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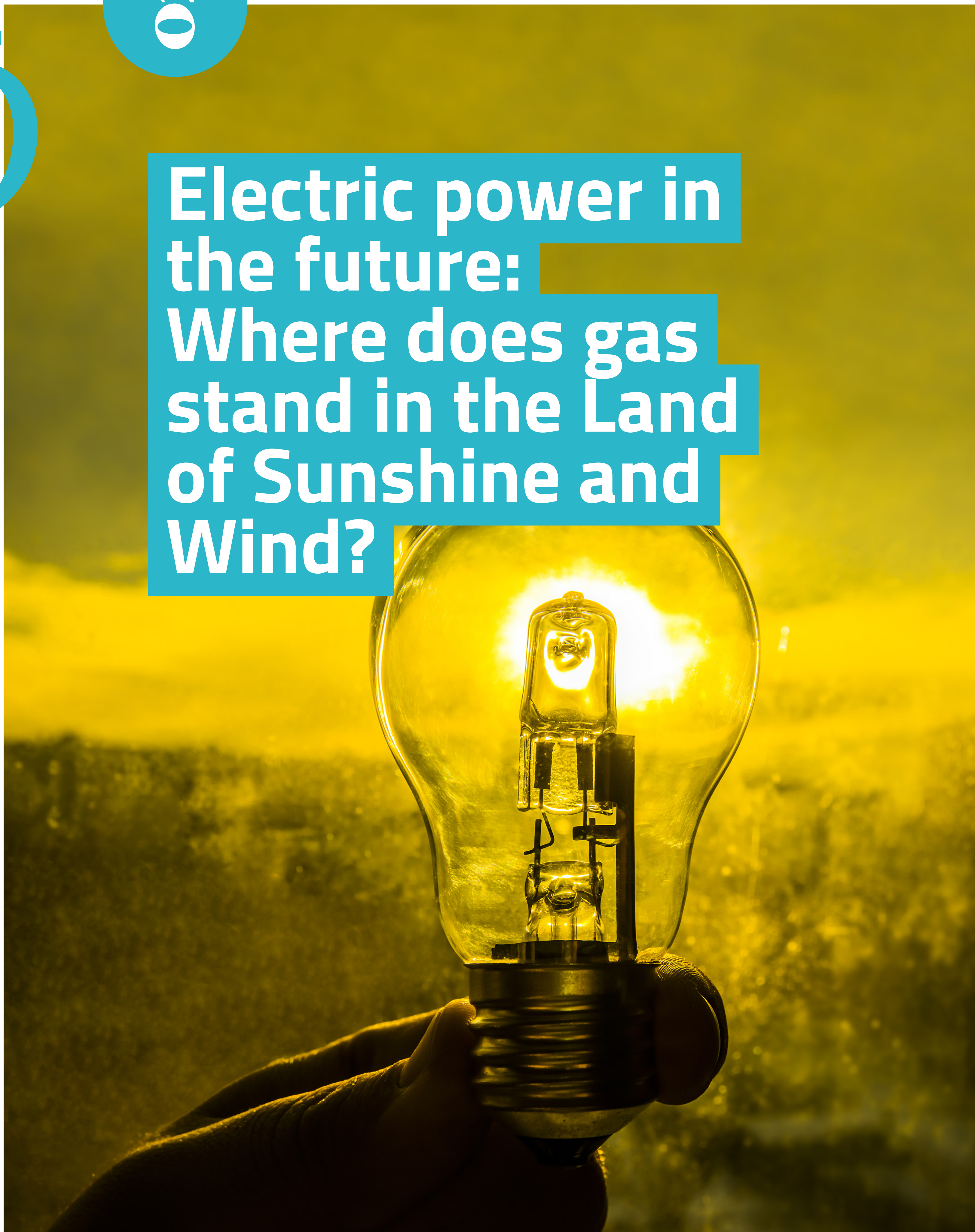
Discussion Paper
April | 2020

Electric power in the future: Where does gas stand in the Land of Sunshine and Wind?



(Instituto Escolhas)

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Whenever the issue of Brazil's energy potential comes up, it is oftentimes stated that the country is "Blessed by God," in reference to Jorge Ben Jor's song "País Tropical" ("Tropical Country," freely translated). This blessing refers to Brazil's natural privileges when it comes to a wide host of energy sources, from renewables to fossil fuels. And, just as discussions about energy transition gain momentum and are included in governments' agendas, that privilege seemingly gives Brazil an unique place in the world.

Nevertheless – to use another cliché – not everything is peaches and cream in the tropics. The very same country that garnered attention in regards to how it used its abundant water resources to generate electric power and launched ethanol as an alternative to oil byproducts must now deal with specific hurdles. The main one concerns finding an ideal balance across all available energy sources so as to ensure a reliable energy supply with affordable prices for customers, in addition to the lowest potential socio-environmental impact.

> **"Globally speaking, natural gas is increasingly viewed as a fuel that will spearhead energy transition from the "oil age" to the "clean energy age." There are abundant reserves.**

Renewable sources still hold the lead in Brazil's energy expansion; nevertheless, this growth has mostly come from using resources that experts dub "intermittency," such as wind and photovoltaic solar energy. The use of water resources with high energy storage capacity seems to have reached its peak. Even current hydroelectric plants are now showing that they can no longer operate as "energy system batteries," whether due to significant variations in climate change-induced rainfall rates, or due to reservoir sedimentation problems.

The country therefore has increasingly relied on thermoelectric generation as a way of securing consistent energy for Brazil's energy system. And the fuel that has stood out within this role is natural gas, particularly after the discovery of large oil reserves at the Pre-salt region, located mainly between the Santos and Campos sedimentary basins located in Brazil's Southeast region.

Globally speaking, natural gas is increasingly viewed as a fuel that will spearhead energy transition from the "oil age" to the "clean energy age." There are abundant reserves - according to the BP Statistical Review of World Energy, global reserves accounted for 196.9 trillion cubic meters (m^3) as per the last day of 2018 -, spread across several parts of the planet.

And due to its potential for being liquefied and transported anywhere, gas emerges as the initial solution in this stage thanks to its role as a baseline energy provider – something that is limited in the case of renewable sources. Moreover, among its fossil-sourced fuel "brothers," like oil and coal, it has the least environmental impact when burned, thereby contributing towards the reduction in greenhouse gas (GHG) emissions.

Nevertheless, just as it brings answers, natural gas also raises questions, some of them still rarely discussed. In spite of being cleaner than its fossil fuel counterparts, natural gas issues more greenhouse gas emissions than sources like wind and solar energy. A significant part of natural gas reserves are associated with oil reserves – as in the Brazilian Pre-salt – and are difficult (and costly) to access. Furthermore, its post-production use involves complex and large-scale logistics investments, whether in gas pipelines or in liquefaction or regasification plants.

Going back to the energy sector, at least two of the three technologies used in thermoelectric power plants require water for cooling. As explained below, this is a concern in Brazil because of the instability that has been impacting the country's water supply system during the last few years, and that has changed hydroelectric generation itself. It seems that we will have less water for several types of uses, particularly in the arid Brazilian Northeast.

This region has gained the spotlight in the last couple of years thanks to its robust expansion of wind power generation. Although at first the Northeast benefited from government grants to ensure the construction of power plants -- similar to what has happened with photovoltaic solar energy - wind energy has scaled up and become competitive. Moreover, wind energy has become the country's chief energy system regulator because of how it complements the nation's hydroelectric system. Brazil's Northeast still has enormous exploration potential both for wind and solar energy. The supposed "intermittency", however, means that these sources are relegated to secondary status because of the need for consistent energy. Does this mean that we are leaving behind our "Pre-wind" and "Pre-sun" phase for the age of the Pre-Salt?

"Nevertheless, just as it brings answers, natural gas also raises questions, some of them still rarely discussed. In spite of being cleaner than its fossil fuel counterparts, natural gas issues more greenhouse gas emissions than sources like wind and solar energy."

"Today, Brazil's Northeast is a major provider of wind power, and it has already become a key player in regulating the country's energy system. The region is a sort of wind Organization of the Petroleum Exporting Countries (OPEP); nevertheless, it still has not given itself its due financial credit to this end. Thus, will it really be necessary to replace wind energy expansion in the region with thermoelectric power plants, which will demand a supply infrastructure or gas imports?," asks Sergio Leitão, Executive Director of Instituto Escolhas.

While the falling price of oil in the context of the Coronavirus pandemic may seem like a bottleneck for renewable energies, as well as for new electric power generation and storage technologies, this very same slump in prices may make for a more interesting – and profitable – bet on these sources compared to oil, and even to natural gas. The 2020 issue of the International Renewable Energy Agency (IRENA) "Global Renewables Outlook" report suggests that recovering economies post Covid-19, in addition to limiting global warming to a 1.5º rise in temperatures, following the Paris Agreement, may be achieved through a comprehensive and swift transition to renewable sources, which would also change the role played by natural gas in this energy transition.

Thus, the purpose of this paper is to draw on these assumptions to discuss the role that gas plays in Brazil's energy expansion. Its significance as a baseline energy and output provider is undeniable. Nevertheless, the topic discussed in this paper concerns how to best use this resource, taking into account its interaction with other sources available in the country – as well as the correct appraisal of each source's attributes in Brazil's energy planning and, as a result, in energy contracting auctions -- particularly those related to renewables. In light of that, we consider factors such as water use restrictions, the concept of "intermittency" applied to wind and solar sources, and technological innovations potentially capable of streamlining the role of renewables in energy transition.

Planning trends: gas is fashionable

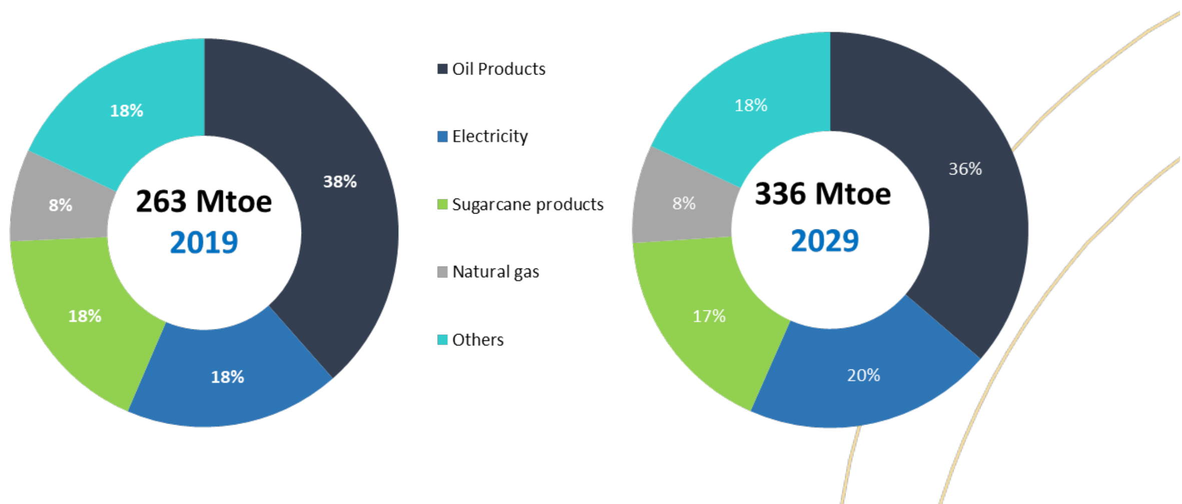
Drafted by the Energy Research Office (EPE), the Ten-Year Energy Expansion Plan (PDE) is the main reference document concerning Brazil's energy planning. Published in January 2020, the PDE 2029 estimates that R$ 2.3 trillion will be invested in Brazil's energy sector in the coming ten years. Of this overall sum, R$ 1.9 trillion will be allocated to the oil, natural gas and biofuel sectors, whereas R$ 46 billion will be allocated to expand energy generation and transmission.

