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# STRATEGIC ASSESSMENT OF GEOTHERMAL DEVELOPMENT IN ECUADOR

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## ABSTRACT

This paper presents a holistic overview over the current status of geothermal development in Ecuador. The methodology was based on "Strategic Thinking", evaluating the information while taking into account internal and external factors of the geothermal power projects situation in CELEC EP, the National Company of Electricity of Ecuador responsible of executing them. For this work, fourteen interviews were conducted with relevant actors from Ecuador and recognized experts from Iceland, Japan, Chile and Nicaragua. In addition, some successful cases from Iceland and Nicaragua are described to help the appraisal of information. The acquired information of the Ecuadorian case was processed with the SWOT tool and further actions are proposed. This report does not give the final answer about what Ecuador's current situation is and what steps should be taken, but it contributes to the continuing discussing about the next steps to develop geothermal resources in Ecuador.

## 1. INTRODUCTION

The Democratic Republic of Ecuador is located in the northwest of South America at the Equator. The population is around 17 million people in a territory of 256,370 km$^2$ (INEC, 2018), the official language is Spanish and the GNP was 104,296 MUSD for the year 2017 (BCE, 2018). The currency is US dollar and the economy is substantially dependent on oil. The Constitution of Ecuador establishes Electricity as a public service and the government significantly participates in electricity generation through the National Utility Electrical Corporation of Ecuador – CELEC (its Spanish acronym).

Ecuador has been developing geothermal prospects since the mid-1970´s with an interruption from the early 1990´s until 2010 when the Ministry of Electricity and Renewable Energy decided to resume the investigation (Beate and Salgado, 2010). Ecuador is part of the Pacific Ring of Fire where the Nazca Plate subducts under the South American Plate causing volcanic and geothermal activity. In five prospects surface exploration surveys have been carried out and in one of them, Chachimbiro, a 2000 m deep exploration well was drilled in 2017.

Geothermal power development is complex and time consuming. It requires the development of a propitious environment to put down roots and to grow steadily. The following assessment aims to

analyse the strategic position of geothermal energy development in Ecuador from different points of view and to draft an outline of the next steps to boost the growth of this technology.

## 2. METHODOLOGY

"*Strategy is, in fact, the starting point for many projects*" (Ingason and Jónasson, 2018, in prep.). If a country wants to develop its geothermal projects, it is advisable to start by doing a strategic assessment that should later become a strategic plan. This research is based on Strategic Thinking, following the directions and lessons of the book Project Strategy by Dr Helgi Thór Ingason and Dr Haukur Ingi Jónasson (2018, in prep.)

It is important to differentiate between strategic thinking and strategic planning. The first one focuses on assessing the organisation in terms of values, mission, its status and vision for the future. Strategic planning, on the other hand, describes how to reach the vision and sets SMART (specific, measurable, achievable, relevant and time-bound) objectives in a doable plan bearing in mind the possible risks (Ingason and Jónasson, 2018, in prep.).

The aim of this work is to create a holistic overview about the current status of the geothermal development in Ecuador and to give insights into the strategic planning. Five main steps shown in Figure 1 sum up the research methodology.

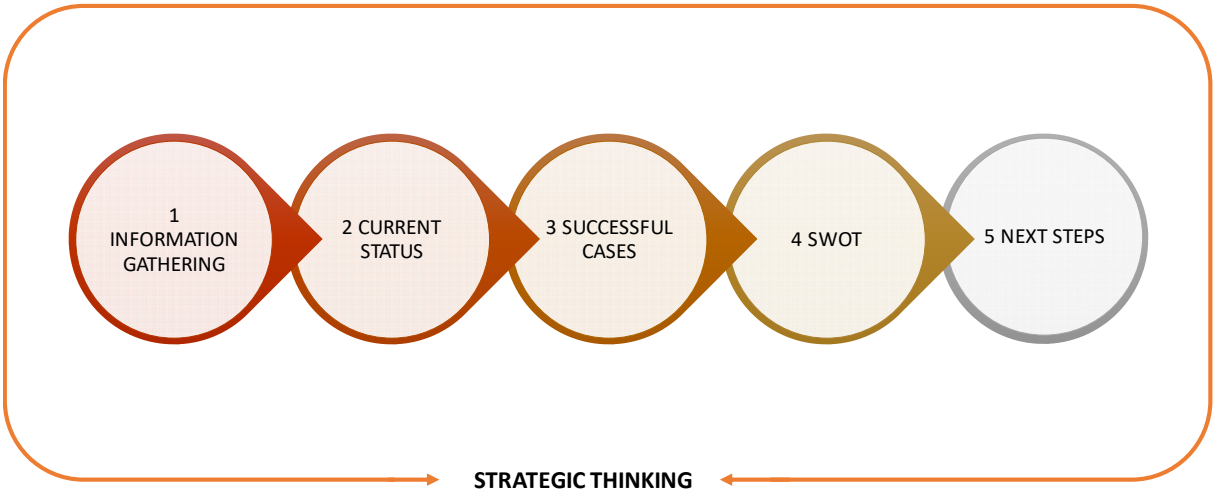


FIGURE 1: Methodology of work

Gathering information is the first step. Literature about strategic planning will be reviewed here, to apply the methodology and establish the requirement for the gathered information. In this work, the internal and external factors of the geothermal development environment will be established. Therefore, detailed information is going to be collected from scientific publications, public official information, other countries strategic plans, internal reports, own knowledge and specialist interviews. The main resource of information will be face-to-face and remote interviews with relevant people using the open questioning technique prepared in advance based on the necessity of information.

The second step will be to understand the current status of geothermal development in Ecuador. For that, it is necessary to classify internal and external environment as shown in Figure 2. For this research, the body of analysis will be the Strategic Public Company Electrical Corporation of Ecuador – CELEC EP, in charge of the geothermal development. What is the situation like today? This is the main question to answer.

To describe the internal environment, the analysis will be done taking into consideration everything that is in hands of CELEC EP or constitutes part of it. The internal environment factors are governance, internal financing, availability of resources, capabilities and customers. These factors were chosen considering that any change within them affects the geothermal development in Ecuador directly.

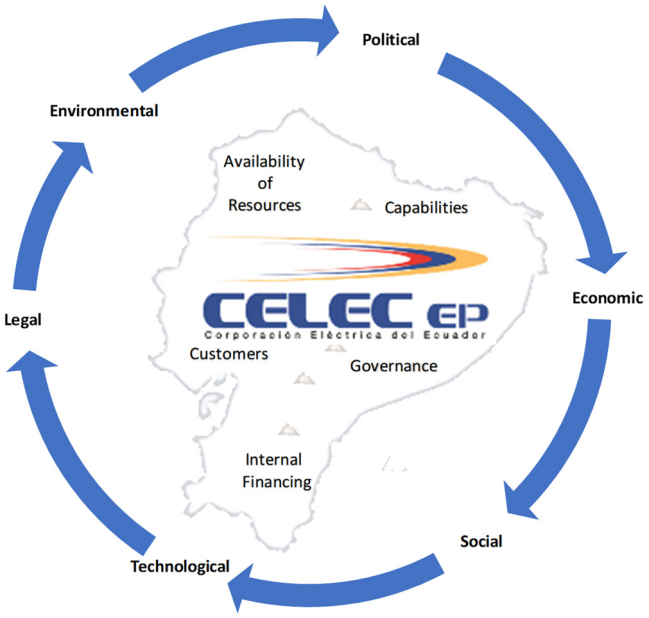


FIGURE 2: Internal and external factors of geothermal development of Ecuador

The governance factor will focus on the organisational structure of the company and the decision-making process. Internal financing factors contain information on the actual money which is intended for geothermal power projects, the ongoing funding and the financing. Availability of resources consists of the investigation of geothermal resources in Ecuador. Capabilities contain the infrastructure and human capital available in the company. Finally, under the term customers the Ecuadorian energy matrix and the opportunities for geothermal are described.

The external environment is described similarly, the analysis will be done utilising PESTLE which classifies the external factors into political, economic, social, technological, legal and environmental. Political refers to the current vision of the government concerning geothermal projects and what the position of CELEC in the governmental structure is. Economic factors are the country's status and the possibility to get external financing. Social factors describe who the interested parties are and how they perceive geothermal power projects. Technological factors depict about traditional and new geothermal technology solutions. Legal factors summarize the laws and regulations applicable to projects. Under the last point, Environmental, we describe environmental issues, standards and climate change impact of geothermal projects.

| SWOT | | |
|---|---|---|
| STRENGTHS | INTERNAL FACTORS | WEAKNESSES |
| | *GOVERNANCE* | |
| | *INTERNAL FINANCING* | |
| | *AVAILABILITY OF RESOURCES* | |
| | *CAPABILITIES* | |
| | *CUSTOMERS/MARKET* | |
| OPORTUNITIES | EXTERNAL FACTORS | THREATS |
| | *POLITICAL* | |
| | *ECONOMIC* | |
| | *SOCIAL* | |
| | *TECHNOLOGICAL* | |
| | *LEGAL* | |
| | *ENVIRONMENTAL* | |

FIGURE 3: SWOT analysis

In the third step, we will analyse successful cases of geothermal development comparing other processes, performance, best practices, lessons learned and innovative solutions approached. Iceland and Nicaragua were taken as examples.

In the fourth step, we carry out a SWOT analysis, a very adaptable tool that provides a structured way of processing information, bringing out the essentials and showing the results in a comprehensive matrix. This technique can be applied at all levels from individuals through to products, services, locations business units and whole organisations to evaluate strengths and weaknesses of the internal environment and opportunities and threats implemented by the external environment (Figure 3).

After having extracted the Ecuadorian geothermal development "strategic position" from the SWOT, the next step will be to take action: "Build on your strengths, shore up your weaknesses, capitalize on your opportunities and recognize your threats" (Olsen, 2007). At the end of this study we define next steps and give recommendations that could be used as a baseline to start working in the future strategic plan.

## 3. INFORMATION RESOURCES

For gathering information, this research is based on interviews with experts and active actors in different parts of geothermal development in Ecuador, Iceland, Japan, Chile and Nicaragua (see Urquizo, 2018, Appendix I). To complement the research, other resources were consulted such as public national information, official reports, scientific publications related to the topic, results of discussion boards, other countries strategic plans, guides to develop geothermal and the author's own experience of working in development of geothermal power.

### 3.1 Interviews

As was explained in the methodology, after the internal and external factors were established, a list of specialists was compiled and topics were proposed as shown in Table 1 and Figure 4.

