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Incentive Regulations for Renewable Energy: A Critical Analysis

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***Keywords*— Compensation scheme, feed-in tariff, renewable energy, renewable portfolio standard, regulation, subsidies, swap, tendering.**

***Abstract*— Regulations tools to incentivize the use of renewable electrical sources are used worldwide, with different mechanisms. This work evaluates the most used ones, based on experiences across the globe, defining them, evaluating their advantages and disadvantages and their impacts in the cost of electricity, in technology prices and in the change of the power generation mix. The discussed methods are Feed-in tariff, compensation schemes (net-energy metering and net-billing), Renewable Portfolio Standards and Renewable Energy Certificates, subsidies, tendering and fiscal measures. After the regulation evaluation, a brief analysis of the encouraged technologies is performed, analyzing how these tools distort the electricity market and the long-term impacts of encouraging the use of variable and inverter-based generation. Also, it is dedicated some effort in discussing the consequences of many incentives, as seen in Germany, Spain and Brazil.*

I. INTRODUCTION

The distributed generation through renewable electrical sources is assuming a notable space in the electrical generation mix worldwide. This tendency is guided by sustainable development policies focused in environmental preservation, in special climate change issues, which started mainly with the signature of the Kyoto Protocol in 1997. The objective aspired with the Kyoto Protocol was to reduce the emission of GHG gases in 5% from 2008 to 2012, and to reduce 18% from 2013 to 2020 considering the level of emissions measured in 1990, with the main goal of limiting the increase of the global temperature (United Nations, 1997) (United Nations, 2012). In the Paris Agreement, signed in 2015, the goal is to avoid the increase of the world average temperature over 1.5°C in the better case, and 2°C in the limit.

From this global initiative, Nations started to develop own political measures to reach these targets, focused in three major areas: reduction of emission of GHG, energy production through renewable sources and energetic efficiency measures. As implications to these objectives, political incentives for the installation of renewable sources started to be created, in order to increase the penetration of renewable sources in the electrical generation mix and also leading to the change of the role of the consumers in the context of electrical energy generation. Consumers not only consume electrical energy, but also generate electrical energy and model their demands actively (Brown, Hall & Davis, 2020). Some examples of countries that had success in this expansion are the USA, China with aggressive policies of renewable sources expansion and the European Union, highlighting Spain, Germany, United Kingdom, and Italy.

To tackle the economical dimension for electrical energy generation companies, and for consumers, different strategies of political financial incentives have been developed around the world to make the renewable electrical generation economically viable. These types of incentives for the generator owners and utilities can be divided in the payment of special tariffs; indirect payment through energy or billing credits; fiscal policies, tradable certificates of energy origin, imposition to generators to source a certain amount of energy from renewable energy sources (RES) and tendering. Furthermore, these strategies can be combined in hybrid approaches, to use their advantages and reduce their disadvantages.

All these strategies have advantages and disadvantages and each state have decided which one to use, based on previous experiences or research. The objective of this work is to present the definition of the main regulation strategies, their advantages and disadvantages based on successful and unsuccessful examples, to present a critical analysis of each case and discuss future implications of such regulations.

In chapter 2 it is presented the definitions of the main employed regulation tools to incentive renewable energy sources. In chapter 3, examples of use of each regulation tools are depicted, and their advantages, disadvantages and applicability are discussed using as references cases of application in different countries. Chapter 4 discusses future impacts caused using incentive regulations and the future acceptability of renewable energy sources worldwide. Finally, chapter 5 summarizes the main conclusions regarding this work.

II. DEFINITION OF INCENTIVE REGULATIONS FOR RENEWABLE ENERGY SOURCES

Different strategies of regulations have been established around the world to incentive the production of electrical energy by renewable electrical sources. The main ones are described in the following sub-sections.

2.1. Feed-in Tariff

Feed-in Tariffs (FIT) are characterized by the payment of a special tariff value by the Transmission System Operator (TSO) or Distribution System Operator (DSO) to electrical energy producers, according to the amount of energy generated through renewable sources and injected in the network for a certain period (normally between 15 and 30 years). The FIT can be fixed, where its value is established in the beginning of the period, or premium, where generators receive an additional value added to the market value for the electrical energy generated (Baitelo, 2011). Albeit being paid by the TSO or DSO, the FIT cost is divided equally among all final consumers, leading to the increase of the electricity bill. Anyhow, in this case, governments only act as regulators, not necessary funding this policy. FIT is used to ensure a return for the investors, creating a higher demand for this type of technologies and leading to a further development of technologies. Feed-In Tariffs are considered for some authors, especially by Mendonça, Jacobs and Sovacool (2009), as the best legislation tool to incentive RES.

To define the FIT for a specific location, some features must be defined. Firstly, the type of technology, type/size of plants, which will be supported by FIT shall be defined. Secondly the tariff calculation method shall be established, as explained by Mendonça, Jacobs and Sovacool (2009), considering the investment cost for each plant, grid-related and administrative costs, operation and maintenance cost and fuel cost. This calculation may lead to different values of tariffs for different types of technologies and size of the plants (less mature technology shall be rewarded with higher tariffs and larger plants shall be rewarded with lesser tariffs). The duration of the tariff payment shall be established, but it can be changed for new installations according to the penetration or development of such technology. It is also suggested, in the definition of the FIT, that all energy generated by renewable sources shall be purchased and distributed by grid operators, having priority dispatch.

As a counterpart, the limitation of the amount of generation supported by the FIT, or even the cessation of this tariff, has the capacity of restraining new projects, previously viable because of the tariffs. Such decision can be made to hold back the expansion of distributed generated or can be caused by economic crisis (Caramizaru & Uihlen, 2020).

2.2. Electrical energy compensation

Some mechanisms to compensate electrical energy injected by generators, limited to a certain capacity, have also been developed in regulations in the world. In this case, there are two main mechanisms used: net metering and net billing. These mechanisms can have different formats as per Hughes and Bell (2006), where it is reported that 22 different formats were found in different countries.

