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History and Present Situation of the Neuquén Geothermal Project.

Luis Carlos Mas

Rioja 385. Neuquén (8300). Argentina

lmas@epen.gov.ar

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ABSTRACT

The Neuquén Province is located in western central Argentina, on the northern side of the Patagonia region. Because of its location, has got an important number of geothermal resources; between them, we can mention the main two geothermal fields researched and developed in the country, Copahue and Domuyo.

Copahue has, for the first time in South America, completed a technical and economical feasibility study and a demonstration geothermal power plant, and a district heating system. However at present, both are out of service.

In Domuyo, a prefeasibility study has been completed with satisfactory results. Also, a heating system is functioning for a small group of huts in the village of Aguas Calientes.

There are also other zones within the provincial territory, which have geothermal resources. Although lacking the same characteristics as the previous ones, they could still be used in various uses.

However, during the 90's important resources were not adequately investigated or developed because of economical and political reasons, and the international political scenario.

Since 2001, the economical and political conditions have improved in Argentina, and are now more favorable for developing these resources. Recently a new national law was created, that promotes the development of renewable energy.

However, at present, the geothermal projects have not reactivated in similar way to the increasing of the necessities of the energy market; nor the possibilities of this natural resource.

This situation of the geothermal energy is comparable with the others main renewable energy resources, that Argentina and mainly the Patagonia region have got important reserves, as wind, hydraulic and solar.

1. INTRODUCTION

The territory of Argentina, has special conditions for geothermal resources. At the beginning of the tertiary period, about sixty five millions of years ago, began the uplifting of the Andes Rift; one of the largest cordilleras of the world. In the Neuquén Province, this mountain chain is characterized mainly by the presence of volcanic systems. Some of them are still active at present. Copahue is one of these cases.

This volcanic region is located mainly in the west side of the province, on the border with the Chile Republic. Some of the other main volcanoes of the Neuquén Province, are Domuyo, Lanín, Tromen, Auca Mahuida and Batea Mahuida. Most of them have some associated hot springs.

Another geological characteristic of the Neuquén Province, is the presence of a sedimentary basin, where there are many oil fields. The Neuquén basin is the main oil and gas producer of Argentina. The total production of gas and oil in the basin is about 48 and 42 % respectively for Argentina.

Some oil wells coproduce some geothermal waters out of the volcanic region. It is possible to consider that these geothermal resources are associated with some fault structures, and deep waters circulation (intraplate).

In this region, there is an important hydric basin, with two rivers, Limay and Neuquén, where some hydroelectrical dams were installed. The hydroelectrical production is about 4,302 MWh, 46 % of the total of Argentina.

In the near future, it a new hydroelectrical dam is planned on the Neuquén river, named Chihuidos, with an installed capacity of about 478 MWe.

From all this resources, Neuquén Province is a region, where the main income comes from the energy business. Even the large amount of energy generated in this province, most of the generation points are located at the southeast or the east of the territory.

The State Provincial Company of Electricity (EPEN), installed a distribution network that tried to cover the main surface as much as possible. But there are some regions, mainly located at the west and the north, that because of geographical causes, do not have a reliable electrical transmission system.

The geothermal interest in Argentina began on the 50's (Sierra et al 1998), with the request of the Argentine's Government, to italian company Laderello S.pA. to complete preliminary studies of the geothermal areas of the country. From these studies the Copahue Geothermal Field was interesting, with high enthalpy characteristics.

In 1971, a UNDP experts mission concluded that Copahue would be worthy for an exploratory project. Three years more studies began, by a special Commission, at Copahue and Domuyo.

During the 70's, 80's and early 90's the geothermal project had continuity. A prefeasibility study and a heating system to a little group of huts were developed at Domuyo. At Copahue a technical and economical feasibility study, the installation of a Demonstration Power Plant at Copahue, and three exploratory wells were completed.

At that time, the political and economical scenario underwent some profound modifications in Argentina, following similar changes on an international level. This,

led to the privatization of electric energy production, transport and distribution throughout Argentina (Mas, 2005).

Nevertheless, in 1997-1998 the Neuquén Government installed a district heating system at Copahue village. By this time, the geothermal project had lost the continuity that characterized it during the previous years. That continuity was not recovered until today.

Over the last seven or eight years, Argentina broke a drop curve of some economical parameters; and began a period with an increasing of the economical activity, production of primary materials, and the industrial activity. Consequently, it rose the energy demand, with values that in some cases was not so easy to satisfy.

