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Incentive pertaining to energy the generation distributed in Ecuador

Incentivo a la generación distribuida en el Ecuador

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Abstract

Reducing solar infrastructure costs is one of the main reasons for its global growth. In Ecuador adjustments to the legal framework have to be made to encourage the installation of small photovoltaic solar structures for electricity customers connected to low voltage distribution networks for their personal consumption, and any surplus energy be injected into the grid. Three business models pertaining to the distributed microgeneration of PV have been considered, for which we consider two applicable measurement systems: the first one is called "net metering" where the net value of the energy (the difference between the one injected into the network and the one consumed) is determined, and the second known as "Feed-in Tariff" - FIT where the energy injected into the grid is set at a special incentive price. The cost of energy produced by a photovoltaic system in Ecuador is USD/kWh 0.1342 with a discount rate 7%, CF (capacity factor) at 15%, while a discount rate 10%, CF at 20% the cost reduces to USD / kWh 0.1229. These values however, do not take into account the bank of batteries or the land, these values are increasingly more competitive in relation to non-conventional renewable sources.

Keywords: solar, photovoltaic, measurement, microgeneration, net, harmonic.

Resumen

La reducción de los costos de la infraestructura solar es una de las principales razones de su crecimiento mundial. En Ecuador se requiere realizar reajustes al marco jurídico que incentive la instalación de pequeños emprendimientos solares fotovoltaicos (de clientes del servicio eléctrico) conectados a las redes de distribución de baja tensión para consumo propio, y los excedentes sean inyectados a la red. Se plantean tres modelos de negocios para la microgeneración distribuida fotovoltaica, mismos que consideran dos sistemas de medición aplicables: el primero denominado *netmetering* donde se determina el valor neto de la energía (diferencia entre la inyectada a la red y la consumida), y el segundo conocido como «*Feed-in Tariff*» – FIT donde se determina la energía inyectada a la red a un precio especial como incentivo. El costo de la energía producida por un sistema fotovoltaico en el Ecuador es de USD/kWh 0,1342 con la tasa de descuento del 7 %, el CF (factor de capacidad) = 15 %, mientras que con la tasa de descuento del 10 %, CF = 20 % el costo de la energía alcanza a USD/kWh 0,1229, valores que no contemplan el banco de baterías ni de los terrenos, estos valores son cada vez más competitivos en relación con las fuentes renovables no convencionales.

Palabras clave: solar, fotovoltaico, medición, microgeneración, red, armónico.

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1. Introduction

The intensive use of energy sources of fossil origin has caused significant environmental impacts in global terms, especially through the emission of CO_2, one of the main gases responsible for global warming of the planet or the socalled «greenhouse effect», which is a cause for climate change. Studies have determined that out of a total of 1 trillion tons of CO_2 released on the planet since the beginning of industrialization, 80% corresponds to emissions of the last 50 years [1]. For this reason, more and more non-conventional renewable energies are taking precedence around the world, with the development of new forms and applications, such as distributed or embedded generation in electrical distribution systems. Generally, distributed generation is defined as the generation of electricity by relatively small plants (less than 10 MW) in relation to the centralized plants, with sufficient capacity to allow their interconnection at any point of the electrical system considering the following aspects: end and location; nominal power and voltage level; and, characteristics of the energy delivery zone.

It is estimated that the installation of distributed generation leads to benefits by reducing costs in transmission and distribution losses in the order of 5 to 10% of all generated kWh, and there are also costs avoided in the expansion or repowering of transmission and distribution systems, cost reduction for infrastructure maintenance, increased reliability for consumers close to distributed generation, and faster attention to the growth of demand due to shorter implementation times in relation to centralized generation. Among the main disadvantages of distributed generation is the lack of coordination of protection equipment, the desensitization of protections, difficulties in reconnection, voltage variations, overvoltages, overvoltage resonance, harmonics [2].