In the case of net metering, the exceeding electrical energy generated by prosumers and injected in the electrical grid is used to discount the energetic consumption from future periods. Some authors characterize the net metering system as the system where the value of the energy exported and imported have the same value and only one energy meter is required (Dufo-Lopez & Bernal-Agustin, 2015). In some cases, where the levies related to the use of the grid is paid, the consumer shall have two different energy meters to allow the utility to measure the amount of energy consumed from the operator and calculate the levies.

Net metering has some modalities according to the regulation of the countries. In the simple modality, if there is a negative difference between the injected and exported energy, the consumer shall pay to the utility; if the difference is positive, the consumer has no compensation (Dufo-Lopez & Bernal-Agustin, 2015). The buyback scheme is an extension of the simple modality, where the utility pays for the excess energy generated by the prosumer (Hughes & Bell, 2006). The rolling credit scheme is characterized as the case when the customer-generator has exported more energy than imported during the billing period, earning energetic credits that can be spent during a certain period to be defined by the regulation established in each country (Dufo-Lopez & Bernal-Agustin, 2015). The utilities have two possibilities at the end of the validity of the credits, give no financial compensation for the remaining credits of the prosumer or pay for the credits in the end of the defined compensation period, in this last case the scheme is known as net metering with rolling credit and buyback (Hughes & Bell, 2006). The use of one energy meter for the net-metering is presented in Fig. 1.

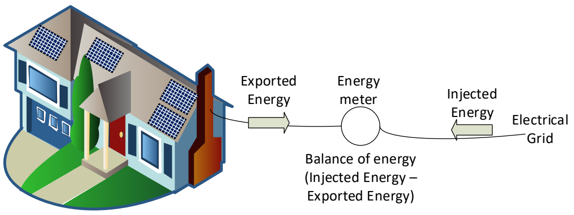

Fig. 1: Net-metering scheme

In the case of net billing, exceeding electrical energy generated by prosumers and injected in the electrical grid is used to discount the energetic consumption in monetary terms. Some authors consider net billing as the scheme where the generator buys energy for the retail price and sells the exceeding generator for a different price. In this case, two meters are necessary. In the simple modality, if there is a negative difference between the cost of the injected and exported energy (different values for injection and importation), the consumer shall pay to the utility the difference, and if the difference is positive, the consumer has no compensation. The buyback scheme is characterized as the case where the customer generator pays for the imported energy and the utility buys the exported energy. The rolling credit (with or without buy-back) is the same as for the net metering, but with monetary credits (Dufo-Lopez & Bernal-Agustin, 2015). Fig. 2 presents the use of two energy meters for the net-billing practice.

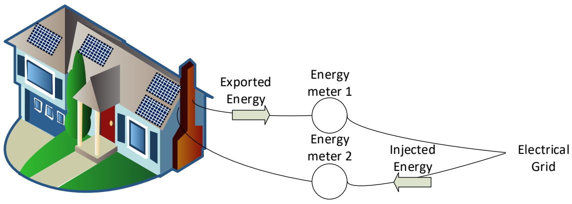

Fig. 2: Net-billing scheme

In the other hand, to detain the growth of DER installation, the exceeding electrical energy generated and injected into the electrical grid cannot be compensated or even the injection of electrical energy by the prosumers can be forbidden as in Colombia (Rickerson et al, 2014).

2.3. Renewable Portfolio Standard / Renewable Energy Certificates

Renewable Portfolio Standard (RPS) requires electricity suppliers to source a certain quantity of electrical energy generated from renewable sources, generally in MWh. These policies have the main goal to increase or maintain the participation of renewable energy in the electrical energy mix.

To design this type of policy, some factors shall be analyzed. Firstly, the eligible renewable electrical sources shall be defined according to the geographical availability of resources, typically wind, solar, geothermal, landfill-gas and ocean-based energy resources are used. Further on, the regulator shall define the amount of energy from eligible RES that shall be sold in the electricity market during a defined period. The amount can be given in absolute generation or installed capacity or even as a percentage share of electricity sales. Finally, it is necessary to ensure for the investors that the renewable energy market will continue to exist over the life of the installation, thus a government entity shall enforce penalties for utilities, which do not comply with the designated RPS. Therefore, some methods shall be used to track the renewable energy origin (Heeter, Speer & Glick, 2019). The most used method is known as Renewable Energy Certificate (REC), which have different nomenclatures according to the country where it is established and has a similar approach as carbon credits. REC purchasers can be voluntaries or by compliances need. The voluntaries are organizations that focus on reducing their GHG emissions, by establishing their own goals or even just by knowing the origin of their electrical energy (Energy Sage, 2020). The compliance buyers are the utilities participating in the RPS, that are obliged to source a quantity of electrical energy produced by renewable sources and can use RECs to prove the origin of the electrical energy.

Renewable Energy Certificates (REC) increase flexibility and ease tracking. A REC is a certificate associated with the generation and injection of each MWh from renewable sources in the electrical grid. It is enough for utilities to demonstrate compliance with the RPS to regulators to purchase certificates, instead of directly buying the electrical energy.

REC shall contain the information about the used resource, period of generation and its location. In some states, it is allowed for the generators to unbundle the generated energy from the REC, being allowed to sell two different goods. This action frees generators to deliver electrical energy directly to users in real time, allowing the renewable electrical energy to be generated where it makes more sense, avoiding costs for new installations of transmission and distribution and giving a geographical flexibility for the generated energy (United States Environmental Protection Agency, 2008).

This practice is presented in Fig. 3 and Fig. 4. RPS associated with RECs benefits

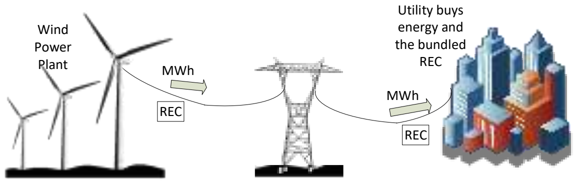

Fig. 3: Utility buys the REC bundled with energy

Fig. 4: Utility 1 buys electrical energy and utility 2 buys the unbundled REC.

