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Renewable energy sources: from subsidies to market mechanisms.

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Corrected Version

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“Everyone has the right to an ecologically balanced environment, good of people’s common use and essential to a healthy life quality, enforcing the Government and society the duty of defending and preserving it to present and future generations”.

Artigo 225 da Constituição Federal (our translation)

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ABSTRACT

Renewable energy sources (RES) have received subsidies to be introduced in many countries' energy mix. In Brazil, after years of huge subsidies, there are major concerns regarding market reliability and a fair price signal, which must be in line with the global energy transition. In this scenario, RES are fundamental to achieve climate goals. However, they have already achieved technology maturity and are the cheapest new build capacity, so subsidies are no longer necessary to promote their expansion. Mechanisms available such as Renewable Energy Certificates (RECs) are presented in this research as an alternative to replace RES subsidies and to value their attributes. The objective of this thesis is to analyze the impact of renewable sources subsidies on energy tariff and to discuss alternatives to promote these sources sustainable attributes. From a qualitative approach based on international experiences and a case study of one of the largest distribution companies in Brazil, the author concludes that a replacement from subsidies to certificates market may be on the right path to policy makers.

KEYWORDS: Brazilian electricity market; Energy transition; Greenhouse gases emission; Renewable energy certificates; Renewable energy sources; Subsidies.

RESUMO

As Fontes de Energia Renovável (FERs) receberam subsídios para promover sua expansão na matriz energética de muitos países. No Brasil, após anos com valores enormes de subsídios, surgem outras preocupações como confiabilidade do mercado e sinais de preços justos, que devem estar alinhadas à transição energética global. Neste contexto, as FERs são fundamentais para o cumprimento dos compromissos climáticos. Entretanto, elas já atingiram a maturidade tecnológica e são as fontes mais baratas para a introdução de novos projetos de geração, dessa forma os subsídios não são mais necessários para promover a expansão dessas fontes. Outros mecanismos como os Certificados de Energia Renovável (CERs) são apresentados nessa pesquisa como uma alternativa para a substituição dos subsídios destinados às fontes de energia renovável e para valorizar os seus atributos ambientais. Através de uma abordagem qualitativa baseada em experiências internacionais e um estudo de caso de uma das maiores distribuidoras de energia do Brasil, o autor conclui que a substituição dos subsídios para o mercado de certificados pode ser o caminho certo para os formuladores de políticas.

PALAVRAS-CHAVE: Mercado de eletricidade brasileiro; Transição energética; Emissão de gases de efeito estufa; Certificados de energia renovável; Fontes de energia renovável; Subsídios.

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ABREVIATION AND ACRONYMS LIST

ABRADEE	Brazilian acronym of Brazilian Association of Electricity Distributors
AIB	Association of Issuing Bodies
ANEEL	Brazilian acronym of Regulatory Electricity Agency
AR6	Sixth Assessment Report
BNDES	Brazilian acronym of Development National Bank
BT	Low Voltage Consumers
CCEE	Chamber of Commercialization of Electric Power
CDE	*Brazilian acronym of* Energy Development Account
CDM	Clean Development Mechanism
CER	Certified Emission Reductions
CfD	Contract for Difference
CMA	meeting of the Parties to the Paris Agreement
CO_2	Carbon Dioxide
COP	Conference of Parties
DG	Distributed Generation
EBIT	Earnings before Interest and Taxes
EECS	European Energy Certificate System
EPA	Environmental Protection Agency
EPE	Brazilian acronym of Energy Research Company
ERU	Emission Reduction Units
ESG	Environmental, Social and Corporate Governance
ETS	Emission Trading System
EU	European Union
FIT	Feed-in tariff
GDP	Gross Development Product
GEF	Global Environment Facility
GHG	Greenhouse Gases
GO	Guarantee of Origin
GoB	Government of Brazil

GW	Gigawatt
IBOVESPA	Brazilian acronym of São Paulo's Stock Exchange
IEA	International Energy Agency
IET	International Emissions Trading
IGP-M	Brazilian acronym for General Price Index of the Market
I-REC	International Renewable Energy Certificate
ISE-B3	B3's business sustainability index
JI	Joint Implementation
KPI	Key Performance Indicator
kV	kilovolt
kW	kilowatt
kWh	kilowatt-hour
LC	Low Carbon
LCOE	Levelized Cost of Electricity
LEC	Levy Exemption Certificates
LEED	Leadership in Energy and Environmental Design
LULUCF	Land-use, land-use change and forestry
MCTIC	Brazilian acronym of Ministry of Science, Technology, Innovation and Communication
MMA	Brazilian acronym of Environment Ministry
MMDG	Micro or Mini Distributes Generation
$MtCO_2$	Million tons of Carbon Dioxide
MW	Megawatt
MWh	Megawatt-hour
NDC	National Determined Contribution
NIS	National Interconnected System
OECD	Organization for Economic Co-operation and Development
ONS	Brazilian acronym for Electric System National Operator
PDE	Brazilian acronym for the Ten-Year Energy Plan
PV	Photovoltaic

PROINFA	Brazilian acronym for Program of Incentive to Electricity Alternative Sources
RE100	100% Renewable Energy
RECs	Renewable Energy Certificate
RES	Renewable Energy Sources
ROC	Renewable Obligation Certificates
ROI	Return on Investment
SINARE	Brazilian acronym of GHG Emission Reduction National System
SDG	Sustainable Development Goals
tCO_2e	Equivalent Carbon Dioxide tons
TE	Brazilian acronym for Electricity Tariff
TUSD	Brazilian acronym for Tariff of Usage of the Distribution System
TV	FIT Time-varying feed-in tariff
US	United States
WB	World Bank
WTO	World Trade Organization
ºC	Celsius Degree

SUMMARY

1 INTRODUCTION

1.1 INITIAL CONSIDERATIONS AND MOTIVATIONS

Brazilian electricity market had two major reforms in the past three decades. As many other countries who started the process of liberalization in the 1990's, Brazilian first reform was done in mid90s, with the main object of liberalizing the market and to promote private investment in a complex sector (DAGLISH et al., 2021). A study from the Organization for Economic Co-operation and Development (OECD) (2005), evaluated the benefits of market liberalization in several regulated sectors and the results demonstrated an annual benefit of 1% to 3% of USA GDP and 2% to 3.5% of European Union GDP associated with markets liberalization (INTERNATIONAL ENERGY AGENCY, 2005).

The second reform was dated from 2004, as consequence of the 20% electricity rationing in 2001-02. Both reforms aimed to attract investments in new capacity to the sector to increase supply security. The former created ANEEL (*Brazilian acronym of Regulatory Electricity Agency*) and ONS (*Brazilian acronym for Electric System National Operator*), and the latter CCEE *(Brazilian acronym of Chamber of Commercialization of Electric Power),* and EPE (*Brazilian acronym for* Energy Research Office), and also introduced a centralized forward market for utilities by procurement long-term electricity auctions to attend their demand.

Daglish et al. (2021) concluded that this movement added more volatile prices to regulated contracting environment and prices in periods of crises higher than pre-reform period. Thus, it is better for consumers a market-based system, without a centralized figure, in order to mitigate long term periods of volatility and prices increase.

Arguments pro the centralized auction model point out that in terms of tariff accessibility, it is considered the lowest cost. The model is used to purchase electricity to attend distributors' consumers, and it reduces the costs of electricity that are passed on to consumers (FERREIRA; OLIVEIRA; SOUZA, 2015).

However, since 2017, a third reform attempt, called by the Government of Brazil (GoB) as the electricity sector modernization has been under discussion. There are big concerns that led to these improvements needs, such as market reliability and fair price signal (MME, 2017).

This decision follows best practices of international cooperation efforts towards a clean energy future, whose first multilateral agreement regarding GHG reduction was the Kyoto Protocol, signed in 1997 during the year of Conference of Parties (COP). In this agreement, mandatory rules to reduce CO_2 emissions were established for each country member who had signed the protocol. Goals were settled considering each country development level, where developed countries, listed on the Annex I of the Protocol, had mandatory goals established in average of 6% reduction based on 1990's GHG emissions level, to be achieved between 2008 and 2012. The goal was different for each country (KURIYAMA; ABE, 2018; UNFCCC, 1998). The development countries had no mandatory reduction goal, therefore, if they could reduce emission deliberately, they could trade carbon credits.

Besides, in 2015, a new multilateral agreement was achieved - Paris COP, where it was discussed global warm due to GHG emissions. In this COP, it was agreed that the temperature could not increase more than 2ºC compared to pre-industrial levels. Therefore, the goal evolved from carbon emissions to temperature growth. Hence, it wasn't established countries' individual goals and the certifications became noncompulsory (UNFCCC, 2016).

Brazil had sanctioned the agreement on September 2016, compromising with procedures to reduce GHG emissions. It was defined a National Determined Contribution (NDC) to reduce emissions in 37% up to 2025 and 43% up to 2030, considering 2005 emissions. Thus, emissions cap for these years are 1.300 $MtCO_2$ and 1.200 $MtCO_2$, respectively (RATHMANN et al., 2017). However, regarding only the electricity market, according to the GoB energy long term plan, called Ten Year Energy Plan (PDE 2031 in Brazilian acronym), there is a forecast of an increase of more than 20% in GHG emissions in the production, transformation, and use of energy by the electricity sector (EPE, 2022a).

Brazilian electricity grid is interconnected by a transmission network, which connects all the regions of the country, the National Interconnected System - NIS (ONS, [2022?]). Due to the interconnection, electricity that is injected on network is not traceable, in other words, the generator injects electricity on transmission point, and it is not possible ascertain where it is being consumed. There is a separation between power agreements and operation framework. Moreover, there is a voluntary market of renewable certifications, which may be used to solve the information asymmetry issue in electricity markets, considered market failures (HULSHOF; JEPMA; MULDER, 2019).

Global electricity sector has been pressed to be updated in regulatory, commercial, and operational affairs. This fact is related to electricity industry be conditioned to technological and socio-environmental factors that affect current business models.

In 2020, through the publication of a provisory act, converted into law 14.120, the GoB established a deadline to define guidelines to consider environmental benefits related to low Greenhouse Gases (GHG) emissions in energy sector, towards Paris agreement targets. This mechanism would bring additional revenue to renewable energy generators, besides the Renewable Energy Certificates (RECs) which are already voluntarily traded (MME, 2019; BRASIL, 2020).

Those guidelines were established in decree 11.075, published on May 19th 2022. It defined the procedures to create Climate Change Mitigation Sector Plans and created the GHG Emission Reduction National System (SINARE in Brazilian acronym). The Climate Change Mitigation Sector Plans shall set the goals towards anthropic emissions reduction and GHG removal, with the objective of achieving NDC's target. Those goals must be measurable, checkable, and consider each sector specificity. They will be monitored through the GHG inventory of sectoral agents.

It also defined the Emission Reduction Brazilian Market as an environmental management mechanism to reach emission reduction commitments through the use and transaction of certified credits of emission reduction.

The GHG Emission Reduction National System will be a digital tool operationalized by the Ministry of Environment. It was created with the objective of being a single registration center of GHG emissions, removal, reduction, and compensation and of trading, transferences, transactions and retirement of emission reduction certified credits. The SINARE will also have the mechanism of integration with international regulated markets. Emissions reduction and removal additional to the sector goals will be recognized as certified credits if they meet the System's certification standard.

GoB has been doing many policies and incentives to promote renewable energy in line with global initiatives to mitigate GHG emissions. These actions together with technology progress have made renewable sources increasingly competitive. However, one of the main themes in the modernization of the Brazilian electricity sector has been the reduction of subsidies, since such subsidies are so high that became a burden to consumers and are no longer necessary to promote new renewable power plants as presented by EPE (2021). The third reform attempt begun to put an end date to one of the biggest subsidies (applied on transmission and distribution costs) and a schedule to reduce subsidies to small renewable projects.

Subsidies are used by governments to correct either market failures or to achieve policy goals or social goals. Some examples, it may determine that consumers with low incomes may not pay for electricity; subsidies to emerging technologies, such was wind and solar power in the beginning of the century when they had higher costs than non-renewable sources. This kind of subsidy should be temporary and totally withdrawn as the technology becomes well known and its prices goes down (TAYLOR, 2020).

1.2 OBJECTIVES AND RESEARCH QUESTION

In Brazil, with the Modernization of the Electricity Sector reform attempt, some initial measures were taken, the transmission costs subsidies have already been withdrawn from projects that enter into commercial operation from March 2026 on (Law 14.120/2021), and subsidies to small projects (MMGD) were kept fully for requests made until January 2023 and will last until 2045. Consequently, as there are still significant subsidies, major concerns regarding market reliability and a fair price signal are under discussion yet, which must be in line with global energy transition. Even though these sources do not need subsidies for their economic viability, there is still a public interest in privileging renewable sources, however, by using market mechanisms, such as the trade of clean energy certificates. There is already a voluntary certification market, but it is not mature enough.

All in all, this thesis seeks to answer the following questions: is the replacement of renewable energy subsidies for certificates market a step in the right direction?

The main hypothesis is that subsidies for renewable energy sources (RES) in Brazil have had a high impact on consumers tariff and just one of them, regarding transmission costs, was withdrawn long after they were no longer needed. In 2022 those subsidies reached around USD 1.6 billion. Distribution generation have received USD 0.6 billion in 2022 (ANEEL, [2023]b) . On the other hand, it is necessary to address climate issues on energy market and to spur RES growth to achieve NDCs.

Subsidies for incentivized sources were withdrawn by enactment of law 14.120 in March 2021. However, the law established a deadline of 12 months for new renewable generation projects to keep the benefits for the period of the grant. This deadline caused a race for grants request and by the end of 2022, there was an additional request capacity of 41 GW in grants under the former rules to receive subsidies. This volume of requests used up all the transmission capacity (ONS, 2022). Besides, with this volume of grants, subsidies will increase in next years and will only be completely removed from consumer's tariff by 2050.

Distribution Generation subsidies have also begun to be withdrawn, by the enactment of Law 14.300 in January 2022. This law also gave a deadline of twelve months for new projects to keep receiving subsidies for the period of the grant, so requests made until January 2023. This deadline has also caused a race of project grant requests, with an additional capacity of around 32.3 GW only between October 2022 and January 2023, with an estimative of additional USD 51.2 billion in subsidies (SALOMÂO, 2023). However, even for requests after this period, those generators will have the subsidies withdrawn partially up to 2028. Only after 2029, requests for this kind of project will not receive any subsidy (BRASIL, 2022). Thus, the main objective of this research is to analyze the impact of renewable sources subsidies on electricity tariff and to discuss alternatives to replace them to market mechanisms, because politically it is an arduous task to simply eliminate them, and also because those are preferred sources.

To achieve the main objective, this research has two secondary goals, study subsidies and certificates policies around the world, and study carbon markets and how their experiences can be applied to certificates markets in Brazil.

1.3 METHODS

This thesis aims to study RES Subsidies and Renewable Energy Certificates Markets in Brazil through a theoretical qualitative analysis of international and local indicators, based on a literature review of how those mechanisms were applied around the world. Afterwards, it was studied Brazilian Electricity Market and its regulation used to spur RES in its electricity mix.

Finally, the author presents a case study of the renewable energy subsidies impacts on the tariff of one of the largest distribution companies in Brazil, with the main objective of quantifying the costs that are transferred to consumers, causing an imbalance.

This research uses data and information collected from public reports from sector institutions as the Brazilian Regulatory Agency (*ANEEL in Brazilian acronym*), the Energy Research Office (*EPE* in *Brazilian acronym*)*,* the Ministry of Mine and Energy (*MME* in *Brazilian acronym*), the Chamber of Commercialization of Electric Power (*CCEE in Brazilian acronym*)*,* the Ministry of Science, Technology, Innovation and Communication (*MCTIC in Brazilian acronym*), among others. In addition, this research does a literature review based on articles, books and other studies that addresses this subject.

1.4 DISSERTATION STRUCTURE

This thesis is divided in 7 chapters. Chapter 1 - Introduction, is the introduction of the thesis's theme, explaining the motivations for this research, the objectives and research question and the methods used, finally the thesis structure is presented in this part.

Chapter 2 – "Environmental Agreements and Indicators" presents domestic and global GHG emissions' indicators and the projections for futures years. In this chapter it is presented Brazilian's NDC targets for 2025 and 2030 and the initiatives to achieve these goals. Furthermore, a historic comparison among other markets and Brazil. In this chapter, mandatory and voluntary carbon prices history are studied.

Chapter 3 – “Brazilian Energy Market” presents Brazilian electricity regulatory framework and the free market evolution, the electricity mix advancement and projections, and RES historic prices. This chapter shows that RES became relevant in the Brazilian electricity mix in the past years, and their prices became the cheapest for new-build capacity. Auction data is presented to reveal RES prices progress in Brazil and in the world.

In Chapter 4 – “Analysis of Renewable Energy Subsidies”, international experience for the introduction and the removal of subsidies is presented. In this chapter, initiatives to fund sustainable project are presented, for Brazil and International initiatives. The chapter analyses Brazilian RES subsidies and their regulatory framework. A calculation of the impact of the subsidies from incentivized sources and MMDG on a consumer bill is simulated. In this section, there is a forecast of subsidies considering recent requests.

In Chapter 5 – “Renewable Energy Consumption Verification”, the Renewable Energy Certificates is approached, with mandatory and voluntary markets around the world and in Brazil. There are sections of this chapter that explains why the certificates are used in voluntary markets, such it is Brazil, and some international private initiatives that demands them. The chapter also presents a study that compared companies that use renewable energy in their consumption with their peers that do not claim for RES use.

Chapter 6 – “Incentivized Sources Subsidies Calculation” is a case study of one of the largest distribution companies in Brazil, Enel SP. First, Brazilian tariff’s composition is explained. Then, the chapter presents a calculation of subsidies impact on energy tariff of residential consumers connected to this distribution company network.

Finally, Chapter 7 – “Conclusions” presents final considerations of this thesis and its contribution to the subject of the study.

2 ENVIRONMENTAL AGREEMENTS AND INDICATORS

The objective of this chapter is to collect government indicators for international and Brazilian GHG emissions. Emissions history and projections based on the ten-year energy plan elaborated by EPE are presented. Although national emissions are lower than other countries, Brazil has a plan to mitigate emission and accomplish its NDC, that includes the adoption of a carbon price scenario.

2.1 DOMESTIC MARKET INDICATORS

The project “Options to mitigate greenhouse gases in key-sectors of Brazil”, an initiative from MCTIC, has the objective to promote efforts to mitigate GHG emissions on key economy sectors, such as industry, transports, energy, and others. The initiative is supported by Global Environment Facility (GEF), which provides resources and has a partnership with the United Nations Program for the Environments (MCTI, [20--]).

This project has a methodology to forecast energy consumption up to 2050 and, based on this projection, it is possible to estimate GHG emission in this time frame. This estimative methodology is called bottom-up, where the supply is projected based on demand. Demand is estimated according to each sector projections and their energy intensity. Besides, this model considers political factors, technology changes, GDP, and so on, not only a past continuity. Then, some optimization models are used to project supply at the least cost with those data, considering other factors like GHG emissions reduction (MCTI, [20--]).

This initiative projects three scenarios: reference, low carbon, and low carbon with innovation. For low carbon scenarios (LC), the best available technologies to reduce emissions were considered, and then, different levels of carbon price were adopted: 0, 10, 25, 50 and 100 dollars per equivalent carbon dioxide tons (US$/t$CO_2$e) (RATHMANN et al., 2017).

According to MCTIC, a LC0 scenario (low carbon with carbon price equal to zero) may be used to accomplish NDC’s target for 2025, whose total cost of mitigation measures is reaching USD 1.7 billion. On the other hand, to achieve NDC’s target for 2030, it will be necessary to adopt the LC10 scenario, where mitigation measures should include other sectors, totalizing USD 11.1 billion costs (see table 1). The main mitigation actions are energy efficiency, coal thermal plants replacement to biomass, hydro power plants repowering, the use of energy from solid urban waste and of effluent treatment plants to produce biomethane and electricity, among others (RATHMANN et al., 2017).

Table 1 - CO2 mitigation targets

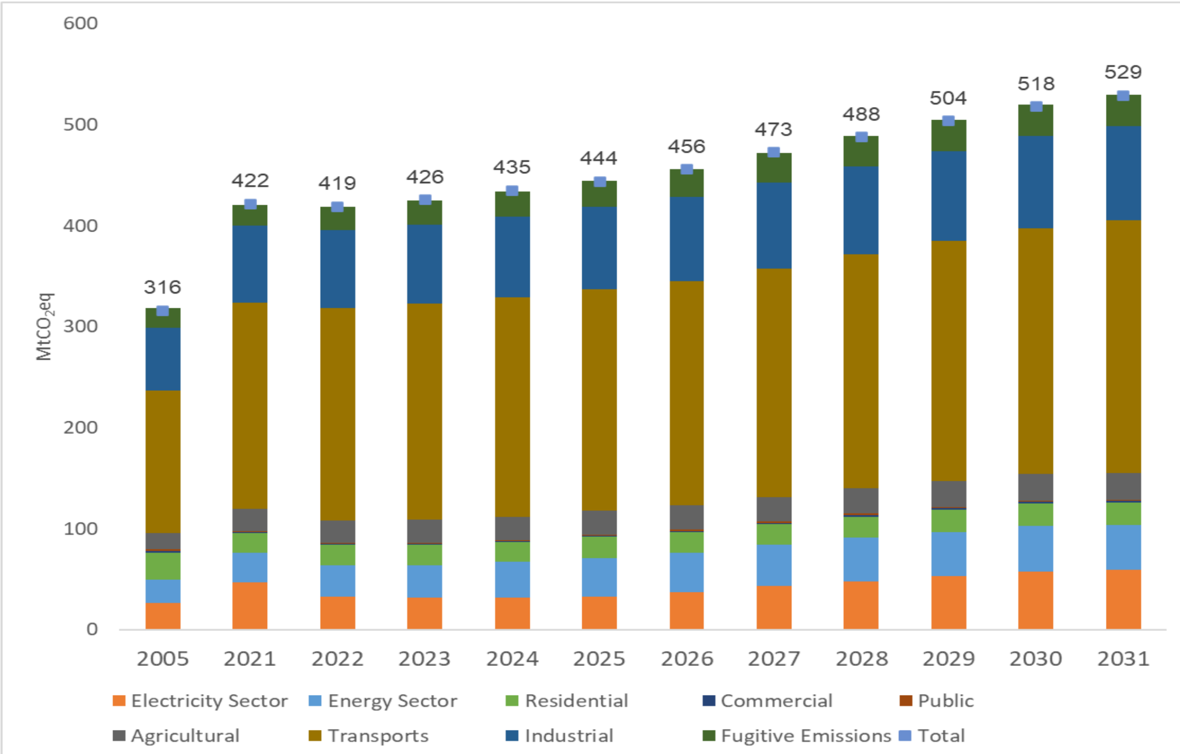
NDC	Target ($MtCO_2$)	Scenario	Carbon Price (USD/tCO_2e)	Mitigation Measures Cost	Mitigation Potential (MtCO2e)
2025	1300	LC0	0	1.7 bi	55.3
2030	1200	LC10	10	11.1 bi	239.8

Source: the author, based on RATHMANN et al. (2017)

Furthermore, according to EPE (2020), CO_2 emissions in Brazilian electricity mix had little change from 2018 to 2019 and there is a tiny reduction in 2020. There is an expectation that there will be an increase close to 22% in the next 10 years (see figures 1 and 2). The share of emissions in each sector is almost the same in the next 10 years. It seems that basically all sectors might be increased by that ratio, and it is important to adopt mitigation measures in all the sectors.

