Proceedings World Geothermal Congress 2020+1
Reykjavik, Iceland, April - October 2021

Current Status of Geothermal Development in Honduras

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ABSTRACT

The use of geothermal resources in Honduras is currently developing significantly. At a national level, there are sites with potential for low, medium, and high temperature, which can be used for direct use and generation of electricity.

In 2017, the first electric power generation plant in Honduras came into operation with a capacity of 35 MW, and it is located in the western part of the country. This plant is currently delivering to the National Interconnected Grid an average of 25 GWh of electricity per month. It provides benefits such as the introduction of stable renewable energy to the national electricity system, diversification of the energy matrix, and utilization of the potential of renewable resources that had not been used.

Likewise, some international cooperation is directly supporting and promoting the use of geothermal resources in the country. This support is being done through specialized training in the geothermal issue and preparation of a regulatory framework that encourages investments in geothermal energy. A process for the emission of a geothermal energy policy is being prepared, with the objective to establish the strategic lines for the development of renewable geothermal resources in a sustainable manner. There is also an initiative to update the potential geothermal mapping around the country and the Central American region, as well as the analysis of the investment climate and barriers and opportunities of geothermal energy in Honduras.

Currently, research has been carried out, which has identified the development of pilot projects for the use of geothermal resources of low and medium temperature for direct uses. It focused on the sustainable development of communities and with an orientation to encourage the local production and socioeconomic development of the less benefited areas of the country.

1. INTRODUCTION

The world is moving toward an era of high costs of energy supply, which requires an adaptation of policies and country strategies. It has not only greatly increased the monetary costs but also environmental costs and social and political impacts. This is the result of many factors. First, the enormous increase in global energy demand, driven by continued population growth and economic development, while the rate of discovery of new energy deposits has declined.

Environmental costs have also increased as the environment's capacity to absorb effluents, and emissions have become largely saturated from the processing and end-use of energy. Environmental impacts include those caused by particulate matter, acid rain, and greenhouse effects. These impacts result in climate change, to which developing countries are most vulnerable because they lack the infrastructure and facilities to accommodate new circumstances. This results in costs in terms of public health, permanent damage to ecosystems, and risks to the safety of goods and people.

Honduras is also exposed to socio-political risks for its heavy reliance on imported energy, with obvious effects on the balance of payments and the risk of supplying disruptions by geopolitical events. This situation will not change much, even when taking advantage of the full national energy potential.

Considering all the above, this paper presents the Honduras current status of using geothermal natural resources for the generation of electricity and direct-heat uses. Highlighting these possibilities is important for promoting further development of geothermal resources in Honduras and, thus, taking advantage of the geothermal potential at different sites around the country.

2. BACKGROUND

In 1976 began the geothermal development in Honduras, the United Nations, in conjunction with experts from several countries, carried out a study. Thanks to the support, the study of thermal manifestations was done, in which were identified the areas of interest for the development of geothermal energy in Honduras.

Through the years, the government of Honduras requested various technical and financial supports to international organizations for further geothermal development. So that in 1985, USAID offered its collaboration for improving the status of geothermal development in the country. A deeper study was conducted through Los Alamos National Laboratory with the following objectives: Defining a master plan for national geothermal development; Pose an alternative to geothermal power generation; and Continuing investigations of the geothermal resource at a national level (Henriquez, 2011).

Geothermal research and wide recognition in Honduras were made at five sites (Platanares, San Ignacio, Azacualpa, Pavana, and Sambo Creek). Currently, the National Company of Electricity has carried out geological and geochemical studies for identifying new sites for the geothermal development for electricity production. These sites are El Olivar, Namasigue, and La Barca (Table 1).

According to geological and geochemical results obtained, Platanares was selected based on the temperature gradient, and three wells were completed to depths ranging from 428 to 679 m. The geothermal team, Los Alamos / USGS, presented a report to ENEE, recommending geothermal assessment feasibility levels in this area.

