OBSTACLES AND STRATEGIES OF ACHIEVING GEOTHERMAL ENERGY TARGET OF 1000 MW IN ECUADOR: A TECHNO-POLITICAL OVERVIEW

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ABSTRACT

This paper explores the key challenges and strategies for achieving the geothermal energy target of 1000 MW in Ecuador. Despite the new political decision to address the change of energy matrix based on new renewable power developments, there are other factors to be considered before achieving this goal. At first, the energy policy concentrating on the regulatory gap to promote geothermal energy projects is assessed. Furthermore, the technical and economic potential of geothermal power with a focus on the latest investment and institutional support in the geothermal energy sector is addressed. Current investment and prioritisation of other energy resources (renewable and non-renewable) in Ecuador is also discussed. Finally, the environmental issues regarding geothermal developments in the Ecuadorian context are highlighted.

1. INTRODUCTION

1.1 Background

In May 2015, the National Balance of Electric Power reported by the Ecuadorian Electricity Council (CONELEC) revealed that 25,557.81 GWh of electricity were consumed and produced in a 5,445.77 MW installed capacity nationwide. Approximately, 1680.86 GWh of electricity were imported through the transboundary imports from Peru, Colombia and other sources, which represent an installed capacity of 635 MW (CONELEC, 2015). Interestingly, the energy matrix (EM) of Ecuadorian electricity sector was 46.61% from renewable energy and 53.39% from non-renewable energy. The shares of renewable energies were 43.23% for hydroelectricity, 2.5% for biomass turbo-vapor, 0.48% for solar energy and 0.39% from wind farms. On the other hand, the non-renewables were represented by diesel internal combustion engines (27.22%), natural gas turbo-gas (17.95%) and diesel turbo-vapor (8.23%). Therefore, as the refinery capacity is not sufficient to support the energy consumption, Ecuador has to import derivatives of petroleum reaching over 38,700 Boe (barrels of oil equivalent) at a growth rate of 3.7% annually (Carbajal et al., 2013).

Despite the balanced use of fossil fuels and renewable resources in the Ecuadorian electricity sector, the country is addressing a cleaner renewable energy matrix through the building of eight new hydroelectric projects by 2016 (Albornoz, 2013). According to the Minister of Renewable Energy and Electricity, Esteban Albornoz, the new hydro-power plants will produce almost double the maximum current demand of Ecuador. However, less attention has been focused on the development of geothermal power plants.

Therefore, it is clear that the development of geothermal power plants could be one of the options to diversify the Ecuadorian energy matrix (E-EM). However, it is important to analyse these developments by taking into account the geothermal potential that the country possesses. Only 5 volcanoes have been investigated of the more than 40 active, mostly due to their potential for electricity generating purposes (Beate, 2010; Lloret & Labus, 2014). Other geothermal resources were explored to determine their direct use for industrial processes. Most of these investigations are currently in the exploration stage (Beate & Urquizo, 2015). The Ecuadorian Electricity Corporation (CELEC-EP), a public company, is conducting research in the field of exploring geothermal electricity with the scientific and technical support of the National Institute of Renewable Energy of Ecuador (INER), both under the Ministry of Renewable Energy and Electricity. The CELEC-EP has identified three geothermal prospects for electricity generation (Beate, 2010), while INER is exploring different industrial direct uses in other geothermal prospects (Lloret & Labus, 2014).

1.2 Brief political and economic background

Since the Independency of the Spanish conquest (1822) to 2008, Ecuador has had 19 National Constitutions (National Legislative Assembly, 2008), which have tried to stabilise the country politically. Unfortunately Ecuador has been marked by repeated cycles of political instability (Beittel, 2013). From 1996 to 2006, three popularly elected presidents could not complete their terms and were forced to resign because of mass protests and congressional disapproval, as a result Ecuador had six presidents during that decade (Conaghan, 2007). After the 2006 election, Rafael Correa, a left-leaning and U.S.-Europe-trained economist, became President of Ecuador establishing three terms of political stability during the last seven years (Beittel, 2013). He is the longest serving Ecuadorian president in history and his Party (Alianza PAIS) has the majority members in the unicameral legislative assembly (Eichorst & Polga-Hecimovich, 2014). The results are political stability; a new National Constitution with new policies such as Rights of the Nature; and detailed plans to secure energy, environment and natural resources for future generations (National Legislative Assembly, 2008; SENPLADES, 2012a).

