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Geothermal Country Update for Peru, 2015-2020

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ABSTRACT

The National Energy Policy for Peru 2010-2040 (approved by Supreme Decree N° 064-2010-EM) promotes energy efficiency and the development of renewable energy technologies at local, regional and national levels. It states explicitly the usage of geothermal energy for the improvement of national energy security; however, geothermal energy has not been included in the energy matrix yet, because it is only at a surface exploration stage. There have been conducted four Renewable Energy Resources (RER) auctions in the country, but there were awarded just solar, wind, biomass and small hydropower projects. Moreover, it has not been determined the sealing price for the electricity generation through geothermal energy for the country, and there has not been explored any other economical mechanisms for its promotion until now.

Nowadays, the geothermal energy utilization is still restricted to direct use in local pools and balneology centers for tourism. According to the Master Plan for the Development of Geothermal Energy in Peru, there is a geothermal potential of 2860 MWe nationwide for electricity production, being the most promising areas in the southern part of Peru associated to active volcanism. In that sense, the Mining and Metallurgical Geological Institute (INGEMMET) continue with its research program for updating the country's potential, finding a new geothermal area in the region of Tacna called Paucarani, with the a potential of 72 MWe. Moreover, in 2018 it executed an assessment in the Casiri-Kallapuma geothermal zone with an estimated potential of 135 MWe.

In terms of the regulatory framework, the country has a specific regulation for geothermal electricity generation like the Organic Law for Geothermal Resources, Law Nº 26848, and its regulations approved by Supreme Decree N° Nº 019-2010-EM and an auction system regulated by the Supreme Decree N° 1002, "Law for the Promotion of the Investment in Electricity Generation using Renewable Energy". However, there has not been any deep exploration yet, nor any project executed. In spite of the scenario, there is a huge potential for the development of geothermal technology for electricity generation and for direct use in the southern parts of the country, especially due to the expected entrance of new mining projects and the necessity of ways for facing frost in high altitude areas.

1. INTRODUCTION

Peru is one of the South American countries with the greatest geothermal potential, because it is located inside the Pacific Ring of Fire, where it occurs the subduction process from the Nazca Plate into the South American one, which has controlled the geological evolution of the Peruvian territory along the time from the Mesozoic up to date, originating the formation of the Andes Mountain Range, where there are located the most actives volcanoes of the country. As a consequence, magmatic and tectonic processes have allowed the development of geothermal reservoirs in these regions.

The most promising geothermal resources are related to active volcanism processes that occur mainly in the regions of Tacna, Moquegua, Arequipa and Ayacucho, between the coordinates 15°30' and 17°30' of South Latitude. The main active volcanoes of the country are Misti, Ubinas, Huaynaputina, Ticsani, Sara Sara, Sabancaya, Coropuna, Ampato, Tutupaca, Yucamane, Purupuruni and Casiri. However, there are more volcanoes from which there is little knowledge about their activity level (Fidel et al., 1997; De Silva and Francis, 1991; Fig. 1).

The evaluation of the geothermal potential of the country started at the beginning of the 70's with the national inventory of thermal manifestations, executed by the Mining and Metallurgical Geological Institute (INGEMMET). From that time until now, INGEMMET has conducted different geothermal assessments in cooperation with international institutions, which were focused mainly on the Southern Peruvian Volcanic Range. The information generated and updated, has allowed to delimit six geothermal regions throughout the country (Fig. 1), being Region 5 the most promising region due to its characteristics of medium to high enthalpy geothermal areas, associated to active volcanism (Vargas & Cruz, 2010).