2. Analysis of photovoltaic solar energy worldwide

2.1. Production of photovoltaic solar energy

The world energy supply went from 6,642 million tons of oil equivalent (TOE) in 1980, to 10,939 mil-lion TOE in 2005; to 12,170 million TOE in 2010; and, to 13,105 million TOE in 2015; with an average annual growth rate of 1.8%, in the last decade (2005-2015) [3]. In this period of 35 years, the global energy matrix did not present significant structural modifica-tions in terms of the use of primary sources of energy. Thus, it is essential to consider new sources of less polluting primary energies, such as natural gas and renewable energies. In this field, photovoltaic solar energy has shown the greatest growth among renewa-ble energies in recent years.

The installed global capacity of electricity in photovoltaic solar panels experienced exponential growth, reaching around 227 GWe by the end of 2015, producing about 1% of total electricity or 0.5% of total primary energy in the world [3–15]. This type of energy has been installed mainly in regions with fewer solar resources (Europe and China), while high resource regions (Africa and the Middle East) are still not exploited. During the last decade, Germany has been the leader of photovoltaic capacity installation, followed by China, Japan, Italy and the United States. The solar energy projections made for 2050 considers a high level of penetration with which participation may be between 18 and 31% of total generation [4–17].

Cost reduction of the solar infrastructure is one of the main reasons for global growth. The global costs of photovoltaic panels fell by 50% in the United States between 2006 and 2011, with an even more accentu-ated fall of 60% between 2011 and 2015 [5].

2.2. Distributed generation in low voltage mesh networks

The dynamic behavior of distributed generation is dif-ferent from that of conventional machines (generators) because the time constants of the elements that com-pose them are small. Currently, the potential of dis-tributed generation to contribute reactive power during and after a failure, thus improving short-term voltage stability, is emphasized. However, the greatest concern lies in the disconnection resulting from disturbances. Consequently, it is likely that in the case of disconnec-tions, regulations impose an injection of reactive pow-er in order to ensure the system's safety.

Consolidated Edison of New York Inc., a major American distribution company that serves densely populated metropolitan areas, points out the difficulty of sending power to the low voltage meshed grid with distributed generation points, and suggests using adequate protection systems to eliminate possible disconnections. Furthermore, it recommends dimensioning the generation in relation to the demand (keeping the distributed generation always lower than the minimum demand). The protection systems to be used can be minimum load relays or reverse power relays, or the use of dynamically controlled inverters that modulate the gener-ation according to the load [7].

The difficulty of sending power to the network is due to the difficulty of coordinating distributed generation protec-tion systems with those of the network.

2.3. Distributed generation business models (international case)

For companies in the electricity sector, the results cannot be only economic, they must also be measured in terms of improving the quality of the service and of environmental benefits.

In the international arena, and specifically in the North American solar market, three business models are applied. Currently, with the modernization of the sector and the in-troduction of environmental goals for the generation of en-ergy, hybrid forms of these models have emerged.

Model 1. The electricity distributing companies own the photovoltaic solar generation assets and perform the installation, opera-tion and maintenance of the infrastructure in the company's own premises or those of residential or commercial custom-ers who receive payment for the use of roof space. The energy injected into the network belongs to the electricity companies.

Model 2. The electric distribution companies finance solar photovol-taic generation systems for customers and other stakehold-ers, taking into account the high initial investment costs for the acquisition of panels and other complementary equip-ment. Under this model, the excess generated energy is in-jected into the grid and customers can enjoy the economic compensation of energy (net of energy).

Model 3. The electric distribution companies hire solar photovoltaic energy generated by third parties through a PPA (power purchase agreement), avoiding any relationship with the microgenerators (consumers with generation). In this model, distribution companies carry out traditional energy contract-ing activities for resale to consumers. The contracts are es-tablished with few generators avoiding relationships with micro generators or roof owners.

To facilitate the use of the energy resources of distribut-ed generation, it is essential that the agents of the wholesale and retail market have transparent and non-discriminatory access to electricity networks and measurement infor-mation. This can be considered as something normal; how-ever, concerns grow when the local distribution company is also a market participant [8].