Even though it was written before the devastating global crisis caused by the Coronavirus pandemic, thereby impacting its estimation of socio-economic indicators for 2020 as well as for the following years, the document's importance to determine the country's energetic future still stands. And in spite of its contents including figures relating to PDE's last issue – which will certainly be lower for its 2021 edition -- the aim of the paper is to signal trends that we will need to keep an eye on to establish whether they will still be included in Brazil's energy matrix design.

Generally speaking, the PDE 2029 foresees an annual growth of 2.5% in Brazil's overall energy consumption until 2029. The per capita energy consumption is set to increase 1.9% per year in this same time frame. Still, average consumption per person will be significantly lower than that recorded in developed countries, according to the report.

Thus, the final energy consumption in 2029 should reach 336 million tons of oil equivalent (Mtep) compared to 263 Mtep last year. When we only take into account electric power, this source's participation in the final consumption is expected to rise from 18% to 20.3%.

Final energy consumption evolution by source



Source: EPE, PDE 2029

[1] The Ten-Year Energy Expansion Plan is an informative document for society as a whole, and is intended as a recommendation, and not as a resolve, for the energy sector's future outlook, in accordance with the Government's ten-year plan. The PDE 2029 is the latest version.

The tendency of Brazil's economy to become increasingly electrified is discussed in the study. In planning terms, overall electricity consumption is set to grow 3.8% per year until 2029. Most of this growth will come as a result of Brazilians' access to electronic gadgets that make life more convenient and bring comfort to their daily lives, such as air-conditioners. In regards to vehicles, however, expectations are grim: only 3% of vehicles circulating in the country in 2029 will use electric power as their source of fuel.

Energy transition, including global economies' increasing decarbonisation, also shapes the expansion of Brazil's energy system. With that said, and just like what has already being going on, the increased participation of non-controllable sources, such as wind and photovoltaic solar energy, becomes, on one hand, even more pervasive in the energy matrix, while, on the other, hydroelectric plants record a lower participation in the grid.

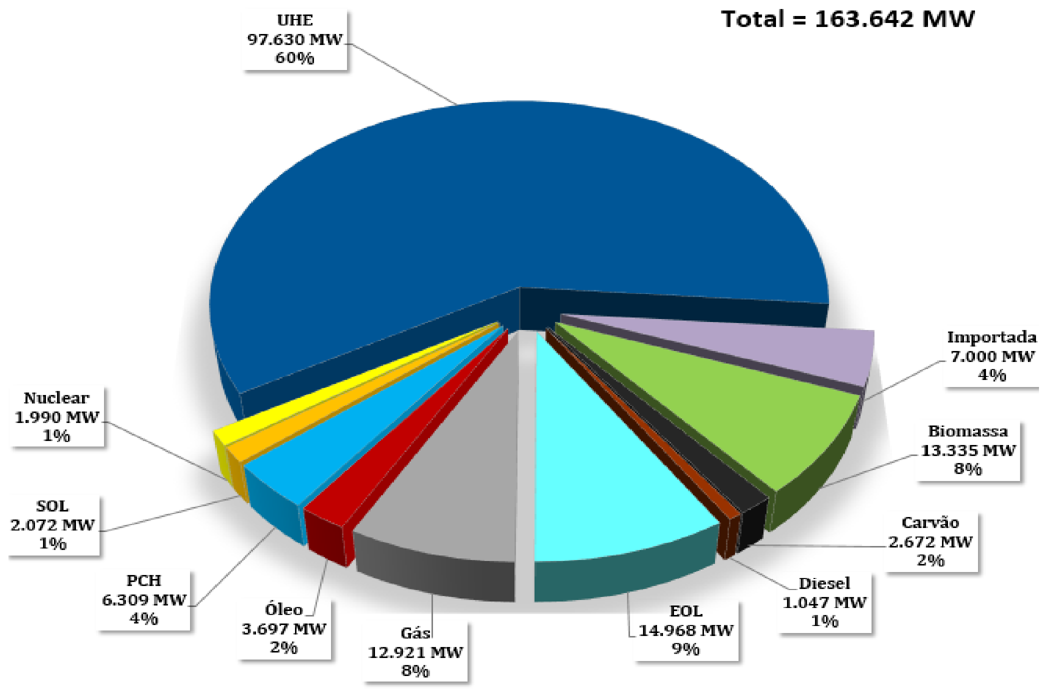
The PDE 2029 states the following for wind energy – the renewable alternative that is already leading Brazil's energy expansion: "This Plan upholds the importance of aiming for the development of wind energy in a continuous and harmonious manner in light of this source's market in the Country. However, **surg-**

ing its participation in energy supply leads to challenges, such as the need to expand sources of complementary power (bolding is ours) due to its restricted ability to meet production-related power and variability needs, even if we take into consideration the portfolio effect across industrial complexes."

"Complementary power expansion" will come as a result of thermoelectric power. Thus, the PDE points to "natural gas as the fuel that will step up to expand thermoelectric power generation." **"Imported LNG denotes standard fuel used to develop new power plants both in the short and long-term. Nevertheless, the development of Pre-salt oil reserves, as well as the discovery of new post-salt basins in the country, such as in the state of Sergipe, may lead to a considerable rise in the supply of low-cost natural gas in Brazil, consequently contributing to the nation's energy matrix already pursuant to its ten-year planning horizon."** (bolding is ours).

To determine a reference scenario, EPE took into consideration open and combined-cycle natural gas-fired thermoelectric power plants (UTEs) "with variable costs concerning LNG, and featuring three operating options: flexible; with inflexibility levels ranging from 50% to 100%; and combined-cycle plants "using domestic gas with lower fuel costs and inflexibility levels of 50%."

Capacidade Instalada no SIN no final de maio de 2019

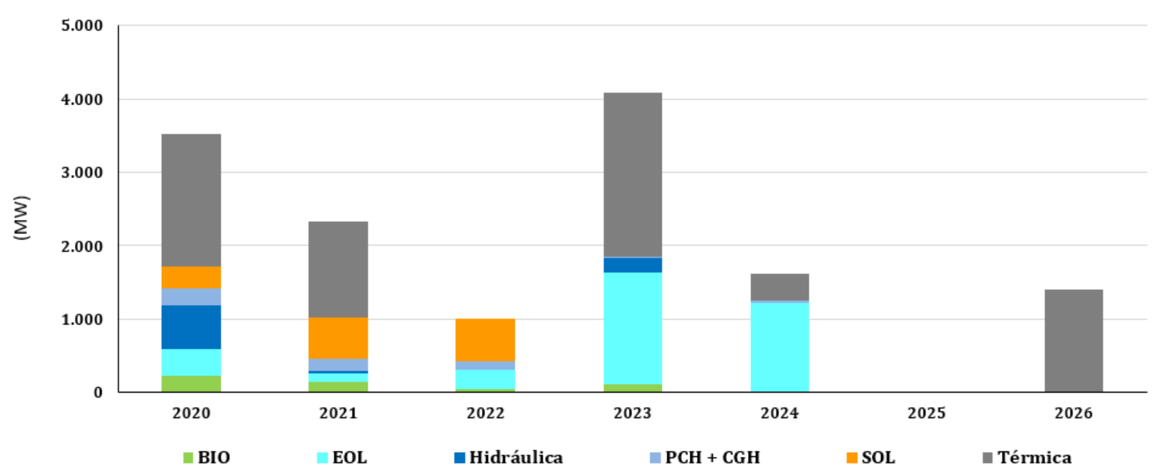


Fonte: EPE, PDE 2029

Nota: O montante apresentado como PCH inclui também as CGH existentes.
A oferta inicial considera 2.975 MW de usinas termelétricas cuja potência disponível é nula

Aimed at appraising the expansion of the energy sector's industrial complexes, the PDE 2029 uses a National Interconnected System (SIN) with 164 GW of installed capacity as its baseline, as well as an additional 14,000 MW of previously installed capacity – "of which approximately 50% will be comprised of renewable sources," the document points out.

Gráfico 3-3 - Expansão contratada até 2019 – Incremento anual de capacidade



Usinas que iniciam operação comercial, de acordo com o DMSE, a partir do segundo dia do mês são consideradas no incremento do mês seguinte.
As usinas termelétricas a óleo diesel, óleo combustível e gás natural retiradas da expansão nas datas de término de seus contratos não estão contabilizadas nesse gráfico.

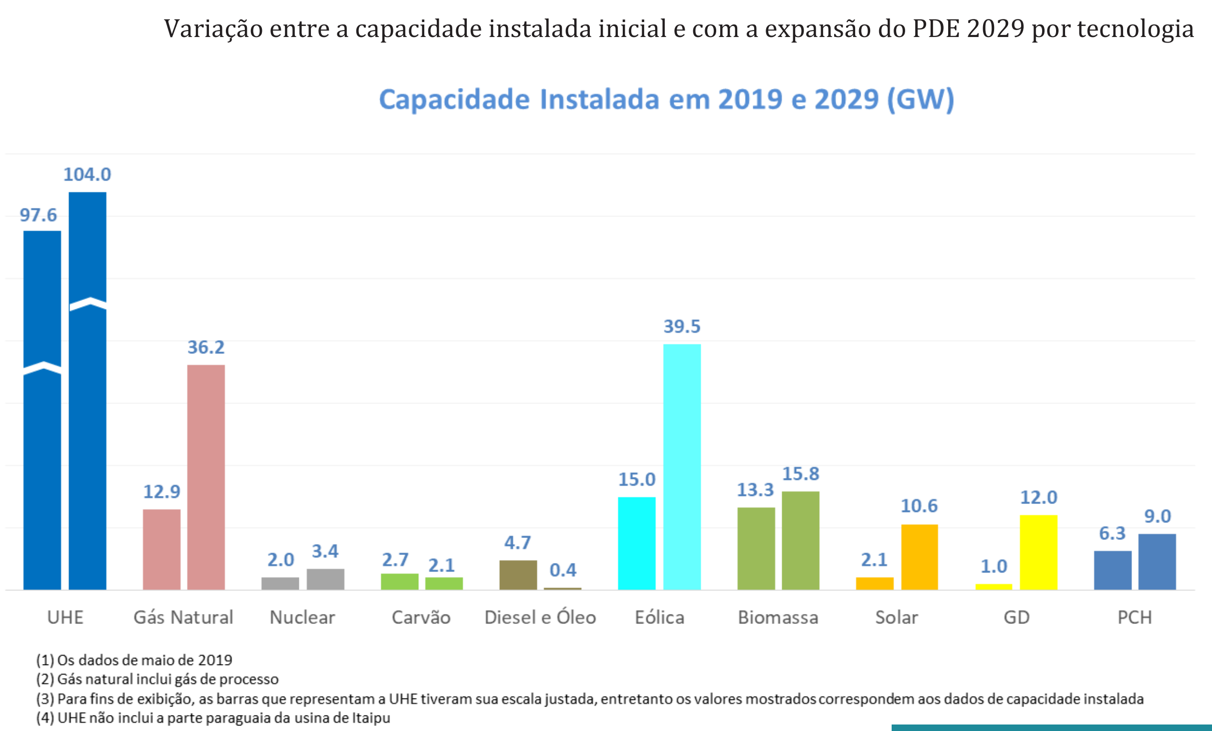
Graphs were created in Portuguese only.

