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Factors of Photo Voltaic System Cost Affect in Ecuador

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Abstract

A photovoltaic system is a set of devices that take advantage of the energy produced by the sun and convert it into electrical energy. The impact produced by the possibility of using solar energy in a controlled manner for different uses and purposes has allowed the development of complete systems of transformation, storage and distribution of the energy produced with photovoltaic systems as appropriate. The production of electricity from solar radiation using solar cells and photovoltaic panels is an application that has yet fully disseminated in Third World countries, such as Ecuador. The generation of electric power will depend on the hours that the sun shines and affects the solar panel, the type and quantity of modules installed, orientation, inclination, solar radiation that reaches them, quality of the installation and the power that can be delivered to the user. Ecuador is in a privileged location in terms of solar radiation, because the equatorial line that divides the planet into two hemispheres passes through it, being almost perpendicular the radiation it receives. In addition, this does not change during the year and there a constant angle of incidence, characteristics that give photovoltaic solar energy a great potential for use. In the investigation, an analysis of how the prices of photovoltaic systems affect the Province of Manabí, the methodology used has been the bibliographic review to know as much as possible about what replenishes the costs of photovoltaic systems.

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1. Introduction

The impact produced by the possibility of using solar energy in a controlled manner for different uses and purposes has allowed the development of complete systems of transformation, storage and distribution of the energy produced with photovoltaic systems as appropriate. The production of electricity from solar radiation using solar cells and photovoltaic panels is an application that has yet to be fully disseminated in Third World countries, mainly in Ecuador.

For a few years, governments and public institutions in many countries have begun to increase their awareness, not only against the limitations of natural resources but also against the economic consequences of remaining dependent on the importation of primary energy sources. Some countries, whose instability can increase prices unpredictably. The production of energy, based on traditional systems, is debated in a constant challenge of economic and environmental sustainability. The increase in the price of fossil fuels and the expenses associated with the reduction of impacts make the production of renewable energies a determining factor (Zaid *et al.*, 2017).

Electricity is not present in nature as a source of primary energy, therefore, it is only available through the transformation of some other form of energy using different technologies. That is why all types of fossil fuel generating plants have emerged, however, it has been noted that this form of generation produces pollution and devastation of natural resources globally. The so-called "alternative energies" are those whose use does not generate pollution and among them, we can mention wind energy, solar energy, biomass, hydraulics among others. The generation of this type of energy does not produce pollutants, especially solar energy, which is why lately it has become relevant due to the poor state in which the ecosystem is located.

In recent decades, the applications of photovoltaic systems have grown rapidly and are paving the way for solar energy to become a competitor as a source of competitive and mature alternative energy for Europe and the world (Energías Renovables, 2014; Arauz *et al.*, 2017)).

In the market, it is difficult to find the same price of photovoltaic solar panels even though it can generate the same power, have the same performance or equal production of electric energy.

The analysis of the costs of this type of facility depends on different factors, from technical (type of installation, investment cost, maintenance and conservation), to economic policies (interest rates and inflation), environmental (ecological costs) and social (tastes and preferences, fashions, etc.) as well as their manufacture, the material they have been manufactured and the place where they were manufactured (3.Universidad Politécnica de Tulancingo, 2015)

2. Materials and Methods

For the compilation of the theoretical information, it was based on several reliable documents from recognized web pages and with the help of some texts provided in web libraries, and attaching help and recommendations from our tutor and some Electrical Engineers. The Inductive-deductive method was applied based on observation and research techniques for the collection of data and information, which is presented in this work through texts, images, and tables that detail the most relevant points of this research and annexing the concepts specific, which are very important to facilitate the understanding of the subject.

To talk about the factors that include a photovoltaic system in the cost, it is fundamental to know what a photovoltaic system is, what its function is, the types of systems that exist to the present, of which these systems are composed, so as to be able to determine what are the factors that influence the cost of a photovoltaic system?

Basic concepts:

Photovoltaic system Set of devices that take advantage of the energy produced by the sun and convert it into electrical energy.

Factors Elements that can condition a situation, becoming the cause of the evolution or transformation of the facts. A factor is what contributes to certain results obtained when the responsibility for variation or changes falls on it.

Solar cell. Also called a cell, photocell or photovoltaic cell, it is a device capable of converting energy from solar radiation into electrical energy

3. Results and Discussions

In order to develop this research, we start with the basic concepts:

Photovoltaic system Set of devices that take advantage of the energy produced by the sun and convert it into electrical energy.