2.4. Intelligent networks for the control of distrib-uted generation

The fundamental key of a smart grid is the integration of all the elements that are part of the electrical network. The concept refers to the incorporation of technologies to take a census, monitor, analyze the information of its elements and transmit it in real time for the best performance of the electrical networks, controlling the power flows among which the distributed generation is located, detecting faults to produce automatic reconnection without affect-ing performance. This allows the areas of coordina-tion of protections, control, instrumentation, meas-urement, quality and energy management, etc., to be linked in a single management system with the primary objective of achieving an efficient and ration-al use of energy [9]. The implementation of smart grid systems in Ecuador is aligned with the execu-tion of distributed microgeneration projects.

2.5. Technical aspects for interconnection with the electrical network

Figures 1 and 2 presents forms of connection be-tween a home with photovoltaic generation and the electrical network, corresponding to model 2 de-scribed above. Figure 3 corresponds to model 3.

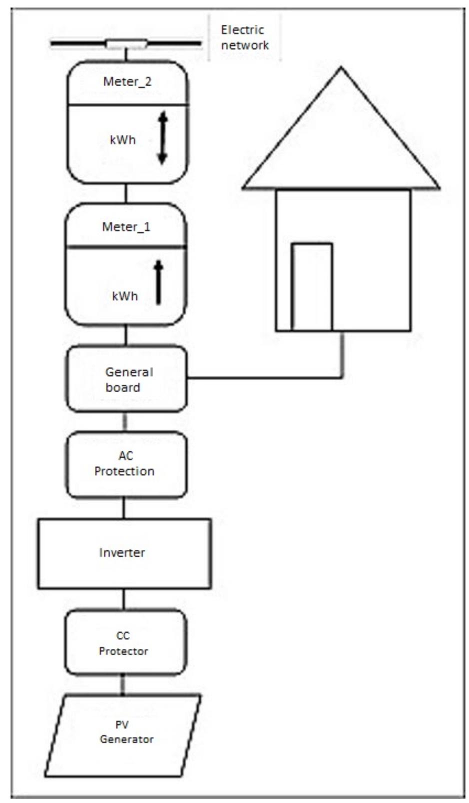

Figure 1. Recommended connection point when there is no incentive for photovoltaic distributed generation [9].

In Figure 1, photovoltaic energy is delivered to the load and the surplus is injected into the electricity net-work (distribution system). Meter 1 records the energy injected into the network. The advantage is that meter 2 rotates in one direction when energy is consumed by the client and in the opposite direction when it is injected into the network (the meter determines the net value of energy), this measurement system is known as netmetering [9].

In radial distribution systems with distributed generation, the power flow can be in the substation—load direction, as well as in the load—substation direction. Therefore, the voltage drop can also occur in both directions. In this last case, situations could arise in which the upper voltage limits are exceeded in some nodes depending on the amount of photovoltaic generation.

In the case of having some kind of remuneration to the surplus of photovoltaic energy, the connection indicated in Figure 2 can be started, prior to the regulation of the price of this surplus energy (meter 1 will record the surplus of injected energy to the network and meter 2 the energy consumed by the client, with the possibility of implementing a single smart meter). This system of surplus energy is known as «Feed-in Tariff» - FIT [9].

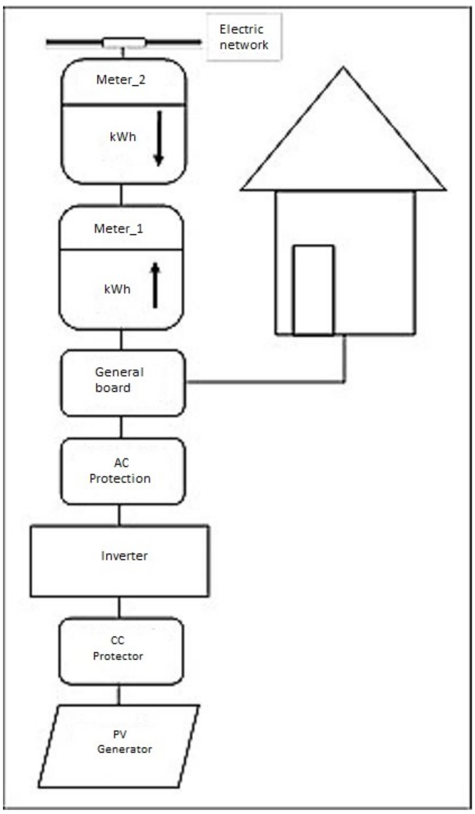

Figure 2. Recommended connection point when the surplus of the distributed photovoltaic generation has an incentive [9].

