Low and Moderate Enthalpy Geothermal Resources to Desalinate Sea Water and Electricity Production

Héctor Gutiérrez[1], Salvador Espíndola[2*]
[1]Comisión Federalde Electricidad, México
[2]Instituto de Ingenieria, UNAM, México
[*]Corresponding Author: sespindolah@iingen.unam.mx

Baja California, on the northwest part of Mexico and close to the border with the largest economy of the world, has shown a rapid and continued growing of its industrial and touristy activity triggered for real state demand, since thousands of retired Canadian and American people are moving south searching for nice ocean view places and warmer weather along the Mexican coast. This baby-boomers phenomena is producing a strong increase of goods and services in the region but, specifically on the fresh water demand, in a zone where this resource is highly stressed and not easy to access or supply.
On the other hand, this though and arid region with extreme temperatures, 0ºC in winter up to 50ºC during summer, has been blessed with abundant renewable energy sources. Solar, wind, geothermal, tidal, hydrothermal vents, and other resources are widely spread along the 1,200 miles through the Baja Peninsula. That is why the National University of Mexico (UNAM) formed three years ago a professional-multidisciplinary research group –IMPULSA IV- in order to promote and implemented technological solutions to desalinate sea water through the use of renewable energy sources, Alcocer, et al (2008).
It is well known that in a traditional thermal desalination plant, the main component of the cost of the desalinated water comes from steam extracted from a power generating plant or power taken from the grid. In the case of Baja California, geothermal heat that rises from geological faults has already increased temperature of water near to the boiling point. In IMPULSA project a combined analysis of multiple effect distillation plant (MED) and a multi stage flash plant (MSF) was performed in order to be able to desalinate sea water using the hot geothermal fluid instead of the traditional steam supply from a thermal plant.

Keywords: Desalination, Low Enthalpy, MED.

Baja California Geothermal Resources

For purposes of this paper, we have divided the Baja California Peninsula in three arbitrary zones in order to present a summary of the principle sites with geothermic potential in the Peninsula (Fig.1). The northern zone is comprised of the area from the U.S. border on the northern part to the 30th parallel. The mid zone, comprised of the area between the 30th and 26th parallel, and the southern zone is from the 26th parallel to the south end of the Peninsula.

Northern Zone, Mexicali Valley

There are at least 20 sites in the northern part of the Baja California Peninsula in which there is geothermic manifestation. The most well known and largest are the Cerro Prieto Geothermal Fields, in Municipal Mexicali, where the state owner power company, Comision Federal de Electricidad (CFE) has drilled more that 300 wells to extract steam necessary for power generation. At Cerro Prieto field it is installed 720 MW of geothermal power capacity that means up to 45% of the electric energy consumed in the cities of Mexicali, Tijuana, Tecate and Rosarito.

A few kilometers from Cerro Prieto it has been identified at least five geothermal sites; all associated with the Pull-apart system between the Imperial and Cerro Prieto faults systems. However, in none of them it has been successful in obtaining sufficient temperature to be able to use them for power generation, even for example, the Tulecheck Field, where a temperatures of 165ºC has been registered, in the Airport field 112ºC and in Guadalupe Victoria up to 230ºC in a well 3,100m deep.

In the western part of the Cucapah Mountains there is a large plain, Laguna Salada (Salted Lagoon) where a multiple geothermal and geophysical soundings has been found and three deep exploratory wells where drilled. However, the maximum temperature reported in one of them was only 101ºC. To the south of this plain, it is reported agricultural wells with estimated temperatures up to 250ºC.

Ensenada

In the western part of the Baja California Peninsula, south of the city of Ensenada, several geothermal sites have been identified (Alvarez, 1993), springs appearing, hot soil, steam escaping, wells and hot norias, where geothermal potential has been identified from direct measurements of the natural discharges and in the wells of the area, particularly in the Maneadero Valley, Punta Banda, Santo Tomas and San Carlos, all of them associated with the occurrence of Agua Blanca Fault, one of the regional structures predominately oriented NW 48º.

