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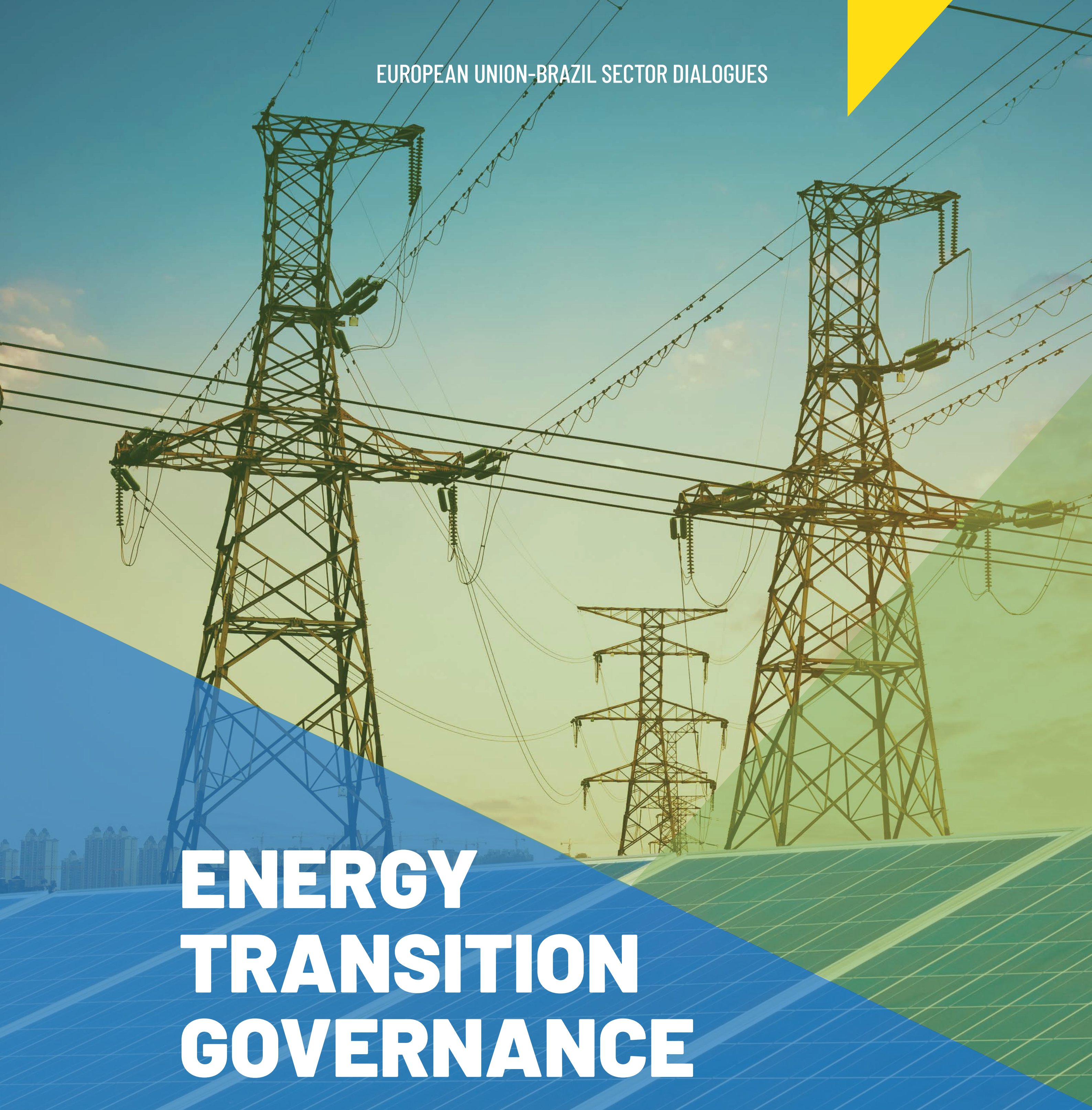

ENERGY TRANSITION GOVERNANCE

Addressing the new governance of the industry, and the regulatory challenges

Dialogues
EUROPEAN UNION · BRAZIL

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INTRODUCTION

This report was created within the scope of the EU-Brazil Sector Dialogues (10th Call), focusing on energy policy, i.e., "Energy Transition – Addressing the new governance of the industry, and the regulatory challenges". The project results from the partnership entered between the Directorate-General for Energy to the European Union (DG ENER) and the Brazilian Ministry of Mines and Energy (MME).

The purpose of the Sectoral Dialogues' Initiative is to narrow the cooperation between the European Union (EU) and Brazil. The objective of this Dialogue is to help improve the understanding on the challenges, and opportunities in the energy transition, by exploring new architectures of the market, new regulation formats, and new governance methods currently emerging on both sides of the Atlantic. With a one-year duration, the main goal of this dialogue was to extend the cooperation between the UE and Brazil, in terms of design and implementation of new governance frameworks, and energy regulation. Improved governance and regulatory frameworks can provide more opportunities for mutual investments across regulated segments, such as power, thus fomenting competitiveness, creation of job opportunities, and growth for Brazil, and the UE.

To a lesser or greater extent, both the EU Member States and Brazil have undertaken critical reforms to the energy segments. This process depends on a few pillars: the liberalisation of power and natural gas sectors, with the elimination of monopolies across potentially competitive segments, and the creation of regulated markets; the introduction of an independent regulation focused on protecting consumers and the network segments - distinguished as natural monopolies[1]; the privatization of old public monopolies, usually coupled with the unbundling of the activities, and the creation of new actors (i.e., system operators, market operators, among others).

A new wave of reforms now encompasses the entire industry, in terms of the energy transition towards a low carbon economy. Such movement is subject to the new public policies on climate and energy, of which the Paris Agreement is the utmost expression. The transformation requires new governance and regulation solutions, since it is marked by processes for resources decentralisation, increasing levels of self-production, digitalization, and electrification of new usages – based on green power. To that end, it takes adjustments to the old competitive environment for efficient allocation of resources, combined with innovative means for the participation of citizens, consumers, and producers. Standing out in this process, we need to integrate the growing renewable and distributed energy resources across the power systems, which calls for decentralised coordination through adequate mechanisms that ensure reliability and resource adequacy – crucial and timeless goals of the energy policy.

In 2016, the European Commission proposed a New Legal Framework for Europe, known as "Clean Energy for all Europeans", which was approved between 2018/2019. This legal framework confronts similar issues while proposing improvements for the consolidation of the Euro-

1 Newbery (2001).

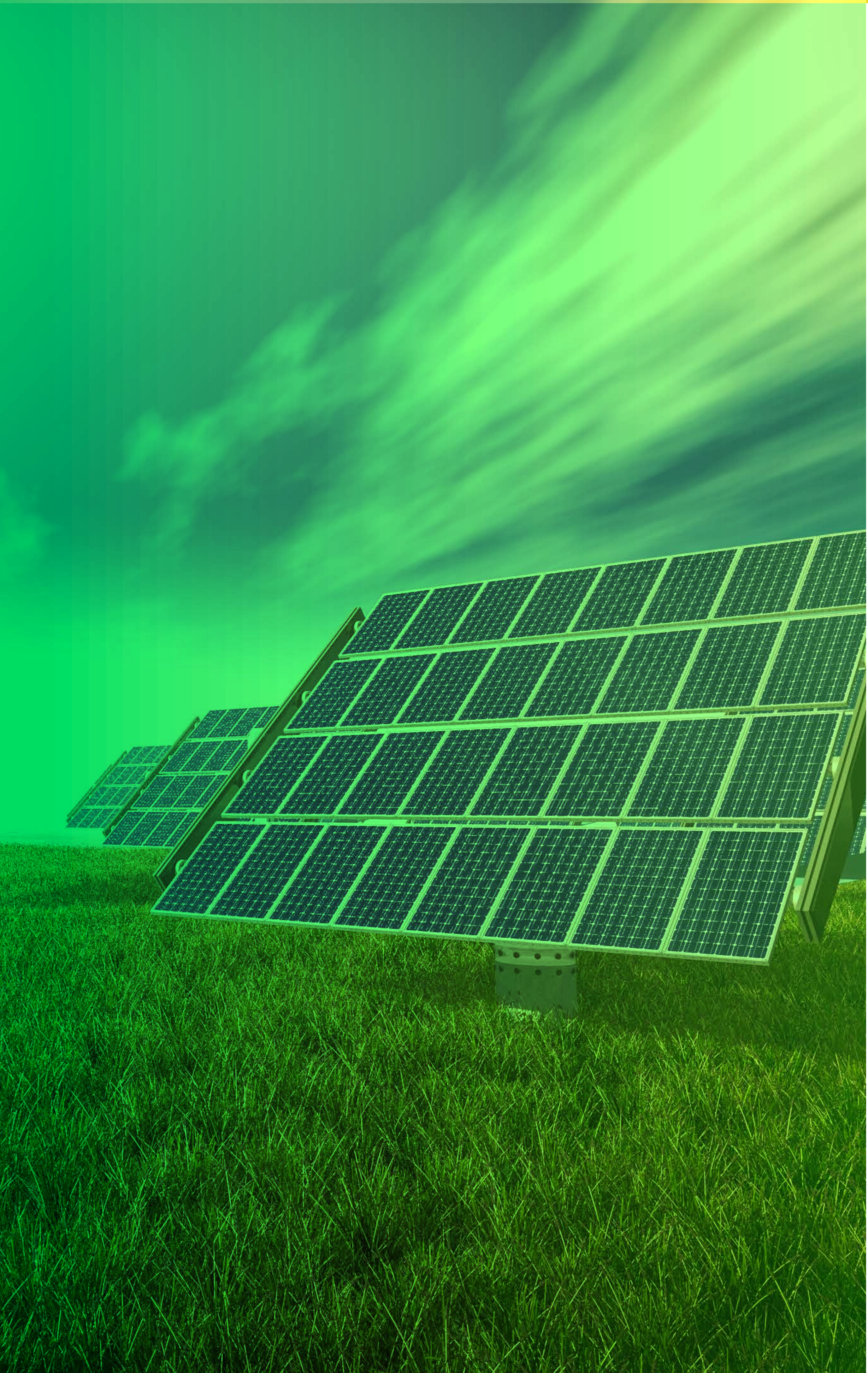
pean Common Market for energy, and acceleration of the transition underway – which is a continuously implementation and improvement process. So, no matter how different the implementation level of the Directives may be, as far as the primary energy options and the reform to Member-States' respective energy segments are concerned, the European experiences are an essential source of information for the current Brazilian phase of the reforms. In the case of Brazil, the reforms focus on the power and the natural gas sectors.

The Brazilian experience, in turn, with an electric matrix typified for such high participation of renewable technologies is a source of inspiration for the European Energy Transition. It also stands out the country's capability to develop a biofuels industry with international relevance and projection, as well as the potential for natural gas production in the pre-salt polygon. It is especially interesting to investigate the responses developed on the recent experience of a country rich of resources, yet still challenged by an institutional-political and regulatory framework – peculiar of a middle-income country.

Therefore, it becomes evident the opportunity theses Energy Dialogues provide towards extending the understanding the transition challenges. Benefiting from such opportunity requires us to grasp a deeper understanding of the policies, concepts, and practices of the adaptive governance, and transitional regulation. These are the actors of this process: policymakers, regulatory agents, incumbent companies and new competitors, investors and members of the academia, and the civil society.

This one-year long project included: a Brazilian delegation mission to the European Union (September/2019), a European mission to Brazil (November/2019), a workshop held at the MME in Brasília (November/2019), and this Report, which summarizes the main topics addressed throughout the Dialogue.

Attached to this paper, you will find the reports on the missions, and the summary of the workshop. This report provides a brief introduction to the energy transition topic. Furthermore, it highlights the key challenges and opportunities (Chapter 2), which examines some essential subjects, addressed within the scope of the project with various participants (Chapter 3) and, finally, brings the authors' conclusions and recommendations, based on the work performed, and the opinions gathered.



1. ENERGY TRANSITION: CHALLENGES AND OPPORTUNITIES

The current energy transition has a clear political origin, in that it concerns the need to avoid climate changes, and therefore, substantially reducing the Greenhouse Effect Gases. This endeavour shall only succeed if it goes global, i.e., if it involves all countries and all segments. That was the understanding achieved during the 1992 Conference, in Rio de Janeiro, which produced the United Nations Framework Convention on Climate Change. Next, there was the Kyoto Protocol (1997), and then the Paris Agreement (2015), which set goals and procedures for the international cooperation on the subject.

Furthermore, the use of fossil fuels does not stand only as a mid-term /long-term threat to the climate. Still, it is also a degradation factor for the air quality within urban centres, thus posing as a concrete and visible form of threat to public health.

Since the energy segment (across its different levels, i.e., extraction, transformation, and final usage) is the main responsible for the greenhouse effect gases, it was inevitable calling it to play a decisive role in the global effort towards decarbonisation. The public interventions can be found in different ways: through taxation, the introduction of technical standards for efficiency and emissions, the definition of quotas, and allocation of subsidies, among others.

By the end of the last century, various countries started subsidizing renewable sources of energy – first at a research and development level, and then through small pilot projects, and, finally through large-scale investments. These public policies allowed to drastically cut down the cost for the exploitation of renewable energy sources, making them competitive, as compared to fossil sources. Nowadays, we can see a similar process in terms of power storage, especially when it comes to fuel-based batteries.

The new information and communication technologies, on the other hand, have emerged to accelerate the digitalization, allowing for the introduction of new business development, which would not be feasible otherwise. For instance, consider the controlled charging (also referred to as smart charging) of electric vehicles in the power distribution grids. However, that would not be possible without the generalized and capillary digitalization of energy. With an uncontrolled charging, on the other hand, the massive diffusion of electric vehicles would soon lead to the collapse of the power system.

Although it resulted from a restriction – i.e., limiting greenhouse effect gases – energy transition has created and continues creating countless opportunities. They correspond to several new levels of freedom enabled by new technologies, new attitudes and behaviours, new legal frameworks, among other things.

The generalisation of the observational and controlling conditions of the overall energy systems, and power system possibly grant them unprecedented plasticity and resilience – and even unattainable before that. The freedom that technologies offer us today – i.e., being able to shape power systems for so many new, and alternate paradigms for the organization of physical and economic transactions, composing the metabolism of the energy – represent a huge opportunity. Such freedom, on the other hand, poses new challenges, not exclusively of a technical nature (reliability, security), but also economic (efficiency) and ethical (equality) that need to be confronted.

Paraphrasing Tom Jobim, we could affirm that the energy transition is not a process "built upon a single note". There are as many energy transitions as combinations of ambition, participation, technologies, and models we can conceive and create. There is a nearly infinite scale of options available to choose. This broad freedom, however, does not spontaneously create a new energy architecture. It is forceful for us to understand that not all "notes" match together and that efficient architecture demands coherence, selectivity, and sobriety.

Like in the song,..."*There's so many people who can talk and talk and talk /And just say nothing or nearly nothing /I have used up all the scale I know /and at the end I've come to nothing or nearly nothing"* (One Note Samba)... – An efficient energy transition cannot be designed through blind experimentation with different technologies, comprising a random combination of all models available. We ought to define well the goals, criteria, and governance of the process – flexible, adaptive governance, paired with adequate transitional regulation. Energy Transition requires conscious choices, translated into consistent governance frameworks, and explicit and transparent regulation policies. Otherwise, it becomes a *pout-pourri*: "*Anyone who wants the whole show do-re-mi-fa-so-la-si-do He will find himself with no show/ better play the note you know*".

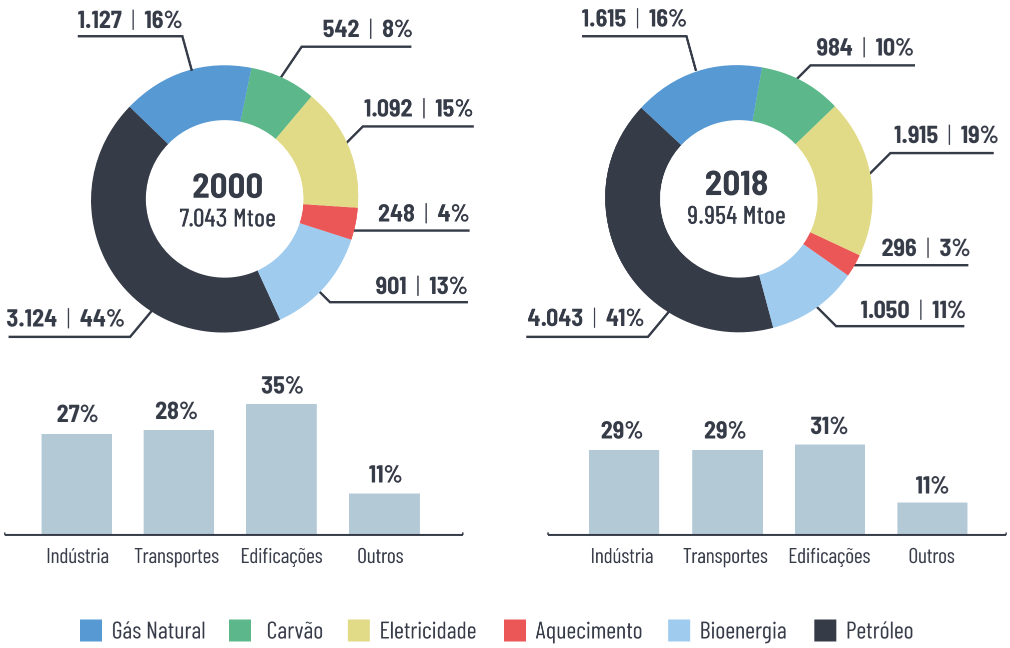
In this chapter, we will start by analysing the role of renewable energy sources – basically, the one note that stands out, the most visible sign, and economically most powerful, the lowest common denominator among all energy transitions. Next, we will expand the horizon towards other changing factors, by contextualizing the renewables into the framework of new energy architectures. The last two sections bring a brief description of the issues for the governance and regulation linked to the new architectures, and the energy transition, overall.

1.1. Panorama of Renewable Energy Worldwide

In this century, the global demand for electricity increased by 70%, reaching 19% of final power consumption in 2018 (Chart 1). The demand across the developing countries has tripled, boosted up the Chinese growth. Even so, nearly one billion people worldwide have no access to electricity, especially in Africa, and Asia. Oil remains the primary energy source, responsible for 41% of the final consumption. However, the global investment in the power sector in 2017 (750 billion dollars) exceeded the investments in the oil and gas segment for the second consecutive year (IEA, 2018a).

The transition towards a low carbon economy translates into decarbonisation of the electric matrices, while concurrently expanding the electric energy matrices. In the long run, increased demand for electricity should continue reflecting the decarbonisation strategy of the economies, with electrification trend for other end usages, such as transportation, and heating.

Chart 1 - Final consumption of energy per fuel type, and segment, worldwide

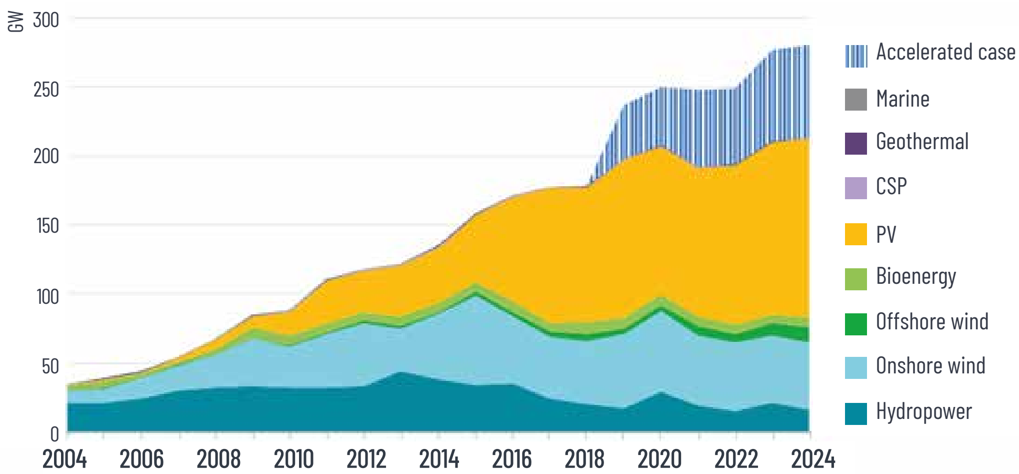


Mtoe = millions of tonnes of oil equivalent

Source: Own elaboration based on IEA data (2019c)

The power sector accounts for 40% of the CO2 emissions, 30% of which derives from coal-power generation. On average, the power sector emits approximately 0.5 t of CO2 per megawatt-hour generated. Since 2000, global emissions grow at a lower annual rate (approximately 2.3% per year) than the power generation expansion, thus reflecting the increase of renewable technologies penetration in the electric matrices (Chart 2) (IEA, 2019c).

Chart 2 - Annual addition of capacity in terms of renewable energy sources per technology – projections 2018~2024



Source: IEA (2019b)

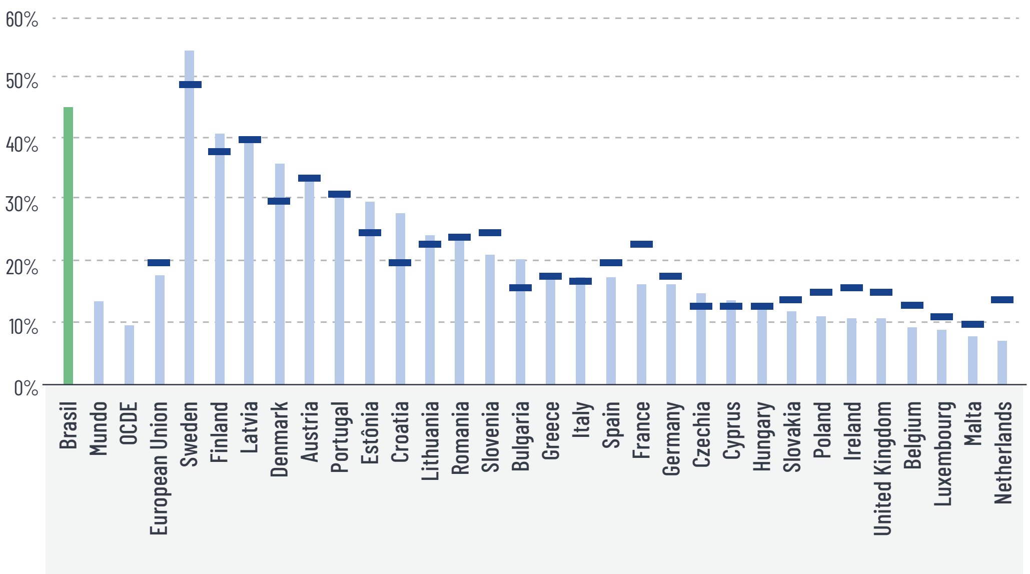
Since the Industrial Revolution, the successive technological paradigms were founded on the growing use of fossil fuels. In 2018, 81% of the world energy demand was supplied by oil, natural gas, and coal. The Intergovernmental Panel on Climate Change (IPCC) ascribes most of the 0.08 and 1.2 °C average temperature rise in the world – regarding a pre-industrial level – to the emissions of greenhouse effect gases derived from human activities (IPCC, 2018).

The studies gathered by the IPCC indicate that the 1.5 °C race above the level during pre-industrial time can bring in severe consequences for the environment, with the increase in occurrences of extreme temperatures and the elevation to the level of the oceans, which makes it urgent significantly reducing the anthropogenic emissions of greenhouse effect gases.

During the 21st Convention among the signatory parties to the Convention-Framework of the UN on Climate Changes, held in 2015, in Paris (COP21), they strengthened the goal to keep global warming below the 2 °C elevation to the current level in the pre-industrial period, with the corresponding efforts to avoid its raising above 1.5 °C.

The participation of the renewables in the world energy matrix has reached only 14%, with lower participation across the member-countries to the Organisation for Economic Co-operation and Development (OECD) (10%) [2]. While the European Union registered renewables participation of 18%, Brazil reaches a significantly higher level, of 45%. Chart 3 presents the relative participation of renewable energy sources for Brazil, and for the European Union's countries, as well as the targets they set for 2020.

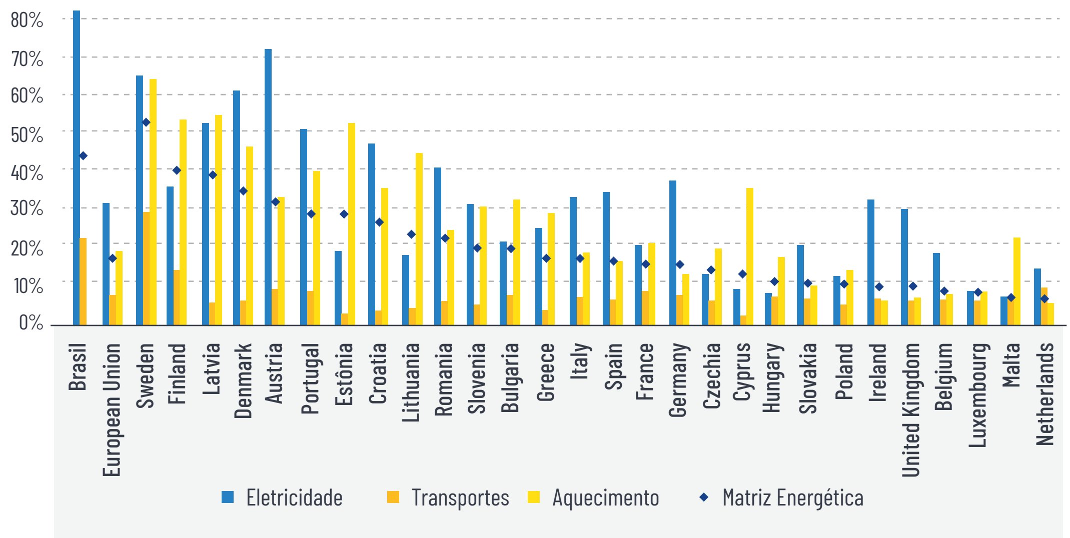
Chart 3 - Participation of renewable sources in the energy matrix for the European Union and Brazil in 2018, and Goals for 2020



Source: Own elaboration based on Eurostat and MME data (2019)

2 Since 2017, Brazil has been trying to become a member of the Organisation for Economic Co-operation and Development (OECD).