In Figure 3, corresponding to model 3, the customer is billed according to energy consumption (meter 2) at the applicable tariff, and the photovoltaic generation is sold to the electricity distribution company at a price regulated for that purpose (meter 1 will record the en-ergy injected into the network).

It is concluded that model 3 is the most feasible to install in Ecuador at the present time, because the pric-es of energy sold by distribution companies to final consumers is affected by a direct subsidy from the State, which would prevent a netting of the excesses of photovoltaic generation in suitable economic condi-tions that guarantee investment recovery.

Therefore, it is convenient that the customer is in-voiced independently for the energy consumed by the network, and that photovoltaic energy produced is billed independently at the appropriate price covering the costs of photovoltaic production established ac-cording to the methodology indicated in section 3.4.

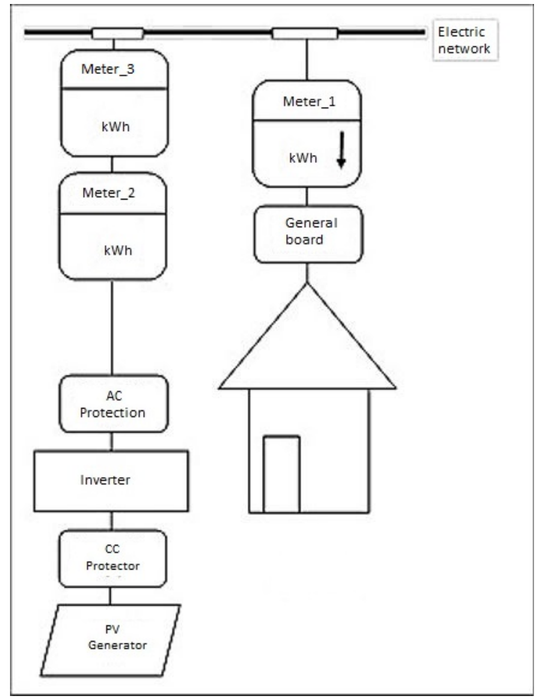

Figure 3. Recommended connection point when are incentives to distributed photovoltaic generation are in place [9].

2.6. Incentives for solar photovoltaic generation (international experiences)

Some countries are adopting financial incentive mechanisms for photovoltaic solar energy through the application of tariff systems such as the so-called feed-in tariff, which is the payment made by electricity distributing companies for energy generated and injected into the distribution networks by customers of the electric service [11].

Since 2006, the federal government of the United States provides a federal tax discount of 30% of the cost of acquiring solar photovoltaic systems for residential and com-mercial customers. In addition to the federal incentive, some states offer discounts on other taxes [11]. For example, Florida proposed an energy premium price over 20 years with a gradual reduction of the annual rate of 5%; Washington offered an incentive to this type of energy for residential and commercial con-sumers as well as public institutions. This incentive consisted of a fixed value (not linked to the kWh pro-duced) for a period of 5 years [16]. However, the net metering system is also one of the regulatory incen-tives used for photovoltaic solar energy in the United States. The model implements the concept that active energy produced with mini or distributed microgenera-tion compensates the consumption of active energy demanded from the electricity grid by the customer. That is, the consumer pays the electricity distribution company the net value that results between the differ-ence of the energy consumed and the energy generated [12].

The per capita increase in electricity in the metropolitan areas of large cities contrasts the growing difficulty of building transmission and distribution lines and networks in these areas, which in some cases must be buried. For this reason, distributed generation will have a preponderant role in future regulation of the energetic matrix of those areas.