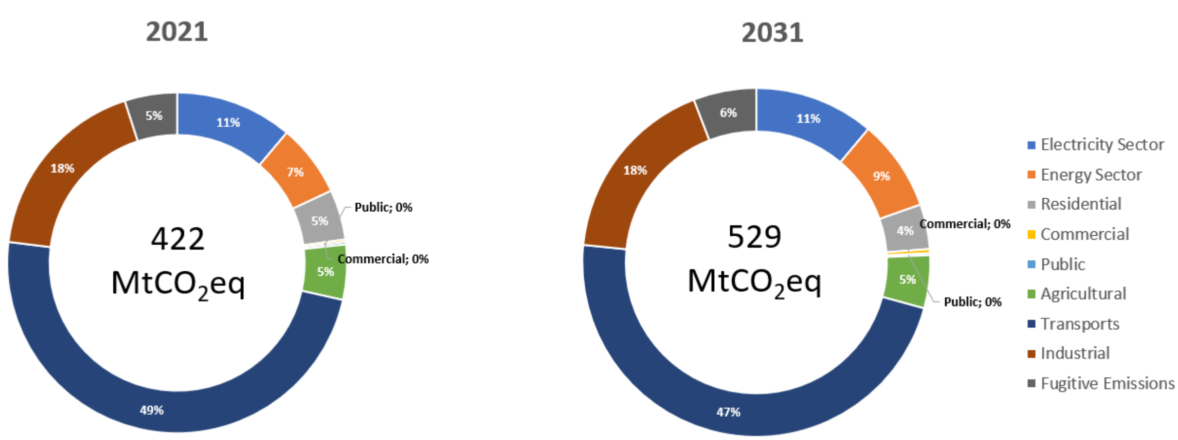
Between 2000 and 2021, average annual ratio of emissions growth was of around 2.1%. The projection for the period between 2021 and 2031 is an increase of 1.7% per year.

Figure 1 - CO2 emissions advancement on Brazilian electricity mix



Source: the author, based on EPE (2021a)

Figure 2 - Progress of sector's share on GHG emission by production and use of energy

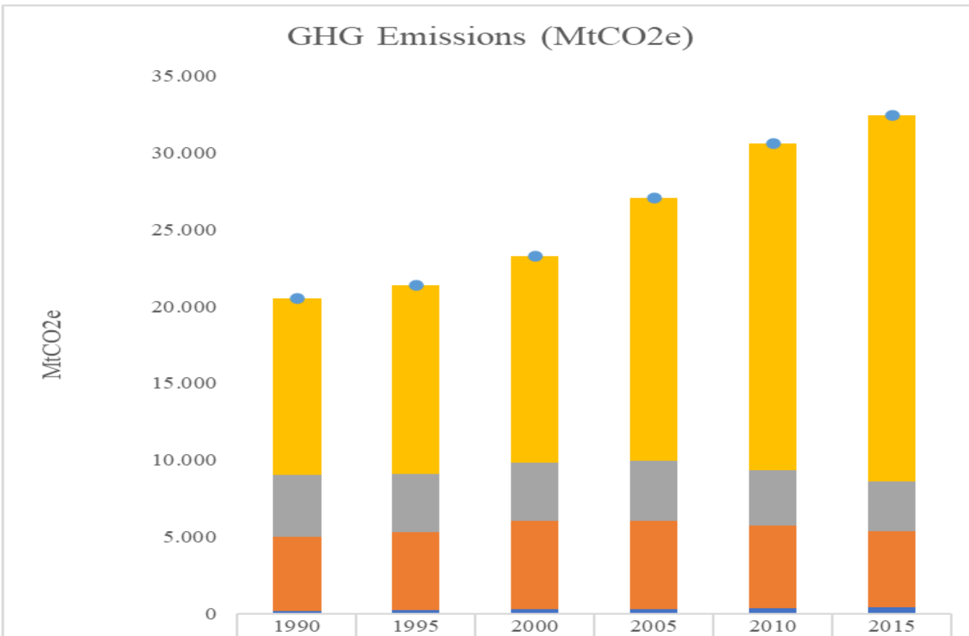


Source: the author, based on EPE (2021a)

2.2 GLOBAL EMISSION INDICATORS

Figure 3 shows GHG emissions progress on energy sector in Brazil, United States, European Union and Worldwide. Global emissions had increased approximately 58% from 1990 to 2015, according to International Energy Agency (IEA, [2021?]). The United States presented emissions growth between 1990 to 2000, then since 2005 emissions level began to fall. On the other hand, European Union countries had a downtrend in most of the analyzed periods, comparing the years of 1990 and 2015, there is a reduction of about 20% on total emissions.

Figure 3 - GHG Emission



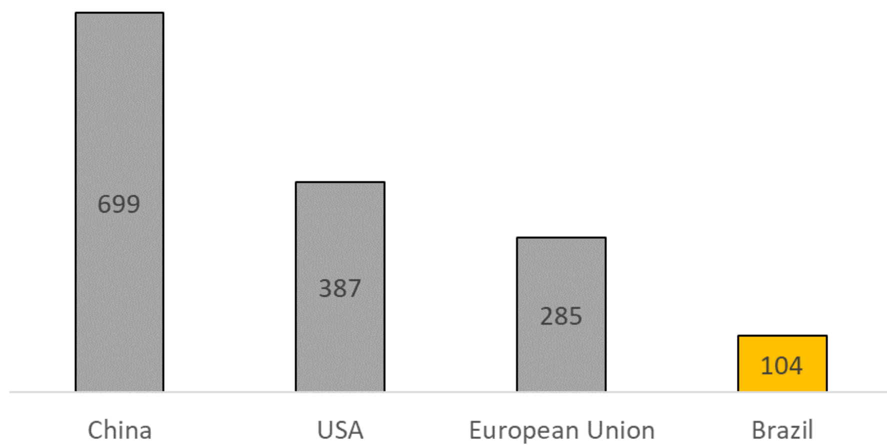
	1990	1995	2000	2005	2010	2015
Others	11.507	12.276	13.439	17.131	21.231	23.837
European Union	4.024	3.812	3.786	3.923	3.613	3.216
USA	4.804	5.074	5.729	5.704	5.352	4.928
Brazil	187	225	286	316	375	449
World	20.522	21.387	23.240	27.074	30.571	32.430

Source: the author, data from EPE (2020); IEA ([2021?]); RATHMANN et al. (2017)

Emissions level per megawatt-hour of generated electricity in Brazil is about seven times lower than in China, four times lower than in United States and a third of European Union’s level (see figure 4). In 2021, Brazilian electricity mix emitted 126 kg CO_2 -eq/MWh. There was an increase compared to previous years because of low reservoirs levels due to drought, so there was more thermoelectric dispatch (EPE, 2022b).

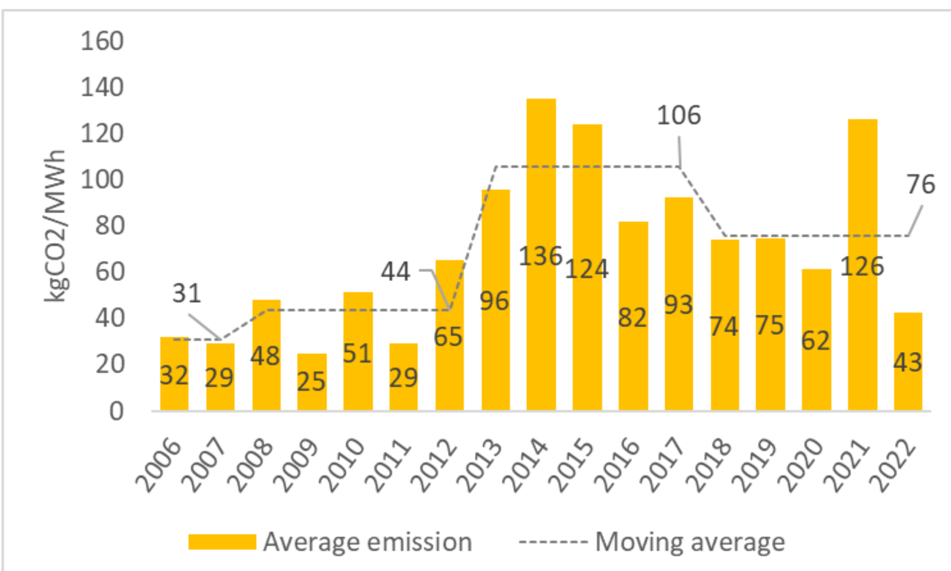
In 2022, due to the increase on RES production, average emissions dropped to 43 kg CO_2 -eq/MWh, which was the lowest in the past ten years (see figure 5) (MCTI, 2023).

Figure 4 - Electricity generation emissions in 2019: kgCO2 emitted per MWh generated



Source: EPE (2022b)

Figure 5 – Emission factor on electricity grid



Source: the author, based on MCTI (2023)

Soares (2020) compared the goals of Renewable Energy share in Brazil with other countries under the Paris Agreement. It was evaluated the share of those sources in each country electricity mix in 2013/2014 and their goals up to 2030. In this analysis, Brazil will still have the share of renewables greater than other countries, except Norway (see table 2).

Soares (2020) suggests that for reaching Brazil's goal of renewable increase in its energy mix, there is a forecast of structural changes on the electricity sector. Although there is no consensus about that, since many authors points that Brazilian energy mix has a high share of renewables already and the increase of renewables will have a low contribution in achieving the targets. However, RES considered variable such as wind power and solar plants will have its share increased, making the system more complex to operate, since they are non-dispatchable. Another issue is the reduction of water reservoirs. These issues will contribute to a more volatile system in the production of electricity.

Table 2 – Goal of Renewable Energy Share on final energy in selected countries

Country	Share in	Goal			
	2013/2014	2020	2030	2040	2050
UE-28	16.0%	20.0%	27%		
Germany	13.8%	18.0%	30%	45%	60%
Brazil	39.4%		45%		
California		33%			
China	11.1%		20%		
Spain	16.2%	20.8%			
Portugal	27.0%	31.0%	40%		
Norway	69.2%	67.2%			

Source: adapted from Soares (2020)

Glasgow Climate Pact reaffirmed the Paris Agreement temperature goal and recognized that to limit temperature increase to less than 1.5ºC, it will be necessary to reduce GHG emissions by 45 per cent by 2030 regarding the 2010 levels and to net zero until 2050. It also demonstrated with serious concerns that the Parties NDCs are implicating in an increase of 13.7 per cent above 2010 levels (see table 3) (UNFCCC, 2022a).

Table 3 – NDC's update

	Estimate in gigatons of carbon dioxide equivalent (Gt CO_2 eq)	Change compared to 2010, on average (%)
Total global GHG emissions (without LULUCF) in 2030	53.8 (50.8-56.9)	+13.7
Total GHG emissions in 2030 for the 151 Parties that communicated new or updated NDCs	40.4 (38.5-42.2)	+5.9
Total GHG emissions in 2030 for the 74 Parties with long-term mitigation visions, strategies, and targets	29.7 (29.0 to 30.4)	-5.2

Source: UNFCCC (2021)

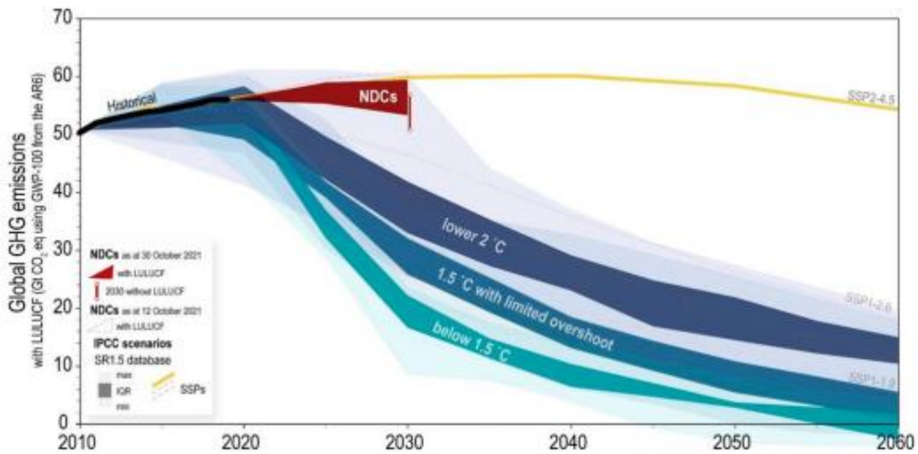
In figure 6, it is possible to understand that current declared NDCs are far from the target of keeping temperature up to 2ºC above pre-industrial level. To reach this goal, GHG emissions should have a steeper drop.

The most recent report from The Intergovernmental Panel on Climate Change (IPCC), the Sixth Assessment Report (AR6) alarms that actions that have been done towards addressing climate change issues and current plans are not enough to avoid temperature growth. Currently, global warming has reached 1.1ºC above pre-industrial levels, considering the usage of fossil fuels, non-renewable energy and land use. The world is experiencing climate disasters as extreme weather events everywhere (IPCC, 2023).

The report highlights that measures to reduce GHG emission need to be accelerated and need to be cut by almost 50% by 2030. Policy makers and private investors must work together to fund low carbon technologies and projects. Although many adaptation measures had been taken, financial flows for them are not enough, mainly in developing countries (IPCC, 2023).

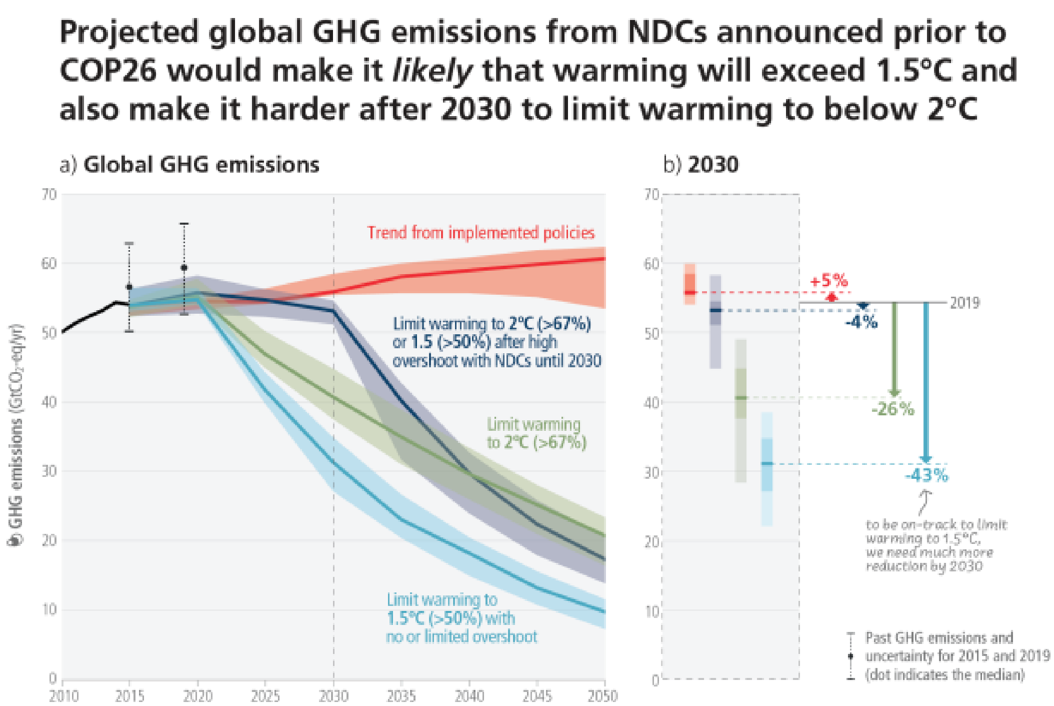
Considering NDCs announced by October 2021, emissions in 2030 will make it difficult to limit global warming under 2ºC. Evaluating the policies to reach the NDCs, there are gaps between them, as demonstrated on figure 7 (IPCC, 2023).

Figure 6 – GHG Emissions Forecast considering NDCs and targets



Source: UNFCCC (2021)

Figure 7 – Global emissions scenarios



Source: IPCC (2023)

2.3 CARBON MARKETS

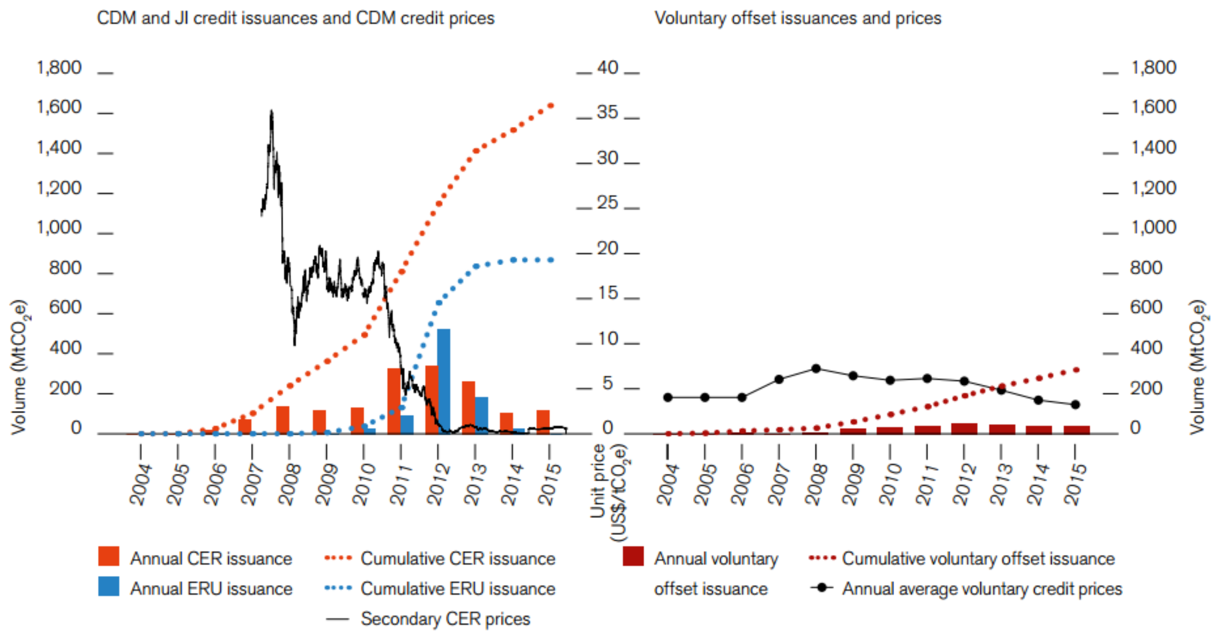
Carbon prices may be used to increase profitability of low carbon projects. They are useful in a scenario whose costs to reduce emissions are positive. When costs to reduce emissions are negative, other policies may be more effective, like reducing information asymmetry and others. An environment with emissions reduction costs is extremally high, carbon prices may be used with other policies. In other words, carbon price is a tool to be used in a wider set of policies (EPE, 2020c).

The Kyoto Protocol was the first global boundary for the creation of carbon markets. Three mechanisms were created so Annex I countries could reach their targets: International Emissions Trading (IET), an Emission Trading System (ETS) that allows emitters to trade their emissions units; Joint Implementation (JI) and Clean Development Mechanism (CDM), offset mechanisms where Annex I Parties could join low-carbon projects and get credits for it, the last one was the most used offset mechanism, with the largest number of countries.

CDM emitted Certified Emission Reductions (CER) and JI Emission Reduction Units (ERU). Peak price of CER was achieved between 2007 and 2008, at USD 35/tCO_2e (figure 8). By 2012, demand for those certificates began to saturate, and prices went significantly down.

It reached USD 90 billion in GHG emission reduction projects in developing countries by 2014. In 2015, Paris Agreement took place with noncompulsory goals. Carbon markets switched from mandatory to voluntary (THE WORLD BANK, [2022?]).

Figure 8 – Carbon offset issuance and prices



Source: The World Bank ([2022?])

On the Paris Agreement, it was established that the Parties, countries who had committed to the Agreement, should take actions to hold global average temperature increase under 2 ºC above pre-industrial levels and to make the best efforts to keep this increase under 1.5 ºC above pre-industrial levels. This is an important target to reduce the risks of the climate change. The Parties should define and communicate their NDC towards this target.

In the Article 6 of the Agreement, it was defined that countries could pursue reductions of GHG emissions more ambitious than what was declared on their NDCs. The countries that can reduce more than their NDC, could voluntarily transfer their mitigation outcomes to other countries, avoiding that the emissions' reductions are double counted on both NDCs. It was also established that the COP should designate a body to supervise this voluntary emissions trading mechanism. This mitigation mechanism should aim the promotion of global emissions mitigation and incentivize the contribution of public and private initiative (UNFCCC, 2016). The first meeting of the Supervisory Body for this mechanism took place on July 2022 in Germany.

The rules, modalities and procedures for this mechanism were adopted in Glasgow, the third session of the meeting of the Parties to the Paris Agreement (CMA). It was defined that companies could trade their emissions' reductions to other companies located in other countries. A company that buys those credits could claim them as their own emission reduction to meet their obligations or to achieve net zero targets (UNFCCC, 2022b).

In 2021, Voluntary Carbon Markets (VCM) have grown faster global wise as they are more aligned with governments and private sector now that the rules of Article 6 of the Paris Agreement have been settled. VCM has achieved the mark of USD 2 billion, with near 500 million credits traded (see figure 9). Besides the number of credits issued, prices also went up from 2020 to 2021, around 60%, which added more value to this market. Figure 10 compares prices from 2020 and 2021 by each category. Global weighted average price went from USD 2.52/tCO2e in 2020 to USD 4.00/tCo2e in 2021. Renewable energy was the second biggest market, with a volume of 211.4 million credits and a value of USD 479.1 million (FOREST TRENDS ASSOCIATION, 2022).

Figure 9 – Voluntary Carbon Market Size by Value of Traded Carbon Credits

Source: Forest Trends Association (2022)

Figure 10 – Voluntary Carbon Market Transaction Volumes, Prices, and Values by Category

	2020			2021		
	VOLUME (MtCO2e)	PRICE (USD)	VALUE (USD)	VOLUME (MtCO2e)	PRICE (USD)	VALUE (USD)
FORESTRY AND LAND USE	57.8M	$5.40	$315.4M	227.7M	$5.80	$1,327.5M
RENEWABLE ENERGY	93.8M	$1.08	$101.5M	211.4M	$2.26	$479.1M
CHEMICAL PROCESSES / INDUSTRIAL MANUFACTURING	1.8M	$2.15	$3.9M	17.3M	$3.12	$53.9M
WASTE DISPOSAL	8.5M	$2.69	$22.8M	11.4M	$3.62	$41.2M
ENERGY EFFICIENCY / FUEL SWTICHING	30.9M	$0.98	$30.4M	10.9M	$1.99	$21.9M
HOUSEHOLD / COMMUNITY DEVICES	8.3M	$4.34	$36.2M	8.0M	$5.36	$43.3M
TRANSPORTATION	1.1M	$0.64	$0.7M	5.4M	$1.16	$6.3M
AGRICULTURE	0.5M	$10.38	$4.7M	1.0M	$8.81	$8.7M

Source: Forest Trends Association (2022)

3 BRAZILIAN ELECTRICITY MARKET

In this chapter, the progression of renewable energy sources in Brazilian electricity mix and the projection of new capacity added for those sources are demonstrated. The main objective is to understand the share of those sources on electricity mix and the importance of them for the future. In section 3.2, historic prices of those sources are analyzed using two methodologies, procurement auction prices and LCOE, a comparison with world data is presented.

3.1 REGULATORY FRAMEWORK

The concept of regulation emerged in Brazil with the state reforms, when state companies began to be privatized. Then, private companies' activity needed to be regulated (LEAL; REGO, 2019).

In the past, it was common that electricity companies have verticalized operations, owing the generation, transmission, and distribution. Those companies were responsible for market growth, since they could attract investments because the risk of investing in them was low, and they could transfer the costs to consumers through regulated tariffs. The tariff increases were approved so that the return-on-investment rate was appealing (IEA, 2016).

Energy markets' liberalization was deployed, or at least considered, in International Energy Agency (IEA) member countries, with the objective of having markets with accessible prices, less environmental impacts and reliable access (IEA, 2017).

The liberalization usually begins with generation and transmission companies, with the main goal of opening completely the market for small business and residential consumers, whose benefits are being able to select their own supplier and to have more flexibility of consumption in peak (BARTON, 2000). To be able of capturing even more benefits, it is necessary to put together technology and consumption. For example, the consumer could turn off some equipment, such as heaters, when prices are higher. Besides, the use of technology makes easier to change suppliers, adding more competitiveness to the market.