Therefore, according to the PDE 2029, **“the guaranteed output trade balance signals a need to contract a new energy supply to meet the needs of the energy sector as a whole, ranging from 13,000 to 25,000 average-MW for contracts backed by new enterprises included in the ten-year planned horizon.”** (bolding is ours). This recommendation takes into account the removal of the 15,512 MW-capacity thermoelectric power plant National Interconnected System. Removal of natural gas plants, on the other hand, results from termination of contracts in regulated environments (Electric Energy in Regulated Environments - CCEAR), amounting to an overall output of 4,576 MW, in addition to the end of financial grants related to the Thermoelectric Priority Program (PPT) established in 2000, totalling 2,941 MW. The study further reports that 3,321 MW-capacity thermoelectric power plants were removed due to the end of their useful lives; it does not, however, point out which of them are natural gas-fired plants.

Nevertheless, the aforementioned indicator is not in any way a guarantee that these plants will cease their operations or stop supplying the system. Thus, EPE points to the fact that 9,000 MW of this output can be reused by means of “retrofitting in light of the expansion of new higher fixed cost and more efficient power plants.”

Even if we consider that the participation of thermoelectric power plants

> **“just like what has already being going on, the increased participation of non-controllable sources, such as wind and photovoltaic solar energy, becomes, on one hand, even more pervasive in the energy matrix, while, on the other, hydroelectric plants record a lower participation in the grid.”**



Graphs were created in Portuguese only.

Fonte: EPE, PDE 2029

This has a direct impact on the role of natural gas in the energy matrix. We can see that its participation doubles in the ten-year horizon.

Expansão da Capacidade Instalada Total por Fonte de Geração

FONTE	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
	MW										
RENOVÁVEIS	**146.712**	**149.482**	**151.058**	**152.673**	**160.195**	**167.469**	**173.587**	**180.117**	**186.746**	**193.445**	**200.198**
HIDRO[a]	101.926	102.512	102.570	102.592	102.788	102.783	102.811	103.212	103.637	104.159	104.701
CENTRALIZADA	101.288	101.899	101.935	101.935	102.139	102.139	102.139	102.523	102.942	103.436	103.958
AUTOPRODUÇÃO	638	613	635	657	649	644	672	689	695	723	743
PCH e CGH	6.458	6.714	6.922	7.081	7.437	7.852	8.244	8.651	9.077	9.509	9.956
CENTRALIZADA	6.385	6.610	6.787	6.898	7.207	7.545	7.845	8.145	8.445	8.745	9.045
GD	73	104	135	183	230	307	399	506	632	764	911
EÓLICA	15.045	15.424	15.532	15.797	20.319	24.532	27.534	30.537	33.542	36.550	39.561
CENTRALIZADA	15.017	15.370	15.477	15.742	20.263	24.475	27.475	30.475	33.475	36.475	39.475
GD	28	54	55	55	56	57	59	62	67	75	86
BIOMASSA[b] e BIOGÁS	19.928	20.465	20.861	21.160	21.793	22.471	23.085	23.673	24.296	24.905	25.535
CENTRALIZADA	13.412	13.643	13.790	13.840	14.135	14.415	14.695	14.975	15.255	15.535	15.815
AUTOPRODUÇÃO e GD	6.516	6.822	7.071	7.320	7.658	8.056	8.390	8.698	9.041	9.370	9.720
SOLAR	3.354	4.367	5.173	6.043	7.857	9.831	11.913	14.045	16.194	18.322	20.444
CENTRALIZADA	2.182	2.480	3.037	3.622	4.622	5.622	6.622	7.622	8.622	9.622	10.622
GD	1.172	1.887	2.136	2.421	3.235	4.209	5.291	6.423	7.572	8.700	9.822
NÃO RENOVÁVEIS	**28.801**	**30.808**	**32.351**	**32.593**	**34.641**	**36.440**	**36.707**	**41.012**	**43.556**	**45.460**	**50.785**
CENTRALIZADA	22.672	24.473	25.778	25.778	27.704	29.293	29.239	33.114	35.319	36.915	42.059
URÂNIO	1.990	1.990	1.990	1.990	1.990	1.990	1.990	3.395	3.395	3.395	3.395
GÁS NATURAL[d]	12.921	14.436	15.741	15.741	17.859	21.234	22.662	25.679	28.315	31.339	36.190
CARVÃO	3.017	3.017	3.017	3.017	3.017	3.017	3.017	3.017	3.017	1.790	2.083
ÓLEO COMBUSTÍVEL[e]	3.697	3.697	3.697	3.697	3.697	2.510	1.028	657	226	25	25
ÓLEO DIESEL[e]	1.047	1.333	1.333	1.333	1.141	542	542	366	366	366	366
AUTOPRODUÇÃO	6.129	6.335	6.573	6.815	6.937	7.147	7.468	7.898	8.237	8.545	8.726
TOTAL BRASIL	**175.513**	**180.290**	**183.409**	**185.265**	**194.835**	**203.909**	**210.294**	**221.129**	**230.303**	**238.905**	**250.983**
ITAIPU 50Hz [c]	**7.000**	**7.000**	**7.000**	**7.000**	**7.000**	**7.000**	**7.000**	**7.000**	**7.000**	**7.000**	**7.000**
TOTAL DISPONÍVEL	**182.513**	**187.290**	**190.409**	**192.265**	**201.835**	**210.909**	**217.294**	**228.129**	**237.303**	**245.905**	**257.983**

Notas: (a) Os valores da tabela indicam a potência instalada em dezembro de cada ano, considerando a motorização das UHE.
(b) Inclui usinas a biomassa com CVU > O e CVU = 0 (bagaço de cana). Para as usinas a bagaço de cana, os empreendimentos são contabilizados com a potência instalada total.
(c) Em gás natural, é incluído também o montante de gás de processo.
(d) Usinas termelétricas movidas a óleo diesel e óleo combustível são retiradas do Plano de Expansão de Referência nas datas de término de seus contratos, conforme reduções apresentadas nesta tabela.
(e) Parcela da UHE Itaipu pertencente ao Paraguai, cujo excedente de energia é exportado para o mercado brasileiro.

Fonte: EPE, PDE 2029

Graphs were created in Portuguese only.

in the Brazilian energy matrix only grew three percentage points from 2019 to 2020 – from 15% to 18% -, we are nonetheless able to see how in the reference model introduced by the PDE 2029, natural gas-fired thermoelectric power plants' installed capacity increases threefold in the ten-year horizon that the study bases itself on. This is the highest expansion percentage across every source accounted for in the study.

It is worth noting that this paper is based on the PDE 2029-proposed reference scenario. However, EPE's plan makes projections that take additional contexts into account, such as expansion with distinct demand forecasts. In this particular case, there is a 6,500 MW decrease in the expansion of flexible LNG-fired thermoelectric power plants (open-cycle and combined-cycle).

Another scenario suggested in the report includes a higher supply of Brazilian natural gas, resulting from an increase in energy production in Pre-salt oil fields and its production in the Sergipe-Alagoas Basin in Brazil's Northeastern coastline, in addition to expectations created by the New Gas Market established in July 2019. Taking into account lower gas prices in the country, PDE expects an increase of 2,600 MW in installed capacity in gas-fired thermoelectric power generation. Additionally, as a result of the input's lower price, the document's subchapter projects a greater thermoelectric power dispatch in the baseline, and consequently, greater inflexibility in using these plants.

Nevertheless, the paper points out that "the what if concerning a greater supply of Brazilian national gas for which a lower production cost is expected, showed that if we rely on 'flexibility premiums', then options with specific inflexibility levels may prove to be more economically attractive. It also stresses, however, that the added benefit resulting from inflexible power plants decreases, thereby requiring increasingly lower prices as new inflexible plants join the expansion."

In regards to natural gas production, the PDE 2029 expects a production peak of 155 million m³/day in 2028 with a slight decrease from 2029 onwards, which may be recovered after new reserves are added. The main contributions would be expected to come from the Santos and Campos Basins in the Pre-salt region; Sergipe-Alagoas; Solimões in the Amazon; Parnaíba in upstate Piauí; and the state of Maranhão. Most of this volume will concern oil-related gas.

The paper takes into account "high reinjection rates" of natural gas to improve the recovery factor of Pre-salt oil. Still, it finds that the volume to be made available to the market from Natural Gas

Processing Units (UPGNs) is significant: around 116 million m³/day.