Chart 4 - Participation of renewable sources in energy matrices – Electricity, Transportation, and Heating in the European Union and Brazil



Source: Own elaboration based on Eurostat and MME data (2019)

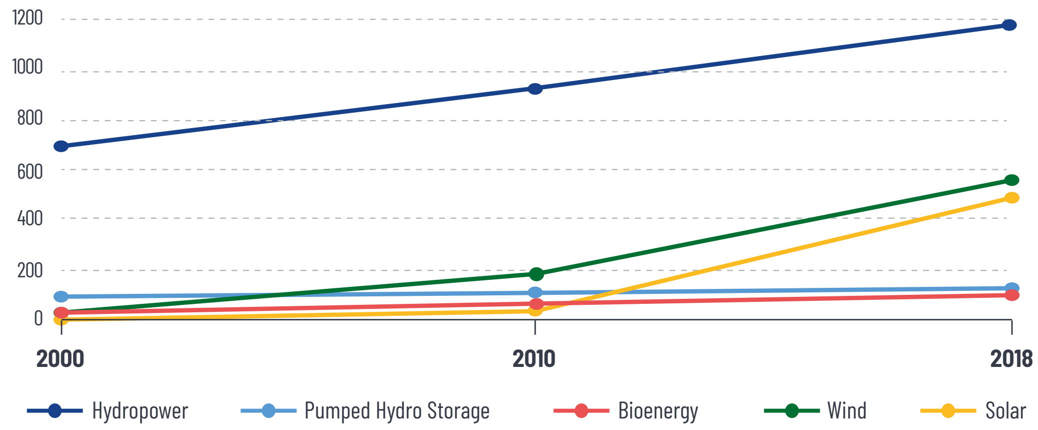
The high participation level of renewable technologies in the Brazilian energy matrix can be explained to a large extent to the hydric predominance in the power generation: which the country counts on 83% of renewables in its power generation matrix, the global average is of 25% - in the world and the OECD countries. Chart 4 shows the participation of the renewables in the power generation, transportation, and heating segments across European Union countries and Brazil.

As one of the main decarbonisation instruments, renewable energy sources' participation is growing across the power systems. This movement derives from specific policies of combined support in the past couple of years, with a significant reduction to the cost of the investments. For illustration purposes, the wind and solar-based sources of power generation accounted for 7% of the global power generation in 2018, as compared to the 0.2% achieved in 2000. Between 2010 and 2017, the cost for solar panels has dropped by 70% for utility-scale projects, and between 40% and 80% for small-scale projects (distributed generation). However, these are still 20% to 60% more expensive than utility-scale projects across most regions. At that same period, the average cost for onshore wind farms decreased by 20%, while offshore wind farms cost decreased by 25% in the past five years (IEA, 2018a, and 2019c)[3].

Solar and wind technologies already account for half of the new capacity of electricity generation added each year. They are the two energy sources with the most significant annual investments. In 2018, the wind power installed capacity reached 563 GW and photovoltaic solar panels 485 GW, which accounts together close to the globally hydropower installed capacity (Chart 5).

3 Fossil fuels participation, on its turn, remained continuous in the period, including the coal-power generation, boosted up by the Chinese demand. In relative terms, nuclear power lost its position to natural gas, and new renewable sources (IEA, 2018a).

Chart 5 - Renewable energy installed capacity worldwide (GW)

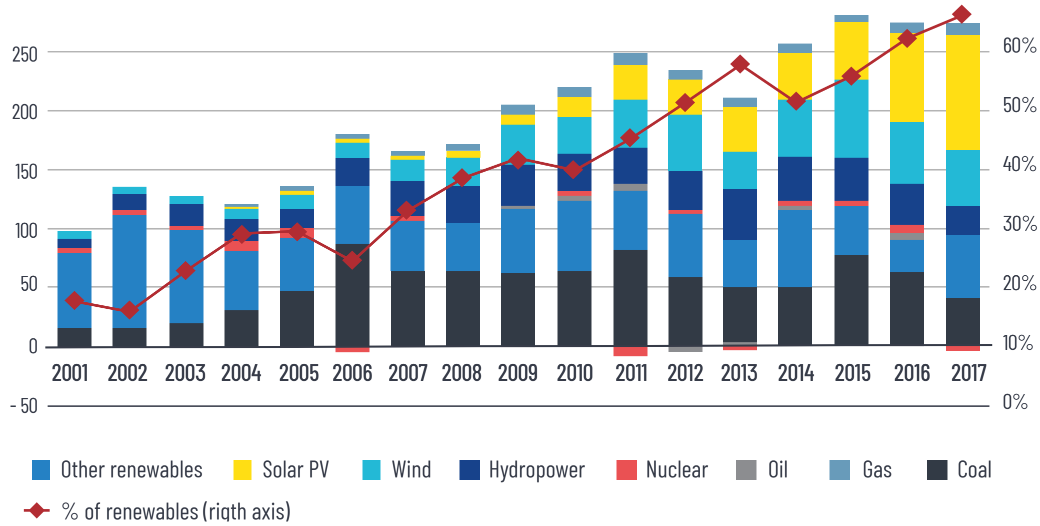


Source: Own elaboration based on IRENA data (2019)

Table 1 shows the distribution of renewable sources (hydropower, wind, solar, and bioenergy) throughout the world, and for the representative selected countries. Notably, 44% of the installed capacity is concentrated in Asia (nearly 80% in China, and India), 23% in Europe (22% in Germany), 16% in North America (68% in the USA), 9% in South America (64% in Brazil), and 9% in the rest of the world. China concentrates 28% of the world hydropower capacity, being 33% from wind, and 36% from solar sources (IRENA, 2019).

Since 2012, renewable technologies account for over half the yearly addition of the world installed capacity, as compared to less than 20% in 2002 (Chart 6). Wind and solar power have been jointly accounting for at least half the annual growth since 2016, with added generation supplying nearly the total incremental demand for electricity (IEA, 2016a).

Chart 6 - Annual addition of installed capacity worldwide (2001~2017)



Source: IEA (2018b).

Table 1 - Renewable energy installed capacity worldwide (GW) in 2018

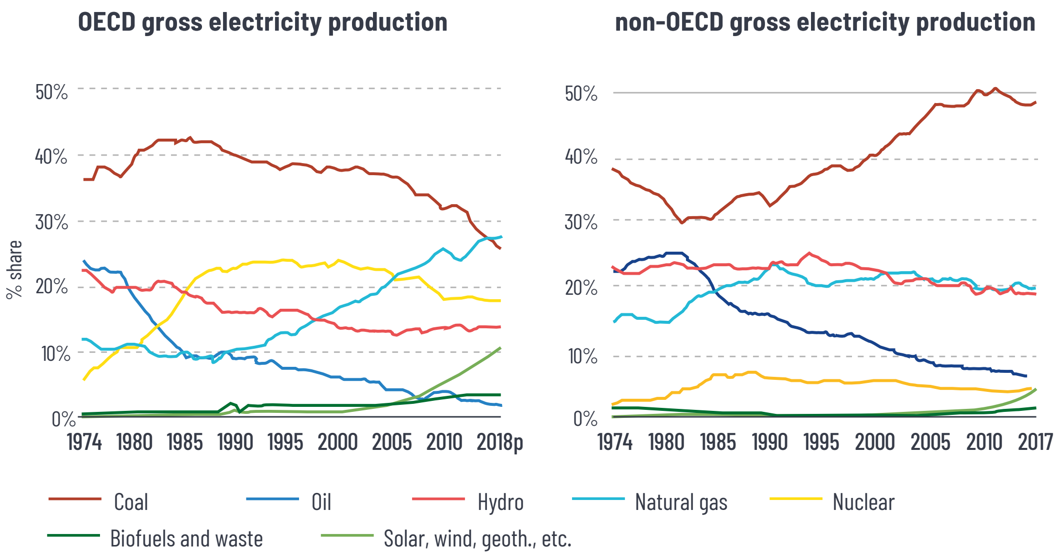
Regions / Countries	Hydropower	PHS/[a]	Wind	Solar	Bioenergy/[b]	Total	%/[c]
World	**1,171.6**	**121.0**	**563.7**	**485.8**	**115.7**	**2,457.9**	**100%**
Asia	**478.7**	**65.2**	**229.0**	**274.9**	**36.2**	**1,084.0**	**44%**
China	322.9	29.4	184.7	175.0	13.2	725.2	67%
India	45.3	4.8	35.3	27.1	10.3	122.7	11%
Japan	28.2	21.9	3.7	55.5	2.3	111.5	10%
Europe	**191.9**	**28.3**	**182.5**	**121.7**	**38.5**	**562.9**	**23%**
Germany	5.6	5.5	59.4	45.9	9.0	125.5	22%
Denmark	-	-	5.8	1.0	1.3	8.1	1%
Spain	16.8	3.3	23.4	7.0	1.0	51.6	9%
France	24.0	1.7	15.1	9.5	1.7	52.0	9%
The Netherlands	-	-	4.5	4.2	1.1	9.8	2%
Italy	18.6	3.9	10.3	20.1	3.5	56.5	10%
Norway	32.5	-	1.7	0.1	0.1	34.3	6%
Portugal	7.2	-	5.2	0.7	0.6	13.8	2%
United Kingdom	2.2	2.4	21.7	13.1	6.4	45.9	8%
North America	**177.3**	**19.3**	**112.0**	**57.1**	**16.6**	**382.3**	**16%**
Canada	80.6	0.2	12.8	3.1	2.5	99.2	26%
USA	84.0	19.1	94.3	51.5	12.9	261.8	68%
South America	**169.9**	**1.0**	**18.7**	**5.5**	**17.2**	**212.2**	**9%**
Brazil	104.2	-	14.4	2.3	14.8	135.7	64%
Other Regions	**153.8**	**7.2**	**21.5**	**26.7**	**7.3**	**216.6**	**9%**
Eurasia	83.8	1.4	7.2	5.7	2.0	100.0	46%
Africa	32.5	3.2	5.5	6.1	1.6	48.8	23%
Oceania	13.2	1.4	6.6	10.0	1.0	32.2	15%
Middle East	16.1	1.3	0.6	3.2	0.1	21.3	10%
Central America	8.2	-	1.7	1.7	2.6	14.2	7%

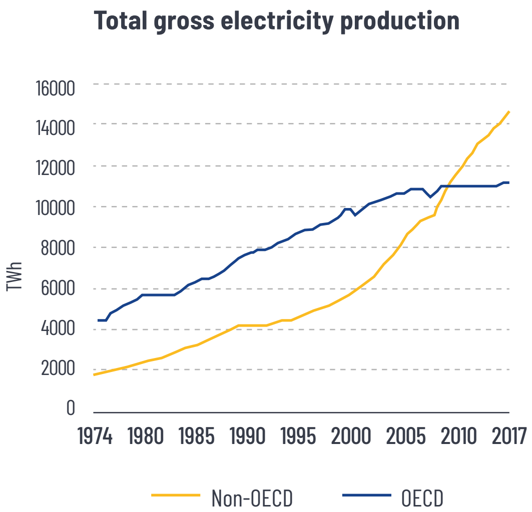
/a Pumped Hydro Storage; /b includes solid biofuels (i.e., biomass and residues), liquid, and biogas.
/c the percentage for regions refer to the total worldwide, and that for the countries to the total for each region.
Source: Own elaboration based on IRENA data (2019).

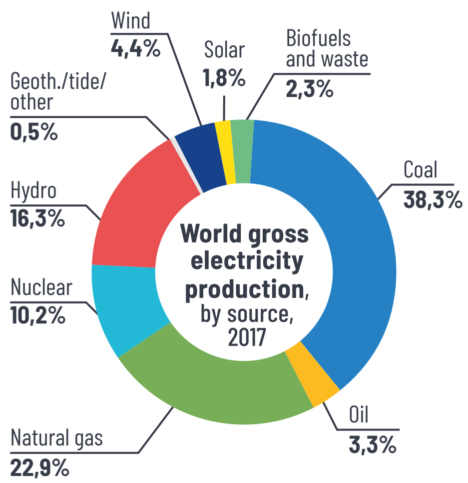
The expansion of the installed capacity comes with investments, and improvements to the grid (transmission and distribution), which account for approximately 40% of the total annual investment amount, thus signalling the strategic relevance of these assets for the industry (IEA, 2018a).

Although the renewable sources already account for half the investment amounts in China (210 billion dollars in 2017), and one third in India, approximately 150 GW from new coal-fired plants shall also be installed until 2020 worldwide. Mostly boosted by the China effect, the expansion of fossil fuels-driven throughout the 2000s (Chart 6) has increased the relative participation of coal in power generation in developing countries (not OECD members) while developed countries were enforcing the reduction of coal usage in their electricity matrices (Chart 7).

Chart 7 - The share of energy sources in electricity generation







Source: IEA (2019a).

Total annual electricity production in non-OECD countries surpassed the total generation in OECD countries, reaching 14 thousand TWh around the current decade (IEA, 2019a). In 2016, the participation of the renewable energy sources in the world generation matrix was of 24.5%, and the nuclear source was of 10.4%, thus resulting in 35% of carbon-free generation. Fossil fuels still account for most of the generation matrix – coal still being the primary energy source (38%), followed by natural gas (23%), and oil (3%) (Chart 7).

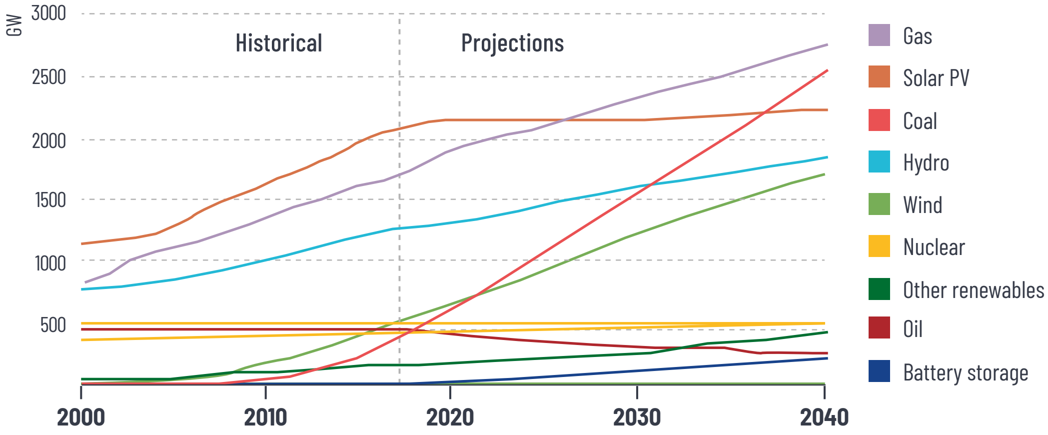
In developed countries, coal has been mostly replaced by natural gas, whose leadership in the power generation in the '90s was boosted by (i) gas-driven technological innovations, (ii) stable and competitive prices, and (iii) for the liberalisation process within the power sector. The dash for natural gas made it the second most important source for the energy matrices across developed countries, surpassing the hydropower and nuclear generation in the 2000s. Then, the shale gas boom in the USA reinforced the market penetration of gas as a replacement for coal.

In developing countries, the participation of coal increased, following the lead of Chinese growth, while the relative participation of natural gas remained the same in this period. At the beginning of this decade, the North-American experience with shale gas, the prospective opportunity to reproduce it beyond North-American frontiers and circumstances, and the LNG (liquefied natural gas) trading expansion pointed-out to the potential promise of natural gas as a fuel bridge. That's it, a resource that enable the energy transition towards the decarbonisation of the economies, while the renewables leadership was still not proving feasible – economically, and technically speaking. However, the expansion rhythm of new renewable energy sources in the past few years challenges the notion that natural gas as the transition fuel, opening space for the direct pathway for decarbonisation of the economies.

The International Energy Agency forecasts a 60% expansion in power generation for 2040 (additional 15 thousand TWh) with coal remaining as the leading global energy source matrix, reducing its current relative participation from 38% to 25%. Concerning installed capacity, natural gas may excel coal by the half of the next decade – led by the Chinese efforts in removing coal from their energy matrix, following the initiative "*turn China's skies blue again*". The solar energy is bound to achieve such standard by 2030, as per IEA projections (Chart 8). Although the Agency bets on the continuous growth of gas in the global power matrix, it forecasts an exponential expansion of the solar PV capacity to overcome the wind installed capacity in the coming years, the hydropower by 2030, followed by coal (IEA, 2018a).

The promulgation and permanence of decisions made in the past along the route to the industrial expansion – typified by significant maturity term investments - indicate the existence of path *dependence* and trajectory *lock-in*. Recent investments on fossil fuels delay future decarbonisation paths, bringing along the potential risk of becoming *stranded assets* in the medium term. Within a context of high uncertainties, the growing penetration of renewable energies, and their response to decisions increasingly decentralized have been transforming different systems and power segments in the world.

Chart 8 - Expansion of the Global Power Matrix, as per IEA forecast



Source: IEA (2018a).

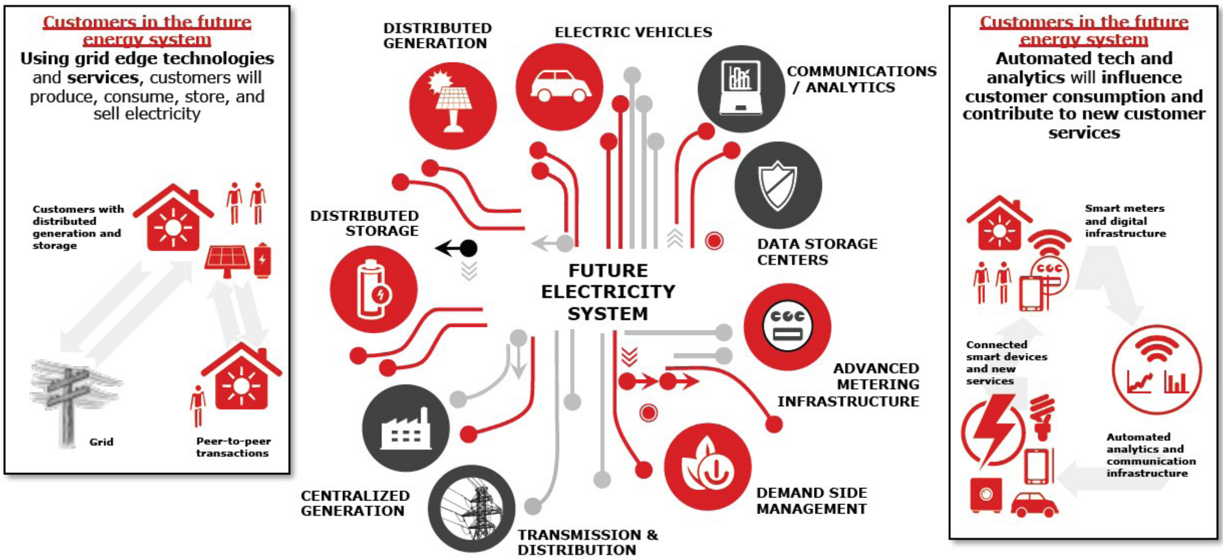
1.2. Transforming power systems: transition drivers

Power systems are going through a profound transformation. Originally conceived around a vertically integrated chain with transmission and distribution interconnecting the centralized generation to final passive consumers, the power systems are seeing the multiplication of distributed energy resources (DER). Defined as resources installed near or within consumption centres capable of provide electricity services, the DER encompass distributed generation plants, demand response and management, storage, electric vehicles, control devices, smart metering and smart devices (Pérez-Arriaga et al., 2016). Distributed resources enable the consumption administration and management in a remote, independent, and prompt manner, provided by the development of information and communication technologies that transform consumer goods into services. Figure 1 summarizes technologies included in these recent transformations.

The integration of new resources and players in the current centralized systems is one of the main challenges of the industry. In the energy transition context, distributed resources emerge as a solution for the decarbonisation of the systems, challenge the centralisation of the grids, and convert once passive consumers into new players.

Two significant drivers guide the ongoing changes, with overlapping and persistent breakdowns: the rising tide of markets, and the green wave. The rising tide of markets promoted by the liberalisation during the 1990s displaced the legal--regulatory outline from costs to prices and market – and their possible configurations, *with market design* subject to continuous improvement. The green wave, on its turn, grew in intensity starting from 2000s, forcing the entry of variable renewable energies, mainly in thermal power matrices. The green wave intensified in response to pressures from the environmental agenda for reduction of greenhouse effect gases emissions. However, it spread essentially because of the significant reduction to the costs of the renewables, as observed in the last decade (Hansen & Percebois, 2017).

Figure 1 - The changing power sector



Source: WEF (2017)

The oil crises back in the 1970's triggered the first step to introduce new renewable energy sources, as explained by Bushnell (2011) and Yergin (2012). In the United States, for instance, *the Public Utilities Regulatory Policies Act* (PURPA), enacted in 1978, which fostered the efforts towards energy efficiency and stimulated the use of renewable energies as source for energy independence, following the path of the oil crisis.[4] The PURPA proved the feasibility of electricity generation through smaller-scale technologies, and through business models unrelated to utilities, thus providing independent power producers (IPP) with competitive freedom, which would set the liberalisation of the power industries in the following decades.

The combination of these two fronts results in simultaneous transformations in the systems, and in the power industries. At the same time, this affected the physical operating logic of the systems, and the structure of the links chaining the industry.

The new technology innovation wave enabled by digitalization makes the energy resources management less of a matter of optimizing technologies. The recent changes to technologies and behaviours have empowered an increasing number of consumers that become active participants in decision-making processes. At the same time, these consumers may become prosumers and co-decision makers. Even the new means of providing information in a more frequent and contemporary manner already produce vital behavioural changes, thus importantly affecting production and consumption decisions[5].

The decentralization and the complexity of the resources, along with the multiplicity of agents pose new challenges to the gover-

4 In Brazil, the driver for the pioneer pro-ethanol ("Proálcool") program was also the energy independence, with a key legacy towards the introduction of renewable resources in the Brazilian energy matrix.

5 Using a database built on field experiments about the introduction of dynamic tariffs, Faruqui et al. (2017) realized that consumers are price-sensitive, and cut down their consumption during peak demands. In turn, the extent of the demand response depends on tariffs design, availability of enabling technologies, implementation of the program, and on the consumers' characteristics.

nance of energy systems, both in terms of technical aspects (operation, and interconnection), and in terms of market design. So, it is necessary to adopt new arrangements of shared responsibilities, and new regulation paradigms (Vasconcelos, 2019a).

The introduction of the variable renewable energies into power systems – initially subsidized – has become a dominant path towards energy transition, to the detriment of pricing efforts to internalize environmental externalities (Newbery, 2016). Standardising, and modularising renewable resources, and especially photovoltaic solar and wind power, triggers decentralisation in the industry. The digitalization of the grid, using smart metering, allows instant communication among devices, agents, and applications, while optimizing gains from decentralisation. Technologies scalability can potentially democratize access to electricity – including through decentralized microgrids – and expand the consumption standard. Together, the digiltalization, decentralisation, and democratization can, therefore, outline the economies decarbonisation trajectory, including subsidies to the electrification for other usages – which account for the four D's of the energy transition (Parag & Sovacool, 2016).

Although the drivers of the changes (the rising tide of markets, and the green wave) presuppose a clear and well-defined transition, their potential outspreads generate effects with still undefined outlines and uncertain reach. Such drivers converge towards an agenda of similar questions and challenges across the different power sector and systems. However, there are no single and pre-defined solutions that rescind from the need to consider the different local realities specifics.

2. CURRENT AND COMMON INTEREST TOPICS

2.1. Introduction of Variable Renewable Energy

The expansion of the power systems through vertically integrated monopolies and the predominance of controllable generation sources (dispatchable) have bespoken the relevance of costs as a comparison metric of the industry to guide investments, and justify public policies (Joskow, 2011). There is a recurring idea in that a specific generation source becomes competitive when its levelized cost of electricity (LCOE[6]) by the expected average generation becomes lower than the average electricity price or to the average tariff for a particular region (*grid parity*), consisting in a rule of thumb to indicate the competitiveness of the sources.

However, as broadly discussed in the economic literature[7],the strict comparison of levelized cost is not enough, besides inadequate to compare variable sources (uncontrolled) and dispatchable sources (controllable). The reason for such inadequacy derives from ignoring the value of the power in time and space, and the integration costs of the sources. Introducing variable renewable energies (VRE) stresses the differences between the marginal values perceived by each source – increasingly more susceptible to "where, when, and how" of the electricity generation. As a result, it is necessary to have greater space-time granularity to select different attributes of the sources, with improvements to the operation, concerning planning, and pricing aspects.

