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Challenges of the Insertion of Natural Gas in a Renewable Energy Mix

The Brazilian experience.

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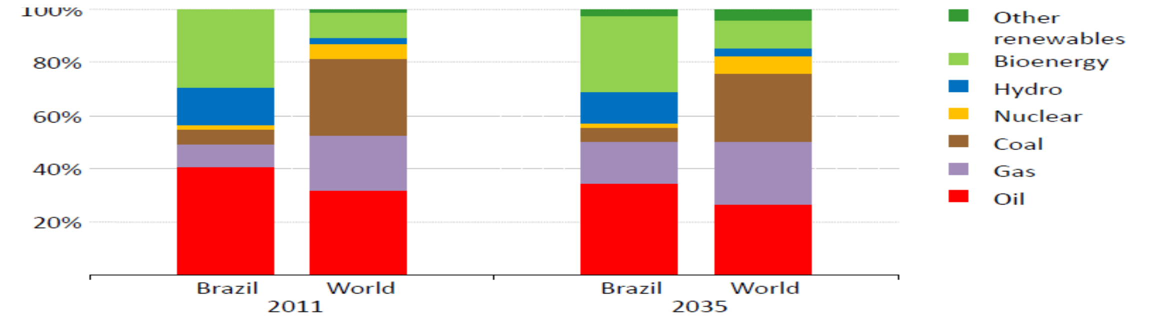
Background: The composition of the Brazilian energy mix has uncommon characteristics when compared to the world's energy mix, for being mostly composed of renewable sources (43%). However, the share of hydrocarbons, with 41% oil derivatives and 9 % natural gas, tends to rise in the mid-term.

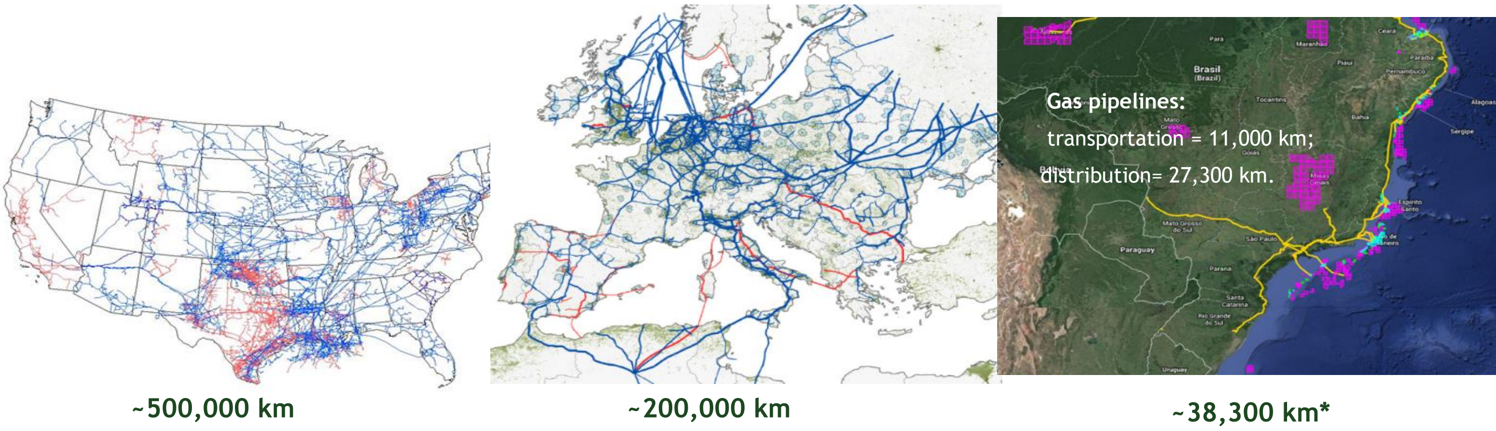
Figure 1: Energy Matrix - Brazil vs. World



SOURCE: IEA/WEO_2013

There is a significant uptrend expected in oil production in Brazil for the upcoming years, with the exploitation of the promising pre-salt fields. Although the potential supply of natural gas associated to the pre-salt fields is high, the current stage of maturity of the natural gas industry in Brazil can compromise the monetization of future resources. With transportation infrastructure underdeveloped for the country's dimensions, distribution grid concentrated in few regions, which can be seen in figure 2, and without storage capacity, in addition to the line-pack of some pipelines, transferring the potential gas supply from the offshore fields to the distant market in the continent can pose-a major challenge.

Figure 2: Natural Gas Grid – USA, Europe and Brazil



Therefore, although there is still large potential demand for natural gas in the industrial, commercial and residential segments in Brazil, monetization via thermal generation will be determining for the expansion of supply, encouraging the necessary investments on the costly offshore transfer infrastructure and subsequent onshore transportation, benefitting all other segments. For its strategic nature related to the use of future resources, we will analyze the challenges of the integration of gas in the Brazilian power system.

History and current situation

In 2002, when Brazil faced a power supply rationing, due to the low levels of the reservoirs utilized for hydroelectric generation, the Federal Government launched the PPT – Thermoelectricity Priority Plan, which saw in gas-fired thermal generation a complementary solution to meet the needs for expansion of the power supply in Brazil. This triggered the expansion of the natural gas-fired thermal generation in the country, which today represents about 14,281 MW, in other words 10.3 % of the whole generation capacity installed, considering all sources.

The Brazilian electrical system has highly unique characteristics: consumption is still expanding at high rates; hydroelectricity is the predominant source in the hydrothermal mix; and the country's continental territory is practically entirely integrated by the National Interconnected System (SIN).