Factors Elements that can condition a situation, becoming the cause of the evolution or transformation of the facts. A factor is what contributes to certain results obtained when the responsibility for variation or changes falls on it

Solar cell. Also called a cell, photocell or photovoltaic cell, it is a device capable of converting the energy coming from solar radiation into electrical energy.

Description of photovoltaic systems

Photovoltaic systems are based on the capacity of photovoltaic cells to transform solar energy into electrical energy (DC). In a system connected to the electricity grid, this energy, through the use of an inverter, is transformed to alternating current (AC), which can be used in homes, industries, public facilities, transportation, among others.

The generation of electric power will depend on the hours that the sun shines and affects the solar panel, the type and quantity of modules installed, orientation, inclination, solar radiation that reaches them, quality of the installation and the power that can be delivered to the user.

The devices through which solar energy is absorbed are solar cells. These are elements of photovoltaic systems that have the capacity to produce electrical energy by taking advantage of the sunlight that falls on them. The solar cells are manufactured with semiconductor materials, such as silicon, which have the function of receiving photons that travel through the sun's rays and transform them into direct current. Figure 1 shows the incidence of solar radiation on solar panels built with semiconductor materials (Renewable Energies, 2014; González *et al.*, 2017).

Figure 1. Incidence of solar radiation on solar panels
Source: (Renewable Energies, 2014)

Once the photons that emit the solar radiation come into contact with the atoms present in the solar cells, electrons are released that begin to circulate through the semiconductor material with which the cells are manufactured and energy is produced.

A photovoltaic system can be "interconnected" which is the most convenient for residences or businesses with access to the electricity network as seen in the previous figure, they can also be connected directly to the load or the low voltage lines in the form of microgrids (Saltos *et al.*, 2017) and with this, energy losses that may occur during transmission are reduced.

With this system, the generated energy is injected into the electrical network, distributing it through the electrical lines depending on where they are connected (distribution, medium voltage, low voltage or directly connected to the load). The other option is a system isolated from the electricity grid or autonomous that allows the supply of electricity in places inaccessible to the electricity grid. These systems are used mainly in country houses, rural areas, berry systems in the sea, telecommunication antennas in others (Tulancingo, 2015; Belvinel *et al.*, 2018)).

Main components of autonomous photovoltaic systems

Autonomous photovoltaic systems usually have the following elements: photovoltaic modules that are formed by solar cells, structure for modules, operating instruments, regulators and voltage controllers, electrical storage batteries, switches, wiring and electrical network around the site if the energy is used. Figure 2 shows the schema of the fundamental components that are used for autonomous or isolated systems.

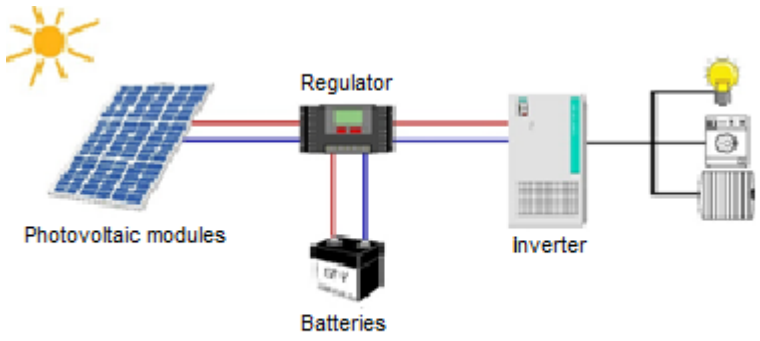

Figure 2. Components of an isolated system
Source: (Renewable Energies, 2014)

Determination of conclusive factors in the price of photovoltaic systems

It is difficult to find the same price of photovoltaic solar panels even though it can generate the same power, have the same performance or equal production of electrical energy

There are certain factors that influence to a greater or lesser extent the performance of a solar cell. These can be of internal or external origin as characteristics of the material, the thickness of the wafer, active surface, contact geometry, etc., can also be environmental factors such as temperature of operation and spectral composition of the radiation.

Among the aspects that influence the price of a solar panel has a lot to do with quality since not all panels are manufactured in the same way.