The Electricity Free Market in Brazil began with the enacting of Law nº 9,074, from 1995, which authorized free consumers, that fulfilled all the established requirements, to select their own electricity supplier. However, the law remained only on paper until 1999, when the first consumers accessed the free market. Since then, Brazilian electricity sector has been changing to meet the significative market players growth (ROCKMANN, 2019).

During the 1990s, the project of restructuring the Brazilian electricity sector (called RE-SEB in Brazilian acronym) began, aiming to attract private investments so the sector could expand the generation park offer and spur opening the deregulated market to consumers, increasing competitiveness (ROCKMANN, 2019).

With the reform, there was the creation of many institutions. In 1997, the Brazilian Regulatory Agency (ANEEL in Brazilian acronym) was created, whose responsibilities were to regulate and to supervise the generation, transmission, distribution, and commercialization. Moreover, the creation of a regulatory agency was crucial to attract private investments because there was an expectation that it would reduce regulatory risks (PARENTE *et al.*, 2007).

In 1998, Law nº 9,648 established that the sector growth would be borne by private capital, through the auctions. It also created the Electric System National Operator (ONS in Brazilian acronym). It was the milestone of the unbundling process for the activities of generation, transmission, and distribution, ensuring the access to distribution and transmission to players that would choose the free market (ROCKMANN, 2019).

The market should be self-regulated, so the Energy Wholesale Market (MAE in Brazilian acronym) was constituted in 1999, its rules were ratified by ANEEL in 2000 [10]. In 2004, the Chamber of Commercialization of Electric Power (CCEE in Brazilian acronym) was created to replace MAE. In that same year, the Electric Sector Monitoring Committee (CMSE in Brazilian acronym) and the Energy Research Office (EPE in Brazilian acronym) were instituted, the first one is responsible for electricity supply safety, while the second one has the main responsibility of sector long term planning (CCEE, 2020).

3.1.1 Free market evolution

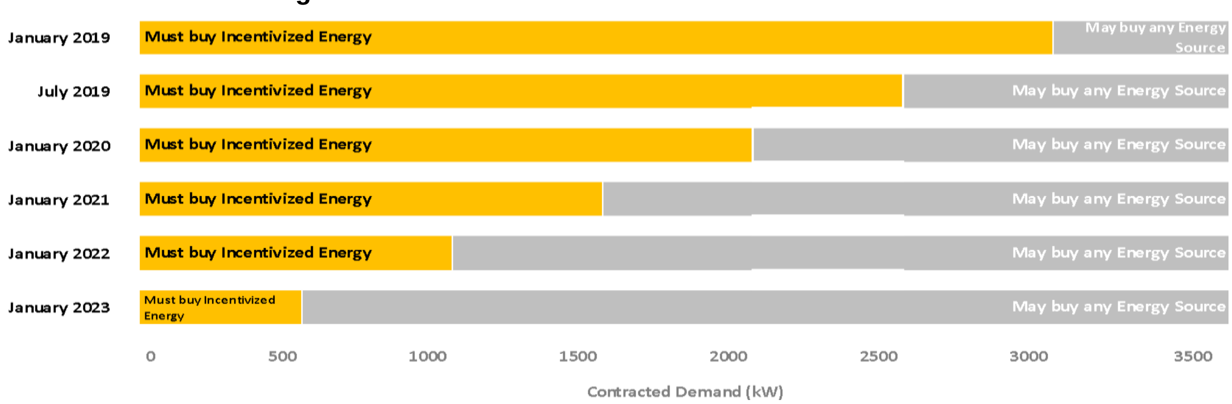
Currently, consumers connected in high voltage may access the free market depending on the contracted demand. That is, they can choose their electricity supplier. These consumers must have more than 500 kW of contracted demand or a group of units from the same economic group or sharing a physical area, whose contracted demand summed is more than 500 kW.

However, there is a group of consumers that must buy electricity from renewable sources to access the free market, so called "incentivized sources" (MME, 2019). This group is defined according to the consumers' demand, and it is defined as those with less than 500 kW of demand.

To spur the deregulated market expansion, it was important to update the rules so that consumers may choose from any generation source, incentivized or conventional, and therefore, to extinguish this obligation (MME, 2017). This subject began to be discussed in a public hearing in 2019, whose proposal were to reduce gradually the contracted demand limits.

This limit has already been changing over the years. Until 2019, consumers with more than 3 MW and voltage above 69kV could choose their supplier of any kind of source. After 2019, the voltage restriction was withdrawn. The demand restriction has been reduced in the past year, as shown in Figure 11 (MME, 2019). The types of electricity and consumers are described on table 4.

Figure 11 – Contracted demand limit reduction schedule



Source: the author, data from MME (2019)

Table 4 – Electricity Products and Consumers

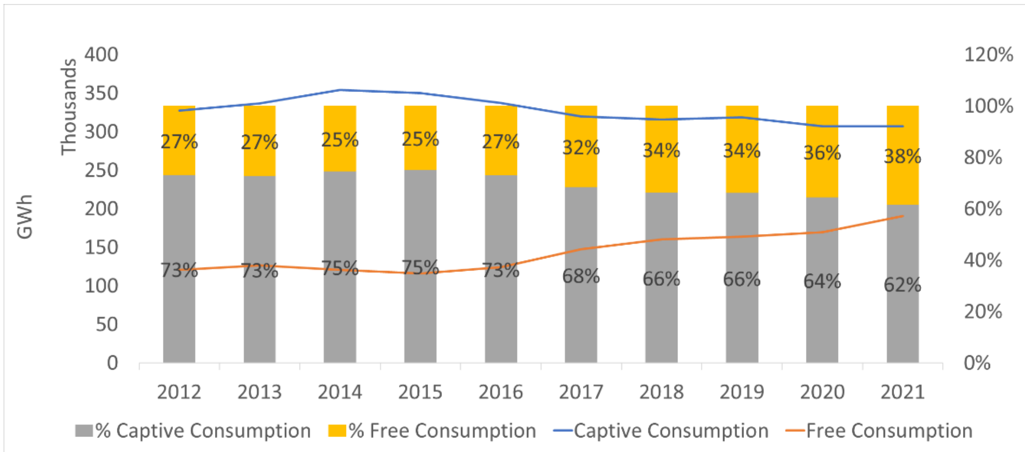
Electricity Products	Description
Not Special Conventional	Only Free Consumers may acquire this kind of electricity and it does not have a discount on transmission or distribution tariff
Special Conventional	All consumers may acquire this type of electricity and it does not have a discount on transmission or distribution tariff
Special Incentivized	All consumers may acquire this type of electricity and it have a discount on transmission or distribution tariff
Not Special Incentivized	Only Free Consumers may acquire this kind of electricity and it have a discount on transmission or distribution tariff

Source: Soares (2020, our translation)

In 2004, the free market had a consumption of 6 GWavg, which at that time represented around 15% of country's total consumption (ROCKMANN, 2019). In 2021, total free market load was around 21.8 GWavg, representing 38% of total country's consumption (figure 12) (EPE, 2022a).

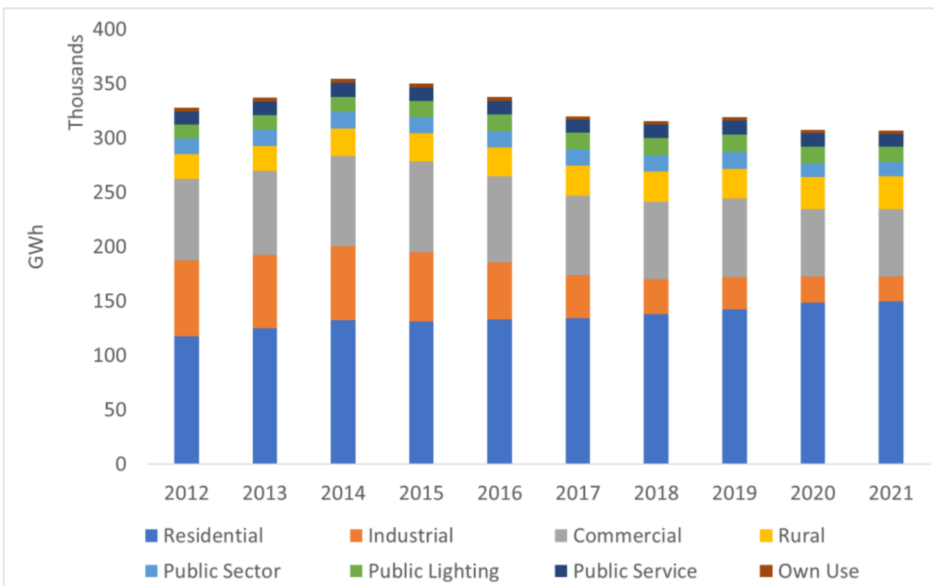
Figure 13 exhibits captive market consumption from 2012 to 2021, indicating a decrease, mainly in the industrial consumption. This decrease is explained by the migration of those consumers to the free market, shown in figure 14. Figure 15 illustrates residential and industrial consumptions share in 2021 in both captive and free market. The residential sector is 100% in the captive market, because regulation does not allow them to access the free market, while industrial consumption is 87% in the free market.

Figure 12 – Captive market and free market consumption



Source: the author, data from EPE (2022a)

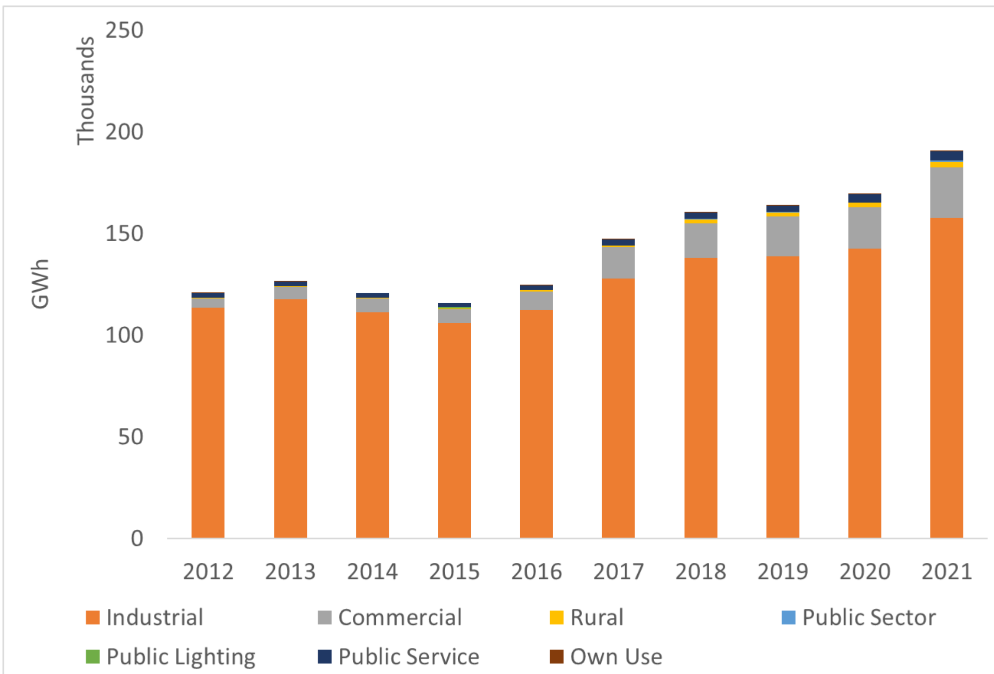
Figure 13 – Captive consumption by sector



Source: the author, data from EPE (2022a)

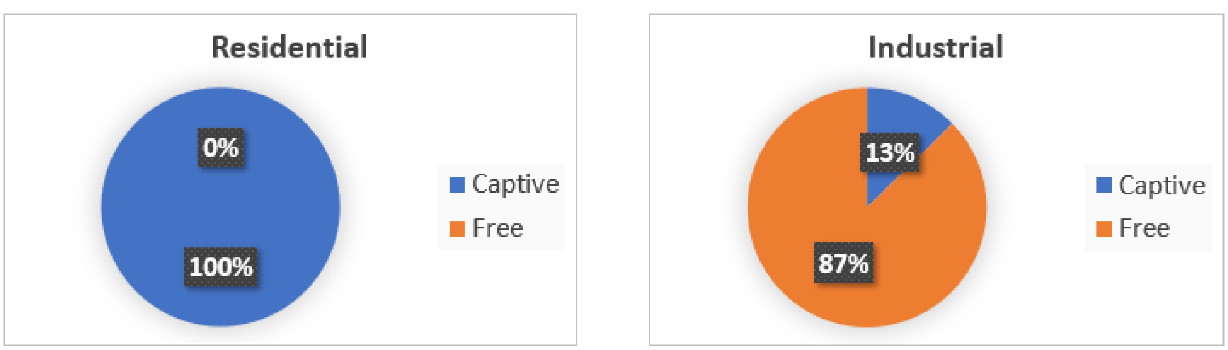
Costs to migrate from the captive market to the free market used to be higher because consumers had to pay for meter installation, which was mandatory to access the free market. In 2016, this obligation was withdrawn, then the free market became more economically appealing (ANEEL, 2015a). Moreover, distribution tariffs were more expensive at that time. Finally, in 2016 prices in the free market were cheaper due to a consumption reduction caused by economic recession and higher reservoir levels. This conjuncture was responsible for a massive migration to the free market, and the number of free consumers increased more than twice compared to the year before (figure 16) (CCEE, 2021).

Figure 14 – Free consumption by sector



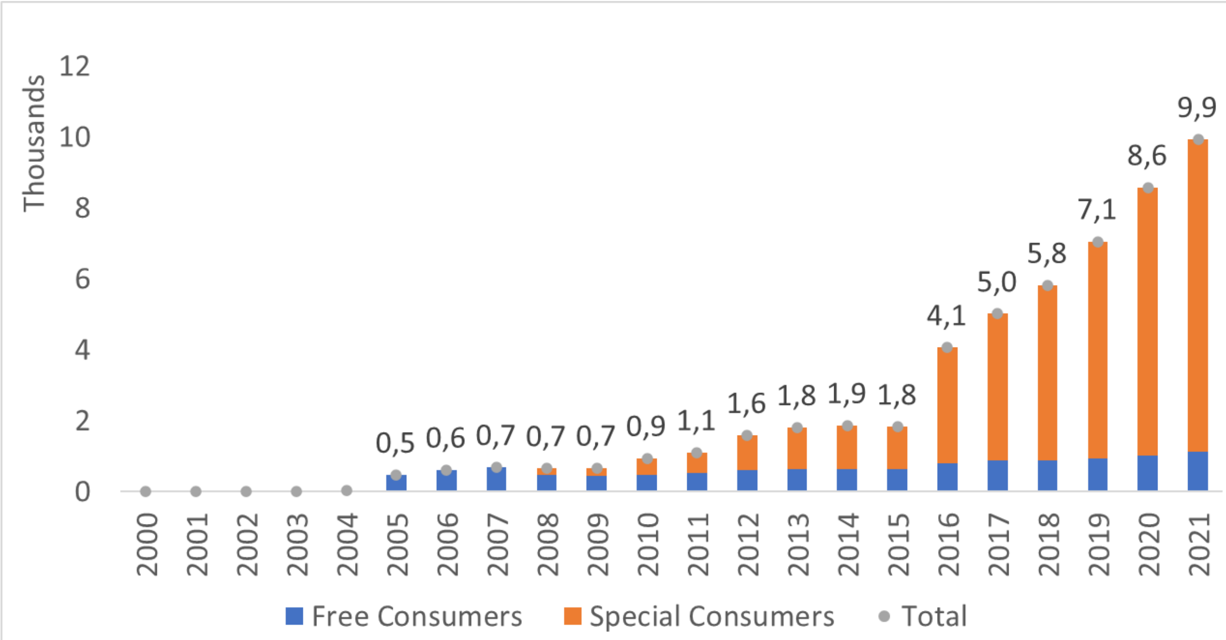
Source: the author, data from EPE (2022a)

Figure 15 – Residential and Industrial Consumption in 2021



Source: the author, data from EPE (2022a)

Figure 16 – Number of consumers at free market



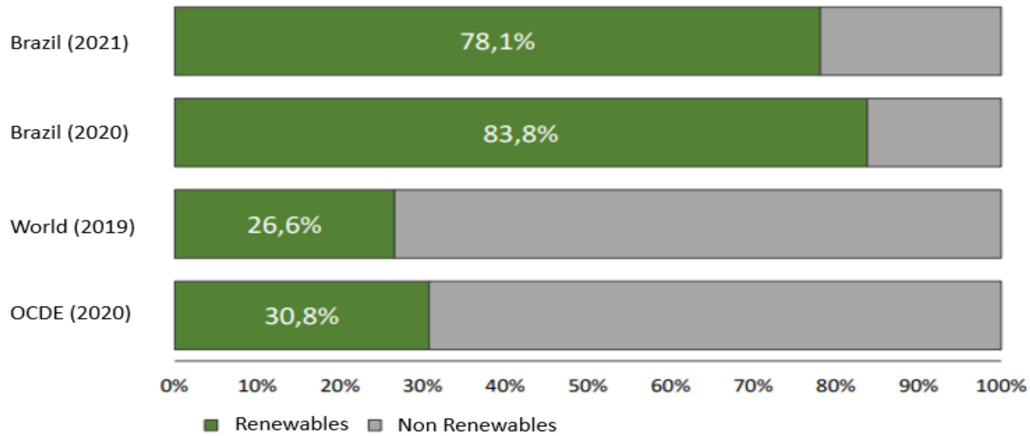
Source: the author, data from CCEE (2021)

3.2 BRAZILIAN ELECTRICITY MIX

Brazilian electricity mix in the 1990's was mainly composed by big hydro power plants with large reservoirs, thermopower plants were responsible for around 10% of the supply, it had just around 2% of biomass and did not have significative share neither of wind power nor solar PV sources (EPE, 2006). Since then, there was an important growth in the share of those renewables. In 2021, the share of wind power, solar and biomass reached 17% of Brazilian total generation (EPE, 2020a).

Furthermore, Brazilian electricity mix has already a high share of renewables, including hydro power plants. In 2021, the share of renewable energy production was 78%, with growth in the wind and hydro power plants (figure 17). There was a reduction compared to 2020 because of the draught, that reduced hydro power generation and increased thermal generation. Worldwide, the share of renewables in 2019 was 26,6% and in OCDE countries it was 30,8%, in 2020.

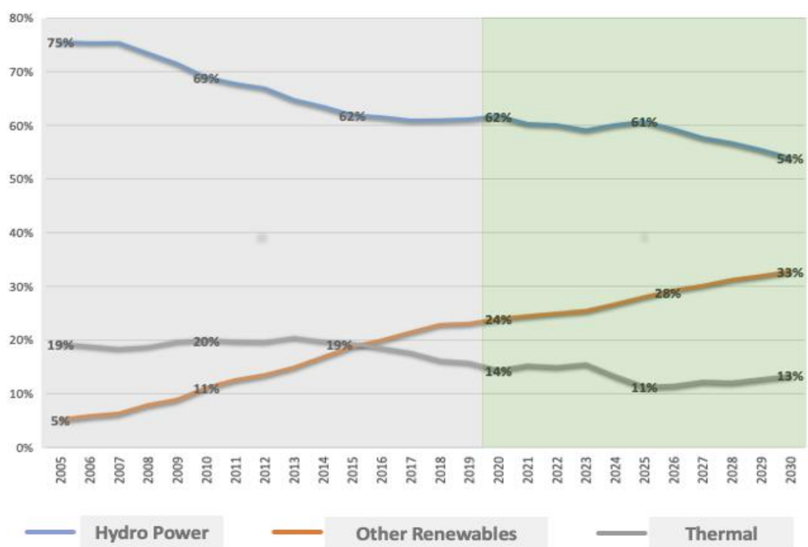
Figure 17 – Renewable's share in Brazilian electricity energy mix



Source: EPE (2022b)

Renewables sources share is supposed to increase in the next years. According to EPE (2021a), in its ten-year energy expansion plan, wind power, solar and small hydro power plants will have around three times installed capacity compared to 2020 data (figure 18).

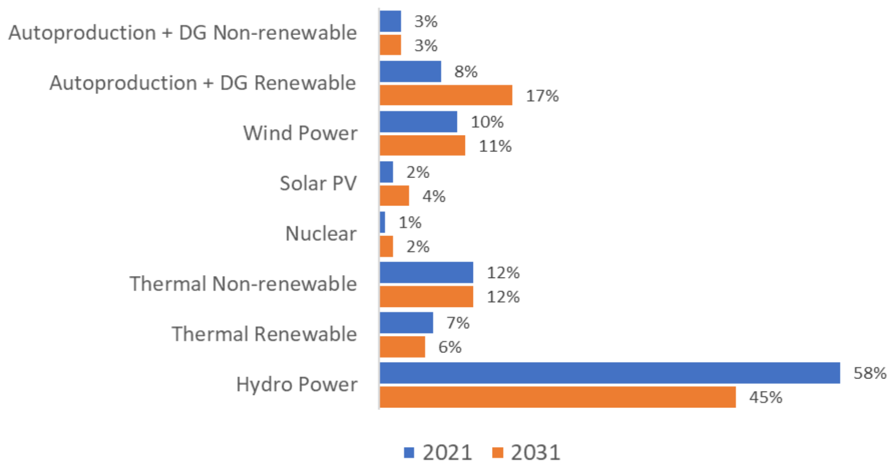
Figure 18 – Electricity source's share of installed capacity in central generation



Source: EPE (2021a)

The capacity growth will be supported mainly by those renewables, whose share in the electricity mix should go from 27% in 2021 to 38% in 2031 (figure 19). According to EPE, besides the great potential to increase electricity mix with wind and solar because of Brazil's weather conditions, by using those sources there will be a cost reduction (EPE, 2022a).

Figure 19 – Installed Capacity share in 2021 and 2031

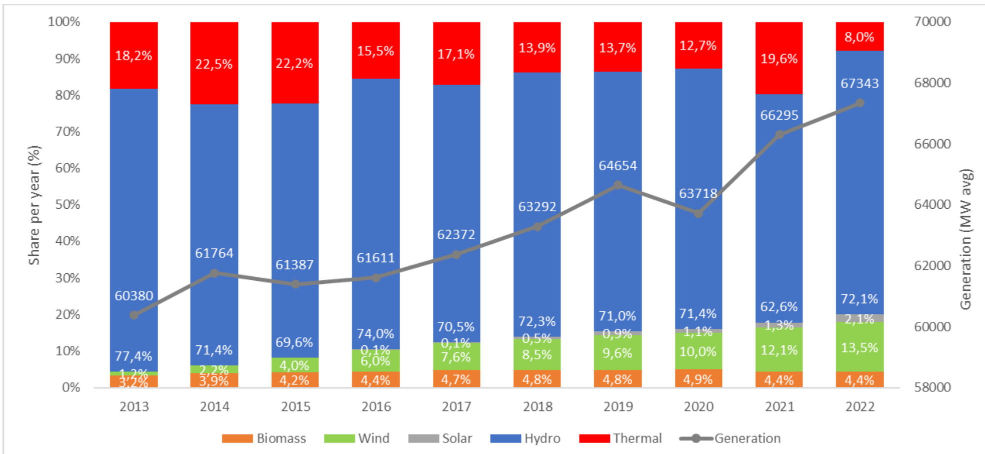


Source: the author, based on EPE (2022a)

In 2022, Brazil reached over 92% of renewable energy generation, the highest percentual in the past 10 years (see figure 20). It was a production of 62 GW average. The source with the greatest increase in electricity production was solar centralized, with 64.3% more than 2021. It was produced 1.4 GW average and the source reached 4% of the electricity mix. The hydraulic source had an increase of 17.1% compared to the previous year, mainly due to a good period of rainfall, it was responsible for the production of 48 GW average. Wind power had an increase of 12.6% from 2021, with a production of 25 GW average. Currently, there are 891 wind farms. Finally, biomass had its production increased by 0.3% compared to 2021, producing 3 GW average in 2022 (CCEE, 2023b).