In 2011, the Human Development Index (HDI) by United Nations Development Programme (UNDP) illustrated major progress in income, access to education and energy in Ecuador (UNDP, 2011). The UNDP – HDI ranked Ecuador 83rd, close to the neighbouring countries of Colombia (87), Brazil (84) and Peru (80). Furthermore, according to the World Bank Group (TWBG), the Gross National Income per capita has increased from 7,589 USD in 2005 to 10,310 USD in 2013 which places Ecuador near the average of South American countries (TWBG, 2014; UNDP, 2011).

During 2007-2013 term, investment in the energy sector increased to 5,000 million USD, 360 % more than the investment in 2000-2006 term (Albornoz, 2013). Although, 926 million USD were invested to import energy between 2002 and 2012, only 13.7 million USD were received for the energy exports (Orejuela, 2014). In 2013, oil rents also increased to 2,795 million USD after the last renegotiation of 24 oil contracts with multinationals (El Telegrafo, 2013). On the other hand, the State Budget, according to figures released by the Ministry of Finance on December 31, 2013, showed a deficit of 5,059.7 million USD. Therefore, it is clear that there is commitment from the Ecuadorian government to diversify the EM. However, there are other factors to address before achieving the goal of diversifying the energy generation through renewable resources especially geothermal energy.

2. STATE OF THE GEOTHERMAL ENERGY DEVELOPMENT

The Geophysical Institute of the National Polytechnic School (IG-EPN Spanish abbreviation) of Ecuador reported that at least 30 volcanoes which have experienced thermal activity in the country during last five centuries (Mothes et al., 1998). Recently, the IG-EPN by permanent monitoring had identified 84 volcanoes (IG-EPN, 2015). Of which, 60 are inactive volcanoes, 5 are active, 16 are potentially active and 4 are in the eruption process (Figure 1) (IG-EPN, 2015).

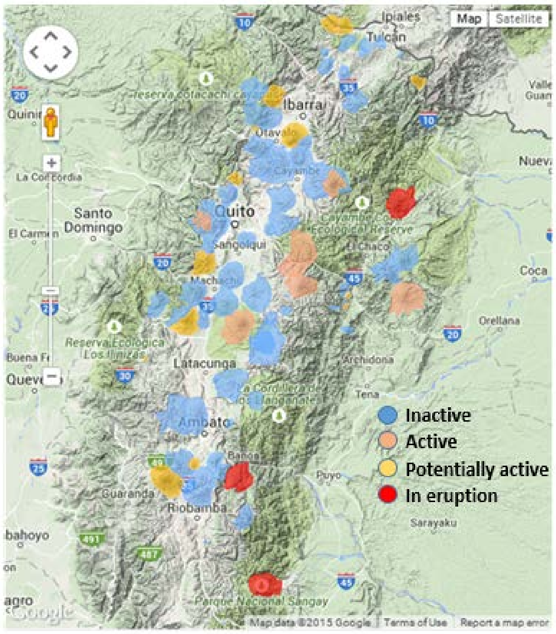

Figure 1: Volcanoes in Ecuador (IG-EPN, 2015).