A massive introduction of VREs adds uncertainty, while changes the planning perspective, and operation of power systems. Historically, supply was based on the liquidity and safety of controllable (fossil) fuels. The VRE generation comes with (i) more significant variability; (ii) lower foreseeability concerning resources availability; (iii) increase of the impact of locational restrictions to exploit the sources (especially for wind); (iv) reduced capacity factor (average usage of the installed capacity); and (v) negligible variable costs of the operation. With a reduced production scale, the modularization of the VREs stimulates the distributed generation, while opening space for decentralized decisions. Within an industry marked by centralized arrangements, this process influences the level and the rhythm of the penetration of such sources.

The variability of the VRE increases boundary conditions' restrictions, both

6 The LCOE concept - expressed in a year on year-based average, considers fixed costs and projected variables for the entire economic life of the production plant, levelled per unit of generated power (MWh), projected per the expected capacity factor (Stoft, 2002).

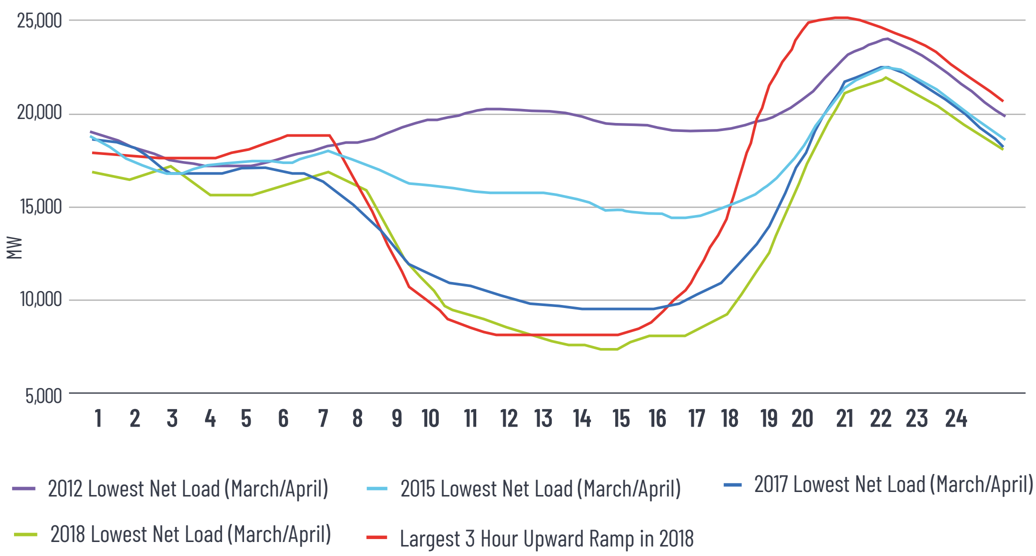
7 For reference, please, check, for instance, Joskow (2011), Borenstein (2008, 2012), Hirth (2013), Schmalensee (2016), Finon (2016), and Romeiro et al. (2020).

in terms of the static balancing (instantaneous) between supply and demand, and the dynamic balancing related to resource adequacy for a certain level of defined *reliability*. The variability requires an instant response from the residual system responsible for coping with the demand not serviced by the VRE, for accommodating recurring and hard to anticipate fluctuations.

Consequently, the residual system's flexibility becomes a vital instrument for supply reliability. The duck curve was initially identified by the California Independent System Operator (CAISO). It illustrates changes to the load behavioural pattern in the system, as derived from the massive introduction of solar generation. At the same time, reveals oscillations in the marginal value of the energy throughout time (Figure 2). The curve reflects the concentration of distributed solar energy along the day and creates a valley in the demand curve (load) supplied by the centralized generation. With the disruption in solar power availability, by the end of the day, the residual demand (reduced of the solar distributed generation) jumps up at reduced periods. Such stressed load ramps require the system to promptly respond, especially from centralized generation – the current primary flexibility source.

In this context, some resources become strategic, namely for storage (reversible hydropower plants, hydro reservoirs, and batteries), interconnection with other regions, and markets, and broader response, and management of the demand – overall considered less sensitive to instant variations of energy prices. Given the difficulties to expand the flexibility of such alternative instruments – because of physical, cost, or coordination restraints – the responsibility of generation resources increases. Therefore, further participation of the VREs interferes in the resource adequacy, while imposing new modulation costs for the technologies, overall, with a few levels of flexibility. This, in turn, jeopardises the compensation for the assets in operation, and the maintenance cost of pre-existing levels of supply reliability.

Figure 2 - Duck Curve Observada na Califórnia



Source: CEC (2018)

The renewable energy industry and a broad range of specialized studies seek to emphasize positive externalities from renewable sources not absorbed in market prices or optimized marginal costs of the operation (shadow prices). Overall, the practice is to number the allegedly exclusive advantages of such sources. Several studies list value-based attributes in terms of opportunity costs (avoided), aggregated as hidden and unconsidered benefits (Brown, 2016).

Standing out among the externalities, and benefits usually related to the VRE, there are: (I) the replacement of fossil fuels to reach the emissions reduction targets; (ii) the contribution to energy security; (iii) the reduction of losses on transmission, and distribution through the distributed generation close to the load; (iv) postponing of new investments on centralized capacity and the expansion of the grid; (v) the employment stimulation (*green jobs*); (vi) reduction of local environmental impacts; (vii) energy scarcity mitigation; (viii) encouragement to the "emerging industry" in the country; and (ix) cost reduction through scale economies, and learning curves (Borenstein, 2012, Edenhofer et al., 2013, Brown, 2016).

Nonetheless, all sources are subject to integration costs – even if negatives, i.e., comprising as integration benefits. So, the energy marginal value depends on the market penetration level, and on the characteristics of the system in which they are introduced. The costs for integrating the variable sources relate to (i) the *balancing costs* to maintain the instantaneous balance between supply and demand; (ii) the investments needed, and the enhancement of the transmission and distribution grids (*grid costs*); and (iii) adequacy of the system's resources (*adequacy costs*) related to dynamic balancing. So, the relation between levelized cost and average electricity price does not set absolute competitiveness (and undetermined) of the source, but rather a relative one. In a particular system, technology proves to be competitive for a certain price, and a specific volume of energy (Ueckerdt et al., 2013).

The International Energy Agency already includes this systemic approach in its analysis (IEA, 2018a). Concerning the expansion of the VRE, the public policies and the regulation should be outlined in a way to consider both the benefits and the integration of potential costs.

2.2. Solar distributed generation

Overview of distributed generation

In 2018, the photovoltaic distributed generation (PVDG) accounted for 40% of all solar power installed capacity worldwide (IEA, 2019b). The reduction to solar panels cost, public policies, and incentive instruments boosts the expansion of the PVDG. In this sense, over 50 countries has adopted the *Net Metering*[8] (IRENA/IEA, 2018). This mechanism allows the distributed generators to get credit for the excess energy injected into the grid, to be deducted from future consumption. Besides the NM, other mechanisms can be used to value the PVDG power generated, such as the "Net Billing", the "Buy-all, and Sell-All". The parameters of the adopted mechanisms are calibrated differently across the countries, overall being subject to periodical adjustments.

8 Policy consisting of power compensation mechanism through which the bill sent to consumers includes the net consumption from the grids production / injection. For further references, check IEA/IRENA (2018).

Table 2 - Photovoltaic distributed generation capacity forecast (GW)

	2018	2019	2020	2021	2022	2023	2024	2024 (Speed up)
World	**213**	**258**	**305**	**354**	**407**	**466**	**530**	**619**
China	**51**	**71**	**92**	**115**	**141**	**171**	**205**	**237**
United States of America	**25**	**29**	**34**	**39**	**44**	**50**	**56**	**61**
Europe	**79**	**87**	**95**	**103**	**111**	**120**	**130**	**150**
France	5	5	6	7	8	9	11	13
Germany	33	36	38	41	43	46	48	57
Italy	16	16	17	17	18	18	19	20
The Netherlands	4	5	7	8	10	11	13	16
Spain	4	4	5	5	6	6	7	8
Asia-Pacific	**50**	**60**	**71**	**81**	**92**	**102**	**112**	**139**
Australia	8	9	11	12	14	16	17	19
India	4	7	9	12	16	19	22	36
Japan	34	39	43	46	49	52	54	57
South America and Central America	**1**	**2**	**2**	**3**	**4**	**5**	**7**	**8**
Argentina	0	0	0	0	0	0	1	1
Brazil	0	1	1	2	3	4	5	5
Chile	0	0	0	0	0	0	1	1
Eurasia	**1**	**3**	**4**	**5**	**5**	**6**	**6**	**7**
Sub-Saharan Africa	**1**	**1**	**1**	**2**	**2**	**2**	**3**	**4**
Middle East	**2**	**2**	**3**	**3**	**4**	**4**	**5**	**9**
& Northern Africa	**2**	**2**	**3**	**3**	**4**	**4**	**5**	**9**

Source: IEA (2019b)

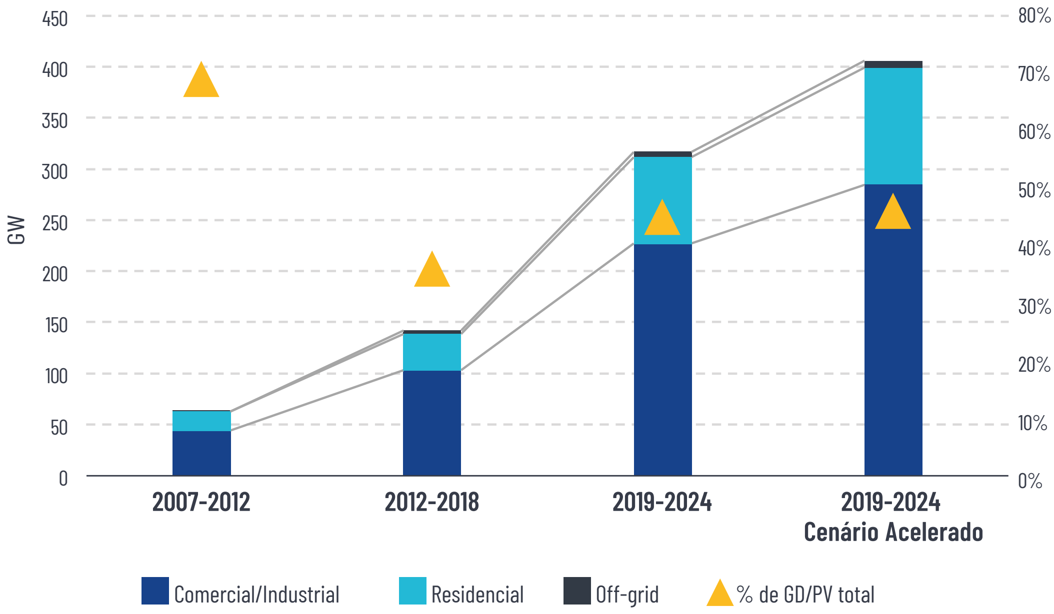
The PVDG's levelized cost of energy (LCOE) is lower than the electricity tariffs in many countries, especially in the absence of subsidies. For illustration purposes, the IEA (2019b) forecast a cost reduction in solar power generation between 15 and 35% for 2024.

The elevation of the tariffs also contributes to the PVDG attractiveness, especially within a context of volumetric tariffs, as well as the compensation credit availability, and prospective lower interest rates. In Brazil, the average return over the investment in PVDG for low voltage residential consumers dropped from 13.1 years, in 2013, to 5.3 years, in 2019 (EPE, 2019a).

The International Energy Agency (IEA, 2019b) estimates that the world installed capacity of renewable energy will increase by 50% by 2024, thus reaching a 3.7 TW generation. Solar power should account for nearly 60% of this expansion, thus becoming the source with the most substantial installed capacity worldwide until 2040 (IEA, 2018a).

According to the IEA (2019b) estimates, the global installed capacity of PVDG will grow from the 213 GW, in 2019 to approximately 530 GW in 2024 – or 619 GW, considering a speed up scenario, boosted by the commercial and industrial segments. Unlike with the residential segment, the consumption in the commercial, and industrial segments occurs during solar generation availability, which increases the benefits for the power systems.

Figure 3 - Accumulated expansion of Solar energy Distributed Generation (GW)



Source: IEA (2019b)

Nowadays, five countries account for 75% of the PVDG installed capacity: China, Japan, the United States of America, Germany, and Italy (Table 2). Regarding the PVDG participation on total PV solar capacity should range from 36%, within the 2012-2018 period, to 45% within 2019-2024 period (Figure 3). For Brazil, the EPE (2019a) forecasts an installed power of 11.3 GW for 2029, against the 1.8 GW registered in 2019.

In 2018, Europe registered 37% of the total PVDG installed capacity in the world. The European countries with the most extensive participation of solar distributed generation (PVDG) in their energy matrix are Germany, Italy, France, The Netherlands, and Spain. Together, they account for approximately 80% of the installed capacity in Europe (IEA, 2019).

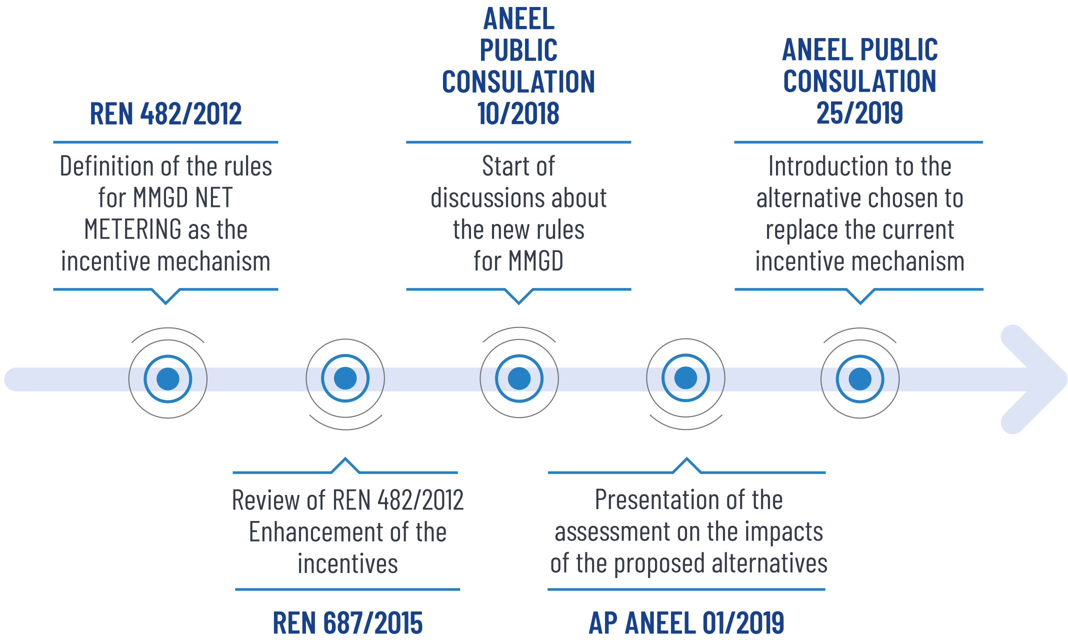
The distributed generation in Brazil

The distributed generation in the Brazilian energy matrix achieved 2 GW of installed capacity in December 2019, thus exceeding the estimated 1.3 GW in micro-and-mini-distributed generation (MMDG) plants for 2019 (EPE, 2019a).

The reduction to small-scale projects installation costs between 40% and 80% enabled the exponential growth of MMDG installations in Brazil (IEA, 2018a), along with the electricity tariffs increase, and incentive policies, as the Net Metering. The Normative Resolution n. 482/2012 allows consumers to generate their electricity from renewable sources or qualified cogeneration, supplying the exceeding power to the local distribution grid. Among the motivating goals were promotion of benefits as the postponing of investments in the expansion of transmission and distribution systems, low environmental impact, reduction to grids loading, mitigation of losses, and diversification of the energy matrix.

In 2015, the ANEEL published the Normative Resolution n. 687/2015, increasing the capacity limit from 1 MW to 5 MW (or 3 MW for hydro sources), while establishing the possibility of remote self-consumption (*virtual net metering*) and the possibility of consortium with multiple consumer units

Figure 4 - Brazilian Distributed Generation Regulation Timeline



Source: Elaborated in-house

for share generation. The Resolution also increased the validity term for power compensation credit from 36 to 60 months. This review enabled DG installations to become more attractive.

As anticipated in REN 482/2012, the ANEEL opened the Public Consultation 10/2018, aimed at starting the discussions on a new regulation for MMDG. The verified growth in the installed capacity, approximately 70% higher than estimated by ANEEL to define the regulation revision date appoints to the necessity to review the rule, focusing on the economic aspect.

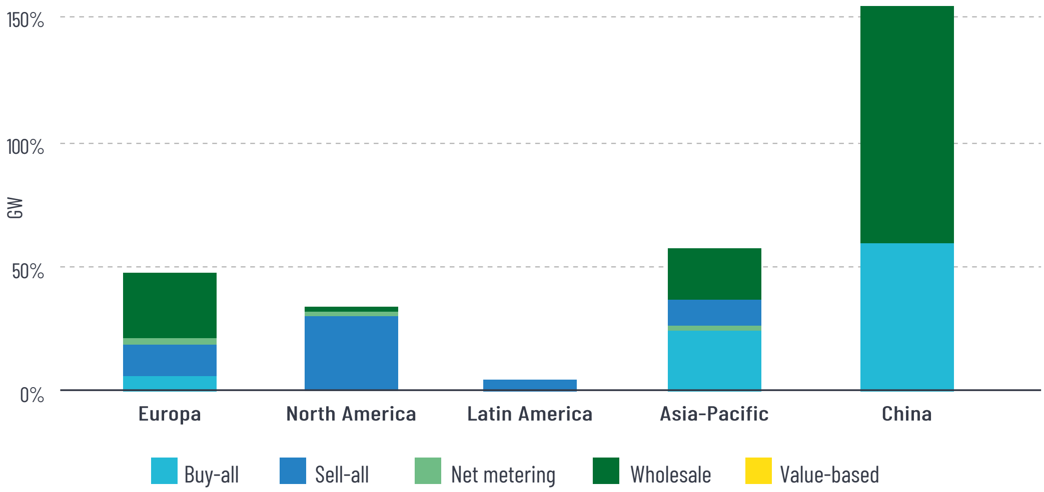
Public Hearing 01/2019 introduced the Regulatory Impact Analysis (RIA), simulating the possible impacts caused by the replacement of the current power compensation system, given the different alternatives listed in PC n. 10/2018. In the context of volumetric tariffs and compensation mechanism considering the full retail tariff, ANEEL standpoint is that maintaining the current compensation method will entail significant crossed subsidies between prosumers and consumers devoid of distributed generation.

Then, the Agency opened a new CP in 2019 (n. 25/2019) aimed at showing the analysis on the contributions of AP n. 01/2019, while collecting subsidies to perform new rules applicable to the MMDG. Since then, robust discussions on the topic intensified, which hindered the process of redefinition of rules under a regulatory scope.

The distributed generation in Europe

The introduction of distributed generation in Europe is more advanced, not only for its more extensive participation in the energy matrix but also with more appropriate incentive policies, given the reassessment on the need for subsidies. Speed up expansion resulted from directives the European Commission elaborated, with mandatory transposition onto the sovereign right of the Member States and generous incentive schemes.

Figure 5 - Compensation mechanism for the Distributed generation anticipated for 2019-2024



Source: IEA, 2019

The *feed-in tariffs* (FIT) applied through the *buy-all sell-all* mechanism ranged from 400 EUR/MWh to 500 EUR/MWh, in 2006-07; then, they lowered to 200 EUR/MWh to 250 EUR/MWh, in 2011-12 (IEA, 2019b).

The trend is that they will reduce the incentives and that European countries will adopt the *buy-all-sell-all* compensation mechanism, with a compensation rate based on the electricity value, which entails a compensation between 20 and 80% below the retail fee for the surplus generation (IEA 2019b). The *Council of European Energy Regulators* (CEER) reasons that using the *Net Metering* as the compensation system should be avoided, as it forces the network to act as a battery (storage) without the due compensation. At the same time, it reduces consumer's sensitivity to the power cost variations in time (CEER, 2016).

Among the European countries reviewed, only The Netherlands adopts the NM policy as the compensation system, besides using the retail fee as the compensation rate for the power exported into the grid, which is similar to the system adopted in Brazil. The main difference between both countries is that the power credits in The Netherlands should be consumed in one month, while in Brazil this term is of 60 months. The other countries adopt the power self-consumption-based mechanism measured in real-time, compensating the prosumers with a fee that reflects the actual value of electricity.

In Europe, the self-consumption valuing gained importance from the power prices increase and also the "*EU Renewable Energy Directive* (2018/2001)", to create a more favourable environment for the self-consumption while requiring European Union Member-States to remove regulatory and financing barriers towards the self-consumption of renewable energy.

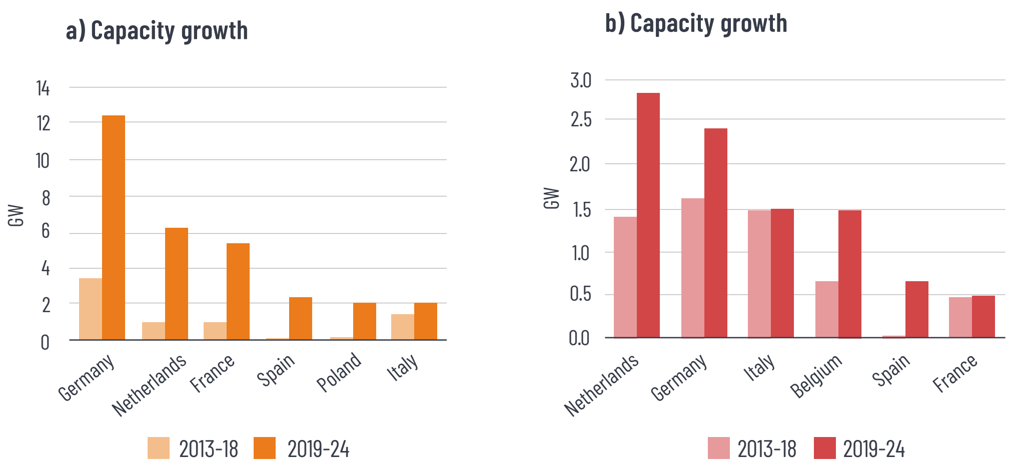
As per the forecasting, throughout the period between 2019 and 2024 the increase in residential installed capacity will be led by The Netherlands, followed by Germany, Italy, Belgium, Spain, and France (IEA, 2019b). In the business segment, the increase to the installed capacity within the same period should be of 37 GW, with Germany, France, The Netherlands, Poland, and Italy accounting for 80% of that growth.

Table 3 - Current policies of Compensation for the Generated power through the Solar distributed generation in Europe

Country	Buy-all Sell-all	Net Metering		Real-time self-consumption models	
		Energy Accounting	Remuneration of grid exports beyond energy accounting	Energy Accounting	Remuneration of grid exports beyond energy accounting
Germany		N	N/A	Y – real time	Value-based
France	S	N	N/A	Y – real time	Value-based
Spain	N	N	N/A	Y – real time	Value-based or Wholesale
The Netherlands	N	Y – Monthly basis	Retail	N	N/A
United Kingdom	N	N	N/A	S	Value-based
Y	N	N	N/A	Y – real time	Value-based
Denmark	N	N	N/A	Y – real time	Value-based
Italy	N	N	N/A	S	Value-based

Source: IEA (2019b)

Figure 6 - Installed capacity growth of Solar distributed generation – Business (a) and Residential (b)

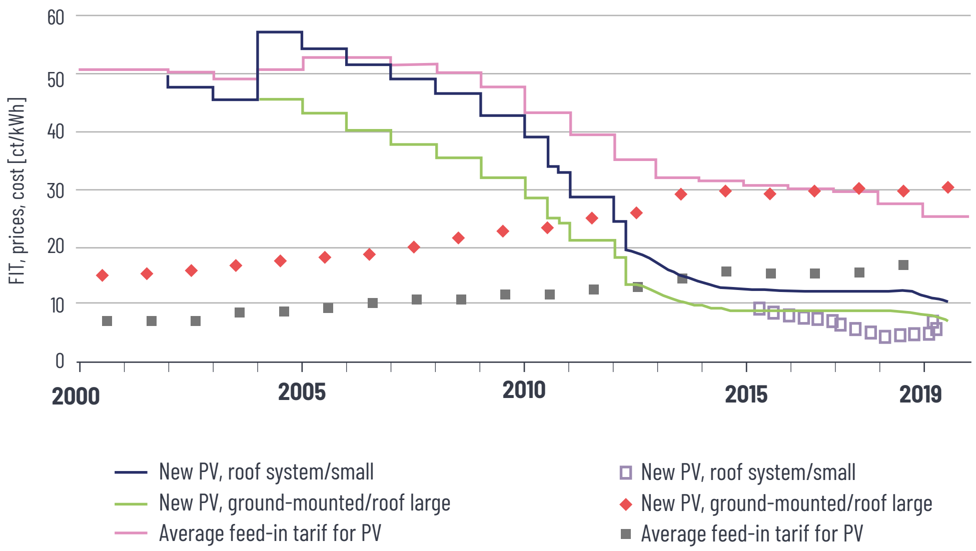


Source: IEA (2019b)

According to the International Energy Agency (IEA), the business photovoltaic generation capacity in Germany should increase by nearly 50% from 2019 to 2024. This growth is possible because of the high cost of electricity tariffs and of the cost reduction of PVDG installation. One third of that increase should occur among smaller consumers (<100 kW), and the remainder among larger business consumers (>100 kW).