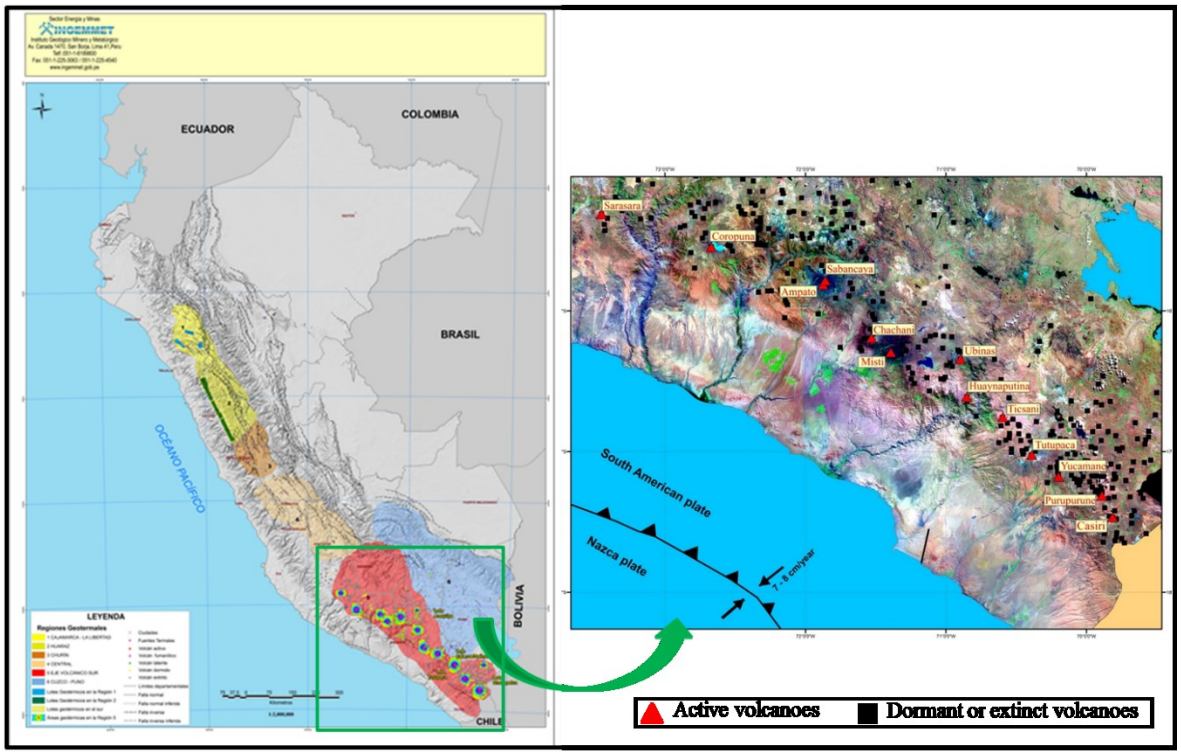

Fig. 1. Geothermal regions map of Peru (Vargas & Cruz, 2010, De Silva and Francis, 1991)

The development of the geothermal industry in Peru has not had a significant advance, in spite of having a specific regulation for geothermal electricity generation like the Organic Law for Geothermal Resources, Law Nº 26848, and its regulations approved by Supreme Decree N° Nº 019-2010-EM and an auction system regulated by the Supreme Decree N° 1002, "Law for the Promotion of the Investment in Electricity Generation using Renewable Energy", published on May 2008. From then until now, there has not been determined the sealing price for the electricity generation through geothermal energy and this technology has not been included in any of the four Renewable Energy Auctions conducted at the time in the country. The Ministry of Energy and Mines (MINEM) and the Supervisory Body for Investment in Energy and Mining (OSINERGMIN) were supposed to run a new auction in 2018, however, this was not executed.

From the publishing of the Organic Law for Geothermal Resources, Law Nº 26848 in 1997 and its first regulation emitted by Supreme Decree N° 072-2006-EM, the development of the geothermal energy industry has limited to:

- Promotion and diffusion of the importance of the development of geothermal energy in the country through written media, workshops, conferences, talks, among others, whose main purpose were to motivate and sensitize local, regional and national authorities regarding the usage of geothermal resources and its inclusion in the national electricity matrix.
- Further surface geothermal studies conducted by INGEMMET in the geothermal areas of Tacna, Moquegua and Puno regions.
- Modification of the Regulations of the Law N° 26848, with the new regulation published by Supreme Decree N° Nº 019-2010-EM.
- Execution of the Master Plan for the Development of Geothermal Energy in Peru in 2012 with the cooperation of the Ministry of Energy and Mines (MINEM), the Japan International Cooperation Agency (JICA), West Japan Engineering Consulting (West JEC) and the Mining and Metallurgical Geological Institute (INGEMMET).
- Modification of the Master Plan of the Regional Conservation Area Vilacota Maure in Tacna region (2018), in order to include the geothermal generation as a compatible activity of the area.

2. GEOLOGY BACKGROUND

The Geothermal potential of Peru is related to the subduction of the Nazca plate beneath the South American plate, originating magmatic activity and heat flows that exist along the western flank of the Peruvian Andes. In this area there are volcanic centers, being the most important (with recent activity) located in the southern region of Peru, such us: Paucarani, Tutupaca and Yucamane in Tacna; Ubinas, Ticsani and Huaynaputina in Moquegua; Chachani, Misti, Ampato, Hualca Hualca, Sabancaya and the volcanic belt Andahua in Arequipa; and Quimsachata in the Vilcanota valley in Cusco. These volcanoes have effusive and explosive phases of activity (Fig. 1), with a regional structural NE-SW alignment, with hot springs associated to them. Furthermore, these volcanic and structural activities have originated fracturing in the volcanic rocks and in the basement which controls the recharge, circulation and discharge of geothermal fluids in deep and shallow areas.

The high temperatures recorded in the manifestations are mainly due to the existence of heat sources (magma chambers), that may be in contact with deep aquifers, or through deep structures that conduct the heat towards the surface, increasing the water temperature of the shallow aquifers. Most of the hot springs in this region have juvenile origin (either magmatic or volcanic).

In the Early Pliocene, it was given a renewed uplift of the Andes, reaching heights that exceed 3,000 m above sea level, accompanied by an andesitic volcanic activity, gradually circumscribed to the southern part of the country. Local sequences were developed around many volcanic apparatus, with explosive and effusive phases, forming stratovolcanoes aligned in the N-NW direction. In the high parts of the Western Mountain range, from Northern Chile to 13° S approximately, the alignment of volcanic apparatus known as the "Barroso Mountain Range", remained the same during the Pleistocene. On the other hand, in the Southern part of Peru, it was produced a volcanism fissure of acid explosive type, registering ignimbrites from 4 to 5 million years ago.

