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The Path of Direct Uses of Geothermal Energy in Nicaragua

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ABSTRACT

Geothermal energy has been utilized since ancient civilizations in thermal baths and evolved industrially in the 20th century, led by Iceland in urban heating and energy production. The Central American Energy Strategy 2030 aims to replace the use of fossil energy resources with renewable energy, highlighting geothermal energy for its base capacity and low climatic impact. Nicaragua is located in the Pacific Ring of Fire, possessing significant geothermal potential. Two Geothermal Master Plans have identified a potential of over 1500 MW, encompassing 12 Pacific sites covering 27,200 km2 of Nicaraguan territory. To develop direct applications of geothermal energy in the country, fundamental strategies are required, which start from the identification of potential uses, considering the characterization and classification of known thermal manifestations. This involves many actors and a broad spectrum of applications. Local planning processes and decision-making are crucial, thus local governments must play a fundamental role in this process, where academia can be important in project presentation and development. A Path of direct uses of geothermal energy is proposed for Nicaragua, consisting of four phases: 1. Reform of the regulatory framework, including aspects specific to direct uses that should not impose administrative and economic burdens on projects. 2. Human resource development, encompassing both specialized and technical training for project management within communities. 3. Development of technological capabilities that meet project requirements. 4. Identification and evaluation of geothermal resources with appropriate criteria for low-temperature project applications. All of the above is aimed at fostering the development of direct geothermal utilization projects in Nicaragua.

1. INTRODUCTION

The direct use of the Earth's heat has been employed since ancient civilizations through balneotherapy. However, the industrial and larger-scale use of this energy occurred in the twentieth century, with Iceland being the pioneer country. By 1920, Iceland had already begun providing heating to greenhouses using geothermal energy. By 1930, the first district heating system (district-heating) was established in Reykjavik to provide heat to 70 houses (Woodhouse, 2016).

Through the Central American Energy Strategy 2030, the Central American Integration System (SICA) region promotes the use of renewable energies to replace fossil energy resources, seeking to increase the use of geothermal resources in the Central American region. For energy production, geothermal energy offers base load capacity and the advantage of minimally affecting the environment due to the low emission of greenhouse gases at a competitive cost and efficiency in performance, making it superior to solar and wind energy in several cases. Beyond energy production, geothermal energy can be directly applied in various sectors (heating/cooling), tourism (e.g., thermal pools/hot springs), agribusiness (e.g., drying of agricultural products, pasteurization, cooling of products), and other industries, health and housing (Federal Institute of Geosciences and Natural Resources, 2023).

Due to its location in the Pacific Ring of Fire, Nicaragua is a country with high geothermal energy potential. Its use for energy production began in the 1970s. To date, two Geothermal Resources Master Plans have been carried out, identifying a geothermal potential of more than 1500 MW in the Pacific Volcanic Mountain Range of Nicaragua, where two Geothermal Power Plants have been installed (Empresa Nicaragüense de Electricidad, 2021).

In Nicaragua, an area of 27,200 km2 has been identified in the Pacific zone with excellent potential for the development of geothermal energy (Carranza, 2014), the estimated potential is 1519 MW, which are distributed in 12 areas.

Table 1. Geothermal Potential in Nicaragua

No	Geothermal Area	Potential (MW)	Generation (MW)
1	Momotombo	154 MW	77[1]
2	San Jacinto Tizate	167	72
3	El Hoyo-Monte Galán	159	-
4	Managua-Chiltepe	111	-
5	Casita-San Cristóbal Volcano	225	-

[1] At present it generates between 20 - 25 MW, source: https://enel.gob.ni/geotermicas/

6	Telica Volcano - El Ñajo	78	-
7	Support Boiler	153	-
8	Mombacho Volcano	111.5	-
9	Masaya Caldera	99.5	-
10	Tipitapa	9	-
11	Cosigüina Volcano	106	-
12	Ometepe Island	146	-
	Total	**1519**	**149**

Source: Own elaboration based on (Carranza, 2014).