Various private companies' investors have been making efforts for developing geothermal power plants, but the country barriers have limited the execution of these projects. Until 2017 the first geothermal plant in Honduras started up, in 2018, the geothermal electricity generation represents the 3% of the energy matrix in Honduras (Figure 1).

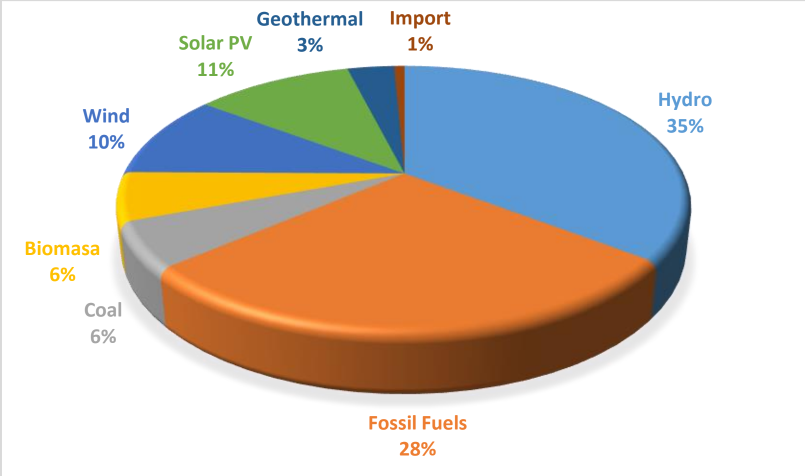

Figure 1: Generation by Sources, 2018

N.	Project Name	Location	Temperature C° Geoghemical	Water Clasification
1	Platanares	Santa Rosa de Copan	225	HCO_{3}-NA
2	San Ignacio	Francisco Morazán	190	HCO_{3}-NA
3	Azacualpa	Santa Barbara	185	SO_{4}-NA
4	Pavana	Choluteca	170	SO_{4}-NA
5	Sambo Creek	La Ceiba	155	SO_{4}-NA
6	El Olivar	Cortes	170	HCO_{3}-NA
7	Namasigue	Choluteca	185	CL-NA
8	La Barca	Cortes	185	HCO_{3}-NA

Table 1: High-Temperature Hot Spring, ENEE 2019

2. LEGAL FRAMEWORK

Honduras currently has legal instruments to encourage the use of natural resources for sustainable energy purposes. This is with the aim of promoting investment, but in an appropriate manner, guaranteeing the country's sustainable development and the contribution of climate change mitigation.

General Law on Electrical Industry (Decree No. 404-2013): the main objective is to regulate the activities of generation, transmission, distribution, and commercialization of electricity in the national territory; the importation and exportation of electrical energy, in accordance to what´s stablished in the International Treaties on the matter, subscribed by the country; the national electricity system operation, including the relationship of the neighboring countries' electricity systems, with the electricity system and the regional Central American electricity market.

Law for the Promotion of Renewable Energy Generation (Decree No. 70-2007): the main objective is to promote public and private investment on national renewable electrical energy.

Climate Change Law (Decree No. 297-2013): the main objective is to establish the necessary principles and regulations to plan, prevent and respond to the climate change impact in the country in an adequate, coordinated and sustainable form. In the same way, its purpose is to adopt practices oriented to reduce environmental vulnerability and to improve the adaptation capacity. That allows developing prevention and mitigation proposals in response to the effects produced by climate change.

General Law on the Environment (Decree No. 104-93): the main objective is to protect, conserve, restore, and sustainably manage the environment and natural resources. These resources are of public utility status and social interest. The Central Government and municipalities will promote the rational utilization of those resources in order to allow their preservation and economic use. The public interest and common good are the foundation of every action in defense of the environment.

General Water Law (Decree No. 181-2009): Its purpose is to establish the principles and regulations applicable to the proper management of water resources for the protection, conservation, valorization and use of water resources to promote the integrated management of this resource at the national.