During the Quaternary, and as part of a continuous geological process, several volcanic, glacial, alluvial, lacustrine, marine, and wind sediments have been deposited along the territory. The volcanic Pleistocene deposits corresponding to the volcanic ejections glaciation that are present in southern Peru, have a link to the volcanic apparatus of the "Barroso Mountain Range". The volcanic chain forms part of the Western Cordillera range, following an apparent alignment in the NW-SE direction in Peru and in the N-S direction in the North of Chile. The geometric characteristics of each of the volcanoes that make up this chain, show that tectonic activity is contemporaneous to the extensional orogeny that experiment the Andean Mountain range close to the Middle and Recent Quaternary (Sebrier et al, 1985). It is important to remark that in the Northern and Central regions of Peru, volcanic activity ceased 8 million years ago (Marocco, 1980). Furthermore, the extensive Quaternary volcanism, favored the presence of anomalous high heat flow along the Peruvian Andes, with geothermal surface manifestations such us hot springs, mud pools, fumaroles and steam sources.

Peru has geological maps that are continuously updated by INGEMMET at 1:1000 000, 1:100 000 (Fig. 2) and 1:50 000 scales, the last one partially developed. These maps describe rocks with their composition and geological age; structures such as faults, fractures, folds and minerals with economic value (view in the http://geocatmin.ingemmet.gob.pe/geocatmin/).

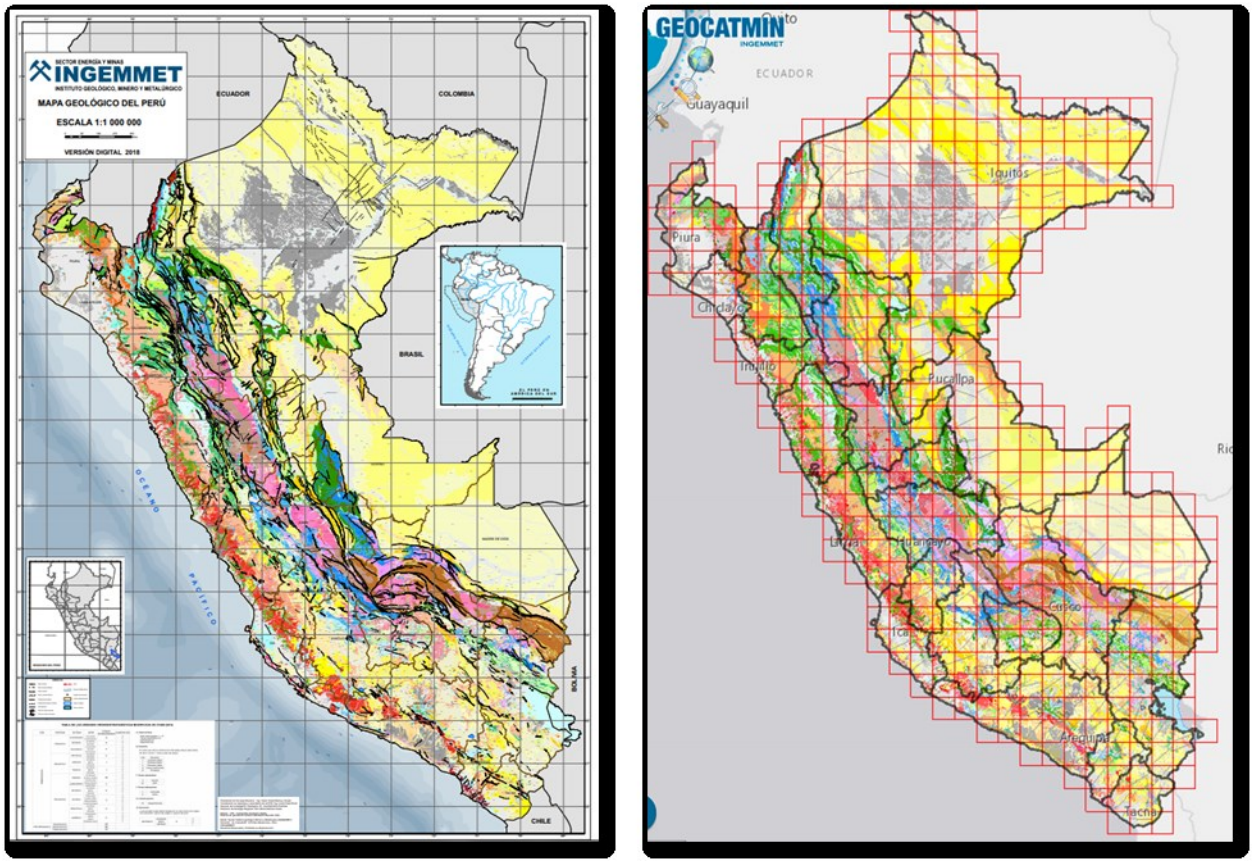

Fig. 2. Peruvian geological maps at 1/1 000 000 and 1/100 000 scales.

Volcanic rocks from Paleogene and specially Neogene of the "Barroso Mountain Range" that evidence a recent volcanism, dominate the most promising geothermal resources with high enthalpy and are related to the "Southern Peruvian Volcanic Range" (Fig. 3), where the rocks overlay Cretaceous and Jurassic substratum (Chocolate Formation and Yura Group).