Table 1 shows that projects have only been developed in two of the 12 identified areas, and geothermal resources are only being used for electricity generation. To develop the applications of direct geothermal energy uses in the country, fundamental strategies (e.g., promotion of pilot projects and incentives) and guidance support are required. This should begin with the identification of potential uses, taking into account the characterization and classification of known thermal manifestations. Many stakeholders should be considered, and a broad spectrum of applications, as well as planning processes and local decision-making, must be taken into account. Therefore, the Ministry of Energy and Mines, International Cooperation and local governments should play a fundamental role in this process. The academy can also contribute significantly by presenting proposals for project applications of direct geothermal energy uses.

2. ROUTE FOR DIRECT USES PROJECTS

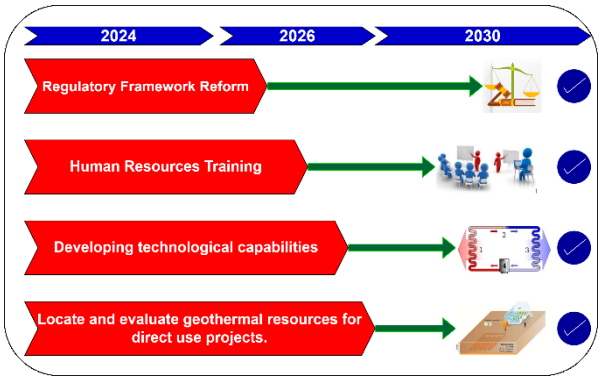
With the support of the Inter-American Development Bank and the German Cooperation, options are currently being explored for a pilot project in the dehydration of fruits, grains and another for conditioning spaces with refrigeration or air conditioning, with the application of heat pumps. There are also possibilities for dairy processing and drying bricks. Additionally, the option of green hydrogen production should be evaluated, for which it is very important to establish a methodology to identify the mechanisms that determine the development and dissemination of an emerging technology in a system.

This route should consider technical, environmental, economic, legal, social and political aspects. It should also consider mitigating factors for projects such as temperature ranges, product or service markets, the availability of technical advice and government or local support, whether public or private financing, etc.

The energy issue is an essential component for sustainable development in Nicaragua's National Human Development Plan (PNDH), that is, for the well-being and progress of current and future generations. Three aspects of vital importance are recognized in the Energy Sector Action Plan (Martinez, 2023), these are:

1. Universal access to energy, as an indispensable element for achieving national human development goals. Universal access to energy dramatically improves the quality of life of the population, opens up new productive opportunities and often contributes to the protection of the local and global environment. On the other hand, such universal access must recognize and compensate for serious inequalities in the distribution of wealth and income, both globally and nationally.
2. Transformation of the electricity generation matrix from oil-based generation to renewable energies, thus contributing, among other things, to taking advantage of the country's renewable potential and reducing greenhouse gas emissions attributable to the energy sector.
3. Rational and efficient use of energy, thus contributing to the conservation of natural resources, strengthening energy security and the country's competitiveness.

Taking into account the above and considering the update of the NHRP (2022-2026), the 2030 Agenda and the Sustainable Development Goals (SDGs), the following route is proposed:
Scheme 1. Pathway for direct geothermal projects



Source: Own elaboration

According to the route proposed in Scheme 1, the route has four stages, which could start in parallel at the beginning of 2024. These stages are: reform of the regulatory framework, training of human resources, development of technological capabilities and location and evaluation of geothermal resources for direct-use projects. Details of these stages are given below.