3. PLATANARES GEOTHERMAL POWER PLANT

In 2017, the Geothermal Project Platanares began its commercial operation, it is the first geothermal power plant through geothermal resources in Honduras, owned by the company GeoPlatanares S.A. of C.V. The project has an installed capacity of 35 MW, and is located in the Municipality of La Unión, San Andrés de las Minas, Copan La Unión Department, Santa Rosa de Copan, HONDURAS (Figure 2). This plant is currently delivering to the National Interconnected Grid an average of 25 GWh of electricity per month (Figure 3).

The geothermal project has the permits required by the government of Honduras, Operation Permit, Power Purchase Agreement (PPA), Environmental License, and Construction Permits. This project has been executed by ORMAT, which was responsible for the supply, transportation to the worksite, construction, installation, and start-up and testing of the power plant. This project has a BOT configuration (Build, Operate, and Transfer).

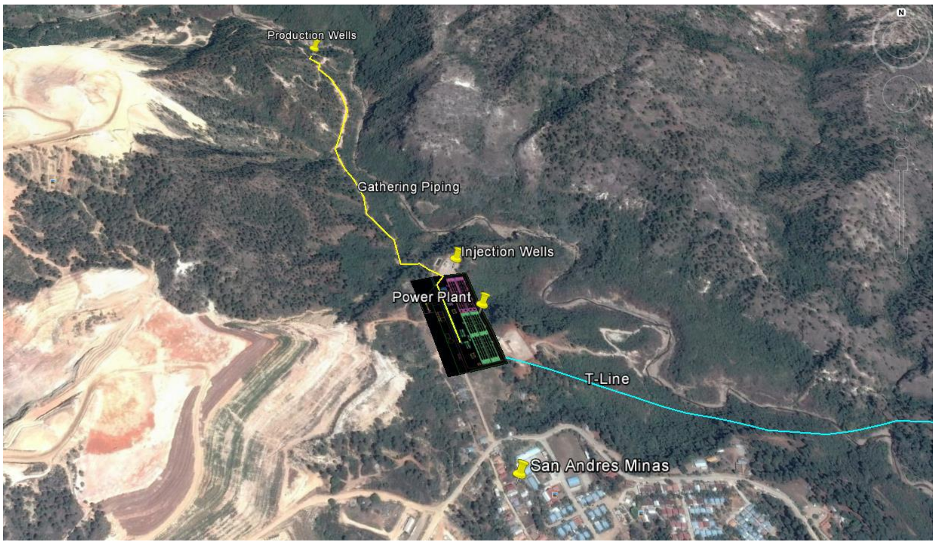

Figure 2: Platanares Geothermal Power Plant Location

Location of the site	Santa Rosa de Copan, Honduras
Minimum ambient temperature	4.4 ° C
Maximum temperature	35 ° C
Relative Humidity (RH)	85%
Annual rainfall	2,000 mm rain, without snow
Height above sea level	800 m
Barometric pressure	0.9 Bar
Wind pressure	185 kph, as Per IBC 2012
Seismic coefficient	0.25, as per IBC 2012