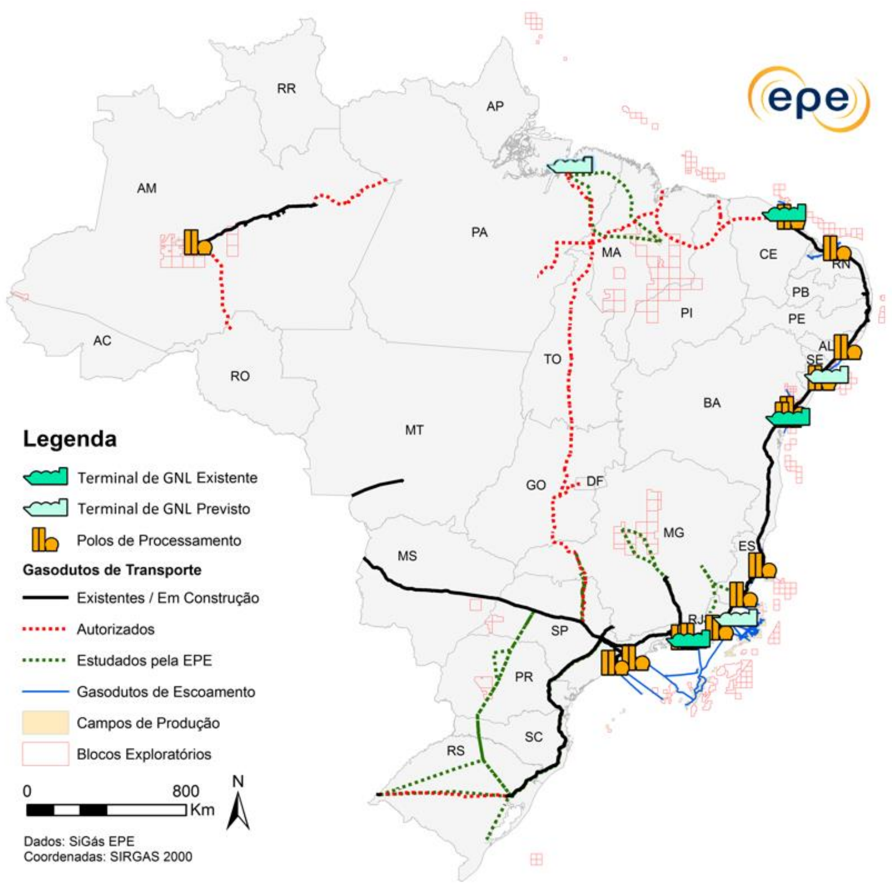
When it comes to the fuel's infrastructure, though, the PDE 2029 projects a LNG terminal with a 21 million m³/day regasification capacity in Barra dos Coqueiros in the state of Sergipe, which is linked to the Port Sergipe I UTE (maximum demand of nearly 6 million m³/day); a second one holding a 21 million m³/day regasification capacity in São João da Barra in the state of Rio de Janeiro, more specifically in the Açu Port, linked to the Novo Tempo UTE and the GNA II UTE (maximum demand of approximately 6 million m³/day, each); and a third featuring a 15 million m³/day regasification capacity in Barcarena in the state of Pará, linked to the Novo Tempo Bacarena UTE (maximum demand of nearly 3 million m³/day), and able to meet other industrial demands.

Recommending regasification terminals underscores the PDE's findings that imported LNG will be the fuel spearheading natural gas-fired thermoelectric power plant expansion both in the short and long-term. However, it also shows an uncertainty towards how Brazilian-produced natural gas will be supplied in logistical terms – reinjected to foster oil production, and build gas pipelines and liquefaction terminals in production plants – as well as the competitive difference of its price compared to imported gas.

Now, these uncertainties have merged with the effects of the Covid-19 pandemic, particularly the sharp drop in demand, which resulted in oil's price plummeting in the global market. This slump casts doubts on Brazil's Pre-salt project development due to production costs that exceed oil prices, which, in turn, also impacts projected gas-related supply volumes.

The same applies to the New Gas Market. Its intention of increasing the number of fuel transportation and supply providers to drop natural gas prices has become unclear. This stems from the expected slump in the demand for this fuel, in addition to a probable lack of interested parties in an investment that, for the

Infraestrutura existente e em construção de oferta e transporte de gás natural



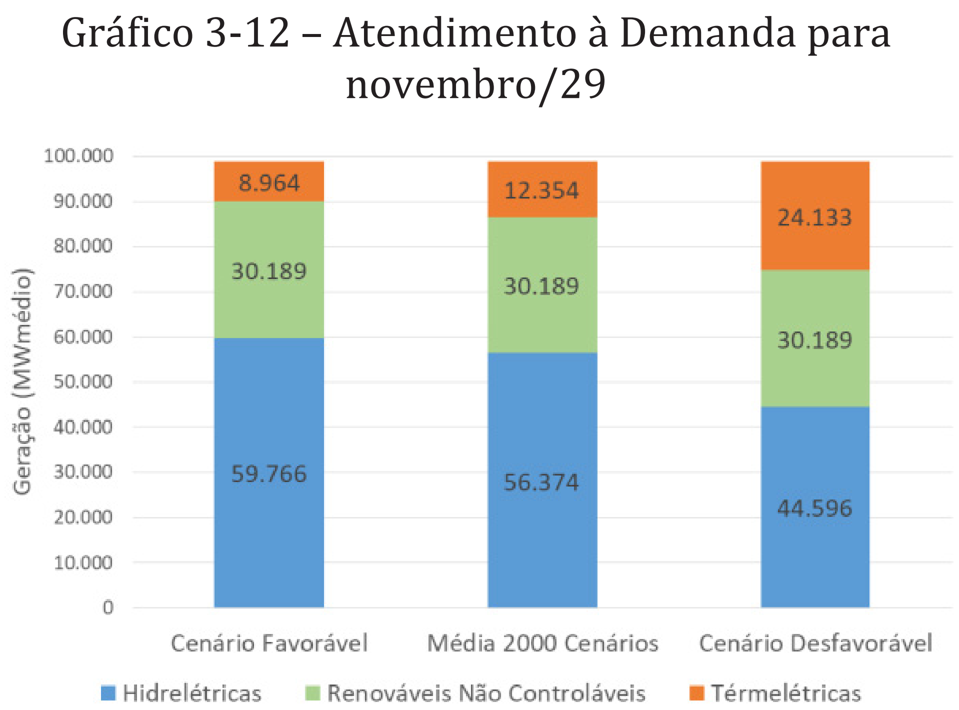
Fonte: Elaboração EPE

Graphs were created in Portuguese only.

time being, proves to be risky.

As a result, the "LNG solution" becomes ever stronger for thermoelectric power, which in spite of having started out seemingly as a temporary fix, now shows every sign of potentially lasting much longer than expected. And with Brazilian gas production falling much lower than projected volumes, in addition to the expansion of baseline energy UTEs – regardless of perceiving this increase as lower, and also as a direct effect of Covid-19 -, the trend is for the imported product to become the driving force behind this expansion.

Another issue worth noting – and which may directly impact water use for thermoelectric power plant generation – is the projection shown for November 2029, which takes into account dispatching requirements pursuant to hydroelectric reservoirs' affluent levels. If, one hand, the PDE points to highly uncertain thermoelectric power dispatch – which, in the simulation undertaken may range from averages of 9,000 MW to 24,000 MW -, consequently favoring flexible power plants, on the other, it fails to consider clearly potential conflicts concerning water use if we talk about open or closed-cycle power plants.



Fonte: EPE, PDE 2029

Graphs were created in Portuguese only.

We cannot state, though, that the PDE 2029 report failed to consider water use. In a specific chapter where it discusses ten socio-environmental subjects that should be taken into account for Brazil's energy expansion, especially in regards to thermoelectric power plants, the PDE 2029 shows how projects geared towards Brazil's Northeast should be particularly considered due to water scarcity. Nevertheless, the plan does not examine the matter more thoroughly, only stating that the right choice of technologies may help to mitigate said issues.

Energy sources: value or price?

Energy contracting auctions in regulated markets have gained distinction for bringing together a wide host of different source providers. At first, and with the aim of making non-water renewables' participation more significant in the energy matrix, as well as lowering their costs, auctions geared specifically towards wind and solar energy were held. Now, though, thanks to the supply industry's increased participation and growth, in addition to more affordable equipment prices, said sources also partake in auctions from other sectors, such as hydroelectric and thermoelectric power, though they do not compete directly among themselves since the EPE sets different reference prices for each source.

It is widely known that each source does indeed have its own price as a result of its specific attributes, technologies deployed, supply contracts, etc. Nevertheless, numerous uncertainties still linger as to whether EPE-set reference values take into consideration appropriate attributes that should be considered when the product is priced. This would actually increasingly enable sources to directly compete with each other, leading to gains for both the energy system and for customers.

"The level of competition that an auction has is a direct result of the price of energy. This is even more evident in the free market, where the generator securing the contract is the same offering the cheapest energy. Things like restricting offers in specific times or monitoring attendance in auctions are not appraised at this time. In the regulated market, this appraisal only takes place partially when decisions are made as to which energetic volumes will be supplied by which sources, such as, for instance, by thermoelectric, wind or solar energy. Still, this appraisal is not comprehensive," explains Bernardo Bezerra, the technical director of PSR – Energy Consulting and Analytics.

With this in mind, in 2018 PSR, in partnership with Instituto Escolhas, produced the study "What are the real costs and benefits of electric power generation sources in Brazil?," based on the PDE 2026. The article argues that Brazil's energy planning should use a specific methodology that enables an appropriate appraisal of each source's particular attributes. It would allow for the removal of distortions, which give the impression that a given source is cheaper than another.

"In 2018, wind energy was contracted at R$ 100 per megawatt-hour (MWh), while thermoelectric power was contracted at R$ 210, on average. The technical reasoning for this stems from the fact that the system requires the most expensive source to ensure reliability. However, there were no existing methodologies at that time to estimate whether said price difference was accurate, or whether it does indeed pose an actual difference. Our efforts aim to adequately appraise each source's attributes so as to avoid this supposed divergence in prices, which is not accurate," Bezerra underscores.

The methodology suggests appraising specific attributes across five different factors: 1) Investment and operating costs, where renewable sources have an edge; 2) Services that extend beyond energy supply (modulation, seasonality, robustness and reliability), which benefit thermoelectric power plants; 3) Infrastructure costs either resulting from or avoided by the generator, in which case biomass-fired thermoelectric power plants have an edge; 4) Government grants and exemptions, which mainly benefit wind, solar and small hydroelectric central stations (PCHs); and 5) Environmental costs, which are higher for thermoelectric power plants because of their greenhouse gas emissions, while lower for renewables like wind and solar energy.

"One of the methodology's key points relates to how its use does not intend to favor any specific source. Instead, its deployment entails a diversified portfolio of sources for an enhanced supply of Brazil's energy system"

One of the methodology's key points relates to how its use does not intend to favor any specific source. Instead, its deployment entails a diversified portfolio of sources for an enhanced use of Brazil's energy system: "given that the appraisal of attributes undertaken by this study takes into consideration the complementarity among generation sources operating jointly, the optimal expansion plan should not necessarily only choose the option with the lowest cost," stresses the document.

The report evidences how the contracting model implemented by Brazil from 2013 onwards, whereby auctions are held separately for each source, made sense since water sources dominated the expansion. Nevertheless, the generation mix started to change, with fossil fuel-fired thermoelectric power plants leading the way, after which wind plants had a greater participation and, finally, in recent years, photovoltaic solar plants have secured a greater share in this market.

"This situation started generating problems that did not exist before. An example of this is how thermoelectric power plants were used to offset hydroelectric stations' reduced capacity in Brazil's Northeast, a result of continuous draughts in the last few years. This led to a surge in costs due to higher fossil fuel prices and higher greenhouse gas emissions. Furthermore, climate change – which may impact energy supply from several sources -- makes it increasingly important to consider every source as a whole rather than each source individually. We say this because the sustainability of the energy matrix needs to be deemed a key factor, in addition to its safety and reliability," the paper continues.

When we apply the appropriate methodology for appraising attributes on projections submitted by the PDE 2026 report, the Escolhas/PSR study puts forward two distinct possibilities: 1) An enhanced participation of renewable sources in Brazil's energy matrix in 2026, without, however, leading to any significant price increase for customers; and 2) A 68% increase in the participation of wind, solar and biomass energy in 2035, accounting for 44% of the overall matrix constitution, a change that would occur without impacting said sources' megawatt-hour competitivity and attractiveness for consumers.