In the case of Brazil, by issuing a decree in 2004, for the first time the figure of distributed generator is created, delineating the market to be served. This mar-ket was basically constituted by the electricity distribu-tion companies, which could acquire up to 10% of their demand from distributed generators [8]. In this way, an important market niche opens up for photo-voltaic distributed generation, especially when commercial and industrial maximum generation coincides with the customers' peak demands.

After the Fukushima nuclear disaster in Japan, and the disabling of nuclear reactors, this country established incentive policies for distributed generation with non-conventional renewable energies, especially solar photovoltaic, for which, starting in 2012, the Feed-in Tariff (FIT) model became effective. The regulation contemplates prices for energy between 39.6 to 47.5 cUSD/kWh depending on generation capacity [9–16].

Germany is another country that has applied distributed generation by applying the Feed-in Tariff (FIT) model for capacities of less than 30 kW, with the dis-tribution companies under obligation to grant access and payment of the energy injected into the grid with prices of 24 cUSD/kWh, in addition to a set of state subsidies for the installation [9–16].

In England, as in Japan and Germany, the prices of distributed generation energy through the Feed-in Tariff (FIT) model are greater than the energy demanded to encourage households to install photovoltaic panels in their houses. Energy prices include values between 19.8 and 24.3 cUSD/kWh for capacity ranges up to 50 kW [9–16].

In Spain, the Feed-in Tariff (FIT) system was implemented, granting a prize price calculated on the base of the market rate, financing lines, providing spe-cial investment conditions and fiscal incentives [16].

The application of preferential prices for distributed generation in these countries has been adequate, considerably increasing generation through non-conventional renewable sources, especially solar photovoltaic energy.

In Ecuador, the Organic Law of Public Electric Power Service does not contemplate the exemption of tariffs, taxes and other charges that affect the importation of materials and equipment not produced in the country, for the installation of systems destined to the use of non-conventional renewable energies such as solar energy.

3. Analysis of photovoltaic generation in Ecuador

3.1. Solar potential in Ecuador

Through the former National Electricity Council - CONELEC, Ecuador developed a solar Atlas for electric generation purposes. The data presented in Figure 4presents the global solar energy averaged from total daily sunlight values (direct and diffuse), expressed in Wh/m^2/day. In this Figure we can see the areas with the highest sunlight in the country and, therefore, with the greatest potential for photovoltaic generation, as is the case of the provinces of Loja, Imbabura and Carchi [6].

The approximate average value of global solar radiation in Ecuador is 4,575 Wh/m^2/day.

The estimated solar potential for power generation purposes in the country is 312 GW equivalent to 456 TWh per year or 283 MBEP (million barrels of oil equivalent) per year. This value is approximately fifteen (15) times the technical and economically usable hydroelectric potential of the country.

In spite of Ecuador having a high energy potential, the development of photovoltaic solar energy is still incipient, particularly in distributed microgeneration; for September 2017, ARCONEL reports that effective capacity for this type of energy was 25.6 MW, which represented 0.34% of the country's total capacity, having produced 35.3 GWh/year equivalent to 0.15% of total production of energy. In addition, in Ecuador there is no information regarding photovoltaic panels that can be categorized as distributed microgeneration. The aforementioned statistical information refers to photovoltaic power plants with a capacity between 0.37 MW and 1 MW, with the vast majority of plants close to the latter val-ue.

3.2. Photovoltaic generation residential load

The analysis of the typical residential load curve in Ecuador, per unit (pu) named P in relation to the pho-tovoltaic generation in pu, named PV, as well as the result of the difference of P — PV (see Figure 5), leads to the conclusion that there will be energy flow in the direction from the electricity network to the res-idence between 16.30 to 9.00, and the flow will be reversed (from PV generation to the electricity grid) from 9.00 to 16.30, relieving the distribution system. This schedule could be shifted in time according to the load curve P. At the time (period) of maximum residential load demand (P) (between 19.00 and 20.00), the

