Solar Energy in Latin America and the Caribbean: The Current Situation and Perspectives in the Use of Solar Energy for Electricity Generation

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Abstract: Without a doubt, Latin America and the Caribbean will significantly contribute to the continuous global solar capacity expansion during the coming decades. The whole region could grow its current installed solar power capacity by a factor of 40 by 2050. It is expected that by 2050, solar power would represent the second-largest power source behind wind power, generating around 25% of the world's power. The International Energy Agency (IEA) projected, in 2014, that under its high renewables scenario, by 2050, solar PV and concentrated solar power (CSP) would contribute about 16% and 11%, respectively, of the worldwide electricity consumption. Solar power is expected to be the largest source of electricity generation at the world level in 2050. In total, global solar power capacity would increase around 14-folds, rising from 578,6 GW in 2019 to over 8.000 GW by 2050. Annual investments in solar power are likely to exceed US$7 billion.

Keywords: Solar energy, Solar power, Solar photovoltaic, Solar thermal, Solar PV parks, Electricity generation, Energy integration, Latin America and the Caribbean.

INTRODUCTION

Without a doubt, Latin America and the Caribbean will significantly contribute to the continuous global solar capacity expansion. Latin America and the Caribbean could grow their installed solar power capacity by a factor of 40 by 2050, according to a new report issued by the International Renewable Energy Agency (IRENA) entitled "Future of Solar Photovoltaic: Deployment, investment, technology, grid integration and socio-economic aspects (2019).

It is expected that by 2050, solar PV would represent the second-largest power source behind wind power, generating 25% of the world's power. In total, global solar power capacity would increase around 14-folds, rising from 578,6 GW in 2019 to over 8.000 GW by 2050. Annual investments are likely to exceed US$7 billion. While solar energy remains the highest in Asia, North America, and Europe, market growth is set to shift to other regions globally, particularly to the Latin American and Caribbean region.

"Solar PV and other renewables sources represent the most effective and ready solution for addressing growing energy demand and limiting carbon emission at the same time," said IRENA's Director-General Francesco La Camera. "Renewables are practical, affordable, and climate-safe. They are key to sustainable development, enabling energy access, spurring economic growth, creating employment, and improving health. Particularly solar energy is set to become one of the most prominent power sources in 2050. Projected growth rates in markets like Latin America showcase that we can extend the energy transition to all countries. It's possible."

The IEA report entitled "Global Energy Review 2020" shows that renewable electricity generation increased by almost 3% during the first months of 2020, concerning the same period of 2019. Two reasons are behind this increase. One is because new wind and solar PV projects were completed over the past year, and another, renewables are generally dispatched before other electricity sources. Along with depressed electricity demand, power grids have managed heightened shares of wind and solar PV.

The IEA (2014) Energy Technology Perspectives 2014 report indicates under its high renewables scenario that by 2050 solar PV and concentrated solar power (CSP) would contribute about 16% and 11%, respectively, of the worldwide electricity consumption, and solar power would be the largest source of electricity generation at the world level. The combined shares are solar PV (10%) and solar thermal electricity (7%). It is expected to put solar power fourth in the global electricity supply by 2050, after wind energy, hydropower, and nuclear energy. According to the

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report mentioned above, solar power is expected to become the first electricity source by 2040, and it is likely to provide 27% of the global generation by 2050. Separately, solar PV and CSP is expected to rank third and fourth, respectively, after wind energy and hydropower. Solar power is projected to surpass both natural gas and bioenergy-based power by 2050.

If accompanied by sound policies, the energy transformation driven by renewables, particularly solar power, can bring substantial socio-economic benefits to many countries globally and, in particular, in the Latin American and the Caribbean region. The global solar industry has the potential to employ over 18 million people by 2050, four times more than the 4,4 million who are employed today (IRENA Future of Solar Photovoltaic: Deployment, investment, technology, grid integration and socio-economic aspects, 2019).

Similarly, rooftop solar PV systems' deployment has increased extensively, making solar PV in some markets more attractive than buying electricity from the electrical grid. The competitiveness of distributed solar power is clearly raising deployment in large markets, such as Brazil and Mexico, among other countries in the region.

According to the report mentioned above and IRENA Renewable Energy Statistics 2020, the following are some statistical highlights related to the role that solar PV could play at the world level and in the Latin America and the Caribbean region in the future:

- Accelerating solar PV can cut energy-related CO_2 emissions by 21% in 2050 (nearly 4,9 gigatons annually);
- Solar PV could cover 25% of global electricity needs by 2050, becoming the second-largest generation source after wind energy.
- Global solar PV capacity could reach 14 times current capacity levels already installed, reaching more than 8.000 GW by 2050. With over 50% of installed capacity in 2050, Asia (mostly China) would continue to dominate solar PV power, followed by North America (20%) and Europe (10%). At the world level, solar PV capacity grew 14-fold between 2010 and 2019, with 578.553 MW installed at the end of 2019. The Latin American and the Caribbean solar power capacity grew 71-fold from 122 MW in 2010 to 8.680 MW in 2019[1].
- Annual solar PV investment would have to increase by 68% on average globally, from US$114 billion in 2018 to US$192 billion in 2050;
- Solar PV project costs, already below marginal fossil-fuel costs in global terms, are set to decline further in the decades ahead. Global Levelized Cost of Electricity (LCOE) for solar PV will continue to fall from an average of US$0,085 per kWh in 2018 to between US$0,14 and US$0,5 per kWh by 2050. A recent solar and wind power auction in Colombia was awarded for an average electricity price of US$0,27 per kWh;
- Due to innovations, solar PV remains a fast-evolving industry. Floating PV is one of the most prominent examples, with global cumulative installed capacity exceeding 1 GW in 2018. Battery storage and electric vehicles are key solutions to support the electrical grid, manage high shares of solar PV, and to guarantee the flexibility of the power system;
- Rooftop solar PV systems have spread rapidly thanks to supporting policies, such as net metering and fiscal incentives;
- Energy transformation brings socio-economic benefits. The global solar industry could employ over 18 million people by 2050.

According to World Energy Outlook 2019, it is important to single out that investment in renewables is likely to reach a cumulative total between now and 2040 of around US$10 trillion. Global annual average investment in renewables in billion US dollars (2018) is shown in Table **1**.

Based on the data included in Table **1**, the following can be stated: the solar PV power generation is expected to decrease by 7% in one of the scenarios mentioned in Table **1**, while in the other solar PV increases 41%. For this reason, the current solar PV policies should be changed at the world level to achieve an increase in the role of solar PV in the world energy mix during the period 2031-2040.

[1] In 2018, solar PV again dominated total renewable and power capacity additions, adding twice as much capacity as wind and more than all fossil fuels and nuclear together. Solar PV additions in 2018 reached around 97 GW (IRENA Renewable Energy Statistics 2020, 2020).

Table 1: Global Annual Average Investment in Renewables in Billion US Dollars (2018)

		Stated Policies		Sustainable Development		Change 2018 vs 2031-2040	
	2018	**2019-30**	**2031-40**	**2019-30**	**2031-40**	**STEPS**	**SDS**
Renewables-based power generation	304	329	378	528	636	24%	109%
Wind	89	111	122	180	223	37%	151%
Solar PV	135	116	125	179	191	-7%	41%
End-use sectors	25	117	139	124	145	456%	480%
Total	**329**	**456**	**517**	**652**	**781**	**57%**	**137%**
Cumulative		*5. 477*	*5. 166*	*7. 829*	*7. 802*		

Note: Renewables for end-use include solar thermal, bioenergy, and geothermal applications for heating.
Source: World Energy Outlook 2019.

TYPES OF RENEWABLE ENERGY SOURCES USED IN THE LATIN AMERICAN AND THE CARIBBEAN REGION FOR ELECTRICITY GENERATION

There are six different types of renewable energy sources used for generating electricity in the Latin American and the Caribbean region. These are the following:

- Hydropower;
- Wind power;
- Solar energy;
- Geothermal energy,
- Bioenergy;
- Hydrogen.

Hydropower was the world's main renewable energy source used for the generation of electricity in 2017 (4.006 billion kWh), with 64% share of the total renewables electricity generation (6.251 billion kWh), and 16.5% with regard the world output (24.322 billion kWh), followed by wind power with 1.129 billion kWh, bioenergy with 583 billion kWh, solar energy with 425 billion kWh, and geothermal with 80 billion kWh, according to the EIA International Electricity data 2020.

Solar power is one of the worldwide fastest-growing renewable energy sources. However, its participation in Latin America and the Caribbean countries' energy mix is still very small. In 2019, the solar PV park capacity installed in the region reached 8.680 MW and generated in 2018 a total of 13.406 GWh. No CSP facilities were operating in the region in 2019. A total of 41 countries are now using solar energy for electricity generation and heating in the Latin American and the Caribbean region. Out of this total, 12 countries are located in South America and 29 in Central American and the Caribbean subregions (IRENA Renewable Energy Statistics, 2020).

Many countries in the Latin American and the Caribbean region, concerned about the environmental impact of electricity generation from fossil fuels or large-scale hydropower plants, have been turning to solar power as an environmentally benign alternative, among other renewable energy sources.

Two solar power technologies are widely used today for electricity generation at the world level, and their utilization is likely to increase in the future. These solar technologies are the following:

- Solar photovoltaic (PV);
- Solar thermal (CPS).

According to Morales Pedraza (2012), solar PV technologies (see Figure **1**) convert sunlight directly into electricity by using photons from the Sun's light to excite electrons into higher energy states. The resultant voltage differential across cells allows for a flow of electric current. Because individual solar cells are very small and produce a few watts of power, they should

Figure 1: Solar PV plant.
Source: Image by Stock Snap from Pixabay.

be connected together in solar panels arranged in arrays to increase electricity output. The arrangement of arrays is one major advantage of photovoltaic technologies because they can be made in virtually any size to fit a specific necessity and use.

One popular solar PV application is in solar panel installations on residential roofs (see Figure **2**), which can be scaled to accommodate house size and electricity needs. Although solar PV technology is used more often today for electricity generation in small residential houses, it also can be scaled up to create larger power plants to generate electricity for the electrical grid (Morales Pedraza, 2012).

At present, solar PV's cost is generally too high to compete with wholesale electricity. However, in sunny locations, the cost can be as low as 23% per kWh, which may be competitive with the delivered price of electricity to retail customers in areas where electricity prices are high. In some isolated rural areas, the use of solar PV can be the only means to provide electricity to the population living in these areas (Morales Pedraza, 2012).

