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THESIS TO OBTAIN THE DEGREE OF
MASTER IN ENVIRONMENTAL SCIENCE

Evaluation of a solar energy application as a water supply solution for households in the city of San Luis Potosí

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ENREM MASTER PROGRAM

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Abstract:

The following work analyzes the potential for solar photovoltaic technologies in the Mexican city of San Luis Potosí. The actual natural resources, legal framework and natural resources potential are linked to a common need of the city which is deficient water supply. This deficiency not only brings energy need but also health issues that need to be addressed. Recommendations of how the policy makers can support the introduction on solar PV technologies are given in the final discussion.

Dedication

This thesis is dedicated to my parents Lobelia and Jorge Luis who have always been there for me and try to take care of me despite the distance. To my godparents Claudia and Gilberto who supported me at all times. To my family: my grandmother Carmelita, my brother Gerardo, my sisters Diana Lobelia and Marian and my cousins that gave me their attention and encouragement. To the members of my family that are already gone. To my best friends, who helped and encouraged me to go on. To my girlfriend Claudia Marcela, who supported me and was always by my side while completing this project.

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Lastly, I offer my regards to all of those who supported me in any respect during the completion of the project.

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Introduction

1 Overview of the problematic

San Luis Potosí is a city in Mexico and the Capital City of the State of the same name. It is located at 22° 09´ 04” latitude North and 100° 58´ 34” longitude west, 363 km. north-northeast of Mexico City and at a mean altitude of 1860 meters above sea level. The weather of the region is dry (semi-arid conditions). The metropolitan area includes the city, three delegations: La Pila, Villa de Pozos and Bocas, and the municipalities of Soledad de Graciano Sánchez, Cerro de San Pedro, Zaragoza, Mexquitic and Villa de Arriaga.

Because of climatic and geologic conditions, the city has always suffered water scarcity. Precipitation is about 386 mm/year reaching 450 mm/year on the higher areas. In conjunction with this is the geologic nature of the ground, which consists of materials with a very low porosity. This causes the area to have a low natural recharge. Furthermore, the population has grown intensively during the last five decades, causing the city to expand and consequentially contributing to lower the recharge capacity of the subterranean aquifer, because of the large portions of sealed ground.

The estimated population of the city and metropolitan area according to the last census made by the INEGI (acronym in Spanish for the National Institute of Statistics and Geography) in 2010 was 1’185,716 inhabitants (1’040,443 inhabitants for the San Luis- Soledad Area):

Table 1: Population of the San Luis Potosí city and its metropolitan area. INEGI 2011.

Municipality	Inhabitants	%
San Luis Potosí	772,604	65.2%
Soledad de Graciano Sánchez	267,839	22.6%
Villa de Reyes	46,898	4.0%
Villa de Arriaga	16,316	1.4%
Zaragoza	24,596	2.1%
Mexquitic de Carmona	53,442	4.5%
Cerro de San Pedro	4,021	0.3%
Total	1,185,716	100.0%

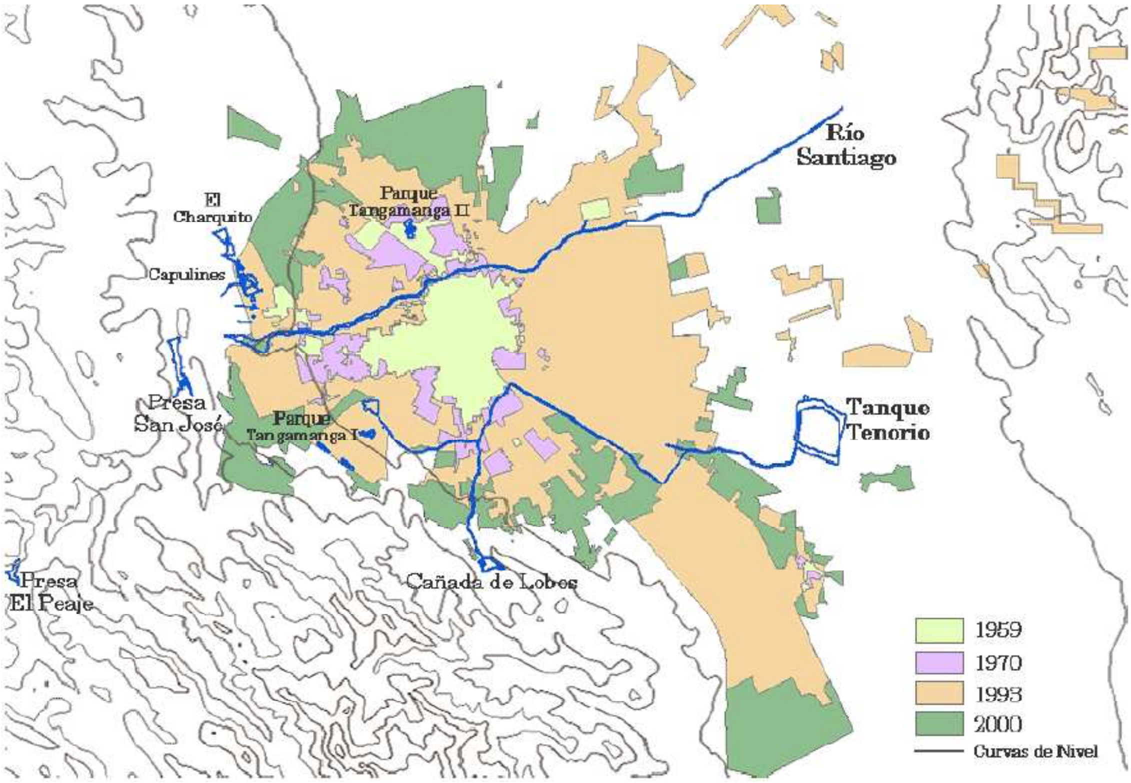


Fig. 1: Growth of San Luis Potosí City. COLSAN 2003

The city has experienced the mentioned growth always dealing with insufficient capacity to deliver water to households.

Water Supply Problematic:
In terms of supply (Contreras, Galindo 2008), 92% of the water used for the development of the city of San Luis Potosí comes from subterranean sources while the remaining 8% comes from superficial ones. The shallow aquifers, from which the city used to mainly obtain water, present nowadays contamination due to infiltration of wastewater. The exploitation of groundwater is done mainly at depths between 180 and 350 meters, but the lowering of groundwater levels has led to the need of deeper perforations in some areas of the city, reaching from 700 and up to 1000 meters. Three problems can then be identified:

- Continuous increase in the costs and energy requirements for groundwater extraction.
- The quality of the water in the network.
- Insufficient quantity of water to satisfy all the needs of the city.

The San Luis Potosí Aquifer can be characterized as an urban aquifer for the following reasons (COLSAN, 2003):

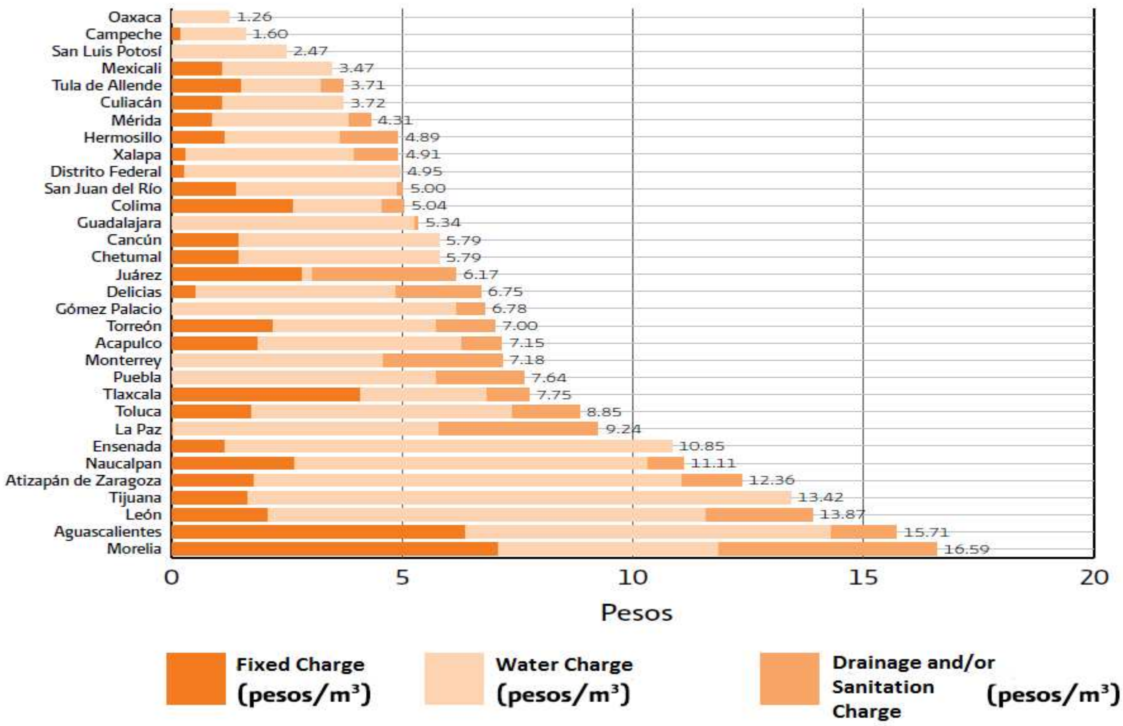
1. Most of the extracted volume is destined for domestic consumption, operation of the municipal network, industrial, commercial and service sector use.
2. An important area of the aquifer is located is located exactly below the urban sprawl, so that its conditions are directly affected by the urban growth and dynamics: recharge areas may or have been already affected, there are risks of contamination and the extraction and monitoring infrastructure are some examples.
3. The uses and priorities given to the resource mark the kind of exploitation given to it.

It can be said that the aquifer is over exploited, not only because of the population growth, but also because of the inadequate economic growth planning. In the last decades, the city has experienced significant growth in both population and economy due to its strategic position, being equally close to the cities of Guadalajara, Monterrey and Mexico which are the biggest in the country. Today, the city can be counted among the top ten regarding industrial productivity. Factories that require high amount of water for their processes were allowed to establish in the industrial area and are provided with the resource from wells either controlled by them, the local authority INTERAPAS (Metropolitan Inter-municipal Organism of Water, Sewage and Sanitation) or CONAGUA (National Water Commission).

Water Supply Network Problematic:
According to studies performed by INTERAPAS, 9093 leaks in household areas and 14,000 irregular water takes that caused an estimated loss of 35.0 million m^3/year (41% of total supplied) were found (INTERAPAS 2004). The losses caused by the leaks in the distribution network were attributed to old piping, inadequate construction and/or low quality materials and distribution network deterioration (Contreras, Galindo 2008),.

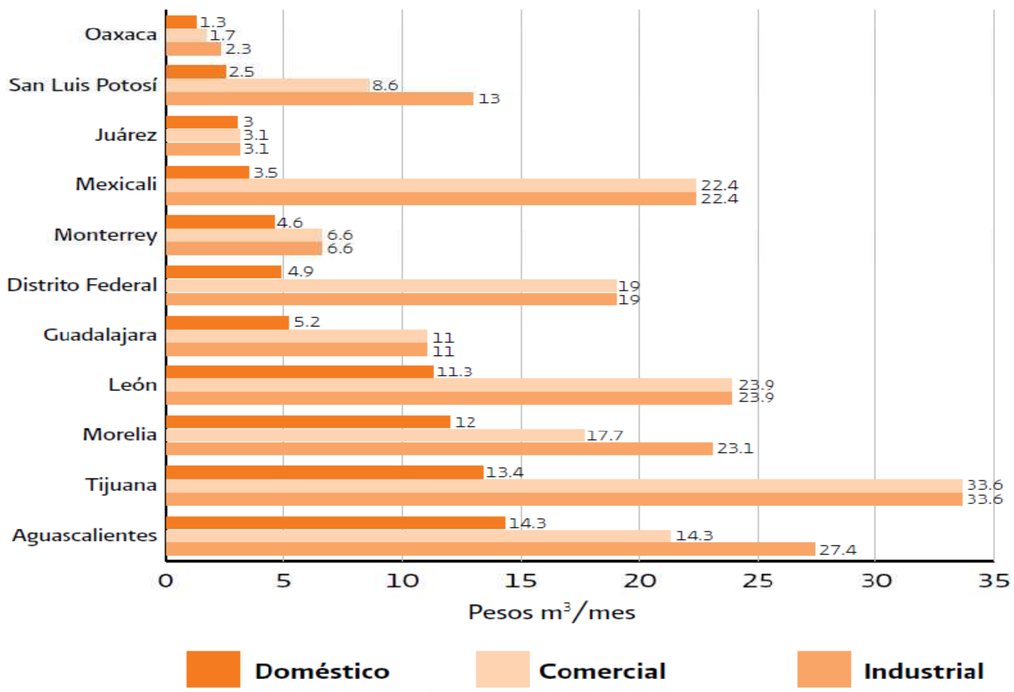
On top of the issues mentioned, not only are water shortages a common reason for interruption in the water services, but also the city lacks enough pumping power to provide the whole city with continuous supply (INTERAPAS 2010). Even though, according to the 2010 edition of “Water Statistics in Mexico” published by CONAGUA, the city of San Luis Potosí seems to have very low tariffs for the use of water, drainage and sanitation in comparison to other cities, as can be seen in the following graphs:

Graph 1: Domestic water, drainage and/or sanitation tariffs in selected cities of Mexico, 2008.



Note: Highest applicable tariff for 30 m^3/month consumption.
Source: CONAGUA. Subdirección General de Agua Potable, Drenaje y Saneamiento. 2010.

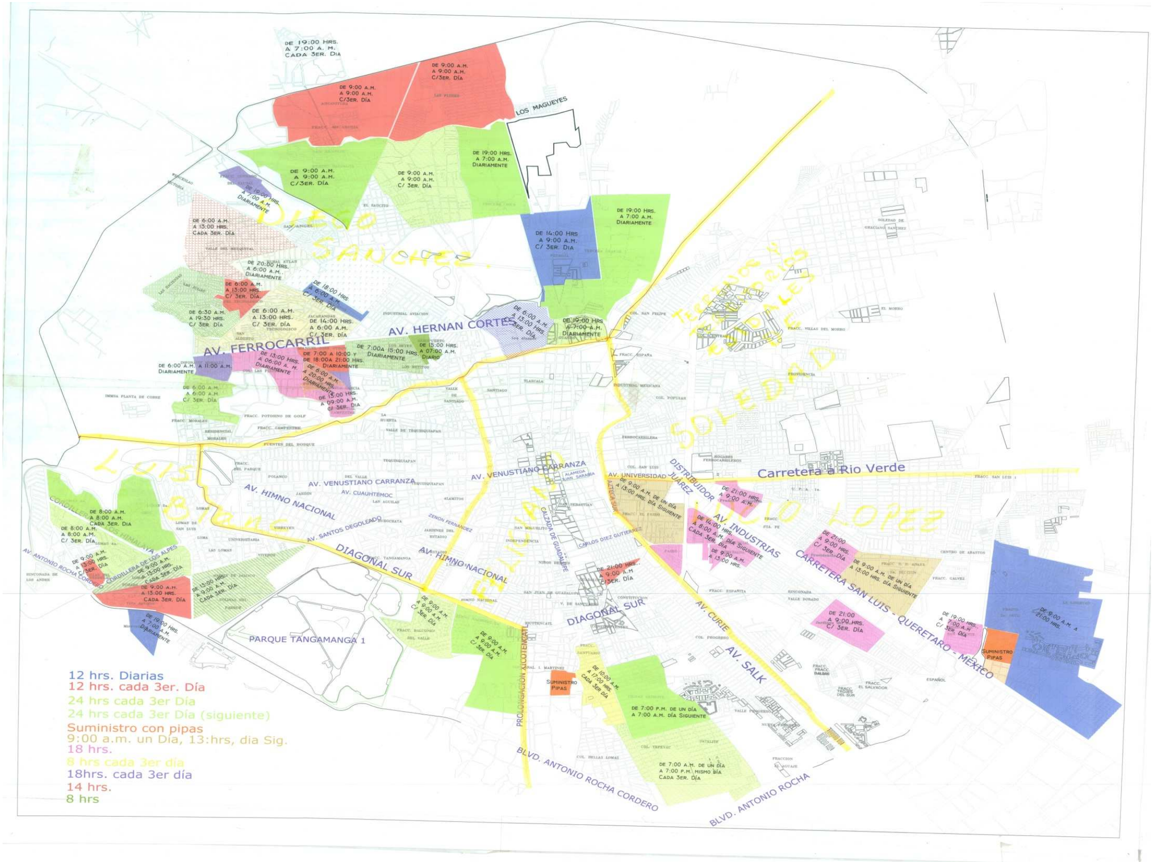
Graph 2: Tariffs comparative for domestic, industrial an commercial uses in select cities, 2008.



Note: Highest applicable tariff for 30 m^3/month consumption.
Source: CONAGUA. Subdirección General de Agua Potable, Drenaje y Saneamiento. 2010.

Additional Energy Requirement Problematic:

Because of these shortages and lack of capacity, the houses have been historically built with a storage buffer. Normally, the water is received from the public network in a cistern typically of one m^3 capacity. This practice has prevailed since still a great part of the city cannot be provided with a daily water supply and receives it under a schedule.



Color code	Intermittent Supply Scheme
	12 hrs/day
	12 hrs every 3rd day
	24 hrs every 3rd day
	24 hrs every 3rd day (next)
	Cistern truck supply
	9:00 a.m. of one day until 13 hrs of the next day
	18 hrs
	8 hrs every 3rd day
	18 hrs every 3rd day
	14 hrs
	8hrs
	Uninterrupted

Fig. 2: Water Distribution in SLP. INTERAPAS 2010

Figure 2 shows the areas where the water supply is intermittent. For each colored area, water is supplied in times ranging from twelve hours every third day of the week to 18 hours daily. The map shows that there are even some places where the water has to be transported using cistern trucks. The procedure of the water supply to the houses becomes then as follows:

1. Water is received from the public network in a cistern (1 m^3), where it is stored.
2. In order to be used, the stored water has to be pumped to a second tank on top of the houses, typically of about 400 liters of capacity, but this varies according to the number of people inhabiting the house.
3. The pumped water is then distributed to the house by gravity.

Even though nowadays some of the houses are located where the public network can provide the service twenty four hours a day, most of them preserve the existing infrastructure of the cistern. It is then estimated that about 90% of the houses in the metropolitan area buffer their household water supply.

The past issues described generate an energy need derived from the water supply to households in San Luis Potosí that are intended to be addressed in the research:

- Pumping capacity for the houses.
- The need to keep storages clean and water disinfected.

Today, the pumping capacity is fulfilled by equipping each house with an electrical pump. These pumps have typically ½ HP and are able to pump a maximum flow rate of 40 lt/min for older models and around 80 lt/minute max for the newer models. Not only do these pumps are mostly operated manually, which leads to damaged equipment when left alone running for long periods of time, but also they are a source of noise and a liability to people renting a property: rental contracts include a clause that makes the tenant responsible for any damage caused to the equipment if it is determined that it was misused, which often leads to conflicts between the tenant and the landlord. New housing complex developments located around the city must ensure the water supply to the area by having a well when there is no capacity from the network or an elevated tank when the capacity is limited. Some of these developments make use of a "variable speed system" which consists of a big cistern as the main buffer and a series of electrical pumps that start operating according to the water demand of the houses in order to keep a minimum of 2 bar (30 psi) household water pressure. Other developments use the traditional system, having individual cisterns and pumps for every house. Social housing keep costs for these equipments low and provide the manually activated pumps while more expensive ones provide already automatic pumps to prevent the aforementioned damages. The important fact continues to be the need of energy to pump water and the continuation of the use of water storages for buffering.

Regarding the storage of the water, the world health organization (WHO 2003) has defined a guideline to appropriate quantity and quality of water:

Table 2: Summary of requirement for water service level to promote health. WHO, 2003.

Service Level	Access Measure	Needs Met	Level of Health Concern
No access (quantity collected often below 5 l/c/d)	More than 1000m or 30 minutes total collection time	Consumption – cannot be assured Hygiene – not possible (unless practiced at source)	Very High
Basic access (average quantity unlikely to exceed 20 l/c/d)	Between 100 and 1000m or 5 to 30 minutes total collection time	Consumption – should be assured Hygiene – hand washing and basic food hygiene possible; laundry/bathing difficult to assure unlesscarried out at source	High
Intermediate access (average quantity about 50 l/c/d)	Water delivered through one tap on-plot (or within 100m or 5 minutes total collection time	Consumption – assured Hygiene – all basic personal and food hygiene assured; laundry and bathing should also be assured	Low
Optimal access (average quantity 100 l/c/d and above)	Water supplied through multiple taps continuously	Consumption – all needs met Hygiene – all needs should be met	Very Low

It also declares that where optimal access is achieved, but the supply is intermittent, a further risk to health may result from the compromised functioning of waterborne sanitation systems. This would be the case of San Luis Potosí. Given the intermittent supply of water, it is subject to contamination in both storages, so periodical cleaning of these storages should be made. However, this is not always performed as regularly as it should be (if it is performed at all), leading to possible health issues. Water can become contaminated by bacteria, pathogens, insects' larvae, mold and algae, among others. This in any case result in energy needed to be used in order to get suitable water for household use.

1.1 Objectives

General Objective:

- To contribute with information that foments and promotes the use of technologies that take advantage of solar energy to satisfy part of the city's energy demand.
    - Applications for the city.
    - Characteristics of solar energy technologies.
    - Possible economic benefit of solar technologies today and for the future.
    - Energy saving and environmental benefit of solar technologies.
    - Actual constraints.

Specific Objective:

- Evaluate the feasibility of applying PV systems of different capacities to cover part of the city's energy demand.
  - Propose different system options adapted to the city needs.
  - Economic aspects.
  - Environmental and health aspects.
  - Specific advantages of the system proposed.

1.2 Methodology

A system working with renewable energy sources and designed to address both the pumping and the water supply and sanitation energy needs is to be proposed, following these steps.

i. Assessment of the solar resource and resources needed.
ii. Research of possible technologies to be used.
iii. System design.
iv. Evaluation and cost adjustment of the proposed design.
v. Investment Evaluation.
vi. Further advantages (fossil fuel use reduction).
vii. Conclusions.

System design

2 Assessment of the current local conditions

2.1 Electricity Supply:

In Mexico, about 75% of the installed capacity for electricity generation comes from conventional fossil fuel plants. In the case of San Luis Potosí, there are several fuel oil plants and combined cycle plants in the state that provide the electricity for most of it. The closest to the city of San Luis Potosí is located in Villa de Reyes and has a capacity of 700 MW. Another plant is located near Valles City, with a capacity of 500 MW. In comparison, the presence of renewable technologies in the state is reduced to about 20 MW in small and medium hydropower plants.

For the residential sector, the electricity supply characteristics are:

Table 3: Characteristics of the electricity supply in Mexico.

Plug Type	Type of Current	Nominal Voltage	Frequency	Number of wires
A, B	AC	127/220	60 Hz	2, 3, 4

The B type is the most common plug. The voltage can be varied (in accordance with the CFE) between +/- 10%, providing this way a range of 114 to 140 Volts. The neutral wire of the secondary distribution system is grounded.

The same as in the rest of the country, solar energy does not figure as an important source of electricity generation. However, the city of San Luis Potosí is located in one of the most privileged areas of the country in terms of solar irradiation. At about 211 – 244 W/m^2 and together with the weather characteristics like low precipitation conditions, low cloudiness and low temperatures in the early hours of the day, solar technologies (specially photovoltaic and solar thermal) seem to be an interesting option. In fact, the use of solar thermal heaters is becoming increasingly popular as an alternative to conventional gas heaters.

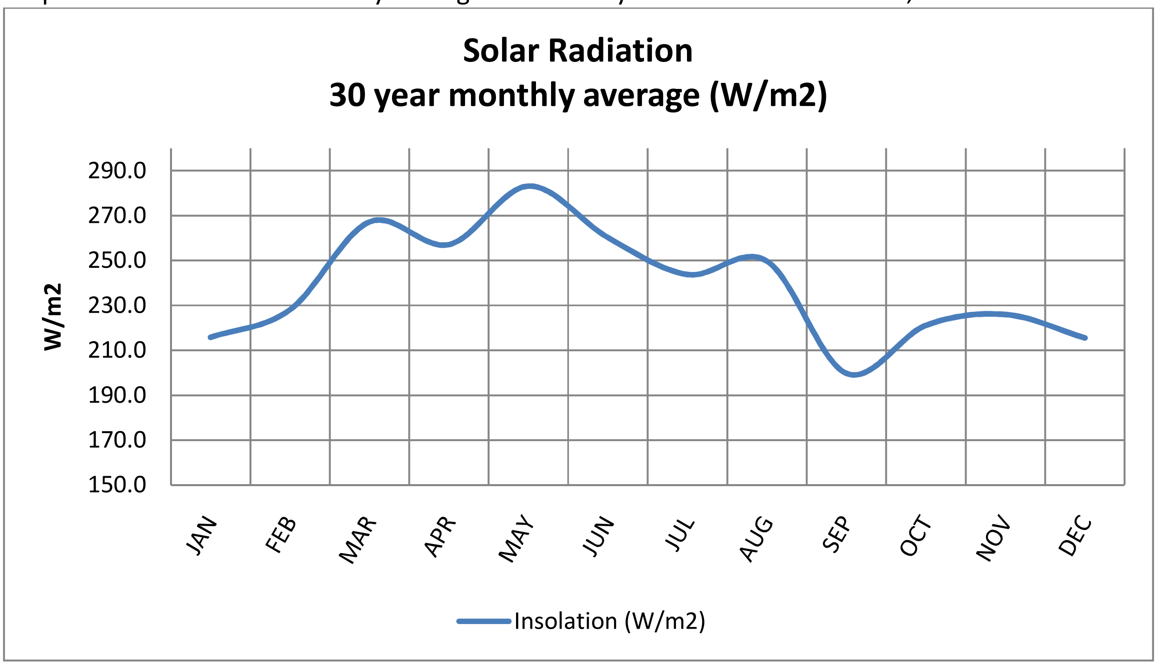
Another reason to consider the application of solar technologies in this area is the fact that more than half of the state's electricity consumption is done just by the inhabitants of the city of San Luis Potosí. Together with the metropolitan area, the proportion ends up being quite high, as it will be demonstrated. Most of this consumption is done by the industry sector, but the residential sector, which accounts for around 14% of the city's total, is already higher than the whole consumption of most of the other major cities in the state.

