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**Article**

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# Study of the Benefit of Solar Energy through the Management of Photovoltaic Systems in Colombia

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**ABSTRACT**

One of the biggest problems in energy management is the impact on the environment. For this, it is necessary to propose new techniques and strategies which reduce pollution. Examples such as carbon dioxide and other greenhouse gas emissions promote an increase in the carbon footprint. This carries the search for resources from renewable sources as sunlight, wind, rain, waves, etc. From these sources, solar energy could be used in Colombia, especially the Atlantic Coast, due to high solar radiation in this region. This study is going to collect information about the advantages and disadvantages of using photovoltaic systems (PV systems) for solar energy management with a good cost-efficiency ratio. On the other hand, the development of solar energy will be studied and compared with other energy sources. In Colombia, there is a set of energy and regulatory policies around small self-generators with renewable energy sources, which can be natural or legal persons, that is, self-generators could be civilians, merchants, or small industries. Finally, it will be discussed about the energy plans as a proposal for improved energy management in the future.

**Keywords:** Energy Efficiency, Renewable Sources, Energy Management, Photovoltaic Cells, Solar Energy
**JEL Classifications:** L78, L90, O31, Q20

## 1. INTRODUCTION

The energy transition of several countries from fossil fuels energy to clean energy due to the problems of the energy crisis and environmental impact. This transition has caused these countries to experiment and investigates unconventional sources for obtaining energy. So, several projects and studies have been carried out on the use of renewable sources in the last 40 years to mitigate problems such as the emission of greenhouse gases, pollution with toxic waste, and accelerated global warming (Edenhofer et al., 2011).

Unconventional Sources of Renewable Energy (FNCER for its acronym in Spanish) are those available energy resources worldwide as biomass, geothermal, hydroelectric, eolic, solar, and sea energy (Top Cable Colombia, 2019). The energy from the sun has several advantages, such as pollution-free use, renewable, and inexhaustible. However, this energy presents some disadvantages that include variability, low power, and high technology requirements. These disadvantages lead to the need to use large-area equipment. Solar energy can be transformed into electricity, heat, eolic, or it can be used for drying and distillation (Rodríguez, 2008).

DeGunther conducted a study (DeGunther, 2009) on the advantages and disadvantages of using solar energy which determined that PV solar systems can be installed on urban constructions, buildings, and houses (even in places with difficult energy accessibility), present low cost of maintenance and have constant development and high availability; but, PV solar systems require large areas of land to install, these systems are affected by the weather, have a high cost of installation and limited technical support.

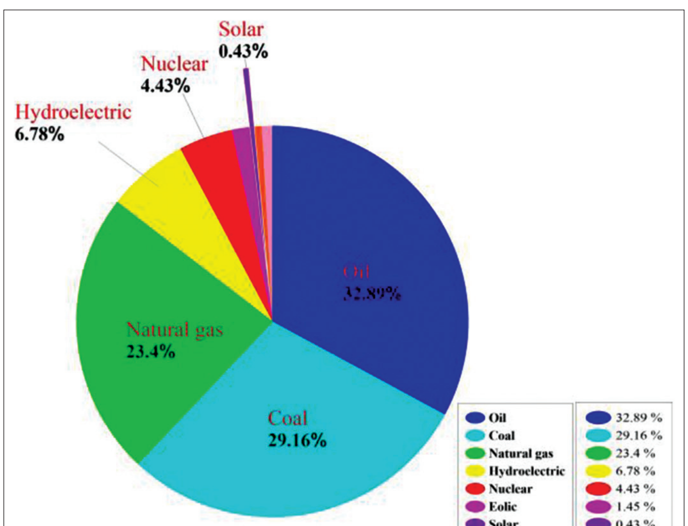
One of the tools for the use of solar energy is the photovoltaic system, but it is necessary to know about solar irradiation, that is, it must be known and interpreted the solar radiation map of the area where it will be implemented the photovoltaic system. In Colombia, Hydrology, Meteorology and Environmental Studies Institute (IDEAM), and Energy Mining Planning Unit (UPME) present the annual radiation maps in Colombia. This solar radiation map offers horizontal global radiation, sunshine, days without sunshine, ultraviolet (UV) radiation, and ozone column. In a technical way, daily hours with sunshine and solar radiation in a specific place are necessary for the design and installation of a photovoltaic system (Pulgarín, 2020).

In 2015, UPME cited several scenarios about the market and energy management in the future. For example, there is a scenario which emphasizes that it is feasible to dispense with 80% of fossil and nuclear energy, this causes that 70% of the energy market depends on renewable energy by 2050. Another scenario suggests that the full use of renewable energy can be projected to satisfy energy demand by 2030. Eolic turbines, solar plants, PV solar plants, systems of solar houses, geothermal plants, hydraulic plants, and energetic tidal systems would be the systems of energy supply with an energy production around 2.006.75 MW. Finally, the last scenario would be energy marked based on Oil, gas, carbon, and renewables, similar to the current market but with some improvements for environmental impact (UPME, 2015b).