However, the growth of the energy demand, didn't mean the factor that made possible, the developing of the geothermal project in Neuquén.

In fact, the national energy matrix remains heavily dependent on hydrocarbons.

2. COPAHUE

The Copahue area is located on the central western part of the Neuquén Province, at about 37º S and 71º W; at the border with the Republic of Chile. It is about 380 km from Neuquén city, capital of the province.

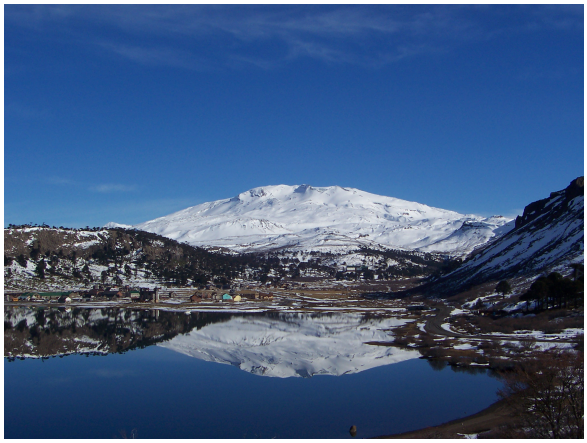

Figure 1: On the center, Volcano Copahue. On the front is Lake Caviahue, in which coast is the village of the same name.

The sector of the Andes Range corresponding to the territory of the Neuquén Province, is characterized by volcanic formations, of relatively young ages. The majority of the volcanos are located on the Chilean side; many of them with strong activity at present. On the Argentinian side, the Copahue is the main complex of the west central area, that characterized and gave the name to a System; “Copahue Volcanic Basement” (Zócalo Volcánico de Copahue) (Ramos, 1978).

Copahue is a volcanic complex, that began about 4.3 million years ago, during the Pliocene (Linares et al., 1999). The evolution of this complex, created a semi-elliptical valley, formed by a caldera, about 20 by 15 km in size, and with an altitude of between 1,600 and 2,900 meters above sea level.

In 1976 the first exploratory well, COP-1, was drilled to a depth of 954 meters. At that point drilling was suspended for economic reasons. In 1981, and after some other new studies, the well was technically modified and finished to a final depth of 1,414 meters (Mas, 2005). It produced superheated steam, with the following parameters;

static temperature = 250°C

static pressure = 4.0 MPa

flow rate = 12 – 15 t/h (1.0 – 1.4 MPa)

During the 1980's, the geothermal project in the Neuquén Province had an important development. During this time, a Regional Center of Geothermal Energy (CREGEN) was formed by the National Energy Secretary, the National University of Comahue (UNCo), and the Neuquén Province Energy Entity (EPEN).

In 1986 a second well was drilled at Copahue (COP-2), a final depth of 1,240 meters. It was developed by CREGEN, with financial assistance from the National Government. The parameters of this well are the following;

static temperature = 235°C

static pressure = 3.5 MPa

flow rate = 6 t/h (0.6 MPa)

In 1988 a Demonstration Power Plant was installed, on the COP-1, with a capacity of 0.67 MWe. In that year, a technical and economical feasibility study began, with the cooperation of the Japan International Cooperation Agency (JICA-EPEN, 1992).

In 1991 the Feasibility Study was finished with satisfactory results. A third exploratory well was drilled (COP-3) to a depth of 1,067 meters. The well produces superheated steam with the following calculated data;

static temperature = 240°C

static pressure = 4.0 MPa

flow-rate: 50 – 60 t/h (1.0 MPa) (calc.)

The final result of this study was the project for a power plant of about 30 MWe, with an important feasibility factor (JICA, 1992).

As was said, at that time, the geothermal project lost the continuity that characterized it. Even given that, on 1997-98 the Neuquén Government developed a district heating project, at the village of Copahue, with the main purpose of melting snow, at the streets of the village, using geothermal steam from two wells. The aim of this system, was to extend the tourist period in winter.

One of the wells used for this purpose, was COP-2, and a fourth well, COP-4, was drilled that also produces superheated steam:

static temperature = 235°C

static pressure = 4.0 MPa

flow rate = 50 t/h (1.0 MPa)

This heating system, has got the potential to be used to heat buildings in the village; but at present, only one building had been connected to the system, but it is not in operation.