Table 2: Characteristics of the Platanares Geothermal Plant site

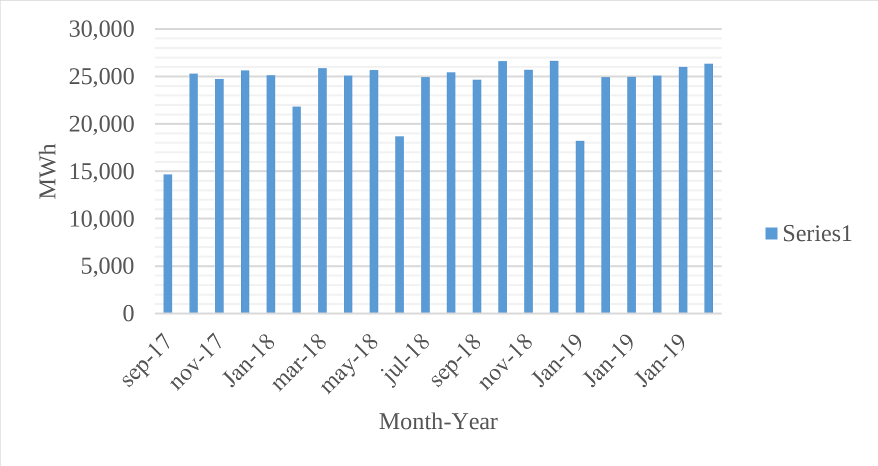

Figure 3: Electricity Generation MWh 2017, 2018 and 2019

4. COOPERATION FINANCIAL PROGRAMS FOR GEOTHERMAL DEVELOPMENT

The international cooperation has strongly supported the geothermal development in the Central American region, such as the German Agency for International Cooperation. This cooperative is implementing the geothermal development program in Central America, which includes the following objectives:

- Feasibility studies for four pilot projects on direct use of geothermal energy.
- Module on direct use of geothermal energy (2 courses for graduate students of LaGeo).
- Introductory course on direct uses in industrial applications (4 courses: 2 in Honduras, 1 in Nicaragua, 1 in Costa Rica).
- Mapping of the geothermal resources of the region.

Similarly, the Geothermal Energy Development Program is being executed "Geothermal Development Facility (GDF)" (Figure 4). It is the first multi-donor fund (KFW, IDB, GIZ, BCIE, CAF, JICA, BGR, NDF, EU, WB, among others) created to promote geothermal development in Latin America. This initiative is directly oriented to the Mitigation of Climate Change. This fund is being coordinated by the Central American Bank for Economic Integration (CABEI). This program has the following components:

Risk Mitigation Fund (RMF - KfW): This Fund is available for risk reduction in exploratory drilling. All aspects involved in the drilling phase are considered, as design and cost analysis, obtaining permits, Environmental Impact Studies for drilling, well tests, among others. This fund has a maximum availability per project of 6 million dollars, equivalent to 40% of the total investment in the exploratory drilling phase. In case of not being successful, would be non-refundable funds in full and in case of successful return of 80 % of the total loan amount. At the same time, all aspects involved in the Feasibility study phase are considered, such as project location study, loan permits, and procedures, the establishment of baseline and business models, technical exploration of the site, prospective exploration, re-evaluation of models of business, feasibility analysis, among others. This fund has a maximum project availability of 0.6 million dollars, equivalent to 40% of the total investment in the exploration and feasibility study phase, which is in the category of non-reimbursable funds in its entirety.

- Pre-feasibility studies
- Contingency subsidies for exploratory drilling and feasibility studies

Development Loan Facility (DLF – BCIE):

- Bridge financing for production drilling.
- Financing of investments in the plant station.