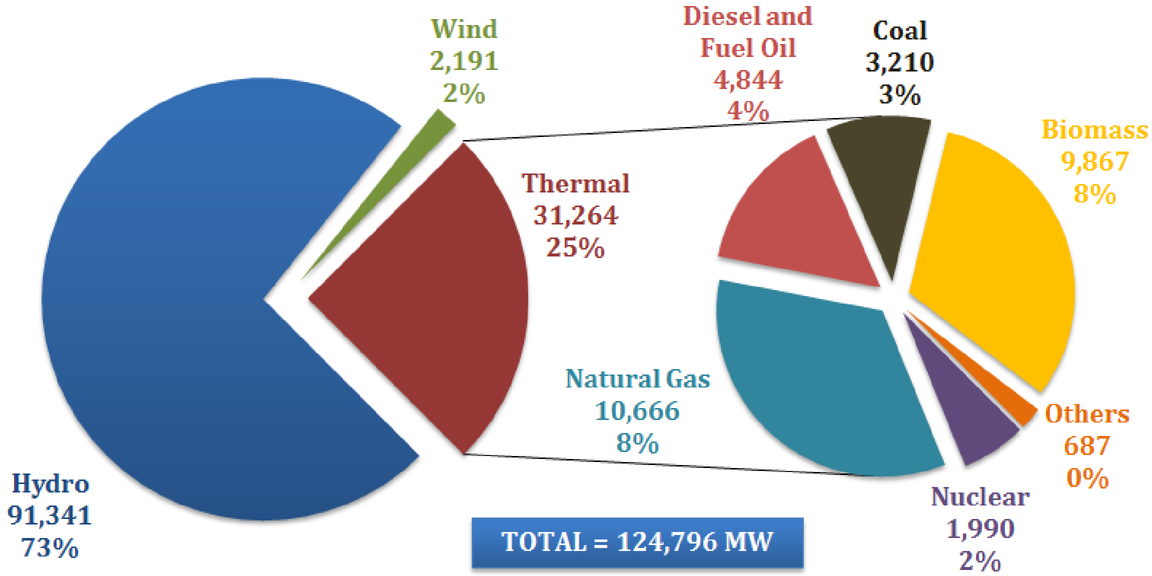
After the rationing that occurred in 2001, the consumption of electricity in Brazil rose an average of 4.5% per year. But since the country still has a low per capita consumption of electricity (2,545 kWh/year), a continuous growth of the demand of 4% per year is expected in the long-term. In order to respond to this significant rise, the installed capacity should expand continuously at high rates.

The Brazilian generation complex is predominantly hydroelectric, counting on hydroelectric plants that have large storage reservoirs. The storable water volume represents an energy reserve in excess of 200 TWh, which is currently equivalent to about five months of the national load, currently representing a limited backup for the system (ONS, 2013). By allowing the offsetting of the steep hydrological variations, typical of a tropical climate, the large reservoirs condition the present and future operation to the volume of water held in the reservoirs and to the expected inflows. The decision to store water, however, depends on the existence of dispatchable firm sources that do not depend on climatic factors, and thermal plants enable the management of the reservoirs, mitigating the risk of an energy deficit.

The National System Operator (ONS) centralizes the dispatching, determining an order of merit where the lower cost generation plants are the first to be activated. Through computer models, the ONS optimizes the optimum hydro-thermal dispatch of the National Interconnected System - SIN, determining the marginal operation cost (CMO) of the system.

Since thermal dispatch implies on expenses with fuel and the installed hydro generation capacity is much larger, the operation privileges hydroelectric plants, even though they are further away from the consumer centers. The thermoelectric complex thus becomes a complementary backup for the hydro reserve, to be activated in adverse hydrological circumstances. Following this operative logic, the current thermoelectric complex, practically fully flexible, presents low fixed costs, but admits high variable operational costs. The costs of fuel oil and diesel-fired thermal plants can top R$ 1,000/MWh.

Figure 3: System Installed Capacity



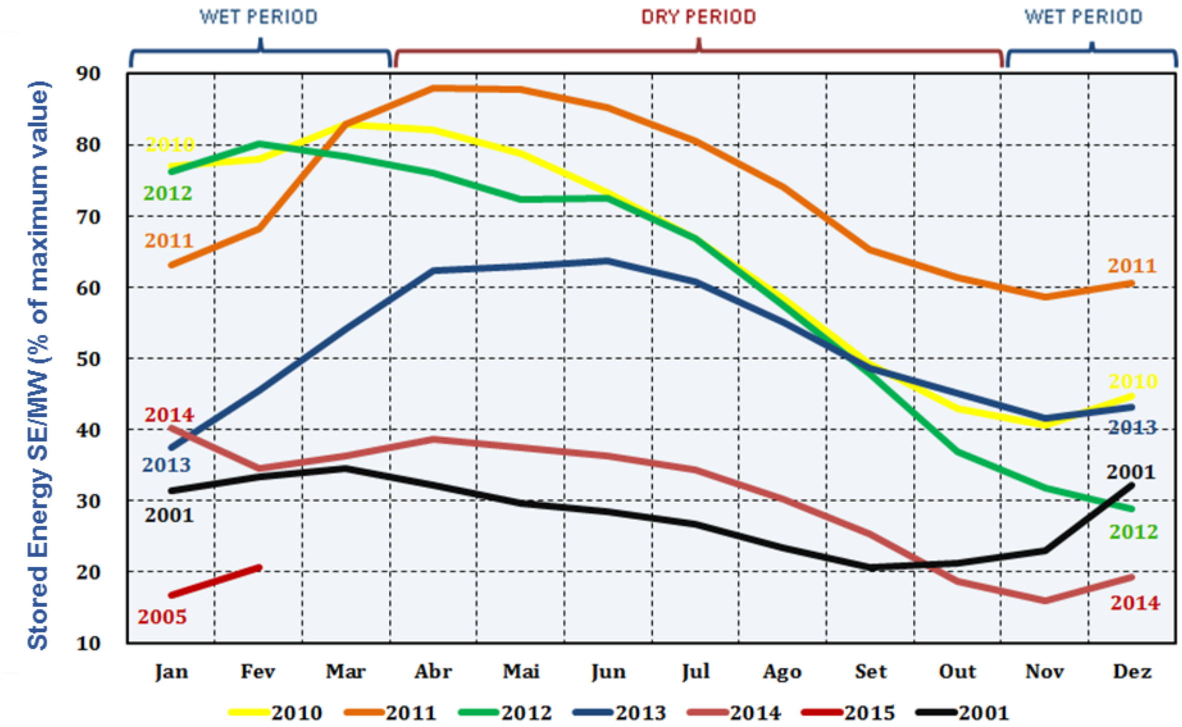
Source: EPE, (2014)

