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Geoenvironmental Aspects of the Development of Las Pailas Geothermal Field, Costa Rica

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ABSTRACT

Las Pailas geothermal field is located in a very special area where different socio-economic activities, natural conditions (biological-ecological and geological) and an important geothermal resource converge.

All geoscientific, environmental and social-economic information available support the exploitation of this resource and the construction of a geothermal binary power plant of 35 MWe. It is necessary and a possibility with continuous and careful monitoring as well as varied necessary mitigation measures of take advantage of the geothermal resource that is immersed within an area of special biological-ecological context.

Following the philosophy and the guidelines for sustainable development should be the door to future geothermal operations within protected zones like national parks and natural reserves in Costa Rica; actually it is impossible for legal reasons (Law of National Parks of Costa Rica).

With all environmental considerations, the geothermal exploitation is an excellent opportunity for ICE (Costa Rican Electric Company), for the country and for the Earth planet. It is a real opportunity to show that "sustainable development" is possible and Las Pailas geothermal power plant will comes an excellent example.

1. INTRODUCTION

Geothermal resources have been known and used in many ways for thousands years, but in Costa Rica its exploitation started in Miravalles geothermal field in 1994.

The current electricity generation system in the country is based on a programme oriented mainly towards the utilization of renewable natural resources. The Costa Rican Institute of Electricity (ICE) is the institution dedicated to generation, transmission and distribution of electricity in all the country. Geothermal constituted the second most important energy resource in the year 2008, with a generation equivalent to around 12% of the total electrical energy produced in the country.

Las Pailas geothermal is located in the northwestern part of Costa Rica, in the south slope of the Rincón de la Vieja volcano (Figure 1). It will be the second geothermal field in the country (after Miravalles).

Las Pailas will enter in operation in the 2011 according with ICE plans, generating 35 MWe from a binary power plant (Pailas I). This geothermal field is located in a very special place where different economic-social and natural conditions coexists with an important geothermal resource.

This geothermal power plant will be come in an important example of "environment development", with great benefits for the country and the environment.

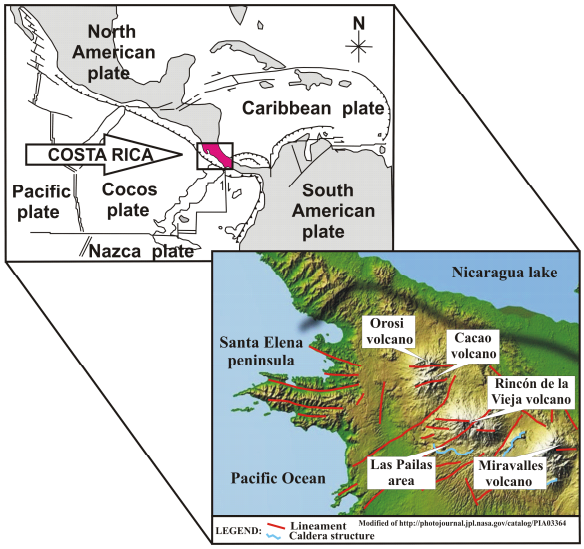

Figure 1: Tectonic context of Costa Rica, with special reference to the northwest part of the country (from Barrantes, 2006).

2. LAS PAILAS GEOTHERMAL FIELD LOCATION

2.1 Geological setting

The location of Las Pailas geothermal field is clearly related to Quaternary volcanism, in particular with the Rincón de la Vieja volcano. It is a composite stratovolcano in the north-western part of the country, belongs to the Guanacaste Range (Figure 1), and forms a NW trending ridge (Figure 2) consisting of several eruptive centers (Kempter 1997). It erupts mainly materials of basaltic-andesitic - andesitic to dacitic-rhyolitic composition (including lavas, tuffs, pyroclastic flows, ignimbrites, domes and lahars), with ages varying between 8 and 1 million years (Mainieri, 1976; Kempter 1997; Molina 2000; Arias, 2002; Deering et al, 2006). The last active period occurred in the mid 90's, generating ash deposits, throwing blocks and tephras, with the generating of lahars and mud flows on the Caribbean side of the Rincón de la Vieja complex (GeothermEx, 2005).