## 2. WORLDWIDE ENERGY OUTLOOK

In 2014, a report about the energy consumption in the world (Arriols, 2020) explained energy sources are varied in different countries. The information obtained in the study is shown in Figure 1. This Figure shows that solar energy consumption was

**Figure 1:** Report on percentages of energy consumption in 2014




Source data: Prepared by the author based on data from (Arriols, 2020)

only 0.43%; also, it is shown that energy consumption was based on oil, natural gas, and carbon. In numbers, 85.5% of consumption was fossil energy, and 10.1% of consumption was renewable energy.

In 2018, a statistical study conducted a report which showed that 18.9% was renewable energy of the total energy consumption came from renewable energies, of this percentage, 8.3% was used in transport activities. On the other hand, energy consumption from renewable sources increased from 9.6% in 2004 to 18.9% in 2018. Further, the European Union proposed an increase to 20% for 2020 (Eurostat Statistics Explained, 2020).

In that same year, 171 GW were installed around the world; this added 2351 GW to total worldwide consumption. Renewable Energies increased by 7.1%, while photovoltaic solar and eolic energy improved by 7.9%, it represented 84% of the new worldwide power. European Parliament proposed 32% renewable energy for 2030. Renewable resources achieved competitiveness due to great technological improvements (Asociacion de Empresas de Energías Renovables, 2018). The previous report showed the data in Figure 2.

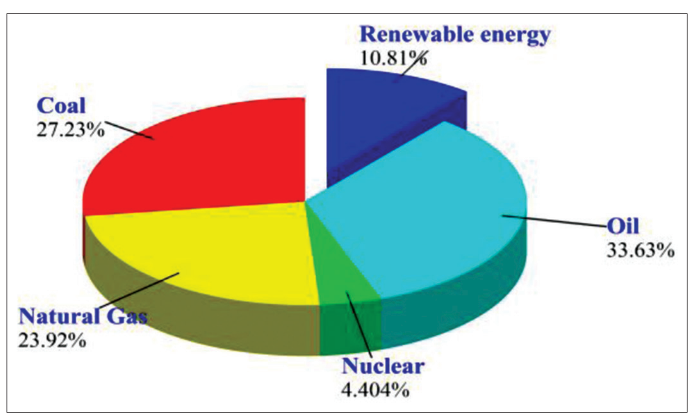
In the previous figure, it is shown that renewable energy represented 10.81% of worldwide energy consumption. Also, the highest consumption was due to oil with 33.63%. On the other hand, Figure 3 is shown in European energy consumption.

## 3. USE OF SOLAR ENERGY AND OTHER FNCER IN COLOMBIA

For the use of solar energy in Colombia, it is necessary to know about the radiation map. As it is desired to take advantage of this situation on the coast, it should be seen as the radiation map of IDEAM (Figure 4).

In Colombia, the average radiation index is 4.5 kW/m²/d, which is above the average of Germany (3.0 kW/m²/d), the country with the highest energy production from PV solar energy. Departments such as Vichada, Guajira, Atlántico, and other departments of the

**Figure 2:** Report on percentages of worldwide energy consumption in 2018




Source data: Prepared by the author based on data from (Asociacion de Empresas de Energías Renovables, 2018)

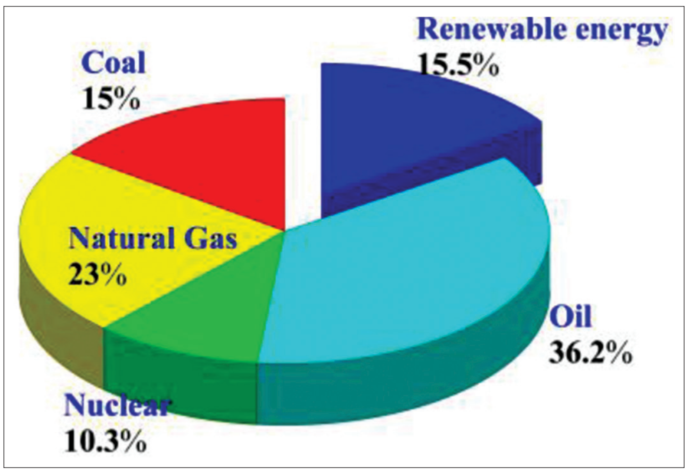
Atlantic coast have a higher radiation index (Table 1) comparable to the desert area index. Colombia has installed 10 MWp of PV solar systems in zones not interconnected (ZNI). $CO_2$ emissions due to the use of solar energy do not exceed 50 kg $CO_2$ eq/MWh against 450 kg $CO_2$ eq/MWh produced by fossil fuels (UPME, 2015a).