2.1. Reform of the Regulatory Framework

Nicaragua's current regulatory framework does not contain a specific law covering the activities and development of a heat market. In the current legal framework, geothermal heat is for the sole purpose of electricity generation and is covered by Law 443, "Law for the Exploration and Exploitation of Geothermal Resources," overseen by the Ministry of Energy and Mines (MEM). This means that it is clear that the legal regulations for concessions and licenses (Resolution No. 017-INE-1999) of the Nicaraguan Energy Institute (INE) only contemplate those aspects that are pertinent to the supply of electricity. Given that any action in the subsoil affects water resources, the National Water Authority (ANA) must be approached, which is fundamentally governed by Law 620, "General Law of National Waters" (ANA, 2019). The environmental aspect is also another factor to consider and therefore it has to be addressed with the Ministry of Environment and Natural Resources (MARENA), which has a unit dealing with Water Resources and Watershed Management. The legal basis for MARENA's actions is contained in Law 217, "General Law of the Environment and Natural Resources," approved in 1996. All laws have their own regulations for their execution, but for the purposes of a quick analysis of the legal part, we will omit the presentation of the regulations (Jirón & Reyes, 2020).

The above reflects that it is necessary to analyze legal and policy provisions and identify needs to develop action-oriented strategies, policies, and other regulations to promote the implementation of direct geothermal uses.

Diagram 2 shows the institutional role played by the different governmental entities in the development of geothermal projects in Nicaragua.

Role of governmental institutions in the monitoring of Geothermal Projects

Source: Own elaboration, based on (Martínez, 2023).
Currently, Nicaraguan legislation establishes two types of concessions:

1. Exploration for a period of 3 years with an additional 2 years optional.

2. Exploitation for a period of 30 years, which can be extended for an additional 10 years. Both concessions include tax exemptions for temporary and definitive imports, for required local purchases, and during commercial operation, income tax exemptions for 10 years and municipal taxes for five-year periods (Martínez, 2023).

It is advisable that they consider the aspects of concession exemptions and tax exemptions for projects linked to the direct uses of geothermal energy. Likewise, it is very important to consider the provisions identified by (Woodhouse, 2016), which are proposed below:

1. If structures are required, a construction permit may be necessary. Balneological and food processing uses may require a permit from the Ministry of Health (MINSA).
2. If water extraction is to be carried out, a permit may be required for the extraction, and if water disposal is needed (if there is no reinjection well), a permit will be required to carry it out. In both cases, the permits could be granted by MARENA and ANA.
3. A sketch of the site showing the proposed location of the wells or thermal points to be used, including identification of construction materials, approximate depth of the well and the distance of the well from the property boundary.
4. A schematic diagram showing the system to be installed.
5. A statement indicating the heating capacity of the system and confirming that a specialist engineer has reviewed the calculation.

6. Request an Environmental Compliance Approval for the installation of vertical geothermal systems deeper than five meters.

Finally, the specific regulation applicable to the direct uses of geothermal energy should not be subject to the general regulations for the exploration and exploitation of geothermal resources. This is to avoid an excessive administrative and economic burden on projects, which could discourage the development and promotion of these initiatives.

2.2 To train specialized human resources for direct use applications.

The role of the academy is very important to guarantee the success and sustainability of the projects over time. It is necessary to identify institutions where geology, engineering, renewable energy and architecture careers are taught, as well as research centers, in order to strengthen these institutions through collaborative networks involving various institutions and companies with a common interest. Coordination of events is essential to facilitate the exchange of information, allowing the sharing of diverse experiences and the enhancement of the academic offerings in the field of direct uses of geothermal energy.

The academy should strive to:

