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SUPPLEMENTARY RENEWABLE ENERGIES



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Paulo César Fernandes da Cunha

Authors

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Lavinia Hollanda

Renata Hamilton de Ruiz

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Desktop Publishing

Bruno Masello and Carlos Quintanilha

bruno@bmmaisdesign.com.br



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Renata Hamilton de Ruiz

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PRAIA DE BOTAFOGO, 190, RIO DE JANEIRO - RJ - POSTAL CODE 22250-900 OR POSTAL BOX 62.591 - POSTAL CODE 22257-970 - TELEPHONE (21) 3799-5498 - WWW.FGV.BR

Institution of technical and scientific, educational, and charitable nature created on December 20, 1944 as a private legal entity with the purpose of fully acting in all scientific matters, and emphasizing in the field of social sciences: administration, law and economy, thus contributing to the country's social and economic development.

Supplementary Renewable Energies: Benefits and Challenges

Luciano Freire

The Brazilian potential for Supplementary Renewable Energies is enormous. We have excellent solar irradiation indices of centralized or distributed photovoltaic power generation, from Oiapoque to Chuí, from east to west, with greater intensity throughout the northeastern semi-arid region. Our winds are differentiated: constant, unidirectional and provide high productivity factors, as well as above to those found in Europe. The potential for power generation associated to sugarcane biomass, reforestation and wood waste, and there are thousands of small power plants located throughout the country.

As if the abundance was not enough, these sources are highly supplementary in several forms of seasonality. In the Southeast Region, for example, during the dry period in which

power production is reduced, sugarcane is harvested and therefore power is intensively produced with bagasse burning. Production of wind power in the Northeast is also supplementary during the dry period in the Southeast, because wind is more intense in that region. Finding regions where wind speed is greater in the evening with perfect daytime association photovoltaic solar generation is common in daily seasonality. There are several other forms of complementarity, which separate or combined, give the same time, flexibility and consistency in power production.

To leverage and color with sustainable reality all such benefits we will face enormous challenges: from the technology development,

through the break of paradigms in transmission and distribution power grids, and to a new regulation.

More than inevitable, the progress of renewable energy sources is desirable due to the many added benefits that can be synthesized in sustainable development where the social and economic growth is obtained preserving the environment for current and future generations. This journey involves the entire society: Government, institutions, economy sectors and citizens.

In this context, FGV Energia took the initiative to collect several perspectives on the theme starting with important concepts to understand the problem, going through the global and Brazilian outlook and to the dilemmas noted in the sector. Such an initiative shall contribute to start a debate intended to solve these dilemmas, forecast new challenges and seek robustness in our power sector model.

Luciano Freire - Director of Engineering at QG Energia. He was the former member of CCEE, works in the power distribution, generation and trade for over 25 years. Luciano is an electrical engineer graduated from PUC - MG and master in automation by UNICAMP.



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We also take this opportunity to express our gratitude to our colleagues at FGV Energia. The collaboration spirit improved by questions and differences are the basis for a broader and multidisciplinary perspective on the sector.

BRUNO MORENO R. DE FREITAS

Researcher FGV Energia

LAVINIA HOLLANDA

Coordinator of Research FGV Energia

PAULO CÉSAR FERNANDES DA CUNHA

Senior Consultant of FGV Energia

RENATA H. RUIZ

Researcher FGV Energia

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Executive Summary

- Electricity became essential for the activities of the modern society. Virtually any activity we perform requires electricity - or a form of power. However, from generation to consumption, the entire power production chain causes significant environmental impacts, as well as social and economic. The magnitude of such externalities will depend on the technologies we are using to generate electricity.
 - Since the moment the power matrix is being planned, from the definition of the percentage of each source in the energy mix, other possible grids are being waived, with their opportunity costs. Therefore, the power matrix chosen must have the best return possible - not only financial and economic, but also social and environmental - inside a limited options chain.
 - Choosing to include alternative sources indicates a lower social and environmental impact matrix; however, it will also have an economic repercussion. Alternative sources as wind, solar, biomass and PCH are known for being able to reduce the emission of greenhouse gas - GHG, as well as to prevent the removal of populations and impacts on soil use. However, the higher costs of such sources in relation to traditional sources, increased operation complexity and eventual transaction costs associated to the need of changes in current regulatory and business models of the sector bring important challenges to be overcome.
-

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- The Brazilian power matrix is recognized as renewable because it was built mainly based on hydraulic generation. Over the years, fossil thermal and nuclear sources were introduced in the matrix, leading to a hydrothermal matrix, with majority flow and on the basis of hydraulic source and complementary thermal flow. With the dissemination of concepts related to sustainability included in the political agenda of several countries - and also due to water difficulties faced in the last years - the Brazilian power matrix needs to be renovated and diversified. It becomes even more relevant in this scenario to discuss about possible impacts and dilemmas from an inexorable transformation of the Brazilian electric mix.
 - From this scenario, **FGV Energia** brings another publication: FGV Energia Supplementary Renewable Energies Booklet - FRE. The purpose of the Booklet is to bring a vision on the theme, noting possible impacts of including FRE in the matrix and the system, and to promote discussions about the theme. We will introduce some concepts, as well as a brief description of technologies comprising such new sources in the first chapter. In the second chapter, we will address the global and Brazilian scene, reporting the current inclusion stage in major world markets. In the third and last chapter, we will address some of the dilemmas that need to be discussed and faced in order to achieve a sustainable energy mix.
-



Initial Concepts

The so-called **conventional power sources**¹ already present a very high competitiveness level due to past technology advances. However, due to related discussions primarily related to environmental matters and energy independence and safety, new technologies were developed to supply power - **alternative sources** of power. All of these technologies have a characteristic in common: they use a **primary energy**² source considered renewable. The renewability of these sources occurs through their continuous cycles that will be repeated in relatively short periods of time - unlike fossil fuels used in the conventional generation, which have a period of formation of millions of years and are present in the nature in limited quantity.

Some renewable sources for the generation of power already exist in commercial scale such as wind, solar photovoltaic, biomass thermal and mainly hydraulic. Large hydraulics usually have regularization reservoirs, being called controllable power plants. New arrangements of

large power plants are being designed without regularization reservoir (run-of-river) in order to reduce flooded areas and environmental impacts. Some smaller power plants with low environmental impact can be classified as Small Power Plants

-
1. In this publication, fossil fuel and nuclear thermal and large power plants will be considered conventional power sources.
 2. Primary energy is any form of power available in the nature before being converted or transformed.

- PCH according to a few regulatory specifications that will be reported later. Within the **concept of renewable sources that will be addressed in this document, the so-called Supplementary Renewable Energies (FRE) only include PCH.**

Renewable sources have an intrinsic and common characteristic: they all present **variability**³ in the availability of energy resource. Variability is defined as the fluctuation in power or energy delivery presented by a source due to the energy resource availability - which may vary because of the weather, plant location and period of the year (or even the day). Wind and photovoltaic sources may undergo a sudden drop in power delivery due to reduced intensity in power resource. Thus, these sources are considered high variability FRE. In the case of PCH and biomass, the availability of the power resource is more constant at least for a time of the year - during the dry period, in the case of PCH, and in crops, for the case of biomass - then being considered low variability FRE.

Another aspect related to renewable generation is the **dispatchability**. A technology is implementable when it can be triggered when

the system operator requires. FRE are not considered dispatchable once they only start to operate when the power resource triggering the generation plant is available.⁴ The concept of dispatchable source also comprises a technology's **flexibility**. Such concept has two forms: (i) from a technical point of view, it happens when a source achieves optimal operation quickly (a few minutes) and can be turned on and off/reduced several times within a short time; or (ii) from the economic and financial point of view, for contract terms of fuel supply. That is, flexible sources can be used to better optimize the dispatch to meet the load. **Alternative renewable sources are considered variable and non-dispatchable and thus do not have a flexibility level.**⁵

Thus, these sources usually act supplementing conventional sources, which are dispatched on load basis - hence the term FRE.

There are several ways to reduce FRE variability. One of them would be through energy storage, which will be further detailed below. However, storage technologies still do not have economic feasibility. Today, developing these technologies is a major challenge for the industry of renewable power sources. On the other hand,

-
3. In the case of forest biomass thermal plants, depending on the project, they may provide steady energy to the system.
 4. Controllable, fossil thermal and nuclear power plants are considered dispatchable plants.
 5. Forest biomass thermal plants, depending on the project, may present dispatch possibility.

GHG emission levels in FRE generation are significantly lower than those of conventional thermal sources, and generate less waste and thus are technologies that have **low environmental impact**.

In addition, using these resources is also an advantage from the strategic point of view once they reduce the dependence on foreign fuels⁶ to generate electricity.

FRE TECHNOLOGY



SMALL CENTRAL POWER PLANTS (PCH)

PCHs do not have large reservoirs; therefore, their generation varies according to the period of rain. Its productivity depends on the available flow and water drop height - so the most favorable locations to install these plants are rivers with steep slopes. Its greater advantage is the greater simplicity in project design and implementation steps, and operation. Through Brazilian regulatory definition, PCHs installed power varies from 3 to 30 MW and their reservoirs have smaller areas than 13 km², excluding the channel of the regular riverbed.



WIND POWER

Wind power consists in turbines that convert kinetic wind power into electricity. Wind power is only available when wind speed reaches certain minimum and maximum levels, and generation varies depending on such speed. It is an extremely low operating cost source, almost zero, which means it is a priority in the system operator dispatch whenever it is available. However, its low predictability and high variability increase the uncertainty in generation. Wind parks installed dispersedly tend to present lower variability risks than a single park. Thus, countries where wind potential is spread have greater advantages exploring this source than countries with a limited geographic potential. Technology developments over the past two decades have improved this source's performance and equipment reliability, making the installation cost drop considerable and being already competitive in relation to conventional sources in places where wind conditions are favorable.



SOLAR POWER

Solar power is the most abundant source of power in the planet and can be reused through two different types of plants: (i) photovoltaic, which consists in photovoltaic panels installed in the same relatively large area, usually made of silicon, capable of converting sunlight directly into electricity; and (ii) heliotherm focused on electricity generation by heating a fluid and working similarly to a conventional thermal plant. Out of these two, photovoltaic technology is being proved as the most competitive one. In the global market, the cost of solar modules presented a 5-time reduction in the last 6 years and its expansion is being faster than expected. Despite the drop in prices, this source still needs incentive mechanisms to reach competitive levels. However, its operational cost, as in the wind energy, is almost zero. Therefore, this source should be always given dispatch priority when available. Solar power also has high variability varying the level of direct sun radiation, which changes due to the day of the years and place, and also instantaneous conditions as the presence of clouds.

CONTINUES ►

6. Pereira, Camacho, Freitas, & Silva, 2012.

FRE TECHNOLOGY



BIOMASS THERMAL

The main biomass advantages related to fossil fuels are in the low amount of toxic elements and the fact that the biomass has neutral GHG emissions. While biomass is being cultivated, atmosphere carbon is being stored due to the process of photosynthesis. When there is combustion of biomass the same carbon stored is released again, so that this cycle has neutral GHG emissions. The efficiency of this source is quite variable because the composition of the biomass depends on the raw material growth conditions. In general, the biomass has low energy density if compared to fossil fuels. However, this technical disadvantage is offset by the environmental gains provided by this source. But biomass cultivation for energy use is arguable' due to the confrontation with the agricultural and food industry. Thus, the trend is to have a power biomass use from by-products of other industrial processes as in the case of ethanol and sugar, through sugarcane bagasse.