Anyway, there were other studies, which served to confirm some of the characteristics of the geothermal reservoir. In

that sense, it is possible to mention the studies on heat flow and structure of the field (Mas et al, 2000); and some geothermometric studies of the reservoir (Mas et al, 1993; 1995 and 2005).

During the last years, appeared the necessity to abandon the first well drilled, COP-1; because of very important technical problems of the wellhead. In 1998, COP-3 was abandoned the because of technical and environmental problems.

Unfortunately the COP-1 fed the Demonstrative Power Plant, so at this moment, it would be no possible to put it on service again, as was planned.

At present, the Government of Neuquén Province, created a State Agency for the Development of Investments of Neuquén; which is responsible for finding investors, interested in the development of the geothermal project, with the installation of a power plant of about 30 MWe.

3. DOMUYO

Domuyo is another volcanic complex, located at the north of the Neuquén Province, at the northern extreme of the Del Viento Range. This range characterized a structural unit, defined by (Bracaccini, 1970) as Height of the Wind Range (Alto de la Cordillera del Viento). It is defined by two important structural lineaments of northwest direction (Ramos, 1978); one of them is Barrancas Lineament, and the other is The Chillán Lineament. Those lineaments, in association with other structural features conditioned the formation of many volcanic systems of this region; one of them is the Domuyo.

The Domuyo Volcano is the highest peak of the Patagonia region, with an elevation of 4,709 meters above sea level. The other main peaks of the Domuyo complex are Domo, de las Papas, and Covunco.

This system is characterized by a basement consisting of sedimentary rocks and volcanic–pyroclastic rocks of permian–triassic age (JICA, 1984). Some mesozoic formations of sedimentary and pyroclastics rocks, unconformably overlie the basement rocks. At the end of tertiary, acidic volcanism took place emplacing lava flows and pyroclastics rocks that covered the basement and mesozoic formations. These rocks of acidic activity are called Domuyo Volcano Complex (JICA, 1984).

Figure 2: On the center, Volcano Domuyo. On the left, in first place, is the Hill Domo, where the main studies were developed.

In 1982, an agreement was signed between the governments of Argentina and Japan, by which a Prefeasibility Study at Domuyo was developed. This project was constituted in three phases. The studies developed were geology; geochemistry of soil, rocks, waters, steam and gas; geophysics with gravity survey, seismic prospecting, and geoelectrical prospecting; and the drilling of 13 gradient wells to about 100 meters depth, and a multipurpose well of 366 meters.

The first phase covered an area of about 15,000 km^2; the second one was of about 200 km^2; and third one was about 40 km^2.

In this area, there are several geothermal Springs of high temperature; La Bramadora, El Humazo, Los Tachos, Las Olletas, Aguas Calientes, Ailinco and Rincón de las Papas.

La Bramadora is the highest altitude hot spring, with about 3.200 meters above sea level. It is located at the east of the Domo hill, but on the slope of the Domuyo. It is a vapor dominated manifestation, with fumarolic gas of volcanic origin. The gas is rich in Ca^{++} and $SO_4^{=}$ and the rate $SO_4^{=}/Cl^{-} > 1$. From the gas composition, it is seen that the temperature is high (JICA, 1983).

El Humazo is located on the valley of the Manchana Covunco Stream, at the northwest of the Domo. It is a water–vapor mixed type, sodium chloride. Another one is Los Tachos, located on the valley of the Covunco Stream, at the southwest of the Domo. This is the widest hot spring, and is also water-vapor mixed type and sodium chloride. The geothermometric temperatures of El Humazo, and the eastern part of Los Tachos are over 200ºC.

Las Olletas is located at the west and not so far from El Humazo, also on the valley of the Manchana Covunco, but with some differences with El Humazo; this appear at the bottom of the valley; instead, Las Olletas appear at the top, on a flank of it. It consists in water dominated type, also sodium chloride. In some cases, appear a kind of geysers type phenomena. The temperatures of the waters are about 93ºC.

Aguas Calientes, is a hot water spring, that appear at the west of the Domo, and at the southwest of Las Olletas. Their occurrence is below a thick formation of pumiceous tuff, of tertiary-quaternary age. It consists in many water springs, with temperatures of about 60ºC.

The western part of Los Tachos, Las Olletas, and Aguas Calientes are water dominant type, sodium chloride; with almost zero emission of steam. Their geochemistry temperature indicates between 160ºC to 190ºC.