[2] http://www.escolhas.urg/wp-content/uploads/2018/11/Quais_os_reais_custos_e_benef%C3%ADcios_das_fontes_de_gera%C3%A7%C3%A3o_e%C3%A9trica_no_brasil-SUM%C3%81RIO-EXECUTIVO.pdf

The last thing we need is a water shortage

Regardless of the source used, thermoelectric power is not ranked first among the country's sectors with the highest water consumption. On the contrary: thermoelectric power plants actually record the lowest use of water resources across all consumptive sectors.

According to data published in the National Water Agency's (ANA) "Conjuncture of Water Resources in Brazil 2019" report for last year's numbers, the thermoelectric sector accounted for an overall water withdrawal of 93 m^3/s in 2018, corresponding to 4.5% of the overall 2.048 m^3/s water withdrawal by consumptive sectors.

When we look at consumption – in other words, the percentage of water that is not returned to water resources -, thermoelectric power plant participation is even lower: 3 m^3/s (0.3% of the overall 1.101 m^3/s), thereby securing a 90m3/s volume returned in this segment.

Nevertheless, thermoelectric power plants' growing participation in Brazil's energy matrix forced ANA to take a closer look at the segment. This is what the agency states in its "Handbook of Consumptive Water Uses in Brazil", also published in 2019.

"The growing trend to use this option in energy generation, the large water-related demand, and the way that residual water is returned to the environment forced ANA to make projections for the sector. Adding this supply group represents a challenge and, at the same time, the potential to better appraise the use of water resources in Brazil.

UTEs' water demand depends on technologies, the type of fuel and the cooling system, in addition to incidental environmental conditions. Inadequate operations – oftentimes to complement unmet hydroelectric energy demands– also have a significant impact on intra and interannual projection variations," argues the chapter on thermoelectric power.

As a result, ANA's rising concern with the increase in UTE numbers in the National Interconnected System is very clear. The agency also points to the condition in which the water is returned to the source waterbody – how the liquid is used for cooling, and how its return to the environment occurs in high temperatures, something that may impact fauna and flora at the source waterbody.

The numbers below evidence water withdrawal variations per state and Brazilian region in 2017.

When we look at Federative units, we see that the state of Rio de Janeiro topped the water withdrawal ranking with 21% of the overall sum, nearly twice the percentage recorded for the state of Santa Catarina (13%), in second. This can be explained by the fact that Rio de Janeiro state's territory holds the largest thermoelectric power plant installed capacity in the country. However, it is important to point out that Rio de Janeiro has seen a number of water supply crises during this time.

The six states with the highest thermoelectric power-related water withdrawal percentages - Rio de Janeiro, Santa Catarina, São Paulo (11), Pará (9%), Maranhão (9%) and Pernambuco (8%) – cluster 72% of the overall demand, amounting to 79.5 m^3/s, which corresponds to 3.8% of the overall withdrawal.

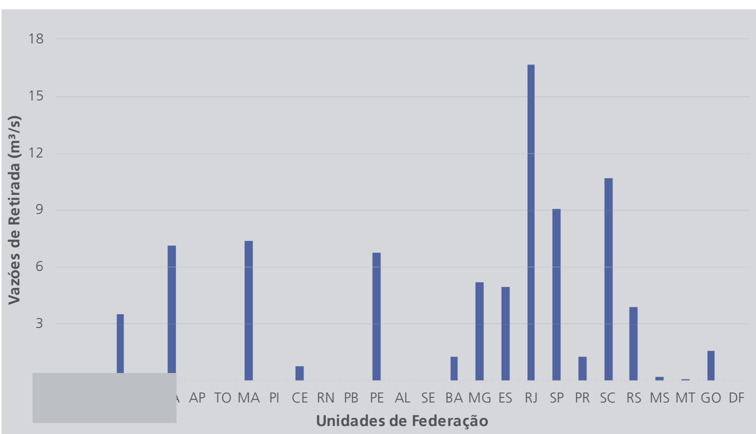


Figura 41 - Vazões de Retirada (m³/s) para termelétricas nas UFs

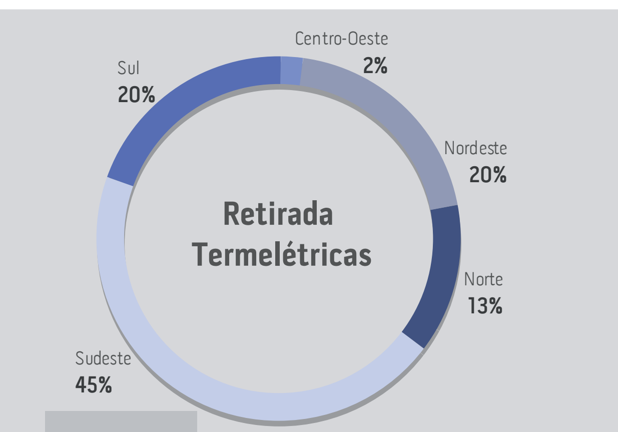


Figura 42 - Percentuais de Retirada (UTE's), por Região, em Relação à Retirada Total

Source: Handbook of Consumptive Water Uses in Brazil

Graphs were created in Portuguese only.

Maria Paula Martins, former Oil and Natural Gas Under Secretary for the state of Rio de Janeiro

"Brazil's energy system has always been variable even for hydroelectric plants due to differences in water regimes throughout the country. Wind plants' assurance is the Brazilian transmission grid, which already undertakes this role for hydroelectric plants."
Maria Paula Martins, former Oil and Natural Gas Under Secretary for the state of Rio de Janeiro

A former Oil and Gas Undersecretary for the state of Rio de Janeiro, Maria Paula Martins witnessed from upclose the development of thermoelectric power plant projects in said state, in addition to the state of Espírito Santo, where she served as the General Director of the State Energy Regulatory Agency (ASPE). She draws attention to how gas-fired UTEs changed their location over time.

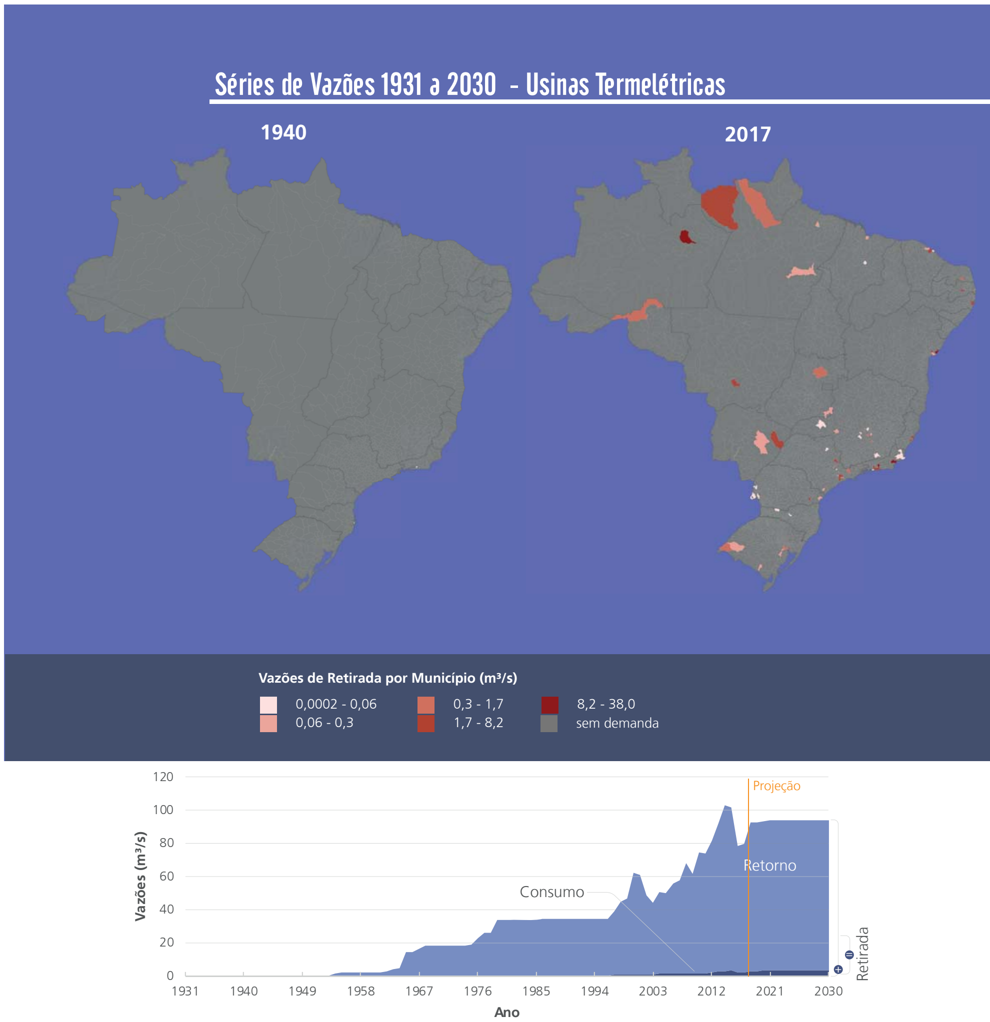
"Before, projects sought to be near gas pipelines. In recent years, however, thermoelectric power plants are being built or planned near natural gas production complexes. With this, areas close to the coastline are favored, near offshore gas arrival points in the coastline and Natural Gas Processing Units (UPGNs). Thus, water removed from rivers for cooling would only take place after all other withdrawals for several uses," she recalls.

Still, the ANA-produced report finds that "around 100 UTEs really do require significant water volumes to run – accounting for nearly 45% of the overall installed capacity." Furthermore, the document states that "even though it is a significantly novel intensification benefit, UTE-related water withdrawal exceeds, at national level, the sum of every other withdrawal for mining and household supply purposes in rural areas."

The handbook points to the fact that new plants that were beginning their operations, as well as UTEs that were already operating when the paper was produced, would result in said plants' average demands reaching 93.7 m^3/s in 2021. Again, it is important to note that said projection was made before the context of the current Covid-19 global pandemic; nevertheless, as previously stated, it serves its use as an indicator.

However, thermoelectric power plants' dispatching capability in Brazil's energy matrix – for scenarios with low hydroelectric reservoirs, as well as for ensuring wind and photovoltaic solar sources – can lead to an upward revision of ANA's water withdrawal projections.

The agency points to figures from 2014 and 2015, when the thermoelectric power demand exceeded 100 m^3/s. Said years recorded water shortages that impacted hydroelectric generation, consequently forcing the Operator of the National Electricity System (ONS) to further engage UTEs. "Thus, future scenarios of thermoelectric power plant water use may be highly impacted by water conditions," underlines the handbook.