Soares (2020) suggests that the increase of renewable sources in the electricity mix is important to achieve climates goals defined on the NDC. But there are other reasons for policy makers to spur those sources. Those type of projects are constructed in less time, the number of investors is greater and so is the easiness of investments and financing the projects and they also increase the resilience of the system, due to the decentralization of generation.

Figure 20 – Brazilian generation mix



Source: CCEE (2023b, our translation)

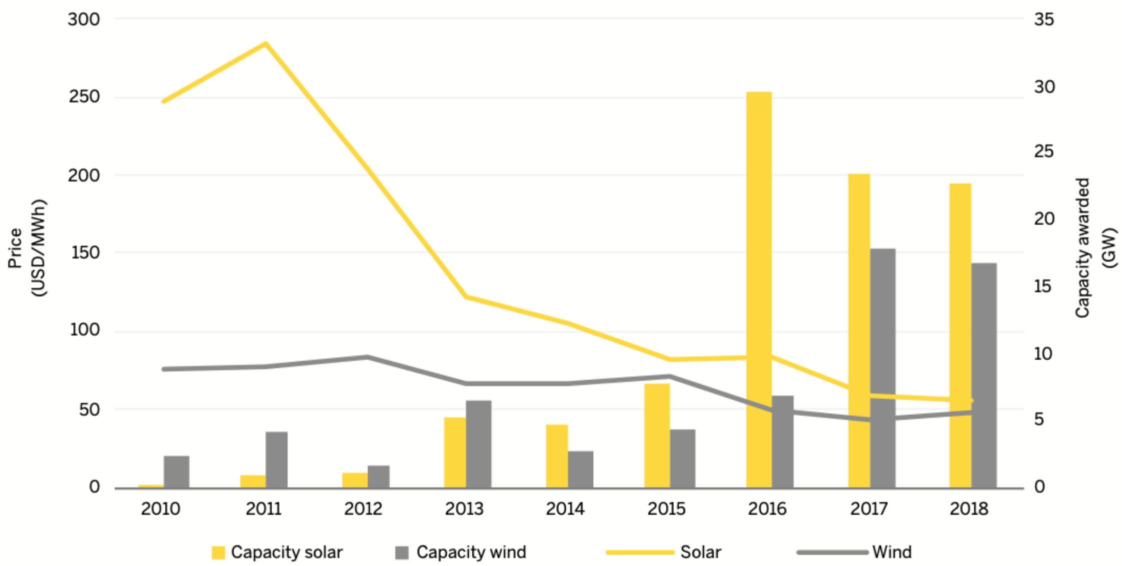
3.3 RENEWABLE ENERGY PRICE PROGRESS

3.3.1 Procurement electricity Auctions

Throughout the years, renewable sources generation technology has been evolving and, therefore, their prices went significantly down. An important data that shows this trend are procurement renewable electricity auctions prices. Figure 21 shows that solar source used to be contracted at the price of around USD 250/MWh in 2010 and went down to USD 58/MWh in 2017. It also happened to the wind power, whose prices went from USD 75/MWh in 2010 to USD 43/MWh in 2017 (IRENA, 2020).

Brazilian electricity procurement auctions for renewables had similar trend, in which prices have fallen throughout the years, as shown in figure 22. Solar power plants were allowed to sell since 2014. In 2015, solar and wind power prices were the highest seen in past ten years auctions, with an average price of USD54/MWh and USD 32/MWh[1], respectively. The electricity procurement auction for new power plants, held on October 2019, also showed a reduction in renewables prices trajectory, with the lowest prices for solar. The auction contracted 1,152.2 MWavg to start supplying in six years, and the cheapest sources were solar and wind, with average prices of USD15.80/MWh and USD18.87/MWh, in this order (CCEE, 2023a).

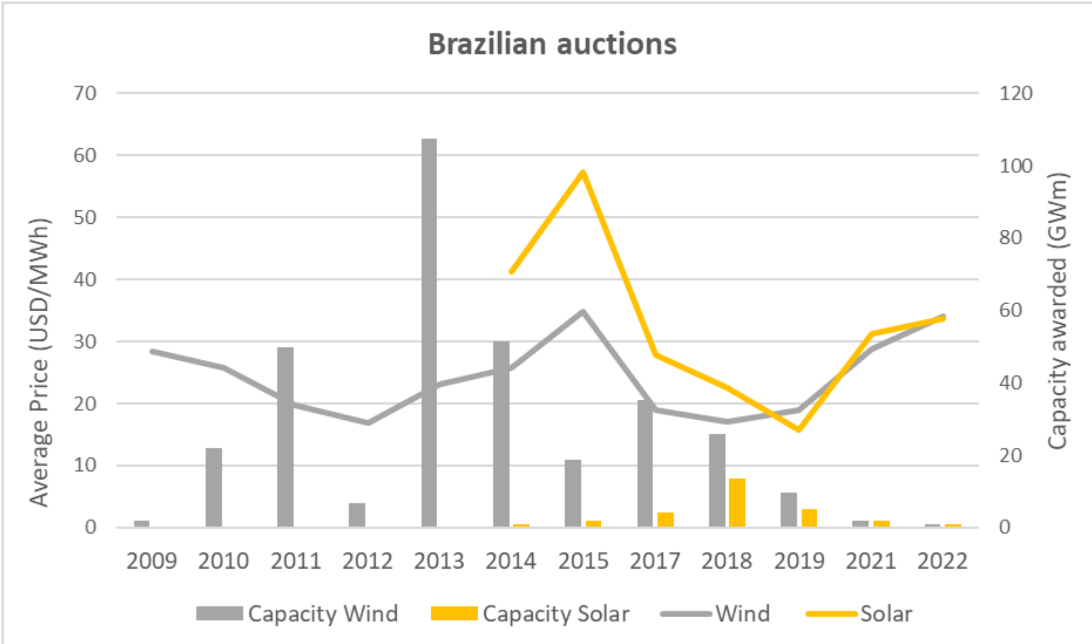
Figure 21 – World average auction prices



Source: IRENA (2020)

[1] Exchange rate 1 USD = BRL 5.5805 (December 31st, 2021).

Figure 22 – Brazil average auction prices



Source: the author, with data from CCEE (2023a)

3.3.2 Levelized cost of electricity (LCOE)

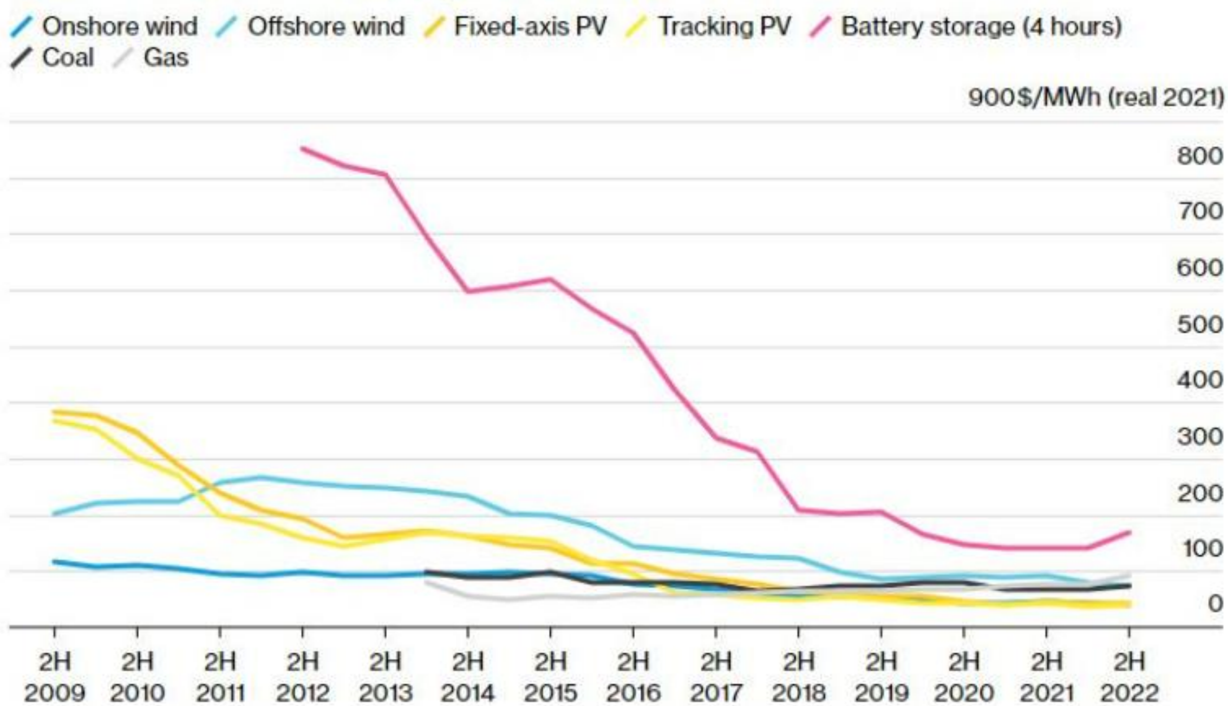
Another methodology used to compare costs of many sources in different countries is to calculate the levelized cost of electricity (LCOE), this index considers costs of all stages of project development and operation. Global wise, solar PV and onshore wind sources are the cheapest for new-build capacity of generation. In 2019, the LCOE for solar PV and onshore wind was USD 50/MWh and USD 44/MWh, respectively (BLOOMBERGNEF, 2020).

The global benchmarks for solar PV and onshore wind are China and Brazil. For the first one, the LCOE is USD 38/MWh getting close to coal-fired power plants costs of USD 35/MWh. In Brazil, with lending rates falling on past years, wind projects can reach a LCOE of USD 24/MWh, the cheapest in the world (BLOOMBERGNEF, 2020).

LCOE for the global benchmark in each source has fallen on the past decade. The benchmark is calculated with latest annual capacity additions using a country weighted average (BLOOMBERGNEF, 2020).

Offshore wind LCOE has also fallen in past years. In 2022 it reached a value of USD 72/MWh and became USD 3/MWh cheaper than coal and USD 18/MWh cheaper than combined cycle gas turbine, which had an increase of 23% in its benchmark. The increase in coal and gas projects is due to higher commodity prices. The benchmark LCOE for gas is at USD 93/MWh, which is more than twice solar and onshore wind LCOE. Benchmarks are demonstrated on figure 23 (BLOOMBERGNEF, 2022).

Figure 23 - Global levelized cost of electricity benchmarks, 2h 2022

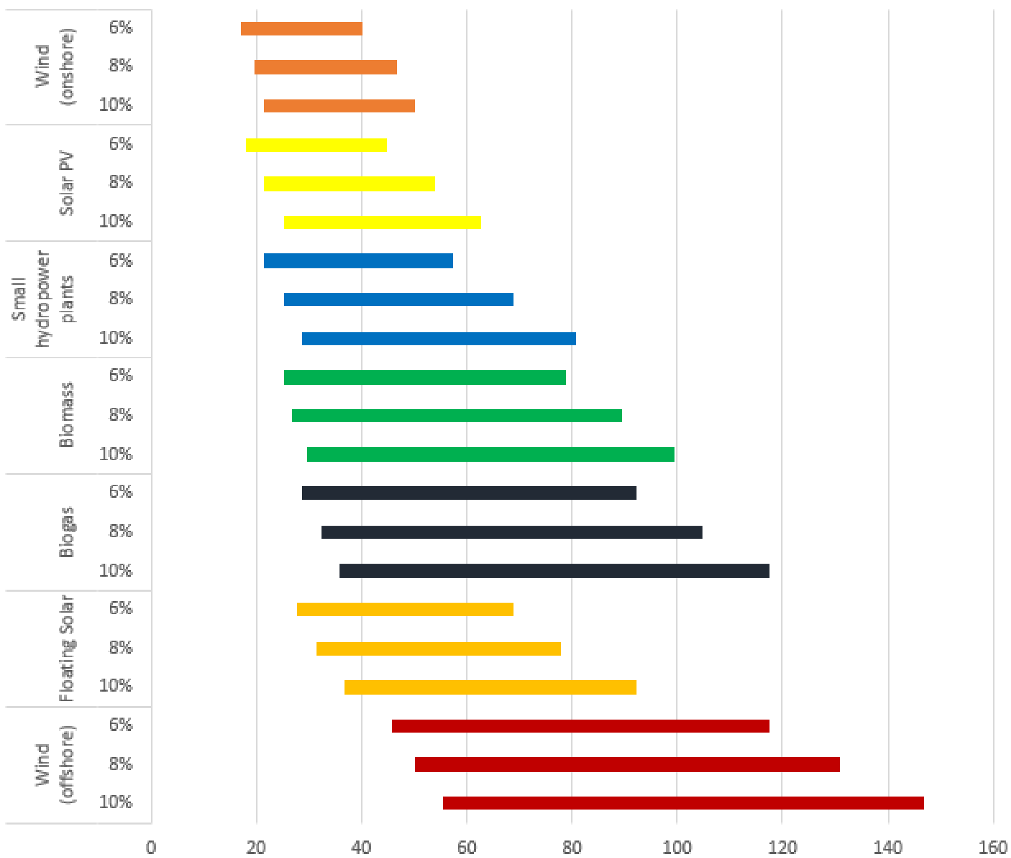


Source: BloombergNEF (2022)

EPE (2021b) analyzed renewables sources LCOE in Brazil, using generation CAPEX ranges, O&M, fuel costs and performance. The study attributes reference values for capacity factor and life cycle for each source. The sources considered in the study are wind, solar PV, small hydropower plants, biomass, biogas, floating PV and offshore wind. For the calculation, the discount rate used followed the Weighted Average Cost of Capital (WACC) methodology. Thus, for each source its was calculated a minimum and a maximum LCOE with three different discount ratio, 6%, 8% and 10%. The results are shown on figure 24. Wind and solar PV are the cheapest sources, with a minimum cost of around USD 20/MWh. Biomass, biogas and offshore wind were the renewable sources with the highest LCOE ranges, because of the fuel's prices or CAPEX variability.

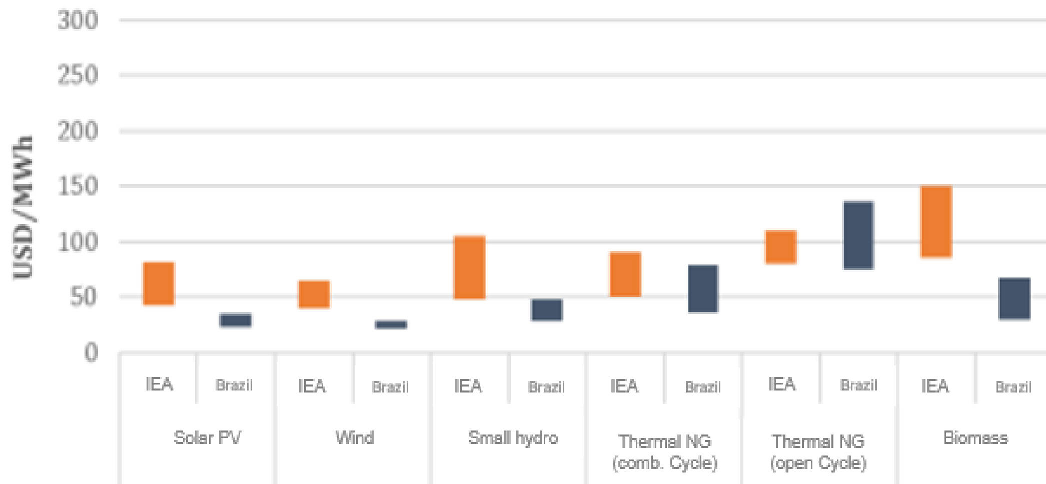
EPE (2021b) compared the results obtained in the study with international data from different sources, such as IEA, IRENA, LAZARD and NREL. Figure 25 shows IEA and Brazil's LCOE. In this analysis all Brazilian sources are bellow IEA's costs, except Natural Gas thermal.

Figure 24 – LCOE (USD/MWh) – Renewables



Source: the author, adapted from EPE (2021b)

Figure 25 – LCOE comparison: Brazilian references x International References (IEA)



Source: EPE (2021b)

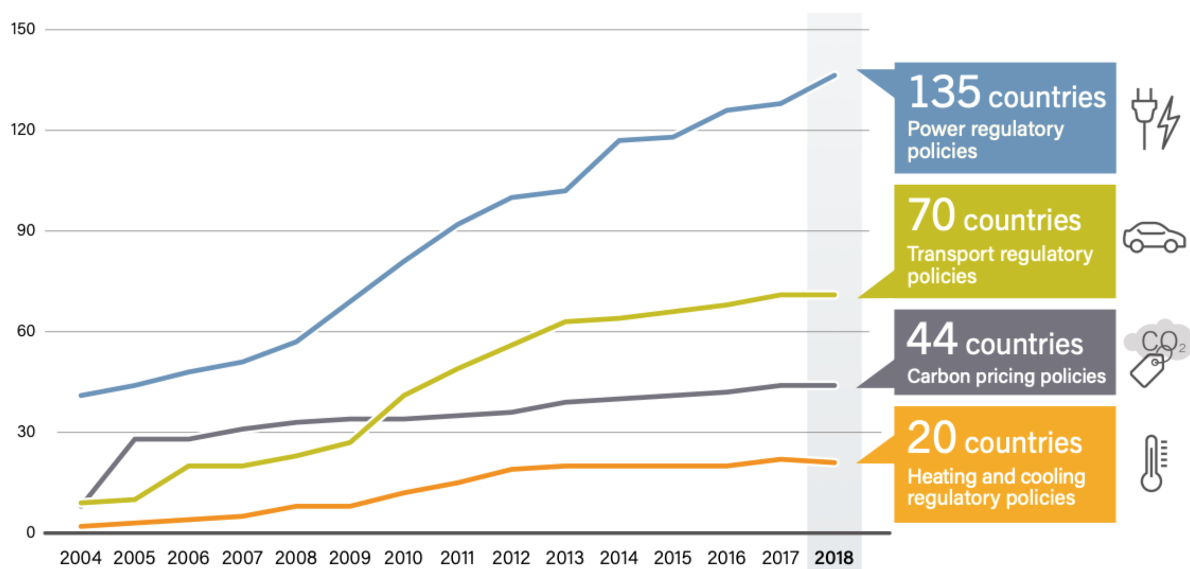
4 ANALYSIS OF RENEWABLE ENERGY SUBSIDIES

This chapter's goal is to study national and international renewable energy subsidies policies. The section 4.1 presents a bibliographic review of renewable energy subsidies around the world. Section 4.2 has some initiatives from governments to fund sustainable projects through investments. Section 4.3 presents Brazilian regulatory framework of the subsidies and estimates the impact of the benefits granted by them.

4.1 SUBSIDIES AROUND THE WORLD

To achieve global climate goals, many countries have established policies to increase renewable energy into their power system. These policies are tailored according to each country or region needs, and may be fiscal incentives, regulation, public financing, feed-in tariffs (FIT), net metering, quotas, among many others, or a mix with some of them (REN21, 2019). Figure 26 shows the number of countries with renewable energy regulatory policies and divides it into four categories: power, transport, carbon pricing, and heating and cooling.

Figure 26 – Countries with Renewable Energy Regulatory Policies

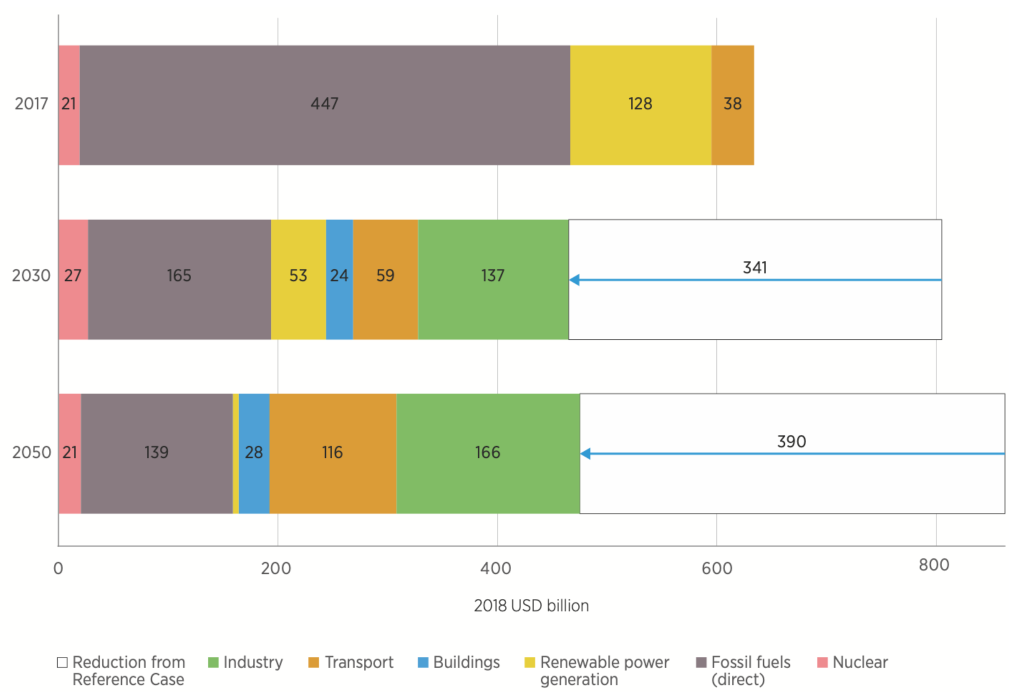


Source: REN21 (2019)

There are subsidies for any kind of electricity generation in the world. Taylor (2020) calculated that in 2017 the world`s total direct energy sector subsidies were more than USD 634 billion. From this amount, fossil fuels accounted for 70% (USD 447 billion) and renewable energy generation for around 20% (USD 128 billion). For renewable energy generation, solar PV is at the top of the rank and have received around 48% (USD 60.8 billion). Onshore wind power comes right after, with 25% of the total amount (USD 31.6 billion). The third and fourth ones in the ranking are biomass (17%, USD 21.9 billion) and offshore wind (5%, USD 6.6 billion), in this order.

Taylor (2020) estimates that renewable energy power generation subsidies will decrease in the next years since they are getting more cost competitive in ten to fifteen years. Therefore, in 2030 a reduction of USD 53 billion is expected compared to 2017. On the other hand, total generation capacity of these sources will increase considerably. In this estimate, subsidies will be close to zero in 2050 and renewables will achieve higher levels of generation and lower costs (Figure 27).

Figure 27 – Energy sector subsidies estimates



Source: Taylor, (2020)

According to Taylor (2020), some of new renewable energy technologies are cheaper than existing non-renewable ones, such as coal or nuclear power plants. For this reason, those power generation will increase without needing subsidies. However, given the urgency of electricity generation transition for reaching global goals of reducing carbon emissions, new technologies may be required, and they might have higher prices. Regulators across the world will have the challenge of balancing higher costs to reduce climate changes.

There is not a consensus on how to define and calculate a subsidy (see figure 28). Each organization adopted its own methodology for this matter. For example, IEA (International Energy Agency) considers it as a government action to lower the cost or to raise the price of energy production, and it is applied to fossil or renewable sources. On the other hand, WB (World Bank) and OECD has a specific definition only for fossil fuels. The first one considers a subsidy as a deliberate policy action by the government, and the last one defines it as a direct budgetary transfer and tax expenditures. The definition used by the WTO (World Trade Organization) is that a subsidy may be a financial contribution or a price support by a government or any public body. This definition has universal acceptance and is often referenced.

Subsidies may be indirect, those that are not direct payments or discounts but another kind of support, or direct, such as feed-in tariffs, fiscal benefits, among others (BATLLE, 2011).

In Europe, many countries have RES subsidies and the difference in each country is what kind of subsidy is applied and how they allocate it among consumers or taxpayers. In Austria, for example, RES subsidies costs are allocated according to the consumer voltage, with a flat rate in each voltage. In Netherlands, the State has a budget for paying the subsidies, so it is paid by all taxpayers. In Portugal, there is a tariff added to energy price, in EUR/MWh. In Spain, those costs are charged in the grid access tariff (BATLLE, 2011).

