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Feasibility of a photovoltaic system for irrigation at the Santa Edwiges ranch in the municipality of Delicias, Chihuahua

Factibilidad de sistema fotovoltaico para irrigación en rancho Santa Edwiges del municipio de Delicias, Chihuahua

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Abstract

This investigation was carried out in the Santa Edwiges ranch located in Delicias Chihuahua, the problem of the increase in the costs of electrical energy for pumping water is a situation that reflects a decrease in the profits of the ranch, through this information the option is presented to implement the photovoltaic system as a sustainable option to reduce costs and thus reduce greenhouse gases provided by renewable energy through the use of solar panels, to analyze the information the capital budget methodology was used to determine its feasibility economic and methodological tool to calculate the emission factor of an electrical system and determine the level of carbon dioxide emissions generates electricity. The results of the investigation were the implementation of the system that would be generated with an investment of $636,000 and would stop emitting around 20,000 kg of CO_2 into the atmosphere, which represents a significant advance for the environmental impact, in relation to the analysis of economic indicators. It was that for the moment, the implementation of solar in Rancho Santa Edwiges is not recommended, since better performance is generated by not making the investment.

Photovoltaic system, Sustainable, Renewable energy, Solar panels

Resumen

Esta investigación se realizó en el rancho Santa Edwiges ubicado en Delicias Chihuahua, el problema del aumento de los costos de energía eléctrica para bombeo de agua es una situación que refleja una disminución en las ganancias del rancho, a través de esta información se presenta la opción de implementar el sistema fotovoltaico como una opción sostenible para la reducción de costos y así reducir los gases de efecto invernadero que otorga energías renovables a través del uso de paneles solares, para analizar la información se utilizó la metodología de presupuesto de capital para determinar su factibilidad económica y la herramienta metodológica para calcular el factor de emisión de un sistema eléctrico y determinar el nivel de emisiones de dióxido de carbono genera electricidad. Los resultados de la investigación fueron la implementación del sistema que se generaría con una inversión de $636.000 y dejaría de emitir alrededor de 20.000 kg de CO_2 a la atmósfera lo que representa un avance significativo para el impacto ambiental, en relación al análisis de indicadores económicos. Fue que por el momento, no se recomienda la implementación de solar en Rancho Santa Edwiges, ya que se genera mejor rendimiento al no realizar la inversión.

Sistema fotovoltaico, sustentable, Energía renovable, Paneles solares

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Introduction

Currently the use of renewable energies such as the photovoltaic system is increasing, not only for use in homes but also in the industrial and agricultural sector, obtaining electricity in a natural, clean and environmentally friendly way; this technology in turn generates a sustainable development pathway as in some places it is not easy to connect to the electricity grid due to the isolation of their location (SENER, 2012).

According to the Spanish Photovoltaic Union, up to 2015, there was a 25% increase in photovoltaic capacity worldwide compared to 2014. The countries with the highest generation of this technology are: China with 15.2 GW, Japan 11 GW, United States of America 7.3 GW (UNEF, 2016).

In line with this worldwide increase and according to a report issued by the Ministry of Energy, in Mexico in 2015 the installed capacity increased by 6.63 % compared to 2014, for electricity generation from 18,000 (MW) implemented until 2014 to 19,265 for 2015, which represented an increase of 28.31 % of the installed capacity at national level (SENER, 2016). For this reason and the installed capacity in our country, the Rancho Agrícola Santa Edwiges has been affected in terms of the payment of electricity, since in periods of time when the irrigation of crops is more intense, consumption and electricity costs increase due to the pumping of the well and sometimes it has been necessary to reach payment agreements with the Federal Electricity Commission due to the high amount to be paid (Velasco, 2017).

Given these problems, the aim is to find a viable alternative that helps to reduce the cost of electricity, such as the photovoltaic system, and if it also achieves a positive environmental impact, it will be seen as an option for electricity generation. For this reason, the economic feasibility of this system for water irrigation was evaluated to determine its implementation in the Santa Edwiges Agricultural Ranch in the municipality of Delicias, Chihuahua.

