GEOTHERMAL RESOURCES AS AN IMPORTANT RURAL HERITAGE TO MITIGATE THE ENVIRONMENTAL IMPACT FROM TERRITORIAL DEVELOPMENT IN ANDEAN REGION

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Abstract
The remote and vulnerable regions of the Andean Cordillera, piedmont areas and valleys, hold a rich heritage and a vast potential for the rural development. The past decade a concern grew out about the complexity and dynamics of the territorial transformation in Argentina. The absence of planning and regulations that seek proper land use and the resources distribution, show that some territorial processes in various scales will irreparably affect the long-term local sustainability. This research work is aimed at proposing rational guidelines for resource and land usage in the Valley of Iglesia of northern San Juan, Argentina, through the valuation of heritage and natural resources, specifically the optimized usage of geothermal energy sources of this region. Therefore, a territorial strategy has been devised to assess the local heritage, their characteristics and the level of social involvement of the communities and the incoming entrepreneurships towards the conservation of their patrimony and natural ecosystems. Furthermore in this study, a critical area prone to irreversible deterioration has been detected, for which case a comprehensive tourist project has been proposed while considering the rational resource and land usage through the consensus and motivation for action of all parties involved. It is concluded that the patrimonial identity constitutes the genetic value of culture to find better solutions for rural development. The intrinsic relationship of the geothermal potential and the community, is considered as true agent of development for heritage conservation, diversification of land use and community inclusion.

Keywords: Tourism strategy, geothermal resources, local heritage.

Introduction

The hypothesis that gives place to this work is the following: a touristic strategy that takes into account patrimony values leads to sustainable territorial development. The District of Iglesia, in San Juan province, Argentina owns a strategic location and is under the pressure of different territorial processes at varied scales, mainly in relation with mining and tourism. This gives the region opportunities as well as threats for its development (see Sanchez-Alfaroa, et al., 2015).
The World Heritage Convention points out that the cultural and natural heritage is among the priceless and irreplaceable assets, not only of each nation, but of humanity as a whole (UNESCO 1972). The sustainable development of the land promotes the link between nature and culture, provides alternative economical solutions (Sanchez-Alfaroa, et al., 2015), reorients the technologic-scientific potential, proposes new values, believes, feelings and knowledge, and revalues the different forms of living (Martinez, 2006).

Therefore, the abilities of local communities and heritage resources are emphasized. Besides, harmony between man and nature is promoted with the aim of avoiding that it remains submitted to the needs of self-realization of man (Albuquerque, 2004). The concept of conservation, is considered as the need of natural balance, diversity, evaluative change in the environment and the planned management of natural resources (Melendez, 2010).
Touristic development in Argentina rescues valuable discoveries. Las Termas de Reyes (Jujuy), Rosario de la Frontera (Salta), Río Hondo (Santiago del Estero) (see Kaiser, 1967) constitute poles of touristic development based on the use of natural spring waters of geothermal energy (National Secretariat of Energy, 2014). Due to the nearness to the Andes Mountains, San Juan Province, presents an elevated geothermal potential. There are 61 natural manifestations in the province that are known at present (Carrizo y Quinteros, 2001). The location of Las Flores, Iglesia District, present an elevated geothermal potential (Wetten, García and Pelegrino, 1984). The availability of renewable energy resource of geothermal origin, is studied to give a design of a touristic strategy of low environmental impact for developing the territory preserving the natural ecosystem (Moeck, 2014). Geothermal resources of Iglesia were studied to make a survey of strengths, drawbacks, opportunities and threats specific of those manifestations.

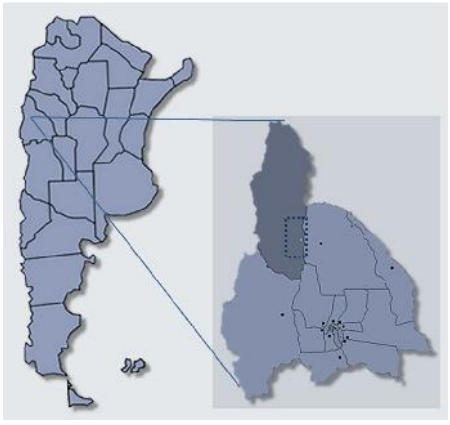

Figure 1. Argentina, San Juan. Location of the study sector Iglesia-District.

