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Economic Comparison of Build Geothermal Power Plant Iran and El Salvador

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ABSTRACT

EL Salvador is the smallest and the most density populated country in Central America while Iran is the second largest country in the Middle East in a region that is very different from El Salvador. Also these two countries are different in terms of energy sources. El Salvador is already producing 204 MW of electricity from geothermal resources while Iran has the fourth largest fossil fuel reserves and the largest natural gas reserves in the world and is planning its first pilot geothermal power plant. This study gives an overview of the current conditions in these two countries and their differences. It was also carried out with the aim of finding out the challenges towards construction cost of geothermal power plants to promote geothermal energy in these two countries.

1. INTRODUCTION

Iran has one of the biggest fossil fuel reserve in the whole world. Iran's energy mix is dominated by fossil fuels which satisfy around 98.5% of Iran's total primary energy demand (Figure 1). The remaining 1.5% come from a combination of hydropower, biofuels and other renewable sources as well as nuclear (BP, 2018). While El Salvador is the largest producer of geothermal energy in Central America and only 25% of its energy consumption comes from fossil fuel sources and the rest 75% is renewable resources (32% of the hydropower, 30% of geothermal, 10% biomass and 3% of photovoltaic) (UT, 2018).

In El Salvador the share of the renewable energy in the generation of electricity, is remarkably higher than Iran and renewable energies are now the principal source of electricity generation in El Salvador.

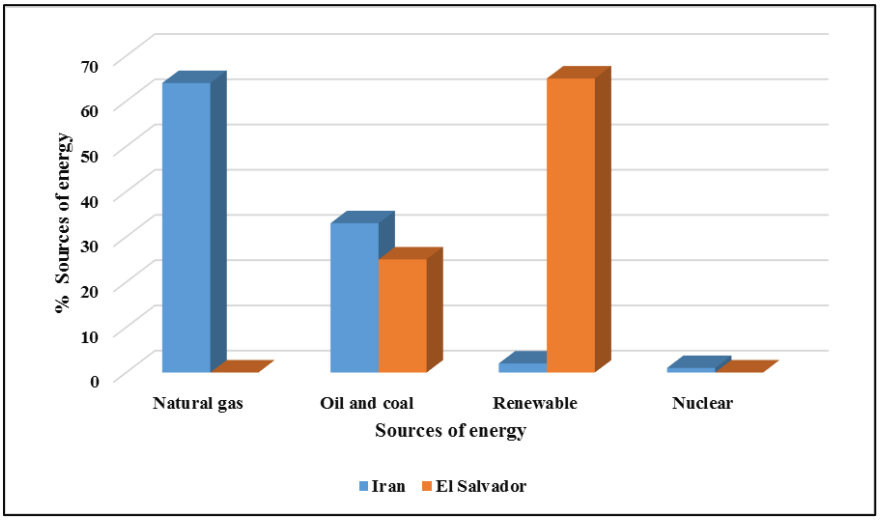

Figure 1: Comparison total primary energy consumption between Iran and El Salvador (BP, 2018 and UT, 2018)

Iran's average wholesale electricity tariff is 0.03 U.S. Dollar per kWh for households which makes the electricity tariffs in Iran among the lowest in the world compared to e.g. 0.25 U.S. Dollar per kWh electricity for households in El Salvador (Globalpetrolprices.com, 2019). In Iran the price of gasoline is 0.29 USD per litre while in El Salvador it is 0.91 USD per litre (Globalpetrolprices.com, 2019).

It should be considered that in countries like Iran with abundant and cheap fossil fuels although power generation from renewable energy is not economically beneficial, it will be achieved some other benefits by approaching to use more natural resources capacity. First: A reduced domestic demand for fossil fuels will yield in an increased competitiveness in global energy markets. Reduced domestic demand will allow Iran to export more of its reserves of oil and natural gas to client states abroad.-Second: reducing domestic fuel use will allow the government to ease its costly subsidies while simultaneously meeting growing electrical demand through more sustainable and cost-effective renewable energy sources (MEI, 2016).

