Chapter 7: Renewable Resources in Baja California

Summary

In Mexico, the Comisión Federal de Electricidad (CFE) is a government entity created to generate and distribute energy in Mexico. CFE is operating a 720 MW capacity geothermal power plant at Cerro Prieto, located in the valley of Mexicali. In the Gulf of California there are prospects of geo-presurized hydrothermal deposits under the sea at the location known as Wagner Fossa. Wind energy in Baja California is not now being exploited. It is potentially productive in some areas of the Rumorosa mountain range and at the Cañon de San Martin in the Valle de la Trinidad. Wind pattern measurements have been carried out and investors' interest is growing for wind farms of different sizes (1500 MW, 250 MW, 50 MW). Solar radiation in Baja California is quite significant. Solar photovoltaic (PV) electricity is widely used for lighting, communications, and appliances throughout the state of Baja California in rural areas and small towns not connected to an electric grid. Some fishing cooperatives have also installed solar-based and hybrid solar wind systems in isolated fishing camps. To take advantage of the excellent insolation in the Baja California area, CFE studied the technical and economic feasibility of integrating a solar steam system into a conventional gas-fired combined cycle generation plant to be constructed at the site of the proposed liquified NG terminal near Costa Azul, 30 km from Ensenada. Micro-hydroelectric power plants may be built at the irrigation district in Mexicali (5MW) and at the Rio Colorado-Tijuana Aqueduct (60 MW), which currently supplies water to the Carrizo dam near Tecate. There is a potential tidal energy project, known as a "proyecto Maremotriz Montagne", that is planned for the Gulf of California. It has a planned capacity of 800 MW. While significant technical potential for renewable energy exists in Baja California, additional study is required to fully characterize the resources and refine estimates. Additional details of the energy situation in Baja California can be found in Appendix G.

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7.1 Technical Potential

The Secretariat of Energy (SENER, 1999) encouraged the National Energy Savings Commission (CONAE) to promote the development of renewable energies in Mexico to reduce its dependence on hydrocarbon fuels. In 1966 CONAE, along with the National Association for Solar Energy (ANES), organized a forum to discuss the potential steps to promote renewable energy sources. The result was the creation of the Advisory Council for the Promotion of Renewable Energies (COFER). This group is made up of representatives from industry, commerce, academia, government, and development banks. The aim of COFER is to promote the use of renewable sources of energy in Mexico within a market framework. It also serves as an advisory group to identify projects and for the design and development of programs and policy related to renewable energy, including small hydro, solar, biomass, and geothermal. SENER (1998) estimates that by 2008 close to 559 MW will be installed in such systems, producing approximately 1,836 GWh/y.

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7.2 Legal Framework

Each renewable energy source requires an adequate legal and regulatory environment that favors its development. Mexico's existing legal framework allows power generation projects using renewable energy under self-supply, small production, independent construction, and export schemes. The Public Service for Electric Energy law does not constrain power generation to a specific technology. Even though environmental costs are not expressly considered when pricing the Mexican electric market, there are a few legal provisions that promote the use of renewable energy.

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7.3 Renewable Emission Reduction Projects

Renewable resources can reduce pollutant air emissions. Because of this, renewable resources have played an important part in the negotiation of international agreements, many of which have included the active participation of the Mexican government.

The Mexican government ratified the Kyoto Protocol in the Daily Federal Gazette (DOF) on November 24, 2000. The Mexican Interministerial Committee was established to comply with the commitments of the Kyoto Protocol.

As a result of the general concern for environmental damage produced by the emission of pollutant gases, the international community decided to execute the Kyoto Protocol to the United Nations Framework Convention on Climate Change (Kyoto Protocol). The Kyoto Protocol includes several mechanisms to enhance the exchange of emission-reduction units (ERUs). The Clean Development Mechanism, as described in Article 12 of the Kyoto Protocol, allows developed countries (mostly the European Union, Canada, and Australia) to certify the reduction of greenhouse emissions in Exhibit II counties (such as Mexico) as a result of the implementation, development, and operation of renewable energy. The Mexican government ratified the Kyoto Protocol in the Daily Federal Gazette (DOF) on November 24, 2000. On January 24, 2004, an accord creating the Mexican Interministerial Committee for Emission-Reduction Projects and Greenhouse Capture was published in DOF. This committee was established to comply with the commitments of the Kyoto Protocol.