STORAGE

As previously described, one of FRE major disadvantages is the fact that it does not guarantee continuous power supply for the system due to variability in renewable energy resources availability. Despite all the advantages related to environmental issues, energy independence and use of a low-cost energy resource, the variability of such sources may cause undesirable impacts in the operation of a system with high inclusion of FRE.

One of the factors that may reduce such impacts in the system is **energy storage**. From the point of view of a **centralized** system, the most common form to store energy - and with the lowest cost - is through

conventional power plants reservoirs. Depending on the design, the useful volume of these reservoirs can have multiannual regularization, which ensures good availability of hydroelectric power throughout the operating year.

Other technologies can be used for storage; however, at a lower scale and for small time intervals.⁷ These have the task of shaping the energy load to the instant demand curve; however, they are not yet used on a large scale in the world.

On the other hand, in a **distributed system** - in which electricity generation will also be in residences, shopping centers and industries, and not only power plants dispatched

7. The storage technology that most stands out for small time intervals is Pumped Hydro Power Plants that have two reservoirs (one upper and one lower), used for daily regularization. Other storage technologies are mainly several batteries and others still being tested.

by a central operator - energy storage may represent a change in the power sector paradigm. For presenting a modular nature, FRE (especially solar photovoltaic) have great potential to be an alternative generation source in the consumer unit close to the load center, without incurring power transmission costs. However, distributed generation was not fully established, mainly due to the high costs of

distributed storage technologies, making the consumer/generator unit still depend on centralized generation. **New and promising technologies are emerging in the market, with an interesting potential of costs reduction and that may promote an intense reorganization of the power sector in the world, as in the case of Tesla batteries.**

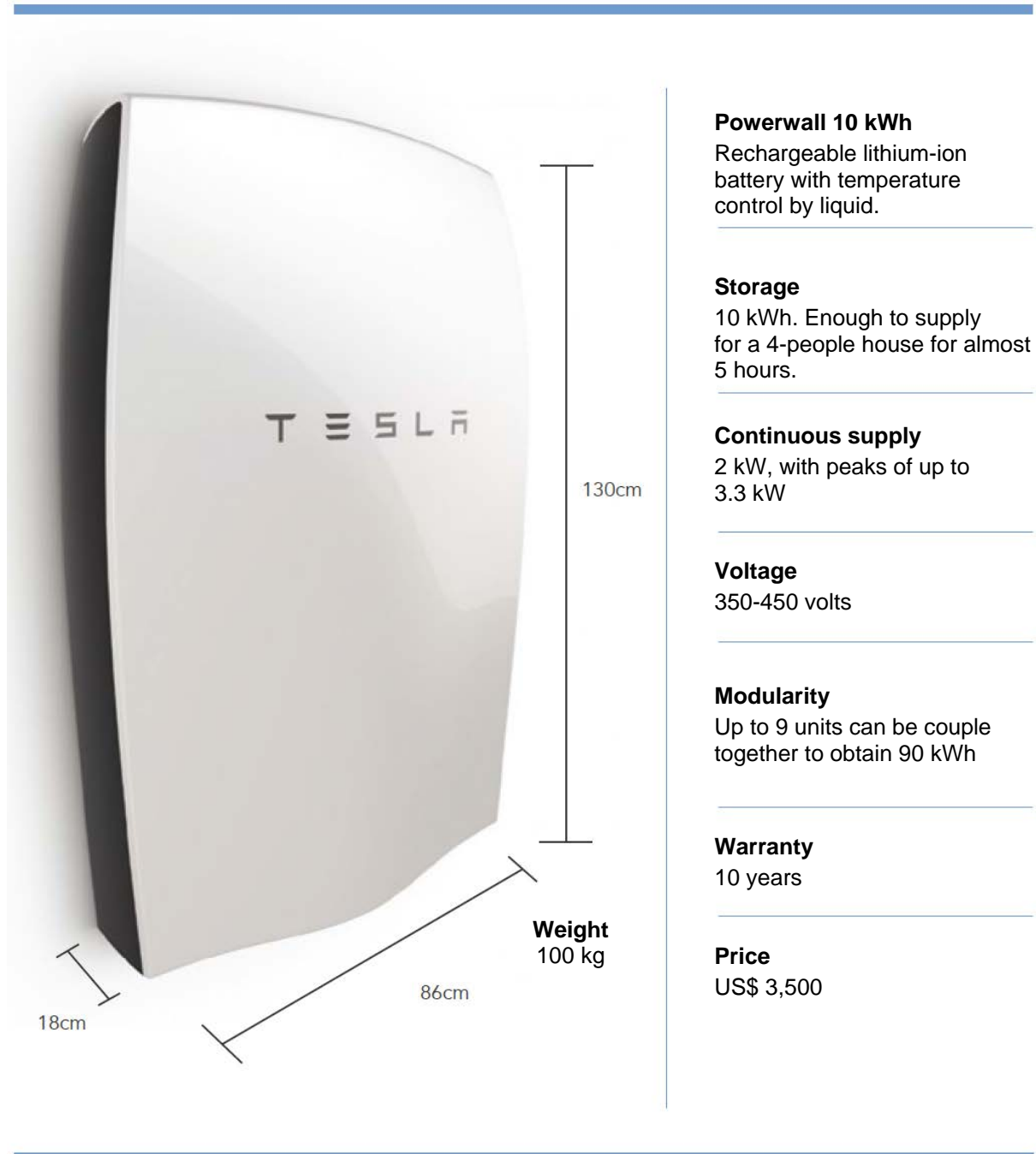
Distributed Storage Technology

Chemical batteries tend to be used for storage on a small scale. The American company Tesla Motors started to invest heavily in highly efficient lithium-ion batteries, with the initial aim of storing electricity in electric car engines. **However, this new technology may also be used in residences to storage distributed power.** This device is expected to allow FRE producing units to storage it during lower consumption periods and thus disconnect entirely from distribution networks - which would mean a major technological breakthrough in the current power sector model, in addition to being a great solution for remote locations.

Among the different types of batteries, the lithium-ion battery showed the largest decline in cost, from US\$ 2,000/kWh in 2009 to approximately US\$350/kWh. A rechargeable lithium-ion battery with 7 kWh capacity today costs approximately US\$ 3,000, while the model with capacity to 10 kWh (enough to supply for a 4-people house for nearly 5 hours) costs US\$ 3,500. Such price tends to drop even more after the inauguration of Gigafactory, expected for 2017. The Tesla plant, in partnership with Panasonic, received investment of US\$ 5 billion and is expected to increase total storage capacity for this type of technology to 35 GWh by 2020.

CONTINUES ►

FIGURE 1: TESLA MOTORS POWERWALL BATTERY



Source: Tesla, 2015

Transport and electric sector integration is also weighted in a medium and long-term scenario. Hybrid and electric vehicles promotion is thought of as the future of displacement, either to public or individual transport. New technologies, as hybrid and electric cars, are expected⁸ to become increasingly accessible and account for 60% of the domestic fleet in 2050, which shall reach 130 million vehicles. Electric cars will demand a specific infrastructure for supply and represent an energy consumption not yet quantified.

Power storage in electric vehicles may have a dual function: (i) store energy for transport, properly; (ii) store energy for other uses, even injection in the network for certain periods. To ensure electric vehicles represent a lower environmental impact than internal combustion vehicles, the power matrix must be clean and do not heavily depend on fossil fuels.

INCLUSION OF FRE

FRE growth started during the 90s and intensely accelerated in the 2000s.

In 2011, the FRE industry already moved USD 260 billion annually. The Renewable Energy

Policy Network for the 21st Century (REN21) study⁹ indicated that the main reasons for such scenario were:

- dissemination of Government incentive policies;
- increases conventional power costs;
- expressive reduction in FRE technology costs; and
- scale economies in production processes.

FRE inclusion in power matrices of several countries happened after overcoming many obstacles. In general, there is no single factor that have caused a positive impact in an isolated and significant way in FRE integration in a country. Instead, the association of several actions under different aspects - political, financial, tax, regulatory, technological and environmental¹⁰ is what determines the extent to which a renewable technology can be exploited.

POLITICAL AND REGULATORY ASPECTS

Historically, the promotion of FRE-based technologies is being made from

8. EPE, 2014.

9. REN 21 - Renewable Global Future Report, 2013.

10. Abdmouleh, Alammari, & Gastli, 2015.

Besides setting Energy Policy goals associated to the greater inclusion of FRE, softening regulatory issues by defining clear rules for the market is necessary

guidelines established by the governors of a country in their Energy Policy. Many assumed, for example, the inclusion of FRE in their matrices through GHG emission reduction goals or related to sustainable development. Others, for geopolitical matters, in order to stop having to import fuels for power generation.

However, in order to achieve expressive development of such sources, besides setting Energy Policy goals associated to the greater inclusion of FRE, softening regulatory issues by defining clear rules for the market is necessary. Thus, risks associated to projects are reduced, thus attracting the participation of different players.

The public interest to disseminate FRE also favors the introduction of financial incentive mechanisms so as to enable projects whose costs are not yet competitive, but considered interesting for the country due to its Energy Policy.

As a form of inducing investments risk, regulatory instruments are important to encourage the FRE market. Such instruments can be implemented through different mechanisms that can be generally classified in two categories: (i) energy purchase mechanisms; and (ii) mechanisms of access to the connection network. Arrangements in energy purchase mechanisms ensure that there will be market to acquire energy from a certain source. For mechanisms of access to the connection network, the regulation enables access of the generation system to the network, thus ensuring the flow of energy generated by the current system.

FINANCIAL AND TAX ASPECTS

FRE projects not only present a high initial investment compared to conventional sources, but are also of high risk due to the innovative technology and uncertainty in resources availability in some cases. Still, ERCs are

Regulatory Alternatives to Promote FRE

Feed-in-Tariffs (FIT): Energy purchase arrangements with fixed prices for electricity generated by FRE with long-term agreements (15-20 years) and purchase obligation of such power by utility companies. These prices are pre-established by the Government, usually above power prices of other conventional sources and vary according to the source of FRE.

Power auctions: Made to enable the contracting of a pre-determined amount of power under a long-term PPA¹¹ (15-30 years). Competition in the auction can be intrasource (in the case of specific auctions for each source) or intersources (when there is more than one source in the same auction). The auctions system encourages intrasource competition, making the best projects of each technology win the action and resulting in reduced significant costs for several technologies. On the other hand, in the case of auctions with different sources participating, FRE projects may not be as competitive with other technologies. However, compared to FIT auctions tend to provide less guarantees for developers mainly because of uncertain occurrence frequency and long periods between auctions.

Renewable Portfolio Standard (RPS): Regulatory term that requires supplier companies or group of power consumers to produce or use a certain part of their power from FRE.