The system's generation complex at the disposal of the ONS counts on about 124 GW installed capacity. The hydro source represents a little more than 70% of this total, with thermoelectric share reaching about 25% of the mix and 2% wind. Within the thermal generation complex, natural gas is the most important energy source, contributing with more than 8% of the total installed power of the SIN, followed by biomass (8%), fuel oil and diesel (4%), coal (2.6%) and nuclear (1.6%). Although wind energy still presents a reduced share, contributing with a little more than 2 GW, by 2016 it should reach 14 GW, considering the projects already contracted, diversifying the Brazilian power mix (EPE, 2014).

The hydro expansion, however, faces countless obstacles. Most of the remaining usable hydro sources are concentrated in the Amazon, a region that faces socio-environmental resistance to the construction of the plants, in addition to not having favorable geographic characteristics for large reservoirs. The remaining hydro potential should be utilized by run-of-the-river plants, which do not have reservoirs, aggregating more intermittent energy to the mix.

In light of the difficulties of the hydro expansion, the increased intermittence in the mix (run-of-the-river hydroelectric plants, wind, seasonal biomass and the newcomer solar) and the continuous rise of the demand, the system watches at a gradual loss in the reservoir recuperation capacity, making Brazil's power supply increasingly more dependent on the rainfall patterns. While in 2002 the system counted on over 6 months of energy storage, in 2013 it had already been reduced to 5.4 and should reach 2017 with a reserve equivalent to 4.7 months (ONS, 2013).

Figure 4: Steep Annual Depletion of the Southeast/Midwest Reservoirs



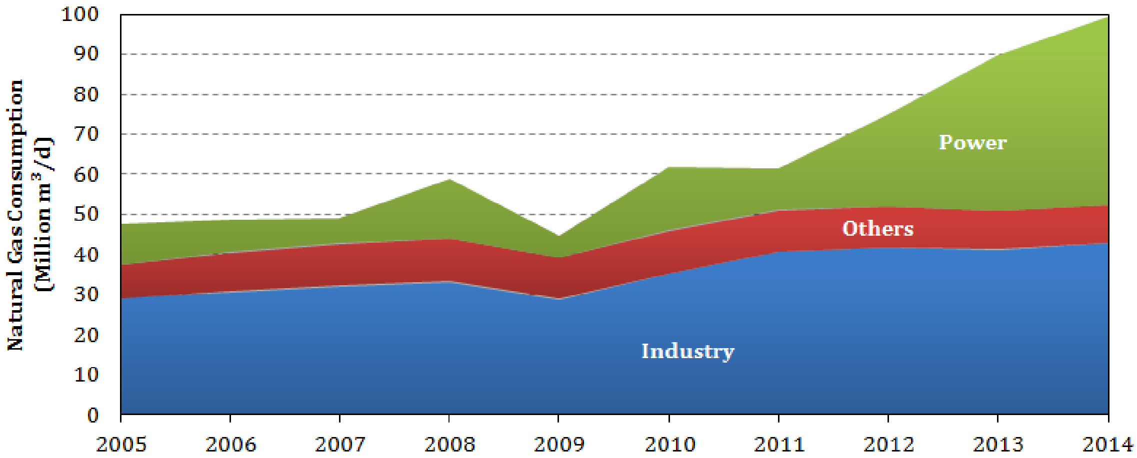
Source: ONS, (2015)

The result is the increasingly steeper depletion of the reservoirs, which conditions the supply guarantee to the occurrence of favorable hydrology, risking affordable rates. As observed in Figure 4, the reservoirs of the country's Southeast and Midwest region, which account for 70% of the total capacity of the SIN, are currently at a lower level than registered in 2001, the power rationing year.

In order to tackle the loss of normalization of the reservoirs, the operator has continuously dispatched, since the end of 2012, the full flexible thermal generation complex conceived to operate sporadically, which implies on unbearable costs to the entire sector. Since then, the share of thermal generation in supplying the load of the SIN went from less than 10% to 25%, currently reaching 30% of the load.

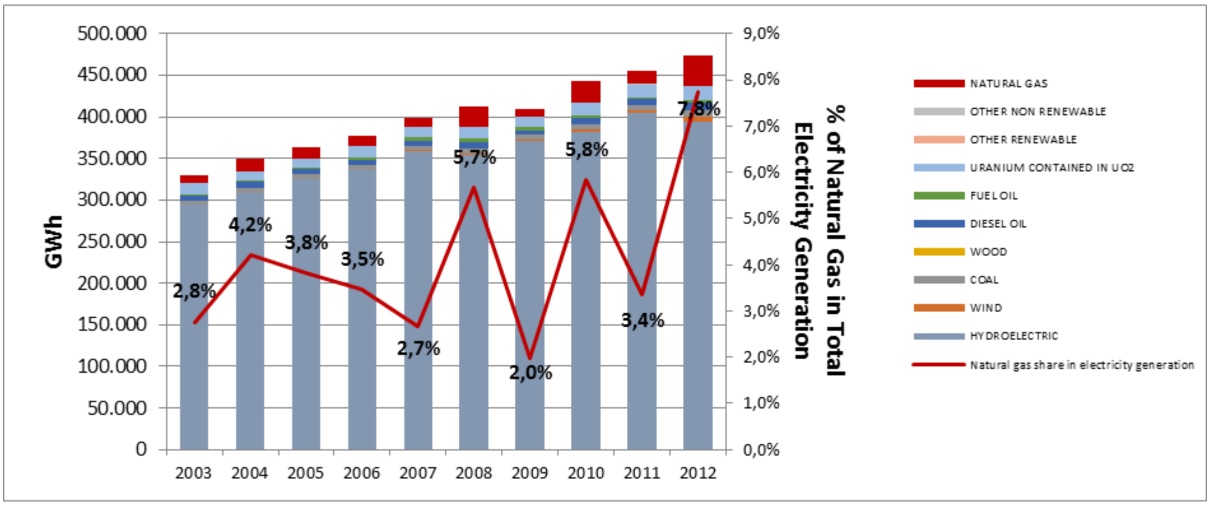
This change in the system's modus-operandi changed the frequency of dispatch of natural gas-fired thermal plants. The graph in figure 5 presents the history of the share of natural gas in industry and in power generation, evidencing the great volatility of thermal consumption, with emphasis to the significant recent growth.