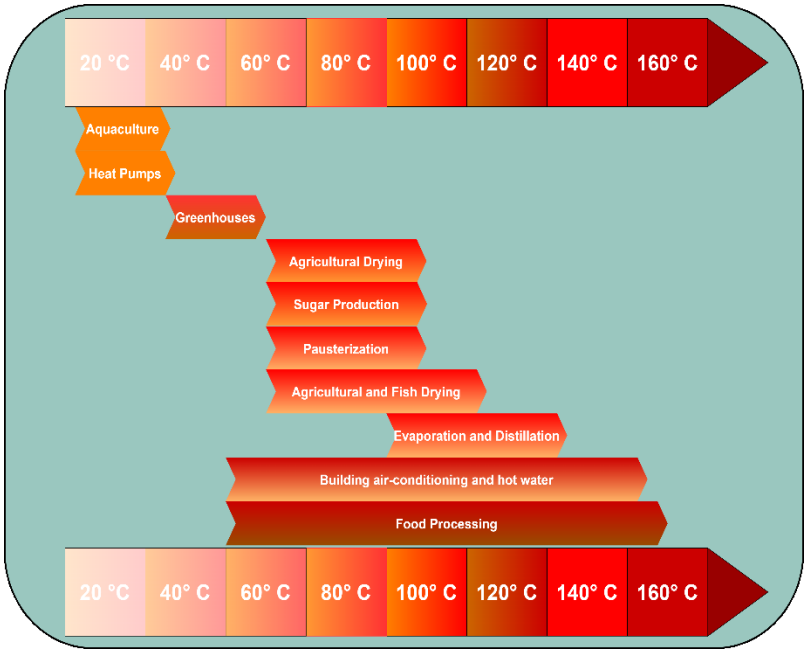
1. Develop the training of specialists in direct-use applications based on national and local needs.
2. Establish connections with the industry to integrate technological, design and engineering aspects of direct uses of geothermal energy into the curriculum.
3. Implement human resources training in the areas of interest as a crucial element contributing to the sustainability of the initiatives.

2.3 To develop technological capabilities for the design and construction of commercial equipment and facilities for direct uses.

In Nicaragua, there is high potential for the use of geothermal energy. Currently, almost 100% of applications are focus on electricity generation. However, the applications of direct uses of geothermal energy present an excellent opportunity for social, economic and environmental development in the 27,200 km2 identified as having the best geothermal potential in the country.

Diagram 3 illustrates an adaptation of Lindal's diagram, identifying possible direct-use applications based on the socioeconomic and environmental characteristics of the country's areas of interest.

Scheme 3. Direct use applications for areas of interest in Nicaragua



Source: Own elaboration, based on (Aviña, 2023) adapted from (Lindal, 1973).

It is important to mention that regardless of the application of geothermal resources (electricity generation or direct uses), the main restriction for this type of energy is the difficulty in its transportation, so it is preferably used in places close to the point of generation or obtaining (Instituto Mexicano del Petróleo, 2017).

The Food and Agriculture Organization of the United Nations (FAO) details certain direct uses, which are mentioned below:

1. Drying of agricultural products;
2. Greenhouse heating;
3. Fish farming;

4. Saltwater greenhouses;
5. Milk pasteurization;
6. Preheating and heating for food processing;
7. Evaporation and distillation in industrial processes;
8. Peeling and blanching of fruits and vegetables;
9. Food sterilization, among others

Considering the sector in which the applications are used, technological development is recommended for Nicaragua in the following areas:

2.3.1 Agriculture and agribusiness

These direct uses have been identified as a good socioeconomic and environmental alternative for Nicaragua, specifically in the western part of the country, according to (Jirón & Reyes, 2020). In this area, the predominant crops are beans, corn, sorghum, peanuts, sesame, vegetables, fruits, and sugar cane, of which fruits, vegetables and sugar cane present an interesting option to generate a value chain for these products. Therefore, the dehydration and drying of citrus fruits, pineapple, bananas, plantains, pitahaya, Flor de Jamaica, grains and the processing of sugar cane and peanuts become the best development alternative for the application of direct uses of geothermal energy.