It is important to single out that, based on installed cost per megawatt, solar PV installations are relatively costly because the panel components are expensive, and the conversion of solar energy to electricity in the cells still is inefficient[2]. However, from conversion efficiencies levels between 5% and 6% achieved in the first solar cells built in the 1950s, there has been an improvement to efficiencies between 12% and 18% for modern commercial wafer-silicon cells. Nevertheless, for some solar panel technologies, the efficiency level could be even higher.

Several factors affect a cell's conversion efficiency value. These factors are, according to the USA Department of Energy Photovoltaic Cell Conversion Efficiency Basics (2014) and Kumar (2017), the following:

- Reflectance;
- Thermodynamic efficiency;
- Charge carrier separation efficiency;
- Charge carrier collection efficiency;
- Conduction efficiency values.

Because these parameters can be difficult to measure directly, other parameters are measured instead, including quantum efficiency, open-circuit voltage (V_{OC}) ratio, and fill factor. Reflectance losses are accounted for by the quantum efficiency value, as

[2] According to Wikipedia Solar cell efficiency (2020), solar cell efficiency refers to the portion of energy in the form of sunlight that can be converted via photovoltaics into electricity by the solar cell. In 2019, the world record for solar cell efficiency at 47,1% was achieved by using multi-junction concentrator solar cells, developed at National Renewable Energy Laboratory, Golden, Colorado, USA (Geisz *et al*., 2018).

Figure 2: Solar panel installations on residential roofs.
Source: Image by skeeze from Pixabay.

they affect "external quantum efficiency." Recombination losses are accounted for by the quantum efficiency, V_{OC} ratio, and fill factor values. Resistive losses are predominantly accounted for by the fill factor value and contribute to the quantum efficiency and V_{OC} ratio values. Efficiency gains, coupled with other technological advances, have reduced the cost of electricity produced by solar PV parks. The sustained dramatic decline in the cost of electricity from solar PV parks continued in 2019. There is a fall "in the global weighted-average LCOE of utility-scale PV plants declined by 82% between 2010 and 2019, from around US$0,378 per kWh to US$0,068 per kWh in 2019, with a 13% reduction year-on-year in 2019. At an individual country level, the weighted average LCOE of utility-scale solar PV declined by between 66% and 85% between 2010 and 2019" (IRENA Renewable Power Generation Costs in 2019, 2020)[3].

Besides, the efficiency of solar panels is expected to improve as the technology continues to be developed. Although prices for electricity from solar PV may not become widely competitive with wholesale prices for electricity from conventional generating technologies within the next 25 years, they may be competitive with high retail electricity prices in sunny regions. Solar PV technology is already gaining market share in countries where declining prices and government-backed financial incentives to use renewable energy sources for electricity generation have led to increasing the use of this type of energy source for this specific purpose.

Without a doubt, energy efficiency is the primary factor for fuel of choice in most regions because of its cost-effectiveness. Energy efficiency measures generally offer an attractive payback, although the barriers to their deployment, such as access to finance or lack of information, have to be successfully addressed (World Energy Outlook 2019, 2019).

The other solar technology available is solar thermal (see Figure **3**). Solar thermal technologies produce electricity by concentrating the Sun's heat to boil a liquid and using the steam to rotate a generator turbine in much the same way that electricity is produced from steam plants powered by oil, coal, or natural gas.

There are two main types of CSP. These are the following:

[3] The complete citation is the following: IRENA (2020), Renewable Power Generation Costs in 2019, International Renewable Energy Agency, Abu Dhabi.

Figure 3: Solucar PS10, the first solar thermal power plant based on a tower in the world that commercially generates electricity.
Source: SOLUCAR PS10 (2) Author: afloresm.

- Towers;
- Parabolic troughs (see Figure **4**).

A solar thermal power tower consists of a large array of sun-tracking mirrors, which are used to reflect the Sun's rays onto a central tower. When the rays hit the central tower, their heat is transferred to a fluid medium that is boiled to produce steam. Solar thermal power towers have been demonstrated successfully, but they are not yet a mature technology that can be applied successfully in all countries. The world's largest solar power tower is the 15 MW Solar Tres Power Tower in Spain. The most commonly used solar thermal technology is the parabolic trough. A parabolic reflector focuses the Sun's rays on a heat pipe that runs the trough's length and transports heated fluid to a central power station. Most parabolic trough installations consist of a field of reflectors concentrated on a central location, where the working fluid is heated to produce steam (Morales Pedraza, 2012). No CSP facilities are operating in the Latin American and the Caribbean region in 2019.

Solar parks can be constructed between 10 MW and 200 MW capacity using the parabolic collector technology. From a commercial point of view, it is better to construct a solar park as larger as possible. Without a doubt, through the establishment of mass production for mirrors and absorbers and the further development of heat storages, solar parabolic collector power plants will, in the future, be economically comparable with conventional power plants using fossil fuels.

Solar thermal power plants are designed to be large scale grid-connected plants, but at present, they cannot be used as baseload generators because they do not

Figure 4: Parabolic troughs.
Source: USA Department of Energy SkyTrough Parabolic Solar Collector.

produce heat at night or during the day when clouds block the Sun. Some advances have been made in storing solar energy by using it to heat liquid sodium, which can be used later to boil water and produce the steam needed to power a generator turbine. However, the process is time-limited and can extend a plant's operations by only a few hours at best. In some cases, storage times of four to sixteen hours have been achieved, sufficient to allow electricity from solar thermal generators to be sold when it is more valuable, during the peak demand hours between 7 and 9 am and between 5 and 7 pm (Morales Pedraza, 2012).

Today, electricity from residential solar PV is marketed to compete with high-priced retail electricity. In the future, utility-scale solar PV may compete with wholesale electricity generation, provided that further technological advances are achieved. Solar thermal power plants are intended to compete with the wholesale generation, especially from peaking power plants. They may become more competitive over time if heat storage technologies improve, costs decrease, and policies to mitigate carbon dioxide emissions are adopted.

In the specific case of Latin American and the Caribbean region, solar energy is more evenly distributed. Good portions of the region lie within the so-called "Sun Belt Region" of the highest solar radiation. Thus, except for site-specific adverse microclimates, solar energy is a predictable and reliable energy resource. It is susceptible to being transformed into heat and electricity using several technologies in different development and commercial availability stages. Solar irradiance maps are available for Mexico, Colombia, Brazil, Argentina, and a few other countries (Huacuz *et al*.,1992).

One of the sunniest places on Earth, Chile's Atacama Desert (see Figure **5**), has the highest solar irradiance at the world level and the potential to generate enough electricity to power all of South America.

But the location has several elements that make its exploitation difficult. These elements are the following:

- It is a desert, which covers over 100.000 km^2;
- It is in Chile's remote north, far from major cities;
- The need to build transmission lines connecting the solar power plants built in the northern desert to the densely populated area south of the country.

If Chile agreed to connect those solar PV parks to Peru's power grid, and if this last country extended it to Brazil, Bolivia, and Ecuador, then millions of people throughout the South America subregion could benefit from the use of this clean energy source for electricity generation without the need to build new power plants in their countries.

Electricity demand is increasing rapidly in Latin America and the Caribbean. Electricity consumption is projected to rise by more than 70% by 2030. To meet this electricity demand, Latin America and the Caribbean countries are increasing the current level of energy generation from fossil fuels, especially natural gas, with a modest expansion in the role of renewable energy sources within the regional energy mix from 64% to 70% by 2030. But if the countries in the region increase the role of renewable energy source within the

Figure 5: The Atacama Desert.
Source: Image by Monica Volpin from Pixabay.

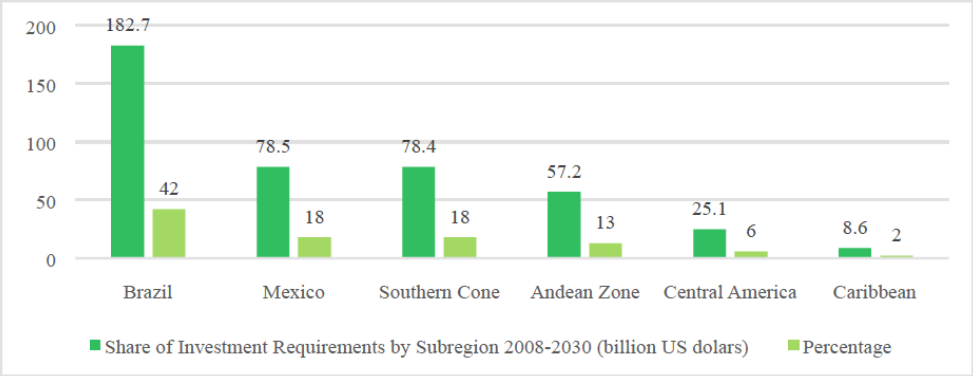

Figure 6: Share of investment requirements by subregion in billion dollars during the period 2008-2030. Source: The World Bank.

region energy mix up to 80%, and expands cross-border connections, then Latin America and the Caribbean countries can save billions of dollars in investments in the energy sector, avoid blackouts and reduce their greenhouse gas emissions, according to the Inter-American Development Bank findings (2011) (Viscidi and Yepez, 2018).

According to World Bank sources, the share of investment requirements by subregion in billion dollars during the period 2008-2030 is shown in Figure **6**.

According to Figure **6**, the following can be stated: Brazil is the country within the region with the highest investment share with 42% of the total (US$182,7 billion), followed by Mexico with 18% (US$78,5 billion), the South Cone with also 18% (US$78,4 billion), the Andean Zone with 13% (US$57,2 billion), Central America with 6% (US$25,1 billion), and the Caribbean with 2% (US$8,6 billion). By subregion, the Southern Cone is the subregion with the highest percentage with 18%, followed by the Andean Zone with 13%, Central America with 6%, and the Caribbean with 2%. It is projected that this situation will not change during the coming years.

Latin America and the Caribbean already has the largest share of renewable energy source within the region energy mix at the world level. However, energy policies and energy trade dynamics vary within different Latin American and Caribbean countries. The countries leading the way in using solar energy for electricity generation in the region are Brazil, Mexico, Chile, Honduras, Peru, and Argentina[4].

It is important to single out that more than 80% of the regional electricity generation comes from large hydroelectric dams. For this reason, and considering the negative impact on the environment of large dams and its social and environmental costs, including deforestation and displacement of communities, there is a limited appetite for building more dams in the region. Natural weather phenomena like El Niño also make the hydroelectric supply less predictable, causing serious limitations and cuts in electricity supply in Brazil and Venezuela, among other countries in the past.