**Table 1: Radiation index per department or region**

| Department or Region | Radiation average index (kW/m²/d) |
|---|---|
| Guajira | 6.0 |
| Atlantic coast | 5.0 |
| Orinoquía | 4.5 |
| Amazon | 4.2 |
| Andean region | 4.5 |
| Pacific coast | 3.5 |

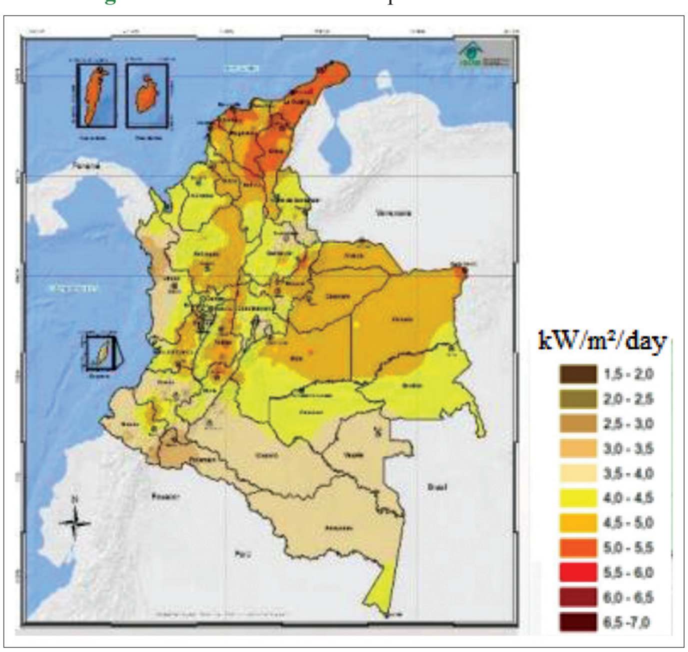
Source data: Prepared by the author based on data from (UPME, 2015a)

**Figure 3:** Report on percentages of European energy consumption in 2018




Source data: Prepared by the author based on data from (Asociacion de Empresas de Energías Renovables, 2018)

**Figure 4:** IDEAM radiation map of Colombia in 2018



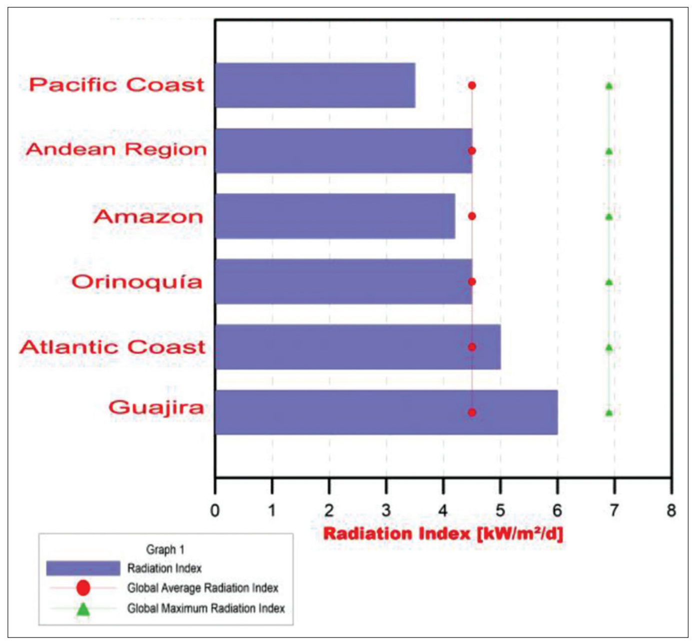

Source of data: Taken from (IDEAM, 2018)

The data shown in the previous Table is plotted and compared with the global reference indices in Figure 5.

Currently, the dominant energy in Colombia is hydraulic energy, which does not generate $CO_2$ significant emissions but is affected by the phenomena of the boy and the girl. For all this, The Colombian Association of Renewable Energies SER plans to give stability to the Colombian energy generation system. SER seeks to take advantage of the high solar radiation in Colombia to turn this country into a great energetic solar generator since it presents high radiation indices per 12 daily hours in departments such as Guajira, Atlantic, and Valle. This indicates greater efficiency, and it may be presented as an alternative to the global energy crisis (Arango, 2019; Procolombia, 2018). Figure 6 shows the principal energy resources in Colombia.