The Renewable Energy Sources Act (EEG) was enacted in 2014 and revised in 2017, and it was a key factor for the growth of renewable energies participation in the German electric matrix. Problems derived from the high levels of penetration of the renewables and the continuous increases to power tariffs have driven the reviews to the EEG, considering that the other consumers are who fund the FIT financing (crossed subsidy) (NREL, 2017). In the past 15

Figure 7 - Evolution of the Tariffs, FIT and costs.



Source: Fraunhofer ISE (2020)

years, since its implementation, the compensation rates for photovoltaic energy had a quicker reduction than any other renewable energies source – i.e., approximately 80% for small roof-integrated installations, and 90% for medium-sized systems (Fraunhofer ISE, 2020).

After the 2017 review, the compensation for up to 100kW installations would be performed through the fee-in-tariffs (FIT) system. For consumers with a higher installed capacity, the surplus power should be traded directly in the market. As anticipated, initially, the incentives would be removed as soon as the PV installed capacity reached 52 GW. The Climate Action Programme 2030 has set a limit increase, extending the subsidy validity term, contributing to a more optimistic expansion plan. Therefore, in 2018, they approved the review to the most recent incentive mechanism, which reduces, even more, the compensation rates between 2019 and 2024 (IEA, 2019b).

The International Energy Agency (IEA (2019b) anticipates that the residential photovoltaic capacity in The Netherlands will increase by more than double between 2019 to 2024, as the use of the Net Metering (NM), along with the tax incentives results in an attractive potential economy for consumers to install the DG system. The Netherlands government introduced the NM in 2004, through changes made to the Electric Power Act, 1998. The initial limit for the installations was up to 3000 kWh/year of power; in 2011, the limit was expanded to 5000 kWh, and in 2012, the limit was abolished (London et al., 2020). Initially, this mechanism was intended to be used up to 2020. However, they extended the Net Metering term to 2023, when this compensation mechanism will undergo a gradual reduction.

Like in Brazil, the efficiency of the NM started being questioned, based on the following factors: (I) installation costs reduction; (ii) losses in tax collection; and (iii) absence of incentives for self-consumption, considering that the grid has a zero cost storage role, which does not reduce the necessary capacity for the grid (London et al., 2020).

2.3. The flexibility of the resources for the energy transition

To face the challenges deriving from the integration of variable energies (not controllable) and distributed resources, the International Energy Agency (IEA, 2014 and 2018a) emphasizes the importance of providing the transforming systems with flexibility. Among the potential resources for the system, the following stand out: the flexibility of the generation plants (*flexible generation*); the demand response (*demand-side flexibility*); interconnection (*improving grids*); and storage (*storing energy*). Figure 8 matches the resources flexibility to the position in the grid (centralized versus distributed) and to the response capacity agility and duration – from seconds, for the frequency regulation, to months, for the seasonal conditions of regularization.

The broader flexibility of the generation plants (*flexible generation*), with lower participation of inflexible technologies, accommodated a more considerable variation of the VRE, thus mitigating the restrictions to temporal arbitrage. Not only the offer, but all the other resources of the system should respond to the time variability costs. The demand must reply to the variability and instantaneous scarcity signals (*demand response*) through smart grids and automation, reducing the three heterogeneity dimensions – temporal, spatial (with locational prices), and delivery intervals, upon reaction to the momentary conditions of the available resources. The demand response can be coordinated through *microgrids* to aggregate local resources, thus constituting virtual generation plants interconnected to the grid (*virtual power plants*).

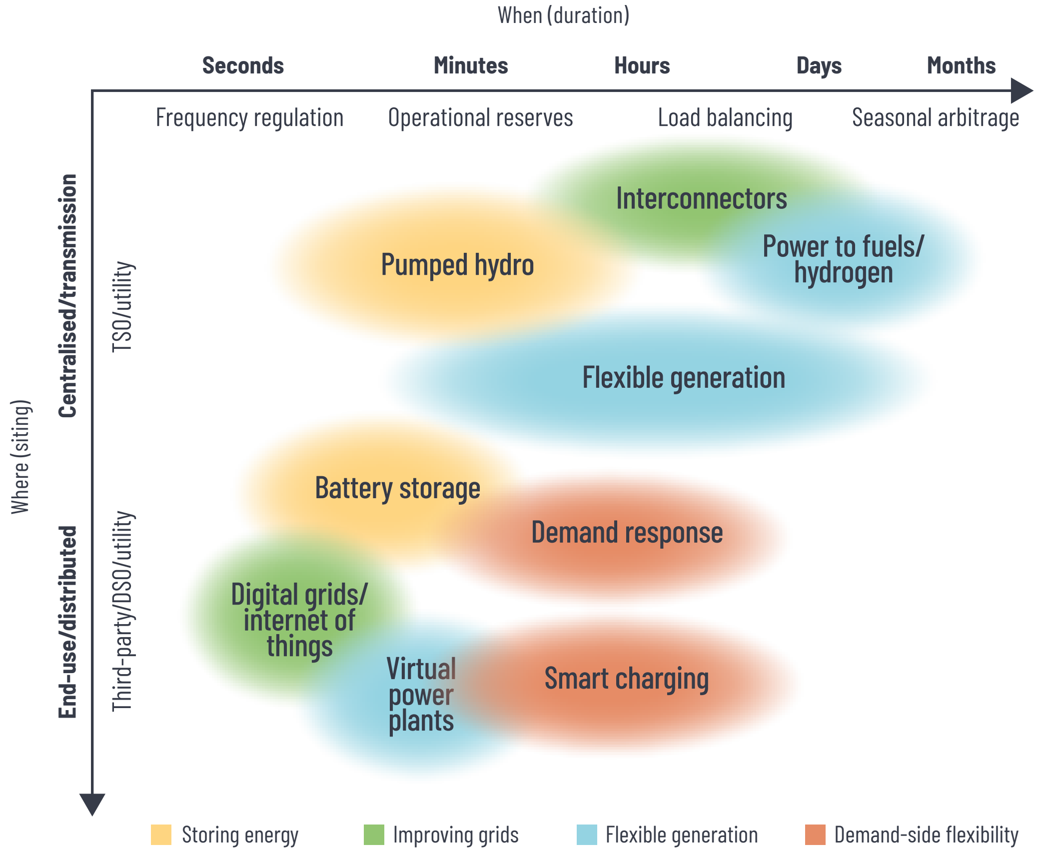
The VRE should also adopt technologies or practices capable of internalizing tax variation costs into the system. For instance, the solar panels can be installed with smart inverters capable of providing the system with inertia and reducing the impact on the frequency control. Technological innovations also reduce the variability, as an example of improvements to wind turbines and blades that allow the leverage of lower speed continuous winds (IEA, 2019a).

The expansion of the interconnection with other regions and markets (interconnectors) reduces the transmission restrictions, thus reducing the variation level of the residual demand. The refinements and improvements to the distribution grid (digital grids/internet of things), in turn, can facilitate the penetration of the resources distributed with multidirectional flows, thus expanding the arbitration within the space and reducing the integration costs related to the network.

Power can be directly or indirectly stored in different manners – through chemical energy storage (battery, hydrogen), Flywheel energy storage (kinetic energy) or potential energy storage (reversible plants or Pumped Hydro Storage – PHS). Storage (Pumped Hydro storage/ battery) also reduces the temporal variability and the unforeseen effects from the availability of the sources (lead-time), besides catchment processes during abundance periods. Depending on its location within the grid (whether concentrated or distributed), storage can reduce locational restraints even further.

Reversible plants account for nearly the full power storage, with 153 GW, which corresponds to 2% of the installed capacity worldwide (IEA, 2018a). The remaining technologies total 4 GW, with the exponential growth of lithium batteries. The International Energy Agency forecasts an expansion of 26 GW from PHS (70% in China) and 22 GW from batteries (IEA, 2019b) until 2023. Batteries within small-scale facilities already account for 45% of added capacity, strengthening the decentralisation trend.

Figure 8 - Flexibility resources



Source: IEA (2018a).

The informed storage capacity (153 GW worldwide) does not consider hydropower plants with reservoirs. Such inventory is justifiable because, overall, the literature does not consider hydropower reservoirs not associated with reversible plants as an explicit source of storage (IEA, 2018a, Newbery, 2018). Newbery (2018) estimates that the water reservoirs contain power two thousand times higher than the volume stored across pumped hydro plants.

The water contained within Brazilian hydropower reservoirs corresponds to 212 TWh. With over 100 GW of installed hydropower, the stored energy is not used for storage per se because it is handled to regulate the high hydrological variation from tropical affluence while supplying power subject to intertemporal optimization of the resources.

Norway alone detains nearly half the water storage capacity of Europe, with hydropower plants' reservoirs corresponding to approximately 85 TWh. With a little more than 30 GW of installed hydropower capacity, the Nordic country counts with over one thousand hydropower reservoirs, across their mountains and valleys, while benefiting from limited evaporation or sedimentation – which are recurring problems in Brazil. The remaining 90 TWh volume, stand out Sweden (34 TWh), Spain (18 TWh), France (10 TWh), Switzerland (8 TWh), Italy (8 TWh) and Finland (5 TWh)[9].

In the future, electric vehicles will be able to provide significant indirect storage, besides contributing to an agile

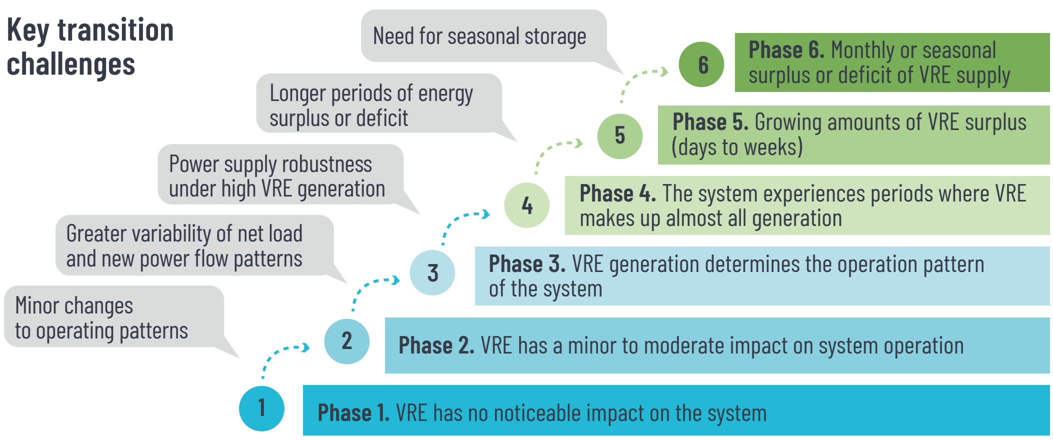
9 For further references, see Graaback et al (2017).

frequency control (ancillary service) and changing their charging rate (smart charging). Therefore, electric vehicles consist of distributed energy resources, adding storage, handling the demand, and providing flexibility services for frequency control. The abundance of electricity in the future, at a reduced marginal cost – provided by the VREs – will further be able to trigger other technologies capable of providing storage and flexibility, such as the use of hydrogen as fuel (*power to fuels/ hydrogen*).

The International Energy Agency classifies the introduction of the VRE into electric systems into six different phases, based on the sources penetration level and features of the systems. The classification of the phases includes the identification of specific integration challenges (Figure 9). Phases are as follows:

- Phase one represents the initial and marginal implementation of the VREs across the systems, with no noticeable impacts or even benefits deriving from the positive correlation with the load.
- In the second phase, the penetration (from 5% to 10% of the generation) starts having moderate impacts with differences between the load and the residual load. Most countries are positioned between these two embryonic phases.
- In phase three, the generation at the VREs (above 10%) significantly impacts the operation of the systems, enabling significant flexibility to maintain the pre-existing reliability. Among the systems that have already reached this phase (Chart 9), the IEA identifies mainly those in Germany, Italy, United Kingdom, Uruguay, California and Japan (Kyushu subsystem).
- In phase four, the VREs start controlling the generation across specific periods, which demand robust flexibility options to ensure the stability of the system, as well as operational and regulatory improvements. Denmark, Southern Australia, and Ireland have already reached this phase.
- In phase five, the VRE generation often starts exceeding the total demand of days or weeks (negative residual demand), momentarily supplying the instant demand for some periods. With the possibility

Figure 9 - Challenges and Different Phases of VRE Integration into Systems



Source: IEA (2018a).

of recurring non-use, the additional capacity of the VRE loses value (curtailment), which demands a flexible reserve capable of expanding the interconnection with other areas and markets, expanding storage capacity, and directing the demand to periods of over-supply. Therefore, the electrification for other purposes, such as transportation and heating become strategic.

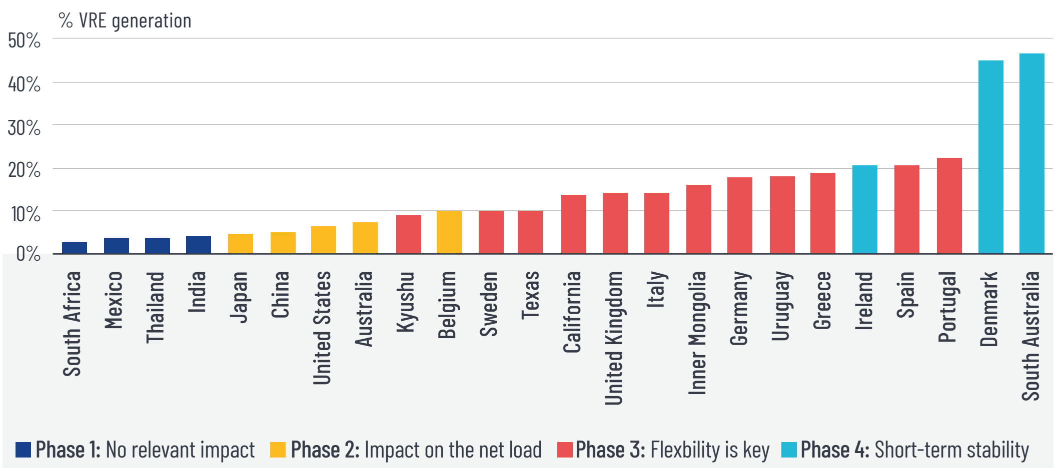
- Phase six is marked by seasonal surpluses or deficits from VRE generation for prolonged periods, making seasonal (multi-annual) storage and possibly the use of synthetic fuels such as hydrogen essential. While reviewing the VREs, the Agency does not identify countries or regions with systems that are already in the latter two phases. However, the variability of Brazilian tropical hydrology and the existing capacity of hydropower reservoirs could position the country within this dimension, where there are monthly or annual deficits or surpluses while demanding a seasonal reserve to supply the inherent seasonality.

Figure 10 shows the correlation between specific resources from each source of flexibility – *power plants generation, grids, demand-side response* (DSR) and storage - to the six phases of the VRE integration, in addition to indicating improvements to regulations and markets to facilitate the transition between the phases.

The transition at the early integration phases requires using pre-existing flexibility resources, thus promoting the retrofit of previously installed plants, enhancements to the distribution and interconnection network, compliance with the demand of heavy consumers (industry) and expanding technologies already matured, such as reversible plants for storage. As per the forecast, the availability of VRE should be improved, while creating actual short-term markets, which in turn, would favour the transactions among neighbouring systems.

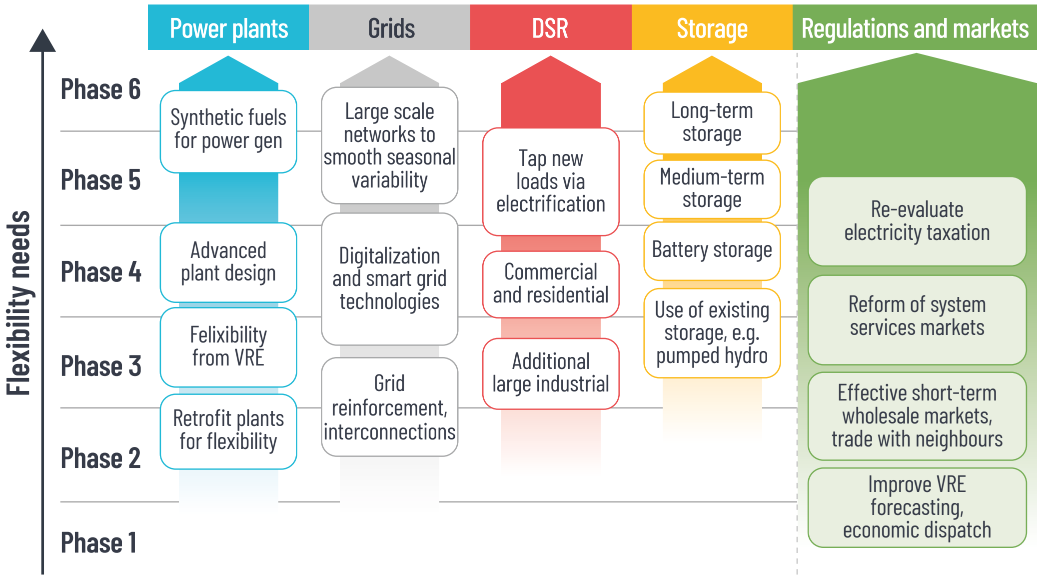
The transition to intermediate phases requires flexibility to supply from the VRE and dispatchable plants with specific design for more considerable variability; network digitalization and use of smart metering and devises; extension of demand response for commercial and residential con-

Chart 9 - Classification of Countries per Impact and Phase of the VRE Integration



Source: IEA (2018d)..

Figure 10 - Flexibility resources based on the Integration phases



Source: IEA (2018a).

sumers; use of batteries for storage; and regulatory improvements to compensate for the new resources and services. The transition to higher phases of integration demands the providing the new resources with flexibility, such as generation with synthetic fuels (hydrogen); broad interconnection of regions with different resource availability patterns to minimize the seasonal variation (smooth effect); electrification of other end uses, such as transportation; medium and long-term seasonal storage; and reassessment of the incentives framework, in terms of taxes and subsidies.

The rate of forced disruption of the VRE (*curtailment*) generation is one of the main indications of lack of flexibility in systems, for technical or regulatory reasons. In Texas (ERCOT), *the curtailment* rate declined from 20% (in 2009) to less than 2% (in 2017) because of the investment in transmission subject to granular pricing in time and space (IEA, 2018a).

Currently, the primary source of flexibility in the systems is in the generation plants, which accommodates the variation of the residual load – given the restriction on demand response to dynamic price and to storage and interconnection limitations. The technical flexibility of the generation plants relates to (i) the capacity and response speed (modulation) to increase or decrease generation; (ii) the ability and speed to reduce and maintain a constant generation; (iii) the time required to go into operation; and (iv) the minimum time the plant must remain in or out of operation (IEA, 2018c).

Hydropower and natural gas-fired thermal plants are the traditional flexibility providers – on the systems offering side, thus contributing to the reliability and resilience of the grid through ancillary services of spinning reserve and frequency regulation. Overall, the average rate of the period change for the power generated by hydropower plants is higher than that of gas-fired thermal plants. However, a hydraulic generation often faces operating restrictions related to the multiple uses of the reservoirs and minimum flow requirement (turbine-driven). Therefore, gas-fired thermal plants can more frequently follow the variations to residual load than hydroelectric plants, as is the case in the United States. The North American exception is California, which high VRE penetration also demands the latent flexibility of hydroelectric generation (Uría-Martínez et al., 2017).

2 .4. The Role of the hydropower

Overview and peculiarities of the Brazilian power system

Considering the energy transition underway, with the massive introduction of variable renewable energies and distributed resources, Brazil stands out as an emblematic case. With a renewable matrix, extensive interconnection capacity, hydropower predominance and regulation water reservoir and energy storage, the Brazilian system is equipped with high flexibility. The development of the Brazilian hydropower system coped with the variability of non-controllable renewable source (hydropower generation), managing it through water reservoirs and interconnections.

The energy matrix is predominantly renewable, i.e., 86% of the installed capacity from renewable sources. In January 2020, the system registered 170 GW of installed capacity, out of which, 67% from hydropower plant, 22% from the thermal power plant, 9% from the wind power plant, and 2% from the solar photovoltaic power plant. The fuels used to fire thermal power generation can be split as follows: natural gas (40%), biomass (35%), oil and diesel (11%), coal (8%) and nuclear (5%) (CCEE, 2020).

Hydropower participation still prevails, while water reservoirs (70% in the South-east/Central West) provides a 212 TWh power reserve, which corresponds to a little more than four months of the annual load. The supply of variable renewable resources is highly complementary, since the availability of wind power and sugar cane biomass is higher during the drought period, between April and October.

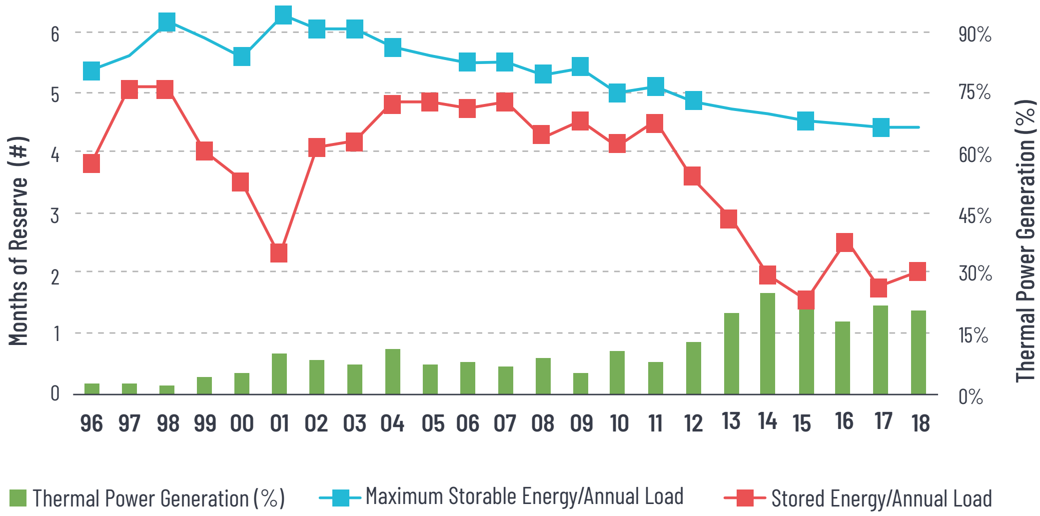
Besides the diversified production park, the country has a vast high voltage grid – the National Inter-connected System (SIN). Counting on large volumes of investment, the SIN interconnects the entire territory of the country practically, enabling the electrical energy interchange among the different regions - South, South-east/Central West, North-east and North.

Regardless of being able to attract significant investments in power grids and production, the per capita consumption is low in the country: 2,525 kWh/citizen (EPE, 2019a). Moreover, the power consumption of the SIN has stopped moving at about an average of 65 GW since 2014, following the economic crisis. The SIN annual instant peak demand, on the other hand, reached its historical record in January 2019, surpassing 90 GW, thus reflecting the increasing consumption on the side of summer peak demand in response to high temperatures. The higher demand for power points out to a new paradigm in the Brazilian system.

The hydropower participation reaches 80% of the generation of the entire SIN during humid periods (summer) but can drop by nearly 60% during drought periods in years with unfavourable hydrologic conditions. This broader span in hydropower generation is a new condition for the Brazilian system, as it used the reservoirs to regulate the affluence, thus mitigating the hydraulic generation variations.

The gradual loss of the reservoirs' regulation capacity is a trend that translates into a smaller ratio between reserves and months of load, as illustrated in Chart 10. Since the 2000s, the ratio between maximum power that can be stored in the reservoirs and the annual load has been steadily decreasing, i.e. being reduced from six months to about four months at present. The ratio between the energy effectively stored in the reservoirs and

Chart 10 - Loss in regulation water reservoirs in Brazil



Source: Own elaboration based on the National Electrical System Operator (ONS) data

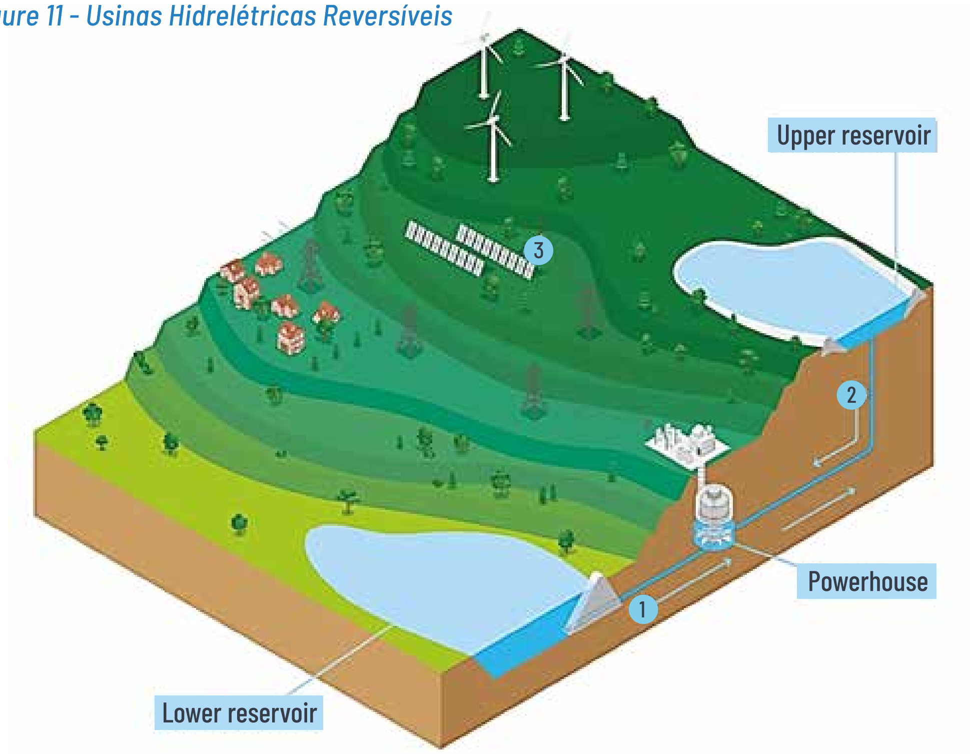
the annual load indicates the need for complementation from other sources. If in one hand, the 2001 crisis resulted in power rationing, the same level of hydropower reserves verified in the past couple of years was supported by a more significant generation – as a complement to the hydropower, especially from the gas-fired thermal plants.