Green Pricing Schemes: Consists in the payment of a voluntary premium by consumers to support the generation of FRE electricity.

Green Certificates: Certificate obtained to ensure the generation of a power unit from FRE, usually 1 MWh of electricity. Such certificates can be combined to achieve RPS and also promote a tool for trade between consumers and generators.

11. Power Purchase Agreement.



are usually lower scale technologies and their greatest potential lies precisely in smaller - and often decentralized projects. In this context, the role of the Government has been essential in the early stages of technology development, and also in commercial scale technologies' development.

Structures and conditions can be created to encourage initial incentives by financial entities in specific technologies. On

the financial side, incentives can be created as the fund with attractive rates and conditions, provided that the source is renewable. Other types would include market guarantee with purchase price that enable projects. On the fiscal side, incentives could be used in two ways: (i) exemption/reduction for FRE, which caused low social and environmental impact; and/or (ii) surcharge of conventional generation by such externalities.

TECHNOLOGICAL ASPECT

In early development stages, FRE needed to overcome technology and economic barriers, which can be accelerated through **public sector incentive and funding programs for R&D**. Such programs help to reduce capital and operating costs, improve the efficiency of these technologies and increase their reliability. Progresses in storage technologies and greater intelligence of the electrical systems in the world allows for a greater penetration of renewables without damaging energy safety. As they mature, technologies provide innovative options for policy, regulation and market.

ENVIRONMENTAL ASPECT

Air quality is being affected in several countries due to increased consumption of power mainly through fossil fuels. In fact, 84% of total emissions of

CO₂ and 64% of GHG emissions globally come from the power sector.¹² Thus, environmental concerns are being increasingly highlighted in the international scenario. With the diffusion of carbon footprint¹³ in the 90s, environmental pressure is being conducted in countries that have large amounts of carbon emissions as a result of power generation from coal thermal, fuel oil and natural gas.

ERCs are being included in the matrices of several countries. Technologies are being increasingly enhanced, thus causing an impact in generation plants' efficiency and reliability, as well as in power costs. To include these new technologies, several aspects equally important should be noted in order to make such inclusion efficient. Several countries already presented high levels of renewable participation, thus reducing emissions and diversifying their matrices. Brazil is also being positions with the annual contracting of thousands of FRE megawatts.

12. Abdmouleh, Alammari, & Gastli, 2015.

13. Carbon footprint measures the total quantity of greenhouse gas emissions caused directly or indirectly by a person, organization, event or product.



Outlook for Commercial FRE

Most countries have enacted policies to regulate and promote renewable sources in the power sector, influenced by the need to mitigate climatic changes, reduce the import of fossil fuels, develop more resilient and flexible power systems and create economic opportunities. Until 2014, the world had already installed 700 GW of capacity in renewable sources.

EUROPEAN UNION

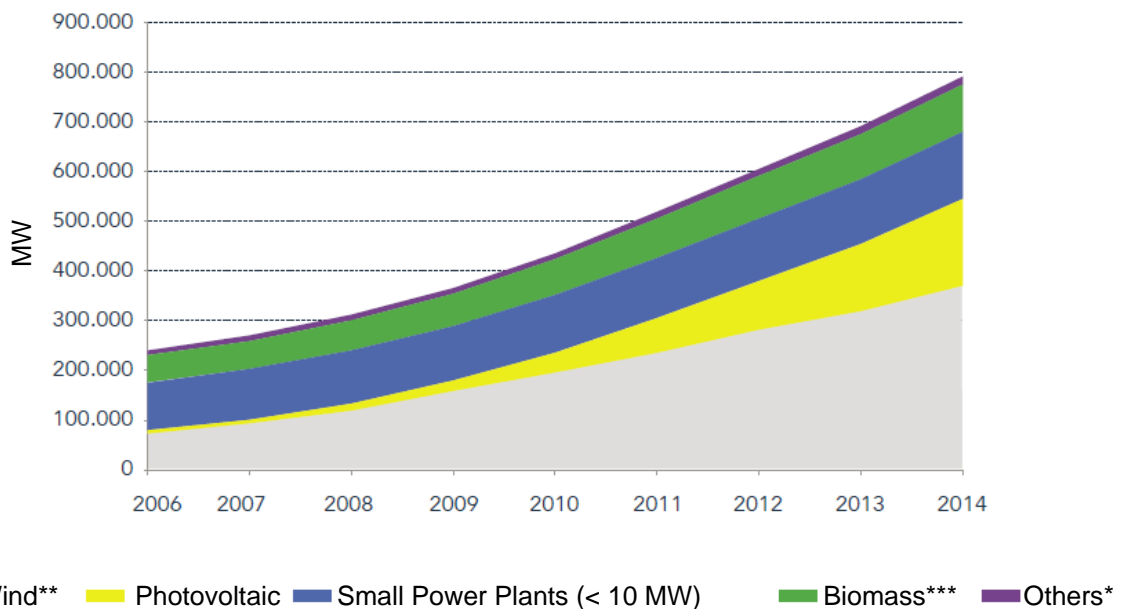
Mainly guided by socio-environmental and climatic matters, the European Union understood the need to formulate an effective strategy to change the power matrix in Member States since 1980. Several policies were

created gradually until today in order to include FRE generation participation in the EU, addressing regulation, technology aspects and financial incentives. Today, still motivated by its 20-20-20 policy in 2020¹⁴, some Member States of the EU stood out in relation to the installed capacity of FRE technologies as Germany.¹⁵

¹⁴. Goal of 20% reduction in GHG emissions to 1990 levels, increase for 20% of participation in energy consumption from renewable sources and increase in 20% of energy efficiency by 2020.

¹⁵. Ernst & Young, 2015.

CHART 1: INSTALLED CAPACITY OF SELECTED RENEWABLES IN THE WORLD, 2006-2014 (MW)



Source: Prepared by the author from IRENA data, 2015.

* Others - Tidal+Geothermal+Heliotherm

** Wind - Onshore+Offshore

*** Biomass - Solid Biomass+Renewable Waste+Biogas+Biofuels

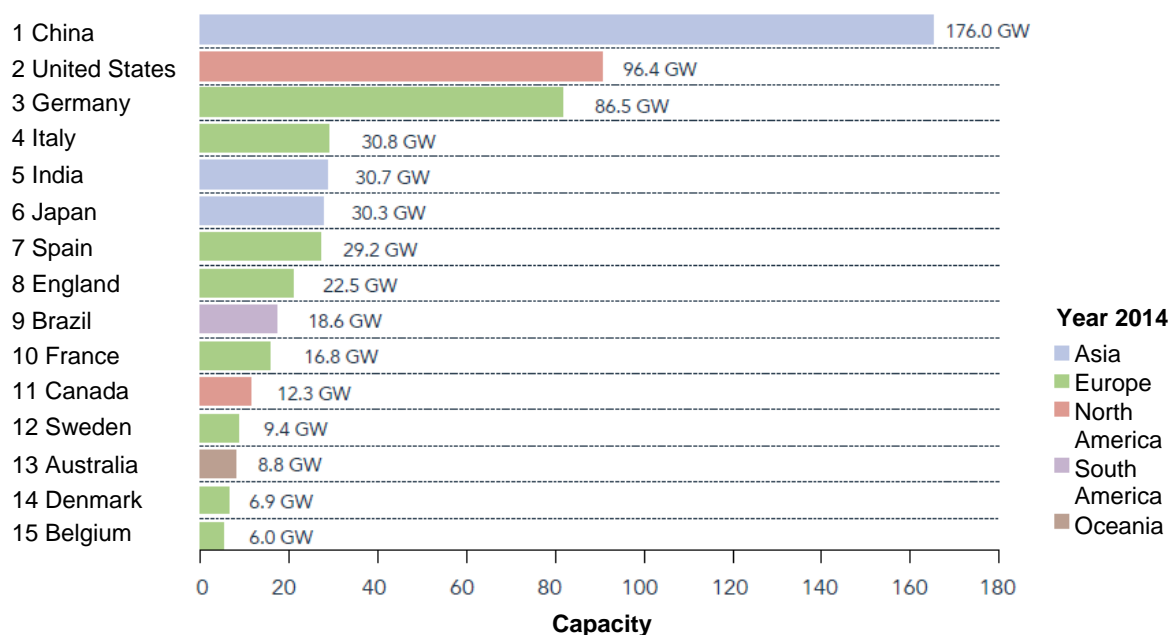
UNITED STATES

Due to the greater autonomy, several initiatives were adopted by different states in order to respond to the growth of popular interest in a renewable power matrix and less intensive in

carbon. In general, the implementation of such incentive policies is encouraged by diversification, decarbonization and decentralization¹⁶ pillars along with plans to reduce dependence on imported fuels

16. Carley, 2009.

CHART 2: INSTALLED CAPACITY OF FRE PER COUNTRY BY 2014



Source: Prepared by the author from IRENA data, 2015.

*Small + Wind Power Plants (Onshore and Offshore) + Biomass (Solid and Gas) + Photovoltaic

and improved energy safety. With the plan called New Energy for America¹⁷ for the first time in the USA, a positioning in the federal level encouraged FRE formerly inexistent. However, different movements of each state hinder the measuring of results of policies at

national scale. Despite this, the USA is considered one the most FRE attractive markets. This year (2015), the USA committed to establish FRE participation goals of at least 20% by 2030 along with Brazil.

17. Plan led by Barack Obama and Joe Biden to invest in renewable sources in order to reduce reliance on oil, mitigate the global climatic crises and create jobs for Americans.

TABLE 1: RANKING RENEWABLE ENERGY COUNTRY ATTRACTIVENESS INDEX (RECAI) OF FRE MARKETS ATTRACTIVENESS

Rank	Previous Rank	Market	RECAI Index	Specific Rank per Technology							
				Wind Onshore	Wind Offshore	Photovoltaic	Heliotherm	Biomass	Geothermal	Hydraulic	Sea
1	(1)	China	75.8	1	2	1	3	1	13	1	16
2	(2)	USA	73.4	2	8	2	1	2	1	3	9
3	(3)	Germany	66.5	3	3	5	27	8	8	10	27
4	(5)	India	64.1	5	16	4	5	15	14	6	11
5	(4)	Japan	63.0	14	9	3	26	3	3	4	10
6	(6)	Canada	60.4	4	12	11	23	13	18	5	6
7	(7)	France	59.0	9	7	7	27	9	15	15	5
8	(8)	United Kingdom	58.2	11	1	13	27	5	20	25	2
9	(9)	Brazil	57.0	6	25	10	8	4	32	2	24
10	(10)	Australia	56.2	19	19	9	9	20	11	24	12
11	(11)	Chile	55.6	25	22	6	2	21	10	17	14
12	(13)	The Netherlands	54.3	12	4	23	27	10	24	32	30
13	(15)	South Africa	54.0	18	28	8	4	33	35	18	19
14	(14)	Belgium	53.6	26	5	19	27	11	21	29	31
15	(12)	South Korea	52.3	23	14	12	24	12	28	16	3
16	(16)	Italy	52.1	24	21	15	11	14	7	14	23
17	(18)	Turkey	52.0	10	24	26	14	34	6	9	20
18	(17)	Denmark	51.8	13	6	32	27	16	35	36	17
19	(20)	Sweden	51.4	8	11	36	27	7	26	12	13
20	(22)	Mexico	50.6	17	30	16	18	31	9	30	21

Source: Ernst & Young, 2015.