2.4. Tendering

Renewable energy tendering is a mechanism where governments call for tenders to procure a specific quantity of electricity or capacity to be built at a strike price or government may offer a fixed budget to bidders and the quantity of electricity for that budget is bided. In general terms, the participants submit a bid with a price per unit of electricity, through which they are capable to make the project affordable. The bids are evaluated and then it is signed a Power Purchase Agreement (PPA) between the winner and the government as stated by the International Renewable Energy Agency (2015) and by Hochberg and Poudineh (2018). The winner is chosen by the lowest-price bid. This is a more competitive approach, allowing generators to further develop their technologies.

The tendering mechanism for long-term contracts is a regulatory intervention in response to the absence of efficient short-term market price signal. This ensures long-term revenues for generators, especially for renewable electrical sources, which have problems to dispatch energy in times where the electricity price is higher (Hochberg & Poudineh, 2018).

To design auctions some features shall be considered according to International Renewable Energy Agency (2015) and to Hochberg and Poudineh (2018). First, the volume of auction shall be defined in terms of MW, MWh or budget, additionally the number of rounds shall be established. Next, the types of technologies able to compete shall be defined among the following options: technology neutral (any technology), technology specific (a certain kind of technology, example only renewable sources) and standalone (only one type of technology is allowed).

The conditions allowing suppliers to participate shall be defined, being the auctioneer responsible to define minimum requirements (reputation, experience), the necessary documentation and penalties for not completing the goals in the contracts. More participants tend to be part of auctions, if there are lesser barrier to enter and if the perception of the risk is low. This is important to prevent collusion and price manipulation

The auction procedure shall be established. The following options exist: sealed bid is when suppliers shall provide bid information to auctioneers and the offers are opened in the day of the auction. There are some variations to this type of auction, in some the winner is the one who bided the lowest value, however the PPA is signed according to the second least value. The other one is known as pay-as-bid, where the supplier is compromised to the value that it has offered. Another type of auction is the iterative process, where bidders are able to gradually disclose their bids during the rounds. The most common used is the descending clock auction, where in each round the auctioneer proposes a lower price in each round and bidders make their offers until the supply and demand match. There is also the hybrid approach, where characteristics from both methods are used .

After being selected, the winner and the auctioneer sign the PPA. It is important that auctions occur frequently, in order to allow the suppliers to foresee future auctions and further develop their products.

2.5. Fiscal policy and Subsidies

Fiscal policies as incentive correspond to credits or taxes exemption, to allow the consumer to overcome the initial cost of the investment (Baitelo, 2011). While subsidies are characterized as the ceasing of money by the government with the intent of keeping the products prices accessible to the people. Acting in this manner, the consumer has access to cheaper credit or even directly to cheaper products. Another approach is the act of divestment of subsidies given by governments to a certain type of technology and invest this remaining money in a different technology. This exchange is known as swap.

Additionally, the introduction of new consumers able to generate their own may lead to a tariff system restructuration can lead to new taxes targeted in prosumers. And in the case of subsidies, they can be temporary or even not be granted by the government.

2.6. Hybrid Approaches

By knowing the objective of each regulation tool, their advantages and disadvantages, governments may use hybrid approaches to tackle different types of renewable energy sources according to technology prices and sizes of power plants (utilities or consumer scales).

III. IMPACT ANALISYS OF THE REGULATION TOOLS

This sub-section discusses the positive and negative impacts of each type of incentive regulation based on cases around the world.

3.1. FIT

The FIT policy was considered as the main responsible for the growth of prosumers in many countries, as Germany, Spain, China and in some American states, as California, among others, as it gives an investment return safety for investors during a certain period. By having such security, the demand for these technologies grows, technology development is incentivized, and concurrence arises. This type of incentive can support different technologies and plant sizes, as stated by Mendonça, Jacobs and Sovacool (2009).

This kind of regulation is used mostly in the European Union (EU), highlighting the case of Germany, where this type of regulation is a mature case to be discussed. Since 1990, Germany established distributed generation incentive policies, starting by the 1000 Roofs Program combined with the Feed-In Electricity Act (from the German *Stromeinspesegesetz*) in 1991, which were the first laws to introduce the feed-in tariffs for distributed and renewable generation. With the rise of environmental policies in the EU, focused on the reduction of GHG emission, increase of energy generation by renewable sources, and energetic efficiency, Germany promulgated in 2000 the Renewable Energy Sources Act (from the German “*Erneuerbaren-Energien-Gesetz”*), which is known as EEG (Peter et al, 2015). With the EEG, the German target to 2020 was to increase the penetration of renewable sources in its electrical energy matrix. The objectives are to reach 35% of this type of generation until 2020, 55% until 2025, from 65% until 2040 and finally to reach 80% until 2050 (International Renewable Energy Agency, 2015).

The EEG was the tool to reach the set goals, by establishing two types of FITs paid for the generated electrical energy by renewable sources: the fixed and the premium. In the fixed tariff, utilities buy the amount of energy generated by consumers using renewable sources for a fixed tariff for 20 years, to ensure security for the investment. In the premium tariff, generators can sell electricity directly in the energy market, receiving a bonus. Additionally, renewable energy generators were granted priority dispatch and connection to the closest grid point, entitling grid operators to pay for infrastructure improvements (Peter et al, 2015). The amount paid for generators by end users was established as the EEG surcharge, which is the difference between the cost of the FIT paid to energy producers and the market price of the electricity.

In 2004, the first reform of EEG was implemented. In this reform, the photovoltaics installations received more stimulus that other RES, caused by the low interest in this kind of source in the period (Ramalho et al, 2017), being the FIT divided by the size of the installation. This reform has also established an annual 5\% regression in the FIT (Ramalho et al, 2017).

In 2009, the new version of the EEG issued established a higher reduction in the FIT and a complete modification in the annual regression, where the amount paid started to vary, when a defined threshold of annual capacity installed in the previous year was reached (Ramalho et al, 2017).

The new reforms from 2012, 2014 and later in 2017, created the term EEG 2.0. In 2012, the main modification was related to the regression rate of FIT, which became determined monthly based on the growth of capacity of RES in electrical generation mix. In 2014, all systems with a capacity higher than 100kWp could only apply for the FIT premium (the smaller ones could still choose between FIT fixed or premium) and all systems above 10kWp should pay a tax on self-consumption, in order to compensate the surcharge caused by the introduction of the FIT (Ramalho, 2017). The EEG 2.0 in 2017 introduced the tendering system for renewable generation sources installation exceeding 750kW, over the FIT model (Agora, 2015).