The Rincón de las Papas and Ailinco springs are water dominated type, Ca-Mg bicarbonate, located on the northern part of the field; the first one at the north of Las Papas Hill,which is located at the north of Domo volcano; and the second one is at the west of the first. The temperature of the waters are about 40 ºC, and the geochemical temperature is between 130ºC to 175ºC.

On the last phase was drilled a multipurpose well, planned to rich 400 meters of depth. By some technical problems, it arrived to 366 meters. It was measured a temperature of 172ºC; with a lithology capable to contain geothermal fluids. It wasn't tested as a geothermal well, because it was not the purpose of it.

This study obtained satisfactory results; and revealed a geothermal reservoir with interesting features; determining at least two zones of very good expectation for drilling exploratory wells.

On 1987, was developed a heating system for a little number of huts, located at the edge of the Aguas Calientes stream. This system is fed by the hot waters of a nearby manifestation, in a simple way, without the necesity of pumping.

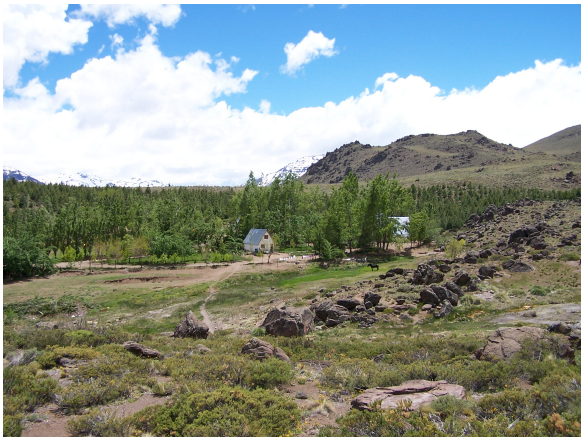

Figure 3: The little village of Aguas Calientes.

This little village of six huts, is used during summer time for touristic purpose; and because of its location, it is difficult to provide fuel for heating. At present, this system is still working with satisfactory results.

The huts are used during summer time, for touristic purposes, because of the existence of very popular baths near that place; one of them is the Aguas Calientes Stream, and some Baths not so far from them. Another one is the Rincón de las Papas Baths. The mentioned stream is the result of fresh cold water, fed with a lot of hot water springs with temperatures about of 60ºC, that convert a cold water stream in a hot one, with temperatures that in some months of the year, arrives to temperatures over 40ºC, and are use for immersion baths.

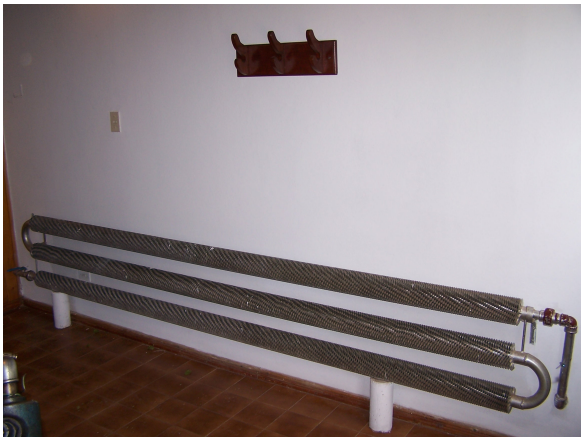

Figure 4: Heater of a hut of Aguas Calientes.

The Domuyo Geothermal Project was suspended, in order to prioritize the Project Copahue, which had a more significant degree of progress; including increase energy demand for the further development of tourism in Caviahue-Copahue.

Neverthless, the characteristics of the geothermal area Domuyo are very interesting, and would provide an important energy resource for the northern zone of the Neuquén Province, because it has very interesting possibilities in terms of tourist.

4. OTHER GEOTHERMAL ZONES

In the Neuquén Province there are some others geothermal zones. Most of them, associated with volcanic systems, as Lanín in the southern side of the province, and Tromen in the northern.

4.1 Lanín

It is located near the city of Junín de los Andes; about 430 km from the Neuquén city, on the southweast of the province, on the border with Chile.

Lanín is a holocene basaltic volcano, that form part of an axe with a direction of about east-west, with the volcanoes Villarrica and Quetrupillán in chilean territory; and by other side in the territory of Argentina, it form a volcanic complex with others volcanoes as El Escorial, Huanquihue, Arenal and others.

Figure 5: Volcano Lanín.