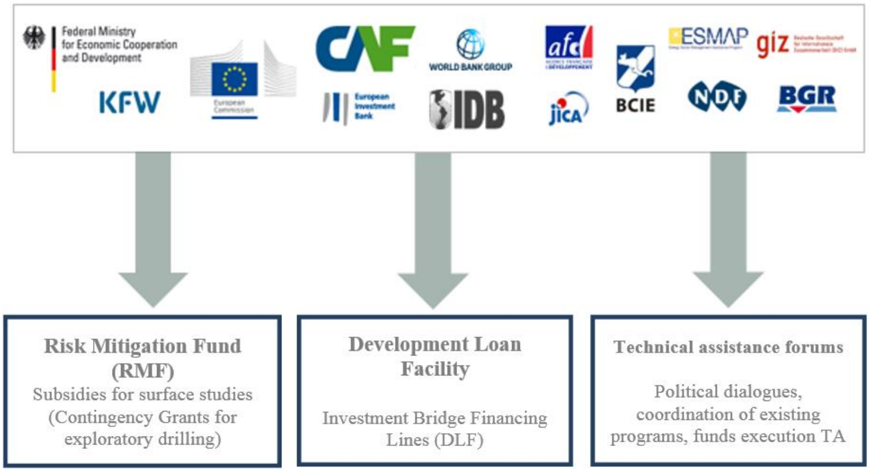

Figure 4: Scheme Geothermal Development Facility

5. INVESTMENT CLIMATE AND OPPORTUNITIES OF GEOTHERMAL DEVELOPMENT IN HONDURAS

The development of geothermal energy in Honduras implies a multidisciplinary process and joint work by all the actors involved. A study has been carried out to visualize the panorama of investment in Honduras on geothermal energy, through which several barriers have been identified that have impeded the development of geothermal energy in Honduras. Some of these barriers are political, legal, institutional, educational, technological, and social limitations. However, the existing platform has been used to create an acceptable development of the geothermal resource.

In 2018, the Ministry of Energy was created, the governing body of the national energy sector with faculties to regulate all types of energy issues, which was an important institutional barrier in Honduras. The Ministry is currently working on the elaboration of integral long-term energy policy and also working on a specific policy for the development of geothermal energy.

There is a weakness in the creation of a structured legal and technical framework for environmental and social issues for the development of renewable energy projects, specifically for geothermal projects in order to ensure the safety of developers and investors, and to reduce the appreciation of risk by the non-acceptance part of the communities to this type of project.

Financing and flexible financing programs or schemes for risk reduction in exploration and exploitation are important barriers for geothermal development in Honduras and the region. There is a need for an incentive policy for this type of investment in geothermal energy.

There is a lack of human resource capacity, specialized equipment for research, exploitation, and exploitation, drilling technologies, among other resources necessary for research and development of geothermal resources in the country.

6. PROSPECTION FOR THE GEOTHERMAL ENERGY GENERATION

The Honduras energy matrix has strong participation of hydro and biomass energy generation. These technologies currently have a high level of vulnerability to climate change, and hydroelectric energy can be affected by drought due to climate change. As well as biomass energy is affected by pests that invade forests and agricultural plantations. Such reason is considered for the scenario of substitution to geothermal energy in prospection to 2030 (Figure 6, 7) as a sustainable alternately for supplying the national energy demand growth, which is estimated around 5% annual (Figure 5).

It is important to indicate the opportunity to incorporate a non-conventional renewable energy technology (Geothermal power plants) to the National Electric Grid. This technology should meet all the technical, economic, political, environmental and financing requirements regarding the National Energy Policy, as indicated in prospection the great contribution in the energy matrix in terms of installed capacity and energy generation. The prospection has been analysed and has determined prioritizing the incorporation of Geothermal technology that generates a high level of investment, high percentage of plant factor, low risk in relation to the vulnerability of geothermal resources to climate change, generates an average price according to other renewable technologies tariff, technically is firm energy that gives stability to the National Electrical Grid, exists a national potential for promoting distributed generation and finally encourages and promotes non-conventional technologies.

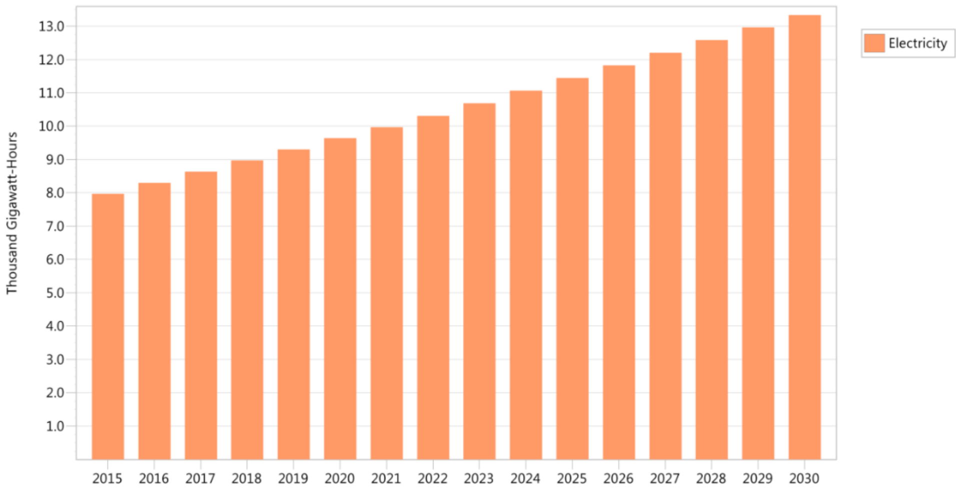

Figure 5: Demand projection of Electric Power (Trend)

