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# Using Low Enthalpy Geothermal Resources to Desalinate Sea Water and Electricity Production on Desert Areas in Mexico

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## ABSTRACT

It is well known that Mexico has extensive geothermal resources throughout the country, some of them dedicated to power generation since Mexico has more than 950 MW of geothermal capacity installed. However, at east Pacific Rise along the Baja Peninsula several geothermal resources are located where a continuous heat flow and hot water discharge occurs right at the seashore. Most of these systems are located near important tourist and recreational areas where neither potable-water nor power electricity is available.

Mexico's National University (UNAM) through the IMPULSA Program has been working with local scientists and engineers to use these extensive but not well assessed geothermal resources in order to generate electricity or for desalination using the hot geothermal water. Geological and geophysical studies are being conducted to identify and characterize underground structures governing heat and water movement along with chemical geothermometer behavior.

The aim of this work is to assess the geothermal potential at La Joya, near the City of Ensenada, by using the hot geothermal seawater through new thermal processes, MED (multi effect distillation), MSF (multi stage flash) mixture, and LE-MED (low energy multi effect distillation) in order to use the hot seawater as heat source for desalination with very little energy consumption, thereby avoiding the use of steam, as well as reducing the cost of the fresh water produced and at the same time promoting the use of renewable resources in the country. An innovation introduced with this design is the use of hot seawater to heat not only the first one, but all the chambers in the desalination plant, a unique Mexican design. Prototype desalination plant design has already been achieved and the extensive Lab tests shown very promising results.

The IMPULSA project has also designed a power generation system PWG (Pressurized Water Generator) for low enthalpy geothermal resources like the ones at La Joya. The innovation of this system is the use of a high speed turbine and a pressurized water cycle, to avoid the use of large heat exchanger areas.

## 1. INTRODUCTION

Baja California, on the northwestern coast of Mexico, close to the border with the largest economy in the world, has shown a rapid and continued growth in its industrial and tourism activity, triggering a demand for real state, as thousands of retired Canadians and Americans are moving south searching for ocean view homesites and warmer weather along the Mexican coast. This baby-boomer 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, though, this region with its extreme temperatures, 0ºC in winter up to 45ºC 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 throughout the Baja Peninsula. That is why, three years ago, the National University of Mexico (UNAM) formed a professional-multidisciplinary research group –IMPULSA IV- to promote and implement technological solutions to the desalination of 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 cost of desalination of water comes from steam extracted by 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 to near the boiling point. In the IMPULSA project a combined analysis of a multiple effect distillation plant (MED) and a multi stage flash plant (MSF) was done in order to be able to desalinate sea water using the hot geothermal liquid instead of the traditional steam supply from a thermal plant.

## 2. BAJA CALIFORNIA'S GEOTHERMAL RESOURCES

More than 60 hot spots have been identified along the inland Baja Peninsula, Torres (2000) but a dozen or more sites located along the seashore show mass and heat discharges at almost boiling temperatures. Most of these places are good candidates to install a desalination plant coupled with a thermal desalination system in order to take advantage of the geothermal resources where it is expected to lower the energy consumption of the desalination process. Fig. 1 shows most of the geothermal resources in Baja Peninsula followed by a brief description of these areas.

### 2.1 Northern Zone

#### 2.1.1 Mexicali Valley

There are at least 20 sites in the northern part of the Baja California Peninsula in which geothermic manifestations have been identified. The most well known and largest area are the Cerro Prieto Geothermal Fields, in the Mexicali County, where the state owned power company, Comision Federal de Electricidad (CFE) has drilled more that 300 wells to extract the steam necessary for power generation. In Cerro Prieto Fields 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 there have been at least identified five geothermal sites; all associated with the Pull-apart system between the Imperial and Cerro Prieto faults. However, in none of them has successful temperature been obtained to be able to use them for power generation. For example, the Tulecheck Field, where temperatures of 165ºC have been registered, or in the Airport field at 112ºC or 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 multiple geothermal and geophysical soundings have been made and three deep exploratory wells were drilled. However, the maximum temperature reported in one of them was only 101ºC. To the south of this plain, are reportedly agricultural wells with estimated temperatures up to 230ºC.


**Figure 1: Baja California Geothermal Resources**

2.1.2 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 natural discharges and in the wells of the area, particularly in the Maneadero Valley, Punta Banda, Santo Tomas and San Carlos, all associated with the occurrence of Agua Blanca Fault, one of the regional structures predominately oriented NW 48º.

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 hot springs nearly at boiling temperatures that have been measured on the surface, encouraging studies of these sites in order to start projects of desalination of seawater through the use of thermal energy.