2.2 Solar Resource

2.2.1 Solar Radiation

The solar resource in Mexico, particularly of the northern half, appears to be quite high. When compared to Germany, one of the world's leading countries in the application of solar energy technologies and exploitation of solar energy particularly with photovoltaic installations, the solar resource and thus the market for solar technologies in Mexico has a quite high untapped potential. Germany has an average solar radiation of 2.84 kWh/m^2.day (1037 kWh/m^2.year), while Mexico has a significantly higher average of 5 kWh/m^2.day (1825 kWh/m^2.year). San Luis Potosí is above the national average with 5.4 kWh/m^2.day (1971 kWh/m^2.year – average solar harvest according to SENER/SEMARNAT). The SMN (abbreviation in Spanish for "National Meteorological Service") counts with an observatory in the city that keeps record of several climatic variables of the area, such as maximum and minimum temperatures, temperature at 8 a.m. and solar radiation. For this last variable it counts with over 30 years of measurements for global radiation over a horizontal plane. The multiyear monthly average is provided in the following graph:

Graph 3: Solar Radiation monthly averages for the city of San Luis Potosí. SMN, 2011.



The data from the National Meteorological Service observatory actually places the multiyear solar radiation average on 239 W/m^2. This observatory is located in the park Tangamanga II, about four to five kilometers north of the center of the city. Readily available are also measurements from the CONUEE (abbreviation in Spanish for “National Commission for the Efficient use of Energy”) and also satellite measurements from RETscreen. When comparing these measurements with each other and testing for the correlation coefficient it can be said that the three sets are strongly correlated. This is important for the following reasons:

Ground observations approach: When assessing the solar resource of a region one approach is to use ground stations. When properly maintained, ground stations provide highly accurate data which is why they are a critical part of any solar resource assessment, especially the ones which try to achieve high levels of financing and it’s also necessary to sort out and understand the local variability effects since observations are the best way to understand them. There are limitations to this approach like the fact that there are very few on-ground observations around the world and setting one up would limit the amount of data that can be collected to a short term in order to start a project as soon as possible. Luckily, for the case of San Luis Potosí, this limitation does not apply since the observatory has been working for more than three decades. Another limitation is that it is inaccurate to extrapolate these measurements to other locations. In 1999 a study determined that more than 25 km. away from a very high quality observation station it becomes better to use satellite derived data (Zelenka et al., 1999). This gives a better idea of how important it is to use on-site observations and not the ones from some nearby location, not to mention how that would also vary the performance and the prices. If the station is not properly maintained, that would increase the level of uncertainty for any project and since this is the initial data, this uncertainty will increase throughout the whole project development process.

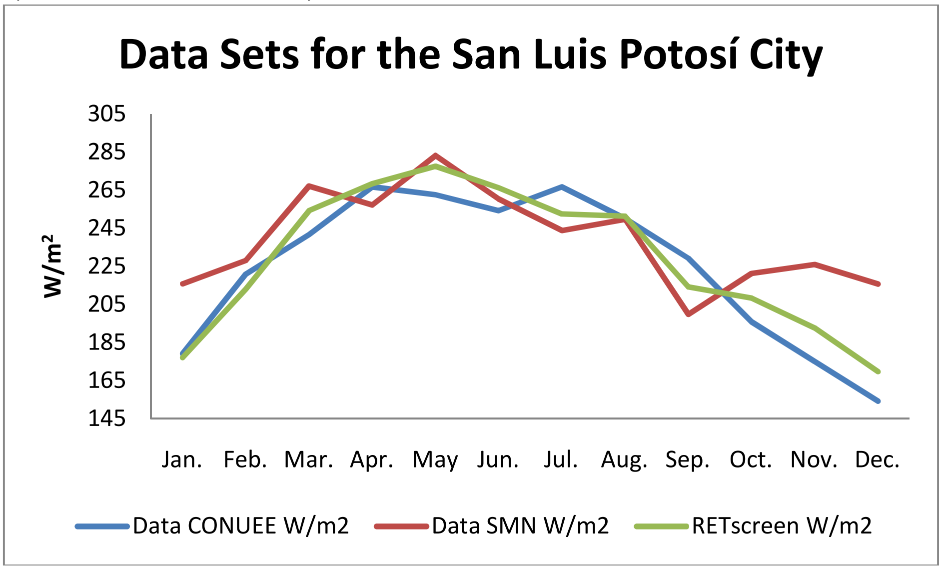
Satellite data approach: Then there are satellite derived assessments. These represent a consistent global approach given that nowadays there is an increasing number of people and companies that are beginning to take an international approach and want to look at different countries all around the world. Being able to have a consistent global approach is incredibly valuable because it enables them to understand which countries or regions they might be interested in investing in. It also helps to understand the inter-annual variability captured with multiple years of data, which is not available from observations in most locations and in most cases where a limited number of ground observations are available. Investors cannot wait long periods of time until a high quality set of observations is collected, so having the extra information to supplement any short or long term observations becomes crucial for a project to be attractive.

As mentioned before, satellite derived data has been proven to be the most accurate source of irradiance information beyond 25 km. of a well maintained ground station (Zelenka et al., 1999). The limitations to this approach are that this data has a greater level of uncertainty than observations over the same period of time. There are also some known issues with satellite modeling like, for example: areas of high albedo (reflectance), turbidity modeling (particles in the air) has proven to be very difficult to be done correctly and finally over time there can be satellite degradation. All of these add up to the level of uncertainty of satellite assessment.

Combined approach: The best way to get the highest level of certainty is the combination of the two approaches. The ground station observations can be used to improve the accuracy of the satellite data and the satellite data can used to put those observations into the longer term context and the spatial context, which would be the case for San Luis Potosí. The resulting data from this combination would be consistent and continuous. Limitations to this combined approach are, for example, that the algorithm for correcting the satellite data to the ground observations must have a very good accuracy. To achieve this is not really easy. Also, if the ground station data is also not accurate, the correction accuracy of the satellite data will also be limited, drastically increasing the uncertainty of the project.

Thanks to the fact that observational and satellite derived data is available for the city of San Luis Potosí and that they are strongly correlated, this last approach is already possible. For the purposes of this work, it will be assumed that the observatory has been well maintained over the years and that any disturbance in the accuracy of the measurements is lightened in the average results because of the quantity of data.

Graph 4: Combined data sets of ground and satellite observations. Source: Own display with data from SMN, CONUEE and RETScreen, 2011.



Correlation coefficient for the solar radiation data sets of the San Luis Potosí city.

SMN/CONUEE:	0.712	Good
SMN/Retscreen:	0.863	Strong
CONUE/Retscreen:	0.954	Very Strong

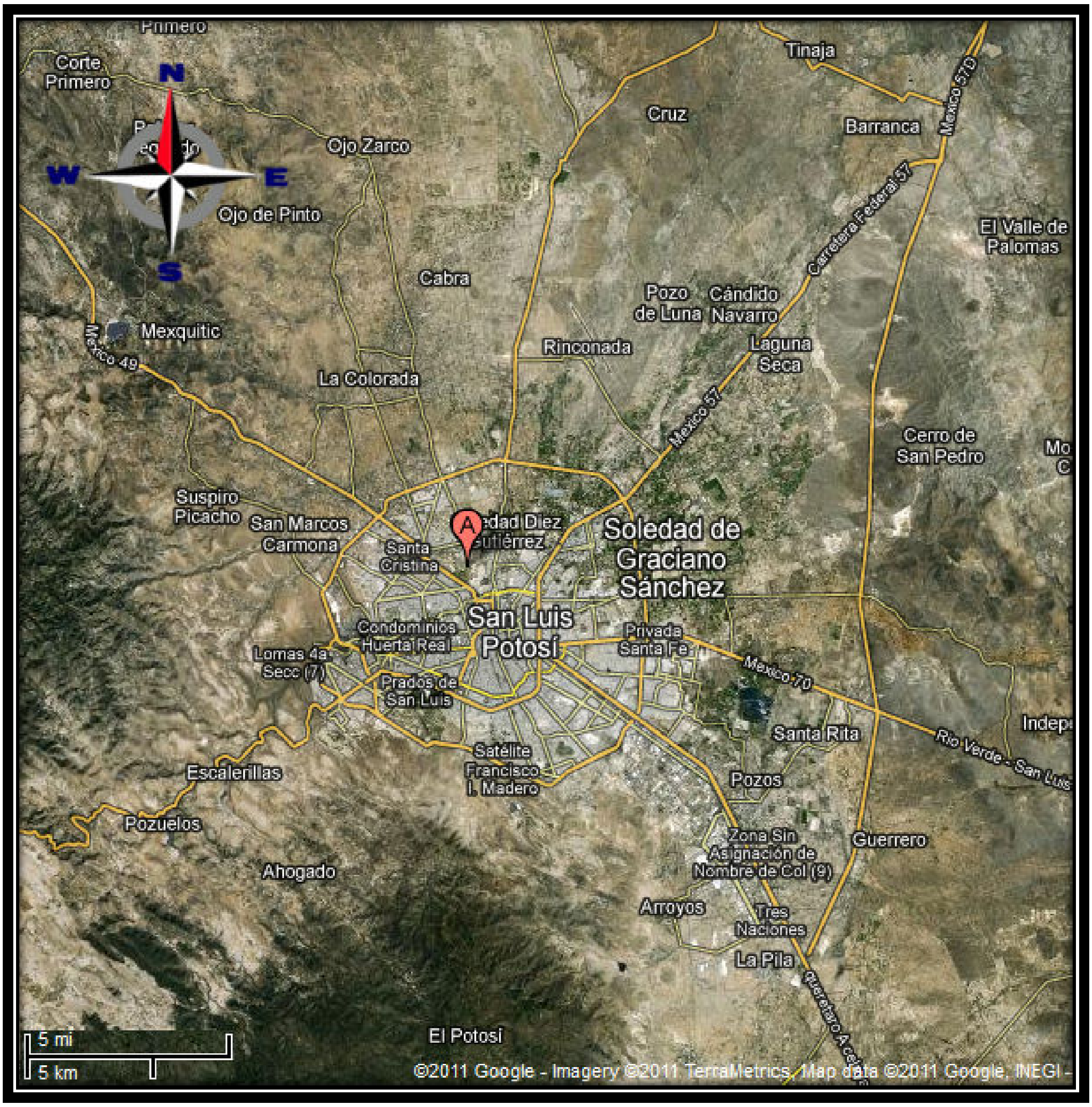


Fig. 3: Location of the SMN climatological observatory in the city of San Luis Potosí.

The solar resource is also affected by the elevation of the place being assessed. The higher the elevation, the less atmosphere there is above the place of interest and the less scattering due to turbidity and the suspended particles in the air. Consequently more sun rays will hit the surface of the collectors. San Luis Potosí has an elevation of 1860 meters above sea level that results in positive conditions for solar energy harvesting. Along with the turbidity, snow cover data and a measure of how much time the sky is covered or clear the clear sky irradiance can be calculated. Then it would be possible to get calculations for direct normal irradiance (DNI), global horizontal irradiance (GHI) and diffuse irradiance (DIFF) and finally it can be decided whether a place is suitable for solar energy based technologies.

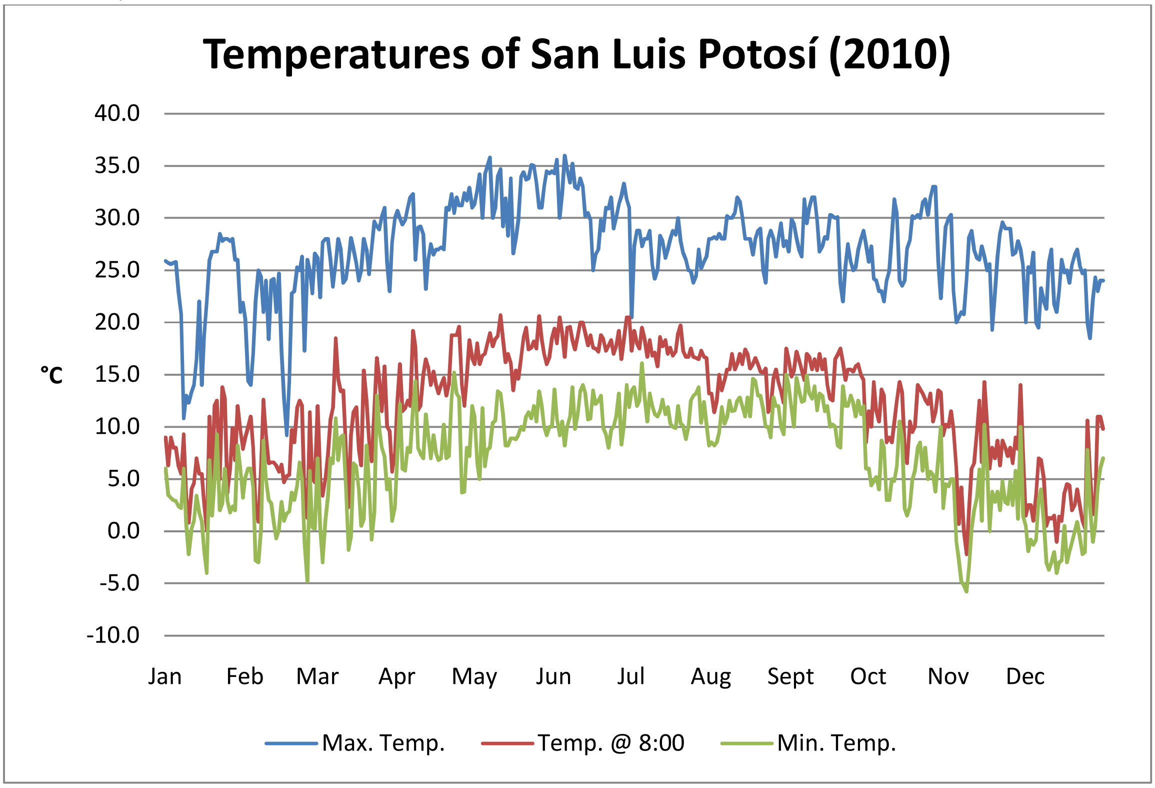
2.2.2 Weather

To have a better and more accurate understanding of the solar resource not only the solar irradiance should be taken into account but also the other weather variables that are going to have a key influence, such as:

Temperature:

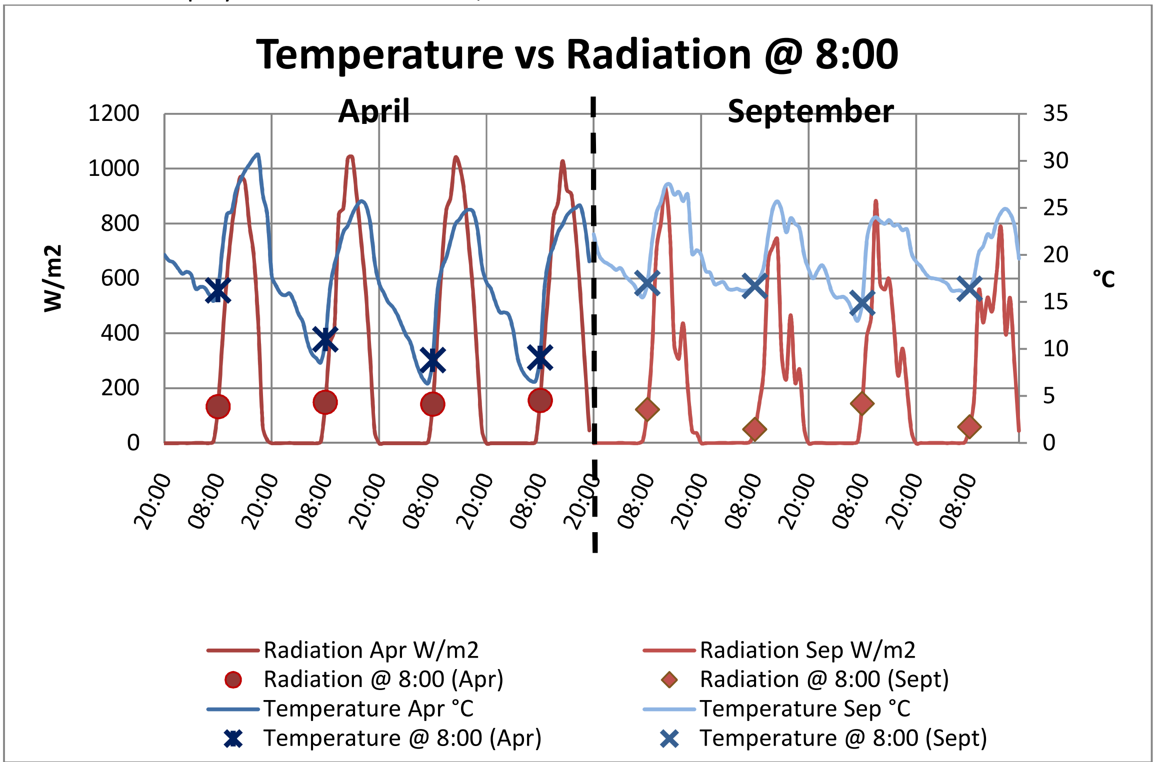
Besides intrinsic properties, the performance of a photovoltaic module is also governed by external parameters - one of the most important of them being the cell temperature. For maximum power output of the module, we need lower operating temperatures but higher irradiance. The typical temperature coefficient of power is -0.5%/°C for mono- or polycrystalline silicon cells. The cell temperature of open-rack modules, however, is governed by several external factors such as ambient temperature, irradiance level, wind speed, wind direction, and tilt-angle of the module in the array (Bharti et al., 2011). Even though the efficiency of solar panels tends to decrease as temperature goes up, high temperatures are very good for solar thermal technologies.

Graph 5: Daily temperature profile of San Luis Potosí through 2010. Source: Own display with data from SMN, 2011.



The city of San Luis Potosí has low temperatures at night and a slow rate of temperature rise in the morning particularly throughout the first four to five months of the year. This is beneficial for photovoltaic cells given that they'll work in the morning at relatively low ambient temperatures and some good amount of irradiance which leads to higher efficiencies. Typical minimum temperatures go from approximately -8 °C to 10 °C during winter and autumn months and from approximately 1 °C to 15 °C during the spring and summer times. Maximum temperatures occur during the second half of the day and can go up to 30 °C and 35 °C in the same periods respectively, which can lead to lower efficiency of PV cells while the highest irradiance levels occur at the same time. This in turn results beneficial for solar thermal technologies.

Graph 6: Comparison of temperature vs. radiation during selected April and September days. Source: Own display with data from SMN, 2011.

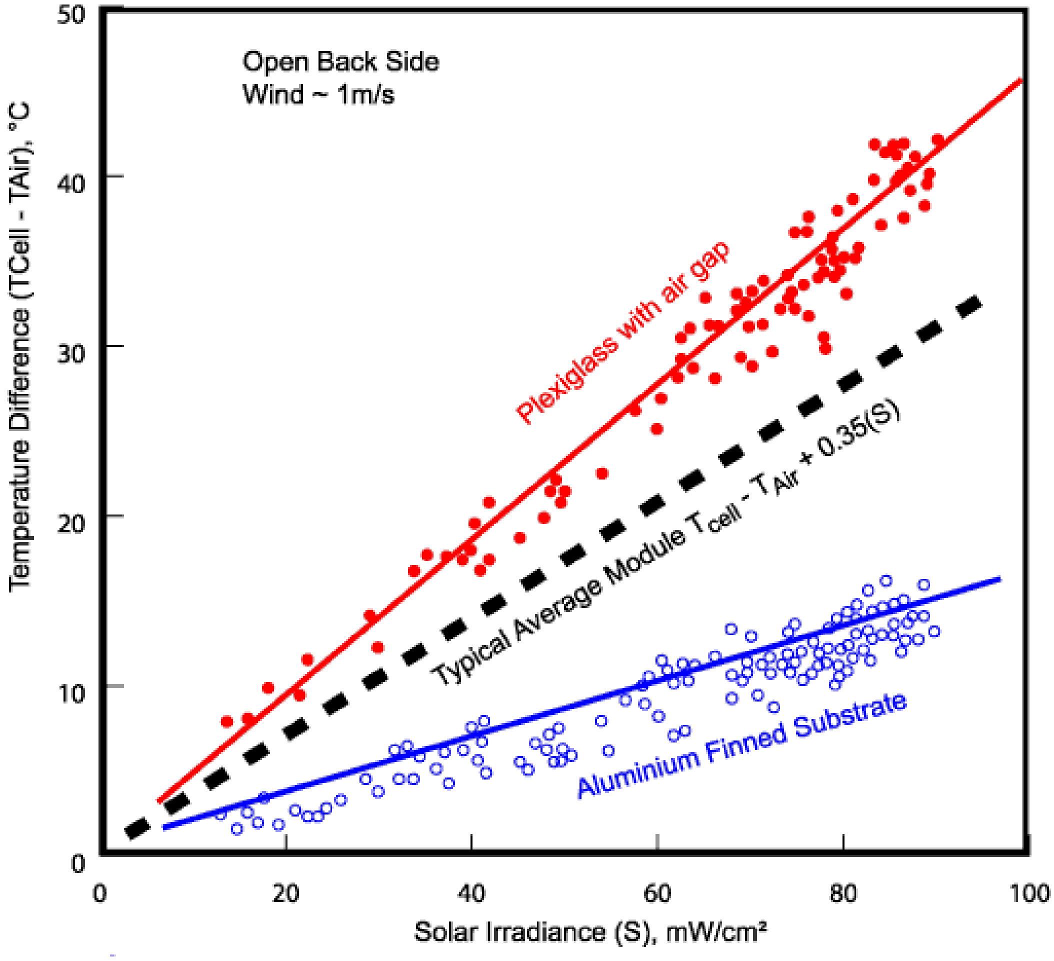


In order to determine the power output of the solar cell, it is important to determine the expected operating temperature of the PV module. The Nominal Operating Cell Temperature (NOCT) is defined as the temperature reached by open circuited cells in a module under the following conditions:

- Irradiance on cell surface = 800 W/m^2
- Air Temperature = 20 °C
- Wind Velocity = 1 m/s
- Mounting = open back side.

The equations for solar radiation and temperature difference between the module and air show that both conduction and convective losses are linear with incident solar insolation for a given wind speed, provided that the thermal resistance and heat transfer coefficient do not vary strongly with temperature. The NOCT for best case, worst case and average PV modules can e seen in the following graph. The best case includes aluminum fins at the rear of the module for cooling which reduces the thermal resistance and increases the surface area for convection (Christiana Honsberg and Stuart Bowden, PVCDROM, 2010).

Graph 7: Temperature increases, above ambient levels, with increasing solar irradiance for different module types. (Ross and Smokler, 1986).