The more significant annual depletion of the water reservoirs reflects a structural change to a system transforming. This trend derived from (i) the restraints of the expansion of new hydropower plants with storage reservoirs, (ii) the increase of hydric seasonability due to the more vigorous participation of run-of-the-river plants, (iii) the growing participation of variable sources and (iv) the expected load increase in the long-term. Consequently, the system demands further complementation from other sources to meet demand: both to generate power and to provide flexibility to accommodate the variations in the availability of renewable sources, and to guarantee the supply during peak demand in the Summer time.

The importance of reversible power plants for flexibility and the opportunity to rearrange and repower the Brazilian Hydropower park

Hydropower plants offer a significant capacity of modulating their production, considering their water storage capacity. This is especially important for the successful integration of power production with renewable sources with time variation characteristics. In some cases, such plants feature reversibility, sometimes operating in pump mode – pumping water from the lower reservoir to the upper one when there is an excess of renewable production. This is the case of wind production during the night periods and solar photovoltaic production during the daytime period.– Other times, turbinating water in periods of more substantial consumption for generate electricity. Therefore, the plant verifies an increased modulation capacity for the generation park, essential to operating an electrical system with large volumes of wind and solar photovoltaic production (Figure 11).

Figure 11 - Usinas Hidrelétricas Reversíveis



1 During periods of low demand reflected by lower prices, renewable energy such as wind and solar is used to pump water uphill.

2 When demand increases, water from the upper reservoir runs downhill through the turbines to produce electricity.

3 Pumped storage combined with variable renewable energy can provide reliable, dispatchable and low carbon electricity to domestic and industrial consumers.

Source: IHA (2018)

If advanced technological solutions are adopted, reversible hydropower plants currently have a high-speed response capacity, while being able to cope with production or pumping ramps that are key to accommodate the variability of renewable production, as well as consumption variations.

Within the scope of the Sector Dialogues, it is distinctive the learning from the reversible plants' experience in Portugal. The increase in hydropower pumping capacity in that country is undoubtedly one of the reasons for the success of the operation with large volumes of wind production. The Portuguese production system has operated several hundred hours in recent years exclusively with renewable source production (wind, solar PV, hydropower, and biomass). In 2016, there was a four consecutive days event in which the system also operated without any thermal power plant in operation, in addition to exporting the production surplus to Spain.

The current Brazilian installed capacity for hydropower production is truly relevant, and it counts on significant water reservoirs, but no reversible plants. Some plants with dams can be rearranged to include pumping capacity. Developing a solution with pumped hydropower plants can be done by rearranging/repowering existing plants, as has been done in Portugal in the last 20 years.

Considering the foreseeable increase in wind and solar PV power production over the next few years in Brazil, it is recommendable adopting a repowering policy in some hydropower plants, so they will include a reversibility feature, which, would allow for the optimization of the integration of renewables, thus ensuring adequate operating safety.

Given the possibility of expanding reversible hydropower plants, the efficiency in expanding the alternative – i.e., natural gas combined cycle plants – is questioned concerning their capability of coping with the renewable production variation, based on technical, energy and economic standpoints. The marginal operating cost of such plants is expressive. Also, these plants are a source of CO2 emissions. They do not provide the operating flexibility, as compared to that obtained with the new generation of reversible hydropower plants, which is a crucial characteristic to cope with the variability of renewable resources. While assessing the available strategic options for Brazil – within a scenario of an expected increase in the availability of natural gas mostly coming from the Pre-salt layer – we must include the alternative of using part of the natural gas that would be used in the combined cycle plants to other consumer segments or even be exported, thus contributing to the improvement of the Brazilian trade balance.

This option could become feasible by rearranging the significant hydropower park available in Brazil to incorporate greater participation of reversible plants and repowering. Making such architecture economically desirable and feasible – i.e., more sustainable under an economic, social, and environmental perspective, and also better aligned with the transformation experienced by the industry worldwide – depends on changes in the Brazilian power segment concerning its governance and further prominence of the market mechanism. For illustration purposes, we must emphasize that pricing differentials deriving from granularity increase are essential to generate incentives for the implementation of reversible power plants. As an essential part of this process, within the scope of the power sector modernization, they are implementing hourly prices strategy. Therefore, persevering in that direction is urgent.

As per the International Hydroelectric Association estimates, more than half of the current installed hydropower capacity should undergo repowering or modernization by 2030, reaching the entire park by 2050 (IHA, 2018).

Despite having a vast hydropower park, largely amortized, Brazil registers few investments in re-powering and improving its plants, with reduced efforts to obtain energy conversion efficiency and increase installed capacity (EPE, 2019b).

Considering the current scenario of the hydropower park (115 GW), approximately 50 GW refers to plants with over 100 MW power, which have been in operation for more than 25 years and have not been through an efficiency improvement process, totalling about 50 plants. Considering these plants alone, the EPE (2019b) conducted a study that indicates the energy gains derived from repowering, comprising synergistic gains from the centralized operation of the system, with an average magnitude of 441 MW of firm energy. The study indicates the potential of repowering with an expansion of up to 20% of the current capacity (10 GW). Also, it identifies the potential recovery of the expansion of some installed plants with a magnitude of 7.2 GW.

In the 1980s, Eletrobras and CESP performed an inventory study on generation capacity towards the implementation of reversible plants. Recently, EPE (2019c) resumed the re-evaluation study to find possible facilities to implement reversible plants in Brazil, with a preliminary focus on the State of Rio de Janeiro. The study pointed out the potential of fifteen new plants, totalling 21 GW of installed capacity.

2.5. Renewal of the Concessions in the Power Sector

Many countries use concession granting as a primary legal and economical instrument to enable the exploitation of resources and activities in different infrastructure sectors. The grant allows more players to participate – especially those with private capital – in areas historically subject to the operation of vertical monopolies, generally restricted to public services. Such overture enables skilled agents to strive for greater efficiency of the operation and expansion of the services.

Bidding for the grant unfolds as a critical element to promote – through contestability – the selection of the most capable and skilled agents to provide goods and services across the different sectors and their segments. This is the case of the procurement for the market in non-competitive segments (i.e., natural monopolies) with competition being restricted in the entry (through auctions) or for awarding the right to use public domain resources (Kerf et al., 1998; Guasch, 2004). This also includes hydropower potentials, whose grant might imply in the execution of a long-term Power Purchase Agreement (PPA).

Renewal of Concessions in the European Union

As previously reported in this Report, the liberalisation reforms held in the 1990s have had a significant impact both in Europe and in Brazil - although the crisis of the early 21st century interrupted this process in Brazil. These reforms include new entry into segments that allow for competition and (free) access to the grids.

The European Union Member States need to abide by the Guidelines, aimed at introducing competition into all segments of the power Sector, promoting energy integration. However, the European Power Sector is still marked by the low overture among the countries, given the reduced integration of the systems, which compromises the physical access to the different regional markets.

The European Commission seeks to ensure equal conditions of access to grants among all agents, forcing transparent bidding in competitive awarding processes. From this perspective, renewing the grants in force could become a barrier to the contestability and the overture the European Commission aspires. However, Member-States are resistant to the overture process without reciprocity assurance from the other Member States. The main concern is that asymmetrical access to resources might disfavour national businesses – whose capital is not necessarily controlled by the State or national private groups. Such apprehensiveness is especially evident in terms of hydropower potentials exploration (Dutra & Engler, 2019).

Hydropower is the leading renewable source in the European Union. Its exploitation is strategic for the transition underway and the energy union across the Member-States, favouring the insertion of other renewable sources into the matrix - aimed at supplying at least 27% of demand by 2030 - and ensuring secure, sustainable and accessible energy for all, under the terms of Clean Energy for All Europeans.

The right to exploit hydropower is granted between Member-States through concession or permission. Permission is awarded to a party interested in exploiting the activity, which overall entails defining rules or obligations concerning utility services supply. For this reason, permissions for hydropower exploitation tend to be granted only for low-installed capacity, which do not interfere with the provision of public services. Under this regime, overall, the terms are prolonged or even undetermined, while the hydropower generator owns the plant. For operations with permission grants limited by the scarcity of technical or natural resources capacity – which is the case of hydric potentials exploitation, the EU Services Directive (no. 2006/123/EC) establishes that permission granting should be awarded transparently, through an impartial selection process (Glachant et al., 2015).

Concession contracts, on the other hand, are under specific rules, obligations and rights related to the utility services supply. Contracts should comply with the EU concession rules (Directive 2014/23/EU), ensuring public, competitive, open, and transparent tendering. In addition to Specific Directives, the grants and procurement process should comply with the right to free enterprise (Article 49 of the Treaty on the Functioning of the European Union (TFEU)) and the freedom to provide services (Article 56 – TFEU). Also, they are still subject to the application of rules on antitrust matters, thus limiting abuses from the dominant position.

Member-States reject the idea of promoting competitions in the European energy market through public tender for the exploitation of hydropower generation. If in one hand, the competition upon renewal of the grants is an opportunity to acquire hydropower plants, on the other hand, countries fear that opening the access to the hydropower park - overall, with a strong presence and high state control – might compromise national strategic interests.

Competition within the context of a public tender or renewal of the concessions may not occur with the same level of openness between countries due to the different legal systems. Some countries use a regime of authorization (e.g., Sweden) or a mixed regulatory regime of authorization and concession (e.g., Germany and Spain) (Battistel & Straumann, 2013).

In mixed regulatory regimes, the exploitation of the facilities takes place by authorisation. However, using the hydric resources requires a concession. In Germany, concession terms range from 40 to 80 years. So, when the concession ends, German States need to decide as to the renewal, by request from the concessionaire or for bidding. In this case, the new concessionaire becomes the owner of the facilities upon compensation for the previous owner.

In Norway, a non-EU European country, rules are limiting private participation. The concessions for hydropower exploitation should have at least 70% of public capital. This, in turn, obliges private parties to establish a consortium (Battistel & Straumann, 2013).

Currently, there are infringement procedures in progress before the European Commission against eight Member States. Their statutory and nonstatutory rules still do not comply with European directives on the competition for concession grants or renewals for the exploitation of hydropower potentials (EC, 2019). Non-compliant Member-States are as follows:

- Austria, Germany, Poland, Sweden, and the United Kingdom – The Commission considers that the procurement process for granting new permits to build and operate hydropower plants is not transparent and impartial.

- Italy – The Commission considers that the procurement process for expired permits of existing hydropower plants is not transparent and impartial.
- France and Portugal – The Commission considers that the legislation and regulation in these countries are not in compliance with the UE laws and regulations, allowing concessions to be renewed or extended without the due procurement process.

These experiences are relevant in the current context experienced by Brazil. France and Portugal face challenges that are close to the dilemmas faced in Brazil concerning the termination of concessions. From a legal standpoint, the available options consist of renewing or rebidding concessions grants of network assets (transmission and distribution) and generation (hydropower plants) (Dutra & Engler, 2019).

In France and Portugal, the local communities establish a Concession-Granting Authority for the exploration of power distribution. Procurement for the existing grants – currently held by the EDF (Électricité de France) and the EDP (Energias de Portugal), respectively – will take place mostly in the coming years. The decentralized ownership of the areas to be tendered makes it challenging to coordinate and harmonize future concessions. The transmission is operated by a single concession nationwide, for a term of approximately 50 years.

According to the EU Directives, both countries have already liberalized and unbundled their respective power and natural gas sectors. Also, they implemented spot markets for power trading. However, hydropower concessions renewal is still subject to questionings by the European Commission. In both countries, generation concession grants can be if 75 years.

In Portugal, along with the overture of the power sector and the creation of the Iberian market (MIBEL), they implemented the early termination of Long-term Power Purchase Agreements (PPAs) for the hydropower plants held by the EDP, which was indemnified for the PPAs termination. Also, the terms of the concessions were extended for the remainder of each plant's life cycle. The extension, carried out in 2006, is still a matter of questioning in the European Commission due to possible impairment to competition (EC, 2019; Dutra & Engler, 2019).

France has also faced resistance to the rebidding of concession grants held by the EDF. The expired and not renewed concessions remain under the control and operation of the original concessionaire, under an extension regime ("delais glissants") basis. The concession agreements valid through 2023 represent approximately 20% of total hydropower (26 GW).

The existence of many concessions in the same basin, with externalities for energy production - as it also occurs in Brazil - constitutes one of the elements of resistance. In France, they have been facing hydropower concessions renewal issues since 2006, when they (i) published the General Council of Mines report (Leuteutrois et al., 2006), (ii) suppressed the right of preemption of the current concessionaire, and (iii) established royalties charges proportional to the income of the renewed concession grants (Dutra & Engler, 2019).

The Energy Transition Law of 2015 established the barycentre method to homogenize the term and object of the concession in each basin. The method is about grouping the concessions within the same basin to the detriment of individually bidding the plants, offering a new set for each region with a single due date. So, to harmonize the validity terms, some concessions are extended after the agreed term, while others have their termination anticipated. The new term of effectiveness applicable to the set of assets is determined by weighting the due dates of the different contracts proportionally to the different income verified, thus preserving the economic-financial balance of the current concessionaire. Those with extended terms indemnify concessions with their termination term anticipated.

Renewal of Concessions in the Brazilian Power Sector

In Brazil, the Federal Constitution of 1988 (art. 175) determined that all concessions or permissions must be granted through a bidding process. The provision determined the overture of the sector, favouring the competition with the admission of private agents. However, this provision made the renewal of the concessions controversial.

Bidding process requirement stood up as a dramatic change to the power sector since the existing concessions were not granted after a bidding process. The duration of many of those concession agreements was for an open-ended term, or the agreed term had expired. In line with the Constitution, the General Law on Concessions (Law no. 8,987/95) determined that generation concessions for open-ended terms should be put up for bidding in two years. However, a subsequent law – specific to the sector (Law no. 9,074/95) – allowed the extension of the existing concessions granted without a bidding process for another 20 years, aiming at ensuring the quality of service at adequate costs. Furthermore, the law limited to 35 years the term for new generation concessions but allowed its extension for an equal period. New transmission and distribution concessions were limited to 30 years, extensible for an equal period.

In 2004, the sector model instituted by Law 10,848, known as the New Model, determined to hold centralized auctions to award concessions grants concurrent with the signing of power purchase agreements for the regulated market. In this context, the Law reiterated the maximum term for new generation concession contracts at 35 years, although no extension was foreseen. For the existing generation concessions, the Law revised the term, restricting it to the maximum required for amortization of the investments, limiting the extension to 20 years - at the discretion of the Concession-Granting Authority, while observing the conditions outlined in the respective agreements.

An essential change in this legal framework took place in 2012. Provisional Measure No. 579/2012, converted into Law No. 12,783/2013, allowed a one-time-only conditional extension of the concessions falling due for a period of up to 30 years. Until then, the existing generation, transmission and distribution concessions that had been renewed for 20 years – after the enactment of Law 9,074/1995 – could not theoretically be renewed (Batista, 2009). The concessions falling due in 2015 represented (i) 20 GW of installed power, i.e., approximately 20% of the country's total power at the time; (ii) 95,000 km of distribution lines, i.e., 85% of the translation lines of the affected concessionaires; and (iii) 38 energy distribution concessionaires, which together accounted for approximately 120 TWh supply (TCU, 2011).

With the 2012/13 legal amendment, the transmission and distribution concessions were extended, subject to efficiency and quality targets set and monitored by the regulatory agency (ANEEL). The extension of the generation concessions was subject to a change to the trading regime. Under the previous one, the power plant had autonomy to trade the electricity in the regulated and unregulated (free) markets. Concerning power plants that accepted the terms proposed by the government, they were entitled with quotas of firm energy (physical guarantee) for the regulated market to cover only the costs related to the operation and maintenance of the plants, which value is determine annually by ANEEL.

The legislation moved on as outlined by the Constitution, i.e., to require a bidding process before a concession granting. However, the legal provisions that followed overlapped distinct legal determinations for renewal of the concessions, enabling for different interpretation lanes. The prevailing interpretation is that the renewal possibility is an administrative clause and, as such, it is susceptible to the intervention of the State, and it does not typify vested right (Batista, 2009).

The periodic rebidding process for asset concessions whose investment is related to a long-term lyfe cycle (hydropower) or a continuous service nature (network assets) does not create an efficient framework of incentives (Brown, 2012). On the contrary, it opens room for uncertainties related to the calculation of indemnification of reversible assets and may, consequently, generate perverse incentives for underinvestment. In this sense, it is relevant to reassess the optimum term of the concessions established by law.

The generation concessions in Brazil involve significant disputes of inframarginal rent, considering the predominance of hydropower generation, which have high fixed cost and low marginal cost of operation.[10] The European experience tends towards longer terms (Glachant et al., 2015), revealing the need to revisit the term of the concessions and the method of assessment as to the convenience of renewal.

The scenario with concessions close to the expiry date in the coming years, make it imperious for Brazil to address the issue. Although the bidding process is the rule recommended by the Brazilian legal-regulatory framework, renewal is a common practice adopted by the Concession-Granting Authority. The renewals occurred throughout the 2000s, and more significantly after the edition of Provisional Measure n. 579, indicate the need for more explicit rules and procedures to mitigate or better discipline the discretionary power of the Concession-Granting Authority. In turn, this would confer the concessionaires in force with due predictability and incentives, without restraining the necessary contestability towards the adequate infrastructure service provision.

2.6. Digitalization of Networks in Europe

Networks digitalization and smart metering allow instant communication between agents, devices and applications while optimizing the gains from the ongoing decentralization process. Access to the new digital platforms could facilitate the insertion of distributed resources, democratizing the dissemination of new technologies and resources.

The implementation of smart metering is strategic for utility providers within an energy transition scenario. Smart metering is the first step towards the digitalization of the networks and their transformation into smart grids, enhancing the insertion of distributed energy resources and the applica-

10 Inframarginal rent derives from the difference between the generation marginal cost and the average electricity price. Under the cost-of-service tariff regime, inframarginal income is shared (or collected) with consumers upon tariff reviews. In market regime, the concessionaire can appropriate the rent, generating disputes for sharing among the concessionaire, consumers, and taxpayers.

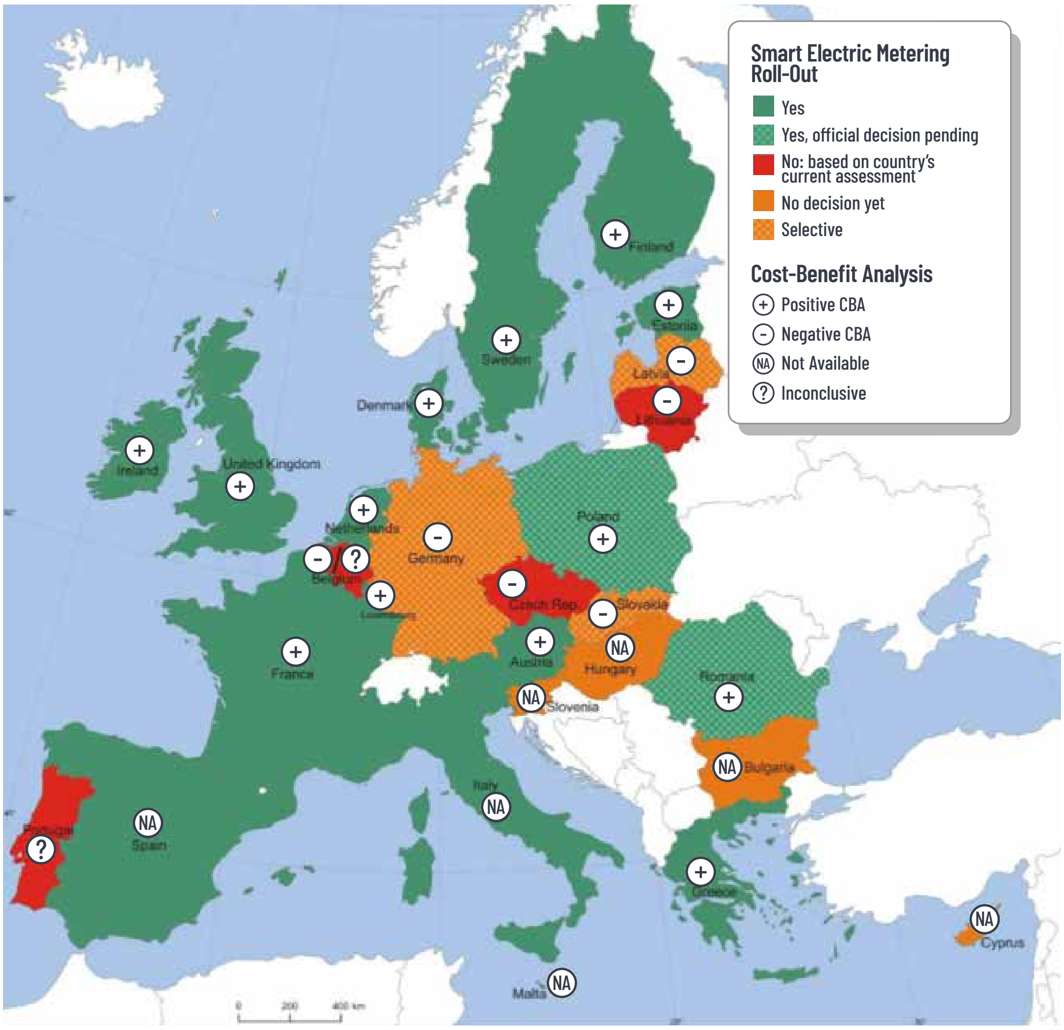
tion of multi-part tariffs that signal the real value of energy to consumers.

The functionalities of the smart metering infrastructure enable the development of demand management programs; the application of alternative pricing mechanisms; the incorporation of distributed generation; the promotion of energy efficiency actions; the dissemination of electric vehicles with smart charging mechanisms; besides the insertion of other distributed resources.

The International Energy Agency estimates that 40% of the global investments in the power sector in 2017 (750 billion dollars) were allocated to network assets (transmission and distribution). Smart metering reached the figure of 18 billion dollars, tripling the records in 2010. More than 60% of the smart meters in the world are installed in China. Still, several countries have already implemented smart metering on a large scale, such as Italy, Canada, Denmark, Finland, Norway, Spain, and Sweden (IEA, 2018a).

Anticipating potential net gains with the digitalization of the grids, the European Union - in its Third Energy Package - established a target for the Member States to implement 80% of smart mete-

Figure 12 - Roll-out of Smart Metering in Europe (cost-benefit analysis)



Source: JRC (2014)

ring systems by 2020, subject to prior feasibility analysis. The Third EU Energy Package determined the implementation of smart metering for electricity (Directive 72/2009) and, optionally, for natural gas (Directive 73/2009).

The European Union Commission Recommendation n. 2012/148/EU determined a Cost-Benefit Analysis (CBA) for an economic assessment of the massive implementation of smart meters, seeking to identify and quantify advantages, disadvantages, and risks (JRC, 2012). Therefore, Member States could condition the implementation of smart metering to a prior positive assessment of the long-term cost-benefit analysis. For positive results, the Directive set a target for the implementation of at least 80% by 2020 but did not set any targets for natural gas.

Approximately two-thirds of the CBAs that the Member States conducted indicated net positive benefits. Figure 10 presents the results achieved by each country. Italy was the first European country to complete the implementation of smart metering, followed by Sweden. Smart metering in the European Union is expected to exceed 70% in electricity consumers (200 million) and 40% in natural gas (45 million) in 2020.

Following the Third Energy Package, the recommendation of the Energy Efficiency Directive n. 27/2012 is to consider new services based on smart metering data, demand response and adoption of dynamic tariffs. The new guidelines gathered in the recent "Clean Energy for All Europeans Package" reinforce the importance of digitalization to achieve the expanded goals of renewable energy sources, energy efficiency, the interconnection between systems and reduction of the emissions for 2030.

Among the countries that did not adhere to the massive roll-out of smart metering, Portugal is an emblematic case, facing obstacles for the advancement in smart grids. The next section illustrates the main dilemmas underlying the digitalization – pillar of the energy transition, which emerge from the experience with smart meters' implementation in Portugal.

The Portuguese experience in introducing smart meters

Portugal started installing smart meters early in 2007. At the time, they launched a pilot program in Évora with the installation and operation of 35,000 smart meters (InovGrid Project). The program was an ambitious project comprising the definition of advanced technical requirements for smart meters, i.e., using them also as a communication gateway with end consumers (households and buildings) management systems, in addition to making information available for the distribution network operators, aimed at enabling the visualization of low voltage (LV) networks.