Wurster and Hagemann (2020) analyzed features in Belgium, Austria and Germany in order to understand what were important conditions that led to a high expansion of renewable energy and found out that countries with a generous feed-in tariff program were more successful to achieve this goal. They classified it as a necessary condition to increase renewable energy share in countries' mix.

Figure 28 – Definitions for energy subsidies

DEFINITION	FOCUS/ METHODOLOGY	STRENGTHS	WEAKNESSES
WORLD TRADE ORGANIZATION (WTO) "A financial contribution by a government or any public body within the territory of a Member", or when "There is any form of price support...(where) a benefit is thereby conferred."	• How energy subsidies distort trade • Dispute settlement	• Near universal acceptance • Often referenced • Used by many as basis for their analysis	• Not widely used by some of the main institutions involved in subsidy reform
INTERNATIONAL ENERGY AGENCY (IEA) "Any government action directed primarily at the energy sector that lowers the cost of energy production, raises the price received by energy producers or lowers the price paid by energy consumers. It can be applied to fossil and non-fossil energy in the same way."	• On consumer subsidies, rather than producer subsidies • Fossil and renewables • Price-gap approach	• Broad definition • Explicitly covers all energy	• Applied only to consumer subsidies • Disagreement over reference prices • Can miss a range of subsidies • No nuclear numbers
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT (OECD) "Both direct budgetary transfers and tax expenditures that in some way provide a benefit or preference for fossil fuel production or consumption relative to alternatives."	• The inventory of support is first step to identifying subsidies to a sector • Inventory approach	• Broad definition of "support" • Inventory approach adds to transparency	• Can miss a range of supports delivered via price measures (prevalent in developing countries) • No estimates for nuclear or renewable subsidies
WORLD BANK (WB) "A deliberate policy action by the government that specifically targets fossil fuels, or electricity or heat generated from fossil fuels."	• Support countries in their subsidy measurement	• Good overview of approaches to subsidy calculation	• No recent subsidy cal-culations of their own • No estimates for nuclear or renewable subsidies
INTERNATIONAL MONETARY FUND (IMF) "Pre-tax consumer subsidies arise when the prices paid by consumers, including both firms (intermediate consumption) and households (final consumption), are below supply costs including transport and distribution costs. Producer subsidies arise when prices are above this level. Post-tax consumer subsidies arise when the price paid by consumers is below the supply cost of energy plus an appropriate "Pigouvian" (or "corrective") tax..."	• Understanding magnitude of subsidies to support reform • Price-gap and inventory approach	• Includes unpriced negative externalities	• Data intensive • No estimates for nuclear or renewables

Source: Taylor, (2020)

Austria has introduced a feed-in tariff subsidy in 2002 (WURSTER; HAGEMANN, 2020). This decision was made early, towards a common goal in European Union to increase renewable energy sources in their countries' energy mix. Belgium delegated policies to federal states, some of them adopted green certificates with a quota system for them. Germany also began moving towards a renewable generation mix in 2000, with a feed-in tariff program for 20 years.

Batlle (2011) discussed a method to allocate renewable energy subsidies costs, since it must be paid by somebody. It has studied the case of Spain, where RES subsidies increased consumers tariff by around 10%, using feed-in tariffs. With this policy, they introduced 25% of renewables in their energy mix.

The article proposes that it would be more efficient to allocate total cost spent with RES subsidies to the consumption of the other energy sources (coal, oil and its derivatives, gas and electricity) in Spain. Therefore, each of these sources' consumption would have their costs increased with RES costs according to the proportion of the source in the energy mix.

According to Wurster and Hagemann (2020), quota's systems may be used to promote investments in renewable energy generation. Policy makers should define quotas for utilities, retailers or even consumers to buy from renewable sources. In some countries, these quotas are sold as green energy certificates by generators.

In the United Kingdom, a feed-in tariff policy was settled in 2010 with the objective of increasing solar PV capacity through microgeneration of electricity. By December 2014, 55% of its total solar PV capacity was installed under FIT program, which represented over 98% of installations (KAY, 2015). The study analyzed a period from April 2010 to 2014 and reached the conclusion that in the beginning, FITs were necessary to achieve the goal of introducing solar PV generation into country's mix, in a period that solar installation costs were higher. As the installation costs were decreasing, FITs were dropping as well. FITs were set at USD 43.3 p/kWh in the beginning, and it was reduced to USD 16 p/kWh in August 2012.

According to Kay (2015), subsidy policy using FIT to introduce solar PV generation was successful and necessary when the technology was not well known and more expensive. Also, the subsidy was reduced whereas installations were getting cheaper, gradually.

LI *et al.* (2020) provides information regarding renewable energy generation and its targets in Australia. The country has committed with Paris Climate Agreements to reduce its emissions by at least 26% by 2030 (data base 2005). To meet this target, Australian authorities established renewable energy generation targets. In this context, Australian retailers should acquire generation certificates, both large- and small-scale types. The government has also given subsidies such as money support and feed-in tariffs. Some states have implemented the time-varying feed-in tariffs (TV FITs) to also encourage consumers to reduce their consumption during peak periods, by putting a higher price in those periods.

Anaya and Pollitt (2017) analyses Distributed Generation (DG) benefits when it is connected on distribution grid in Great Britain with smart connections. It allows operators to manage DG according to load, generation and network restrictions. To increase DG deployment, the regulator has been using subsidies that are paid by consumers, such as FIT, ROCs (Renewable Obligation Certificates), LECs (Levy Exemption Certificates) and CfDs (Contracts for Difference). The conclusion of the study is that introducing an incentive payment for DG smart connections will benefit more the generators than the wider society, which pays for the subsidies. Anaya and Pollitt (2017) suggested that generators should pay a smart connection fee instead of receiving incentives for it.

4.2 INITIATIVES TO FUND SUSTAINABLE PROJECTS

4.2.1 Brazilian Initiatives

To achieve Brazilian NDC's targets up to 2030, there might be necessary to implement public policies, such as: industrial energy efficiency label with minimum efficiency standards; carbon pricing instruments; investments funds in energy efficiency and decarbonization; specific credit lines for energy efficiency; and others (RATHMANN et al., 2017).

Brazil has indicated on its NDC its intention of reaching 10% efficiency on electricity sector to achieve 2030's target through efficiency improvements of equipment and optimization in electricity consumption habits to limit consumption increase in this period (BANCO INTERAMERICANO DE DESENVOLVIMENTO, 2018).

The Environment Ministry (MMA)'s plan to fund actions towards energy efficiency and the generation target is by nongovernmental sources, such as exclusive financing lines (BANCO INTERAMERICANO DE DESENVOLVIMENTO, 2018).

The Development National Bank (BNDES in Brazilian acronym) has a credit line for investments in renewable energy generation and for technology deployment of these sources, under the Climate Fund *(Fundo Clima*). In this program, it is possible to fund projects up to USD 6.4[2] million, representing 80% of eligible items, with an interest rate inferior to 5% per year (BNDES, [2019?]).

4.2.2 International Initiatives

The World Bank has a branch for environmental and social development. Within the scope of actions associated to the environment, there are patterns established for resource efficiency and pollution prevention (WORLD BANK, 2016). The Global Environment Facility Trust Fund (GEF) is administered by the World Bank and may be reached by developing countries to achieve the objectives of agreements and global conventions related to the environment. Besides, the requesting country should have ratified one of the agreements the fund supports, like the COP (GEF, [2023?]).

Therefore, in addition to governmental subsidies to incentivize renewables generation and consumption, there are other initiatives to spur this type of project such as exclusive credit lines from BNDES and The World Bank. Policy makers and other institutions are fomenting actions towards an energy consumption with lower impacts on GHG emissions.

Institutions and investors are now recognizing that ESG factors also influence risk-return analysis of their investments, with a direct impact on their financial performance. In March 2020, more than 3,000 institutions, accountable for USD100 trillion of assets under management, signed on to the United Nations Principles for Responsible Investment (UN

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[2] Exchange rate 1 USD = BRL 4,6947 (April 18th, 2022).

PRI), where they committed to incorporate ESG matters on their investments decision-making analysis (THE WORLD BANK, 2020).

The sustainable development goals (SDGs) are a set of 17 goals with the purpose of solving social, economic, and environmental problems by 2030. Although it is important to understand SDGs as a guideline to ESG actions, investment's decision process in sovereign debts needs to consider environmental and social issues at local level. Other factors like geopolitical issues, internal politics, demographics, and social dynamics are already being used in risk assessments. This approach makes it possible to understand the connections between ESG factors and investments performance.

4.2.2.1 Chile

As an example, Chile has developed a policy to achieve its Nationally Determined Contributions (NDCs) under Paris Agreement, ratified in February 2017. There were commitments defined in five areas: mitigation; adaptation; construction and capacity building; technology development and transfer; and financing. Chile's major goal is to reduce CO2 emissions per unit of GDP by 30%, using 2007 levels as a baseline (REPUBLIC OF CHILE, 2019).

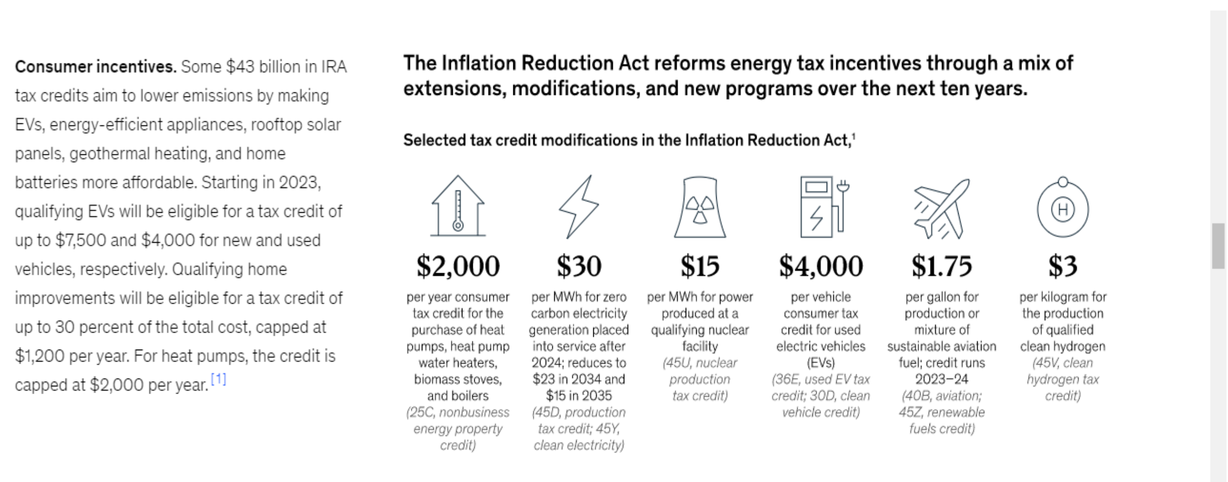
To achieve its Long-Term Climate Strategy, Chile has established a framework to emissions of Green Bonds by the government, whose payments are made by the Treasury. Besides, they are promoting a green asset class to attract foreign investment. Chile's green bonds intend to promote a transition to low carbon, climate-resilient and environmentally sustainable economy. The expenditures eligible as green expenditures are tax expenditures (subsidies and tax exemptions); operational expenditures; real assets, such as land energy efficiency, etc.; intangible assets that includes research and innovation, human capital, and organization; and capital transfers to public or private entities (REPUBLIC OF CHILE, 2019).

4.2.2.2 United States

Recently, the United States signed the Inflation Reduction Act of 2022 (IRA), with the intention of significantly reducing the country's carbon emissions by the end of this decade, allocating roughly USD 400 billion in federal funds for clean energy. The money will be distributed using a combination of grants, tax incentives, and loan guarantees. The largest share goes to clean electricity and transmission, with USD 250.6 billion, then to sustainable mobility, including EV incentives, accounting for USD 23.4 billion (BADLAM et. al., 2022).

Incentives for private investment should be offered. Tax credits make up the majority of the USD 394 billion in funding for energy and environment. With expected tax benefits totaling USD 216 billion, corporations will benefit from the greatest amount. These are intended to stimulate private investment in industry, transportation, and sustainable energy. The bill contains direct pay incentives, which allow an entity to claim the full amount even with a tax liability smaller than the credit (BADLAM et. al., 2022).

Figure 29 – Consumer's tax incentives in the IRA



Source: Badlam *et. al.* (2022)

By lowering the cost of EVs, energy-saving appliances, rooftop solar panels, geothermal heating, and house batteries, an estimated USD 43 billion in IRA tax credits for consumers aims to reduce emissions. From 2023 onward, qualifying EVs will be entitled to tax credits of up to USD 7,500 for new cars and USD 4,000 for used cars. A tax credit of up to 30% of the total cost of qualifying home renovations will be available, with an annual cap of USD 1,200. The credit for heat pumps is capped at USD 2,000 annually (see figure 29) (BADLAM et. al., 2022).

4.2.2.3 European Union

The EU Renewable Energy Directive provides regulation basis for the growth of renewable energy across all economic sectors and encourages cooperation among member states. It has been strengthened because of the provisional agreement on the March 30th, 2023, between the European Parliament and the Council. The agreement increases the EU's legally binding renewable aim for 2030 from the current target of 32% to a minimum of 42.5%, nearly doubling the present share of renewable energy in the EU. In addition, it was decided that the EU will take steps for a goal of 45% renewable energy by 2030 (EUROPEAN COMMISSION, 2023a).

The agreement highlights the EU's commitment to reduce greenhouse gas emissions by 55% by 2030 and achieve energy independence through a quicker deployment of domestic renewable energy sources. Progressively lowering energy prices and reducing the EU's reliance on imported fossil fuels would result from a significant scaling up and acceleration of renewable energy in power generation, industry, buildings, and transportation (EUROPEAN COMMISSION, 2023a).

The EU's long-term growth plan, the European Green Deal, aims to make Europe carbon neutral by 2050. One of the 'Fit for 55' recommendations made by the Commission in July 2021 is to revise the Renewable Energy Directive to make the EU's climate, energy, land use, transportation, and taxation policies suitable for lowering net greenhouse gas emissions by at least 55% by 2030, in relation to 1990 levels. By the end of the next decade, renewable energy deployment must be accelerated and increased for Europe to achieve climate neutrality and implement the European Green Deal (EUROPEAN COMMISSION, 2023a).

The Recovery and Resilience Facility (RRF) is one part of a comprehensive response that aims to lessen the economic and social effects of the coronavirus pandemic while also improving the sustainability, resilience, and preparedness of European economies and societies for the opportunities and challenges presented by the green and digital transitions. It will help the member countries to reach climate neutrality by 2050. The European Commission will borrow money from the capital markets on behalf of the EU. The RRF made available EUR 723.8 billion, divided in EUR 385.8 billion in loans and EUR 338 billion in grants (EUROPEAN COMMISSION, [2023?]).

The RRF redirects around 41% of the funds to actions towards reducing GHG emissions, an amount of EUR 203 billion. For instance, Croatia and France have received EUR 91 million and EUR 1.4 billion, respectively, for decarbonization and energy efficiency supporting. The investments are used in major reforms in a variety of policy areas. As an example, Greece, Portugal and Spain, has made reforms to increase investments in offshore renewables and introducing green hydrogen, by making licensing simpler (EUROPEAN COMMISSION, 2023b).

In May 2022, the European Commission presented a plan to minimize EU's dependence on Russian fossil fuels, with the objectives of saving energy, increasing clean energy production, and diversifying its suppliers, the REPowerEU. The RRF provides EUR 225 billion in loans for the REPowerEU. Additional EUR 20 billion should be available in grants, coming from the EU Emission Trading System allowances (EUROPEAN COMMISSION, 2022).

4.3 SUBSIDIES IN BRAZIL

Brazil has adopted almost all kinds of subsidies to promote renewable energy generation (see table 5), but green certificates, renewable energy quota and rebates (SOARES, 2020).

Table 5 – Incentives instruments to Not dispatchable Renewable Sources

Instrument	Definition	Utilized in Brazil
Feed-in tariffs	The generator receives a fixed rate ($/MWh) during a defined period	Yes
Renewable Energy Quota	To establish a market reserve with defined amount to buy from specific technologies	No
Green Certificates	To separate electricity delivery from its sustainable attribute. Consumers are obligated to buy an established number of theses certificates	No
Auctions	Definition of specific criteria, qualification, and analysis of projects to promote competition in price offers by available market	Yes
Sector or Fiscal Incentives	Exemptions or tax benefits for renewable electricity production	Yes
Direct cash transfers and rebates	Direct cost reduction, so the project developer needs to invest less on its projects	No
Subsidized financing and private bonds emission with exempted taxes	Subsidized financing made by development banks or private bonds emission without taxes	Yes
Net metering	Consumers may inject electricity in the utility grid and receive it as a credit when it generation does not cover its consumption	Yes

Source: adapted from Soares (2020)

Policy makers have established subsidies programs such as PROINFA, a feed-in tariff subsidy, tariff discounts for RES and net metering for micro or mini Distributed Generation, that will be explained in the next sessions. In addition, there are some taxes exemptions applicable to RES (see table 6).

Most subsidies are paid by electricity consumers through sector charges tariff, where there is a centralized account called CDE (Brazilian acronym of Energy development account), which centralizes costs and incomes for subsidies and other government programs. This account is part of the distribution tariff and is managed by CCEE. This account was created by law 10,438, 2002. Almost all consumers pay a sector charge, in its distribution tariff, which is used to fund this account. So, most subsidies are paid by all the consumers.

Table 6 – Taxes benefits applied to Not dispatchable Renewable Sources

Tax	Incentive to RES
Tax on circulation of goods and services (ICMS in Brazilian acronym)	Exemption on renewable electricity generation equipment
Tax on industrialized goods (IPI in Brazilian acronym)	Most part of equipment is exempted
PIS/PASEP and Cofins	Incentives Special Regime for the Infrastructure Development (Reidi in Brazilian acronym). This program assures exemption for five years after project registry for the sale or import of new machines, gadgets, instruments, and equipment for construction of infrastructure projects
Reduction on income tax for priority projects	Reduction on income tax for priority projects

Source: adapted from Soares (2020)

4.3.1 PROINFA

The Program of Incentive to Electricity Alternative Sources (PROINFA in Brazilian acronym) was created in 2002 by the Brazilian federal government. It was a FIT subsidy with the main goal of promoting the use of renewable energy sources for electricity generation. It spurred the increase of RES such as wind, small hydro and biomass in the Brazilian electricity mix. Generators received financial incentives to develop projects for those kind of sources through long-term contracts for the sale of electricity generated from these sources at a fixed price, which was higher than market and sufficient to cover the costs and to get the expected financial return.

Law 10,438, enacted on April 26th, 2002, established the program and provided the legal framework for its implementation, where it was defined the types of RES eligible for the program, the criteria for selecting projects, and the financial incentives to be provided to companies that invest in these projects. Since its creation, PROINFA has been regulated by several other laws, decrees, and resolutions, which have established the specific rules and procedures for implementing the program (BRASIL, 2002). The main regulatory instrument for PROINFA was Decree 5,025, issued on Mach 30th, 2004, which established the criteria for selecting projects and the procedures for contracting and monitoring them (BRASIL, 2004).

PROINFA has been successful in promoting the use of renewable energy in Brazil, contributing to the development of new renewable energy projects and the creation of new jobs in the sector. It has also helped to reduce greenhouse gas emissions and improve the sustainability of the Brazilian energy sector.

The goal of the program was 3,300 MW of installed capacity, being 1,100 MW of each source (wind, small hydro and biomass), located in various regions of Brazil. Until December 31st, 2011, the program had supported the implementation of 119 renewable energy projects in Brazil, with a total installed capacity of 2,649.87 MW. This amount is divided in 41 projects from wind farms, with 963.99 MW of installed capacity, 59 small hydro plants, accounting for 1,152.54 of installed capacity and 19 biomass thermal plants, totalizing 533.34 MW of installed capacity.

The long-term contracts for those sources should be celebrated by the *Centrais Elétricas Brasileiras S.A* (Eletrobrás in Brazilian acronym). The generators received a fixed rate varied according to the type of renewable energy source and the year of the contract, and it was adjusted annually to reflect changes in the inflation rate and the exchange rate. The costs of the program should be paid by all electricity consumers in their consumption proportion, except consumers classified as “low income”. Consumers receive a quota of the electricity generated under PROINFA, proportional to their consumption.

The fixed prices were valid for the duration of the contracts, 20 years. Prices were defined according to each source, and it was agreed that they would be readjusted every twelve months. For wind power, initial prices were USD 41.71/MWh (ELETROBRÁS, 2004a), small hydro plants had an initial price of USD 23.89/MWh (ELETROBRÁS, 2004b), and biomass had the lowest price at USD 19.14/MWh (ELETROBRÁS, 2004c). It was defined that if the project benefited from the carbon credit commercialization, the price should be reduced.

Considering that contracts were signed in 2004, there had been 20 years of readjustment for those generators. Current prices are at USD 158.51/MWh for wind plants, USD 90.78/MWh for small hydro and USD 72.74/MWh for biomass (see table 7). Those prices are much higher than current market prices. In the last electricity auction, wind power prices were at USD 34.16/MWh (see figure 22), so PROINFA price for this source is USD 124.35/MWh or 364% higher than market prices.

Table 7 – PROINFA prices

Source	Baseline price[3] (USD/MWh)	Database	Readjustment Index	Current prices[4] (USD/MWh)
Wind	41.71	May/2004	IGP-M	158.51
Small hydro	23.89	May/2004	IGP-M	90.78
Biomass	19.14	May/2004	IGP-M	72.74

Source: the author, data from ELETROBRÁS (2004a; 2004b; 2004c)

4.3.2 Incentivized sources subsidies

It was established in Law 9,427/1996, that for specific renewable generators it would be given a discount in the transmission and distribution tariffs of at least 50% (BRASIL, 1996). To increase the share of consumers buying energy from those sources, consumers would also receive the same discount in their tariffs (CCEE, [2023]). It is important to highlight that in Brazil, both generators and consumers pay distribution/transmission tariffs.

The discounts vary according to generation source, capacity, and the year they received the grant or won an auction. There is a market reserve of those sources with a discount in the transport (transmission and distribution) tariff, depending on energy type, that goes from 50% to 100%.

Incentivized 100% energy type, comes from the following sources:

a. Thermal energy produced with at least 50% from biomass, biogas from landfill or biodigesters of plant or animal waste, as well as sludge from sewage treatment plants.
b. Wind, biomass or qualified cogeneration, with the beginning of the plant's commercial operation between 04/23/2003 and 12/31/2003.

[3] Exchange rate 1 USD = BRL 5.0798 (March 31st, 2023).

[4] Prices readjusted until March/2023 (BCB, 2023).

c. Small hydraulic plants, with more than 1 MW power capacity, with the beginning of the plant's commercial operation between 10/01/1999 and 12/31/2003.

Incentivized 50% energy type comes from the following sources:

a. Solar with the beginning of the plant's commercial operation after 12/31/2017, with less than 30 MW power capacity.
b. Solar with the beginning of the plant's commercial operation until 12/31/2017, from the 11º year on. Before that, they would receive 80% discount.
c. Biomass with the beginning of the plant's commercial operation before 04/23/2003 and after 12/31/2003, with less than 30 MW power capacity.
d. Wind with the beginning of the plant's commercial operation before 04/23/2003 and after 12/31/2003, with less than 30 MW power capacity.
e. Small hydraulic plants, with the beginning of the plant's commercial operation before 10/01/1999 and after 12/31/2003, with less than 30 MW power capacity.
f. Solar, wind, biomass or qualified cogeneration, with power capacity above 30 MW and bellow 300 MW, which had been won new energy auction from 01/01/2016 on (ANEEL, 2004).

