The Iberian and Brazilian Power System Sustainability

Ribeiro C. André, MS Student, IST, J.J.E. Santana

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Abstract

The full concept of sustainability in the Iberian electricity sector context, mostly influenced by the European policies and its adopted subsidies mechanisms, depends on the political circumstances on the market design formulation, and its management concerning the subsidized agreements still in force. Over the years, the renewable sources insertion in the energy contractual environments, in which is considered the daily market as the most suitable for sustainability, has affected not only the market price by making it volatile, but also the profitability of the conventional sources and the uncertainty of future investments on the energy sector. Representing the Iberian energy market, the Portuguese power system is the main case study adopted in this paper, in which is analyzed its climate targets and power generation development, mainly supported by the subsidy mechanisms designed to reach environmental objectives, and its political causes that have directly affected the current market design.

For comparison and possible solution purposes, the Brazilian scenario was adopted as the second case study and subject to the same analysis criteria. Thereafter, based on their comparison it was possible to realize that the international environmental targets and the feed-in mechanism European trend have directly influenced both scenarios. Furthermore, since the renewable energy sources have reached a better stage of maturity, their subsequent subsidies handling combined with its energy market-driven design, differentiated the two case studies by making the Brazilian as sustainability benchmark. According to its analysis, the profitability of the plants with different operating costs is assured, and, therefore, sustainable.

***Index Terms*— Daily Market, Feed-in Tariff, Powers System Sustainability, Profitability of plants with distinct operating costs and subsidies histor**

I. Introduction

After the oil crises of the 70s, different countries which had their energy matrix composed of its derivatives, in order to reduce the external dependency and their exposure to future price variations, formulated several private and state initiatives to encourage the energy generation based on alternative sources. Through the following decades, and increasingly stringent environmental policies, these initiatives were directed towards an appealing inclusion of renewable sources, thus reducing the environmental impacts that were previously caused by conventional plants and increasing the sector's energy efficiency [1].

However, the growing inclusion of renewable sources and the recent design elaboration of the European energy market provided a scenario that placed the sector's sustainability and its market competitiveness at risk. At the scope of the study, based on the Iberian energy market, the Portuguese electricity system was adopted as a case study.

Not different from the European context, the Portuguese State also adopted subsidy mechanisms aimed at the inclusion of renewable sources, which allowed to achieve the main environmental objects and targets.

Influenced by the feed-in subsidies model trend adopted by different European Union (EU) members, such as Germany and the Netherlands, the initiative with the greatest impact in Portugal's electricity system is also based on this model, formulated in 1988 and known as Feed-in Tariff (FIT) [2].

Over the years, without significant reductions in its tariffs and the better mature stage reached by the subsidized sources, the market design elaborated by the Iberian Electricity Market (MIBEL) did not provide a sustainable coexistence between the conventional sources and the recently included renewable sources at the energy daily market [3].

In the Brazilian context, although it has also been influenced by the oil crises and has adopted the same feed-in subsidy mechanisms for renewable sources, through the Incentive Program for Alternative Electricity Sources (PROINFA), the political context of its market design, and the government management towards subsidized sources currently in force resulted in a sustainable energy contractual environment [4]. Because of this, the Brazilian tariff system has been suggested as a reference by the researchers in this field, and a possible solution for the Iberian market design.

This paper is organized as follows: In session 2, both case studies will be addressed based on the main perspectives of the economic sustainability, composed of the environmental targets and policies; the development of their energy matrixes; and its energy market context formulation. Once concluded both broad scenarios according to these perspectives as below further clarified, in order to support the researcher's suggestions based on the Brazilian electrical system as a reference, in section 3 their current market design, subsidies further management, and their broad results are compared. The 4th and final session is dedicated to the conclusion, based on the case studies presented and pointed out the events that led the Iberian market to the current impasse, and the Brazilian electricity to the sustainability reference.