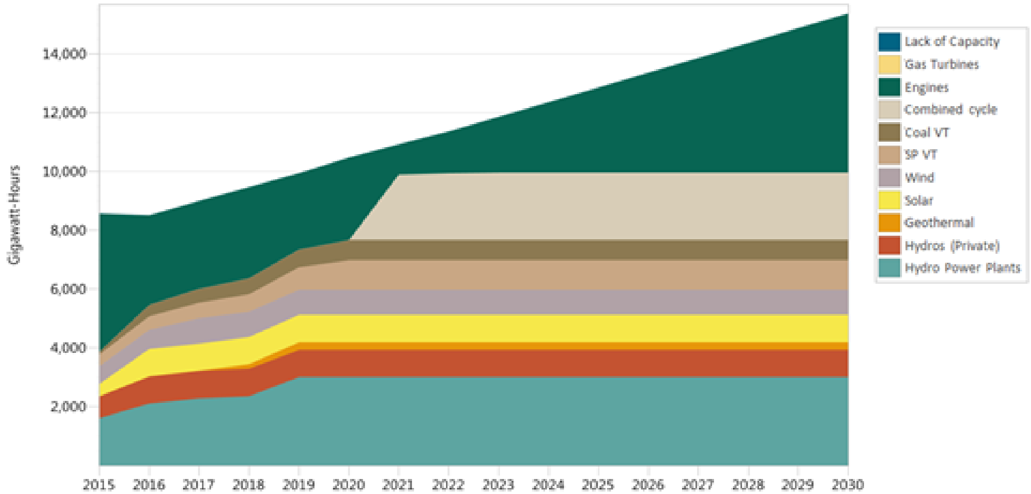

Figure 6: Projection of Energy Generated by Technology (Trend)

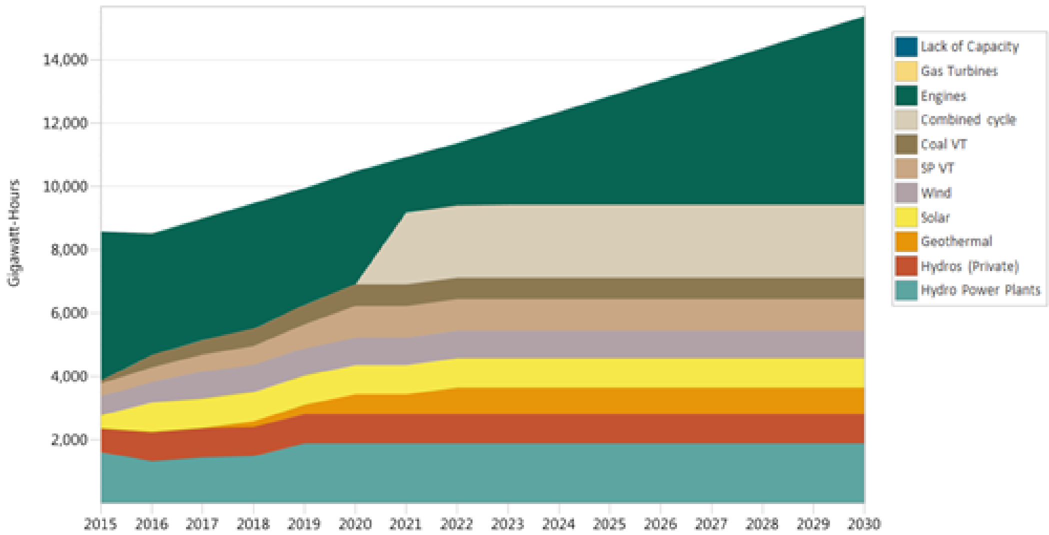

Figure 7: Projection of Energy Generated by Technology (Dry Scenario)