4.3.2.1 Estimative of incentivized sources subsidies benefits

Electricity with 50% discount is priced at an average of USD 46.41/MWh[5] for long term contracts. Electricity from incentivized sources with 50% discount is sold in the free market with a premium for granting the benefits in the distribution tariff. Prices varies

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[5] Exchange rate 1 USD = BRL 4,6947 (April 18th, 2022).

according to market volatility. For long-term contracts this premium was at USD 8.1/MWh[6] on April 2022, or 21% above conventional sources price (DASHBOARD DCIDE, 2022)[7].

However, the consumers enforced to buy incentivized sources, have a financial benefit with the discounts in either distribution or transmission tariff. A simulation of a consumer bill may be seen in table 8. This thesis used as example, a medium size industry, with a contracted demand of 500kW with Enel São Paulo (the distribution company of the Brazilian most important economic city), using its tariffs ratified by ANEEL (ANEEL, 2021b). It was adopted a load factor of 64% and 54% in peak and off-peak periods, in this order.

In the free market, with price references of April 2022 for long term contracts and distribution tariffs, this consumer would save USD 26.34/MWh in the free market, an economy of 26% on its energy bill. This saving comes from three tariff components (tariff composition is better explained in section 6.1). The first one, is the electricity tariff that is negotiated on free market at around USD 46.4/MWh for both peak and off-peak periods. In the captive market, this consumer would pay USD 93.48/MWh for peak period and USD 58.28/MWh for off-peak period, representing 16% discount on its total bill.

The second component is the 50% discount on consumer’s demand tariff, instead of paying USD 3.12/kW, it would pay USD 1.56/kW, in this case, it would represent a tariff of USD 7.69/MWh and a discount of USD 3.84/MWh, a saving of approximately 4% on this consumer’s total bill. Finally, because of this client’s tariff modality and the use of incentivized source, it would have a discount on its charges tariff for peak hours, saving more 6.8% of total bill.

If there were no incentives for renewable energy consumption, this consumer would pay in the free market USD 15.69/MWh less than in the captive market or it would have 16% savings in its bill, regard the electricity component only.

This calculation does not consider taxes (Pis, Cofins and ICMS) charged in electricity bill. Although there is a tariff discount for consumers that purchase electricity

[6] Exchange rate 1 USD = BRL 4.6947 (April 18th, 2022).

[7] It is important to notice that electricity market prices are very volatile, changing practically every day. So, the date the analysis was made is important for the results.

from incentivized sources, in most Brazilian states, they are charged for the taxes of the whole regulated tariff, without considering the discount.

If there was no difference among sources and the subsidies are withdrawn, prices tend to equalize. However, a consumer buying electricity from the free market and without tariff discounts would pay less for it, as shown on table 8 (Free Market Without Subsidies – Energy without premium). In this case, this consumer would save around USD 23.83/MWh, representing a 24% reduction of its captive bill. Energy price would not have the premium of USD 8.1/MWh, and there should be a trend of prices equalizing to other sources, at around USD 38.26/MWh.

In this case, it is noted that demand and peak sector charges, that would receive discount for the use of incentivized source would be equal to captive market tariffs. Thus, they would pay the correct prices for those accounts and the deficit would not have to be distributed among other consumers.

Table 8 – Simulation of a medium size consumer bill with a load factor of 64% in peak hours and 54% in off-peak hours, with and without subsidies

Enel SP	Tariff	Captive Market Bill	Free Market Bill	Savings	Free Market Without Subsidies	Free Market Without Subsidies – Energy without premium
Peak Energy	$93.48/MWh	$2,056.00	$1,020.92	$1,035.68	$1,020.92	$841.82
Off Peak Energy	$58.28/MWh	$10,548.41	$8,399.40	$2,149.01	$8,399.40	$6,925.86
Demand	$3.12/kW (or $7.69/MWh)	$1,560.27	$780.14	$780.14	$1,560.27	$1,560.27
Peak Sector Charges	$142.60/MWh	$3,137.13	$1,755.85	$1,381.29	$3,137.13	$3,137.13
Off Peak Sector Charges	$17.03/MWh	$3,081.63	$3,081.63	-	$3,081.63	$3,081.63
Total ($)	-	$20,384.04	$15,037.93	$5,346.11	$17,199.35	$15,546.71
Total ($/MWh)	-	$100.41/MWh	$74.08/MWh	$26.36/MWh	$84.73/MWh	$76.58/MWh

Source: the author

4.3.2.2 Incentivized sources subsidies regulatory updates

In 2021, Brazilian government began to withdraw subsidies for new renewable energy generation by changing Law 9,427, that has created them. All new renewable generation granted after March 2022, are not receiving incentives anymore. Although this is a big step towards regulatory modernization, all renewable generators who already have the benefits and the ones who have received the grant until this deadline to construct the plant up to 48 months of this date, will continue to receive the benefit until the end of the grant (BRASIL, 2021).

For this reason, subsidies reduction for this kind of sources will be perceived in energy tariffs only in 2045 and 2050. Furthermore, this change made a lot of renewable energy project developers to enter with the request of grant until the established deadline. According to ONS, by the end of 2022, there were approximately 3,000 requests for grant with the subsidies in ANEEL, totalizing 41 GW of additional capacity with subsidies. Most projects are destinated to the free market in the north of Minas Gerais and in the Northeast region. This volume of requests used up all the transmission capacity (ONS, 2022).

Considering this volume of additional capacity with subsidy, the author did a rough estimate on table 9 for the annual costs of these subsidies, with basic assumptions. Most of this new capacity will be from wind and solar PV power plants, whose average capacity factors are 40% and 30%, respectively. So, it was adopted a medium capacity factor of 35% to estimate yearly generation of 125.7 GWh. For consumers discount on distribution factor, it was used the value calculated on table 7 of USD 10.6/MWh, this discount will vary depending on the consumer voltage, consumption, contracted demand, load factor and distribution tariffs. Finally, generators have a discount of 50% on its transmission tariff that was estimated in USD 0.7/kW. In this scenario, this 41 GW of additional capacity would add around USD 1.4 billion per year of subsidies. Considering that grants are for 30 years, it would be a total of approximately USD 40.9 billion due to this additional capacity with subsidies.

This additional capacity with the incentive may be smaller because even though there was a great number of requests, some of those projects may not come off the paper.

Table 9 – Estimative of additional subsidies costs

Number of grants with subsidy by the end of 2022	Additional Capacity (GW)	Estimated Capacity Factor	Estimated annual generation (GWh)	Total tariff discount for consumers - $10.6/MWh	Total discount for generators – around $0.7/kW[8]	Total additional subsidies per year
3,000	41	35%	125.7	$ 1.3 billion	$ 28.3 billion	$ 1.4 billion

Source: the author

4.3.3 Distributed generation subsidies

Captive consumers have high subsidies to become self-producers if they produce or buy electricity from Micro or Mini Distributed Generation (MMDG), which are systems up to 75 kW and from 75 to 5 MW, respectively. A net metering incentive is applied and if generation is greater than consumption, the consumer will inject it in the utility network and may use it as a credit for the next sixty months (ANEEL, 2015b). As those consumers pay volumetric tariffs, the compensation applies to generation, transmissions, and distribution costs, as charges and taxes.

There are also some commercial options, they may choose among either local self-consumption, where generation is located at the same site as the consumption or remote self-consumption, where generation is in a different site but is using the same distribution company network. In the latter, it is allowed shared generation, through a consortium.

Table 10 shows tariffs components that are not applied to MMDG consumers, they are exempts of paying for sector charges and electricity tariff. Since the utilities have fixed and variable costs, those exemptions end up being carried to the other consumers, because MMDG consumers do not have to pay any of them. EPE (2021a) had pointed out that a review in the net metering incentives is important. Regulatory updates are occurring in many countries for MMDG subsidies towards a modernization in electricity sectors.

[8] Exchange rate 1 USD = BRL 5.0683 (April 10th, 2023).

Table 10 – Tariff components applied to consumers with and without GD

Tariff component	Consumer with GD	Consumer without GD
Availability cost (group B) or contract demand (group A)	x	x
Sector charges (R$/MWh)		x
Electricity tariff (R$/MWh)		x
Flags (R$/MWh)		x

Source: the author, based on ANEEL (2025b)

According to regulation (ANEEL, 2015b), neither PPA nor leasing contract charged per energy units are allowed in this net metering program. However, many generators sell this electricity by doing a remote DG through a consortium with their costumers, who receive the electricity and pay to the generator a tariff equivalent to their captive bill minus a discount, which varies from 5% to 20%, depending on the region they are located and other market factors. Since they cannot sell the electricity to the consumers, they usually make a leasing contract, where they rent part of the generation plant to the consumers in the consortium.

4.3.3.1 Estimative of DG subsidies benefits

An estimative of this subsidy was made to illustrate how much a consumer with this kind of generation could save. It was adopted two scenarios, the first one is the benefit of DG for a consumer investing in a system, as illustrated in table 11. The second scenario, very usual in the market, is a consumer purchasing electricity from a generator, in a leasing contract. In this scenario, generator gets most of the benefits, as demonstrated on table 12.

For calculations in table 11 and 12, it was considered a consumer connected in low voltage (B3 – conventional, class of consumers is better explained in section 6.1) with a consumption of 1,500 kWh, using its tariffs ratified by ANEEL (2021b).

Table 11 – Estimative of a consumer with DG bill, considering consumer investment

Enel SP	Tariff	Bill without DG	Bill with DG	Savings	Total discount
Electricity	$61.21/MWh	$91.82	$0	$91.82	
Sector Charges	$65.42/MWh	$98.12	$0	$98.12	
Availability	100 kWh	-	$12.66	-$12.66	
Total		$189.95	$12.66	$177.28	93%

Source: the author

As calculated in table 11, a consumer investing in distributed generation, could save around 93% on its total electricity bill. For this type of consumer, this benefit comes from the electricity and sector charges tariff, a total of USD126.63/MWh. By using a DG system, the consumer would have to pay only for the availability of 100 kWh, which is multiplied by the total costs (electricity and sector charges). There is a caveat in this simulation, it was not considered the costs of acquisition of the DG systems.

Considering that is usual in the market that generators invest in DG systems and sell electricity to consumers through a leasing contract, it was simulated a consumer bill in this modality in table 12, considering the same assumptions for consumer type, consumption, and distribution tariffs from table 11. In this kind of modality, it is usual that the generator keeps most of the benefit coming from the subsidy, by given to consumers a fixed discount from distribution tariff. In this estimative, it was considered a discount of 10%, which gives the generator a price of USD 105.53/MWh.

Table 12 – Estimative of a consumer with DG bill, considering consumer purchasing electricity from a generator through a leasing contract

Enel SP	Tariff	Bill without DG	Bill with DG	Savings	Total discount
Electricity	$61.21/MWh	$91.82	$0	$91.82	
Sector Charges	$65.42/MWh	$98.12	$0	$98.12	
Availability	100 kWh	-	$12.66	-$12.66	
Electricity Price paid to generator	$105.53/MWh	-	$158.29	-$158.29	
Total		$189.95	$170.95	$18.99	10%

Source: the author

Considering market prices for electricity used in section 4.3.2 of USD 46.41/MWh[9] (DASHBOARD DCIDE, 2022), there is a big distortion from prices in the free market and prices charged for DG connections, for basically the same kind of electricity. Those prices may also be compared with electricity auction prices. In 2022, the solar PV source was sold in the auction for an average price of USD 33.7/MWh (see figure 22), with an even more sharp difference.

4.3.3.2 Distributed generation subsidies regulatory updates

In the beginning of 2022, Law 14,300 was published, establishing the "legal milestone" for MMDG. It was defined the criteria and deadlines to keep the subsidies. Those who registered until January 7th, 2023, will receive full subsidies until 2045, after this date subsidies will begin to be withdrawn according to table 13 (BRASIL, 2022).

Table 13 – DG subsidies withdrawn

Year	Percentage to be paid by the generator
2023	15%
2024	30%
2025	45%
2026	60%
2027	75%
2028	90%

Source: the author, based on Brasil (2022)

The commercialization of the electricity generated for MMDG system remained forbidden, however generators keep using leasing contracts to sell the electricity and benefit from a higher tariff in this modality. Though, this regulation allows distribution

[9] Exchange rate 1 USD = BRL 4.6947 (April 18th, 2022).

companies to purchase surplus electricity from MMDG through a public call, in its concession area.

The deadline of twelve months to keep receiving full subsidies for this kind of generation, caused a race to register new projects in this modality. From October of 2022 to January 2023, ANEEL received 486.6 thousand requests for DG projects, with total capacity of 32,298 MW. This volume is equivalent to two Itaipu hydropower plants and is twice the volume of requests from October 2021 to September 2022, which was 15,100 MW, according to the Brazilian Association of Electricity Distributors (Abradee in Brazilian acronym), as shown in figure 31 (SALOMÃO, 2023).

They pointed out that this amount of extra capacity will add USD 51.2 billion[10] in subsidies in consumers tariffs up to 2045. Previous projects had already added USD 41.1 billion of subsidies until the same period, with a total of USD 92.3 billion. On average, costs to be borne by consumers will be approximately USD 2.3 billion per year.

The mini DG (modality with projects from 75 kW to 5 MW) was responsible for less number of requests but greater capacity. The number of requests was of 26,472, accounting for 25,231 MW of installed capacity and USD 1.8 billion per year of subsidies (see figure 30). It indicates that generators will keep selling the electricity through leasing contracts and receiving higher prices due to subsidies.

EPE projected different scenarios for MMDG growth in Brazil, the reference one, is with current net metering rules until 2028, resulting in an installed capacity of 37.2 GW in 2031. The alternative scenarios considers that subsidies will be withdrawn from tariffs in different percentages. The lower scenario project 27 GW of installed capacity in 2031 (EPE, 2022a).

In 2023, the current installed capacity is 20 GW, distributed in 1.87 million generation plants and 2.44 million consumers receiving this electricity (ANEEL, 2023a). The number of customers with solar PV installed on rooftop is around 63% of total, approximately 1.54 million consumers with a total installed capacity of around 15.5 GW. There are approximately 900 thousand consumers with DG in remote systems, around 4.6 GW of installed capacity.

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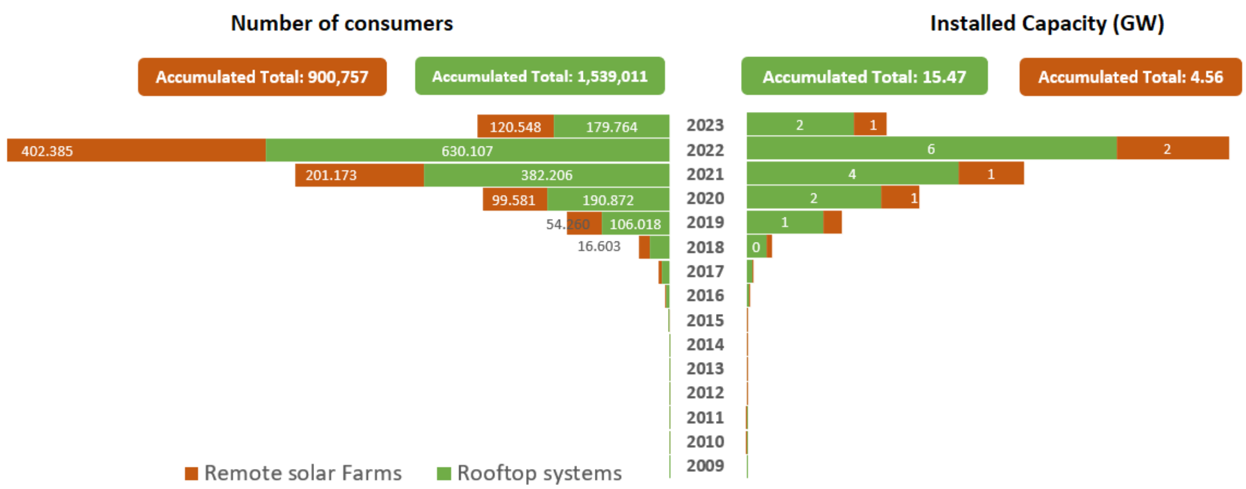
[10] Exchange rate 1 USD = BRL 5.2915 (March 24th, 2023).

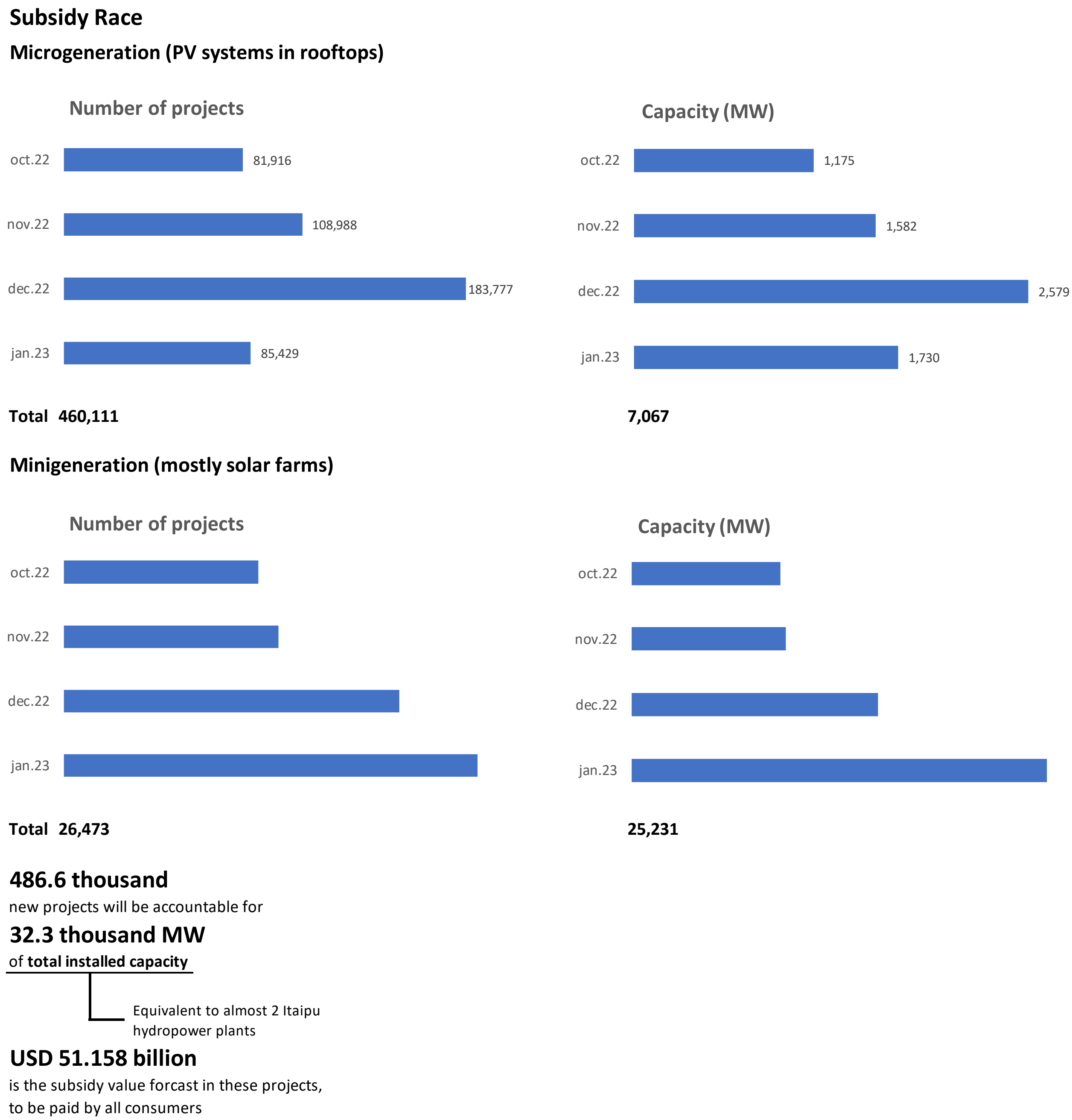
Figure 30 brings data with number of consumers and installed capacity in both rooftop and remote systems. 2022 was the year with the greatest addition in capacity and in number of consumers for both modalities. This may be related to the deadline to keep receiving full subsidies.

Figure 30 – Evolution of Distributed Generation Growth



Source: The author, data from ANEEL (2023a)

Figure 31 – Subsidy Race



Source: Salomão (2023, our translation)

5 RENEWABLE ENERGY CONSUMPTION VERIFICATION

This chapter is a bibliographic review of renewable energy certificates, mandatory and voluntary markets, around the world. Sections 5.1 and 5.2 explain Guarantees of Origin and RECs, in this order. Sections 5.3 and 5.4 study the use of the certificates and the benefits of them. Finally, section 5.5, explains the voluntary certificates market in Brazil.

5.1 GUARANTEES OF ORIGIN (GO SYSTEM)

Certificates GO (Guarantee of Origin) were adopted by European Union to testify renewable sources use. The certificates are valid for one year and expire in case they are not “consumed”. Countries from the Union should choose their own certifier who is responsible for GOs. It is possible to pick multiple certifiers since there is geographical overlap and they may be public or private (HULSHOF; JEPMA; MULDER, 2019).

Countries decided to adopt an international standard to GO’s certificates (HULSHOF; JEPMA; MULDER, 2019). This standard is the EECS (European Energy Certificate System), a unified international system whose objective is to assure that certificates can track energy source and its generation method and guarantee that certificates are not double counted (ASSOCIATION OF ISSUING BODIES, [entre 1998 e 2023]). EECS are negotiated in a single electronic platform, operated by AIB (Association of Issuing Bodies) (HULSHOF; JEPMA; MULDER, 2019).

Hulshof, Jepma and Mulder (2019) analyzed GO Systems’ markets, and their conclusion is that certificate’s prices have a high volatility. Markets appear to have a constant certificate surplus. A positive influence in these certificate markets is the use of an international pattern.

5.2 RECs

RECs are voluntary certification that used to be managed by AIB (HULSHOF; JEPMA; MULDER, 2019). The RECs segregate attributes linked to consumption of renewable energy from energy supply because they are products sold separately (CHUANG et al., 2018). There is a tendency in consumers demand for RECs to increase, insofar as they increase their incomes (KAMERSCHEN; PORTER, 2004).

Markets that do not use RECs may have the “free-rider effect”, because users who do not consume renewable energy sources benefit from an electricity mix with a lower emission factor. However, markets with RECs being retired to the consumers will have the energy who generates them withdrawn from the network’s emission factor calculation. The result will be a network with a higher emissions factor (CHUANG et al., 2018).

Feed-in Tariff’s (FIT) programs are another example that could cause the “free-rider effect” because they are usually paid by taxpayers and may interfere on market’s competitiveness. In Taiwan, due to FIT programs, generators have more incentives to sell their energy directly to the government with better tariffs. For this reason, companies have no incentive to buy renewable energy and its sustainable attributes, and REC’s market is almost inexistent. Therefore, in markets where there is free competition in energy sale, RECs’ use may be an important mechanism to indicate the real value of a sustainable consumption (CHUANG et al., 2018).

In China, RECs’ market trading is an incentive mechanism to energy generation that may benefit the State economically, by reducing spends with subsidies programs. However, the use of RECs alone may not be enough to achieve renewable energy generation goals and should be associated to FIT programs (ZHANG et al., 2018).