Maiores Vazões Retiradas (m³/s) por Município (2017) - Termelétricas

Ranking	UF	Município	Vazão Retirada (m³/s)
1°	RJ	Rio de Janeiro	16,246
2°	SC	Capivari de Baixo	10,620
3°	MA	Imperatriz	7,036
4°	PE	Ipojuca	6,682
5°	SP	Mogi Guaçu	4,989
6°	ES	Serra	4,872
7°	PA	Barcarena	3,750
8°	AM	Manaus	3,468
9°	RS	Canoas	2,596
10°	PA	Oriximiná	2,206

Destacam-se, em diferentes unidades da federação, demandas em municípios com concentração de termelétricas de maior porte, e que possuem alta variabilidade anual e intranual de acionamento. Observa-se no gráfico diversos anos de pico da demanda, os mais recentes em 2014 e 2015, em função de condições hidrológicas desfavoráveis para a geração hidroelétrica. Nas décadas de 1930 e 1940 não havia retirada de água para esse uso no Brasil, tendo a série iniciado em 1954 na cidade de São Paulo.

Resultados detalhados de séries históricas de usos consuntivos, para todos os municípios, podem ser acessados em www.snirh.gov.br/usos-da-agua.

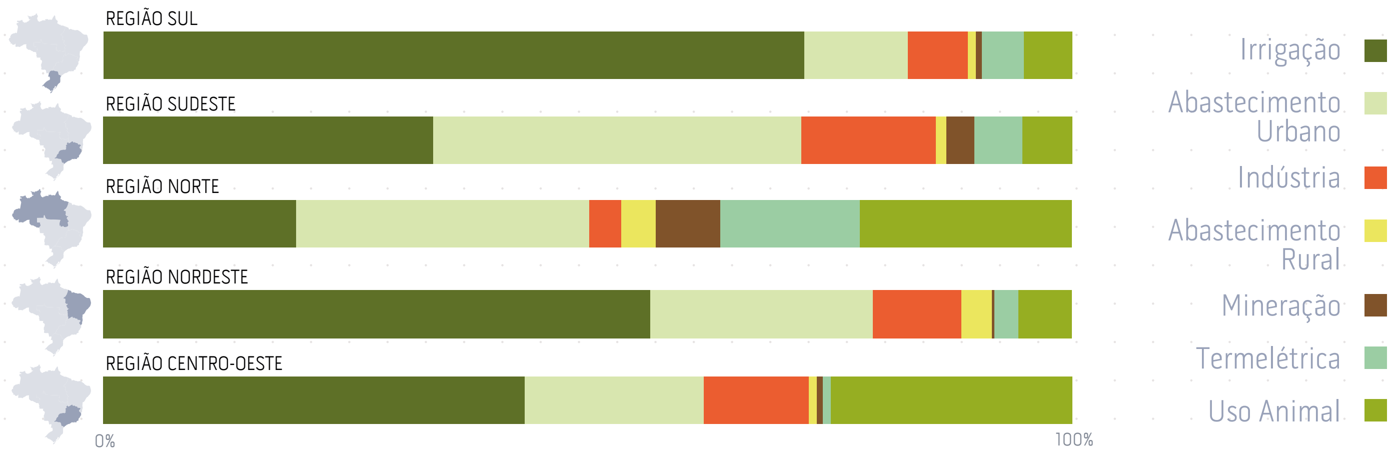
Source: Handbook of Consumptive Water Uses in Brazil

We go back now to the "Handbook of Consumptive Water Uses in Brazil 2019". The report emphasizes the significant increase in water supply demand in the country that took place in the last two decades, reaching 80%. Moreover, water withdrawal for a wide host of consumptions is expected to increase by 26% until 2030 (based on 2018).

The chart below shows water demand per region in Brazil. It is important to underscore our next assessment: conflicts entailing water use between the agricultural sector, for irrigation purposes; and electric power generation, particularly in regards to thermoelectric power used for cooling purposes.

Graphs were created in Portuguese only.

DEMANDA DE ÁGUA POR REGIÃO GEOGRÁFICA

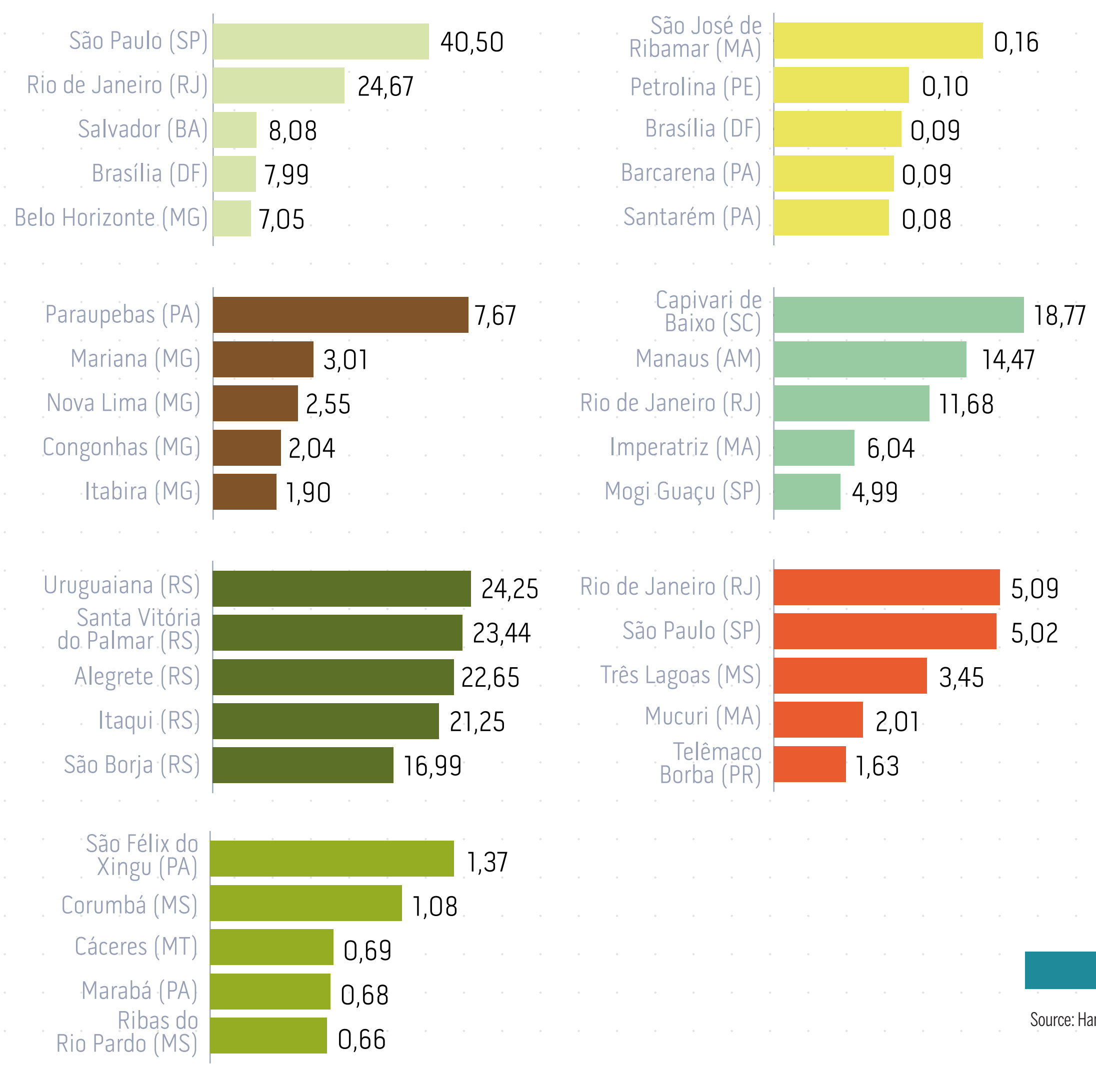


MUNICÍPIOS DO BRASIL COM AS MAIORES RETIRADAS DE ÁGUA EM 2018

POR FINALIDADE (Em m³/s)

As escalas variam conforme a finalidade

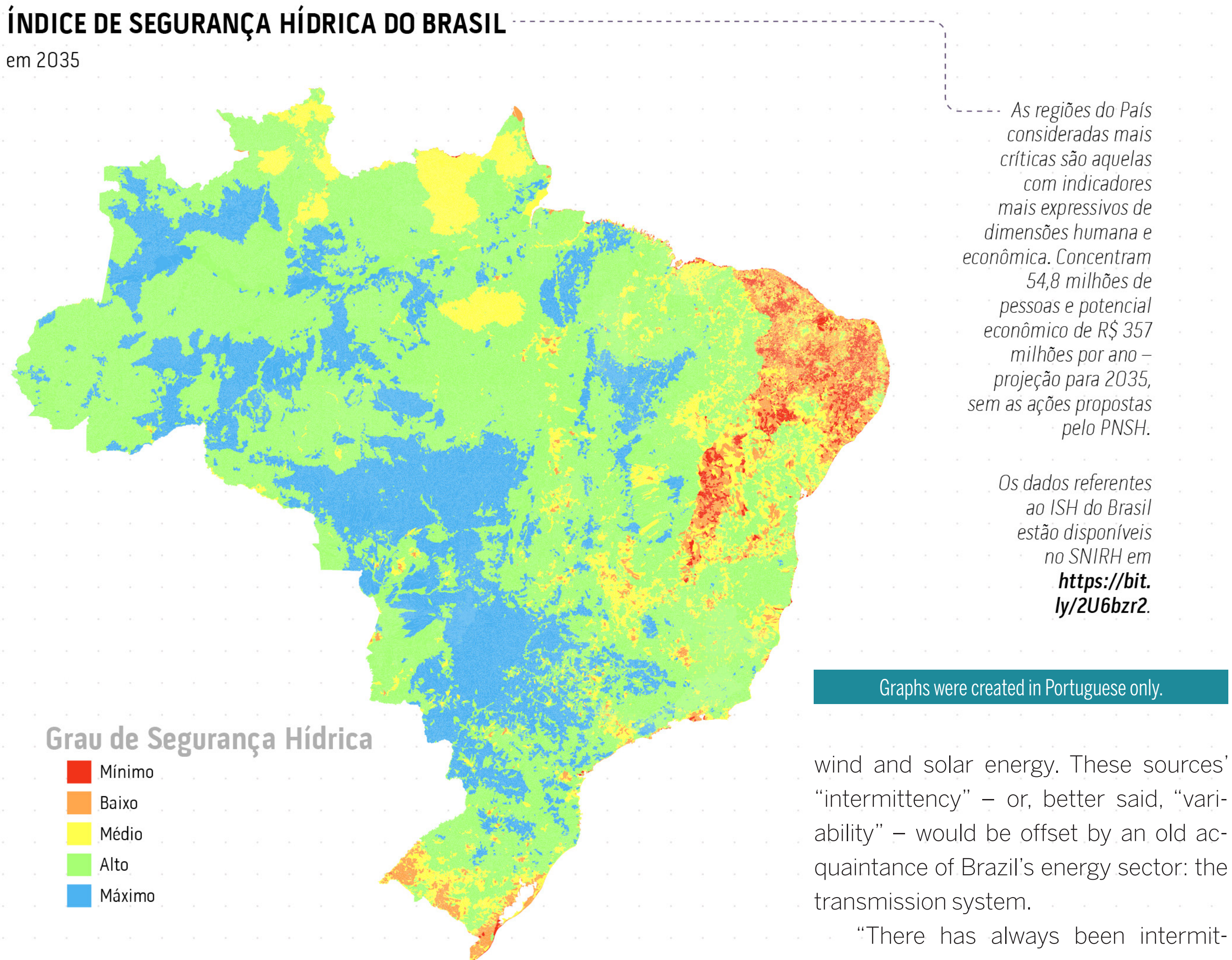
Os dados referentes a todos os municípios do País, para os diferentes usos, entre 1931 e 2030, estão disponíveis em: ***https://bit.ly/2UfoLu1***



Graphs were created in Portuguese only.