An approximate expression for calculating the cell temperature is given by (Ross, 1980):

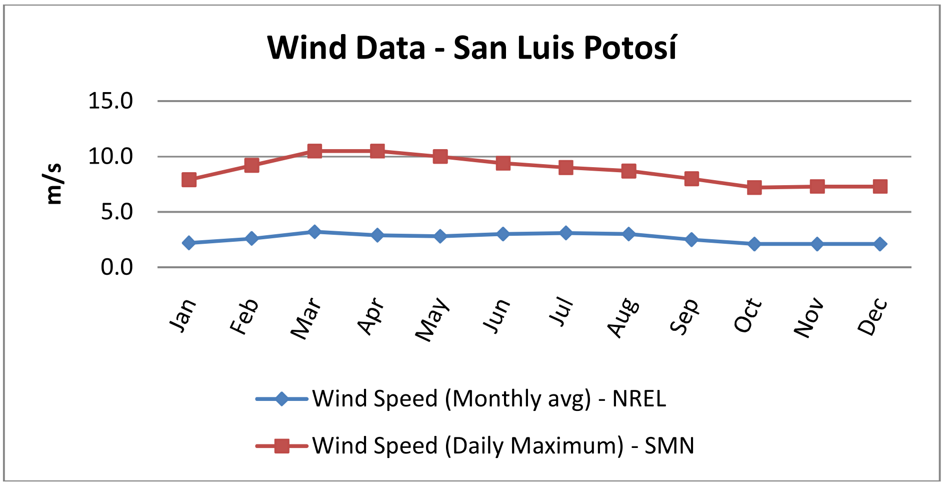
$$T_{Cell} = T_{Air} + \frac{NOCT - 20}{80} S$$

Where:

S = insolation in mW/cm^2. Module temperature will be lower than this when wind velocity is high, but higher under still conditions. Module design, including module materials and packing density, have a major impact on the NOCT. For example, a rear surface with a lower packing density and reduced thermal resistance may make a temperature difference of 5°C or more. Both conductive and convective heat transfer are significantly affected by the mounting conditions of the PV module. A rear surface which cannot exchange heat with the ambient (i.e., a covered rear surface such as that directly mounted on a roof with no air gap), will effectively have an infinite rear thermal resistance. Similarly, convection in these conditions is limited to the convection from the front of the module. Roof integrated mounting thus causes higher operating temperature, often increasing the temperature of the modules by 10°C. (Christiana Honsberg and Stuart Bowden, PVCDROM, 2010).

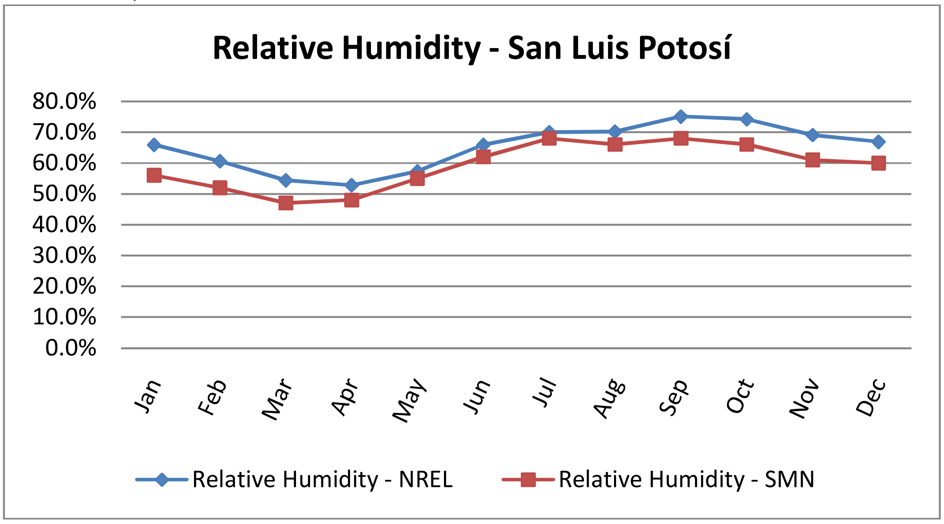
Wind speed:
Solar radiation, when used in conjunction with wind speed and time of day, can also be an indicator of atmospheric stability. Also, it can help understand the amount of particles that will be dragged by the wind to a solar panel which in the case of San Luis Potosí results useful because. The desert like surrounding of the city brings considerable quantities of dust especially during the windy days.

Graph 8: Typical wind conditions in San Luis Potosí. Source: Own display with data from SMN and NREL, 2011



Humidity:
This variable can also affect the turbidity of an area and should be taken into consideration for its calculations.

Graph 9: Typical Relative Humidity conditions in San Luis Potosí. Source: Own display with data from SMN and NREL, 2011.



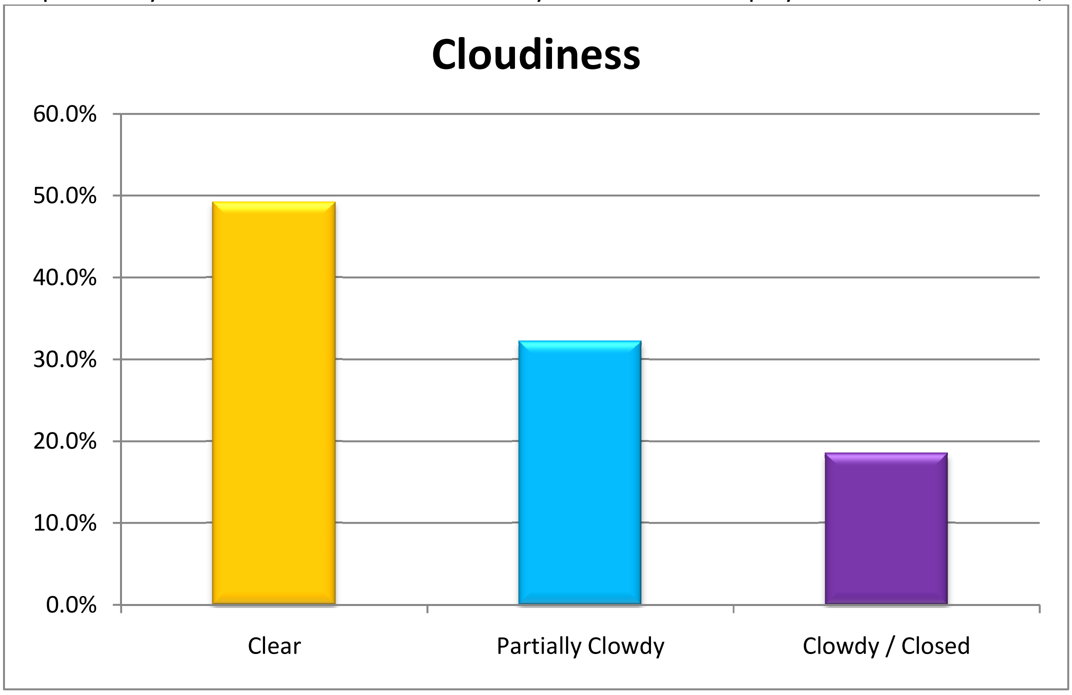
Cloudiness:

As mentioned before, the typical amount of cloud coverage during the year is a key factor to determine how good the solar resource of an area is. For the city of San Luis Potosí, where rain is not excessive, it can be affirmed that the conditions are favorable for PV systems, given that 50% of the time the sky is clear during the year. To add up, another 32% of the time, the sky is partially covered which means that at least some amount of sunrays will reach the panels. Only 18% of the time it is considered to be densely clouded or closed.

According to the SMN the sky is considered to be:

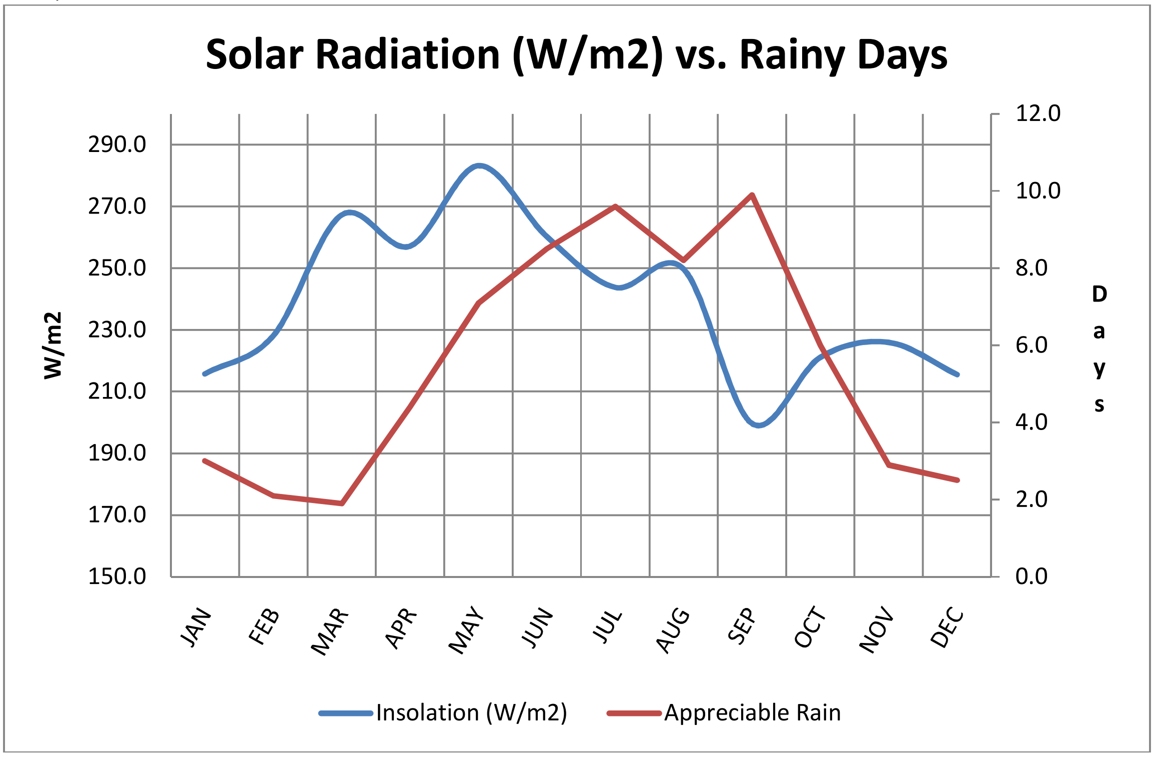
1. Clear – when no clouds or up to a maximum of 25% (2/8) of the sky is covered.
2. Partially cloudy – when more than 25% (2/8) and up to 62.5% (6/8) is covered.
3. Cloudy when more than 62.5% (6/8) but not 100% of the sky is covered.
4. Closed when 100% (no clearings) of the sky is covered.

Graph 10: Sky conditions of San Luis Potosí City. Source: Own display with data from SMN, 2011.



A very clear relationship can be appreciated when plotting together the solar radiation data with the number of rainy days per month. Solar radiation clearly decreases during the rainy season.

Graph 11: Solar Radiation vs. Days with Rain in San Luis Potosí. Source: Own display with data from SMN, 2011.



Further weather considerations:
Although not common, thunderstorms and hail occur for short periods of time during the year. Particularly hail has an effect on the design of the solar panels. Accurate weather data will help provide the longer term context needed to build this kind of projects.

2.3 Tariff Scheme

The Mexican tariff scheme for the residential sector, as organized by the CFE, is determined by the following factors: region, season of the year and level of consumption. Some examples of the CFE electricity bill are provided in the annex section.

2.3.1. Region

Due to its extension and location, several climate conditions are present through the Mexican territory ranging from arid to temperate and up to alpine. The climate is the most significant factor in the consumption of electricity mostly because it determines what equipment is needed in order to have a certain level of temperature comfort. Hot dry climate regions make use of evaporative coolers as well as air conditioning while regions with hot humid climate use only air conditioning equipments. Temperature also plays a big role in electricity consumption and its regionalization since, for example, in the state of Durango the lowest temperatures are registered, reaching as low as -26 °C on occasions, while the highest temperatures occur at the highest places of the

Mexicali desert in the state of Baja California Norte but also at the Huasteca region in the central state of San Luis Potosí, reaching above 50 °C. This also defines if a household needs to have heating and even the intensity in which other cooling devices like refrigerators are needed in order to preserve food and other perishables.

The first subdivision of the scheme then divides the country in seven regions with different tariffs for each one. The regions are defined mainly by the climate conditions based on the minimum average temperature during summer as follows:

Table 4: Temperature ranges that define residential tariffs. Source: Own display with data from CFE 2011.

Tariff	Minimum average temperature during summer of the region
1	< 25°C
1A	≥ 25°C and < 28°C
1B	≥ 28°C and < 30°C
1C	30°C
1D	31°C
1E	32°C
1F	≥ 33°C

2.3.2. Season of the year

Although the tariffs are mainly defined by the minimum summer temperature of the region, the extreme temperatures mentioned before can occur during the winter. For this reason, most of the tariffs described in Table 3 are also divided in summer and winter ("out of summer") terms. In order to calculate the electricity expenses it must be taken into account that for each region, the summer term comprehends the six hottest successive months of the year according to the observations of the thermometric stations in that area, which means that for every region the summer term may be different from the other, having the possibility to start from February to May. The rest of the months correspond then to the "out of summer" term. Such division does not apply only to the Tariff 1 region.

The effects of the temperature in the consumption throughout the country can be seen in the annual average use of electricity consumption per user: According to CFE data from 2010, the northern states of Sonora, Sinaloa and Baja California have the highest average volume (kWh) per user. The predominant climate of the three of them is arid and they normally register the highest temperatures throughout the year. On the other hand, states like Oaxaca and Hidalgo with hot-humid to temperate-humid climates, along with colder states in the center of Mexico like Zacatecas, Mexico and Puebla have the lowest average volume per user.

2.3.3. Level of consumption

Furthermore, each of the seven tariffs has another subdivision which depends on the level of consumption of each client. Three ranges are then defined within each tariff as: basic, intermediate and high consumption. The last one is referred to as DAC tariff level which stands for "De Alto Consumo", meaning High Consumption in Spanish. Clients are classified within these ranges depending on their average monthly consumption rates.
The limits for each region to be classified into the DAC tariff can be found in the following table:

Table 5: Monthly average consumption limits to enter the DAC tariff. Source: Own display with data from CFE, 2011.

Tariff	Limit (kWh/month)
1	250
1A	300
1B	400
1C	850
1D	1,000
1E	2,000
1F	2,500

For practical purposes, Tariff 1 will be used as an example given that the city of San Luis Potosí belongs to this region:

Fixed charge: Equivalent to 25 kWh (minimum monthly consumption)
Basic Tariff: consumptions up to 150* kWh
Intermediate Tariff: consumptions above 150* kWh and below 250 kWh
DAC Tariff: consumptions above 250 kWh

* The CFE website indicates that the Basic tariff limit is 140 kWh. However, the actual printed electricity bill indicates that the limit is 150 kWh and does with this the calculations of the invoice

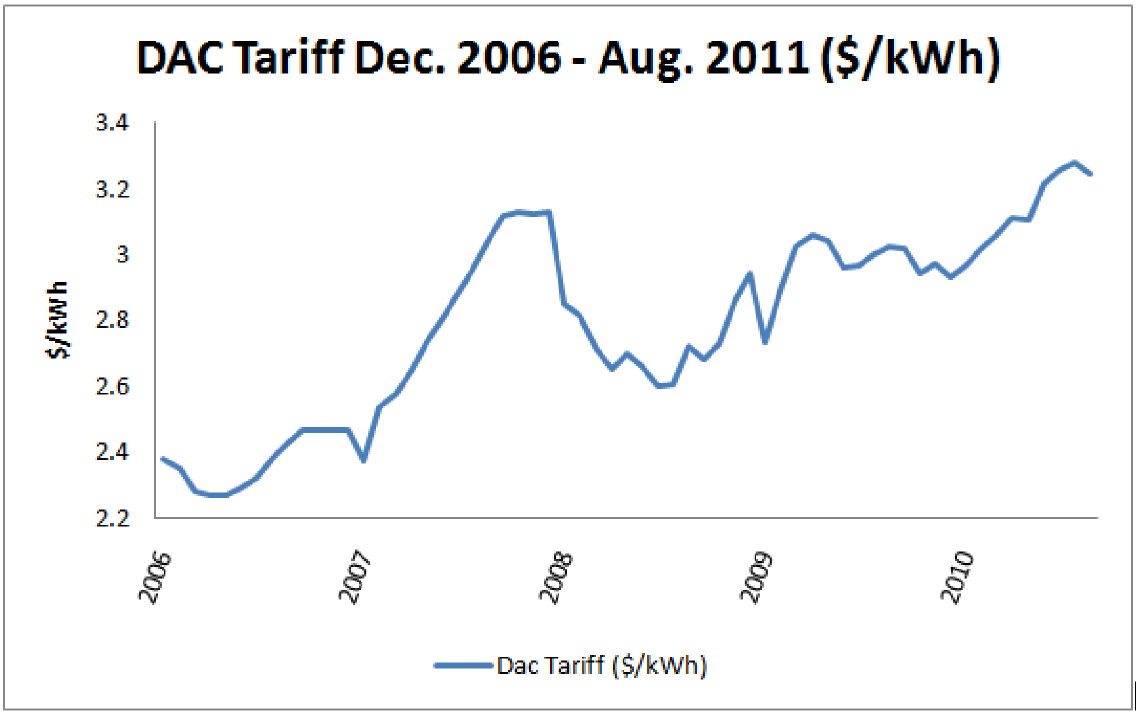
Table 6: Tariff 1 - Charges for a monthly average consumption up to 150 kWh (MX$/kWh). CFE, 2011.

Range	Basic 1-75 kWh	Intermediate
Dec. 2010	0.709	0.852
Jan.	0.711	0.855
Feb.	0.713	0.858
Mar.	0.715	0.861
Apr.	0.717	0.864
May	0.719	0.867
Jun.	0.721	0.87
Jul.	0.723	0.873
Aug.	0.725	0.876
Sep.	0.727	0.879
Oct.	0.729	0.882
Nov.	0.731	0.885
Dec.	0.733	0.888

Table 7: Tariff 1 - Charges for a monthly average consumption above 150 kWh and below 250 kWh (MX$/kWh). CFE, 2011.

Range	Basic 1-75 kWh	Intermediate 76-125 kWh	Excee-ding
Dec. 10	0.709	1.181	2.497
Jan.	0.711	1.185	2.505
Feb.	0.713	1.189	2.513
Mar.	0.715	1.193	2.521
Apr.	0.717	1.197	2.529
May	0.719	1.201	2.537
Jun.	0.721	1.205	2.545
Jul.	0.723	1.209	2.553
Aug.	0.725	1.213	2.561
Sep.	0.727	1.217	2.569
Oct.	0.729	1.221	2.577
Nov.	0.731	1.225	2.585
Dec.	0.733	1.229	2.593

Graph 12: Tariff 1 - Charge for a monthly average consumption above 250 kWh Dec. 06 – Aug. 11. Source: Own Display, based on CFE data, 2011.



The amount charged for the electricity in each tariff is adjusted on a monthly basis. While basic and intermediate consumption rates are calculated for the whole year, high consumption rates, as well as the fixed charge associated with it, are calculated each month depending on adjustment factors that reflect inflation and the changing price of fossil fuels as follows:

Monthly adjustment factor

$$FA_m = \beta \times [\gamma \times FAC_m + (1-\gamma)] + (1-\beta) \times FAI_m$$

Where γ = 0.983, m = month of the year

For the calculation of the adjustment factor for fixed charges β = 0

So that it becomes: $FA_m = FAI_m$

For the calculation of the adjustment factor for consumed energy using the DAC tariff β = 0.35

$$FAC_m = \frac{ICC_{m-1}}{ICC_{m-2}}$$

Where ICC_m is the cost index of the fuels used to produce electricity, and is calculated as the pondered sum of the fuel prices (P_c) as follows:

$$ICC_m = \sum_{c=1}^{5} \alpha_c \times P_{c,m}$$

The c sub index expresses each one of the five fossil fuels used and the prices are used without the added value tax.

Table 8: α Coefficient for DAC tariff determination. Source: Own Display with data from CFE, 2011.

Fuel	α_{2006}	α_{2007}	$\alpha_{2008-2011}$
National Fuel Oil	0.0265	0.0265	0.0713
Imported Fuel Oil	0.1097	0.1097	
Natural Gas	0.696	0.696	1.0975
Industrial Diesel	0.0034	0.0034	0.0022
Imported Carbon	0.2253	0.225	0.1939
National Carbon (MICARE)	0.3039	0.304	0.2547

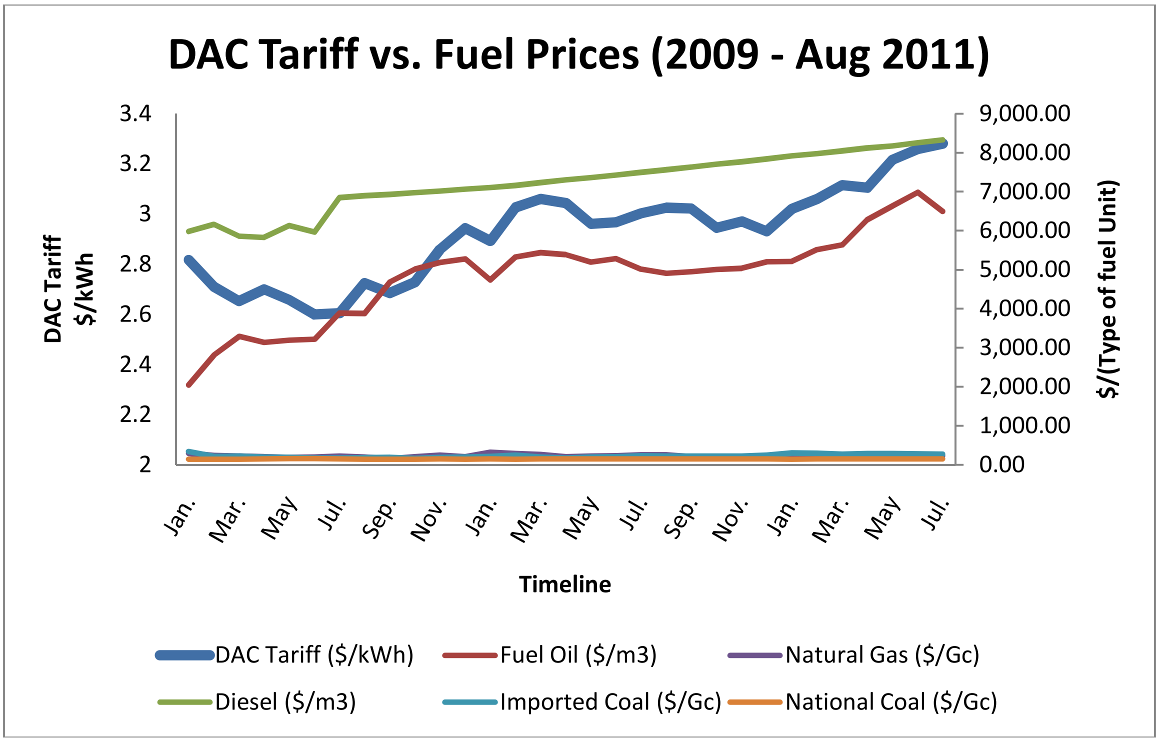
Table 9: Price determination methodology ($P_{c,m}$) for DAC tariff. Source: Own Display with data from CFE, 2011.

Fuel	Price Determination
National Fuel Oil	Average of the producing centers, PEMEX quotation, annual firm value, in MXP per cubic meter
Imported Fuel Oil	
Natural Gas	Mobile average of the four immediate previous months, PEMEX quotation for the center sector or the one that substitutes it, annual firm base, in MXP per Gigacalorie
Industrial Diesel	low sulfur, PEMEX quotation for the rest of the country, without creditable taxes, in MXP per cubic meter
Imported Carbon	Petacalco average, including management of ashes and import tax, in MXP per Gigacalorie
National Carbon (MICARE)	Main supplier quotation of the Río Escondido coal basin, including management of ashes, in MXP per Gigacalorie

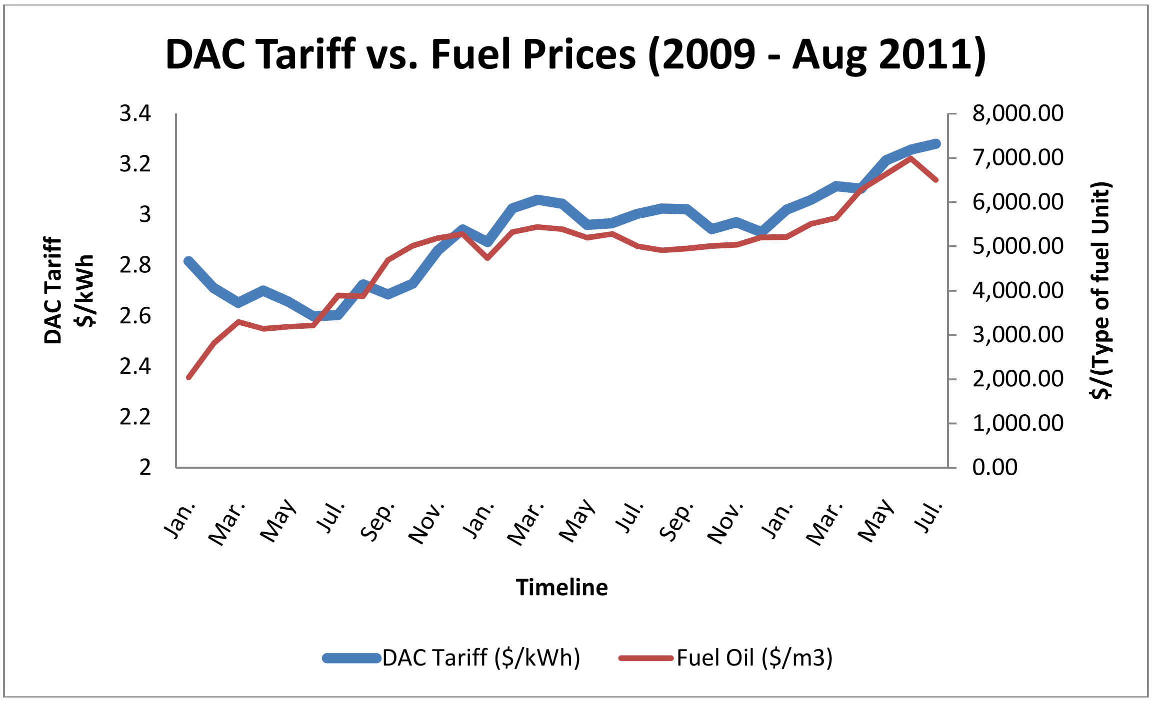
Even though the actual strategy includes already as a goal a certain growth of the renewable in the national energy matrix the main strategy is of energy efficiency, phasing out fuel oil based generating facilities and replacing them with natural gas ones.