Background

Solar photovoltaic energy is the use and exploitation of sunlight to produce electrical energy. This technology was discovered by Alexandre Edmund Bequerel in 1838, which is described as the generation of an electromotive force in a semiconductor device to absorb light radiation, since photovoltaic cells convert light energy from the sun into electrical energy (Sapiain, 2010).

The use of this technology started with a pilot device made by Bell Laboratories in the United States of America in 1954 with low efficiency. Later, in the 70's, the Energy Research and Development Agency was created in the same country and this institution promoted the use of renewable energy sources in industrialised countries; the main countries that benefited from this technology were Spain, Australia, Germany, Japan, among others (Grupo NAP, 2002).

In Mexico, the implementation of photovoltaic energies at national level, particularly in the agro-industrial sector, began to take off in the 21st century, since previously the country did not give great importance to renewable energies. According to the Ministry of Energy (SENER) and the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) there are about 120 000 agricultural wells in the country and of these about 70% have high electricity consumption according to the activity they perform (SAGARPA, 2016). According to this information in Mexico, the states of Sonora, Baja California Sur, San Luis Potosí, Nuevo León and Chihuahua have the highest solar irradiation at national level, reaching a maximum of 8-9 kWh/m² as shown in Figure 1, and are considered an ideal area for the development of technologies from renewable resources (Anchondo, 2009).

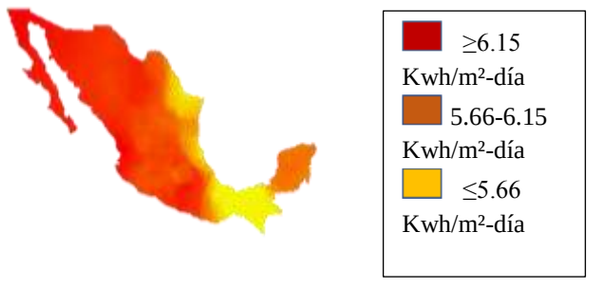

Figure 1 Map of solar radiation in Mexico
Source (*SIGER, 2014*)

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Annual average daily solar radiation Source: Geographic Information System for Renewable Energy in Mexico (SIGER) of the Institute of Electrical Research.

This is why the state of Chihuahua has made significant progress in terms of solar energy, as it is currently a national leader in the use of solar panels and projects of great relevance such as the Central Los Santos Solar I defined as the second largest nationally, this project will generate approximately 40.1 Giga watt hours (Gwh) of electricity during its first year of installation, equivalent to the energy used by 5,838 households in an annual consumption (Rodriguez, 2016).

In particular, the Santa Edwiges agricultural ranch located in the municipality of Delicias Chihuahua, has a total area of 50 hectares, of which 40 hectares are planted with perennial and annual crops such as alfalfa, corn, chili, and recently the planting of walnut trees, these crops depend heavily on significant water consumption for their optimal development (Velasco, 2016). This property has been affected by increases in the costs of electricity tariffs to achieve the extraction of water recommended for irrigation, these expenses range in consumption of $0.00 per month when the agricultural well is not much used this in the period from May to October which are considered low season, and in the months of January to April as well as November and December have a higher consumption having a monthly average of $ 25,000 this causing a deficiency for the ranch (Velasco, 2017).

Problem statement

Currently the Santa Edwiges ranch has the 9M electricity tariff, this is the one used in the service of pumping water for agricultural irrigation in medium voltage, this rate has federal government subsidies implemented in agriculture has a cost of $0.28 for the first 5000 Kw of consumption and gradually increases as consumption rises.

Due to the irrigation used for the crops grown on the ranch, most of them require a large consumption of water for their optimal development.

Currently, the irrigation module No. 5 provides 10 thousands of water per hectare, this property has been affected by the expense in the consumption of electricity and this has brought as a consequence an indebtedness of the producer towards the Federal Electricity Commission, to mention some, it has come to make payment agreements to settle the economic commitment, in a way it has been a setback for the financial situation of the producer.

It is for this reason and due to the lack of knowledge on the part of the producer about the alternatives of electricity generation in a renewable way such as the use of photovoltaic energy, it will be investigated whether it is feasible or not to achieve the implementation of this system in the agricultural ranch.

Justification.