2.1.3 Punta Banda-Maneadero

This area is characterized by the intense hydrothermal activity, submarine as well as on the shore of the coast, intense emanations of steam and hot water in the sea bed have recorded temperatures of 102ºC to 110ºC at a depth of 30 meters, as well as at different 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 here are La Joya, Agua Caliente and La Bufadora.

2.1.4 Ejido Uruapan

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

2.1.5 Santo Tomas-Ajusco

Along the length of the Santo Tomas Valley and Canyon, some thermal springs have been identified during the rainy seasons. There are reports of springs with temperatures of about 47ºC and in one of this thermal norias measured temperatures of 176ºC have been obtained..

2.1.6 San Carlos-Ensenada

To the NE of the Maneadero Valley, in the San Carlos Canyon several hot springs have been reported with temperatures of 47ºC to 50ºC. Even at the City of Ensenada there are springs and norias that have been used for years in the public baths named Acapulco, Lourdes and La Providencia.

In the Gulf of California or Sea of Cortez, 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 extreme desert zone in the north of the peninsula of Baja California has been converted into an important tourist area, where there are several areas along the coast in the upper part of the gulf, the majority of which are aimed at recreation and fishing. The main sites are:

2.1.7 San Felipe-Punta Estrella

In the port of San Felipe, around the Machorro Hill area, there are various manifestations of thermal activity 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 irridescence in the area, for which many residents of the area have solar panels for 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.

2.1.8 Puertecitos-El Coloradito

The geothermic area of Puertecitos is located on the east coast of the 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 the existence of springs in the inhabited areas 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 a spring where 56ºC has been registered.

### 2.2 Central Zone of the Peninsula

2.2.1 Tres Virgenes

This geothermic area is located some 33 miles northeast of Santa Rosalia, Baja California Sur (BCS), in a large 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 several fumaroles and boiling pots are seen, hot springs, mud pots 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, feed by the steam extracted from the deep geothermal wells.

2.2.2 Santispac

20 kilometers to the south of the town of Mulege, 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.

2.2.3 San Nicolas-El Volcan

This is an important thermal area with abundant geothermal features. Hot water wells have been found with 65ºC-70ºC 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 are hot springs on the sand of the beach, unfortunately the sea invading the area makes it difficult to measure actual temperature.

2.2.4 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 sodium-chlorate composed and a temperature between 181ºC and 262ºC has been estimated.

2.2.5 Agua Caliente-Comondu

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 geothermal 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.

### 2.3 Southern Zone of the Peninsula

2.3.1 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) on the property some 200m from the beach. This hot well was abandoned because they were searching for fresh cold water for use at the Hotel.

2.3.2 Agua Caliente-La Paz

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

2.3.3 Los Cabos

At the southern extreme of the Peninsula of Baja California, is one of the major tourist zones in Mexico, where there is 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 a 84ºC well but, they abandoned it because they were not able to use that hot water in the reverse osmosis process.

## 3. HOT WATER TECHNOLOGICAL DEVELOPMENTS

Due to the abundance of geothermal resources along the coast of the Baja California Peninsula, the IMPULSA group has implemented two programs in order to desalinate sea water. 1) In case of low temperature geothermal resources (under 140ºC) it can desalinate sea water through a thermal process (LE-MED). 2) In case of hot water resources (>140ºC) it can be used to generate electricity with a PWG system and that power feed a reverse osmosis plant to desalinate sea water.

### 3.1 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 used as an energy source to run the system. The main idea with this LE-MED system (Fig. 2) is to avoid the use of fossil fuel sources in the scheme of the desalination process. These would significantly reduce the cost per desalinated cubic meter.

We consider this one of the most relevant themes in the IMPULSA project. It is a rare case in today's world that allows a big savings in energy yielding desalination as a sustainable concept. The cost per desalinated cubic meter by this process using 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 the IMPULSA project is studying various ways for future incorporation of the problems related with scaling. Later on will come the construction of a laboratory prototype to test the whole system, Fig 3.

