Socioeconomic Analysis of Incentive Public Policies for the Use of Renewable Energy per Consumer Class in Brazil

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***Abstract*—This work presents the application of an economic model of the electricity market for evaluation of social policies to encourage the use of renewable energy sources in Brazil. With this model it is possible to represent the economic flows of the regulated electricity company and the consumer, resulting in quantitative measurements of consumption, income, price and quality, items needed for the evaluation of socioeconomic policies. The employed methodology will lead to an economic macro analysis of these policies for different classes of residential consumption. As a result, it will be established a connection between the type of consumer and the best incentive policy to be adopted, in order to evaluate its ability to promote socioeconomic welfare and to encourage the effective use of renewable energy sources in microgeneration for different scenarios.**

***Index Terms*-- Economic Market Model, Public Policies, Renewable Energies, Smart Grid, Socioeconomic Welfare.**

I. Introduction

The continuous growth in energy consumption, environmental and social impacts of conventional generation sources, the heavy dependence on hydroelectric generation (combined with an energy crisis due to an unprecedented period of drought), has motivated a critical thinking about new alternatives and possibilities for the generation of electricity in Brazil. According to the National Electricity Energy Agency (ANEEL) [1], the Brazilian energy matrix is currently composed of 62.1% of hydropower, which illustrates the extreme dependence of the country on this energy source. The use of renewable energies, in addition to diversify the country's energy matrix, may also provide higher reliability and security of supply.

In 2002, it was created by the government the Incentive Program for Alternative Sources of Electric Energy (PROINFA) with the main purpose of financing, through the National Development Bank (BNDES), large generation projects using wind turbines, small hydroelectric power plants and biomass, but not contemplating solar energy.

However, there are still missing programs and incentives for small and medium consumers buying energy from renewable energy sources, as in some countries of Europe, Asia and North America [2]. Following this trend, ANEEL created the Resolution 482/2012 laying down the general conditions for micro and mini generation access to the electricity distribution system. It was established that the consumer-producer (PROSUMER) besides being able to generate power for their own consumption, can also export the surplus to the grid, thus creating energy credits.

The incentives for distributed generation on a smaller scale are clear: besides generation staying close to the load, then reducing losses, postponing investments in the distribution and transmission systems expansion, the environmental impact is reduced and the energy matrix is diversified. Moreover, the stimulus to install energy micro generators units, in addition to improving the energy matrix, may assist in the economic competitiveness in this sector, compared to conventional sources [3].

Although some incentives have been conducted to encourage these new renewable sources, such as solar (PV – Photovoltaic Systems) and wind, this is not enough. Brazil has a high potential for utilization of both technologies, however, presently the solar energy generation in the country represents only 0.01%, and the wind represents 4.21% of the current national energy matrix. Thus, it is necessary a study for evaluating specific public policies incentives for the use of these renewable and distributed energy sources, aiming at maximizing the Socioeconomic Welfare, main focus of regulation in the electricity business.

Therefore, the aim of this paper is to apply an economic model of the electricity market to evaluate incentive public policies, firstly for the residential class of consumption, in order to maximize the socioeconomic welfare. Possible forms of incentives in different scenarios can be evaluated, such as inclusion of tariff flags. To explain and quantify such issues, the electricity market model should be able to deal with

The authors acknowledge the financial support in part by ANEEL (through R&D projects), FAPEMIG, CAPES and CNPq – Brazil.

978-1-4673-6605-2/15/$31.00 ©2015 IEEE

bidirectional flows of energy and economic values, expressing the interaction of electric utilities with their customers or prosumers.

II. The Distributed Generation Scenario in Brazil

The Resolution 482/2012 was created by ANEEL in order to establish the general conditions for access to distributed micro and mini generation in power distribution systems. This resolution established the power compensation system in which the active energy injected by micro or mini generation is transferred through a kind of free loan to the distributor, and then matched with the consumption of active electricity that same consumer unit or another unit of the same owner, with the credits that were generated [4].