The good news is that renewable energy sources like wind, solar, and geothermal are abundant in Latin America and the Caribbean, and costs are declining rapidly. Wind and solar capacity in the region have "increased significantly as the cost of producing electricity from these sources has dropped over the last several years" (Viscidi and Yepéz, 2018). This trend is expected to continue in the future.

Over the next ten years, increasing the use of renewable energy for electricity generation while connecting transmission lines between countries would have save US$30 billion compared to the current trajectory. Renewables have zero fuel costs, and extending power lines is much cheaper than building new power plants, according to the Inter-American Development Bank. Mexico, Brazil, and Chile have huge potential to increase the use of solar power for electricity generation. In 2019, around 41% of solar PV capacity in Latin America and the Caribbean were installed in Chile (2.648 MW). For this reason, the country leads the solar energy revolution in the region, followed very closely by Brazil, with 38.5% of the total (2.485 MW).

[4] Other countries that have significantly increased their solar energy capacity have been El Salvador, Dominican Republic, Puerto Rico, Panama, Guatemala, Cuba, Colombia, and Bolivia.

CHILE

In 2014 Chile was on the verge of an energy crisis. In that year, a drought reduced 33% of Chile's hydroelectric power electricity generation. In response to this national disaster, Chile invested its efforts to increase the use of solar energy for electricity generation. The aim was to reduce the country's dependency on hydropower and the use of fossil fuels for electricity generation. Why was solar energy selected to overcome the future energy crisis in the country? Because of its flat ground and abundant solar radiation, Chile has immense solar power potential, and the government and the energy industry decided to use these immense energy resources.

The Atacama Desert possesses some of the largest solar power potentials on Earth. Due to the quick expansion in solar energy use for electricity generation, the country soon became the first in Latin America and the Caribbean to produce more than 1 GW of solar energy. Chile now relies on renewable energy for around 23% of its power as of December 2019; 47% of this energy is solar energy.

It is important to single out that since the beginning of solar power use for electricity generation in Chile, its energy cost has dropped considerably. It is expected that this trend will continue during the coming years.

Chile's expansion of its solar energy sector has improved its people's lives. The government aims to move away from the country's dependence on fossil fuels, which still account for 55% of electricity production. During the last decade, Chile has invested nearly US$7 billion to increase the use of renewable energy sources for electricity generation, with more than 80 solar projects in progress (Solar Feeds, 2019).

The solar PV capacity in Chile reached 2.648 MW in 2019 and generated 5.218 GWh in 2018. In Chile, the solar PV grew 1.324-fold from 2012 to 2019, rising from 2 MW in 2012 to 2.648 MW in 2019. Simultaneously, the electricity generated by solar PV parks in Chile grew 625-fold from 2013 to 2018, rising from 8 GWh in 2013 to 5.218 GWh in 2018, generating around 7% of its electricity country level, according to IRENA Renewable Capacity Statistics 2019. In July 2020, installed solar capacity in Chile had risen to 3.104 MW, with another 2.801 MW under construction, according to solar PV magazine LATAM (2020).

The solar power plant in the Atacama Desert is the largest solar power plant in South America with 123 MW capacity. Shortly, the solar PV plant is expected to generate 196 MW of solar energy. By 2035, Chile plans to produce 65% of its electricity from renewable energy sources, which is likely to increase to 70% by 2050 (Solar Feeds, 2019). Chile has 15 solar PV parks in operation. The largest solar PV park in Chile is Romero Solar PV Park, with an installed capacity of 246 MW[5]. Other solar PV projects are, according to Wikipedia Solar power in Chile (2020), the following:

- The 70 MW Salvador Solar Park went online in November 2014. It was expected to produce 200 GWh of electricity per year. The solar PV plant is located approximately 5 km south of El Salvador, in the Atacama region. It is one of the first in the world to supply competitively priced solar energy to the open market without government subsidy, according to Sun Power Corp. (2015);

- The 60 MW Lalackama I solar PV park went online in 2014 and can to produce 160 GWh of electricity per year. The nearby 18 MW Lalackama II solar PV park went online in May 2015 and can generate approximately 50 GWh per year, according to Wikipedia Solar PV in Chile 2020;

- The 141 MW Luz Del Norte (Light of the North) solar PV plant, located 58 km northeast of the city of Copiapó in the Atacama region, began construction in October 2014. The first two blocks of this project (approximately half of the project's total capacity) was connected to Chile's central power grid in October 2015, according to Business Wire (2016);

- The 79 MW Pampa Norte solar PV plant began operating in April 2016 at 32 km southwest of Taltal in Chile's Antofagasta region. It uses approximately 258.000 polycrystalline silicon photovoltaic modules and can generate more than 200 GWh per year, according to Enel Green Power (2016);

- The 97 MW Carrera Pinto solar PV plant is located 60 km from the city of Copiapó in the Atacama region. The first 20 MW of the solar PV park was connected to the grid in early January

[5] The 246 MW El Romero single-axis tracking solar PV park began operating in November 2016 at Vallenar in the Atacama region, with a 493 GWh annual average output, according to MercoPress (2016) and Acciona Energy (2016). It uses 776.000 polycrystalline silicon photovoltaic modules.

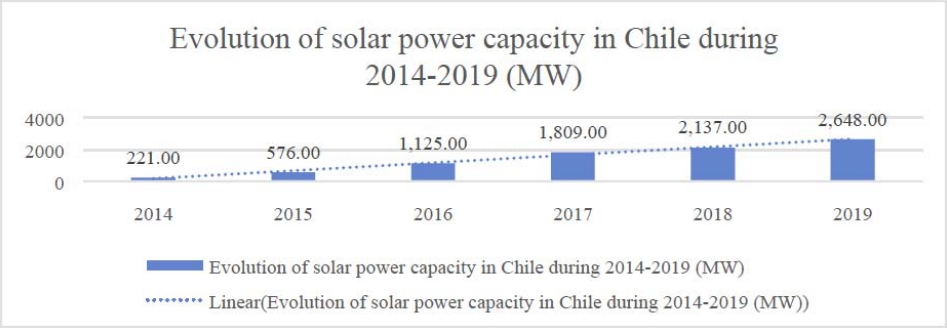

Figure 7: Evolution of the solar power capacity in Chile during the period 2014-2019.
Source: IRENA Renewable Energy Statistics 2020.

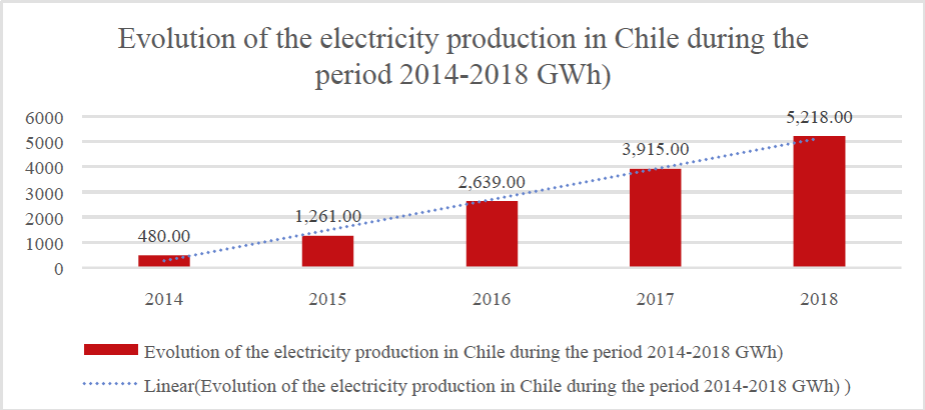

Figure 8: Evolution of solar power electricity production in Chile during the period 2014-2018.
Source: IRENA Renewable Energy Statistics 2020.

2016, with the remaining 77 MW connected in August 2016. The solar PV power plant is capable of generating over 260 GWh per year, according to Enel Green Power (2016);

- In October 2017, at the Tierra Atacama Hotel, a solar PV system "with 155,88 kWp in combination with a battery storage system was put into operation", according to National Geographic (2017).

Finally, the evolution of the solar power capacity in Chile during the period 2014-2019 is shown in Figure **7**[6].

According to Figure **7**, the following can be stated: Chile's solar energy capacity grew significantly (almost 12-fold) during the period 2014-2019, rising from 221 MW in 2014 to 2.648 MW in 2019. It is expected that solar power participation in the country's energy mix will continue to grow during the coming years.

The electricity production using solar power plants during the period 2014-2018 is shown in Figure **8**.

Figure **8** shows that the electricity generation in Chile using solar power plants grew significantly (almost 11-fold) during the period 2014-2018, rising from 480 GWh in 2014 to 5.218 GWh in 2018. It is expected that the use of solar energy for electricity generation in Chile will continue to grow during the coming years.

MEXICO

Mexico is one of the countries with attractive solar irradiation profiles within the Latin American region. It is also one of the few countries of the world located within the most favorable sunbelt on the planet. "Moreover, Mexico has emerged as one of the top markets for solar PV in recent years, owing to its aggressive deployment of solar PV plants" (Mordor Intelligence,

[6] All solar power capacity installed in Chile until 2020 is in solar PV.

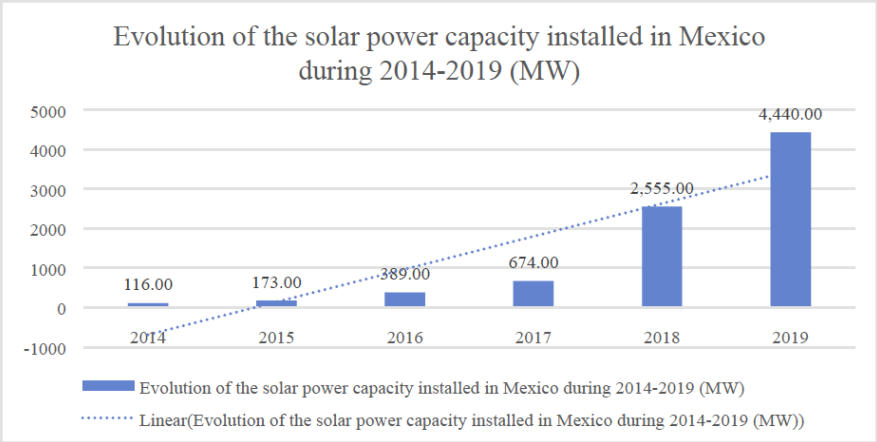

Figure 9: Evolution of the solar energy capacity installed in the country during the period 2014-2019. Source: IRENA Renewable Energy Capacity Statistics 2020.