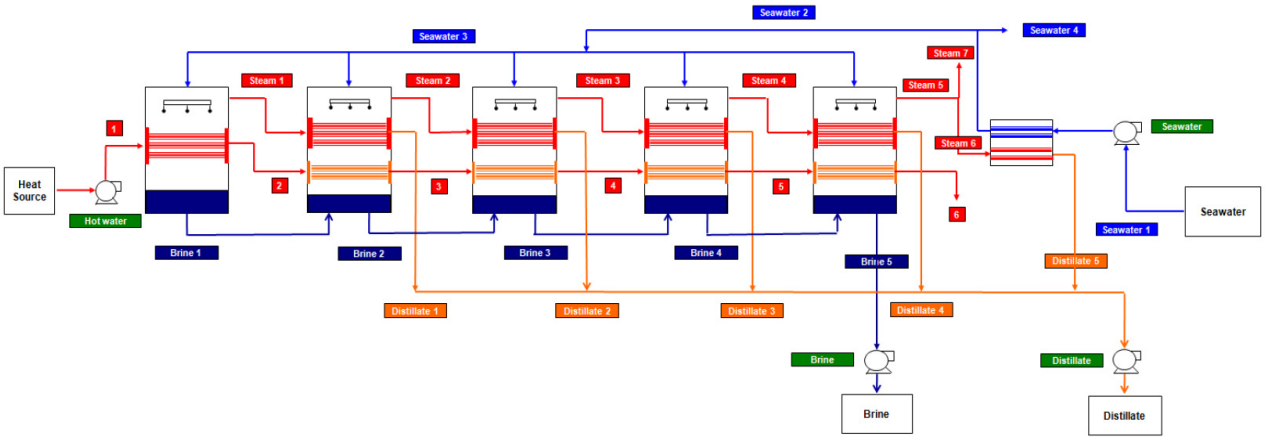


**Figure 1: MED-LE Flow Diagram**

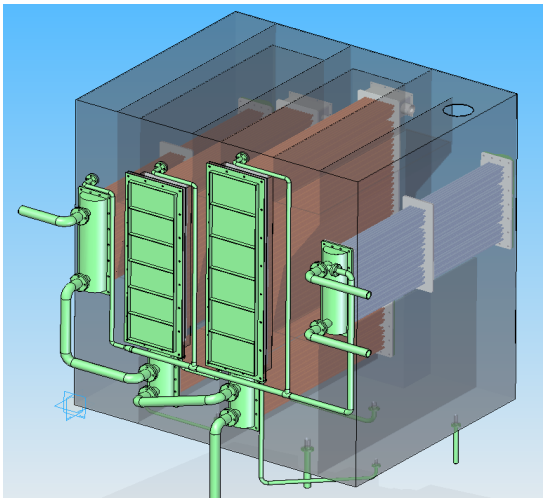

**Figure 2: Basic IMPULSA MED-LE Design**

The main 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, not using the fuel necessary to generate steam for desalination. Saving up to 30 to 40% of the desalinated cubic meter cost has been estimated, corresponding to the cost of the fuel to produce steam by traditional desalination methods (Figure 4).

The continuous economic results of the project estimate that it can lower the cost up to 30% of $m^3$ desalted with thermal technologies through the use of hot seawater as a source of energy for desalination.

### 3.2 Geothermal electricity generation, PWG. (Pressurized Water Generation).

The following project proposes the use of the hot geothermal water located in abundance in the Baja California Peninsula, as part of distribution 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).

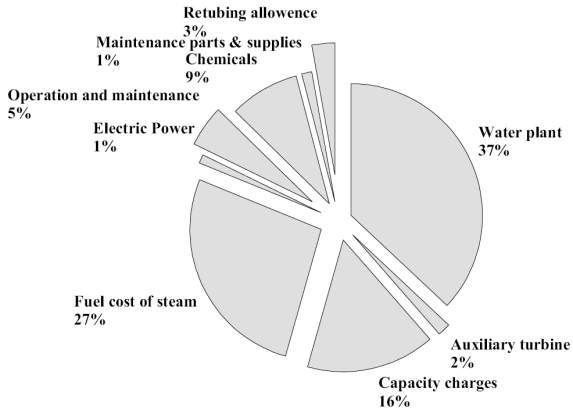


**Figure 3: Integrated cost of a thermal desalination project. Semiat (2000)**

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. In this design the secondary fluid is water at high pressure and temperature. First 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 (Fig. 5).

