RE-Energizing the Border: Renewable Energy, Green Jobs and Border Infrastructure Project

Solar Energy Potential
in Mexico's Northern Border States

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INTRODUCTION

Mexico's geographic location and its world-class solar resources make it a prime candidate for solar energy development. To date, however, investment in the sector and government support for the industry has been quite limited, and solar energy has lagged far behind wind and geothermal generation. This paper argues that the northern border states of Mexico provide an extraordinary opportunity for investment in solar energy for local consumption by businesses and residential customers. Nonetheless, it is unlikely that large-scale generation for the national grid or for export to the United States will make economic sense in the near future. Several barriers continue to hold back the sector. Initiatives at Mexico's state and national level are needed to pave the way for private investment. In the long run, solar energy holds the potential to significantly strengthen Mexico's energy sector and economic development.

METHODOLOGICAL NOTE

Due to the difficulty in obtaining comprehensive data regarding the development of solar energy in Mexico, much of the information in this report was obtained from site visits, personal communication with state government officials, journal and newspaper articles. A total of thirty-three journals and newspapers were analyzed. Three of these have a national circulation, while the rest were local newspapers from Mexican Border States. When possible, the information found in newspapers was confirmed by a second or third publication.

The proliferation of governmental and non-governmental organizations that promote and regulate the development of renewable energy in Mexico, combined with the lack of a single agency serving as an information clearinghouse, complicates comprehensive analysis of renewable resource development. Energy projects below 1 MWp (MW peak power) have no reporting or regulatory obligations. Such small, often unreported projects are the most common use of solar energy in Mexico. In fact, there are only two CRE-approved Photovoltaic (PV) projects, one 3.8 MWp in Aguascalientes and another in 30 MWp in Jalisco.

In addition to many national and international private sector firms, the main agents involved in the development and regulation of renewable energies in Mexico are:

Government Institutions
CFE: Federal Commission of Electricity, (CFE, Comisión Federal de Electricidad)
CONUEE: National Commission for Energy Savings, (CONUEE, Comisión Nacional para el Uso Eficiente de Energía)
SENER: Ministry of Energy, (SENER, Secretaría de Energía)
CRE: Energy Regulatory Commission (CRE, Comisión Reguladora de Energía)

Non-Governmental Organizations
ANES: National Solar Energy Association, (ANES, Asociación Nacional de Energía Solar)

Inter-governmental Organizations
BECC: Border Environment Cooperation Commission
NADB: North American Development Bank

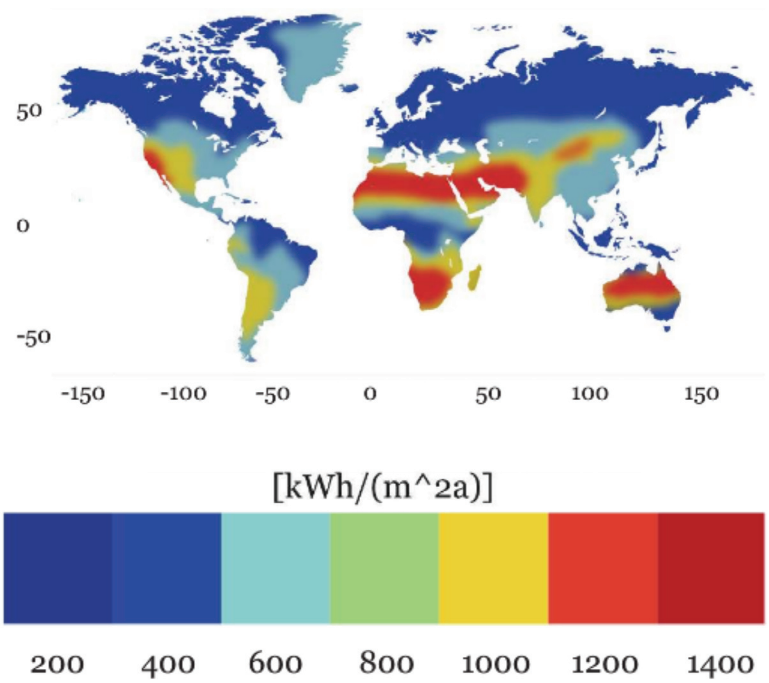
MEXICO'S GLOBAL GEOGRAPHIC POSITION

Solar radiation is unevenly distributed around the world. It varies in intensity from one geographic location to another depending upon latitude, season, and time of day. In recent years, there has been growing demand to identify geographic areas with favorable conditions for solar energy development. This resource mapping is of central importance for developing countries that have started solar projects for energy production and distribution.[1]

For convenience and simplicity, it has been generally established that the geographic distribution of total solar radiation is divided in terms of intensity into four broad sun belts around the globe. The most "sun-favorable" belt exists between 15°N and 35°N. This includes the regions that are naturally endowed with the most favorable conditions for solar energy applications. These semi-arid regions are characterized by having the greatest amount of solar radiation, more than 90% of which comes as direct radiation because of the limited cloud coverage and rainfall (less than 250 mm per year). Moreover, there are usually over 3,000 hours of sunshine per year.[2]

The majority of developing countries fall within the more favorable regions, between 35°N and 35°S. For this reason, they can depend on solar radiation as a steadfast source of energy that can be readily and cheaply exploited by both rural and urban

Map 1: Global Solar Irradiation



Source: International Energy Administration, 2003.

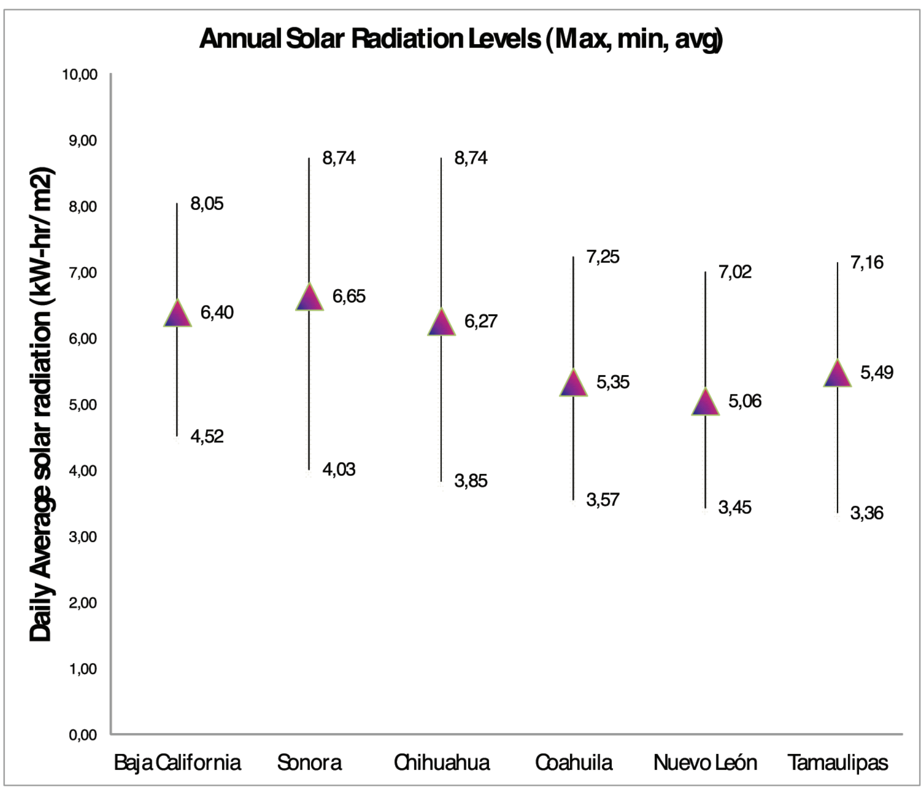
households for a multitude of purposes. Mexico's total territory lies between the latitudes 14° and 33°N and the longitudes 86° and 119°W, making it one of the few countries that lie 100% within the most favorable sun belt on the planet.

Mexico has a high level of solar radiation. It receives, for example, twice as much solar radiation as Germany. Across Mexico, daily radiation varies between 4.4 kWh/m2 and 6.3 kWh/m2 of solar energy, which is comparable to regions in Africa, the Andes and parts of Oceania.[3] This means that crystalline photovoltaic panels would require an area of approximately 100,000 hectares, or one thousand square kilometers, to meet all of Mexico's energy needs. In Germany or Canada, by comparison, the same technology would require twice the area and therefore double the investment to deliver the same amount of energy (184 TWh).[4]

THE NORTHERN BORDER

Mexico's six northern border states cover nearly half of the country's total surface. The six states have a predominantly arid desert climate with a high level of solar irradiation. According to the CONUEE database of 2008, in this northern half of the country there is an average daily solar irradiation of 5.853 kWh/m^2. Baja California has a higher rate of irradiation, with an average rate of 6.4 kWh/m^2.[5] The largest Mexican state, Chihuahua, is recognized as having one of the highest solar irradiation levels of the world. The president

Figure 1: Solar Radiation Levels in Border States



Source: La Comisión Nacional para el Uso Eficiente de la Energía (2008).

of Mexico's national Solar Energy Association has predicted that the state could become the largest global reserve for the solar industry: "We could become the Saudi Arabia of Latin America due to our solar potential and total surface area."[6]

As shown in the chart above, all six states have a large potential for solar development. These numbers are among the highest in the world and far exceed those present in many countries that have invested heavily in solar power development. For example, the average radiation levels in Germany (the global leader in solar development with 4.88 GW of installed solar capacity) range from 2.6 to 3.7 kWh/m^2, just over half the levels found in Mexico's border states.