Two semi-circular structures have been proposed in this zone. The first one is a festooned border caldera which extends from Las Pailas to the northwest (Borinquen area) and is referred to as Alcántaro (Kempter, 1997) or Cañas Dulces caldera (Molina, 2000; Arias, 2002). The other structure is called Guachipelín caldera (Chavarría et al., 2006) but sometimes also referred as San Vicente caldera (Molina, 2000).

This zone is characterized by several structures and fault systems with different strikes, but most important systems follow NE-SW and NW-SE regional structural trends; with important geothermal manifestations in this last direction.

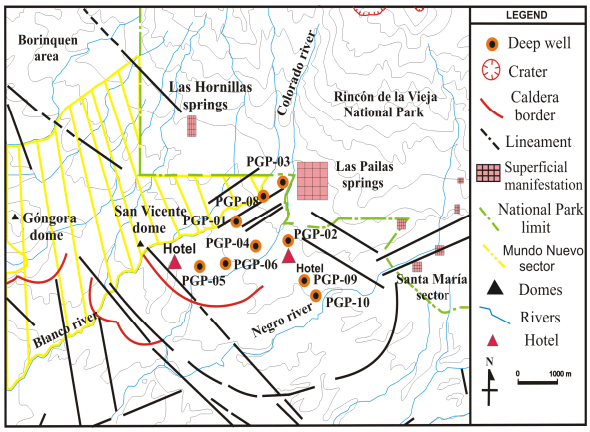

Figure 2: Main structural features of Las Pailas geothermal field; also hotel locations, deep geothermal wells, and National Park and Mundo Nuevo limits.

2.2 Natural conditions

Las Pailas geothermal area is located in a very special context, with beautiful places to visit and enjoy. In the northern part is the Rincón de la Vieja National Park, in the eastern part there is an ONG's Guanacaste Dry Forest) natural reserve called Mundo Nuevo administrated by the Guanacaste Conservation Area (Natural Resources Ministry); and two mountain hotels inside the geothermal area. Near the area there has been discovered a great quantify of petroglifos (prehistoric draws in stones) and prehistoric graves, an important part of our cultural heritage.

The pacific side of the volcano is in an area of rainy forests with a transition to rainy dry forests, with some parches of secondary forest and native grassland growing over the volcanic products, in accordance to altitude and human impact influence. The mean annual temperature is 24-26ºC and around 14ºC in volcano tops, with 2500-3000 mm of annual mean precipitation (May to November) and 4-5 dry months (December-April); the Caribbean side is humid to very humid, with 3000-4000 annual mean precipitation (full year).

Due to the differences in altitude, precipitation, volcanic soil conditions and slope type, Las Pailas geothermal area display diverse habitats. In the Rincón de la Vieja national park there have been observed more than 300 species of birds, many mammals and some reptile species (including snakes and turtles).

For that reason, around 40000 to 45000 tourists visit the Rincón de la Vieja National Park every year, traversing across the private lands and the geothermal locations.

Many tourists coming to the two mountain hotels located in Las Pailas area: Guachipelín and Rincón de la Vieja Lodge; both buildings are inside the geothermal field, very close to the national park. Some hot springs and other geothermal manifestations are utilized as tourist attractions. Continuous negotiations have been made with the hotel's owners and some of their lands are now ICE properties.

One important consideration can be made in this point. The country's environmental laws not permit exploration and exploitation of geothermal resources in the national park system lands. For this reason, it is impossible to the ICE explore in the Rincón de la Vieja national park area, despite the fact that geoscientific studies have shown the main geothermal resource is possibly inside the national park territories (Barrantes, 2006).