ASIA

The markets that most stand out in the advance of FRE in Asia are China, India and Japan. After enacting the Renewable Energies Act in 2005, China presented expressive growth in FRE offer and now is the greatest global market with approximately 180 GW installed. However, its power matrix remains predominantly thermal with a representative inclusion of coal. Encouraged by the diversification in its matrix and reduced local emission of pollutant gases, which have great impact in public health, China intends to increase the renewable participation in its matrix.

In India, FRE had a significant increase in participation in its power matrix and the country represents one of the largest global markets with great attractiveness. In 2008, the Federal Government launched the National Action Plan on Climate Change (NAPCC) consisting in 8 core missions, one of which is the Jawaharlal Nehru National Solar Mission (JNNSM). The greatest purpose of the solar mission was to achieve rate parity from solar technologies in 2022, with a 20 GW capacity - expected to increase to 100 GW by 2030 and 200 GW by 2050.

Japan has energy safety as its main purpose,

also presenting expressive goals to reduce GHG emissions. Nuclear expansion was rethought by its governors after Fukushima accident in 2011, but it is now being resumed. However, the scarcity of fossil energy resources makes Japan find an alternative in FRE being ranked 4 in the installed capacity ranking of these sources.

AFRICA

The North African region located in the sun belt, comprised by Morocco, Algeria, Tunisia, Libya and Egypt, have great physical potential for FRE development, particularly wind and solar sources. This region not only draws the attention of local Governments, but also Europe due to the geographic proximity and for already having an incipient possibility to interchange electricity between the continents. There is a strong current, represented by Desertec¹⁸ concept, spreading the existence of a robust transmediterranean system in a medium- or long-term horizon, thus promoting greater decarbonized electrical supply for Europe and a significant increase in FRE participation in these countries - now based on fossil fuels, especially natural gas. However, important geopolitical matters are preventing the feasibility of such projects.

18. Desertec Concept <http://www.desertec.org/>.

LATIN AMERICA

Over the last 20 years, the economy and power consumption average growth in Latin America was greater than global averages, and electricity production more than doubled from 1991 to 2001. This region is known for having the cleanest power generation matrix in the

world in terms of carbon intensity. Currently, small and large power generation represents nearly 50% of the power matrix in this region.

Fossil fuels with high environmental impact as fuel are being gradually replaced by natural gas and FRE have gained more prominence, representing 9% of current



Wind generation is promising with a total potential of 143 GW for towers 50 meters-high.

installed capacity in the continent. Ten countries (including Brazil) have official targets to increase FRE implementation. Chile established a goal to reduce GHG emissions in the power sector and intends to have 10% of its generation through FRE by 2024. Along with Mexico, the country has been achieving significant increases in solar and wind installed capacity. Uruguay is currently the continent country with the greatest development and foreign investments in FRE with the greatest wind per capita installed capacity in 2014. Brazil has also played an important role in this sense, mainly because it has 37% of Latin America installed capacity. This will be addressed below.

HOW IS BRAZIL NOW?

Brazil has several energy resources throughout its territory, and the renewables are the most available ones. The Brazilian hydroelectric potential is one of the greatest in the world, reaching 260 GW, out of which only 35% is being used mainly in the Southeast region. Wind generation is also promising with a total potential of 143 GW for towers 50 meters-high, mainly in the Northeast and South Brazilian regions. If measures are made at greater heights, this potential may reach 500 GW considering the latest technology advances. The quality of Brazilian winds is also something that draws the attention as they are constant and without major sudden bursts.

We are located in the sun belt of the planet. The place with the worst irradiation in Brazil has better indices than the best place in Germany, the country with the greatest solar power market in the world.

From biomass, the potential is closely linked to the sugar industry, with waste from sugarcane bagasse, whose production is mainly concentrated in the Southeast and Northeast. However, since the agricultural industry is highly relevant for the country's economy, Brazil also has potential to use other types of agricultural waste to generate power, if there is technology development for such. Lastly, solar power also has great potential since we are located in the sun belt of the planet. Solar irradiation throughout the Brazilian territory is interesting. As a comparison, the place with the worst irradiation in Brazil (the South) has better indices than the best place in Germany (also in the South), the country with the greatest solar power market in the world.

Brazil has one of the largest interconnected power systems in the world, the National

Interconnected System - SIN. It is comparable to the European interconnected system with extensive transmission networks connecting the four subsystems: SE/CO, S, NE and N. SIN was designed to use energy power throughout Brazil, thus making power reach these places in case one of them had availability and the other hadn't, and mitigating risks and stabilizing global energy costs.

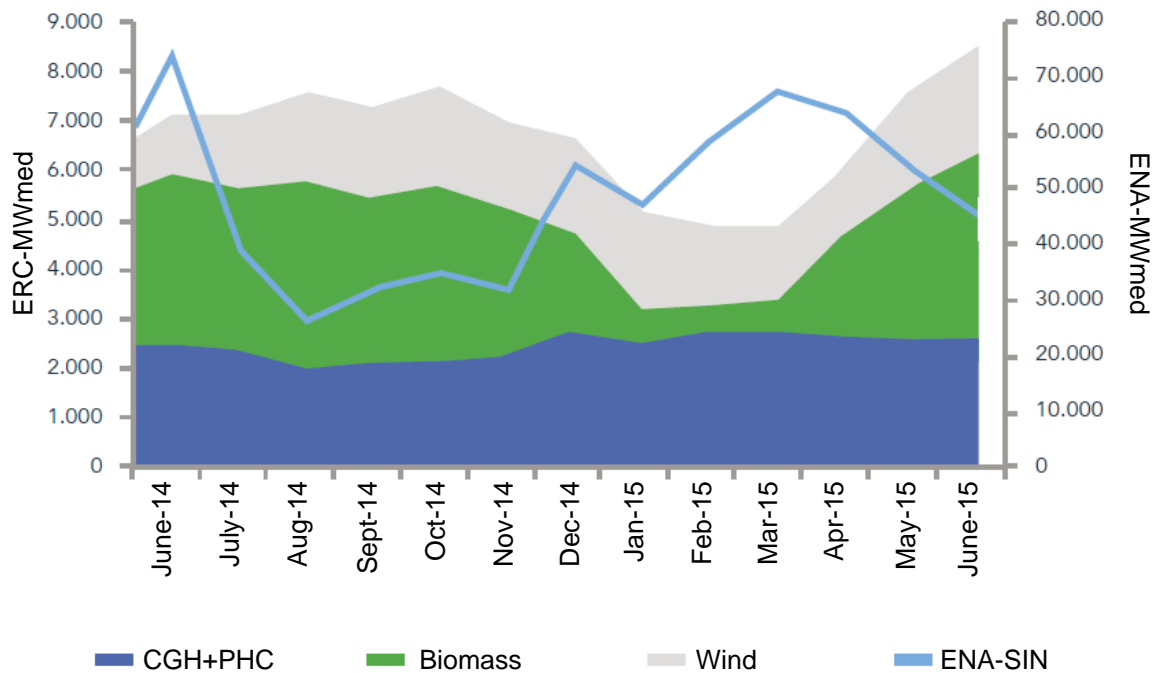
FRE availability in Brazil is supplementary to the hydroelectric regimen, especially in the Southeast, which has the greatest storage capacity. It is also supplementary to the SIN load especially concentrated in the Southeast. Wind generation reaches its peak in September/October when water availability is still not abundant in Brazil.¹⁹ Biomass generation, for being linked to

¹⁹ In Brazil, the wet period of the Southeast is during summer (November to February), while the dry period is in the winter (June to September).

the sugar sector, is more expressive from May to November due to the harvest period of sugarcane. Finally, solar generation happens more during summer due to higher heat stroke, precisely in the greater cooling demand period -

and most part of this demand occurs during the day. Such FRE strong complementarity with hydroelectric generation allow for a better use of the country's energy resources.

CHART 3: FRE GENERATION IN BRAZIL (MWAVE)²⁰



Source: Prepared by the author from CCEE data.

²⁰ ENA - Affluent Natural Energy is Energy that can be produced from natural inflows to reservoirs. Values are expressed in average MW or percentage of the long-term historic average MLT (history of 82 years).

PCH participation is also significant; however, its expansion has been restricted due to environmental matters.

After the 2001 rationing, it was noted the need to increase the offer of electricity with the expansion of other unconventional sources, in addition to hydrothermal dyad. To include electricity conversion technologies with renewable nature, the Federal Government launched the Program of Incentives for Alternative Sources - PROINFA, in 2002. The Program first established the expansion of 3.3 GW of installed capacity equally distributed among wind, biomass and PCH sources. Still, energy sale contracts would be entered into with Eletrobrás and generators for a 20-year period based on a reference value established by technology and set by the Ministry for Mines and Energy - that is, they would work as some kind of FiT. PROINFA is still in force and its costs are shared among all SIN consumers (except those benefited by the Social Rate). PROINFA is considered an important movement to include FRE in Brazil by sector agents.

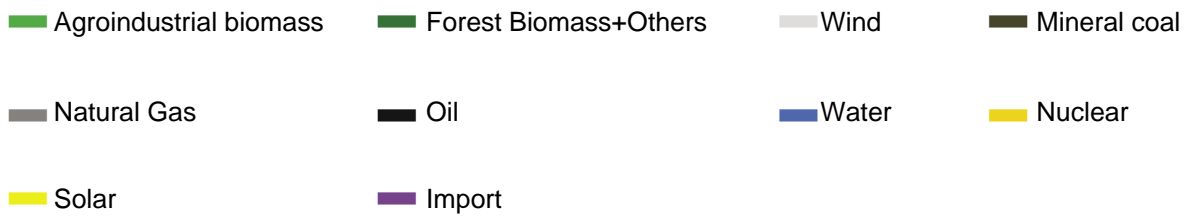
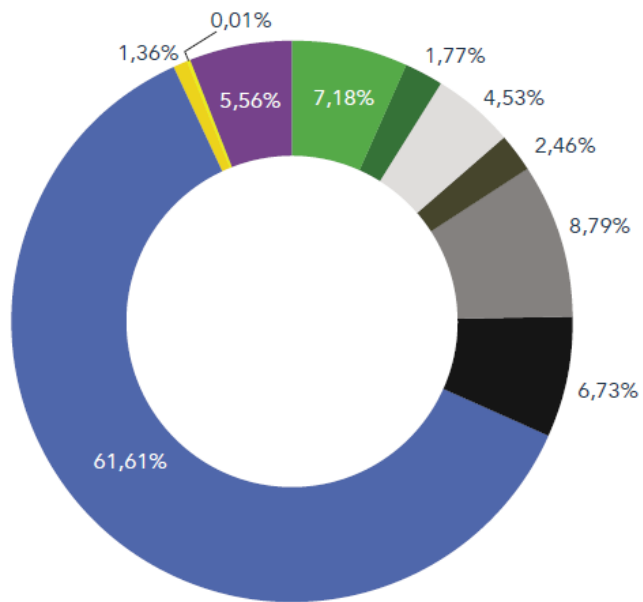
However, since the inclusion of FRE in auctions in 2009 (LER 2009), FRE has been expanded rapidly in Brazil, especially the wind source. Annually, dozens of wind parks projects won Federal generation auctions and today this source already represents over 7 GW of installed capacity in the country.²¹

Biomass is also important in fluctuating renewable energy generation. Today, it is the first FRE and the third source in SIN installed capacity²² with almost 13 GW installed, only behind the natural gas hydroelectric and thermal source. Many sugar plants had the opportunity to increase their cash flow, investing in combined heat and power plants that use process wastes as sugarcane bagasse to generate electricity. PCH participation is also significant; however, its expansion has been restricted due to environmental matters.