2020). In 2018, for the first time, with 2.555 MW newly installed capacity, the country surpassed the barrier of 25.00 MW. Besides, solar technologies' declining costs "are becoming competitive with fossil fuel sources, and additional subsidies on solar systems are further driving the solar power market" (Mordor Intelligence, 2020). However, the absence of new initiatives, limited land, and an underdeveloped power grid could limit the solar PV market's growth during the coming years.

Regardless of what has been said above, many ambitious solar energy projects are lined up, which may increase the solar market estimated growth rate. In Mexico, the financing wave associated with the construction of solar PV parks is fueled largely by the Mexican government's renewable energy goals. According to the government and energy industry goals, it is expected that solar power reached, in 2024, around 35% of the entire country's electricity generation, and by 2050, around 50%. "The higher investment and government policies are expected to provide good opportunity to the Mexican solar energy market during the forecast period" (Mordor Intelligence, 2020).

It is important to single out that the increase in solar energy installations during the period 2015-2018 increased the demand for decentralized solar energy systems. The Mexican government's ambitious renewable energy targets are expected to improve Mexico's solar energy market during the coming years.

Without a doubt, among Latin American countries, Mexico looked the most promising in 2019 with a solar PV capacity installed of 4.440 MW, followed by Chile with 2.648 MW and Brazil with 2.485 MW (IRENA Energy Capacity Statistics, 2020). Mexico has 39 operational solar PV parks across 11 states in 2018 (Bellini and Zarco, 2019). The largest solar PV parks in the country are Villanueva Solar PV Park, with an installed capacity of 828 MW[7], Don José Solar PV Park, with an installed capacity of 260 MW, and Magdalena II with an installed capacity of 220 MW (Wikipedia List of photovoltaic power stations, 2020).

Mexico has an aim to reduce carbon dioxide emissions by 50% in 2050. This goal can only be achieved by increasing the role of renewable energy sources, particularly solar power, in the future country's energy mix.

The evolution of the solar energy capacity installed in the country during the period 2014-2019 is shown in Figure **9**.

According to Figure **9**, the following can be stated: solar power capacity installed in Mexico during the period 2014-2019 increased by a little more than 38-fold, rising from 116 MW in 2014 to 4.440 MW in 2019. It is important to single out two elements:

- The country reported a significant increase in solar power capacity installed in the last two years of the period under consideration in comparison to previous years;
- The trend reported during the period 2014-2019 will continue during the coming years, with the

[7] This is the largest solar PV park in Latin America and the Caribbean, constructed by the Italian energy company Enel, increasing national solar PV capacity significantly (Bellini and Zarco, 2019).

aim to reach the goal established by the government related to the role of renewables, in particular solar power, within the country's energy mix by 2050.

Finally, it is important to know that the country has only 14 MW capacity installed in CSP since 2018.

The evolution of the electricity generation in Mexico during the period 2014-2018 is shown in Figure **10**.

Based on the data included in Figure **10**, the following can be stated: solar electricity generation increased significantly in the last two years of the period under consideration compared with previous years. During the whole period, solar electricity generation increased by 6,2-fold, rising from 221 GWh in 2014 to 1.363 GWh in 2018. According to the government and energy industry goals for 2050, it is expected that the participation of solar energy in the country's energy mix will continue the trend shown in Figure **10**.

BRAZIL

Brazil reportedly has the cheapest solar energy market in Latin America and the Caribbean, with a rate of US$16,95 per MWh (Solar Feeds, 2019). In 2019, the renewable energy capacity installed in the country reached 141.933 MW, out of which 2.485 MW is in solar PV. Undoubtedly, Brazil is one of the emerging countries in expanding solar power capacity at the world and regional levels. In 2019, Brazil's installed renewable energy capacity accounted for almost 60% of the total renewable capacity installed in Latin America and the Caribbean. In 2018, the Brazilian solar PV park electricity generation reached 3.987 GWh, representing only 0,007% of the world's total solar electricity generation and 27,7% of the regional solar electricity generation.

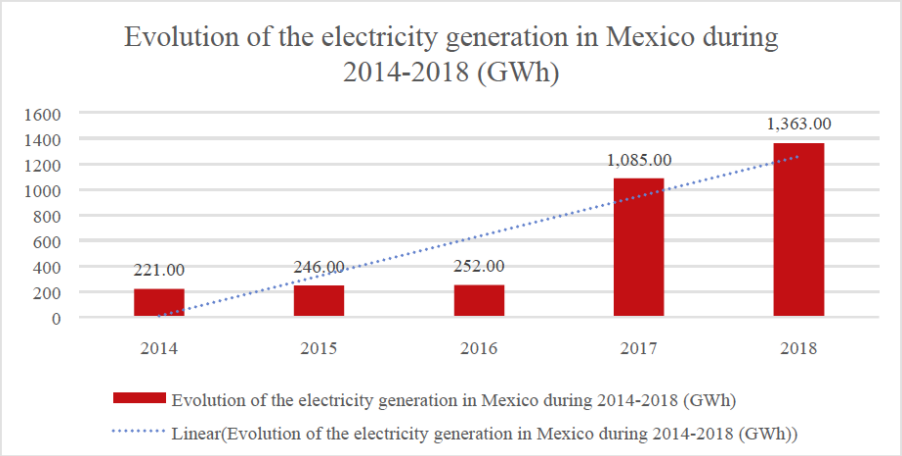

Figure 10: Evolution of the electricity generation in Mexico during the period 2014-2018.
Source: IRENA Renewable Energy Statistics 2020.

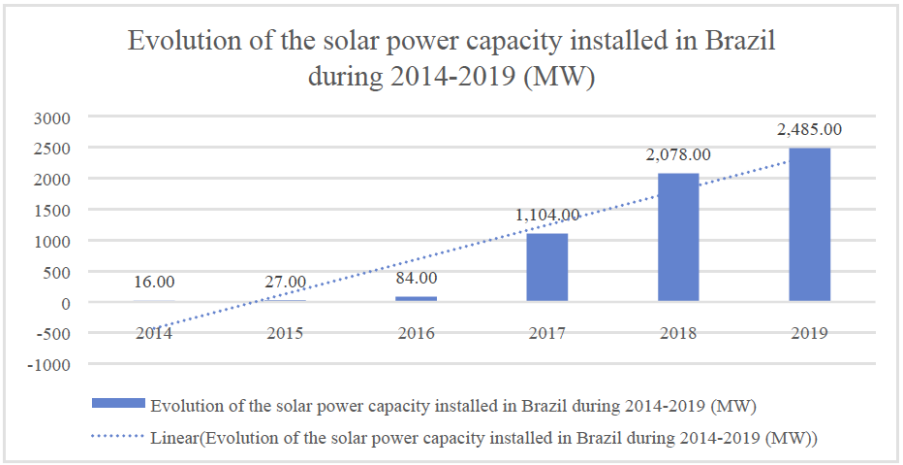

Figure 11: Evolution of the solar power capacity installed in the country during the period 2014-2019.
Source: IRENA Renewable Energy Capacity Statistics 2020.

The evolution of the solar power capacity installed in the country during the period 2014-2019 is shown in Figure **11**. On the other hand, the evolution of solar power electricity generation in the country during the period 2014-2018 is shown in Figure **12**.

Based on the data included in Figure **11**, the following can be stated: solar power capacity installed in Brazil increased significantly in the last three years of the period under consideration. Considering the whole period, solar power capacity installed in the country increased 155,3-fold, rising from 16 MW in 2014 to 2.485 MW in 2019. It is expected that the trend shown in Figure **11** will continue without change during the coming years, increasing the participation of solar power in the country's energy mix.

Based on the data included in Figure **12**, the following can be stated: solar power electricity generation increased significantly during the last two years of the period under consideration. If the whole period is considering, then solar electricity generation increased 249,2-fold, rising from 16 GWh in 2014 to 3.987 GWh in 2018. It is expected that the trend shown in Figure **12** will continue without change during the coming years.

According to the latest information available in the National Electric Energy Agency (ANNEL), 317 solar PV parks operate in Brazil, and 23 solar PV parks are under construction. Between the solar PV parks in operation, 295 solar PV parks are registered as mini and micro-generators, which means that they consume the energy produces by them. The other 22 solar PV parks provide energy to the local electricity network and are sold to large companies and shopping malls, among other costumers. The largest solar PV parks in Brazil are Pirapora Solar Park with an installed capacity of 400 MW, Ituverava Solar PV Park with an installed capacity of 254 MW, and the Nova Olinda Solar PV park with an installed capacity of 292 MW (Wikipedia List of photovoltaic power stations, 2020).

Like Mexico, Brazil has also set a target to bring down its carbon emissions by more than 40% by 2030 (Solar Feeds, 2019).

HONDURAS

Honduras has a large potential for solar PV electricity generation. Within Central America and the Caribbean, Honduras is the country with the highest solar power capacity installed in 2019. In that year, the total solar PV energy capacity in Honduras reached 514 MW representing 23,2% of the total solar PV capacity installed in Central America and the Caribbean, followed by El Salvador with 391 MW, Dominican Republic with 279 MW, and Panama with 198 MW. These solar PV parks generated in 2018 a total of 997 GWh, representing almost 40% of the total solar PV electricity generated in Central America and the Caribbean.

The evolution of solar power capacity installed in Honduras during the period 2014-2019 is shown in Figure **13**. On the other hand, the evolution of solar power electricity generation in the country during the period 2014-2018 is shown in Figure **14**.

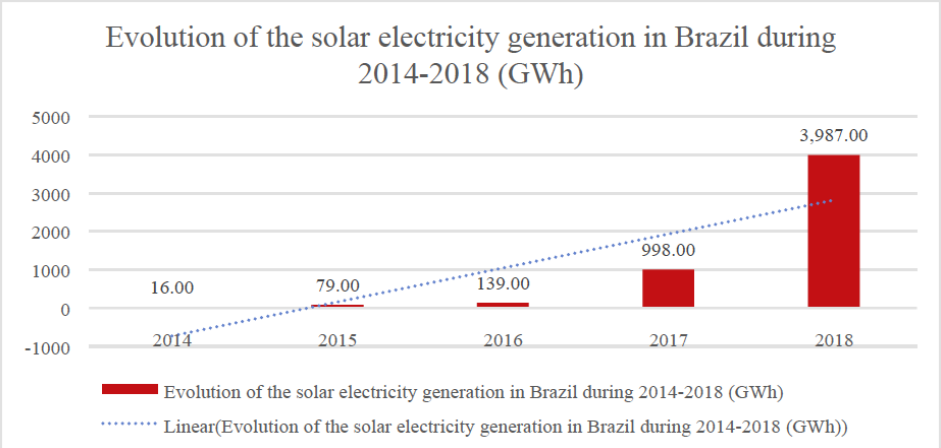

Figure 12: Evolution of the solar power electricity generation in the country during the period 2014-2018. Source: IRENA Renewable Energy Statistics 2020.