LEGAL ENVIRONMENT AND BARRIERS TO SOLAR DEVELOPMENT

Mexico's legal and regulatory framework regarding renewable energies has evolved in recent years. Mexico's National Development Plan 2007–2012[7] goal is:

> *"To promote efficiency and clean technologies (including renewable energy) for power generation. To achieve this, it is essential to promote low carbon intensity energy sources such as wind, geothermal and solar. In turn, it is essential to integrate policies to promote low-emission public transport, provision for tax incentives to promote sustainable energy projects, conduct an economic assessment of the benefits of this type of energy and, ultimately, encourage research into technologies of lesser energy intensity."*

These targets are set under the Law of the Public Electricity Service (LSPEE), which allows individuals to generate electricity exclusively for self-supply, cogeneration or for sale to the CFE. Cogeneration permits and contracts for the sale of surplus energy are provided by the CRE.[8] In the case of solar-electric (PV or Concentrated Solar Power, CSP), systems can be connected to the grid and the surplus sold to CFE through the permit. The price paid to individuals by CFE has been at or below conventional electricity costs.

The most important step taken to promote Mexico's market for clean energy was the Congressional approval of November 2008's, Law on the Use of Renewable Energy and Financing the Energy Transition (LAERFTE). This legislation establishes the goal of having 8% of total electricity generation from renewable sources (excluding large hydro) by 2012. The installed capacity of renewable non-hydro would have to grow 2.13 times in four years (2008 to 2012) in order to achieve the LAERFTE goal.[9]

Of direct relevance for solar power is the provision in the LAERFTE for the provision of financial resources that during the first year dedicates 55% of its budget to the creation of a Green Fund to encourage mature technologies such as photovoltaics, 10% for a Rural Electrification Fund in which PV systems are the main solution, and 15% for the Fund for Research and Technological Development of Renewable Energy (FIDTER). The remaining 20% can be used to promote non-mature technologies, biofuels and non-electrical applications. The government will allocate 600 million pesos annually to encourage public and private investment in mature technology renewable projects, and another 400 million a year for investment in R&D and non-mature renewable technologies.[10]

Moreover, the Interconnection Agreement for Renewable Energy Sources of the Energy Regulatory Commission (CRE) determines the requirements, terms and conditions for interconnection

of renewable energy sources to the national grid applicable for intermittent sources of energy (such as solar energy) in facilities with storage capacities less than those that are required independently. Thus, the excess energy can be sent to the network for use when needed. SEMARNAT and the Finance Ministry (Hacienda) have a program for accelerated depreciation of investments that benefit the environment. This is, however, a one-time charge that can be made against tax payments, and is only a minor incentive for solar development. Although this legal framework is a step towards development, some other incentives should be considered that have proven successful in other parts of the world, including feed-in tariffs (above-market pricing for renewable energy sales), subsidies to investment, soft credits on capital investment or other mechanisms to help overcome the extra cost of using solar systems.

Barriers to Solar Development in Mexico

Institutional

There are no specific targets for increased solar capacity by the government. Although there are significant subsidies for conventional energy, the tax incentives for investment in solar energy are not sufficient to promote market growth. In addition, environmental externalities are not considered in the economic analysis of energy projects.

Financial

In general knowledge, there is little understanding of the life cycle of a solar project. It is not clear how a project can be developed, for it does not follow any established local pattern of construction or investment. The development steps are taken according to the situations that the project is currently in; steps, that have specific financial parameters. From the beginning to the conclusion of a project, it is uncertain how much it will cost. Flow analyses are not exact, adding to this, that the number and capacity of government and private financing programs are very limited. There are no mechanisms for "soft" loans or feed in tariffs to promote the use of solar systems in Mexico despite their successful application in other nations.

Technical

According to several installers consulted within ANES; in autonomous off-the-grid PV systems, lack of maintenance has caused failures to the PV systems after just a few years of operation. There is a need to train technicians to install and maintain systems and provide greater customer satisfaction, furthering development of the market. Finally, low level legislation (operating procedures) is needed to have minimum standards of quality and performance of photovoltaic products and solar projects.

An important barrier to the development of the solar industry in Mexico with regards to manufacturing solar panels is that solar panel manufacturers in Mexico currently have to source most of their inputs from abroad. According to the manufacturers, the Mexican industry does not have the sufficient know-how or technology to meet the specific quality requirements and characteristics used in solar panel manufacturing. Some of the unmet requirements include low panel efficiency outputs, low cover glass quality with low useful life expectancy, and inadequate design and dimensions of the panel frames.

Social

The lack of knowledge and information about PV Solar Energy in Mexico means that many rural consumers do not understand its potential benefits. With respect to energy consumption and costs, households rarely take a long-term perspective and consequently fail to identify the potential savings small-scale solar system would in some cases provide. Moreover, the rural community remembers the failures of the Solidaridad program, which was developed by the administration of former Mexican president Carlos Salinas de Gortari in the late 1980s. The program's objective was poverty alleviation, and one of the proposals was to install PV Solar Panels in rural communities. The program failed, partially because the solar systems were using car batteries that died just after a few months and were rarely replaced. Still remembered by the rural population, this experience left many rural residents with the impression that PV and other solar solutions are useless and with a strong preference for a grid connection.

Political

Unfortunately, decision makers are often uninformed about solar energy as well. This has greater consequences because policymakers have made decisions and declarations that have restricted the development and growth of solar energy in the country and given it a negative public image. For instance, when the electric taxi fleet for Mexico City was first announced, the government stated that the energy for recharging the cars would come from solar panels installed in the recharging stations, clearly an overstatement since the stations have an area of only 100 m2.

As a result of public policy blunders and a lack of effective educational campaigns, most of the population is not aware that, when properly applied, solar systems can generate substantial financial and energy savings.

EXISTING AND POTENTIAL PROJECTS IN THE NORTHERN BORDER REGION

In recent years, the number of solar projects under development in the northern border states has grown dramatically. From the west to the east coasts, the Government of Mexico, CFE, and international private investment firms and energy companies have been working together to exploit Mexico's solar reserves. Solar investments from Mexican, Spanish, U.S., and Chinese firms have been nourishing the state and national economies, creating employment and growth.

This activity comes as no surprise as the region is well endowed with solar radiation throughout the year. The table below presents the solar potential of each state:

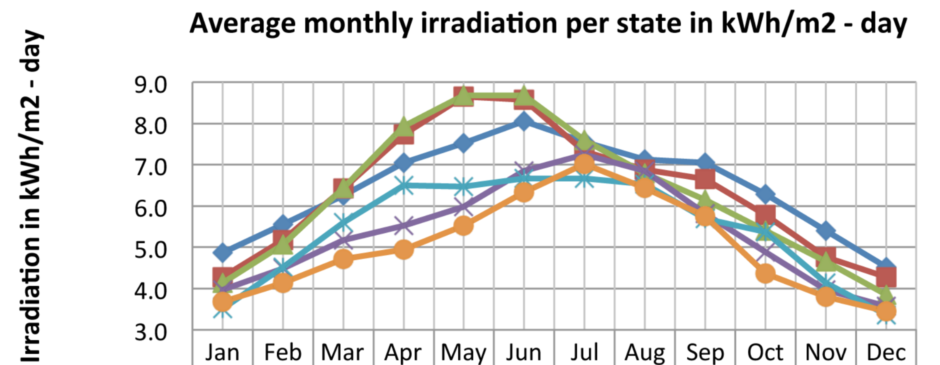
Baja California

A solar project at the CFE's geothermal field in Cierro Prieto, Baja California is expected to start operating by the end of 2012, generating 5 MW of peak power in order to produce an annual average of 10,000 MWh. The photovoltaic cells have an estimated useful lifetime of 25 years.[11]

Another planned solar project (still not under construction) in Baja California would be the first integrated solar energy plant (one company makes the whole system) in Mexico. Baja Sun Energy has announced it will establish a plant in the "Silicon Border" solar and clean technologies park in the city of Mexicali.[12] Based on calculations of energy employment rates and analysis on expected energy generation, the solar plant is expected to generate around 1,071.93 GWh per year and will create around 87 jobs.

