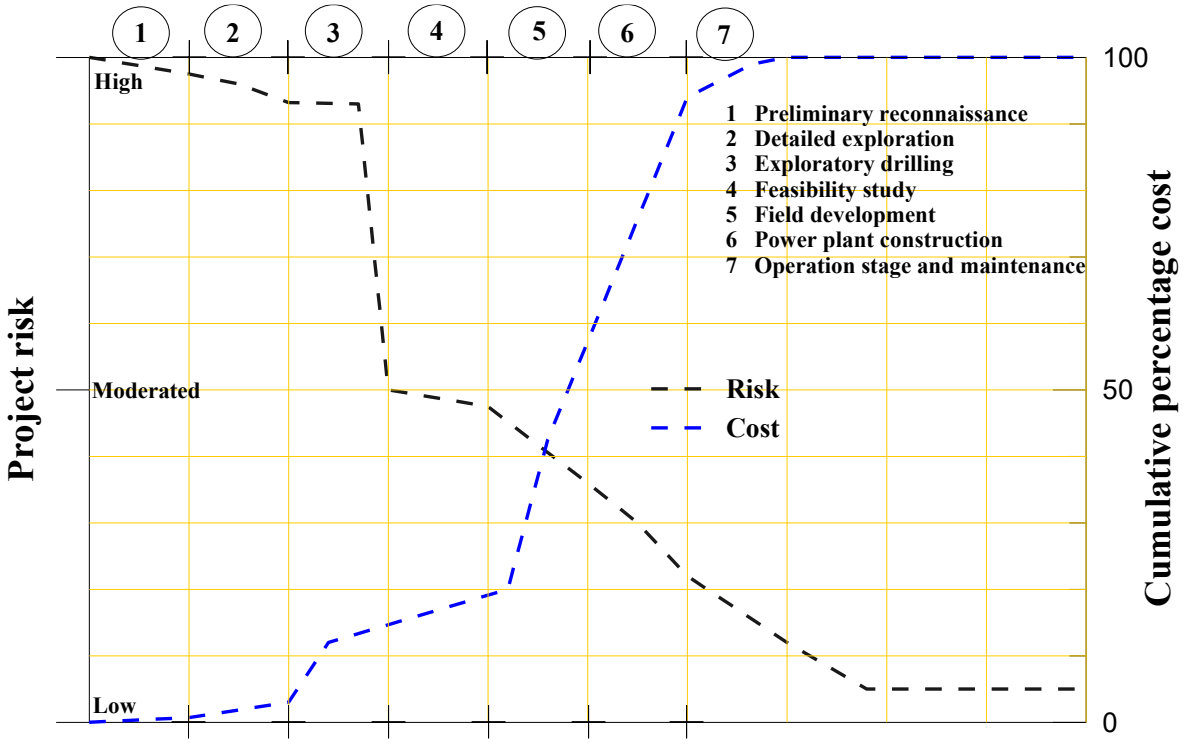

Figure 4. Distribution of cumulative percentage cost, related with risks along the different development stages of a geothermal project (ESMAP, 2012; Geothermal Energy Association, 2014).

According with last thing "Instituto Nacional de Electricidad y Energías Limpias" (INNEL) inside the consortium, IDB, SENER, "Nacional Financiera" (NAFIN), launched calls, firstly for drillers and few days after, for developers-investors. The call for drillers is focused for drilling exploration wells and is known as "Licitación" and the other one, for developers is known as "Convocatoria".

As support of this idea it is appropriate to mention that IDB has carried studies related to obtain an inventory about geothermal capabilities in zones of México and Central America; in Countries of South America and in the Caribbean. Geothermal potential which have been inventoried by IDB is shown in Table 1. Additionally, in the last five years IDB has supported with economic resources geothermal projects of "Cerro Pabellón", Chile (50 MWe); "Cosiguina", Nicaragua (100 MWe); "Las Pailas", Costa Rica (100 MWe) and "San Vicente y Granadinas" (5 MW).

Table 1. Inventory of geothermal potential in South America, Central America, Caribbean and México (taken from IDB, 2018).