A. The environmental targets and policies

The analysis of environmental policies and its objects, in the context of the case studies presented in this paper, was adopted as one of the factors of sustainability because it is based on them that the subsidies to renewable sources are formulated. On those grounds, it is possible to have a better perspective of the guidelines that changed the energy sectors in the past years, and what are the main objectives to date and future expectations.

B. Power generation development

The evolution of energy matrixes and its resultant development based on the subsidies in recent years defined the second sustainability factor addressed in this paper. Following the analysis of the adopted subsidies mechanisms, their results, and their subsequent subsidies management, it is noteworthy the intermittency characteristic that the different renewable sources present and the required compatibility between themselves and the conventional energy sources, through which the supply security is assured. Based on the environmental targets contextualized in the previous factor it is possible to understand the urgent aspect that they presented and better contextualize the impacts that they caused in the energy contractual environment.

C. Energy market formulation

The third and last sustainability factor adopted in this paper addresses the causes and political context analysis that led both case studies to the recent policymaking of their respective energy market designs. Based on this approach, it is possible to establish a full perspective of how the first two factors, environmental goals and the evolution of the energy balance, affected the current energy market and its reliability.

II. CASE STUDIES

A. Portuguese Power System

Representing the Iberian energy market, the first case study adopted in this paper and subject to analysis based on the perspectives described in the introduction, was the Portuguese Electric System. Its power system development was highly politically influenced by the European context, once it formally became a member of the EU, in 1986. Its analysis, however, has as its initial reference the oil shocks from the 70s.

1) Environmental targets and policies

Employed as an economic development indicator, there is a correlation between the evolution of economic activity and the consumption of electricity. Since the first industrial revolution, in the century XVIII, the electricity sector represents a crucial role in the development scenario [5]. Later on, the accelerated economic growth based upon environmental constraint absent, allied to the distribution network development over the years, which no longer conditioned the power producers to the industrial core's spot, created a scenario characterized by reckless electricity generation based on pollutants processes. As result, the required restatement on the environment policies has become evident over the past few decades, and the first international initiative and proper environmental policies at the global context occurred in 1973, through the declaration of the Council of the European Economic Community, where it was prepared the 1st Community Environment Policy Program [6].

In the Portuguese context, the first report on the environment's current status was prepared by the National Board of Scientific and Technological Research (JNICT), in 1969. Afterward, as an EU official member since 1986 and its basic environmental political infrastructures and maintenance funded by them, the directives known as Leis Básicas do Meio Ambiente e das Associações de Defesa do Ambiente were drafted in 1987, which means the first environmental legislative acts. It was a milestone in the Portuguese environmental policies, and through these, the first impact assessments were measured not only based on ecological impacts but also the industrial and urban waste management [7].

As shown in the following figure, between the 1990s and the recent years, the emission of Greenhouse Gas (GHG) has been the main environmental target success indicators, and the Portuguese scenario compared to the European's, has shown proportionally optimistic results.