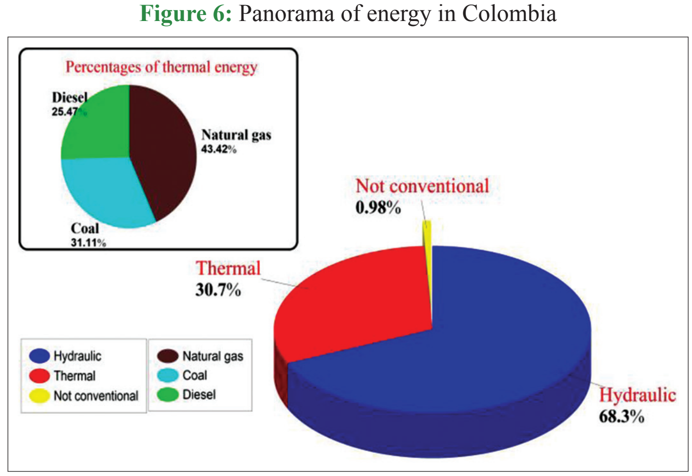
Despite the fact that Law 1715 in 2014 promotes the use of FNCER, there is no regulation for the sale of surpluses, which

**Figure 5:** Radiation Index in Colombia




Source data: Prepared by the author based on data from (UPME, 2015a)

**Figure 6:** Panorama of energy in Colombia




Source data: Prepared by the author based on data from (Arango, 2019) are prohibited. On the other hand, there are no technical standards for the selection, installation, and maintenance of PV equipment (UPME, 2015a).

### 3.1. Historical Energy Regulations and Policies in Colombia

Colombia has generated several policies and laws about the rational use of energy. These laws and policies look for the improvement of the conditions of renewable energy acquisition. In the last three decades, Mines and Energy Ministry (MME in Spanish), Energy Mining Planning Unit (UPME), and Energy and Gas Regulation Commission (CREG) have adopted some laws and decrees to regulate the solar energy use. To begin with, the energy regulation, Law 29, was issued in 1990. This law impulse the investigation of Rational Use of Energy (URE in Spanish) through Colciencias. In 1992, Policies on Alternative Energy Sources, Present, and Future based on Law 1 of 1984 that promotes the use of alternative energy sources through the management of local energy resources and FNCER evaluation. Later, Law 164, in 1994 that controls greenhouse gas emissions and climate change. In that year, UPME was assigned to elaborate a National Energy Plan and the Electricity Sector Expansion Plan. Subsequently, more energy management plans were created that promoted sustainable development and the use of clean energy to reduce environmental impact and pollution.

Law 620 in 2000 established a protocol against climate change, this stimulated use of clean energy. Law 697, in 2001, adopted standards and strategies for the efficient use of energy. In 2003, Decrees 3652 y 3683 were created to establish the Program of Rational and Efficient Use of Conventional and Unconventional Energy (PROURE). In the last decade, Resolution 18 0919 of 2010 promoted the use of alternative energy, and Law 1715 in 2014 delegated some functions to CREG about taxes for the sale, transportation, and distribution of FNCER (Gómez et al., 2017).

### 3.2. Current Energy Regulations, Strategies, and Policies in Colombia

The government set a goal, which is to increase the use of FNCER integrated into the National Interconnected System (SIN in Spanish). A possible solution is the use of Stand-alone Photovoltaic Systems that supply energy to places inaccessible to conventional electrical sources, substituting diesel or gasoline plants that pollute the environment. The government also exposed one of the cleanest energy programs in which it will seek to replace the dependence of hydroelectric power to renewable energy sources for energy production. This is because the phenomena of the boy and the girl affect water levels and, therefore, the obtaining of energy through hydroelectric sources (CPS, 2020).

Currently, Colombia is in a phase of the energy transition, so there is a current legal framework for the use of FNCER. These tools promote efficiency in energy production, energy savings, and response to energy demand (CPS, 2020).

Today, the tools and legal framework that foment the FNCE and the FNCER is Law 1715 of 2014. This law exposes the limits and incentives of the use of renewable energy, such as solar or eolic energy (Celsia, 2016; CPS, 2020). This Law starts defining Unconventional Energy Source (FNCE) as "*available energy resources that frequently countries do not use which are environmentally sustainable such as nuclear and FNCER*" and FNCER as "*available energy resources which are environmentally sustainable such as biomass, hydroelectric, eolic, solar, geothermal and marine.*" Further, Law 1715 has like purposes of guiding public policies and of defining tributaries tools which guarantee the fulfillment of commitments with the government; to incentivize the use of FNCE, specially FNCER promoting efficiency in energy production, energy savings, and response to energy demand; and finally, to stimulate investment, investigation, and energy product development through the use of FNCER. Articles 11, 12, 13, and 14 establish incentives due to the use of FNCE. These benefits are a special deduction from income tax, accelerated depreciation, VAT (IVA in Spanish) exclusion of goods and services with the use of FNCE, and exemption from tariff charges. To obtain any of these four benefits, a license issued by ANLA and another issued by UPME are required (UPME, 2014).