The following graphs show the tendency of the DAC (unsubsidized) tariff along with the prices of the fossil fuels used for electricity generation in Mexico, according to the Energy Ministry (prices in MX$):

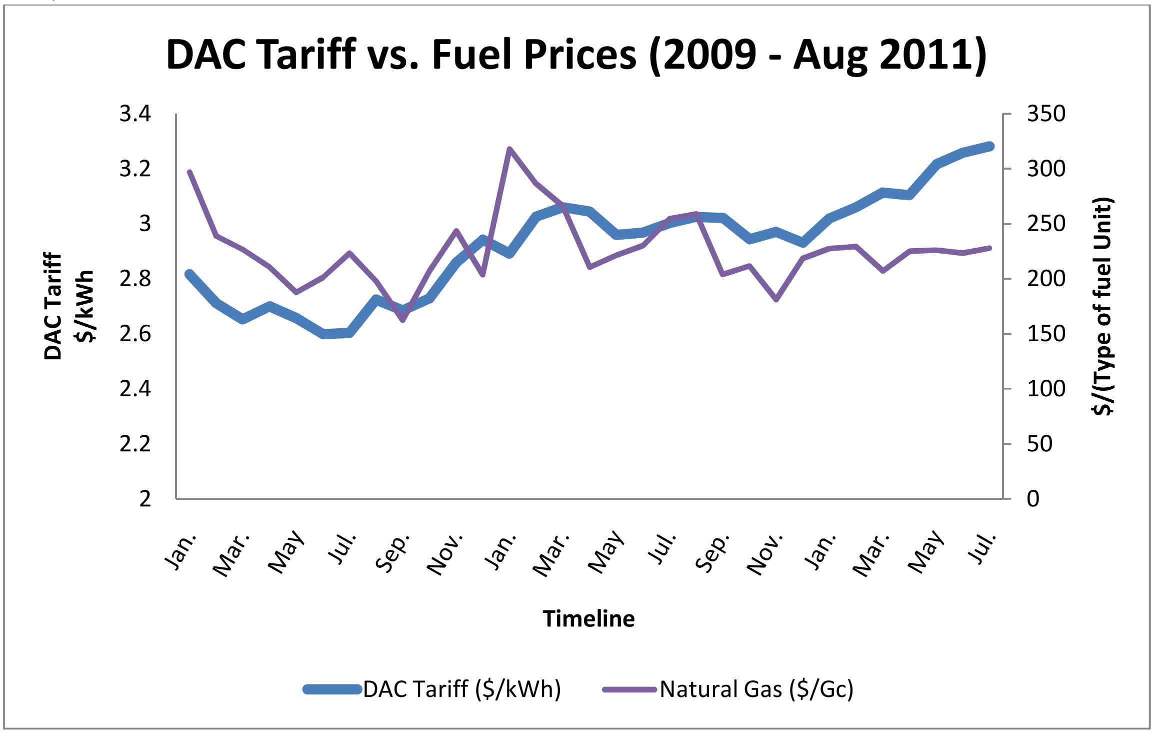
Graph 13: DAC Tariff vs. Fuel Prices (2009 - Aug 2011). Source: Own Display, based on CFE data, 2011.



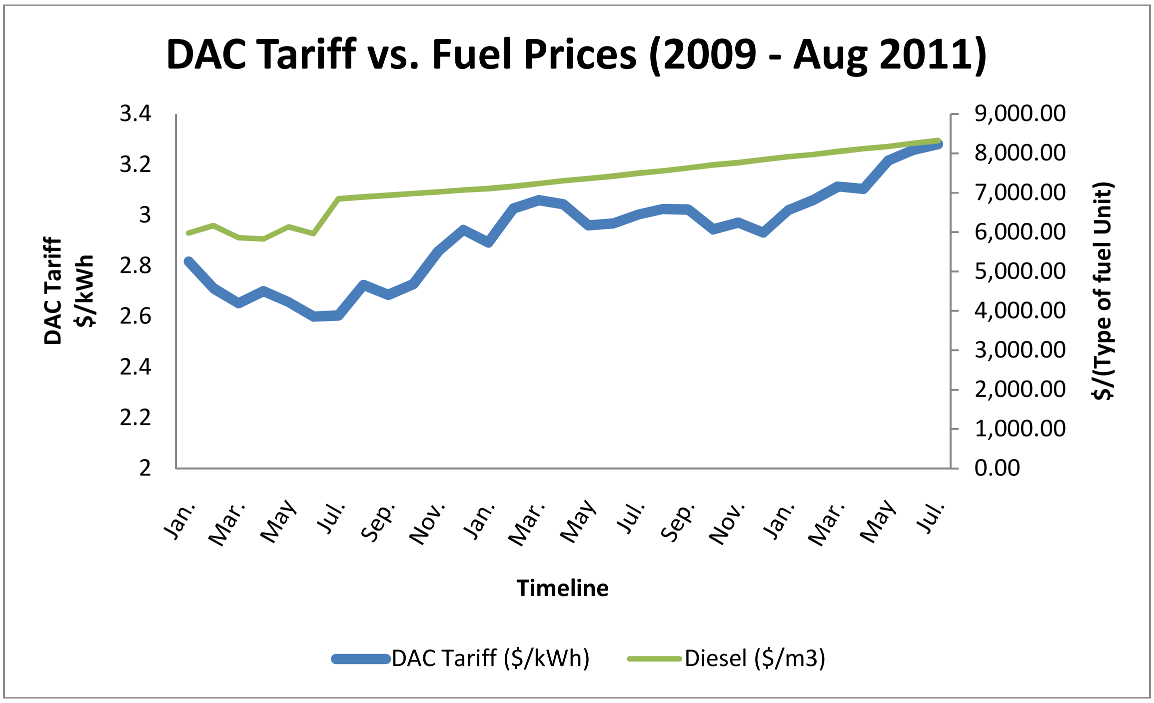
Graph 14: DAC Tariff vs. Fuel Oil Prices (2009 - Aug 2011). Source: Own Display, based on CFE data, 2011.



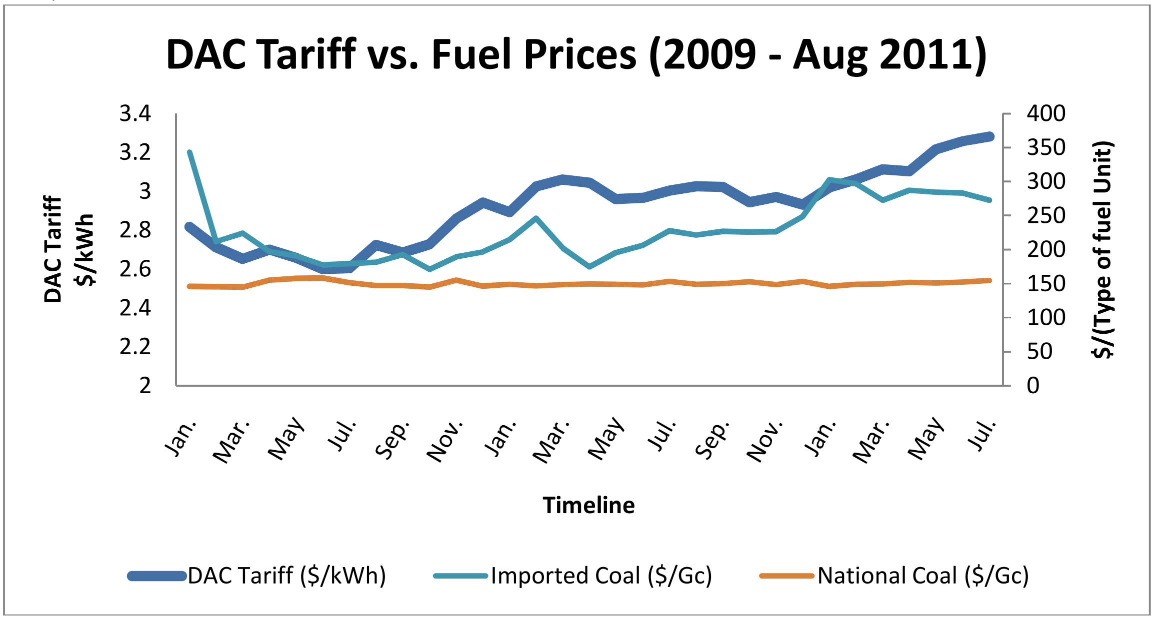
Graph 15: DAC Tariff vs. Natural Gas prices (2009 - Aug 2011). Source: Own Display, based on CFE data, 2011.



Graph 16: DAC Tariff vs. Diesel prices(2009 - Aug 2011). Source: Own Display, based on CFE data, 2011.



Graph 17: DAC Tariff vs. Natural Gas prices (2009 - Aug 2011). Source: Own Display, based on CFE data, 2011.



The adjustment factor for inflation is calculated as follows:

$$FAI_m = \frac{IPP_{m-2}}{IPP_{m-3}}$$

Where IPP_m stands for an index of producer prices that is determined monthly as a pondered average of seven indexes selected from the "Sistema de Precios Productor del Banco de México", which means "Producer Price System of the Bank of Mexico" in Spanish. It is done as follows:

$$IPP_m = \sum_{d=1}^{7} \delta_d \times IPP_{d,m}$$

The d sub index expresses each one of the six divisions selected out of the manufacturing industry along with the large construction division. The divisions and the large division selected, as well as their corresponding δ values are:

Table 9: δ Coefficient for the IPP_m calculation - DAC tariff. Source: Own Display, CFE, 2011.

Code	Division / Gran Division	δ_{2011}
3.03	Wood industry and its products	0.0228
3.05	Chemical, oil, rubber and plastics industries	0.1927
3.06	Mineral and non metallic products	0.0577
3.07	Basic metal industries	0.0607
3.08	Metallic products, machinery and equipment	0.3862
3.09	Other manufacturing industries	0.0159
4	Construction	0.264

The Price indexes, denoted $IPP_{d,m}$, will be notified by the Bank of Mexico, classified by the origin of the production, based on December 2003 = 100, or the ones that substitute them.

2.4 Policies and Subsidies

For the first period of 2010, the subsidies to the electricity for the residential sector accounted for 36,259 millions of pesos (constant pesos for 2010) in the first period of the year (January to June). This amount represented an increase of 17.8% from the same period of 2009. The relationship price – cost relationship for both periods was 0.41, meaning that the price charged to the residential customer was only 41% of the actual costs of producing the electricity. Furthermore, subsidies exist for public lighting and pumping, agricultural pumping, general medium voltage users and general high voltage users. Altogether, the subsidies for the first period of 2010 accounted for 50,220 millions of pesos that reflected of 8.2% over the previous year and price cost relationships for that period of 0.66 for 2009 and 0.71 for 2010.

It can then be affirmed that the reason behind the price differences is the strong subsidies that are applied to the electricity, following the decade long policy of providing cheap electricity for all the population. The Basic tariff is the most subsidized also because of the political idea that prices for the poor inhabitants, who commonly consume less electricity, should be lower. From then on, each category and range of consumption enters lower subsidy schemes until the DAC tariff to which no subsidies are applied. The limits to each one of the regions are established so that they also reflect the impact of the temperature on electricity consumption but also because of the political idea to not discriminate people living in areas with higher temperatures with higher electricity costs.

The household income also plays an important role in the consumption habits of electricity. The higher the income, the more quantity and the more diverse the equipment available in each house and most probably the higher the consumption. Other social factors like family size, habits, and living area affect the final consumption. Family sizes tend to be bigger in rural areas which, at the same time, have lower income levels compared to the urban ones. This is why for a great number of families in Mexico electricity costs are a significant monthly expense. This is the reason behind the high subsidies by the government of electricity prices for households, particularly for low consumption ones. The following table shows the amount paid by the basic tariff users throughout the seven regions:

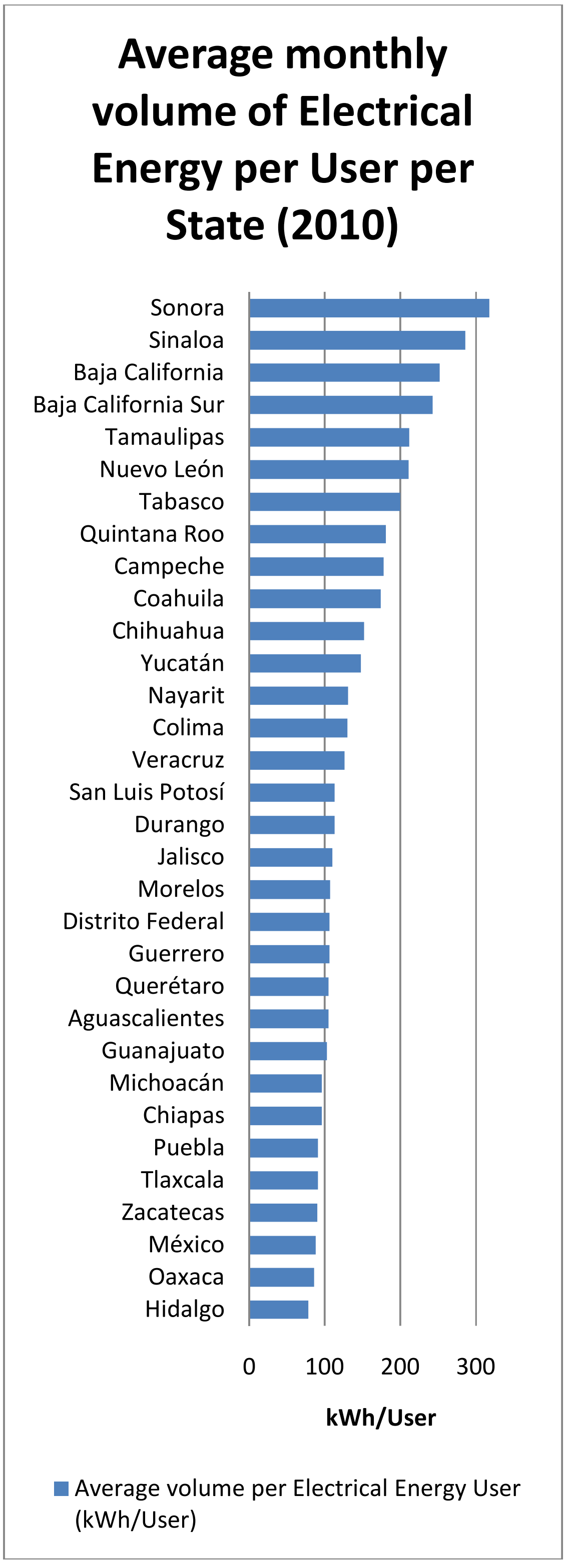
Table 10: Invoice examples. Source: Own Display, based on CFE data from July 2011.

Tariff	Monthly Consumption Limits for DAC Tariff (kWh/month)	Basic Tariff Limit (kWh/month)	Invoice Example: Basic Tariff, 150 kWh ($)	Invoice Example: Basic tariff limit ($)	Minimum average temperature during summer of the region
1	250	150	120	120	< 25°C
1A	300	150	102	102	≥ 25°C and < 28°C
1B	400	225	99	155	≥ 28°C and < 30°C
1C	850	300	96	208	30°C
1D	1,000	400	94	280	31°C
1E	2,000	750	56	461	32°C
1F	2,500	1200	56	764	≥ 33°C

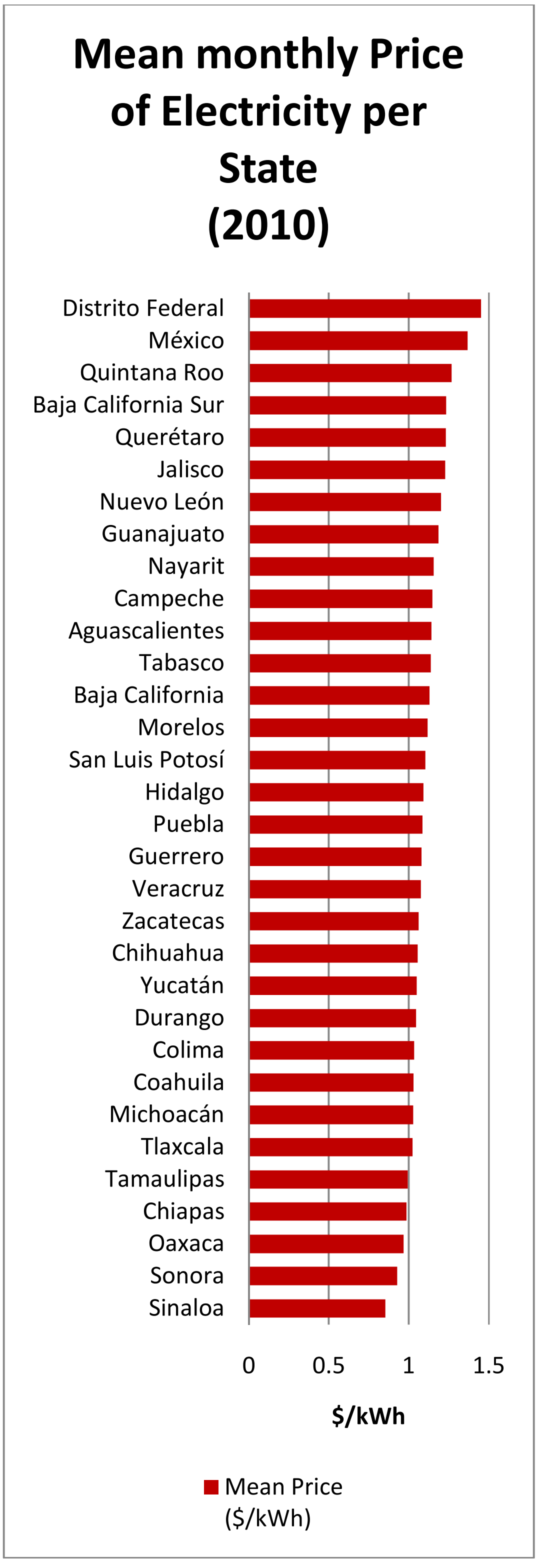
According to data from the CFE of 2010, the states of Sonora and Sinaloa, having the highest temperatures and the highest average volume per electrical energy user have the lowest mean price ($/kWh) of electricity sold to the residential sector, followed by Oaxaca and Chiapas that have low income, while states with high income like Mexico City, Mexico State, Quintana Roo, Baja California Sur, Querétaro, Jalisco and Nuevo León have the highest mean price.

The state of San Luis Potosí, having areas with semi-arid and hot humid climates, is classified in two of the regions. However, the city of San Luis Potosí and its metropolitan are all within Tariff 1 territory. This division may be the reason why this state appears to have slightly higher consumption per user and mean price, as seen on the graphs 18 and 19.

Graph 18: Average monthly volume of Electrical Energy per User per State (2010.) Source: SENER.



Graph 19: Mean monthly Price of Electricity per State (2010). Source: SENER.



2.4 Legislation

Mexico already counts with some legislation that has started regulating the use of renewable energies along with their incorporation to the national electricity network. The LAERFTE, "LAW FOR THE USE OF RENEWABLE ENERGY AND THE FINANCING OF THE ENERGY TRANSITION" (DOF 28-11-2008) published on the 28th of November, 2008 aims also to promote energy efficiency and sustainability by means of reducing the dependence on fossil fuels as the primary energy source and the research and development of clean technologies. It defines renewable energies as "those, whose source lies in natural phenomena, processes or materials that can be transformed into usable energy for mankind, which regenerate naturally, so that they are available on a continuous or periodic manner" and states that the following are considered renewable energy sources:

a) Wind.
b) Solar radiation in all its forms.
c) The movement of water in natural or artificial channels (although it limit hydropower stations to 30 MW to be ruled by this law).
d) Ocean energy: tidal, wave, marine currents, thermal and marine salt concentration gradient.
e) Geothermal.
f) Biofuels (determined by the "Law on the Promotion and Development of Bioenergy").
g) Any other that the SENER determines that accomplishes the characteristics of the included definition of renewable energies.

This law provides general information about the regulatory frame and directs to several other laws, regulations, programs and the "National Strategy for the Energy Transition and Sustainable Energy Use". These are:

1. Law of Electric Energy Public Service: Articles 3 and 36 define what is considered as public service in terms of electricity generation and the types of permissions and conditions for each type for the generation of electricity.
2. Methodology for the determination of charges for electrical energy transmission services for renewable energy sources.
3. Interconnection Contract for Renewable Energy Sources or Cogeneration Systems: First published the 27th of June 2007 specifically for solar energy sources, it has been recently modified and published the 8th of April 2010 to be a generalized contract for all kinds of renewable sources considered by the LAERFTE. There are two different contracts:
    a. Small Scale: This contract deals with capacities of up to 30 kW and voltages below 1 kV and that do not require the use of the supplier's system (CFE) to carry power to their charges. Of special interest for this work given that it is established that the maximum installed power allowed for residential users is 10 kW. Users of the general low voltage service the limit goes up to 30 kW. The meters and measurement equipment to be used to determine the energy delivered by the "Generator" (client) to the "Supplier" (CFE) and vice versa have to be installed by the Supplier at the expense of the Generator. The meters must have the capacity of performing the Net Metering between the energy delivered by the Supplier and the Generator. For invoicing purposes, when the difference is negative it will be considered as a credit in favor of the Generator that must be compensated during the next 12 months of it will be cancelled. When the difference is positive, the credit would be issued in favor of the Supplier and will be invoiced according to the applicable tariff of the normal supply contract.

   b. Medium Scale: This contract deals with capacities of up to 500 kW and voltages higher than 1 kV and lower than 69 kV that do not require the use of the supplier's system (CFE) to carry power to their charges.
4. Law of Income Tax: Determines the maximum authorized deduction percentages, which is 100% for the case of fixed assets such as machinery and equipment for energy generation from renewable sources.
5. General Law of Ecological Equilibrium and Environmental Protection and Regulations of the General Law of Ecological Equilibrium and Environmental Protection (Environmental Impact Assessment and Protected Natural Areas): Determines what kind of works require the permission of the SEMARNAT (Ministry of Environment and Natural Resources) in terms of environmental impact, specifically the ones pertaining to the Electrical Industry and the terms of building in protected natural areas.

2.6 Additional Considerations

CFE additional requires the installation to have specific technical characteristics in order to allow it to connect to the network and supervises and inspects them.

It is also worth mentioning that for the residential sector, when a conventional one way meter is already installed, its cost will be deducted of the Net Meter cost. The charge for a conventional meter is around $1500.00 while a net meter would cost approximately $2500.00. The Generator would then pay the difference of $1000.00 to the CFE for the net meter.

According to the CFE, the city consumptions per season during 2010 were:
Total winter consumption: 1.411.424 MWh
Total summer consumption: 2.000.296 MWh
Average monthly consumption: 284.310 MWh

If the consumption difference in summer and winter are taken into account along with the solar resource and weather data, it can be assumed that PV modules can benefit from the solar resource throughout the year and solar thermal equipment could also represent a particularly good advantage during the winter season, especially during its last months.

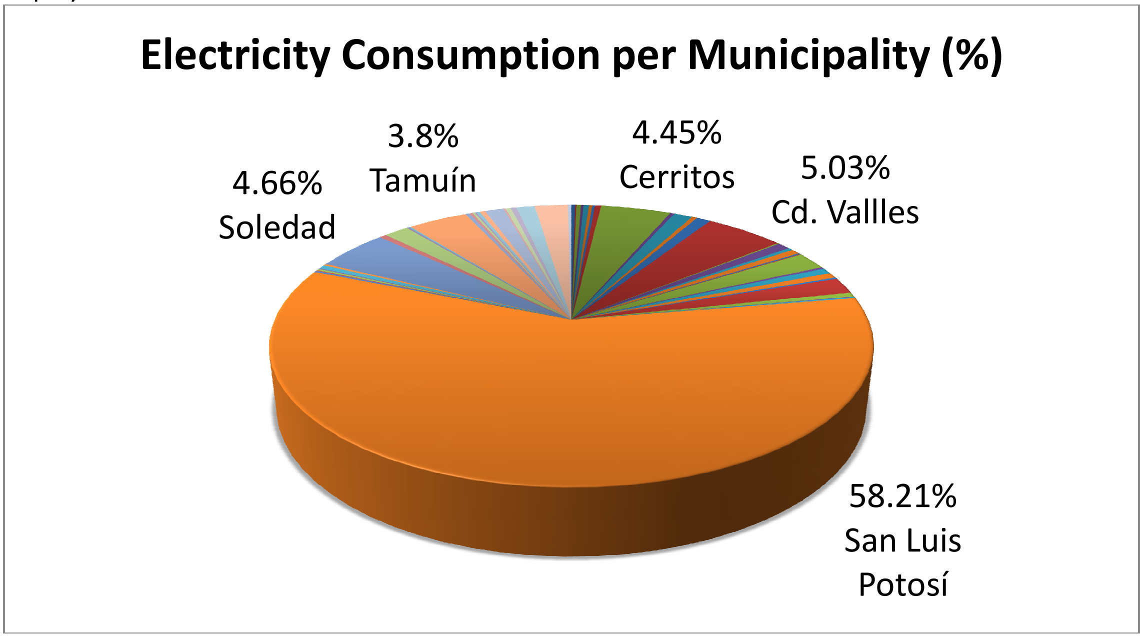
Also to be taken into consideration is the fact that, according to the last census done by INEGI in 2010, roughly 74% of the houses in San Luis Potosí and Soledad are owned by their inhabitants. This figure is important given that the owner of a house would be more motivated to invest on their property.