However, the tax issue is a concern. Although this distributed generation scheme is not characterized as a purchase and sale transaction of energy, in 2013 it was approved an agreement establishing the state tax on sales and services (ICMS) calculation, which is based on all energy that reaches the consumer unit from the distributor, without considering any power compensation by the micro or mini-generator. That is, this tax is levied on all energy consumed during the month [5]. Moreover, in the case of the federal taxes (PIS and COFINS), there is no legislation clarifying how the collection should be made so that the utilities have been charging the full amounts of these taxes on their consumers.

ANEEL understands (though it is not its institutional competence) that the taxes (PIS / COFINS and ICMS) should focus only on the difference, if positive, between the energy consumed and the injected energy, and if the injected energy portion is larger than the consumed one, the tax calculation basis should only be the cost of system availability. In line with this, the state of Minas Gerais has issued a law stipulating that the ICMS in the state must be charged just in case of a positive difference between the energy consumed and the injected by the distributed generation.

The incidence of taxes, both state and federal, on the compensation system shall be analyzed and discussed, because they strongly impact on the reduction or increase in the investment payback. Since the publication of the ANEEL 482/2012 resolution, a slow process of adoption of distributed micro and mini generators was initiated in Brazil. However, the number is still small (533 units [5]) if analyzed the potential for expansion of this type of generation in this huge country.

III. Public Policies

The Brazilian Government has shown interest in encouraging consumers to join the form of distributed micro and mini generation from renewable and sustainable energy sources. For this objective, public policies are required to promote a balance between all agents in the electricity market.

Thus, at first, the benefits must be shared to both, the consumers and the electricity utility. It should be noted that, by an economic principle, the incentive policy must generate a socioeconomic welfare in the energy market greater than the one previously existing. Otherwise, if the gains to society in general are smaller, it is not worth implementing this policy and a better alternative must be envisioned.

Another point to consider is that the incentive should be proportional to the consumer's economic investment capacity. That is, an industrial consumer usually does not need to receive economic stimuli in the same proportion as a residential customer. In both cases, it should be evaluated the availability or lack of resources, the desired goals with the specific public policy and the aggregated direct and indirect results expected to maximize the socioeconomic welfare generated by the public policy.

A. Taxation

One of the issues that should be considered in formulating incentive policies is the tax issue. The taxes reduction causes stimulation in any consumer class and it is reflected in the reduction of investment payback. Taxes levied in the country impacting renewable energies are many. Among them, it can be highlighted the state tax ICMS, and federal taxes PIS and COFINS. These taxes causes has an additional cost of over 40% over the consumers interested in purchasing their own generation system through alternative sources [6].

The exemption of ICMS for the injected energy into the network from the micro generation is a policy that can be adopted, because as mentioned earlier, the ICMS is still charged on the basis of all the energy consumed in the month, not considering any power compensation from the self-generation. The only portion that is not taxed by the government is the portion that is generated by the panel and already consumed by PROSUMER.

There is a prediction that the ICMS exemption of energy generated from renewable sources and injected into the network may occur, because CONFAZ (National Council of Treasury Policy) will discuss a new draft agreement. Although it is a positive step, because it is not binding, there is no guarantee of its effectiveness throughout the country. The same proposal of incidence of tax only on the net energy consumption can also be extended for PIS and COFINS federal taxes. The tax exemption can benefit, for example, both residential consumers, who supply the network with the surplus generated by micro generation, as industries interested in mitigating the cost of their electricity bill.

B. Credit Lines

Taxation is an obstacle that needs to be reviewed and discussed by the responsible authorities in order to make renewable generation a more economic viable investment. However, for a generalized dissemination, other measures will be necessary such as the creation of credit lines to facilitate the purchasing of equipment. Government political action through public banks may create credit lines with attractive rates and reasonable terms. In addition to the credit line for the consumer to invest, utilities can also receive some kind of stimulus in their business towards a sustainable world. The distribution companies hold all the information and data of consumers and the operational knowledge of the electricity network, and thus, they can conduct studies to identify the best places for installation of distributed generation on the network.