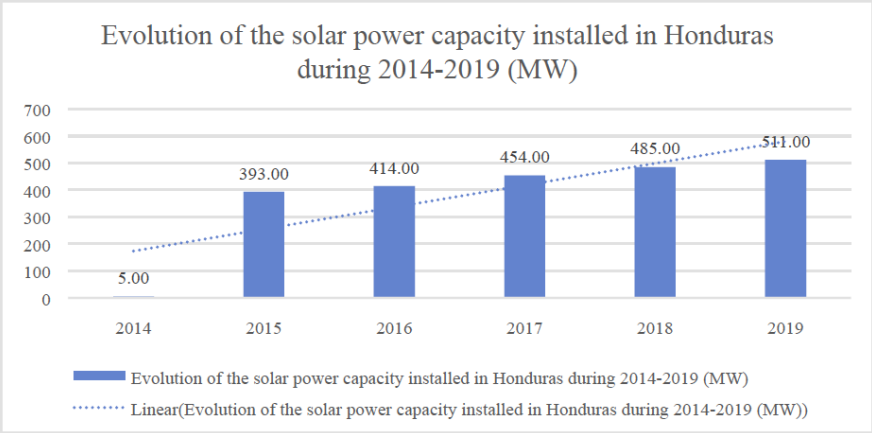

Figure 13: Evolution of the solar power capacity installed in the country during the period 2014-2019. Source: IRENA Renewable Energy Capacity Statistics 2020.

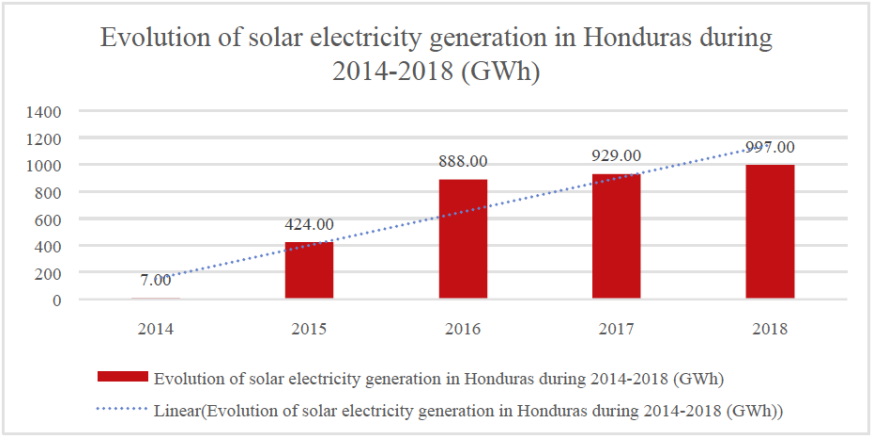

Figure 14: Evolution of the solar power electricity generation in the country during the period 2014-2018. Source: IRENA Renewable Energy Statistics 2020.

According to Figure **13**, the following can be stated: solar power capacity installed in Honduras increased significantly between 2014 and 2015 (78,6-fold). If the whole period is considered, then the increase was 102,2-fold, rising from 5 MW in 2014 to 511 MW in 2019. It is expected that this trend will continue without change during the coming years.

Based on the data included in Figure **14**, the following can be stated: solar power electricity generation increased significantly during 2014 and 2015 (60,6-fold). If the whole period is considered, then solar electricity generation increased 142,4-fold, rising from 7 GWh in 2014 to 997 GWh in 2018. It is expected that the trend shown in Figure **14** will continue without change during the coming years.

PERU

Without a doubt, Peru has favorable conditions for the development of solar energy projects. However, the country's solar potential has not been exploited yet. The greatest potential for solar power generation in Peru is found in its northern and southern zones. According to the Solar Atlas of Peru prepared by the Ministry of Energy and Mines, Peru has a high annual solar radiation between 5,5 and 6,5 kWh per m^2 in the mountains; between 5 and 6 kWh per m^2 on the Coast, and in the Jungle, between 4,5 and 5 kWh per m^2. In 2019, the total solar energy capacity in Peru reached 341 MW, more than countries like Uruguay (248 MW), Bolivia (120 MW), and Colombia (90 MW)[8]. This solar PV capacity is located in more than seven solar PV parks, representing 3% of the total solar PV park capacity installed in South America in that year.

The evolution of the solar power capacity installed

[8] In, 2019, two South American countries have a solar power capacity installed higher that Peru. These countries are Chile (2.648 MW) and Brazil (2.485 MW).

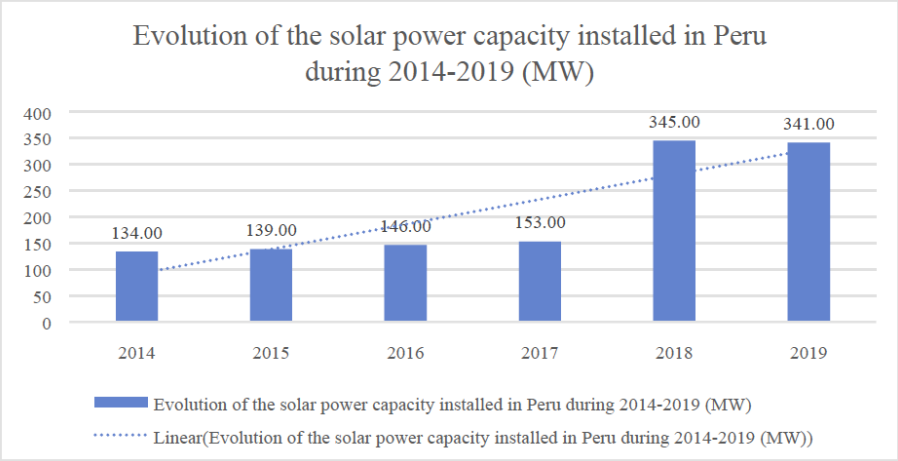

Figure 15: Evolution of the solar power capacity installed in the country during the period 2014-2019. Source: IRENA Renewable Energy Capacity Statistics 2020.

in the country during the years 2014 and 2019 is shown in Figure **15**.

According to Figure **15**, the following can be stated: solar power capacity installed in Peru increased significantly between 2017 and 2018 (2,3-fold). If the whole period is considered, then the increase was 2,5-fold, rising from 134 MW in 2014 to 341 MW in 2019. It is expected that this trend will continue without change during the coming years.

On the other hand, the evolution of solar power electricity generation in the country during the period 2014-2018 is shown in Figure **16**.

Based on the data included in Figure **16**, the following can be stated: solar power electricity generation in Peru increased significantly after 2017 (2,2-fold). If the whole period is considered, then solar electricity generation increased 3,2-fold, rising from 247 GWh in 2014 to 797 GWh in 2018. It is expected that the trend shown in Figure **16** will continue without change during the coming years.

It is important to know that Peru's government has set energy targets that renewable energy should meet 60% of the total consumption by 2025 (Solar Feeds, 2019). The use of solar energy plays an important role in achieving that target.

In 2018, the solar PV park Rubí was inaugurated by the government. "It is the largest solar power plant in the country that boasts over half a million solar panels in the southern city of Moquegua." (Mordor Intelligence, 2020) The Rubi solar PV plant was built at the cost of US$170 million and had a production capacity of 144,48 MW (Jenner, 2018).

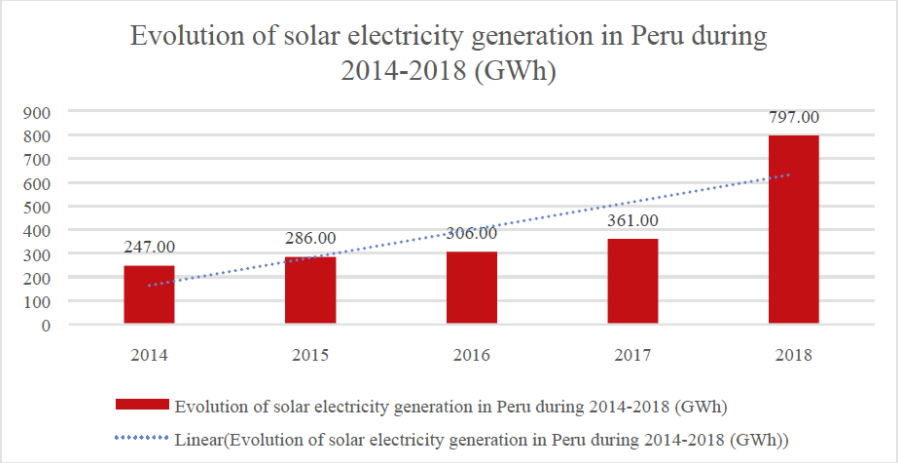

Figure 16: Evolution of the solar power electricity generation in the country during the period 2014-2018. Source: IRENA Renewable Energy Statistics 2020.

In 2018, the solar PV parks operating in Peru generated 797 GWh, representing 7,4% of the total solar PV electricity generated in South America in that year. Without a doubt, in Peru, there is still very little use of solar energy for electricity generation, limited its use to some towns in the mountains and Jungles that are not reached by the interconnected electrical system. However, solar power is an option that has great potential for development at the national level during the coming years. According to the Ministry of Energy and Mines (MINEM), the demand for renewable energy is likely to grow at 10% per year, boosted by industrial growth (Solar Feeds, 2019).

URUGUAY

In 2019, almost 98% of the energy consumption of Uruguay was derived from renewable energy sources. In particular, the new diverse energy mix of the country is provided by hydropower for 55,6%, wind energy for 33,6%, bioenergy 6%, solar power for 2,8%, and thermal energy for 2%, according to the paper entitled "Renewable Energy Revolution in Uruguay" (2020).

According to the document mentioned above, "the process of reconversion of the national energy matrix, characterized by a strong partnership between the public and private sectors, began developing a comprehensive long-term energy plan, the National Energy Policy 2005-2030". This plan's overall objective is to diversify the country's energy mix, reduce dependency on fossil fuels, improve energy efficiency, and increase the use of endogenous resources, mostly all renewable energy sources available in the country. The National Energy Policy 2005-2030 was approved in 2008, and in 2010 it was endorsed by all political parties represented in Congress (Renewable Energy Revolution in Uruguay, 2020).