The type and amount of locations of spring waters are detected and it is determined their importance according to variables such as, mineralization level, basin flow and temperature at well head. Once the diagnosis and assessment of natural resources is obtained in the field, a sustainable strategy is designed through the proposal of a Thermal Village. This one is oriented to health care and hygiene of users and the possibility of providing touristic services with local identity.
This work tries to serve as a contribution to the lack of planning of high-risk areas of destruction by the dynamics of transformation territorial that suffer, considering the touristic potential and the use of renewable energies of low environmental impact. This is pretended so as to strengthen the local identity and guarantee the heritage conservation and inclusion of local communities about their development.

2. Work development

2.1 Description of the aim of study

As regards the site, the area of study corresponds to Iglesia District, in San Juan Province, Argentina (see Figure 1), which occupies the 22% of the provincial territory and has a surface

of 19.801 Km2, a low population density of < 0,3 Inhabitants/Km2 with 9.141 individuals (Census 2010). Iglesia District is located in an oasis area of mountains at an average height of 2000 meters over the sea level. It limits to the west with Chile. The dryness characteristic is in contrast with the minimal presence of meltwater, rivers, streams and slopes which give place to such oasis. As regards those springs of geothermal origin, the study is centered in small inhabited nodes, among which are Chigua, El Chinguillo, Malimán, Colangüil, Angualasto, Tudcum, Rodeo, Guañizuil, Las Flores, Villa Iglesia, Zonda, Campanario, Tocota, Bauchazeta, and Bella Vista. In fact, according to its geographical location and the quality of the energy resource of geothermal origin, Las Flores is clearly outstanding above the rest of the communities.

2.2 Geothermal Energy

Iglesia Geothermal resources are an opportunity for the development of the area. Geothermal energy is generated inside the Earth. The most external layer, inhabited by human beings, Lithosphere, it has a variable thickness within 100 and 70 km and constitutes a thermal insulator (Moeck, 2014). In normal conditions, the Lithosphere temperature gradient is increased about 3°C/100m of depth (National Secretariat of Energy, 2014). The study area, close to the Andean Mountains, presents a more elevated thermal gradient. These springs, suggest the potential existence of energetic resource of geothermal origin. Andean valleys have spring waters with temperatures variable between 20 and 90°C. The enthalpy is the measurement unit of thermal energy and it is measured in calories per gram of water (Moeck, 2014). When the temperature is under the boiling point (<100°C) corresponds to “low=medium” enthalpy and, logically when it is above it, is the “high” enthalpy (Sass and Lehr, 2013). Geothermal energy of low enthalpy is applicable to industries, agriculture and farming, balneology and hydrotherapy and air conditioning of buildings, among other activities (Lund, Freeston and Boyd, 2005).

The advantages of geothermal energy are based on the fact that it is present 8760 h/year (the whole year), it is silent with low environmental impact, it does not depends on the relation day/night or winter/summer (Moeck, 2014), neither from the sky state or less from the hydrological conditions of the site (Sass and Lehr, 2013).

2.3 Survey

The survey on those factors influencing the local system and the analysis of the District heritage leads to the elaboration of a proposal of sustainable solution. Thus, Strengths, Opportunities, Weaknesses and Threats (SOWT), are analyzed, synthesizing the relevant aspects that conditioning, prevail, affect or favored the development. The subjective assessment of those variables of influence is summarized in the determination of Units of Cultural Landscape (UCL).

3.1 SOWT Diagnosis

In the diagnosis of the area is included the study of geographical situation, environmental, population, patrimonial resources and the detection of the main economic activities. The system structure of micro-region is studied according to subsystems of nodes, networks, areas and their gravitations that give evidence of the processes and functions over the area at different scales and hierarchies (Figure 2).

Resources that reveal the potential development of the area are: the Natural Reserve of Biosphere of San Guillermo, Valle del Cura with metalipherous deposits, Cuesta del Viento reservoir, Termas de Pismanta Hotel, the opening of the National Route N°150 and the construction of the bi-oceanic corridor, that linking Coquimbo (Chile) and Porto Alegre (Brazil)

ports. The exceptional characteristics of Iglesia District based on its heritage resource, favors touristic development. Besides, this particular landscape of spreading inhabited Andean oasis, linked as a network due to their agricultural-farming activities is originated by the same geography location (Figure 2).
The organizational structure is given essentially by the mining industry and the growing touristic activity. Lack of policies associated to those processes recognized in the diagnosis, foster the inappropriate use of land in favor to economical speculations and external processes to the area. The future use of local natural resources is affected by all these. The local vulnerability is intensified by those flaws detected in preservation and protection actions of the local heritage on behalf of the authorities and also of some communities.
In addition, the trivialization of the heritage in relation with tourism is a relevant risk of anthropogenic origin, which is associated to the lack of knowledge and awareness for the care of nature and culture. Although, there is a positive attitude of the community to work in defense of the heritage is evidenced.