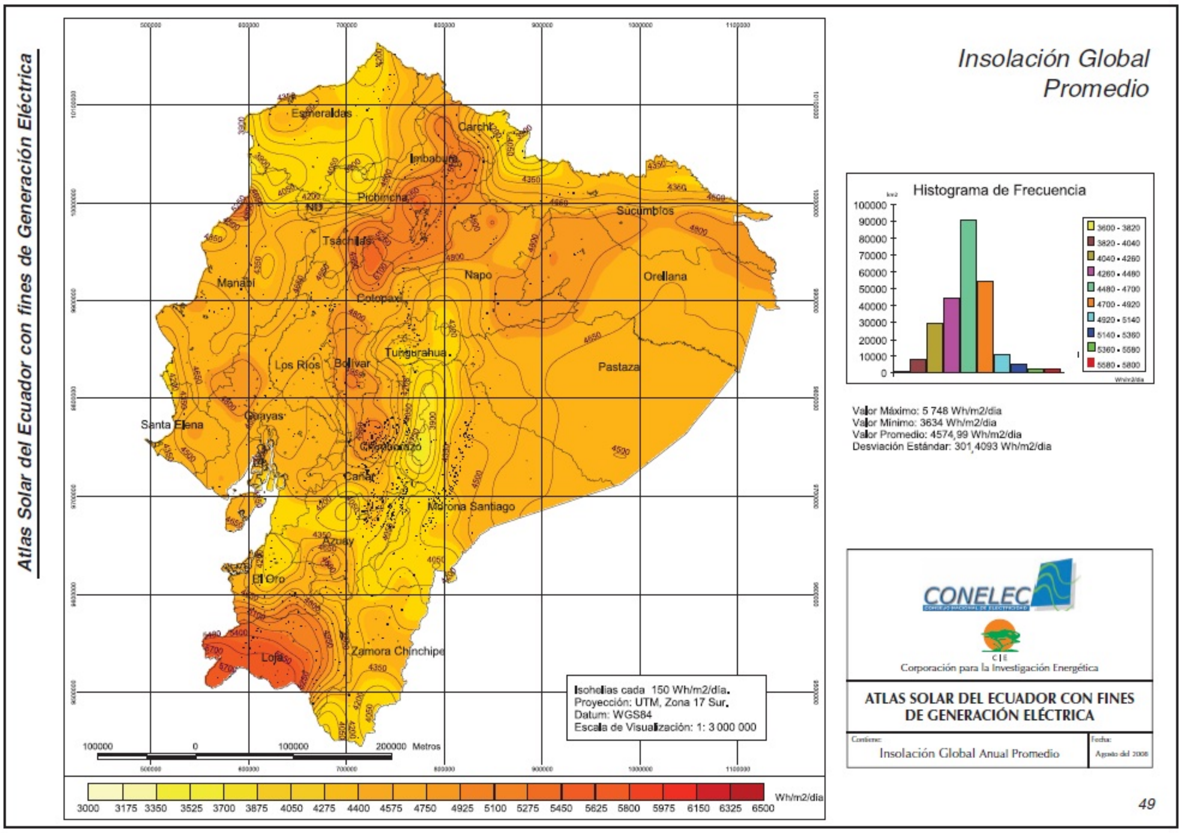

Figure 4. Solar map of Ecuador for power generation purposes [6].

PV photovoltaic generation does not re-duce the flow of energy absorbed by the residence to the electricity network due to the absence of a battery bank.

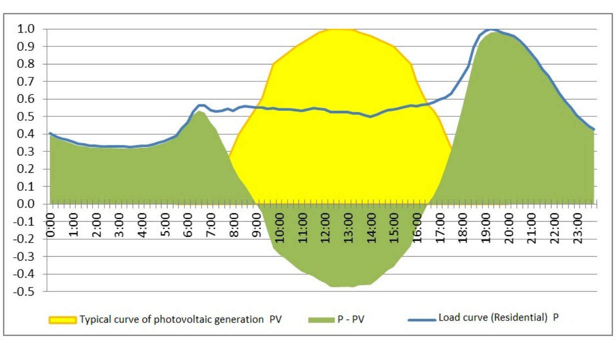

Figure 5. Residential load curve resulting from the use of pho-tovoltaic generation [10].