One of the components in solar panels is silicon: crystalline mono silicon, consisting of a single crystal of silicon, dark blue, crystalline polysilicon, consisting of a set of silicon crystals, performance somewhat lower than those of the group 1. Its color is a more intense blue and the amorphous silicon, the less efficient, but at the same time the least expensive, used in applications such as watches and calculators (Vacarezza) as seen in Figure 3.

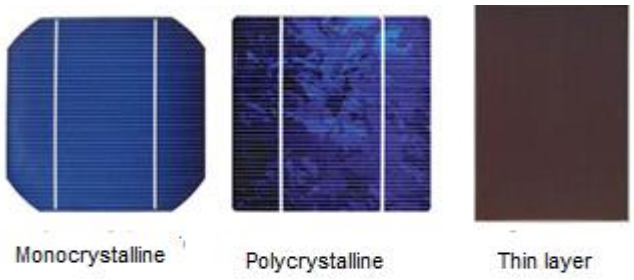

Figure 3. Photovoltaic cells according to silicon types (Renewable Energies, 2014)

With these cells, you can build panels or photovoltaic modules that are integrated by different cells connected in series or parallel as seen in Figure 4.

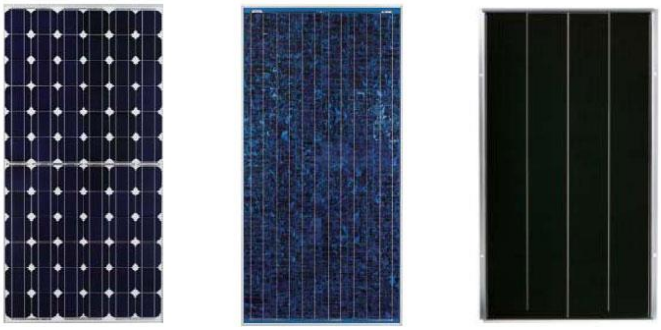

Figure 4. Types of solar panels according to silicon used
Source: (Renewable Energies, 2014)

From the point of view of photovoltaic solar technology, when analyzing its development regarding efficiency and cost, a positive scenario is found. In 1883 the North American inventor Charles Fritts built the first selenium solar cell with an efficiency of 1%, currently, the most advanced multifunction solar cells register efficiencies of the order of 45% although they are not very commercial. However, monocrystalline silicon cells with an efficiency of close to 25% have a much lower cost, determined by Swanson's Law. The Law of Swanson says that whenever the production of photovoltaic solar modules doubles, the cost goes down 20%, in such a way that, in 1977 they had costs of $ 76,76 USD / W, while in 2014 they had been reported 0.36 USD / W. Combining the improvement of solar cell manufacturing technology to increase efficiency and its production in large volumes with the decrease in cost, the scenario is quite flattering (Tulancingo, 2015; Suarez et al., 2018).

The prices of photovoltaic systems internationally have low compared to Ecuador and other Third World countries, in Ecuador for different reasons they continue to be high and are not yet available to the general population.

Investment costs of solar energy equipment

Because it is a relative value since it changes over time and the advance of technology, mainly, investment costs have identified as of September 2007, as shown in table 1.

Table 1
Investment costs made using solar energy for equipment that meets the needs of the CAIS-ZA-URUZA

Component	Quantity	Power (W)	Price ($)
Module F.V.S.M.	6 pieces	100 of 100 Watts	71,926.80
Controlador CCX 12/30/3071,926.80f	1		1,836.00
Inversor Cargador CD/CA Trace TS612	1	600 W, 12V	7,857.00
Inverter Charce CD / AC Trace TS612 1	20	13W	4,740.00
Lamp accessories	p/20 lamps		364.00
(Cable, switches, staples, etc.)			
Balastra	20	2 W, 12V	3,520.00
Solar Cable Battery 115 A-H	6		9,120.00
Accessories set ora battery	4 Juegos		168.00
(screws, terminals, etc.)			
Telmex type outdoor cabinet for 3 batteries	2		111,45380
TOTAL			$111,453.80

Source: Condumex (Ruiz *et al.*, 2007)

The initial investment of a photovoltaic or solar energy system is greater compared to the conventional system (6 modules of 100 Watts, each one, cost $ 111, 453.8 while in the traditional system it is zero dollars), an amount that must be covered by the user, although it is also the traditional system -via taxes or limiting the creation of options.