These initial data clearly illustrate the geothermal resources for possible power plants and direct applications in the country. However, technical and scientific studies are required to determine a more accurate potential of these resources. In 1979, the former Ecuadorian Institute of Electrification (Ex-INECEL), the Energy Organization of Latin America (OLADE), the private company AQUATER and the Bureau of Geologic Research in Mines from France carried out the first geothermal studies in Ecuador (Lloret & Labus, 2014; Parra, 2013). Field surveys and hydrology analysis along three zones of the Ecuadorian Andes resulted in the first geo-volcanological report identifying the three most favourable geothermal prospects: Chalupas in the Napo Province, Chachimbiro in Imbabura Province and Tufiño on the Ecuador-Colombia border (Lloret & Labus, 2014). Currently, the National Institute of Renewable Energy of Ecuador (INER) has reported the up-to-date state of the geothermal prospects of high and low enthalpy (INER, 2015a).

2.1 Geothermal energy potential

The Ministry of Electricity and Renewable Energy, presents a gross estimation of the economic-feasibility of geothermal potential at 1000 MW nationwide (Orejuela, 2014). However, Beate (2010) in the Plan for the utilization of geothermal resources in Ecuador (PUGR-E), based on Stefansson (2005), suggests that Ecuador's geothermal potential could reach up to 3000 MWe taking into account only 20 active volcanoes and 8000 MWe taking into account 30-40 volcanoes from the more than 40 active volcanoes in the country. Currently, of the eleven prioritised prospects in the PUGR-E only four have reached the prefeasibility studies up to pre-drilling stage (Beate & Urquizo, 2015; Lloret & Labus, 2014; Oliveros & Urquizo, 2014). These geothermal prospects are the Bi-national (Ecuador-Colombia) project 'Tufiño-Chiles-Cerro Negro', the Chachimbiro geothermal prospect in the Imbabura Province, the Chacana-Cachiyacu and Chacana-Jamanco geothermal prospects in the Napo Province, and the Chalpatán geothermal prospect in the Carchi Province. Additionally, advanced studies have been conducted on the Chalupas geothermal prospect in the Napo Province, though, these have been temporarily delayed by CELEC EP (Lloret & Labus, 2014).

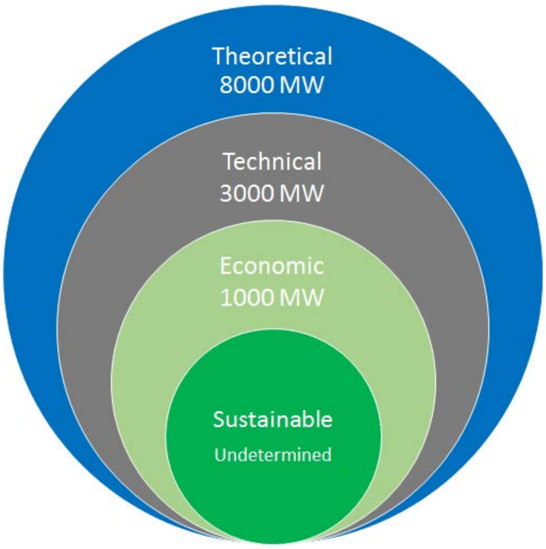

Figure 2: Geothermal potential in Ecuador (Beate, 2010; Lloret & Labus, 2014; Orejuela, 2014).

2.2 Most advanced geothermal prospects

Table 1 summaries the main features of the most advanced geothermal prospects in Ecuador. Four geothermal prospects have reached the prefeasibility studies with sufficient data from geological, geochemical and geophysical surveys, conceptual models, risk assessment and location of first drilling sites. Only one of the most advanced prospects requires extra studies to support its estimated potential for electric and non-electric purposes, the Chalupas prospect. Additional potential prospects without sufficient studies can be found in INER (2015a) and Beate (2010).

Table 1: Most advanced geothermal prospects in Ecuador (Almeida et al., 1990; Beate, 2010; Beate & Salgado, 2010; Beate & Urquizo, 2015; INER, 2015a; Lloret & Labus, 2014).

