PROJECT, DESIGN AND MANAGEMENT (PDM)
https://www.mlsjournals.com/Project-Design-Management
ISSN: 2683-1597

(2025) Project, Design and Management 7(1), 123-142. doi.org/10.35992/pdm.v7i2.4209.

USE OF SOLAR PANELS IN PLAYA DEL CARMEN MEXICO
USO DE PANELES SOLARES EN PLAYA DEL CARMEN MÉXICO

Uzziel Japhet Vega Cadena[1]
Autonomous University of the State of Quintana Roo, Mexico
(uzzielvc@uqroo.edu.mx) (https://orcid.org/000900082732-6437)
Janette Carolina Ruiz Moedano
Autonomous University of the State of Quintana Roo, Mexico
(jcruiz@uqroo.edu.mx) (https://orcid.org/0009-0005-0042-7834)
David Reyes Coronado
Autonomous University of the State of Quintana Roo, Mexico
(davrey@uqroo.edu.mx) (https://orcid.org/0000-0003-3870-265X)

Manuscript information:

Recibido/Received: 11/11/2024
Revisado/Reviewed: 28/11/2024
Aceptado/Accepted: 18/02/2025

Keywords:
solar energy, sustainability, solar panels, environment.

ABSTRACT

Given the growing demand for energy in Playa del Carmen as a result of the growth that the international tourist destination has had in recent years, interest in renewable energies has been promoted, especially solar energy. This study analyzes and proposes the implementation of solar panels in the region and its environmental and economic impact, as well as the domestic viability of the use of this technology. Solar panel installation has increased by 40% since 2019, with most users reporting a 30-50% reduction in their electricity bills. Furthermore, 70% of respondents were willing to recommend this technology to others, highlighting its contribution to reducing the local carbon footprint. The results show that the use of solar panels is not only viable, but also beneficial for the local economy and the environment. Government incentives and the high solar potential of the region are key factors that encourage their adoption, however, there has been a lack of knowledge in some sectors about the use of this technology, which in the face of previous stereotypes has slowed down its use, educational and dissemination campaigns are therefore required to inform about its benefits, its uses and procedures in addition to the facilities that allow recovering the initial investment and promote the use of technology in the home environment.

Palabras clave:
energía solar, sostenibilidad, paneles solares, medio ambiente.

RESUMEN

Ante la creciente demanda de energía en Playa del Carmen producto del crecimiento que el destino turístico internacional ha tenido en los últimos años, se ha impulsado el interés por las energías renovables, especialmente la solar. Este estudio analiza y propone la implementación de paneles solares en la región y su impacto ambiental y económico, así como la viabilidad doméstica del uso de esta tecnología. La instalación de paneles solares se ha

[1] Corresponding author.

	incrementado un 40% desde 2019, la mayoría de los usuarios reportaron una reducción del 30-50% en sus facturas eléctricas. Además, el 70% de los encuestados mostró disposición para recomendar esta tecnología a otros, destacando su contribución a la disminución de la huella de carbono local. Los resultados evidencian que el uso de paneles solares no solo es viable, sino también benéfico para la economía local y el medio ambiente, Incentivos gubernamentales y el alto potencial solar de la región son factores clave que fomentan su adopción, sin embargo, ha existido un desconocimiento en algunos sectores sobre el uso de esta tecnología, lo que ante estereotipos anteriores ha desacelerado su uso, se requieren entonces campañas educativas y de difusión que informe sobre sus beneficios, sus usos y trámites además de las facilidades que permitan recuperar la inversión inicial y promover el uso de la tecnología en el ámbito doméstico.

Introduction

In this article an extensive analysis of secondary sources was carried out to generate a cross-sectional descriptive documentary research, initially giving a context that goes from the general to the particular of renewable energy as well as its concept, current situation and benefits; based on the documentary research, the feasibility of the use of solar panel energy in the Riviera Maya, in the city of Playa del Carmen in the municipality of Solidaridad Quintana Roo, Mexico, is analyzed.

The inertia of constant change seems to have no end before the immensity of the universe, the constant discoveries and research, as well as the new theories, the knowledge accumulated over time and the constant innovation in all areas, not only evolve day by day, but second by second, perhaps as a response to the immensity previously mentioned, since, as Francis Bacon points out, the human being enters into a dynamic of participative evolution that allows giving order to scientific research and theories, developing them to solve the unknowns of our universe; of course, the curiosity of the human being has always been the ambitious engine of such evolution (Bacon, 1779). However, at times, paradoxically, we see omissions of previous knowledge or theories, some significantly basic, that seem to disappear with the passage of time or intentionally and that would allow us to return to the basics, giving a greater context to the present and the future.

Concepts or postulates conveniently disappear or are lost in time if they favor some interests and in some cases knowledge and theories or practices of the optimal use of natural resources that have been accumulated over time have significant omissions, again in favor of the interests of a few, although it is also convenient to point out that not always all common practices promote common benefits; human beings seem to have, among several of their differences with other beings, the capacity to convert into a communicable experience every experience they get from the reality that surrounds them, but the weight of generational or personal interests can stop the evolution in search of a common welfare (Cordón, 1991).

It would be convenient then to think that in order to achieve the closest thing to a balance in the use of resources it is vital of course to understand and not forget the past, but also to have a deep knowledge of the present and adapt all the knowledge poured throughout the history of humanity in favor of it towards the future, thus promoting a mix of asymmetric and timeless time thinking (Stokes, 2016). A thinking that allows to obtain the best of the past, including the most representative mistakes, to adapt incessantly to the present, but always considering the future and detonating actions that transcend in time beyond today, taking into account the aspects that the environment, in time, will bring with it, but also, in an essential way, always keeping in mind the premise that resources "ARE NOT INFITIMATE".

On the benevolent side of the application of knowledge in favor of the common good, we can say that, as of 2015, global renewable energy consumption has increased by an average of 2.3%, which allowed for stable carbon emissions as a consequence of relatively stable energy consumption and economic growth. According to the International Energy Agency (2017), the cited effects are linked to an increase in renewable energy (RE) penetration in addition to improvements in energy efficiency.