Mexico and Central America (19,720 MW)	
Mexico	6,510
Costa Rica	2,900
El Salvador	2,210
Guatemala	3,320
Honduras	990
Nicaragua	3,340
Panama	450

Southamerica (14,660 MW)		
Argentina		2,010
Bolivia		2,490
Chile	2,350	
Colombia		2,210
Ecuador		1,700
Peru		2,990
Venezuela		910

Caribbean (16,390 MW)	
Dominica	1,390
Grenada	1,110
Guadaloupe	3,500
Jamaica	100
Martinique	3,500
Montserrat	940
Neth. Antilles	3,000
St Kitts&Nevis	1,280
Saint Lucia	680
St Vin. & Grend.	890

TOTAL POTENTIAL = 50,770 MW

3. MEXICAN GEOTHERMAL PROGRAM

The Mexican Geothermal Program (PGM) is the instrument designed by IDB for giving financial support to reactivate exploration and possible exploitation in new geothermal zones in Mexican territory. It has two main lines, the first one the call for proposal for drillers, which will be designated as "Licitación", another one is the called for proposal for investors-developers having a permissioned geothermal zone, denominated as "Convocatoria" (INEEL, 2018).

INNEL as technical arm of the consortium IDB-SENER-NAFIN was selected for launched both; Licitación and Convocatoria, using official government media and electronic. In the design of these launches it was considered the times period in order to have an ordered sequence between evaluation process of applicants to Licitación and Convocatoria.

The Licitación is public and international requesting proposal of costs for drilling geothermal wells at 3500 m depth with characteristics of about 350 °C and 350 bar. The applicant drillers must show besides entire drilling equipment and in excellent work conditions, professional work team with consolidated experience, financial and administrative robustness and capabilities for solving troubles related with drilling. All the presented documentation must be supported accredited bodies widely acknowledged.

The Convocatoria for investors-developers was focused to those having permissioned or concessioner zones by SENER. INEEL in coordination with IDB designed an evaluation pattern for applicants of "La Convocatoria" which considers: Robustness backing of geoscientific studies developed in their permissioned zone, drilling wells program; Complete design of the project considering National development plan; Applications for economical develop of nearby communities; Environmental protection; Business experience and its professional and technical staff skills.

The interesting of the PGM is that IDB announces that absorbs the risks of drilling costs in cases of exploratory wells failed, so the investor is released of any debt. If the well results successful, investor has an authorized credit through financing for paying it to 15 years.

4. TECHNICS FOR RESULTS OBTENTION

The "Programa Geotérmico Mexicano" (PGM), basically is focused for developing exploration in new zones through drilling of at least three Wells in zones of investors which have permission or concession. PGM involves "Licitación" (for drillers) and "Convocatoria" (for investors-developers).

For "Licitacion" and "Convocatoria" evaluation are used technical criteria appropriate to each one activity related with both two. According to IDB suggestions the bases of "Licitacion" mention that winner of the drillers would be which offers the lowest prices and accomplish with solicited requirements in the published document. Besides, for "Convocatoria" case, would be selected four developers-investors showing the best geothermal characteristics of their zone and also accomplish with solicited requirements in the published document. The different criteria could be applied for best proposal selection, for both cases, are mentioned following.

4.1 Parameters for "Licitacion" results evaluation

The analysis techniques include comparative tables of unitary costs related with concepts catalogue, shown by each applicant driller in his proposal. The requirement establishes drilling rig capacity until 3500 m depth, considering possibility of deviations in 12 ¼ inch hole in some cases and, possible working temperatures until 350 °C. Additionally in order to include equipment movements costs were established three possible zones for drilling operations, which are: a) South-east Mexico, b) North-west Mexico and; c) Passageway of Neovolcanic belt (from Colima estate, to Veracruz estate).

It is of main importance in evaluation, the drilling rig capacity with technical characteristics of each one of the systems components (Power, hoisting, circulating, rotary, well control). It is necessary to analyze for each one of the systems of the drilling rig, the work conditions, inspections and its useful life.

Similarly, must be analyzed capabilities, experience and technical scholar preparation of each one of the components work team proposed for to carry out the job. The "Licitacion" emphasized that technical personnel experience must be of five years and ten petroleum or geothermal wells with 3500 m depth.

Another of the relevant aspects that must be considered in drillers evaluation is communications facilities, logistic and administration in order to assure quick responses in necessary situations. This implies a backing administrative group with quick responses to demand for supplying materials, tools and any consume subject under non expected conditions during drilling.