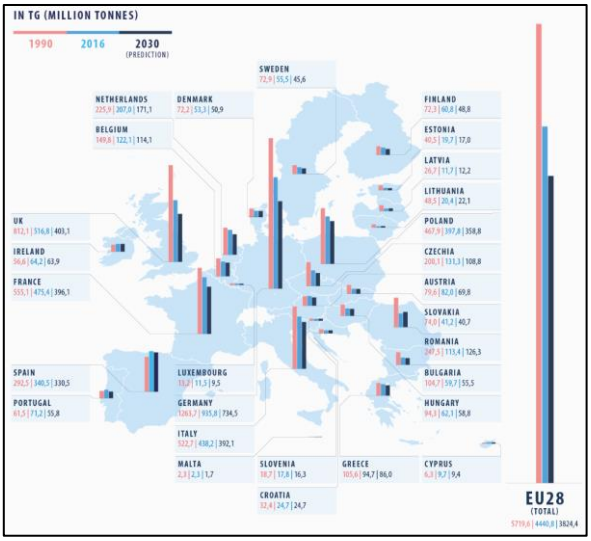

Figure 1 – European GHG emission

From the 1990s onwards, along with the environmental targets previously established, the stricter objectives later established were clearly following the pattern of European policies. The latest environmental targets for the coming years were named in 2008 when the European Parliament approved the environmental initiative known as climate change package 20-20-20. Through this initiative was settled a 20% reduction in GHG emissions, a 20% increase in the share of renewable energy and a 20% energy efficiency improvement. In order to accomplish this, the electricity sector initiatives were designed accordingly and essential over the years [8].

According to the Renewable Energy Association (APREN), these goals were achieved as expected, and their effect on the power system development is better addressed in the following section [9].

2) Power generation development

The changes in the Portuguese electricity sector were more significant since the aforementioned oil shocks. Initially, based on the objectives promoting the oil product replacement, the government encouraged the biggest consumers to switch to the available alternative sources, in 1976. This initiative was based on differentiated prices mainly for biogas and biomass plants. In the same year, the first discussions regarding nuclear technology also emerged. Later on, taking into account conflict numerous protests from the environmental community first and foremost with the Chernobyl accident in 1986, this option was definitely ruled out by the sector [10].

As well as Portugal's entry into the EU community had an impact on the environmental settings since 1986, in the electricity sector it also had a substantial impact at those aimed at enhancing biogas and biomass plants, and at the ensuing initiatives, as the community program, EC VALOREN in 1987. Through this, loan facilities up to 30% of the startup capital, and medium and short-term subsidies were formalized and further alternative sources emerged, such as Mini-Hydroelectric Plants (CMH), which is defined as the hydroelectric plants characterized by an installed power lower than 10MW. Also as a consequence of becoming a member of the EU, influenced by the trend of the model of feed-in subsidies used by the other member countries, in 1988 was elaborated the subsidy policy with a major impact on the renewable sources introducing in the Portuguese energy matrix, known as Feed-in tariff (FIT) [2]. Its main actions were to expedite the licensing process and subsidies of up to 90% of contractual fees. In addition, through this mechanism, the renewable plants installed until 2012 were subsided and there was not a restriction in the energy injected into the grid [11]. On the grounds of a broader perspective, follows the illustrated progress by each technology over the past few years and its greater inclusion in the energy matrix, based on its subsidies and mature stage.

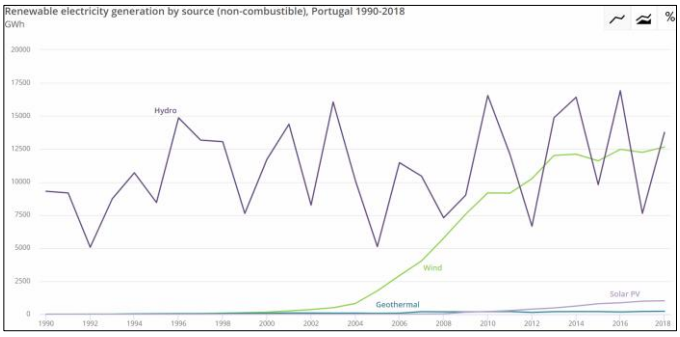

Figure 2 - Renewable sources progress

As illustrated, alternative sources such as wind and solar had a meaningful increase in the energy matrix, since 2002 and 2010 respectively. The electricity sector strategies went beyond the energy supply independence and supply diversity, as stipulated in previous subsidies. From 1990 on, they were focused on the environmental targets, from the first environmental legislative acts, in 1987, to the goals set by the Parliament through the climate change package 20-20-20, in 2008. All in all, according to the Ministry of Industry and Energy (MIE), the sector's intention was “to guarantee energy supply and availability to the country, in the amount required, within price conditions that contribute to the competitiveness of the national economy and with respect for the environmental constraints” [12]. Later on, the energy market liberalization became a priority and its legislation proceedings triggered, as below referred.