In Tijuana, a public-private project resulting from an agreement between

Figure 2: Average Monthly Irradiation per State in Border States



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Baja California	4.9	5.6	6.2	7.1	7.5	8.1	7.6	7.1	7.1	6.3	5.4	4.5
Sonora	4.3	5.2	6.4	7.7	8.6	8.6	7.3	6.9	6.6	5.8	4.8	4.3
Chihuahua	4.1	5.1	6.4	7.9	8.7	8.7	7.6	6.8	6.2	5.4	4.7	3.9
Coahuila	4.0	4.5	5.2	5.5	6.0	6.8	7.2	6.8	5.8	4.9	4.0	3.6
Tamaulipas	3.5	4.5	5.6	6.5	6.5	6.7	6.7	6.5	5.7	5.4	4.1	3.4
Nuevo León	3.7	4.1	4.7	4.9	5.5	6.3	7.0	6.4	5.8	4.4	3.8	3.5

Source: Comisión Nacional para el Uso Eficiente de la Energía. CONUEE 2008.

the city of Tijuana and the Maquiladora Industry and Export Association (Asociación de la Industria Maquiladora y de Exportación) seeks to create a sustainable city that would be ranked within one of the first 20 green sustainable cities in Latin America.[13] Sixty-thousand middle-income houses would be built with solar technology infrastructure, generating thousands of jobs. Plans have also been put in place to potentially build up to an additional 1 MW in solar capacity to provide extra energy to the community.[14]

In March 2012, solar energy company SolFocus announced that it will help build a 50-megawatt Concentrator Photovoltaic (CPV) power plant near Tecate, Mexico. The project will be developed in phases by SolMex Energy S.A. de C.V., a company formed by the Mexican Grupo Musa and Synergy Technologies of the United States. Grupo Musa is a land and real estate developer and will use the energy produced from the first phase of generation in its plants. The project is expected to eventually reach a 450-megawatt capacity, making it one of the largest CPV solar farms in the world. Construction will start in late 2012, and the first 50 MW of generation are expected to come online in late 2013. The investment for the first four 50MW stages totals $720 million dollars, and as noted by SolFocus CEO Mark Crowley, "this project in Mexico will turn dormant land into jobs and low-cost, reliable electricity."[15] The application of CPV equipment is key in this instance because it overcomes one of the major local impediments to using solar power, the extreme heat in the Mexicali Valley, which greatly reduced both the efficiency and lifespan of regular solar panels.

The Spanish firm Siliken has plans to build a solar farm for photovoltaic energy near Tijuana. The objective of the firm is to establish business relationships in Mexico at a local level in order to consolidate operations of strategic future projects. In May 2011, the firm invested $25 million dollars to create five production lines and up to 500 jobs.[16]

The Kyocera solar panel manufacturing plant in Baja California highlights the employment benefits that can come not only from the installation of solar panels and the construction of large solar plants, but also from the production of solar panels for residential applications. The plant at present has a maximum capacity of 300 MW in panels every year (although it produces, on average, 10–12 MW per month), for export to the United States. During a site visit, Kyocera executives noted that the possibility to double maximum capacity at the plant exists, but due to current lack of demand from the Mexican market, expansion does not make economic sense. The factory employs 350 people directly, but it is estimated that distribution and installation activities result in the creation of a further 35 jobs per MW installed.

The Kyocera plant also highlights another challenge in Mexico's solar sector. The factory is largely devoted to the assembly of solar panels, with most components imported from abroad. Kyocera executives commented that it is extremely difficult or impossible to find suppliers in Mexico for most of the components due to factors including cost, quality and technical specifications. A national policy to promote the solar industry in Mexico is required in order to drive investment in not only solar panels but also the production of parts and components.

Electronic engineering already has a strong reputation in the country, so much so that Freescale Semiconductor (one of the leading manufacturers of integrated circuits in the world) established an R & D center in Guadalajara and is hiring hundreds of Mexican engineers. Furthermore, there is a strong glass industry and diversification in the plastics sector. There are already Japanese, German and American companies that manufacture PV modules in Mexico, but other actors are expected to enter the national market since the country is well-equipped to meet their demand for labor and knowledge. Mexico should draw on the many international programs that exist for financing renewable energy projects and R & D facilities.

Chihuahua

Chihuahua, the largest state in Mexico, has shown great interest in solar projects, with a large number already under development, mainly in households and commercial buildings. In fact, Chihuahua is emerging as the leading state in Mexico in the use of solar panels for residential applications and thus serves as a useful case for explaining how solar panels may be able to establish a foothold in the Mexican market. The use of solar panels in these locations could save up to 50% in electricity consumption and at the same time provide significant environmental benefits. In the event that residential energy production surpasses local consumption, the surplus would be kept by the CFE. This works by discounting the amount of surplus produced from the own household electricity meter.

Currently, the CFE has two rates: the first, denominated 1B, is for households that consume less than 800 kWh each two-month period, which is subsidized by the government at a rate of $2 pesos per kWh; the second rate, denominated HDC (High Domestic Consumption), is for households that consume more than

800 kWh bimonthly, and is $4 pesos per kWh consumed. Over the past few years the number of households with HDC-level consumption has grown by 10%. It is normally in these households that solar systems are installed. For example, if in a certain household the consumption level is 1,300 kWh every two months, a solar system could be installed to generate 600 kWh or more so that the resident will only have to pay CFE for the remaining 700 kWh and, importantly, would pay at the lower 1B rate. This would mean that a customer will pay only $1,400 pesos every two months in electricity costs, as opposed to $5,200 pesos at the higher rate, producing overall savings of $3,800 pesos every two months.

Sigma Comercio y Consultoria, an energy company, has established the goal of installing a solar panel system in every residence in the state.[17] In order to achieve their goal Sigma made a business alliance with EFM-Solar (a firm in Chihuahua). The solar systems will be produced and installed by Sigma and they will be leased by EFM-Solar, who will offer client financing plans from five to eight years. The projections of energy saving are expected to be around 300% of the original energy expenses (previous to installing the solar system) and by the time the financing is paid off the system will be owned by the client. Currently, the price is $1,500 USD per solar panel, including installation. It is calculated that households consuming 800 to 900 kWh per bimester would require systems with two to three panels. This is a substantial upfront cost for residential customers, but the availability of financing and considerable savings in electricity bills should encourage them.

Beyond the direct economic impact of residential applications of solar PV, we should also point out that if a customer were to acquire a partial independence from the national grid this would provide a range of other benefits. In Mexico, as in many developing countries, the public utility is infamous for errors in billing, the resolution of which requires a visit (or sometimes multiple visits) to the company's offices. This can be a frustrating experience. Second, the CFE supply in many parts of Mexico is unreliable, with power outages and spikes that can damage sophisticated electronics. Partial independence of supply by installing an on-grid solar PV can eliminate that problem. Nonetheless, total independence, when the grid is available, is not a good idea since batteries or a generator would be required to have power at night. Lastly, it should be mentioned that the prospect of encouraging residential solar PV applications to not only satisfy individual demand, but also feed back into the national grid using a generous feed-in tariff (the rate the company pays to any producer of energy big or small that saves them any energy consumption), could provide extra income for families and serve as a significant source of new capacity. At the time of writing, however, neither a feed-in tariff, nor a truly "smart-grid" that would allow for this kind of development are within sight in Mexico.

Sonora

In Sonora, the second largest state in the country, CFE is developing the solar field Agua Prieta II. The objective is to include the solar field in a CFE combined cycle central project called CCC Agua Prieta II First Phase which is being developed in a joint venture between the CFE and the consortium of firms formed by Abener Energy, Abengoa Solar and TEYMA, a Uruguayan subsidiary of Abengoa that is specialized in sustainable development projects. It will be the first hybrid solar-gas plant in Mexico.

The project consists of the development, design, construction and testing of a field with the capacity to generate 14 MW, and it is expected to avoid the emission of more than 19 thousand tons of CO2 per year. The Mexican government has received $49.35 million dollars for the acquisition, installation and management of the field from the Global Environment Fund (GEF) of the World Bank.[18]

The Los Alisos wastewater treatment plant in Nogales is expected to be completed in May 2012, with an investment of $407 million pesos distributed among federal resources through Conagua, the state government of Sonora, the Environmental Protection Agency (EPA) and OOMAPAS, the Nogales municipal water provider.[19] It will use photovoltaic panels to generate electricity to be used for the treatment plant. The EPA has offered to invest $700,000 dollars as well as the National and State Water Commissions who have offered an equal co-investment, both subject to CONAGUA's approval in order to develop the solar plant. No specific data could be found on the size or planning of the solar plant. Based on the size of the investment and taking into account current installation prices for PV, we estimate that the capacity of this system will be in the order of 350 KWp. The Los Alisos project sets an important precedent for the use of solar power in water treatment, both in terms of reducing carbon emissions and of producing savings for the local authority, as the solar power will be cheaper than electricity provided by the CFE.[20]

Coahuila

Although there has been little development of solar power in the state of Coahuila, the conditions within the state make it an intriguing prospect. State Congressman Carlos Orta Canales has proposed an amendment to the state Law for the Promotion of Rational Energy Use, which seeks to promote solar and wind projects. His proposal is to create an economic fund to finance renewable energies in the state, promoting the clean generation of electricity while prioritizing small and medium companies.[21]

Japanese companies have shown great interest in investing in Coahuila due to the state's geographical position near the United States (in order to produce and export across the border); they are also aware of the state's high solar irradiation levels and skilled workforce. Therefore, even though they are primarily interested in gas mining and automobile production, they are also focusing on producing solar power, hoping to sell energy to both the United States and Mexico. During Governor Rubén Moreira Valdez's recent tour of Japan and Korea he met with Japanese companies who are interested in investing in Mexican solar energy, including technology giant Sharp Corporation. The companies were mainly interested in the possible installation of solar parks in the Northern part of the state, especially La Laguna and Piedras Negras.[22]

Nuevo León

In the state's main city, Monterrey, a solar energy cluster is being developed by the Energy Research Center of the UNAM, the University of Monterrey, the University of the Isthmus, the Advanced Studies Investigation Center of the National Polytechnic Institute, the enterprise Peñoles and the Science and Technology State Council of Coahuila. Furthermore, Sanyo Energy produces solar panels at a plant in the city for export to the U.S. market.