Nowadays there are other energy alternatives that use a renewable resource such as solar energy, including the photovoltaic system. This technology is used in the generation of electricity used at residential, commercial, industrial and agricultural levels, as well as in the extraction of water for irrigation, and is also known for the environmental benefits it provides. This is why the feasibility of implementing this system was analysed to determine if it is a good option as an investment in the agricultural ranch and also the technological importance that this system represents by substituting the use of fossil fuels and contributing to environmental improvement by reducing CO2 emissions that are generated.

Frame of reference

Photovoltaic energy has been a great scientific contribution in the environmental and technological field, With the passage of time this system became more sophisticated, approximately in 1955 the United States of America implemented a photovoltaic system at the request of the National Aeronautics and Space Administration (NASA) in spacecraft to reduce the use of chemical batteries and nuclear energy, then in the 70's the idea of giving more use to solar panels was given the application was experimented in water extraction by pumps generated by solar energy and thinking of reaching areas where there was no electricity (Mendez, 2009).

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With the arrival of the 21st century and more technological, social and environmental innovations and in search of a clean, sustainable and renewable technology, it is increasingly common to find the implementation of photovoltaic systems, organic systems, biomass, wind energy, trying to counteract the damage to our planet by implementing the use of renewable energy in residential, industrial, agricultural, livestock, aquaculture, manufacturing, among others (Garcia, 2007).

According to solar energy technology and market demand, there is a wide variety of solar panels, such as silicon panels, which are the most commonly used, these are guaranteed by companies with an average yield of 80% in their first 25 years of useful life, as well as monocrystalline panels, which generate an efficiency of between 15% and 21%, including polycrystalline panels, as they are cheaper than monocrystalline panels and their efficiency is around 14% (Rivas, 2017). Up to 2015, according to data from the National Inventory of Greenhouse Gas and Compound Emissions, 309,553 GWh of electricity was generated, 79.7 % of which was generated in conventional power plants and 20.

According to information from the database of the National Institute of Ecology and Climate Change (INECC), electricity generation emits 19% of total greenhouse gas emissions in Mexico, with an equivalent of 127 billion tonnes of carbon dioxide (CO2) annually (SENER, 2016) Currently the energy tariff in Mexico dictated by the Federal Electricity Commission (CFE) used in the service of pumping water for agricultural irrigation in low or medium voltage is the 9M, as shown in Table 1, this rate is variable according to the required use of irrigation for each need, is determined monthly and for the month of November 2017 would apply the rate mentioned below:

Energy tariff 9M of Comisión Federal de Electricidad. November 2017	
$10.146	First 5,000 kilowatt-hours.
$11.87	Next 10,000 kilowatt-hours.
$12.471	Next 20,000 kilowatt-hours.
$13.606	For each additional kilowatt-hour over and above the above

Table 1 Comisión Federal de Electricidad's 9M energy tariff November 2017
Source: Federal Electricity Commission, November 2017

The regulation issued by the Federal Electricity Commission for the use of photovoltaic system in our country has certain restrictions for the installation of solar panels, you have to develop a contract for interconnection to the electricity grid (Annex 1) and in this it is mentioned that the production of energy emitted by solar panels is determined on a monthly basis, and the amount of Kw generated by the photovoltaic system has an annual cut-off date in the month of December of each year, in addition to the installation of a bidirectional meter, which is responsible for measuring the energy emission of the panels (Barrera, 2017).

Conceptual framework

The generation of renewable energy is considered as coming from various natural sources, which are produced continuously by water as hydropower, wind generates wind energy and by the sun that forms solar energy and biomass (Villas, 1999), the latter being known as solar energy, which reaches the earth in the form of electromagnetic radiation (Sarmiento, 2007), these radiations are captured by cells that are included in a photovoltaic system that can be defined as the direct transformation of solar energy into electricity (Mendez Muñiz & Cuervo, 2002).

This technology is possible through solar panels, devices capable of capturing solar radiation for its use, and with this we seek to reduce the use of fossil fuels produced by chemical reactions and form the gas, coal and oil (Mendez Muñiz & Cuervo, 2002), and thus achieve sustainable development by meeting current needs, without putting at risk that future generations can achieve the same way to meet their needs (De Juana, 2008).