3) Energy market formulation

The third determining sustainability factor is the political background behind the energy contractual environment formulation, taking into account the recent renewable sources and its subsidies adjust during different mature phases, and the market-driven conditions for both economies sake - the conventional and renewable sources. In the Portuguese case study, its recent market formulation was highly politically influenced by the European context and consolidated as it is today, in 2007.

Previously, the electricity sector management in the European Union atmosphere occurred thought the economic accordance between them after the second world war, first approached by the European Economic Community, in 1957. Over the coming years, their individual economic development and its resulting growing electricity demand, aligned with the economic facilities through this community, arose the idea of an energy market based on the same energy policies. Thereat, in 1996 was drawn the Directives 96/92 / EC characterizing the first European initiative toward this purpose [13].

In the Portuguese scenario, due to great external influence and supported by the energy sector's strategies, the Portuguese National Electric System (SEN) was firstly divided into two subsystems, based on the regulated and liberal characteristics. In the following years, according to the EU initiatives and the trend towards the liberalization of the energy market, the liberalized market motion was consolidated in 2003. In this context, due to their geographic positions and electricity sector similarities, a unified energy market between Portugal and Spain came up thought MIBEL design. Henceforth 2001, based on the Collaboration Protocol, its policies discussion and integration processes are characterized by several adjustments and extended approaches [14]. Consolidated in 2007, the current energy market is defined as the following perspective:

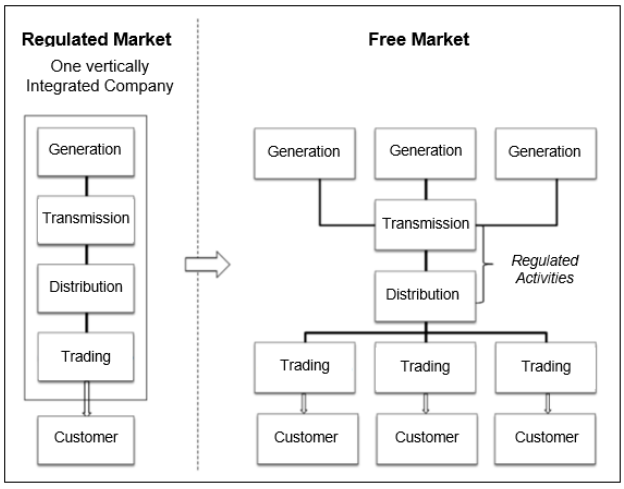

Figure 3 – Portuguese energy market perspective

Composed of conventional and renewable generators, the generation segment consists of Producers under Ordinary Regime (PRO) and Production under Special Regime (PRE), respectively. As the companies dedicated to the commercialization, both producers could also play the trader role in the free energy market. Currently, this represents more than 90% of the transactions carried out in the sector and, therefore, it was adopted for later comparison [11] [3]. The Portuguese regulated market is thought an extinguishing phase and its consumers have their prices established by the Energy Services Regulatory Authority (ERSE).

Regarding the free unified market, MIBEL is under entities regulation from both sides, Portuguese and Spanish, through which its trading prices are established according to the different market functionality managed in this environment. Like in further European electrical systems, the daily market is considered as the most suitable for tariff sustainability and, in the Portuguese context, most of the energy commercialization is formalized through it.

However, the increasing subsidized sources incorporation in the energy matrix revealed that the current market design did not provide sustainable coexistence between the different sources present in it, by turning the prices volatile and generating uncertainty for future investments. [3].

B. Brazilian Power System

The second case study adopted in this paper, and eventual reference solution for the Iberian tariff system, the Brazilian Power System was analyzed in the same way as the first case, according to the established sustainability factors previously taken.