2.3.2 Air conditioning of spaces

Two types of applications can be analyzed:

a. With heat exchanger

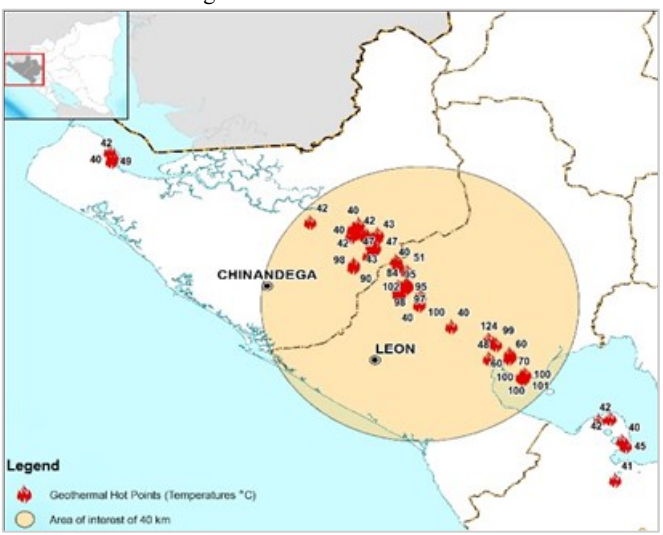
This is achieved by pumping the geothermal fluid to a heat exchanger, which transfers the energy to the air conditioning system; then the system is returned to the aquifer through an injector well (Secretaría de Energía, 2018). Given the existence of two geothermal plants intended for electricity generation, once the regulatory framework update is resolved, cascade system configurations could be enhanced for application in cold chains and food processing; this could be beneficial since, in addition to taking advantage of the remaining fluid with sufficient temperature for another application in series, investment costs can also be distributed among the different applications, making the projects more profitable.

b. Heat Pumps

They are thermal machines that use the temperature gradient between the subsoil or groundwater and the environment to condition spaces either for heating or cooling (Secretaría de Energía, 2018). In the case of Nicaragua, air conditioning could be valued in houses, offices, hotels, schools, hospitals, and recreational centers.

2.3.3 Balneology

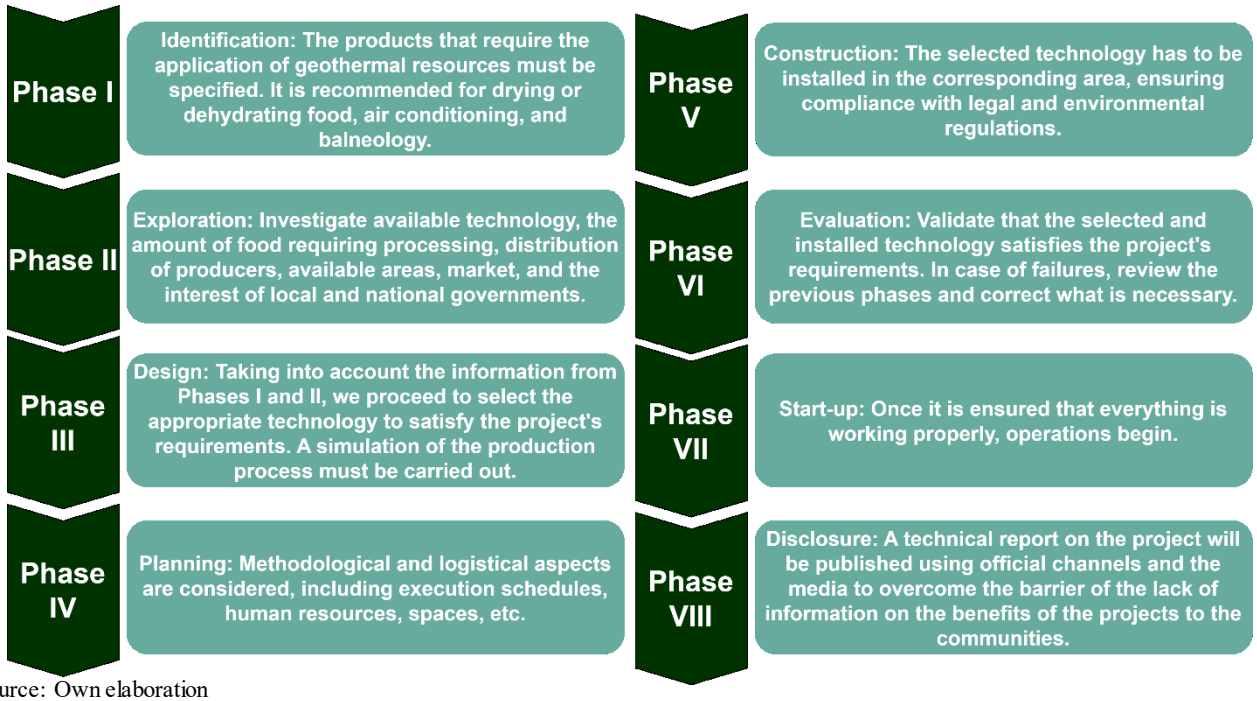
Balneology is the oldest use that has been given to geothermal energy and is one of the most widespread uses, since the springs can be used as thermal baths. According to (Jirón & Reyes, 2020), in the Pacific strip, particularly between the departments of León and Chinandega, 56 hot spots have been identified with surface temperatures in the range of 40° - 102° C, reflecting the existing potential for the use of geothermal resources for recreation or therapy with balneology. These points are mainly located in the western part of the country in an area of 40 km2 and can be visualized in Figure 1.