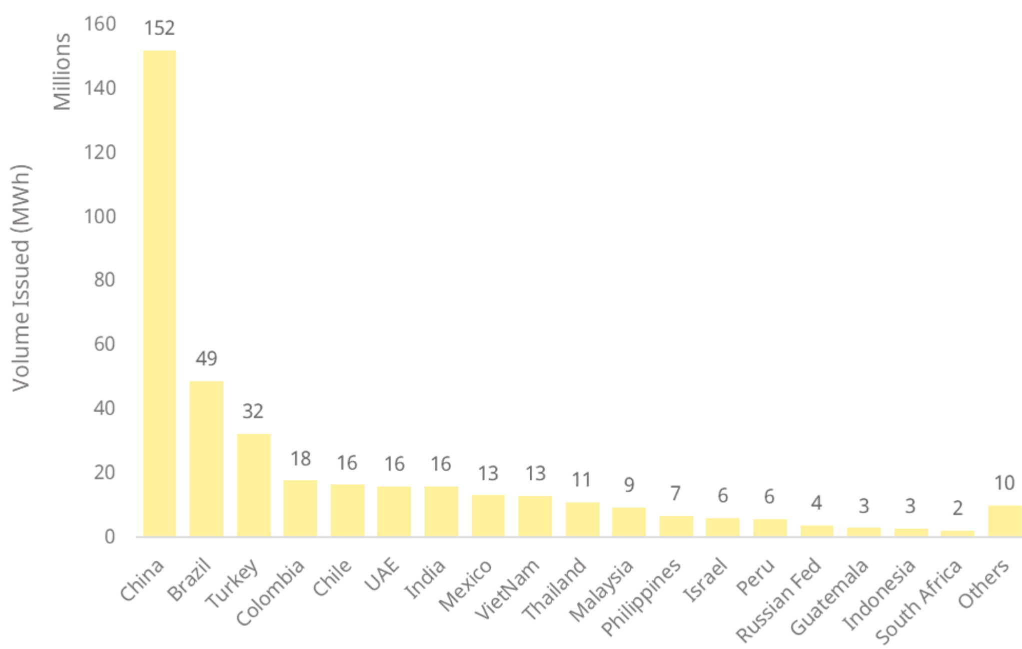
There is an international known certification, called I-REC, that was developed by The International REC Standard Foundation (I-REC Standard), a non-profit organization that was created to promote the use of RECs as a tool for promoting renewable energy worldwide. The I-REC standard has created a robust tracking system for products related to renewable energy generation. It is recognized by major reporting frameworks like the GHG Protocol, CDP and RE100, as a reliable instrument to track electricity consumption (I-REC STANDARD, [2023]).

The I-REC Standard is a global standard that enables organizations to purchase RECs to offset their GHG emissions and demonstrate the commitment to supporting renewable energy.

The I-REC Standard is recognized by a growing number of international organizations and is used by a variety of stakeholders, including governments, companies, and NGOs. It is an important tool for accelerating the transition to a low-carbon economy by promoting investment in renewable energy and supporting the development of new renewable projects.

Overall, while there is no mandatory market for I-RECs, their use is becoming increasingly common and recognized as a credible way of tracking and reporting renewable energy use.

Figure 32 – I-RECs issued around the world



Source: the author, data from I-REC Standard (2023)

In 2021, 163.8 million I-RECs were issued in 43 countries that have this voluntary market, considering generation of that year, this is equivalent to approximately 18.7 GWavg of renewable energy generated. In 2022, the issuance is at 122.8 million by March 2023, this number should increase in the next months, since it is possible to issue I-RECs from the previous year. The country with the greatest number of certificates issued was China (around 152 million). The second one was Brazil, with almost 49 million I-RECs issued (see figure 32) (I-REC STANDARD, 2023).

5.3 GLOBAL INITIATIVES FOR RENEWABLE ENERGY CONSUMPTION

There are global initiatives for companies to take accountability for their impact on society and to adopt mitigation measures, like the use of renewable sources for energy consumption. By joining a global initiative, those companies can impact positively their local environment and influence suppliers, utilities company and the governments for policy making (RE100, [2023]).

One such initiative is LEED certification (Leadership in Energy and Environmental Design), a voluntary certificate in buildings that classify them according to sustainable indicators such as water consumption and energy. LEED was created in 1998 in the United States and is recognized in over 160 countries, the biggest concentration is in the Americas. One of the requirements to get this certification is to generate or consume renewable energy, and I-RECs are accepted to testify it (MARTEK et al., 2018; VAN DER HEIJDEN, 2015).

Companies from industrial and commercial sectors are responsible for 50% of world's energy consumption. The RE100 is a global corporate initiative whose objective is companies' commitment with 100% of renewable energy consumption in all their operations up to 2050. This initiative aims to accelerate world energy transition and, consequently, to eliminate carbon emissions associated with those company's energy consumption. Each enterprise may establish their own goals to converge with global goal and they should report annually their progress towards the target (RE100, [2023]).

Beyond this initiative's sustainable appeal, research among members revealed that transition to clean energy consumption also results in costs reduction, because those sources are more and more competitive compared to other sources (ANDRILLON, F. *et. al.*, 2018).

Companies report their goals and how they are performing towards these goals. There is a well-known global disclosure system used for companies and cities to measure, disclose, manage, and share environmental information called The Carbon Disclosure Project (CDP), which is a non-profit charity. The organization was established in 2000 with the aim of gathering information on GHG emissions and climate change strategies from companies worldwide and making this information publicly available (CDP, [2023]).

The CDP works with institutional investors, corporations, and governments to encourage companies to measure and mange their environmental impacts, including carbon emissions, water usage, and deforestation risks. The CDP operates through an annual reporting cycle, where companies respond to a questionnaire that asks about their carbon emissions, climate risks, and opportunities. The responses are analyzed, scored, and benchmarked against industry peers and best practices, and the results are shared with investors, companies, and other stakeholders. The CDP is funded mainly by governments, philanthropic grants and service-based membership (CDP, [2023]).

The CDP is recognized as a leading global authority on corporate environmental disclosure and has over 18,700 companies and 1,100 cities reporting through its system. There are 746 investors with over USD 136 trillion in assets and more than 280 large buyers with over USD 6.4 trillion in procurement budget that request companies they negotiate with to disclosure their environmental impact through CDP. For cities, using the CDP platform is free and voluntary, so governments that decide to report their climate action efforts receive a score and feedback about their actions. The number of cities reporting through CDP has increased by 17 times from 2011 to 2020, 68% of those cities have taken actions to reduce emissions (CDP, [2023]).

5.4 SUSTAINABLE COMPANIES FUNDABILITY

Increasingly, companies are accounted by their impact on society and how their activities affect the environment. However, reducing their negative impacts by itself will not be enough, whereas they should be concerned with those issues and be able to solve problems society is facing (HART; DOWELL, 2011).

Companies that use renewable energy present higher financial indicators compared to their peers. To reach this conclusion, indicators ROI (return on investment), Tobin’s Q e Operating Margin from companies listed on EPA’s Fortune 500 Top Green

Power Partners were analyzed. This list shows American companies with higher renewable energy consumption (SHIN et al., 2018). EPA uses green power certification to assure that consumers are buying renewable energy. This is a voluntary green power market used as best practices to validated energy origin (EPA, [2022]). That study selected a sample with 60 companies for this analysis in a period from 2007 to 2013. These indicators were compared with average of companies in the same sector and the result is that companies with a renewable energy consumption strategy have better indicators (SHIN et al., 2018).

An impact evaluation on environmental costs in the financial services sector shows that by reducing environmental costs, there is a long-term increase in companies results. The environmental costs are measured by the amount of natural resources used in firms' process or the amount of GHG emitted multiplied by their environmental damage costs to population, data were collected from Trucost Plc, the largest database of GHG emissions. The main aspects that corroborate with this result are: increase on companies' reputation; more qualified employees are hired; increase on productivity and competitivity; reduction on capital costs and profit increase.

Moreover, there is a greater awareness of environmental aspects on companies located in North America and Europe than in Asia. To reach this conclusion, the study compares some indicators as net income and total environmental costs in a sample of 4,924 companies from 29 countries between 2002 and 2011. The highest median net income was in North America, USD 575 million, Asia Pacific companies presented a median net income of USD 14 million. In the other hand, US firms have higher total environmental costs (USD 12.2 million), while Asia Pacific firms' median is almost half of it (USD 5.9 million) (JO; KIM; PARK, 2015).

In Brazilian stock exchange, there is an index called ISE-B3 (Brazilian acronym for B3's business sustainability index) which includes companies with best ESG (Environmental, social, and corporate governance) practices. This index evaluates companies since 2005 and since then, companies listed in its portfolio presented 294.7% profitability, while Ibovespa presented 245% (ISEB3, [2019]). Analyzing indicators of wealth generation on companies that are listed on ISE-B3 and comparing with same indicators of companies that are not included on this index the conclusion is that there are not significant differences between these two groups (SOUZA; FARIA, 2018).

A study conducted by Capgemni in collaboration with the RE100, evaluated financial performance of companies with renewable energy consumption strategy and compared it with their peers without those strategies. Companies committed with the RE100 were evaluated as matures on energy transition subject, because they have specific targets and report annually their advances towards the target, presenting commitment and trustworthiness. The study analyzed EBIT (Earnings before Interest and Taxes) and Net Profit Margin (ANDRILLON, F. *et. al.*, 2018).

The study's results are on table 14 and figure 33, showing the number of companies that were evaluated in each sector and the result of the comparison, in this order. The Y-axis of figure 33 shows the EBIT percentage difference between RE100 companies and their competition. The X-axis presents the result of net profit margin percentage difference. For example, IT & Telco RE100 member companies have an EBIT around 8% greater than their competition who are not RE100 members.

Table 14 – Number of companies considered on financial performance analysis

Sector	# Of Companies	# Of RE100 Companies among them
Consumer Packaged Goods	451	16
IT & Telco	525	23
Manufacturing	742	19
Health Care	194	4
Retail	481	14
Financials & Services	457	34
Travel, Logistics & Hospitality	260	6
Construction & Real Estate	352	6
TOTAL	3462	122

Source: data from Andrillon, F. *et. al.* (2018)

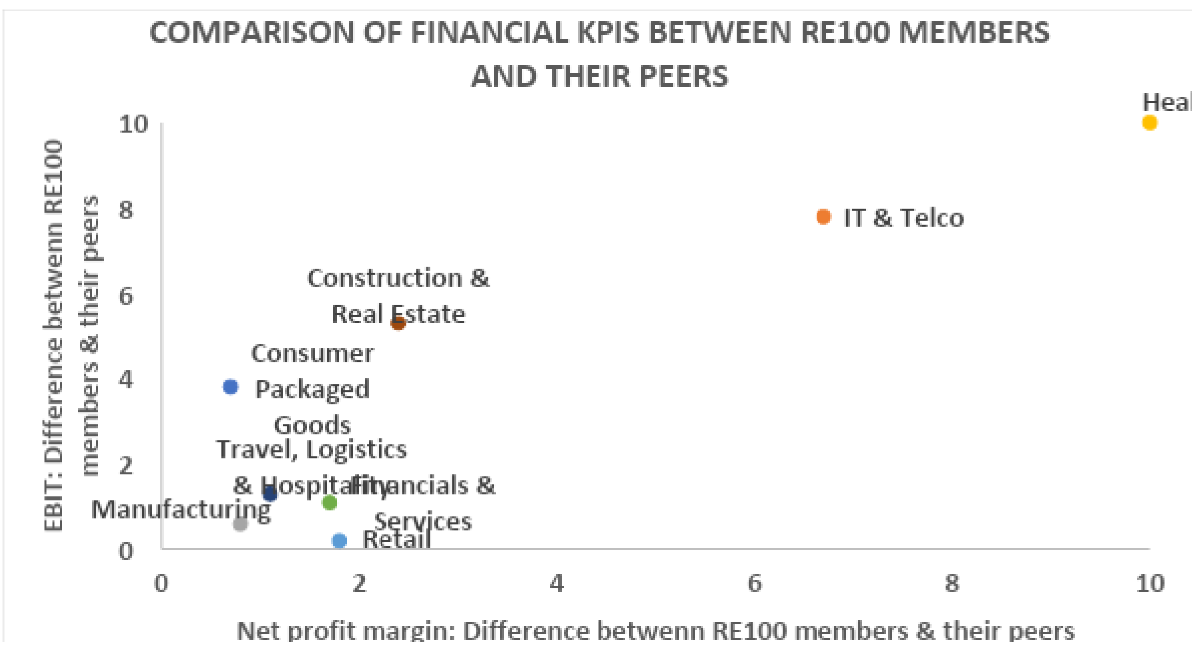
The results corroborate with the hypothesis that RE100 member companies present greater financial performance than their competition in both indicators that were evaluated. The sectors highlighted in the figure 33, health services and "travels, logistics and hospitality" have some caveats because there are a low number of companies in the

RE100 sample. However, these caveats do not interfere on study conclusion: the RE100 members present greater financial performance than their peers.

The study indicates that market leader companies in their sectors invest more in renewable energy and, for this reason, play a role model to be followed by competition. Besides, there are other benefits associated with this strategy, such as new financial sources in business model that focus on ESG (Environmental, Social and corporate Governance) and *green bonds,* where companies have access to funds with low interest rates.

To achieve their target of 100% renewable energy consumption, companies establish some strategies. One of them is to buy certificates, such as RECs, GO and I-RECs, that separates the renewable attribute from energy supply, because it is possible to measure those attributes and link them with company's consumption. Certificates are used as a tool to meet the initiative criteria, avoiding double counting.

Figure 33 - Financial indicators comparison between RE100 companies and their peers



Source: figure based on Andrillon, F. *et. al.* (2018)

5.5 VOLUNTARY CERTIFICATES MARKET IN BRAZIL

In Brazil, there is no mandatory market for renewable energy certificates. So, private initiative may create and trade certificates in a voluntary market. The most well-known certificate used in Brazil is the I-REC, traded in I-REC platform. This is a voluntary certification to reduce GHG emissions of the scope 2, which addresses emissions from production and consumption of electricity energy. The certification service is paid and follows international patterns, although it is adapted to each country's features (I-REC STANDARD, [2022]).

Totum Institute is the local I-REC issuer in Brazil. This issuer has an agreement with CCEE to obtain and validate generation data from suppliers that emit the certificates. The certificate is associated to the power plant, month, and year of generation. An I-REC is equivalent to one megawatt-hour generated.

Certificates may be traded on the same emission market or between interconnected markets, for example, Argentina and Brazil.

The power plant is a Register in the I-REC's platform, which is the agent capable of issue the certificates according to their generation. Registers may be producers, self-producers or distributed generation plants. The Register cannot sell the certificate directly to a final costumer, it can only be done by a Participant.

A Participant is a market player, trader, or consumer who trades certificates from their primary account to the primary account of another market player. They may also redeem certificates on their behalf or on behalf of their clients to their retirement account.

When a Participant transfers a certificate to another account, it waves his rights to redeem or transfer this certificate. The participant must deliver the certificates in a redemption account, so the consumer is able to claim the certificate's attributes.

When an I-REC is retired it is cancelled and may not be transacted anymore. At this time, the certificate's attributes are finally handed out to the consumer who bought it. With this mechanism, it is possible to audit mandatory rules or voluntary claims for the certificates.

A player who wants to trade the certificates on I-REC's platform must pay some fees, described on table 15 and 16. Any consumer may buy I-RECs to claim renewable energy consumption attributes.

Table 15 – Registrant Fees

One-time device registration fee (5-year validity) & Renewal fee (after 5 years and more 5-year validity)	
Single devices > 499 MW	BRL 12,500
Single devices between 5 MW and 499 MW	BRL 7,200
Single devices < 5 MW	BRL 3,500
Single devices < 1 MW	BRL 750
Single devices < 250 kW	BRL 30
Issuance fee (per MWh)	BRL 0.184
Issuance fee (per MWh) self-consumption	BRL 0.29

Source: the author, with data from I-REC Standard (2023a)

Table 16 – Participant Fees

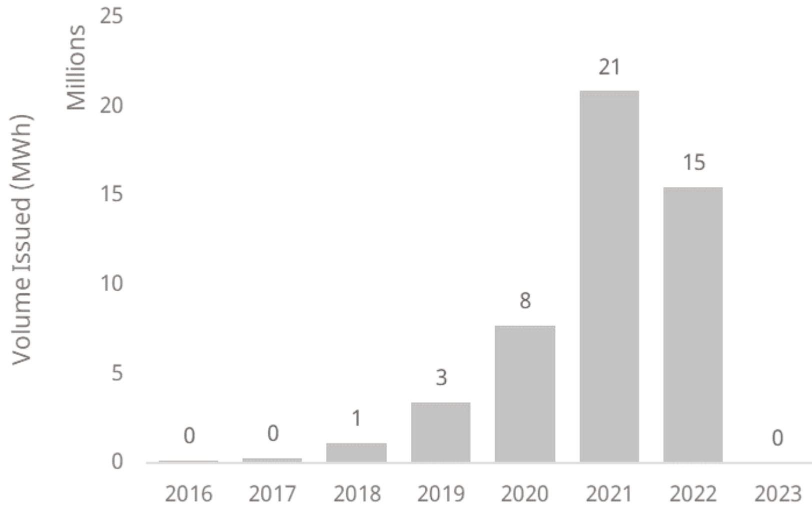
One-time trade account opening fee	EUR 500.00
Annual trade account fee	EUR 2000.00
Additional redemption account fee	EUR 0.00
Redemption fee (per MWh)	EUR 0.06

Source: the author, with data from I-REC Standard (2023a)

The I-REC market in Brazil has grown exponentially in past years. The first year of issuance was in 2016 with 95.519 certificates issued. Every year, this number has grown more than twice. In 2021, Brazil has issued 20.8 million I-RECs, equivalent to 2.4 GWavg of renewable generation, figure 34 exhibits the growth since 2016 (I-REC STANDARD, 2023b).

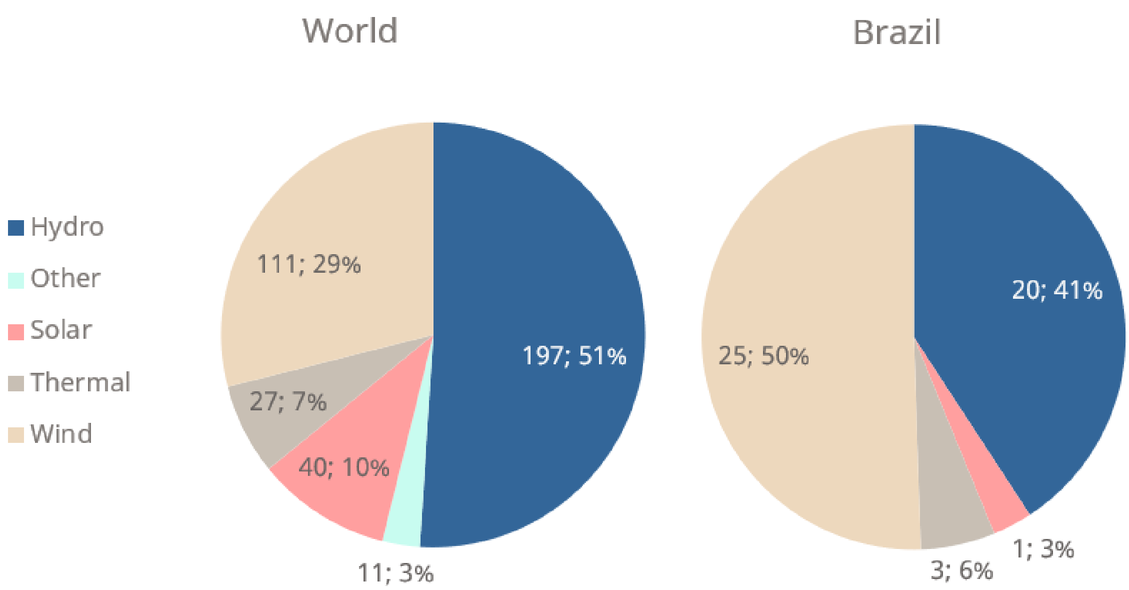
In figure 35, there is a comparison of renewable sources issuing the I-RECs in the world and in Brazil. Worldwide, most of the I-RECs are from hydropower sources, which accounts for 51% of the issuance (197 million I-RECs). The second one is wind power, that has issued 29% of total I-RECs in the world (111 million). The third and fourth places are with solar and thermal sources, with 10% and 7%, respectively. In Brazil, the source that has issued more I-RECs is wind power with 41% of the Brazilian total issuances (25 million).

Figure 34 – I-RECs issued in Brazil



Source: the author, data from I-REC Standard (2023b)

Figure 35 – Total I-RECs issued per source (million MWh)



Source: the author, data from I-REC Standard (2023b)

According to Pinter and Yadav (2022), in 2022 I-RECs in Brazil and China, major two issuer countries, were being traded at average prices of 30-50 cent/MWh. Those prices are low compared to Nordic Hydro GO traded at EUR 2.30/MWh.

6 INCENTIVIZED SOURCES SUBSIDIES - CASE STUDY

This chapter presents a case study of a distribution company with the simulation of the impact of RES subsidies that were better explained in chapter 4.3.2 on a residential consumer electricity bill. The objective of this case study is to show that although subsidies were important to introduce RES on Brazilian electricity mix until they have relevance and became cost competitive, it caused an imbalance on residential consumers' tariff.

6.1 TARIFF'S COMPOSITION

The electricity generated in Brazil is transported by the transmission's companies, which deliver it in the consumption center, where the distribution companies are responsible for delivering it to final consumers. Consumers need to pay the costs to remunerate all this chain. Since distribution and transmission business are natural monopolies, it is regulated by ANEEL, whose major attribution is to assure fair prices to final consumers while maintaining economic-finance balance of concessionaires (ANEEL, 2022a).

The tariff is divided by: Electricity Tariff (TE in Brazilian acronym) and the Tariff of Usage of the Distribution System (TUSD in Brazilian acronym), the latter includes costs of electricity transportation (transmission and distribution) and sector charges. The final tariff will have the addition government taxes: Program for Social Integration and Contribution for the Financing of Social Security (PIS/COFINS in Brazilian acronym), ICMS, and Public lighting (CIP in Brazilian acronym) (ANEEL, 2022a).

Consumers are classified by class of consumption, group, subgroup, and tariff modality. The class of consumption is divided into five categories: Residential, Industrial, Commercial, Rural and Public Power (ANEEL, 2022b).

The group and subgroup classify consumers according to their voltage connection (ANEEL, 2021a):

a. Group A: Consumers connected in medium and high voltage, divided by 6 subgroups:
    a. Subgroup A1: > 230kV

   b. Subgroup A2: 88kV ≤ consumer ≤ 138kV
   c. Subgroup A3: 69kV
   d. Subgroup A3a: 30kV ≤ consumer ≤ 44kV
   e. Subgroup A4: 2,3kV ≤ consumer ≤ 25kV
   f. Subgroup AS: < 2,3kV, in a subterranean network
b. Group B: consumers connect in voltages inferior to 2,3kV, divided by 4 groups:
   a. Subgroup B1: residential
   b. Subgroup B2: rural
   c. Subgroup B3: the other classes
   d. Subgroup B4: Public lightening

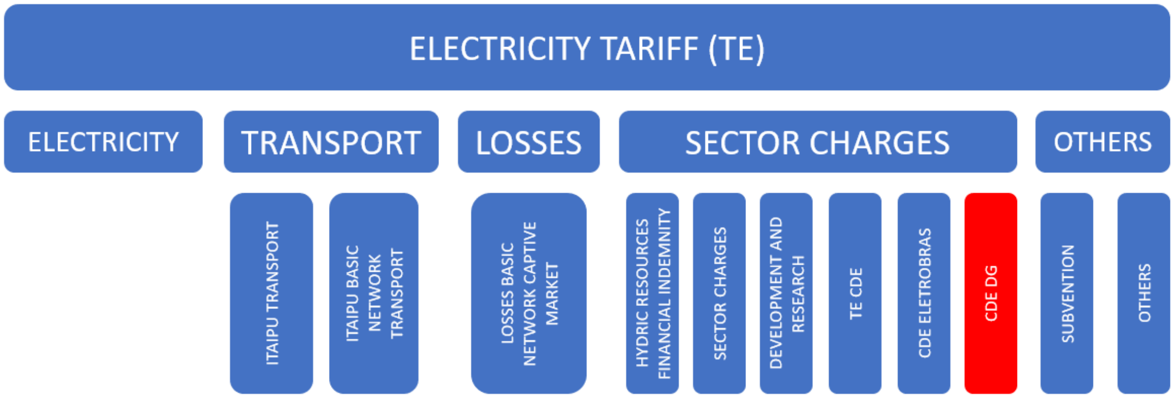
For group A, there are two tariff modalities: blue and green. The blue is available to all subgroups in the group A and is characterized by two demand tariffs, one for peak and the other for off-peak hours, but there is only one tariff for sector charges in both tariff posts. The green modality is available for subgroups A3a, A4 and AS and has only one demand tariff, but two sector charges tariff, separated by peak and off-peak hours (ANEEL, 2022c).