El Salvador does not have similar fossil resources of Iran and imports roughly 30% of the country's fuel requirements for electrical production. Therefore the Salvadoran government wants to expand the country's natural resource capacity in order to decrease fossil fuel dependency. In 2007, the Salvadoran government passed Decree 462 which grants tax breaks to companies who develop renewable energy projects and 10 years of import tax exemption to machines and equipment. In addition, the Salvadoran Government released their 2010-2024 National Policy and hopes to modernize and expand the country's natural resource capabilities in order to increase the contribution of these energy sources to the national energy supply (Privacyshield.gov, 2019).

2. GEOTHERMAL ENERGY IN EL SALVADOR AND IRAN

The exploration of geothermal resources in El Salvador began in the mid-1960s. Geothermal reconnaissance in the country provided 18 areas classified as low- and high-enthalpy areas. The geothermal energy production in El Salvador dates back to 1975, with the first 30 MW Unit in Ahuachapán and has been one of the main sources of electricity in the country, supplying up to 41% of the national electricity demand in 1981. Since 1996, Comisión Ejecutiva Hidroeléctrica del Río Lempa (CEL), the National Electric Utility Company, has embarked on projects to recover and expand geothermal electricity generation, all in the midst of wholesale reform of the electricity legislation and regulation. Geothermal generation now competes favorably with other energy sources in an open market. Today, there are two geothermal fields in operation: Ahuachapán and Berlin with an installed capacity of 95 MW and 109 MW, respectively. The geothermal resources provide 25% of the electricity needs of the country. The country is in the process of developing geothermal energy projects in the areas of San Vicente and Chinameca, where drilling is being undertaken to confirm the resource. Exploitation is scheduled in San Vicente and currently temperatures of about 250°C and 230°C have been experienced (Guidos and Burgos, 2012).

In Iran exploratory, injective and descriptive drilling projects has been started in 2002 for further identification of potentials in Meshkinshahr in the same year. The first phase of this project has been completed in year 2004 and three exploratory and two injective wells were drilled, two out of three exploratory wells were successfully tested. Second phase of the project has been also started since 2005 and the main activities performed under this phase are as follows (SATBA, 2019):

- Completing the production, descriptive and injective drillings – making 11 geothermal wells ready for operation with a total depth of 26 745 m.
- Starting the activities regarding field development project and construction of geothermal power plant and tendering for 5 MW pilot plant and the testing of the wells.
- Preparing the drawings of a preliminary phase of geothermal atlas of Ardebil Province.
- Preparing the master plan of different types of direct applications of geothermal energy in Meshkinshahr
- Preparing a three dimensional geologic model of Meshkinshahr
- Performing the environment monitoring and improvement studies of Meshkinshahr geothermal power plant
- Performing the construction geology studies and preparing the relevant map for Sabalan area and hydrological studies for this region.

3. INVESTMENT IN GEOTHERMAL ENERGY

3.1 Iran

In order to start constructing a renewable energy power plant in Iran, an applicant should request for permission. Application form included project information such as location and estimated capacity of the plant to be submitted to Renewable Energy and Energy Efficiency Organization (SATBA).

SATBA will verify the information and issue a construction permit to the applicants. After issuance of the construction permit, the applicant shall obtain other necessary permits such as environment preservation, grid connection and land permits. Thereafter, a power purchase agreement would be signed with SATBA. The project company (Seller) is required to periodically submit progress reports to SATBA. SATBA controls and supervises the construction, and coordinates the grid connection tests and inspections through the Iran Grid Management Company. The plant must be commissioned within 18 months of the conclusion of the power purchase agreement, otherwise the tariff in force at the time of commissioning will be applied, rather than the tariff in force at the conclusion of the power purchase agreement (WFW, 2016). On the implementation of the legal obligations of Iran's ministry of energy, the guaranteed electricity purchase feed-in tariff for geothermal are notified as follows (Table 1):

Table 1: The guaranteed electricity purchase tariff for geothermal energy (SATBA, 2019)

Technology type	Guaranteed purchase tariff (IRRs/kWh)	Guaranteed purchase tariff (UScents/kWh) 2016	Guaranteed purchase tariff (UScents/kWh) 2019
Geothermal (including excavation and equipment)	4900	16	12