Methodology

This case study was carried out on the Santa Edwiges ranch located on the Delicias-Rosales Highway Km 2.0 in the municipality of Delicias Chihuahua, the location of the municipality is shown in figure 2, it is located in the central-southern region of the state of Chihuahua, with a territorial area of 534.93 km² bordering the municipalities of Meoqui and Rosales to the north, and the municipality of Saucillo to the south, occupying a territorial extension of the state of Chihuahua of 534.93 square kilometres.

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Figure 2 Geographical Location of the Municipality of Delicias, Chihuahua, Mexico
Source: National Institute for Federalism and Municipal Development

In order to know the energy consumption costs, the receipts of the Federal Electricity Commission were analysed for a trial period of 12 months, as well as the depth of the agricultural well, which is 100 metres, and the water extraction used for irrigation of the property is 80 litres per second, based on this information, the feasibility cost of the project was analysed.

The data collection techniques were generated through an analysis of the monthly bills issued by the Federal Electricity Commission to determine the energy cost of the Santa Edwiges ranch, and based on the results of consumption and the data on the depth and discharge of water from the agricultural well, the corresponding quotations were determined for the cost of establishing the photovoltaic system, as well as the information on the discharge of water for irrigation of the crops grown on the ranch.

The analysis of the financial indicators was based on the methodology of the Capital Budget Evaluation Procedure (BRIGHAM & BESLEY, 2001) and the costs of implementing the system were determined according to the financial indicators NPV (Net Present Value), IRR (Internal Rate of Return, Benefit/Cost Ratio), this information determined the results based on economic feasibility.

To determine the environmental impact of the carbon dioxide emissions emitted per kWh, it was based on: "Methodological Tool: Tool for calculating the emission factor of an electricity system based on seven steps" (UN, 2015):

1. Identify relevant electricity systems.
2. Choose whether to include "off-grid" power plants in the project's electricity system (optional).
3. Select a method to determine the operating margin (OM).
4. Calculate the operating margin emission factor according to the selected method.
5. Identify the group of power units to be included in the construction margin (BM).
6. Calculate the construction margin emission factor.
7. Calculate the combined margin emission factor (CM).

Approach

The research was carried out in a quantitative way determined by the Kwh consumption of the agricultural ranch Santa Edwiges in a period from 2014 to 2017, and in the same way the use of the photovoltaic system and the potential of electricity generation with this system and jointly the environmental exploitation that renewable energy implies were analysed.

Type of research

It was determined in a descriptive research based on the management and use of the photovoltaic system, highlighting its qualities, efficiency for environmental sustainability as well as the economic constraints to achieve the implementation of the system for pumping in the Santa Edwiges ranch.

Design

The case study was carried out in a non-experimental manner since the handling of the information did not have control over the variables to be evaluated. It is also defined as a simple transactional research based on the research and applications that have been done before on this system as well as the places where it has been implemented and the results it has had in an economic and environmental approach.

Variables and indicators

The study variables assessed were

a. Cost of establishment
b. Operating cost
c. Maintenance cost

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d. Amount of energy produced
e. Initial investment
f. Cash flows

Financial Indicators

– NPV (Net Present Value)
– IRR (Internal Rate of Return)
– DRP (Discounted Payback Period)
– RB/C (Benefit-Cost Ratio)

Determining as dependent variable the cost of setting up the photovoltaic system. This research work was carried out in the Santa Edwiges agricultural ranch, the property is located in the municipality of Delicias, Chihuahua, and was conducted between the months of January 2016 to November 2017.

Data processing

The Excel program Office 2010 was used as a fundamental support tool for the elaboration and analysis of the results obtained on this project, referring to the financial indicators, the costs of the traditional system and likewise the costs with the implementation of the photovoltaic system, also analysed the monthly electricity consumption in a period of three years from 2014 to 2017 with the conventional way through the Federal Electricity Commission and the analysis if the photovoltaic system is implemented, together the environmental impact of the photovoltaic system was evaluated and the emissions that would be saved with this technology.