Since the energy policy's approval in 2010, the public and private investment in Uruguay's renewable energy reached 17% of GDP or nearly US$7 billion (Solar Feeds, 2019).

In 2019, Uruguay's total solar energy capacity stood at 258 MW, increasing 7 MW (2,8%) with respect to 2018. The country generated, in 2018, a total of 415 GWh by solar PV parks. Currently, it represents only 2% of the country's electricity generation. Undoubtedly, wind energy and hydropower have had more importance in the country's energy mix than solar PV. it is a fact that solar electricity share within the total electricity generation in the country is currently very limited. Besides, there are no prospects for large growth in using this type of renewable energy source for electricity generation in the short term. Regardless of what has been said, solar power has good development opportunities in distributed generation, as electricity prices are constantly rising.

The evolution of the solar power capacity installed in the country during the period 2014-2019 is shown in Figure **17**.

According to Figure **17**, the following can be stated: solar power capacity installed in Uruguay increased significantly between 2016 and 2017 (2,7-fold). If the whole period is considered, then the increase was 62-fold, rising from 4 MW in 2014 to 248 MW in 2019. It is expected that this trend will continue without change during the coming years.

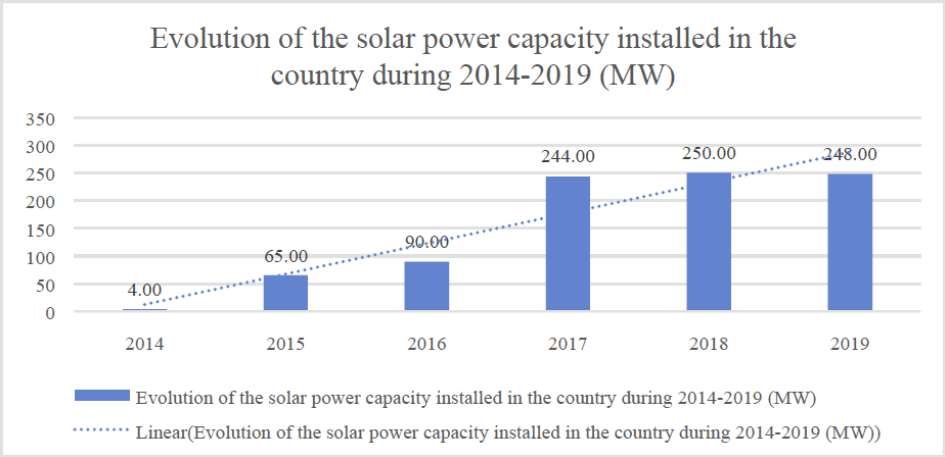

Figure 17: Evolution of the solar power capacity installed in the country during the period 2014-2019. Source: IRENA Renewable Energy Capacity Statistics 2020.

The future potential to generate electricity by solar PV plants in the country is promising, considering that Uruguay receives 1.700 kW per m^2 of sunlight a year on an average.

The evolution of the solar power electricity generation in the country during the period 2014-2018 is shown in Figure **18**.

Based on the data included in Figure **18**, the following can be stated: solar power electricity generation in Uruguay increased significantly after 2015 for the next three years. If the whole period is considered, then solar electricity generation increased 138,3-fold, rising from 3 GWh in 2014 to 415 GWh in 2018. It is expected that the trend shown in Figure **18** will continue without change during the coming years.

For the time being, Uruguay has put a strong emphasis on providing solar energy in remote rural areas, especially rural schools that are far from the electrical grid. The aim is to make hospitals, public buildings, sports clubs, and hotels energy-efficient by using solar panels. (Solar Feeds, 2019).

According to Bellini (2019), the following are the solar PV parks operating in Uruguay:

- The 9,5 MW Natelu solar PV park SA;
- The 9,5 MW Yarnel solar PV park;
- A 75 MW solar PV capacity was added through the El Naranjal and Del Litoral solar PV parks in the department of Salto, in northern Uruguay;
- 65 MW La Jacinta solar PV park, which has been in operation since October 2015.

However, it is important to single out that, right now, there is already a considerable surplus of energy in the country. For this reason, there is no need to construct new power plants for electricity generation to satisfy the current and near-future electricity demand. Based on what has been said before, there is only one development plan for constructing a 10 MW solar PV park capacity by a public company in the short term. But, immediately, there will be no calls from the government to implement this project.

Nevertheless, if the government manages to advance in certain energy strategies under consideration, then, in that case, some possibilities to increase solar power's role within the country's energy mix could be a realistic option. These strategies involve, among others, the following:

- The use of electric vehicles;
- The export of energy;
- Expected growth in demand, for example, in industrial consumption, which today does not seem very realistic given the current economic context, but could be in the future;
- Provide electricity to remote rural areas of the country located far away from the electrical grid.

ARGENTINA

Argentina is committed to increasing the use of solar energy for electricity generation during the

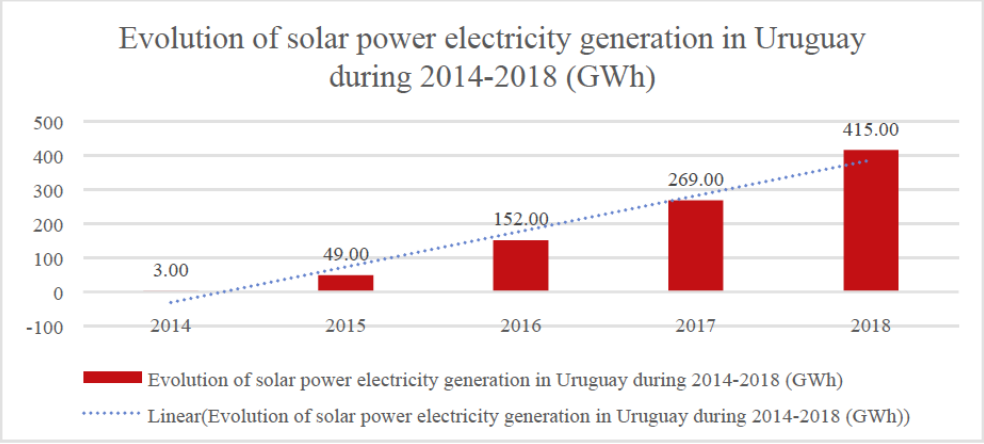

Figure 18: Evolution of the solar power electricity generation in the country during the period 2014-2018. Source: IRENA Renewable Energy Statistics 2020.

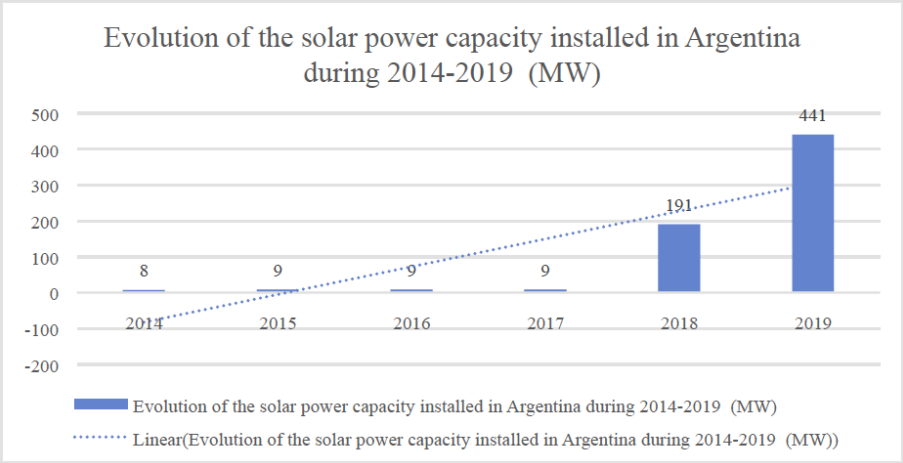

Figure 19: Evolution of the solar power capacity installed in the country during the period 2014-2019. Source: IRENA Renewable Energy Capacity Statistics 2020.

coming decades. Currently, Jujuy city is completely reliant on the supply of solar energy.

Argentina is reported to have the Earth's second-largest solar power reserves. In 2019, the country's total solar energy capacity was 441 MW, an increase of 250 MW (or 2,4-fold); the solar PV capacity installed in the country in 2018 was 191 MW.

The evolution of the solar power capacity installed in the country during the period 2014-2019 is shown in Figure **19**.

According to Figure **19**, the following can be stated: solar power capacity installed in Argentina increased significantly after 2017 (49-fold). If the whole period is considered, then the increase was more than 55-fold, rising from 8 MW in 2014 to 441 MW in 2019. It is expected that this trend will continue without change during the coming years.

In 2018, solar PV capacity installed in the country generated 108 GWh, an increase of 92 GWh (or 6,8-fold) the electricity generated in 2017 (16 GWh). The evolution of solar power electricity generation in the country during the period 2014-2018 is shown in Figure **20**.

Based on the data included in Figure **20**, the following can be stated: solar power electricity generation in Argentina increased significantly after 2017 (6,8-fold). If the whole period is considered, then solar electricity generation also increased 6,8-fold, rising from 16 GWh in 2014 to 108 GWh in 2018. It is expected that the trend shown in Figure **20** will continue without change during the coming years.

Finally, it is important to single out that in recent years, Argentina's government had invested US$1,8 billion "in producing clean energy, and there is a drop in

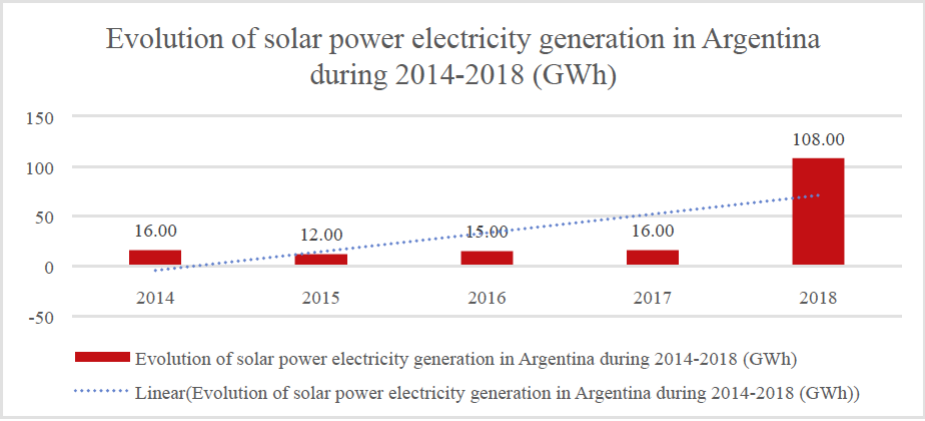

Figure 20: Evolution of the solar power electricity generation in the country during the period 2014-2018. Source: IRENA Renewable Energy Statistics 2020.

greenhouse gas emissions by 30%" (Solar Feeds, 2019).