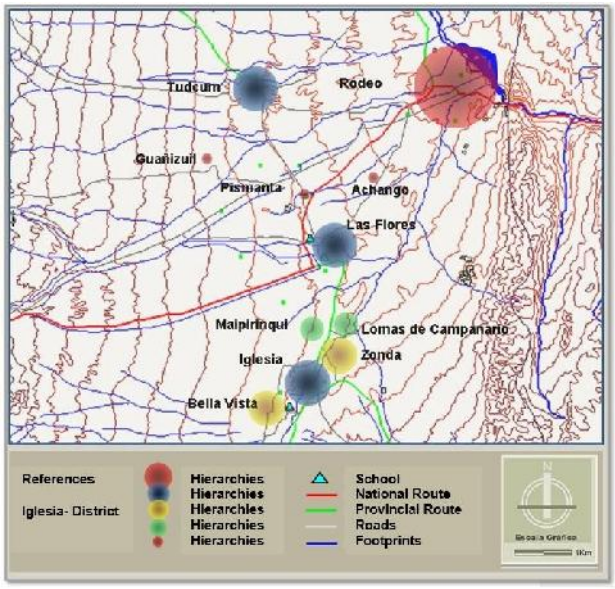

Figure 2. Synthesis of the system structure, subsystem nodes, networks and populated areas.

A patrimonial map is built from the analysis and assessment of resources, where nine units (UCL) are detected, as areas, with their respective assessments and cultural diversities (Figure 3). In relation with the strengths of the Iglesia District, the area UCL7 (Las Flores, Figure 4) is identified with the resources of greater patrimonial significance and developing opportunities. It is underlined the potential value of lands with high landscape level and with springs of geothermal water that flow in natural way (see red points in Figure 4). Within UCL7 five thermal springs are identified assessment in Table 1).
The subdivision of UCL7 into five Sub-Units of Cultural Landscape due to the localization of areas with different heritage potentialities is shown in Figure 4. The area of Las Flores is recognized, due to its strengths and opportunities, with the best potential to start the strategy of touristic development. The risk of future impairment that means to be located over the future bioceanic corridor (red line in Figure 4) obliges to anticipate the possible harming processes for the territory.

The underground water is not polluted and it has optimal conditions for its usage in balneology and medical applications. Data obtained from the following variables: mining, flow, acidity/salinity and temperature, which define the quality of the geothermal resource. About the, mineralization, an international acknowledgment is conferred to the composition of water in UCL7 due to benefits in the treatment of respiratory, digestive, circulatory, dermal, motor, immunologic and psychological affections (De Michele, et al.; 2008). Sub-units SUCL7.1 and SUCL7.4 constitute basins with sedimentary fillings. According to the analyses carried out at lab by CRAS_INA (1984), Pismanta and Rosales are recognized by the presence of minerals as sulfur, copper, calcium, zinc, magnesium, and silicon. The mineral quality of the water is considered good since it presents sandstones levels of the tertiary, quaternary and recent alluvial deposits of variable granulometry.

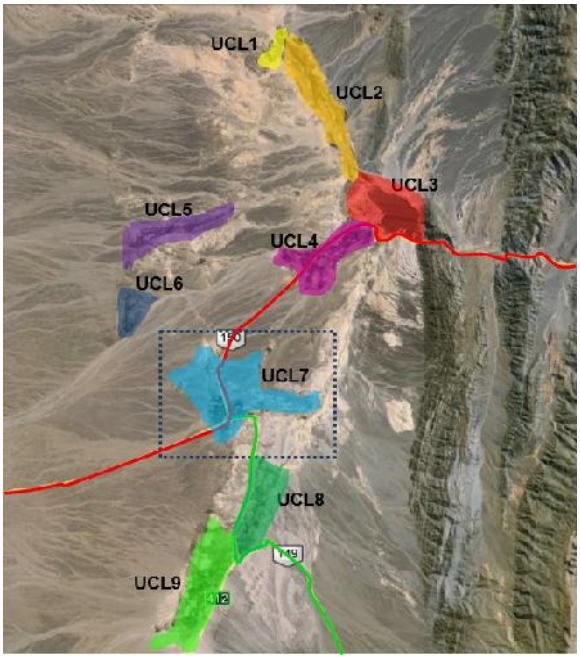

Figure 3. Iglesia valley with 9 (nine) Units of Cultural Landscape (UCL).