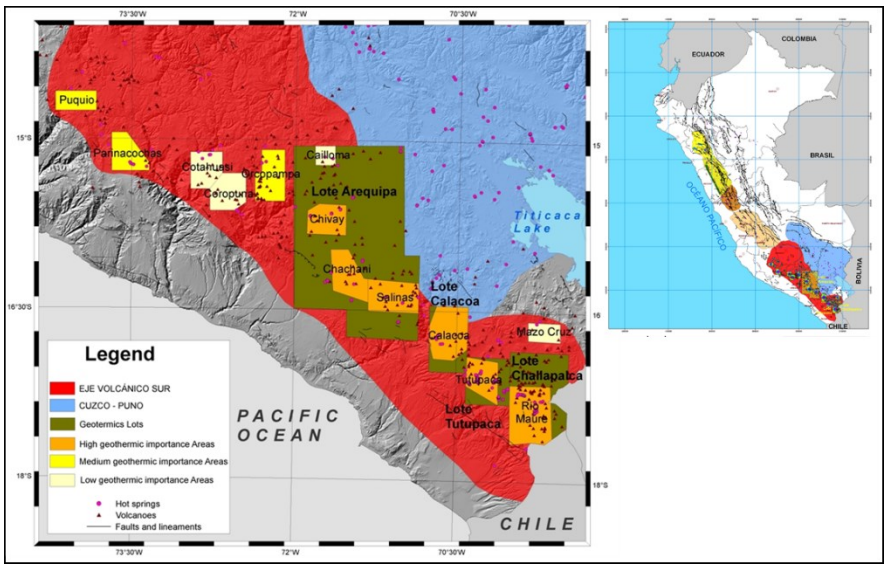

Fig. 3. Southern Peruvian Volcanic Range (region 5) in color red.

3. GEOTHERMAL RESOURCES AND POTENTIAL

The Master Plan for the Development of Geothermal Energy in Peru completed in 2012, estimated a geothermal potential of 2860 MWe applying the volumetric method. From this potential, 420 MWe were found in 5 geothermal zones (Calientes, Borateras, Chungara-Kallapuma, Ancocollo y Tutupaca) in the region of Tacna (West Japan Engineering Consultants, 2012, Fig. 4). After these studies, INGEMMET continued with the evaluation and characterization assessments for the geothermal resources, implementing some instrumentation measures for exploration works (laboratory equipment, acquisition of magnetotelluric equipment, etc.).

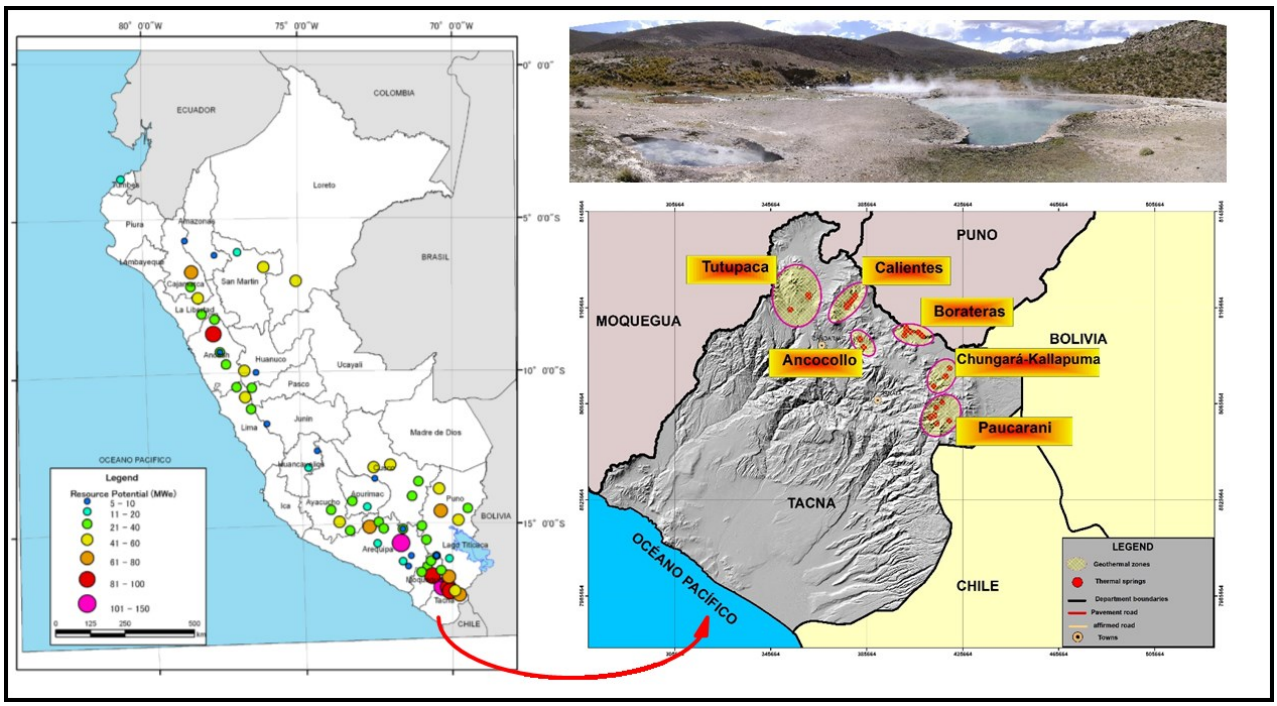

Fig. 4. Potential geothermal map of Peru and Tacna geothermal zones studies by INGEMMET (West Japan Engineering Consultants, 2012; Cruz et al, 2013, 2018).