Figure 5: Gas Consumption History per segment



Source: MME

Figure 6: Natural Gas Generation History in Brazil



SOURCE: BEN – National Energy Balance

The restructuring of the Brazilian electrical sector, employed in response to the rationing faced in 2001, defined a Cost Benefit Index (ICB) to compare the technological alternatives – thermal, wind and solar generation – complementary to the primarily hydro expansion of the mix, evaluating them in the disputes for the product availability in new energy auctions by the distributors' market.

The ICB calculation methodology was conceived under the perspective of the singularities of the Brazilian electrical system. The calculation of the ICB boosts the competitiveness of projects with low fixed cost and high variable cost, by oversizing the physical guarantee attributed to thermal plants with low expected generation. After ten years of uninterrupted conduction of auctions for the expansion of the installed capacity, the implicit view in the calculation of the ICB regarding the optimum operation of the Brazilian generation complex and its desirable expansion route was revealed to be mostly mistaken. (ROMEIRO, 2014)

The loss of the degree of normalization of the water reservoirs points to a shift in the operative paradigm of the Brazilian electrical system. If before, the operation and expansion they were guided by the minimization of spilling of inflows and expenditures with fossil fuels, which demanded complementary sources to hydroelectricity, now a significant part of the hydro generation should be avoided by substitute sources in order to mitigate the depletion of the hydro reservoirs. (ROMEIRO, 2015)

However, the operating model of the Brazilian electrical system and the prices of natural gas supply contracts have not encouraged natural gas producers to supply. Only a gas production project, located in the State of Maranhão, was successful in being primarily dedicated to gas-fired thermal generation, above all, due to the fact that it is an *onshore* non-associated gas field. In this case, due to the lack of access to gas pipeline infrastructure, and by the proximity to power transmission lines, thermal generation has shown to be an adequate strategy for the monetization of these gas reserves.

In thesis, natural gas-fired thermal generation could be an excellent source complementary to hydro generation in Brazil, expanding the security in the power supply, were it not for the four factors that limit, on the Brazilian producer's side, the use of national natural gas for this purpose:

(1) the natural gas available in Brazilian basins is predominantly associated, therefore it needs to be constantly produced in order to allow the production of fuel oil, the primary objective of the majority of E&P projects in Brazil;
(2) most of the natural gas produced in the country originates from offshore fields, which significantly raises the production and offloading costs, limiting the competitiveness of natural gas;
(3) the country has a modest transportation infrastructure, about 50 times smaller than in the USA, taking in account that Brazil is a country with similar dimensions to the United States.
(4) the absence of a seasonal consumption segment able to absorb the large volumes of gas available when thermal plants are not generating.

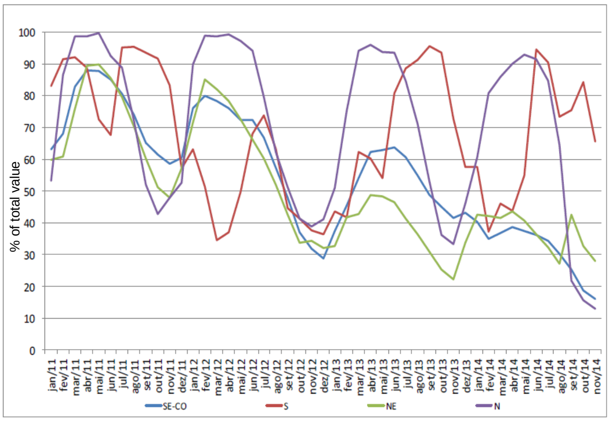
Some defend that the limitations in hydroelectric generation are a conjuncture issue, but an evaluation of the evolution of this source points to the need for actions to promote and expand the availability of power generation, which, not being possible through the construction of new hydro reservoirs, should be made possible through other sources such as gas thermal generation.

It is possible to see in figure 7 that the hydro storage recovery capacity has been reduced year after year, which represents a reduction in the firm power supply capacity from this source.