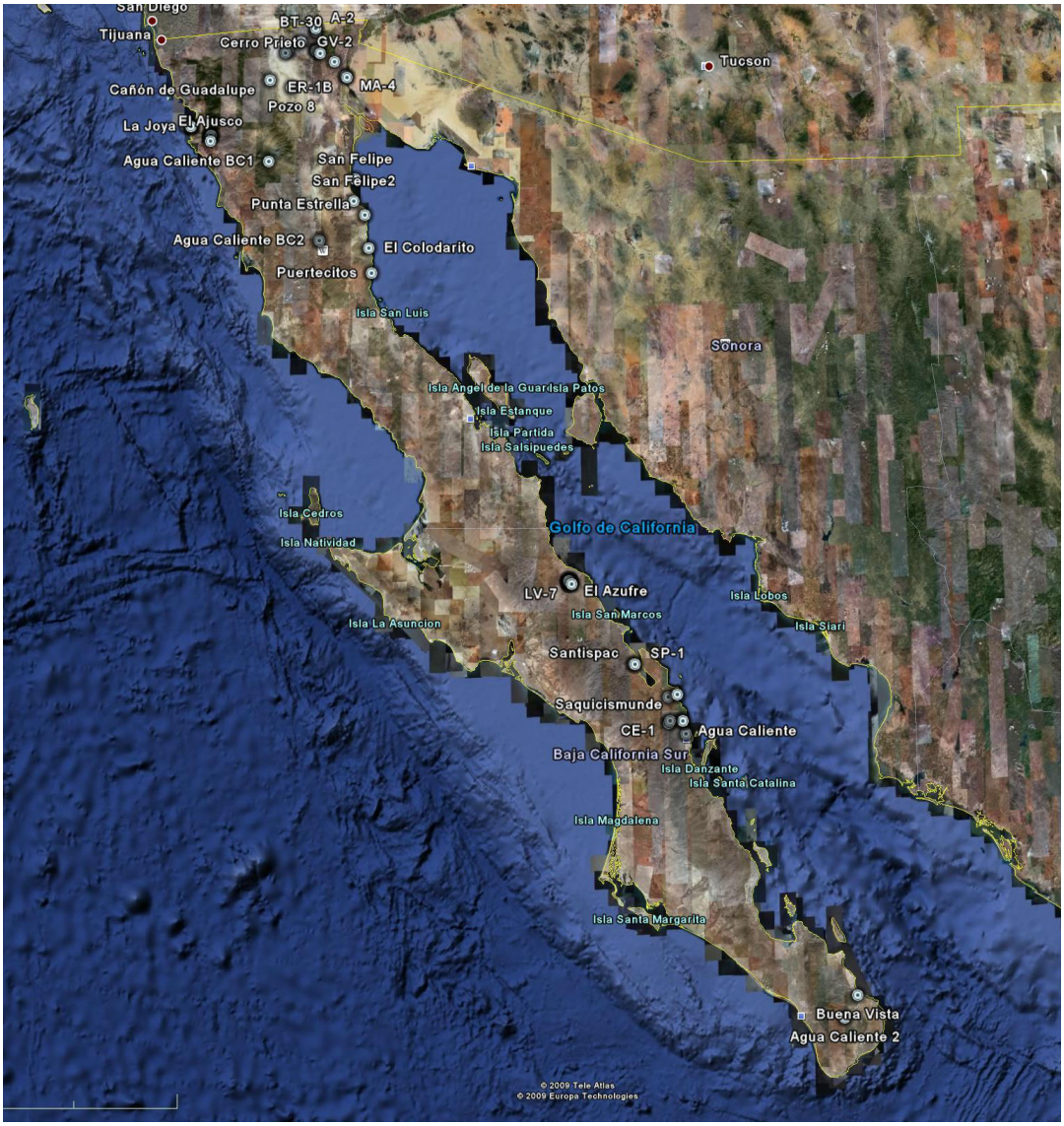

Figure 1 Baja California Geothermal Resources. Impulsa, UNAM, showing main geothermal fields Cerro Prieto (720 MW) and Las Tres Vírgenes (10MW) operated by Mexican National Utility, CFE. Also most of places with geothermal features a long of the sea shore.