The implementation of FIT in Germany, along with the reduction in the prices of the technologies, led to a vigorous increase in the percentage of the total electrical energy generated by renewable sources as presented in Fig. 5. In 1990, from the total amount of electricity generation, 4% were generated by RES. In 2019, 41.8% of the total amount was generated by renewable sources, highlighting the wind sources with 20.3% of participation.

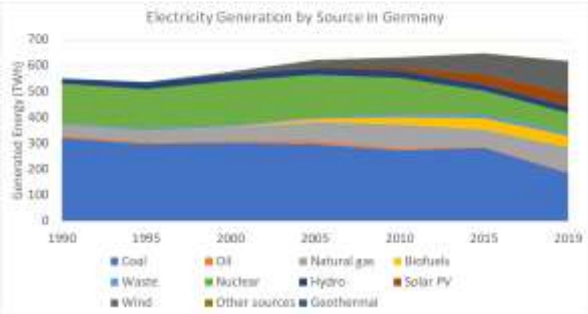

Fig. 5: Participation of renewable sources in the electrical generation mix. Based on the International Energy Agency (2019).

Currently, wind energy occupies a prominent position in the total share of electrical energy generation, incentivized since the 00's. Solar energy started to compose the generation mix after 2004, when FIT for photovoltaic technologies increased. With the reduction in its price, specially caused by the expansion of Chinese industry, proportionally higher than the reduction of the FITs, a great expansion can be seen, leveraged by the increase in the number of prosumers, as presented in Fig. 6.

The highest disadvantage for this tool is the increase in the energy price for all end users, to cover the Feed in Tariff for producers. The EEG surcharge corresponds to more than 20¨% of the tariff in 2019, thus, even with the reduction of the retail electricity price since 2011, the total tariff increased approximately 20% until 2020. The evolution of the average electricity tariff for German consumers, with a yearly consumption equal to 3500kWh is presented in Fig. 7. In developing countries, such magnitude of increase could lead to a social problem. Thus, the overall benefits shall be analyzed by the legislator before defining the chosen regulation for this incentive.

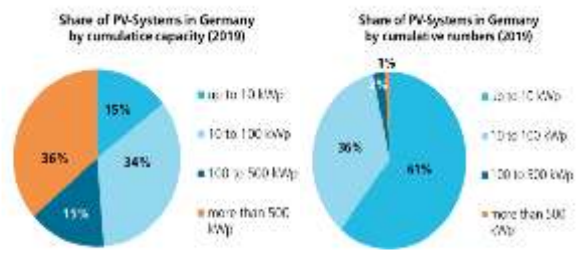

Fig. 6 Share of PV systems in Germany by cumulative capacity and number of systems. Based on the Institute Fraunhofer (2019)

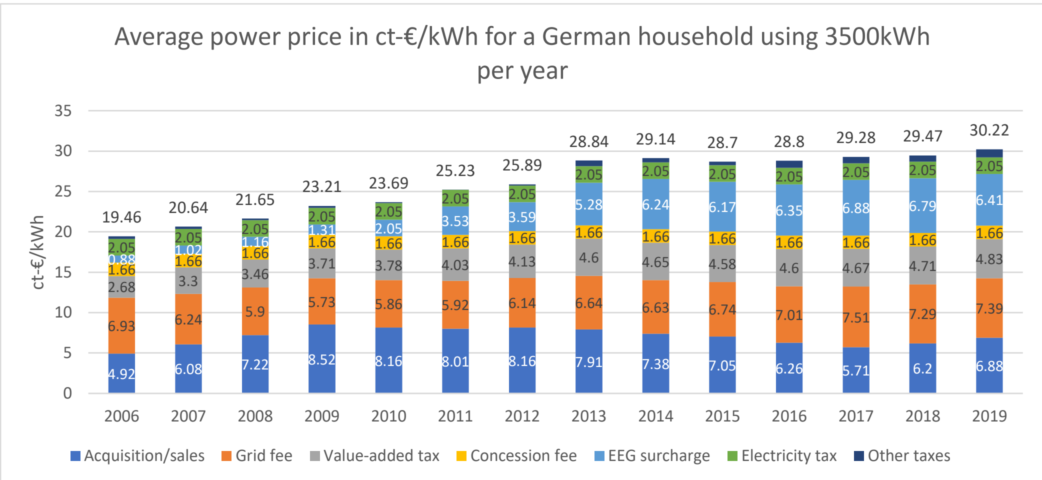

Fig. 7 Composition of average electricity tariff for a Germany consumer of 3500kWh per year. Based on the German Association of Energy and Water Industries (2019).

3.2. Compensation

Net metering and billing scheme encourage the rise of prosumers and distributed generation, as it is applicable specially for small generation plants. Thus, if a country has the interest of expanding the participation of renewable energy in the electrical energy mix, other policies shall be established reaching large-scale power plants.

One state that has established an incentive regulation of net metering since 1996 is the state of California, in a program called Net Energy Metering (NEM).

NEM 1.0 was introduced in 1996 with the objective of encouraging the installation of costumer-sited renewable resources, known by the term distributed energy resources (DER). The scheme net metering with rolling credits was adopted for residential photovoltaic system with less than 10kW of installed capacity, where energy credits were valid for 12 months. In the end of the period, utilities should purchase them at the avoided costs rate or if no credit was left, the prosumer was charged with the standard rate (Camara, 2017). These rules were valid until the amount of energy generated by DER reached a cap of 0.1% of utility's aggregate consumer demand (Aurora Solar Inc., 2017). Many changes in the regulation were performed since 1996 to allow more consumers to become prosumers. These modifications are listed below according to Camara (2017):

- Modifications in 1998 and 2001 allowed a higher number of consumers to become prosumers, including commercial, industrial, and agricultural sectors and enabled installations with installed capacity up to 1MW to integrate the NEM.

- In 1998, the obligation of utilities to pay the excess generation was extinct, however in the contract between the consumer and utility, a tariff could be agreed between both parts. In 2009, the payment of the excess of generated energy was re-established, being paid the value equal to the 12 months electricity retail rate moving average and the credits could be rolled for more 12 months.