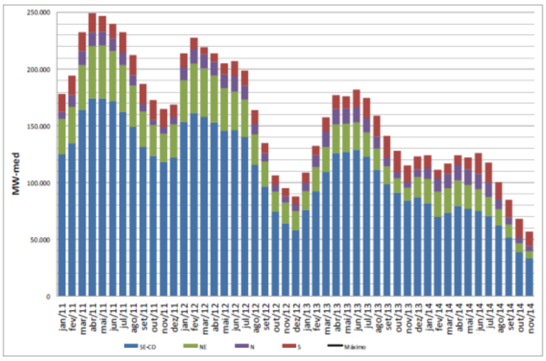
Figure 7: Electrical System Storage and Inflow (2011 – 2013)

Energy Stored

% of Storage Capacity



MW-med

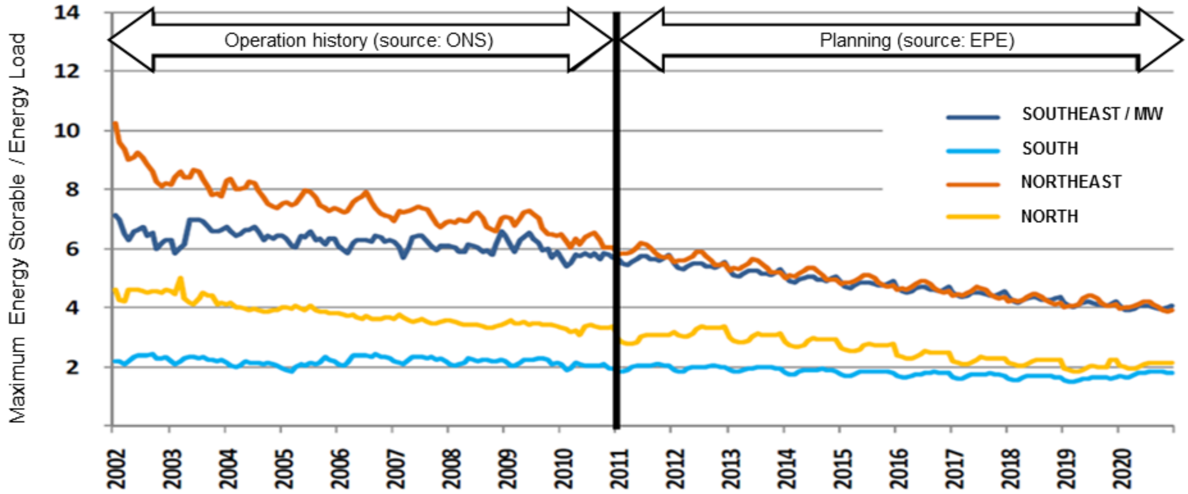


SOURCE: MME/ ONS

The situation of the hydro power reservoirs in Brazil can be further evaluated by the normalization capacity (stored energy vs. consumed energy) of these reservoirs. Figure 8 presents the balance between the power supply and demand.

According to specialized consultancy firms in the electrical area, in 2015, at the end of the dry period (low rainfall), which generally occurs in Brazil between the months of April and October, we will have an enormous risk of expanding the flawed power supply, maybe the biggest since the systematic monitoring of power generation began in Brazil.

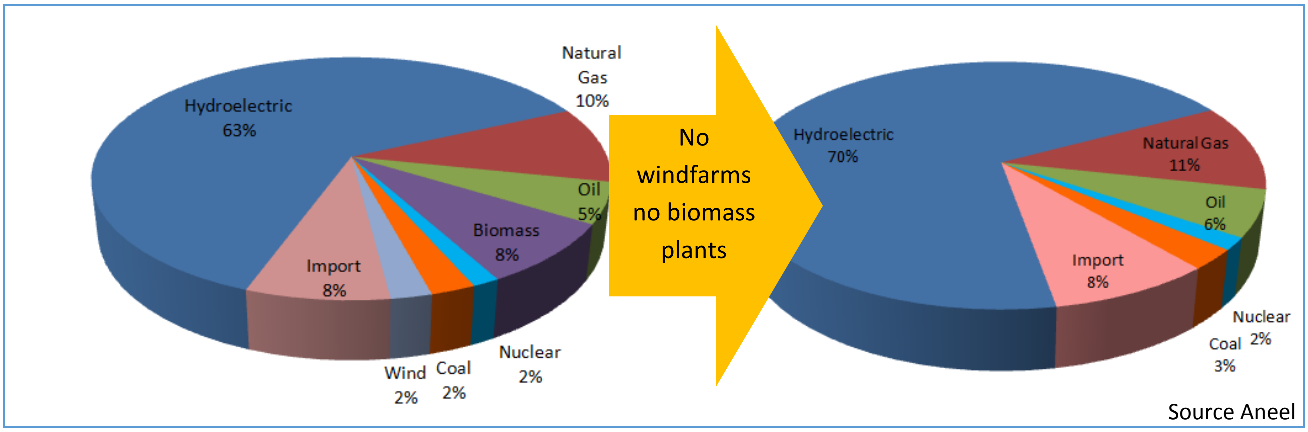
Figure 8: Balance between power supply and demand



Source: PDE, elaboration IEE

In addition, it is important to mention that the power purchase auctions stimulated the implementation of a large number of biomass-fired thermal plants (sugarcane bagasse) and wind energy projects, renewable energy sources, but with great seasonality.

Figure 9: Brazilian Energy



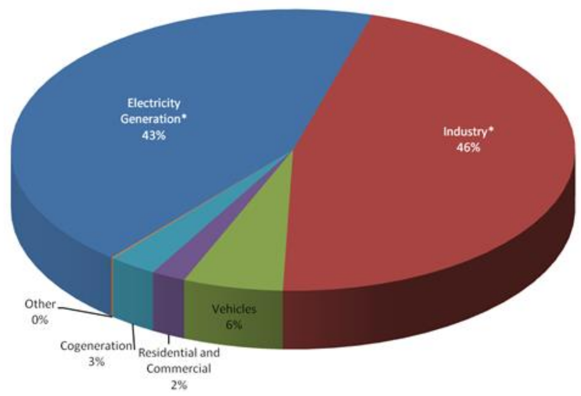
Petrobras, entrusted by the Federal Government, assumed the responsibility for the natural gas supply to meet the thermal generation expansion needs, maintaining the objective to operate complementarily to hydro generation. As such, unable to expand the supply of domestic gas to satisfy characteristics of the electrical sector, Petrobras decided to back thermal generation in the import of LNG.

Due to the seasonality of the Brazilian electrical generation complex, and the consequent difficulty in predicting this sector's gas demand, Petrobras opted to build three floating regasification terminals (FSRU) and contract natural gas in the international *spot* market.