Method

Importance of Renewable Energy

Recognition of the importance of renewable energy and energy efficiency has been permeating the planet thanks to globalization, highlighting their role as key strategies to combat climate change, in addition to the generation of new economic opportunities and the social function that provides access to energy to millions of people who lack modern energy services; in 2014, the United Nations General Assembly issued a declaration calling for a decade of sustainable energy for all (SE4ALL), encouraging the quest to increase the share of renewable energy sources in the energy system from 18% in 2010 to 36% in 2030. (Ballesteros, 2016)

According to the International Renewable Energy Agency (IRENA) it has been estimated that RE grew approximately 19.3% of global energy consumption in 2016; renewable energy sources such as biofuels, wind energy, solar photovoltaic, hydroelectricity and solar thermal are the most used resources for cooking or heating in some remote or rural areas in developing countries and only 10.2% of these sources are considered as renewable energy (REN21, 2017).

Canada, Denmark, Germany, Spain, the United Kingdom and Brazil have undertaken actions focused on the development of technologies that enable the use of a large number of renewable resources to produce energy; analyzing this international experience it is possible to glimpse that renewable energy becomes a priority in the energy agenda and not only in developed countries but in those that are on that path, even in all those countries that have emerging economies since the positive impact on the environment and society and therefore the economy is undoubted (Olabi, 2016).

Context of Renewable Energies in the World

In the scientific context and in the quest for new discoveries, research has been carried out dating back to the nineteenth century, the idea of harnessing energy in the environment dates back to 1838 where the French physicist Alexandre Edmond Becquerel conducted experiments that allowed him to discover that through the use of sunlight using two metal electrodes was possible to generate electricity and for the year 1866 the French researcher Augustin Mouchot would create the first parabolic solar collector, which by capturing solar rays that were concentrated by a set of mirrors heated the water in a boiler, at the time of boiling generated steam that powered a motor. It is evident that the resources of other times have been consumed and today scientific efforts concentrate their projects on the postulate that conventional energy sources are no longer as profitable compared to alternatives, this as a result of increased cost competitiveness; today renewable energies are more frequent and used and their profitability is being increasingly recorded in rural areas that are generally likely to have limited access, which strengthens their role in the provision of essential energy services and support to the productive sector (Robles and Rodriguez, 2018).

Renewable energies are thus a pillar in the clean energy transitions that have increased due to their deployment in the heat and transportation energy sectors, which is one of the main enablers of keeping the increase in average global temperatures below 1.5°C; in the Net Zero Emissions scenario, it is proposed that by 2050, renewable energies will enable almost complete decarbonization of electricity generation. Meanwhile, renewable transport fuels and renewable heat contribute to significant emission reductions in transport, buildings and industry.

Consistent with what was described at the beginning of this article, it is pertinent to point out that renewable energies have advantages and disadvantages, some of which

are shown in the following table:

Table 1
Renewable energies advantages and disadvantages

Renewable energies	
Advantages	**Disadvantages**
They are considerably clean and are valued as fundamental tools against climate change since they do not emit Greenhouse Gases.	Some renewable energy sources are intermittent (solar, wind) and there is no operational control because they operate when the resource is available (i.e. they require other support sources to guarantee continuous production, sometimes these support alternatives can be fossil fuels or hydroelectric power plants).
Due to their nature of being inexhaustible resources, they strengthen the energy independence of the regions.	Some renewable energy sources require construction of considerable dimensions that affect the ecosystem where they are implemented, such as wind farms, which can modify the environment and produce vibrations or noise.
When biomass is produced, it is decentralized, which can support the reduction of external dependence on primary fossil fuels, since it has a high degree of technological development and its long-term supply is reliable, allowing the development of small and modular projects distributed geographically.	The shadow effect of wind turbines, like the rest of the tall structures, will cast a shadow on neighboring areas when the sun is visible, which can alter the ecosystem or even affect the performance of a solar energy source if it is to be used.
By 2040, solar and photovoltaic energy are expected to provide more than half of the additional electricity generation under the current scenario of established policies and sustainable development.	Wind turbine structures and turbine rotors can affect the habitat and fauna, changing their habits or even causing accidents when they collide with them.
Offshore wind energy has a high technical potential to meet the current and future electricity demand, it has great advantages such as the maximum use of higher wind speeds with less variability.	Designing materials that can withstand extreme marine conditions is perhaps one of its main challenges, in addition to subsequent maintenance.
They are sources of employment in the localities where they are used, and have also reduced their costs,	It is not possible for them to be available in every type of territory and sometimes it is not possible to

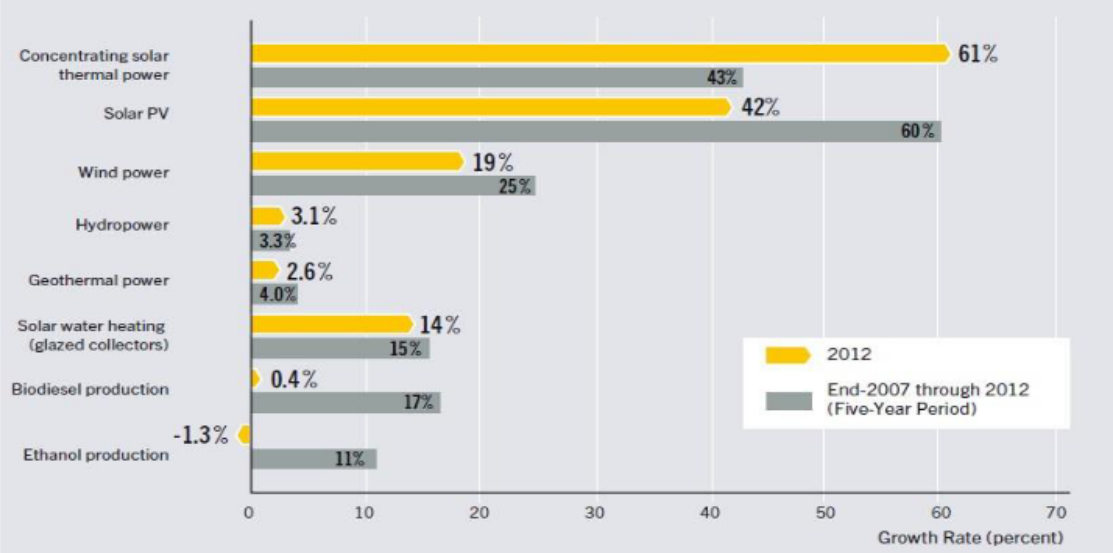
making them more competitive.

change their location, there is no standardization and each region has a different availability of natural resources that allow their use, which causes a variation from one source to another in obtaining energy.