The currency of payment under the guaranteed power purchase agreement (PPA) is the Iranian Rial (IRR), where the power price in IRR have remained unchanged since 2016 but the IRR has depreciated in value against the dollar in the last years (WFW, 2018). This PPA agreement is for a 20 years' period with the specified tariffs. Tariffs will be multiplied by 0.7 after adjustment of article 3 of

Economic Council Directive starting from the first day of the second of 10 years until the end of the contract. The power plant for different types of biomass and small hydro power has to be constructed and operated within 30 months since the notification of the contract. Tariffs will be proportionately increased up to 30% in accordance with the instructions under article 6 of Economic Council Directive, for power plants constructed using local equipment, technologies know-how, design and manufacturing (SATBA, 2019).

The present policy seems to be unfavourable to attract private sector participation. This is evident in the presence of no field developers since geothermal exploration begun in the Iran.

3.2 El Salvador

In El Salvador the generation units participating in electricity market must be registered in the Registry of Electric Sector Operators coordinated by Superintendencia General de Electricidad y Telecomunicaciones (SIGET) and will be subject to compliance with the current Environment Law.

Geothermal and hydroelectric projects, SIGET will grant concessions, which establish conditions of use of resource, for a maximum period of fifty years. Legal frameworks have been developed to encourage investments in electricity sector. For example:

Law of Tax Incentives for the Promotion of Renewable Energies: This law search to use rational resources; decrease dependence on fossil fuels, reduce environmental pollution, reduce greenhouse gas; use energies renewable in power generation; promote investments for development of electricity generation projects with renewable sources such as geothermal, wind, hydroelectric, solar or biomass; and promote research to exploration and development sustainable projects. Law applies to activities related to new investments or construction of generation power plant. Tax incentives are applied as exemption taxes import and rent whose details are presented below (JICA and CNE, 2012):

- During the first 10 years, developers will have tax exemption for the import of machines, equipment, materials and storage used exclusively in previous investments or construction of power generation plants including installation of transmission and distribution cables;
- Exemption from import tax payment applies to projects up to 20 megawatts (MW) and must be requested to the Ministry of Finance 15 days before the import of the machinery, equipment, materials and necessary storage for uses exclusively for the purpose of the project in question. For this purpose, it will be mandatory to prepare the Project documents with a designated format by SIGET.
- It is allowed to have tax rent exemption for 5 years in the case of projects with power between 10 MW to 20 MW and for 10 years in the case of smaller projects that do not exceed 10 MW. The law begins to apply from the first fiscal year in which the operation begins and generates income.

Special Law on Public-Private Partnerships: Promotion of project development through Public-Private alliances for provision of infrastructure and public services.

Investment Law: This search equal treatment for national and international investors, free transfer abroad of benefits and dividends related to investment and access to local funds (JICA and CNE, 2012)

List Merit and Dispatch of Generating Units: The generating units are sorted in a list of merit in ascending order based on their variable costs, thus seeking to minimize the total operating costs. This means that, depending on the hourly energy demand, the units with the lowest variable costs are being called to inject until obtaining a generation level that allows supply levels to be met. The last unit to be dispatched in each hour will be the marginal unit, and its variable cost will establish the Marginal Operating Cost (CMO) of said hour, that is, the cost with which the energy will be remunerated in that hour.

Currently, in El Salvador, the energy matrix is composed of geothermal energy, biomass, hydroelectric power, thermal energy and photovoltaic energy, in addition to including imports resulting from transactions in the Regional Electricity Market (MER). Current order merit list is illustrated in the figure 2. Are two type variable cost one is variable cost combustible and variable cost not combustible. Geothermal power plants, biomass, and non-conventional renewable energies (solar and wind), their value in merit list is null or practically null compared to thermal power plants, because they do not use fossil fuels as primary source. However, for this technologies noncombustible variable cost is between 4 and 10 $ / MWh (UT, 2018).

El Salvador works under the figure of the Regulatory Market of the System, whose objective is to allow generators to buy energy to supply their contracts if they have not been able to supply the contracted energy with their own generation. In addition, those generators whose dispatch is greater than their commitment in contracts, can sell their surpluses in the System Regulatory Market.