Despite consulting several sources among newspapers, industry reports and government data, no large solar projects could be found in Nuevo León.

There are several micro projects for rural electrification in the state, some being in the order of dozens of watts and the largest on the order of kW, however it is not a well extended practice and the actual number could not be computed. There are also a number of small projects for local solar lighting, including one on the access road to a waste transfer facility others in public parks.

Durango – A non-border state with potential

Although not a border state, Durango offers us a vision of what could be possible for northern Mexico in general. The municipality of Canatlán has drawn the interest of entrepreneurs from all over the world due to its excellent solar resources. It is one of the locations in the Americas with the highest levels of solar irradiation, registering 60% more hours of sunlight per year than the European average. Durango receives, on average, 5kWh/m2 of solar radiation for 295 days a year and has an average temperature of 17°C.24 In the municipality of Canatlán, an agreement has been established between ejido farmers and the Spanish company Siliken, which will invest 350 million dollars. The solar plant project is expected to produce 1000 MWh per year and to reduce emissions equivalent to the amount produced by 4,000 cars per year. This project will not only provide electricity to the 31,401 inhabitants of the entity and its surroundings, but will also generate around 600 jobs. The plant will also be connected to the national electricity grid, operated by the CFE and surplus electricity generated by the plant will be sold at a fixed price for the first twenty years.[23]

Another important project is owned by the French company EOSOL, which will invest $100 million dollars in the Industrial and Logistics Center of Durango (CLID). The project consists of a solar plant that will be ready to operate by the end of 2012. Durango Governor Jorge Herrera Caldera stated: "We will have to prepare ourselves to become the solar capital of the world."[24]

EMPLOYMENT OPPORTUNITIES FROM SOLAR POWER

The development of clean energy creates many local jobs. In fact, according to the United Nations Environment Programme report on green jobs, non-fossil fuel technologies create more jobs per unit of capacity installed than coal and natural gas.[25] Green jobs, which are jobs that play a direct role in reducing the negative environmental impact of enterprises and economic sectors, can also protect the economy from the political and economic risks associated with over-reliance on a limited array of energy technologies and fuels. Because Solar Energy Projects are new to Mexico, they are hard to establish, finance and develop. Accurate calculations of the potential of these projects for job creation can help overcome these obstacles since reducing poverty levels and raising employment rates is a major goal throughout Mexico. Government and private companies are equally interested in fulfilling this objective, along with raising GDP and income. The development of a solar industry can be analyzed from three perspectives: 1) the manufacturing of the equipment (either thermal or photovoltaic), 2) their suppliers, and, 3) the installation and use of the solar solutions. These three are generally assumed to be independent systems, each with their own supply chain, suppliers, workforce, logistics, etc. For instance, the copper provider making the strips in a PV panel is different from the copper provider who manufactures connecting wires. Another example is a

photovoltaic manufacturing plant that produces several models of panels and uses local manpower and energy sources. Their suppliers provide the required goods to produce the panel and its packaging (cells, copper strips, chemicals, EVA, glass, electronics, aluminum profiles for the frame, cardboard, packaging supplies, etc.). While some of these suppliers will be located in the vicinity of the manufacturing plant, the selection of suppliers cannot be based solely on the proximity to the plant or the cost; there are other important dimensions to be taken into account. In a specialized product such as PVs, quality is of paramount importance since the products are made to be long-lasting, with warranties in the order of 20–25 years.

According to a Greenpeace-EPIA report,[26] there are multiple areas of employment that will benefit from large-scale solar development:

- Solar module production: Requires a skilled workforce with a background in chemistry, physics or related academic disciplines
- PV system integrators: Technicians and engineers are required for the integration of solar systems (panels, infrastructure, controllers, inverters, batteries, wiring, etc). Furthermore, white collar employees are needed to cover the area of management, contracting, design and marketing.
- Installation: Qualified and certified "solar installers," including electricians, roofers, plumbers and other construction workers, are needed for effective installation.
- Operation and maintenance.
- Recycling of PV modules: Staff with a background in chemistry, physics or related academic are needed to ensure environmentally safe recycling.
- Research and development: Scientists and engineers are needed to move technological development forward.

Calculating Solar PV Job Creation Potential:

Among the common RPS technologies (Renewable Portfolio Standard), solar photovoltaic creates the most jobs per unit of electricity output, with an employment multiplier for solar PV of 0.87 with a range of 0.23 to 1.42 job years per GWh. The difference between PV and Thermal is that PV converts directly solar energy into electricity and thermal uses an indirect approach by heating a fluid and then using it to power a conventional turbine-generator. The correlation between capacity factors,

Definitions:

- JOB YEARS: one job year is full-time employment for one person for one year.
- DIRECT JOBS: includes those jobs created in the design, manufacture, delivery, construction/installation, project management and operation maintenance of the different components of the technology or power plant under consideration.
- INDIRECT JOBS: refers to the upstream and downstream
- INDUCED JOBS: accounts for the expenditure-induced effects in the general economy due to the economic activity and spending of direct and indirect employees.

equipment lifetime, energy production and job creation for solar PV and thermal can be analyzed in the table below.[27]

Solar Thermal Energy has thus far been mainly applied to residential projects and private initiatives, such as the so-called new "Green Mortgages."[29] Solar PV is much more advanced in terms of technology, installation and production, but the main problem with PV is the maintenance and expected lifetime of the glasses and copper tubes needed for each PV cell. PV has an expected capacity factor of 25 years, but many of the polymers and glasses that are used (for example, EVA polymer) do not last that long.

Employment Development

Several studies that have been carried out to determine the effect of investment in solar energy technologies on the labor market have concluded that the creation of jobs is greater than an equivalent investment in conventional technologies. For example, an analysis led by the U.S. Public Interest Research Group shows that a renewable energy investment program that would generate 20% of the energy required by the U.S. would create three to five times more jobs than a similar investment in fossil fuels.[30] Meanwhile, the U.S. Worldwatch Institute has conducted a study that concludes that solar energy investment would generate between 100% and 150% more jobs than using coal or nuclear power. This helps justify public investment in these new energy sources because job creation increases the wealth available for investment and consumption, which results in a multiplier effect of spending while simultaneously reducing the marginal costs of electricity generation (Aitken, 2003).[31]

Table 1: Energy Production and Job Creation Correlation for Solar[28]

Energy Technology & Source	Capacity Factor	Equipment Lifetime	Direct jobs (in job yrs/ MWp)	Indirect jobs (in job yrs/ MWp)	Total jobs/ MWp (MW peak)	Total jobs/ MWa (MW avg)	Total Job-Yrs/ GWh
PV1 EPIA Greenpeace '06	20%	25 Years	37	1	2.48	12.4	1.42
PV2 REPP '06	20%	25 Years	32.34	0.37	1.66	8.32	0.95
PV3 EPRI '01	20%	25 Years	7.14	0.12	0.41	2.03	0.23
Solar PV Average	20%	25 Years	25.49	0.50	1.52	7.58	0.87
Thermal1 NREL '09	40%	25 Years	10.31	1	1.41	3.53	0.4
Thermal2 NREL '06	40%	25 Years	4.5	0.38	0.56	1.4	0.16
Thermal3 NREL '01	40%	25 Years	5.71	0.33	0.45	1.12	0.13
Thermal Average	40%	25 Years	6.84	0.53	0.81	2.02	0.23

Table 2: Employment Impacts of Solar Energy in the World, 2009

Sector	# Jobs Created	Year	Location
PV Sector	170,000	2008	**Worldwide**
CSP Sector	624,000	2008	**Worldwide**

Source: Mujgan Cetin, N. E. (2011), "Employment impacts of solar energy in Turkey," Energy Policy. Volume 39, Issue 11, November 2011, pp. 7184–7190

The studies predict that by 2030 around 10 million full-time jobs will be created by solar power development, meaning that more than 500,000 jobs will be created in the area of solar energy production in just a few decades.