In a context of preservation, the growth rates of renewable energies in the world have grown gradually, it is true that some regions and companies continue with environmentally unfriendly practices, enriched with information to carry them out that is transmitted as mentioned globally; however, the pressure of the common good even if not forcefully seems to influence more and more allowing the rates of growth rates of renewable energies to grow gradually and diversify in the different alternatives to make use of it as we see in Figure 1 that compiles information during the period 2007-2012 (REN21, 2015).

Figure 1

Annual growth rate of renewable energies (2007-2012)



Note. Wind and photovoltaic are the types of renewable energy that have shown the greatest acceptance and use in the period from 2007 to 2012. Taken from RENEWABLES 2015 GLOBAL STATUS REPORT, https://www.ren21.net/wp-content/uploads/2019/05/GSR2015_Full-Report_English.pdf

86% of power generation capacity in Europe is attributed to renewable energy sources, particularly wind and photovoltaic (REN21, 2017). In 2014, Germany's share increased to 24% from 10.5% in 2010; on the other hand, renewables are responsible for about half of Scotland's electricity production (REN21, 2015).

The U.S. renewable energy sector contributed to more than 15% of electricity generation, wind and photovoltaics produced electricity significantly, but bioenergy generation remained stagnant (REN21, 2017).

Brazil for its part occupies the first position in new installed renewable energy capacity in Latin America and the Caribbean, with 2.5 GW of generation capacity with wind power by 2014 (REN21, 2015), while Uruguay is the country that has added the highest wind power generation capacity per capita. By 2016, wind energy accounted for 22.8% of the country's total electricity consumption (REN21, 2017).

The installed capacity of renewable energy is the largest in Asia, China is the country with the largest solar, wind and hydropower production capacity while Thailand has already surpassed European countries in solar power production and Pakistan in addition to the Philippines have significantly increased their wind power capacity (REN21, 2015).

With 59% of Australian electricity generated by hydropower plants and 32% by wind power, Australia has the largest share of renewable electricity capacity in the Oceania region (REN21, 2017) and Africa has seen an increasing number of renewable energy installations, in fact currently, South Africa is undertaking the first wind power installations and has secured its place in the top 10 solar power markets, ahead of India. and that Kenya having more than half of the world's installed geothermal capacity (REN21, 2015).

The challenges facing renewable energies mainly concern the electricity sector, which continues to be the sector with one of the most sustained growth rates, based on solar photovoltaic and wind energy, which have grown significantly in recent years, clearly taking advantage of the already significant contribution of hydroelectric energy; however, electricity represents only one fifth of global energy consumption and finding a more important role for renewable energy sources in transportation and heating remains fundamental for the energy transition.

Renewable energies are a resource with a much broader and to some extent inexhaustible use and consumption scheme compared to fossil fuels, promote self-sufficiency in the country's energy matrix, are less harmful to the environment and support the reduction of climate change; therefore, the complex interconnection of sustainability and energy is today the basis for transformation processes that seek to change the way societies behave as well as global goals, the environmental crisis can only be addressed by reaching a deep and meaningful agreement between nature and humanity, while seeking to reverse the effects caused by pollution and disproportionate anthropogenic global warming. The seriousness of the problem poses a global mobilization factor for society and opens the door to other forms of environmental and cultural assessment (Perino et al., 2021).

Types of Renewable Energy

The UN defines renewable energies as energies derived from natural sources that can be replenished faster than they can be consumed, such as wind and sunlight, which are considered to be relatively abundant sources of self-renewal in certain ecosystems. Generating renewable energies produces a considerable lower amount of emissions compared to burning fossil fuels, which is why switching to renewable energies is essential to influence the crisis caused by climate change (UN, 2024).

Table 2 shows the general characteristics of each of the types of energy, where it is evident that their generation and classification is related to the source or natural resource from which they obtain the engine that drives them:

Table 2
Types of renewable energy.

Bioenergy	This energy is obtained from biomass, i.e. organic matter such as forestry, agricultural or livestock waste, rapidly rotating forest plantations, energy crops, organic components of municipal solid waste and other organic waste (Edenhof, 2011).
Solar energy	It comes from the sun and the electromagnetic radiation it produces is used directly with technologies developed to capture such radiation by means of cells, photoelectric cells, solar collectors or heliostats (Vivanco, 2020).
Geothermal energy	It is obtained from the heat available in the earth's interior. The steam output from the planet's interior is used to drive turbines. The required groundwater temperature has to be above 150°C (Schallenber, 2018).
Hydropower	It generates electricity by storing water in reservoirs or lakes and as the water moves at lower elevation levels over a period of time, the moving water produces kinetic energy, which is then converted into electrical energy through its flow in a hydroelectric power plant.
Wind energy	It is the energy produced by the movement of air masses or wind, thanks to which turbines, blades or devices that eventually produce energy move. During the day, the lack of density causes the air masses to heat up and rise, which contrasts with the cold air of the oceans and lakes, causing movement and winds (González et al., 2022).

America and Mexico in Renewable Energies

The Latin American and Caribbean region is one of the richest sources of renewable natural energy in the world where non-conventional renewable energy has great potential, in fact, it is estimated that the region could meet the energy demands of the economic growth of the entire area if it used only a small portion of its non-hydroelectric renewable capacity (Centro Mexicano de Derecho Ambiental, 2017), and although the region continues to rely on fossil fuels and hydropower Latin America and the Caribbean is experiencing a strong silent and complex movement in the renewable energy sector is slow progress (Tejeda et al., 2007).