TABLE 1: List of people who were to be interviewed

| Company/Institution | Country | Name | Department | Position | Topic of the conversation |
|---|---|---|---|---|---|
| Ministry of Energy and Non Renewable Resources | Ecuador | Marco Valencia | Undersecretariat of Generation and Transmission | Undersecretary | Vision of the Ministry to develop geothermal and financing of new projects |
| CELEC EP - Headquarters | Ecuador | Jorge Ortiz | Directorate of Expansion Planning | Technical Specialist | Projections of electrical sector in Ecuador, why Geothermal is important to the matrix |
| CELEC EP - Termopichincha | Ecuador | Carlos Cajas | Projects Sub management | Sub manager | State of art of geothermal in Termopichincha |
| CELEC EP - Termopichincha | Ecuador | Tanya Cobos | Projects Sub management | Social Specialist | External and internal stakeholders in Ecuador. Do people understand and agree geothermal? |
| CELEC EP - Termopichincha | Ecuador | Francisco Astudillo | Projects Sub management | Projects specialist | State of art of geothermal in Termopichincha |
| Ministry of Foreing Affairs | Iceland | Engilbert Guðmundsson | Foreign Minister Office | Advisor | What are the financist looking for in geothermal. Role of development banks and cooperation agencies in the early stages of geothermal projects. |
| ÍSOR | Iceland | Ólafur Flóvenz | Chief Executive Officer | CEO | Are necessary local geoscientific capabilities to develop geothermal? |
| MANVITT | Iceland | Kristinn Ingason | Geothermal Plant Division | Manager | Technologies and opportunities for geothermal in developing, tips for beginners |
| Reykjavik Geothermal | Iceland | Thorleifur Finnsson | Project Development | Head of Project Development | What do a private investor is looking in a country? What does Ecuador need to attract private investment in geothermal? |
| LANDSVIRKJUN | Iceland | Bjarni Pálson | Research and Development Division | Manager Geothermal Deparment | Sustainable development of geothermal in a National Power Company |
| HS ORKA | Iceland | Kristín Vala Matthíasdóttir | Resource Park | VP Resources | Sustainable development of geothermal in a Power Company (private vision) |
| POLARIS ENERGY NICARAGUA S.A. | Nicaragua | Julio Guidos | Reservoir Deparment | Manager | Private Geothermal Developing in the LAC region |
| Geothermal Specialist | Japan | Manabu Sugioka | Consultant | Geothermal Specialist | Main obstacles to develop geothermal in South America |
| Carcelén, Desmadryl, Guzmán, Tapia - Abogados | Chile | Jerónimo Carcelén | Partner | Natural Resources Lawyer | How to create a good environment to develop geothermal (Results of Chilean Geothermal Table of Discussion) |


FIGURE 4: Interviewed specialists, positions and countries

The people listed were chosen because of their expertise or involvement in geothermal development. In Ecuador, *Marco Valencia,* the Undersecretary of Generation and Transmission in the Ministry of Energy and Non-Renewable Resources was selected. All the new electricity projects pass through his department. He has a long professional career with experience in the operation of the electrical system CENACE, CELEC EP and the Ministry of Electricity and Renewable Energy. During his work in CELEC EP, he was in charge of the Expansion and Planning Directorate and the Renewable Energies studies including geothermal. He is also a professor in the National Polytechnic School (EPN) in Quito.

*Jorge Ortiz*, is a technical specialist in the Directorate of Expansion Planning in CELEC EP – Headquarters. He has a long experience in technical studies to optimize the planning of power generation in Ecuador. He has received awards and recognition for his research and is now actively working on finding the best way to leverage renewable energies according to the high hydroelectrical Ecuadorian matrix.

*Carlos Cajas* is sub-manager of projects in CELEC EP Termopichincha, the branch of CELEC in charge of geothermal. He did a training programme in El Salvador and worked actively at the first geothermal exploration well in Chachimbiro. He also has experience in the operation of thermoelectric power plants, since his last position was Head of Jivino Power Station in the Amazon. His current task is to develop Renewable Energy projects for Termopichincha.

*Tanya Cobos* is the social and communitarian relations specialist in CELEC EP Termopichincha. She has been working with the communities and local authorities in all the geothermal projects run by CELEC EP. Her excellent work is reflected in the good relations and acceptance that the company has in the communities in the vicinity of the projects.

*Francisco Astudillo* is a project specialist form CELEC EP Termopichincha. He has experience working in the team to supervise the construction of a thermoelectrical power plant, developing wind resources, studies and doing field work and document elaboration for procurements in the Chacana and Chachimbiro geothermal projects. He is currently supervising the planning of the next stage of the Chachimbiro project.

Unlike Ecuador, Iceland is a country with a long experience in geothermal exploitation. The people interviewed for this project represent different sectors such as financing, private investment,

geoscientific research, international experience, and consultancy, and come from national and private companies. The experts were selected based on suggestions by the Director of UNU-GTP, Mr. Lúdvík Georgsson, who helped to find a wide variety of people representing different aspects of the development of geothermal power in Iceland.

The list of Icelandic experts starts with *Engilbert Gudmundsson*, a well-recognized specialist in project financing. He worked as Chief of the Democratic Institutions Section of the United Nations Integrated Peacebuilding Office in Sierra Leone, as World Bank Country Manager for Sierra Leone, as Vice President of the Nordic Development Fund and as General Director of the Icelandic International Development Agency (ICEIDA). Currently, he is an advisor of the Ministry of Foreign Affairs in Iceland. He has a great expertise in project financing in developing countries and collaborated as a lecturer in the Project Management Programme of UNU-GTP.

*Ólafur G. Flóvenz* is the Chief Executive Officer of ÍSOR - Iceland GeoSurvey. He has been in this position for 15 years and is an expert on the development of geothermal power. He has a PhD degree in geophysics and was an adjunct professor of the University of Iceland. He understands the importance of building capabilities and geoscientific research in Iceland.

*Kristinn Ingason* is the Manager of the Geothermal Plant Division of Mannvit Engineering, a consultant company that works in every stage of geothermal development. Mr. Ingason is a mechanical engineer whose experience in geothermal goes from district heating to different projects for Krafla, Bjarnaflag, Hellisheidi, and Theistareykir power plants. He has worked in innovation projects such as the Iceland Deep Drilling Project (IDDP) and has international experience from geothermal projects in Slovakia, USA, Serbia, Chile, Hungary, St. Vincent, Canada and the Philippines.

*Thorleifur Finnsson*, the Head of Project Development in Reykjavik Geothermal, is an electrical engineer with 25-years experience in the power industry. He has long experience involving deregulation of the Icelandic electricity market, project-managing, pre-feasibility and feasibility studies for power projects, developing and negotiating project agreements and power purchasing agreements and establishing projects in Asia and Africa (RG, 2018).

*Bjarni Pálsson* is the manager of the Geothermal Department in the Research and Development Division of Landsvirkjun – the National Power Company of Iceland. His experience involves managing the overall power project portfolio of the company, including hydro, geothermal and wind power projects. He did project management for exploration and development of a new geothermal power plants at Krafla, Bjarnaflag, Theistareykir, and for the new geothermal fields Gjástykki and Hágöngur. He also managed the IDDP project in Krafla and gave international advice through Landsvirkjun Power. He is a board member of the International Geothermal Association and the Geothermal Association of Iceland.

*Kristín Vala Matthíasdóttir* is the Vice President of Resources at the Resource Park of HS Orka. She has around ten years of professional experience in chemistry, reservoir management and the geothermal industry. The programme that she is currently working on is focused on fostering a "society without waste" using the streams that flow to and from the companies in the park to the greatest extent achievable. She is also the chairman of the Iceland Geothermal Association and a board member of the International Geothermal Association.

To complement the point of view of Iceland, *Julio Guidos,* the Manager of the Reservoir Department of Polaris Energy Nicaragua S.A is also on the list. He has been occupying this position since 2015. His main challenge was to create a team and develop the necessary labs, geoscientific and reservoir services that the company uses the most to maintain sustainable production. Before joining Polaris, Mr Guidos was the Director of Geothermal Exploration projects in LaGeo S.A., where he developed geothermal conceptual models, located drilling targets and supervised different geothermal projects in El Salvador and Latin America. For his performance in the Geothermal Diploma Course by University of Auckland

in New Zealand, he won the Mitsubishi Prize in 1991. He was a lecturer in the Geothermal Specialization Programme at the National University of El Salvador from 2012 to 2014 (PENSA, 2018).

The Japanese specialized consultant *Manabu Sugioka* provides key insights due to his more than 10 years of experience in geothermal and natural resources projects. Mr Sugioka worked as a JICA expert and advisor from 2010 to 2018, analysing projects from Indonesia, Costa Rica, Bolivia, Philippines and Ecuador. Under JICA cooperation, he worked at assisting the project management of Laguna Colorada in Bolivia, in developing the field, in procurement processes under financer´s regulation, negotiation with financers, procurement and administration. He also worked as an advisor for geothermal development at CELEC EP Termopichincha, Ecuador, from September 2015 until March 2018. As a geophysicist, he carried out studies on Ecuadorian prospects, developing capabilities in the company. He helped in the design of a geothermal department, the planning of new prospection and next steps for the Chacana project and he assisted in the project management of the Chachimbiro geothermal project.

Finally, *Jeronimo Carcelen*, a recognized Chilean Natural Resources Lawyer, is well-respected as a global expert. He is currently working as an international visiting adviser at Dechert in Washington D.C. His experience involves mining and geothermal exploitation. He was a very active participant in the *Geothermal Table* carried out in Chile (December 2016 – July 2018), organized by the Ministry of Energy and attended by actors and experts of the geothermal sector. The aim of the table was to identify the main barriers to geothermal development and to design a framework that favours the revitalization of the sector (Ministerio de Energia, 2018).