Geothermal prospect	Location	Project status	Possible applications	Estimated potential
Tufiño-Chiles-Cerro Negro	Border Ecuador – Colombia, 35 km of the city of Tulcán.	Final prefeasibility study. May/2009, first drilled hole reached a depth of 554 m.	Electricity generation Direct Uses	138 MWe 230 ºC
Chachimbiro	Imbabura Province, 17 km from city of Ibarra, on the east slopes of the Western Cordillera	Prefeasibility studies to pre-drilling stage (geological, geochemical and geophysical surveys, conceptual models, risk assessment and location of first drilling sites)	Electricity generation Direct Uses Cascade projects	113 MWe (Almeida et al., 1990) 81 MWe 1500 m depth
Chacana (Four reservoirs: Cachiyacu, Jamanco, Chimbaurco and Plaza de Armas)	Napo Province, on the Eastern Cordillera, 60 km east of Quito	Prefeasibility studies to pre-drilling stage (geological, geochemical and geophysical surveys, conceptual models, risk assessment and location of first drilling sites)	Electricity generation Direct Uses Cascade projects	Jamanco, 13 MWe Cachiyacu, 39 MWe Oyacachi, 104 MWe 1-3km depth
Chalpatán	Very near to Tufiño–Chiles-Cerro Negro prospect, 20 km of city of Tulcán.	Prefeasibility studies to pre-drilling stage (geological, geochemical and geophysical surveys, conceptual models, risk assessment and location of first drilling sites)	Not suitable for electricity production. High potential for direct uses.	120ºC, representing a potential energy resource of 484,000 GWh
Chalupas	Napo Province, 70 km SSE from Quito, at the crest of the Eastern Cordillera.	Prefeasibility studies with insufficient data to support the geothermal conceptual model Detailed geology, geochemistry, resistivity and geophysics are required, temporarily delayed.	Electricity generation Direct Uses Cascade projects	283 MWe (Almeida et al., 1990)

3. ENERGY POLICY IN ECUADOR

The general guidelines for the energy sector are provided in The National Constitution of 2008, and in the National Plan of Living Well (NP-LW) 2009 – 2013 (Albornoz, 2013; National Legislative Assembly, 2008; SENPLADES, 2012a). The Energy Sector Agenda and the Master Plan of Electrification were developed from those principles in order to develop the roadmap in the diversification of the E-EM. Albornoz (2013) described the new regulations in the energy sector since the New 2008 National Constitution. The constitution contains new policies for the environment, energy and productivity sector such as: 'The Rights of the Nature'; detailed plans to secure energy, the environment and natural resources for future generations; and the proposals to change the E-EM and Productivity Matrix (PM) (Correa et al., 2013; National Constituent Assembly, 2008; SENPLADES, 2012a, 2012b).

There are six articles in the constitution that consolidate the new energy policy in Ecuador (Moya, 2014). Art. 413 illustrates that the state shall promote the development and use of environmentally clean technologies, while Art. 313 explains that the State controls these developments based on The Rights of Nature in Arts. 71-74, and the use of green technologies in Art. 15 (National Constituent Assembly, 2008). In the NP-LW, the strategic goal is to maximise the use of renewable energy sources in the EM by promoting energy green and efficient technologies. Furthermore, Policy 4.3 and Policy 5.3 of the NP-LW provide guidelines to diversify the E-EM and encourage the reduction of dependency on imported energy resources (SENPLADES, 2012a). The final outcomes of these national policies are: the Institutional Strategic Plan 2013-2016 of the National Electricity Council (CONELEC); the Strategic Plan 2013-2017 of the Electric Corporation of Ecuador (CELEC-EP); and the Institutional Strategic Plan 2014-2017 of the Ministry of Electricity and Renewable Energy (MEER) (CELEC-EP, 2013; CONELEC, 2012; MEER, 2014). The financing and finalisation of the construction of geothermal power projects in the country will be supported by MEER (2014) and CELEC-EP (2013). In general, therefore, it seems that geothermal developments are supported in the Ecuadorian energy framework although a specific Geothermal Law has not yet been established.