The model of complementary hydro-thermal generation was shown to be highly complex due to various factors, among which:

(1) in years of low precipitation, the high demand for gas for thermal plants has found a heated international LNG market and consequently with higher prices, costs that need to be transferred to the electrical sector;
(2) in years of high rainfall, such as in 2011, the production, transportation and treatment systems of the gas produced in the country, as well as the LNG import infrastructure remain idle, causing losses in the remuneration of these assets;
(3) the difficulty in determining in advance the high or low occurrence of rainfall makes the operation of both sectors (electrical and gas) even more complex, hindering, among other aspects, the definition of the level of purchases of loads of LNG.

Figure 10: Natural Gas Demand per sector in Brazil - 2013



Source:MME 2015

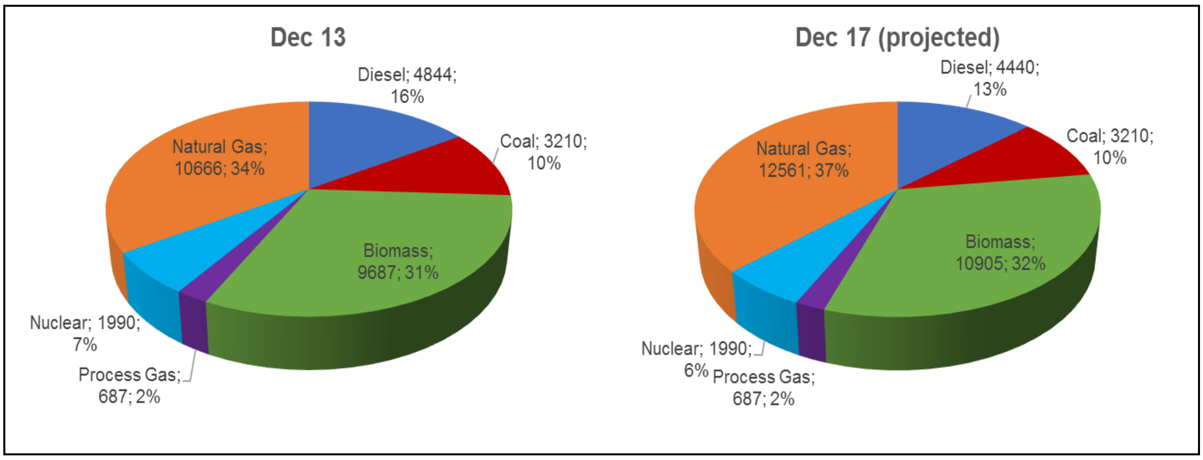
Moreover, the electrical sector was also responsible for a major change in the profile of the supply and demand of the natural gas sector.

In 2013, from 90 million m³/d of natural gas consumed in the country, about 46% went to industrial sector and 43% went to the electrical sector. Since the trend is that the percentage destined to the latter sector will continue to rise, industrial consumers have been consequently suffering with the limited supply.

In order to meet the growth of the thermal demand, the country became a major LNG importer with average monthly purchases of up to 21 MM m3/d (~20% of the total demand) paying the high prices of the *spot* market, which has been strongly influenced by the rising Asian prices.

The Government, recognizing the importance that natural gas may have in the energy supply, has been seeking means to expand its share in the energy mix, stimulating above all domestic production. Signs of this initiative were the enactment of Law 11.909 in 2009 – known as the Gas Act, the discussion and publication of the Ten-Year Pipeline-Road Transportation Grid Expansion Plan– PEMAT and the promotion of the 12th Round of Bids for Hydrocarbon Exploration and Production Areas, focused on onshore gas production.

Figure 11: Brazilian Thermal Power Generation by Source (MW)



Source EPE – PDE 2023

As one can see in figure 11 the EPE – the Brazilian Energy Research Company, the agency responsible for preparing the Brazilian energy plan, has projected a growth of the share of natural gas in thermal generation. According to the EPE, the share of natural gas goes from 34% in 2013 to 37 % in 2017, which is, as previously said, a way to increase security in power generation.

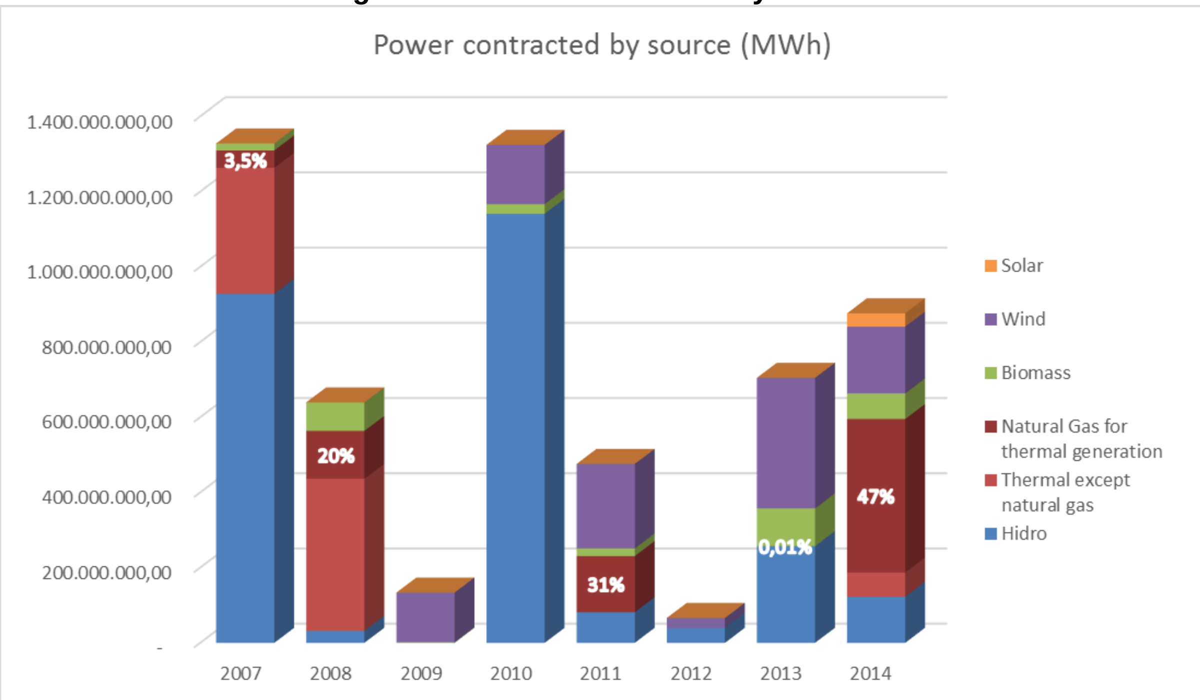
Although the Federal Government sees the future substitution of the import of LNG for domestic gas as a solution to cut the cost of thermal generation – expanding the security in the power supply - the difficulties remain for the gas sector also due to the difficulties that the complementary hydro generation model adopted brings to the production of associated gas.