3. Solution proposal: Solar pumping/disinfection

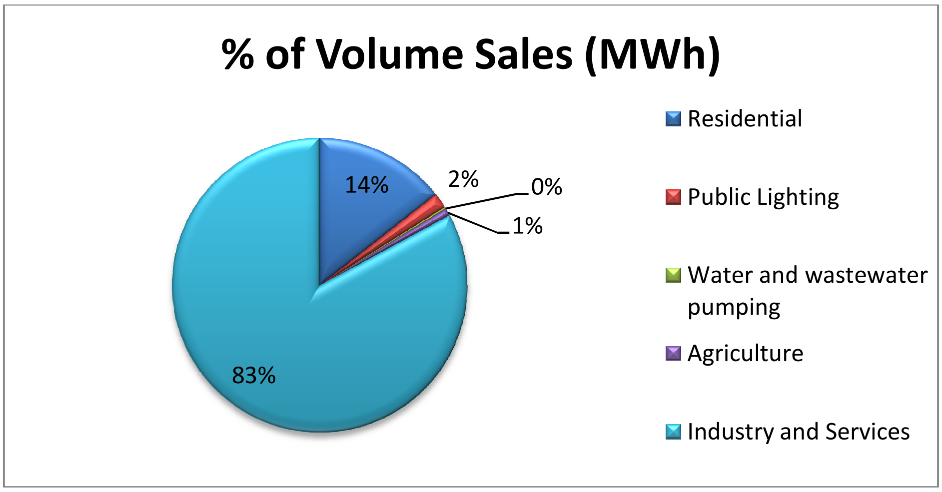
Justification for addressing the energy needs derived from pumping and disinfecting:

The City of San Luis Potosí is by far the biggest most important city of the state in economical, industrial and population terms. As such it consumes approximately 58.21% of the total electricity production of the state which according to the most recent census amounts 4,636,915 MWh (INEGI, 2011). Furthermore, in Soledad and San Luis Potosí 14% of that consumption is done by the residential sector totaling 420,386 MWh.

Graph 20: Electricity consumption per municipality in the state of San Luis Potosí. Source: Own display. INEGI 2011.



Graph 21: % of Electricity Consumption (MWh) per type of service. Source: Own display. INEGI, 2011.



Taking into account the numbers mentioned in the introduction about the solar pumping needs which are:

- INTERAPAS estimates that around 90% of the households that receive water from the public network have the cistern/pump-tank infrastructure.
- The actual available pumps have typically ½ HP power capacity (373 W).
- They are able to pump a maximum flow of 40 to 90 lt/min of water, depending on the kind of pump being used.

And additionally, taking into account the last data from the 2010 census:

- An average of 4 persons per house.
- It has been estimated that around 244,418 households count with electricity and water supply from the network, which means almost the same amount of pumps (90%).
- The minimum amount of water for every person every day is 100 lt/person/day according to the World Health Organization (WHO, 2003)

It can be estimated that a potential minimum of 13,7 MWh/day are used only in pumping the water from the first storage to the second. However, if we take into account that CONAGUA estimates a consumption of 290 lt/person/day (CONAGUA, 2010) the number goes to a theoretical maximum of 39.66 MWh/day. This last figure represents approximately 4.2% of the residential sector consumption.

Furthermore, new residential developments are required by INTERAPAS to assure the water supply for the new homes. For these new developments, depending on the number of houses, either an elevated tank or a "variable speed" system (higher capacity) is implemented. The first one has an obvious need for pressure that can either come from the public network or from an extra pump. The second option consists of a buffer cistern that holds large quantities of water and an array of electrical pumps that start when more pressure is needed (they aim to keep a constant 2 bar of pressure in the pipes). Both of these strategies could also work taking advantage of solar energy.

Proposed Solution

In order to address the problems described above which are:

- The energy need derived from storing and pumping water at each house.
- Necessary energy to secure the water quality.
- Dominance of conventional fossil fuel electricity generating facilities.

A Photovoltaic installation is proposed consisting of:

- Fixed solar modules mounted on the roofs of the houses
- Inverter
- Pump
- Disinfection unit
- Net meter
    - Interconnection to the grid.

Justification for the proposed solution:

The use of renewable technologies to fulfill the needs of the city, even the small ones brings the common advantages:

- No emissions or contamination of any sort.
- Independence from fuels and other forms of powering.
- Very little or no noise generation.

In the case of solar panels and pumps:

- Simplicity of operation and maintenance.
- Resource abundance.

The main disadvantage of implementing the solar PV technology is that a high initial investment is required. However, solar modules have experienced a rapid decrease in price throughout the decade, as shown on the following figure, making the initial capital cost decrease as well. A trend that will most probably continue and that will make solar PV technologies feasible in more markets.

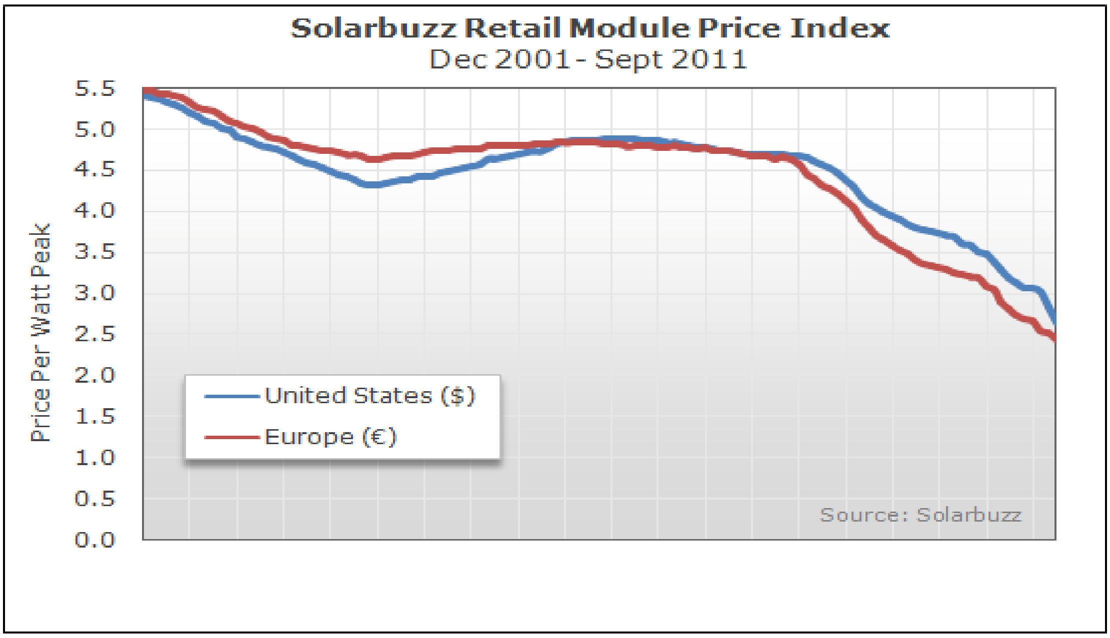


Fig. 4: Retail Module Price Index. Solarbuzz, 2011.

The same trend seems to be present in solar electricity prices. The following figure shows indexes of grid-connected solar-system cost in price per kilowatt hour (after financing). These indexes are based on the Solarbuzz solar module retail price survey and draw exclusively on module prices in the high power band exclusively (> 125 Watts). They include full system integration and installation costs.

Solar Electricity Sunny and Cloudy in US cents per kWh		
Residential Installed System	$14,125	-1.1%
Sunny Climate	29.53	-1.0%
Cloudy Climate	64.96	-1.1%
Commercial Installed System	$253,761	-1.3%
Sunny Climate	19.97	-1.4%
Cloudy Climate	43.93	-1.4%
Industrial Installed System	$1,843,101	-1.3%
Sunny Climate	15.56	-1.5%
Cloudy Climate	34.24	-1.4%

Fig. 5: Solar electricity index prices. Solarbuzz, 2011

The pumping operation is most needed during the day when the washing, cooking and bathing activities are performed. This means that the energy resource is most abundant during the hours that it is most needed. It also means that there will be an energy saving during the peak hours, helping significantly to the reduction of greenhouse emissions and the use of fossil fuels, thus reducing the future cost of electricity.

The following option was taken into account for the design of the system:

- The possibility to operate the existing the existing pumps with the DC current provided by the solar panel (addition of an inverter).

Since the actual pumps use AC current, the PV system is better suited to be connected to the grid and use the actual electrical installation of the houses. With the addition of the installation of a two way meter, the system would be allowed to feed the extra energy produced using the benefits of the Net Metering scheme.

Even though it is claimed that the water from the public network is 100% treated with some kind of disinfection method (CONAGUA, 2010), in the practice this is not always the case. Disinfecting the water that is stored in the cisterns would represent a great improvement not only because the water would reach the users clean but also because the need to continually clean the cisterns and the roof tank would be significantly lowered. Most of the times, proper cleaning and maintenance of these storages are not performed with the frequency required or are not even performed at all.

For the part of disinfection, two technologies have been chosen to be evaluated:

- Ultraviolet Lamps (UV)
- Anoxic Oxidation (AO)

Table 10: Disinfection Methods Comparison. AUTARCON, 2010.

	Thermal Treatment	UV	AO
Disinfection efficiency			
Bacteria	++	++	++
Virus	++	++	+
Protozoa	++	+	+
Removal of Particulate Matter	NO	NO	YES
Discoloration	MEDIUM/HIGH	LOW	HIGH
Residual Disinfectant	**NO**	**NO**	**YES**
Maintenance Cost	VERY LOW	HIGH	LOW
Investment Cost	VERY LOW	HIGH	HIGH
Energy Consumption	**VERY HIGH**	**HIGH**	**LOW**
Running Costs	VERY HIGH	LOW	LOW

Solar pumping / pumping / photovoltaics

I. Technical principles

Photovoltaics:

Photovoltaic (PV) panels consist of an array of photovoltaic cells most commonly made out of silicon that produce electricity from the solar radiation using the photoelectric effect. These cells, also when arranged as panels, consist of a solid structure with no moving parts thus bringing simplicity to the installation and operation of photovoltaic systems. The panels work well in cold or hot weather and are so reliable that most manufacturers offer a 20- 25 year warranty on solar modules.

"Three key elements in a solar cell form the basis of its manufacturing technology. The first is the semiconductor, which absorbs light and converts it into electron-hole pairs. The second is the semiconductor junction, which separates the photo-generated carriers (electrons and holes), and the third is the contacts on the front and back of the cell that allow the current to flow to the external circuit. The two main categories of technology are defined by the choice of the semiconductor: either crystalline silicon in a wafer form or thin films of other materials.

Crystalline Silicon Solar Cells – Market Share 80-90%

Historically, crystalline silicon (c-Si) has been used as the light-absorbing semiconductor in most solar cells, even though it is a relatively poor absorber of light and requires a considerable thickness (several hundred microns) of material. Nevertheless, it has proved convenient because it yields stable solar cells with good efficiencies (15-17%, half to two-thirds of the theoretical maximum) and uses process technology developed from the huge knowledge base of the microelectronics industry.

Two types of crystalline silicon are used in the industry. The first is monocrystalline, produced by slicing wafers (up to 150 mm diameter and 200 microns thick) from a high-purity single crystal boule. The second is polycrystalline silicon, made by sawing a cast block of silicon first into bars and then into wafers. The main trend in crystalline silicon cell manufacture involves a move toward polycrystalline technology.

For both mono and polycrystalline Si, a semiconductor junction is formed by diffusing phosphorus into the top surface of the silicon wafer. Screen-printed contacts are applied to the front and rear of the cell, with the front contact pattern specially designed to allow maximum light exposure of the Si material with minimum electrical losses in the cell." (Extracted from Solarbuzz "Technologies" webpage, 2011).

Thin Film Solar Cells – Market Share: 10-20%

In order to make less expensive solar cells strong light absorber materials are being used as an alternative way of building solar cells. These materials only need to be about 1 micron thick, so materials costs can be significantly reduced.

"The most common materials used are amorphous silicon (a-Si), or the polycrystalline materials: cadmium telluride (CdTe), copper indium (gallium), and diselenide (CIS or CIGS). Each of these materials can be deposited over a large area onto substrates of about 1 meter, and hence can be used for high volume manufacturing. The thin film semiconductor layers are deposited onto either coated glass or a stainless steel sheet. A transparent conducting oxide layer forms the front electrical contact of the cell, and a metal layer forms the rear contact.

Amorphous silicon is the most developed of the complex thin film technologies. In its simplest form, the cell structure has a single sequence of p-i-n layers. Such cells suffer from significant degradation in their power output (in the range of 15-35%) when exposed to the sun.

Thin film cells are laminated to produce a weather-resistant and environmentally-robust module. Although they are less efficient, thin films are potentially cheaper than c-Si because of their lower materials costs and larger substrate." (Extracted from Solarbuzz "Technologies" webpage, 2011).

In Mexico, the market of photovoltaic energy is only beginning. The majority of the installed capacity used to be found on off-grid domestic and non-domestic applications (like agriculture). In the last years the number of grid connected installations has significantly increased: only in 2010, 5,587 kW of solar PV power capacity that included the first centralized 1MW installations (inaugurated at the end of 2010), reaching a total of 30,606 kW. This brought solar energy from a 0.057% share of electricity production in Mexico to a 0.44%.

Table 11: PV power installed during calendar year 2010. Source: EIA. National Survey Report of PV Power Applications in Mexico 2010. Huacuz, Jorge; Agredano, Jaime. 2011.

Sub-market/ application	off-grid domestic	off-grid non-domestic	grid-connected distributed	grid-connected centralized	Total
PV power installed in 2010 (kW)	1022	620	2945	1000	5587

Even with the number going up, no funds has been allocated to promote PV production, installations, or enhanced feed-in tariffs. The budget for PV projects research during 2010 was around twenty million Mexican Pesos, and was provided by Federal government agencies. No

Regarding the production of PV modules and additional equipment, the most common PV modules in México are polycrystalline. Two national companies: ERDM and Solartec, assemble currently PV modules and sell them in the national market, one of which produced in 2010, 2MW of solar modules. Three international companies: Kyocera, Sanyo and UNISOLAR, assemble PV modules in Mexico and export them to be sold in the international market. UNISOLAR assembles thin film solar modules. No national production of Grid Connected PV Inverters.

Analyzing specific cases of 1-2 kW roof mounted systems in Mexico, it has been possible to determine that for 2010 the average price for a grid connected system is of MX$80,50 per W_p. This is a significant improvement given that the same figure for 2008 was MX$138,60 per W_p.

Solar pumping / pumping:
Solar pumping tends to be treated as a separate kind of photovoltaic system. This is mainly because it is normally used in projects at remote areas, where no grid connection is available and that aim at providing the needed amount of water to households of small isolated populations and other agricultural activities instead of electricity production. Solar pumps are also used, among other things, for water supply in private homes. A water pump can be powered by its own PV array, or by a main system that powers lights and appliances. Normally, an elevated storage tank or a second pump called a booster pump may be used to provide water pressure to the house's water pipes. For the city, this elevated tank can have a high capacity to serve several households or apartment buildings (bigger pump) or a low capacity (400 – 800 lt) to serve an individual home.

Solar water pumps are specially designed to utilize DC electric power from photovoltaic panels given that they must work during low light and reduced power conditions without stalling or overheating. However, the models commonly used in a city with individual household pumping needs are designed to use the AC power from the electricity grid. Solar powered and conventional centrifugal pumps are available. They are used in higher volume, low head pressure applications but the solar powered pumps are very inefficient at low RPM and require more power to operate than positive displacement pumps. The low efficiency and high power requirements of centrifugal pumps translates into very high cost systems when compared with the low power and higher efficiencies of positive displacement pumps (commonly peripheral pumps in San Luis Potosí). In the city of San Luis Potosí the pumps used in the households are mostly external (surface) centrifugal pumps, some submersible centrifugal pumps and peripheral pumps. Some commonly found examples of this kind of equipment, manufacturers and suppliers are:

- The Truper ½ HP peripheral pump operates at 120V/60 Hz with a maximum flow of 40 lt/min to a maximum height of 40 m and from a maximum depth of 8m.

- Centrifugal pump models of the same characteristics can pump a maximum flow of 80 to 90 lt/min of water to a maximum height of 23 meters, e.g. Truper and Rotoplas ½ HP centrifugal pumps.
- Several other manufacturers like Grundfos offer additional options, some that surpass these numbers and addition security measures like self priming and more sophisticated electronics at a higher cost but also higher energy efficiency, e.g. JP and MQ models (higher power) and some others to adapt to different energy consumption profiles e.g. CM models.

Positive displacement pumps have an expanding cavity on the suction side and a decreasing cavity on the discharge side. Liquid flows into the pumps as the cavity on the suction side expands and the liquid flows out of the discharge as the cavity collapses. The volume is constant given each cycle of operation. Positive Displacement Pumps, unlike centrifugal pumps, will produce the same flow (constant flow) at a given speed (RPM) no matter the discharge pressure.

A centrifugal pump converts the input power to kinetic energy in the liquid by accelerating the liquid by a revolving device - an impeller. The most common type is the volute pump. Fluid enters the pump through the eye of the impeller which rotates at high speed. The fluid is accelerated radially outward from the pump chasing. A vacuum is created at the impellers eye that continuously draws more fluid into the pump.

The energy created by the pump is kinetic energy according the Bernoulli Equation. The energy transferred to the liquid corresponds to the velocity at the edge or vane tip of the impeller. Faster revolutions of the impeller or bigger impeller sizes mean that the velocity of the liquid's energy transferred to the liquid will also be higher. Centrifugal pumps are constant head machines (not constant pressure). A surface pump is one that is mounted at ground level. A submersible pump is one that is lowered into the water.

If the PV system is not connected to the electricity grid, the main parts include the solar module, the battery (for energy storage), the battery regulator (also known as a charge controller), attachment structure and associated connections, and wiring. A pump charge controller (current booster) is an electronic device used with most solar pumps. It enables the solar pumps to operate more efficiently in low sunlight conditions and provides input points for float switches and water level sensors. They are considered a necessary part of a well designed solar pump system in the case that the pump is chosen to be operated directly with the solar panel.

If the PV system is connected to the electricity grid, the main parts include the solar module, an inverter (which turns direct current power to alternating current), wiring, and support structures. Additionally, the acquisition of a bidirectional meter (net meter) should be considered.

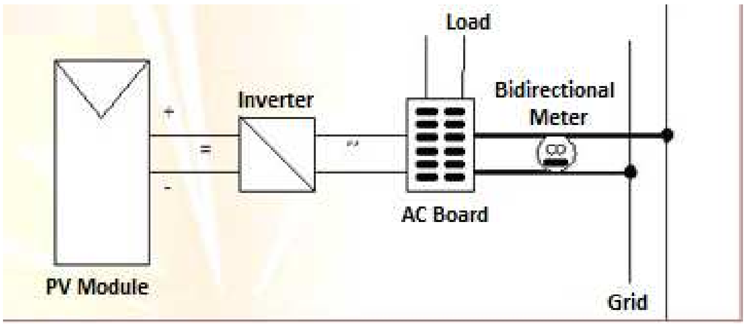


Fig. 6: Grid connected system schematic. Adapted from: Alternativa Energética 2009.

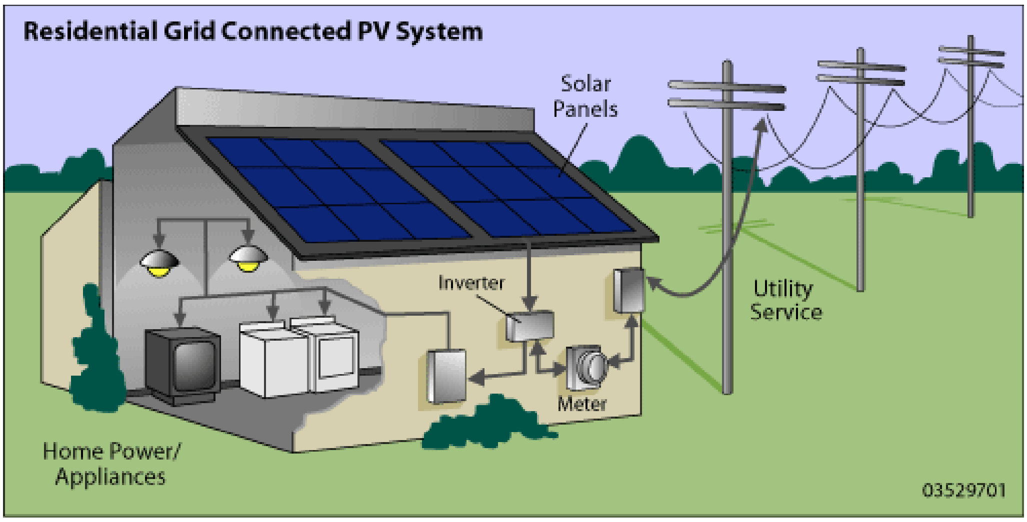


Fig. 7: Example of grid connected system. Source: Energy Savers. U.S. Department of Energy, 2011.

A solar tracker may be used to tilt the PV array as the sun moves across the sky. This increases daily energy gain by as much as 55%. With more hours of peak sun, a smaller pump and power system may be used, thus reducing overall cost. Tracking systems do not work well in windy climates and add cost and complexity to the system given that there will be more moving parts in it that will increase the maintenance need. The wind conditions in the city of San Luis Potosí could be enough to discourage the addition of solar tracking devices to the system.

Solar pumps are less expensive than fossil fuel and other renewable alternatives such as windmills and are easier to install and maintain. They provide a consistent supply of water and can be installed on the roofs or high structures to improve electricity production. They are especially adaptable for houses and other buildings in the city where other kinds of renewable alternatives are impractical. The PV array may be placed some distance away from the pump itself, even several hundred meters away, providing the flexibility needed for houses with cisterns. Solar pump installations tend to be most competitive if designed for small applications.

II. Costs

Since it is considered that most of the households already have a pump that uses the AC current from the grid, the grid connected installation is considered. The cost of the pump can then be subtracted from the initial investment. Sample costs of the common type of pumps are also provided since they are significantly lower than the cost of a solar pump. As mentioned above, since the grid is available to virtually all households, further savings can be achieved when delivering the extra energy to the grid.

- Sample system:
  - Pump: sample retail prices of ½ HP centrifugal pumps are
    - $1700.00 MXP for peripheral pumps.
    - $1900.00 MXP for centrifugal external pumps.
  - Inverter: sample prices for DC 12 V input voltage equipment

Table12: Inverter sample prices and capacities. Source: Own display with data from ERDM, 2011.

Model #	Enviro-techs 200W	STECA SOLARIX SINUS 550I-L60	SMA Solar SUNNY BOY SB 700 US	SMA Solar SUNNY BOY SB 1100/1200	FRONIUS IG-2000	STECA GRID 2000 = SLAVE	FRONIUS IG-3000	FRONIUS IG-4000
Price (US$)	$199,99	556,67	1.154,13	1.188,36	1.825,35	1.239,70	2.140,40	2.958,05
Power (W)	200	550	700	1100/1200	2000	2000	3000	4000

  - Solar modules:
    - 2009: Typical price MX$67,50 MXP/$W_p$. Best price $54,00 MXP/$W_p$.
    - 2010*: Typical price MX$43.33 MXP/$W_p$. Best price MX$28.47,00 MXP/W_p.

* The remarkable drop in prices was mainly because of high inventory levels of PV modules in the international market and the favorable exchange rate between the Mexican Peso and the US Dollar.

Another approach to calculate the cost is taking the 2010 price of MX$80,50 per W_p for grid connected PV systems and addition the rest of the costs.

III. Energy Requirements

½ HP = 373 W per pump

IV. Advantages/Disadvantages

Advantages:

- Unattended operation
- Low maintenance
- Easy installation
- Long life

Disadvantages:

- High capital costs
- Water storage is required for cloudy periods
- Repairs often require skilled technicians

Ultraviolet (UV) disinfection systems

I. Generalities

Ultraviolet disinfection is a means of killing or rendering harmless microorganisms present in water and other environments. These microorganisms can range from bacteria and viruses to algae and protozoa. The ultra-violet rays, similar to the sun's UV but stronger, alter the nucleic acid (DNA) of viruses, bacteria, molds or parasites, so that they cannot reproduce and are considered neutralized.