3.1 Change of the energy and productivity matrix

These legal instruments allow the development of programs, plans and projects to re-direct the energy system to be more effective, efficient and environmentally friendly, known as the Change of the EM (Albornoz, 2014; Correa et al., 2013; Orejuela, 2014). Simultaneously, a change to the Productive Matrix is proposed. Ecuador's economy has been characterized as a supplier of primary goods in the international market, such as petroleum, and importer of goods with higher added value such as diesel (SENPLADES, 2012b). The Production Matrix change is focused on the transformation of agriculture and industry sectors (Correa, Cely, Peña, Vallejo, & Molina, 2010; Espinoza, 2014).

The change to the E-EM has been outlined by the National Secretariat of Planning and Development (SENPLADES) in the seventh strategy of the NP-LW (SENPLADES, 2012a). As the E-EM merely reaffirms the position of the country as an exporter of commodities with low added value and an importer of industrial goods with high added value, the SENPLADES (2012a) outlines the strategies to increase the use of other renewable energy resources such as geothermal energy in the EM. At the same time, the imports of oil derivatives must be reduced to a minimum. Poveda (2013) reports the complete EM structure identifying its share of oil (90%), natural gas (4%), hydroelectricity (4%), wind, biomass and solar (less than 2%). More specifically, the current installed capacity of the electric EM is accounted by the largest share of non-renewable electric energy (48.64% - 2892.96 MW) followed by renewable (40.68% - 2419.52 MW) and international interconnections from Peru and Colombia (10.68% - 635 MW) (CONELEC, 2015). Additionally, Albornoz (2013) remarks that eight new hydroelectric power plants will add 2,773 MW to the electric network by 2016. This clearly shows: firstly, that the geothermal power plants have not yet been developed, and secondly, that the future electricity consumption of the new industries proposed in the change of the PM has been disregarded. Thus, geothermal developments might take the place of electricity imports or help to reduce fossil fuel consumption in non-renewable energy plants.

The transformation policy of the PM of Ecuador is established in objective No. 11 of the NP-LW (SENPLADES, 2012a). As SENPLADES (2012b) and MEER (2014) argue that Ecuador's economy has been characterised as a supplier of primary goods in the international market (petroleum) and an importer of goods with higher added value (gasoline); so, the inclusion of new industries is necessary. The SENPLADES has identified nineteen strategic production sectors to be industrialised (Espinoza, 2014). This discourse of change of Ecuadorian economy is based on the principles of Living Well or Sumak Kawsay (translation from the Indigenous Ecuadorian language), which promote plurality and equality (Cely, Peña, Vallejo, & Molina, 2010; SENPLADES, 2012a, 2012b; Vanhulst & Beling, 2014); and according to Glas (2014a), this change will guarantee quality jobs, the eradication of poverty and the achievement of Living Well for Ecuadorian citizens.

Cely et al. (2010), Espinoza (2014) and Glas (2014a) explain that this change is focused on the transformation of three sectors, agriculture, industry and services, which may use geothermal fluids in the heating process. Furthermore, the SENPLADES along with the Vice President and the Ministry of Strategic Sectors of Ecuador have identified nineteen production sectors and strategic basic industries which will act as triggers for other industries; these have been called industrializing industries (Espinoza, 2014; Glas, 2014; Glas, 2014b). Cely et al. (2010), Poveda et al. (2013), Espinoza (2014), SENPLADES (2012b) and MEER (2014) do not give sufficient consideration to the estimation or calculation of the future demand of electricity by the new industries. However, Correa et al. (2013) in the Master Plan of Electrification estimates a dramatic increase in the demand of power (installed capacity) by 21.6% by 2017 based on current growth trends in population and its electricity consumption, the incorporation of heavy loads to the system and changes to the country's productive energy matrix. For this reason, the use of geothermal resources to produce electricity or to use it directly in the new industries and electric loads would play an important role in the supply and demand of energy.