Added Geothermal Technology

7. CONCLUSIONS

7.1. Various technical studies conducted along with surface manifestations of hot springs show that Honduras has geothermal potential that could be used for different purposes. The country location and geological, geochemical, and geophysical characteristics illustrate this possibility. The geothermal resources of Honduras have started to be exploited, but there are different uses such as electricity production and several direct uses that have been studied and identified which may develop in different parts of the country.

7.2. 40% of the energy matrix of Honduras currently depends on fossil energy resources and 60% on renewable resources. Thus, developing the estimated 120 MW geothermal potential for the production of electricity will significantly contribute to the country's objectives with respect to increased electricity generation from renewable sources.

7.3. Honduras energy matrix has strong participation of hydro and biomass energy generation. These technologies currently have a high level of vulnerability due to climate change. Hydroelectric energy will be affected by drought due to climate change, as well as biomass energy is affected by pests that invade forests and agricultural plantations. This reason is important to establish the opportunity to incorporate renewable energy technology (Geothermal power plants) to the National Electric Grid. As a non-conventional technology that meets all the technical, economic, political, environmental, and financing requirements regarding the National Energy Policy, and also as an alternately for supplying the national energy demand growth.

7.4. Honduras currently has legal support to encourage and promote the use of renewable resources for power generation. Within the legal framework are: an energy policy including an exclusive section for the geothermal resource, a Promotion's Law of electricity generation through renewable energy, the General Law of Electrical Industry, the Climate Change Law, General Water Law, and the General Environmental Law, with the main goal for contributing for the country sustainable development and the security for the international investment.

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APPENDIX

TABLE 1. PRESENT AND PLANNED PRODUCTION OF ELECTRICITY

	Geothermal		Fossil Fuels		Hydro		Nuclear		Other Renewables (specify)		Total	
	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr	Capacity MWe	Gross Prod. GWh/yr
In operation in December 2019	35	297	1,010	3,106	710	3,249	0	0	845	2,527	2,565	9,179
Under construction in December 2019	0	0	100		150		0	0	100			
Funds committed, but not yet under construction in December 2019												
Estimated total projected use by 2020	35	297	1,110		810				900			

TABLE 2. UTILIZATION OF GEOTHERMAL ENERGY FOR ELECTRIC POWER GENERATION AS OF 31 DECEMBER 2019

1) N = Not operating (temporary), R = Retired. Otherwise leave blank if presently operating.

2) 1F = Single Flash; B = Binary (Rankine Cycle); 2F = Double Flash; H = Hybrid (explain); 3F = Triple Flash; O = Other (please specify); D = Dry Steam

3) Electrical installed capacity in 2019

4) Electrical capacity actually up and running in 2019

Locality	Power Plant Name	Year Com-missioned	No. of Units	Status[1]	Type of Unit[2]	Total Installed Capacity MWe[3]	Total Running Capacity MWe[4]	Annual Energy Produced 2019 GWh/yr	Total under Constr. or Planned MWe
Santa Rosa de Copan, Honduras	Platanares Geothermal Plant	2017	2	Operation	B	35	35	297	35
Total						35	35	297	35

TABLE 3. UTILIZATION OF GEOTHERMAL ENERGY FOR DIRECT HEAT AS OF 31 DECEMBER 2019 (other than heat pumps)

1) I = Industrial process heat — H = Individual space heating (other than heat pumps)
C = Air conditioning (cooling) — D = District heating (other than heat pumps)
A = Agricultural drying (grain, fruit, vegetables) — B = Bathing and swimming (including balneology)
F = Fish farming — G = Greenhouse and soil heating
K = Animal farming — O = Other (please specify by footnote)
S = Snow melting

2) Enthalpy information is given only if there is steam or two-phase flow

3) Capacity (MWt) = Max. flow rate (kg/s)[inlet temp. (^oC) - outlet temp. (^oC)] x 0.004184 (MW = 10^6 W)
or = Max. flow rate (kg/s)[inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

4) Energy use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (^oC) - outlet temp. (^oC)] x 0.1319 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.03154

5) Capacity factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171
Note: the capacity factor must be less than or equal to 1.00 and is usually less,
since projects do not operate at 100% of capacity all year.