To prepare the interviews, a matrix of internal and external factors versus interviewers was prepared to match the required information with the field of expertise of the interviewees (Figure 5). The interviews were designed with open questions and they were sent before the appointment via email.

| INFORMATION MATRIX | | Marco Valencia | Jorge Ortiz | Carlos Cajas | Tanya Cobos | Francisco Astudillo | Engilbert Gudmundsson | Ólafur Flóvenz | Kristinn Ingason | Thorleifur Finnsson | Bjarni Pálson | Kristín V. Matthíasdóttir | Julio Guidos | Manabu Sugioka | Jerónimo Carcelén |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **INTERNAL FACTORS** | | | | | | | | | | | | | | | |
| Governance and procedures | Structure of the company | | ■ | ■ | ■ | ■ | | | | | | | | | |
| | Decision making process | ■ | ■ | ■ | | | | | | | ■ | ■ | ■ | ■ | |
| | Stakeholders | | | ■ | | ■ | | | | | ■ | ■ | ■ | ■ | |
| Internal Financing | Where is the money coming from in geothermal | ■ | ■ | ■ | | | ■ | | | | ■ | ■ | ■ | ■ | |
| | Working with JICA and GDF | ■ | ■ | ■ | | ■ | ■ | | | | | | ■ | ■ | |
| Availability of resources | What exists until now | | | ■ | | ■ | | | | | ■ | ■ | | ■ | |
| | Intellectual capital | | | | | ■ | | ■ | ■ | | ■ | | | ■ | |
| Capabilities | Structural capital | | | ■ | | ■ | | ■ | | | ■ | ■ | ■ | ■ | |
| | Human capital | | | ■ | | | | ■ | | | ■ | ■ | ■ | ■ | |
| Custommers | Projection of the demand | | ■ | | | | | | | | | | | | |
| | Is Geothermal necessary for the system? | ■ | ■ | | | | | ■ | | | | | | | |
| **EXTERNAL FACTORS** | | | | | | | | | | | | | | | |
| Political | Structure of the electrical sector for geothermal | ■ | ■ | | | | ■ | | | | ■ | ■ | ■ | ■ | ■ |
| | Politic internal and external | ■ | ■ | ■ | | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ | ■ |
| | Role of the institutions | ■ | | ■ | | ■ | ■ | ■ | | | ■ | ■ | ■ | ■ | ■ |
| Economical | Development banks vision or last movements | | | | | | ■ | | | ■ | ■ | | | ■ | ■ |
| | Promoting geothermal investment in the region | ■ | | | | | ■ | | | ■ | ■ | | | ■ | ■ |
| Social | Is geothermal accepted? | | | ■ | ■ | ■ | | | | ■ | ■ | ■ | ■ | ■ | |
| | Is geothermal well known? | ■ | | ■ | ■ | ■ | | | | ■ | ■ | ■ | ■ | ■ | |
| Technological | Last tendencies to develop geothermal | | | | | | ■ | | ■ | ■ | | ■ | ■ | ■ | |
| | New technology? More efficient? | | | | | | | | ■ | ■ | | ■ | ■ | ■ | |
| Legal | How are regulations in the region for private and public companies? | ■ | | ■ | | | ■ | | | ■ | ■ | ■ | ■ | ■ | ■ |
| | Current laws and regulations for electrical sector | ■ | ■ | ■ | | | ■ | | | | ■ | ■ | ■ | | ■ |
| | Existen regulations and laws | | | ■ | | ■ | | | | | ■ | ■ | ■ | | |
| Environmental | Environmental Regulations | ■ | | | | | | | | | | | | | |
| | International concerns about climate change support Renewable energies development | ■ | | | | ■ | ■ | | | ■ | | | | | |

FIGURE 5: Information matrix

## 4. DESCRIPTION OF THE GEOTHERMAL SECTOR IN ECUADOR

The body to be analysed is the *Strategic Public Company Electrical Corporation of Ecuador – CELEC EP* which was in August 27th, 2010, by the former Ministry of Electricity and Renewable Energy, through Official letter No. 882-DM-SGP-2010, commissioned to develop geothermal power projects. The Figure 6 below represents the structure of CELEC EP.

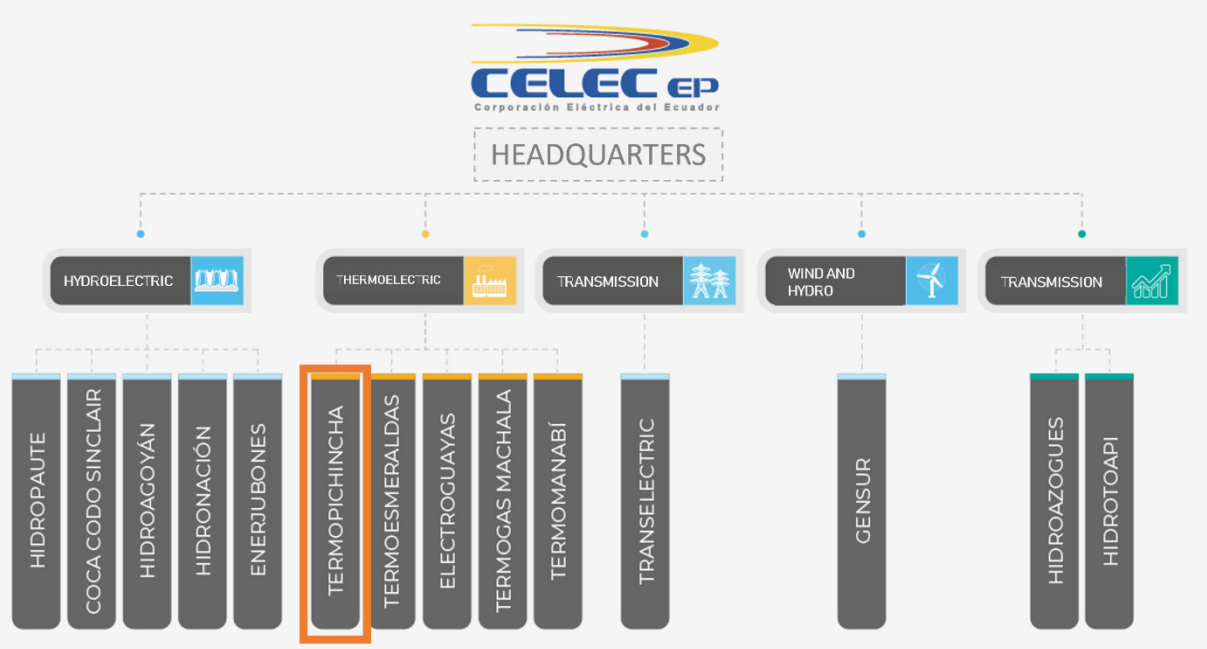


FIGURE 6: Structure of CELEC EP (CELEC EP, 2018)

### 4.1 Internal factors: Governance and procedures

CELEC EP is a state-owned company in charge of carrying out the generation and the complete transmission of electricity in Ecuador. The installed capacity of CELEC EP is 5.624 MW what translates to 90% of generation capacity of the country (Urquizo, 2018, interview with Ortiz).

CELEC EP has 14 branches (Figure 6). Geothermal projects are carried out by the branch in Termopichincha which has a project department. This department is conducting, among others, research on renewable energy projects such as wind, biofuel, solar and geothermal, but its structure was created to develop thermal projects. Today, the sub manager and nine people are working in this department. However, there are no permanent positions for geothermal research; thus, no geoscientific personnel are working here.

Inside CELEC EP, the procedure to approve projects is described in the following. First, the division in charge of the projects analyses the needs of the project and proposes the stages and budget. Then, the sub-manager of the division (Projects in Termopichincha) sends the proposal to the manager of the branch. If the manager agrees and the budget is less than two million dollars, the decision to proceed with the project can be made, otherwise the request is sent to CELEC EP headquarter to be approved through the Headquarter Planning Directorate and the General Manager. If the budget of the project is more than twenty million dollars, the General Manager has to request to the Board of Directors to approve it. When the size of the project with regards to power is defined, the department in charge coordinates the interconnection with CELEC EP Transelectric (the branch responsible for transmission of electricity) or with the nearest distribution company if the project is small (Urquizo, 2018, interviews with Cajas and Ortiz).

The Board of Directors consist of the Secretary of Planning and Development (Spanish acronym SENPLADES), Ecuador's Coordinator of Public Companies (Spanish acronym EMCO) and the Ministry of Energy and Non-Renewable Natural Resources (Spanish acronym MERNNR) (CELEC EP, 2018).

### 4.2 Internal factor: Internal financing

The majority of the power generation projects in the last decade were developed with government investment through the Ministry of Economy and Finances. The loans mainly came from China Export – Import Bank (EXIMBANK – CDB) and from multilateral organizations such as IDB and CAF (Spanish acronym which stands for Andean Development Bank) (Urquizo, 2018, interview with Valencia).

For geothermal research, CELEC EP has been using its own funds and recently with Japanese support through the Japanese International Cooperation Agency (JICA). So far Ecuador invested around ten million US dollars in the research of Chachimbiro, Chacana, Tufiño – Chiles – Cerro Negro, Chalpatan, Baños de Cuenca and acquisition of equipment (geophysics and laboratory). JICA and CELEC EP signed an agreement in June 2015 to complete the feasibility studies for the Chachimbiro project, including the first exploration well with non-reimbursable funds from JICA (approx. 10 M USD). Based on the results of the drilling, JICA plans to analyse the possibility to finance the next stage through an Official Development Assistance (ODA) engineering and services loan. Also, JICA sent a geothermal specialist to advise, review results, train and work with the CELEC EP team for two years.

Currently, planning for the next stage of the Chachimbiro project is in progress. This consists of around 6 wells, a wellhead power plant and the design and budget for a 50 MW power plant (next stage). Based on this plan, an appraisal mission from JICA is going to review the project and recommend the next stage of financing. CELEC EP Termopichincha manages this process through CELEC EP Headquarters. Once the appraisal is approved, the beginning of the loan procedure must be authorized by the Board of Directors of CELEC EP.

After the corporation has decided to continue with the project with the finance of JICA, the government of Ecuador has to decide, who is going to take the loan, the company itself or the government. After that confirmation, the Ministry of Economy and Finances has to analyse the loan terms and conditions to approve it. If the Japanese government approves as well, it issues a sovereign guarantee.

CELEC EP Termopichincha had agreed upon further cooperation to finance other projects than Chacana. This includes a grant from the Geothermal Development Facility (GDF) to fund 40% of the gradient studies. The contract is under revision, because the applicable law and dispute settlement was established outside Ecuador and the approval from the National Attorney is required before signing a contract. The total CELEC EP budget is reviewed and approved by ARCONEL every year, the Agency that controls the price of electricity.

Finally, to develop new projects in the field of electrical generation, private investment will be promoted by MERNNR under public tenders within an equal and transparent framework to obtain the best technical and economic proposals for the required energy. Ecuador will also continue looking for cooperation to develop the first stages of other projects and exploring other ways through Public Private Partnership. Since CELEC EP owns 90% of installed capacity of the country, it is open to analyse alternatives (Urquizo, 2018, interviews with Valencia and Ortiz).

### 4.3 Internal factor: Availability of resources

The location of Ecuador in the active convergent plate margin of South America makes it a place with active volcanoes and intense seismicity. The geothermal exploration started in the middle of the 1970’s

to 1990's when the low cost of oil made this energy less attractive and the programmes were closed. In late 2008, the Ministry of Electricity and Renewable Energy decided to resume geothermal investigation and implemented the "*Plan to leverage the geothermal resources in Ecuador*" where a compilation of the 70's to 90's studies was done (Beate and Urquizo, 2015). After the delegation of the Ministry in 2010, the next advances in exploration were carried out by CELEC EP:

*Chachimbiro*: This project is located 130 km north from Quito and 20 km west of Ibarra. Geology, geochemistry, and geophysics surveys were carried out and the first exploratory 2000 m deep well was drilled in late 2017. A temperature of 235°C was verified and the planning for the next stage is in progress. Around six wells and a well head power plant is under planning for the next stage.