- Finally, in 2013, the system level capacity cap was increased to 5% of the utilities aggregate peak demand and utilities could charge a monthly fee for the prosumers.

In 2016, by the approximation of the established cap, it was decided to revise the NEM program, creating NEM 2.0. NEM 2.0 was written based on the experience with the NEM 1.0. Overall, the highest problem observed was the electricity rate shift from the prosumers to the default customers. This happens because the prosumers stop paying or pay less fixed costs for transmission and distribution systems, and these costs are transferred to the default customer. It was estimated that the regular customers had an increase in their bills of $65 yearly and the amount tends to surge as the number of prosumers continues to grow. This occurs mostly in the residential market, where 98% of the installations of new PV system occurred in 2019 (Petek, 2020).

NEM 2.0 defined that the new prosumers would have to pay a fixed interconnection fee, in the moment of the installation of DER (around $75 to $150); prosumers would pay a non-bypassable charge, which is approximately 3 cents per kWh consumed from the grid, independent from the energy exported to the grid; prosumers would be automatically enrolled in the Time of Use (TOU) pricing, aiming the reduction of the income of prosumers during off-peak hours (Camara, 2017) (Petek,, 2020).

Fig. 8 presents the amount of new installations supported by NEM 1.0 and 2.0 and the cumulative capacity. After 2009, the number of new installations grew rapidly, considering the definition of the mandatory payment for excess energy and fiscal policies adopted in California. It is possible to highlight 2014 and 2015 with the highest increase in the number of systems.

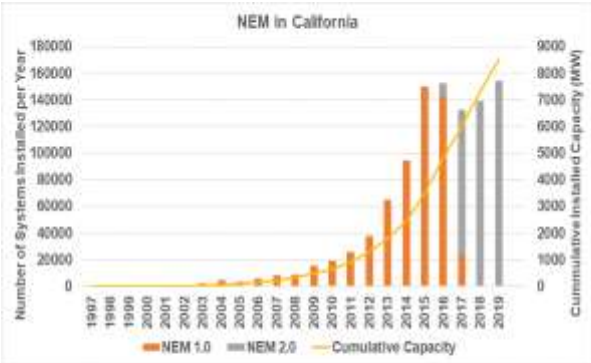

Fig. 8:Systems installed yearly using NEM 1.0 and 2.0. Based on Itron (2020).

Another cause of this rise is the increase in the price of electricity, depicted in Fig. 9. Especially after 2014, the electricity price took a rise tendency, being one of these factors the fixed cost shift to the regular consumer.

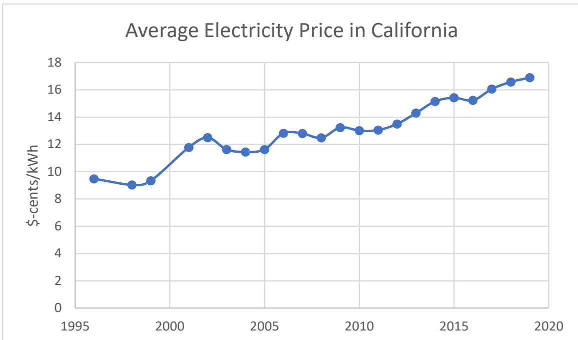

Fig. 9:Electricity price in California from 1996 to 2019 Based on (United States Energy Information Agency, 2020).

3.3. RPS and RECs

As explained in the previous section, RPS impose utilities to source a certain amount of energy from renewable sources. This strategy does not require financial investment from the government and is characterized as a market-oriented strategy. This encourages competition to develop renewable technologies, as in this case the utilities will prefer to buy energy or RECs from cheaper electrical sources.

States in the USA were ones of the first to implement such policies in their territories. The first state was Iowa in 1983, and after the publication of California's intended policies related to renewable sources in 1995, the number of states with such regulations increased (Wyser et al, 2007). Currently 29 states plus the District of Columbia impose mandatory RPS and another 8 states allow voluntary RPS. From these states, five have already reached their goals for 2020 and the remaining have goals until 2040/2045 (Zhou & Solomon, 2020). These goals can be changed through the years, with the intentions to expand or strengthen them, or they can be changed to incentivize a specific electrical energy resource.

During the 00's, the USA have seen an increase in the capacity of non-hydro renewable electrical generation. RPS established a total of 168TWh increase from 2000-2018, however the total amount rose by 371TWh in the period. A relationship between the technology development and the RPS is stated, being the reduction of costs seen as one of the factors of the growth of the participation of renewable generation apart from the goals established in the RPS. Along with the reduction of the costs are other policies implemented by the states and voluntary green power markets (Barbose, 2019).

Fig. 10 presents the annual addition of renewable capacity in the USA. It is possible to see, that the percentage of renewable energy generation installed as established in RPS reduced along the last years. Since 2014, the participation of non-RPS in RES installation was over 50%, reaching the smallest number of 30% in 2018. The evolution of technologies and their consequent reduction of prices makes their voluntary installation attractive for investors.

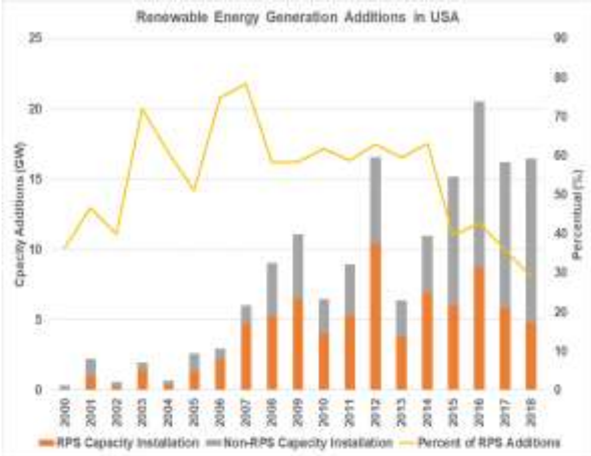

Fig. 10:Annual renewable capacity additions in the USA. Based on (Barbose, 2019)

Finally, the advantages seen for the RPS regulation is the market-oriented policy enabling scale economy; the control of the expansion in the beginning of the cycle; RPS can be applied in a monopoly or open electricity market; contracts concern only energy producers and utilities. Additionally, international initiatives are created to allow the trade of certificates outside the own country's territory, by using International RECs (I-RECs). These initiatives tend to integrate the world in the same goal and to benefit countries with a green electrical energy generation mix. These standardized certificates are traded in North America, Europe, Latin America, Asia, Africa, Middle East and Latin America (Brazil) (Jensen, 2020).