REGIONAL ENERGY INTEGRATION

Without a doubt, the integration of clean energy sources improves energy security, reduces costs, and increases the national electrical grids' reliability. The use of all available renewable energy sources for electricity generation by Latin America and the Caribbean countries can complement each other. Why? The answer is simple. Due to the different locations of the countries within the region, their energy sector can supply energy at different times of the day and year to different countries. For example, Bolivia, Peru, and Chile can produce vast amounts of solar energy during the day that can be supplied to other countries within the region. Besides, regional energy integration would allow countries to take better advantage of this situation and reduce the need to build their own energy infrastructure to satisfy their energy needs.

The increased use of renewable energy sources for electricity generation combined with regional integration would allow Latin American and the Caribbean countries to diversify their energy sources and suppliers. These actions will protect them against the impact of climate change on the electricity supply level by hydropower plants operating in the region. They will also reduce the negative impact on the environment caused by the use of fossil fuels for electricity generation in many countries of the region.

If the current trend in fossil fuel consumption for electricity generation continues without a change in the future, then the region's carbon dioxide emissions will increase by 19% until 2030. Other dangerous air pollutants like sulfur and nitrogen will grow by over 50% up to 2030. However, if the region expands the use of renewable energy sources for electricity generation and promotes regional grid integration, carbon emissions will drop by 15% and other contaminants by 10% (Viscidi and Yépez, 2018).

Today, the regional energy integration in Latin America and the Caribbean can be considered in an early development stage. The region needs to add thousands of cross-border transmission lines to take full advantage of its potential. Political obstacles and mistrust between countries are impeding that the regional integration moves faster. Regrettably, this situation will not change soon, and political mistrust between countries will not disappear, at least during the coming years or perhaps decades.

It is important to stress that, due to historical reasons, most countries in the region are reluctant to rely on their neighbors as a secure energy supplier and are given high priority to the development of their own energy sources. For this reason, they are given more importance to achieving energy independence than the costs to produce that energy and the sustainability of their national energy system. South American countries should welcome the advantages of electricity diversification and integration of their national electrical grid's interconnection due to their national energy sources' complementary. However, it is unlikely that this happens anytime soon.

Undoubtedly, Central American countries would greatly benefit from expanding their national electrical grid at the subregional level, given their high electricity prices and dependency on imported oil for electricity generation. Subregional energy integration can move ahead during the coming years if the electricity market's regulatory framework is strengthened to encourage investment in the energy sector. Regrettably, the energy integration process is moving slowly within the subregion, and this trend is not going to change in the near future. The political and economic situation in the subregion and the political mistrust between governments are, among others, relevant factors that make subregional energy integration much more difficult.

Finally, it is important to single out that despite that these measures are technically and economically reasonable, they require governments to challenge the strict control that many countries in the region have over their national power systems. Besides this concrete action, governments should adopt specific measures to eliminate all political obstacles that limit subregional energy integration. That is not easy to change due to political mistrust between several Latin American and Caribbean countries. Still, an integrated energy grid would be good for the whole region and at the world level.

SOLAR ENERGY CAPACITY INSTALLED IN LATIN AMERICA AND THE CARIBBEAN

In the region, in 2019, the solar power plant capacity installed reached 8.680 MW and generated in 2018 a total of 13.406 GWh. All solar capacity installed in the region is solar PV. The highest solar power

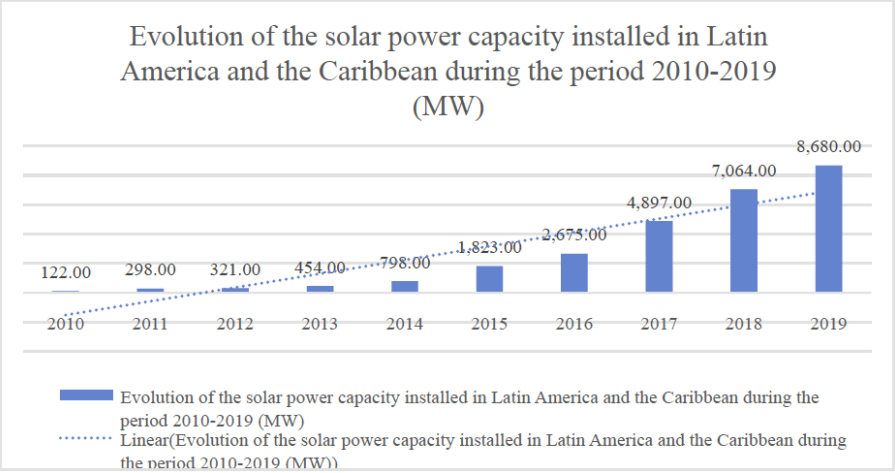

Figure 21: Evolution of the solar power installed capacity in the region during the period 2010-2019. Source: IRENA Renewable Energy Statistics 2020.

capacity is installed in the South American region (74,4% of the total).

The evolution of the solar power capacity installed in the region during 2010-2019 is shown in Figure **21**.

According to Figure **21**, the following can be stated: the solar power capacity installed in the region during the period 2010-2019 increased by 71,1-fold, rising from 122 MW in 2010 to 8.680 MW in 2019. It is expected that the solar power capacity installed in the Latin American and the Caribbean region will continue to increase during the coming years. The solar PV capacity of several countries and their total electricity consumption share can be found in Table **2**.

Notes:

1. 2018 Snapshot of Global Photovoltaic Markets (2018); International Energy Agency; 2018. Report IEA PVPS T1-33: 2018.

2. Renewable Capacity Statistics (2019); IRENA 2019, pp. 24–26; ISBN 978-92-9260-123-2; Retrieved 3 May 2019.

3. IEA PVPS Snapshot of Global PV 2019 (2019); IEA; 2019.

4. Snapshot 2020 – IEA-PVPS(2020); IEA-PVPS.org; Retrieved 10 May 2020.

Table 2: Solar PV Capacity of Several Countries and Share of Total Electricity Consumption

	2017[1]		2018[2][3]		2019[4][5]		Share of Total Consumption[1]
Country	**Added**	**Total**	**Added**	**Total**	**Added**	**Total**	
Brazil	900	1.100[6] 1.004[8]	1.313 974[8]	2.413 2.078[8]	2.138 2.078[8]	4.551[7] 2.485[8]	1,7% (2019)[4]
Mexico	150	539 674[8]	2.700 1.881[8]	3.239 2.555[8]	1.187 1.885[8]	4.426 4.440[8]	2,6% (2018)[3]
Chile	668	1.800 1.809[8]	337 328[8]	2.137	511	2.648	8,5% (2019)[4]
Honduras	-	451 454[8]	34 31[8]	485	26	511	14,8% (2019)[4]
World total	95.000	401.500 388.557[8]	108.500	510.000[3] 488.752[8]	117.000	627.000[4] 586.434[8]	3,0% (2019)[4]

Source: Different sources.

5. Renewable Capacity Statistics 2020; irena.org; Retrieved 23 May 2020.

6. Brazil To Hit 2 Gigawatts Of Installed Solar By End Of 2018 (2018); Clean Technia; 15 May 2018.

7. Beneficios da Fonte Solar Fotovoltaica ao Brasil (2020); Infográfico Absolar; 2020.

8. IRENA Renewable Energy Capacity Statistics 2020.

In 2018, solar PV contributed between 7% and 8% of Chile's total electricity generation (Wikipedia Growth of photovoltaic, 2020). The largest penetration of solar power in electricity production at the world level is found in Honduras with 14,8%. "There are more than 24 countries around the world with a cumulative solar PV capacity of more than 1 GW" (Wikipedia Growth of photovoltaics, 2020). In the region, Brazil crossed the 1 GW total installations mark in 2017 with a national consumption share of 1,7%; Chile did it in 2016 with a national consumption of 8,5%. The available solar PV capacity in Honduras is sufficient to supply 12,5% of its total electrical power needs (Wikipedia Growth of photovoltaics, 2020). The national consumption share of solar power electricity generation in 2018 was 2,6%.

SOLAR ENERGY ELECTRICITY GENERATION IN LATIN AMERICA AND THE CARIBBEAN

In 2019, the total solar power generation in the Latin American and the Caribbean region reached 13.406 GWh, an increase of 5.512 GWh (1,7-fold) of the electricity generated in 2017 (7.894 GWh).

The evolution of the electricity generation in Latin American and the Caribbean region during the period 2010-2018 is shown in Figure **22**.

Based on the data included in Figure **22**, the following can be stated: the solar PV electricity generation increased 149-fold during the period under consideration in the Latin American and Caribbean region, rising from 90 GWh in 2010 to 13.406 GWh in 2018. It is expected that this trend will continue without change during the coming years. The major increase in solar power generation will likely be registered in the South American subregion during the coming years.

ADVANTAGES AND DISADVANTAGE IN THE USE OF SOLAR POWER FOR ELECTRICITY GENERATION

The use of solar power for electricity generation in Latin American and the Caribbean region is one of the fasting-growing renewable energy sources at the regional level. This trend will continue without change during the coming years.

The use of solar power for electricity generation has some advantages and disadvantages concerning other conventional and renewable energy sources. According to Solar Power Nerd (2020), RA Financial Portal (2020), Whitburn and Sepco (2012), the following are the main advantages and disadvantages in the use of solar power for electricity generation:

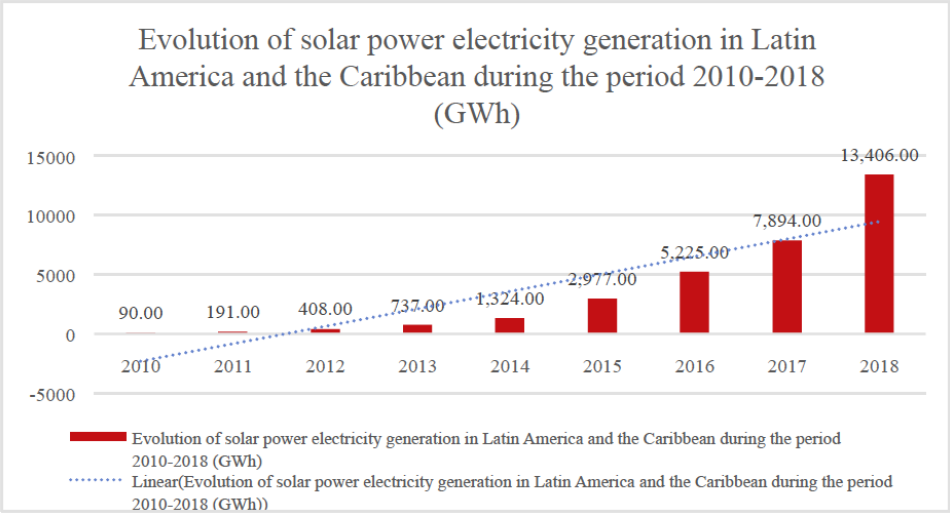

Figure 22: Evolution of the electricity generation in the Latin American and the Caribbean region during the period 2010-2018. Source: IRENA Renewable Energy Statistics 2020.