In order to understand the concentrated solar power technology the following example is included. The Solucar Complex is an Abengoa Solar Project constructed in 2004 in Seville, Spain. It is a 1.2 billion euro CSP solar plant that currently operates at 183 MW and it will have a capacity of approximately 300 MW using tower, parabolic trough and PV technologies. The project currently occupies 2,471 acres. It created 1,000 jobs during manufacturing and construction, 300 operating jobs and another 50 for R&D. The plant currently supplies clean electricity to approximately 94,000 households.[32]

Based on the Abengoa Project in Seville, Spain, the numbers for CSP direct and indirect jobs are:[33]

- 4 jobs per MW peak for manufacturing
- 6 jobs per MW peak for contractors and installation
- 0.3 jobs per MW peak for operation and maintenance

However, in order to calculate the Employment Rates and projections for each of the current solar projects in Mexico, we need to focus on the employment prospects for solar PV. Three studies were taken into account in creating the measurements for job impact:

EPRI:[34] the Electric Power Research Institute reports that construction employment for solar energy is 7.14 jobs per MWp for PV and operating employment is 0.12 jobs per MWp for PV.

Source: Abengoa Solar, S.A.

$$\mathbf{TTPF} = \frac{Energy\ produced}{Capacity\ per\ year} = \frac{Total\ irradiation(Panel\ efficiency)(Cell\ Area)(365\,\frac{days}{yr})}{Installed\ capacity\left(24\,\frac{hours}{day}\right)\left(365\,\frac{days}{yr}\right)}$$

Pollin's Analysis:[35] Pollin reports that solar technologies potentially create more jobs per million dollars of output when compared to traditional power generation technologies. Solar generation creates 5.4 direct jobs per million dollars of output and if indirect jobs are included the number rises to 9.8 jobs per million dollars of output.

Greenpeace-EPIA:[36] The EPIA and Greenpeace estimate that[37]

- 10 jobs per MW peak are created during production
- 33 jobs per MW peak during installation
- 4–6 jobs per MW peak for research and production

Based on the parameters laid out by these three sources, we created a methodology to calculate energy generation data, solar panel manufacturer´s technical information and energy and employment rates for each of the potential and operating projects in Mexico's northern border. This is necessary in order to compute the actual use of the planned solar projects and hence the jobs related to them. This methodology cross-references data from each project (direct jobs, installed capacity and types of panels, among others) generating a non-dimensional variable called Theoretical Technical Plant Factor (TTPF) which is calculated with the following equation:[38]

For which:

- TOTAL IRRADIATION: is the variable that measures the amount of KWh per square meter per day in a geographically specific region. (KWh/m2/day).
- PANEL EFFICIENCY: is the efficiency reported by the panel manufacturer = η (%).
- CELL AREA: is the total area of cells in a panel module times the number of modules involved in the project. Generally polycrystalline cells are 6x6 inches, or 0.1524 x 0.1524 meters. (m2).
- INSTALLED CAPACITY: measured in KW, this is the same as the KWp reported for each project.

What TTPF interprets is the fraction of the area below the curve of total insolation per day. It is "theoretical" because the Daily Isolation Curve is also "in theory" a speculative gaph.

Solar Panels

For the potential and developed projects in Mexico's northern border, the solar panels being used are mainly silicon polycrystalline, and typically have one of the two following sets of specifications:

Table 3: Solar Panels Commonly Used in Mexico

Specifications	Panel 1	Panel 2
Cell Dimensions	0.1524x0.1524 m	1.640x0.990 m
# Cells/Module	80 cells	60 cells
Panel Efficiency	15.5%	15.4%

THE ANALYSIS

There are currently seven plants either in construction or planned for Mexico's northern states.[39] Through our methodology, it is possible to take the published data and compute the rest of the project specifications. The jobs related to each project can then be computed using each of the three criteria previously described. The projects and assumptions taken are outlined below in table 4.

The employment rate from these projects can be easily referenced to the "Sustainable City" project, due to its unitary capacity. For the economic considerations, we used a national average price of electricity of $1.41 pesos per kW h (SENER, 2011) and an average dollar exchange rate of 12.83 pesos per dollar (see table 5).

As has been shown, the computation of the social impact of solar projects developed in Mexico is not straightforward. In recent years many politicians, local governments and companies have used the solar projects like a "green flag" to show their environmental concern; the data they provide, however, is often incomplete, overestimated or even non-coherent.

Table 4: Mexican Solar Projects in the Border States

Project	Location	Capacity (MWp)	Comments
CFE Geothermal Field	Cierro Prieto, BC	5	Capacity declared as hard data
Sustainable City	Tijuana, BC	1	Capacity declared as hard data
CFE Agua Prieta II	Agua Prieta, Sonora	14	Capacity declared as hard data
Integrated Solar Energy Plant	Mexicali, BC	12.2	Greenpeace criteria used to compute capacity
Solar PV Farm	Tijuana, BC	10.5	500 jobs declared, used Greenpeace criteria to compute capacity (68 MW if EPRI criteria is applied)
Los Alisos	Nogales, Sonora	0,35	$1,400,000 USD investment declared, used international PV costs to compute capacity
SolFocus	Tecate, BC	50	Capacity declared as hard data. First stage of 9 planned to reach 450 MW in the future. CSP installation
Siliken Solar Farm	Canatlán, Durango	12.5	600 jobs declared, used Greenpeace criteria to compute capacity (82 MW if EPRI criteria is applied)

Source: Author's calculations based on data as cited in section five of this report.

Table 5: Jobs Calculations for the Tijuana Sustainable City Project

Methodology 1: EPRI		Methodology 2: Pollins Capacity Factors		Methodology 3: Job Rates EPIA - Greenpeace	
Construction	7	Direct	1	Production	10
Operation	.12	Indirect	2	Installation	33
				R&D	5
Project Energy Output: $ 201,710 USD					

Table 6: Jobs related to Mexican Solar Projects in the Border States

Project	Location	Jobs*
CFE Geothermal Field	Cierro Prieto, BC	35.6
Sustainable City	Tijuana, BC	7.12
CFE Agua Prieta II	Agua Prieta, Sonora	99.68
Integrated Solar Energy Plant	Mexicali, BC	86.86
Solar PV Farm	Tijuana, BC	74.76
Los Alisos	Nogales, Sonora	2.5
SolFocus	Tecate, BC	356
Siliken Solar Farm	Canatlán, Durango	89
Total		751.5

*Based on the EPRI study coefficients.
Source: Author's calculations based on data as cited in section five of this report.

For instance, they may declare a large investment that will create far too many jobs, but when the investment is compared to the international cost of solar plants, the capacity results far lower than originally stated and hence the social impact would not be as large as originally declared.

In order to get a realistic and conservative estimate of the total amount of jobs related to the solar projects in Mexico, the EPRI criteria was considered. This criterion is based on technical factors and normalized with respect to the total plant capacity. In the following table the jobs associated to the eight solar projects are shown.

The aforementioned social impact is related to a total capacity of 105.5 MW (installed and planned) of PV and CSP projects. The actual number of jobs will vary according with the size of the project that is, the smaller the project the larger the amount of jobs per MW associated. In order to have an estimate of the maximum number of jobs related to the solar projects, the Greenpeace-EPIA criteria would give an estimation of 5,060 jobs. (For detailed energy employment rates test analysis on the eight current operating and potential projects in Mexico's Northern Border, please see Appendix 2 where project by project, their technical specifications concerning employment rates, types of jobs, energy generation and expected economic production are explained.)

After conducting a triple analysis on the eight potential projects, it is clear that each specialist gives his or her own point of view. EPIA and Greenpeace forecast high employment rates per MW produced. Pollins, on the other hand, gives low, practical and cost-reduced employment rates per millions of dollars of energy output produced. EPRI forecasts are the most viable figures, which, based on construction and operation factors, predict reasonable employment rates for each project and seem to have enough personnel for construction, operation and management that will be practical and efficient for the solar plant.

CONCLUSIONS

Mexico's world-class solar resource offers the prospect of large-scale future development of solar PV energy in the country, and the northern Border States appear to be the ideal geographic location to drive such development. The projects that already exist highlight the potential for generating not only clean electricity, but also employment and economic growth for local communities.

The development of a mature industry in the solar sector needs to be approached from different angles. On one side there is the availability of the solar radiation, both direct and indirect. The nature of this radiation will have a strong geographical component allowing for some zones where photovoltaic solutions are suitable and others where solar collectors (solar thermal and concentrated photovoltaic) are more suitable. This usually has to do with the spectrum of radiation in question: high concentrations of UV radiation are more suitable for PVs, with infrared radiation for thermal applications.

For renewable energy to become a reality in the country and an engine of sustainable development in Mexico, it will require an innovative and comprehensive approach. Such an approach should set specific goals, promote and conduct research and development, and increase the industrial competitiveness of Mexican companies. A solar industry is not composed only of the application in question, but also of the upstream and downstream industries involved. This means that Mexico will have to develop supply chains, installation,

services, and maintenance industries to be able to build an effective solar sector.

It is unlikely, however, that it makes economic or environmental sense to produce all of the components in Mexico. To produce a truly "clean" solar PV industry, it may make more sense to produce the more energy intensive components in parts of the world where the energy is drawn predominantly from renewable resources such as hydroelectric power plants. Norway's Renewable Energy Corporation, for example, is a leading manufacturer of silicon products for PV and uses hydroelectric power in both its plants in Norway and in Quebec, Canada.