7.4 Geothermal Technical Potential

The Federal Electricity Commission (CFE) is a federal government entity created to generate and distribute electric energy in Mexico (Constitucion Politica de los Estados Unidos Mexicanos, 1988). In 1982 CFE created the Geothermal Electrical Projects division whose specific function is to coordinate all geothermal-related activities in Mexico. CFE was responsible for Mexico becoming the third largest geothermal producer worldwide (959.5 MW), behind the U.S. (2,228 MW) and the Philippines (1,909 MW). The following is a brief summary of geothermal activity in the valley of Mexicali, currently under development by the Mexican government for the production of electricity.

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Cerro Prieto (Baja California) is the most important site being developed by the Mexican government. It is located in the Mexicali Valley (115.16 longitude west, 32.25 latitude north) between the Pacific and American tectonic plates and near the San Andreas fault. The plain is a delta, and the geological area is composed of unconsolidated clays, sand, and gravel that rest on sedimentary rocks of sandstone, lutites, and limonites.

Some of the wells in the field were drilled at the end of the 1960s. However, it wasn't until April 1973 that two 37.5 MW units began operating. Currently the site has a capacity of 720 MW distributed over four plants, Cerro Prieto I-IV (180, 220, 220, and 100 MW respectively). The first section has four generators, each of 37.5 MW capacity, which operate on a single-flash system and one 30 MW unit, which operates on medium and low pressure steam (dual-flash) obtained from residual water from the single-flash unit. Cerro Prieto II and III have four turbo-generators, each of 110 MW capacity and each operating on medium and high pressure steam (dual-flash). Cerro Prieto IV is a 100 MW plant with four turbo-generators, each of 25 MW capacity operating on high pressure steam (single-flash). From a total of 268 wells drilled at Cerro Prieto, 126 were under production as of 1999. Well depths vary from 600m to 3,500m. Out of these, 31 were operated by Latina S.A., a private company, which provided 30 percent of the steam utilized. This company financed the drilling of 12 of the 42 wells drilled during the period between 1995 and 1999. According to Alonso (1988), the Cerro Prieto geothermal reservoir has an estimated capacity of 1,200 MW and a proven capacity of 840 MW. Since 720 MW of the 840 MW of proven capacity have been developed, the technical potential for new capacity is 120 MW.

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Outside of the valley of Mexicali, the prospect of geo-pressurized hydrothermal deposits under the Gulf of California shows significant potential for additional geothermal electric generation for the Baja California region. Geo-pressurized evaluations have been performed (Grijalva, 1986) in the northwest area of the Sea of Cortez at the location known as Wagner Fossa. The tests show an energy potential 1000 times richer than that estimated at Cerro Prieto. If fully exploited, these resources of energy could supply Mexico with 20 times its current total energy consumption. This prediction is based on the amount of helium isotope measured in pressurized water at 600°C or higher.

7.5 Energy Sources in Mexico

To date, geothermal energy, along with other alternative sources such as solar, wind, marine, and biomass, have contributed marginally to the energy balance in Mexico. This can be observed in Table 7.1, which shows the national energy balance for 2001 (Secretariat of Energy, 2004). At the state level, the production of electricity from geothermal resources represents 65 percent of the total energy produced in Baja California (CFE, 1999), equivalent to 9.6 million barrels of oil in a conventional power plant. This figure increased to 76 percent with the expansion of the Cerro Prieto power plant in 2000, made possible through a private construction, lease and transfer contract.