1) Environmental targets and policies

Different from the European scenario, in the Brazilian environment scenario a substantial part of GHG emissions originated from agricultural activities. According to the executive director of the national environmental education, Brazil has had a history of irresponsible extractivism for many years and it does not have optimistic predictions anytime soon [15].

Over the past few decades, a restatement of the environmental policies has also become evident and the first initiative large impact from the Brazilian community occurred in the environmental conference in 1994, in which also EU members were part of it, known as ECO-92. However, in the 1990s the Brazilian political situation was quite unstableand the environmental initiatives until 2012 had no results.

According to the following figure, only from 2014 on its environment initiatives had initial effects, a period in which studies and plans for expansion of the sector, called Energy Research Office (EPE), supported the environmental goals.

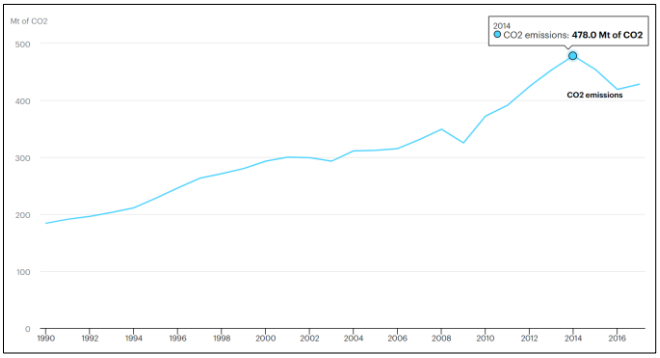

Figure 4 – Brazilian GHC emission

From 2015, aimed at reaching the targets willingly adopted by the Brazilian power system at the conference known as COP-15, its subsidies directed to the alternative sources inclusion and its electricity sector's policies were decisive to increase energy efficiency and the diversity of the matrix, until 2020 [16].

Although the power generation segment is mainly composed of renewable sources, the emission GHG reduction goals did not reveal an expected result nowadays. As recent evidence, based on 2018 records, while the Portuguese scenario should present a 6% decrease in this year characterized by COVID-19, the Brazilian projects an increase of 20%. As a threat to the environmental agreements established until then, this is happening due to the sharp forest deforestation in the current government [17].

2) Power generation development

In Brazilian energy history, oil consumption as a primary source of energy was linked to its economic development since many years ago, not only in the electricity sector but also in the transport industry. As well as the first case study, initiatives to substitute fossil fuels thought alternative sources were triggered also by the oil shocks in the 1970s.

These initiatives were formulated from 1975 onwards and raised significant results not only in the transport industry but also in the power generation, through the development of ethanol-based on cana-de-açucar [18].

In parallel, great hydroelectric plants were also built, as the Itaipu plant, and the national oil company Petrobrás was subjected to a private placement in which the capital was used for oil extraction improvement.

Over the years, the following hydroelectric plant characteristics led the country to invest in further alternative sources: The water reservoirs that great plants imply has a huge environmental impact, raising criticism from the community; And its power generation is conditioned to the rainfall regime [19].

Until the beginning of the '90s, the electricity sector is characterized by early stages of development of the alternative sources and small oil reserves discoveries. However, over that time the Brazilian political context also faced dictatorship issues and successive economic crises, preventing any further financial support on the electrical sector. As a consequence, after the government's restructuring and the sudden energy demand increase, combined with a long drought period that severely reduced water reservoir levels and the responsible entities mishandling, a severe energy crisis occurred in 2001, referred to as national blackouts.

These events triggered different government efforts, such as the entities restatement, and in the following next years, the larger promoting initiative in the Brazilian sector was drafted, known as the Incentive Program for Alternative Sources of Electric Energy (PROINFA).

Like the Portuguese initiative FIT, the PROINFA was also based on the feed-in tariffs mechanism, which has subsidized the energy generation based on long terms contracts. [20].Through this initiative, other sources of energy started to stand out from 2002, as illustrated below.