The power factor of the electric network in the inter-connection node (electricity-customer network) is gradually decreasing as photovoltaic generation in-creases, because active power is decreasing while reac-tive power will be supplied by the network (variation of the power triangle). The IEC 61727 standard states that the power factor must be greater than 0.9 induc-tive when the load of the inverter is greater than 50%.

The harmonic voltage distortions introduced in the network by photovoltaic generation are a consequence of the voltage drop coming from the harmonic currents produced by the inverter that cross the impedances of the network. Total harmonics should be analyzed based on the number of individual photovoltaic panels connected to the network. According to IEC 61727, the total distortion of current harmonics must be less than 5% at the inverter output.

One of the specific requirements of IEC 61727 re-lated to voltage levels, indicates that it should be in the range between 85% and 110% of the nominal voltage of the electrical network. Likewise, the frequency must vary a maximum ± 1 Hz from the nominal fre-quency of the network.

The insertion of photovoltaic panels in the electri-cal networks in low tension leads, as a consequence, to an increased lifespan of distribution transformers (MT/BT) for load relief, in addition to allowing the entrance of new consumers without modifying their capacity [10].

3.3. Ecuadorian regulatory framework

In Ecuador, the Organic Law of Public Electric Power Service does not clearly specify the aspects necessary so that small photovoltaic ventures (natural persons), connected to the distribution networks (low voltage) can produce energy for their own consumption and surpluses for marketing through the electricity net-work. In this area, there is a need for the law to con-template regulations, rules, etc., for the implementation of distributed generation with non-conventional re-newable technologies, especially solar photovoltaics for the residential or domestic sector, due to the high energy potential determined by the levels of sunshine, by granting different types of incentives. Electric dis-tribution companies based on these new regulations should facilitate the participation of distributed genera-tion and carry out ex ante technical validation activi-ties, to ensure that there are no restrictions in the elec-tricity grid and its ex post verification [7].

Taking Japan and Germany, which established higher tariffs for the energy injected into the network in relation to the invoicing price for the customer's consumption, as points of reference with the purpose of establishing incentives for a real possibility of savings in electric payments on a medium and long term, this FIT incentive system presents lower risk to the investor and produces—over the years—a reduction of the incentive (reward) according to the decrease of investment costs of energy technology, differentiating the size of the plant and the geographical location in a way that allows a homogeneous technology distribution. In addition, this regulatory FIT instrument has been widely imple-mented in Spain and Denmark [13–16].

Until recently, Ecuador applied a policy of preferential prices for non-conventional renewable sources (wind, biomass and biogas, geothermal and hydroelectric) in the production of electricity that could be said to correspond to a Feed-in Tariff system, this incentive was established through the Codified Regulation N.° CONELEC 001/13, which was repealed in June 2016 [14]. This regulation did not contemplate any price for photovoltaic solar energy, revealing a strong deficien-cy in the incorporation of this type of renewable energy.

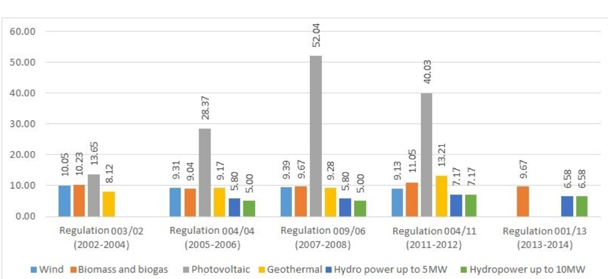

Figure 6. Renewable energy prices in Ecuador.

Figure 6 shows the evolution of prices approved by the former CONELEC in just over a decade, where the highest price for photovoltaic solar energy occurs in 2007 and 2008 (gray bars).

3.4. Costs for implementation of photovoltaic genera-tion in Ecuador

The cost of photovoltaic generation depends on the investment costs of the equipment, the costs of operation and maintenance, the energy delivered by the panels and the capacity factor.