This scenario can generate value to the utility, which reduces losses, delays investment and therefore creates value for its investors. A new business model can be integrated into the traditional role of power distribution: the effective management of the generation and consumption distributed in partnership with the consumer, responsible for the demand, which also can be managed accordingly and sustainably. Thus, it is relevant the development of studies for financing options for each agent, so that the micro generation could be wisely widespread in the distribution network.

C. Examples of Encouraging Microgeneration

A public owned bank, CAIXA ECONOMICA FEDERAL, started the Income Generation and Renewable Energy Project in the program “Minha Casa Minha Vida”, in Juazeiro, Bahia. Families that are part of the program are the first to receive wind and solar micro generation systems. The electricity generated by local microsystems will supply the areas of collective common use.

The included pilot project have received an investment of R$ 6.2 million. The funds were from the CAIXA Environmental Fund, created in 2010 in order to allocate up to 2% of the annual profit of the bank to support environmental projects. Thus, the company expands its role in promoting citizenship, economic and environmental sustainability in the country. [7]

In the US, the Arizona Public Service (APS), a dominant power provider in this state, proposes its own solar business model: install solar panels on the roof of 3,000 customers at no cost and pay each one US$30 per month as a credit in their electricity bill for 20 years, for the renting of their houses roof and also for the electricity that solar systems will deliver to the APS network. For the consumer, this represents an economy of US$360 per year in the consumer energy bill, or US$7,200 at the end of the program [8].

D. Electricity Tariff Flags in Brazil

In Brazil, there are several classes of electricity consumption such as residential, industrial, commercial, rural, street lighting and other classes. The initial focus of this article is to study public policies applied to residential consumers. The other classes can be studied and addressed in future studies.

1) Consumer Class of Interest: Residential

This section will detail the residential consumption subclasses, addressing the main characteristics and possible encouragement public policies.

a) Individual residential consumer:

The individual residential consumers are supplied in low voltage, and each unit can be classified into single-phase, two-phase or three-phase. Because they are individual consumers they could receive a subsidy for the purchase of a microgeneration system, since for them, the initial investment might be very high. It is necessary also to note that, for the physical installation, the residence must have a suitable structure to receive this microgeneration system safely.

b) Collective residential consumer:

Here, are regarded residential consumers residents of buildings and condominiums. They can receive electricity at low or medium voltage. As these inhabit a common use installation, together they can invest in a microgeneration system to be installed on the roofs of buildings. Thus, all energy produced would attend the loads in common use and the remaining would be injected into the grid, producing credits on energy to be used in the future. Because it is a group of residents, they have greater investment capacity compared to the individual residential customer cited before. Accordingly, such consumers should be strongly encouraged to invest in a microgeneration system because the possible generated benefit can be great, and the individual investment might be affordable.

c) Low income residential consumer:

Inside the residential class, there are also low-income residential customers whose tariff is set according to specific criteria. This sub residential consumer class is characterized by customers who consume less than 100 kWh per month. For these users are applied tariff discounts, thus creating the benefits of a lower rate for them, who most need. However, in order that this discount does not affect the economic and financial balance of the concessionaire, is necessary to increase the electricity tariff of other users. To avoid this cross subsidy, one can think about a public policy of encouraging the self-production: This is, for example, the donation of a micro-generator (solar or wind) through which the low-income user can sell power to the utility with a contracted rate. The product of sale works as an equivalent discounted rate [9].

E. Scenarios for Study

From January 2015 in Brazil, is being adopted the system of tariff flags for the energy bill. This system is a different way to present a cost that is already included in the energy bill, but it is usually not perceived by consumers. Currently, the cost of purchase of energy by the distributors is transferred to the consumer within one year after its occurrence, when the electricity fare is adjusted. With flags, the signaling of the cost of electricity generation is monthly, i.e., if there was an increase in the power generation cost, there is an additional already in the month of occurrence [10].