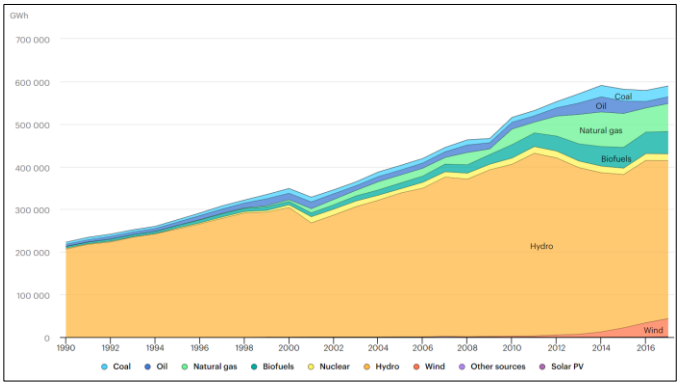

Figure 5 – Brazilian power generation development

The drought periods, in which the hydroelectric reservoirs are at their lowest levels, coincide with the periods of greater winds intensity. For this reason, the wind as an energy source attracted many investors in the years after the crisis, resulting in its greater inclusion in the power generation, as previously illustrated.

As overall results through the PROINFA initiative were formalized subsidy contracts and provided credit lines to new renewable plants installed until 2011 and, through this, the Brazilian energy matrix today is composed of more than 80% of renewable sources [21].

3) Energy market formulation

Initially linked to the activities of hydroelectric power plants, the old sector management model was a state monopoly, characterized by a vertical structure and a unique energy contractual environment, until 1995. Over the last years, the power generation growth based on the greater inclusion of renewable subsided sources drew attention to the need for old model restatement. The first approach in this context was triggered only after the energy crises of 2001, by creating new entities responsible for the expansion of the sector and greater contracting environment control, as follows [22].

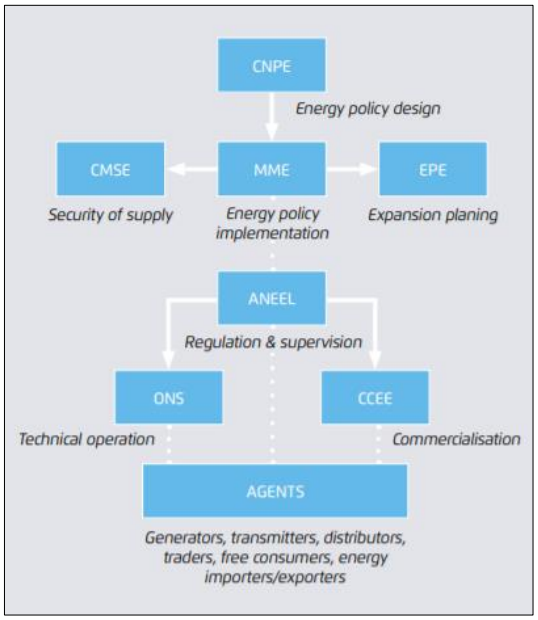

Figure 6 - Brazilian power system entities

The power system restatement and its market design were established by the New Industry Law, formalized in 2004, which is regulated by autarchic entities (state-owned companies independent) and ensures the full unbundling of the sector. Among the entities created in this context, draws particular attention: the EPE, responsible for the sector's expansion plans; the National Electric Energy Agency (ANEEL), as principal regulation and supervision entity; and the Electric Energy Trading Chamber (CCEE), responsible for executing energy auctions and maintains records of all the energy contracts [22].

The electricity is currently commercialized in two separate markets: the regulated electricity market (ACR), in which the generation and distribution agents formalized contracts via government auctions, and the Free market (ACL).

Despite the free-market has been the most adopted as an international trended approach, including in the Portuguese scenario, the regulated market in Brazil represents more than 70% of overall electricity consumption [23].