As an example, a contracting process of 75 kWp has been taken through the public procurement platform. The average import cost of the modules reached USD/Wp 1.11 and the investors USD/Wp 0.32. This amount must also include national components of labor, support materials for the modules, wiring, and the necessary protective equipment for the installation, which in sum reaches USD/Wp 0.27 (this does not consider the cost of the land nor batteries). Thus, the total investment cost for photovoltaic generation is USD/Wp 1.69. The cost of energy can be calculated by applying the following expression [8–11]:

$$C = \left\{ \left[\frac{r \times (1+r)^N}{(1+r)^N - 1} \right] + OM \right\} \frac{I_{nv}}{8.76 \times C_F} \qquad (1)$$

Considering, the discount rate r = 7% as an opportunity cost; The useful life of the system N = 20 years; the annual operation and maintenance costs OM = 1% of the total cost of the investment; the total initial investment Inv = 1690 USD/kWp; and, the capacity factor CF = 15%; in this way, the cost of the energy produced by the photovoltaic system is cUSD/kWh 13.42. Applying the same expression with capacity factor CF = 20% for another place in Ecuador with high levels of sunshine, the cost of energy reaches cUSD/kWh 10.74. These values are increasingly com-petitive in relation to the production of hydroelectric energy and other non-conventional renewable ener-gies. Depending on the geographical location in which the photovoltaic solar panels are installed, the cost of producing the energy could vary between the values recorded. It is estimated that by the year 2020, it will be possible for the cost of solar photovoltaic energy to be reduced to such an extent that it will become a competitive energy source in comparison with conven-tional technologies. Concomitantly, policies should adapt to avoid negative externalities compared to other types of unconventional renewable energies [16].

3.5. Need to create a regulatory framework in Ecuador for the development of photovoltaic generation

It is advisable to adapt the legal framework of the Ec-uadorian electric sector, which would encourage the installation of distributed mini and microgeneration with the use of non-conventional renewable energies, especially solar photovoltaics, considering the ade-quate levels of sunshine existing in Ecuador, allowing for investment in the private sector for this type of initiatives, and creating the right incentives for such investment to be possible. For this purpose, the first step is to establish a power quota that can be developed in photovoltaic generation for each distribution company and each type of customer, and which does not affect the operation of the distribution system. Additionally, it must be ensured that prices paid for said production, while they incorporate an incentive to the investment, do not cause an economic imbalance to the distribu-tors.

In the reforms to the legal framework, the application of a FIT is recommended, for which prices of the energy injected into the distribution network should be established, which could be in the order of 20.0 cUSD/kWh and capacity ranges of up to 4 kW for residential customers, for a period of 20 years. The range of capacity for commercial and industrial customers should be determined based on studies that demonstrate its feasibility. Distribution companies will carry out traditional energy contracting activities for resale to consumers, which could be referred to as the application of the modified model 3 indicated in section 2.3. In this way, customers who are part of the program would have economic benefits of the 2:1 order in terms of the rela-tionship between the price of the energy injected into the grid versus the billing price of the energy purchased from the distributor.

4. Conclusions and recommendations

The generation of distributed electric power through photovoltaic solar systems is an excellent alternative for the management of supply expansion, especially for models in which distributed generation is considered.

In Ecuador there is no legal framework that encourages the participation of distributed mini and microgeneration with non-conventional renewable energies, especially in the case of photovoltaic solar energy.

A reformation of the Ecuadorian legal framework is adviced, so it includes incentives for the installation of distributed generation by residential, commercial and industrial customers through renewable energy systems, especially photovoltaics. Among the incentives, the elimination of tariffs in the importation of equipment, preferential prices in the sale of energy to the electricity distributing companies, and ease of in-terconnection to the distribution networks should be considered.

The application of the Feed-in Tariff (FIT) model is recommended, for which prices of the energy injected into the distribution network should be established, which could be in the order of 20.0 cUSD/kWh, capacity ranges of up to 4 kW for residential customers, for a period of 20 years. The range of capacity for commercial and industrial customers should be determined based on studies that demonstrate its feasibility.

The Ministry of Electricity and Renewable Energy is leading the implementation process in electricity companies of a series of automation systems (SCADA, intelligent measurement, DMSOMS, etc.), which in the future will facilitate the installation of distributed mi-crogeneration.

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