Some direct negotiations between ICE, the National System for Conservation Areas (SINACs) permitted some geochemistry, geophysical and geological tests for some months within the Rincón de la Vieja national park, and actuality also is possible important studies and gradient drilling wells inside Mundo Nuevo lands (Administrated by Guanacaste Conservation Area).

2.3 Las Pailas geothermal area exploration history

Around the mid 70s, due to the international oil crisis and the urgency for new energy alternatives, the Costa Rica Electricity Institute (ICE) began geological, geophysical and geochemical studies in the Guanacaste province (northwest part of the country).

The first six gradient wells in the Las Pailas geothermal area were drilled in the years 1975-1976 (Molina, 2000), although higher priority was given to the Miravalles volcano region at the time due to factors such as location, accessibility and other logistical reasons.

A national evaluation of geothermal resources in the country was carried out by ICE in November 1987 to October 1988 for selecting prospective areas suitable for more detailed studies. As a result of this study, two new zones in addition to the Miravalles volcano were chosen as high priority areas for further studies: Tenorio and Rincón de la Vieja volcanoes (Figure 1).

More geoscientific surveys were carried out in the next years in Las Pailas (Rincón de la Vieja area), with a new gradient drilling phase from 1995 to 1996. In 2001 and as part of the energy strategy, drilling of five deep wells began to verify favorable conditions suggested in a previous prefeasibility study (GeothermEx, 2001; Mainieri, 2005).

Three of the first five deep geothermal wells showed good temperature and permeability conditions and were also able to produce fluids of geothermal origin (Castro, 2002) and then the feasibility study was presented for the ICE authorities (GeothermEx, 2005). It is a geothermal field with temperatures near 260°C, of moderate salinity and with a low content of non-condensable gases (Mainieri, 2005).

Independent of the approval of the environmental impact assessment (EIA), and as a part of necessary environmental control, environmental sampling was started in the geothermal area in the last months of the year 1999, to determine the background environmental parameters and to control possible impacts related to the activities of the geothermal project (GeothermEx, 2005; ICE, 2005).

All these data are in the data base of the Management and Environmental Monitoring of Geothermal Resources Centre (CSRG) at ICE. After the EIA was approved (ICE, 2005), the environmental project has continued by gathering information on noise data, water chemical analysis and H2S and CO2 gases in specific points within the project area.

Finally, the Study of Environment Impact was presented and approved according to the effective environmental laws and regulations of the country by the Technical Secretary Environmental National (SETENA) in 2005 (Barrantes, 2006).

2.4 Recent geothermal development

Having approved the respective environmental studies (EIA), GeothermEx (2005) presented to the ICE authorities the results of the geothermal feasibility study, supported by mathematical modelling, confirming the capacity of the field and recommending the installation of a first unit of 35 MWe in the Las Pailas area.

ICE plans to have a binary geothermal plant on-line by the year 2011 (Mainieri, 2005), with new deep geothermal wells phase began in 2008 in Las Pailas area (wells 6, 8, 9 and 10; Figure 2). There are several possible future scenarios for well drilling strategy, based on the results obtained from other wells.

The next step is start the directional drilling wells this same year. In the Mundo Nuevo area began the first exploration studies (geology, geochemistry, and geophysics) and the first gradient well was drilled in the first months of 2009 after many negotiations between ICE and Guanacaste Conservation Area (ACG).

The approximate area of the project is around 10 km2 (Figure 3). Within this area, all the related works of the project are under construction.

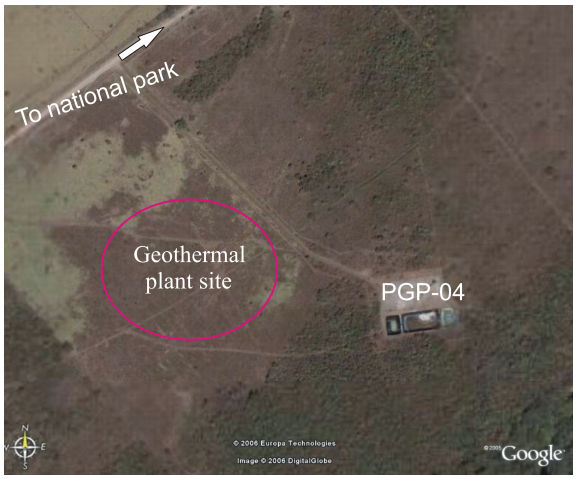

Figure 3: Las Pailas I geothermal plant construction site and the platform for well PGP-04, in relation to the Rincón de la Vieja national park entrance road.