Note: please report all numbers to three significant figures.

Locality	Type[1)]	Maximum Utilization					Capacity[3)]	Annual Utilization		
		Flow Rate	Temperature (^oC)		Enthalpy[2)] (kJ/kg)			Ave. Flow	Energy[4)]	Capacity
		(kg/s)	Inlet	Outlet	Inlet	Outlet	(MWt)	(kg/s)	(TJ/yr)	Factor[5)]
Valle de Sula, CORTES	I and C		80							
La Ceiba, ATLANTIDA	I, C and B		95							
Nationally	B						1.933		45	0.74
TOTAL										

TABLE 5. SUMMARY TABLE OF GEOTHERMAL DIRECT HEAT USES AS OF 31 DECEMBER 2019

1) Installed Capacity (thermal power) (MWt) = Max. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.004184
or = Max. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg)] x 0.001

2) Annual Energy Use (TJ/yr) = Ave. flow rate (kg/s) x [inlet temp. (°C) - outlet temp. (°C)] x 0.131 (TJ = 10^{12} J)
or = Ave. flow rate (kg/s) x [inlet enthalpy (kJ/kg) - outlet enthalpy (kJ/kg) x 0.03154

3) Capacity Factor = [Annual Energy Use (TJ/yr)/Capacity (MWt)] x 0.03171 (MW = 10^6 W
since projects do not operate at 100% capacity all year

4) Other than heat pumps

5) Includes drying or dehydration of grains, fruits and vegetables

6) Excludes agricultural drying and dehydration

7) Includes balneology

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]			
District Heating[4]			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5]			
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	1.933	45	0.74
Other Uses (specify)			
Subtotal	1.933	45	0.74
Geothermal Heat Pumps			
TOTAL	1.933	45	0.74

TABLE 6. WELLS DRILLED FOR ELECTRICAL, DIRECT AND COMBINED USE OF GEOTHERMAL RESOURCES FROM JANUARY 1, 2015 TO DECEMBER 31, 2019 (excluding heat pump wells)

1) Include thermal gradient wells, but not ones less than 100 m deep

Purpose	Wellhead Temperature	Number of Wells Drilled: Electric Power	Direct Use	Combined	Other (specify)	Total Depth (km)
Exploration[1]	(all)					
Production	>150° C	3				1
	150-100° C					
	<100° C					
Injection	(all)	2				1
Total		5				

TABLE 7. ALLOCATION OF PROFESSIONAL PERSONNEL TO GEOTHERMAL ACTIVITIES (Restricted to personnel with University degrees)

(1) Government
(2) Public Utilities
(3) Universities
(4) Paid Foreign Consultants
(5) Contributed Through Foreign Aid Prograr
(6) Private Industry

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	3	5	4	4	4	5
2016	3	5	4	5	5	5
2017	4	6	5	6	6	9
2018	5	8	5	4	4	10
2019	6	8	6	5	5	12
Total	6	8	6	6	6	12

TABLE 8. TOTAL INVESTMENTS IN GEOTHERMAL IN (2019) US$

Period	Research & Development Incl.	Field Development Including Production	Utilization		Funding Type	
			Direct	Electrical	Private	Public
	Million US$	Million US$	Million US$	Million US$	%	%
1995-1999	1	1	0.5	1.5	70	30
2000-2004	1	1	0.5	1.5	80	20
2005-2009	1	1	0.5	1.5	85	15
2010-2014	2	10	1	11	90	10
2015-2019	5	140	2	143	90	10