In addition to renewable energy, countries continue to explore non-renewable technologies such as hydraulic fracturing to take advantage of oil and gas reserves with an estimated expenditure of more than 40 billion dollars to subsidize fossil fuels in the region, which shows that traditional energy sources will not disappear very soon in the Americas or in other parts of the planet (WWF, 2014).

However, the renewable energy market is growing rapidly as the region has great potential, Costa Rica, Uruguay, Brazil, Chile and Mexico represent efforts in the region to accelerate the necessary paradigm shift, according to the World Wildlife Fund, only 6% of the region's energy comes from modern sources, including solar energy, wind energy, biomass energy and geothermal energy, yet this figure is expected to reach 20% by 2050 (WWF, 2014).

Latin America is currently a fast growing region for renewable energies and there is a growing interest in developing this type of resource as its context is framed by a constant high electricity prices in most regions and on the other hand the increase in demand with some export potential, which provides a fertile ground for the use of renewable energy technologies, let us not forget that the region has a long history of hydroelectric generation, which drives support in policies and laws, i.e. power generation is the area that receives the most attention in renewable energy policy and legislation promoting its use by establishing renewable electricity production targets, tax incentives, grid access provisions and financing services and tariff reduction policies, (Robles and Rodriguez. 2018). Currently, most countries in the region already have legislation in the renewable energy sector, with the exception of Bolivia, Guyana and Suriname, which do not yet have programs in this sector (Robles and Rodriguez, 2018).

The establishment of national renewable energy targets provides a clear picture of the status of renewable energy development and the government's planned timeline. Targets can be expressed in a variety of formats, such as capacity in MW or MWh relative to generation or relative numbers, an example of this according to data from REN21 (2015), is that Ecuador had a target of reaching 90 RE in 2017 and a hydroelectric generation target of 4.2 GW in 2022.

This type of energy is still in its initial stages in Mexico, and although the regulatory and institutional framework is good, there are still obstacles to overcome that make it impossible to deploy renewable energies and expand their use. The country is undergoing an energy transition that is consistent with a change in the direction of the energy sector, seeking to diversify primary energy sources and increasing the participation of renewable energies as the main source of energy in the national territory, the main reasons for this transition are the excessive dependence of the Mexican economy on hydrocarbons, as well as the negative environmental impact of the use of conventional energy and the guarantee of energy security (Zúñiga et al., 2017).

In line with the objectives and strategies established in the National Development Plan 2007-2012, the Energy Sector Program 2007-2012 aims, among other things, to balance the portfolio of primary energy sources, promote the use of renewable energy sources and biofuels, and address the energy issue, to attack alleviate the increase in greenhouse gas emissions and to achieve these objectives, PROSENER defines a medium-term strategy and script.

Discussion on the Relevance of Solar Energy and Solar Panels

The photoconductivity of selenium was discovered by the Englishman Willoughby Smith, who in his experiments noticed how the conductivity of selenium rods increased exponentially when exposed to intense light, which led his compatriots Richard Evans Day and William Grylls Adams to create the first selenium photovoltaic cell, the amount of light we receive from the sun is undoubted and its use since then has attracted the attention of scientists; The amount of energy that reaches the Earth from the Sun per year is 175.the amount of energy that the human being consumes is 17 TW, but only if we take advantage of the energy of this star.

In this context Mexico is a great place for renewable energies since there are regions where the radiation is 130 watts per square meter, Germany is one of the main nations that generates more electricity through photovoltaic systems in the world, although it receives half the solar irradiation of Mexico, the electricity production in Mexico is less than that of Germany, a few years ago this production was only about 100 MW and is currently estimated at 2,015 MW which shows a considerable growth (s.a., September 14, 2023).

From 2007 to 2012, the total installed capacity in the world for some renewable energy sources increased significantly and rapidly wind energy increased installed capacity by just over eight times, while geothermal energy has increased by just over a third compared to 2001 however solar energy increased it by 38 times (Upton & Snyder, 2017).

In this order of thought, we find that solar energy is undoubtedly one of the fastest growing technologies not only in the aforementioned period but also in 2012, with global efforts in research and development in this field (Manzano et al., 2014). Further evidence of solar PV progress is provided in Table 3, which shows the global capacity for solar PV over the period 1995 to 2012 (Mercure et al. 2011).

Renewable energy has been gradually replacing conventional fuels in five different markets: electricity generation, water heating, space heating, transportation fuels, and power supply in off-grid rural centers (Tsai et al., 2017). Table 3 identifies the advantages and disadvantages of photovoltaics.

Table 3

Advantages and disadvantages of photovoltaic solar energy.

Photovoltaic solar energy	
Advantages	Disadvantages
Clean, renewable, infinite and silent	Large initial investment
Economically remunerated to production for sale to the grid	Difficult to store
Subsidies	Complex and costly module manufacturing process
Short energy pay-back	Not competitive with other energies at present
No moving parts and modular	Variable production according to climate and time of year

Note. Photovoltaic Solar Energy. (2007, December). Official College of Telecommunications Engineers: https://www.coit.es/sites/default/files/informes/pdf/energia_solar_fotovoltaica.pdf

As mentioned above, photovoltaic solar energy is received through panels or solar cells of which there are up to four generations, the first of silicon, the second of thin film and the third of copper, gallium and selenium, where efficiency is similar, the last generation of photovoltaic cells are the organic ones.

The third and fourth generation cells can be used in windows, suitcases and clothing, the difference between these devices and the first generations is that the latter absorb light and have equipment that can charge mobile devices. The next generation of solar cells is intended to be more efficient, since most modern organic cells, in addition to being flexible and semi-transparent, are already created by design and the challenge is to make them stable so that they can be easily replaced if they fail.

In 2003 the cost of producing solar energy was seven dollars per watt, so the return on investment was long term, in addition to the need for backup or storage for night and day use, i.e. the area of opportunity lay in the storage capacity of the energy generated, the weakest point of photovoltaic systems. The production of one watt in pesos was 75.53 pesos, as a consequence of the exchange rate, while the cost of solar panels in the United States was US$3.50 per watt and in Mexico it was US$6.65 per watt.