An UV system is comprised of the following:

- UV light source called a "lamp" or "bulb".
    - Class B UV systems typically deliver a dose of 16 mJ/cm^2, and are normally chosen by people on municipally treated water or private water supplies unlikely to be unsafe.
    - Class A systems deliver a dose of 30 to 40 mj/cm^2, enough to be used on water supplies which are not considered safe. A dose of 40 mj/cm^2 is widely recognized by health departments as sufficient for this type of application.
- Protective transparent housing for bulb — usually quartz
- Power supply
- A water chamber for the water to travel through for treatment
- Filters for pre- and/or post-treatment
- For larger Class A systems, there may be a bulb replacement indicator light and/or alarm

UV disinfection is used in air and water purification, sewage treatment protection of food and beverages, and many other disinfection and sterilization applications. UV systems alone are neither intended to treat water that is visually contaminated nor intended to convert wastewater to safe, microbiologically potable water.

II. Costs

Sample equipment with flow capacities of up to 55 lt/min, range from US$200,00 – US$500,00. The US$500,00 equipment is better suited for the conditions in SLP.

- UV lamp replacement approximately every year (9000 hours of continuous operation).
    - Extra yearly cost of: US$80,00

Filter prices vary from US$100,00 – US$200,00

- 10 – 5 micron
- 38 – 76 lt/min
- 4 – 8 months recommended filter replacement
- 10 years recommended filter cartridge replacement

A yearly overall average of US$150,00 cost of spare parts (O&M) will be considered.

III. Energy Requirements

Sample equipment requires from 45 – 60 W of power.

IV. Advantages/Disadvantages

The use of UV light as means of water disinfection has been a proven process for many years. The benefit of the UV disinfection process is that it does not use any chemicals so it does not change the water chemistry. Additionally appears to be effective against bacteria, viruses, mold spores, fungi, oocysts (cryptospridium and giardia), and other microbiological contaminants. A major advantage of UV treatment is that it is capable of disinfecting water faster than chlorine without cumbersome retention tanks and also without harmful chemicals. There is also a wide range of commercial equipment available that can handle flow rates from 40 – 200 lt/min, so disinfection could be performed while pumping water from a ground level cistern to the elevated tank in the city of San Luis Potosí.

A disadvantage of this disinfection method is that residual disinfection is not possible. This means that any contamination that could happen in the distribution system will go untreated. For the case of San Luis Potosí, the water stays stored overnight in the roof tanks, where it may become contaminated by bacteria, pathogens, etc.

Another disadvantage is that pre-filtration is required to maintain effectiveness given that sediment and other contaminants can create a "shadow" which prevents the UV rays from reaching the harmful microorganisms. UV disinfection equipment also needs several spare part replacements.

Finally, a constraint of the operation of these devices is that the UV lamp needs to operate for several minutes to reach full UV output. Excessive on/off cycling of the UV lamp greatly reduces its life expectancy. Additionally, the continuous operation of the unit minimizes the chance that untreated water will be consumed. Since the actual pumps in San Luis Potosí would take approximately 10 – 15 minutes to fill the second storage tank, an operative measure is needed.

Anoxic Oxidation (AO) disinfection systems

I. Generalities

The use of chlorine as a disinfectant is commonly accepted worldwide. Chlorination is a popular choice because of its residual disinfection characteristics. Its effectiveness is very simple to test; it is only needed to measure the residual chlorine at the point of consumption to ensure proper disinfection.

Anoxic oxidation systems use electrolytic cells to produce chlorine. The basic operating principle involves electrolyzing a concentrated brine solution which generates chlorine at the anode and hydrogen together with sodium hydroxide at the cathode. The hydrogen is allowed to vent whereas the chlorine is allowed to remain in contact with the electrolyte thus forming sodium hypochlorite. Basically, the formation of sodium hypochlorite occurs as follows:

Salt + Water + Energy → Sodium Hypochlorite + Hydrogen Gas

With Anoxic Oxidation Systems the water is disinfected via filtration and the production of the minimal required quantity of chlorine. No chemicals have to be added into the water. There are two kinds of systems which can either use common salt (NaCl) dissolved (added) in the water or get the chlorine from a separate tank filled with salt solution to produce the desired amount of chlorine. When the second option is used the solution is commonly called “brine”. The salt brine solution together with the electrolytic cell generates a solution of primarily sodium hypochlorous (chlorine) acid.

II. Costs

Sample device prices that go from US$450 – US$750.00 are considered.
A small extra cost of salt should also be considered.

III. Energy Requirements

Sample device power specifications go from 100 – 200 W. An average of 150 W will be used for the simulation.

Even though the UV process normally requires more energy than the AO process, no commercial equipment was found that specifically serves as a water disinfection unit for a household. The smallest equipment found, used for pools, will be used for the simulation.

IV. Advantages/Disadvantages

Probably the biggest advantage of this disinfection method is that the chlorine remains in the water providing a continuous disinfection of water storage in tanks and even from one storage tank to another. The chlorine is produced from ions naturally present in the water, so no chemicals are added.

The filter, pump and electrolytic cell can be easily cleaned with a soft brush and if necessary a vinegar or lemon juice which are certainly available in the city. Depending on the place and intensity of use this maintenance would have to be performed every one to three months only.

Some disadvantages of this technology are that it is still not commonly applied to individual houses. Commercial equipment is already being used to supply isolated communities. A system that consists in PV panels, electrolytic cell, control unit, flow meter, filter, pump, tank and structure has recently been launched and has already been deployed to provide poor isolated communities with clean drinking water. The cost of the system is approximately €10.000,00.

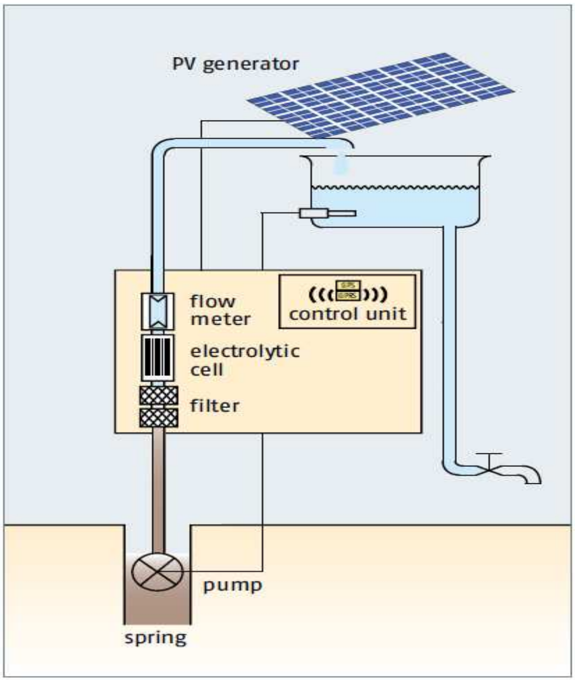


Fig. 8: SuMeWa system developed in Germany. AUTARCON, 2011.

Smaller equipment versions are commonly used to maintain pools.

Also, the production flow of clean water in such systems is very slow (4 – 10 lt/min) compared to the flow of the pumps already used in San Luis Potosí (40 – 80 lt/min). For this reason, the anoxic oxidation system would need to be installed on the buffer cistern rather than between the pump and the roof storage tank. This way, the system will be able to handle the flow and would disinfect both storages. Attention should be taken to how the device would be protected from low flows or flow stops from the public water supply network.

Other disadvantages specific to chlorination are undesirable tastes and odors, the requirement of additional equipment (such as tanks) to guarantee proper contact time, and extra time to monitor and ensure proper residual concentration level. There is also the concern about the possible disinfection by-products. Chlorine can also react with other organic impurities present in the water and produce trihalomethanes (TMH's) that are listed as possible human carcinogens.

4 System Design

The following parameters will be used:

Annual O&M costs of PV system:	0.8%
Annual price increase - electricity tariffs:	8%
VAT (Mex. IVA):	16%

For the sizing of the PV module a value of 1750 kWh / kWp installed was used and an adjustment factor of 1,2. As a rule of thumb, it will be considered that the price of the PV module is 40% of the total cost (PV module price + rack, wiring, etc.).

An exchange rate of MX$12,40 / US$ is used for the equivalences.

Requirements (for the city of San Luis Potosí)

Fixed roof mounted modules with a tilt angle equal to the latitude (22°) of the place and facing the equator (south) is used.

Summarizing:

- Average water requirement: 1160 lt/day
- Pumping capacity: 40 lt/min – 80 lt/min
    - Pump power: 373 W
    - Pump Cost (optional): US$150,00

A cost of MX$1.000,00 - $2.500,00 is considered within the initial investment for the bidirectional (net) meter as well as the installation costs.

UV and AO systems of the same cost will be used. Their respective characteristics are listed below.

- UV System
    - Sizing of the equipment
        - UV unit power 60 W
        - Flow Range 55 lt/min (MAX) – Adjusted to 50 lt/min

        - PV Panel 50.6 W_p → Scaled to 60 W_p
        - Inverter 200 W

    - Cost Analysis
        - UV Unit US$500,00 10 year life expectancy
        - O&M US$150,00 yearly

        - PV Panel US$117,00 1x60 Wp @ US$117,00 each. 25 years l.e.
        - Inverter US$199,99 15 year life expectancy
        - Other parts US$238.75 rack, cables, etc.

        - Total Cost PV US$555,74
        - Total Cost US$1.055,74

        - Total Cost +pump US$1.205,74
        - PV System O&M US$200,00 yearly total

- AO System
    - Sizing of the equipment
        - AO Unit power 150 W
        - Flow Range 7 lt/min

        - PV Panel 140 W_p → Scaled to 150 W_p
        - Inverter 200 W

    - Cost Analysis
        - AO Unit US$500,00 20 year (cell life expectancy)
        - O&M $0,00

        - PV Panel US$292.5 3x50 Wp @ US$97,50 each. 25 years l.e.
        - Inverter US$199,99 15 year life expectancy
        - Other parts US$238.75 rack, cables, etc.

        - Total Cost PV US$731,25
        - Total Cost US$1.231,25

        - Total Cost+Pump US$1.381,25
        - PV System O&M US$98,5 yearly total

5 Cost Adjustments:

5.1 Energy Savings & Production

The energy production of the systems was simulated using the HOMER software. Presented here are the main results of each report. The complete reports are included in the Annex section. All money amounts are in US$.

Energy costs savings under current conditions

- AO System cost savings under current conditions

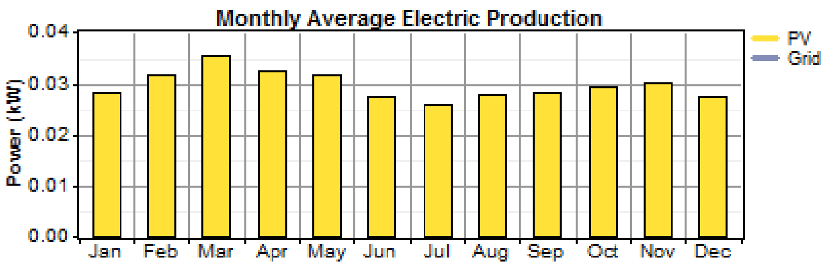
Estimated energy feed: 260 kWh/year.

System architecture

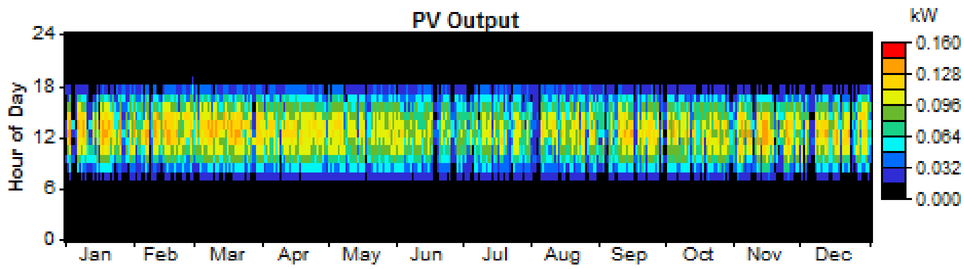
PV Array	0.15 kW
Grid	1,000 kW
Inverter	0.2 kW
Rectifier	0.2 kW

Electrical

Component	Production (kWh/yr)	Fraction
PV array	260	100%
Total	260	100%



PV



Monthly delivered energy.

Month	Energy Purchased	Energy Sold	Net Purchases	Peak Demand	Energy Charge	Demand Charge
	(kWh)	(kWh)	(kWh)	(kW)	($)	($)
Jan	0	19	-19	0	-1	0
Feb	0	19	-19	0	-1	0
Mar	0	24	-24	0	-2	0
Apr	0	21	-21	0	-1	0
May	0	22	-22	0	-2	0
Jun	0	18	-18	0	-1	0
Jul	0	17	-17	0	-1	0
Aug	0	19	-19	0	-1	0
Sep	0	18	-18	0	-1	0
Oct	0	20	-20	0	-1	0
Nov	0	20	-20	0	-1	0
Dec	0	19	-19	0	-1	0
Annual	0	236	-236	0	-17	0

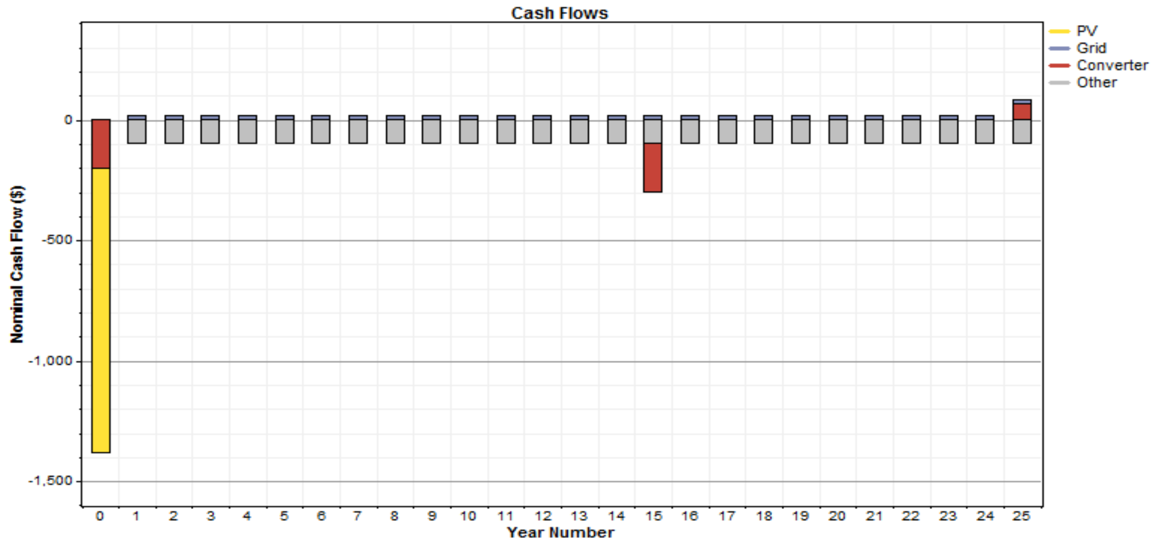
The investment was simulated using four levels of consumption: Basic, intermediate, DAC 1 and DAC 2:

- Basic Tariff – Consumption up o 150 kWh/month

The summary shows that the system is not a feasible investment with the current conditions given that only negative cash rates are achieved, mainly due to the relatively high O&M costs. The total energy produced is 260 kWh/year. Since the energy saved would have been charged at a rate of US$0,07/kWh, a total energy cost saving of US$17,00/year could be achieved.

Cost Savings & production summary

Total net present cost	$ 2,310
Levelized cost of energy	$ 0.916/kWh
Operating cost	$ 86.9/yr

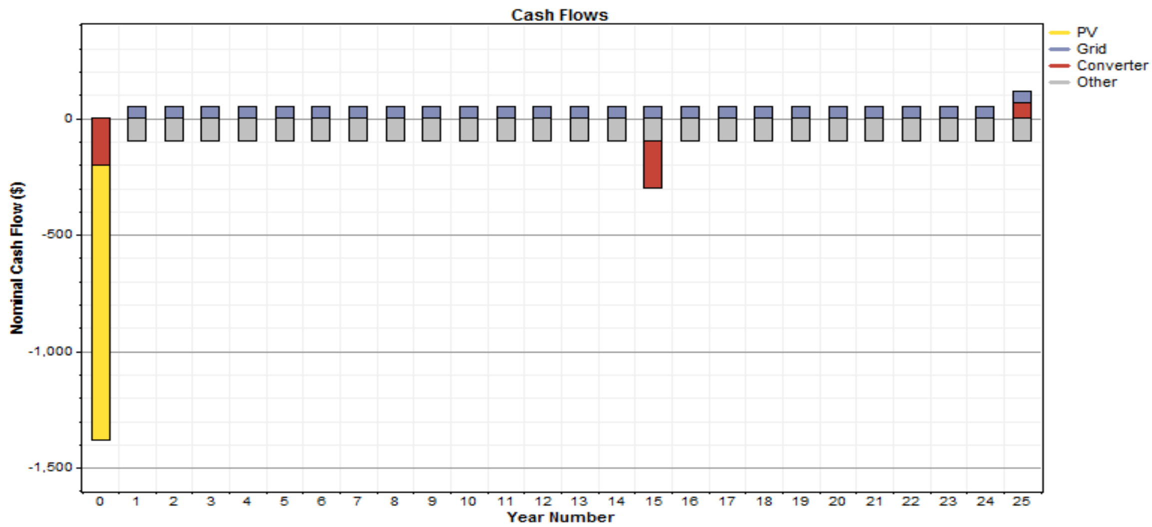


- Intermediate Tariff – Consumption up to 249 kWh/month

The summary shows that the system is not a feasible investment with the current conditions given that only negative cash rates are achieved, mainly due to the relatively high O&M costs. Once again, the total energy produced is 260 kWh/year. Since the energy saved would have been charged at a rate of US$0,205/kWh, a total energy cost saving of US$48,00/year could be achieved.

Cost Savings & production summary

Total net present cost	$ 1,969
Levelized cost of energy	$ 0.781/kWh
Operating cost	$ 55/yr

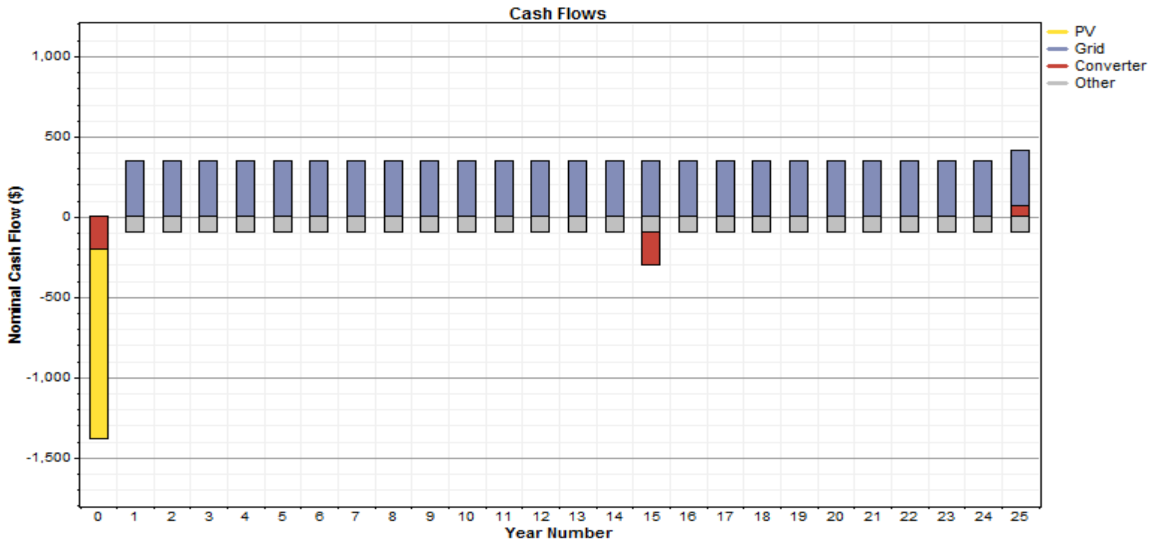


- DAC Tariff – Consumption of 250 kWh/month

The summary shows that the investment is already feasible. In this case, the system helps to go from the unsubsidized DAC tariff back to the subsidized scheme of the intermediate tariff. This means that an energy cost saving of US$345,00/year can be achieved, given that the saved energy would have been charged at a rate of US$1,461/kWh. The investment would be fully paid off after approximately 6.5 years.

Cost Savings & production summary

Total net present cost	$ -1,197
Levelized cost of energy	$ -0.475/kWh
Operating cost	$ -242/yr

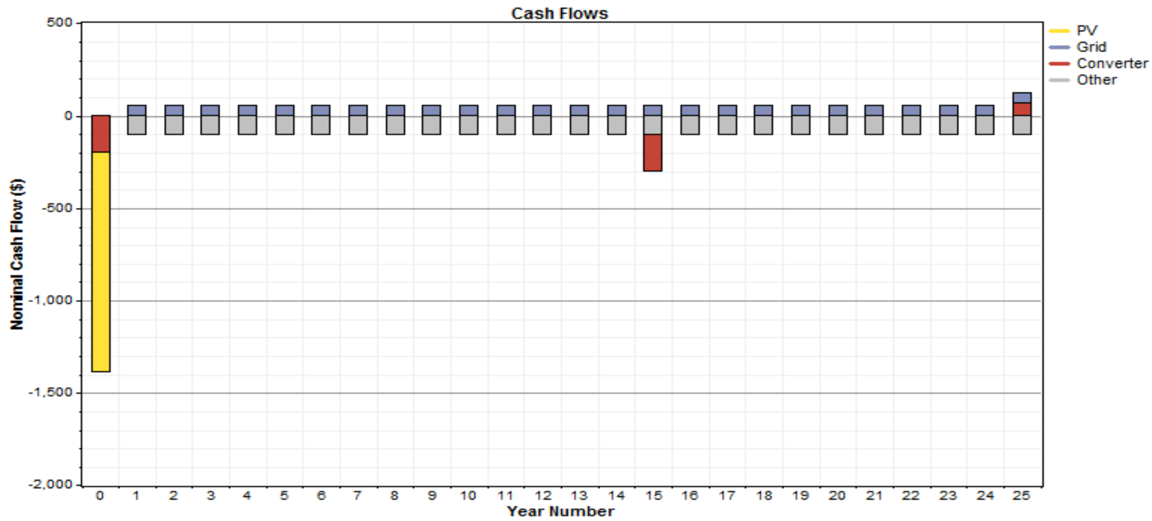


- DAC Tariff – Consumption of 300 kWh/month

For this second range of DAC tariff the system is not a feasible investment. The amount of energy delivered by the PV system does not yield a significant price difference even though it is in the unsubsidized range and is not enough to reach consumption amounts with subsidy schemes. The energy saved would have been charged at a rate of US$0,25/kWh, a total energy cost saving of US$48,00/year is achieved.

Cost Savings & production summary

Total net present cost	$ 1,856
Levelized cost of energy	$ 0.736/kWh
Operating cost	$ 44.4/yr



- UV System cost savings under current conditions

Given that the proposed UV system would deliver a smaller amount of energy to the grid, the simulations do not need to be done. Even though the O&M costs of such systems are greater than the ones of AO systems, if used as well by DAC tariff users to enter a more subsidized scheme it would bring the same benefits though it may not be as feasible for potential Intermediate tariff users. In order to expand the investment window of the system, a higher capacity solar module should be considered

- Comparison to world prices:

Currently the price trend of solar energy generated electricity for residential use is a small but steady decrease of roughly 1%. Prices are on average:
US$0,2953 / kWh sunny weather
US$0,6496 / kWh cloudy weather

Compared to the prices calculated above of around US$0,70 – $0,90 Mexico appears to be within range.

5.2 Further savings

If the system were to be used, the energy savings (in MWh) could amount to:

If DAC users (3%) invested in the system:
Minimum of: 1716,4 MWh/year (4,7 MWh/day)
0,50 % of Residential consumption

If all users invested in the system:
Approx: 57 213 MWh/year (156,75 MWh/day)
16,6 % of Residential consumption

These figures would be equivalent to approximately the monthly amount of fossil fuels shown in table 13, calculated from the monthly average use of fossil fuels for the electricity generation reported by the Energy Ministry (SENER):

Table 13: Monthly fossil fuel saving scenarios. Source: Own Display based on data from SIE, 2010 - 2011.

	Unit	DAC	ALL
Fuel Oil	lt	2093.9	69795.1
Diesel	lt	97.7	3255.7
Carbon	kg	3357.8	111926.6
Natural Gas	m^3	2331.9	77731.0

6 Investment Evaluation

Under current conditions

- Result discussion

Due to the elaborate scheme of subsidies applied to the conventional sources electricity, special considerations for an investment of this kind should be taken into account. Designing a system that provides a partial amount of the electricity requirement of a house and that at the same time brings the consumption from one tariff level to another is already a very good alternative for an investment. Furthermore, users of the DAC tariff could invest in systems that cover their whole requirement. UV systems can also become feasible with proper design. However, the higher need of maintenance and spare parts lowers the benefits from using such systems in conjunction with PV installations.