Given that the zone described has been changed into a tourist development, the major part of the usage of thermal water is utilized directly for use in the tourist areas along the coast of the Maneadero Valley, there are various beaches where at low tide you can see springs of water with boiling temperatures that have been measured on the surface, resulting in the study of these sites in order to start projects of desalination of seawater through the use of thermal energy. The main locations are:

Punta Banda-Maneadero

This area is characterized by the intense hydrothermal activity, submarine as well as the length of the coast, showing emanations of steam and hot water in the sea bed having temperatures of 102ºC to 110ºC at a depth of 30 meters, as well as at diverse tourist camps along the coast where some norias have been dug that provide temperatures of 45ºC to 98ºC just at depths of 1.5 meters and in wells dug in the area. The most distinctive sites are in the area of La Joya, Agua Caliente and the Bufadora.

Ejido Uruapan

On this area there are a group of springs located on the margins of the arroyo that drops into the Cañon de la Grulla, located some 3 kilometers NE of the Agua Blanca Fault. One channel of this spring has been measured as from 250 liters per minute with temperatures of 50ºC to 65ºC. This water is used by the residents of the village as thermal baths and laundries and they have built pools and pits for the purpose.

Santo Tomas-Ajusco

Along the length o the Santo Tomas Valley and Canyon, are thermal springs during the rainy seasons. There are reports of springs with

temperatures of about 47ºC and in one thermal noria they measured temperatures of 176ºC by using geothermometers.

San Carlos – Ensenada

To the NE of the Maneadero Valley is the San Carlos Canyon where there the springs of San Carlos and Agua Caliente, reporting temperatures of 47ºC to 50ºC. In the same city of Ensenada there are springs and norias that have been used for years in the public baths of Acapulco, Lourdes and La Providencia.

To the Gulf of California or Sea of Cortes, is the volcanic providence of Puertecitos, where recent tectonic activity and the volcanic and rock activity of the zone have given rise to various thermal springs along the coast (Figure 1). This desert zone in the north of the peninsula of Baja California has been converted into an important tourist development area, where there are several sites along the coast in the upper part of the gulf, the majority of which are aimed at recreation and fishing. The main sites are:

San Felipe-Punta Estrella

In the port of San Felipe, around the Machorro hill area, there are various manifestations of thermal activity located along the coastline, where there is at least one spring with 50ºC and a noria where a temperature of 30ºC has been found at a depth of only 2m. At this site, apart from the thermal resources, there have been several studies done for the feasibility of installing a solar power plant, owing to the high degree of iridescence in the area, for which many residents of the area have solar panels for the energy in their houses. 25 kilometers to the south of San Felipe, in Punta Estrella, there is a thermal spring that has given readings of 33ºC.

Puertecitos-El Coloradito

The geothermic area of Puertecitos is located on the east coast of Baja California Peninsula, 76 km south of the port of San Felipe. This area is considered as a place of geothermic interest owing to the presence of recent volcanic action in surrounding areas and for the existence of springs in the inhabited areas as along the coast as well, registering temperatures in the range of 55ºC to 77ºC. An exploratory well has been drilled on this site but only got to a depth of 375m when they started to have problems drilling. The maximum temperature registered there was 44ºC. To the north of Puertecitos, on the coast and some 30km inland there is a hydrothermal manifestation in an area known as Coloradito, where abundant hydrothermal alteration has been observed in the outlying rocks around the spring where 56ºC has been registered.

Central Zone of the Peninsula

Tres Virgenes

This geothermic area is located some 33 miles northeast of Santa Rosalia, Baja California Sur (BCS), in an ample area remarkable for the hydrothermal activity in the middle of the region of the Tres Virgenes, as the three main volcanoes are known, La Virgin, el Azufre and La Reforma. In this area are numerous thermal zones where small boiling pots are seen, hot soil, hot water springs, smokers and a large zone of hydrothermal alteration. This area has been widely studied (Lira, 1985) and developed by CFE, the national power company, installing on site a 10 MW power plant, operating on the steam extracted from the wells drilled in the geothermal field.