3. ENVIRONMENTAL IMPACT STUDIES

3.1 Legal aspects and other environmental studies

Costa Rica had many laws on with environmental aspects, but with the approval of the Organic Law of the Environment in 1995 (Zeledón, 1998), important and more scientific and realistic criteria were established to permit the viability of a project (or not).

This law has the fundamental objective of improving the environmental quality and life of the inhabitants of the country, integrating nature and man and establishing the necessary environmental procedures to follow in order to establish any type of project. In addition, it establishes the National Environment Technical Secretary (SETENA) as being in charge to transact and to approve, or not to transact, and to pursue projects in environmental matters, according to laws and procedures.

In February 2000, ICE presented to the SETENA, a Preliminary Form of Environmental Evaluation (FEAP) with the purpose of initiating feasibility studies in the Las Pailas area. This first stage consisted of the drilling of 10 deep exploratory wells in the zones called Las Pailas and Borinquen (5 wells in each area).

Receiving the environmental permissions from the respective authorities, the drilling stage of the geothermal development began in the year 2001, but the environmental activities for that reason ICE started environmental studies in Las Pailas area since the year 2000, some months before the first deep geothermal well was drilled (ICE, 2005). Those studies were oriented at obtaining base data (background), with the objective to gain knowledge of the environment's quality (physical and chemical).

The first monitoring data were obtained on superficial water quality, air quality (H2S and CO2 concentrations) and noise, and then critical sites were chosen as points for sampling and reference according to local environmental conditions. Additionally, the collection of climatic data began (temperature, rainfall, etc).

From 2002, a higher level environmental phase began in the project area, including biological variables (flora and fauna), social variables, and the baseline data were strengthened, especially with regard to physical and chemical aspects such as atmospheric quality, hydrology and soils.

Later, archaeological and landscape studies were added, and then a complete environmental profile of the area of the Las Pailas geothermal project was obtained. Environmental monitoring has, to date, continued as an essential part of the development of the Las Pailas project.

In December 2004, SETENA communicated to ICE that the environment evaluation process must continue and it would be necessary to carry out an Environmental Impact Assessment (EIA) according to established laws and procedures. The study generated prevention and compensation measures in all its aspects.

The study was approved in 2005 (ICE, 2005) and new plans, including the drilling of new deep wells and the building of a power plant in the Las Pailas area started in the year 2008, with the aim of initiating operations in 2011.

3.2 Land requirements

According to ICE (2005), the approximate area needed for the Las Pailas project is around 10 km2. Within this area ICE will construct all buildings and other works related to the project (Figure 2), including: (a) provisional facilities, (b) roads and other access to the power plant site and the new drilling platforms, (c) new deep wells, (e) pipelines, (f) the separator stations, (g) a sub-station and energy transport lines, and (h) the power plant including offices. The size of the area affected by the construction of a power plant of 35 MWe is estimated to be about 2.5 km2, covering a rural zone without forest cover.

The development of the Las Pailas geothermal field take advantage of the human resources, laboratories, drilling equipment, camping and other specialized infrastructure available in the ICE-Miravalles geothermal field (Barrantes,

2006). In addition, it is important to mention that many of the necessary roads and most of the deep well platforms already exist, because ICE is planning for new deep wells to be drilled by means of directional drilling using mainly the existing platforms.

Finally, an important aspect to consider concerns options for routing electrical transmission lines between the power plant (future substation Pailas) and Liberia town (around 12 km to the south), as part of the ICE interconnected national system (SNI).