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Table 7.1: Energy Balance in Mexico (2001)[1]

Energy Source	Production (petajoules)	% total
Coal	239.1	2.4
Hydrocarbons	8,700.9	89.4
Crude Oil	6,811.7	70.0
Condensate	137.7	1.4
Non-associated gas	430.2	4.4
Associated gas	1,321.3	13.6
Electricity	445.7	4.6
Nuclear	96.7	1.0
Hydro-electric	291.8	3.0
Geothermal	57.1	0.6
Wind	0.1	n.s.*
Biomass	348.8	3.6
Sugar cane bagasse	93.0	1.0
Fire-wood	255.8	2.6
Total	9,734.5	100.00

*Not significant
Source: Sener, 2004[2]

[1] Sener www.sener.gob.mx, 20 May 2004.
[2] Sener www.sener.gob.mx 20 May 2004.

7.6 Wind Energy

The search for resources to diminish the high cost of electricity as well as to promote a road towards sustainable development, protection of the environment, and use of natural resources has led the Secretariat of Infrastructure and Urban Development of the State of Baja California to analyze the feasibility of promoting the production of electricity using wind energy.

This effort has been carried out based on the 2003 study by the Center for Higher Education and Research of Ensenada (CICESE) titled, "Wind Energy in Potentially Productive Areas in Baja California." This study was based on available data for the Rumorosa mountain range in relation to meteorology, climatology, geography, and topography. The information was provided by the National Water Commission (CNA), the National Institute for Statistics, Geography, and Informatics (INEGI), CICESE, and the State of Baja California.

The objective of the study was to determine the following: wind patterns for a one year period, possible locations for the establishment of wind farms, recommendations for the construction of sustainable and profitable wind farms.

The evaluation criteria to determine the potential production areas included the following:
* Average annual wind magnitude (minimum of 5.5 to 6 m/s)
* Proximity of energy transmission lines
* Proximity of centers of energy consumption

Daily wind registries (velocity and direction) were obtained from seven meteorological stations within the study area. Monthly and annual averages were projected after processing the data. The result was that high intensity winds are produced during the day, coinciding with the time of greater demand of electricity in urban areas. Table 7.3 shows a list of the potential areas where this resource can be developed. The study area is shown if Figure 7.1.

Table 7.2: Wind Energy Locations in Baja California

Station	Ave.Wind Speed (knots)	Ave. Wind Speed (M/s)	Standard Deviation	Energy (watts/m2)
Pino Suárez	20.2	10.9	4.5	1299.6
Jacumé	15.5	8.3	3.7	581.6
La Rumorosa	14.9	8.0	4.0	516.4
El Hongo	12.0	6.5	2.6	274.0
El Pinal	11.7	6.3	2.9	254.7
La Puerta	11.5	6.2	2.5	238.2
El Centinela	17.2	9.3	4.9	793.7

Figure 7.1: The Wind Study Area in Baja California

To determine the location of a wind farm, one must measure the daily and seasonal wind velocity at various locations. Wind velocity is also affected by the terrain and elevation. For this reason, it is important to install one or several automatic meteorological stations that collect data such as humidity, solar radiation, and other climatic elements that could be relevant to each site.

Mexican specialists have concluded:

- Baja California has the potential to produce electric energy using wind power.
- Jacume and Pino Suarez are the areas with the highest potential for energy production.
- Specific studies for these areas must be carried out.
- The Baja California state government is particularly interested in participating in projects such as those that generate energy from wind farms.

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Several wind projects are being proposed in Baja California.
A) Short-term: A pilot project in the area described, with major potential that possesses the following characteristics:

- Four 1,500 kW wind turbines
- Annual production of 15,768 MWh/y
- Plant factor of 0.3
- Two hectares of land
- An approximate investment of U.S. $6 million

B) Medium-term: Development of a wind farm of 50 MW capacity to supply several state government agencies:

- 34 1,500 kW generators
- Annual production of 134,000,000 kWh/y
- Plant factor of 0.3
- 200 hectares of land
- An approximate investment of U.S. $50 million

The government of Baja California is currently promoting these wind projects through two of its offices, the Secretariat of Economic Development (SDE) and the Secretariat of Infrastructure and Urban Development (SIDUE). Applications for financial support have been sent to the Bank of North America (BNA) and the Interamerican Development Bank (IDB). Proposals to develop these projects have been submitted by Lahmeyer International (Germany), International Eolic Generation (Spain), and Zemer Energia S.A. de C.V. (Mexico).