The ACR is fundamentally characterized by energy auctions and, being one of the first countries to adopt this mechanism on a large scale, it was through this that Brazil became a guaranteed supply reference. Based on the consumption estimation made annually by the distributors, EPE carries out technical studies of the candidate's generators to meet this demand. Afterward, based on these estimations and EPE's analysis, the Ministry for Mines and Energy (MME) formulates the related auction guidelines and thereafter led by the ANEEL entity [22].

One of the main advantages provided by this contractual environment presents is that the auctions guidelines are set according to the sector's expansion plans, and includes contract type offered, contract indexation, and lead time. Meaning, though different guidelines auctions it is possible to split up the energy volumes that are to be contracted between the different generation technologies, even new future power plants [22].

This is one of the main factors that provided the sustainability of the Brazilian tariff system and, therefore, a reference.

III. Case Studies Results and Comparison

By performing both case studies analysis based on the main sustainability factors, stands out the relation between them, and their effects on the energy contractual environment. Even contextualized by different political events and geographically located in different contexts, the environmental objectives and the subsidy mechanisms adopted in both case studies are quite similar.

Regarding the first approach, the Brazilian environmental condition differs from the Portuguese, by presenting critical results. Its GHG emissions remain a challenge for its own government and future environmental conferences [17]. Regarding the subsidies aimed at renewable sources inclusion, its main mechanism most widely used in both case studies was based on feed-in tariffs.

As previously mentioned, thought long-term contracts this mechanism offers fixed subsidies based on the energy generation to the renewable energy producers. At the same time that these mechanisms brought a quick result in both scenarios, they were also the subject of criticism for bringing disadvantages in the current market design, by making them unstable. [3]

For comparison purposes, follows the ideal approach based on alternative sources that have different mature phases. Until it reaches a sustainable stage at the energy matrix, the subsidies must be adjusted according to its different consolidation phases.

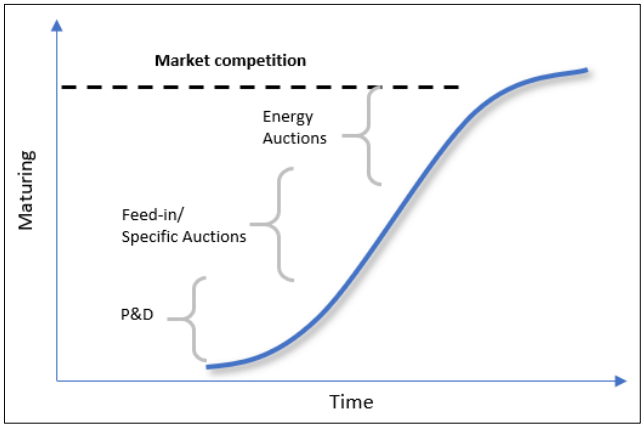

Figure 7 - Subsidy development model

In the first introduction phase, when the candidate technology is completely undeveloped, as the first approach the sector invests in Research and Development (R&D). Subsequently, characterized by its high initial capital and uncertainty revenue, the alternative source under development still depends on the feed-in mechanism or exclusive auctions. In the third and final phase, through general energy auctions, its consolidation stage allows a natural competition between further alternative sources [24].

While other countries that have adopted the same feed-in mechanism, such as Germany and the Netherlands, through market-oriented fee reduction mechanisms, Portugal currently face difficult sustainability circumstances, overburdened by subsidized renewable generators. Over the years, without significant subsidies reductions, and further consolidation phases reached by the renewable technologies provided a scenario in which subsidized generators could offer their energy production at very low prices [3].

As shown in the following figure, the impact of their inclusion in the daily energy market made their prices highly volatile, compromising the profitability of other conventional sources and becoming unattractive to new investments.