These issues are also part of the challenges that gas sector faces in other countries that have adopted a renewable and seasonal energy mix, such as Germany. The security in power generation that gas-fired thermal plants offer is utilized as backup in countries that seek to expand the share of renewable sources that are generally seasonal, however this security is often not recognized, and is consequently not remunerated by the electrical sector, such as in the Brazilian case.

By selecting the topic *Combination with renewables and electricity* as one of the pillars of the WGC 2015, the IGU recognizes that the topic is an important part of the future challenges of the gas industry of many of its member countries.

In the Brazilian case, what has been verified from past auctions is a large contracting of biomass and wind renewable sources, as well as hydroelectric plants.

Figure 12: Power Contracted by Source



Source: CCEE

Although in its 2023 Ten-Year Energy Expansion Plan the EPE makes a strong forecast of growth of natural gas generation between 2019 and 2023, a series of challenges need to be equated, in order for the forecasts of table 1 to come true. For such it requires much closer talks between the hydroelectric sector and gas producers/importers, including other generators in this debate – wind, cogenerators, etc. and environmental area representatives, to present fundamental contributions not only in the selection of the best energy/environmental alternative both considering its use and the impact of its implementation.

Table 1: Evolution of the Installed Capacity by Source

SOURCE	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
	MW										
RENEWABLES	**103.399**	**110.335**	**118.653**	**125.444**	**133.193**	**142.849**	**146.046**	**149.740**	**154.472**	**158.947**	**164.135**
HIDRO	79.913	82.629	87.183	92.193	96.123	100.935	101.874	103.344	106.167	108.941	112.178
IMPORT	6.120	6.032	5.935	5.829	5.712	5.583	5.441	5.285	5.114	4.925	4.716
OTHER	17.366	21.674	25.535	27.422	31.358	36.331	38.731	41.111	43.191	45.081	47.241
SMALL HYDROPOWER STATION	5.308	5.538	5.671	5.701	5.854	6.289	6.439	6.619	6.799	6.919	7.319
WIND	2.191	5.452	9.019	10.816	14.099	17.439	18.439	19.439	20.439	21.439	22.439
BIOMASS	9.867	10.684	10.845	10.905	10.905	11.603	12.353	13.053	13.453	13.723	13.983
SOLAR	0	0	0	0	500	1.000	1.500	2.000	2.500	3.000	3.500
NONRENEWABLES	**21.397**	**22.224**	**22.843**	**22.843**	**22.843**	**24.248**	**24.748**	**26.248**	**27.748**	**29.248**	**31.748**
NUCLEAR	1.990	1.990	1.990	1.990	1.990	3.395	3.395	3.395	3.395	3.395	3.395
NATURAL GAS	10.666	11.442	12.169	12.169	12.516	12.516	13.016	14.516	16.016	17.516	20.016
COAL	3.210	3.210	3.210	3.210	3.210	3.210	3.210	3.210	3.210	3.210	3.210
FUEL OIL	3.442	3.493	3.493	3.493	3.493	3.493	3.493	3.493	3.493	3.493	3.493
DIESEL	1.402	1.402	1.294	1.294	947	947	947	947	947	947	947
PROCESS GAS	687	687	687	687	687	687	687	687	687	687	687
TOTAL	**124.796**	**132.559**	**141.496**	**148.287**	**156.036**	**167.097**	**170.794**	**175.988**	**182.220**	**188.195**	**195.883**
	Relative Participation (%)										
RENEWABLES	**82,90%**	**83,20%**	**83,90%**	**84,60%**	**85,40%**	**85,50%**	**85,50%**	**85,10%**	**84,80%**	**84,50%**	**83,80%**
HIDRO	68,90%	66,90%	65,80%	66,10%	65,30%	63,70%	62,80%	61,70%	61,10%	60,50%	59,70%
OTHER	13,90%	16,40%	18,00%	18,50%	20,10%	21,70%	22,70%	23,40%	23,70%	24,00%	24,10%
NONRENEWABLES	**17,10%**	**16,80%**	**16,10%**	**15,40%**	**14,60%**	**14,50%**	**14,50%**	**14,90%**	**15,20%**	**15,50%**	**16,20%**
NUCLEAR	1,60%	1,50%	1,40%	1,30%	1,30%	2,00%	2,00%	1,90%	1,90%	1,80%	1,70%
OTHER	15,60%	15,30%	14,70%	14,10%	13,40%	12,50%	12,50%	13,00%	13,40%	13,70%	14,50%
TOTAL	**100,00%**	**100,00%**	**100,00%**	**100,00%**	**100,00%**	**100,00%**	**100,00%**	**100,00%**	**100,00%**	**100,00%**	**100,00%**

Source: EPE – PDE 2023

Some actions could be taken, in the Brazilian case, to contribute to the expansion of the supply, in competitive bases, of thermoelectric energy generated with natural gas. It is necessary to promote more integration in the energy sector planning, strengthening the indicative nature of this planning to avoid *ex post* economic decisions.