In 2008, the Portuguese Republic Assembly enacted Law no. 12/2008, which prevented the acknowledgement of the cost with the power, gas, and water smart metering systems. Ever since then, this Law has been the main barrier to the installation of smart meters in Portugal. Even so, the Distribution Network Operators (DSOs) of Portugal - EDP Distribuição and ten cooperatives - have installed over two and a half million meters in the last twelve years, for a total of approximately six million consumers.

Overall, the installation of the meters occurs through pilot projects and own initiatives, considering the efficiency gains that can be obtained, particularly in the detection of commercial losses. More recently, by the end of 2019, the Portuguese regulator (ERSE) published a regulation on Smart Grids, which paves the way for the acknowledgement of some of the costs associated with the installation of metering and counting devices, provided that the efficiency benefits for the electrical system are proven. Since this is a recent regulatory measure, we cannot tell how successful it will be.

The European experience, however, indicates the possibility of betting on a rapid mass rolling-out of smart metering, due to the potential benefits they bring to the power system. Among them, the following benefits stand out: reducing measuring costs, allowing fraud detection (remotely), the changing of contracted demand, power cuts in case of non-payment of the electricity bill, and also ensuring the development of solutions that enable some degree of management of low voltage networks and predictive control solutions. In turn, they enable for the accommodation of large volumes of the distributed generation directly connected onto LV networks, in terms of self-production and for technical management of production linked to energy communities in the LV networks.

2.7. Energy Efficiency

Importance of energy efficiency for the energy transition in progress

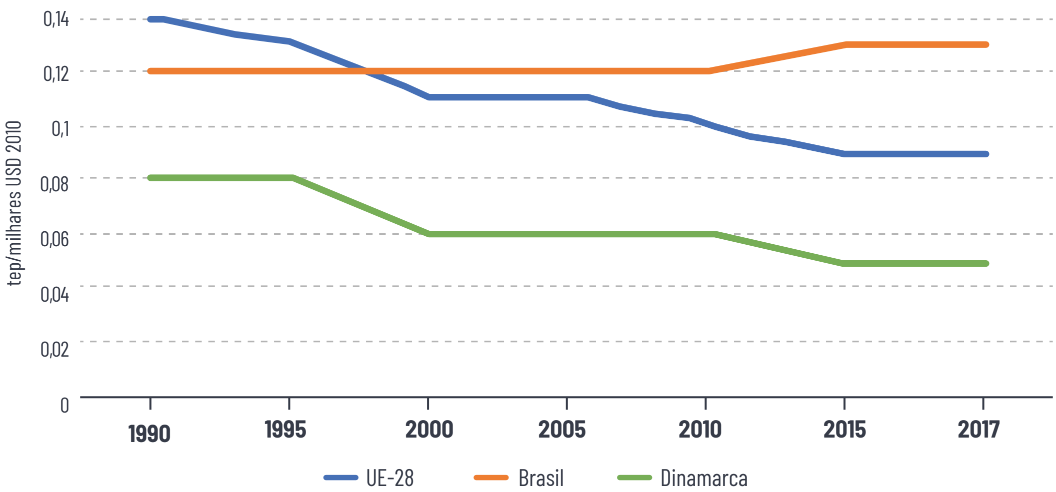
The transition to a low carbon economy requires, on the one hand, the massive adoption of renewable energy sources and, on the other, the use of more efficient solutions. The first concerns mostly energy supply, while the latter deals with demand.

Introducing renewable energy into the grid also adds efficiency to the system when the electricity is no longer generated from centralised fossil-based resources. By its nature, the conversion of primary energy into useful energy induces significant losses in the form of heat, causing fossil-based generation systems to be inefficient.

Brazil starts from a very privileged energy matrix, given that the renewable component in electricity generation (83%) and transport (20%) is traditionally extremely high. Notwithstanding the increase of fossil fuel (coal, oil and potentially pre-salt gas) in electricity generation and transport can deteriorate this privileged situation and reduced the overall efficiency of Brazilian energy matrix. As a result, Brazil is moving in the opposite direction to decarbonisation, contrarily to the path currently pursued by the European Union.

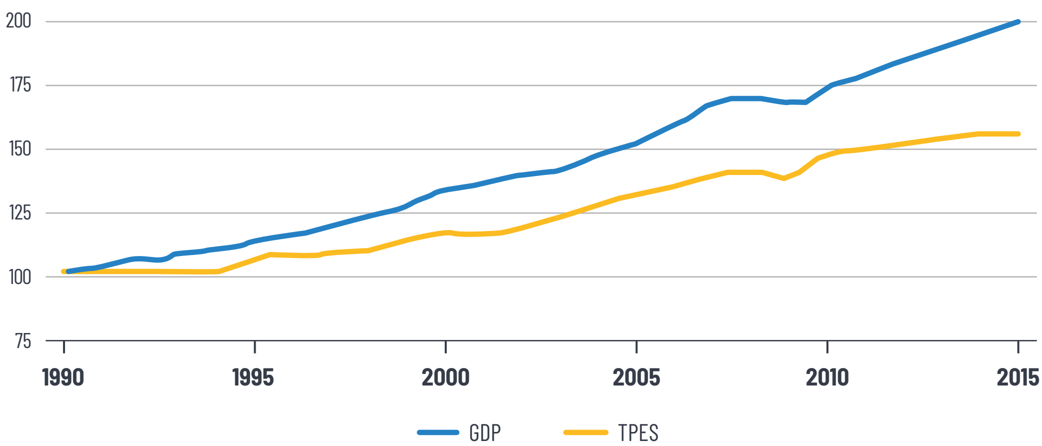
Typically, the indicator used to measure the energy efficiency of an economy is referred to as energy intensity that, overall, measures the amount of energy needed to produce one unit of Gross Domestic Product (GDP). As such, the smaller the amount of energy needed to produce one unit of out-put, the more energy-efficient the economy is. In the Brazilian case, we can observe the growth of the energy component that integrates the production. At the same time, at the level of the 28 Member States of the European Union, there is a gradual reduction of it (Figure 13). At a global level, however, it is observed a dissociation between the production growth and the energy demand, which, in turn, indicates the introduction of efficiency into the economic system. Therefore, the dynamics of both curves –

Figure 13 - Energy intensity in terms of GDP (toe/ thousands of USD - 2010)



Source: Own elaboration based on the International Energy Agency data

Figure 14 - World GDP and total primary energy supply (TPES) (1990=100, GDP in USD 2010)



Source: International Energy Agency

production and energy – evolve towards opposite directions (Figure 14).

`Energy efficiency is defined as the ability to produce the same product or better, provide the same service or better, using less energy. There are several ways to improve the energy efficiency of a production centre or service provider, typically through the definition of policies or introducing technological improvements, management enhancements and behavioural changes.

Among the economic advantages of introducing energy efficiency, you can count on the possibility of freeing up financial resources for other areas, such as health and education, which are essential at both national and sub-national levels. Energy efficiency also induces other multiple direct and indirect benefits, such as job creation, improved health conditions, poverty reduction, increased energy security and industrial productivity, among others.

Traditionally, there is a growing concern in enlarging electricity production and in planning to build more generation plants to meet demand expectations, while neglecting the potential that energy efficiency can have. This has undoubtedly been the case in Brazil, especially with the rationing crisis in 2001-2002. The International Energy Agency, on the other hand, has described energy efficiency as the "first fuel" – comparing the megawatt generated to the negawatt avoided – given the high potential across all countries worldwide, thus equating it with other available energy resources.

Energy efficiency is the fastest and cost-effective option to reduce emissions. The International Energy Agency considers that there is room for potentially reduce the emissions by merely introducing around 40% of energy efficiency using the available technologies (IEA, 2019d).

In this sense, the first step before deciding for the construction of new plants should be to draw up and implement serious and ambitious energy efficiency programmes, as this might be key to not unnecessarily invest resources in the construction of new infrastructures, such as transmission lines and generation plants, especially if they are fossil fuel-based.

In Brazil, there are multiple reasons for the adoption of energy efficiency, in addition to those explained above. It is evident the need to react to a change in hydrological regimes, which compromises the hydropower generation. On the other hand, the generalized increase to the residential demand, by the extensive use of air conditioning for cooling, as well as its use in hours of higher power demand, puts pressure on power system. As a result, the need for power increases. Finally, we must emphasize the contribution of energy efficiency as a strategic resource, and not as a last resort, generally used in critical moments - like the 2001 rationing in Brazil, with impact to several dimensions.

In addition to the reasons mentioned, it is necessary to improve the supply and the sustainability of isolated energy systems, which still exist in Brazil (especially in the North of the country). Sustainable supply solutions for these systems are valuable opportunities for introducing efficiency and renewable energy sources.

The role of energy efficiency targets as a pillar of the Clean Energy for All Europeans

By the end of 2019, the European Commission presented the European Green Deal, a package of measures that should enable European businesses and citizens to benefit from an energy transition towards sustainability, aiming to achieve emission neutrality by 2050. In this political stand, they affirm that the smart integration of renewable energy, energy efficiency and other intersectoral sustainability solutions should lead to the decarbonisation of the economy at the lowest possible cost. Energy efficiency is thus one of the key pillars for the energy transition within the European area.

In the European Union, there are measurable quantitative targets equally in force towards increasing energy efficiency (32.5%), along with targets for renewable energy penetration (32%) and decarbonisation (40% compared to 1990) by 2030. Therefore, there is a set of structuring Directives in force which the Member States must transpose into national law, implement, and adequately monitor.

In the field of energy efficiency, the Directives comprise: the buildings sector - in Europe, they account for approximately 40% of the electricity demand; energy efficiency in combined cycle plants – heating and electricity generation (cogeneration); labelling and ecodesigning products that use electricity; energy efficiency in heating and cooling, given the high impact these systems have on the operation of the buildings and the industry; and a specific Directive on the mobilisation of private investments in energy efficiency. All these directives are further framed by a generic directive on targets, metrics, and rules towards achieving the 2030 objectives.

The European experience shows the high impact of setting regulatory frameworks and developing secondary legislation, accordingly, driving the economic practices towards energy efficiency. Ecodesign and product labelling directives are role-models, where limiting the market access to the worst solutions in terms of energy efficiency can have an incredibly significant impact on energy demand. Such measures, along with close monitoring of the technological developments, have had an extraordinary impact on the reduction of the demand.

An analysis simulation for the implementation of policies of this nature – especially designed for Brazil (U4E, 2019) – estimated the potential to avoid investment in approximately 13 new plants for 500 MW each until 2030 if best practices in terms of minimum performance standards (MPS) were adopted for five products: lighting, small air conditioning units, domestic refrigerators, industrial electric motors and distribution transformers.

The European Directive on the energy performance of buildings is also role-model when it comes to new buildings and significant renovations, introducing demanding and mandatory codes for the building stock. This market has been transformed, with energy efficiency solutions automatically present in all buildings. In the Brazilian case, the mandatory nature-based migration to a system of building codes and energy labelling, and not a voluntary-base one – as seen so far, would surely have clear impacts on the efficiency of the buildings.

Informing and training professionals and the population is essential, and it should not be neglected. The role of the universities, vocational and technical training centres, along with educational campaigns in schools, has proved effective in mobilizing capacities within institutional and productive sectors. The abundance of international initiatives supporting this type of measures could leverage the development of the necessary educational frameworks.

According to Article 4.2 of the Paris Agreement, every signatory party to the United Nations Framework Convention on Climate Change (UNFCCC) should prepare, communicate, and maintain Nationally Determined Contributions (NDCs). NDCs are actions that countries should undertake to reflect their post-2020 endeavours to address climate change and be in line with the overall ambition of the Agreement.

NDCs should be updated every five years if not earlier, to increase their ambitions and reflect the information needed for greater transparency. Developing countries and the Small Island States also benefit from a clause to develop their NDCs, reflecting their circumstances (Article 4.6). Most developing countries condition at least part of their NDCs' mitigation actions to receiving support, whether financial, technological, or for capacity-building. In the current NDC, Brazil has identified the following components as energy efficiency measures:

- Industry: promoting new standards for clean technologies, improving energy efficiency and low carbon infrastructure
- Transport: continue to promote efficiency measures and improve transport infrastructure and public transport in urban areas.
- Power Sector: achieve 10% in efficiency gains by 2030.

In 2020 there is an opportunity to update the NDC recorded targets, within the official reviewing process foreseen in the Paris Agreement. Updating is an opportunity to increase the ambition for energy efficiency by adding further details, sectors, and quantitative targets.

The importance of the governance of energy efficiency policies for their design, implementation, and monitoring

The governance of the power sector is an essential pillar in the transition to a sustainable economy. The creation of a robust, stable, and well-articulated regulatory framework is fundamental. This requires the development of a well-defined legal framework, identifying the main activity segments, as well as the relevant secondary laws and regulations, monitoring and verification programmes and procedures. The programmes should be of mandatory implementation in nature. Implementation and supervision must be carried out by duly independent, trained entities with adequate human resources.

In Brazil, one can identify a set of programmes in the energy efficiency domain that are little updated, which experience slow implementation processes, mostly voluntary and implemented by the energy system operators (e.g., PROCEL).

This situation causes a paradox and possible conflicts of interest at the level of market operators. Besides, the Ministry is understaffed to properly handle the energy efficiency programmes, which limits their capacity to define routes, measures, strategies and evaluate results. With the due enhancement to the energy efficiency department of the Ministry of Mines and Energy, along with the support from the EPE, the appropriate resources and qualification, they could run a specific program for energy efficiency.

Another aspect of the governance impacting energy efficiency concerns the energy pricing structure, which should reflect its real cost. Energy subsidies limit the search for best practices in the rational use of resources by not demonstrating their real cost. However, the transformation towards the implementation of real energy prices often stands as challenges for the most vulnerable communities and segments. This is why energy efficiency programmes should be well integrated with the transition to energy "realistic tariff" and have the proper financial support to assist the most vulnerable population in the first instance, to cause the best practices and technologies to be quickly adopted.

Making business and energy efficiency market models viable is also a structuring pillar for the exploitation of this strategic resource. In this direction, numerous mechanisms could leverage invigorating energy efficiency solutions in the Brazilian market, such as the creation of a regulatory environment favourable to electric utilities and the implementation of energy performance contracting; the development of aggregate purchases; green bond markets; revolving funds; pay-per-service, among others.

2.8. Restructuring the Natural Gas Sector in the European Union

The Brazilian natural gas sector has come to a turning point in its transformation process. Strategies to implement the transition could benefit from the experience of the reforms experienced in the European Union, still in progress, towards the liberalisation of the industry. The parallel is especially relevant considering Brazil's federated nature and its distinctive local realities, can compare to the general EU Directives – to be implemented by the different Member States. The following paragraphs are intended to briefly describe the main characteristics of the EU's liberalisation process, and lessons learned that could be incorporated into the development process of the industry in Brazil.

European liberalisation started about 20 years ago with the first Directive for Natural Gas (Directive 1998/30/EC), followed by other Directives and Regulations, such as Directive 2009/73/EC, Regulation (EC) No. 715/2009.

The restructuring of the gas sector in Europe - implemented with a robust top-down approach - has pursued the introduction of competition and the creation of a single, global European gas market, supported on the fundamental principle of providing sustainable, secure and affordable energy for all consumers.

The established political tools aimed explicitly at reducing influential positions to achieve those goals, based on two significant examples: the experiences of the gas industries in the United States and the United Kingdom, leaders in the Western liberalisation processes.

The initially implemented tools followed classic recommendations of increasing network competition: unbundling of services from the incumbent, in a gradual and growing process; non-discriminatory third-party access to the grids and regulation of the network access tariffs.

Together with these guidelines, other regulations and recommendations have been implemented and transposed as liberalisation tools, in addition to other instruments established by the relevant sectoral agencies - such as balancing rules, virtual trading points (VTP), among others.

As far as regulation is concerned, one of the critical lessons learned from the European experience is that the liberalisation process and its tools can be useful in creating competition, which is why they are implemented together, as a package of combined and integrated interventions.

In particular, regulations that promote market development - such as mechanisms to increase liquidity and reduce barriers (VTP, market mechanism-based balancing, market opening, among others) - have proven to be the main facilitating factors as competition triggers across the gas sector. In gas markets where governments have maintained a position as significant shareholders or tried to maintain their presence in the sector, they have experienced a lower level of competition (Opolska, 2017).

Starting from the identification of the status of the EU gas market, the ongoing liberalisation process is briefly described , as well as the main issues to be addressed in the coming years.

Overview of the EU gas market

Trends in gas supply and demand

The European Union has always been dependent on natural gas imports. Nowadays, given the reduced domestic production, the EU imports more than 75% of its demand – via regasification terminals (LNG) or pipeline (gas from Russia) (CER/CEER, 2019).

Although in the coming decades the European domestic production might benefit from the development of renewable gases – for example, biomethane from anaerobic digestion and green hydrogen from natural gas (power-to-gas) –, the impact is not yet evident, while its current contribution is still limited. Another possible but still limited internal source of gas is the production of biogas (4% of EU consumption), used mainly for electricity generation.

Despite the observed reduction in the annual demand (3.7% in 2018), the planned phasing out of electricity generation from coal by many EU member states in the coming years - as a consequence of decarbonisation commitment statements - might stimulate a further increase in the demand for gas in the coming years.

Induced by the changes in the power generation, together with increasing levels of electrification in many consumer sectors (heating and cooling, transport, among others), that possible demand increase emphasizes the relevance of maintaining a continuous integrative vision among the sectors (sector coupling), while adopting a holistic approach to adequately address the problems arising from the inevitable interactions between different energy industries.

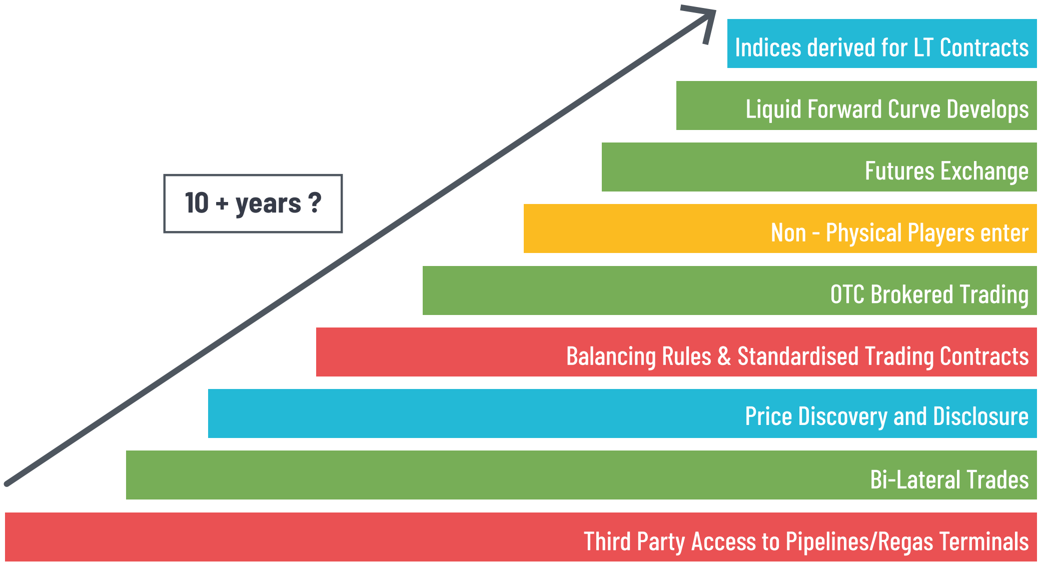
In this respect, it is worth emphasizing that the development of the European liberalisation process can significantly benefit from partial alignment - where applicable -, the improvement of the laws and regulations and the power sector regulation.

European Gas Market Operating Indicators

The path to reaching the maturity of a trading hub (Figure 15) translates into a long and gradual process, starting with third-party access to essential infrastructures, enabling trading through bilateral contracts among more agents. The more significant interaction between supply and demand in the market results in more reliable pricing signals, attracting more traders and enabling negotiation by the over-the-counter market, which requires clear balancing rules and standardized contracts. With con-solidated liquidity, the entry of agents without physical delivery allows the development of a futures market, with price index marking out long-term contracts.

Heather (2015) considers that the path to maturity can be tortuous, and involves, on average, more than a decade for its achievement. Each step cycled through

Figure 15 - Pathway to Maturity of Trading Hubs



Source: Heather (2015).

requires a continuous commitment from governments, suppliers, and the system operator for a smooth transition. Countries with domestic production or well-supplied by competitive gas sources tend to achieve success in less time and establish more liquid *hubs*.

In Europe, numerous indicators are generally used to assess the level of market operation, in quantitative terms - such as the number of active and independent participants, the volume of traded products, churn rates, among other things - and in qualitative terms - such as political determination and cultural attitude towards the liberalisation and integration processes.

At the national level, the number of active independent participants, overall, is considered as a clear sign of market maturity and competitiveness. At the same time, the products and volumes traded are used to point to the market's ability to provide a reliable price signal.

However, the churn rate is usually considered the most significant and "concise" indicator for assessing local market success and maturity. In this sense, a high churn rate commonly implies a myriad of participants, products and volumes traded. In other words, the churn rate provides a global picture of market liquidity. It is often chosen by traders as a quick and easy indicator to decide whether to enter a new market (ACER, 2019b).

To date, only a few gas hubs in Europe have churn rates above or close to 10, which is considered a minimum to identify a mature and robust market – without distortions or manipulations (Heather & Petrovich, 2017).

At a higher level, to assess the European Gas Target Model (EU GTM), price signals are recorded as significant indicators of the overall operation of the integrated market, accurately: (i) price frequency - i.e., a measure of transparency for the activities of balancing, risk management and efficient resource allocation - (ii) price convergence between over-the-counter (OTC) and foreign exchange markets; and also (iii) price correlation between adjacent markets (ACER, 2015).

In particular, the level of correlation or price convergence between neighbouring gas hubs indicates the trading efficiency and the integration degree between different markets and systems (cross-border trading). Allowing gas to move freely, without physical and non-physical barriers, is a strategic and valuable objective for Europe.

On the other hand, the price misalignment between adjacent markets in Europe is a clear sign of insufficient transport capacity (physical limitations) - reflecting, for example, infrastructure limitation - or sub-optimal use of current physical capacity (non-physical limitations) - related, for instance, to poor or slow implementation of contract management processes, ineffective measures to use the capacity release, lack of procedures to provide flexibility, among other things (Chyong, 2019).

In this context, there are European regions with a high price alignment between markets (notably, North-Western Europe), which indicates the constitution of integrated market areas offering tangible benefits for consumers. On the other hand, there are still regions with evident price misalignment (notably, South-Eastern Europe), resulting from physical congestion or the need to improve capacity allocation - such as “use it or lose it” procedures, recently implemented in Italy. Figure 16 shows the current level of development of gas trading areas (hubs) in the European Union.

Methodology to implement and improve the EU GTM

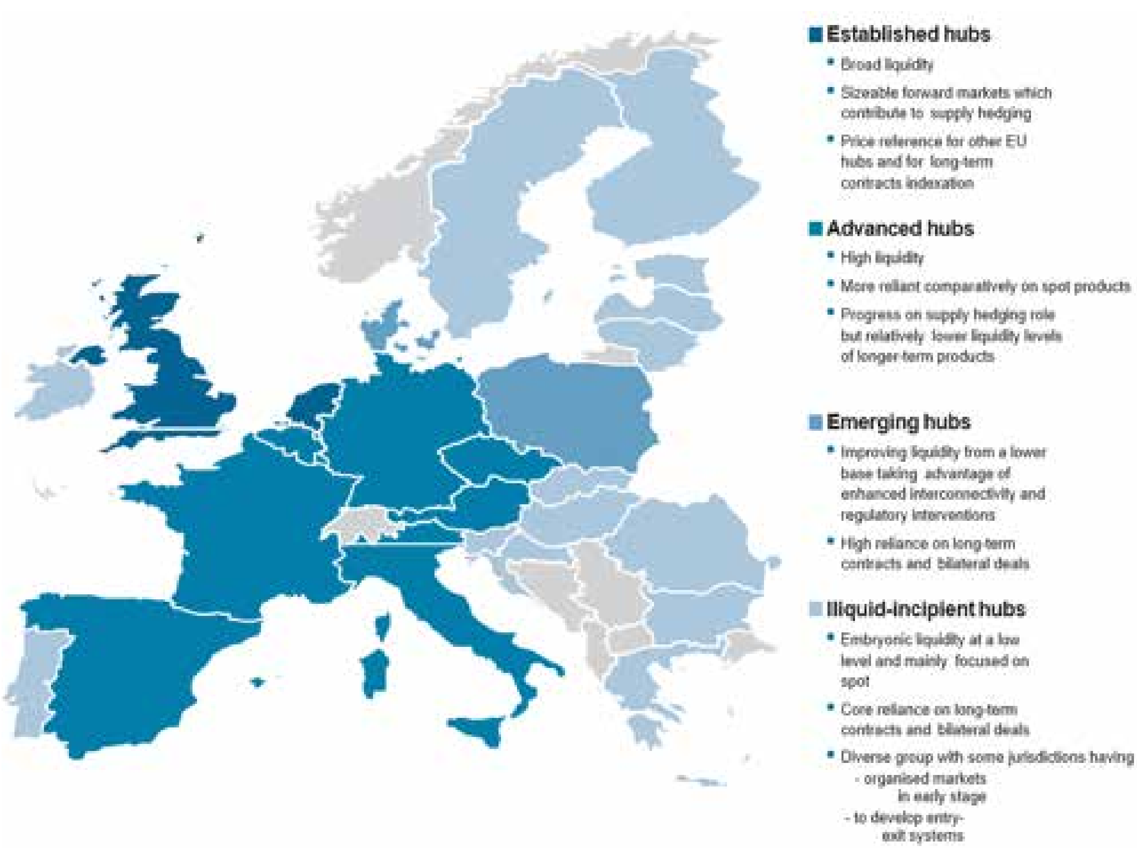
Regardless of the general consent as to the benefits deriving from the gradual implementation of the European Gas Target Model (EU GTM), the process and framework of the model need continuous improvement: whether because of reduced competition or due to structural, regulatory or institutional issues - e.g., inadequate levels of infrastructure or dependence on a single or restricted source of supply.