Santispac

20 kilometres to the south of Mulegé, in the central part of the Bahia de Conception, a hot spring has been identified (44ºC) on the beach of the inlet at Santispac, in an area influenced by the fractured region of NW-SE which allows the overflow of hot water to mix with the sea water. Through the use of geo thermometers it is estimated that the temperatures of formation can be on the order of 180ºC. At this site a slim hole was drilled to a depth of 500m where the temperature was registered at 85ºC maximum.

San Nicolás-El Volcán

This is an area of thermal manifestations of 65ºC- 70ºC temperatures located 70 km to the north of Loreto, BCS, and 9 km southeast of San Nicolás. On this site various hydrothermal activities have been observed, steaming ground and hot water discharges in the arroyo of San Nicolás. A little further south in the area known as Puerto Púlpito there have been manifestations of steam on the sand of the beach, the sea invading the area makes it difficult to measure actual temperature.

El Imposible-El Centavito

There is a hot water well located in the San Juan Valley, 30 km northeast of Loreto that averages 46ºC. From the chemical analyses of this well, we know that it is a sodium-chlorate composed and a temperature estimated to be between 181ºC and 262ºC estimated by geo-thermometers.

Agua Caliente-Comondú

In this area there is a hot spring (59ºC) located some 25 km to the north of Loreto in the El Caballo Arroyo and 3.5 km from Boca Bataques beach. This spring flows through a fracture parallel to the structural system of the zone, and owing to the presence of recent volcanic action there is an area of high geothermic interest, however, in a slim hole drilled by CFE it only

registered 97ºC at 500m depth. The temperatures estimated by geo-thermometers at this site are on the order of 176ºC.

Southern zone of the Peninsula

Buena Vista

In front of the Bahia de Las Palmas some 60 km NE from San José del Cabo BCS, there is the Hotel Buena Vista where they found a hot water well (58ºC) inside of the property some 200m from the beach. This hot well was abandoned because they were searching for fresh cold water well to be use at the Hotel.

Agua Caliente-La Paz

4 km to the west of the town of Agua Caliente, between the towns of Miraflores and Santiago, in municipal La Paz, there is a hot water spring (50ºC) with water bubbling up over the granite rocks.

Los Cabos

At the southern extreme of the Peninsula of Baja California, is one of the major tourist zones in Mexico, where an impressive development of hotels and the service infrastructure has been built in the last 10 years, increasing drastically the need for water and energy in the area. The operator of the municipal water system has a 200 lt/sec desalination plant fed by beach wells. At the beginning they drilled some wells registering temperatures of 35ºC to 72ºC (Lopez, et al, 2006) including an 84ºC well but they were not able to use that hot water in the reverse osmosis process.

Hot water technological Developments

IMPULSA project has implemented two programs in order to desalinate water. 1) In case of low temperature of geothermal resource (under 140ºC) we can desalinate sea water through a thermal process (LE-MED). 2) In case of hot water resources (>140ºC) it can be use to generate electricity with a PWG system and then that power feed a reverse osmosis plant to desalinate sea water.

LE-MED (Low Energy-Multi Effect Distillation)

The LE-MED system is an original IMPULSA design that comes from the technological mixture of a MED and a MSF thermal desalination plants. The operation basics of traditional MSF and MED plants started preheating sea water to its boiling point using steam usually extracted from a thermal power generator, then the preheated sea water is evaporated and the steam free of salts is condensate as fresh water. The remaining water leaves the plant as concentrated brine. The new IMPULSA LE-MED does not use steam in the process at all, instead geothermal hot water is use as an energy source to run the system. The main idea with this LE-MED system is to avoid the use of fossil fuels sources in the scheme of the desalination process. These would reduce significantly the desalinated cubic meter cost.

We consider this is one of the most relevant themes in the IMPULSA project. It is a rare case in the world that allows a big savings in energy yielding desalination into a sustainable concept. The price of desalinated cubic meter by this process taking advantage from the geothermal natural heat will depend strongly on the materials required and additional sources of energy for pumping and vacuum.