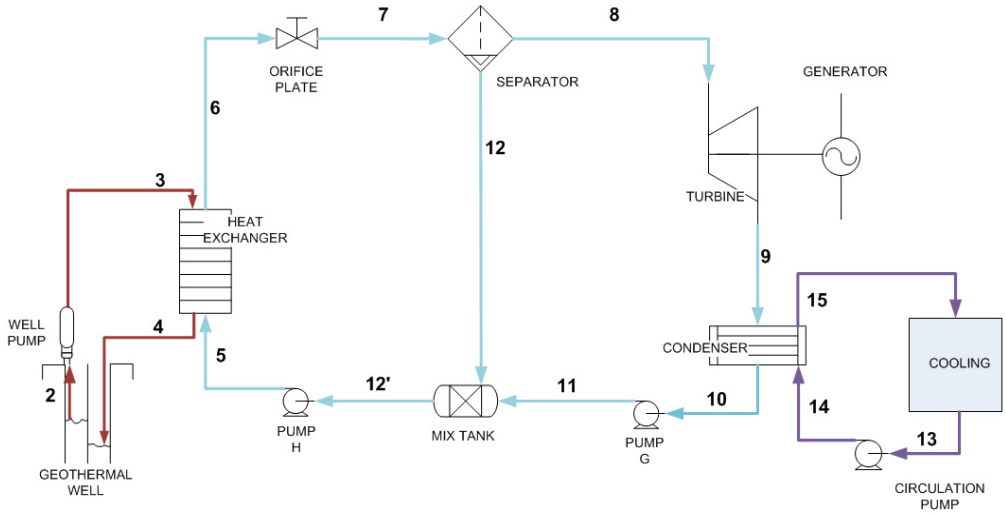


**Figure 4: PWG Flow Diagram**

The conventional systems of binary generation use great chambers for 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, constant stops, are required for service and maintenance of the shell and tube heat exchangers.

The proposal consists of the installation of plate type heat exchangers that will improve the heat transfer, take 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), high velocity (30,000 rpm) integrating the most advanced turbine design.

PWG system could generate energy at costs of 4 to 6 USc/kWh, strongly depending on the installation equipment's cost, well drilling, operation, and maintenance costs.

## 4. LA JOYA, CASE STUDY

The IMPULSA geothermal project "La Joya" is located in northeastern Baja California in Ensenada County, (Fig 1) where exploratory studies have been developed by Mexico's National University (mapping superficial manifestations, geochemistry, geology, geophysics, satellite thermal images) Arango, et al. (2007) as a result of this work, in order to exploit the research site in "La Joya" a hot water beach well site has been selected and programmed to be drilled, the preliminary studies shows that temperatures up to 180°C are feasible in the test site, so we decided to test the two systems described (MED-LE desalination plant and the PWG generator). Also the potential of the zone is described for each system, as follow:

1. For the MED-LE project IMPULSA has just finished the thermodynamic analysis and the basic constructive design (Fig. 3), laboratory design will be prepared for testing in La Joya site. The basic info of the prototype is shown in the next table,

We estimate that the desalination potential of the La Joya zone is up to **1 m3/s** possible to be generated from a renewable source of energy, the preliminary estimated cost per cubic meter is **0.8 US$/m3** and the cost break down is as folow:

| Laboratory model data | Flow rate [kg/s] | Inlet temp. [°C] | Outlet temp. [°C] | Concentration [ppm] |
|---|---|---|---|---|
| Hot Water | 1.4 | 85 | 46 | 4,000 |
| Sea water(Condenser) | 3.6 | 25 | 36 | 35,000 |
| Sea water inlet to chambers | 0.6 | 36 | | 35,000 |
| Brine | 0.38 | | 41 | 56,000 |
| Product | 0.23 | | 41 | 10 |
| Recovery rate | 37% | | | |
| Performance ratio | 1.4 [kg/MJ] | | | |
| Maximum Vacuum Pressure | 0.78 [bar] | | | |
| Auxiliary power consumption | 2 [kW] | | | |

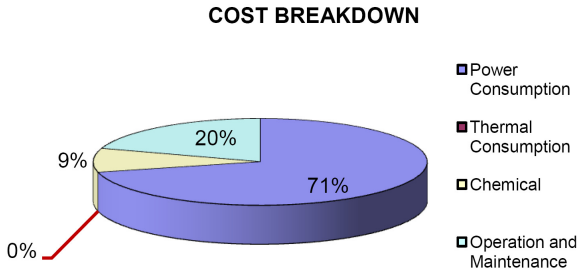


**Figure 5: Cost break down**

2. The estimated electrical generation potential based on the preliminary exploration data analysis shows that it is up to 30 MW distributed in the zone, including La Joya site (1 MW). The PWG laboratory prototype is under construction, and its power capacity will be 14 electrical kW generated by

the experimental La Joya well (1st stage), the basic data from the system is presented in the next table:

| Laboratory model data | Flow rate [kg/s] | Inlet temp [°C] | Outlet temp [°C] |
|---|---|---|---|
| Geothermal Well | 1.4 | 140 | 106 |
| Cycle working fluid | 1 | 96 | 136 |
| Cooling Fluid | 1.5 | 27 | 49 |
| Power Output | **14 kW** | | |

## FINAL REMARKS

Intensive use of the coast line geothermal resources in Baja California is one of the big challenges for IMPULSA in Mexico, helping to solve the power and fresh water scarcity on this region of the country. Since it is located in a very arid zone but with abundant natural resources i.e., 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 to the use of renewable energies while several research projects of IMPULSA allow post graduate students to finish their Engineering degrees.

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

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