Results

The results obtained from this research are mentioned below:

1. Analysis of the costs incurred in the management of this system.

According to the measurement of electrical energy consumption, a result was obtained for the use of 101 solar panels of 260 Kw each, with an inverter of 10,000 w and also 101 structures to support the panels, all this including the installation, interruption boxes, connector boxes and the start-up of the system, this technology would generate a capital investment of $636. 054.32.

By implementing the system a generation of 51, 984 Kwh per year would be achieved and with this information it would be possible to cover the demand that currently has the agricultural ranch Santa Edwiges from the planting of 40 hectares of alfalfa, walnut, corn and chili, and would occupy an area of 307m² for the installation of solar panels. The maintenance costs of the photovoltaic system are practically null, since this technology, due to its structure, does not require maintenance, since when it rains, the system practically cleans itself and its content is resistant to inclement weather.

Likewise, the monitoring of the inverter is guaranteed for 10 years by the company, and it also has a 25-year guarantee of 80% of production in the solar panels. According to the measurement of electrical energy consumption, the result obtained was the use of 101 solar panels of 260 kW each, with an inverter of 10,000 w and also 101 structures to support the panels, all this including the installation, interruption boxes, connector box and the start-up of the system, this technology would generate a capital investment of $636. 054.32, by implementing the system a generation of 51, 984 Kwh per year would be achieved and with this information it would be possible to cover the demand that currently has the agricultural ranch Santa Edwiges from the planting of 40 hectares of alfalfa crops, walnut, corn and chili, and would occupy an area of 307m² for the installation of solar panels.

The maintenance costs of the photovoltaic system are practically null, since this technology, due to its structure, does not require maintenance, since at the time of rain, this system is practically self-cleaning and its content is resistant to inclement weather. Likewise, the monitoring of the inverter is guaranteed for 10 years by the company, and it also has a 25-year guarantee of 80% production in the solar panels.

2. Calculation of the Financial Indicators

Based on the results obtained in the Excel 2010 programme, the following information was obtained as shown in table 2, evaluating the system over 25 years, determining three variables such as the implementation of solar panels with financing, with own acquisition and without the solar panels, this is how Rancho Santa Edwiges is at the moment:

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Concept	VAN	TIR	Relation B/C	PRD
Financial indicators with the implementation of solar panels and financing.	$872,481.33	77.59%	1.81	1.44
Financial indicators with panels and own financing.	$1,099,133.26	101%	1.52	1
Financial indicators without panels.	$2,200,818.78	0	1.88	1

Table 2 Project indicators
Own Source

In the previous results it can be identified that the option of investing in the panels is viable according to the activity reflected in the income and expenditure of the Ranch, as it shows an IRR of 77.9% with respect to a TREMA of 38.9%, a NPV of 872,481 compared to an investment of approx. 600,000 which means that the project is profitable in 25 years, even the calculations were made for five years and showed the feasibility of the project, however the investment period is very long compared to the return that is received. In addition, the analysis was carried out with own financing, obtaining also satisfactory results in which, due to the fact that a financial institution will not be used, the profitability of the project is increased, with an IRR of 101% and an NPV of more than one million pesos.

Determination of the environmental impact of the photovoltaic system as a source of alternative energy

The Rancho agricola Santa Edwiges in the period of analysis from September 2015 to September 2016 generated an annual consumption of 52500 Kwh, which means that multiplied by 0.385 Kg of CO2 Eq/ Kwh would stop emitting 20,212.5 Kg of CO2 eq /Kwh, this if the photovoltaic pumping system is implemented. This information would help to mitigate the environmental impact caused by the damage to the ozone layer and compared to the emissions generated by the consumption of 1,811 litres of gasoline in a car, which would be on the same scale as the spread of CO2 emitted into the atmosphere.

However, it has been proven that economically it is not advisable to implement this system for this particular Ranch, since the greatest benefit would be in the reduction of the environmental impact and not in the specific interests of the Ranch, which refer to the reduction of costs in the consumption of electricity. The best option identified was not to make the investment because although strong emissions of electricity are generated in periods of low consumption, these cannot be accumulated for more time than the cycle established by the CFE, so that although enough energy is generated so that over time the present project is feasible, the economic benefit is not so representative for the agribusiness.