Since 2015, INGEMMET has a national geothermal research program, from which it develops studies by region, applying geological, geochemical and geophysics (magnetotelluric) assessments with the purpose of updating the geothermal potential map of the country. From that time, INGEMMET has conducted studies in the geothermal zones of Pinaya, Jarpaña, Atecata and Coline in the Puno and since 2017 in Paucarani, Casiri-Kallapuma, Kovire (Borateras) in the Tacna region. All these studies are listed in Table 1 below.

On its Institutional Strategic Plan from 2016 to 2021, INGEMMET included the development of geothermal resources assessments in the country. For this reason, in 2016, it conducted the geothermal characterization of manifestations between the Ubinas and Huaynaputina volcanoes in the region of Moquegua, and acquired 2 magnetotelluric equipment. In 2017, it executed a geothermal

assessment in the geothermal area of Paucarani and in 2018, it developed a similar study in the Casiri-Kallapuma geothermal zone in the region of Tacna, which increased the potential of the region by 207 MWe, with a new total of 492MWe (Cruz et al, 2017, 2018 Fig. 4).

Between 2019 and 2020, INGEMMET expects to investigate the Kovire (Borateras) and Ancocollo zones applying geological, geochemical and geophysical (magnetotelluric) assessments that include hydrogeology studies. It is important to mention that INGEMMET not only executes geothermal assessments, it also makes itinerant workshops with local people in order to tell them about the geothermal activities that the researchers carry out in their communities. This activity is very important for getting permission for the conduction of the studies.

Table 1. Geothermal studies conducted from 2015 to 2020 by INGEMMET (Source: Own elaboration).

Province	Region	Geothermal zone	Resource potential confidence level between (60% to 80%)(Mwe)	Estimated by
The Master Plan for the Development of Geothermal Energy in Peru			2860	JICA (West Jec, 2012)
Santa Lucia	Puno	Jarpaña- Atecata, Coline, Pinaya	63	INGEMMET, 2015
Ubinas-Omate	Moquegua	Hot spring characterization		INGEMMET, 2016
Palca	Tacna	Paucarani	72	INGEMMET, 2017
Tarata	Tacna	Casiri-Kallapuma	135	INGEMMET, 2018
Tarata	Tacna	Kovire (Borateras)	expand the study	INGEMMET, 2019
Tarata	Tacna	Ancocollo	expand the study	INGEMMET, 2020

4. GEOTHERMAL UTILIZATION

In Peru, geothermal resources have been traditionally used for recreational and touristic purposes, due to its location in areas of great tourism attraction. However, the use of these resources in Peru is still mainly limited to entertainment and balneology in places such as Baños del Inca in Cajamarca, Callejón de Huaylas in Huaraz, Churín in Lima, Calera in Arequipa and Aguas Calientes in Cusco. Today, the use of geothermal sources in balneology activities (hotels, spas and recreation) in Peru has increased, from the usage of traditional techniques to the construction of hotels located in Cusco (Aguas Calientes) and Arequipa (Colca Canyon).

On the other hand, since 2006, INGEMMET based on the Supreme Decree N° 05-2005-MINCETUR and the Law of Water Resources, Law N° 29338 and its regulations, has granted the certification and physical –chemistry classification of waters, for touristic use. Up to now, there has been granted 59 authorizations for the usage of geothermal sources for touristic purposes, mainly in the regions of Arequipa and Cajamarca (report of the hydrogeological department of INGEMMET, 2019).

The greatest amount of hot springs of Peru are found in the regions of Cajamarca, Cusco, Ancash, Lima, Arequipa Moquegua y Tacna. Cajamarca is the region that has been standing out in the number of specialized services to take advantage of the hot springs, like the attention of guests for health purposes (Garcia, 2015; Fig. 5).

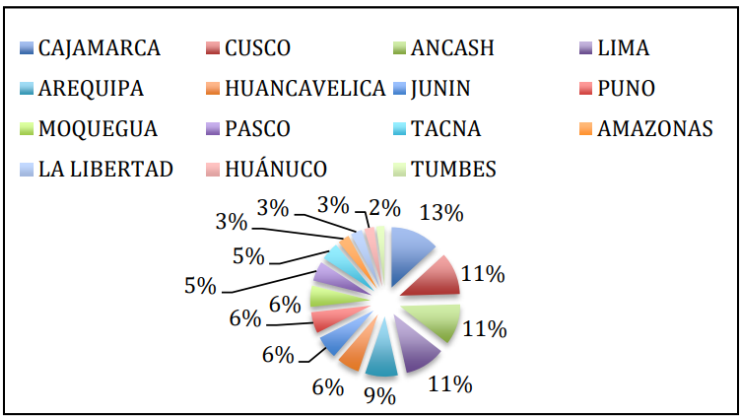

Fig. 5. Geothermal manifestation distribution by region.

5. DISCUSSION

Regulatory framework

Peru is a country with a varied topography, great climate diversity and tremendous renewable energy potential from geothermal, wind, solar and hydro resources. The variability in oil prices; the vulnerability of the country to dry seasons, climate phenomena and natural gas supply; and the contribution to global warming of greenhouse gasses from the combustion of fossil fuels in the energy

and transportation sectors, require the diversification of the energy matrix of the country, which has motivated the Peruvian Government and the Ministry of Energy and Mines to enact some legal regulations, like the ones depicted in Table 2.