In this context, the presence of LNG regasification or underground storage terminals in the trading areas is (i) fundamental means to ensure the security of supply and (ii) strategic means to provide a minimum level of short-term flexibility and market contestability, even if these resources are not used at their maximum or optimum capacity.

However, to ensure high price convergence, easy access to suppliers, increasing the stability of trading in the market, reduced transportation charges and long-term contracts with sufficient capacity for expansion, it is necessary to adopt measures to improve the legal-regulatory framework. However, the methodology and process for identifying and implementing the necessary measures are complex and delicate, as they involve different European regions with different local realities, a variety of national regulatory authorities and even different sectors impacted.

In this sense, it is of crucial importance to have a centralized regulatory authority (supra-national), established by law, to monitor the market operation indicators, using metrics and data available from other national/regional organi-

Figure 16 - Current Development Level of Trading Hubs in the EU



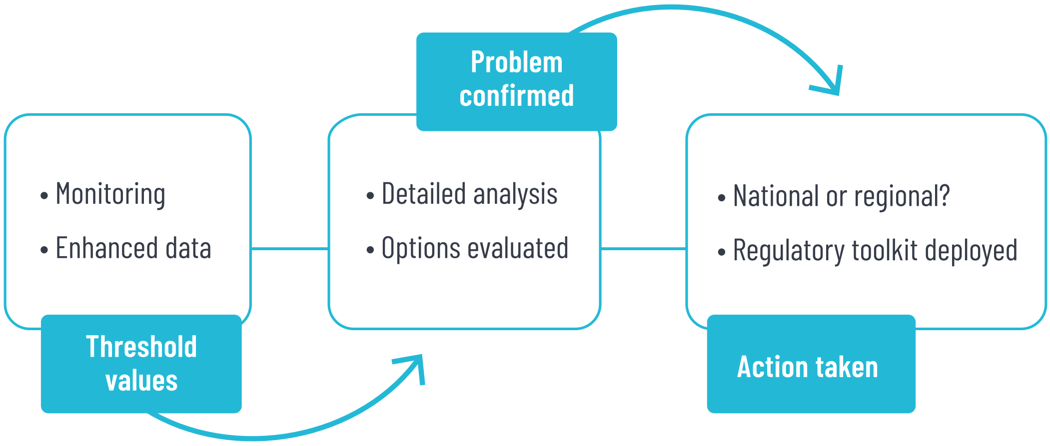
Source: ACER (2019a)

zations or regulatory authorities, adapting them as needed to follow up on the sectoral evolution (Vasconcelos, 2019b; ACER, 2019a).

One of the most relevant roles of the central authority is the definition, together with the National Regulatory Agencies, of the threshold levels of indicators that reveal necessary market improvements. It falls to the central authority to carry out an in-depth analysis of the relevant market issues, identifying causes and proposing improvement solutions for the liberalisation instruments, such as gas or capacity release programmes, tariff adjustments, among others.

Following the current European debate on the right methodology to improve the level of market integration, actual measures should only be adopted after public consultations, cost-benefit analysis, and decision sharing among national authorities. Figure 17 shows this process, in which the Central Agency, following the principle of subsidiarity, only intervenes in cases of controversy between national authorities.

Figure 17 - Decision Making of the Supranational Regulatory Agency in the EU



Source: ACER (2019a)

Areas for improvement and future-related issues

Avoiding unfair market practices

Overall, the implementation of the model (EU GTM), along with the introduction of market regimes for balancing and daily transactions, produces positive effects for the objectives set. However, some European regions where competition and market opening can be further improved through legal processes and regulatory instruments.

For example, among the instruments against market manipulation are administrative and legal requirements for market participants (such as formal license and registration), which are essential to prevent unfair practices and, consequently, socialization of their costs (ACER, 2019a).

However, for these actions to be practical, it is necessary to develop a shared legal framework beforehand, and at the European level - equivalent in Brazil to the federal level - aimed at:

- Making decisions promptly, which requires the ability of the transmission system operators (TSO) and national regulatory agencies to perform exante verifications of market participants.
- Avoiding, at the same time, the introduction of excessive requirements posing barriers to entry for new players.

To make the latter condition effective and inexpensive, it is necessary to establish a system of shared acknowledgement across Europe, defining an agreed on a minimum set of standards in terms of reliability and financial solvency of the participants, as well as a system of mutual licence revocation.

In practice, this would require the adoption of a standard alert system for malicious behaviour, a kind of "blacklist" in the form of a shared database, accessible to National and Central Regulatory Authorities, as well as by the European Association of Gas Transmission System Operators (ENTSOG).

Infrastructure and New Products

In the EU's experience of liberalisation, the development of physical infrastructure is an essential aspect of creating an open, interconnected, and well-integrated market. As a rule, its development falls to the network operators (TSO), supervised by the regulatory agencies, which also determine the level and methods used in compensation for the investments.

Meanwhile, the European regulatory agencies and the operators may have different views on the infrastructure needed for the development of the gas market, especially when it comes to deciding on the construction of infrastructure interconnecting in other systems.

As the market restructuring process evolves, additional issues also arise from the development of technologies, which bring new activities and products. Below, we present a few examples:

- Infrastructure planning is still mostly carried out separately for power and gas, while the boundaries between these two sectors are becoming increasingly blurred due to increasing levels of electrification of consumption and power-to-gas projects, which may require coordinated planning and cost-benefit analysis;
- Gas and electricity grids may compete with one another, as each is not the only means of providing low-carbon forms of energy to consumers. Therefore, the role of operators must be clear to avoid market distortions due to vested interests, which translates into actions to promote or block specific emerging technologies.
- New infrastructure and assets are emerging, such as networks dedicated to hydrogen transportation and distribution, whose governance and regulation have not been defined yet.

To address all these issues, there is a first response in the evolution of the configuration of gas governance, which should follow the direction, as far as possible and when applicable, adopted by the power sector.

For example, according to the EU Agency for Cooperation between Energy Regulators (ACER), the operators should submit their work and development plans to the central Agency for approval, even after undergoing a process of amendments and modifications. In other words, the sector needs a closer oversight, as the risks of conflicts of interest grow – which is increasingly frequent because of the changes introduced by the decarbonisation policies and related technological developments.

Also, investments in low-carbon or "green gas" assets should be encouraged only after conducting cost-benefit analyses and properly considering if traditional assets are at risk of not fully recovering – for example, those dedicated to delivering just one product. In this sense, not only the new developments should be carefully assessed, but also the possible need for decommissioning of assets, which should be subject to a thorough analysis.

Dynamic and Adaptive Regulation

The continuous decarbonisation process - which involves mixing biogas, biomethane or other low carbon gases with natural gas or introducing them into networks as a full replacement for natural gas - requires the definition of a set of new technical standards and quality parameters, otherwise internal or external barriers will arise.

That was the case in Europe, for instance, when they started mixing biomethane from anaerobic digestion in natural gas grids. In fact, despite the economic incentives anticipated by many countries to promote the production of biomethane, in many cases, the development of this resource has been delayed due to the lack of agreement on minimum quality parameters to inject biomethane into the networks safely.

Regulation should focus on monitoring technological developments and applying adequate definitions for new products and goods, which would result in the establishment of a valid taxonomy. Further-more, considering the increasing levels of distributed production of green gases injected into the local networks, it is likely that they will need a centralized European Distribution System operator (European DSO) to draw up a Distribution Network Code.

Another relevant question is understanding if the new generation technologies - except for those related to initial incentives granted by national governments - should be considered as part of a monopoly or a market context. The new technologies should be on an equal footing with other technologies when it comes to considering the tariffs they pay for network connections, which also implies the need for information on the ease of access to new producers to be provided by the TSOs and DSOs.

A similar situation concerns the development of new networks specific for one particular gas, such as hydrogen networks. Although the regulation of such infrastructure may seem premature regarding some aspects, the regulatory uncertainty may also be detrimental to new investments. As an initial commitment, only a few fundamental principles can be established, such as granting non-discriminatory access to third-party networks, while adopting an approach of learning before regulating.

As a general rule, if there are uncertainties as to which new technologies would succeed, it is reasonable to adopt a prudent and dynamic approach, avoiding technologically non-neutral decisions and encouraging results-based visions - which support efficient results and investments - while providing an appropriate regulatory environment to test new technologies in a typical “sandbox” or “pilot project” context, leaving the market to choose the best technologies and projects.

Harmonisation of transport tariffs and integration of the sectors

A crucial aspect of the European gas market integration relates to the transport tariffs and capacity allocation on interconnections. Currently, gas tariffs are mainly based on public input, and output models, where the basic principle to establish tariffs lies cost reflectivity, especially for cross-border capacity. In this scenario, interconnection tariffs vary widely, from less than EUR 0.5/MWh to EUR 2.00/MWh within the EU and up to EUR 3.00/MWh for external borders.

The cascading effect of the transport tariffs – based on the movement of gas in different systems – is a source of concern. This phenomenon is referred to as “tariff pancaking”, i.e., when repeated exit and entry tariffs are charged, often over short distances, for gas passing through several small entries and exit zones. In this situation, the revenues allowed to operators (TSO) are part of the calculation process to quantify entry and exit tariffs between systems. Furthermore, how operators’ assets are valued and how the national regulatory agencies calculate their revenues are not always transparent or homogeneous. However, they do have a material impact on tariffs and, indirectly, on the transactions between systems.

One possible solution is the so-called inter-operator compensation (inter-TSO - ITC), which ensures the recovery of the revenues of operators whose systems are affected by the flows. In the case of mergers in the market, this involves gradually rebalancing border interconnection tariffs to higher tariffs at the external borders within integrated areas.

Naturally, wherever an ITC mechanism is used, the calculation of an operator's revenues (TSO) should be assessed based on commonly shared criteria. In this context, the implementation of a global Tariff Network Code is a priority for harmonising tariff structures as well as the definition of entry and exit systems, taking into account the topology of the infrastructure and the typical patterns of physical flows and congestion.

As green infrastructure develops, investments in new natural gas infrastructure can generate sunk costs, making it necessary to coordinate and harmonize them with neighbouring states, especially if there is a shared impact.

Another harmonisation opportunity arises from the differences between gas and electricity tariffs, which could lead to distorted decisions when the two energy sources compete, which is increasingly common as the integration of sectors grows. For instance, electricity transmission could compete with gas transport in power-to-gas projects. In a case like that, the regulators must ensure the network tariffs to provide level conditions between gas and electricity, defining tariffs that reflect the costs imposed on the networks.

At the same time, transmission (DSO) and transport (TSO) systems' operators should be prevented from investing in competitive activities, to avoid distortions: the guiding principle should always be the unbundling of regulated and non-regulated activities.

2.9. Natural Gas Perspectives in the Brazilian Transition

Natural gas is a strategic ally in the energy transition of many countries. Its lower greenhouse effect gases emission factor contributes to the immediate reduction of the level of emissions when its insertion displaces other fossil fuels. For this reason, natural gas is seen as a bridge-fuel.

In 2018, natural gas accounted for 12% of the country's internal energy supply, behind oil and derivatives (34%), sugarcane derivatives (17%), hydropower (12%), firewood and charcoal (8%), among others. Electricity generation, on the other hand, accounts for 33% of the total consumption of natural gas, followed by industry (28%) and the energy sector (21%). In industry, natural gas represents 11% of energy consumption - behind electricity (21%), sugarcane bagasse (16%), and coal (14%). In transport, the participation of gas in consumption levels is even lower, only 2% in 2018, compared to the relevance of diesel (43%), gasoline (26%), ethanol (19%) and biodiesel (4%). As to the residential consumption, natural gas participation is marginal, i.e., only 1% in 2018, behind electricity (46%), LPG (25%) and firewood (25%) (MME, 2019).

EPE (2019a) projects an average gross production of 250 million cubic meters per day (MMm³/d) for 2029, compared to 130 MMm³/d in 2020. However, the ability to have this gas generation reach the market is limited by the high rate of re-injection of associated gas (to oil) into the offshore production fields. As a result, EPE (2019a) projects a net supply of domestic gas production of 138 MMm³/d in 2029, compared to 83 MMm³/d in 2020.

In Brazil, the potential supply of natural gas in the Pre-salt suggest a massive insertion of the resource in the energy matrix in the next years. The expectations, including those explicitly stated in the policies being designed for the energy sector, are of an increased production of gas associated with oil. As a result of the positive shock of supply in the domestic market, they are seeking to create conditions for the development of a competitive gas market, contributing to reduce its price. In this sense, gas could expand its participation in the industrial and transport sector and, mainly, in electricity generation.

Natural gas-fired thermal power generation proved to be a crucial element in the recent expansion of the generation park in Brazil, as attested by the results of the last energy auctions and the indicative planning of EPE. The expansion is mainly based on thermal plants supplied by imported liquefied natural gas (LNG) in new regasification terminals. The perspective of gas use associated with the Pre-Salt resources points to the possibility of inserting even more gas into the Brazilian matrix – moving in the opposite trajectory of the efforts gathered by the European Union for the next years.

Although the Brazilian power system is structured around Hydropower plants with large reservoirs, interconnected in the extensive National Interconnected System (SIN), since the 1990s there is no significant expansion of reservoirs. The new hydropower plants installed are run-of-the-river type, with no capacity for multi-annual regularization, thus intensifying the variability of supply. With the loss of reservoirs' regularization and the increase in variable supply, there is a more profound depletion of the water reserve and the need to complement electricity generation and capacity to meet the peak demand of the system.

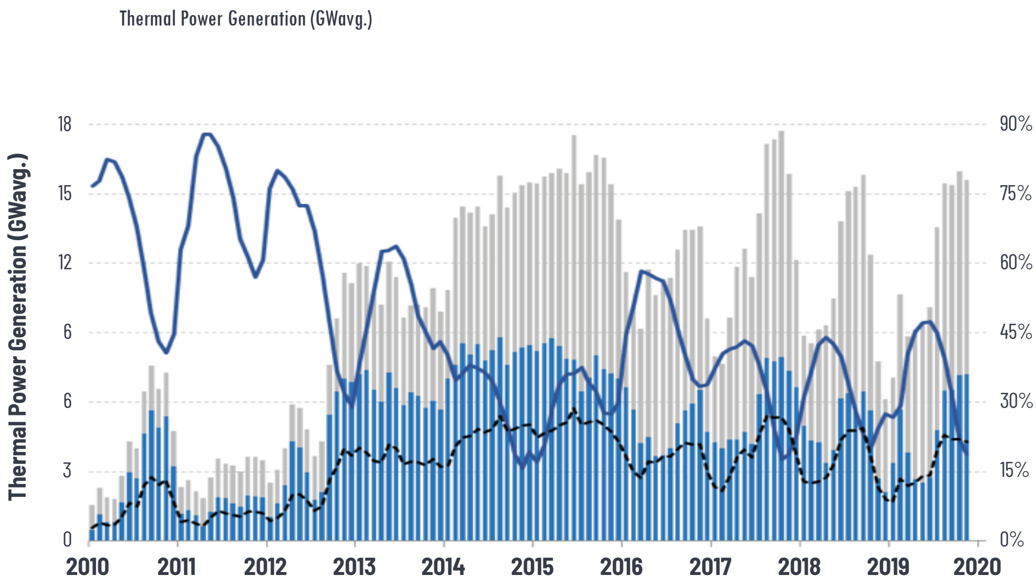
In this context, the contribution of thermal power plants, mainly natural gas-fired ones, both for energy generation and for flexibility provision, should be highlighted. Chart 11 shows the increase of thermal complementation and its variability, depending on reservoirs' level in the South-East/Middle-West region (responsible for 70% of the total volume of the country), with an increasingly higher depletion throughout the year. The graphic shows the contribution of gas-fired thermal plants' generation and that of other fuels, revealing the growing role of this energy source in the Brazilian matrix. Since 2012, the complementation by thermal generation has jumped from the historical average of 5% to 20%, with increasingly significant oscillations between wet and dry periods.

The optimization of the Brazilian hydrothermal park has always recommended flexible thermal plants that are incompatible with the domestic supply, mainly composed of associated gas (Table 4). Consequently, the centralized management of Petrobras and the LNG imports were the solutions found to reconcile the flexibility needs of gas supply.

The larger thermal complementation in energy generation configures a new operating paradigm of the Brazilian system. In this new context, there is space both for thermal plants at the generation base and for flexible thermal plants. The perspective of increasing the gas supply (associated) from the Pre-Salt and less coordination of Petrobras in the gas chain, after the strategy and the commitment of divestiture, might benefit a more massive insertion of the gas into the matrix.

Before the Bolivia-Brazil gas pipeline (GASBOL) started operating, in 1999, the

Chart 11 - Thermal Power Generation and the Energy Stored in Hydro Reservoirs in Brazil



Source: Own elaboration based on the National Electrical System Operator (MME) data (2019)

supply of natural gas in the country was limited, focused primarily on industrial activities. Bolivian gas and the increase of production associated with oil have opened new markets for gas, including for the thermal power generation. Since then, the diffusion of gas-fired thermal plants in Brazil has been alternated phases of expansion and stagnation.

ALNG imports have gained representativeness in the national gas supply, especially boosted up by the demand for guaranteed supply and flexibility of thermal generation by the power sector. The CNPE Resolution n. 4/2006 determined the implementation of projects for LNG imports as a priority, aiming at assuring the availability of natural gas for the national market to prioritize the supply from thermal plants and to facilitate the adjustment of the gas supply to the characteristics of the national market using flexible supply (Dutra et al., 2017).

The regasification terminals made the supply guarantee more robust in the country but did not contribute to the development of the gas market. Without a guarantee of third-party access in the Gas Law (Law N. 11,909/2009), the import was restricted to Petrobras. The expansion of the gas pipe-lines also did not take off after the Law, which provided for the concession of new pipelines through a complicated process structured around the 10-years Expansion Plan for the Pipeline Transport Network (PEMAT).

Since 2014, new thermal power plants associated with new regasification terminals have been contracted at the energy expansion auctions. On the one hand, the expansion via LNG reflects the asymmetry between the domestic gas supply profile – predominantly associated (inflexible) – and the demand for flexible thermal generation by the power sector in Brazil. On the other hand, the option for LNG also reflects the difficulties faced by new competitors to access the existing infrastructure, compromising the development of the industry in the country.

Table 4 - National Balance of Natural Gas supply and demand in Brazil (average amounts in a million m^3/d)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	% 2019	% 19/11	EVOLUTION
+ National Production	**66,0**	**70,6**	**77,2**	**87,4**	**96,2**	**103,8**	**109,9**	**111,9**	**122,4**	**100%**	**86%**	
Onshore	16,8	16,7	20,6	23,3	23,0	23,8	21,5	22,0	22,7	19%	35%	
Offshore	49,1	53,9	56,6	64,1	73,3	80,0	88,4	90,0	99,7	81%	103%	
Associated	48,6	49,0	51,4	58,6	70,2	78,2	84,8	88,7	99,9	82%	106%	
Non-Associated	17,3	21,6	25,8	28,8	26,1	25,6	25,1	23,3	22,5	18%	30%	
- Reinjection	11,1	9,7	10,6	15,7	24,3	30,2	27,6	35,1	43,2	35%	289%	
Onshore	7,8	6,8	6,1	7,3	8,4	9,1	8,2	8,4	8,5	20%	9%	
Offshore	3,3	2,9	4,6	8,4	15,9	21,2	19,4	26,7	34,7	80%	951%	
- Loss and Flare	4,8	4,0	3,6	4,4	3,8	4,1	3,8	3,7	4,4	4%	-9%	
- E&P Consumption	10,2	10,6	10,9	11,5	12,2	12,9	13,4	13,7	15,0	12%	47%	
- Natural-gas Processing Units	3,4	3,5	3,6	3,6	3,8	4,2	4,6	4,3	4,5	4%	31%	
= Domestic Supply	**36,5**	**42,8**	**48,5**	**52,2**	**52,2**	**52,4**	**60,5**	**55,1**	**55,4**	**45%**	**52%**	
+ Importation - Bolivia	26,8	27,5	31,8	32,8	32,0	28,3	24,3	22,1	18,7	69%	-30%	
+ Importation - Argentina	0,0	0,0	0,2	0,2	0,5	0,0	0,0	0,0	0,0	0%	0%	
+ Importation - LNG	1,7	8,5	14,6	19,9	17,9	3,8	5,1	6,9	8,3	31%	387%	
= Importation Supply	**28,5**	**36,0**	**46,6**	**52,9**	**50,4**	**32,1**	**29,4**	**29,0**	**27,0**	**100%**	**-5%**	
- Losses in pipelines	3,4	3,9	3,7	5,8	3,9	4,3	4,3	5,3	5,5	7%	62%	
= National Supply	**61,6**	**74,9**	**91,4**	**99,3**	**98,6**	**80,3**	**85,6**	**78,9**	**76,9**	**100%**	**25%**	
- Non-Thermal Power Plant Demand	51,2	52,0	51,3	52,4	52,7	50,7	51,3	51,2	48,9	69%	0%	
- Thermal Power Plant Demand	10,4	23,0	40,1	46,8	45,9	29,6	34,3	27,7	29,0	31%	179%	
= Total Demand	**61,6**	**75,0**	**91,4**	**99,2**	**98,6**	**80,3**	**85,6**	**78,9**	**77,9**	**100%**	**27%**	

Source: Own elaboration based on the National Electrical System Operator (MME) data (2019)

Between 2014 and 2019, approximately 8 GW of power of new natural gas-fired thermal plants were contracted, corresponding to 40% of the total contract in the New Energy Auctions (LEN) in this period (Table 5). It is noteworthy mentioning the relevance of the LNG-powered thermal plants connected to new regasification terminals, which account for 80% of the total gas-fired thermal plants to be installed. Except for the Rio Grande thermal plant, with revoked concession, and the Jaguatirica thermal plant, located in the isolated system of Boa Vista, the expansion of gas-fired thermal plants will add about 6.6 GW of power to the SIN.

The average price, as adjusted by the IPCA for 2019 and weighted per the contracted energy, reached R$ 255/MWh. The average price of gas-fired thermal plants is 16% above the average price of all New Energy Auctions (LEN) held in the period, weighted by the contracted energy of each project.[11] The declared investments of gas-fired thermal power plants amount to approximately R$22.5 billion, adjusted by the IPCA.

Reforms in the Gas Industry in Brazil

The regulation of the natural gas industry is divided between activities subject to federal and state jurisdictions. The National Petroleum, Natural Gas and Biofuels Agency (ANP) regulates all upstream and midstream activities in the chain - exploration, production, gathering, treatment, import and transportation. The Petroleum Law (Law No. 9487/1997) and the Gas Law (Law No. 11,909/2009) constitute the primary legal frameworks of the sector. The distribution of natural gas, on the other hand, by force of the Constitution, is explored directly or through concession granted by the States.

Article 25 (paragraph 2) of the 1988 Constitution delimits the State's prerogative to "piped natural gas public services", corresponding to the distribution of the molecule by pipelines, without including the trading of the gas. However, in most state concessions, there is no explicit unbundling of both activities, yet, so far, there is no regulation for the free consumer figure.

Furthermore, natural gas may be distributed and traded in liquefied (LNG) or compressed (CNG) formats by other companies, subject to federal regulation. It should not be extensible to the legal monopoly of the distributors. Trading activities by other modes could favour the development of the market, internalizing the energy in the country. Since gas does not have a captive market and can be replaced by other energy sources in all its uses, there is a continuous competition with other energy sources. Since it can also be transported and traded by other modes, the expansion of the network without prior feasibility study should not be pursued, ruling out universalisation policies without economic rationality.

Reforms in the gas market abroad, such as in the United Kingdom, Spain, Italy, and France, have successfully implemented the separation of distribution (network) and trading, bringing competitiveness and transparency to the sector. The process at times faces resistance, especially at the beginning, from incumbent companies. But the result is to bring the benefits of increased competition in supply to consumers, which is economically viable and produces efficiency gains (Herweg, 2017).

11 Auctions' average price for thermal plants translates into the Cost-Benefit Index (ICB) of the projects, representing an expected value of the energy price, projected per future hydrological scenarios. The price of energy, in fact, perceived by the captive consumer over the years, will depend on the evolution of the cost of natural gas, the indexation chosen by the generator and, mainly, the effective thermal generation..