The analysis and criteria that prevailed for the selection of the definitive route included: a cartographic study of possible ways; trying to prevent impacts in primary forests (without or little human effect) and secondary forests (with human effects but in actual recuperation) and forest plantations; avoiding impacts on Rincón de la Vieja National Park; reduce, as possible, interference with tourist activities in the area; adapt the design to the landscape compositions; diminish the access construction; and avoid breaking the continuity of forests because of negative biological effects (ICE, 2005).

3.3 Air monitoring

During operation normal geothermal plants produce non-condensable gases which are released to the atmosphere. Two of these gases have high importance as they affect people's health and contribute to global warming: hydrogen sulphide (H2S) and carbon dioxide (CO2). The Organic Law of the Environment defines this type of waste as an atmospheric contamination (Zeledón, 1998).

The equipment used is a portable monitoring station that registers data on both H2S and CO2. The measurements are done weekly, with additional measurements during production tests of deep wells. Gas concentrations remained quite similar during the weekly monitoring.

Hydrogen sulphide (H2S) is a poisonous gas, common in volcanic areas and as a decompositional product of organic matter. In very high concentrations, it can cause the death of humans, but at low concentrations it may have some effect on vegetation.

The H2S detection equipment has 0.0003 ppm as the detection limit, and an error range of 0.001 ppm. The measured values of H2S were generally 0 (zero), however values of 0.005 ppm were sometimes registered. It is important to emphasize the presence of fumaroles and the volcano near the project area, since these are natural sources of H2S emission, which in stable climatic conditions can locally give high signals for H2S. In Costa Rica, the maximum permitted value for H2S is 0.03 ppm (ICE, 2005).

Carbon dioxide (CO2) is another very common gas. In its natural form it is found in the atmosphere, and in some excess in volcanic zones. In high concentrations it can lead to mental disorder, headache and, finally, loss of consciousness. In comparison with other sources of electrical energy production, the amount of CO2 emitted in geothermal plants is relatively low and additionally do not produce gases of NOx type (Kubo, 2003; GeothermEx, 2005).

The CO2 values varied in the range 300-600 ppm as normal values in the atmosphere, taking into account the error range of normal equipment. The equipment used for monitoring CO2 registers data in the range from 0 to 10000 ppm and has an error range of 100 ppm for maximum concentrations. In Costa Rica the maximum permitted limit is 5000 ppm.

3.4 Water (superficial and groundwater)

The area of direct project influence included the following river basins: Blanco river, Negro river, Colorado river and Victoria and Zanja Tapada creeks (Figure 2). They display a radial and parallel drainage pattern. In general, they are all mountain rivers and creeks.

The micro basin of Victoria creek (Figure 2), due to its proximity to most of the drilled wells, and to being used as the primary source of supply of high-quality water for Curubandé town and Guachipelín hotel, seems to be a place of high vulnerability (ICE, 2005).

The waters of these rivers and creeks are "crystalline" in appearance through most of the year, but despite that are not appropriate for human consumption due to their geochemical characteristics: they are usually acidic and sulphated due to the thermal and mineral contributions of the nearby geothermal springs (ICE, 2005).

In general, the waters of this fluvial system display pH values varying between 3.9 and 8.3, depending on the spring water type contribution. Its low pH value seems to be one of the main reasons for the absence of fish in the Blanco river. In other rivers, pH-values allow the existence of aquatic life in their waters, but still the studies show a low biodiversity in this fluvial system (Cháves, 2004; ICE, 2005).

The environmental studies included the chemical characterization of the water of each river, with concentrations determined for Na, CO3, Cl, Ca, SO4, Fe and TDS (total dissolved solids). The temperature and conductivity of the waters were also measured in the field and in the laboratory. Comparative data for each river and creek included in the study, show that SO4 -2 was the predominant ion both during rainy periods as well as dry ones, followed by Ca+2, whereas the Na+ and Cl- contents were smaller (Cháves, 2004).