In order to obtain a backing robust related the proposal of applicant drillers, a comparative analysis (Vaca-Serrano, 2008; Williams et al., 2008; Shevenell, 2012; Thorhallsson and Sveinbionrnsson, 2012; Gul and Aslanoglu, 2018) related on the drilling costs of the different wells, petroleum and geothermal along the entire world is shown in Figure 5.

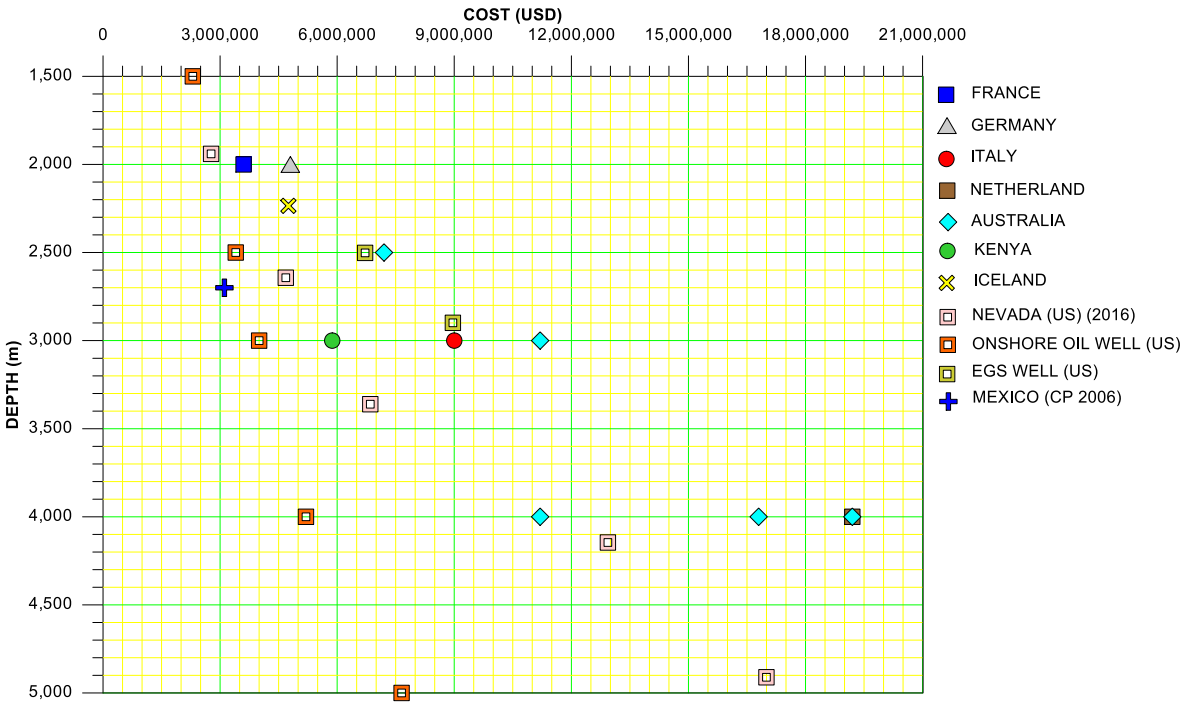

Figure 5. Drilling costs, of different type wells (petroleum and geothermal) along the entire world related with different depths, adding wells data of Cerro Prieto geothermal field (modified from Gul and Aslanoglu, 2018).

The support documents, that must be analyzed, related to requirements for showing technical and economical solidity, capability professional and operative, are next:
Document of the lawful conformation of the enterprise or consortium.
Type of conflicts to that has been confronted and their resolution.
Financial status of the last five years.
Evidence about ten petroleum or geothermal wells, drilled during last five years.
Evidence of backup capital for the "Licitacion" jobs.

4.2 Parameters for “Convocatoria” results evaluation

Evaluation for the first stage considers mandatory that an investor-developer must satisfy that has right permission or concession over a geothermal area. With this fulfillment could be considered prepared for acceding to evaluation process. At this stage, all the documentation is proportioned by SENER and must be updated to date of application submit.