Evidently with this information it was to be expected that there were important budgetary limitations that made this type of energy generators which meant that it was

restrictive and only available to some, but in the last three years, the cost of solar panels has dropped about 60%, so that the average price of 1.81 dollars per watt was reduced to 0.7 dollars per watt, the cost per watt between 22.9 pesos in 2007 and 8.8 pesos in 2010 evidently the variation also responded to the exchange rate of the US currency at that time.

The use of solar panels has made it possible to document their benefits and highlight some good practices in various parts of the world, among which we can mention Freiburg, Germany, which is a global benchmark in the use of solar energy and urban sustainability, since the city has integrated solar panels in public and private buildings, maximizing solar collection and thanks to local policies, new developments must include photovoltaic systems or comply with energy efficiency standards, thus achieving a significant reduction in carbon emissions through a combination of renewable energy and sustainable transportation where residents actively participate in solar cooperatives, sharing the energy generated and reducing costs. Power, G. (2016, August 31) Isabel. (2024, December 18).

Another notable example is San Diego, United States, which is a leader in the use of solar energy in North America with energy equity programs, "San Diego Solar Equity Program" that facilitates access to solar panels for low-income families, covering up to 100% of the cost of installation, in addition to offering subsidies and financing for residential solar installations, which has driven its massive adoption, San Diego is one of the cities with the highest installed capacity per capita in the U.S., thanks to local policies that encourage the energy transition. Ini, L. (2022, 12 August), Admin. (2024, October 3)

Singapore and Barcelona are 2 other examples that have made a successful implementation in the use of solar energy, Singapore on the other hand combines urbanization with sustainability, due to limited space, makes use of building integrated solar panels (BIPV), such as photovoltaic windows and green roofs with solar systems, in addition to implementing floating solar projects to maximize the use of water as an energy generating surface. GetSolar. (2024, 4 July), Granda, C. (2024, 14 June). Barcelona, Spain has had a mandatory regulation since 2006, which requires the installation of solar thermal panels in new buildings and major renovations as well as encouraging collective projects where communities share the energy generated by common solar systems. (S/f). Sotysolar.es. evoconfort. (2025, January 13).

In Mexico, participation in projects related to this type of energy has increased in photovoltaic energy generation in states such as Sonora, Baja California, Baja California Sur, San Luis Potosí, Guanajuato, Chihuahua, Coahuila, Yucatán, Jalisco and Morelos.

Now, talking about this type of energy in a domestic environment we can find that, in the United States, a solar system for a house cost between $15,000 and $29,000 depending on the user's consumption, it also represented more than half of the average household income, so the government applied fiscal policies to help the dynamism of the solar sector and the panel market.

Previously, the cost of producing one watt of solar energy was $1.7 in 2017, so the supply has increased and the costs in the market are lower, i.e., companies, industries and families are increasingly opting for the installation of photovoltaic systems thanks to the reduction of costs and government support, with the cost of solar production being 32.16 pesos per dollar.

For 2019, the cost of solar energy was US$0.244 per watt and the average annual exchange rate was 19.24 pesos per dollar, meaning that better prices can be offered for their photovoltaic systems. The payback period for the investment in solar energy can be reached in 3 years, taking into account the price, the cost per watt in Mexico was 2.23 pesos in 2020, in the last 20 years, the cost of solar panels has gone down, making them

affordable for families and their domestic use. In addition, storage batteries are no longer necessary.

The solar panel has a 20-year warranty, if there are no faults in the solar panel after installation, the supplier company will no longer need to contact the customer; however, some companies offer additional services after installation, such as monitoring the photovoltaic system to see at what times of the day it is producing more solar energy or simply indicating that the system is working properly.

The management in Mexico with the Federal Electricity Commission (CFE) has changed since 2014 with the National Program for the Sustainable Use of Energy (PRONASE), which together with the Special Program for Climate Change 2014-2018 authorizes the installation in the home or business its own Distributed Generation Power Plant and Distributed Clean Generation of less than 0.5 MW, through its management makes an interconnection contract with CFE Basic Services Supplier. In order to make the request for the interconnection contract for a power plant with a capacity of less than 0.5 MW that were published in the Official Gazette of the Federation on March 7, 2017, the following is requested:

- Interconnection Request.
- Map of the geographic location of the Power Plant and geographic coordinates.
- One-line diagram of the Power Plant and Load Centers that will share the same Interconnection/Connection point.
- Technical data sheet of the generation used (generator technology).
- Data sheet and certificate of the power inverter or current matching system
- Copy of the last receipt, without debts.

Once the solar energy panels are installed, a bidirectional meter is installed, which is basically a meter with similar characteristics to the conventional ones, the difference is that it supports two sources of electricity supply, the bilateral connection allows the user to consume energy from the CFE in the event that it does not generate the amount of energy required for its consumption, it should be noted that in the case of generating more energy than the user needs, this is sent to the CFE and the bilateral meter makes the record so that you get a credit balance.

Below is an image of how the installation could look in a house, taking into account that the wiring is hidden over the electrical spaces for the light installations of the house (Figure 2).

Figure 2

Example of installations in a house

Results

Conclusions

It is evident that the use of solar energy in the domestic sphere is one of the markets with the greatest potential in Mexico. The current costs, as well as the policies and administration of this type of energy alternative allow more and more users to select it as an alternative that not only has less impact on the environment but also promotes savings and eventually the recovery of the investment is relatively short depending on the user's consumption. In Mexico there are several institutions that finance and promote photovoltaic systems for the housing sector, MSMEs and agribusinesses, these institutions have lists of reliable suppliers, which are verified through third parties or by the institution itself.

The presence of more than 600 companies that have entered the distributed photovoltaic generation market in Mexico was identified, but the information reported in these portals does not necessarily reflect the total universe of companies with participation in the Mexican market, there are at least 28 national and foreign companies that manufacture photovoltaic panels that are certified with the FIDE seal.

A registry of 563 project development companies was created by FIRCO, an institution that has supported the installation of photovoltaic systems in agribusiness, the states with the highest concentration of companies are Sonora, Jalisco, Nuevo Leon, Chihuahua, Sinaloa, Mexico City, State of Mexico and Baja California (Gerardo, 2023).