The Baja California 2000 project was proposed by Fuerza Eolica S.A. de C.V. in partnership with Enron Wind Corporation (U.S.), with an estimated cost of U.S. $170 million (Fuerza Eolica, 1999). The project aimed at producing and supplying non-polluting, reliable electric energy with a peak production capacity of 120 MW in the town known as La Rumorosa. This project would allow the five state municipalities of Baja California (Tijuana, Mexicali, Ensenada, Tecate, and Rosarito) a savings equivalent to 15 percent of the electricity costs for public lighting in its first twenty years of operation. The project planned to have an initial capacity of 60 MW, made up of two 30 MW capacity modules and two future modules of the same capacity for a combined capacity of 120 MW. The wind generators would produce in excess of 300 million kWh per year. This project would eliminate the production of 132,000 ton/yr of CO_2, equivalent to the amount of CO_2 absorbed by six million trees. Additionally, more than 420 ton/yr of CO_2 would not be emitted into the atmosphere and 65,000 barrels of oil would be saved.

In 2003, Spanish investors visited Baja California to analyze the feasibility of constructing a 250 MW wind farm at the Cañon de San Martin in the Valle de la Trinidad (Rivero, 2002). This project could potentially generate 4,000 MW with an investment of U.S. $250 million. The benefit would be a 50 percent reduction to current electricity rates. Installation of six monitoring towers to measure meteorological and wind variables was proposed. To date no work has been completed.

There is evidence of significant wind resource potential in the border area that has the potential to contribute to multiple isolated power grids throughout the Baja California. The U.S. Department of Energy's National Renewable Energy Laboratory (NREL) has developed and published wind power maps of Baja California Norte based on limited historical surface data and proprietary modeling techniques. While not eliminating the need for specific site wind surveys, these maps can be used to identify the magnitude of the wind resource and its relative proximity to the transmission grid.

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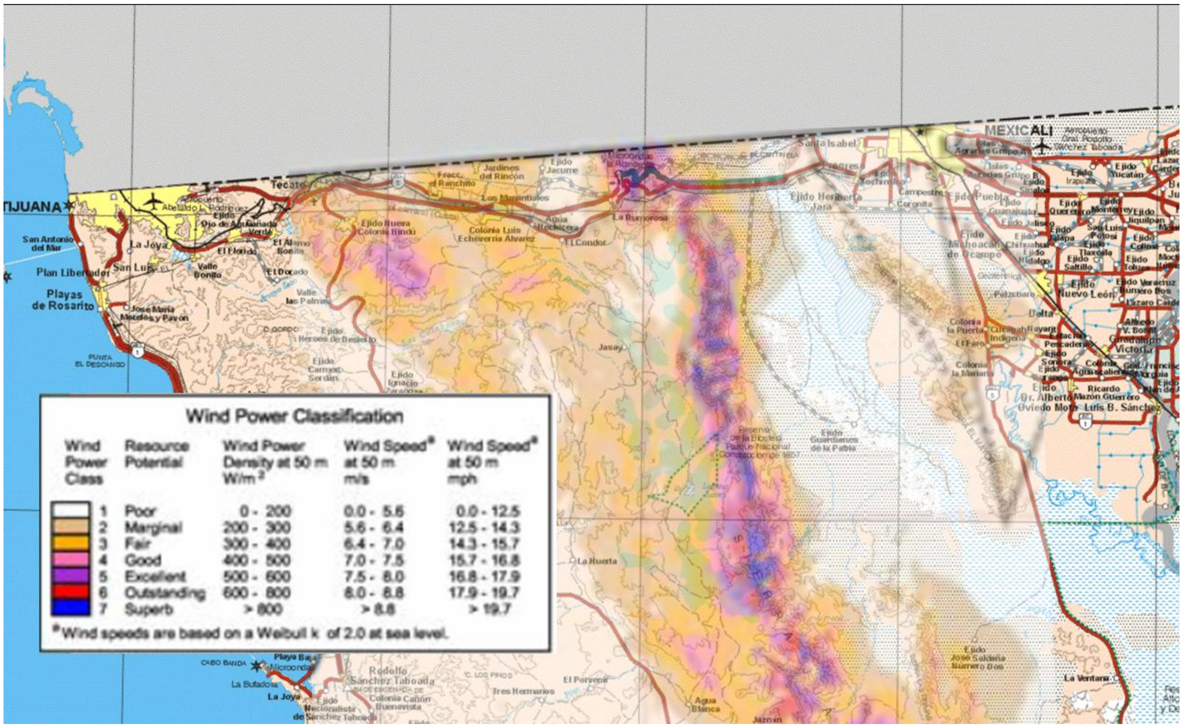
Figure 7.2 shows the wind power densities along the Juarez Mountains and in the area of La Rumorosa, located between Mexicali and Tijuana. The two double circuit 230 kV CFE transmission lines connecting the Rosita to La Herradura substations follow in proximity to the road that traverses the area with the highest wind potential. The proximity of Class 6 and 7 winds along a major transmission corridor suggests a substantial potential to develop wind power in the area. Additional study of the available information is needed.