The spring water flow in UCL7 oscillates among 11.000l/h and 1800l/h (liters/hour), which represents an important drawback, conditioning the capacity values of touristic load, and therefore, the maximum number of visitors that the area can afford (Table 1). The load capacity considers the ecosystem tolerance to adverse impacts over the society, economy and culture of an area and it is defined to determine the ability of recovering in the short time without decreasing the satisfaction of the visitor (National Commission for Natural Protected Areas, 2006).

Acidity/ Salinity, as regards the ph-value (acidity/salinity) it is observed that these variations are negligible respect the study by Wetten, García and Pelegrino, 1984. In relation with the geological conditions and chemical composition, similar values are registered in all the extension of SUCL7.1 (ibídem).

The temperature denoted the real potential of geothermal resource of UCL7 Sub-units, with an average temperature in wellhead, of 35±9ºC, i.e. of low enthalpy. Those of Centenario, Rosales, and Poblete, in SUCL7.1, have the greatest values of the zone of study, with water temperature

at wellhead varying between 42±2ºC and 38±2ºC. Other feasibility studies were carried out in wells VI-3 and VI-4 registering a temperature of 27,5±2ºC and 23±2ºC, respectively. Less temperature value was registered by these ones and, in time, less flow than Rosales and Centenario (Table 1).
In general, it is observed that natural spring waters in UCL7 are located in surroundings with elevated landscape value, which increased the heritage value of geothermal resources. The geographical location, accessibility and infrastructure, provide strength to the development of a thermal touristic strategy.

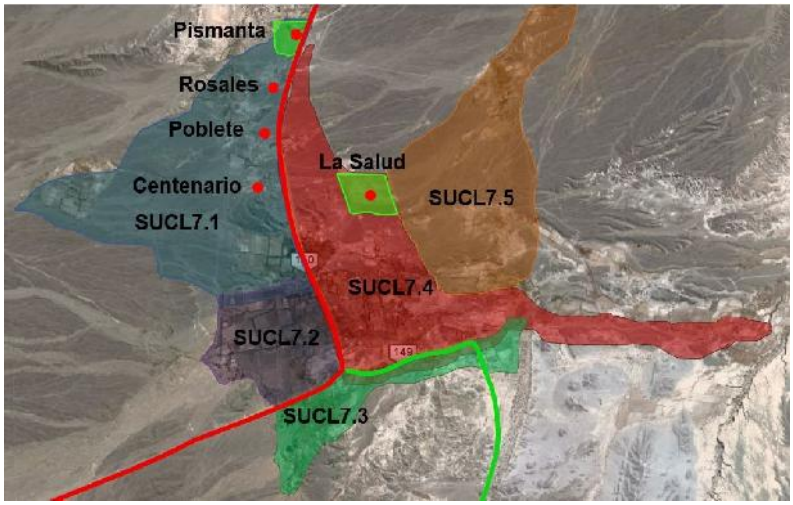

Figure 4. Las Flores, Sub-Unit of Cultural Landscape (SUCL).

2.5. Touristic Strategy in SUCL7.1

The analysis of data from the survey allows checking out the initial hypothesis, in which it is affirmed that a touristic strategy which considers the assessment of the local heritage makes the sustainable territory development easier. The strategy is focused in the use of geothermal resource as motor of "micro-scale" development at region level. It is also foreseen that at a long term it will produce opportunities of development and co-operation with other communities (see Sanchez-Alfaroa, et al., 2015). The design of the touristic strategy over SUCL7.1 in Las Flores, are superposed the own potentials of the structural, touristic-social, environmental and patrimonial systems, and the areas of intervention are determined.
The structural system is built through the location of three access sectors to the hydro resource: natural spring waters, water melt from the mountains and the reserve of the Cuesta del Viento dam. The geographical location (latitude, length and height), the accessibility and the availability of roads and, in general, the economical link between the different UCL of the District (Figure 2), that constitute poles of development, give force to the proposal. The system articulates public or semi-public nature areas through the structural subsystem of cycle lanes and foot paths.
The Touristic-social system considered the balneology and hydrotherapy that provided a product oriented towards fulfilling users' needs. The acknowledgement that the community provides to this initiative is due to the emphasis given to comfort, availability and economy.
The reduced load capacity of the system is considered as a strength, which faces the threat of un-limited growth proposed by the present model. Through an economy of scale, a local system