Today the costs of storing generated energy have also changed in price, technology has improved and this has allowed greater efficiency, Table 8 presents the solar energy storage options we can find.

Table 8

Solar photovoltaic energy storage options

Battery type	Cost	Charging time	Typical capacity	Number of cycles	Annual maintenance cost
Lead-acid	$1,000 - $3,000	8 to 10 hours	50 to 200 Ah	300 to 500 cycles	$500 a $2,000
Nickel-cadmium	$2,000 - $8,000	3 to 5 hours	20 to 100 Ah	500 to 1000 cycles	$1000 a $2,500
Nickel-metal hydride	$3,000 - $9,000	4 to 6 hours	50 to 200 Ah	500 to 2000 cycles	$500 a $2,000
Lithium ion	$5,000 - $15,000	2 to 3 hours	50 to 100 Ah	4000 to 10000 cycles	$1000 a $4,000
Gel	$4,000 - $12,000	8 to 10 hours	50 to 200 Ah	1200 to 1500 cycles	$500 a $2,000
Nickel-iron	$5,000 - $13,000	6 to 8 hours	20 to 100 Ah	2000 a 3500	$300 a $1,200

Note. Characteristics of batteries for isolated photovoltaic systems in rural areas of the department of Santander, Colombia. (n. d.). Santander Technical Units.

Regarding the types of panels we can find great diversity that adapts to the budget and needs of each user, for example:

Flexible solar panels

Probably one of the most pointed out disadvantages of the cost for solar panels are their dimensions, but today this has not been an impediment to promote their innovation, since currently portable flexible solar panels have been developed, whose sales proposal includes their use in:

- Start-up of recreational vehicles and automobiles
- Solar battery chargers
- In homes due to its low cost
- Outdoor expeditions or activities where there are no power plants.
- These are considered to be the best solar panels to be used on maritime vessels as they can be used for are fully waterproofed, which allows them to withstand salt water from the sea

Flexible panels have the following characteristics:

Polycrystalline flexible solar panel

Composed by the union of silicon crystals, they have a fast manufacturing process and are more economical because they use less materials in the production process, they are currently the most known worldwide, they are ideal for use in residential areas and their heating process is very agile and fast, they have a dark navy blue color when they are receiving sunlight.

Flexible monocrystalline solar panel

Their cells are manufactured with high purity silicon crystals, they are blackish in color and have rounded edges, one of the disadvantages is that their manufacture is very slow and their energy expenditure is higher, however, they are characterized because they have a fairly high performance in low light areas, their useful life can be up to 50 years, they are more efficient, but equally, they are more expensive.

Flexible crystalline solar panels

Their cells are manufactured with the same silicon as conventional panels, they are the most common with the only detail that their photovoltaic cells are flexible.

Semi-flexible solar panel

They are quite efficient, usually use 12v batteries, are ideally used to carry out trips both on land and at sea, usually domestic, taking advantage of the lightness they have since they do not weigh more than 2 kilos, they are more expensive than rigid solar panels.

Thin film flexible solar panels

It is a new technology that works by printing the photovoltaic material and then adhering it onto a thin surface, however they are considered to have a shorter lifetime as they lack the protection of silicon.

Costs:

- Flexible solar panel kit. It exceeds $500 and has a range of up to 248 degrees.
- Extremely flexible 12v solar panel. it is around $200 but has the ability to be installed on the curved roof of an air flow
- Flexible solar panel 120w 4. is close to $600 and has a crystal with high light transmission anti-reflective properties,
- Flexible solar panel 200w. costs 170 dollars approximately and has a 10 A current controller.
- Flexible solar panel 300w. its price is around 1000 dollars and has a maximum power in STC (Pmax) of 100w and a maximum voltage of 1000 V DC.
- Flexible solar panel 400w. priced at $450, it offers a high quality silicon material that allows for greater reliability and stability.
- Flexible solar panel 500w. its cost is less than $ 90 has a life of up to 20 years and has a double monocrystalline silicon.

Regardless of the alternative for the user's physical and economic environment, the use of alternative energy generation not only benefits the planet and the user's economy, but it can also gradually make the user independent of energy consumption and payment by using adequate storage sources, in economies of such dizzying growth as the case of Playa del Carmen, located in the Riviera Maya, Quintana Roo and recognized as an international tourist destination that attracts millions of visitors and therefore thousands of people seeking work each year and has generated a growing demand for energy, which has led the region to face significant challenges in terms of sustainability and environmental management, the use of solar panels could impact the dependence on traditional sources of energy, such as fossil fuels, which not only increases energy costs, but also contributes to pollution and therefore climate change.

A testimony of the impact on the acquisition of this type of energy can be found in the case of the Vera family who established their residence in Playa del Carmen 10 years ago and until a few months ago they acquired a house that they rented, the new house is significantly larger than the apartments where they lived and the cost they paid for electricity was around $1500 Mexican pesos bimonthly, with peaks in hot seasons that reached up to $2400 pesos, however, the new house represented new challenges, since it has 3 floors, for the moment they acquired 3 air conditioners, 2 of 8000 btu British thermal unit that can cool a room of between 4 and 8 square meters each and another air conditioner with a capacity of 16000 btu that cools twice as much, on each floor an air conditioner was installed and with the experience they had had they decided to acquire solar panels; as part of the requirements established by the CFE to install the bidirectional meter, an initial billing is required, so the first payment they made without panels was $4495.61 and with the use of solar panels their payment today is $63. The family says that even when they have the technology they take care of their consumption, however they feel less pressure to receive high bills, the investment in solar panels was worth it.

The use of solar panels is presented as an innovative and effective solution to mitigate costs, solar energy is a renewable source that uses solar radiation to generate electricity, and its implementation in Playa del Carmen has gained momentum in recent years. Thanks to its warm and sunny climate throughout most of the year, the region has ideal conditions for maximizing the efficiency of photovoltaic systems. The adoption of solar panels not only represents an environmentally friendly and sustainable alternative, but also offers considerable economic benefits; the initial installation costs are being offset by savings on electricity bills and government incentives that encourage the use of renewable energy. In addition, it is estimated that each PV system installed contributes significantly to the reduction of greenhouse gas emissions, helping to combat climate change.