The system operated by solar energy offers many more advantages. The first is that its useful life is between 20 and 25 years, which means that its investment recovers maximum in seven years, that is, before half of it has elapsed (Rodríguez *et al.*, 2017; Vázquez *et al.*, 2018).

The solar energy system has very low operating costs, almost zero and this is another of its advantages because, if electricity has replaced by solar energy, the Federal Electricity Commission has left to pay, for a space such as CAIS-ZA-URUZA, $ 21, 396.00 per year, an amount that represents a saving or benefit of solar energy (Ruiz, 2007).

Photovoltaic panels have qualities such as low maintenance cost, generation of zero-emissions harmful to the environment and ease of installation. Photovoltaic systems have a higher initial investment but their unit energy production costs were significantly lower than the costs of diesel generators, therefore, generate greater profitability in the medium and long term (Bitar & Chamas, 2017).

Among the different options that exist in the field of photovoltaic systems, it has demonstrated that the incursion in the industrial sector of the market of many countries, such as Colombia, is composed of panels with polycrystalline cells. The decision to assume this technology has based on costs and performance compared to monocrystalline cell technology, which despite having a manufacturing process of greater technological progress, does not present significant differences in its performance, but in its costs of sale to the public. Since this technology is imported and there are no local companies that can compete with the technological advances and manufacturing costs. That has appreciated in other countries such as Germany and China, it is necessary to take into account the cost per unit of power of each technology, which in the case of panels with polycrystalline cells tends to be smaller than that of panels with monocrystalline cells. Below is a comparative table in relation to the cost ($ / W), efficiency and return on investment of both options (table 2) (Bitar & Chamas, 2017).

Table 2
Comparison of monocrystalline vs polycrystalline cells

Cells	Cost (USD/W)	Laboratory efficiency (%)	Direct efficiency (%)	Internal rate of return (%)
Monocrystalline	0.64	24-25	17	19
Polycrystalline	0.51	19-20	15	21

Source: Own elaboration based on information provided by various suppliers

The information related to the cost and efficiency of the cells based on an average of information supplied by various suppliers (Trinasolar, Yingli, Green energy and solar Sungold). Thus, it has been seen that the cost per watt of monocrystalline cells is 25%, more expensive than polycrystalline and, while in terms of efficiency are only 13% more efficient. It is important to note that both the warranty as well as the lifespan of both products are the same. This result in the internal rate of return of photovoltaic systems composed of polycrystalline panels is higher than monocrystalline (21% vs. 19% respectively). This result has based on an average of several studies carried out with both alternatives.

As a general conclusion in Ecuador, Colombia and different parts of the world, electricity generation systems that use solar energy as a resource are viable only if governments have policies to encourage their implementation through the application of tax and monetary incentives. For the Colombian case, the signature of law 1715 of 2014 is the first step for this technology to be attractive and feasible to apply in the national market in the short and medium-term (Bitar *et al.*, 2017).

Accessories and structure of the panels

Installation accessories include the protection pipe for cables, conduits and connection terminals. The connections are composed mainly of two types of cables. The cables that connect the solar panels internally and form the series and parallel connections are AWG12 solar cables for external use. To protect the panels from system inverters in the presence of a peak current or an electrical overload, use a DC protection breaker for each panel rack and an AC protection breaker for the inverter. 34. The structure consists of rails, intermediate clamps, and terminal clamps, which are used to support and fix the panels to the installation surface (Bitar & Chamas, 2017).

Next, the costs of the equipment and installation services associated with the assembly and acquisition of the project have presented. The unit cost ($ US / W) of the solar plant is obtained by dividing the total cost of the project by the nominal power of the system (10kW = 10000W) (table 4) (Bitar & Chamas, 2017).

Table 4
Cost of a model project in terms of unit costs

Teams	Price by unit ($)	Quantity	Total value ($)	Unit value ($)
Panels	418,613	40	16 744,520	0,56
Investors	10 609,817	1	10 609,817	0,35
Transformers	2 747,253	1	2 747,253	0,09
Structure	3 049,457	1	3 049,457	0,10
		Installation	6 670,000	0,22
		accessories	3 000,000	0,10
		$US/W Instalado		**$ 1,53**

Source: self-made

This cost structure does not include costs associated with maintenance because for photovoltaic systems they are very low, given that it was based on the application of water and soap on the surface of the panels, rubbing without excessive force.