In Las Pailas zone there are many surface manifestations, some of them of geothermal origin. Special care must be exercised regarding the springs in the area; in fact many of them are located within the edges of the Rincón de la Vieja National Park and are considered natural attractions for tourists. But perhaps most importantly, they are part of an ecological system that is very fragile (ICE, 2005).

From a geo-environmental perspective, these natural surface manifestations must be monitored regularly for the purpose of detecting any sudden or gradual change in their characteristics such as pH, conductivity, temperature, flow, chemical content, etc, especially during the drilling of geothermal wells and the operation of the Las Pailas geothermal power plant (Barrantes, 2006).

Finally, it is important to mention that waste geothermal water (hot and cold) will be re-injected down to deeper levels through re-injection wells located in areas previously selected based on their characteristics in permeability and their distance from the production areas. Usually, some artificial "lagoons" or "pools" are constructed, that serve as temporary storage (provisional), in case of emergency, during production well tests and/or during maintenance stages of the power plant.

3.5 Vegetation and animal life

Many animal and vegetable species are part of the greater diversity in the Las Pailas zone (Cháves, 2004; ICE, 2005), but like others areas of the world, the deforestation and transformation of forests to grasslands is very common process, and is inextricable linked with habitat loss (Laurance, 1999; Hill and Curran, 2005).

The construction of the power plant will affect the biotic and abiotic environments and it will be necessary to mitigate some activities to compensate for, or lessen, the magnitude of those impacts. For that reason, it is very important to study the forests and the fauna associated with the area to have an idea of the current status and how it will be affected (Cháves, 2004).

Biologically, this zone is considered little studied, but the abiotic conditions and vegetal and faunal associations that converge here correspond to the "dry tropical" and "rainy pre-mountain forests" life zones. This puts greater emphasis on the area directly influenced by the project, i.e. the location of the deep wells and the power plant, as it corresponds to a different and complex mosaic of forest plantations, grasslands and secondary and gallery forests.

The study of flora was correlated with the sampling sites of the fauna. The biological study was conducted in two parcels of 1000 m2 each at previously selected sites. In these an inventory of each tree was made, determining the botanical species, its diameter, commercial height and its total height. In the grasslands and pasturelands, a special sampling zone was not established, but the species of plants and their abundance were counted (ICE, 2005).

A greater diversity of mammals and amphibians was seen in the gallery forests bordering the Rincón de la Vieja national park, but the diversity of birds was superior in the secondary forests. In general, the established plantations and the grassland were habitats of smaller diversity. A total of 29 species with reduced populations and 9 species in danger of extinction were identified. Las Pailas biodiversity (fauna) data are shown in Figure 4, based on data from Cháves (2004).

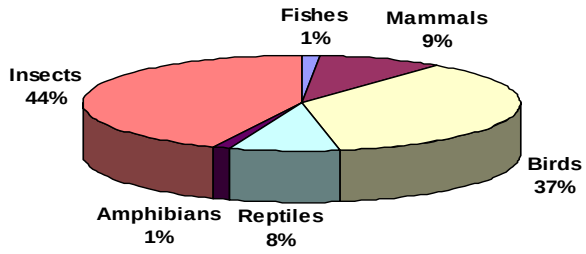

Figure 4: Diversity of animals in Las Pailas area considering only species level; data from Cháves (2004)

The obtained results show that, in spite of the high degree of intervention in this area, a considerable diversity (Figure 5) is experienced for some groups (e.g. for insects, reptiles, birds and mammals) according with Cháves (2004).

Probably these species have managed to survive in the zone thanks to their capacity to mobilize themselves between forest patches and to take advantage of the existing availability of resources in each one, as well as to the proximity of the national park. There is evidence that the degree of isolation between the wooded patches of a fragmented ecosystem as in Las Pailas is relative, and that it depends on the particular natural history of each species (Cháves, 2004; ICE, 2005). But it is also well documented that forest fragmentation lowers species number and alters community composition as a result of this change in forest shape (Hill and Curran, 2005).