Today there are some "tools" to plan and increment the supply of gas and power energy:

1. The Bids Rounds for Oil and Gas Exploration Blocs, promoted by the National Oil, Gas and Biofuel Agency, where new areas are offered for oil and gas exploration;
2. The PEMAT – Ten-Year Pipeline-Road Transportation Grid Expansion Plan, which decisively proposes new gas transportation pipelines, prepared by the Energy Planning Company - EPE and the Ministry of Mines and Energy – MME;
3. Auctions promoted by the MME/EPE for the contracting of new power plants;
4. The PDE – Ten-Year Energy Expansion Plan, whereby the Government indicatively sets the energy planning guidelines , prepared by the EPE;
5. The Annual Electric Operation and Energy Operation Planning, both prepared by the National System Operator – ONS.

These initiatives are fundamental to resolve in a coordinated manner: (1) the gas supply expansion incentive, (2) the construction of infrastructure to monetize this gas, (3) the expansion of the supply of thermoelectric energy, and (4) the greater predictability of the operation of thermopower plants.

Although the tools exist, there is a need to improve them, and above all a coordinated action of the various government agencies (MME/ANP/EPE) and the ONS – the private agent, in order to allow the gas-power integration to be economically viable to society and to the investors operating in the sector.

Some suggestions have been discussed in various technical forums and congresses:

1. The continuity and predictability of Oil and Gas Bidding Rounds, considering that the development of this activity involves a very large volume of human resources and capital that is easily demobilized but takes time to be (re)organized.

Brazil went 5 years without offering blocks for oil and natural gas exploration, having promoted 3 auctions in the same year of 2014: one in conventional areas – with an exploration concession agreement; one dedicated to the pre-salt, utilizing the production sharing agreement regime, and a third in on-shore areas, focused on the search for natural gas.

The lack of continuity of the auctions, in line with the high national content requirements in the projects, hinder the participation of large IOCs, reduces the sector's attractiveness and does not stimulate the emergence of small and mediums international oil companies, which could be attracted to invest in Brazil.

2. The PEMAT, in the terms established in Law 11.909, will be implemented in its determinative way, only including projects that are economically viable according to the government, and of gas supply and demand. If indicative projects could be included in these auctions we could have, for example, alternatives not perceived by the government/planner. Although the methodology employed by the government reveals coherence and precaution, the requirements imposed to have a project included in the PEMAT, as well as the level of detail of the basic project requested, inhibit free enterprise, and up to the moment they have not proposed the expansion of the gas transportation grid, significantly.

Some regulatory issues can also pose difficulties:

- in the intent to create a deverticalized and independent gas transportation sector, the National Oil Agency practically excluded the possibility of the gas producer being the owner of the gas pipeline that will transport its production;
- the absence up to the moment of natural gas swap regulation;
- The tax harmonization necessary both for a gas pipeline crossing various states, and for natural gas swap;
- the coordination of the various schedules to conceive an associated gas project dedicated to a thermoelectric project.

3. The need to revise the rules of auctions for the contracting of natural gas-fired thermoelectric plants, in order to increase its competitiveness. The reduced proposal of natural gas projects in the EPE'S auctions indicates the difficulties in attracting gas producers, above all of national associated gas. Some rules that impose very high obligations and penalties to the supplier of natural gas for a thermopower project suggest a revision, to highlight some:

- The need to confirm up to 25 years of the reserve that will be dedicated to the project, to hedge the power generation agreement's term. This type of confirmation could be for smaller and renewable horizons, and considering that the gas delivery commitment will be included in the SPA – Sales and Purchase Agreement.
- the penalties for gas supply flaws have no cap, which means that the generator can transfer to the natural gas supplier all penalties from the electrical sector, incurred due to a flaw in the generation, including the losses of its clients, all of these without a pre-established limit. These penalties can reach ten times the price of natural gas.
- The thermal plant's limit of inflexibility is set at a maximum of 50%, which hinders the conception of projects with associated gas, which cannot have their flow interrupted to not hinder the oil production. Considering that the Brazilian reserves, as mentioned above, are eminently of associated gas, including those of the pre-salt, there is a mismatch in the planning. Oil sector sees the electrical sector as the only one to enable large gas consumption projects, and the electrical sector does not see the technical difficulties of the production of associated gas, and is not even willing to remunerate the entire infrastructure that will be built for its supply only half the time.
- the current format of the auctions, where gas-fired thermal plants compete with coal and biomass-fired thermal plants, does not favor the analysis of the characteristics of the oil and gas sector, the change of rules and it hinders the comparison between natural gas-only projects.
- natural gas-fired thermoelectric projects can be indexed to Henry-hub or Brent, but the alignment of these index to the international market should be more frequent, and this is another aspect where there is no similarity, for example, biomass-fired thermoelectric plants.

4. The predictability of the dispatch of natural gas-fired thermoelectric plants needs to be improved, not only in the short-term operational planning, but also in the long-term planning. It is necessary to introduce scenarios that incorporate the rising trends of shortage of rainfall. This revision would demonstrate the need for a larger thermal dispatch, which would lead the EPE to calculate a larger physical guarantee for thermal plants, increasing their competitiveness, and reducing its final cost to society.

There is enormous potential for the utilization of natural gas in power generation in Brazil. Nevertheless, there are also major challenges to be overcome, from the development of transportation and distribution infrastructure, to the adequacy of the rules for the contracting of gas by thermal plants, and as previously said it is fundamental to promote an intense dialogue between the power and the oil and gas sectors to come up with a detailed diagnosis of this challenge and propose sustainable solutions so that both sectors can mutually benefit from the expansion of the thermopower market.

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