*Chacana:* This project is located 60 km east of Quito. Surface exploration, geology, geochemistry and geophysics surveys were done and two main prospects were the most promising: *Jamanco and Cachiyacu.* The Cachiyacu area is 5 km inside the National Park Antisana and the Jamanco area is next to the main road. A 500 kV transmission line passes over the project. Gradient studies are planned to locate well targets in Jamanco.

Binational *Tufiño – Chiles - Cerro Negro*: This project is located on the border of Colombia and Ecuador. It was carried out by the two countries through ISAGEN from Colombia and CELEC EP from Ecuador. Geology and geochemistry surveys were done but due to the rejection of the community in Colombia, the project is on hold since 2015.

*Chalpatan*: This project is located in the north of the country around 260 km from Quito and close to the border of Colombia. Surface exploration was done but the results point to a medium- to low-enthalpy resource.

*Baños de Cuenca:* This project is located around 500 km from Quito next to Cuenca City. Geology, gravity and geochemistry surveys were executed. MT studies are planned for a next stage.

More prospects are found throughout the country, but more surface exploration is needed.

The focus of CELEC EP is the Chachimbiro project followed by Chacana Jamanco (Urquizo, 2018, interview with Cajas). The first one has proven to have sufficiently high temperature and efforts will be undertaken to define the size of the reservoir.

Direct uses are also explored. The Institute of Geological and Energy Research – IIGE (formerly: National Institute of Energy Efficiency and Renewable Energies – INER) has carried out pilot projects on greenhouses and space heating and cooling (Andrés Lloret, personal comm., 2018).

### 4.4 Internal factor: Capabilities

Since CELEC EP has 90% of the power generation capacity, the company has good experience in operating hydroelectrical, thermoelectrical and wind farm projects. Geothermal projects are in progress but the company does not have experience in drilling or geoscientific surveys. Consequently, there are no permanent positions for these types of professionals.

CELEC EP Termopichincha has a project department with 10 people: the sub manager, 1 electrical engineer, 2 mechanical engineers, 1 chemical engineer, 2 civil engineers, 1 social specialist and 2 economists. The company has recently terminated the contract of three geoscientists (2 geologist and 1 geochemist) because of budget cuttings.

Regarding infrastructure, CELEC EP Termopichincha has a laboratory for chemical control of water, oil and fuel. This laboratory was enlarged in 2016 and equipment were acquired to develop analytical methods to analyse rocks, water and gases. The sections dealing with water and gas analysis are still under development, while rocks analysis (XRD and thin sections) is already developed. Also, equipment to undertake MT, gravimetry, TDEM and magnetometry surveys are part of the infrastructure available for geothermal exploration. The same personnel of the chemical control laboratory are working in the

developing of the geothermal laboratory for water and gas analysis, therefore it is taking long and some techniques are on hold.

Regarding staff training, 13 fellowships from Iceland (3), El Salvador (7) and Japan (3) have been given to CELEC EP personnel to complete geothermal trainings. Also, attendance to workshops, congresses, technical visits and seminars around the world have been supported in order to understand this industry better. In the same way, CELEC EP received collaboration from IDB to train specific people (9 analysts) to develop analytical methods for the geothermal laboratory at LaGEO, El Salvador. Furthermore, training on-the-job has been done in all the studies developed so far.

Furthermore, CELEC EP has signed cooperation agreements with LaGEO from El Salvador (advisor and training lab people) and IIE from Mexico (advisor). ICE from Costa Rica has also supported CELEC EP with technical visits and technical suggestions. It is important for the company to strengthen the cooperation between countries and to learn from the experience of others.

Certainly, geothermal development requires drilling to verify the reservoir and the real potential or the resource. CELEC EP lacks experience in this field and it is important to analyse accurately future ways to do procurements and contracts that facilitate a normal execution of drilling based on sensible drilling costs. The current contract procedures do not allow to make a flexible drilling contract. It could be interesting to check and adapt the procedures of the National Oil Company.

Geothermal development is also very complex and involves not only the technical departments but also the administrative, legal and human resources departments of the institution. This people should be educated as part of a training plan visiting other successful geothermal companies, understanding more about the history of geothermal and having specific lectures (Urquizo, 2018, interviews with Cajas and Astudillo). It could be useful to them to understand and react better to changes or special situations. More information and experience in managing grants is also important to develop (Urquizo, 2018, interview with Astudillo).

From the interviews, here are a few comments that touch on this aspect of the development of expertise: "*To develop geothermal is necessary to create your own core of expertise*" (Urquizo, 2018, interview with Flóvenz). "*It is necessary that the people of working at the institutions work closely with the experts and little by little develop their own capacity. It is not until a company has gone through the fourth or fifth field that it should start expecting that it can rely in its own people. Of course, the development of capacities should grow gradually according to the stages of the projects*" (Urquizo, 2018, interview with Gudmundsson). "*Surface explorations consume some time but are not that expensive; social, and environmental impacts are not high so it is advisable to do as much as possible here. Then exploration drilling is carried out for more information and the things become more complicated and costly*" (Urquizo, 2018, interview with Ingason).

### 4.5 Internal factor: Customers

The installed capacity in the Ecuadorian National Interconnected System (Spanish acronym SNI) is 6,246 MW (August 2018). CELEC EP has an installed capacity of 5,624 MW what translates to 90% of the generation capacity of the country. This includes hydroelectric power plants (4,000 MW), thermoelectric power plants (1 607 MW) and a wind farm (16.5 MW). Further, CELEC EP is in charge of all transmission systems of the country. The gross energy production to supply SNI in 2017 was 23.94 TWh. Of these 84% was based on hydroelectric generation. CELEC EP covered 88.7% of the country's demand (Urquizo, 2018, interview with Ortiz).

Jorge Ortiz from CELEC EP is a specialist in planning and explained how the master plan is done. According to the law (LOSPEE), MERNNR is responsible to prepare the *electricity master plan*. This

plan outlines the development of the next ten years. MERNNR delegates the projection of the country's demand to ARCONEL.

The distribution companies send the demand projections to ARCONEL including the special projects. After that, ARCONEL analyses five different scenarios with changing special and industrial loads. Then, a future energy study is carried out, including modelling how to cover the demand through an optimization process of the future operation with the software SDDP-OPTGEN. To make the future energy study it is necessary to have an updated catalogue of projects for the model to choose from.

The current project catalogue is not updated because since the 1980s all new inventory of energy resources has been undertaken at a global level. Now, CELEC EP is working on an energy resources inventory including wind, sun, biomass, geothermal and thermoelectricity. The aim of this inventory is to find the complementary sources to be utilized with the existing hydroelectrical system.

In Ecuador, all the big hydroelectric power plants are located in the Amazon area and their production is in line with their status regarding low and high flow of water. The country has an abundance of hydroelectricity in the rainy season from April to September, but in the dry season from October to March, the use of thermoelectricity is necessary. The ideal option for the country would be to use renewables instead and here geothermal comes into play. Geothermal would run at almost 100% capacity during the low flow season for water and the maintenance would be performed during the high flow season for water.

According to Ortiz and Jara (2018), from 2021, due to the increase of demand, the thermoelectric power generation during the dry season will increase annually. In the long term, it is preferable to introduce complimentary renewable energies which have their maximum monthly output during the dry season. In the master plan of electricity 2016-2025 (MEER, 2017), an installed capacity of 150 MW of geothermal electricity is scheduled for 2023. The necessity of geothermal is prevailing and it is important to speed the prospective studies.

Finally, CENACE which is the system operator reports the current operative situation of the SNI and points out problems that must be corrected in the short term. The entire plan is revised every two years (Ortiz, interview).

### 4.6 External factor: Political

The National Development Plan 2017-2021 is the instrument to which all the policy, programmes and public projects are described. This plan promotes the increase the electricity generation through renewable energy sources from 68.8 to 90%. Its Objective 3 is to guarantee nature the rights of the current and future generations, encourage public investment to consolidate and increase the energy matrix based on renewable energies and other non-conventional power sources, with tariff schemes for incentives to the private and associative sectors. Objective 5 is to support the productivity and competitiveness for sustainable economic growth in a redistributive and solidary way. This objective is summarized by the 5.3 public policy: *Guarantee the energy supply with quality, opportunity, continuity and security, with a diversified, efficient, sustainable and sovereign energy matrix as the axis of the productive and social transformation* (SENPLADES, 2017).

In the last decade, Ecuador has been politically stable after going through an unstable period with 8 presidents in 10 years (Urquizo, 2018, interview with Carcelen). This fact allowed the installation of a number of hydroelectric power plants. The policy has been to promote renewable energies to support the battle against climate change and global warming. Now 84% of the produced energy is renewable, which confirms the great effort of the country (Urquizo, 2018, interview with Valencia). This success has created a paradigm. After the installation of numerous hydroelectric power plants in the last decade, people tend to think that sufficient investments have been made and that the electricity sector is fully

developed. As explained above, complementary energy sources should be developed and good communication campaigns are necessary (Urquizo, 2018, interview with Ortiz).

In Ecuador, the electrical sector is based on *The Organic Law of the Public Service of Electricity* (Spanish acronym LOSPEE), issued in January of 2015. The institutional level consists of (Urquizo, 2018, interview with Valencia) the following:

- The Ministry of Energy and Non-Renewable Natural Resources MERNNR, recently formed by Ministry of Electricity and Renewable Energy (MEER), Ministry of Hydrocarbons and Ministry of Mining;
- Agency for Regulation and Control of Electricity (Spanish acronym ARCONEL);
- The National Energy Operator CENACE; and
- Specialized institutes.

At the business level, the generation, transmission and distribution activities can be carried out by:

- Public companies;
- Mixed-economy enterprises;
- Private enterprises;
- Consortiums or associations; and
- Enterprises of popular and solidarity-based economy.

MERNNR is the ruling body and electric sector planner to ensure electricity supply and distribution. The institution is in charge of the identification and follow-up of project executions. It grants licenses, evaluates the electric sector management including the promotion and execution of renewable energy plans and programmes and the mechanisms to reach electric efficiency based on what is established in the Constitution and the law.

ARCONEL is responsible for the development of regulatory instruments required for the efficient operation of the sector. CENACE is in charge of dispatching the generators day by day, and its experience contributes to help the planning of the future electrical matrix. After the recent merger of the ministries, the research institutes merged to the Institute of Geological and Energy Research which is focused on low-enthalpy investigation (Spanish acronym IIGE).

Another important actor is the National Planning and Development Secretariat (Spanish acronym SENPLADES) which consolidates the general planning of the state and institutions. All new projects must be analysed by this institution to be prioritized.