21. According to ABEEólica data (<http://www.portalabeeolica.org.br/>).

22. According to BIG/ANEEL data (<http://www.aneel.gov.br/aplicacoes/capacidadebrasil/capacidadebrasil.cfm>).

CHART 4 - INSTALLED CAPACITY PER SOURCE IN 2015



Source: Prepared by the author from ANEEL data.

The Brazilian market is one of the ten most attractive FRE markets in the world

Solar photovoltaic expansion is still incipient and started to be configured with micro and mini generation projects due to its modular nature, since 2012, with the enactment of Normative Resolution 482.²³ However, since 2014, the Government has been including solar source in power auctions to supply the regulated market. Several projects were enabled in Reserve Auctions 6 and 7²⁴ from solar source, thus exceeding 1.5 GW of installed power. The Brazilian market is one of the ten most attractive FRE markets in the world.²⁵

The Brazilian commitment to encourage FRE development and participation in the matrix is

not solely encouraged by energy safety reasons. Despite not having a quantitative commitment for the reduction of GHG emissions set, such as the countries in Attachment I²⁶ of the Kyoto Protocol,²⁷ Brazil has several other commitments in its National Program on Climate Change (PNMC) that will culminate in reduced emissions. Among the mitigating measures, PNMC²⁸ indicates that Brazil should:

“seek to maintain the renewable energy participation in the power matrix high, thus maintaining the stand out position Brazil always had in the international scenario”

23. In ANEEL Normative Resolution no. 482, dated April 17, 2012.

24. The Energy Reserve contracting mechanism was created to increase the safety of SIN electricity supply, with energy from plants especially contracted for this purpose - whether for new generation projects or existing projects.

25. Ernst & Young, 2015.

26. Attachment I is the group of developed countries whose responsibility for reduced GHG emissions is considered higher than developing countries. Countries are listed at http://unfccc.int/parties_and_observers/parties/annex_i/items/2774.php.

27. The Kyoto Protocol was signed in 1998 defining specific goals within the United Nations Framework Convention on Climate Change.

28. National Plan on Climate Change (<http://www.mma.gov.br/clima/politica-nacional-sobre-mudanca-do-clima/plano-nacional-sobre-mudanca-do-clima>).

Self-Production and FRE - Honda Case

Honda invested a total of R\$ 100 million in the construction of a wind park in order to become self-producer of energy. The project was framed within REIDI (Special Incentive Scheme for Infrastructure Development) and launched in November 26, 2014 in the city of Xangri-lá, State of Rio Grande do Sul, in order to supply for the entire Sumaré plant power demand in the State of São Paulo. This plant has a production capacity of 120 thousand cars per year.

Xangri-lá, in Rio Grande do Sul, was chosen to have the park installed since it already had a proper logistics and infrastructure scheme, in addition to a wind regime that favors power generation. The park has nine turbines of 3 MW each, totaling an installed capacity of 27 MW and annual generation estimated at 95 thousand MWh per year.

Honda's main reason for such an investment was to reduce GHG emissions. In order to increase sustainability in its production chain, the company established an emission reduction goal of 30% in all Honda plants in the world. In the case of Sumaré plant, this goal was exceeded and almost 50% of emissions are already avoided thanks to the use of wind power, which is equivalent to approximately 2.2 thousand tons of CO₂ avoided per year, according to information provided by Honda Energy, subsidiary responsible for power generation. Honda also has plans to supply other plants in Brazil with wind power.

Cars produced by the automaker in this plant receive a stamp, created by ABEEólica in partnership with ABRAGEL certifying that they were produced by 100% renewable sources. Initiatives like these are expected to be reproduced in other places by companies that seek to receive the certification seal.

This measure has been observed, given the rapid growth of FRE in the Brazilian matrix. FRE penetration, especially the wind, has been taking place mainly due to the power auctions scheme implemented in Brazil. Annually, the Government holds power generation auctions in order to promote energy contracting for the captive consumers market - the so-called Regulated Contracting Environment (ACR).²⁹ Since 2007, the Government already conducted 22 auctions with FRE contracting.

Self-production is another possibility for power acquisition, in which self-producers receive grant to produce their own energy and could eventually market the surplus of electric power generated. Some agents choose this type of generation, no longer depending on electricity

supply through the captive market or bilateral contracts for supply reaching some sort of independence in their consumption of electricity.

FRE are increasing their participation in the world electricity generation. The world already presents over 700 GW installed and each year with expected expansion and new incentive policies being adopted. Brazil is not getting behind. With a predominantly renewable power matrix, each year thousands of MW are added both to supply the regulated market through generation auctions, and to the free market. However, some dilemmas with the significant inclusion of FRE are emerging and will be discussed below.

29. There are two types of energy trade options in the Brazilian market: Regulated Contracting Environment - ACR, Free Contracting Environment - ACL. Most part of the power trade in Brazil is conducted through ACR.

30. ABDI, 2014.

Production Chain Development

PCH: Today, the national industry has manufacturers qualified to meet the internal PCH market providing almost all hydromechanics and electric components as gates, valves, turbines and generators. National manufacture covers virtually all micro, mini and small power plant central application fields. One of the matters that decrease PCH industry competitiveness is the customization of projects without having a standard, as in the case of wind plants that reduce scale gains.

Biomass: The biomass thermal plants components industry is almost 100% domestic. Brazil has manufacturers producing turbines, one of the components with highest added value, for average capacity biomass plants. Since most biomass plants are small or can be modulated with some medium turbines, the plants nationalization index is very high. Other components as boilers are also manufactured here.

Wind: Brazil has two major production poles for large components in the wind industry: in the Northeast and South/Southeast region. There are assemblers and manufactures of wind turbines, towers and blades, and most part of components they use are produced domestically. Until recently, importing almost all components was very common. However, in 2012, the Brazilian Bank for Economic and Social Development

- BNDES implemented incentives to develop the country's production chain in order to gradually increase the local content for the wind generation equipment industry. The availability and internal cost of steel is one of the bottlenecks in local supply.³⁰ Another important topic is the fact that part of components are imported, which makes local production feasibility depend on exchange.

Solar: There is an intense debate about whether Brazil should develop the national industry of photovoltaic panels or not, including the production of silicon cells, or whether it should only focus on the assembly and installation of modules. Brazil has one of the largest global reserves of silicon, a raw material for the production of commercial photovoltaic cells. However, cell production is a technology-intensive process, thus it is argued that Brazil would not have comparative advantage or conditions to perform this step.



Expansion Dilemmas

PLANNING, FINANCING OF EXPANSION AND COST OF POWER

PDE 2024 indicates an average growth of the economy from 3.2% p.y. between 2015 and 2024, compared to an expected global average growth of 3.8% p.y. in the same period. In this scenario, Brazilian electricity consumption will increase at an average rate of 3.9% p.y., which would result in an annual average increase of the electricity load at SIN of 2.9 GWave in a ten-year horizon (from the current 62 GWave to 91 GWave). In terms of power expansion, the maximum demand of power is expected to grow 3.8 GW per year, also in the same horizon.

According to the offer expansion planning, the hydroelectric expansion shall offer approximately 28 GW to SIN by 2027³¹ (almost 57% of the total) with emphasis for Belo Monte

and São Luiz do Tapajós projects with 11,233 and 8,040 MW of total power, respectively. Hydroelectric expansion shall occur mostly in the North of the country and through hydroelectric without regulation capacity. The fossil thermal growth shall add 10.5 GW to the system in the ten-year horizon, reaching 14.3% in matrix participation. PDE places natural gas as the main fuel for the expansion of the electricity thermal offer (10%). However, fossil thermal expansion will depend on having fuel at a competitive price for future auctions, which also represents a major uncertainty.

Regarding FRE offer expansion, PDE estimates it will go from the current 16.1% in power matrix participation to 27.3% in 2024, and shall mainly occur in the Brazilian Northeast region. This because the region has the highest wind and solar potential of the country. Expansion

31. Due to plants motorization, part of the capacity can only be added to the system after the ten-year horizon.

of wind source shall lead the renewable expansion since this source has been reaching competitive prices throughout its inclusion, since LER 2009, and shall contribute to 11.6% of the power matrix compared to the 3.7% in 2014. In turn, PCH should not achieve such competitiveness in auction projects and shall represent 3.8% (compared to 4.1% in 2014).

Biomass may have a 8.7% participation and its electricity offer potential may come in two ways in Brazil: through forest biomass or as by-product of the sugar industry using sugarcane bagasse as fuel - currently the most common offer in the country. Lastly, solar power may also have its expansion with great potential in the Northeast reaching 3.3% of the power matrix installed capacity - today close to zero. However, it is still a very incipient market in Brazil with only small³² and R&D projects implemented. Its inclusion in the SIN has been made through reserve auctions until now.

BNDES has been the main long-term funding agent for infrastructure investments in Brazil. The Bank has been an important instrument in the power sector to achieve the feasibility of

many projects, thus promoting attractive rates with high financing percentages for financeable items. The power sector has specific funding facilities for distribution, transmission and generation projects. Within generation projects, there is a division between renewable and non-renewable sources.