In addition to the anecdotal evidence of overturned vehicles on the roads traversing Rumorosa, there have been several attempts to carry out surface wind surveys in the area. In the mid-1990s Cableados Industriales, a Mexican company currently affiliated with Gamesa Eolica, erected several anemometric towers in the area. Other past surface wind speed measurement efforts include Kenetech Windpower (U.S. Windpower). Those data are now kept at NRELand heavily referenced for the preparation of the NREL Baja California Norte wind map. Vestas Wind Systems A/S installed several anemometric towers in the La Rumorosa area in 2002-2003.

Figure 7.2: Wind Power Densities at 50 meters – Baja California Norte



Current efforts in the area include an on-going wind survey by Zemer, a small Mexican energy developer that has retained the services of the Instituto de Investigaciones Electricas (IIE) to analyze the data and prepare a wind power project feasibility study. In addition, a 300 MW wind power project for export initially proposed by Fuerza Eolica, a company now affiliated with Clipper Windpower, is in the early stages of development. It is reported that the land use rights agreements for this project have been finalized with the local community land owners.

The rugged topography of the La Rumorosa area, with several canyons and many ravines, dictates extensive and highly site specific wind surveying in order to assess the overall wind power potential. Given the natural secrecy and reluctance of any commercial developer active in the area to share data, further resource assessment of the wind resource will require public funding and coordination with Mexican government agencies.

7.7 Solar Energy

Solar photovoltaic electricity is widely used for lighting, communications, and appliances such as refrigerators throughout the peninsula in rural areas and small towns not connected to an electric grid. Some fishing cooperatives have also installed solar-based and hybrid solar-wind systems in isolated fishing camps. CFE, in collaboration with the Instituto de Investigaciones Electricas (IIE), has collected information on the maintenance requirements and long-term availability of PV systems. In the long term, the CFE-IIE collaboration may be expanded to develop several hundred MW of solar electricity nationwide within the context of a distributed generation project. A shorter term project will include the development of a grid-connected 1-MW photovoltaic array at a Mexicali substation.