As more residences, hotels and local businesses opt for this technology, Playa del Carmen is positioning itself as a leading example in the transition to a more sustainable energy model. This trend not only improves the quality of the local environment, but can also positively influence the tourist attractiveness of the destination by aligning with the growing expectations of environmentally conscious travelers. In addition, the economic benefits of savings are significant, and although they depend on the average consumption, they give us an idea of the significant savings and return on investment, in this context it should be noted that the cultural environment also plays a role, i.e. not by having panels you will spend more than what you are used to spending.

Returning to the case presented and comparing the billings before and after the use of solar panels, we see that this home on average spent 1355 (kwh) bimonthly without solar panels, which is equivalent to $4495.61 Mexican pesos per bimonth, if it continued with its average consumption, which is unlikely given the hot periods where there are

consumption peaks, annually would be paying $26,973.66 Mexican pesos, that is, if the price per kilowatt were to remain the same, i.e. his annual consumption would be around 8,130 (kwh); today that same household by using 5 solar panels is having a registered bimonthly consumption of 330 (kwh), equivalent to $63 Mexican pesos, about $378 Mexican pesos per year, if we take into account that this consumption has a surplus in favor of the energy generated with the panels and that accumulates to the following period, if we consider that the cost of the panels and installation was $50,000 Mexican pesos, the house is recovering its investment in approximately 22 months, which is totally sustainable in the medium term.

Within the promotion of the use of this type of technology in the state of Quintana Roo, initiatives and public policies have been carried out as well as several projects and efforts where we can include the State Plan for the Promotion of Energy Efficiency and the Use of Renewable Energy Sources (PLANFEER), which promotes not only the use of solar energy but also the efficient design of urban housing and a decrease in deforestation as well as a reduction of waste and energy production with waste; another initiative is the second state-promoted call for Quintana Roo companies to benefit from a financing fund of 15 million dollars to be used in the installation of photovoltaic systems that will allow them to save around 30% of their current invoicing, ensuring that there is no initial investment and obtaining an incentive of 6 months of free energy production. An agreement has also been established with the Word Resources Institute (WRI) to implement energy efficiency measures and update construction regulations, and the Renewable Energy Laboratory (NREL) of the United States has conducted research in the Yucatan Peninsula to enable the transformation of the electricity sector. Joaquín, P., & Joaquín, P. (2021, October 30). The Quintana Roo Welfare Secretariat (Sebien) has awarded Energain de México a contract that will allow 405 solar panels to be installed in 221 homes in the municipality of Solidaridad, where Playa del Carmen is located. Pantoja, H. (2024, 12 August). In summary, the use of solar panels in Playa del Carmen already represents a key strategy to address current energy challenges and promote a more sustainable future, the combination of abundant natural resources and a growing commitment to continuous and persevering private and governmental green practices would put this city on the path to a greener and more sustainable economy (Guevara, 2023).

References

Admin. (2024). *Tendencias en instalaciones fotovoltaicas para 2025.* Helukabel. https://helukabelmexico.com/noticias/tendencias-en-instalaciones-fotovoltaicas/

Arévalo-Molina, J. P., Ortíz-Jiménez, R. D., Gama, E. N., Ramos, O. L., Duque, J. (2014). Diseño e implementación de un prototipo de vehículo solar con almacenamiento de energía. *Revista Científica, 1*(18), 159-165. https://doi.org/10.14483/23448350.5594

Bacon, F. (1779). *Francisci Baconi, baronis de Verulamio Novum organum scientiarum*. apud JJ Stahel.

Ballesteros-Ballesteros, V. (2016). Panorama mundial de las energías renovables e importancia de la energía solar fotovoltaica. *Revista Científica, 26*, 194–203.

Centro Mexicano de Derecho Ambiental. (2017). *Marco jurídico de las energías renovables en México.* Centro Mexicano de Derecho Ambiental.

Cordón, F. (1991). *La naturaleza del hombre a la luz de su origen biológico* (Vol. 1). Anthropos Editorial.

Corcobado, T. D., & Rubio, G. C. (2010). *Instalaciones solares fotovoltaicas*. McGrawHill.

Diez, H., Ortega, M. (2013). *Energía hidráulica en México y el mundo.* Bibliat. UNAM. https://biblat.unam.mx/hevila/Geotermia/2013/vol26/no1/10.pdf

Edenhof, O., Pichs-Madrugaer, R., & Sokona, Y.(2011). F*uentes de energía renovables y mitigación del cambio climático*. Grupo Intergubernamental de Expertos sobre el Cambio Climático https://www.ipcc.ch/site/assets/uploads/2018/03/srren_report_es-1.pdf

Energía Solar Fotovoltaica. (2007). Colegio Oficial Ingenieros de Telecomunicaciones. https://www.coit.es/sites/default/files/informes/pdf/energia_solar_fotovoltaica.pdf

Evoconfort. (2025). *Proyecciones y tendencias 2025: ¿Hacia dónde va la energía renovable?* Evo Confort. https://www.evoconfort.com/proyecciones-y-tendencias-2025-hacia-donde-va-la-energia-renovable/

GetSolar. (2024). *Solar Energy in Singapore: Exploring Projects and Incentives*. GetSolar. https://getsolar.ai/blog/solar-financial-incentives-singapore-2/

Gerardo, M. (2023). *Elementos Económicos y de Mercadotecnia para Dinamizarlo: 2015-2020.* UNAM-Dirección general de bibliotecas. https://tesiunam.dgb.unam.mx

González, K., Ortega, J., Tibanta, E. (2022). Las Energías Renovables y la Sostenibilidad en Territorio. *Dom. Cien, 8*(2), 1401-1417.