Prices adjusted to date (2018)

We can appreciate below the difference of unit costs / Watt, which is due to the arguments mentioned above, and the differences in some accessory, quality of cables, diodes, cells, sealing frames, anti-reflective, finished in general. In some markets, you can see the costs according to its manufacturer and power in table 5 shows three examples.

Table 5
Costs according to three different manufacturers

Maker	Power (W)	Panel cost ($ / W)
Soitec - Concentrix	75W CX-75 CPV Multi-junction	0,65
LDK Solar - LDK	250W-20	49
Sheuten Solar - Multisol	210	0,28

Source: repository.cesa.edu.co (Sebastían, 2018)

Generally, photovoltaic systems have characterized by large capital investments at the beginning by the energy investor that requires a careful economic analysis and planning.

Cost per Watt of Solar Panels by Country

The Cost per Watt of Solar Panels per Country or $/W is a way to compare the costs of generating electricity with solar energy. In order to have a better idea and be able to compare it more easily, a table of all these costs has presented in several Latin American countries in dollars. In other words, how many dollars would have to has spent to buy a solar panel capable of producing a Watt (watt) of electricity? The calculation is very simple; it is obtained by dividing the total cost of the panel between the amounts of watts of maximum or peak power (Wp) that can be produced.

For the costs that will have seen, the following factors must have considered:

a) NOT include VAT.
b) All prices are in US dollars (USD).

c) The variation depends on the location of each country, which generates different transport costs, tariffs and taxes.
d) The variation depends on the supply and demand of each country, the higher the market the prices go down and vice versa.
e) There are different brands, which have different levels of quality and therefore different price levels.

Table 6 indicates the cost of the solar panels per watt of power for the Latin American countries, the data was obtained through a meticulous investigation carried out by CEMAER, considering the costs of different brands and types of solar panels (CEMAER).

Table 6
The polycrystalline, monocrystals, and flexible

	Polycrystalline		Monocrystals		Flexible
	140-160W	240-260W	140-160W	240-260W	100-120W
México	0,79	0,87	0,79	0,67	1,22
Colombia	1,63	1,35	1,23	1,04	1,57
Chile	0,88	1,10	0,98	1,07	3,18
Argentina	2,07	1,72	2,41	1,80	3,30
Ecuador	1,11	1,33	1,23	1,20	3,01
Perú	1,07	1,06	1,15	1,15	2,92
Centroamérica	1,25	1,04	1,25	0,94	2,06

Source: CEMAER (CEMAER)

The prices of Photovoltaic Panels (PV), has been reduced to more than 10 times its price in the last 30 years, however, the current Levelized cost of electricity according to Levelized Cost of Energy "Levelized cost of energy" (LCOE) of the PV panels are still even higher than the prices in the wholesale electricity market. Competitiveness in other markets depends on a variety of local conditions. The LCOE of PV panel systems generally depends to a large extent on the cost of the individual system components, as well as the location and other factors that affect the overall performance of the system. The largest component of the investment cost of photovoltaic systems is the cost of the panel or photovoltaic module.

The cost of operation and maintenance are generally small and often negligible compared to the cost of purchasing a supplier's energy. Since the initial capital cost of photovoltaic installations is high, however, its useful life is between 15 and 20 years, which means that your investment recovers maximum in seven years, that is, before half of it has elapsed.

Photovoltaic systems are more economical than the use of a fuel generator and require almost no maintenance. Photovoltaic systems installed in Ecuador benefit from the geographical position of the country, since, being this country in the middle of the world, solar radiation is constant throughout the year, varying in the rainy seasons.

4. Conclusion

The cost of a photovoltaic system depends on several factors, including technical, political-economic, social and even environmental, but above all the most determined is the type of material with which these systems have been manufactured and their quality.

Photovoltaic systems are a very good alternative for the generation of electrical energy and determinant for extreme situations in case of natural risks where lighting and electricity would be of vital importance.

This work demonstrates the efficiency, the improvement of energy and the viability of these systems, so it is important to promote their implementation either in homes, educational institutions or other building.

Conflict of interest statement and funding sources
The authors declared that they have no competing interest.

Statement of authorship

The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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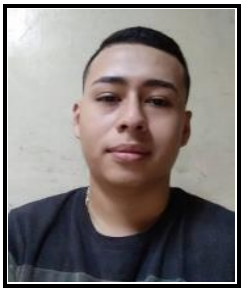

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