Table 5 - Natural gas-fired thermal power plants, winners of the last New Energy Auctions in Brazil

YEAR	AUCTION	Start of Operation / Term	Power Plant	Company / Ownership Consortium	State	Sub-System	Investments (R$ mi)	Capacity (MW)	Physical Garantee (MWavg)	Contracted Energy (MWavg)	Price (BCI) (R$/MWh)	Fixed Revenue (R$ mi/ano)	Natural Gas Source	Business Model
2014	20° LEN A-5	01/01/2019 25 years	MAUÁ 3	AmGT (100%)	AM	N	1,232	583	507	484	203.50	760	On-shore	Gas from the Urucu reservoir
			GNA I (NOVO TEMPO)*	Gás Natural Açu (100%)	RJ (PE)	SE (NE)	3,052	1,238	612	611	206.50	626	Imported LNG	LNG-to-power, regasification terminal with additional capacity for other segments
			RIO GRANDE	Consórcio UTE Rio Grande (100%)	RS	S	2,945	1,238	605	604	206.50	620	Imported LNG	Grant revoked in 2017
2015	21° LEN A-5	01/01/2020 20 years	PORTO DE SERGIPE I	Celse - Golar Power (50%), Ebrasil (50%)	SE	NE	3,295	1,516	867	867	279.00	1.250	Imported LNG	LNG-to-power, regasification terminal with additional capacity for other segments
2015	22° LEN A-3	01/01/2018 20 years	PROSPERIDADE I	Imetame (100%)	BA	NE	93	28	23	23	214.25	26	On-shore	On-shore power generation (gas-to-wire)
2016	23° LEN A-5	01/01/2021 20 years	OESTE DE CANOAS 1	Oeste de Canoas Petróleo e Gás (100%)	MA	N	17	6	3	3	258.00	6	On-shore	On-shore power generation (gas-to-wire)
2017	26° LEN A-6	01/01/2023 25 years	GNA II (PORTO DO ACU III)	Gás Natural Açu (100%)	RJ	SE	3,432	1,673	1,547	1,450	213.91	2,086	Imported LNG	LNG-to-power, regasification terminal with additional capacity for other segments
		01/01/2023 25 years	MARLIM AZUL (VALE AZUL II)	Mitsubishi (20.0%), Patria Investimentos (50.1%), Shell (29.9%)	RJ	SE	1,226	466	421	421	211.90	642	Off-shore (pre-salt)	Monetisation of pre-salt natural gas (gas-to-power), exploiting the existing gathering structure
2018	28° LEN A-6	01/01/2024 25 years	PARNAIBA 5A E 5B	Eneva (100%)	MA	N	1,089	363	326	326	179.98	272	On-shore	Closing for combined cycle of the UTE Parnaíba I (reservoir-to-wire)
2019	1° LEN S. ISOLADO BOA VISTA	28/06/2021 15 years	Jaguatirica II	Eneva (100%)	RR	N	425	126			798.17	429	On-shore (LNG from Azulão)	Supplied natural gas by LNG (truck transportation), liquefied from the Azulão field (AM)
2019	30° LEN A-6	01/01/2025 25 years	MC2 NOVA VENECIA 2	Eneva (100%)	MA	N	405	92	77	70	188.22	85	On-shore	Closing for combined cycle of the UTE MC2 Nova Venécia 2 (reservoir-to-wire)
		01/01/2025 25 years	NOVO TEMPO BARCARENA	BEP (24.75%), Celba (1%), Golar Power (49.5%), OAK (24.75%)	PA	N	1.502	605	584	570	188.95	712	Imported LNG	LNG-to-power, regasification terminal with additional capacity for other segments
		01/01/2025 25 years	PROSPERIDADE II	Imetame (100%)	BA	NE	122	37	35	33	188.90	25	On-shore	On-shore power generation (gas-to-wire)
			TOTAL / AVERAGE				**18,834**	**7,971**	**5,609**	**5,463**	**216.43**			
			EXCLUINDO RIO GRANDE				**15,889**	**6,733**	**5,003**	**4,859**	**222.29**			

* In 2017, ANEEL approved the grant transfer to GNA, in Porto do Açú. Start of operation on 01/01/2021, within a 23 years term contract.

Source: Own elaboration based on the CCEE data.

In Brazil, studies have already pointed out that the net economic benefits of a gas reform also depend on the degree of maturity of the regulation (FGV CERI, 2019). Maintaining the current framework, the mere transfer of shareholding control (or privatization of natural gas distributors) transfers the monopoly without guarantee of non-discriminatory access. Without contractual revision and adaptation to the new model, there is little chance of improvement in use and efficient investments in the network.

The efforts to modernize the natural gas sector in Brazil were intensified with the "Gas for Growth" initiative, in 2016, pointing to a profound reformulation: infra-legal advances, repositioning Petrobras in the chain segments, greater emphasis on antitrust matters, and the expected legal reform. It is worth noting that Petrobras, the incumbent with majority participation in all segments of the chain, actively participates in the reform process - because of its strategic repositioning in the oil and gas industry.

The initiative resulted in numerous infra-legal and regulatory advances but failed to reformulate the Gas Law (Law 11,909/2009).[12] The improvements favoured the extensive contracting of gas-fired thermal plants in the last energy auctions, also driven by the reduction of the LNG price in the international market.

The asymmetry between the inflexible (associated) domestic gas supply profile and the demand for flexible thermal generation, subject to the availability of variable resources, reservoir level and demand behaviour, imposed restrictions to the insertion of thermal plants into the Brazilian system, mainly fired by domestic gas.

Prioritizing the national energy policy, the power sector gradually hardened the requirements for gas supply to the thermal plants to reduce the risks to the security of supply. In this context, the gas industry has joined forces to harmonize gas-electricity integration and modernize the sector to attract more agents and greater competition.

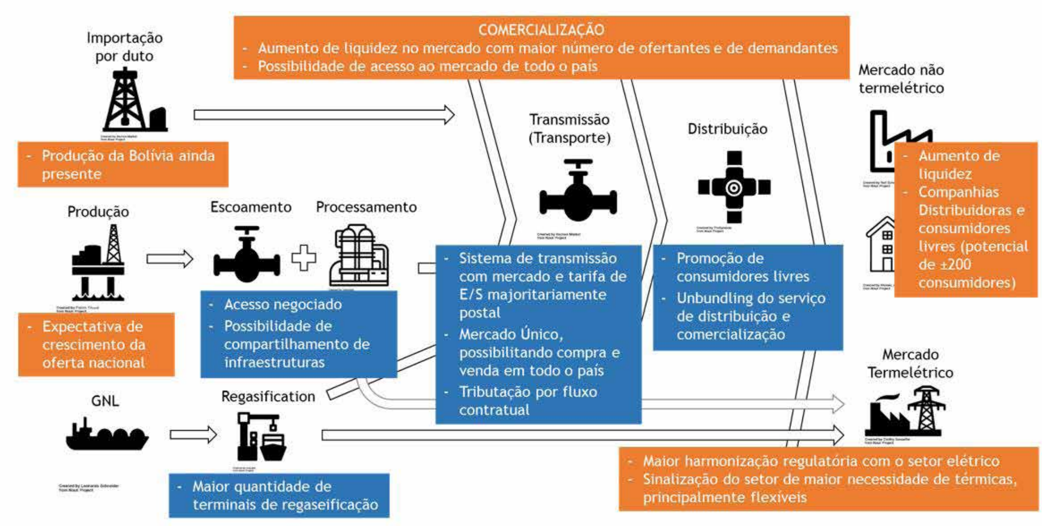
Continuing the infra-legal advances, Decree no. 9616/2018 amended Decree no. 7382/2010, which regulates the Gas Law, aimed at (i) unlocking studies for the expansion of the country's gas pipelines network; (ii) indicating the migration to the entry and exit model in the transportation network; and (iii) determining that the ANP establish guidelines for third party access to essential infrastructure (gathering, processing and regasification terminals) and authorize, regulate and inspect the storage activity.[13]

The current Administration resumed the improvement efforts with the initiative "New Gas Market", aimed at (i) encouraging competition in competitive segments; (ii) harmonizing federal and state regulation spheres; (iii) removing tax barriers; (iv) revising the transport expansion model; (v) establishing the entry and exit model for contracting capacity, and (vi) establishing negotiated access to essential infrastructure. Therefore, this is about eliminating bottlenecks to make the resource reach the market and allow its development. Figure 18 shows the reform trends underway.

12 Among the infra-legal advances, stand out the review of the treatment of penalties in energy contracts for lack of fuel and the new possibilities of fuel indexation, enabling greater insertion of LNG.

13 In 2019, the EPE launched the Pipeline Indicative Planning (SGA) and the Natural Gas Processing and Gathering Indicative Planning (PIPE).

Figure 18 - Trends in the ongoing reform to the natural gas market in Brazil



Source: Petrobras

In June 2019, CNPE Resolution N. 16 defined guidelines to improve energy and regulatory policies in the natural gas market. As a transition principle to a competitive gas market, the Resolution established the integration of the natural gas sector with the power and industrial sectors. Among the measures, the CNPE recommended that the MME, the ANP and the EPE make the necessary arrangements to promote training and capacity building support for State regulatory agencies.

In July 2019, the Administrative Council for Economic Defence (CADE) approved the Cease and Desist Agreement (TCC) related to Petrobras' participation in the gas industry. Also, in July, the Government enacted Decree no. 9934/2019, establishing the Market Opening Monitoring Committee, which includes representatives of the MME, Ministry of Economy, CADE, ANP and EPE.

The following aspects stand out among the measures anticipated by the TCC entered into by and between CADE and Petrobras: (i) the negotiation of third party access to natural gas flow routes and processing units; (ii) the reduction of volumes acquired by Petrobras from other producers and third parties; and (iii) the definition of surplus capacity in the transportation gas pipelines, indicating their demands for gas entry and exit. This was done per distributors' concession area and for internal use, in the transportation systems of NTS and TAG carriers. And, by doing so, they eliminated flexibilities and contractual congestion (contracted and unmoved volumes).

The transition to a competitive market is a fundamental step. Discussions about this topic should be transparent and consider a process of evolution in which the adaptation of the legal and regulatory framework is accompanied by the entry of an increasing number of players into the market, until achieving the goal of a net competitive market. Such measures are essential to promote an energy transition to a low carbon economy that ensures benefits for different groups in society.

3. CONCLUSIONS AND RECOMMENDATIONS

Brazil and the EU have accumulated considerable experience in the liberalisation and regulation of the energy markets. However, the necessary decarbonisation and the possibility of digitalization of the energy sector stands out as new and complex challenges that call for new governance and regulatory solutions.

The energy transition is a global movement, but different approaches have been tested and implemented in different places, at national and local levels. The EU-Brazil Sector Dialogue on Energy has enabled fruitful exchanging of experiences and perspectives on how to build new energy architectures, overall, and on their governance and regulation.

Although this Dialogue on Energy has been limited by time constraints and by the number of professionals and organizations involved in it, one can safely draw some general conclusions. Based on the perspectives of the authors of this report, and the coordinators of the Dialogue on Energy – without pretending to exhaust the topic – the main conclusions are as follows:

1) Energy transitions - there is not one unique energy transition model – each region or country defines their models. These are complex processes where changes in behaviour, technologies and public policies converge. Although the direction of the journey is clear (decarbonisation, digitalization, and so on), the processes do not evolve linearly. Everywhere there are contradictions needing resolution within the respective energy transition. In the EU, their willingness to become the first carbon-neutral continent (by 2050) contrasts with the prolonged retention of coal in their energy matrix, for the sake of social peace and territorial cohesion. In Brazil, on the other hand, the willingness to maintain a traditionally renewable energy matrix contrasts with the desire to use the power sector as an anchor for the natural gas industry, as "imposed" by the oil industry – an essential driver for exports and the country's economy.
2) This combination of firm and clear international commitments with internal inconsistencies and even contradictions in public policies have led to a hesitant regulation, with a little stimulus to the energy transition, and lacking assertive regulatory policies.
3) The growing penetration of electricity in final demand for energy, based on the assumption of carbon-free power sector, is a trend observed worldwide and in Brazil (where it has been traditionally high) and the EU. However, this inevitable trend is not problem-free. In Brazil, climate changes impact on river flows (along with other anthropogenic

factors) have reduced hydropower availability, thus giving rise to idle capacity and investments. In some EU Member States, the large-scale diffusion of wind and photovoltaic plants challenges not only the technical operation of power systems (a problem partly[14] but successfully solved) but also the operation of wholesale markets (a problem yet to be solved).

4) Energy efficiency is recognized as a priority for energy and climate policies. However, its implementation falls short of what would be possible and desirable due to information and financing deficits.
5) The future of gas in the energy transition is unclear. It has recently been approached from a low or non-systematic perspective, i.e., less based on what may be its intrinsic value in the transition than based on exogenous criteria. In Brazil, the willingness to create a substantial demand for natural gas to which to direct the production associated with the offshore oil exploration; in the EU, the willingness to avoid or mitigate idle costs in natural gas infrastructure by replacing it with green gases.
6) The digitalization of energy has also been approached from a little systemic perspective, much based on different pilot projects, thus squandering the enormous transformative and efficiency potential it offers[15].
7) The accumulation of the phenomena mentioned above has triggered the start of a deconstruction process (in a literal and philosophical sense) of the traditional, centralised, mono-sectoral energy architecture and its governance model. The construction of the governance of new emerging multi-level and multi-sectoral energy architectures is still in its infancy, and the lines separating the various stakeholders are evident.

The missions and meetings provided by this edition of the EU-Brazil Dialogue on Energy have identified several points deserving further attention, as listed below, in the form of recommendations:

a) To continue with this Dialogue by promoting high-level meetings between decision-makers and experts from Brazil and the EU on specific topics of common interest, the following, which are recognised as priorities:
   - Operation of power systems with high penetration of renewable sources (centralised and decentralised)
   - Organization of electricity markets with high penetration of renewable sources (centralised and decentralised)
   - The organisation of gas markets and energy transition
   - Formulation of clear policies and targets for digitalization of networks
   - Good practices in the concession of energy assets
   - Good practices to promote

14 Solved undoubtedly at a national level, but sometimes at the expense of parallel flows on neighbouring networks – which is not compatible with the efficient and equitable operation of an interconnected system.

15 Moreover, the digitalization of energy could lead to a significant economic growth in the industrial and service sectors providing equipment and solutions, as well as the creation of numerous job positions.

energy efficiency in the public and private sector
  - Adaptation of the Hydropower parks to the new system flexibility needs
  - Transitional regulation

b) Organise, in 2020, a conference in Brazil (Topic: "Energy 30+30") to present and discuss, on the one hand, the differentiated results of energy liberalisation in the EU over the last 30 years[16] and, on the other hand, the prospects opened by the EU Green Deal for the next 30 years (2020-2050). The conference would be open to companies, academia, financial institutions, and NGOs.

16 The liberalisation began in 1990 with the "Council Directive 90/547/EEC, dated October 29, 1990 on the transit of Electric power through transmission grids"

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ANNEX - MISSIONS & WORKSHOP

MISSION TO THE EUROPEAN UNION

The Mission to the European Union was held from 16 to 20 September 2019. Members of the delegation were as follows:

- Joisa Dutra (FGV CERI), Brazilian expert on the EU-Brazil Sector Dialogues
- Jorge Vasconcelos (NEWES), European expert on the EU-Brazil Sector Dialogues
- Reive Barros (Secretary of the Ministry of Mines and Energy)
- Rodrigo Limp (Director of the National Electricity Agency)

The delegation participated in meetings held in Porto (Portugal), Madrid (Spain), Brussels (Belgium) and Rome (Italy). The delegation fulfilled the following agenda in these countries:

- 09/16/2019, Porto (Portugal): INESC TEC
  Attending Participants: João Abel Peça Lopes (Associate Director); João Claro (Chairman of the Executive Board); Ricardo Bessa (Centre for Power and energy Systems)

- 09/16/2019, Madri (Spain): OMIE (Iberian Energy Market Operator - Spanish Pole) & MIBGAS (Iberian Gas Market)
  Attending Participants: Carmen Becerril Martínez (President), Artur Trindade (Chairman & CEO OMIE), Raúl Yunta Huete (CEO)

- 09/17/2019, Madri (Spain): CNMC (Comissión Nacional de los Mercados y la Competencia)
  Attending Participants: Fernando Hernández Jiménez-Casquet (Director-General for Energy); Rocío Prieto González (Head of Natural Gas Departament), Agustín Alonso Garrido (Natural Gas Department, Energy Division), Jose Antonio Castro Fernandez (Electric Energy Division), Santiago Muñoz (Deputy Director Electric Energy)

- 09/17/2019, Brussels (Belgium): Council of European Energy Regulators (CEER)
  Attending Participants: Annegret Groebel (President), Charles Esser (Secretary-General), and Miuki Tsuchiya (Analyst of Comission de Regulation de L'Énergie – CER)

- 09/18/2019, Brussels (Belgium): DG Energy (Directorate-General for Energy)
  Attending Participants: Paula Pinho (Acting Director, Head of Unite Energy Policy Coordination), Paula Abreu Marques (Head of Unit Renewables and CCS policy), Vasco Ferreira (Energy policy coordination)

- 09/18/2019, Brussels (Belgium): EUROELECTRIC
  Attending Participants: Kristian Ruby (Secretary-General)

- 18/09/2019, Bruxelas (Bélgica): AGORA Energiwende
  Attending Participants: Philipp D. Hauser (Senior Associate International/ Latin Amercia), Andreas Graf (Project Manager EU Energy Policy)

- 09/19/2019, Rome (Italy): ARERA (Autoritá di Regolazione per Energia Reti e Ambiente)
  Attending Participants: Stefano Besseghini (President), Enzo Bencini (Head of National External Relations Unit)

- 09/20/2019, Rome (Italy): ENEL
  Participantes: Livio Gallo (Head of Global Infrastructure and Networks), Maurizio Bezzeccheri (Head of Latin America Region), Robert Denda (Head of Network Technology and Innovation), Viviana Vitto (Head of Market Studies and Strategic Analysis), Irene Rossi (Executive Assistant), Jacopo Santoni (Executive Assistant)

MISSION TO BRAZIL

The Mission to Brazil was held between November 18 and 22, 2019. Members of the delegation were as follows:

- Joisa Dutra (FGV CERI), Brazilian expert on the EU-Brazil Sector Dialogues
- Jorge Vasconcelos (NEWES), European expert on the EU-Brazil Sector Dialogues
- João Abel Peças Lopes (INESC TEC)
- Gabriela Prata Dias (Copenhagen Centre on Energy Efficiency)
- Alberto Biancardi (GSE - Gestore dei Servizi Energetici)

The delegation attended the meetings in Brasilia and Rio de Janeiro, including participation as panellists of the Workshop held in Brasilia, at the headquarters of the Ministry of Mines and Energy on November 18, 2019. The delegation fulfilled the following agenda in Brazil:

- 11/19/2019 - Meeting at the Ministry of Mines and Energy (MME), Secretariat for Energy Planning and Development (SPE)
  Attending Participants: Mr Reive Barros (Secretary), Mr Carlos Alexandre Príncipe Pires (SPE/MME), Mr Luís Fernando Badanhan (SPE/MME), Mr Pedro Ballesteros (DG Energy), Mr Rui Ludovino (Councillor of the European Union in Brazil).

- 11/19/2019 - Meeting at FASE (Forum of Associations of the Power Sector)
  Attending Participants: Mr Charles Lenzi (ABRAGEL - Brazilian Association of Clean Energy Generation); Mr Mario Miranda (ABRATE – Brazilian Association of Electricity Transmission Companies), Mr Luis Roberto Ferreira (APINE - Brazilian Association of Independent Producers of Electricity), Mr Fillipe Soares (ABRACE - Brazilian Association of Heavy Consumers), Mr Marcelo Moraes (ABIAPE - Brazilian Association of Investors in Energy Self-Production; FMASE – Environment Forum of the Power Sector), Mr Marcelo Luís Loureiro dos Santos (ABIAPE), Mr Pedro Prescott (ABIAPE), Mrs Leticia Dias (ABIAPE), Mr Gabriel Pina (ABIAPE)

- 11/19/2019 - Ministry of Economy - Secretariat for Development and Infrastructure, Sub-secretariat of Regulation and Market
  Attending Participants: Mr Gabriel Godofredo Fiuza de Bragança (Under-secretary), Mrs Christiany Salgado Faria (General Energy Coordinator).

- 11/20/2019 - National Electricity Agency (ANEEL)
  Attending Participants: Rodrigo Limp (Director), Mr Rodrigo Santana, Mr Felipe Alves Calabria, Mr Fabio Stacke Silva, Mr Matheus Palma Cruz, Mrs Angélica Ambrosini, Mr Carlos Alexandre Príncipe Pires (SPE/MME).

- 11/20/2019 - Meeting at the Ministry of Mines and Energy (MME), Secretariat for Energy Planning and Development (SPE), Department of Energy Development, General Coordination of Energy Efficiency

Attending Participants: Mrs Samira Sana Fernandes de Sousa Carmo (General Coordinator of Energy Efficiency), Alexandra Albuquerque Maciel (MME).

- 11/20/2019 - Norte Energia Meeting (Belo Monte Hydropower Plant)
  Attending Participants: Mr Paulo Roberto Ribeiro Pinto.

- 11/21/2019 - Meeting at the National Agency for Oil, Natural Gas and Biofuels (ANP), Infrastructure and Movement Superintendence and Superintendence of Antitrust matters, Studies and Economic Regulation
  Attending Participants: Mr Hélio da Cunha Bisaggio, Mrs Melissa Cristina Pinto Pires Mathias, Mr Bruno Conde Caselli, Mrs Luciana Rocha de Moura Estevão, Mr Bruno Valle de Moura.

- 11/21/2019 - National System Operator (ONS)
  Attending Participants: Mr Luiz Eduardo Barata Ferreira and Mr Luiz Alberto Machado Fortunato.

- 11/21/2019 - Eletrobras
  Attending Participants: Mr Pedro Luiz de Oliveira Jatobá (Generation Director).

- 11/21/2019 – CIER (Comisión de Integración Energética Regional)
  Attending Participants: Mr Tulio Marcus Machado Alves and Mr Pedro Luiz de Oliveira Jatobá.

- 11/21/2019 - Associação Brasileira de Energia Eólica(ABEEólica)
  Attending Participants: Mrs Elbia Gannoum.

- 11/22/2019 - Empresa de Pesquisa Energética (EPE), Directorate of Economy-Energy and Environmental Studies
  Attending Participants: Mr Giovanni Machado, Mr Gustavo Naciff, Mr Jeferson Borghetti Soares, Mr Thiago Ivanoski Teixeira, Mr Reive Barros (Secretary – MME).

From left to right: Mr Reive Barros (Secretary of the MME), Mr Bento Albuquerque (Minister of the MME), Mr Jorge Vasconcellos (NEWES, European expert on the EU-Brazil Sector Dia-logues), Mrs Joisa Dutra (FGV CERI, Brazilian expert on the EU-Brazil Sector Dialogues), Mrs Gabriela Prata Dias (Participant of the Delegation, Copenhagen Centre on Energy Efficien-cy), and Mr Thiago Barral (President of EPE).

WORKSHOP "European Union – Brazil Sector Dialogues: Governance of Energy Transition - Opportunities and Challenges", Held at the Ministry of Mines and Energy (Mme) on November 18, 2019

The workshop was organized around four topics, in addition to the opening and closing sessions: (i) Energy Transition Governance, (ii) Electricity, (iii) Energy Transition and Natural Gas, (iv) Market Security and Prudential Regulation. The first panel addressed the drivers of the energy transition in the world and Brazil. The second focused on the challenges of intro-ducing renewable sources into Power Systems and the role of energy efficiency. The third addressed the role of natural gas in the transi-tion, identifying the role of reforms and the prospects of natural gas participation in the energy ma-trices in the coming decades. The fourth panel addressed the challenges of implementing an power market project in Brazil, emphasizing the urgency of improving prudential regulation in the sector.

DIA 18.11.19, NO AUDITÓRIO TÉRREO DO MME EM BRASÍLIA

08:30 - 9:00	**Credenciamento**	
09:00 - 9:30	**Sessão de Abertura**	Ignacio Ybáñez – Embaixador da União Europeia no Brasil Reive Barros – Secretário de Planejamento e Desenvolvimento Energético do MME Rodrigo Limp – Diretor da ANEEL
09:30 - 10:45	**Governança da Transição Elétrica**	Moderador: Jorge Vasconcellos – Perito Europeu Diálogos EU BR Agustín Delgado Martín – Iberdrola – Diretor de Inovação, Sustentabilidade e Qualidade Elbia Gannoun – Presidente da Abeeolica Manoel Moreira – Secretário do TCU Pedro Ballesteros – DG Energy
10:45 – 11:00	**Coffe-Break**	
11:00 - 12:30	**Eletricidade**	Moderador: Rodrigo Limp – Diretor da ANEEL Gabriela Prata Dias – Copenhagen Centre on Energy Efficiency João Abel Peça Lopes – INESC TEC Max Xavier – ENEL Distribuição São Paulo, CEO Mayra Noronha – SolarPower Europe Roseane Santos – Conselheira da CCEE
12:30 - 14:00	**Almoço**	
14:00 - 15:30	**Transição Energética e Gás Natural**	Moderador: Reive Barros – Secretário do MME Alberto Biancardi – GSE - Gestore dei Servizi Energetici Edson Real – Diretor da Golar Power Giovani Machado – Diretor da EPE Gustavo Labanca – TAG, CEO
15:30 - 15:45	**Coffee-Break**	
15:45 - 17:00	**Segurança de Mercado e Regulação Prudencial**	Moderadora: Joisa Dutra – Perita Nacional Diálogos EU BR Arthur Trindade – OMIP (vídeo) Júlio César Rezende Ferraz – Superintendente ANEEL Solange David – Conselheira da CCEE Ricardo Medeiros de Castro – CADE
17:00	**Encerramento**	Reive Barros – Secretário de Planejamento e Desenvolvimento Energético do MME

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