After investors-developers pass the first stage they present all the technical documentation with support scientific, administrative, human resources, economic and environmental (Kpsang, 2016; NREL, 2017). Characteristics which are evaluated in each proposal submitted are described following:

a) Geoscientific studies

The studies carried out must show very good, well documented and robust evidence for indicating appropriate drill sites in geothermal area of investor-developer (Noorollahi et al., 2007; Ndirangu, 2013). The geochemical, geologic and geophysical studies must show extensive application for 3D conceptual model construction. The proposal must include entire design of the well drilling, such as completion depth, casings cementation, testing programs etc., among others. The main objective of these studies and exploratory drilling are for confirming geothermal reservoir existence. A general scheme of different geoscientific studies which help for sites location select for drilling start and well design with its target depth, is shown in Figure 6.

b) Technical visualization

An overall visualization of the proposal must show, detailed plan of the general project and understandable, including: main objective, scope, duration time, cost, human resource, bussines plan, monitoring and evaluation. Additionally, must consider general site characteristics, its diagnosis analysis on the feasibility within the project and simultaneous activities during drilling.

c) Local and national benefits identification

According with Mexico needs and resources, the proposal must consider importance of the project within the framework of the national electricity market and its compatibility with development program 2018-2032. Similarly, it is necessary that proposal considers local effects of the project such as combined heat and power, rural electrification, project benefits for communities, employments, etc. among others.

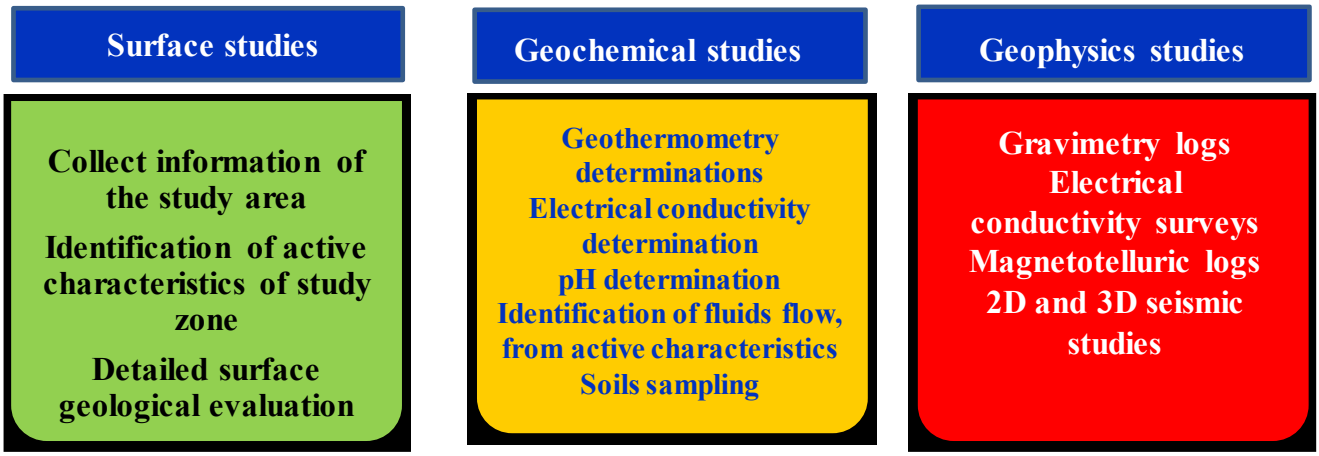

Figure 6. Different geoscientific studies which help for taking decisión the sites location for drilling exploratory wells, with its design and target depth.

d) Permissions and financing plans

In this step is analyzed backing documentation shown by investors-developers related to appropriate authorizations for drilling activites, federal and local licences for carry out activites of the project. Must be considered permits, licences, rights in place or under negotiation ant thoroughly present, robust, feasible and adequate financing plan for drilling program budget. A necessary requirement is to show authorization from "Secretaria del medio ambiente y recursos naturales" (SEMARNAT) the Environmental Impact Manifestation (MIA) in order to prevent and restitute zone conditions before any project.

e) Experience

Technical personnel of the group must show at least ten years of professional experience in geothermal development projects. Additionally, the Enterprise have to show evidence documents supporting experience of at least three years in electric energy generation from geothermal resources.

f) Environmental and social details

Investor-developer must to show robust and documented evidence of all the possible impacts and environmental and social risks could cause the project and its mitigation plans (Simiyu, 2016). Evaluation of this aspect is focused to consider design and methodology used for incorporate communities and introduce the project goodness for helping their development. Presented documentation must show evidence of a solid professional team charged for carrying out environmental and social mitigation plans.