To prioritize projects in Ecuador, MERNNR, the responsible body of the electric sector planning, creates the Electricity Master Plan. The plan identifies the available projects and prioritizes them according to an expansion programme taking into account the improvement in generation, transmission, distribution and energization of isolated rural area in ten years' time. MERNNR delegates different institutions to elaborate specific studies. In the case described in our study, CELEC EP creates the inventory of energy resources and expansion plan, as explained above. Based on this plan, MERNNR specifies which projects are carried out by the government and which could be proposed to private investment, prior to a public selection process.

In order to optimize the size of the government, The Ministry of Electricity and Renewable Energy was merged with the Ministry of Hydrocarbons and The Ministry of Mining. The former ministries did not have experience regarding the drilling and research of underground natural resources as the new ministry has. Currently, the country´s economy is depressed and the government is prioritizing investments in sectors where profits are obtained faster such as hydrocarbons and telecommunications. The current vice minister has experience in the auctioning model which could be useful to develop geothermal prospects (Urquizo, 2018, interview with Carcelén).

The Ministry of Foreign Trade and MERNNR are coordinating new projects and developing mechanisms to invest in electricity generation through private public partnership. The portfolio presented has hydroelectric projects and renewable energy sources such as wind, solar and some hydro (MEER, 2018). Geothermal projects are not in the catalogue but are mentioned. Another option to promote new projects is through private investments with a public selection process (Urquizo, 2018, interview with Valencia). Tax exemptions are being applied and the tax of currency outflows has been waived for new investments to attract more investors.

For renewable energies, the tariff policy is crucial. An example for this is Japan in 2011. After the nuclear plant explosion, the Japanese government speeded to make decisions about feed-in-tariff for renewable energy in the next year (Urquizo, 2018, interview with Sugioka). Especially in geothermal the likelihood to get good concessions increases a lot when the basic research has been done and the first exploration wells drilled. Grants or risk mitigation facilities also help the development. There are some examples from developing countries where *greenfield* concessions were given and did not work out. It is advisable to go stepwise and careful. Geothermal development takes two or three election periods which is about one and a half or twice as long as the development of a hydro power plant (Urquizo, 2018, interview with Gudmundsson).

The changes made by the government are linked to political, institutional and authority changes that could produce delays and roadmap modifications. To develop geothermal, political willingness is one of the most important things (Urquizo, 2018, interview with Astudillo). A good understanding by the authorities of the benefits of each stage of development and the long-term goal is crucial.

### 4.7 External factor: Economical

Ecuador has an oil dependent economy and price variations have direct effects in business dynamics and public institutions. The new plan of the Ministry of Economy and Finances is to reduce the size of the government and boost the private sector. Accordingly, the biggest problem in all state-owned companies is the financial resource required to develop projects and hire staff (Urquizo, 2018, interview with Cajas). In terms of market, Latin America is a pretty risky region, Ecuador's credit ranking is around B- by Moodys and Standard & Poor (TE, 2018).

To encourage private investment, Ecuador has taken big steps to adjust its legal and regulatory framework, with tax exemptions for development of new projects, international arbitration and the waiving of tax for currency outflows for new investments. In the case of geothermal development, the investor needs to have the assurance that he is able to sell the energy at a competitive price (Urquizo, 2018, interview with Carcelen). In South America, the energy tariff is relatively low (Urquizo, 2018, interview with Sugioka).

If the resource is promising, companies are willing to go even on *greenfield* projects. Reykjavik Geothermal and Ormat are good examples (Urquizo, 2018, interviews with Gudmundsson and Finnsson). Greenfield concessions are not the most advisable since the value or the resource is unknown. In most cases, the government does the exploration and then they develop the most suitable business model such as giving it to a private company, contracting an operator, forming a partnership or developing the resource themselves. Mexico is applying Risk Mitigation Facilities from IDB what could be suitable for Ecuador as well (Urquizo, 2018, interview with Carcelen).

In the case of Ecuador, the existence of a high-quality geothermal resource has not yet been verified. At this stage, IDB, World Bank, CAF and some multilaterals could probably support the country geothermal development in both surface exploration and the drilling. The Energy Sector Management Assistance Program - ESMAP of the World Bank has an agreement with ICEIDA to provide Icelandic specialists. Also, the Geothermal Development Facility GDF has provided funding to support around 40% of the drilling cost and the rest could be financed by IDB or another bank (Urquizo, 2018, interview with Gudmundsson).

Currently, the Japanese government, through its Cooperation Agency JICA, is the major supporter of geothermal development and it is willing to continue financing the Chachimbiro project with Official Development Assistance Loans. CELEC EP had also received a grant from the GDF for surface studies and is in the process of signing the agreement. The requirement of the cooperation agencies and multilateral institutions is that all the funds can really contribute to real plant construction (Urquizo, 2018, interview with Sugioka), so consistency and reliability of the government institutions is important to obtain Cooperation and ODA financing.

### 4.8 External factor: Social

So far, social management with the Ecuadorian communities has been successful. None of the current CELEC renewable energy projects has been opposed by the public (Urquizo, 2018, interview with Astudillo). One of the most difficult experiences for CELEC EP was the binational project Tufiño (Chiles, Cerro Negro), where the communities on the Colombian side disagreed with the project even though the Ecuadorian communities were willing to develop the project. The work with the social actors is fundamental as the experiences of other countries illustrate.

The social management of geothermal projects is focused on three levels: communities, public and private institutions. Until now, social viability has been achieved for the field surveys and the first exploratory well. The communities trust in the developer and they see possibilities to generate benefits and opportunities in the future. CELEC EP is careful about avoiding false expectations. People know that long-term projects like geothermal development always help to improve the quality of life of the population. It is even named in Ecuadorian Constitution (Urquizo, 2018, interview with Cobos).

In Ecuador, there is no history of geothermal energy projects, and therefore no benchmark with regards to living close to a geothermal power plant. Therefore, communication and access to accurate and prompt information is very important because, without stakeholders understanding, it is impossible to develop any project. The dialogue is important to learn about people's concerns and expectations to be able to consider them. In addition, a good coordination with local authorities and sectional bodies such as the governor, prefect, municipalities, community leaders, etc. is crucial. These authorities can support the development of projects and commit to promoting them (Urquizo, 2018, interviews with Cobos and Sugioka).

Furthermore, feedback is also essential. The team and companies involved in the project must be aware of known errors to avoid repeating them. The majority of the geothermal areas in Ecuador are touristic because of the thermal springs and their beautiful landscapes. Meticulous technical and environmental care are mandatory in all stages of a project to avoid the risk of weakening the built confidence. During the next steps, the social plan includes mass communication strategies as well as education and training (Urquizo, 2018, interview with Cobos).

### 4.9 External factor: Technological

The geothermal industry is continuously interchanging information about experiences and lessons learned in exploration and harnessing of the resource. No geothermal project is "plug and play", all require research, experience and continued feedback, that makes "innovation" part of the industry (Urquizo, 2018, interview with Matthíasdóttir). Innovation is always part of the process. In Nicaragua for instance, a methodology was developed to control silica scaling (Urquizo, 2018, interview with Guidos). In Iceland, approaches have been developed to clean gas emissions from geothermal power plants with regard to $H_2S$ or $CO_2$, and during the Iceland Deep Drilling Project (IDDP) engineers found a way to use fluids in supercritical state (Urquizo, 2018, interviews with Ingason and Pálsson).

The main and most difficult part in geothermal is the resource development that also requires expensive drilling. A powerful reservoir suitable for electricity generation is not transportable unlike other natural resources. Nowadays, many countries are trying to develop better technology suitable for small scale projects with less than 10 MW capacity. This tendency could promote more projects in the future requiring lower investments. Ecuador should aim at medium to small geothermal projects and develop them stepwise (Urquizo, 2018, interview with Sugioka). Progress is made in the development of more efficient turbines in 50 MW modules.

Technology to model reservoirs is also developing. Aero photography (LIDAR) and satellite technology is used by itself as well as jointly interpreted with MT/TDEM for 1D, 2D or 3D models. The higher the investment, the higher the pay back (Urquizo, 2018, interview with Finnsson). The reservoir should be monitored constantly, not only temperature and pressure but also the chemical composition of the fluids. If the temperature is not high enough, low-enthalpy projects could also be less risky and less cost intensive. There also exist small plants of 150 kW installed capacity run by 100-120°C hot fluid that are very compact, like a data centre container, and could be a solution for remote areas (Urquizo, 2018, interview with Ingason).

Ecuador's long experience in the oil industry could be an advantage because large parts of the technology used in geothermal is adapted from oil and gas exploitation. It also means that experienced people are available on the market as well as people familiar with the international standards (Urquizo, 2018, interview with Ingason).

### 4.10 External factor: Legal

Article 10 of the Ecuadorian constitution declares "*Nature as a subject to those rights given by the constitution and Law*". Within this framework, the whole planning should also focus on reaching harmony but at the same time reasonable utilization of the natural resources to address the intention of implementation of more renewable energies in the matrix. The laws that could be used to develop geothermal are listed below:

- For private or public private investment (Urquizo, 2018, interview with Valencia):
  - The Organic Law on Incentives for Public Private Partnerships and Foreign Investment – APP Law;
  - The Organic Code on Production, Trade and Investment COPCI.
- For public management (Urquizo, 2018, interview with Cajas):
  - The Organic Code of Planning and Public Finance.
- For the electricity sector (Urquizo, 2018, interview with Valencia):
  - The Organic Law on the Public Service of Electricity – LOSPEE
  - Specific regulations about the electrical sector are found in *www.regulacionelectrica.gob.ec*

There is no specific geothermal regulation in Ecuador. Chile has a geothermal law based on mining law but changes have been called for by the investors because the law requires approval after the exploration stage to proceed to exploitation which causes uncertainties in case a good resource is identified (Urquizo, 2018, interview with Carcelén). In the case of Japan, no particular regulation exists that would support geothermal projects. It is advisable to pay attention to detail when formulating regulations because without a correct understanding of the geothermal industry, regulation can limit and stop projects. The experience in a couple of pilot projects could provide valuable inputs to establish a specific regulation (Urquizo, 2018, interview with Sugioka) and it is also important to establish the roles and specific responsibilities of institutions (Urquizo, 2018, interview with Guidos).

### 4.11 External factor: Environmental

Ecuador was the first country in the world to declare nature as a subject of rights in its constitution. Nature is included in the organization of the state and it is mandatory to be as careful as possible when new projects are commencing. This factor is regulated by the Environmental Management Law (Ley de Gestion Ambiental in Spanish) and the Unified Text of Environmental Legislation (TULAS – Texto Unificado de Legislación Ambiental in Spanish) for the electricity sector.