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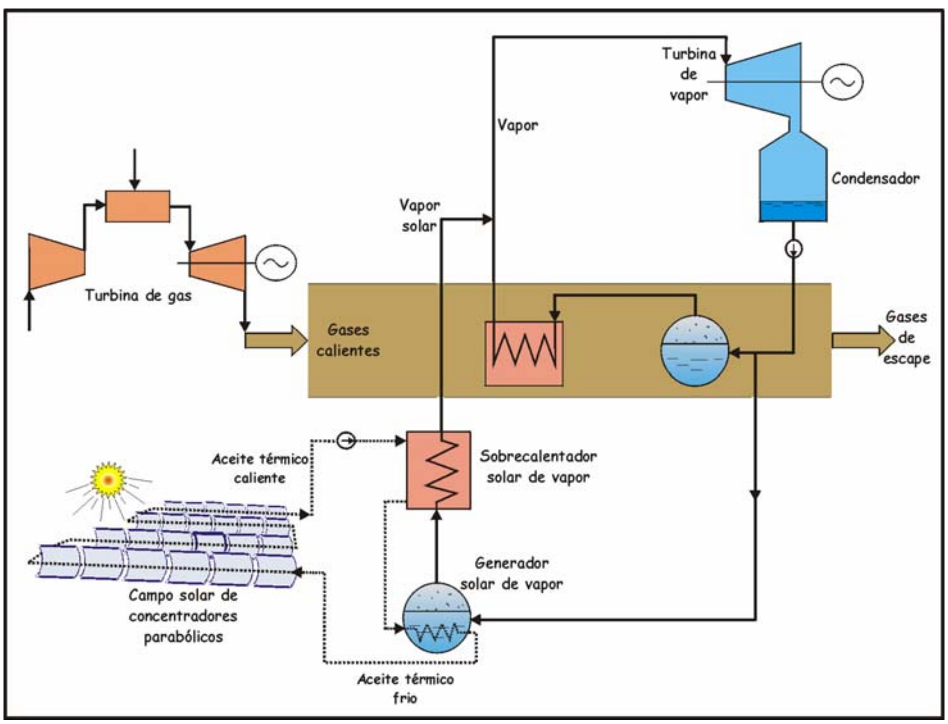
To take advantage of the excellent insolation in the Mexicali area, CFE studied the technical and economic feasibility of integrating a solar steam system to a conventional gas-fired combined cycle generating plant. A field of parabolic trough solar thermal collectors would be used to produce the steam as shown in Figure 7.3. The concept, known as the Integrated Solar Combined Cycle System (ISCCS), was incorporated into the tender requirements issued by CFE on March 14, 2002, for the Mexicali II plant to be located near San Luis Colorado at the eastern side of the Mexicali Valley. The total output of the ISCCS plant was to generate between 198 MW and 242 MW at summer design conditions. The uniquely specialized expertise to design the solar component of the plant elicited complaints from the prospective bidders until CFE agreed to separate the bidding for the traditional and solar components. The tender for Mexicali II was subsequently postponed to be re-issued minus the solar component and relocated to the vicinity of Tijuana in an effort to reduce the east-west congestion on the Mexicali-Tijuana transmission corridor.

A new ISCCS plant with a 25 MW solar component is now contemplated at the Rosarito III generating plant. It is scheduled to enter service in April of 2011.