The analysis reflected an NPV of more than 2.2 million pesos and a benefit-cost ratio of 1.88, which is the highest of the options evaluated. According to the analysis of the financial indicators it was determined that the best option is that the ranch should remain as it is at present, that is to continue its energy consumption in the usual way using the CFE company for the supply of electricity as the cost currently generated from the energy tariff is viable and easy to pay on the contrary as with the placement of solar panels these have a history of annual generation, This means that the energy generated in a period up to the month of December of each year is returned to the CFE and this interferes with the feasibility of implementing the photovoltaic system.

Conclusions

According to the identification of the costs to implement the photovoltaic system would be carried out according to the costs for electricity will require 101 solar panels and the same number of structures for the placement of the panels, similarly it requires an inverter with a capacity of 10000 Watts, ranging in a cost of about $636 thousand pesos. The implementation of the solar panels will be guaranteed by the manufacturer and the installation company for 25 years for the production of the solar panels and 10 years for the inverter required, as well as the monitoring of the same. In addition, according to the ISR law, there is a 100% deduction for the installation of renewable energy generation equipment.

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According to the results of the financial indicators, it was determined that it is better for the Santa Edwiges ranch to continue working as usual with the use of electricity issued by the CFE, since with the installation of the solar panels the energy produced is cut off in the month of December of each year, This means that in the periods when the energy generated by the photovoltaic system is most needed, which are the months at the beginning of the year, there is no accumulated energy and this information reduces the viability of the system due to the restrictions issued by the Federal Electricity Commission, the benefit-cost ratio suggests that for every peso invested there is a profit of $0. 88, this is the most feasible result of the evaluation. In terms of environmental impact, it is extremely important to implement renewable energy systems, given that the planet is suffering more and more damage every day and this technology manages to mitigate the CO2 emissions generated by electricity that go directly into the atmosphere, and today renewable sources seek to be viable because of the green energy they produce.

With the generation of electricity by solar panels, it would be possible to stop emitting about 20 thousand kg of CO2 eq /Kwh in about a year, these data demonstrate the environmental viability with which the use of photovoltaic system is impacting in a sustainable way and thanks to technological advances every day there are more improvements in quality, flexibility and price of solar panels.

Recommendations

It is recommended to the producer to continue working in the same way since the implementation of the photovoltaic system and according to the modifications that the company CFE has had when making an interconnection contract, certain restrictions have been imposed such as the generation of electrical energy that has a duration of one year, that is, that the electrical energy that is generated and not fully used is returned to the CFE and this reduces its feasibility considerably, and also has a period of use until the month of December of each year. In terms of environmental impact, it is important to think of mechanisms that help mitigate the ecological damage generated by the use of electricity, among other things.

This means that in addition to thinking of an economic benefit from the use of renewable energies, we have to think about the future and work in a positive environmental way, to somehow reduce CO2 emissions in the atmosphere.

Annexes

Annex 1. Photovoltaic system quotation

ENERGYMOL
Líderes en Energía Renovable

ENERGYMOL
Leaders in
Renewable Energy

Renewable Energy Services
Chihuahua, Chihuahua, Mexico
Ave. Francisco Villa #6501 Col. Panamericana
Phone: (614)178-4471 (614)211-5271 Office: 2591222
Email: ventas@energymol.com.mx
Visit our website: www.energymol.com.mx
Address to: Lizeth Portillo Garcia
Date: 17/05/2017
Energy Saving System Service Number: 585 010 504 765
Warranty 25 years 80% of production on solar panels
Inverter Warranty 10 Years Factory Defect (MONITORING Included)

Quantity	Unit Price	Total	Kw/Day
101	4,080.65$	412,145.45$	Panels 260 w Canadian Solar
1	76,305.26$	76,305.26$	Investor 10000 w CONERA FORTE
101	640.00$	64,640.00$	Structure
1	Supply and installation	82,963.61$	Fixing of switchgear, wiring, piping, junction boxes, switch boxes, functional testing and commissioning of the system.
Installation			
Total			**$ 636,054.32**
This quotation includes VAT			
Warranty 25 years 80% of production on solar panels			

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