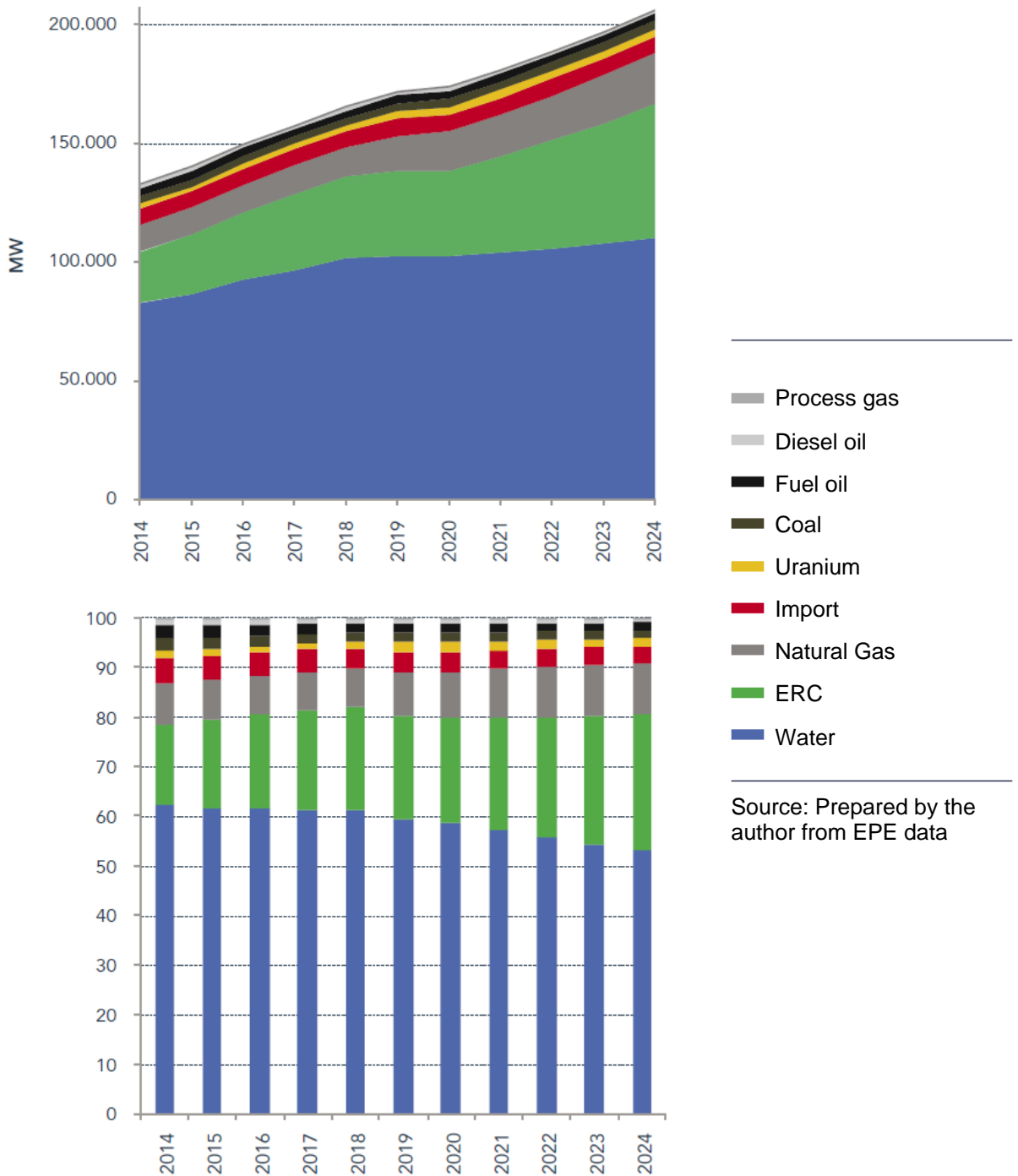
Funding rates are the same for renewable and non-renewable - the difference is the percentage of financeable items. Renewables reach 70% - except power plants of over 30 MW in which the percentage is 50% - while non-renewables have the limit of 70% only for Micro, Small and Medium Companies. Factors that most contribute to FRE projects' feasibility are maximum funding and amortization term, which have greater incentives for FRE, as well as attractive rates that make projects more competitive.

However, in the current Brazilian economic scenario, BNDES capacity to continue promoting FRE with as much attractive rates and conditions is uncertain. According to some news, BNDES has been restricting financing to 50% of FRE projects.³³

32. Mini and micro generation projects related to REN 482 and in World Cup stadiums.

33. Available at: http://www.canalenergia.com.br/zpublisher/materias/Investimentos_e_Financas.asp?id=107575. Access on: 10/21/2015.

CHART 5: EXPANSION OF GENERATION 2014-2024

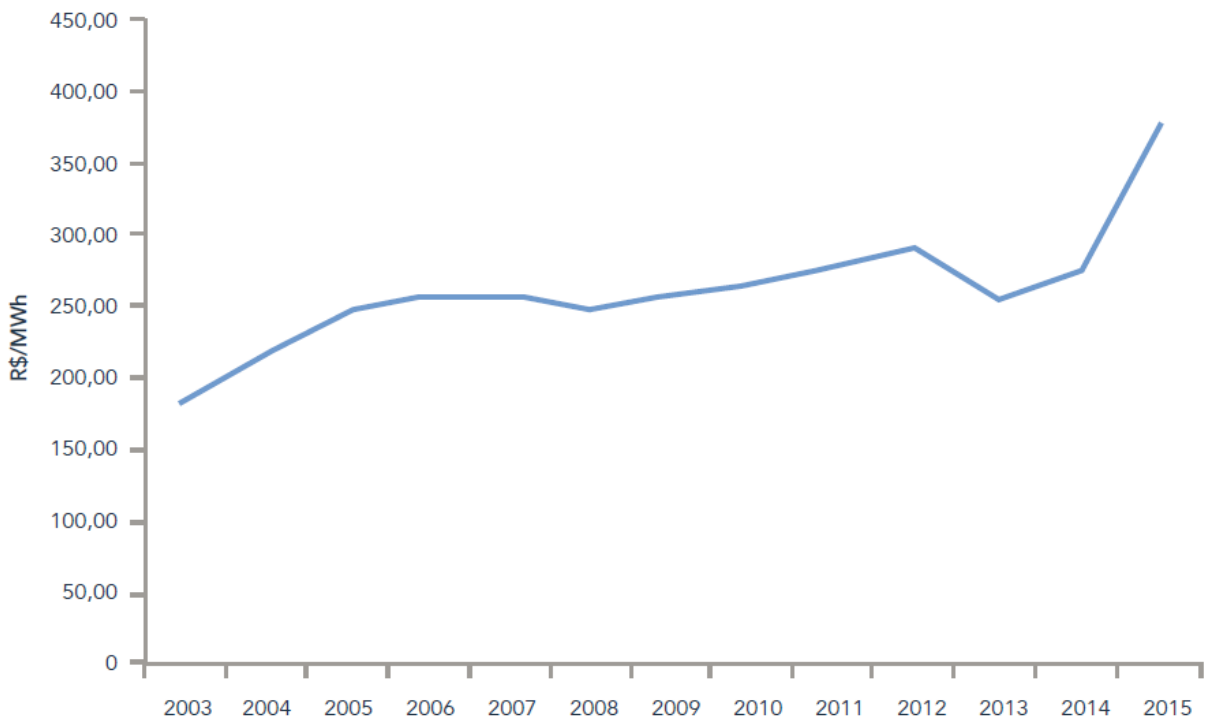


Source: Prepared by the author from EPE data

An alternative to increase the funded percentage are infrastructure debentures, which provide fiscal benefits and count on BNDES participation in their structuring. Investors trend in seeking supplementary funding mechanisms mainly with commercial banks is noted. Some of these already promote financial

support for renewable projects. However, interest rates and funding conditions are far from those offered by BNDES, which makes projects more expensive. Increased costs with funding will be reflected in the final power cost, and will end up causing an impact for consumers.

CHART 6: AVERAGE ANNUAL RATE OF ALL TYPES OF CONSUMERS - NOMINAL VALUES



Source: Prepared by the author from ANEEL data.

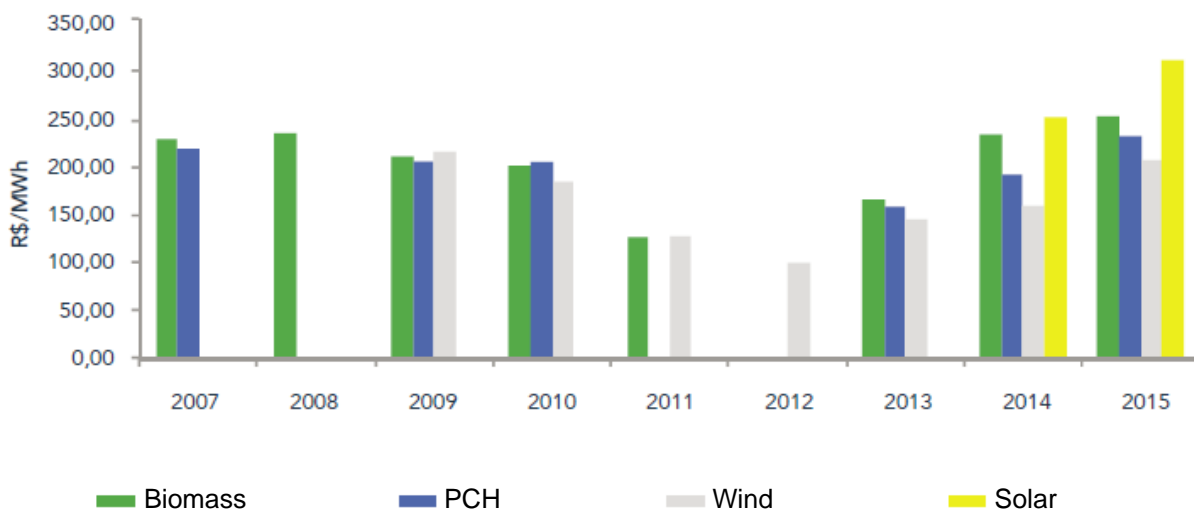
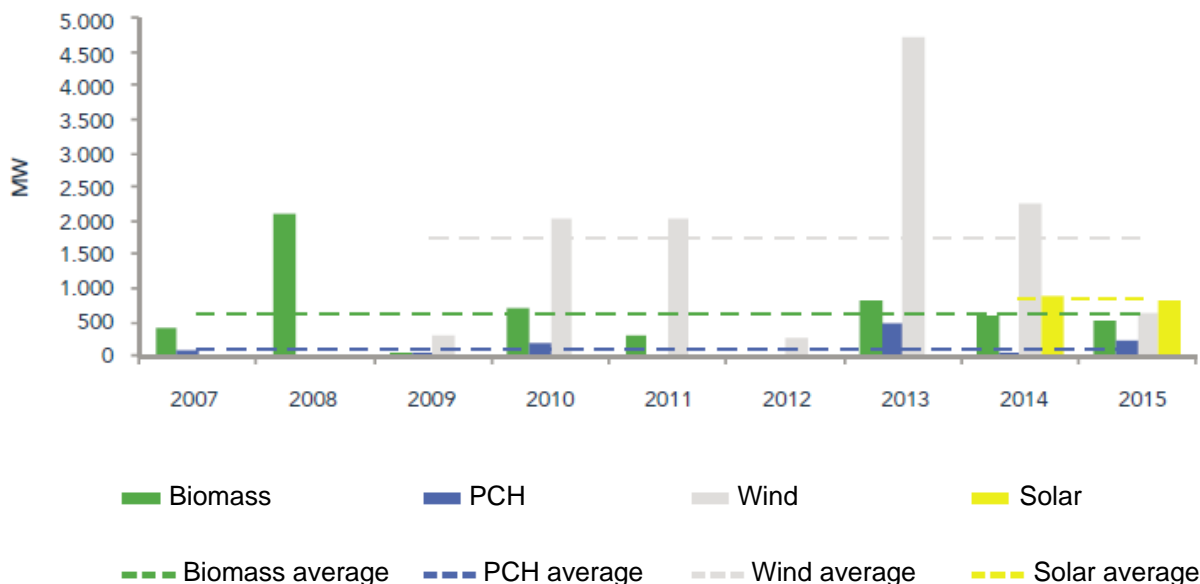


DIFFICULTY TO EXPAND PCH AND BIOMASS THERMAL PLANTS

Average contracting of FRE in auctions reaches approximately 2.5 GW per year, despite being very different for each source. If we count only after the year that had the first inclusion of the

source in an ACR auction, the wind has the higher average with approximately 2GW/year, while biomass had an average of 500 MW/year and PCH only 100 MW/year. The solar, which was included only in 2014, is already the second source with the highest average of annual contracting.