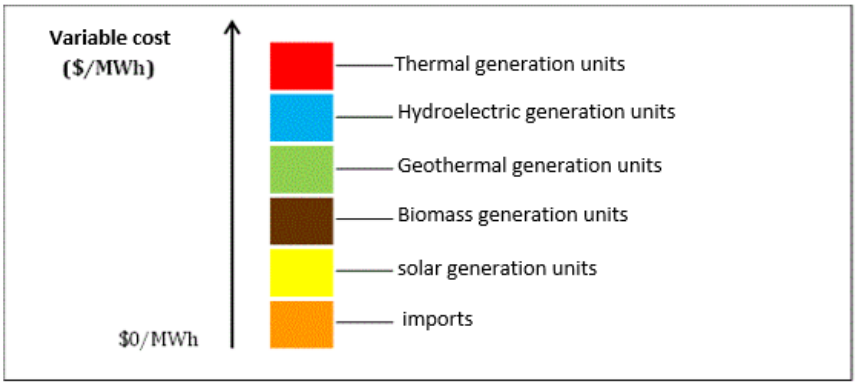

Figure 2. Merit List Order (UT, 2018)

As we mentioned earlier, the price of energy in the MRS is established by the marginal unit in each hour and corresponds to its variable cost. The energy not committed in contracts will be remunerated at the Marginal Cost of Operation (CMO) of each hour, for 2018 this cost was about $112.87/MWh (UT, 2018). Various elements make up the price structure of the Wholesale Electricity Market of El Salvador. This are:

- **System Charges (SC):** Salvadoran legislation establishes that, in order to take energy from generators to consumers, certain fees, known as system charges, must be paid. Most of these are fees of the entities in charge of administering and operating the system. This cost is around 13.14 $/MWh (UT, 2018)
- **Power Payment (PP):** The remuneration of the payment by power is equivalent to a price that is equal to the sum of the annuity of the investment cost, plus fixed costs of Operation and Maintenance of leading generating units, that is to say units that are marginal in the office. The calculation of the payment by power is determined by the SIGET every 5 years, and the value is periodically reviewed. This is around US$7.66/kW-mes UT, 2018)

The total amount equivalent to a single price for the sale or purchase of energy and power and is called, Monomic Price of energy (1)

(1) Monomic Price of energy**: CMO+ SC+PP**

4. COST ESTIMATION OF CONSTRUCTION A GEOTHERMAL POWER PLANT

The primary stages of a geothermal developmental cycle are exploration, resource confirmation, drilling and reservoir development, plant construction and power production. So, these four phases of a geothermal energy project will be used as a baseline plan for the feasibility models presented in this study:

1. Exploration and Confirmation cost;
2. Drilling cost;
3. Power Plant cost;
4. Operation and maintenance cost.

The capital cost for geothermal power plants are different from plant to plant and are depending on the resource chemistry, technology, and temperature employed. The majority of the overall cost is typically attributed to construction of the power plant, due to the high cost of raw materials including steel (46.6% of the total cost). The second highest cost intensive processes are the exploratory and production drilling stages, which together comprise 42.1% of the total cost. Low-temperature reservoirs typically use binary power plants, while moderate- to high-temperature reservoirs employ dry steam or flash steam plants, based on whether the production wells produce primarily steam or water, respectively (Cross and Freeman, 2008).

Capital cost for geothermal power plant includes exploration and confirmation, drilling and power plant costs. Most of the estimations are based on related literature, which present average cost figures. Table 2 shows a summary of costs for a 50 MW power plant in these two countries and Figure 3 illustrate the breakdown of the total capital cost. The “pilot” station in the northwest Iranian province of Ardabil is expected to have an installed capacity of 50 MW so this capacity is selected for this study.

Table 2 illustrates drilling cost in Iran is more expensive than El Salvador (around 30% more expensive) because its demand is very high compared to El Salvador and also there is competition by oil and gas. In addition to drilling cost exploration and power plant costs in Iran are more expensive than in El Salvador. In El Salvador exploration cost around 45% is cheaper than in Iran because they have more technical experience in this topic and in El Salvador, the role of government, in the feasibility and exploratory phases, is critical since private companies are taking on the high up-front costs associated with these phases. It is the key in securing funding from development banks and friendly organization to exploit geothermal resources.