A-ADVANTAGES

1. **A usable form of electricity**. Generally, solar energy is obtained from the radiation of the Sun in a usable form of energy. "The surface of the Earth receives 120.000 terawatts of solar radiation (sunlight), which is around 20.000 times more power than what is needed to satisfy the energy demand of the entire world (Solar Power Nerd, 2020). Hydropower plants need a powerful force of water to move their turbines and generate electricity. A wind turbine needs to be situated in areas where there are strong winds because if not, then the wind generator cannot produce electricity. In the specific case of solar parks, solar panels produce electricity using only the Sun's light;

2. **Solar energy is environmentally clean**. Unlike the use of fossil fuels for electricity generation, the use of solar energy for the same purpose does not emit greenhouse gases to the atmosphere. Solar energy is environmentally safe and clean because it can be replaced without human intervention.

   Perhaps the most relevant advantage of solar power is the fact that it benefits the environment while simultaneously helping the country to make the necessary transition away from fossil fuels to other cleaner energy sources for electricity generation (Solar Power Nerd, 2020);

3. **Small environmental impact**. A solar power park's operation does not rely on constantly mining raw materials or any fuel type. It does not necessarily result in the destruction of forests and eco-systems that occur with many fossil fuel operations. However, destruction can come in many forms, from destruction associated with the site's preparation to more irresponsible practices in vulnerable areas, to accidents (Whitburn, 2019). Finally, it is important to single out that the production and destruction of solar panels could have a negative impact on the environment if not properly handled due to the use of dangerous materials in their production;

4. **Solar energy creates job opportunities**[9]. While more people use solar power, more solar panels are needed to produce electricity. If more solar panels are needed, then the demand to make these solar panels increases, and more workers are needed to produce them. According to different sources, the global solar panel market is expected to reach US$57,3 billion between 2017 and 2022;

5. **Sun is untaxable**. The Sun is a free source of power, and for this reason, should not be taxable;

6. **Solar's avoidance of politics and price volatility**. One of the advantages of using solar energy for electricity generation is to avoid politics and price volatility that characterize fossil fuel markets. While fossil fuels' price has increased, solar energy production's electricity price has more than halved in the past decade. It is expected that the price of electricity produced by solar parks will become even cheaper during the coming decades as better solar panel technology and economies of scale take effect (Whitburn, 2019);

7. **Solar energy is a continued and available free form of energy**. The Sun never loses its energy and is available in almost all countries. It is continuously flowing energy that provides the world with the warmth and heat that is needed. Without a doubt, solar power is a sustainable energy source that meet the needs of the present without compromising the ability to future generations to meet their needs. In other words, solar energy is sustainable because there is no way that the humankind can over consume. According to NASA source, humankind will have access to solar energy for as long as the Sun is alive, another 6,5 billion years (Solar Power Nerd, 2020). The only costs associated with solar power is the cost of initial installation and maintenance of solar parks;

8. **Decentralization of power**. Solar parks can be installed in most sunny locations, either on grids or off grids, and close to the consumers. "The ability to produce electricity off the grid is a major advantage of solar energy for people who live in isolated and rural areas. Power prices and the cost of installing power lines are often exorbitantly high in these places, and many have frequent power-cuts" (Whitburn, 2019);

[9] Solar job opportunities could come in many forms, from manufacturing, installing, monitoring, and maintaining solar panels, to research and design, development, cultural integration, and policy jobs.

9. **It is a salient energy source**. There are no moving parts involved in most solar power parks, except for those solar parks with a following track of the Sun. For this reason, there is no noise associated with most solar parks in operation at the world level;

10. **Low maintenance costs**. The majority of today's solar power systems do not required a lot of maintenance. In the case of residential solar panels, usually, they only require cleaning a couple of times a year. It is important to single out that most solar manufacturers give 20 or 25-year warranties with their solar pane ls (Solar Power Nerd, 2020);

11. **Improving technology**. Solar power technology is continuously improving, increasing the efficiency of solar panels;

12. **Safety**. Solar panels for electricity generation energy are completely safe, and there is no chance of serious accidents (RA Financial Portal, 2020);

13. **Reduce the dependency on energy suppliers as well as on foreign and national conventional energy sources** (Sepco, 2012);

14. **No trenching is needed**. Solar parks can be close to or at the place of installation (Sepco, 2012);

15. **Desalination of water**. One of the solar power uses is water desalination in areas where fresh, drinkable water is scarce.

Besides all advantages associated with solar power use for electricity generation mentioned above, there are some disadvantages in using solar energy for this specific purpose that cannot be ignored. These disadvantages are the following:

B-DISADVANTAGES

1. **High cost**. Solar energy is free energy coming from the Sun. However, the production of solar panels use for electricity generation is quite expensive nowadays. The reason is simple. It is a technology in continuous development, and with these developments, new solar panels with advanced types are also produced. Besides, in the production of solar panels, rare and expensive materials are used, and thus increase its price;

2. **Weather dependability**. Electricity production from solar panels dependent on the Sun's rays. In other words, solar panels cannot produce electricity at night or in the rain and winter seasons with cloudy times. When it is used during the night time, even with the help of batteries, less electricity is produced. In winter in many countries, solar electricity generation is lower than in other seasons because of the lack of sunlight;

3. **Solar parks need a huge amount of space**[10]. It depends on the capacity of the solar parks. A big solar park needs a huge number of solar panels, and for this reason, the space needed is much larger than for smaller solar parks. In the case of solar panels for residential use, the space needed is much smaller.

   Power density or watt per square meter (W/m²) is an important indicator. The global power density for solar radiation is 170 W/m². This is more than any other renewable energy source, but not comparable to oil, gas, and nuclear power. While solar PV systems can be fixed to already existing structures, larger solar PV parks may require up to 3,5 to 10 acres per MW, and CSP facilities require anywhere from 4 to 16,5 acres per MW (Solar Power Nerd, 2020);

4. **Solar power needs a high capital investment**. Solar power is not an ideal investment if investors are on the go. Inventing is solar energy is high, and it will take time to reach its maximum point. In the USA, the average payback period for investing in a solar panel is within seven years and a half;

5. **Product quality and the use of expensive and rare materials**. Nowadays, the production of solar panels is very rampant in the market globally. Each brand has its specifics, has its name, and has its technologies. Quality is essential over quantity because solar energy is everywhere, but solar panels are an investment that needs a wiser choice (Solar Power Nerd, 2020).

[10] Some countries are looking for a solution to the problem of the huge space needed for the construction of solar parks. An elegant solution to this problem is floating solar parks. Trial solar parks off the coast have been constructed in the UK and similar projects are under construction in India, France, and Japan.

However, the production of solar panels requires the use of certain materials that are not only expensive but very rare in nature. That is especially true for solar PV panels that use thin-film solar cells that are based on either cadmium telluride (CdTe) or copper indium gallium selenide (CIGS);

6. **Low efficiency**. The efficiency associated with solar parks is between 18% and 30%. For this reason, a huge amount of area is needed to produce electricity. However, it is expected that the current level of efficiency associated with solar panels could increase significantly in the coming decades;

7. **The storage of solar energy is expensive**. Solar energy storage systems such as batteries makes solar power more stable, but these technologies are today very expensive and not very efficient;

8. **Solar panels are associated with greenhouse gas emissions**. The operation of a solar park is free of greenhouse gas emissions. However, it is also true that while solar power certainly is less polluting than fossil fuels, some problems do exist.

   Some solar panels manufacturing processes "are associated with greenhouse gas emissions. Nitrogen trifluoride and sulfur hexafluoride has have been traced back to the production of solar panels. These are some o f the most potent greenhouse gases and have many thousand times the impact on global warming compared to carbon dioxide. Transportation and installation of solar power sys tems can also indirectly cause pollution" (Solar Power Nerd, 2010). Besides, the disposal of solar panels retired from solar PV parks could have a negative impact on the environment.

CONCLUSIONS

The Earth receives over 120.000 terawatts of energy every year from the Sun – this is more than 20.000 times the energy needed. For this reason, solar energy is perhaps the most elegant solution to humankind's energy needs. The Sun blasts the Earth's surface with more than enough energy to keep going forever. With such an abundant type of energy, the future of solar power is most certainly bright. However, as it stands now, the world only gets about 1% of its energy resources from the Sun. According to expert's opinions, it is entirely feasible that in the next 30 years, this percentage could skyrocket to as high as 27% (Clean Technica, 2015 and Breakthrough Institute, 2014).

But as solar power becomes more widely used for electricity generation by more and more countries, particularly by Latin American and Caribbean countries, new problems emerge in response to new needs created by the increased use of this type of energy source. For example, the demand for space associated with the construction of solar parks, and the solution for storing solar power for its use at night, are two of them.

Undoubtedly, solar panels' price and the cost of the electricity generated by this type of energy source are continuously decreasing, and this trend will continue in the future. Solar technology improvements will ensure that solar power becomes even cheaper than other energy sources during the coming years. "It could well be that by 2030, solar power will have become the most important source of energy for electricity production in large part of the world" (Reid, 2020). This situation will not only have a positive impact on the environment and climate change but will help countries in their transition from the use of fossil fuels for electricity generation to the use of clean energy for the same purpose. Besides, researchers are also continually working to find better CSP solutions that will be more efficient, affordable, and compact.

Without a doubt, solar energy will soon be unbeatable compared to fossil fuels. As a result, many countries will have the possibility to reduce, as much as possible, the use of fossil fuel for electricity generation and its participation in their energy mix. At the same, these countries will have the possibility to increase in the future solar energy participation within the country's energy mix.

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