CHART 7: EVOLUTION OF CONTRACTED POWER AND ANNUAL AVERAGE PRICE CORRECTED IN ACR AUCTIONS WITH FRE



Source: Prepared by the author from CCEE and Acende Brasil Institute data. Monetary Adjustment IPCA (Sept./2015).

Biomass sugarcane power generation is strongly related to the sugar and ethanol market dynamics.

The causes for renewables expansion to be so different in ACR are questioned. One of the arguments addresses the fact that the ceiling price in auctions defined by EPE is not realistic for PCH and biomass, which makes many of the power contracts from PCH and biomass be performed in ACL. That is, there is a relative competitiveness difference between FRE and apparently wind has been showing better results among FRE. **What explains the lower competitiveness in PCH and biomass sources compared to wind?**

Biomass in Brazil is closely linked to the sugar sector, and electricity is generated through combined heat and power and is a by-product

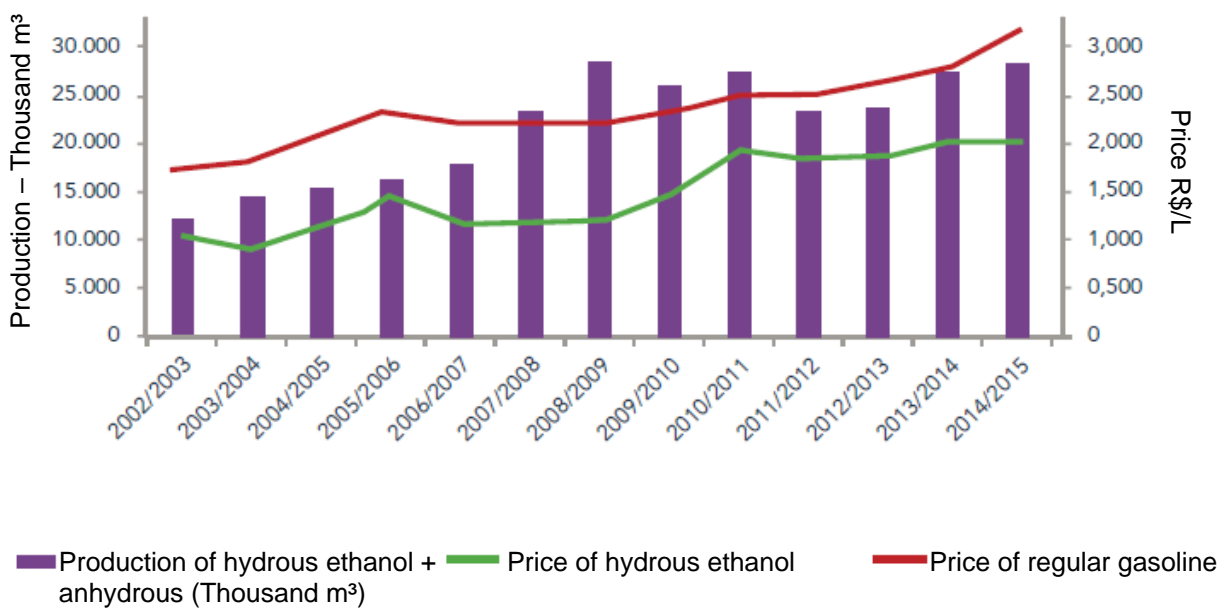
of sugar and ethanol production. Power generation is significantly higher when ethanol is produced - and lower when sugar is produced. **Thus, biomass sugarcane power generation is strongly related to the sugar and ethanol market dynamics.** Hydrated gasoline and ethanol compete in the liquid fuels market, being replaced products³⁴ - in general, ethanol is more advantageous for consumers when its price is 70% below the gasoline price. Since the price of gasoline was being controlled in refineries over the past years, this has influenced the ethanol/sugar market and made it less advantageous for producers to choose the production of ethanol. As a consequence, electricity generation was also threatened.

34. Anhydrous ethanol is blended with gasoline to lower fuel price, increase its octane rating and reduce emissions of pollutants.

Two factors may reduce the dependence of expanded power generation based on sugarcane on the fuels policy. The first one is linked to the technology development with a trend to use sugarcane straw thermo energy, previously disposed - not only bagasse - with the modernization of such plants, thus increasing the plant's efficiency. In addition, the alcohol market development, not only for the

vehicle fuels industry but also for biochemistry has potential to grow. A second and extremely important topic is related to a proper policy of relative prices between fuels allowing greater transparency in the liquid fuels and other energies market. Damming the prices of gasoline in refineries had crucial impact in the ethanol market, thus affecting the feasibility of biomass projects.

CHART 8: TOTAL ETHANOL PRODUCTION AND ANNUAL AVERAGE PRICES OF GASOLINE AND ETHANOL



Source: Prepared by the author from ANP data.

Wind source has reached a greater competitiveness level than other FRE over the years.

Among the four FRE sources present in Brazil, PCH have the lower annual hiring average of installed capacity in ACR auctions. Some facts are relevant and cause a great impact on the sector. The first one is regarding **difficulties with environmental licensing**. Since its implementation often takes place in rivers that usually are not federal, licensing for such projects is granted by State environmental agencies and, eventually, municipal. It is estimated³⁵ that the technical staff responsible for licensing such bodies is reduced and overloaded, thus hindering the release of projects that need their Prior Licenses³⁶ to enroll in ACR auctions.

Throughout over 10 years of ACR auctions with inclusion of FRE, several PCH projects almost

10 GW³⁷, are waiting a technical analysis and are not authorized to participation in auctions. Because of this, projects risk increases significantly and **affects costs and prices of power to be offered in auctions**. With this, **ceiling prices of ACR auctions for PCH end up not enabling such projects mainly because of the risks associated to environmental licensing**.

FRE expansion is unbalanced with a bias for wind contracting. In fact, the wind source has reached a greater competitiveness level than other FRE over the years. Some obstacles pointed to other sources certainly hamper the feasibility of projects that could be part of our power matrix and provide clean and renewable energy to the system.

35. ABRAPCH, 2015.

36. First in the licenses chain in the environmental licensing process in Brazil.

37. ABRAPCH, 2015.

Operation Dilemmas

ERCS AND THE ROLE OF REGULARIZATION RESERVOIRS

With a new matrix being characterized from a significant inclusion of variable sources, as in the case of FRE and run-of-river plants, the system operation will become more complex. Variability in sources increases uncertainty related to the energy resource availability, which causes investments in alternatives to cope with such variability. Still, there is a difference between **power variability** and **energy variability**. Power variability refers to the idea of instantaneous generation and is linked to a very short time period. Energy variability has a medium-long-term nature. Both problems should be faced in a different way.

Power variability is seen in wind and solar photovoltaic sources. Wind may stop blowing in minutes, thus reducing turbine speed and a passing cloud can increase the effect of shading on the photovoltaic panels, sharply reducing the delivery of power. This can cause instability on the network. **How to mitigate**

power variability in these sources for the system?

Since there is a set of parks with the same source concentrated in the same area, connecting them in the same point of the basic network is a possibility, thus making total generation of the set of parks become less variable than that of each park connected separately to the network. A second possibility would be through the hybridization of plants using the same point of connection to the system. For example, for the Brazilian case, which has greater wind and solar potential in the Northeast region, if a photovoltaic plant and a wind one were allocated in the same site it could mitigate power variability, if the wind regime was supplementary to solar generation - as in the case of the Northeast. Besides, hybridization may include other types of technologies - the Brazilian Northeast also has biomass generation potential, which could be used in case of low wind and solar availability at the same time. Lastly,



inclusion of energy storage through batteries could also be used; however, they still have an elevated price.

In addition to hybridization and connection at the same point of the network, the expansion of flexible plants in the system is essential to cope with power variability of wind and solar sources. Flexible sources are represented by controllable power plants and modern thermal plants with source charge or fast starting time that generally use natural gas. Other issues as the improvement of methods and tools to estimate wind and wind generation, and the improvement of wind turbines and wind and solar plants performance to withstand impacts on the network would also help mitigating these

variations.

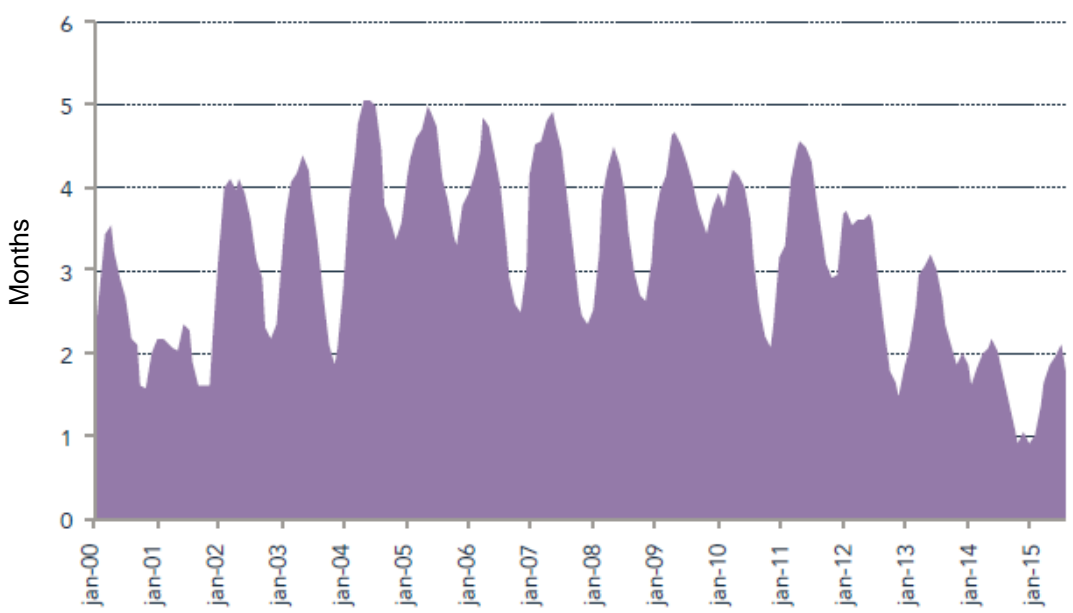
All types of FRE present variability in power generation. However, FRE and the system hydrological regime are complementary to each other in a way. The new arrangement of large run-of-river power plants - that is, also variable and not dispatchable that sum approximately 30 GW - will promote a great power variability to the system in the wet period. In addition, other sources as fossil thermal and nuclear may act as supplementary. At first, regarding the technology to be used, the power variability problem is less complex than power variability. However, other matters related to energy planning may arise with an strategic and political nature hard to solve.