Table 2: Estimated cost of a 50 MWe geothermal power plant

Power plant capacity (MW)	Category	Cost (million USD)- Iran (saber, 2016)	Cost (million USD)- El Salvador (Henriquez, 2018)
50	Exploration and confirmation	17.3	9.8
	Drilling	144	106
	Power Plant	108.08	92.60
	Contingency	16.79	27.5
	Capital cost	286.16	235.9
	Capital cost per MW	5.72	4.7
	Operation and maintenance(every year)	3.94	3.5

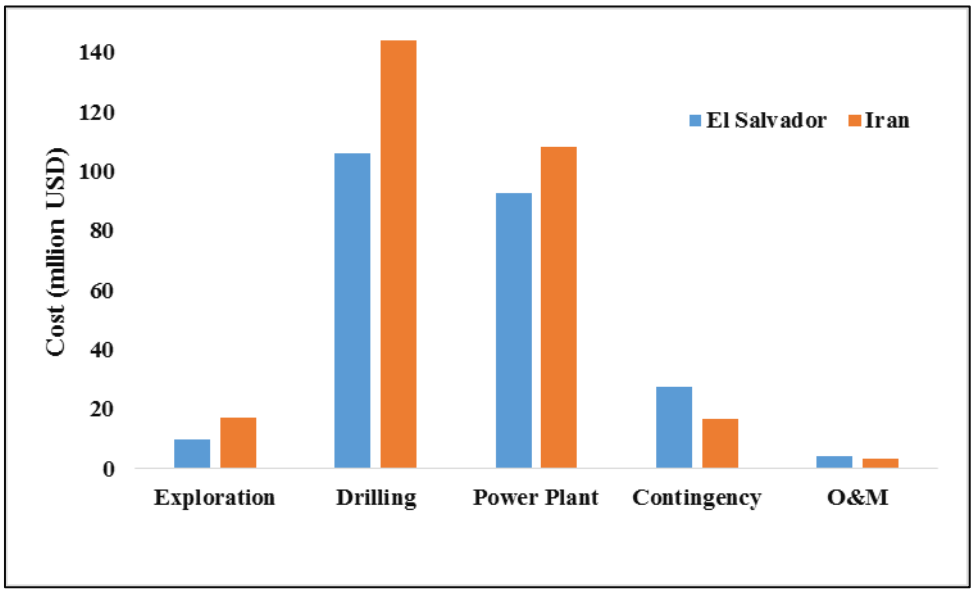

Figure 3: Breakdown of the total capital cost for 50 MW

5. BARRIERS TO THE DEVELOPMENT OF GEOTHERMAL RESOURCES

Development of a geothermal resource has a high cost of research and risk, as the resources to be found in the depths of the earth by means of surface studies and drilling wells. This implies a high risk for developers and investors and it becomes difficult for private developers because they require a high initial investment, mainly in the area of potential exploration sites (Guidos and Burgos, 2012).

5.1 Iran

Geothermal power development projects in Iran are not very attractive for private investors when considering the project cost of exploration and confirmation, drilling in an unknown field, and building a power plant with current electricity tariffs. In order for geothermal power development projects to be successful in the real world the price of electricity in Iran would have to increase at least to 24 U.S.cents/ kWh or drilling cost have to be comparative to costs elsewhere in the world. It would have to decrease at least to USD 1600 /m. These are some of the problems, but they could be solved through the determination and will of the Government of Iran (Saber, 2016).

5.2 El Salvador

The major difficulty of this type of projects is obtaining concessions and EIA approvals. This results in a delay in developing such projects. Typically, this increases the costs of implementation, and may limit the opportunity for undertaking the work. Usually, difficulties in obtaining a response from the institutions have been experienced. Despite the negative impacts of fossil fuels and greenhouse gases, gaseous fuels and import of non-native, thermal energy, these projects face environmental paperwork easier than renewable projects. In El Salvador, this occurs because many institutions such as the MARN do not have departments that specialize in renewable energy projects.

The opposition to the development of geothermal projects is closely associated with the opposition of mines, and environmental groups by the negative impact that may occur to the environment. Therefore this requires arduous negotiations with the communities. However, well designed and managed geothermal projects have little impact on the environment (Guidos and Burgos, 2012).