3.2 Current investment and prioritisation of other energy resources

Ecuador's current energy policy is characterised by the development of eight new hydroelectric power plants and one wind power farm. Additionally, the government has begun the drilling of new onshore oil projects; building one new refinery and repowering another. Also, a new Natural Gas Plant for purification and storage is being built; and a thermal gas power plant is being repowered (Creamer, 2010; Lucero, 2012; Pástor, 2012; Poveda et al., 2013). The current complete EM is based on fossil fuels at over 90% of total consumption including transport, industries and household, where the transport and industry sectors are the highest consumers (Carbajal et al., 2013). When the eight new hydroelectric power plants produce 2,773 MW of extra power to the grid by 2016, Ecuador will have one of the greenest electric energy matrices worldwide with 93% of electricity produced by hydro-power (Albornoz, 2013).

The catalogue of investment for strategic projects exemplifies the current vision to exploit geothermal resources in the country (Glas, Pastor, Albornoz, Guerrero, & Solís, 2012). This establishes the required funds to run the Tufiño-Chiles-Cerro Negro prospect (150 MUSD), the Chachimbiro (162.5 MUSD), the Chacana (185 MUSD) and the Chalpatán prospects (175 MUSD). From this initial government undertaking, the MEER, in its Institutional Strategic Plan 2014-2017, has allocated, in 2014, about 3.2 MUSD in the Chachimbiro geothermal project and 2.1 MUSD in the Tufiño-Chiles-Cerro Negro Project; whereas between 2014 and 2015, it has assigned 4 MUSD in the Chacana Project (MEER 2014). Table 2 illustrates these data in detail. Furthermore, Beate and Urquizo (2015) have identified that, between 2010 and 2015, five new professional personnel have been allocated in the geothermal sector by the government, while three by public utilities, five by universities and fourteen have been paid for by foreign consultants. Beate and Urquizo (2015) have also found that 12.44 MUSD has been invested in the Ecuador's geothermal projects by government in the last decade (2005-2015).

Table 2: Required investment and allocated funds in the most advanced geothermal prospects (Glas et al., 2012).

Geothermal prospect	*Required investment*	*Allocated funds up to date*
Tufiño-Chiles-Cerro Negro	150’000.000 USD	2’100.000 USD
Chachimbiro	162’500.000 USD	3’172.308 USD
Chacana	185’000.000 USD	4’035.017 USD
Chalpatán	75’000.000 USD	No data
Chalupas	No data	No data

4 ANALYSIS OF THE KEY CHALLENGES FOR GEOTHERMAL DEVELOPMENT IN ECUADOR

Ecuador clearly has vast renewable energy resources, particularly the geothermal resource is one of the highest reserves of energy in the country. However, guaranteeing suitable energy security levels based on a diversified EM comes with different challenges. The regulatory gap for geothermal developments and the economic and financial barriers are some of the current government challenges that it has to confront in the energy and productive sector which are undergoing change. Other obstacles to achieve the economic potential of geothermal energy in Ecuador are the lack of permanent research in the field and environmental issues regarding the development of the energy sector. This study will discuss these challenges and the strategies that the current government is putting in practice.

4.1 Regulatory gap for geothermal development

The Ministry of Electricity and Renewable Energy, with the scientific and technical support of Beate (2010), develops and consolidates the ‘Plan for the utilization of geothermal resources in Ecuador (PUGR-E)’. Beate (2010) presents a summary of the areas of geothermal interest known to date in Ecuador. Additionally, the PUGR-E performs a ranking of the priority of the geothermal prospects and develops a strategy for their utilization in electricity generation purposes. Beate (2010) also prepares the terms of reference for three initial geothermal prospects of higher priority, and finally presents general guidelines for an Ecuadorian geothermal law. Throughout the plan, Beate (2010) additionally provides a brief description of the geothermal prospects with their potential for direct uses. This plan has been the guide for continuing the development of geothermal projects.