Geothermal heat points map, with surface temperatures range of 40˚ - 102˚ C Source: Nicaragua's Geothermal Master Plan, MEM, 2001; (Jirón & Reyes, 2020).

Finally, scheme 4 proposes the route to follow in order to strengthen the technological aspects through the implementation of projects for the direct use of geothermal energy.

Route for technological strengthening for the design and construction of commercial equipment and facilities for direct uses.



Source: Own elaboration

2.4 Locate and evaluate geothermal resources for direct uses defined as a priority.

It is very important to update the mapping of geothermal resources of low enthalpy heat, which are susceptible to be applied in direct uses. The update should consider the points that are close to the access routes to major cities to favor logistical aspects. Additionally, around these heat points are producers that can supply raw materials to the projects or are close to populations interested in the services offered.

Currently, MEM has identified three main points with the objective of implementing pilot projects in these areas, according to (Martinez, 2023), these sites are located in:

1. Municipality of Telica, in the Department of León, temperatures between 48-98° Celsius are reported for fruit drying or dehydration.
2. Municipality of Mateare, in the Department of Managua, with temperatures between 33-46° Celsius (decision pending).
3. Municipality of Tipitapa in the department of Managua, with temperatures between 35-88° Celsius, for air conditioning.

III. Conclusions.

1. Nicaragua's geothermal potential presents favorable conditions for the development of projects for the direct use of low enthalpy geothermal energy.

2. It is very important to reform the current regulatory framework for geothermal energy, given that it is aimed solely at electricity generation processes, ensuring that by incorporating the aspects of direct uses, the processes are simplified to avoid an administrative and economic burden on direct use projects.

3. The Academy has a very important role in accompanying the processes of design and validation of technology in direct use projects in order to subsequently influence the training of Specialized Human Resources and the creation of capacities in the communities.

4. It is important to generate a diagnosis of the potential direct uses of geothermal energy, in order to identify the human resources training requirements, with the purpose of identifying the areas of knowledge in which specialists and technicians need to be trained for the development of projects and for their installation, operation and maintenance.

5. It is very important to establish training programs on technical issues related to the different applications of direct uses directed to the personnel of the regulatory bodies, in order to ensure the understanding of the problems and technical implications of the regulations and norms related to the exploitation of geothermal resources for projects of direct uses of geothermal energy.

6. It is necessary to receive technical advice to effectively link the production and marketing of products from direct geothermal applications.

7. It is important to exchange experiences in order to strengthen the processes based on lessons learned from projects developed in other regions.

8. More detailed analyses are needed, including aspects of market, financing, investments, as well as the existence and availability of relevant actors, customers and suppliers, investors and financing institutions necessary to facilitate this type of energy projects.

9. Technology validation must be promoted, ensuring the training of human resources for the design, development and commercialization of technological solutions for direct geothermal energy uses.

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