Moreover, Resolution 030 of 2018 issued by the Mines and Energy Ministry regulates the energy production by small-scale (production less than 100 kW) and large-scale (production between 1000 kW and 5000 kW) self-generators. In addition, this resolution includes merchants and power distributors. This resolution shows and explains the process in which users can produce their own renewable energy and sell their surplus to the National Interconnected System (Electrificadora del Meta, 2017; In The Loop, 2018). About photovoltaic systems, Article 5 of Resolution 030 exposes that the production of these systems must not exceed 50% of the annual average of the minimum hours of daily energy demand (Ministerio de Minas y Energía, 2018).

### 3.3. Policies for Rational and Efficient Use of Unconventional Energy in Colombia

Decree 3683 in 2003 regulates the rational and efficient use of energy; in this way, it will have higher efficiency in the energy supply. In chapter 2, this decree determines the Intersectoral Commission for the Rational and Efficient Use of Energy (CIURE) to advise and support the Energy and Mines Ministry (MME) in this topic. In addition, this decree defines the alignments and scope of the Program for the Rational and Efficient Use of Energy and other Unconventional Forms of Energy (PROURE). Alignments are (Gobierno de Colombia, 2003a, 2003b):

- Promote the rational and efficient use of unconventional energy
- Contribute to the competitiveness of the Colombian economy
- Generate real benefits for consumers and users
- Promote the use of efficient technologies and processes in the energy supply chain
- Develop the use of efficient energy, economical and environmentally low impact.

Simultaneously, the following activities are the PROURE scope:

- Administrative agreements with other entities related to the FNCE
- Activities to achieve academic agreements with the education sector about PROURE

- Strategies that allow the supply of energy services from unconventional resources
- Execute sustainable schemes for the project creation that implement the rational and efficient use of energy
- Promote voluntary funds for Rational and Efficient Use of Energy (URE) projects through financing tools like the Financial Support Fund for the Energization of the Zones Not Interconnected (FAZNI).

Previously, Law 697 of 2001 (Gobierno de Colombia, 2003a) declared URE as public interest for an improvement in the use of energy resources, and that law determined the economic, financial, technological, and environmental viability of PROURE.

## 4. STUDIES AND RESEARCH ON ENERGY MANAGEMENT THROUGH THE USE OF SOLAR ENERGY IN PV SYSTEMS

The use and commerce of electricity from solar sources through the use of photovoltaic systems is faster than it seems. In the last 20 years, the use of solar energy in watts has increased 7 times, and technology has improved significantly. That improvement has caused a significant decline in some technological tools used in this industry. For example, the cost of solar panels has dropped exponentially. That is, the cost per watt of silicon photovoltaic cells has dropped from $76 dollars in 1977 to $0.36 dollars in 2014 (Diamandis, 2014).

The International Energy Agency reported that by the year 2035, 662 GW of solar energy valued at 1.3 trillion dollars would be produced, including research in the area. Another situation that requires investment and research in the use of solar energy is the operation of space satellites. Otherwise, energy storage batteries are constantly improving. Further, these batteries are produced in greater quantity as time progresses, so the price drops considerably. In terms of production, Tesla will produce 35 GW in batteries by 2020 (Diamandis, 2014). Figure 7 shows the estimated cost of lithium batteries until 2025.

In 2014, 6 Ds Paradigm about PV solar energy was established with these six characteristics (Diamandis, 2014):

- Digitized, control of solar electricity has become digitized
- Deceptive, due to the growth of PV solar energy
- Disruptive, solar energy supply can be continuous
- Dematerialized, solar energy is a great and unlimited industry
- Demonetized, the energy sun is free
- Democratized, solar energy is available to everyone.

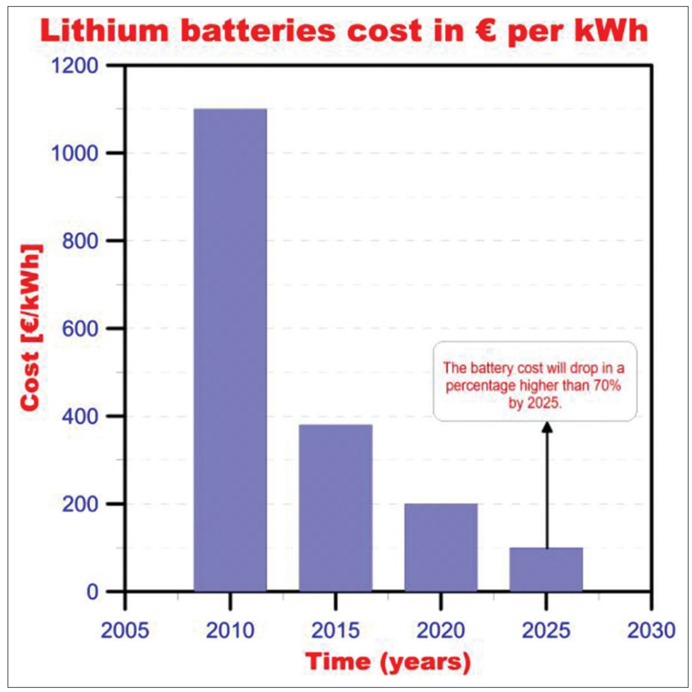
The International Energy Agency predicted annual growth of the PV market by 35%, with 3 144 GW accumulated in installations by 2050 (Mercados Eléctricos, 2012). The predicted costs in dollar per kWh are shown in Table 2.