About two kilometers at the south of the little lake Curi Laufquen, there are some hot springs, located on a deep valley (Del Vo, 1978). The Curi Laufquen lake is located at the west of the lake Epulafquen, which form part of the lake Huechulafquen.

The above mentioned hot springs, are known as Lahuen Co, also as “Epulafquen Baths” (Baños de Epulafquen), and Sosic (1978) mentioned them as Cullu Co. He described them with temperatures of 60ºC and with a dry residue of 1.944 mg/l (Sosic, 1978).

The appearence of them occurs in an area, where crop tuffs and andesites related with the last phases of the quaternary volcanism of this zone; represented by the last eruptions of the Lanin. Upon oral tradition, the last eruptions corresponded to the Huanquihue, located at the southeast of the hot springs, and occurred on the XVII century (Del Vo, 1978).

Since a few years, there was installed a Thermal Spa, that use the natural thermal waters for baths.

Anyway, the geothermal exploration of this zone has been very limited, restricted to some surveys expeditious, because priority was given to the other areas (Copahue and Domuyo) with more advanced studies.

4.2 Tromen

It is located near to the city of Buta Ranquil, on the north of Neuquén Province, and at the southeast of Domuyo; about 450 km at the north of the Neuquén city.

This volcano form part of a complex, defined by Bracaccini (1970) as Tromen Volcanic Massif, that cover an old positive structural preliassic block. It is composed mainly by pleistocenic basalts and andesites (González Díaz, 1978). This complex also present lava flows of holocene age as it is possible to see in the Figure 6. This postglacial volcanism is mainly characterized by adventitious cones, associated to the main volcano.

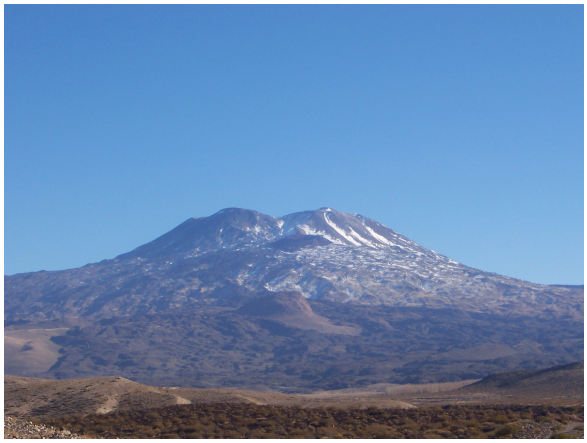

Figure 6: Volcano Tromen.

Although volcanism is very important, the presence of hot springs is not so much; and a few, are restricted to the east-northeast of the complex.

The mentioned hot springs associated to this volcanic complex, consist in hot water, with temperatures below than 30ºC, that appear at the east of Buta Ranquil. The upwelling of this hot waters are associated to the presence of travertine rocks formations.

No studies have been conducted geological or geochemical of this geothermal resources, and not made any use of them.

4.3 Other zones

There are other zones, not related with important volcanic systems such as those mentioned above, however, are references to the existence of hot springs. Most of them on volcanic regions

About 40 km at the south of Lanín, appear another hot water spring, Queñi, at the southern side of a small glacial lake, which gives its name. This zone is located at the west of Lake Lacar, at the west of San Martín de los Andes city.

There are several hot springs at the foots of the hills nearby, and at the alluvium near the lake Queñi (Del Vo, 1978); and the water temperature varies depending of the season (Sosic, 1978). The access to the area of interest is complicated by the geographical conditions, and there is no geological or geochemical studies of this geothermal resources.

About 30-45 km at the north of Copahue, there are two valleys separated by a plateau; one of them is “Valle de las Damas” (The Ladies Valley), and the other is the valley of the river Trocomán, where appear some hot springs. The manifestations are distributed in both valleys, shaping a wide area, of about 20-30 km. Althoug the temperatures are not so high (30ºC), from the widespread of them, we can take into consideration that the heat source, would be important, at least from the standpoint of the area of influence.

5. CONSIDERATIONS

Knowledge and development of the geothermal resources, reached a significant level up to the early nineties. At that time, was finished a Feasibility Study in an area (Copahue), and a prefeasibility study in another (Domuyo); both with satisfactory results.

In the first mentioned area, four wells have been drilled, that produced dry steam. It was installed a Demonstrative Power Plant of 0.67 MWe, of binary type, that functioned till 1996.