The system of tariff flags is composed of three flags: green, yellow and red, operating as a "traffic light" to facilitate the understanding of consumers. They signal the real price of energy in the country and system supply conditions, as shown in Table I. The advantage to the consumer of this new system is that the current flag information could help him to program and save in the months where energy is more expensive, thus better managing their consumption of electricity. To the dealership, the advantage is that it receives additional revenue to be able to pay for the most expensive power purchase costs, such as the thermoelectric [10]. As this new tariff system changes the consumer energy tariff depending on the generation conditions, it also changes the consumption. So, in this work it will be analyzed the consumer classes mentioned in each of the scenarios of tariff flags.

TABLE I. TARIFF FLAGS.

	Green flag	Yellow flag	Red flag
Generation conditions	Favorable conditions of power generation: hydroelectric plants operating normally	Conditions less favorable generation: activated thermal plants	More expensive generation conditions: activated thermal and high demand
Tariff	No change in the energy tariff value	Addition in the bill of R$ 2.50 to each 100 kWh	Addition in the bill of R$ 5.50 to each 100 kWh

IV. THE ECONOMIC MODEL OF THE ELECTRICITY MARKET

In order to evaluate incentives in public policies, it will be presented in this section the economic model of the electricity market used. By applying public policies incentives, inserted in this economic model the socioeconomic welfare maximization produced can be determined.

A. *TAROT Model*

The economic electricity market model used in Brazil, known as TAROT [11] - [16], is illustrated in Figure 1:

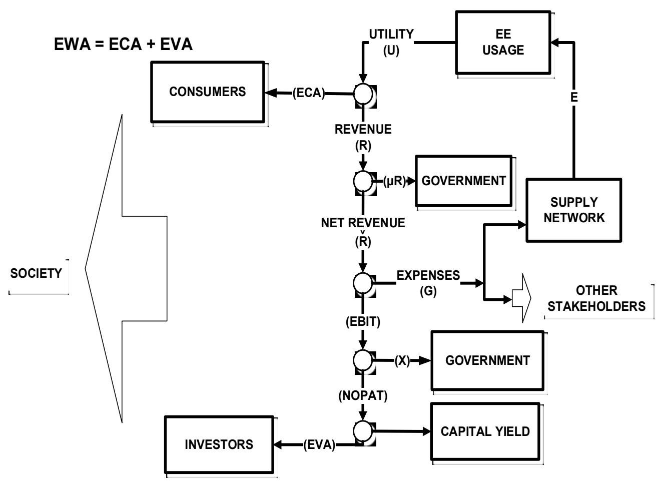

Figure 1. Economic model of the electricity market.

The utility (U), or willingness to pay of the consumer illustrated in the figure 1, reflects the principle of eagerness (a) and satiety (b) by the electricity consumption. Thus, as greater the amount of energy (E) is consumed, the consumer feels less willingness to pay for that product [17]. Thus, the utility can be modeled by the following expression:

$$U = aE - \frac{b}{2}E^2 \quad (1)$$

The electric company, as the energy supplier to the consumer, is remunerated with a revenue (R). Being (T), as the energy tariff, the revenue paid to the electric company is:

$$R = T.E \quad (2)$$

Over this revenue is applied tax rate (μ), which in Brazil is 14%. The result of this discounted tax is the net revenue. With this net income, the electric company should bear the costs (C), taxes (X) and invested capital remuneration. Since this is a universal public service, every consumer receives a surplus (ECA). In the same way, the electric company receives an economic value added (EVA) [12]. Thus, the social welfare (EWA) of this service is the sum of (ECA) and (EVA):

$$EWA = ECA + EVA = (U - R) + (R - C) = U - C \quad (3)$$

Although the bidirectional environment has new functions and relationships between involved agents, the same remains with most of the features that had the unidirectional configuration [17].