### 4.1. Research on Solar Energy as a Revolutionary Opportunity in Colombia

In 2008, it was conducted a study about the state of solar energy at that time, which reported that PV solar systems started to be used in the 1980s. In this decade, it was installed 2 950 systems that used 60 Wp (Peak Watts) PV small generators, and then, these systems escalated up to 4 kWp by 1983. Later, it was used 20 289 modules with 2.05 MWp of power. At that moment, it was implemented solar panels with 50-70 Wp of capacity and batteries of 120 Ah at the cost of US$ 1 500. This study concluded that FNCER should be used for an improvement in the rational use of energy. In addition, it would be a solution to the energy crisis of the country. Besides, this report recollected the data about the radiation index shown in Table 3 (Rodríguez, 2008).

Nine years later, several studies had been carried out about the use of PV solar systems due to the increase in energy demand. In 2017, 32% of the country was not included in the National Interconnected System (SIN in Spanish). However, Colombia increased its PV

**Figure 7:** Estimated cost of lithium batteries by 2025




Source data: Prepared by the author based on data from (Diamandis, 2014)

**Table 2: Predicted costs (Dollar in 2009) of PV electricity by 2050**

| Comparative parameters | 2020 | | 2050 | |
|---|---|---|---|---|
| Energy yields (kWh/kWp) | 2000 | 1000 | 2000 | 1000 |
| Equivalent capacity factor (%) | 22.8 | 11.4 | 22.8 | 11.4 |
| Residential PV (US$/kwh) | 14.5 | 28.6 | 5.9 | 12.2 |
| Utility-scale PV (US$/kwh) | 9.5 | 19.0 | 4.1 | 8.2 |

Source data: Prepared by the author based on data from (Mercados Eléctricos, 2012)

**Table 3: Radiation index previous report**

| Department or region | Radiation average index (kW/m²/year) |
|---|---|
| Guajira | 2000-2100 |
| Atlantic coast | 1730-2000 |
| Orinoquía - Amazon | 1550-1900 |
| Andean region | 1550-1750 |
| Pacific coast | 1450-1550 |

Source data: Prepared by the author based on data from (Rodríguez, 2008) electricity generation from 208.06 kW in 2005 to 12 GW in 2015, very low production for high territorial radiation index. The advantages and disadvantages of solar technology depend on the material of manufacture of the panels. These materials are (Gómez et al., 2017):

- Amorphous Silicon, which presents a low efficiency of up to 11%, this material degrades quickly, but it is cheap
- Monocrystalline Silicon, this material presents a high efficiency of up to 21%. Nevertheless, it has a high cost, and it is complex to manufacture
- Polycrystalline Silicon, which has a medium efficiency of up to 16%, it is easy to manufacture, but it is sensitive to impurities, and it is expensive
- Gallium Arsenide. It has high efficiency, which can exceed 25%. However, it is expensive and toxic, so it is difficult to find.

Generally, in Colombia, there are 12 daily hours of sunshine. With a high radiation index, this factor can be used in areas such as services (commerce, education, nourishment, etc.), residential (houses and buildings), electricity in isolated homes, telecommunications, agriculture, and transport (electric vehicles and mass transportation systems). In 2015, Electric Energy Colombian Institute (ICEL) developed 370 projects of PV solar systems installation, which have a PV module of 53 Wp, a 72 Ah battery, a 12 A regulator, and fluorescent lights. Also, the main import companies of PV cells were studied, from which the data in Table 4 was obtained.

Moreover, this report showed the number of kW predicted in projects by the year 2017, which is shown in Table 5. Finally, this study established an electric demand of 66,174 GWh by 2015 and projected electric demands of 67,476 GWh and 71,412 GWh by the years 2016 and 2017, respectively (Gómez et al., 2017).

Last year, several studies were conducted on the use of PV solar systems. For example, in a report was studied the operation of solar systems; which are formed of (Velasco and Calvache, 2019):

- PV Solar panel. This tool turn transforms solar energy into electricity through the photoelectric effect
- Solar controller which regulates electric energy generated by the panel before being transported to the battery
- Battery is used to store the energy produced by the solar PV system based on its storage volume
- Inverter. This instrument converts the continuous electrical energy produced into alternate energy for general consumption.