Finally, the use of solar energy sources should be maximized, taking into account the location of the country in terms of solar gain. The proper implementation of solar PV and thermal projects to provide some of the base demand of the national electricity sector could reduce the carbon footprint associated with energy use in Mexico while increasing energy security by basing generation on an inexhaustible and permanently available "fuel."

The employment prospects from solar PV are the highest of any readily available energy source. Using three different analytical models this paper has shown that the existing PV projects in the Border States have already created hundreds of jobs. There is huge potential, however, to generate more jobs if both large-scale generation and residential applications can be encouraged. To do so, local and national firms must participate in the PV value chain, encouraging greater job creation and the development of local productive capacity.

This paper has also argued that developing the PV industry in the north will result in the creation of high quality jobs, requiring investments in human capital and human resources. White collar and scientific jobs will be produced in abundance in the border states and the rest of the country if manufacturers insist on local suppliers, and if these suppliers can match the quality and technical requirements of the solar PV industry.

The social impact of new solar PV projects in the north of Mexico lies not only in the generation of new, high quality employment, but also in its capacity to free local populations from the full dependency on the CFE and all of the bureaucratic and energy-delivery inefficiencies that come with it. Residential applications may also result in the possibility of feeding clean electricity back into the system, producing an economic gain and providing a significant base-load from clean power. This, however, is still a distant goal in Mexico, which lacks either a feed-in tariff or a smart-grid that would allow such a system to function.

Based on the computations showed in the present study, it can be seen that the use of solar-based power plants designed to provide large amounts of electricity in Mexico presents several difficulties. There are other renewable resources that need yet to be fully exploited—like hydroelectricity, wind energy and geothermal systems—before turning to solar on a massive scale.

Moreover, these other renewable sources require a lower investment and operational cost per MW installed. The lowest installation cost found for a solar project is that of the plant in Tecate, BC, where SolFocus invested 3,600 USD/kWp; by contrast, the investment cost of a large hydroelectric plant is in the order of 1,000 USD/kWp. Clearly, this presents a serious barrier for the implementation of large solar projects. It is the opinion of the authors that the technology available today for solar production is not adequate to promote its implementation into a national electric system for macro generation. It

would require subsidies or some other financial, tax or quota enforcements to be implemented.

Solar energy does, however, have the advantage of creating a high number of jobs per unit of energy created. The bulk of the jobs related to solar energy are those related to the installation of the panels, hence the obvious solution would be to spread out these jobs by implementing a large number of small solar projects. The SENER is currently assessing a program to implement small PV systems in new social interest housing and facilities. Another application would be the promotion of solar lighting on urban and rural roads. Rural electrification in communities located far away from the national grid is another good use of solar solutions.

The solar PV prospects for Mexico's northern border states therefore present us with a familiar tale. There is enormous potential, it is true, but little has been done to help realize that potential. In order to obtain the largest social benefit from solar energy systems, the advantages of the solar should be emphasized instead of trying to force the use of solar systems in macro generation where its limitations are magnified. A radical shift in Mexico's energy policy environment must occur before the massive application of solar PV takes place, and an integrated industrial policy must match that shift if full advantage is to be taken of the sector. Putting in place a feed-in tariff would be an important start, and working towards a smart grid would also greatly facilitate the transition to renewable energies. These are pending issues for Mexico's next administration, and must be pushed forward by stakeholders in the solar industry.

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APPENDIX 1: SOLAR RADIATION IN MEXICO'S BORDER STATES, CONUEE, 2008

SOLAR RADIATION IN MEXICO'S BORDER STATES

Average monthly radiation in kWh/m^2-day Source: CONUEE, 2008.

Estado	Ciudad	Ene	Feb	Mar	Abr	May	Jun	Jul	Ago	Sep	Oct	Nov	Dic	Mín.	Máx.	Med.
Baja California	La Paz	4.4	5.5	6	6.6	6.5	6.6	6.3	6.2	5.9	5.8	4.9	4.2	4.2	6.6	5.7
	Mexicali	4.1	4.4	5	5.6	6.6	7.3	7	6.1	6.1	5.5	4.5	3.9	3.9	7.3	5.5
	San Javier	4.2	4.6	5.3	6.2	6.5	7.1	6.4	6.3	6.4	5.1	4.7	3.7	3.7	7.1	5.5
Sonora	Hermosillo	4	4.6	5.4	6.6	8.3	8.6	6.9	6.6	6.7	6	4.7	3.9	3.9	8.6	6
	San Luis Río Colorado	3.4	3.8	4.9	6.2	7.3	7.4	6.9	6.1	5.1	4.05	3.3	2.8	2.8	7.4	6
	Guaymas	4.5	5.7	6.5	7.2	7.3	6.8	5.9	5.8	6.3	5.9	5.1	5.6	4.5	7.3	6
	Nogales	3.1	3.9	5.2	6.5	7	7	6.1	5.6	5.2	4.3	3.5	2.9	2.9	7	5.2
	Cd. Obregón	3.6	4.5	5.9	7.1	7.7	7.5	6.07	5.8	5.6	4.9	4.09	3.4	3.4	7.7	5.7
Chihuahua	Chihuahua	4.1	4.9	6	7.4	8.2	8.1	6.8	6.2	5.7	5.2	4.6	3.8	3.8	8.2	5.9
	Cd. Juárez	3.1	3.9	5.2	6.4	6.9	7	6.4	5.6	5	4.2	3.5	2.9	2.9	7	5
Coahuila	Saltillo	3.8	4.2	4.8	5.1	5.6	5.9	5.9	5.6	5.2	4.4	3.6	3.3	3.3	5.9	4.8
	Piedras Negras	3.1	3.6	4.2	4.5	4.8	6	6.7	6.3	4.9	4.1	3.3	2.9	2.9	6.7	4.5
Nuevo León	Monterrey	3.2	3.6	4.1	4.3	4.8	5.5	6.1	5.6	5	3.8	3.3	3	3	6.1	4.4
Tamaulipas	Soto la Marina	3.4	4.2	4.9	4.9	5.1	5.3	5.4	5.4	4.9	4.6	3.7	3.2	3.2	5.4	4.6
	Matamoros	2.9	3.9	5.3	6	6.7	7	6.8	6.7	5.5	5.1	3.7	2.8	2.8	7	5.5
	Tampico	3.3	4.1	4.7	6.4	5	4.9	4.9	4.9	4.6	4.6	3.7	3.2	3.2	6.4	4.5
	Reynosa	2.6	3.5	4.6	5.3	5.7	6	6.1	5.7	4.8	4.4	3.3	2.5	2.5	6.1	4.5

APPENDIX 2: DATA FOR SPECIFIC SOLAR ENERGY PROJECTS IN BORDER STATES

Appendix 2.1 Cerro Prieto, BC

PROJECT	LOCATION	ENERGY	PANEL			
FCE's Geothermic Field	Cierro Prieto, BC	INSTALLED ENERGY GENERATION	MODULE BRAND, TYPE & DIMENSION			
		KWh/year				
		5,000.00	KYOCERA KD 315-80 P Series			
		ANNUAL AVG IRRADIATION	AREA PER CELL	CELLS/MODULE	# MODULES	AREA PER MODULE
		KWh/m^2	m^2			m^2 /module
		5.50	0.02323	80		1.8581
		DAILY ENERGY GENERATION PER PANEL	POWER OUTPUT	TECHNICAL PANEL NOMINAL EFFICIENCY (producer)		INSTALLED PHYSICAL PANELS NEEDED
		KWh/m^2	KW	%		
		1.5840	0.315	15.5%		15,873
		ANNUAL ENERGY GENERATION PER PANEL	ENERGY & EMPLOYMENT RATES			
		KWh/m^2	ENERGY PRODUCED PER DAY			# OF JOBS REQUIRED FOR CONSTRUCTION
		578.16	KWh/day	MWh/day	GWh/day	36
		PANEL FACTOR	25,142.81	25.14	0.03	# OF JOBS REQUIRED FOR OPERATION
		0.914283886	ENERGY PRODUCED PER YEAR			0.60
		THEORIC PLANT FACTOR	KWh/day	MWh/day	GWh/day	# OF JOBS REQUIRED TO GENERATE 1GW/year
		0.20952339	9,177,124.50	9,177.12	9.18	15

EPRI	Capacity Factors POLLINS		Job Rates EPIA - Greenpeace	
CONSTRUCTION	Direct	Indirect	Production	50
36	5	10	Installation	165
OPERATION	$ Energy Output		R&D	25
0.60	$	12,939,745.55		
	USD Energy Output			
	USD	1,008,553.82		
	Millions USD			
	$	1.0086		

COMPARING JOB RATES

	DIRECT	INDIRECT	CONSTRUCTION	OPERATION	PRODUCTION	R&D	INSTALLATION
EPRI	36		36	0.60			
POLLINS	5	10					
EPIA GPEACE	240		165	75	50	25	165