A serious weakness with the lack of a Geothermal Law in Ecuador, however, is that any geothermal project is currently required to base its development on four different laws according to its respective progress. The exploration stage is conducted under the Mining Law, whereas the rules for the use of hydrothermal water resources are defined in the Organic Law of water resources, water use and applications under the authorisation of the SENAGUA (National Agency for Water Issues) (Beate & Urquizo, 2015; Rivadeneira et al., 2014). In addition, the Environmental regulations for electrical activities apply to geothermal projects of an installed capacity of 1MW or more (Betancourt & Moreno, 2014; Noboa, 2001). The produced geothermal electricity is also under the observation of the Organic Law of the public electricity service (Rivadeneira et al., 2015). Therefore, it is clear that these different laws may create difficulties in the development of a geothermal project.

4.2 Economic and financial barriers

The complex equation between income and expenses in the energy state budget and the goals to secure a new greener EM and a new PM without a deficit has been partially solved by Chinese loans-for-oil which had risen to 5,297.8 million USD by 2013 (Escribano, 2013). Since 2009, the China Development Bank started to provide loans to Ecuador, always linked to oil sales to finance the current Ecuadorian energy projects. These investments include the highest hydroelectric projects: Coca-Codo Sinclair (1500 MW), Sopladora (500 MW), Minas San Fransisco (300 MW), Toachi Pilaton (250 MW) and Delsitanisagua (115 MW) (Albornoz, 2013; Hall, Valencia, & Reuters, 2013). Furthermore, due the lack of its own petroleum refinery, the Chinese loans support around 30% of the construction of the new Refinery del Pacifico in Ecuador (Hall et al., 2013).

Ecuador’s economic challenges to address a greener energy sector seem to have been solved by foreign loans especially from China (loans-for-oil). However, this is a solution in the short term, because a long term solution needs to address other challenges such as environmental, political and social. Additionally, E-EM is based on hydroelectric power plants. It is clear that hydro-projects come with environmental degradation such as droughts, floods, water shortages for food and agriculture, and the elimination of aquatic species for human subsistence. Therefore, the EM needs to be diversified taking advantage of the different renewable energy resources that the country possesses e.g. geothermal energy. Escribano (2013) argues that these elements in the EM of Ecuador create a ‘trilemma’ between development, conservation and foreign investment. Furthermore, the country limits foreign investment in the geothermal sector, with present investments from the public sector.

4.3 Instability of geothermal research

The repeated cycle, of geothermal research progress and abandoned (between 1978 and 2008) clearly marked in the Ecuadorian history of geothermal development, has been faced by the current government. Thus, political decisions have been adopted to continually encourage research in geothermal applications. One decision is the establishment of a dedicated government body for geothermal development, the department of geothermal energy in the CECEL-EP. Another remarkable political decision is the creation of the INER, with specific lines of research in geothermal applications. Both CELEC-EP and INER have initiated a strong coordinated research and development of geothermal projects countrywide.

The INER recently launched the ‘Plan of research lines for the development of geothermal energy’ (INER, 2015a), and the ‘Technical manual of land use for low temperature geothermal applications’ (INER, 2015b), which show the detailed geothermal potential in the country for electric and non-electric uses. There is also an important synergy in the field from public universities in the country. The National Polytechnic School (with the participation of the Geophysical Institute and its Schools of Engineering and Science) and the Polytechnic School of the Littoral are also currently supporting both scientifically and technically the development of the geothermal sector. However, best international practice suggests that a civilian organisation joins all the efforts. The creation of an Ecuadorian professional dedicated organisation for geothermal development is paramount in order to face the different challenges of geothermal research and development.