Geothermal projects fall under the general regulation for electricity projects, thus, during the prefeasibility and feasibility stages an Environmental Management Plan is required but not a license. Also, for projects below 10 MWe installed capacity, it is possible to obtain the environmental permission through simple registration while for bigger projects a license is required. Of course, the Environmental Ministry does monitor the activities of the project. The Water Secretariat SENAGUA manages geothermal resources, but this institution is planned to be absorbed by the Ministry of Environment. Permits for land use are provided by municipalities Urquizo, 2018, interview with Cajas).

Regarding the vulnerability of the electrical sector to climate change, several studies have been carried out at a regional level, with the support of international organizations such as OLADE (Spanish acronym for Latin American Energy Organization), in order to establish policies and actions (Urquizo, 2018, interview with Valencia). With regard to environmental changes, geothermal is suitable and must be encouraged. Another important point is the fact that some potential resources are located inside National Parks or buffer areas. This could present a barrier to the development of more projects.

## 5. SUCCESFULL EXPERIENCES IN GEOTHERMAL

### 5.1 Iceland

In Iceland 755 MW of electricity are generated by geothermal as well as 2,040 MWt for direct uses. The country is the leader in MWt/capita in the world (Georgsson, 2018). Electrical production from geothermal started in the 1970´s when people had discussed geothermal but only hydropower had been developed until then. On the other hand, Icelanders had developed geothermal resources to heat their houses and to build greenhouses avoiding to depend on the import of oil for heating that increased very much in price during the oil crises in the 1970's. The very first geothermal power plant was an old turbine from a sugar factory in UK with 3 MW, installed in 1969. This plant operated close to 50 years, but is now being replaced by a new turbine. Another motivation for geothermal development was a big protest against hydropower in Northern Iceland. As a result, a hydropower plant was abandoned and instead the Krafla geothermal field was developed (Urquizo, 2018, interview with Flóvenz).

Geothermal development faces many challenges. During the construction of the Krafla power plant, a volcanic eruption started close by and caused big delays and mistrust into geothermal as a reliable electricity source. Geothermal energy for heating and other low-temperature uses faced other problems that made it an unreliable energy source during the first years. This first development stage was expensive for the society but efforts proceeded nonetheless (Urquizo, 2018, interview with Flóvenz). Today, there are many well stablished institutes and companies working in the geothermal sector in Iceland.

ISOR, the Iceland GeoSurvey, is a self-financed state-owned, non-profit institution, specialized in consulting, training and scientific services in geoscience and related fields. In the 1970's, ISOR started out as part of the Orkustofnun – the National Energy Authority and the budget came from the government. The company build its expertise and promoted major achievements in house heating. Because of the eruption in Krafla, financial support was reduced considerably but the power companies took the responsibility to continue. They knew that research was the key to succeed, so they started to

get involved in research. Today, ÍSOR carries out the research for the geothermal sector in Iceland, financed either by the industry or by energy programmes of the European Union (Urquizo, 2018, interview with Flóvenz).

HS Orka and Landsvirkjun are good examples of private and state-owned companies. HS Orka started in 1976 to drill in Svartsengi and found 240°C hot water to be used for house heating. Electricity production started as a by-product and at first just for own use on site. About 5 or 6 years later, they were able to sustain the fluid and started the transmission of electricity (Urquizo, 2018, interview with Matthíasdóttir). Today, HS Orka operates 2 power plants, in Reykjanes (100 MWe) and Svartsengi (75 MWe and 190 MWt). It is the practice of the company to collect as much data as possible. For instance, they monitor downhole pressure and temperature and take monthly fluid samples to monitor the chemical composition (silica, chloride, conductivity and pH are good indicators to describe the reservoir). Sixty people are employed at the power plants, 35 in operation, 10 in reservoir management, and the rest in sales and administrative positions (Urquizo, 2018, interview with Matthíasdóttir).

Innovation has been the main ingredient to their success in avoiding silica scaling in the separation stations. HS Orka also developed the idea of a Resources Park were the fluids are used for different industries such as carbon recycling, where $CO_2$ from the gas is turned into methanol: The hot fluid is also used for fish farming and fish drying and for the famous spa Blue Lagoon (Urquizo, 2018, interview with Matthíasdóttir).

Landsvirkjun is the National Electricity Company in Iceland. It has operated in the geothermal sector for more than 30 years. The first 3 MWe station commenced operation in 1969, a 60 MWe station in the eighties into the nineties, and a 90 MWe station commissioned in 2017-2018. In its many years of operation, they have faced many challenges. For example, the volcanic activity in Krafla impacted the fluid chemistry, so the main geothermal production zone had to be abandoned and a new area had to be found. Their Board of Directors applied cautious approach in the 45+45 MWe build-up of the recent power plant at Theistareykir. (Urquizo, 2018, interview with Pálsson).

At Landsvirkjun, 50 people are involved in geothermal development. 10 people work in the geothermal department of the Research and Development Division, around 30 people work in the power plants and 10 people in other divisions. For major maintenance activities, the company outsources the routine works to contractors, while the major maintenance is carried out by the people from the power plant in order to challenge them and to get to know the equipment better. Experts in environmental science are shared from other departments and conventional engineering is outsourced. The R&D Division is in charge of drilling, planning and construction and the Energy Division is in charge of the turbine and operation. The company is currently considering to establish a Geothermal Division that is in charge of all aspects of the geothermal operation.

Landsvirkjun is currently selling services to other companies inside Iceland and internationally through Landsvirkjun Power. The geothermal industry is always innovative, Landsvirkjun has developed new methods for resource assessment, improved technical procedures, business development and how to deal with environmental aspects. There are many examples of secondary use of the energy resources, such as the Mývatn Nature Baths, algae farming, use of $CO_2$, $H_2S$ injection, drilling). Landsvirkjun has also contributed to numerous international geothermal research projects, e.g. IDDP, KMT, IMAGE etc. (Urquizo, 2018, interview with Pálsson).

Both HS Orka and Landskirkjun rely on ÍSOR mainly for well logging, temperature and pressure measurements in the wells, seismic monitoring, the analysis of gases, enthalpy measurements, TFT (tracers flow test), and cutting analysis during drilling. Also, none of them has its own rig, so they contract Iceland Drilling or other companies to carry out drilling. There are firms specialized in consulting, evaluation of geothermal fields, engineering, design, drilling and project management such as Verkís, Mannvit, Efla and Vatnaskil. Those firms are also exporting services to other countries. Mannvit works e.g. with GTNLA in Chile (Urquizo, 2018, interviews with Pálsson and Matthíasdóttir).

Furthermore, developers as Reykjavík Geothermal with their geoscientific and financial core are making successful business outside of Iceland, e.g. in St. Vincent and Ethiopia (Urquizo, 2018, interview with Finnsson).

More projects can be found in the portfolios of the companies. Innovation and research are currently focused on the use of fluids in supercritical state at 400-500°C (Iceland Deep Drilling Project and GeoMagma) and opportunities for the use of low-enthalpy fluids such as 150 kW plants that use 100-120°C located in remote areas, and small units with capacities around 10 MW to use resources as close as possible to the end user (Urquizo, 2018, interview with Ingason).

Regarding the legal and institutional side, the roles of the institutions involved in the geothermal sector are well established (Urquizo, 2018, interview with Pálsson):

- Orkustofnun: Exploration permit, operation permit, and re-injection permit;
- Environmental Agency: Main advisors to all permit providers, emissions;
- Local municipality: Construction permit and responsibility for plans;
- Planning Agency: Regional plans, master plan, development plans, environmental impact assessment (EIA or ESIA);
- Regional Health Authority: Operational permit.

The laws involved are the Electricity Act, the Law on survey and utilisation on ground resources which has a special chapter on geothermal, the Law on EIA, the Law on planning and Law on building. With regard to the environment, there is a "*Master plan for preservation and power utilisation of land areas*" where the energy resources are classified into *Utilisation class, On hold* and *Preservation class*. This classification process is based on expert reviews of four issues: preservation value of the area, value of other uses in that area, social impact of that utilisation and the economic impact of the utilisation. The final decision is always made by the parliament after a suggestion from the minister for environment.

In all the interviews with the Icelandic experts, much emphasis was put on working with the people in the vicinity of the prospect. Some examples of cooperation with the local communities are access for tourists, nature baths, supporting innovation start-ups, supporting the local rescue team, providing business to local service providers, tax payments, hiring and training of people in the locality whenever possible, etc. Working with the planning departments of municipalities is good practice, too. Good communication is crucial to get stakeholders on-board as early as possible in the project, asking for their opinion and show that they are heard, including external stakeholders. This keeps the companies on their toes to always do their best.

To finance geothermal projects reservoir assessment is the first step. In the early stages, Iceland was supported by development aid financing (World Bank). Nowadays, new projects are financed by investors, European Union funds, Icelandic Banks or through export credit financing (Urquizo, 2018, interviews with Pálsson and Flóvenz).

Another big aspect of the Icelandic success to develop geothermal resources is the political and social decision to boost this industry. People understand that growth in the geothermal sector is slow and that risks are involved. The only way to achieve this was to learn from mistakes and continue. Iceland is a very good example of the reliability of geothermal energy. Patience, perseverance and continuous development have made this industry strong and one of the cornerstones for the country's wealth.

### 5.2 Nicaragua

The review of the development of geothermal energy in Nicaragua is based on an interview with Julio Guidos (Urquizo, 2018). Nicaragua is a Central American country with 97 MWe of geothermal capacity installed what translates to 10% of the generated energy. The geothermal development began in the 60's with the support of United Nations, when a Master Plan with a National Geothermal Inventory for high- and medium-enthalpy geothermal resources was created. In 1998, the Nicaraguan government created the National Commission of Energy to manage the update of the Geothermal Master Plan. This plan was finished in October 2011 and implicates development potential of 1519 MWe in ten areas alongside Los Marrabios volcanic chain. Currently, efforts are being made by the German Cooperation and the La Salle de León University to introduce low-enthalpy geothermal resources to this master plan. Two fields are in operation: San Jacinto Tizate (72 MWe) and Momotombo (25 MWe).

By means of IDB financing, it was possible to install two well head units with a capacity of 10 MWe in a Public-Private Partnership in the San Jacinto Tizate geothermal field. In 2015, the Canadian company Polaris Infrastructure Inc. (PIF) provided the money to start drilling (12 wells) to reach 72 MWe capacity and that is how Polaris Energy Nicaragua S.A or PENSA was created. The company and concession are completely private. The geothermal power plant generates approximately 12% of the total energy demand in Nicaragua.