For the design of the LE-MED IMPULSA plant, several computer programs have been developed in order to assess mass and thermodynamics balance, heat exchange areas, pumping and vacuum power. At this stage IMPULSA project is studying various ways for future incorporation of the problems related with scaling. Later on it will comes the construction of a laboratory prototype to test the whole system.

The principle benefit of this proposal is to avoid the use of steam in the thermal desalination process and in its place, use renewable resources (hot geothermal water) abundant in the Baja California Peninsula. Thereby not using fuel to generate steam for desalination could save up to 30 to 40% of the desalinated cubic meter cost; this corresponds to the cost of the fuel to produce steam by traditional desalination methods (Figure 2).

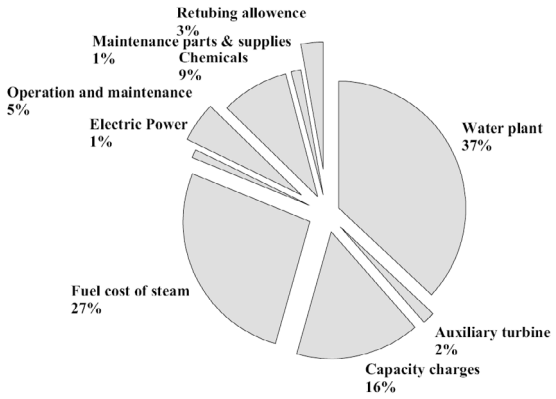

Figure 2 Integrated Cost of a Thermal Desalination Plant. (Semiat, 2000).

The continuous economic results of the project estimate that it can lower the cost up to 30% of cubic meter desalted with thermal technologies through the use of hot seawater as a source of energy for desalination.

Geothermal electricity generation, PWG. (Pressure Water Generation).

The following project proposes the use of the hot geothermal water located in abundance in the

Baja California Peninsula, as part of distributed generation for small plants that in many cases won't be connected to the grid. Under this plan the IMPULSA project of UNAM has developed exploratory surveys to locate, characterize and estimate the potential of hot sources in the Peninsula. The main idea of this project is to generate electricity with the PWG plant, the proposal is the generation of electrical energy by heat transference from a geothermal source into a working compressed liquid (water).

The binary geothermal generation technology that is installed in many parts of the world with organic fluids which are basically preheated and evaporated through heat exchangers (shell and tube system) is already well known. The main difference of the proposal with respect to a traditional binary cycle is the elimination of the heat exchange evaporator, proposing a flash system so that the fluid vaporization is done by the pressure lowering, thereby in order to pre heat the working fluid its is possible to use a heat plate exchanger that is easier to maintain and operate. Also the turbine proposed for the PWG is a high speed turbine with a reduced diameter but higher revolutions. This proposal meets these objectives, having the main goal of generating electricity in a more efficient, sustainable and economically competitive way.

The IMPULSA group has developed a new thermodynamic cycle for the efficient use of geothermal low enthalpy resources. On this design the secondary fluid is water at high pressure and a temperature. Fist the working pressurized fluid is pre heated in the heat plate exchanger, then it is flashed into a separation tank, the steam runs the high speed turbine. Finally the exhausted steam from the turbine is condensate and mixed with the hot water that did not flash in the tank, the mixture is pressurized and the cycle starts again.

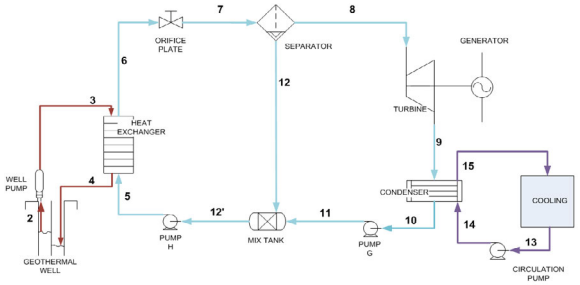

Figure 3 PWG cycle design, (IMPULSA).

The conventional systems of binary generation use great chambers of heat exchange to preheat the working liquids, which are generally organic fluids such as isopentane and isobutane and other heat exchangers to vaporize the fluid and activate the turbine, constants stops, are required for service and maintenance of the shell and tube heat exchangers.