The disadvantages are its complexity to be implemented; investors shall have long-term investment return insurance; it may not support the diversity of renewable sources if the state promulgator does not mandate it and may only support large power plants (higher than 1 MW) (Wiser, Porter & Grace, 2005). In a first moment the cheapest electrical source will be preferred over others, however with their technology development and consequent cost reduction, these other sources start to be incorporated in the electrical power generation mix. This happened in the USA, where in the first years the wind electrical generation was preferred, however in the coming years the solar PV plants started to be used and represented a greater capacity addition.

3.4. Tendering

Tendering regulation is a market-based mechanism, based on competitive auctions in the scope of utility-scale renewable energy development. It allows governments to concede the electrical energy production to third-parties for a certain period, with the winner being the lowest price bid, thus enabling the consumers to pay less for electricity.

Tendering processes are currently used in many countries, and the case of Brazil is discussed. In 2002, after the energy crisis lived in previous years, the Brazilian government introduced competitive auctions for generation procurement. Among others, the reform determined a comprehensive auction system.

The organizations, who actuates in auctions are the Ministry of Energy and Mines, responsible to define technical requirements and general conditions at a high level of planning; the National Agency of Electrical Energy (from the Portuguese *Agência Nacional de Energia Elétrica*) is the regulator of the auctions, coordinating the auction documents; after submission of specifications of the developers, the Company of Energy Research (from the Portuguese *Empresa de Pesquisa Energética* - EPE) evaluates the proposals and technical certifications; the MME endorses the EPE's analysis and the Chamber of Commercialization of Electric Energy (from Portuguese *Câmara de Comercialização de Energia Elétrica*) operates the auction via an electronic platform.

In the Brazilian model, bidders must demonstrate preliminary grid access, environmental permitting and impact assessment, land use rights, and financial qualifications.

The total volume of auctions is defined based on the load forecasted by distribution companies. In reserve auctions, which have the objective to increase the electric system's reserve margin, the government through CCEE decides the auctioned volume and by consequence a reserve energy charge is to consumers connected in the grid. These auctions do not require FECs.

The auction volume is determined in two ways for renewable energy auctions. The first one is a demand function, regulating total offered volume to ensure a suitable supply-demand ratio. In this case, the auction's supply shall be equal to the total offered total volume times the demand function determined by the auctioneer. The second method divides total volume to different renewable sources, according to the proportion of bids from each technology type. For solar and biomass, it is also defined a maximum share that these technologies can represented in the auction (Hochberg & Poudineh, 2018).

The bid format consists of a two-phase hybrid auction design. In the preliminary phase, bidders submit the amount of electricity they would like to offer at the ceiling price, disclosed ahead of the auction. In phase one, the descending clock method is used, where the auctioneer announces a high price, and the bidders must decide if they will supply the quantity presented in the preliminary phase with the price. In the following rounds, the price continues to decrease. The phase ends when the offered energy exceeds the auctioned demand by a margin. In the second-phase, winners of phase-one bid a final sealed-bid price, that cannot exceed the price established in phase-one and are not allowed to change the amount of energy from the preliminary phase. In this phase, bidders do not know the quantity of surplus demand, being incentivized to lower their bids.

Auction bids for variable energy resources are also subjected to settlement rules due to their variable generation to define their price for evaluation by means of a correction factor (positive or negative). This factor correlates the average spot price profile and the project profile, ensuring that different generation bids are evaluated in the same basis. For predicted future spot prices high, variable energy resources' auction bid receive additional compensation. In the other hand, if the future spot price is low, they are penalized. Anyhow, the remuneration of the plant will be based on its original price bid (International Renewable Energy Agency, 2015).

The winning auction bidders sign contracts with the participating distribution utilities, being the total amount of purchased volume distributed proportionally among them. The winners also have a lead time to finish their projects (normally three of five years). The contracts must be backed by firm energy certificates (FEC), which represent the maximum amount of energy offered by means of contracts, issued to all generators connected to the grid (Hochberg & Poudineh, 2018).

Penalties are applicable when there is a difference of 10 percent between the contracted energy and annual generation or if the average production in 4-year basis are less than the contracted. In these cases, generators shall pay the amount of energy undelivered times the contract price or average spot price. For delay or non-completion, it is considered the same logic from before, but considering that 100% of the energy was not delivered (Hochberg & Poudineh, 2018).

In Brazil, from 2004 to 2017 74 electric generations auctions were held, with 8,700,000 GWh of electric generation and US$ 488 billion in investment. During this time, the renewable electricity price decreased (e.g. the average price of wind generation was 52.62R$/MWh, in comparison to the first value of 150R$/MWh) (International Renewable Energy Agency, 2015).

The tendering mechanism is considered one of the most effective in developing utility-scale electrical sources, as it is a market-oriented tool. Even countries like Germany, whose policies were based on FIT, are changing to the tendering process for large-scale plants, as the electricity price for renewable sources is decreasing.

The main advantages of this method are its flexibility, allowing combinations from single, specific types of technologies and neutral technologies to compete for the tendering; it allows the government to discover the electricity price for each type of technology; it also gives the opportunity to governments to control both price and quantity of capacity inserted in its energy power mix; finally, it is a transparent method with commitment between auctioneer and winner parts.

The disadvantages are that it favors the continuation of the current centralized generation, transmission, and distribution model; it can incur high transaction costs with administrative costs for both auctioneers and bidders; and it can lead to a risk of underbuilding and delays in the process, which can be penalized.

3.5. Fiscal subsidies

Fiscal subsidies may be used along with the other types of incentive regulations, complementing them.