Appendix 2.2 Sustainable city, Tijuana, BC

PROJECT	LOCATION	ENERGY	PANEL			
Sustainable City	Tijuana, BC	INSTALLED ENERGY GENERATION KWh/year	MODULE BRAND, TYPE & DIMENSION			
		1,000.00	KYOCERA KD 315-80 P Series			
		ANNUAL AVG IRRADIATION KWh/m^2	AREA PER CELL m^2	CELLS/MODULE	# MODULES	AREA PER MODULE m^2 /module
		5.50	0.02323	80		1.8581
		DAILY ENERGY GENERATION PER PANEL KWh/m^2	POWER OUTPUT KW	TECHNICAL PANEL NOMINAL EFFICIENCY (producer) %		INSTALLED PHYSICAL PANELS NEEDED
		1.5840	0.315	15.5%		3,175
		ANNUAL ENERGY GENERATION PER PANEL KWh/m^2	ENERGY & EMPLOYMENT RATES			
			ENERGY PRODUCED PER DAY			# OF JOBS REQUIRED FOR CONSTRUCTION
		578.16	KWh/day	MWh/day	GWh/day	7
		PANEL FACTOR	5,028.56	5.03	0.01	# OF JOBS REQUIRED FOR OPERATION
		0.91	ENERGY PRODUCED PER YEAR			0.12
		THEORIC PLANT FACTOR	KWh/day	MWh/day	GWh/day	# OF JOBS REQUIRED TO GENERATE 1GW/year
		0.21	1,835,424.90	1,835.42	1.84	15

EPRI		Capacity Factors POLLINS		Job Rates EPIA - Greenpeace	
CONSTRUCTION		Direct	Indirect	Production	10
	7	1	2	Installation	33
OPERATION		$ Energy Output		R&D	5
	0.12	$	2,587,949.11		
		USD Energy Output			
		USD	201,710.76		
		Millions USD			
		$	0.2017		

COMPARING JOB RATES

	DIRECT	INDIRECT	CONSTRUCTION	OPERATION	PRODUCTION	R&D	INSTALLATION
EPRI	7		7	0.12			
POLLINS	1	2					
EPIA GPEACE	48		33	15	10	5	33

Appendix 2.3 Agua Prieta II, Sonora

PROJECT	LOCATION	ENERGY	PANEL			
FCE's Agua Prieta II	Sonora	INSTALLED ENERGY GENERATION KWh/year	MODULE BRAND, TYPE & DIMENSION			
		14,000.00	KYOCERA KD 315-80 P Series			
		ANNUAL AVG IRRADIATION KWh/m^2	AREA PER CELL m^2	CELLS/MODULE	# MODULES	AREA PER MODULE m^2 /module
		5.20	0.02323	80		1.8581
		DAILY ENERGY GENERATION PER PANEL KWh/m^2	POWER OUTPUT KW	TECHNICAL PANEL NOMINAL EFFICIENCY (producer) %		INSTALLED PHYSICAL PANELS NEEDED
		1.4976	0.315	15.5%		44,444
		ANNUAL ENERGY GENERATION PER PANEL KWh/m^2	ENERGY & EMPLOYMENT RATES			
			ENERGY PRODUCED PER DAY			# OF JOBS REQUIRED FOR CONSTRUCTION
		546.62	KWh/day	MWh/day	GWh/day	100
		PANEL FACTOR	66,559.87	66.56	0.07	# OF JOBS REQUIRED FOR OPERATION
		0.91	ENERGY PRODUCED PER YEAR			1.68
		THEORIC PLANT FACTOR	KWh/day	MWh/day	GWh/day	# OF JOBS REQUIRED TO GENERATE 1GW/year
		0.20	24,294,351.41	24,294.35	24.29	14

EPRI		Capacity Factors POLLINS		Job Rates EPIA - Greenpeace	
CONSTRUCTION		Direct	Indirect	Production	140
	100	14	26	Installation	462
OPERATION		$ Energy Output		R&D	70
	1.68	$	34,255,035.49		
		USD Energy Output			
		USD	2,669,917.03		
		Millions USD			
		$	2.6699		

COMPARING JOB RATES

	DIRECT	INDIRECT	CONSTRUCTION	OPERATION	PRODUCTION	R&D	INSTALLATION
EPRI	101.64		100	1.68			
POLLINS	14	26					
EPIA GPEACE	672		462	210	140	70	462

Appendix 2.4 Integrated solar plant, Mexicali, BC

PROJECT	LOCATION	ENERGY	PANEL			
Integrated Solar Energy Plant AAA	Mexicali, BC	INSTALLED ENERGY GENERATION	MODULE BRAND, TYPE & DIMENSION			
		KWh/year				
		87.500,00	KYOCERA KD 315-80 P Series			
		ANNUAL AVG IRRADIATION	AREA PER CELL	CELLS/MODULE	# MODULES	AREA PER MODU
		KWh/m^2	m^2			m^2 /module
		5,50	0,02323	80		
		DAILY ENERGY GENERATION PER PANEL	POWER OUTPUT	TECHNICAL PANEL NOMINAL EFFICIENCY (producer)		INSTALLED PHYSICAL PANE
		KWh/m^2	KW	%		
		1,5840	0,315	15,5%		
		ANNUAL ENERGY GENERATION PER PANEL	ENERGY & EMPLOYMENT RATES			
		KWh/m^2	ENERGY PRODUCED PER DAY			# OF JOBS REQUIRED FOR CO
		578,16	KWh/day	MWh/day	GWh/day	
		PANEL FACTOR	439.999,12	440,00	0,44	# OF JOBS REQUIRED FOR C
		0,91	ENERGY PRODUCED PER YEAR			
		THEORIC PLANT FACTOR	KWh/day	MWh/day	GWh/day	# OF JOBS REQUIRED TO GENER
		0,21	160.599.678,80	160.599,68	160,60	

EPRI	Capacity Factors POLLINS		Job Rates EPIA - Greenpeace	
CONSTRUCTION	Direct	Indirect	Production	875
625	95	173	Installation	2888
OPERATION	$ Energy Output		R&D	438
10,50	$	226.445.547,11		
	USD Energy Output			
	USD	17.649.691,90		
	Millions USD			
	$	17,6497		

COMPARING JOB RATES

	DIRECT	INDIRECT	CONSTRUCTION	OPERATION	PRODUCTION	R&D	INSTALLATION
EPRI	635,25		625	10,50			
POLLINS	95	173					
EPIA GPEACE	4200		2888	1313	875	438	2888

Appendix 2.5 Solar PV farm, Tijuana, BC

PROJECT	LOCATION	ENERGY	PANEL			
Solar PV Farm	Tijuana, BC	INSTALLED ENERGY GENERATION	MODULE BRAND, TYPE & DIMENSION			
		KWh/year				
		68,870.52	KYOCERA KD 315-80 P Series			
		ANNUAL AVG IRRADIATION	AREA PER CELL	CELLS/MODULE	# MODULES	AREA PER MODULE
		KWh/m^2	m^2			m^2 /module
		5.50	0.02323	80		1.8581
		DAILY ENERGY GENERATION PER PANEL	POWER OUTPUT	TECHNICAL PANEL NOMINAL EFFICIENCY (producer)		INSTALLED PHYSICAL PANELS NEEDED
		KWh/m^2	KW	%		
		1.5840	0.315	15.5%		218,637
		ANNUAL ENERGY GENERATION PER PANEL	ENERGY & EMPLOYMENT RATES			
		KWh/m^2	ENERGY PRODUCED PER DAY			# OF JOBS REQUIRED FOR CONSTRUCTION
		578.16	KWh/day	MWh/day	GWh/day	492
		PANEL FACTOR	346,319.65	346.32	0.35	# OF JOBS REQUIRED FOR OPERATION
		0.91	ENERGY PRODUCED PER YEAR			8.26
		THEORIC PLANT FACTOR	KWh/day	MWh/day	GWh/day	# OF JOBS REQUIRED TO GENERATE 1GW/year
		0.21	126,406,673.59	126,406.67	126.41	15

EPRI	Capacity Factors POLLINS		Job Rates EPIA - Greenpeace	
CONSTRUCTION	Direct	Indirect	Production	688.7052342
492	75	136	Installation	2272.727273
OPERATION	$ Energy Output		R&D	344.3526171
8.26	$	178,233,409.77		
	USD Energy Output			
	USD	13,891,925.94		
	Millions USD			
	$	13.8919		

COMPARING JOB RATES

	DIRECT	INDIRECT	CONSTRUCTION	OPERATION	PRODUCTION	R&D	INSTALLATION
EPRI	500.00		492	8.26			
POLLINS	75	136					
EPIA GPEACE	3306		2273	1033	689	344	2273