Controllable hydroelectric expansion with reservoirs have a restriction and will be well reduced - 885 MW out of 30 GW expected for hydroelectric expansion will have regularization reservoir. The expansion of storable energy will be 2.6 MWave and represents less than 1% of the total storable power by 2015. **What will be the role of reservoirs in the system with FRE inclusion?**

If controllable power plants are intended to cope with FRE power variability, the sector

paradigm will be changed. Hydroelectric dispatch has always been made based on load, mainly because it is the cheapest power source in the system and for having rate mode as one of the pillars in the power sector model. With the current records of stored energy compared to system load, we note a reduced capacity of regularization evidencing a trend of reconfiguring the role of reservoirs in the system. Thermal dispatch may become the system's basis, at least during some time in the operating year.

CHART 9: EQUIVALENT SUPPLY MONTHS



Source: Prepared by the author from ONS data.

One of the ways to achieve emissions reduction goals and have rate mode, as well as to act reliably and safely in supply would be through the expansion of controllable power plants

However, if the role of reservoirs continues to be for dispatch on load basis, other sources with high flexibility to cope with FRE power variability should be implemented being represented by modern fossil thermal, usually of natural gas.

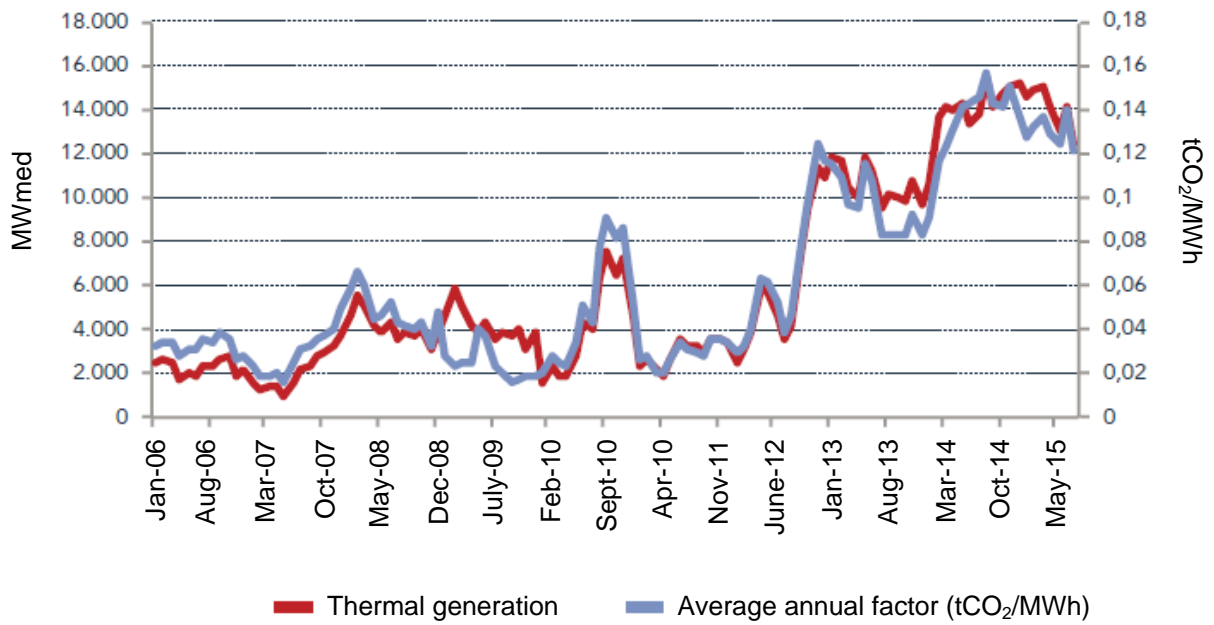
INCREASE IN THERMAL DISPATCH, RATE MODE AND EMISSIONS

Reconfiguring the current system operation forms predictable scenarios under two points of view. First, **if fossil thermal dispatch increases the power price should increase** once fossil thermal power generation costs are significantly higher than hydraulic, going against one of the pillars of the new power sector model, the rate mode. Second, **GHG**

emissions in SIN also tend to increase.

One of the ways to achieve emissions reduction goals and have rate mode, as well as to act reliably and safely in supply would be through the expansion of controllable power plants since this technology is already implemented in Brazil. For example, the expansion in thermal dispatch in the triennium 13/14/15, influenced by unfavorable hydrological scenario, presented an increase in GHG emissions in SIN. However, there is also a very important aspect **related to social and environmental impacts and climatic changes, since the hydroelectric expansion would take place in the North region causing the flooding of large areas with native forests in the Amazon.**

CHART 10: INCREASED CO₂ EMISSIONS DUE TO THERMAL DISPATCH



Source: Prepared by the author from ONS and MCTI data.

Business Model Dilemmas

CHANGE OF THE POWER SECTOR PARADIGM: DG EXPANSION AND THE NEW BUSINESS MODEL OF DISTRIBUTION

In addition to inclusion in ACR auctions, there is a major potential to include FRE in a decentralized way as distributed generation - especially solar photovoltaic. Resolution 482 was essential to expand micro and mini distributed generation and gave rise to a new figure in SEB: the generator/consumer unit. Unit generation is primarily targeted to self-consumption with eventual injections of power in the distribution network. This injection causes a virtual storage of power on the network to be used at another time by the unit, thus promoting a bidirectional flow of electricity in the network.

Such fact causes an increase in the operation and maintenance complexity requiring investments in the network's modernization and intelligence.

In the current power sector model, Brazilian utility companies play the role of distribution itself, offering the so-called "wire service". Moreover, they are responsible for the forecast of demand in their concession area, so that they can hire the necessary power in ACR auctions. Compensation comes from rates, which are different depending on the consumer group. For Group B - captive low voltage consumers - the energy rate is monomial.³⁸ With this, there is no difference

38. Monomial rate is the rate of power supply comprised by prices solely applicable to active power consumption and does not discriminate the remuneration of the various services associated with energy that reaches consumer units.

between what is compensated by the distribution service or the power purchase service. In a scenario of decentralized power generation, this rate mode can bring important aspects for utility companies' business.

With the inclusion of micro/mini distributed generation, the binomial rate model that includes a rate for power consumption and

another related to the use of the distribution network is more proper. Still, the distribution rate could also be itemized among power delivery services where all connected consumers should pay, and injection services in which only micro/mini generators would pay. Being aware of the transaction costs arising from such transformations to be properly addressed is important.



Expansion of FRE participation under the form of distributed generation needs to be followed by an adjustment of the current regulatory model and power sector businesses.

These rate arrangements could enable the participation of several trade agents in the same distribution concession area, causing a competition with possible efficiency gains and reduced energy costs. In this scenario, utility companies would only be responsible for the management and operation of its distribution assets. Clearly there would be an important transformation in the current business model of the power sector bringing several impacts for the several sector agents - in particular, for utility companies. Thus, expansion of FRE participation under the form of distributed generation needs to be followed by an adjustment of the current regulatory model and power sector businesses.

For being generally based on variable energy resources, the distributed generation will still depend on the network when the generation of the system installed in the unit is low. However, as described in Chapter 1,

some technology advances in relation to power storage are being made, and such products are becoming more commercially viable. The promotion of hybrid and electric cars technologies and the integration of transport means to the power sector is also advancing, even though without a forecast of its large scale commercial feasibility.

Finally, a scenario of greater inclusion of distributed generation and new technologies will require investment in intelligence and modernization of the network. Such investments enabled to leverage the benefits of distributed generation, optimizing resources, increasing efficiency and bringing new possibilities for services to be made available to consumers. On the other hand, the necessary investments are enormous, and ultimately will be passed on to the consumer. **How to enable such investments in the current scenario with higher rates and funding difficulties?**

CONCLUSION AND FINAL CONSIDERATIONS

FRE inclusion in power matrices of several countries is being made fast. In order to increase energy independence and safety, and also address social and environmental matters closely related to GHG and air pollutant gases emission, the strategy in the power sector - main responsible for GHG emissions globally - is the increased participation of power generation technologies with low environmental impact.

This trend is no different in Brazil. Despite having one of the most renewable power matrices in the world for having its generation basis from hydraulic source, following the global trend, Brazil has been expanding FRE inclusion in its energy mix in order to maintain the renewable nature of its power matrix. With the abundant and often supplementary energy availability of renewable sources in its territory, Brazil has great potential to use several generation technologies from the main renewable sources - biomass, PCH, wind and solar.

However, FRE expansion in the power matrix is being followed by important dilemmas. The regulation and business model were created when the system was purely hydrothermal, with hydropower dispatch in the basis and supplementary thermoelectric. With the expressive inclusion of FRE in the system, updates and even changes in the system's expansion and operation, not only in practice, but also in relevant regulation, should be made to make the system more robust and reliable bringing efficiency and low cost on rates.

Through this Booklet, **FGV Energia** brought dilemmas and raised some questions observing some possible impacts FRE can bring to the system. After launching this Booklet, **FGV Energia** intends to continue the due searches by promoting discussions and debates, listening to sector and Government agents not only about the dilemmas addressed in the document, but also other relevant dilemmas, that were not indicated in our analyses.

LIST OF ACRONYMS

ABEEólica - Brazilian Association of Wind Energy

ABDI - Brazilian Association for Industrial Development

ABRAPCH - Brazilian Association of Small Hydropower Plants Development

ACR - Regulated Contracting Environment

ACL - Free Contracting Environment

ANEEL - Brazilian Electricity Regulatory Agency

ANP - Brazilian National Agency of Oil

BIG - Information Generation Bank

BNDES - National Bank for Economic and Social Development

CCEE - Electric Power Trade Board

CGH - Hydroelectric Generation Central

ENA - Affluent Natural Energy

EPE - Energy Research Company

FRE - Fluctuating Renewable Energies

USA - United States of America

FIT - Feed-in-Tariff

GHG - Greenhouse Gases

IPCA - Brazilian Broad Consumer Price Index

IRENA - International Renewable Energy Agency

JNNSM - Jawaharlal Nehru National Solar Mission

LER - Reserve Energy Auctions

MCTI - Ministry of Science, Technology and Innovation

NAPCC - National Action Plan on Climate Change

OFA - Other Alternative Sources

ONS - National Electric System Operator

OPEX - Operational Expenditure

PCH - Small Central Power Plants

PDE - Ten-Year Energy Expansion Plan

R&D - Research and Development

PLD - Settlement Price for Differences

PPA - Power Purchase Agreement

PNMC - National Climate Change Program

PROINFA - Program of Incentives for Alternative Sources

RECAI - Renewable Energy Country Attractiveness Index

REIDI - Special Incentive Scheme for Infrastructure Development

REN 21 - Renewable Energy Policy Network for the 21st Century

REN 482 - Normative Resolution 482

RPS - Renewable Portfolio Standard

SEB - Brazilian Electricity Sector

SIN - National Interconnected System

EU - European Union

UHE - Power Plant

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