At first, the company used a lot of consultancy. SKM of New Zealand and then a Reservoir Division were constituted, since the project was designed by operation with generation personnel who had no knowledge about the nature of the resource. Since 2015, less consultancy is needed since the company has its own lab and generates its own data. Technical reports are sent to a recognized consultant to be validated as is required by the investors, that is the IDB and the World Bank.

Approximately 120 people are involved in the company, 13 of them in the Reservoir Division. All infrastructure improvement is performed by the Operational Investment, which is directly financed by PENSA. The company has made good achievements regarding innovation. For instance, they developed their own methodology for controlling the silica incrustations with acetic acid, saving a lot of money. They have also worked on improving the power plant by automating of the system and the communication. All parameters of the power plant and field can be checked with a cellphone. In Nicaragua and in Central America, they are pioneers in their field.

To complement the research and contribution to the industry, the company is also working with universities by means of national and international cooperation agreements. They have students from New Zealand and Nicaraguan National Universities. National students are provided with data, board and transportation to their fields. If international students cannot conduct their experiments in person, the experiment is carried out for them and the data is sent.

Regarding the social program, PENSA has a strategy base of sustainable projects that contribute positively in the workers life, the environment and the communities around the power station San Jacinto Tizate, located in Telica Municipality, Leon Department. That strategy is aligned to the International Finance Corporation Performance Standards on Environmental and Social Sustainability.

When the company started, back in 2005, most of the personnel was local but as the company has grown, people from nearby areas have been hired. PENSA has been certified by the Great Place to Work Institute. Also, strategic alliances have been made with the local government and civil society with emphasis on the community area, the environment and education, reforestation, energy efficiency, and campaigns against forest fires. On example of such a project is that now more than 4500 people have access to drinking water, including 900 homes, 6 public schools and the medical center of the area. This programme was made in alliance with IDB, the Official Development Bank for the Republic of Austria OeEb and Catholic Relief Services (CRS).

Nicaragua has a Law of Exploration and Exploitation of Geothermal Resources (Law No. 882) which was promoted to create interest among foreign investors in developing these resources. Every interested company has to agree to a private - public partnership with the Nicaraguan Company of Electricity ENEL which becomes a shareholder of at least 10% of the project at no cost. This allows ENEL to have a member in the Board of Directors. The concession period can be up to 30 years with the possibility of renewal up to 30 more years. The generation system gives preferences to geothermal generation based on Law 443. The other laws involved in the concession process are the Water Law and The Ministry of Environment Law for EIA.

ENEL has its own geothermal equipment to conduct a monitoring plan where geologists, geochemists and hydrologists take samples, analyse them in the lab and update the data base. The Ministry of Energy and Mining also has a geothermal department and it is in charge of the concession contract. To have a department in each institution with trained people facilitates the negotiation process for concessions and operation. Ministry of the Environment and Natural Resources MARENA and the National Water Authority (ANA) work together with the companies on social and environmental aspects. The Ministry of Health and Municipalities facilitate the dissemination of information.

Nicaragua offers tax incentives for the development of geothermal energy like exoneration of customs taxes and VAT, on machinery, equipment, and materials for construction work, exemption from payment of income tax for a period of 10 years from the entry into commercial operation of the project and exemption from payment of municipal income tax for a period of 5 years from the start of the operation of the project.

Politically, the Indicative Plan of Expansion of the Electricity Generation 2013-2027, which was presented by MEM in 2013, had the goal to have 90% of renewable energies in the matrix in 2027, but after the last update the new goal is 73%. This new projection decreases the 2020 Central American goal to reach 11% of renewable energy to 8%.

Nicaragua is a country with good geothermal resources, with good experience, and organized roles of the government institutions and laws. One of the keys of the success of the San Jacinto Tizate geothermal project was the confirmation of the resource through drilling. The financing only covered the first stage, but after the confirmation of the reservoir and the installation of a small power plant, finding investors for the next stages was significantly easier. Good communication and a healthy relationship with the environment, community and local governments strengthens the industry.

## 6. ASSESSMENT OF GEOTHERMAL IN ECUADOR (SWOT)

### 6.1 SWOT

In Figures 7 and 8, a SWOT assessment is presented, based on the status description of Ecuador above. This exercise gives an overview of the status of geothermal development from the point of view of the author, taking into account the experience acquired in the interviews.

| INTERNAL | STRENGTHS | WEAKNESSES |
|---|---|---|
| GOVERNANCE | - CELEC EP: State owned company has 90% of generation capacity (5.6 GW) and the whole transmission in Ecuador<br>- The branch CELEC EP Termopichincha carries out Geothermal projects<br>- The members of the Board of Directors come from important government institutions that give solidity to the decisions taken and the projects approved. | - There is not an established department of Geothermal Projects neither for Renewable Energies.<br>- There are no permanent positions for Geothermal research; thus, there are not geoscientific people involve. |
| INTERNAL FINANCING | - CELEC EP has a good experience with International Banks and Multilateral Agencies.<br>- Cooperation from JICA served to prove good temperatures through the first exploration well in Chachimbiro.<br>- Next stage of Chachimbiro is under appraisal for a ODA Loan (6 wells, Wellhead Power Plant)<br>- CELEC EP is going to sign a Grant Agreement of 40% of Cooperation Funds from GDF program for gradient studies in Chacana Project<br>- CELEC EP is a productive company and some of the internal budget is allocated for studies of new projects but it has to be approved by ARCONEL.<br>- CELEC EP is willing to analyze alternatives to finance and develop new projects. | - In the last decade, big projects have been developed by means of investment directly done by the government (EXIMBANK - CDB, IDB, and CAF), the loans are being paid but the government is reluctant to invest more in electricity sector.<br>- Every agreement with Laws from a foreigner country (arbitration clause in GDF case) needs approval from the National Attorney and the process is long. |
| AVAILABILITY OF RESOURCES | - Ecuador´s location makes it a place with abundant active volcanoes and intense seismicity that could be a good environment for geothermal reservoirs.<br>- Five prospects has been studied and more along the country are interesting areas.<br>- Good temperature was obtained from Chachimbiro field.<br>- Chacana project has surface exploration and gradient studies will be done.<br>- Pilot projects for a greenhouse and cooling are being done. | - More wells are needed to characterize the fluid and the capacity of the reservoir in Chachimbiro.<br>- Some prospects have just preliminary research.<br>- There is no a map or geothermal resources.<br>- There is a lack of information about the economic feasibility of direct uses |
| CAPABILITIES | - CELEC EP has good experience doing electricity power plants from different technologies.<br>- A lab for rocks analysis is operative now<br>- A lab for water and gases is under development<br>- CELEC EP has geophysics equipment (MT, gravimeter, TDEM, magnetometer)<br>- People trained in El Salvador, Iceland and Japan and more International cooperation is still available<br>- Possibility to sign direct agreements with state owned companies or government research institutions | - CELEC EP does not have experience with geothermal power projects.<br>- Lack of human resources, no geoscientific personnel available to continue with the investigation and development neither to work with consultants.<br>- People in the laboratory is not only working in methodologies for geothermal but also in analysis of fuel for the power plants and the development of geothermal lab takes longer.<br>- Lack of understanding about geothermal in the administrative, legal and human resources areas or electrical sector, especially CELEC EP<br>- CELEC EP does not have experience managing drilling contracts.<br>- Contracting of consultants is a very long process |
| CUSTOMERS/MARKET | The installed capacity of SNI is 6,246 MW. CELEC EP has 5624 MW; it means the 90% of generation capacity of the country distributed in: Hydroelectric plants 4000.2 MW, thermoelectric plants 1607.4 MW and wind power 16.5 MW. Besides, CELEC EP is in charge of all the transmission system of the country.<br>- The gross production of energy to supply SNI in 2017 was of 23.94 TWh and the 84% of that demand was covered with renewable hydroelectric generation. CELEC EP covered the 88.7% of the country's demand with hydroelectric and thermoelectric generation.<br>- The Master Plan of Electricity 2016-2025 is the guide for the expansion and requires geothermal electricity by 2023.<br>- CELEC EP is currently working on an energy resources inventory taking into account the available resources: wind, sun, biomass, geothermal energy and thermoelectricity, with a complementary series regarding the hydroelectrical power installed. Therefore geothermal fits in the vision of the government. | - The real potential of geothermal is not measured yet and takes long time its development. |