Appendix 2.6 Solar Farm Siliken, Canacatlán, Durango

PROJECT	LOCATION	ENERGY	PANEL			
Solar Farm Siliken SPAIN	Canatlan, Durango	INSTALLED ENERGY GENERATION	MODULE BRAND, TYPE & DIMENSION			
		KWh/year				
		82,644.63	KYOCERA KD 315-80 P Series			
		ANNUAL AVG IRRADIATION	AREA PER CELL	CELLS/MODULE	# MODULES	AREA PER MODULE
		KWh/m^2	m^2			m^2 /module
		5.50	0.02323	80		1.8581
		DAILY ENERGY GENERATION PER PANEL	POWER OUTPUT	TECHNICAL PANEL NOMINAL EFFICIENCY (producer)		INSTALLED PHYSICAL PANELS NEEDED
		KWh/m^2	KW	%		
		1.5840	0.315	15.5%		262,364
		ANNUAL ENERGY GENERATION PER PANEL	ENERGY & EMPLOYMENT RATES			
		KWh/m^2	ENERGY PRODUCED PER DAY			# OF JOBS REQUIRED FOR CONSTRUCTION
		578.16	KWh/day	MWh/day	GWh/day	590
		PANEL FACTOR	415,583.58	415.58	0.42	# OF JOBS REQUIRED FOR OPERATION
		0.91	ENERGY PRODUCED PER YEAR			9.92
		THEORIC PLANT FACTOR	KWh/day	MWh/day	GWh/day	# OF JOBS REQUIRED TO GENERATE 1GW/year
		0.21	151,688,008.31	151,688.01	151.69	15

EPRI	Capacity Factors POLLINS		Job Rates EPIA - Greenpeace	
CONSTRUCTION	Direct	Indirect	Production	826.446281
590	90	163	Installation	2727.272727
OPERATION	$ Energy Output		R&D	413.2231405
9.92	$	213,880,091.72		
	USD Energy Output			
	USD	16,670,311.12		
	Millions USD			
	$	16.6703		

COMPARING JOB RATES

	DIRECT	INDIRECT	CONSTRUCTION	OPERATION	PRODUCTION	R&D	INSTALLATION
EPRI	600.00		590	9.92			
POLLINS	90	163					
EPIA GPEACE	3967		2727	1240	826	413	2727

Appendix 2.7 Los Alisos, Nogales, Sonora

PROJECT	LOCATION	ENERGY	PANEL			
Los Alisos, Nogales	Sonora, Nogales	INSTALLED ENERGY GENERATION	MODULE BRAND, TYPE & DIMENSION			
		KWh/year				
		350,00	KYOCERA KD 315-80 P Series			
		ANNUAL AVG IRRADIATION	AREA PER CELL	CELLS/MODULE	# MODULES	AREA PER MODU
		KWh/m^2	m^2			m^2 /module
		5,20	0,02323	80		
		DAILY ENERGY GENERATION PER PANEL	POWER OUTPUT	TECHNICAL PANEL NOMINAL EFFICIENCY (producer)		INSTALLED PHYSICAL PANE
		KWh/m^2	KW	%		
		1,4976	0,315	15,5%		
		ANNUAL ENERGY GENERATION PER PANEL	ENERGY & EMPLOYMENT RATES			
		KWh/m^2	ENERGY PRODUCED PER DAY			# OF JOBS REQUIRED FOR CO
		546,62	KWh/day	MWh/day	GWh/day	
		PANEL FACTOR	1.664,00	1,66	0,00	# OF JOBS REQUIRED FOR O
		0,91	ENERGY PRODUCED PER YEAR			
		THEORIC PLANT FACTOR	KWh/day	MWh/day	GWh/day	# OF JOBS REQUIRED TO GENER
		0,20	12.739.007,09	12.739,01	12,74	

EPRI	Capacity Factors POLLINS		Job Rates EPIA - Greenpeace	
CONSTRUCTION	Direct	Indirect	Production	3,5
2	8	14	Installation	11,55
OPERATION	$ Energy Output		R&D	1,75
0,04	$	17.962.000,00		
	USD Energy Output			
	USD	1.400.000,00		
	Millions USD			
	$	1,4000		

COMPARING JOB RATES

	DIRECT	INDIRECT	CONSTRUCTION	OPERATION	PRODUCTION	R&D	INSTALLATION
EPRI	2,54		2	0,04			
POLLINS	8	14					
EPIA GPEACE	17		12	5	4	2	12

ENDNOTES

1 UNICEF (1984), "Solar Energy: World Distribution," Department of Environmental Health, University of Beirut: http://almashriq.hiof.no/lebanon/600/610/614/solar-water/unesco/24–26.html.

2 Ibid.

3 Diario Oficial de la Federación, 2009. Diario Oficial, 6 de agosto de 2009. México: Secretaría de Gobernación.

4 SENER (2009), Sistema de Información Energética, http://sie.energia.gob.mx/sie/bdiController

5 Uscanga, E. J. (2011), "Tiene BC Potencial en la energía solar," El Mexicano - Gran Diario Regional, 8 November, 2011.

6 Medina, V. R. (2011), "Tiene Chihuahua la mayor reserva solar del mundo," El Sol de México, 5 October 2011.

7 Strategy 10.1 of Chapter 4 on Environmental Sustainability (Sergio Romero D. D., 2011)

8 SENER & GTZ (2006), Renewable Energies for Sustainable Development in Mexico, http://www.sener.gob.mx/res/PE_y_DT/pe/FolletoERenMex-SENER-GTZ_ISBN.pdf

9 Ibid.

10 Ibid.

11 Ibid.

12 Martínez, A. (2011), "En Mexicali, primera planta de energía solar," El Mexicano - Gran Diario Regional, September 14, 2011.

13 Indice de Ciudades Verdes de América Latina (Economist Intelligence Unit, 2010)

14 Gonzalez, J. I. (2010), "Construirán en Tijuana ciudad de energía solar," El Mexicano - Gran Diario Regional, 22 October, 2010.

15 SolFocus, 2012, "First 50 Megawatts of Large Solar Power Plant in Baja California, Mexico Enabled by Cross-Border Collaboration," http://www.solfocus.com/en/news-events/press-releases/2012-03-29.php

16 "Proyecta Siliken una graja solar y energía fotovoltaica," El Mexicano - Gran Diario Regional, 1 November, 2011.

17 "Reducen paneles solares costos de energía en 50%," El Heraldo de Chihuahua, 15 January, 2012.

18 (Notimex, 2011)

19 OOMAPAS: "Organismo Operador Municipal del Agua Potable, Alcantarillado y Saneamiento" is the Municipal Operating Agency for Water and Wastewater in Nogales.

20 (Marquesina Política, 2012)

21 Valdés, D. (2011), "Buscan que se utilice energía solar y eólica," El Diario de Coahuila, 7 December, 2011.

22 "Les interesa Coahuila a empresas japonesas," El Diario de Coahuila, 27 October, 2011.

23 Mendez, L. (2011), "El huerto solar mas grande del mundo." Milenio, 4 September, 2011 http://www.milenio.com/cdb/doc/noticias2011/08bdd7d4361766ee8c1399eb86f873c2

24 "EOSOL invertirá 100 mdd en Durango," Contacto Hoy - Edicion Mundial, 1 November, 2011.

25 UNEP. (2008). Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World. http://www.unep.org/labour_environment/PDFs/Greenjobs/UNEP-Green-Jobs-Report.pdf.

26 Greenpeace-EPIA. (2011). Solar Generation 6: Solar photovoltaic electricity empowering the world, http://www.epia.org/solargeneration

27 Max Wei, S. P. (2010), "Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US?," Energy Policy, Volume 38, Issue 2, February 2010, pp. 919–931.

28 (Max Wei S. P., 2010)

29 An energy efficient mortgage (EEM) (or "green mortgage") is a loan product that allows borrowers to reduce their utility

bill costs by allowing them to finance the cost of incorporating energy-efficient features into a new housing purchase or the refinancing of existing housing.

30 Aitken, D. W. (2003). White Paper on Transitioning to a Renewable Energy Future, Freiburg: The International Solar Energy Society (ISES).

31 Ibid.

32 "Entra en servicio la tercera planta de la plataforma solar Solucar que producirá 50 megawatts," El Mundo, http://www.elmundo.es/elmundo/2010/05/24/andalucia_sevilla/1274721623.html

33 Abengoa Solar (2011) "Energía Solar para un Mundo Sostenible" https://www.abengoasolar.com

34 Mujgan Cetin, N. E. (2011), "Employment impacts of solar energy in Turkey," Energy Policy. Volume 39, Issue 11, November 2011, pp. 7184–7190

35 Croucher, M. (2011), "Capacity factors and solar job creation," Energy Policy, Volume 39, Issue 11, November 2011, pp. 6914–6915.

36 Mujgan Cetin, N. E. (2011), "Employment impacts of solar energy in Turkey," Energy Policy. Volume 39, Issue 11, November 2011, pp. 7184–7190

37 Greenpeace-EPIA. (2011). Solar Generation 6: Solar photovoltaic electricity empowering the world, http://www.epia.org/solargeneration

38 Sergio Romero, B. D.-G. (February 2012). "Theoretical Technical Plant Factor – TTPF," Instituto Tecnológico Autónomo de México, Mexico City, Mexico.

39 However, the data provided by government bodies, news outlets, or public statements vary in nature. Some provide planned peak capacity, others provide an estimation of the energy to be produced, others give only data on the economic investment and some others just give an estimate on the direct and indirect jobs that will be created.

40 CONUEE (2008), "Irradiación Global Media en la Republica Mexicana," http://www.conuee.gob.mx/work/sites/CONAE/resources/LocalContent/7058/1/irradiacion211009.pdf

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