4.4 Environmental issues

Environmental challenges in the process of changing E-EM and PM are evident. Despite the Ecuadorian renewable energy potential and its benefits from scale economies, environmental groups and local communities have increased their opposition to large electric projects (Tissot, 2012). Ecuador has had to import petroleum-derived fuels to produce energy in nine different thermal power plants (TPP) due to a lack of its own oil refining capacity. This has occurred since 1980 when the first TPP was constructed (Peláez-Samaniego et al., 2007). The key problem with this explanation is that during this period an average of 3.5 million CO2 tonnes have been produced and 1100 million USD has been invested every year in the electricity sector with a growth rate of 10% annually (Albornoz, 2013). One strategy to reduce the amount of greenhouse gas emissions due to thermal power plants is that by 2016 the energy mix will be distributed in hydroelectric power plants (96%) and thermal power plants (4%) (Correa et al., 2013). However, the strategy fails to consider the differing categories of environmental damage that hydroelectric projects would cause. For example, in Ambato, one of the biggest cities of Ecuador, currently there are water disputes between the Municipal Water Company, the Hydroelectric Company, the Municipal Electricity Company and indigenous movements (Kauffman, 2013). These issues include water utilities, irrigation, electricity production and fish farming. Therefore, it is clear that the E-EM needs to be diversified using other cleaner energy resources such as geothermal energy technologies.

The Ecuadorian environmental framework considers four categories of geothermal developments in order to provide the respective permits (Betancourt & Moreno, 2014). The first one is established for as installed capacity of 1 MW, which does not require an environmental licence, and it only requires a certificate of environmental record. The second category is for 1-10 MW, the third category is for 10-50 MW and the four category is for geothermal plants of more than 50 MW; all of these categories require an environmental licence and different levels of community participation (Betancourt & Moreno, 2014). The most striking socio-environmental challenge in the geothermal development will be the acceptance by local indigenous communities, which have the perspective of territory as the beginning of their culture and ethnicity (Becker, 2007), and do not see it only as an energy resource. Most of the geothermal prospects are close to indigenous communities of the Andean Mountains where agriculture is the common economic activity (Beate, 2010; Beate & Urquizo, 2015). However, this challenge must be turned into a remarkable advantage in the development of geothermal projects by the participation of local communities in the complete process of electric and non-electric applications. The application of geothermal fluid in direct uses such as grain drying and other agricultural applications would be a major advantage of the geothermal projects close to the indigenous communities, increasing employability and local economic capacity.

5 CONCLUSION

In conclusion, this paper reveals that the Ecuadorian Government is addressing the modification of the energy and productivity sector by changing its EM and PM respectively. This study also argues that less attention has been given to the geothermal sector in comparison with, for example, the construction of hydroelectric power plants. Therefore, it is evident a lack of diversification for the use of renewable resources within the energy mix.

Ecuador clearly has vast hydro potential resources which account for about 22,000 MW of hydroelectricity but the country also disposes of approximately 8,000 MW of other renewable resources with 1000 MW of geothermal resources economically feasible. The CELEC-EP aims to develop 210 MW of geothermal installed capacity by 2021 distributed in three prospects, Chacana (40 MW), Chachimbiro (80 MW) and Tufiño (90 MW). Therefore, there is still a remaining potential to be exploited, which accounts for about 800 MW.

The key challenge that geothermal development faces in Ecuador is related to the lack of a dedicated geothermal law. Currently, more than one law applies to this kind of development, which may frustrate the interest of international developers and international funding bodies. Therefore, economic and financial barriers become significant in the exploration and drilling stages of these developments.

It is clear that the current government has introduced different initiatives to promote geothermal projects nationwide. The establishment of a dedicated department in the Electric Corporation of Ecuador, the creation of a specific research line of geothermal energy in the National Institute of Renewable Energy, the development of the Plan for the utilization of geothermal resource in the country and the support of National Universities are notable strategies to tackle the obstacles of achieving the geothermal target in Ecuador and a greener diversified energy matrix.

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