FIGURE 7: SWOT - strengths and weaknesses

| EXTERNAL | OPPORTUNITIES | THREATS |
|---|---|---|
| POLITICAL | -The National Development Plan 2017 - 2021 promotes the development of renewable energies.<br>- Ecuador is a country with political stability, no longer the country with 8 presidents in 10 years.<br>- The former Ministry of Electricity and Renewable Energy (MEER) recently merged with the Ministries of Hydrocarbons and Mining in the same ministry called Ministry of Energy and Non-Renewable Natural Resources MERNNR<br>- Well-structured Government established in Organic Law on the Public Service of Electricity LOSPEE.<br>- There is a new Institute of Geological and Energy Research IIGE that could support geothermal research with the integration of people from mining research.<br>- To elaborate the Electricity Master Plan, CELEC EP carries out the inventory of energy resources.<br>- The development of new projects, mainly on the generation field will be promoted through private investment or public-private partnership. The new projects and development mechanisms are coordinated by MERNNR and Ministry of Foreign Trade.<br>- The current Vice-minister of mining has very good experience in the auctioning, which could be observed from the geothermal point of view.<br>- There are some tax exemptions for the development of new projects; the possibility of having international arbitration, the tax of currency outflows has been released for new investments. | - Nowadays, a paradigm created when installing so much hydroelectricity and when thinking that what it was built was enough for 10 years and that the electricity sector would not have any further need.<br>- There is a risk to have slower decision making because of 3 sectors in one Ministry<br>- The government is prioritizing the investment in the sectors where the profits are obtained faster such as hydrocarbons and telecommunications.<br>- Changes in the authorities delay or stop the geothermal development<br>- Politicians do not really know about geothermal, its benefits and its stages of development. Geothermal is two or three election periods and needs political willingness.<br>- To promote greenfield concessions and get not good quality investors would delay more the geothermal development.<br>- There is no a policy about specific tariff or drilling funds to promote geothermal development, so there is a possibility to do not have interested investors. |
| ECONOMICAL | - If the resource is sufficiently promising, there are companies which will be willing to come in even on greenfield places.<br>- Some tax exemptions for development new projects are part of the new regulatory framework to attract new investments. There are incentives and guarantees mechanisms for the investments established by the Public – Private Partnership Law.<br>- Have possibilities to approach cooperation agencies or multilateral organizations that can help with finance, both surface exploration and particularly the drill.<br>- ESMAP (through WB or IDB) has an agreement with ICEIDA to provide geothermal experts.<br>- IDB developed a program to finance drilling (risk mitigation )in Mexico and probably is going to replicate the program in other countries of the region<br>- Risk Mitigation Fund (GDF) is going to be active for the next years | - The biggest problem in all government institutions is the financial resource required to develop projects and hire staff.<br>- The country's economy is depressed and together with paradigm mentioned before, the government is prioritizing the investment in the sectors where profits are obtained faster such as hydrocarbons and telecommunications.<br>- To have support from Cooperation Agencies and Multilateral Institutions the government should be consistent and accomplish the agreements or they can stop any financing.<br>- In terms of electricity market, South America has low Tariffs |
| SOCIAL | - Benefit of neighboring populations, since Ecuadorian constitutional framework says that large projects also have to improve the standard of living of the nearby population.<br>- Local authorities, academia and different political instances have supported the development of the geothermal projects; the door is open to talk about this topic.<br>- If the resource is good, private companies will be interested in development of power generation or cascaded utilization of the resource. | - At the minimum error, it would weaken the built trust and it would be threatened or vulnerable to other interests, touristic entrepreneurs, and environmentalists, to mention some.<br>- Possible concerns from the tourist entrepreneurs about geothermal impacts.<br>- There is no an existent power plan in Ecuador where people could understand from a real example so, people could be afraid of a new project.<br>-No access to accurate and prompt information of each aspect to be developed in a geothermal project would generate handling false information regarding real impacts, which would put at risk not only the perception of public opinion but the perception of the life of the population as well.<br>- Activism against Geothermal |
| TECHNOLOGICAL | - Geothermal sector is not so big and a lot of information, experiences and lessons learned in exploration and harnessing is available.<br>- Any geothermal project is plug and play; all require research, experience and continues feedback. That makes innovation always part of this industry.<br>- Medium to small geothermal project could be the main target of development. The technology for small-scale projects are now in the trend. Ecuador can take full use of newly developed technology.<br>- Ecuador has well developed oil industry that can provides equipment, materials and some services for geothermal development. | Very high cost of drilling, the only way to probe a resource. |
| LEGAL | - Nature is a subject of rights according to the Constitution of Ecuador<br>- The Organic Law on Incentives for Public-Private Partnerships and Foreign Investment-, and the Organic Code on Production, Trade and Investment, COPCI are relevant framework for private investment. | - Without correct understanding of geothermal technology, regulation can limit and stop projects.<br>- The Organic Law on the Public Service of Electricity- LOSPEE is a good general framework but specific regulation is still under development |
| ENVIRON MENTAL | The vulnerability of the electrical sector to climate change makes the government to establish policies and actions. Among of this geothermal is promoted.<br>- There is no specific environmental regulation for geothermal until now and it becomes in an opportunity to develop the projects faster, of course according to international standards. | Some promising areas are inside National Parks. |

FIGURE 8: SWOT – opportunities and threats

### 6.2 Next steps

After the SWOT and a reconstruction of some successful examples, the possibilities to improve the geothermal development in Ecuador were analysed. The main goal is to generate electricity from geothermal resources as soon as possible, in a sustainable way. The following steps can act as a baseline for future works and for the development of a complete strategic plan:

- Establishment of a geothermal division with permanent positions to build a core of expertise inside CELEC EP. A team with strategic people in geosciences, reservoir and drilling provides basic information to help the authorities to make decisions. According to the stage of the projects, the company could gradually develop an organigram. Of course, there will be temporal positions, but it is very important to permanently employ trained people.
- Continuation of the Chachimbiro project with JICA financing as soon as possible, develops experience in international financing and drilling services procurement. The personnel of the company should work actively in the project to gradually acquire experience.
- Signing of the agreement with GDF and continuation of gradient studies of the Chacana project. The personnel should work together with the consultants and drill operators to acquire experience.
- Continue looking for cooperation to better define the prospects. Look for more assistance in multilateral institutions and cooperation agencies to involve experts.
- Allocate resources for drilling from internal cooperation and risk mitigation fund, allocate remaining funds to CELEC EP.
- Look for cooperation with other institutions in the government to share personnel, equipment and laboratory analysis.
- Allocate all energy, people and money on identifying potential resources. Locate drilling targets in different projects around the country and allocate budget, cooperation or mitigating risk funds to drill and probe the existence of high-quality geothermal resources. This will guarantee the interest of investors.
- Once having the knowledge of the resource, establish the most suitable business model. Explore better the option of private – public investment for greenfield projects.
- Work with public institutions with experience like ÍSOR or Landsvirkjun in Iceland, to apply their lessons learned and best practices and to build capacities.
- Keep the core personnel updated about the last advances in geothermal research and well connected with others scientific and industry communities.
- Make a strategic plan to introduce low-enthalpy geothermal uses in Ecuador, taking into account the economic and technical feasibility and the national industries that could be related.
- Make a plan to develop the geothermal laboratory and look for more chemical analysts to work on it. People could come from other branches of CELEC EP or even from other institutions but making this laboratory operative will give the company another great tool to proceed faster and to gain as much information as possible which is the key of any sustainable geothermal development. Work in cooperation with experienced countries from the LAC region to analyse samples and to validate laboratory techniques.
- Develop practical training (on-the-job) and internship programmes for people involved in every phase. A good option could be to complement a programme where senior experts work in the company together with less experienced personnel as well as bringing experts from around the world to work with Ecuadorians, using Ecuadorian equipment.
- Design and implement a programme to educate administrative, legal and human resources personnel in order to have a better understanding of the industry and create more empathy and commitment with this development.
- Check the well procurement and contract procedures of the National Oil Company and adapt them to CELEC EP necessities.

- Make good dissemination campaigns to inform society, authorities and politicians about the benefits of each stage of geothermal development and how this energy complements the lack of water and therewith hydro electrical generation during the dry season and the necessity to keep power generation uninterrupted. The experience of others shows that political decisions have an enormous impact in the time and development of geothermal.
- Keep permanent and effective communication with the people in the communities and local authorities in the vicinity of the projects. Keep them updated about the progress of the projects.
- Involve the local communities in the development of the projects to make them see the benefits of job creation, education, projects and so on.
- Building in cautions steps, as Dr. Bjarni Pálsson said, is key. Take advantage of the small-scale technologies to start generating as soon as possible.
- Define the roles of institutions in the management of the resource.
- Tailor a geothermal regulation including the monitoring of the resource once experience has been acquired and the professionals involved have a better understanding of the whole environment of geothermal power generation. Exercises like tables of discussions could be a good tool.
- Develop geothermal projects following national regulations and international standards.
- Prioritize areas outside of National Parks.

## 5. CONCLUSIONS

Strategic thinking should be applied in everything that needs to be assessed to have a complete overview of where we are and what the surrounding environment is like. The methodology elaborated in this paper made the author see and evaluate internal and external factors of geothermal development in Ecuador and helped defining possible next steps based mainly on experts and relevant actors' interviews.

The body of analysis was CELEC EP, the National Company responsible for geothermal development in Ecuador. Some of the main identified strengths are: a strong National Company of Electricity with 90% of the generation capacity of the country, experience in international financing, the support of Cooperation Agencies as JICA and GDF, high temperature in the Chachimbiro geothermal field, a country with good potential for exploitable geothermal resources, equipment for geophysical and geochemical studies, a geothermal laboratory under development, experienced personnel and the clear necessity to include geothermal energy to complement hydro-electrical power generation.

In addition, some of the most interesting opportunities identified are: policies are aligned to develop renewable energies, the new ministry is in charge of electricity, oil and mining so the authorities understand better the exploration phases and could support the procurement and contract procedures making; tax exemptions and other benefits for new investors, the possibility to continue approaching cooperation agencies or multilateral organizations for cooperation, ODA financing or mitigation funds for drilling. Local authorities, academia and different political instances are supportive of these projects. The nearby population will benefit from jobs-creation and services, development of associated industries due to cascade utilization. A well-developed oil industry could offer services for geothermal development, technological development and innovation and the benefits for mitigating climate change due to use of oil.

On the other hand, the following weakness have been identified: no established geothermal departments cause a lack of people educated in geosciences, the possible reluctance of the government to invest more in the electricity sector, and long procedures to sign grants and financial agreements. In most of the projects in the country only preliminary studies have been carried out so far, hence there is a lack of information about the economic feasibility of direct uses and associated industries, lack of experience in geothermal power projects, lack of understanding of the differences between geothermal projects and

hydro or thermal projects especially among the administrative, legal and human resource people. And people in the laboratory are working on analyses of fluids from thermal power plants and do not have enough time to develop geothermal methodologies.

Moreover, CELEC EP has to face some threats: the thinking that the electrical generation system does not need more investment, the possibility to put geothermal on hold to prioritize other fast profit sectors such as hydrocarbons and telecommunications, the delay or stop of geothermal development due to change in authorities, not getting potent investors prolongs the process, not enough financial resource to hire staff, possible concerns from the tourist entrepreneurs, development of a regulations that limit or stop projects because of misunderstanding of geothermal technology and the fact that some promising areas are located inside national parks.

Weaknesses and threats could be dealt with through the correct strategy, and properly utilizing the strengths to take advantage of the opportunities. Some steps proposed in this paper are to focus on probing the potential of geothermal reservoirs in Ecuador through drilling, to continue to the next stage of the Chachimbiro project with JICA ODA financing and complete the Chacana surface studies with the 40% grant from GDF. Once the resource is verified, finding potent investors will be easier. Greenfield concessions are not recommendable unless very capable developers with experience and a good investment plan come into play.

Other possible steps are to build core capabilities in the company which is crucial to assure the decision-making process and the continuous development, to educate administrative and legal and human resources personnel to work in cooperation with other government institutions or companies to share resources (like laboratory or geoscientific people from IIGE) and experiences (like drilling procurement and contract procedures from oil industry). It is advisable to run dissemination campaigns to inform society, authorities and politicians about the benefits of each stage of geothermal development and the big necessity to complement the electrical matrix that currently consists mainly of hydro-electrical power generation that faces a dry season every year. Coupled with this, it is necessary to involve the nearby communities and local authorities.

From the interviews with the experts, it becomes clear that geothermal development takes time and building in cautious steps is the key. That is why it is crucial to maintain continuous progress to achieve the commissioning in the given time. With a better understanding and support from experts a geothermal regulation could be tailored to create a good environment to attract private investment and to monitor correct harnessing of the reservoir.

Very valuable and abundant information was shared in every interview that could be used for further analysis. A complete assessment followed by a strategic plan should be developed together with representatives of institutions from the electrical sector, academy, industry, local governments, stakeholders and others in Ecuador, as well as with people from different departments inside CELEC EP. Discussion tables could be a good way to gather more specific information to complete the SWOT presented in this report and the list of actions. After that, a prioritization of action should be done to turn them into strategies, objectives and goals within an action plan. The action plan should be disseminated, monitored and improved constantly.

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