5. DISCUSSION OF RESULTS

The major owner (CFE) of geothermal zones with generation electricity capacity in México, started last geothermal power plant in 2001 (“Las Tres Vírgenes”). In recent years (2015) a private investor started up power plant for electric generation in "Domo de San Pedro" geothermal field. IDB efforts are focused to support financial in order to reactivate exploration in new geothermal zones.

Consortium IDB-SENER-NAFIN-INEEL designed a fair process, described in PGM, in order to select those investors-developers with permissioned or concessioned geothermal zones by SENER, for being finance support subjects. The selection process takes into account the different characteristics present in a geothermal development Project, such as, technical, finance, environmental and social. Basically, finance support offered by PGM is focused to new geothermal zones development, whose provisional owner is the investor-developer by permission agreed by SENER.

However, it is main to emphasize that from “Reforma Energética” established by Mexican government started auction rounds for geothermal zones. Due to CFE is the original owner of Mexican geothermal fields, has have priority for choosing them from the first opportunity. Afterward Investors-developers participated in later auctions. From results of the different auctions carried out, SENER given permissions to investors-developers for doing exploratory activities in bidding zones. Under this way CFE has exploratory permissions given by SENER of a total 13 geothermal zones in México. In subsequent auctions rounds SENER given exploratory permissions of 14 geothermal zones to applicant investors.

The financial support of IDB related to risks mitigation of drilling exploratory Wells is focused for giving opportunities to investors in order to develop a new geothermal zone, due to uncertainties that appear in the first project stages. It is of main importance that winner investor-developer has a clear knowledge of the reservoir in his permissioned zone in order to give an appropriate well design to driller which has been resulted winner in the “Licitacion” process.

The driller of the well is the responsible of to follow exactly the well drilling design, given by investor, of measurements, tests and its successful completion. If the drilled well does not resulted with attractive geothermal characteristics for energy generation, the cost is absorbed by IDB and, the drilling equipment is moved to next selected location by investor. The PGM establishes that investor has the benefit of select until three locations for well drilling exploratory. An important aspect of the PGM is that investor only will pay those wells which result with characteristics for energy generation. The financial program estimates 15 years for the pay with low rates interest. Another benefit of the PGM, to investors is that drilled wells allows to know directly the reservoir conditions in their permissioned zone, in order to apply development plans for its energy recovery.

6. CONCLUSIONS

The PGM is financed by IDB; through the consortium IDB-SENER-NAFIN INEEL, looking for reactivation of exploration in new geothermal zones in order to increase generation capacity of renewable energies in México.

The IDB financial support is designed for allowance to investors which have geothermal permissioned zones by SENER, power plant construction for electric generation. Through PGM, IDB gives financial support for the drilling, of until three exploratory wells in locations indicated by investor in its permissioned zone which could contain a geothermal reservoir with high possibilities for the project development.

IDB through PGM launched a called for drilling services of geothermal wells ("Licitación") and for field investors-developers ("Convocatoria").

In this work it is shown that selection process for drillers was focused in analyze those that offer the lowest prices for drilling geothermal wells up to 3500 meters depth and most senior experience. Besides, selection process included a detailed analysis of technical and administrative components related with drilling activities of geothermal wells. In relation to equipment parts must be mention: drilling rig capacity, power, accessories availability, rotary, hydraulic and control systems. Regarding logistic resources, is analyzed professional and technical staff experience, financial stability of enterprise and its reliable management.

The call for field developers was focused to those having permissioned or concessioner zones by SENER. INEEL designed an evaluation pattern for applicants of "La Convocatoria" which considers: Solid backing of geoscientific studies developed in their permissioned zone, drilling wells program; Complete design of the project considering National development plan; Applications for economical develop of nearby communities; Environmental protection; Business experience and its professional and technical staff skills.

IDB through PGM announces that absorbs the risks of drilling costs in cases of exploratory wells failed, so the investor is released of any debt. If the well results successful, investor has an authorized credit through financing for paying it to 15 years.

However, in cases of failed wells, these could be applied for alternative geothermal uses. Besides drilled wells allows knowing directly the reservoir conditions in order to apply development plans for its energy recovery.

It is important to consider that efforts of the designed PGM by IDB, are useful looking for beneficiate the geothermal development in México.

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