of production/ consumption and cooperation/management of the local inhabitants, it is possible to guarantee the continuity of these activities and the preservation of biodiversity.
From the touristic projectable instance it is aimed at encouraging and promoting the community association to give birth to local productive ventures. The Environmental system stand by the fact of being "locals" is the premise to give force to the community and the environment.
The values quality of the geothermal resource parameters (see Table 1) places the environmental system as the appropriate scenario to give answer to that user which looks for harmony with the local natural surroundings.

Table 1. Measured values of analyzed in UCL7. Ref. Soil bearing capacity: G (good), R (regular), B (bad).

Measurement position	Flow [l/s]	Acidity [pH]	Temp. [°C]	Geologic age	Soil capacity	Landscape value [1-5]	buildable soil	Mud	Latitude
Well VI-3	3.960	9,2	27,5 ± 2	Quaternary	G	4,5	-	-	30°16' S
Well VI-4	2.988	8,6	23 ± 2	Tertiary	G	4,5	-	-	30°16' S
Spring Pismanta La Holla	6.120	9,7	44 ± 2	Tertiary	G	5	-	Yes	30°16' S
Spring Pismanta WBravo	11.160	9,8	44,5 ± 2	Tertiary	G	5	Yes	-	30°16' S
Spring Rosales	11.880	9,6	42 ± 2	Quaternary	G	4,5	Yes	Yes	30°17' S
Spring Centenario	3.600	9,9	39 ± 2	Quaternary	R	5	Yes	-	30°17' S
Spring Poblete-Bañitos	1.800	9,8	38 ± 2	Quaternary	B	5	Yes	-	30°17' S
Spring, La Salud	-	8,5	22 ± 2	Recent	G	5	Yes	-	30°18' S

The Thermal Valley in SUCL7.1 is meant to be the support for the future sustainable development of Iglesia District. Therefore, it must be considered that a change in the system structure requires the re-accommodation and adaptation of their components, i.e. a joint evolution. In order to achieve these goals the public management of the Town Hall and the Tourism Secretariat of Iglesia District is strengthened through the promotion of public areas, theme parks, organic orchards and areas with local forests that may organize or give support to different activities, either touristic or commercial ones, under a regulation of the use of land in relation to the impact/aptitude.
The Patrimonial system shows the exceptional heritage qualities of the territory are given, mainly, by the renewable energy of geothermal origin and mountain oasis. The Thermal Village proposal (Figure 5) includes those systems detected in a series of actions articulated in areas.
The land use divided in zones is synthesized with references "A" to "F" in Figure 5. The combination of letters refers to the integration of structural, touristic-social, environmental and patrimonial systems from proposals of preservation and rehabilitation of polluted areas, in which is focused the management of the renewable resource, the respect to the environmental and cultural heritage, the quality of the service with own identity, the involved staff, the relation with the local community and the hygiene and security system for users. Those relevant actions that must be taken into account in the proposal of Thermal Village in order to achieve the sustainability of the region are listed below:
1. Exhaustive control of underground water quality, according to its physic-chemical and micro-biological composition, flow and temperature. Quality Control Plan through a sample taken at the wellhead with recording of frequency and results, with the aim of registering quality values.
2. Consideration of a plan of territory ordering in the implementation of the Thermal Village in relation with the surrounding of the micro-region and specifically, of the SUCL7.1

3. Environmental impact of the geothermal exploitation and the touristic-commercial enterprises.
4. Residues control at enterprises through treatment and organization into primary and secondary spring waters. Minimization of elimination of residues through recycling and reusing techniques.
5. Monitoring of the rational use of water, energy and materials.
6. Measures to reuse residual thermal water as an alternative source of rationalized irrigation systems.
7. Environmental impact of the infrastructure, facilities and future enlargements which consider the admissible load factor.
8. Respect for the local plants in parks, to avoid ecological unbalance.
9. Limit in number the infrastructure works, facilities and supporting elements which may transform the landscape quality.
10. Control of noise level and air quality within acceptable ranges.