In Brazil, some fiscal measures were taken, e.g. Agreement number 16/2015, in which the states that adhere to it are allowed to concede exemption from taxes incident to electrical energy supplied by the utility to the consumer unit, in the corresponding amount of the electrical energy injected in the electrical grid by this prosumer (Economy Minister of Brazil, 2015). In California, due to the high number of incentive policies, there was the need to reform the tariff system, where the consumers started to pay a fixed tariff per month, even if no energy consumption from the grid was measured; they were also obliged to adhere to time-of-use tariffs, they also pay for a unique tax to connect their DER installation to the grid and additional tariffs based on the electrical consumption from the grid (Camara, 2017). In the case of Spain, in 2012 new taxes were created and imposed to the self-consumed electrical generation of the owner of the installation (this tax was known as the sun tax) (Rickerson et al, 2014).

The USA federal government has been subsiding the payment of DER with the Solar Investment Tax Credit (ITC). Since 2006, the Americans that install PV system in their household, can deduct part of the installation value in federal taxes. Between 2006 and 2019, it was possible to deduct 30% of this value, in 2020 the percentual value declined to 26% and in 2021 it will be equal to 21%, being 2021 the last year of this subsidy (Solar Energy Industries Association, 2020).

Another approach would be the swap of subsidies from fossil fuels to renewable energy sources. This action is suggested for governments by environmentally friendly organizations, as Greenpeace, Go Fossil Free, among others (Hopke & Hestres, 2017). A case of swap of subsidies from fossil fuel to renewable energy is the case of India, even being an emerging economy country. From the fiscal year 2014 to 2017, the support to petroleum products decreased by almost three quarters, while at the same time, the support for renewable energy has increased almost six times (Bridle et al, 2019).

3.6. Summary

Table 1 summarizes the main features of each regulation tool, where the arrows indicate a rise (↑) or a decrease (↓) in the prices and the number of arrows indicate the influence of each regulation tool in the presented parameters.

Table.1: Summary of regulation tools

Regulation Tool	Electricity Price Influence	Technology Price Influence	Size of the plant benefited
FIT	↑↑↑	↓↓	Large and small plants
Compensation Mechanisms	↑↑	↓	Small scale
RPC / REC	↑	↓↓	Large scale
Tendering	↓	↓↓	Large scale
Fiscal	↑	↓	Large and small plants

IV. DISCUSSIONS ABOUT THE FUTURE OF INCENTIVE REGULATIONS

Incentive regulations for renewable electrical sources are tools used by governments to incentive the expansion of renewable sources in their electrical power generation mix. As seen in previous sections, these tools incentive indeed this rise, however it can lead to distortions in the electricity market.

FIT tools are one of the most flexible, as they can be used directly for any technology and for any size of power plants. This tool can lead to the expansion of distributed generation, quick development of technologies and by consequence reduction of their prices. However along with that, there is a rise in the electricity price for the end user, especially during the beginning of the use of new technologies. Thus, this method is applicable for developed countries, which have the goal to change its electricity power mix in short-term.

After the development of technologies and capacity to concur of conventional ones, in the scale of utilities generation, tendering process are the most suited compared to RPS. Both are market-oriented practices, but the auction method enables end users to pay the cheapest value for the electricity price, it also allows the government to control the amount of energy from renewable sources, having more control in this case to establish its electrical energy policy compared to RPS scheme. In the other side, both mechanisms do not favour distributed generation.

To concur with FIT for distributed generation expansion, the government can establish compensation mechanisms, net-metering or net-billing. The regulator has the capability to create a program that does not burden other consumers in the same magnitude as the FIT, as the example of the last regulations from California.

With this basis, it is possible to conclude that currently the most suited regulation tools to incentive renewable sources are tendering process (utility scale) and compensating schemes (distributed generation).

Along with the regulation incentives, some other questions rise, regarding the encouraged RES:

- For how long should they be kept?

The regulation shall be kept until their cost of generation, considering the whole life cycle, is able to compete with the conventional electrical sources.

- What are the impacts of these technologies in short/long term in relation to the traditional electrical energy sources?

In short-term, the high penetration of inverter-based generators affects the quality of energy, even if other regulation imposes features to inverters to emulate conventional generation, thus their response to transients shall be evaluated carefully.

In long term, it could be interesting to expand the use of firm electrical power sources (e.g. nuclear power plants, as they do not pollute the environment for electricity generation), in parallel to variable electrical sources, aiming a certain level of grid stability while techniques of energy storage and demand response become structured and with good value. The literature indicates installed capacity levels of renewable sources from 20% to 30% of the total installed capacity as a physical and economical limit for the penetration of RES (Prado, Filho & Pereira, 2020).

Additionally, the high penetration of RES affects the formation of the electricity price in two ways. Electrical Systems Independent Operators define the spot price based on energy offers per type of electrical energy sources compared to the demand for a future period (normally the day-ahead), being all the available generators equally remunerated. With a higher penetration of renewable energies sources, the spot price of the electrical system tends to reduce, as the electrical energy price for renewable sources is lower compared to traditional sources. The definition of the least cost price is known as Merit Order Effect (MOE). This effect tends to compromise the remuneration of the traditional sources (Prado, Filho & Pereira, 2020). Simultaneously to the reduction of the spot price, a competition between thermal power plants can arise, to allow them to compete with other electrical sources, prioritizing the least capital cost ones. Fig. 11 presents qualitatively the formation of the electricity price with the presence of RES in the electricity generation mix, where each source offers their generation with specific prices and availability, being the y-axis associated to the price, the x-axis with the capacity and the D curve with the demand.

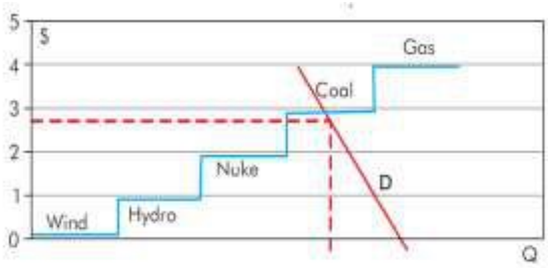

Fig. 11: Formation of marginal cost of operation with the presence of RES (Prado, Filho & Pereira, 2020)

In the case of Germany, the increase in the electricity price (surcharge) was compensated with the reduction of the electricity spot price. However, as presented in section even by reducing the spot price, German residential electricity tariff doubled from 2000 to 2013, what made necessary revisions in the EEG during this period. The rise in the electricity price to compensate the FITs tend to impact more the electricity price.