6. CONCLUSIONS

El Salvador is the no. twelve geothermal energy producer in the world (Lund and Boyd, 2015). Geothermal power in El Salvador represents 30% of the country's total electricity production. In Iran the power sector need to be restructured to develop private sector's participation in construction of geothermal power plant as capital investment cost for geothermal power plant is one of the major obstacle. Important factors that depend on governmental support could help to generate a positive impact on profitability and risk of the investment include: Reducing drilling costs, improved tax incentive laws, large period energy contracts, and public funds for exploration and confirmation phases.

Exploitation of the existing geothermal resource in Iran, it could stop consuming part of its fossil fuel reserves, which could protect the sustainability of its long-term resources, or it could expand its sold market at a higher price at international market. Reduced domestic demand will allow Iran to export more of its reserves of oil and natural gas to client states abroad.

By Considering EL Salvador as a pioneer country in power generation from geothermal resources, Iran could follow their road Map:

1) In El Salvador the role of government in the feasibility study and exploratory phases, is the key in securing funding from international development banks and local organization and private investors to use geothermal resources. Deregulation of this sector causes geothermal energy becoming a competitive energy source for generation of electricity.

2) In Iran the government has implemented laws guaranteeing power purchase for a period of up to 20 years while in El Salvador geothermal projects the government will grant concessions for a maximum period of fifty years.

3) In El Salvador there is tax exemption when importing equipment for electricity generation while in Iran there is no such tax incentive. For the power plant studied in the previous section, around 10 million USD was related to customs clearance and handling costs tax.

4) In addition to the items mentioned, some financial parameters are also different, which affect the results. For example, discounting and loan repayments.

REFERENCES

BP: Statistical review of world energy ,68th ed., (2019), 64 pp.

Cross, J., and Freeman, J.: 2008 geothermal technologies market report, US Department of Energy, report DOE/GO-102009-2864, (2009).

Globalpetrolprices.com: Gasoline prices. Globalpetrolprices.com, website: www.globalpetrolprices.com/gasoline_prices/, (2019).

Guidos, J., and Burgos, J.: Geothermal Activity and Development in El Salvador – Producing and Developing. *Papers written for Short Course on Geothermal Development and Geothermal Wells, organized by UNU-GTP and LaGeo, Santa Tecla, El Salvador*, (2012).

Henriquez J.: Estudio de factibilidad técnica y Económica de las plantas geotermoeléctricas [Study of technical and economic feasibility of geothermal power plants] Presentation at Diploma course for Latin America organized by UNU-GTP and LaGeo, in Santa Tecla, El Salvador, (2018), 32 pp.

JICA and CNE: Plan Maestro para el Desarrollo de Energías Renovables [Master Plan Development of Renewable Energies], Agencia de Cooperación Internacional del Japón and Consejo Nacional de Energía, (2012), final report 3-31 pp.

Lund, J.W., and Boyd, T.L., 2015: Direct utilization of geothermal energy 2015, worldwide review. *Proceedings of the World Geothermal Congress 2015, Melbourne, Australia*, 31 pp.

MEI: Iran's renewable energy potential. Middle East Institute – MEI, Washington DC, Website: www.mei.edu/content/article/iran%E2%80%99s-renewable-energy-potential#_edn6, (2016).

Privacyshield.gov: El-Salvador-Renewable-Energy,website: www.globalpetrolprices.com/gasoline_prices/, (2019).

Saber, N.: Feasibility of private sector's participation in geothermal power generation in Iran. Report 37 in*: Geothermal training in Iceland, 2016*. UNU-GTP, Iceland (2016), 797-816.

Satba: Investment (power plants), SATBA – Renewable Energy and Energy Efficiency Organization, Website: http://www.satba.gov.ir/en/investmentpowerplants, (2019).

UT: Unidad de Transacciones, Website: https://www.ut.com.sv/, (2019).

WFW: Renewable energy in Iran, May 2016. Watson Farley & Williams, briefing, (2016), 6 pp.

WFW: An update on renewable energy in Iran, April 2018, Watson Farley & Williams, briefing, (2018), 6 pp.