Figure 7.3: Schematic of Proposed ISCCC Plant

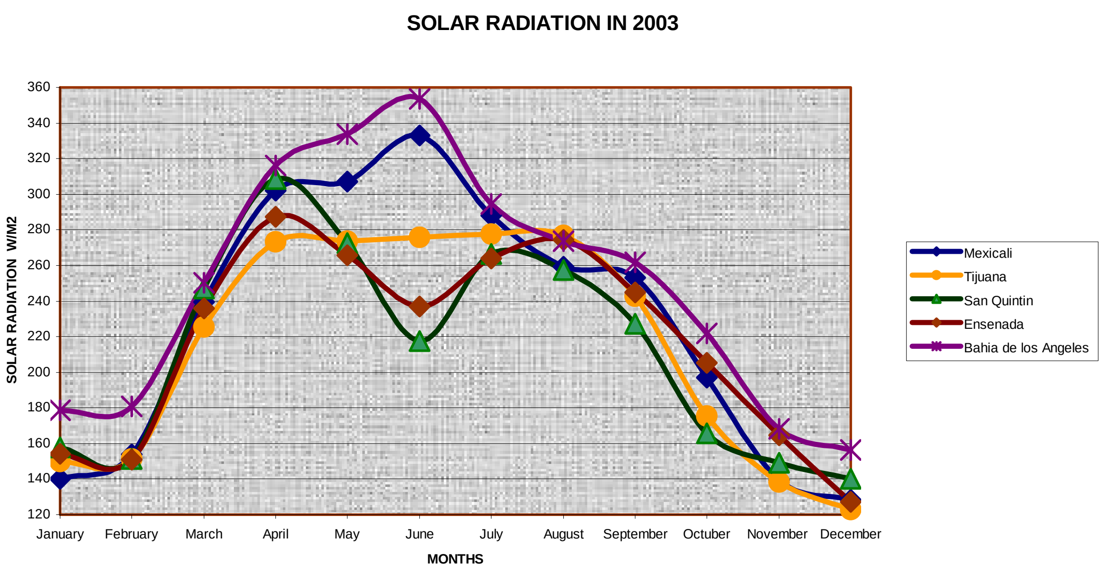


The National Meteorological Service of Mexico (SMN) has a net of monitoring stations measuring and recording solar irradiance. Data is averaged over 10 minute intervals. Six stations in Baja California have been operational since 2000:

- Emilio Lopez Zamora dam (Ensenada)
- Abelardo L. Rodríguez dam (Tijuana)
- Mexicali
- San Quintín
- Bahia de los Angeles
- Gustavo Diaz Ordaz

The data in Figure 7.4 was collected from all stations except the Gustavo Diaz Ordaz station.[3] The Bahia de los Angeles site shows the highest solar radiation in the region, followed by Mexicali. Data analysis from 2000 through 2002 also demonstrates that the tendency is similar for each of these years.

Figure 7.4: Solar radiation from several monitoring stations located in Baja California for 2003



7.8 Hydroelectric Resources

The desert climate conditions prevailing throughout most of Baja California have precluded the development of any significant hydroelectric power. A notable exception, impossible to confirm at the time of this writing, is a 60 MW hydroelectric recovery unit proposed near Tecate to take advantage of water flows in the Rio Colorado-Tijuana aqueduct.

[3] SMN, 2003. Base de datos sobre radiación solar del 2003. Sistema Meteorológico Nacional. México.

7.8.1 Tecate's 1994 Hydroelectric Project

This project proposed the construction of a hydroelectric power station with an installed capacity of up to 60 MW produced by two hydraulic turbines and generators. A switchyard and transmission lines were to be built to carry the power to CFE's 69 KV transmission line near Tecate.

The plant would utilize water delivered from the Rio Colorado-Tijuana aqueduct, which currently supplies water to the Carrizo dam for treatment at the El Florido water treatment plant. The aqueduct supplies about 90 percent of Tijuana's water. This water would be transported to a tank at an elevation 580 m above El Carrizo dam. The aqueduct currently delivers an average of 2 m^3/sec based on the current water consumption level for Tijuana. Based on future water consumption projections, a maximum flow of 3.65 m^3/sec could be expected from the aqueduct. Development of this project was not pursued for unknown reasons.

7.8.2 Micro-hydroelectrics in the Valley of Mexicali

Ten years ago, national studies were carried out[4] to explore the possibility of installing micro-hydroelectric plants in Mexico. In this analysis, the valley of Mexicali was assigned a 10 MW technical potential utilizing the irrigation canal system in Mexicali.

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A later study[5] was conducted to evaluate the supply of electricity to the Autonomous University of Baja California's (UABC) academic and administrative buildings located in the city of Mexicali using micro-hydroelectric units installed in selected locations on the valley's water canals. The study showed that once established the system could provide the 5 MW demand required by UABC.

The two projects have a technical potential of 15 MW.

[4] A.M. Martinez, *Estudio nacional sobre la potencial explotación de microhidroelectricas en Mexico*, 1984, and personal interview with Dr. Mulas,. IIE, Cuernavaca, Morelos, 1994.
[5] N.M.Quintero y R.M. López, Microhydroelectric plants in the valley of Mexicali in Energy and Environment in the California-Baja California Border Region, Edited by A. Sweedler, Paul Ganster, and P.Bennett, IRSC, SDSU, 1995, pp 129-132.

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