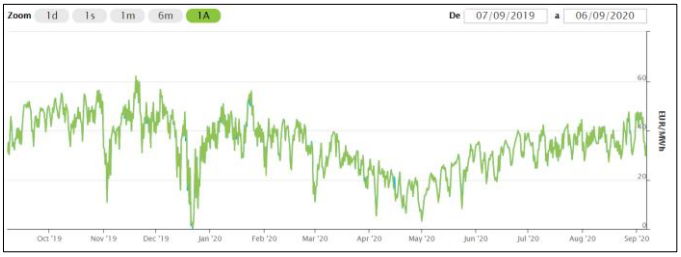

Figure 8 – Daily Market variations

In the Brazilian scenario, besides to annually adjust the subsidy rates based on the PROINFA contracts still in force, its energy production is exclusively commercialized in the regulated market, which its prices are established by the ANEEL entity so as to prevent any impact on the profitability of the other [25]. In addition, the political context of the current energy market design and its auctions dynamics have been effective in promoting the expansion of Brazil's power generation capacity with new investments.

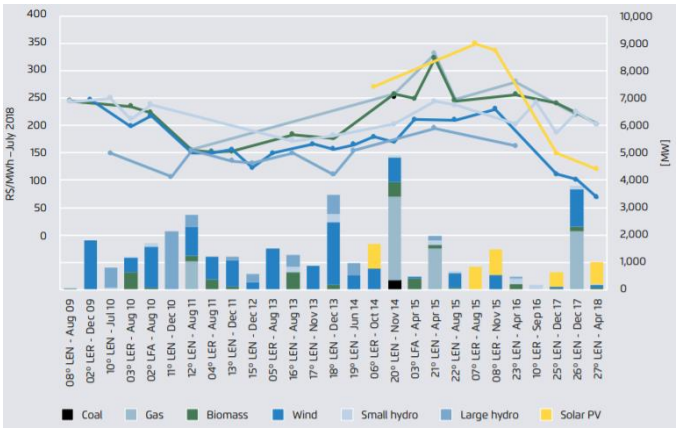

Figure 9 -Average auctions by energy source in auctions

As illustrated, the prices established in the energy market are set according to specific guidelines auctions, and to different technologies. Because of that, this mechanism allows the coexistence and profitability of projects with different operating costs [23].

In summary, the government adjustment approach feed-in tariff still in force aligned with the flexible role that the auctions play, made the Brazilian tariff system sustainable, and, thus, a reference to the Portuguese tariff system impasse.

IV. Conclusions

The sustainability partition approach adopted in this paper, based on the environmental targets and policies, the power generation development of different sources, and the market design political context analysis, provided a broader perspective of both sustainability scenarios and its well-founded comparison.

Regarding the analysis of the environmental targets in both cases, it was possible to contemplate the main initiatives strategies, and expectations aimed at power generation restatement. Initially characterized by small initiatives, they gradually became more stringent after the 1990s.

The power generation development and its main subsidies mechanisms define the second perspective addressed in the paper. In both cases, the first initiatives were triggered by the oil crisis, based on their power generation's current composition and their individual potential energy source.

In the Portuguese scenario, a decisive milestone for a substantial financing increasing of its subsidies, also for the feed-in tariff formulation, occurred when it became a EU member, in 1986. Although the Brazilian electricity sector adopted the same feed-in mechanisms through PROINFA many years after, in 2002, its political context is characterized by a post-economic crisis. In this context, along with the consequent energy crises in 2001, new entities responsible for the sector's expansion plans were created and, later on, all the market design. These events define the third sustainability facto - The main guidelines and the political context of the current energy market design, considering the subsidy mechanisms used in the past few decades.

The main differences between the case studies, and, at last, to provide grounds for the author's suggestion, were: The government adjustments approach, regarding the feed-in tariff still in force, and its individual market strategies; The political-economic causes and context, based on which the current market design were drawn; And the auctions mechanisms presented in the Brazilian sector, through which generators based on different operating costs are subject to prices celebrated through different auctions, resulted in a sustainable and reference tariff system.

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