Source: Handbook of Consumptive Water Uses in Brazil

The map below illustrates ANA-established water security levels in Brazil. In regards to the map, the "Conjuncture" report signals that "the Country's regions dubbed the most critical are those with the most significant human and economic indicators. Together, they cluster 54.8 million people, as well as an economic potential that reaches R$ 357 million per year – projection for 2035 not including efforts recommended by the April 2019 National Water Security Plan (PNSH)."



Source: Handbook of Consumptive Water Uses in Brazil

Graphs were created in Portuguese only.

A quick look at the map shows that, among all regions, Brazil's Northeast is the one with the lowest water security levels (minimum and low). We can also verify low security levels in Rio de Janeiro's metropolitan area, as well as in the country's southernmost region.

In these scenarios, in coastline regions, one of the potential solutions would be to use desalinated seawater for thermoelectric power plant cooling, like what happens at the Angra Nuclear Power Plant in the state of Rio de Janeiro. Nevertheless, since we are still talking about a technology that is somewhat expensive, there are concerns regarding the competitiveness of projects that choose this solution.

Going back to the Northeast region again, however, perhaps the best solution is not thermoelectric expansion, but rather an enhanced use of the region's wind and solar energy. These sources' "intermittency" – or, better said, "variability" – would be offset by an old acquaintance of Brazil's energy sector: the transmission system.

"There has always been intermittency in Brazil's energy system, even in hydroelectric plants. The time of the year when water reservoirs are full in the South is the same time of the year when reservoirs are empty in the Northeast, and the other way around, too. Thus, the National Interconnected System already helped to balance out this difference. Wind plants require complementation, which thermoelectric power plants achieve, and this complementation must use the transmission grid, like it already has for hydroelectric plants," points out Maria Paula Martins.

How much is water worth?

In 2019, PSR produced another study in partnership with Instituto Escolhas: "Electric Sector: how to price water in a scarcity scenario?" Both methodology and results evidence that Government, agents and society should discuss how to define water as an input, and foster new price mechanisms after evaluating three conflict and competition scenarios for water resources. Which factors are responsible for generating conflicts across the country's several water uses?

As previously mentioned, Brazil finds itself in a privileged position when it comes to natural resources. The country holds 12% of the planet's entire fresh water reserves. Then, why is it that in the last years we have faced scarcity problems in several consumptive segments?

The obvious answer, which has been widely reported, entails climate change-related issues. Global climate has changed the country's rainfall rates, consequently impacting our water resources as well as water's availability for consumption.

Nevertheless, the report shows that in addition to environmental impacts, conflicts related to water use, particularly those involving Brazil's energy sector, have come as a result of a lack of planning. In other words, this is not about structural problems, but rather about conjunctural bottlenecks that can be settled – or at least mitigated – with an efficient management.

"Water is an input for all kinds of human activities: energy generation; agricultural and industrial production; urban and rural supply; and for maintaining basin ecosystems. A robust water management should comprise and make all these uses compatible in order to enable a sustainable use of said resources," signals the report.

The paper further poses two conjunctural flaws. The first one relates to monitoring water resources in Brazil, which still lacks data from several areas, such as more accurate information on precipitation and withdrawals, consumption and water return. The second is actually a result of the first: the data gap leads to issues concerning water appraisal and pricing. When it comes to the energy sector, this can lead to extra charges levied on standard rates paid by customers, in addition to even cutting off power generation, thereby jeopardizing the energy supply.

The study examines three distinct cases: the Jaguaribe River Basin in the state of Ceará, where coal-fired thermoelectric power plants Pecém I and Pecém II were erected; the São Francisco River Basin in the Southeast and Northeast regions, home to UTEs and sugar cane bagasse, biomass, biogas and diesel oil, and which has natural gas projects planned for construction; and the Belo Monte hydroelectric plant built next to the Xingu River in the state of Pará. In this paper we will only consider the current status of Ceará's thermoelectric power plants since they are located in the Brazilian region with the most critical water condition, more specifically, the Northeast.

With an overall output of 720 MW, Pecém I began running in 2012. In the next year, the 365 MW-capacity Pecém II plant started its operations. Both plants were contracted in 2007 and 2008, respectively, in energy sector auctions in the A-5 regulated environment. Installed in Pecém's Industrial and Port Complex in the metropolitan area of the capital city of Ceará, Fortaleza, the plants run with coal imported from Colombia, which is unloaded in the neighboring port.

"Located in the Jaguaribe River Basin, the Castanhão Dam supplied water to both Pecém UTEs as a whole (SIRH/CE, 2012) [...] The Castanhão Dam is Brazil's main dam for several types of uses, with its priority being to supply Fortaleza's metropolitan area, where nearly half of the state's population lives. Furthermore, the Castanhão Dam also provides water for irrigation, fish-farming, and regulates the Jaguaribe River's water flow.

> **"Resulting from environmental impacts, conflicts related to water use, particularly those involving Brazil's energy sector, have come as a result of a lack of planning. In other words, this is not about structural problems, but rather about conjunctural bottlenecks that can be settled – or at least mitigated – with an efficient management.**

Aerial view of the Pecém
Thermoelectric Industrial Complex
Enerva Archives

Even though power plants use Wet Cooling Towers (WCTs) whose water withdrawal is significantly lower than that of open-cycle power plants, their consumption is considerably higher – nearly 75% of the withdrawal volume -, and thus, with low water return. Due to their proximity to the coastline, plant licenses could have included a requirement to use desalinated water. However, this did not happen.

In 2016, Ceará's government enacted Law no. 16.103, which created the contingency tariff levied on water resources used in times of critical water scarcity, dubbed the"Emergency Water Charge" (EHE). This charge was created just before the serious water crisis endured by the Castanhão Dam in 2017, at which time its volume dropped to 5% of its overall capacity – the worst situation since 2002, when the dam started operating.

The last EHE (Decree no. 32.305 of August 11th, 2017) contemplated in the study signalled prices ranging from R$ 2.067 to R$ 3.010 per m^3 of water consumed. These figures concern water consumption in the following period – from September 2017 to August 2018.

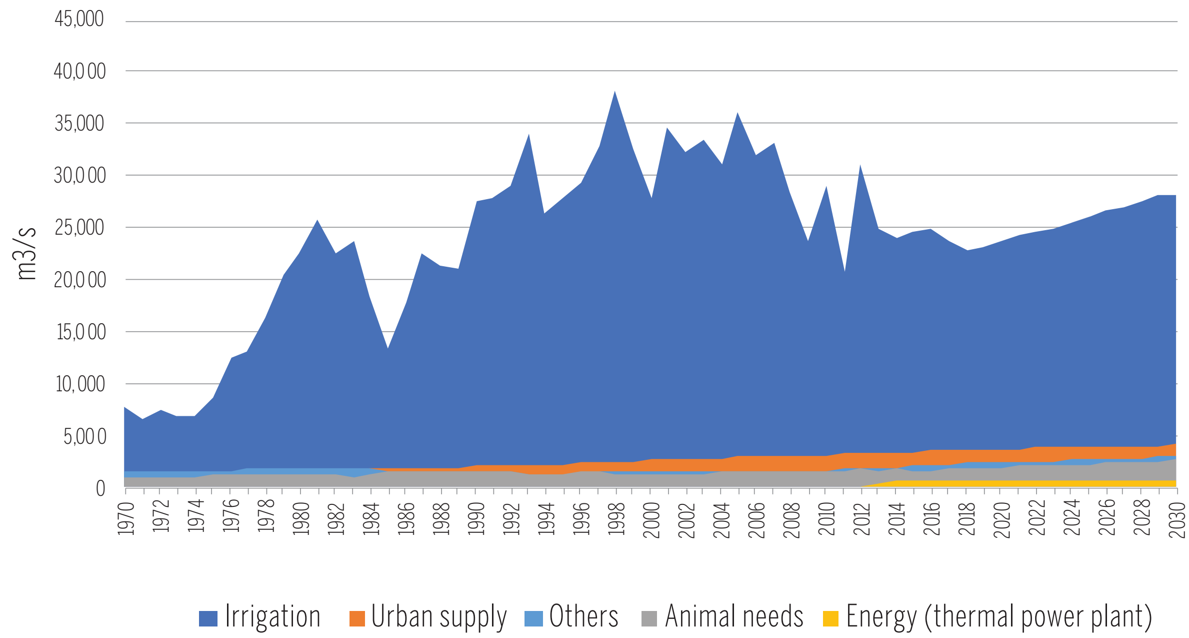
The EHE was collected from Pecém I and Pecém II, although the Brazilian Electricity Regulatory Agency (Aneel) prohibited its transfer to energy costs. Nevertheless, lawsuits ensured the transfer of this additional charge, which amounted to an extra sum of R$ 148 million in electricity bills for all Brazilian consumers from September 2016 to August 2019. The point is that this charge could have been avoided in the first place if water had been adequately priced, basing said value on the Jaguaribe River Basin's criticality level, as the report suggests.

The Jaguaribe River Basin

Criticality Level	R$/m³	Reference
Excellent	0.0135	Minimum Unit Public Price – Ceará state Hydrographic Basin Committee
Comfortable	0.778	25% of the range
Worrisome	1.556	50% of the range
Critical	2.333	75% of the range
Very critical	3.101	Emergency Water Charge in the State of Ceará

This Basin's main water use is for irrigation purposes, which corresponds to 73% of the demand. We can see a strong connection between the increase in water use and the increase in gains from agricultural production (R$ 100 million).

Jaguaribe River Basin water uses



Source: Based on the Handbook of Consumptive Water Uses in Brazil. Brasília: ANA, 2009.

The Instituto Escolha/PSR study projected "this input's opportunity cost for a scarcity situation in the basin. The opportunity cost is the relation between the choice and waiver of the best use, as well as the greatest financial benefit related to water resources" – in this particular case, agriculture.

The Jaguaribe River Basin's Opportunity Cost Variation (R$/m³)

Upper Jaguaribe	0.43 - 4,56
Salgado	0,19 - 1,28
Banabuiú	0,66 - 4,61
Middle Jaguaribe	0,28 - 1,38
Lower Jaguaribe	0,52 - 1,21
The Jaguaribe Basin	**0,38 - 1,59**

The paper argues that "rates for using water resources from thermoelectric power plants should correspond to criticality levels of the water source supplying them. The lowest price considered is the Unitary Public Price (PPU) (*determined by Hydrographic Basin Committees*) concerning rates for the use of water resources set forth for each basin, whereas the highest price is the Emergency Water Charge introduced by the state of Ceará during its 2017 water shortage crisis. Intermediate prices are proportional fractions corresponding to ranges between lowest and highest prices."