Table 2. Legal framework for geothermal generation. (Source: Own elaboration)

Legal Framework		
Geothermal	Electricity market	Renewable energy
- Organic Law for Geothermal Resources, Law N° 26848 - Regulations of the Law N° 26848, Supreme Decree N° Nº 019-2010-EM Renewable Energy"	- Electrical Concession Law, Law N° 25844 and tis modifications - Regulations of the Electrical Concession Law, Supreme Decree N° 009-93-EM	- Law for the Promotion of the Investment in Electricity Generation using renewable energy, Supreme Decree N° 1002 - Regulations of the Electricity Generation using renewable energy, Supreme Decree N°050-2008-EM
Authorization and concession	Definitive concession for the generation with renewable energy resources	Auction renewable energy promotion mechanism, including geothermal
General Administrative Procedure Law, Law N°27444.		

Energy framework

Peru had a total installed capacity of 13,051.6 MW up to December of 2018, with the entrance in commercial operation of new electricity generation plants like the Photovoltaic Solar Plants Rubi of 144.48 MW and Intipampa of 44.54 MW; the Wind farm Wayra I of 132.3 MW; the biogas thermal power plant Doña Catalina of 2.4 MW; the natural gas thermal power plant Santo Domingo de los Olleros of 123.61 MW; and 5 small hydropower plants that sum up a power capacity of 110.66 MW (COES, 2019).

In 2018, the maximum annual demand was 6,884.6 MW, which represented 52.74% of the installed capacity of the system (COES, 2019). This means that currently there is a surplus of installed capacity in the energy sector that can be explained by the delay of important infrastructure and mining projects which are supposed to be the main energy consumers.

In terms of energy, in 2018 the total annual energy production reached 50 816,79 GWh, of which 57.8% came from hydropower plants, 37.2% from natural gas thermal power plants, 0.1% from coal thermal power plants, 0.3% from Diesel2/Residual500/Residual 6 thermal power plants, and 4.7% from renewable plants including wind, solar photovoltaics and biomass power plants (Fig. 6).

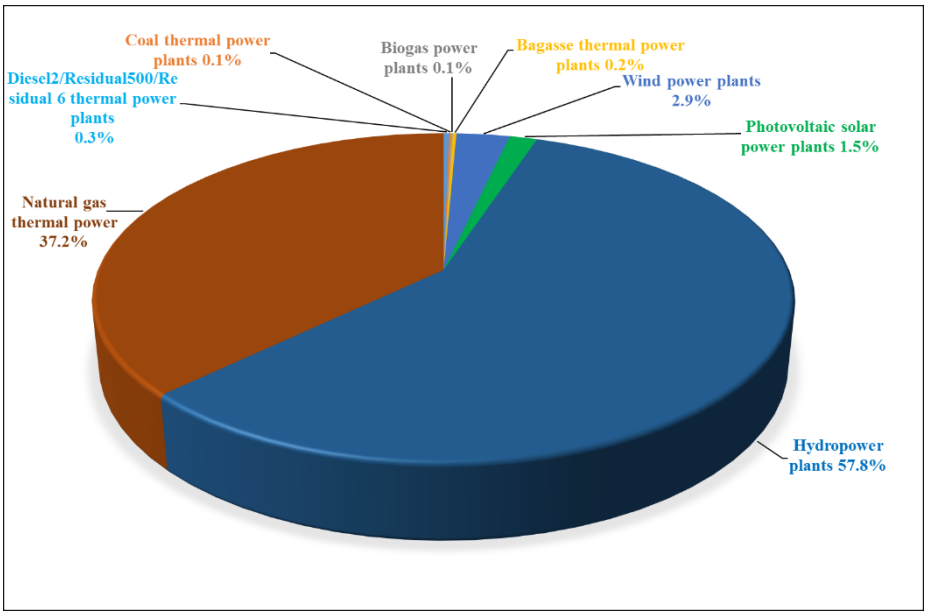

Fig. 6. 2018 Annual energy production distribution by type of power plants (COES, 2019).

The average monthly marginal cost for 2017 and 2018 in the National Electric Interconnected System (SEIN) at the Santa Rosa's reference bar is showed in Fig.7. The average monthly marginal cost for 2017 had a uniform behavior, presenting the highest values during the months of August and September, with an annual average of 9.53 US$/MWh. On the other hand, in 2018 it can be seen an increase in costs in February due to the rupture of the Camisea Gas liquid transport pipe, and in August, because of the maintenance work at the Pluspetrol Natural Gas Plant in Malvinas, which forced the natural gas thermal plants to reduce their electricity generation and, consequently, the cold reserve plants running on diesel started operating. In spite of that, the power surplus and other market distortions made the average monthly short-term electricity cost in 2018 to be US$ 10.69 / MWh (COES, 2019), which is a value that does not allow the development of new energy infrastructure.