This increase in the penetration of RES in electrical generation mix worldwide can also lead to negative spot prices, specifically in countries that do not impose limits for spot prices (Prado, Filho & Pereira, 2020). This situation can happen when the demand is low, and the electrical energy offer is high, especially caused by non-dispatchable power plants (RES); low flexibility of traditional electrical power plants to adjust their energy production; obligations associated to ancillaries services; co-generation contracts; and long term contracts with pre-established electricity prices (Prado, 2020). Fig. 12 depicts this situation, in which the market clearing price is established in the point where the power demand curve and the power supply curves meet. These curves are determined by all bids to sell a certain amount of electrical energy (power supply curve) and to buy a certain amount of electrical energy (power demand curve):

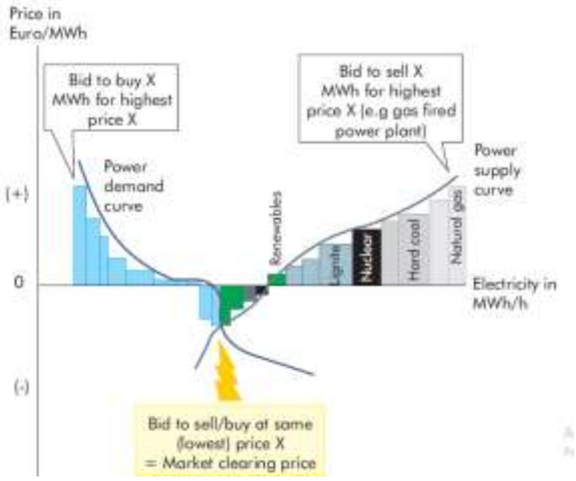

Fig. 12: Formation of marginal cost of operation with the presence of RES (Amelang & Appunn, 2018)

The negative electricity price may not be a problem for generators. In case of incentives like FIT, even if the electricity price becomes negative, the generator shall receive an income, equal to the difference between the FIT and the negative price. Thus, in the case that negative prices are observed, these generators will not stop their energy production.

In countries like Germany, it is expected 1000 hours/year with negative electricity price in 2022. The negative prices are decreasing, from (-) 17.8 Euro/MWh in 2016 to (-) 26.5Euro/MWh in 2018 (Prado, Filho & Pereira, 2020). This fact also affects the energy transactions, where Germany pays more for the importation than for the exportation of electrical energy, reducing the electricity price in other countries.

Another impact of RES in relation to traditional ones is the rise of the stranded costs, associated to investments and changes in the market that impacts the maturity of long-term investments and long-term contracts. This is an argument used against fossil fuel and nuclear divestment or swap of subsidies, which could be the most impacted power plants (Fischer & Baron, 2015). Fossil fuels power plants, specially based on coal, had high fixed costs to be built and to be kept in operation, thus the stranded costs associated to these plants will be the most significant with the decarbonization of the electrical generation mix. In Germany, the most significant stranded costs are associated to the nuclear industry, as they all shall be shut off in German territory by 2022, leading to difficulties to retrieve the investments for the responsible companies (Hammond & Rossi, 2016).

To deal with MOE and stranded costs, it is important that governments respect the contracts signed with traditional electrical sources until its end, creating conditions to deal with the MOE if necessary, and future contracts may include different modalities to deal with MOE

- How are the utilities impacted with the increase of distributed generation?

With the expansion of distributed generation, the utilities income may erode, as prosumers shall consume their own energy, and their distribution systems may become overestimated, leading to tariffs raise. With the rise in the electricity tariff, more consumers may install their own generation devices, leading to the death spiral for utilities (Castaneda et al, 2017). Net metering systems may cause more unbalance to the industry, however along with net-metering systems, tariff restructuration shall be performed to ensure that the consumers do not pay the energy for the prosumers connected to the grid, e.g. prosumers may pay a monthly fee to be connected to the grid, even not consuming electrical energy; prosumers may be obliged to adhere to Time-of-Use tariffs.

- Are the chosen renewable energy technologies with incentives the most suitable for our world?

Variable RES have as characteristic low surface power density (m^2), so, to produce a great amount of energy, a great size of area shall be used. Thus, the expansion of renewable energy sources is limited.

The life-cycle of the renewable technologies (especially wind and solar) shall be evaluated, including what shall be done with them in end of their lives. In this case, a destination for old solar panels and wind blades shall be evaluated by the government along with the producers, avoiding the discard of such components without recycling.

- Are these technologies still going to be socially accepted in the future?

In the short past, high hydroelectrically power plants were acceptable, however their use started to be questioned as their environmental impacts have been experienced. The mentality "green x green" for the current acceptable renewable sources can arise and they can start to be considered aggressive to the environment. For example, impacts in the extraction of kinetic energy from winds could lead to global impacts or even the density of energy is much lower than compared to conventional plants.

V. CONCLUSIONS

Incentive regulations for renewable electrical energy sources have been used all over the world. Different countries have used different mechanisms with distinct results. These results helped to create best practices guidelines for each type of regulation and studies presented their benefits and disadvantages.

For distributed generation, the most suited policies are FIT and compensation schemes. FITs have been used in many countries, highlighting the European experience. This experience has shown that the number of installations and development of renewable sources under this policy rise quickly, however with financial impacts for the remaining end users. Compensation schemes also create financial distortions, however its design can be changed to compensate these distortions.

FITs can also be applied for utility-scale power plants, with the same drawbacks presented for distributed generation. RPS and tendering process allow the government to better control the amount of electricity produced by renewable sources, however RPS frequently lead to the development of the least cost renewable source, what can delay the development of other types. Tendering process has a good approach, as it gives flexibility to the government and also gives to the end users the opportunity to pay cheaper electricity prices.

For future works, the regulation period can be discussed, evaluating the optimal period where their impacts for end users reduces. Additionally, technical solutions for the current chosen renewable sources shall be evaluated, especially for the long-term impacts of their use.

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