Granda, C. (2024). *Principales prácticas de construcción sostenible.* Leaf. https://leaflatam.com/principales-practicas-de-construccion-sostenible/

Guevara, D. (2023. *Paneles solares flexibles. Greentech*. https://www.greentecher.com/panel-solar-flexible/

IEA: International Energy Agency. Bioenergy. https://www.iea.org/energy-system/renewables/bioenergy

IEA: International Energy Agency. Hydroectricity. https://www.iea.org/energy-system/renewables/hydroelectricity

IEA: International Energy Agency. Renewables. https://www.iea.org/energy-system/renewables

IEA: International Energy Agency. VP Solar. https://www.iea.org/energy-system/renewables/solar-pv

IEA: International Energy Agency. Wind. https://www.iea.org/energy-system/renewables/wind

IEA: International Energy Agency. Renewables. https://www.iea.org/energy-system/renewables

IEA: International Energy Agency. Bioenergy. https://www.iea.org/energy-system/renewables/bioenergy

IEA: International Energy Agency. VP Solar. https://www.iea.org/energy-system/renewables/solar-pv

IEA: International Energy Agency. Hydroectricity. https://www.iea.org/energy-system/renewables/hydroelectricity

IEA: International Energy Agency. Wind. https://www.iea.org/energy-system/renewables/wind

Ini, L. (2022). *La ciudad estadounidense de San Diego instala energía solar sin costo en comunidades de bajos ingresos.* Pv Magazine Latin America. https://www.pv-magazine-latam.com/2022/08/12/la-ciudad-estadounidense-de-san-diego-instala-energia-solar-sin-costo-en-comunidades-de-bajos-ingresos/

International Energy Agency. (2017). International Energy Outlook 2017. https://goo.gl/quVQuN

Joaquín, P., & Joaquín, P. (2021). *Quintana Roo fomenta el uso de la energía solar y eólica. Coordinación General de Comunicación.* Gobierno de México. https://cgc.qroo.gob.mx/quintana-roo-fomenta-el-uso-de-la-energia-solar-y-eolica/

Kaku, M. (2005). *El universo de Einstein: cómo la visión de Albert Einstein transformó nuestra comprensión del espacio y el tiempo.* Antoni Bosch editor.

Manzano-Agugliaro, F., Alcayde, A., Montoya, F. G., Zapata-Sierra, A., & Gil, C. (2013). Scientific production of renewable energies worldwide: An overview. *Renewable and Sustainable Energy Reviews, 18*, 134–143. https://doi.org/10.1016/j.rser.2012.10.020

McKern, B. (Ed.). (1993). *Transnational corporations and the exploitation of natural resources* (Vol. 10). Taylor & Francis.

MÓDULO 4: Reguladores, inversores y baterías. (s. f.). Gobierno de Santa Fe. https://www.santafe.gob.ar/ms/academia/wp-content/uploads/sites/27/2019/12/M%C3%B3dulo-4-Inversores-reguladores-bater%C3%ADas.pdf

ONU. ¿Qué son las energías renovables? https://www.un.org/es/climatechange/what-is-renewable-energy

ONU. Organización de las Naciones Unidas. ¿Qué son las energías renovables? https://www.un.org/es/climatechange/what-is-renewable-energy

Olabi, A. (2016). *Renewable Energy and Energy Storage Systems.* Renewable and Sustainable Energy Reviews.

Paneles solares flexibles, claves para tener energía limpia en México. *Gaceta UNAM*. https://www.gaceta.unam.mx/paneles-solares-flexibles-claves-para-tener-energia-limpia-en-mexico/

Pantoja, H. (2024). Se benefician más de 900 familias en Q.Roo con paneles solares. Suncore. https://suncore.com.mx/paneles-solares/se-benefician-mas-de-900-familias-en-q-roo-con-paneles-solares/

Perino, E., Kiessling, R., & Silnik, A. (2021). Energías renovables y sustentabilidad: una eficiente forma de gestionar los recursos naturales. Revista Digital Universitaria (rdu), 22(3). https://www.revista.unam.mx/wp-content/uploads/v22_n3_a4.pdf Power, G. (2016, 31 agosto). Freiburg, capital ecológica de Alemania | Energía Solar en LLeida | Gen Power. Energía Solar En LLeida | Gen Power. https://www.genpower.es/freiburg-capital-ecologica-de-alemania/

REN21. (2017). Renewables 2017 Global Status Report. https://www.ren21.net/wp-content/uploads/2019/05/GSR2017_Full-Report_English.pdf

REN21. (2015). Renewables 2015 Global Status Report. https://www.ren21.net/wp-content/uploads/2019/05/GSR2015_Full-Report_English.pdf

ROBLES, C. y RODRÍGUEZ, O. (2018). Un panorama de las energías renovables en el Mundo, Latinoamérica y Colombia. Revista Espacios, 39(34), 10. https://ww.revistaespacios.com/a18v39n34/a18v39n34p10.pdf

Schallenberg, J. (2018). Energías renovables y eficiencia energética. Instituto Tecnológico de Canarias.

Secretaría de Energía. (2012). *Prospectivas de Energías Renovables 2012-2026.* SENER.

Stokes, P. U (2016) Asimetría temerosa: la búsqueda kierkegaardiana de la dirección del tiempo.

Tejeda, M. A., Gay, G. C., Cuevas, G. G., & Rivera, B. C. (2007). *Escenarios de energìas renovables en Mèxico bajo cambio climático.* SEMARNAT.

Tsai, S.-B., Youzhi, X., Jianyu, Z., Quan, C., Yubin, L., & Jie, Z. (2017). Models for forecasting growth trends in renewable energy. *Renewable and Sustainable Energy Reviews*, 1169- 1178.

Upton, G., y Snyder, B. (2017). Funding renewable energy: An analysis of renewable portfolio standards. Energy Economics, 205-216.

Vivanco, E. (2020, August). Energías renovables y no renovables. Ventajas y desventajas de ambos tipos de energía. In *Biblioteca del Congreso Nacional de Chile/BCN*. Asesoria Técnica Parlamentaria.

WWF. (2014). *Líderes en energía limpia. Países top en energía renovable en Latinoamérica*. WWF.

Zuñiga, I. Y. C., Lona, L. R., & Flores, M. D. R. S. (2017). Tecnologías verdes: energías renovables como una alternativa sustentable para México. *Repositorio de la Red Internacional de Investigadores en Competitividad, 11,* 1557-1575. https://www.riico.net/index.php/riico/article/download/1518/1178