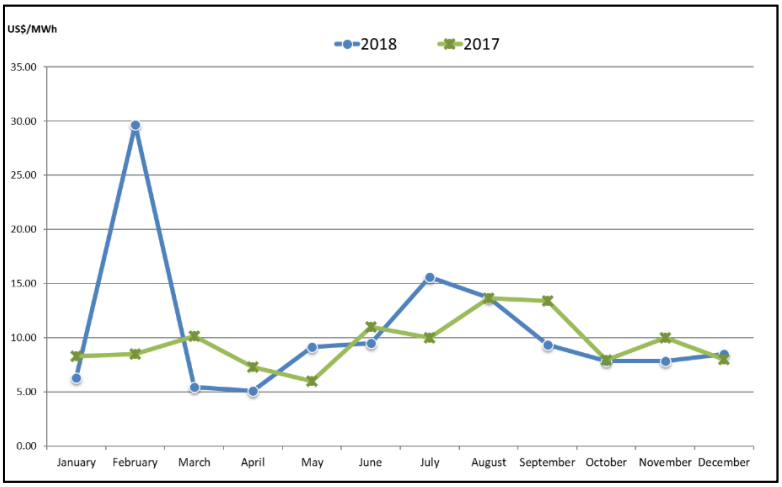

Fig. 7. Average monthly marginal cost of electricity in the SEIN at Santa Rosa's reference bar (COES, 2019)

It is also important to mention that the main demand projects for the year 2018, like the expansion of Antamina and the Toquepala concentrator project, were still in the construction phase, for which no growth has been observed significant during that year. Moreover, big mining projects like Tía María, expected for 2019 have not started their construction phase yet due to social problems, so the expected growth in demand of energy is still uncertain.

Until now, there have been only 4 auctions for renewable energy resources (RER) generation, assigning contracts to solar, wind, biomass and small hydroelectric power plants (less than 20 MW), as shown in Table 3.

Table 3. Maximum and minimum prices awarded in RER auctions in Peru in US$/MWh(Source: Futuro de la Energía en Perú: Estrategias energéticas sostenibles (Rios, 2016).

Type of technology	1st Auction (2009)		2nd Auction (2011)		3rd Auction (2013)		4th Auction (2014)	
	Minimum price	Maximum price	Minimum price	Maximum price	Minimum price	Maximum price	Minimum price	Maximum price
Wind	65.52	87.00	69.00	…	…	…	36.84	37.83
Solar	215.00	225.00	119.90	…	…	…	47.98	48.50
Biomass	52.00	110.00	99.99	…	…	…	77.00	77.00
Small hydropower plants (<20 MW)	55.00	70.0.	47.40	56.45	50.50	64.80	40.00	58.20

In terms of short term energy planning, Table 4 shows the present and planned Production of Electricity. Here is possible to see that until 2020, the Peruvian government does not expect the inclusion of any geothermal project. The forecast consider only the participation of fossil fuels, hydro and wind and solar projects in a small amount.

Personnel

There are few professionals involved in geothermal activities in the country, which are mainly engineers. In recent years, some of these professionals have received training and have developed postgraduate programs in universities and geothermal research centers, such as: LaGeo-El Salvador University, Iceland (United Nations University, Reykjavik University), JICA-Japan, Peru (Major National University of San Marcos), etc.

Nowadays some of these professionals are in the private sector, some of them conduct basic studies at INGEMMET and some of them are in the academic sector. For example, one of the professionals has a "Biomass and Geothermal" course and a "Reservoir-engineering" course at the University of Engineering and Technology (UTEC). Finally, most of these specialists conduct workshops and conference to promote the geothermal industry in the country. Table 5 shows the allocation of professional personnel to geothermal activities in Peru.

Investment

From the 70's in the country, there has been mostly investments in surface geothermal studies. The Mining and Metallurgical Geological Institute (INGEMMET) has received non-reimbursable cooperation financing for the development of geothermal surface studies until 2009. For the period 2010-2014, there were designated governmental funds for these assessments which accounted for approximately US$ 750 000.00, whereas in the period 2015-2019, there were designated an average of US$1500 000.00.

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Table 4. Present and Planned Production of Electricity (Source: 2018 operation annual inform and SEIN medium term operation program COES, 2019).

	Geothermal		Fossil Fuels[1,2]		Hydro[2,3]		Nuclear		Other Renewables[2,4,5]		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	0	0	7,396.0	19,075.64	4,995.1	29,357.91	0	0	660.5	2,383.24	13,051.6	50,816.79
Under construction in December 2019	0	0	0	0	132.2	-	0	0	2.4	-	134.6	-
Funds committed, but not yet under construction in December 2019	-	-	-	-	-	-	-	-	-	-	-	-
Estimated total projected use by 2020	0	0	7,396.0	21,465.00	5,127.30	28,533.00	0	0	662.9	6,534.00	13,186.20	56,999.00

Notes:

1. Includes Natural gas, Coal and Diesel2/Residual500/Residual 6.
2. Energy demand of 2018, to be updated for December 2019.
3. Includes the construction of CH La Virgen - LA VIRGEN S.A.C., CH 8 de Agosto - GENERACION ANDINA S.A.C., CH El Carmen - GENERACION ANDINA S.A.C. and CH Manta - PERUANA DE INVERSIONES EN ENERGIAS RENOVABLES S.A.
4. Includes wind power, solar power, biomass and small hydropower plants (<20 MW).
5. Includes the construction of the biomass power plant “CB Callao - PETRAMAS S.A.C.”

Table 5. Allocation of professional personnel to geothermal activities (restricted to personnel with University degrees).