Finally, this report studied a SWOT matrix in which were shown excellent radiation index in Colombia, low costs of production, transport, and maintenance solar energy, low residue, and high costs of PV solar systems installation. In Figure 8, it shows the scheme of operation of a PV solar system (Velasco and Calvache, 2019).

In that same year, studies were carried out in places with a high radiation index in Colombia, such as Santander, Guajira, and Bogotá. In Santander, a report was conducted about the energy capacity of projects produced through radiation indices obtained by means of a department meshing. This case concluded that the planned project in that department would reach a capacity of 80 MW (AC) (Maldonado et al., 2019). In Bogotá, a survey was carried out with a significant sample of 151 people from strata 3, 4, 5 and 6 to make a comparison between conventional electrical energy and electrical energy from PV systems. From this report, it was obtained that 82.7% of that surveyed think that energy is expensive, and 82.2% agree with the change to PV energy. In conclusion, it was determined that PV solar energy provides a greater economic benefit. It is more efficient, clean, and reliable in Bogotá (Moreno and Ramírez, 2019). Besides, in the Guajira, a thesis was done, which compared the energy cost of PV solar energy against the energy cost of other FNCER. From the thesis, it was concluded that the use of solar energy in Colombia is limited, but with the geographical conditions, it can be a potential country in this industry. Furthermore, the production from solar energy can be cheaper once installed compared to the conventional electric power (Calvo, 2019).

In the present year, a study was made about Clean Energies for Sustainable Development in Colombia. This report compared the use of solar energy as compared with the use of other renewable energies. The study analyzed clean energies in which solar energy appears as one of the main alternatives to reduce the use of conventional sources with great environmental impact. In 2019, the largest renewable energy plant in Colombia was installed with a power of 86.2 MW, equivalent to 80% of renewable energy in the country. As closure, the costs of solar energy will balance in the market, which will make it an affordable alternative. In addition, solar energy will give diversity to the energy market (Sosa and Gómez, 2020).

**Table 4: Main companies imported from PV cells (2005 figures)**

| Company | Investment [US$] |
|---|---|
| Tenesol Colombia Ltda. | 162 861 |
| Melco Colombia Ltda. | 147 220 |
| Coexito S. A. | 123 645 |
| Colsein Ltda. | 83 404 |
| BP Solar España Suc. L. A. | 76 637 |
| Unión Temporal Fulgor Energía | 70 356 |
| Componentes Electrónicas Ltda. | 58 003 |
| Durespo S. A. | 44 203 |
| Energías Integradas CIA. Ltda. | 42 000 |
| Andcom Ltda. | 38 920 |
| Satelice And Solar Services – 3s | 38 010 |
| Proyectos Y Desarrollo Social | 30 260 |
| Solar Center Ltda. | 26 112 |
| Coaxesorios Ltda. | 22 240 |
| Otros | 181 390 |
| Total | 1 145 261 |

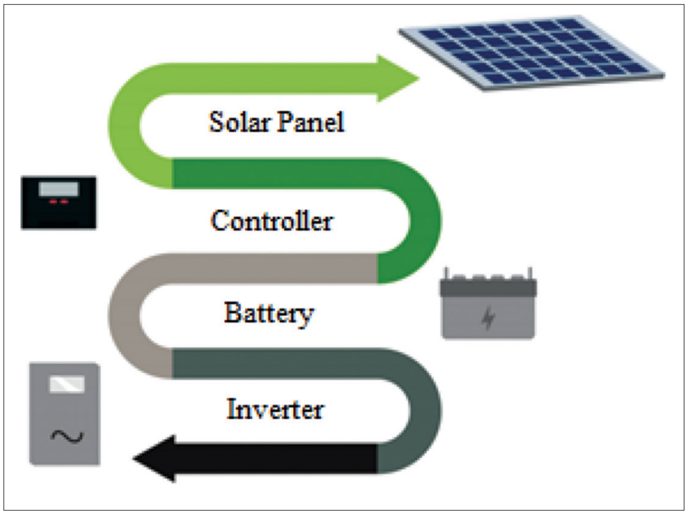
Source data: Prepared by the author based on data from (Gómez et al., 2017)

**Table 5: kW according to project status by 2017**

| Status | Power (kW) | Energy (kWh/month) |
|---|---|---|
| Working | 5,653.70 | 15,231.80 |
| Finalized | 133.44 | 15,239.00 |
| Developing | 39.92 | 4,246.90 |
| In construction | 72 | 10.3 |
| Planning | 87,709.00 | 2,812 809.00 |
| TOTAL | 93,608.06 | 2,847 536.50 |