B. *The Representation of Customers´ Income in the Model*

Assuming that for every consumer there are various goods and services (G&S) available for consumption, including electricity, it is considered beyond this, the existence of other single goods and services (G&S) for no electricity. Similarly, to (1), equation (4) shows the utility to (B & S) for no electricity:

$$\bar{U} = \bar{a}\bar{E} - \frac{\bar{b}}{2}\bar{E}^2 \quad (4)$$

where ($\bar{U}$), ($\bar{E}$), ($\bar{a}$) e ($\bar{b}$) are value of use or utility, consumption, eagerness and satiety for this no electricity (G&S). As every consumer seeks to maximize his total utility ( ), and their consumption is limited by its income, solving this optimization problem, it is possible to reach the equation of power consumption, expressed by equation (5):

$$\frac{E}{E_M} = 1 - \left(\frac{a}{\bar{a}}\right)^{-1}\left(1 - \frac{Y}{Y_M}\right)\frac{T}{\bar{T}} \quad (5)$$

where (E_M) is the maximum consumption and (Y_M) the maximum income for the set of consumers evaluated.

The market model introduced is able to represent basic concepts required for the evaluation of public policies incentives for renewable sources of energy, such as the impact of aggregate income in the consumption of electricity, social welfare produced, and the commercial strategies available [17]. The advantage in using this model is that it is able to represent simply and accurately the scenario in question. Through this economic formulation is possible to retract in a macro-way the economic and regulatory model for the electricity market.

V. TEST CASE

This section illustrates, in a didactic way, how economic model presented can be used to evaluate the results of a public policy incentive. In the example developed, the policy adopted is the exemption of ICMS for energy produced from micro and mini generation of consumer units. To simplify understanding, it is possible to use numerical values suitable for a large Brazilian electric company, as shown in Table II. The parameters of the consumer, as eagerness and satiety are shown in Table II:

TABLE II. ELECTRICITY COMPANY PARAMETERS.

Parameter	Value
Investment (B)	1875 [MR$]
Operating costs factor (e)	210 [MR$/TWh]
Electric Loss factor (p)	3600 [MR$^{2}/TWh^2]
Depreciation factor (d)	0.05
Capital remuneration factor (rw)	0.0726
Tax on EBIT (t)	0.34

TABLE III. ELECTRICITY COMSUMPTION PARAMETERS.

Parameter	Value
Eagerness (a)	3000 [R$/TWh]
Satiety (b)	200 [R$/TWh^2]

It is assumed that the electric company provides an amount of energy E = 12.5 [TWh] from the distributed generation surplus that is injected into the grid, other way, all that energy comes from alternative sources of generation of consumer units.

A. Current Scenario: ICMS Integral Charge

In the present scenario, the rate charged on revenue is μ = 0.34, where 0.30 is due to the ICMS and the remaining 0.04 due to PIS and COFINS. Inserting Data in the model, results the economic value added EVA = 594 [MR$] and consumer surplus is ECA = 15625 [MR$]. The most important economic indicator of the consumption ratio is the socioeconomic welfare, which in this scenario is:

$$EWA = ECA + EVA = 16219\ [MR\$] \tag{7}$$

Figure 2 shows the flowchart of economical electricity market model, representing the electric company in the current scenario. The full value of 30% ICMS is charged on revenue.

B. Proposed scenario: ICMS exemption for renewable energy sources

The proposed scenario uses the same data of the electric company and consumption, but considering now that there will be exemption from ICMS, because the energy is produced through houses micro generators. Therefore, the tax rate on EBIT is μ = 0.04. In this scenario, the net revenue of the company is larger, and so the economic value added, with a value of EVA = 1419 [MR$]. Thus, the produced socioeconomic welfare will be:

$$EWA = ECA + EVA = 17044\ [MR\$] \tag{8}$$

Figure 3 shows the flowchart of the economic model of the electricity market in the proposed scenario.