Under improved conditions

- Scenario 1 – 20% Equipment cost reduction

Proposed Ranges	Net present value (US$)	Feasibility
Basic	$1.372,00	No
Intermediate	$1.485,00	No
DAC1	-$1.682,00	Yes
DAC2	-$1.372,00	No

- Scenario 2 – 50% Equipment cost reduction

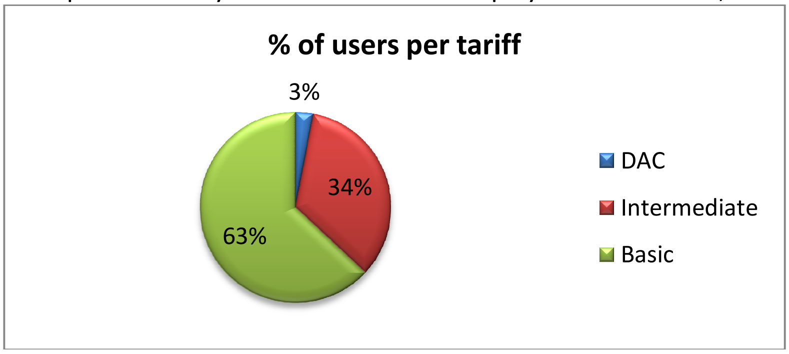
Proposed Ranges	Net present value (US$)	Feasibility
Basic	$611,00	No
Intermediate	$723,00	No
DAC1	-$2.443,00	Yes
DAC2	$610,00	No

- Result discussion

Even with a high reduction in equipment prices and O&M, the subsidy scheme keeps disrupting the potential markets for photovoltaics, being the only feasible solution to invest in a system that would allow a domestic user to enter the mentioned scheme.

This limits the market for PV installations to only 3% of the users in the city plus an undefined percentage of the medium tariff users.

Graph 22: % of users per electricity tariff. Source: Own display. Data from CFE, 2011.



Conclusion

7. Final Result discussion

PV installations to cover part or the total electricity demand of residential users are already a possibility, clearly in the high consumption range. However, the subsidy policy scheme limits the market gravely, slowing down the deployment of these technologies and their growth in our country.

It is then recommended the application in the near future of more robust financing programs that specialize not only in rural off grid solar application but also on grid application in the cities, where the energy demand is higher and the opportunities for new technologies are better. It is also recommended that the subsidy scheme starts being modified in the near future to reflect the actual costs of the electricity. As a policy measure this could take a lot of time to be implemented so a less direct way to level the opportunities would be to create a subsidy scheme for the photovoltaic applications.

Another recommendation to decrease fossil fuel dependency of the country is to combine PV technologies with solar thermal ones. Solar thermal heaters have already been proven a feasible investment in Mexico and are widely available with local retailers in San Luis Potosí. The construction of house complexes that include already a solar thermal heater is being promoted by the government. A solar thermal heater can save from 50% to 75% of the gas used to heat water in a house. This results in that even though the investment in such a heater is considerably higher than investing in a conventional fossil fuel heater, the savings along with the much higher life expectancy of such equipments make it a real option. Solar technologies, which include solar thermal and passive measures, are a possible and sustainable alternative to reduce fossil fuel dependence of the country given the abundance of the resource.

Some other options to support the market penetration of photovoltaics are listed in the following table:

Table14: Support Measures for Photovoltaic Technologies. Source: INTERNATIONAL ENERGY AGENCY - National Survey Report of PV Power Applications in Mexico 2010.

Support measures	Explanation
Enhanced feed-in tariff:	an explicit monetary reward is provided for producing PV electricity; paid (usually by the electricity utility business) at a rate per kWh somewhat higher than the retail electricity rates being paid by the customer
Capital subsidies	direct financial subsidies aimed at tackling the up-front cost barrier, either for specific equipment or total installed PV system cost
Green electricity schemes	allows customers to purchase green electricity based on renewable energy from the electricity utility business, usually at a premium price
PV-specific green electricity schemes	allows customers to purchase green electricity based on PV electricity from the electricity utility business, usually at a premium price
Renewable portfolio standards (RPS)	a mandated requirement that the electricity utility business (often the electricity retailer) source a portion of their electricity supplies from renewable energies (usually characterized by a broad, least-cost approach favouring hydro, wind and biomass).
PV requirement in RPS	A mandated requirement that a portion of the RPS be met by PV electricity supplies (often called a set-aside)
Investment funds for PV	share offerings in private PV investment funds plus other schemes that focus on wealth creation and business success using PV as a vehicle to achieve these ends
Income tax credits	allows some or all expenses associated with PV installation to be deducted from taxable income streams
Net metering	in effect the system owner receives retail value for any excess electricity fed into the grid, as recorded by a bi-directional electricity meter and netted over the billing period
Net billing	the electricity taken from the grid and the electricity fed into the grid are tracked separately, and the electricity fed into the grid is valued at a given price
Commercial bank activities	includes activities such as preferential home mortgage terms for houses including PV systems and preferential green loans for the installation of PV systems
Activities of electricity utility businesses	includes 'green power' schemes allowing customers to purchase green electricity, operation of large-scale (utility-scale) PV plants, various PV ownership and financing options with select customers and PV electricity power purchase models
Sustainable building requirements	includes requirements on new building developments (residential and commercial) and also in some cases on properties for sale, where the PV may be included as one option for reducing the building's energy foot print or may be specifically mandated as an inclusion in the building development

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Annexes:

Annex 1: Electricity Service Figures for the city of San Luis Potosí and Soledad

Electricity service Users per municipality per type of service												
@ 31st of December 2009												
Municipality	Total	Residential	a/	Public Lighting	b/	Water and wastewater pumping	c/	Agriculture	d/	Industry and Services	e/
San Luis Potosí	270,702	228,867		4,440		62		240		37,093	
Soledad de Graciano Sánchez	83,646	75,278		1,126		14		254		6,974	
Total SLP+Soledad	354,348	304,145		5,566		76		494		44,067	
%		85.83%		1.57%		0.02%		0.14%		12.44%	

Electric Energy Sales Volume per municipality per type of service (MWh)											
2009											
Municipality	Total	Residential	a/	Public Lighting	b/	Water and wastewater pumping	c/	Agriculture	d/	Industry and Services	e/
San Luis Potosí	270,702	228,867		4,440		62		240		37,093	
Soledad de Graciano Sánchez	83,646	75,278		1,126		14		254		6,974	
Total SLP+Soledad	354,348	304,145		5,566		76		494		44,067	
		85.83%		1.57%		0.02%		0.14%		12.44%	

Value of Electric Energy Sales per municipality per type of service (Thousands of MX Pesos)												
2009												
Municipality	Total	Residential	a/	Public Lighting	b/	Water and wastewater pumping	c/	Agriculture	d/	Industry and Services	e/
San Luis Potosí	270,702	228,867		4,440		62		240		37,093	
Soledad de Graciano Sánchez	83,646	75,278		1,126		14		254		6,974	
Total SLP+Soledad	354,348	304,145		5,566		76		494		44,067	
		85.83%		1.57%		0.02%		0.14%		12.44%	

a/ Covers the tariffs: 1, 1A, 1B, 1C, 1D, 1E, 1F and DAC.
b/ Refers to tariff 5A.
c/ Refers to tariff 6.
d/ Covers the tariffs: 9, 9M, 9CU y 9N.
e/ Covers the tariffs: 2, 3, 7, O-M, H-M, H-MC, HS, HS-L, HT y H-TL.
Sources:
CFE, Dirección de Operación. Gerencia Divisional de Distribución Golfo Centro; Subgerencia Comercial.CFE, Dirección de Operación. Gerencia Divisional de Distribución Bajío; Subgerencia Comercial.

Annex 2: Reference prices in the US for solar pumping installations:

Sample prices of systems are:

- System (US): $5.000,00 USD
    - PV module of 300W
    - Submersible pump able to deliver 45 lt/min from up to 10 meters depth
    - Rack and controller.
  - Shallow well, high volume systems could cost from $1600,00 to $2.300,00 USD.
  - Deep well, low volume systems can go up to $7.000,00 USD

  - Equipment (US): Solar pump + controller: $500.00 - $1300 USD depending on the pumps technology. A sample cost of $1100 USD would be used because of the similar characteristics with the mentioned pumps.

  - PV module: for the month of September 2011 an average price of $2.65 USD and $2.43 € has been reported (Solarbuzz, 2011). The lowest price for a polycrystalline silicon solar module was $1.61 USD/watt ($1.13 €/watt) from a US retailer. For a monocrystalline silicon module the lowest price $1.48 per watt ($1.04 €/watt), from an Asian retailer and thin film module price was at $1.40 USD/watt ($0.98 €/watt) from a US-based retailer.
  - Inverter: average retail prices ($ per continuous Watt) are $0.714 USD/Watt and $0.5 €/watt.

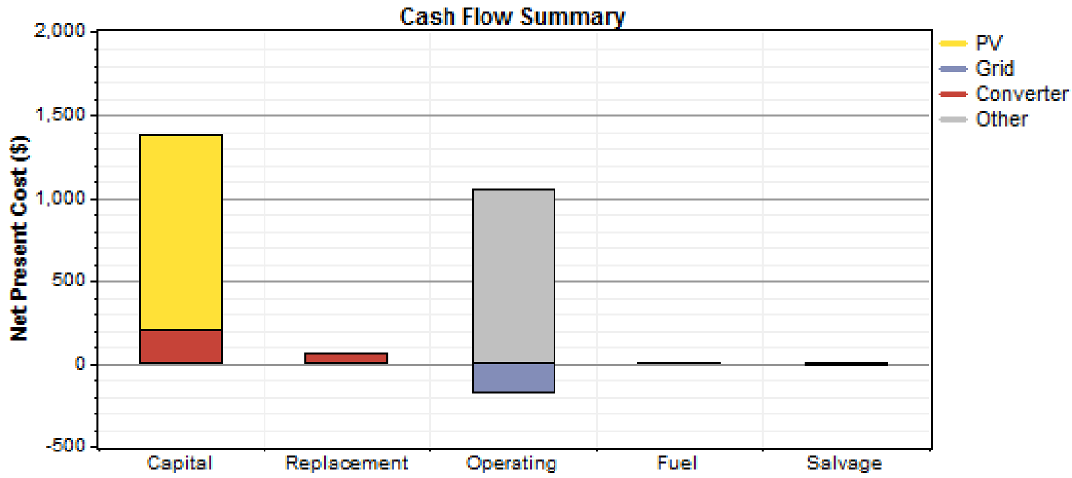
- System (MX): $12.000,00 MXP – $15.500,00 MXP
    - PV module daily power of 120.5 – 238.4 Wh/day
    - Delivery of 8.000 – 14.000 lt/week at a 5 m height and 6,000 – 12.000 lt/week at a 10 m height.
    - 10 Amp charge controller
    - Solar battery of 1,2 kW-h

Annex 3: Section 4 complete HOMER simulation reports.

- AO System cost savings under current conditions
  - Basic Tariff – Consumption up o 150 kWh/month

Cost summary

Total net present cost	$ 2,310
Levelized cost of energy	$ 0.916/kWh
Operating cost	$ 86.9/yr



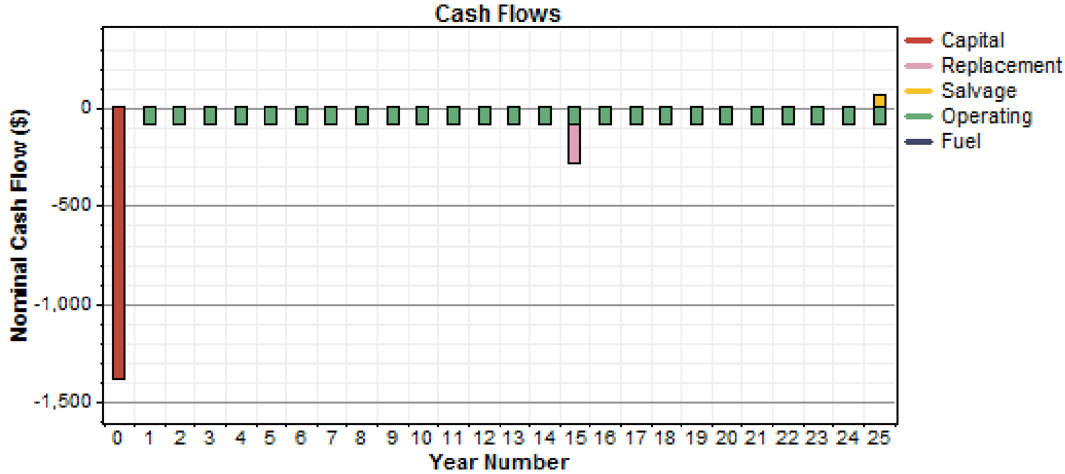
Net Present Costs

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
	($)	($)	($)	($)	($)	($)
PV	1,182	0	0	0	0	1,182
Grid	0	0	-177	0	0	-177
Converter	200	63	0	0	-10	253
Other	0	0	1,051	0	0	1,051
System	1,382	63	875	0	-10	2,310

Annualized Costs

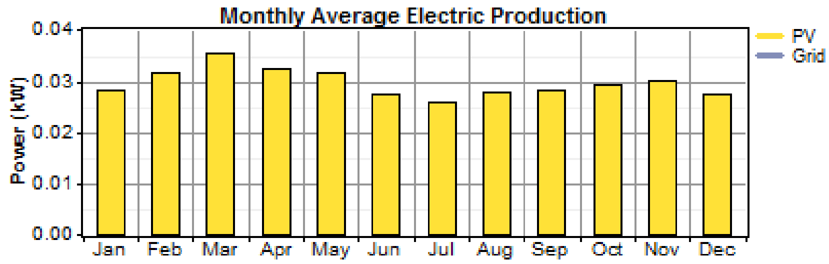
Component	Capital	Replacement	O&M	Fuel	Salvage	Total
	($/yr)	($/yr)	($/yr)	($/yr)	($/yr)	($/yr)
PV	111	0	0	0	0	111
Grid	0	0	-17	0	0	-17
Converter	19	6	0	0	-1	24
Other	0	0	98	0	0	98

System	129	6	82	0	-1	216



Electrical

Component	Production	Fraction
	(kWh/yr)	
PV array	260	100%
Grid purchases	0	0%
Total	260	100%



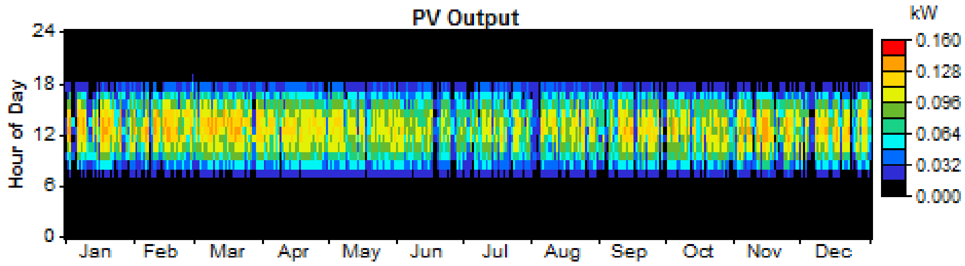
Load	Consumption	Fraction
	(kWh/yr)	
Grid sales	236	100%
Total	236	100%

Quantity	Value	Units
Excess electricity	0.000000111	kWh/yr
Unmet load	0.00	kWh/yr
Capacity shortage	0.00	kWh/yr
Renewable fraction	1.000	

PV

Quantity	Value	Units
Rated capacity	0.150	kW
Mean output	0.0296	kW
Mean output	0.711	kWh/d
Capacity factor	19.8	%
Total production	260	kWh/yr

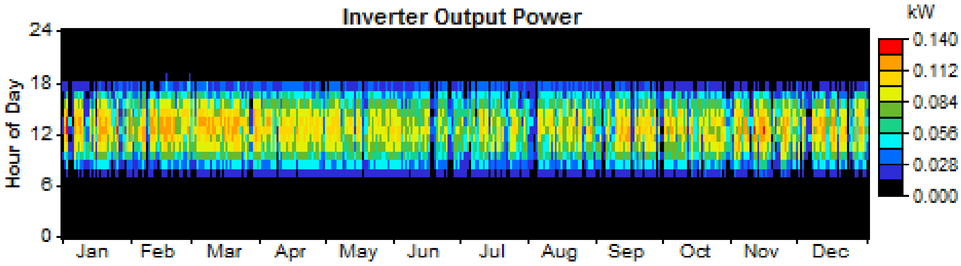
Quantity	Value	Units
Minimum output	0.00	kW
Maximum output	0.143	kW
PV penetration	0.00	%
Hours of operation	4,385	hr/yr
Levelized cost	0.427	$/kWh



Converter

Quantity	Inverter	Units
Capacity	0.20	kW
Mean output	0.03	kW
Minimum output	0.00	kW
Maximum output	0.13	kW
Capacity factor	13.5	%

Quantity	Inverter	Units
Hours of operation	4,385	hrs/yr
Energy in	260	kWh/yr
Energy out	236	kWh/yr
Losses	23	kWh/yr



Grid

Rate: Basic

Month	Energy Purchased	Energy Sold	Net Purchases	Peak Demand	Energy Charge	Demand Charge
	(kWh)	(kWh)	(kWh)	(kW)	($)	($)
Jan	0	19	-19	0	-1	0
Feb	0	19	-19	0	-1	0
Mar	0	24	-24	0	-2	0
Apr	0	21	-21	0	-1	0
May	0	22	-22	0	-2	0
Jun	0	18	-18	0	-1	0
Jul	0	17	-17	0	-1	0
Aug	0	19	-19	0	-1	0
Sep	0	18	-18	0	-1	0
Oct	0	20	-20	0	-1	0
Nov	0	20	-20	0	-1	0
Dec	0	19	-19	0	-1	0
Annual	0	236	-236	0	-17	0

- ## Emissions

Pollutant	Emissions (kg/yr)
Carbon dioxide	-149
Carbon monoxide	0
Unburned hydocarbons	0
Particulate matter	0
Sulfur dioxide	-0.647
Nitrogen oxides	-0.317

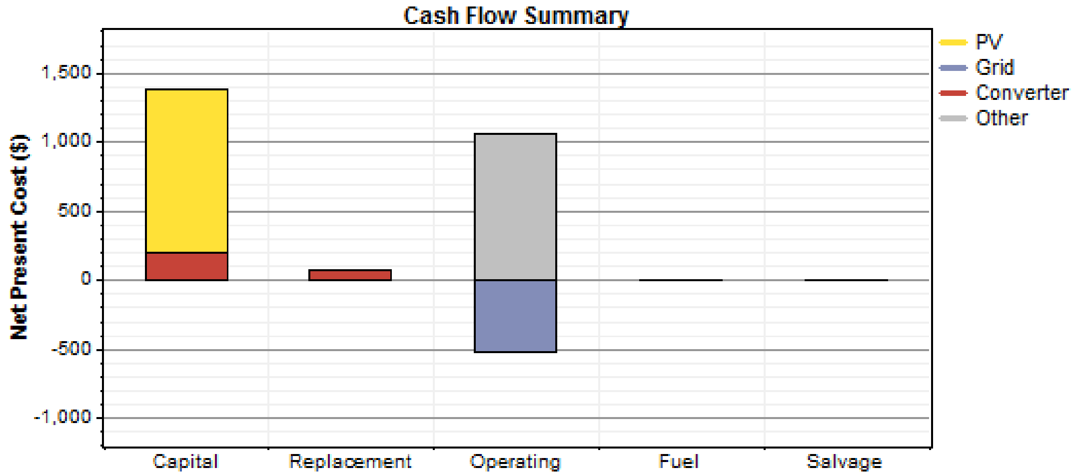
- Intermediate Tariff – Consumption up to 249 kWh/month

- **System architecture**

PV Array	0.15 kW
Grid	1,000 kW
Inverter	0.2 kW
Rectifier	0.2 kW

- **Cost summary**

Total net present cost	$ 1,969
Levelized cost of energy	$ 0.781/kWh
Operating cost	$ 55/yr



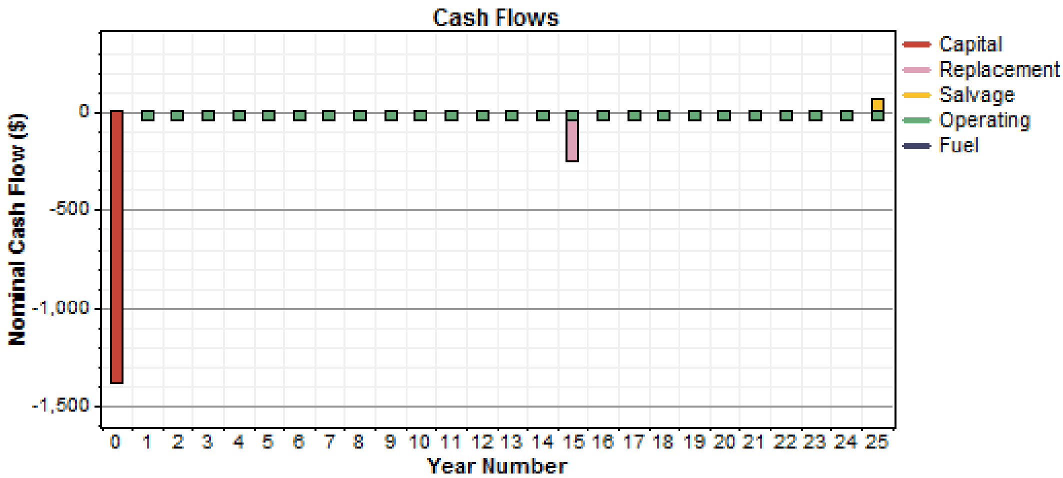
Net Present Costs

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
	($)	($)	($)	($)	($)	($)
PV	1,182	0	0	0	0	1,182
Grid	0	0	-518	0	0	-518
Converter	200	63	0	0	-10	253
Other	0	0	1,051	0	0	1,051
System	1,382	63	534	0	-10	1,969

Annualized Costs

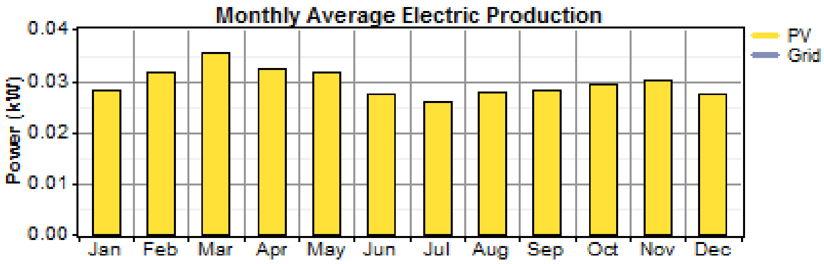
Component	Capital	Replacement	O&M	Fuel	Salvage	Total
	($/yr)	($/yr)	($/yr)	($/yr)	($/yr)	($/yr)
PV	111	0	0	0	0	111

Grid	0	0	-48	0	0	-48
Converter	19	6	0	0	-1	24
Other	0	0	98	0	0	98
System	129	6	50	0	-1	184



Electrical

Component	Production	Fraction
	(kWh/yr)	
PV array	260	100%
Grid purchases	0	0%
Total	260	100%



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Load	Consumption	Fraction
	(kWh/yr)	
Grid sales	236	100%
Total	236	100%

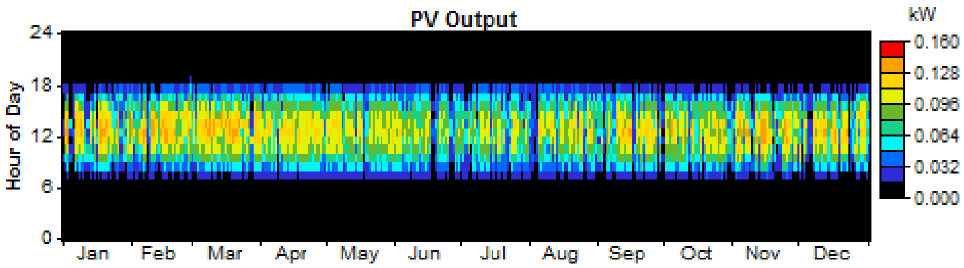
Quantity	Value	Units
Excess electricity	0.000000111	kWh/yr

Unmet load	0.00	kWh/yr
Capacity shortage	0.00	kWh/yr
Renewable fraction	1.000	

- **PV**

Quantity	Value	Units
Rated capacity	0.150	kW
Mean output	0.0296	kW
Mean output	0.711	kWh/d
Capacity factor	19.8	%
Total production	260	kWh/yr

Quantity	Value	Units
Minimum output	0.00	kW
Maximum output	0.143	kW
PV penetration	0.00	%
Hours of operation	4,385	hr/yr
Levelized cost	0.427	$/kWh