Consumers from group B may choose between two tariff modalities: Conventional Monomy, which is a singular tariff for all the hours of the day; and the White Hourly, which has a different tariff according to the hours of the day, and it is not available for subgroup B4 (ANEEL, 2022c).

The tariff structure is a set of tariffs applied to the electricity distribution market and differentiates regulated costs according to consumer's subgroup, class, modality and tariff posts.

The tariff's composition is demonstrated in figures 36 and 37. In figure 36, there is the composition of the Electricity Tariff (TE), which is applied only to captive consumers and has the main objective of reimbursing the distribution company for the costs with the purchase of electricity. Transmissions costs, losses and sector charges are also included in this tariff's component. In the figure, the component CDE DG is highlighted to demonstrate where the subsidy explained on session 5.2.3 is allocated (ANEEL, 2023d).

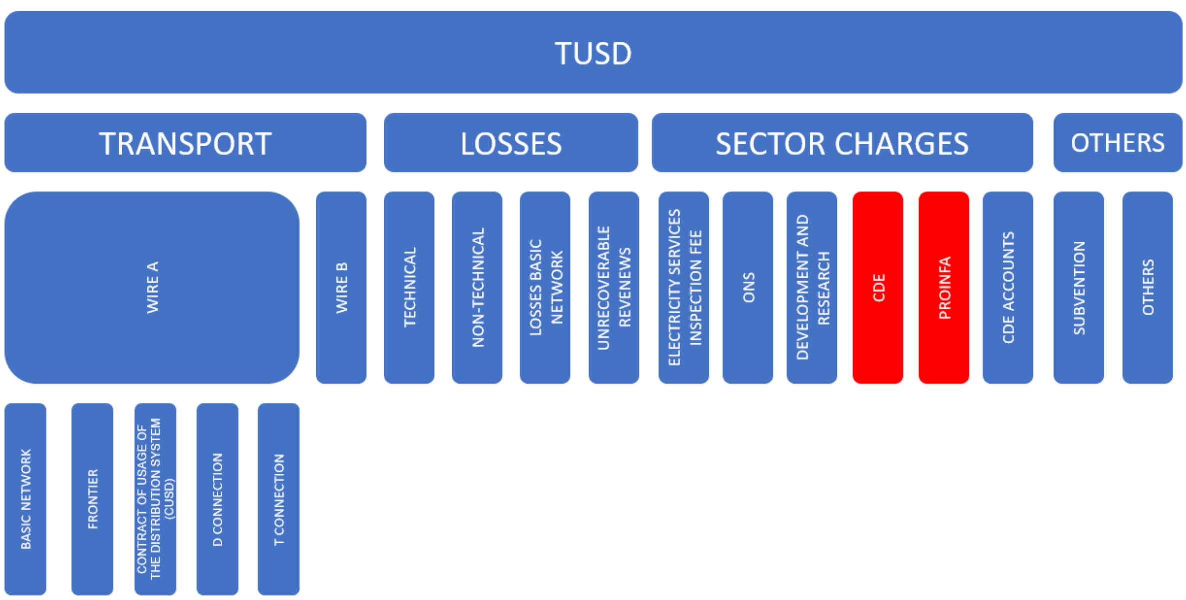
Figure 36 – Electricity Tariff Composition



Source: Adapted from ANEEL (2023d)

The TUSD tariff remunerates the distribution services and the transport component. This part of the tariff also pays for sector charges costs, such as CDE and PROINFA (for more information, see section 5.2.1), as highlighted on figure 37. It is through CDE that incentivized sources subsidies, explained on session 5.2.2 are paid.

Figure 37 – TUSD Tariff Composition



Source: Adapted from ANEEL (2023d)

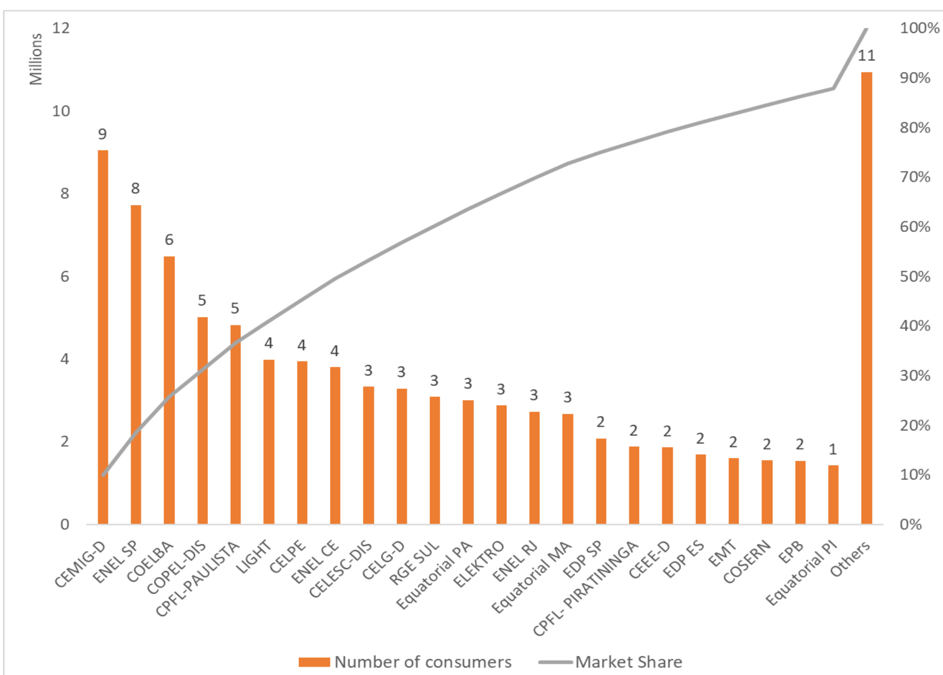
6.2 ENEL SP – CASE STUDY

This thesis analyzed tariff composition in Enel São Paulo (before called Eletropaulo), one of the largest distribution companies in Brazil. According to ANEEL (2023b), in 2023, Enel SP had the second greatest market share in Brazil, in number of consumers, with around 9% of total Brazilian captive market, almost 8 million consumers (see figure 38).

Figures 39 shows CDE costs from 2013 to 2023 and the subsidies in it. In 2022, total subsidies granted summed up USD 6.77 billion, whereas incentivized sources accounted for around USD 1.6 billion, or approximately 24% of CDE's costs (ANEEL, [2023]a).

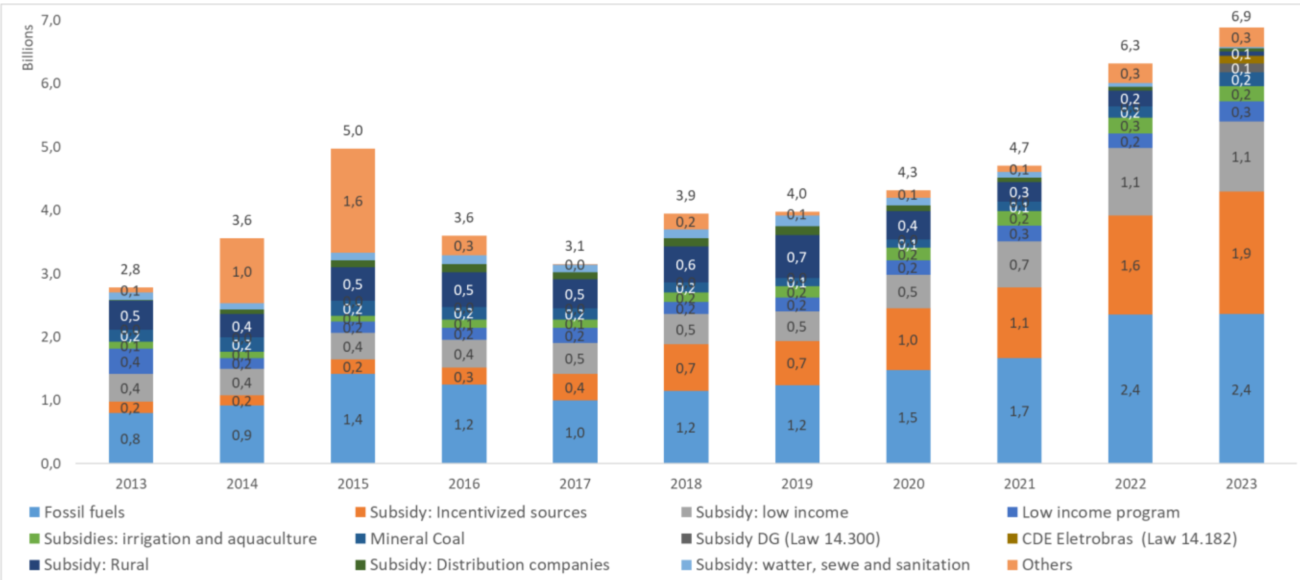
Figure 40 shows all the subsidies included in Enel SP tariffs from 2018 to 2023. Incentivized sources subsidies are the biggest, accounting for almost 56% of the total subsidies of around USD 73.8 million in 2022 (ANEEL, [2023]b).

Figure 38 - Brazilian distribution companies' market share



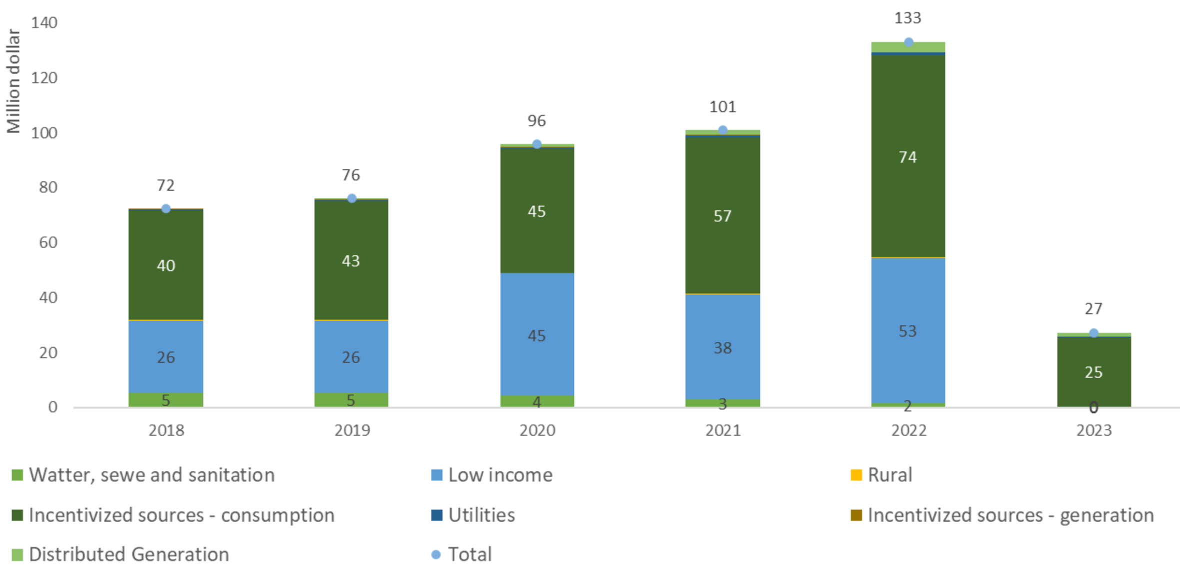
Source: ANEEL ([2023]b)

Figure 39 - CDE's costs in dollars



Source: the author, with data from ANEEL ([2023]a)

Figure 40 - Subsidies in ENEL SP's tariff, in dollars



Source: the author, with data from ANEEL ([2023]b)

In this study, data from ANEEL were collected for the years of 2018, 2019 and 2020, to understand how much subsidies for incentivized energy costed for consumers who did not receive this benefit. Tariffs in Brazil are different according to consumer group, subgroup, class and modality, explained in section 6.1.

The author selected Residential Consumers for this calculation because they are connected to the grid in low voltage, with the highest tariffs. They are not able to select their own supply and negotiate electricity prices, and must pay it for the distribution company, whose tariff is regulated by ANEEL (2018, 2019, 2020).

In 2018, CDE's budget for ENEL SP was USD 380.8 million. Total subsidies, including low-income consumers, was around USD 90 million. Incentivized source subsidies for this year were approximately USD 58.7 million, or 15% of total CDE's budget. This cost is shared among consumers category, in a different ratio, which is shown on table 17. According to this ratio, low voltage consumers (BT) will always pay a bigger part of CDE's budget. For example, in 2023, while low voltage consumers will pay 1 part of CDE's budget, high voltage consumers will pay 0.57 and medium voltage consumers 0.82. Those ratios difference will increase in the next years, leaving a greatest part of CDE for low voltage consumers (ANEEL, 2023c).

To calculate each consumer category tariff, the utility estimates the market for the next tariff cycle (twelve months after the tariff adjustment), using consumption data from twelve months before its tariff adjustment, for every consumer class. In this study, Residential Consumer (B1 – conventional) market was 15.1 TWh for 2018, 15.2 TWh for 2019 and 14.8 TWh for 2020.

CDE tariff for the studied consumer category in 2018 was established at USD 9.52/MWh. Therefore, this class of consumers paid USD 143.6 million in 2018 tariff cycle, or 38% of total CDE's budget for ENEL SP. In 2019, CDE tariff was settled at USD 14.06/MWh with a total of USD 213.4 million paid by these consumers (38% of total CDE's costs). In 2020, this tariff was USD 12.8/MWh, totalizing an account of USD 188.7 million, or 40% of total CDE's costs.

Table 17 – CDE's reference tariffs

Year	CDE's reference trajectory			
	(South, Southeast and Midwest)/(North and Northeast)	High voltage / low voltage	Medium voltage / low voltage	Low voltage
2016	4.53	1.00	1.00	1.00
2017	4.07	0.92	0.97	1.00
2018	3.65	0.85	0.94	1.00
2019	3.28	0.79	0.92	1.00
2020	2.94	0.73	0.89	1.00
2021	2.64	0.67	0.87	1.00
2022	2.37	0.62	0.84	1.00
2023	2.13	0.57	0.82	1.00
2024	1.91	0.53	0.80	1.00
2025	1.72	0.49	0.77	1.00
2026	1.54	0.45	0.75	1.00
2027	1.38	0.42	0.73	1.00
2028	1.24	0.39	0.71	1.00
2029	1.11	0.36	0.69	1.00
2030	1.00	0.33	0.67	1.00

Source: the author, based on ANEEL (2023c)

Total subsidies for incentivized sources accounted 15%, 10% and 10% of ENEL SP CDE's budget, respectively in the studied period. Using the percentage of 38% for the first two years of the study and 40% for the last one, representing the amount Residential Consumers paid for CDE, it was estimated how much they pay for Incentivized Sources Subsidies, as the calculation shown in the Table 18.

In the studied period, distribution tariff for Residential Consumer was set at USD 73.69/MWh, USD 64.43/MWh and USD 54.95/MWh, in this order. The author reaches the conclusion that by paying for this subsidy, those consumers had their tariff increased by USD 1.47/MWh in 2018, USD 1.35/MWh in 2019 and USD 1.29/MWh in 2020, which represents 2.7%, 2.09% and 2.35% of this tariff, respectively.

Table 18 – Incentivized subsidies calculation

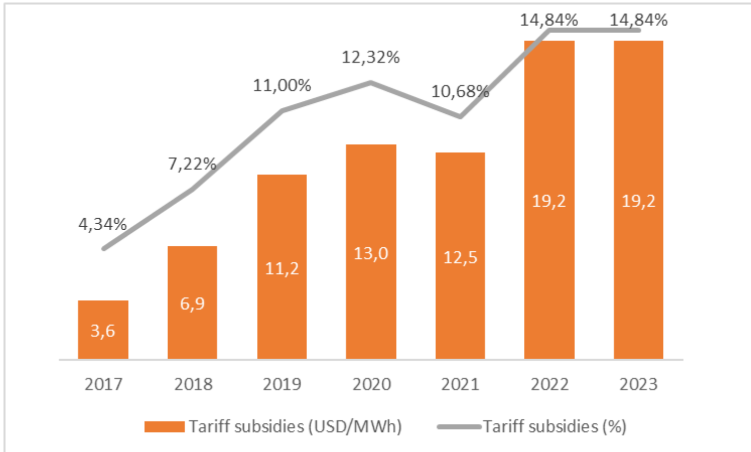
Enel SP Tariff structure	2018		2019		2020	
	Total	B1 – Residential Convetional	Total	B1 – Residential Convetional	Total	B1 – Residential Convetional
(1) Annual Market (MM MWh)	136.12	15.09	138.68	15.18	135.89	14.75
(2) CDE Budget (MM $/year)	380.85[11]	143.62	555.62[12]	213.41	468.64[13]	188.72
(3) Incentivized sources subsidies (MM $/year)	58.71	22.14	53.20	20.43	47.28	19.04
(4) Sector charges ($/MWh)	-	73.69	-	64.43	-	54.95
(5) CDE Tariff ($/MWh) – (2)/(1)	-	9.52	-	14.06	-	12.80
(6) Incentivized sources subsidies ($/MWh) – (3)/(1)	-	1.47	-	1.35	-	1.29
(7) Percentual paid by consumers of subsidies – (6)/(4)	-	2.67%	-	2.09%	-	2.35%

Source: the author, data from ANEEL (2018, 2019, 2020)

ANEEL ([2023]b) calculates how much subsidies represents on residential consumers tariff. In 2023, total subsidies represented almost 15% of Enel SP residential consumer's bill, equivalent to USD 19.2/MWh. The incentivized source represented 3.77%, the second largest value. This number have been increasing in the past years, as demonstrated in figure 41. In Brazil, the average tariff for residential consumers is at USD 137.6/MWh in 2023, subsidies from incentivized sources accounted for 6.64% of total tariff and subsidies for distribution generation represented 1.2% of total tariff. Those subsidies represent an increase of USD 10.8/MWh on consumers average electricity tariff.

[11] Exchange rate 1 USD = BRL 3.8742 (December 31st, 2018).
[12] Exchange rate 1 USD = BRL 4.0307 (December 31st, 2019).
[13] Exchange rate 1 USD = BRL 5.1961 (December 31st, 2020).

Figure 41 – Subsidies share on Residential tariffs in Enel SP



Source: the author, based on ANEEL ([2023]b)

7 CONCLUSIONS

This thesis aimed to answer the following questions: is the replacement of renewable energy subsidies for certificates market a step in the right direction? Thus, the main objective of this research was to analyze the impact of renewable sources subsidies on electricity tariff and to discuss alternatives to promote these sources sustainable attributes. The secondary goal was to study subsidies and certificates policies and markets around the world.

Renewable energy sources had their capacity increased all over the world, since 2010, as demonstrated in figure 21, on section 3.3.1. They used to be more expensive sources, so many countries adopted subsidies to promote their expansion. Since technology has evolved, their prices went significantly down and since 2018 they are the cheapest new build capacity in the world (see figure 23, on section 3.3.2). This thesis reviewed the subsidies policies in some countries: Austria, Netherlands, Portugal, Spain, Belgium, Germany, United Kingdom, and Australia, and how they were implemented and withdrawn when they were no longer necessary.

International experiences studied on chapter 4.1, showed that 135 countries had power regulatory policies in 2018, such as fiscal incentives, regulation, public financing, FIT, net metering, quotas, among many others to introduce those RES on their energy mix, but they had a specific duration and were withdrawn once the goal have been achieved. In 2017, renewable energy generation, have received around USD 128 billion in subsidies, around 20% of total subsidies granted global wise.

The case of Brazil was studied, which has a high percentage of RES in its mix. In 2022, RES generation represented 92% of total generation, according to information disclosed on chapter 3.2. Brazil began to withdraw RES subsidies for incentivized sources in 2021, as discussed on chapter 4.3. Also, distributed generation subsidies began to be withdrawn in 2022. In both cases, the subsidies will continue to impact consumer's tariff until around 2045 and 2050. The author did a rough estimative of incentivized sources subsidies for those new requests on section 4.3.2, that resulted in around USD 1.4 billion per year. Regarding distributed generation subsidies, it was pointed out on section 4.3.3

that the race for new requests may add USD 51.2 billion in subsidies in consumer's tariff up to 2045.

In order to understand the impacts that incentivized sources subsidies already caused on consumer's tariff, the author calculated how much residential consumers in Enel SP (one of the largest distribution companies in Brazil) paid for those subsidies. In the estimates on chapter 6.2, these subsidies represented 2.67%, 2.09% and 2.35% of their distribution tariff, in 2018, 2019 and 2020, respectively. This burden is carried by consumers who do not have other options for their consumption.

The weight of those subsidies is increasing on residential consumer's tariff. As stated on chapter 6.2, in 2023 residential consumers paid 6.64% of its bill for incentivized sources subsidies, and 1.2% for DG subsidies, on average.

The problem of high costs for emerging technology of RES has been surpassed since the technology became well known and cheaper. In Brazil, the last electricity auction held in 2022 had prices of around USD 34.2/MWh for wind sources and USD 33.7/MWh for solar PV sources, as informed on section 3.3.1. Meanwhile, generators receiving subsidies for these types of sources would have a different price in the market, for example generators with incentivized sources had a price of USD 46.4/MWh in April 2022, or USD 8.1/MWh above conventional sources (see chapter 4.3.2). Distributed generators may have prices of around USD 105.5/MWh (see section 4.3.3). In both cases, prices are above electricity auction, market prices and LCOE, for this reason, financial subsidies are no longer necessary to promote their development and construction.

Nevertheless, concerns about climate change are in evidence and governments and companies need to be responsible for their emissions. Glasgow Climate Pact in 2021, and most recent, the AR6 from IPCC, launched in the beginning of 2023, demonstrated serious concerns about NDCs announced from Paris Agreement member countries. Targets on the NDCs will not be enough to limit global warming under 2ºC above pre-industrial levels, according to the research done on chapter 2. Regulators need to step in and make policies towards global climate goals.

In Brazil, REC's market is voluntary, and it is being used by companies who have commitments towards a low carbon consumption, however the supply of certificates in voluntary market is much bigger than demand. Analyzing I-RECs voluntary markets, which are being traded at around USD 0.30/MWh, it can be concluded that RECs in Brazil still do not have economic impact on project to be considered a replacement over subsidies and spur RES expansion by itself. Policy makers might improve those mechanisms.

On section 2.3, carbon markets were studied. They used to be mandatory, and prices reached USD 35/tCO_2 between 2007 and 2008. The Article 6 of the Paris Agreement defines that a country could reduce more than its declared NDC and voluntarily transfer their mitigation outcomes to other countries, creating a voluntary emissions trading mechanism. With the rules of Article 6 have been settled, Voluntary Carbon Markets have grown faster in 2021, reaching a value of USD 2 billion, with near 500 million credits traded. Besides the number of credits issued, prices also went up from 2020 to 2021, around 60%, which added more value to this market. Renewable energy was the second biggest market, with a volume of 211.4 million credits and a value of USD 479.1 million. Prices for RES carbon credits were at USD 2.26/MWh, on average.

Voluntary REC and carbon market together might give additional revenue to investors to replace RES subsidies. It could keep spurring their growth and to allocate costs to polluting sources instead of residential consumers. Furthermore, to achieve NDC's goals for GHG emissions reduction until 2030, it will be necessary to implement a carbon price mechanism.

Besides, there are other incentives to sustainable projects like international initiatives to fund those projects, studied on section 4.2.2. For example, Chile established a framework for the emissions of Green Bonds by the government. The United States signed the Inflation Reduction Act of 2022, with the intention of significantly reducing the country's carbon emissions by the end of this decade, allocating roughly USD 400 billion in federal funds for clean energy. And the EU redirected around 41% of the RRF, approximately EUR 203 billion to fund action towards reducing GHG emissions.

In a nutshell, this thesis concludes that Brazil is following best international practices by switching subsidies for market mechanisms, like carbon credits trading, and doing this transition gradually and slow, eventually even excessively slow.

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