The proposal consists of the installation of plate type heat exchanger that will improve the heat transfer, takes less space and are easy maintenance. The proposed cycle will be water-to-water (pressurized) generating steam by a pressure decrease. The IMPULSA turbine design will be small diameter (10 to 20 cm diameter) and high velocity (30,000 rpm) integrating the most advance turbine design.

The PWG system could generate energy at prices of 5 to 9 Aus ¢/kWh (4 to 6 US ¢) strongly depending of the installation equipment's cost, well drilling and operation and maintenance costs.

Case Study, La Joya, BC.

As a demonstration project, IMPULSA is planning to install two small scale prototype plants in La Joya, a recreational camp, south of the city of Ensenada, BC in order to take advantage of the geothermal resources (98ºC) that has been identified on this beach. Drilling a geothermal shallow (150 m) well near the coast it would produce enough thermal output (140ºC) to run a small power generator, then by use this electricity install and operated a reverse osmosis plant to desalinate sea water. Main target of this project is to assess geothermal reservoir's response at La Joya and at the same time, test and evaluate global performance of both plants for a period of on year. General features of this project are:

Power Generator (PWG)

A 7 kW binary plant will be installed at La Joya Camp, using a geothermal hot water from a well drilled at this resources to produce electricity by this way, a levelized power cost of 8 Aus ¢/kWh has been estimated, which even it is not cheap is lower than electricity tariff on that region 25¢ Aus/kWh (20 US¢/kWh).

Thermal Desalination (LE-MED)

In order to use the power produced on site, a 20 m^3/day desalination plant (LE-MED) is going to be installed at La Joya Camp.

Prototype LE-MED desalination plant has been designed and constructed by IMPULSA group and will be tested and gain some practical experience on scaling, heat rate, heat performance, etc.

Final Remarks

Intensive use of the cost line geothermal resources in Baja California is one of the big challenges for IMPULSA group in Mexico, helping to solve the power and fresh water scarcity on this region of the county. Since it is located in a very arid zone but with abundant natural resources like solar, wind and geothermic as well.

At the same time, an enthusiastic and promising engineering group has been consolidated at the National University; UNAM committed with the use of renewal energies meanwhile several research project of IMPULSA allow post graduated students to finish their Engineering degrees.

Desalination of sea water by using renewable energy is the main goal of the IMPULSA team that through scientific and technological research, the group is promoting the use of clean and environmental friendly energy sources, like the PWG and LE-MED prototype developments.

References

Alcocer, S. M. and Hiriart L. G. (2008). An Applied Research Program on Water Desalination with Renewable Energies. American Journal of Environmental Sciences. 4 (3): 190-197. 2008.

Alvarez, R. J. (1993). Reconocimiento geotérmico en el área de Ensenada, B.C. Comisión Federal de Electricidad. Residencia General de Cerro Prieto. Internal Report.

Arango-Galván, C., Flores-Márquez, E.L., Prol-Ledesma, R.M., (2007). “Geoelectrical image of Punta Banda (Baja California) using CSAMT and ERT data”. Proceedings 13th European Meeting of Environmental and Engineering Geophysics of the Near Surface Geoscience Division of EAGE (Istanbul, Turkey). 5 pp.

Lira, H. H. (1985). Reconocimiento y evaluación de focos termales en el estado de Baja California Sur. Comisión Federal de Electricidad. Gerencia de Proyectos Geotermoeléctricos. Depto. De Exploración. Internal Report.

López, S. A., Báncora A. C., Prol Ledesma R.M., Hiriart L.G. (2006). A new geothermal resource in Los Cabos, Baja California Sur, México. Proceedings 28th New Zealand Geothermal Workshop. 2006.

Semiat,R. (2000) “Desalination: Present and future”. IWRA, Water International, Volume 25, Number 1, March 2000.

Torrez, R. V. (2000). Geothermal Chart of México. Proceedings World Geothermal Congress 2000. Kyushu-tohoku, Japan.