It was established the Regional Center of Geothermal Energy Neuquén (CREGEN), for the research and the development of the geothermal resources, not only in the Neuquén Province, but in other provinces of Argentina. In that way, some studies were developed in the Provinces of Salta, Jujuy, La Rioja, Catamarca, Tucumán, and Santiago del Estero; and technical advisers of CREGEN collaborated on studies in the Provinces of Buenos Aires and Tierra del Fuego.

It is no possible to lose sight of the fact that, Neuquén Province is one of the main energy producers of Argentina. Point that could favors in some way, the development of a geothermal project. Otherwise, the abundance in the energy supply, and the relative low price of the energy, specially with a very low international low price of the oil; influenced the decision not to install a geothermal power plant.

During the nineties, almost all state companies of services of Argentina, were privatized, including many electrical companies. This also meant a change in the regulation of the electricity market.

Even if the new market conditions basically were not so bad, did not serve as encouragement for the development of the renewable energy resources.

During this years, the decrease of the economical and industrial activity of Argentina, was an important factor for the little interest in the development of the geothermal projects.

The exception of this was the installation of the heating system of the village of Copahue; but outside of that, the Neuquén Project was stalled.

On the first years of 2000, the political and economical scenario in Argentina changed, and there was a renewal of interest and encouragement in developing the Neuquén Geothermal Project.

Those changes also produced a reactivation on the national economical activity, the industry and the primary food production. All this, produced an incrementing on the energy demand; which in some moments was not so easy to satisfy. Even that, the price of the energy, remained at lower levels, as a way to facilitate the economical growth.

This fact also helped to take interest to some of the alternatives energy projects. At present, it is possible to mention that there are some areas in Argentina, with very

interesting wind resources; but very few could develop to a significant scale.

On 2007 was sanctioned a National Law, Nº 26.190, which is a national system for the promotion of the renewable energy resources, for the production of electricity. This Act created a number of benefits for investors interested in developing renewable energy. Among other benefits, would create a fund to pay for the generation of electricity with renewable resources. Geothermal, wind, hidro (< 30 MWh), biomass and tidal would receive a remuneration of 0.5 ¢US/KWh actually generated.

On the other hand, there are some Law Resolutions, of the National Secretary of Energy, that promote the generation of electricity, with the possibility of agreeing a price differential with the potential client, for new projects, of production of electricity.

All those actions did not arrive to the goal of promote the production of energy from renewable resources. This fact, not only occur on the production of electricity, but also on the direct use of geothermal waters, except scarce cases.

Usually the explanation for the difficulties for the geothermal projects, are based on the mining risk that every geothermal project has got. But in our country, also wind energy has difficulty, in developing their projects. Wind resources so far studied, have very interesting values.

We can mention very wide regions (e.g. in Patagonia), with wind media velocities over 7 or 8 m/sec, and Capacity Factors of about 40. Anyway, the wind energy development in our country has been very low.

Finally, we should mention the fact that 90% of Argentina's energy, comes from the use of Hydrocarbons. This situation is further complicated if we take into consideration, that hydrocarbon reserves in the country have declined in recent years.

Given this failure of renewable energy in general, and in particular geothermal energy, the National State must ensure as head of the energy system of the country, adequate energy supply, with the application of subsidies on conventional energy sources.

6. CONCLUSIONS

It is not too difficult, to explain the situation during the nineties, when the geothermal project stalled. As was said above, the price of the energy was very low; the demand didn`t grow so much, and was satisfied by the traditional resources of oil and gas, which was produced in quantity and quality sufficient to satisfy the market.

In the current decade economic and political conditions have changed, but the picture of the development of geothermal energy projects in their results have not.

During this time, the demand of energy increased, the production of hydrocarbons decreased, the provision of energy to the market had difficulties during some special moments of the economical activity reactivation, specially considering that the National and Provincial Governments implemented promotion schemes.

With this new conditions, it is not so easy to explain the delay in the development of the geothermal energy, even if it is compared with the backlog of other renewable (e.g. wind), which in much of the world, has had a great development in recent years.

This situation allows us to conclude, that there are other factors, involved in this issue, because even though the economic model gave commercial advantages, private companies did not trust their investments in such projects.

To cut this vicious circle, the first phase should be that the State provides itself with investments in geothermal installations, which ultimately serve to diminish the independence of the national energy system, with respect to hydrocarbons.

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