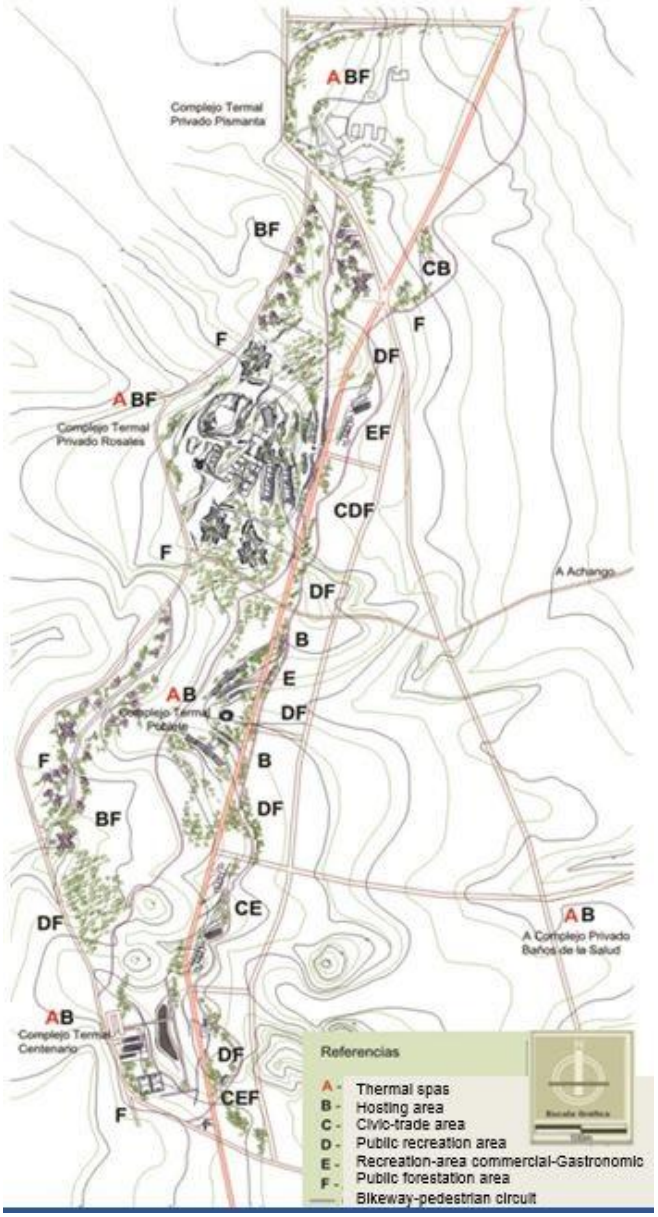

Figure 5. Thermal village proposal for SUPC7.1.

3. Conclusions

The use of conventional energy can be rationalized by using geothermal energy which leads to an important save in energy resources and efficiency for the territory.

Geothermal resource use to preserve the heritage is considered as an optimal measure for the sustainable development of Iglesia District.

The construction of the bi-oceanic corridor which will connect Chile, Argentina and Brazil (Agua Negra Pass) implies scenarios of opportunities and threats. Cultural and natural heritage of Iglesia is strongly conditioned by the lack of regulations in the use of land. Therefore, a touristic strategy is generated to support the sustainable territorial development of the region.

The development of the territory either related with health or with touristic and re-creative ends is based on the quality of the underground water which is not only good for balneology and hydrotherapy but also for the human comfort. Accordingly, the proposal of a Thermal Village of low capacity of load is intended to minimize the environmental impact of the enterprise. The community awareness of sustainability criteria will be carried out through social co-participation, considering the local management as the main resource for its preservation and protection.

A negative environmental impact is reduced with a conscious management. Thus, the Thermal Village is based on the preservation and re-organization of the renewable energy source. This strategy is centered in the respect of local plants and wildlife, the control of resources and territory, the development of spring waters, the treatment of residues and the landscape care, giving priority to sustainability and identity of the region.

The attraction of tourists who seek for benefits associated with health must be considered as an added value to the territory development. Imposing limits over the availability and the use of resources would stop environmental degradation and guarantee touristic activities in the long run.

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