Year	Professional Person-Years of Effort					
	(1)	(2)	(3)	(4)	(5)	(6)
2015	4					1
2016	3					1
2017	7		1			1
2018	7		1			1
2019	7		1			1
Total	7		1			1

Notes:

(1) Government (4) Paid Foreign Consultants

(2) Public Utilities (5) Contributed Through Foreign Aid Programs

(3) Universities (6) Private Industry

6. FUTURE DEVELOPMENT AND INSTALLATIONS

Actually, there has been some companies that had concessions for the usage of geothermal resources; however, there is not any project in the deep exploration phase yet. The Energy Development Corporation (EDC) company is operating in the country through the subsidiary companies Geotérmica Quellapacheta Peru S.A.C. and EDC Energía Verde S.A., and has concentrated its interest in the projects called Quellapacheta in the Calacoa-Putina geothermal field (near the Ticsani Volcano) and Achumani in the Chivay geothermal field - Pinchollo (located near the Huallca Huallca Volcano, in the Colca Valley) (Bona and Coviello, 2016). Explorations carried out by EDC in these areas include geological, geochemical and geophysical studies, which has led them to conclude the first phase of the Peruvian administrative process and have received a grant from a multilateral organization in order to start its exploratory drilling campaign in the Quellapacheta project of 100 MW.

The projections of the energy supply, are established in documents prepared by the Ministry of Energy and Mines (MINEM) such as the “National Energy Plan 2014-2025” (Fig. 8) and the study “New Sustainable Energy Matrix and Strategic Environmental

Assessment" (NUMES) (MINEM, 2012, 2014). Specifically in the NUMES document, it was established a proposal for the participation of geothermal energy in the electricity generation matrix up to the year 2040, as it could be seen in Tables 6 and 7 below.

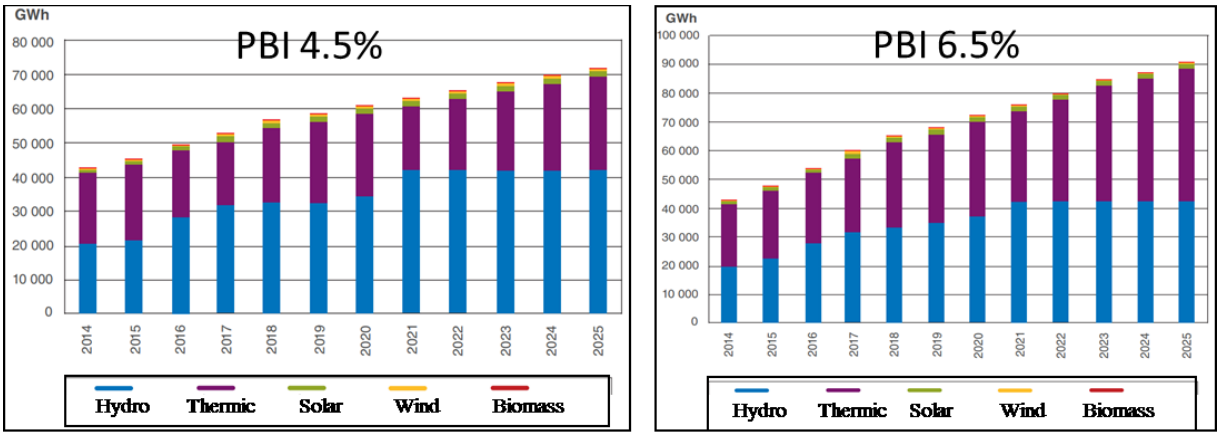

Fig. 8 Electricity Production by Source (MINEM, 2012).

Table 6. Proposed Sustainable Power Generation 2011-2040 for the Peruvian Energy Matrix (Source: MINEM, 2012).

	New Power MW				
Technology	**2011-2020**	**2021-2030**	**2031-2040**	**Total**	**%**
Hydropower	3684	2475	524	6682	36
Thermics	700	2270	5000	7970	43
Winds	592	300	450	1342	7
Solars	140	140	80	360	2
Geothermics	-	1010	490	1500	8
Biomass	282	240	100	622	3
Total	**5398**	**6435**	**6644**	**18476**	

Table 7. Proposed Power Geothermal Generation 2021-2040 (Source: MINEM, 2012).

7. CONCLUSSION

In Peru, geothermal exploration continues at a surface level, the best prospects are located in the southern region and are associated to active volcanism. The Peruvian State grants a budget each year to INGEMMET to develop geological, geochemical and geophysical surface studies; the generated information are published through newsletters and articles that can be accessed from the INGEMMET website.

The development of geothermal energy for electricity production is currently paralyzed; there is not any project in the advanced exploration phase, with drilled wells and a confirmed resource. Therefore, the State has the responsibility to promote this type of projects as part of the National Energy Policy, to develop the industry and technology for the exploitation and development of the geothermal resource. It is required the determination of an economical promotion mechanism and the updating of the geothermal regulation in order to determine the permits required for each phase of a geothermal project (for electricity and direct use) and the institutions involved.

The barriers for the development of geothermal energy in Peru can be summarized as follows: 1) Political decision of the State, 2) High cost and risk in the drilling phase, 3) Lack of transmission lines for the connection to the national grid, 4) Lack of access (roads), and 5) Existence of Natural protected areas near the most promising geothermal zones. These are some of the obstacles that must be overcome for the successful development of geothermal energy in Peru.

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