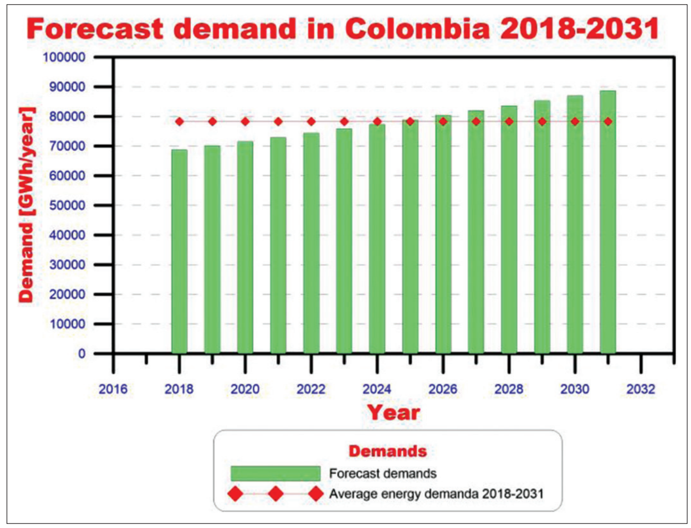
Source data: Prepared by the author based on data from (Gómez et al., 2017)

**Figure 8:** PV solar system structure




Source data: Taken from (Velasco and Calvache, 2019)

**Figure 9:** Estimated demand in Colombia until 2030




Source data: Prepared by the author based on data from (Arango, 2019)

## 5. PROSPECTS AND PROJECTIONS IN COLOMBIA

Mines and Energy Ministry (MME) has decided to increase the use of renewable energy. This increase will be done in the power installations of renewable energy by 50 times compared to the actual conditions. This, after having increased by 12% renewable energy. With the controversy about fracking, the Ministry seeks to expand the energy market in clean and promising energy, such as renewable energy. However, Colombia needs several decades to make a transition from an energy matrix based on gas and oil to another energy matrix based on renewable energy, in a similar way as Norway did (Pardo, 2020).

Currently, the actual energy consumption of the country is around 70,000 GWh/year, with an annual growth of 2% for the next 11 years. UPME hopes 400,000 electric vehicles in circulation by 2030. The Ituango hydroelectric plant should be running to produce 14% of the annual energy production, but the unforeseen events of the project could cause an energy crisis. To achieve the demand projected by UPME (Figure 9), there are two alternatives, which are (Arango, 2019):

- Auction. UPME held an auction in which projects were presented until 2022. These projects vary from updating the energy plan of existing plants to expansion and improvement of these plants; this will guarantee greater reliability in the energy supply
- Renewable energy. The other alternative is the use of the FNCER to find a clean energy matrix. In this case, the main resources are wind, sea, and sunshine. The projects of renewable energy seek to generate and trade around 1183 GWh/year, that is, 1.6% of annual consumption, for the next 12 years from December 2021. Further, the National Government looks to achieve that 10% of the energy matrix is composed of renewable energy.

On the other hand, UPME registers 392 solar energy projects, which will produce 5339 MW. In addition, there are 33 eolic and biomass projects which will produce 2806 MW; these data create a promising panorama in Colombia next year.

The International Energy Agency (IEA in Spanish) explained that PV solar systems would reach 11% of the worldwide energy market by 2050, and PV solar electricity cost will be comparable to the conventional electricity cost. Moreover, IEA seeks to install solar energy distribution networks to the energy market (UPME, 2015b).

In the presentation of the 2050 energy plan (UPME, 2015c), UPME established a new outlook with new architecture, changes in transport, smart grids, improved accessibility to energy, and carbon storage.

## 6. CONCLUSIONS

One of the main problems in energy management is the environmental impact that sources and waste causes. For this reason, some alternatives have been proposed, among which is the use of renewable energy stands out. As renewable energies are clean, they contribute to the environmental impact by reducing the effects of climate change due to low emissions. But this market requires high investments for the transition. This transition would take place from an energy matrix based on fossil fuels to one from renewable sources.

Solar energy, one of the renewable sources, promises a great outlook due to the rapid improvement in photovoltaic technologies and their accelerated cost reduction. Besides, in Colombia's average radiation index is high compared to the average worldwide radiation index, this situation is an advantage for the PV solar energy production. Another main advantage is the low maintenance cost of the PV systems installations. Finally, PV solar electricity can be transported to places that are not easily accessible to conventional electricity systems.

Otherwise, the National Government has determined incentives for the use of renewable sources; this helps research and investment in technologies such as eolic, PV, and hydraulic systems promoting clean energy and energy development in the country. In technological terms, solar panels cost has decreased in percentages greater than 50%. Furthermore, there are several materials that facilitate the production of the solar panel. To finish the conclusion, UPME projected an energy plan to make the energy transition to renewable sources by 2050. This plan seeks to develop the country technologically, energetically, and economically in the next years.

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