The location of the Rincón de la Vieja National Park lands being relatively near the project permits the migration of animal species to the national park. Some of the ICE lands will not be used and instead used as zones of natural forest regeneration. In these cases, biodiversity will benefit directly. This has been demonstrated within ICE lands in the Miravalles geothermal field (Barrantes, 2006).

Figure 5: Las Pailas area is a beautiful place, with high biodiversity (especially mammals and insects)

The project is mainly be developed in areas of extended grassland with isolated and impacted forest fragments; however it is clear that mitigating measures must be considered and implemented in corrective ways with project advancement.

3.6 Social-economic aspects

The construction of an electrical generation project represents a socio-economic factor of national importance and with local effects that can be gradual and different depending on their size and the installed power. Also, the source of generation used defines the degree of impacts for social and biological aspects (ICE, 2005; Barrantes, 2006).

The area of influence of such a project can be direct (primary) or indirect (secondary), based on the location of the power plant, wells and the distance to the nearest towns. A radius of around 500 m is indicative for the area of direct influence on buildings or towns (ICE, 2005).

According to national environmental regulations, the indirect influence area corresponds to the geographic space which is indirectly affected by the project, in a diverse degree of intensity. In this particular case, the nearest locality is Curubandé town, located 12 km away. Hence, it is within the area of indirect influence (ICE, 2005).

ICE with experience from the Miravalles geothermal field on prevention and mitigations, intends, as far as possible, to manage the field in total harmony with the surroundings. It will integrate the project into the landscape and aims at contributing to the area with technological elements of interest that will increase the local tourist potential.

4. FINAL REMARKS

The Las Pailas geothermal project is located in a special and complex place, where private, economic and eco-tourist interests (two mountain hotels) converge with ecological and scenic beauty (Rincón de la Vieja National Park and ONG's private lands) and a geothermal resource with a

possible development, due to national energy interest, represented by ICE. Additional parties of interest would be the inhabitants of Curubandé town; the development of this project could make an important contribution to their socio-economic development with a possibility of more and better job opportunities, and access to goods and services that at the moment they do not or cannot have for different reasons and circumstances.

Special considerations have been granted to the environment (biotic and abiotic), for obvious and diverse reasons. Some are economic but others are ecological, meant for the preservation of local nature. But it is clear that this can become an example where humans, nature and economic apexes converge in the same area at a determined moment. That is the philosophical reason of "sustainable development", in agreement with the principles adopted from the Earth Summit in 1992 (Parson et al., 1992; Kates et al., 2005).

Las Pailas project is a good opportunity for ICE to demonstrate that it is prepared as an institution to develop projects of this kind near protected areas or within them as has been done in other countries, Kenya (Kubo, 2003). Not only "to fulfil" what is demanded by national environmental laws or existing international norms, but also with the possibility "to gain" an image with proven facts.

High-temperature geothermal energy is mainly associated with volcanoes and most of the volcanic zone is declared national parks in Costa Rica. In agreement with present legislation, these areas cannot be "touched"; therefore, the energy associated with them cannot be exploited. This is a serious problem for many developing countries, Costa Rica being one of them.

Like any country that requires development, Costa Rica increasingly needs energy. Costa Rica of the future needs energy. The energy should preferably come from environmentally friendly and clean power sources (as geothermal), that can be exploited economically and contribute in a significant way to the great and increasing national demand for energy.

The geothermal energy represents a viable, economic and technical possibility. This valuable resource must be utilized and perhaps some of their environmental problems can be mitigated. This may therefore, be the right moment to allow a controlled and restricted development within certain protected areas. The benefits will be economic and environmental for the country, and locally for the nearest communities, as they will have better job opportunities available. Economic benefits must be included for the national parks. A new law is necessary in order to permit this, but, more urgently, a new concept about environmental, economic and human development is needed, a real sustainable development.

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