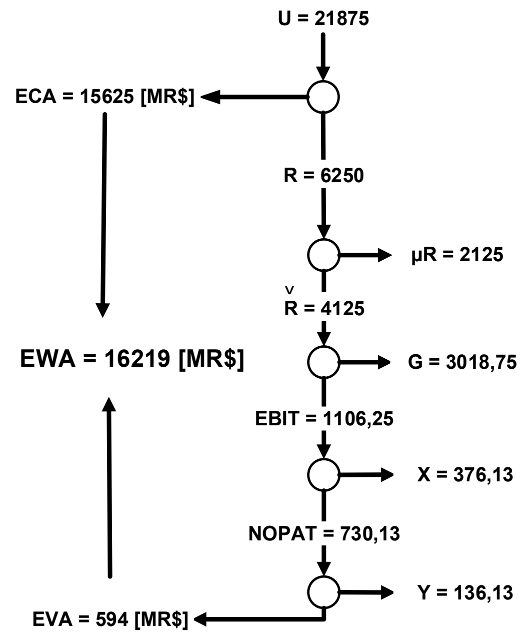

Figure 2. Economic model of the electricity market in the current scenario.

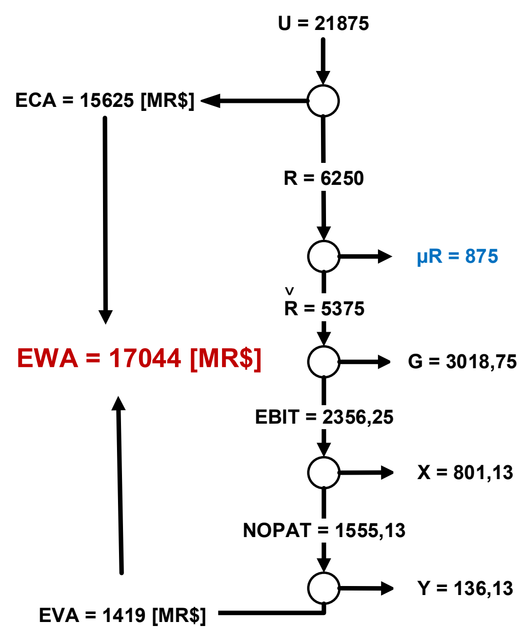

Figure 3. Economic model of the electricity market in the proposed scenario.

It can be concluded that for the example given, the reduction of 30% tax due to the ICMS has resulted in a social welfare increase of approximately 5%. That is, in this scenario, there is an increase in the value added to society through the implementation of this public policy.

It is observed that in this scenario the company has a higher EVA. The regulator, ANEEL, would have the possibility to transfer part of this increase to reasonable tariff of the end user energy consumers. This electric company capital accumulation could also be used to purchase and install micro generators at strategic network locations. This is an easy public policy to be implemented, but this initiative depends on the states and depends of revenue resignation on their financial part. This example, seeks to illustrate how the model can be used to evaluate whether the proposed public policies create value added for society and how they affect other economic variables.

VI. CONCLUSIONS

Based on ANEEL regulation, the Brazilian consumer today can generate their own energy from alternative sources and provide the surplus to the distribution grid, receiving in exchange credits into energy. Despite of some efforts to the insertion of renewable energy sources in Brazil have been conducted, it has not been enough to its spread. Among the main challenges are the tax issue and the creation of credit lines for the purchasing of equipment.

This paper presented proposals for public policies to encourage self-generation and an economic model that can treat in a macro way the effects of these public policies, seeking to maximize the socio-economic welfare produced. The model is able to express the interaction of electric providers' agents (electric utilities) and (consumers or consumer-generators) faithfully and simply. Incentive policies for the other classes of consumer, such as commercial and industrial, will be studied and addressed in future studies.

Impacts encouraging integration of renewable sources through micro generators in consumer units are diverse. It can be highlighted as direct impacts, the increase of the socioeconomic welfare, as shown in the example case, causing the state revenue reduction. Indirect impacts are harder to quantify. Among them, there is the encouragement of these energy sources, providing industrial advancement, the reduction of carbon emissions, less dependence on hydroelectric sources and sustainable development.

The sale of the produced energy through distributed generation encourages consumers to adhere to this way of generation. There is no provision for the sale of energy surplus still in Brazil, but this may be a next step.

ACKNOWLEDGMENT

The authors gratefully acknowledge the contributions of Prof. Jose Wanderley Marangon Lima from UNIFEI.

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