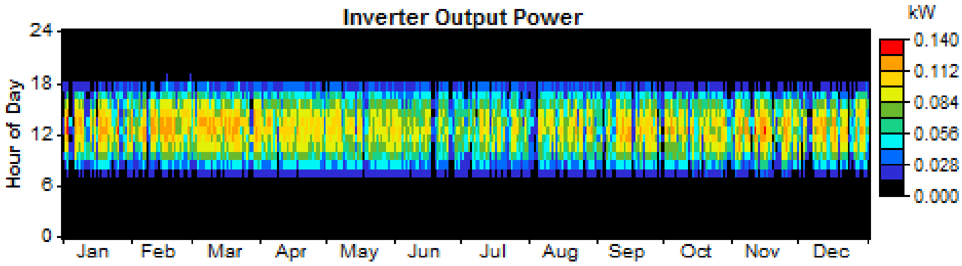


-
- **Converter**

Quantity	Inverter	Units
Capacity	0.20	kW
Mean output	0.03	kW
Minimum output	0.00	kW
Maximum output	0.13	kW
Capacity factor	13.5	%

Quantity	Inverter	Units
Hours of operation	4,385	hrs/yr
Energy in	260	kWh/yr

Energy out	236	kWh/yr
Losses	23	kWh/yr



- **Grid**
- Rate: Intermediate

Month	Energy Purchased	Energy Sold	Net Purchases	Peak Demand	Energy Charge	Demand Charge
	(kWh)	(kWh)	(kWh)	(kW)	($)	($)
Jan	0	19	-19	0	-4	0
Feb	0	19	-19	0	-4	0
Mar	0	24	-24	0	-5	0
Apr	0	21	-21	0	-4	0
May	0	22	-22	0	-4	0
Jun	0	18	-18	0	-4	0
Jul	0	17	-17	0	-4	0
Aug	0	19	-19	0	-4	0
Sep	0	18	-18	0	-4	0
Oct	0	20	-20	0	-4	0
Nov	0	20	-20	0	-4	0
Dec	0	19	-19	0	-4	0
Annual	0	236	-236	0	-48	0

Emissions

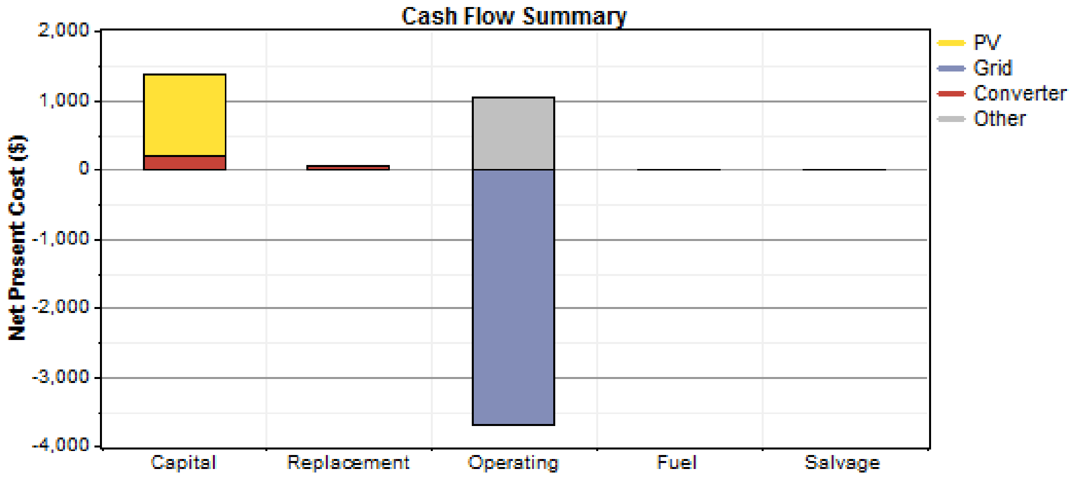
Pollutant	Emissions (kg/yr)
Carbon dioxide	-149
Carbon monoxide	0
Unburned hydocarbons	0
Particulate matter	0
Sulfur dioxide	-0.647

Nitrogen oxides	-0.317

- DAC Tariff – Consumption of 250 kWh/month

Cost summary

Total net present cost	$ -1,197
Levelized cost of energy	$ -0.475/kWh
Operating cost	$ -242/yr

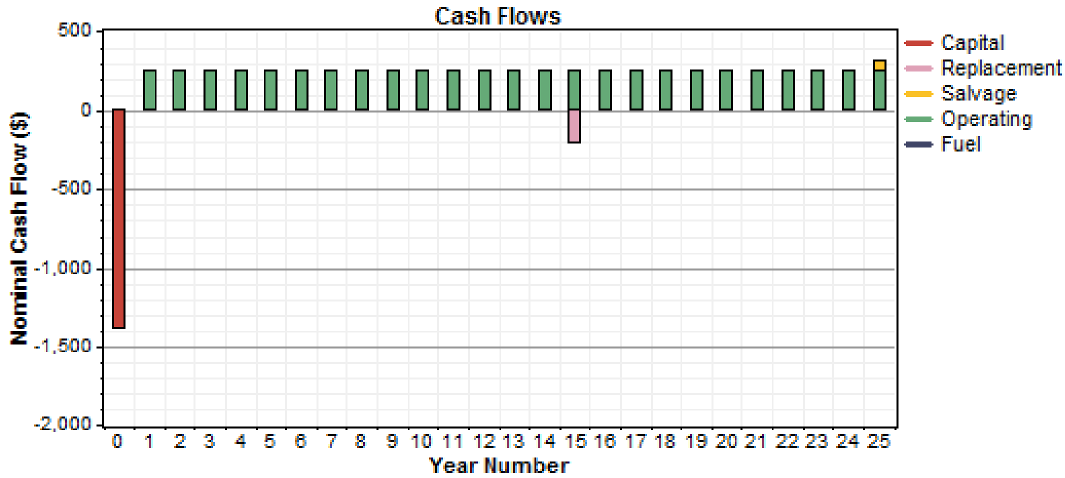


Net Present Costs

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
	($)	($)	($)	($)	($)	($)
PV	1,182	0	0	0	0	1,182
Grid	0	0	-3,684	0	0	-3,684
Converter	200	63	0	0	-10	253
Other	0	0	1,051	0	0	1,051
System	1,382	63	-2,633	0	-10	-1,197

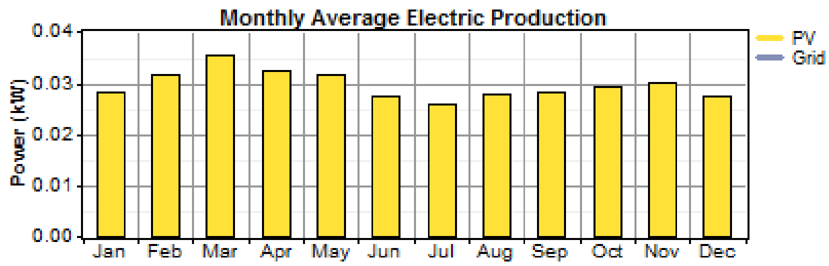
Annualized Costs

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
	($/yr)	($/yr)	($/yr)	($/yr)	($/yr)	($/yr)
PV	111	0	0	0	0	111
Grid	0	0	-345	0	0	-345
Converter	19	6	0	0	-1	24
Other	0	0	98	0	0	98
System	129	6	-247	0	-1	-112



Electrical

Component	Production	Fraction
	(kWh/yr)	
PV array	260	100%
Grid purchases	0	0%
Total	260	100%



Load	Consumption	Fraction
	(kWh/yr)	
Grid sales	236	100%
Total	236	100%

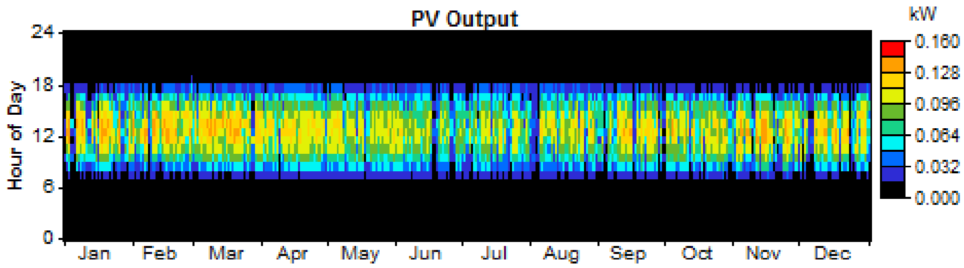
Quantity	Value	Units
Excess electricity	0.000000111	kWh/yr
Unmet load	0.00	kWh/yr
Capacity shortage	0.00	kWh/yr
Renewable fraction	1.000	

PV

Quantity	Value	Units

Rated capacity	0.150	kW
Mean output	0.0296	kW
Mean output	0.711	kWh/d
Capacity factor	19.8	%
Total production	260	kWh/yr

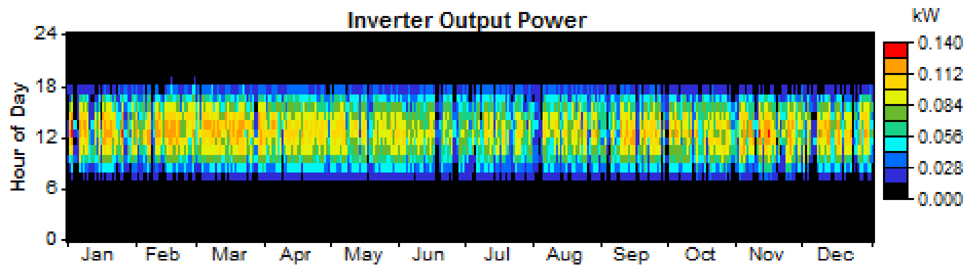
Quantity	Value	Units
Minimum output	0.00	kW
Maximum output	0.143	kW
PV penetration	0.00	%
Hours of operation	4,385	hr/yr
Levelized cost	0.427	$/kWh



Converter

Quantity	Inverter	Units
Capacity	0.20	kW
Mean output	0.03	kW
Minimum output	0.00	kW
Maximum output	0.13	kW
Capacity factor	13.5	%

Quantity	Inverter	Units
Hours of operation	4,385	hrs/yr
Energy in	260	kWh/yr
Energy out	236	kWh/yr
Losses	23	kWh/yr



Grid

Rate: DAC1

Month	Energy Purchased	Energy Sold	Net Purchases	Peak Demand	Energy Charge	Demand Charge
	(kWh)	(kWh)	(kWh)	(kW)	($)	($)
Jan	0	19	-19	0	-28	0
Feb	0	19	-19	0	-28	0
Mar	0	24	-24	0	-35	0
Apr	0	21	-21	0	-31	0
May	0	22	-22	0	-31	0
Jun	0	18	-18	0	-26	0
Jul	0	17	-17	0	-25	0
Aug	0	19	-19	0	-28	0
Sep	0	18	-18	0	-27	0
Oct	0	20	-20	0	-29	0
Nov	0	20	-20	0	-29	0
Dec	0	19	-19	0	-27	0
Annual	0	236	-236	0	-345	0

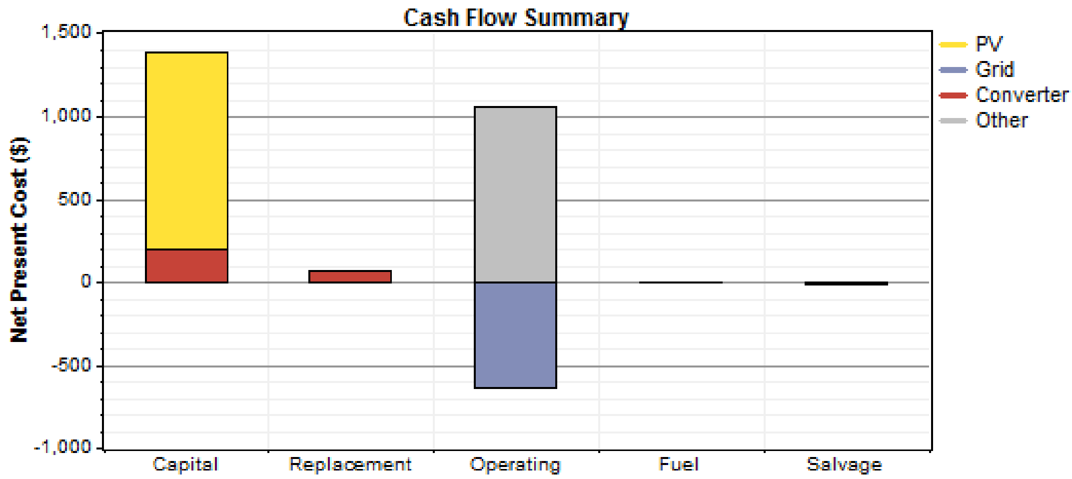
Emissions

Pollutant	Emissions (kg/yr)
Carbon dioxide	-149
Carbon monoxide	0
Unburned hydocarbons	0
Particulate matter	0
Sulfur dioxide	-0.647
Nitrogen oxides	-0.317

- DAC Tariff – Consumption of 300 kWh/month

Cost summary

Total net present cost	$ 1,856
Levelized cost of energy	$ 0.736/kWh
Operating cost	$ 44.4/yr

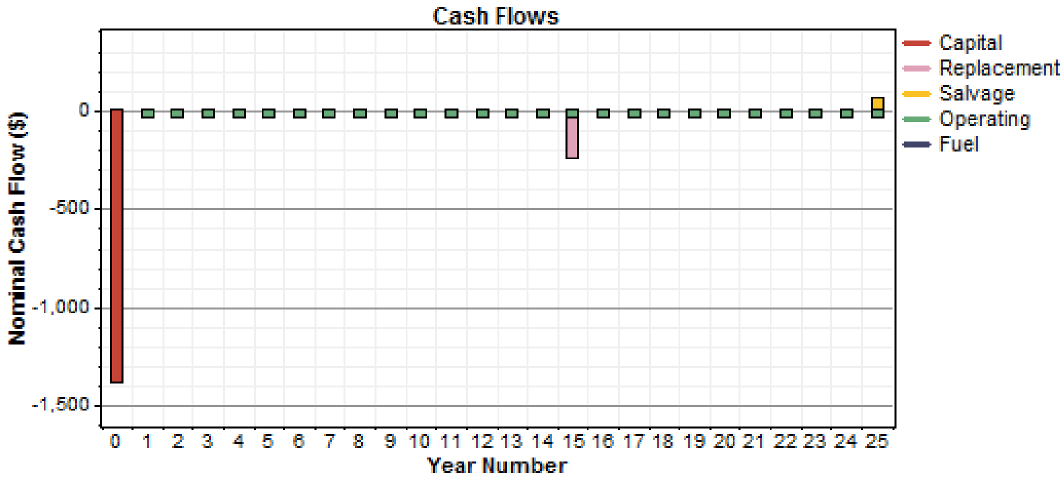


Net Present Costs

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
	($)	($)	($)	($)	($)	($)
PV	1,182	0	0	0	0	1,182
Grid	0	0	-630	0	0	-630
Converter	200	63	0	0	-10	253
Other	0	0	1,051	0	0	1,051
System	1,382	63	421	0	-10	1,856

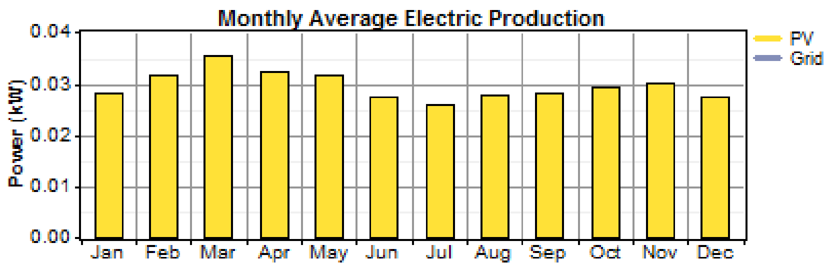
Annualized Costs

Component	Capital	Replacement	O&M	Fuel	Salvage	Total
	($/yr)	($/yr)	($/yr)	($/yr)	($/yr)	($/yr)
PV	111	0	0	0	0	111
Grid	0	0	-59	0	0	-59
Converter	19	6	0	0	-1	24
Other	0	0	98	0	0	98
System	129	6	39	0	-1	174



Electrical

Component	Production	Fraction
	(kWh/yr)	
PV array	260	100%
Grid purchases	0	0%
Total	260	100%



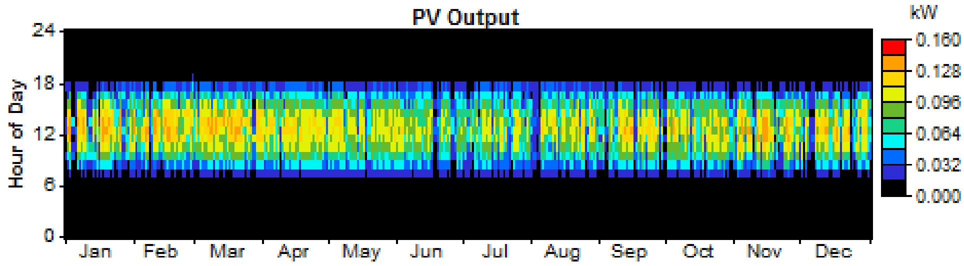
Load	Consumption	Fraction
	(kWh/yr)	
Grid sales	236	100%
Total	236	100%

Quantity	Value	Units
Excess electricity	0.000000111	kWh/yr
Unmet load	0.00	kWh/yr
Capacity shortage	0.00	kWh/yr
Renewable fraction	1.000	

PV

Quantity	Value	Units
Rated capacity	0.150	kW
Mean output	0.0296	kW
Mean output	0.711	kWh/d
Capacity factor	19.8	%
Total production	260	kWh/yr

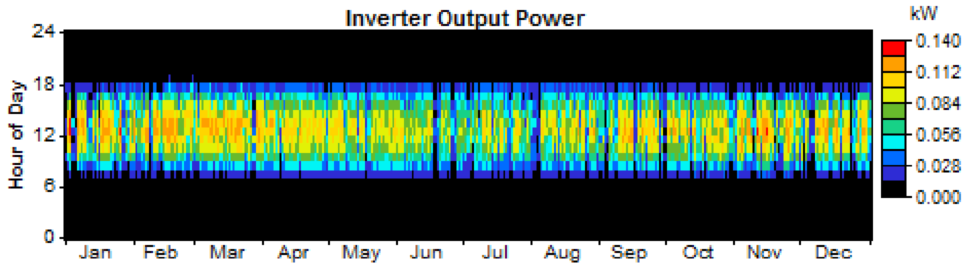
Quantity	Value	Units
Minimum output	0.00	kW
Maximum output	0.143	kW
PV penetration	0.00	%
Hours of operation	4,385	hr/yr
Levelized cost	0.427	$/kWh



Converter

Quantity	Inverter	Units
Capacity	0.20	kW
Mean output	0.03	kW
Minimum output	0.00	kW
Maximum output	0.13	kW
Capacity factor	13.5	%

Quantity	Inverter	Units
Hours of operation	4,385	hrs/yr
Energy in	260	kWh/yr
Energy out	236	kWh/yr
Losses	23	kWh/yr



Grid

Rate: DAC2

Month	Energy Purchased	Energy Sold	Net Purchases	Peak Demand	Energy Charge	Demand Charge
	(kWh)	(kWh)	(kWh)	(kW)	($)	($)
Jan	0	19	-19	0	-5	0
Feb	0	19	-19	0	-5	0
Mar	0	24	-24	0	-6	0
Apr	0	21	-21	0	-5	0
May	0	22	-22	0	-5	0
Jun	0	18	-18	0	-4	0
Jul	0	17	-17	0	-4	0
Aug	0	19	-19	0	-5	0
Sep	0	18	-18	0	-5	0
Oct	0	20	-20	0	-5	0
Nov	0	20	-20	0	-5	0
Dec	0	19	-19	0	-5	0
Annual	0	236	-236	0	-59	0

Emissions

Pollutant	Emissions (kg/yr)
Carbon dioxide	-149
Carbon monoxide	0
Unburned hydocarbons	0
Particulate matter	0
Sulfur dioxide	-0.647
Nitrogen oxides	-0.317

Annex 4: Examples of CFE electric bills.

AVISO RECIBO

CFE Una empresa de clase mundial

Comisión Federal de Electricidad
Av. Paseo de la Reforma Num. 164
Col. Juárez, México, D.F. 06600
RFC: CFE370814-QI0

Número de servicio:
[redacted]

Total a pagar:
$184.00
(CIENTO OCHENTA Y CUATRO PESOS 00/100 M.N.)

Nombre y Domicilio
[redacted]

Ruta: 33DU05B013340430

Fecha límite de pago:
09 JUN 11

Uso:	Tarifa	Hilos
Doméstico	01	1

Medición de consumos

Num. de Medidor	Lectura actual	Lectura anterior	Mult.	Consumo kWh
[redacted]	00241	00032	00001	209

Periodo de consumo

Periodo de consumo	Días	Promedio diario kWh
25 MAR 11 A 25 MAY 11	61	3.42

Facturación

Concepto	kWh	Precio	Subtotal
Básico	150.0000	0.717	107.55
Intermedio	59.0000	0.864	50.97
Suma	209.0000		158.52

Historial de consumo

Facturación	Ene	Mar	May	Jul	Sep	Nov
2011		31	209			

Estado de cuenta

Energía	158.52
IVA 16%	25.36
Fac. del Periodo	183.88
Adeudo Anterior	201.65
Su Pago	-201.00
Total	$184.53

Apoyo gubernamental

Costo de producción	**$797.15**
Aportación Gubernamental	**$638.63**

Avisos importantes

- Nos transformamos para servirle mejor.
- Servicio a Clientes Teléfono 071.

Usted puede pagar sin costo en los principales bancos y cadenas comerciales

Factura:	UE
Folio:	000003790240
No. aprobación:	84533
Año de aprobación	2009
No. certificado:	00001000000100809817

El Gobierno Federal trabaja contra la impunidad, con tu ayuda fortalecemos la lucha
01800FUNCION
Secretaría de la Función Pública quejas y denuncias al Teléfono: 018007126982

Este documento es una representación impresa de un CFD

Cadena original
||2.0|UE|000003790240|2011-05-26T20:35:21|84533|2009|ingreso|Pago en una sola exhibicion|158.52|184.00|CFE370814QI0|Comision Federal de Electricidad|Av. Paseo de la Reforma|164|Juarez|Mexico D.F.|D.F.|Mexico|06600|XAXX010101000|DE LA GARZA MACIAS LEONARDO C|DR MANUEL NAVA 320 5 CP.00000|SAN LUIS POTOSI|SLP|Mexico|209|ENERGIA|158.52|158.52|IVA|16|25.36||
Sello Digital
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Fecha, hora y lugar de impresión: 27 MAY 11 09:45:00 hrs. SAN LUIS POTOSI, S.L.P.

[redacted]

83

Total a pagar:
$184.00
(CIENTO OCHENTA Y CUATRO PESOS 00/100 M.N.)

ÓN DE CAJA

AVISO RECIBO

CFE Una empresa de clase mundial

Número de Servicio: [redacted]

Nombre y Domicilio:

[redacted]

Total a pagar:

$118.00

(CIENTO DIECIOCHO PESOS 00/100 M.N.)

Fecha límite de pago:

11 AGO 11

Medición de consumos

Numero de medidor	Lectura actual	Lectura anterior	Mult.	Consumo kWh
[redacted]	00382	00241	1	141

Uso:	Tarifa	Hilos
Doméstico	01	1

Facturación

Concepto	kWh		Precio	Total
Básico	141.000	*	0.721	101.66
Suma	141.000	*	0.000	101.66

Periodo de consumo	Dias	Promedio diario
25 MAY 11 A 27 JUL 11	63	2.23

Historial de consumo (kWh)

Facturación	Ene	Mar	May	Jul	Sep	Nov
2010	0					
2011		31	209	141		

Estado de cuenta

Energía	$101.66
IVA 16%	$16.26
Fac. del Periodo	$117.92
Adeudo Anterior	$184.53
Su Pago	-$184.00
Total	$118.45

Apoyo gubernamental

Costo de producción	$609.25
Aportación Gubernamental	$507.59

Avisos importantes

- Nos transformamos para servirle mejor.
- Sustituye sin costo 4 focos por 4 lámparas ahorradoras en c de canje autorizados. Mayor información al 01 800 5589343.
- Servicio a Clientes Teléfono 071.
- Aprovecha al máximo la luz del sol... ¡Y ahórrate una luz!

Factura:	UE
Folio:	000004245618
No. aprobación:	84533
Año de aprobación	2009
No. certificado	00001000000100809817

Cadena original

||2.0|UE|000004245618|2011-07-28T17:59:34|84533|2009|ingreso|Pago en una sola exhibicion|101.66|118.00|CFE370814QI0|Comision Federal de Electricidad|Av. Paseo de la Reforma|164|Juarez|Mexico D.F.|D.F.|Mexico|06600|XAXX010101000|DE LA GARZA MACIAS LEONARDO C|DR MANUEL NAVA 320 5 CP.00000|SAN LUIS POTOSI|SLP|Mexico|141|ENERGIA|101.66|101.66|IVA|16|16.26||

Sello Digital

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www.cfe.gob.mx

Número de Servicio: [redacted]

Referencia Bancaria [redacted]

Ruta: [redacted] **Clave de envío:** **Repartir**

Total a pagar:

$118.00

(CIENTO DIECIOCHO PESOS 00/100 M.N.)

TALON DE CAJA

"… and may the force be with you."