For consumers or "prosumers?"

We now go back to the PDE 2029. The study makes the following statement in regards to thermoelectric generation: "It is important to recall that there are measures in place to reduce water consumption in energy generation that may help to avoid said conflicts and, consequently, enable thermoelectric expansion without affecting the population or other users. **Among these measures, we can point to the use of alternative sources (seawater, for instance), water reuse and employing air-cooled technologies or hybrid air-water systems** (bolding is ours)."

Thus, there are already existing technological options capable of lowering thermoelectric project water consumption. A number of power plants already built in the country have been following this trend. Be it in using air-cooled systems, or in using seawater in their operations.

However, socio-environmental issues raised by the PDE, ANA documents as well as by Instituto Escolhas/PSR papers all draw attention to Brazil's Northeast region. It is indeed concerning that part of the thermoelectric expansion envisioned for the country includes building projects in said region using rainwater or lake water. Because of both rainwater and lake water-related risks. Because of the risk of increasing energy sector rates initially proposed in energy contracting auctions in the regulated market, as evidenced in the cases of the Pecém I and Pecém II UTEs, and because said power plants may fail to generate when activated by the ONS due to water shortages.

Experts we heard when producing this paper state that thermoelectric expansion must necessarily include more in-depth information whenever said projects are contracted in centralized auctions, foreseeing technological and/or sustainable innovations. Given that environmental benefits are yet to be adequately appraised in auctions, innovations have a tendency of increasing energy rates, in addition to making said plants increasingly less competitive in comparison to other less complex projects. Thus, innovative projects like these need to have their due space ensured at the moment they are contracted.

The Instituto Escolhas/PSR study describes an example of this when it signals that half of the UTEs built in China use air-cooled systems – thereby certainly meeting that country's energy planning requirements.

"During the planning stage, we even carried out macro location surveys to pinpoint regions with higher water stress rates. However, it is possible to build a thermoelectric power plant anywhere since the Brazilian energy system is developed and interconnected enough to avoid issues relating to project locations.

Thus, it will be increasingly important to take into account water use or technological innovations to reduce impacts during projects' engineering and environmental licensing stages than when we need to think about how to expand the energy supply," states an energy sector source who has already worked with energy planning.

When it comes to projects that use water in their cooling systems, we need to ensure appropriate pricing for thermoelectric power water use, while taking into account additional consumptive uses. For this to happen, though, the Instituto Escolhas/PSR study points out that we need to "enhance water monitoring by means of planning and an efficient management of all data related to water withdrawal, use and return." Adequate monitoring calls for, among other things, restoring flow rate series; enhancing rainfall measurements both in quantity and in geographic/spatial distribution; creating an official database for each thermoelectric power plants' cooling system due to this sector's appraisal being restricted; and, most importantly, avoiding areas with critical water levels when building UTEs with water-based cooling systems.

"Among these measures, we can point to the use of alternative sources (seawater, for instance), water reuse and employing air-cooled technologies or hybrid air-water systems."

Another expert recommendation points to the location of new thermoelectric plant projects. In order to avoid water stress, power plants should ideally be built near the coastline and use seawater for cooling. This is particularly significant because of the natural gas supply. Be it due to Pre-salt oil reserves and enhanced investments resulting from the New Gas Market, or due to LNG regasification – regardless of the effect that the post Covid-19 scenario has on plans to use these resources.

Therefore, discussions on where gas stands in an energy transition to an economy based on reduced greenhouse gas emissions also entail challenges relating to how planning is able to accurately signal this role in our energy matrix, estimating how long gas is expected to remain in this status, as well as how to efficiently replace it, even if gradually, with other sources.

For this to happen, we also need to deconstruct certain concepts related to renewable sources. One of them, which has been increasingly used, is that of "intermittency". It is well-known that wind and solar sources pose limitations, and cannot be activated only to meet consumers' needs. However, this also applies to hydroelectric plants, particularly to run-of-river power plants relying on water sources, in addition to natural gas-fired thermoelectric power plants that require transportation, liquefaction, storage and regasification infrastructure, not including energy supply assurances.

In light of a context that suggests growing flexibility when it comes to using diversified sources, it seems that appraising them with a variability standpoint is significantly more effective than with an intermittency standpoint. "Every source is variable. Nowadays, systems are already flexible and will continue being so even more. Hydroelectric power, which is variable, is nonetheless deemed a baseline energy. It relies on a seasonal system. The same reasoning applies to wind energy, which does not have intermittency , but is also variable. We already know how it lends stability to the Brazilian energy system, complementing hydroelectric generation. The thermal source is also variable since it is subject to logistic and supply issues," stresses Instituto Escolha's Sergio Leitão.

Technological innovation, which has been making big strides, also fully dismisses the concept of "intermittency", in addition to the concept that assures natural gas-fired generation. On one hand, discussions about energy transition evidence a trend to make both small and large-scale batteries more affordable in order to store renewable source-produced energy – the PDE 2029 itself reflects on the inclusion of ion-lithium batteries starting from 2024. On the other, though, the development of new liquefaction, storage and regasification options may render this source's entire current structure obsolete, thereby entailing new – and costly – investments.

In light of a context that suggests growing flexibility when it comes to using diversified sources, it seems that appraising them with a variability standpoint is significantly more effective than with an intermittency standpoint."

In the wake of fossil-sourced natural gas, another option to meet regional and local energy demands emerges: biogas. Originating from an organic source, this biofuel can be used both to generate electric power and to convert it to biomethane, thereby replacing vehicular natural gas (VNG), and moving aside other fossil fuels, such as, for instance, diesel oil.

As the PDE 2029 exemplifies, "this energy source is rich in methane, whose burning power is akin to that of natural gas. Thus, one of the potential ways to use it is in aeroderivative turbines or in electric generation turbines.

There are a number of substrates that can be used to produce biogas, among which those originating from the agro-industrial sector (particularly sugar-ethanol) have the highest potential in the domestic market, in addition to livestock and urban residues."

According to the "The Outlook for Biogas and Biomethane" report produced by the International Energy Agency (IEA) in March, an appropriate use of organic waste can lead to biogas and biomethane supplying 20% of the world's natural gas demand. This would additionally be useful to reduce natural gas carbon footprints, "demonstrating a positive synergy between fossil and renewable fuels," states the PDE 2029.

Renewable energy sources also stand out in another segment included in Brazil's energy planning: distributed generation. In recent years, this type of energy production grew exponentially in Brazil, fostered by Aneel's Normative Instruction No. 482 of 2012. And even though the regulatory agency seeks to review rate exemptions awarded within this group, its growth – which underscores the persona of the "prosumer," in other words, consumers who produce their own energy -- should continue, regardless of potential decreases in its momentum.

If hydroelectric expansion tends to decrease due to the lack of new energy supplies resulting from socio-environmental restrictions, we must look at power plants already running and consider a new alternative: repowering. The

Sergio Leitão, Executive Director of Instituto Escolhas

“The [Northeast] region is a sort of wind “OPEP”; nevertheless, it still has not given itself its due financial credit to this end. Thus, will it really be necessary to replace wind energy expansion in the region with thermoelectric power plants, which will demand a supply infrastructure or gas imports?”
Sergio Leitão, Executive Director of Instituto Escolhas.

PDE 2029 considers the “group of power plants eligible for repowering as those that have been operating for at least 25 years, and feature an installed capacity exceeding 100 MW, not including plants that have already been enhanced and, consequently, had their assured output reassessed. Brazil’s repowering potential is estimated at around 50 GW, spread across 51 power plants across all subsystems.”

The paper continues: “In carrying out efforts to refurbish plants, we must allow for the possibility of technical increments that also lead to an increase in the installed rated power capacity. In a World Bank paper, Goldberg (2011) poses typical capacity gains nearing 12%. EPRI (2000), in turn, believes in typical gains in the installed rated power ranging from 5% to 20%. If we consider this data together with Brazil’s repowering potential, we would therefore have a projected increase of around 2.5 GW to 10 GW in the Country’s output.” This is quite a significant output considering energy demand projections.

Looking at a broader horizon, we can also consider technological innovations potentially capable of adding even more installed capacity to Brazil’s energy matrix. For instance – offshore wind plants already operate in a number of countries around the world. The PDE 2029 finds that offshore wind energy will start running in Brazil effective 2027; however, it emphasizes that this technology is still considerably costly. Despite this, “the growing maturity of this technology at global level, the development of technical, economic and socio-environmental studies, in addition to regulatory progress made in Brazil may change this technology’s competitivity and enable its use in future Plans, consequently bringing important benefits to the future of the energy system,” concludes the EPE.

We know that it is impossible for any plan to predict the future. That is why the PDE underscores the need for the project’s assumptions to be continuously reviewed, which will also change recommendations posed.

In a context of mounting pressure coming from economic players to enhance the exploitation of natural gas in the country, as well as the understanding that the energy system will need to take in a significant part of this expansion, it is important that we discuss the weight

of this enterprise, especially when it comes to restricting the supply of renewable sources.

The pressure that economic players apply for this expansion is conveyed in the New Gas Market federal program and in the 2029 Ten-Year Energy Plan, which give special consideration to gas-fired thermoelectric power plants in the expansion of the energy matrix. Of the 60 GW of installed capacity foreseen under the PDE 2029, over 23 GW is set to come from gas-fired thermoelectric power plants, including new plants and existing retrofitted plants. The PDE 2029 also acknowledges the possibility of LNG's international price remaining more competitive than a significant participation of Brazil's production, which, in turn, will pose the question of whether we will need to invest in the expansion of natural gas exploitation in the country (which may turn out to be an even greater risk factor due to Covid-19-induced slumps in oil prices).

The expansion of natural gas-fired thermoelectric power plants in Brazil's energy matrix is surrounded by both uncertainty and risk factors. The prevailing risk factor concerns an increase in greenhouse gas emissions in the energy sector, a very clear setback in the sector's transition to put an end to all emissions. Additionally, a deepening of the climate change crisis, as well as possibly pricing carbon emissions in the medium-term lead to uncertainties concerning both the obsolescence of these thermoelectric plants and their actual costs. Another clear risk entails the inherent competitiveness of Brazilian natural gas when we take into account the volume of investments needed to expand this supply (gas pipelines and regasification ports), its long-term financial return, and the abundant supply concerning the product's international prices. Moreover, there are doubts as to the economic viability of electricity bill rates generated from natural gas-fired thermoelectric power plants when we consider their distinct uses by the energy sector (whether partially or as an energy reserve).

Thus, if there was already a need to substantially tone down the euphoria related to investment projections for gas expansion in our energy matrix even before the pandemic erupted, this has now become absolutely key due to the global economy's current bleak outlook, thereby avoiding us from making strategic decisions on the country's future without considering every risk factor required for an appropriate appraisal of its impacts.

Support: