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The need of flexibility in hydro systems – the case of Brazil

July 14th 2020

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The need of flexibility in hydro systems – the case of Brazil

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What is Path to 100%?

The world is moving towards a 100% renewable based power systems. **The intermittent nature of wind and solar** challenges the current practices of operations and planning of the grids as increases the need of flexible and dispatchable power generation.

Flexibility turns out to be a key characteristic of future power systems and creates a friendly environment for the deployment of large scale renewable grids.

Understanding the role and the value of such feature is important when defining policies and regulations for the **procurement of flexibility in the long term planning**.

In this webinar, speakers will discuss:

- The role of system flexibility in the transition to 100% renewable energy.
- What is called Flexibility.
- How flexibility is important in Hydro based countries, such as the Brazilian reference case.
- Recommendations for the procurement of flexibility.

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Panelists

Gabriel Cavados
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Moderator

Need of Flexibility in Hydro Systems: The Case of Brazil

Agenda

- **The challenge of the Path to 100 (in general)**
  - The massive introduction of wind and solar
  - Challenges of the operation
  - The role of system Flexibility
- **What about in Hydro Systems such as Brazil**
  - Snapshot of the system
  - Why we need to be flexible
  - The Case Studied
- **Q&A**

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The challenge of the Path to 100 (in general)

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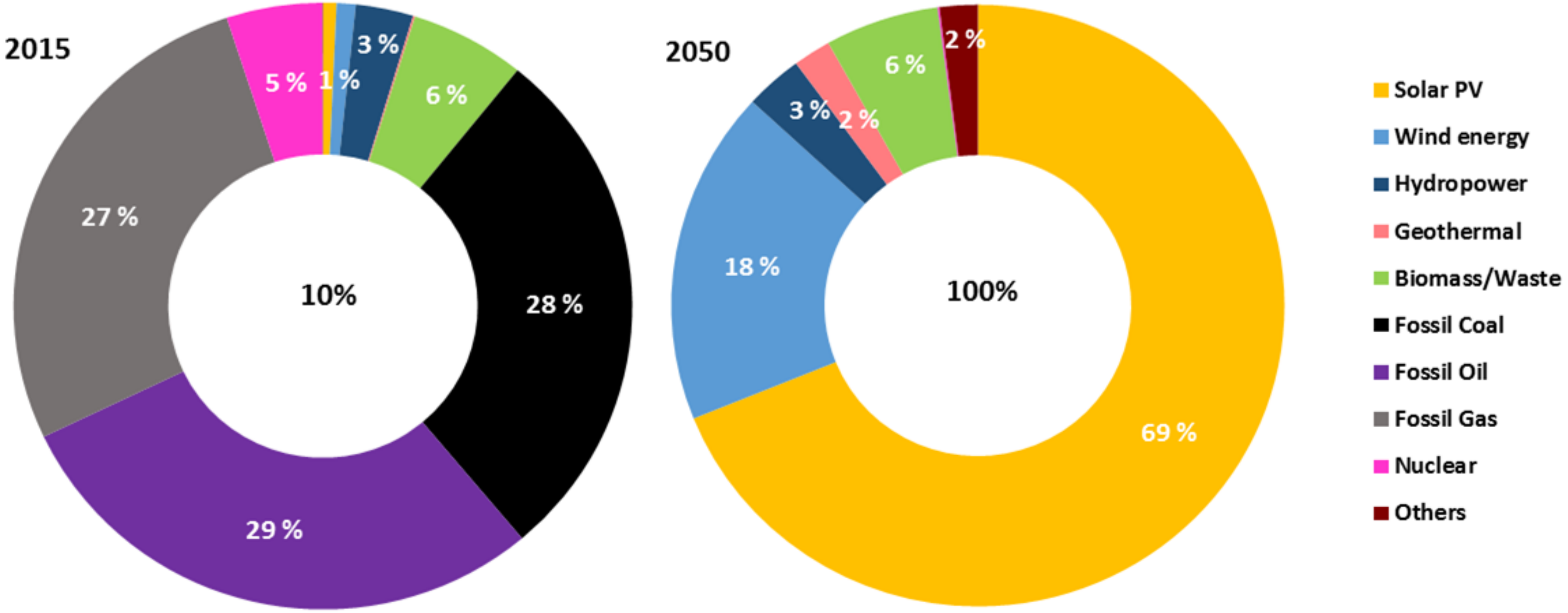
The Path to 100



- Primary energy shifts from being dominated by fossil fuels in 2015 towards solar PV and wind energy by 2050
- Renewable sources of energy contribute just 22% of TPED in 2015, while in 2050 they supply 100% of TPED
- Solar PV drastically shifts from less than 1% in 2015 to around 69% of primary energy supply by 2050, as it becomes the least cost energy supply source

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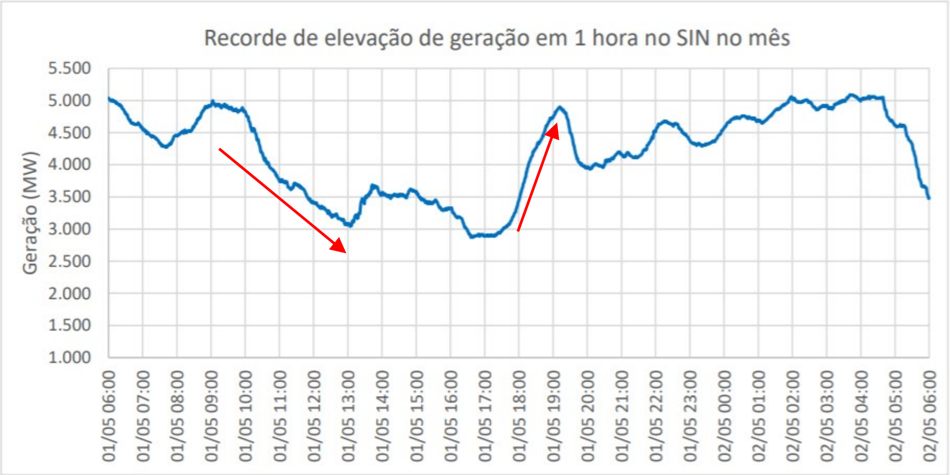
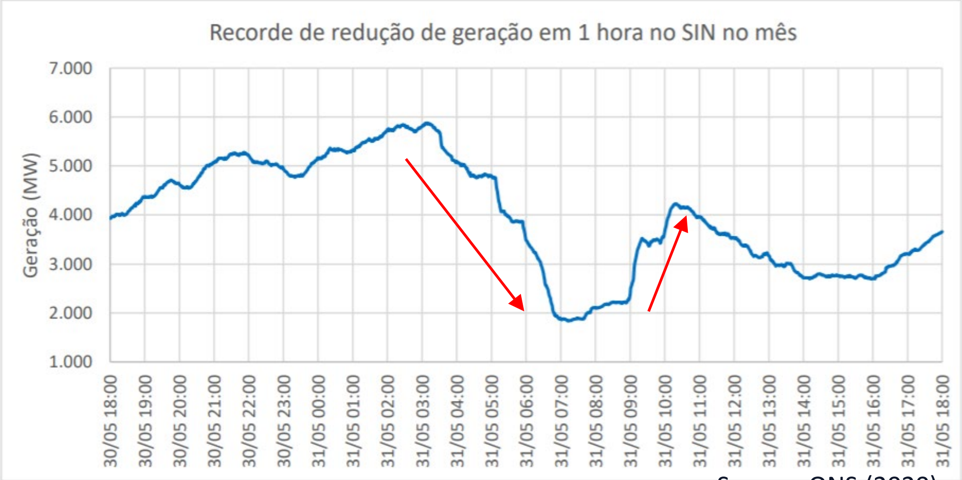
The Challenge of Wind





Source: ONS (2020).

Main challenges introduced by Wind in the grids:

- Zero Marginal Cost: must be used when available.
- Variability / Intermittency in the generation: wind can be blowing and stop to blows in minutes, afecting the wind generation in very short term.
- Stochasticity: it is very hard to forecast how wind is going to behave in the future, especially for short and mid terms time horizons.

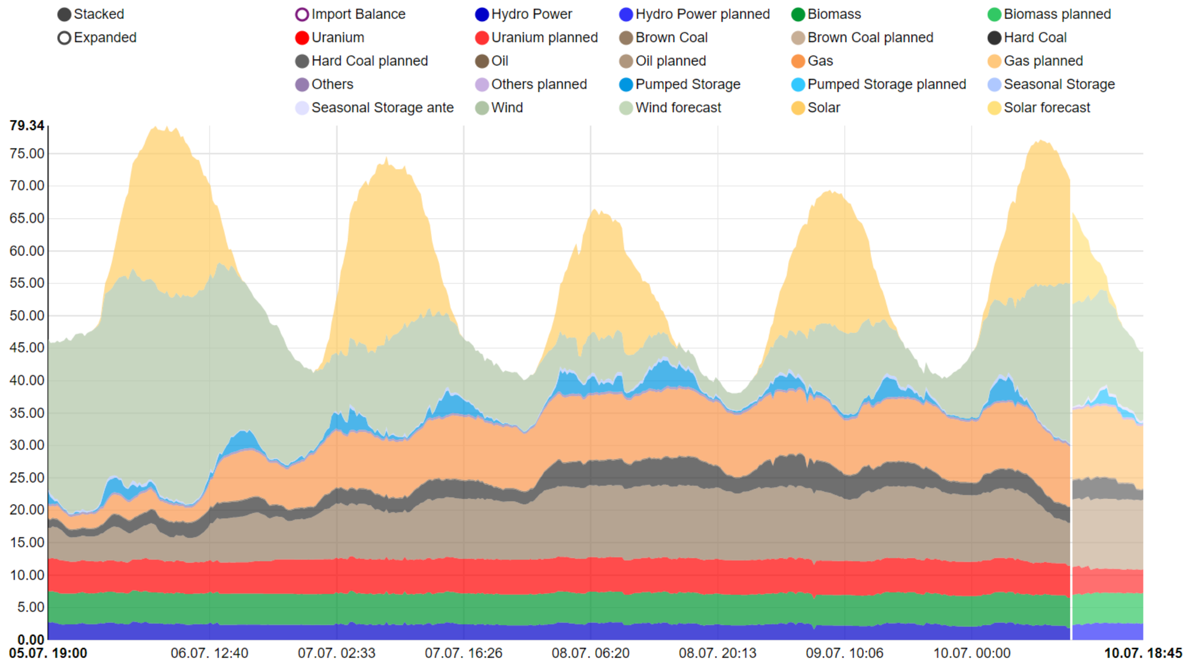
Note: The power system needs to be upgraded to this new reality.

The Challenge of Solar

Main challenges introduced by Solar in the power markets:

- Concentrated during some hours of the day.
- (Also) Zero marginal cost: must be used when available.
- Variability / Intermittency in the generation: solar will be available every day, but clouds are a major challenge creating short term variability.
- Stochasticity: very little compared to solar, but dymanic challenge remais the same.

Again, upgraded may be needed.



Source: https://www.energy-charts.de/power.htm (2020).

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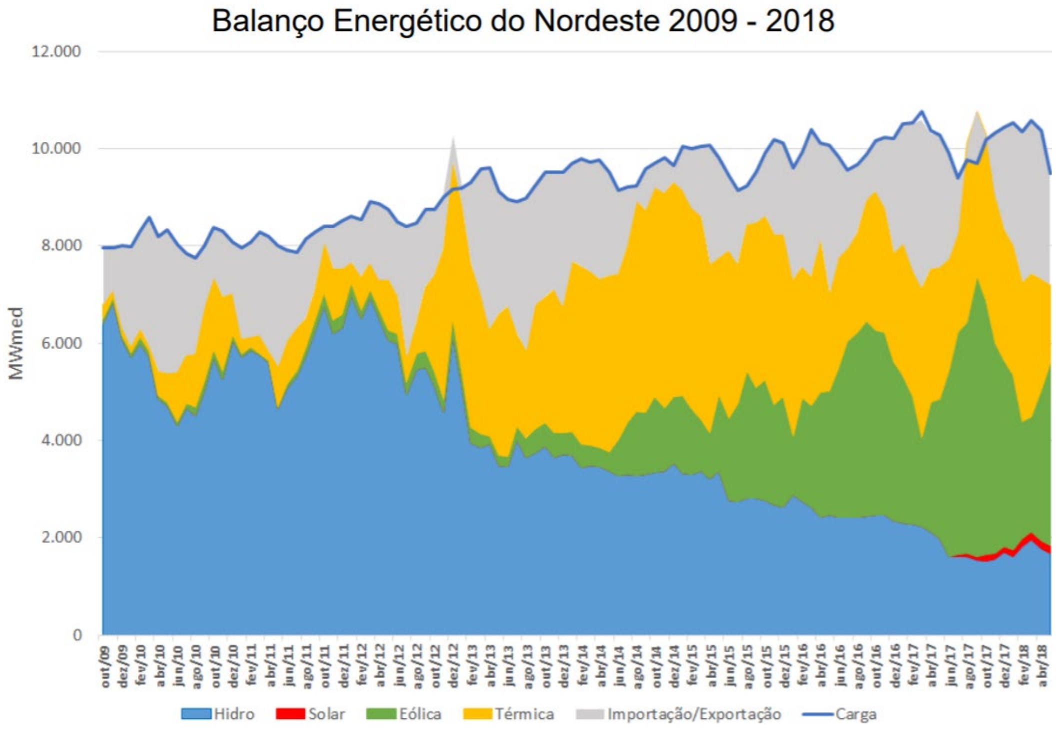
Operator’s Headache

Given the new scenario, the system operator needs to adapt and use the installed portfolio to balance wind and solar.

- The large expansion of wind and solar into the power grids (even in Hydro based systems) lead to the necessity of increasing the system ability to deal with large scale variability in generation.
- **System Flexibility needs to be enhanced as well!**
- Formal definitions of flexibility:

  Flexibility of a power system, can be defined as its ability to respond quickly to fluctuations in net electricity demand. (Nicolisi, 2010)

  A power system can be considered flexible when it has the capacity to maintain supply reliability, at reasonable costs, even when dealing with uncertainties in demand and variability in generation. (Ma et al, 2013)



Source: ONS (2018).

Flexible Technologies

	Technology	Mini stable output (%)	Ramp rate (%/min)	Lead time, warm (h)
Firm RE	Reservoir hydro	5-6**	15-25	< 0.1
	Solid biomass	-***	-***	-***
	Biogas	-***	-***	-***
	Solar CSP/STE[1]	20-30	4-8	1-4****
	Geothermal	10-20	5-6	1-2
Dispatchable non-RE	Combustion engine bank CC	0	10-100	0.1-0.16
	Gas CCGT inflexible	40-50	0.8-6	2-4
	Gas CCGT flexible	15-30*****	6-15	1-2
	Gas OCGT	0-30	7-30	0.1-1
	Steam turbine (gas/oil)	10-50	0.6-7	1-4
	Coal inflexible	40-60	0.6-4	5-7
	Coal flexible	20-40	4-8	2-5
	Lignite	40-60	0.6-6	2-8
	Nuclear inflexible	100******	0******	na******
	Nuclear flexible	40-60******	0.3-5	na******

Source: OECD/IEA (2014)

Type	Maturity stage	Typical power output (MW)	Response time	Efficiency (%)	Lifetime	
					yrs	cycles
Pumped hydro	Mature	100-5 000	sec-min	70-85	30-50	20 000-50 000
CAES	Deployed	100-300	min	50-75	30-40	10 000-25 000
Flywheels	Deployed*/ demonstration**	0.001-20	<sec-min	85-95	20-30	50 000-10 000 000
Li-ion battery	Deployed	0.001-5	sec	80-90	10-15	5 000-10 000
NaS battery	Deployed	1-200	sec	75-85	10-15	2 000-5 000
Lead-acid battery	Deployed	0.001-200	sec	65-85	5-15	2 500-10 000
Redox-flow battery (VRB)	Deployed	0.001-5	sec	65-85	5-20	>10 000
SMES	Demonstration	<10	<sec	90-95	20	>30 000
Supercapacitors	Demonstration	<1	<sec	85-98	20-30	10 000-100 000 000

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Takeaways of Intro Session

1. **High Renewables Grids are the new normal**
    - Drivers are very low-cost variable renewables: solar PV and wind energy
    - Variable renewables are ONLY compatible **system flexibility**
    - Power sector of today provides only little flexibility
    - Dispatchable renewables (hydro dams, bioenergy) are very valuable
    - Power sector requires some **flexible and fast ramping thermal capacities, based on thermal plants**
    - Flexibility is the new king: **fast ramping thermal plants, energy storage (hydro or chemical), DSM, etc.)**
2. **What's not part of a long-term solution**
    - Old fossil and inflexible plants.
    - Nuclear energy: it's high-cost and inflexible

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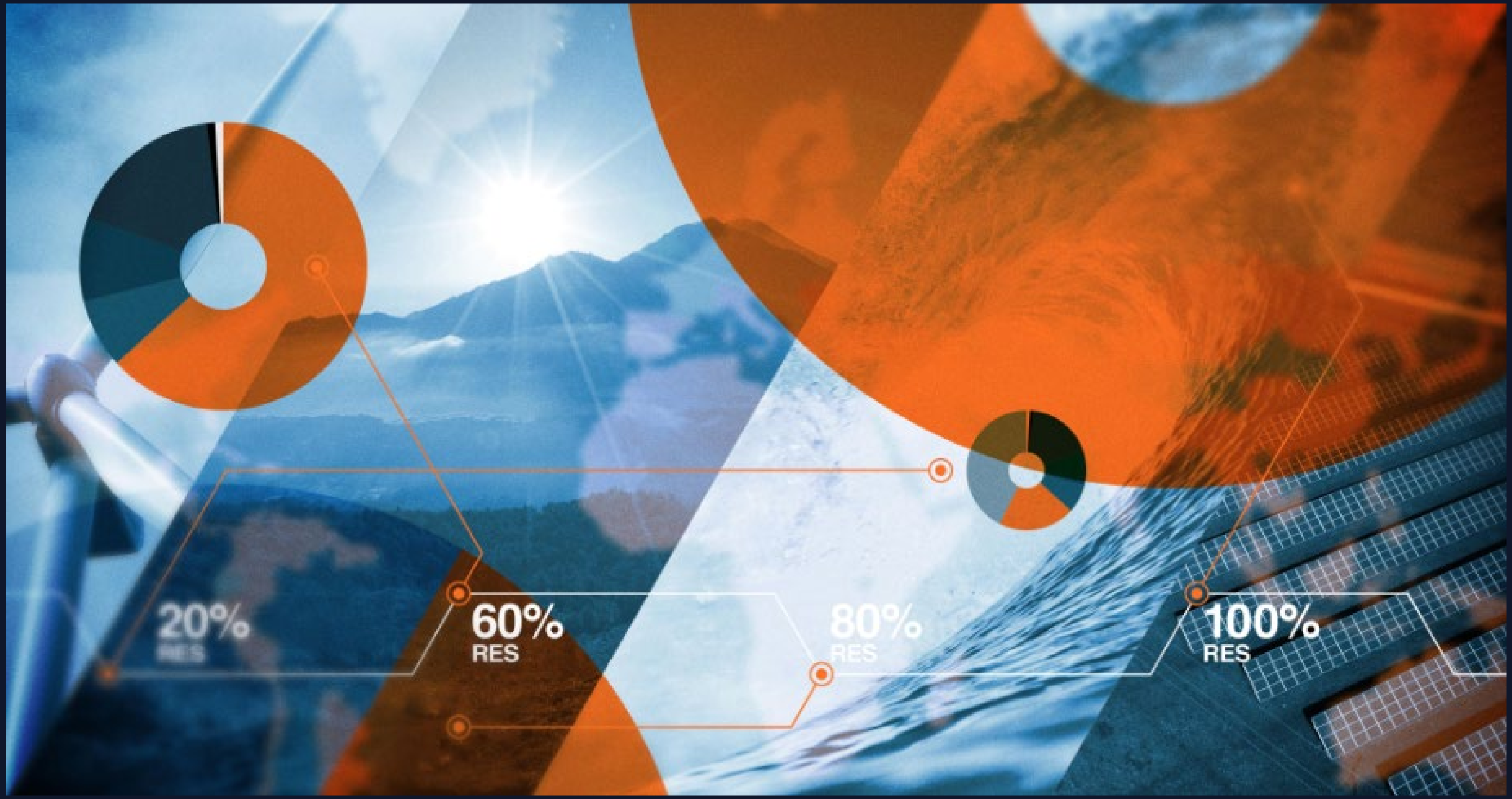
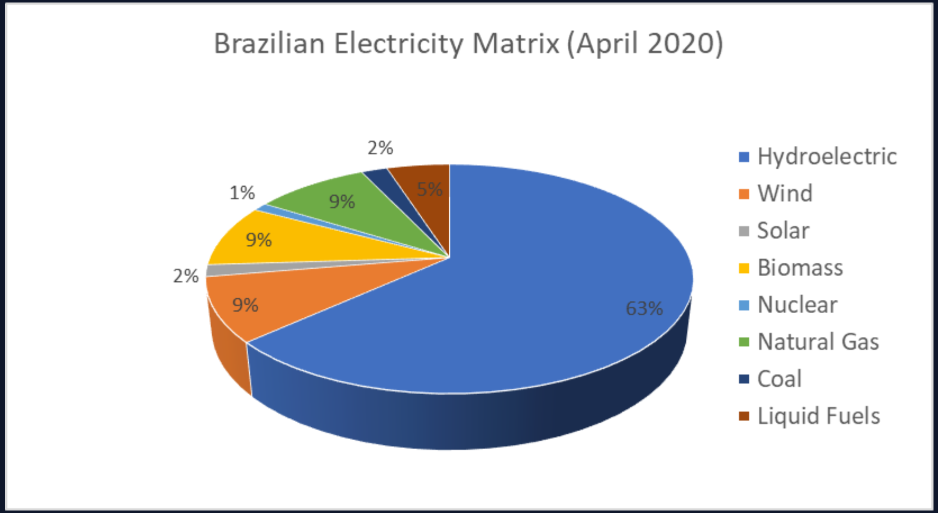
What about in Hydro Systems such as Brazil?

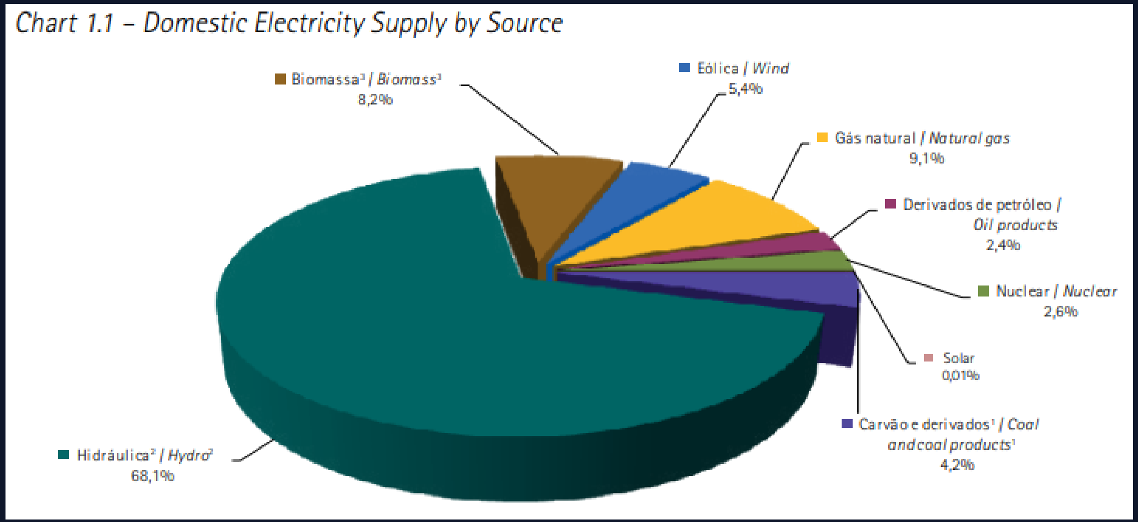


Snapshot of the Brazilian System

160GW in capacity, more than 7000 power plants



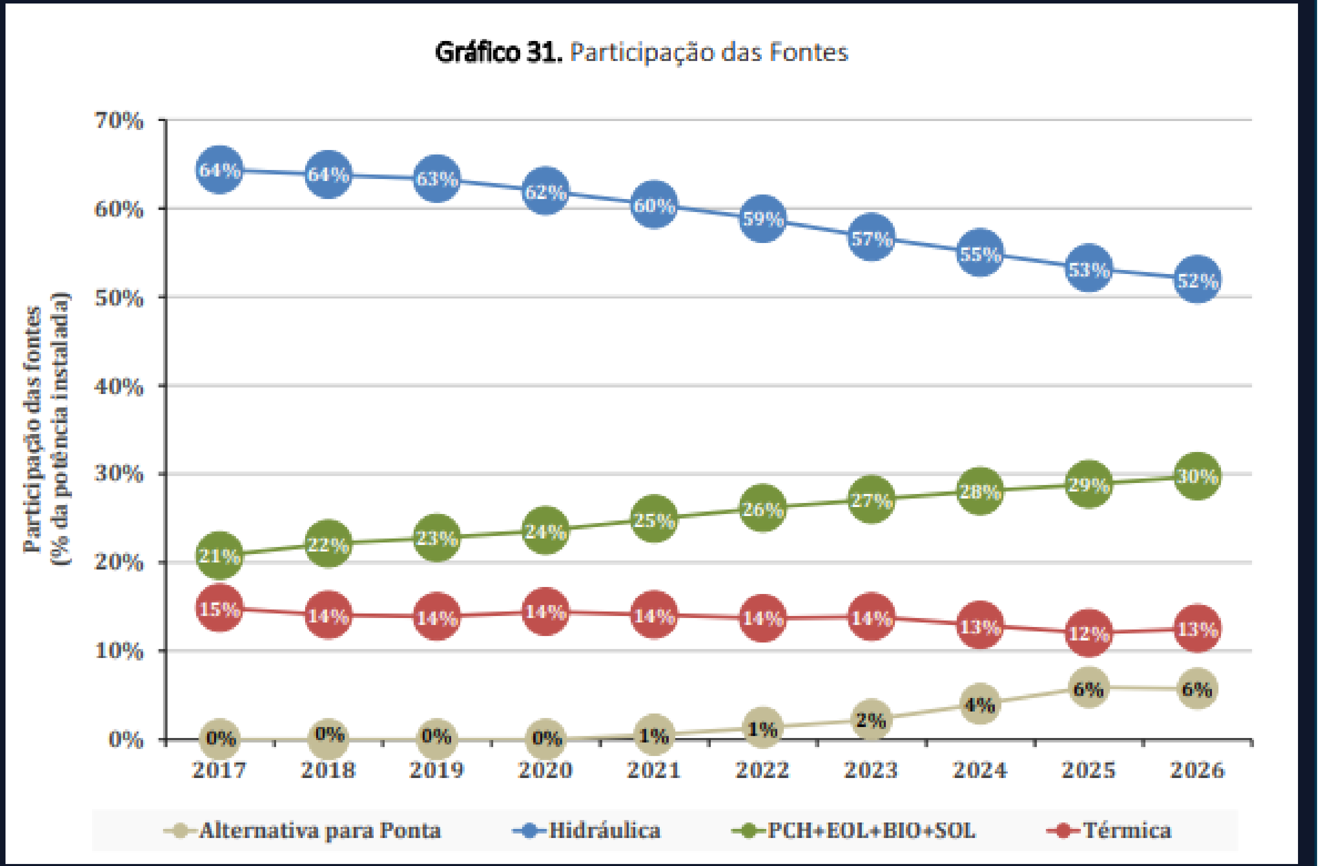
Source: ANEEL, 2020



Source: EPE, 2017

What is the expectation for the future?

- Wind and solar are driven the new energy expansion.
- Very few new hydro plants being considered. Environmental is challenging.
- Hydro continues to play an important role, but its “relative” flexibility is reduced over time.
- Non-flexible thermal plants still important, but limited expansion is expected.
- Considerable addition of flexibility added.



Source: EPE, 2017

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The Case of Brazil

This study was made by Wärtsilä to measure the effectiveness and reliability of hydro power as a system balancer when large amounts of renewables are introduced to the power system. Hydro is thought as a flexible resource that can help support power systems with the intermittency of renewable energy, but this is only true when adequate amount of water is available. The cases studied are:

- A long-term expansion calculation of the power system from 2020 to 2027.
- A comparison of different flexibility options in 2027 using as reference the in-detail accurate short term dispatch model.

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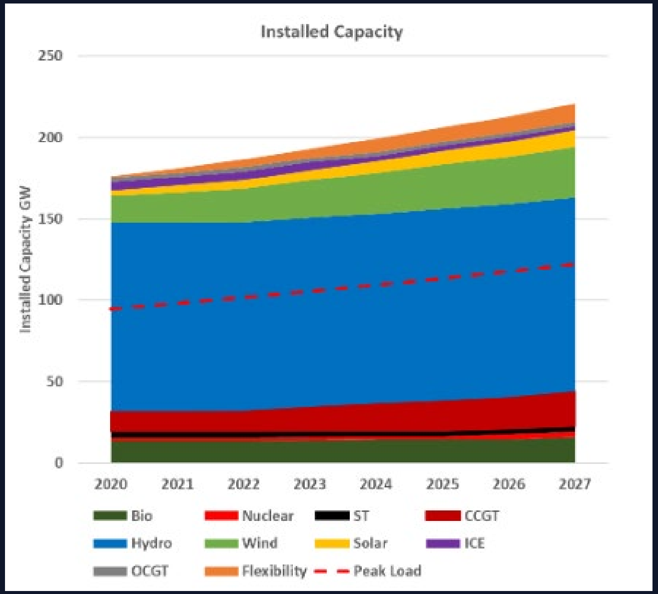
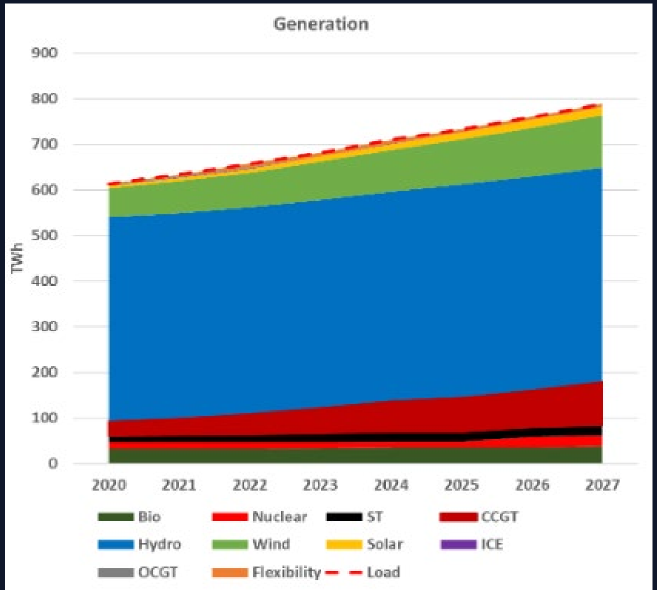
Results of the LT-model





With the increased amount of variable renewable generation, there is a large addition of new flexible generation. Over the studied period approximately 12 GW of new flexible generation capacity is added.

- Electricity demand increases from 600 TWh to nearly 800 TWh
- For energy service, the model is mainly adding new wind and solar (since these are the least cost options for energy), flexible gas, and some new baseload gas plants as new capacity additions.
- Renewables and flexibility are added annually whereas new baseload combined cycle gas (CCGT) is not added until 2023 and onwards.
- Some new hydro, biomass, and nuclear is also installed throughout the studied period, but not in a significant amount.

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Additional notes for LT-model results

- Approximately 9 GW of new baseload gas generation is added. This inflexible fossil baseload addition is explained by the low cost of gas expected and the rising system load that requires firm capacity for maintaining security of supply.
- It should be mentioned that the addition of base load gas is only economical due to the annual renewable additions being limited.
- Wind and solar are added annually to match the continued load growth. In 2027, the installed wind capacity is 31 GW and solar 10 GW, an impressive growth over the 7 years period.
- The role of the flexible capacity is to:
  - Operate as peaking generation
  - Balance the intermittency of the variable renewable resources
  - Balance the seasonal and annual variations of hydro power
  - Provide firm capacity to ensure security of supply

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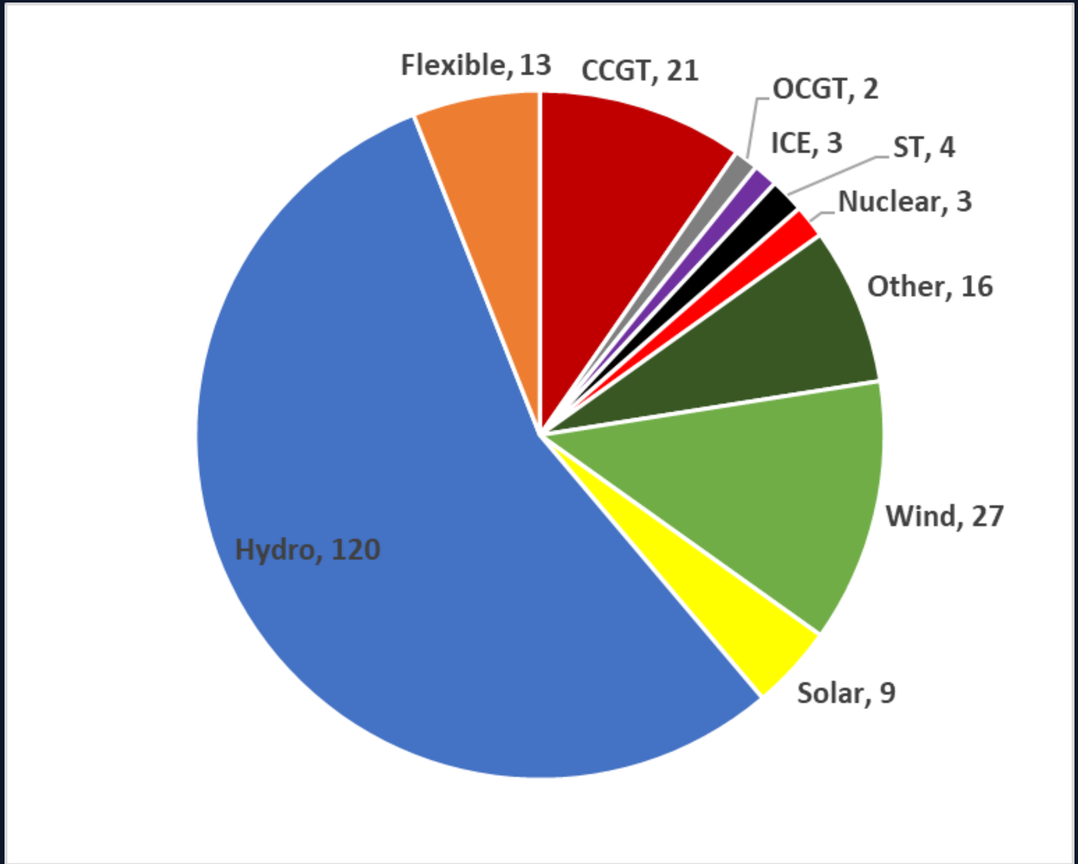
Importance of the ST-model Results

- As highlighted by the LT-model, in order to operate in an optimal way with variable renewables, the system needs to install more than 13GW of flexible technology.
- There are multiple technologies that could possibly fit the definition of "flexible" in terms of power generating assets.
- The idea behind this part of the presentation is to show the results of the short-term dispatch model for the year 2027 and compare different technologies.
- The objective is to identify which would be the best technology mix economically and operationally to make up the needed system flexible capacity.

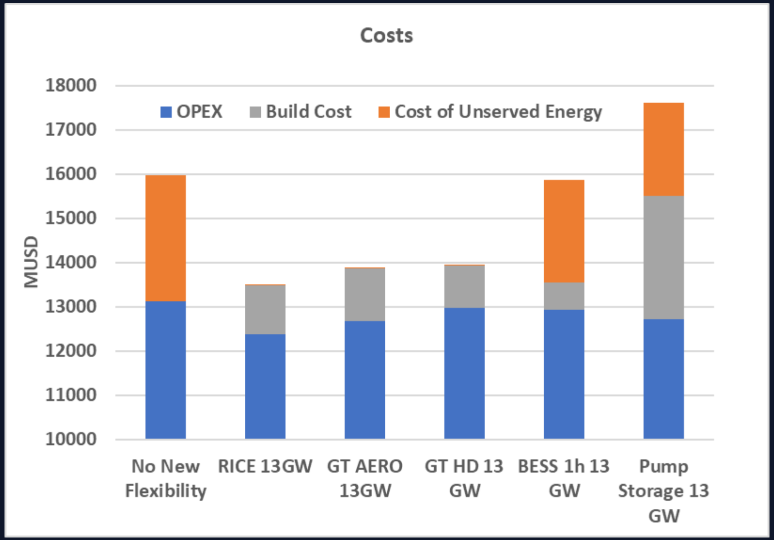


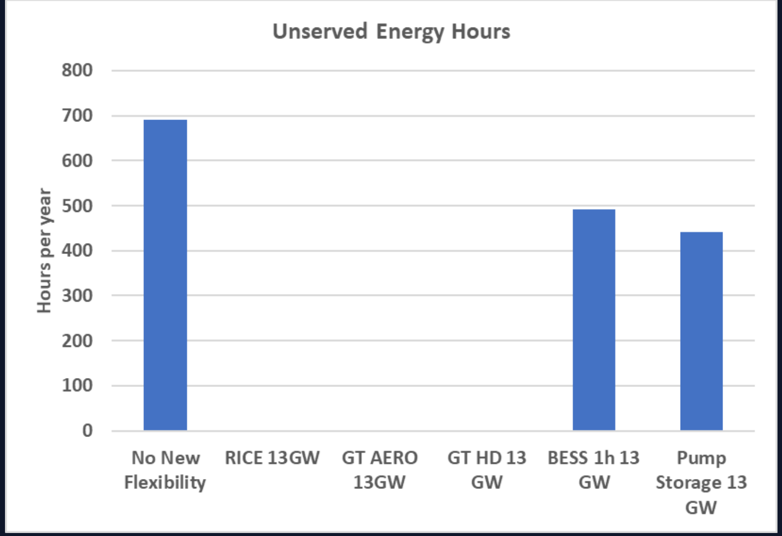
Energy matrix portfolio, 2027.

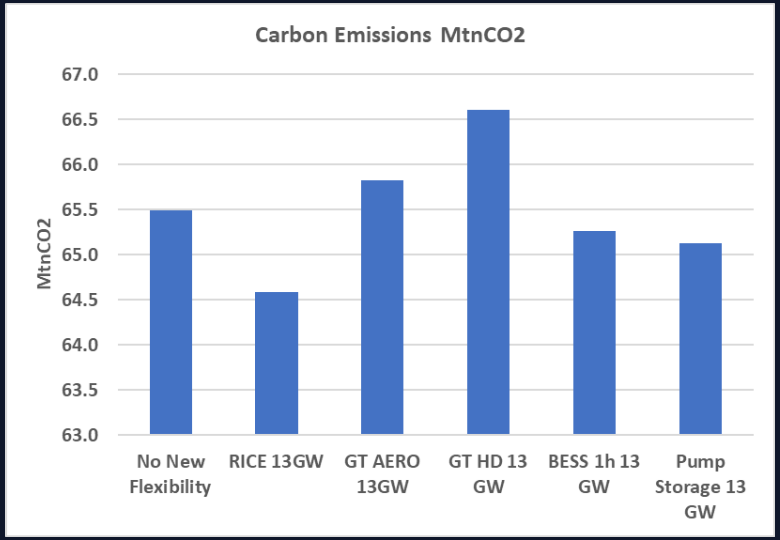
Scenarios and technology studied

Comparison of flexibility options	
Scenario	**Description**
No New Flexibility	No new flexibility added
RICE 13 GW	13 GW Reciprocating Combustion Engines
GT AERO 13 GW	13 GW GT Aeroderivative Gas Turbines
GT HD 13 GW	13 GW GT Heavy Duty Gas Turbines
BESS 1h 13 GW	13 GW of 1h Battery Storage Systems
Pump Storage 13 GW	13 GW and 39 GWh of Pump Storage

Let’s have fun: the results







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Notes for ST-model results

- **The value of flexibility:** without flexibility in the system, the unserved energy increases considerably, which also increases the total cost (value of unserved energy assumed to be 1,200 USD/MWh).
- The least cost scenarios estimated by the short-term model are the ones with flexibility provided by natural gas plants, being the RICE scenario the best.
- The major savings can be attributed to lower Operational Costs of System, specifically higher thermal efficiency and lower start-up costs. Aeroderivative gas turbines (GT AERO) and Pump Storage also cut the operational cost of the system, but pump storages overall cost is highest due to high investment cost.
- Storage options help the system to reduce unserved energy compared to no new flexibility scenario, but does not address the problems during dry years when there is no excess energy to shift.

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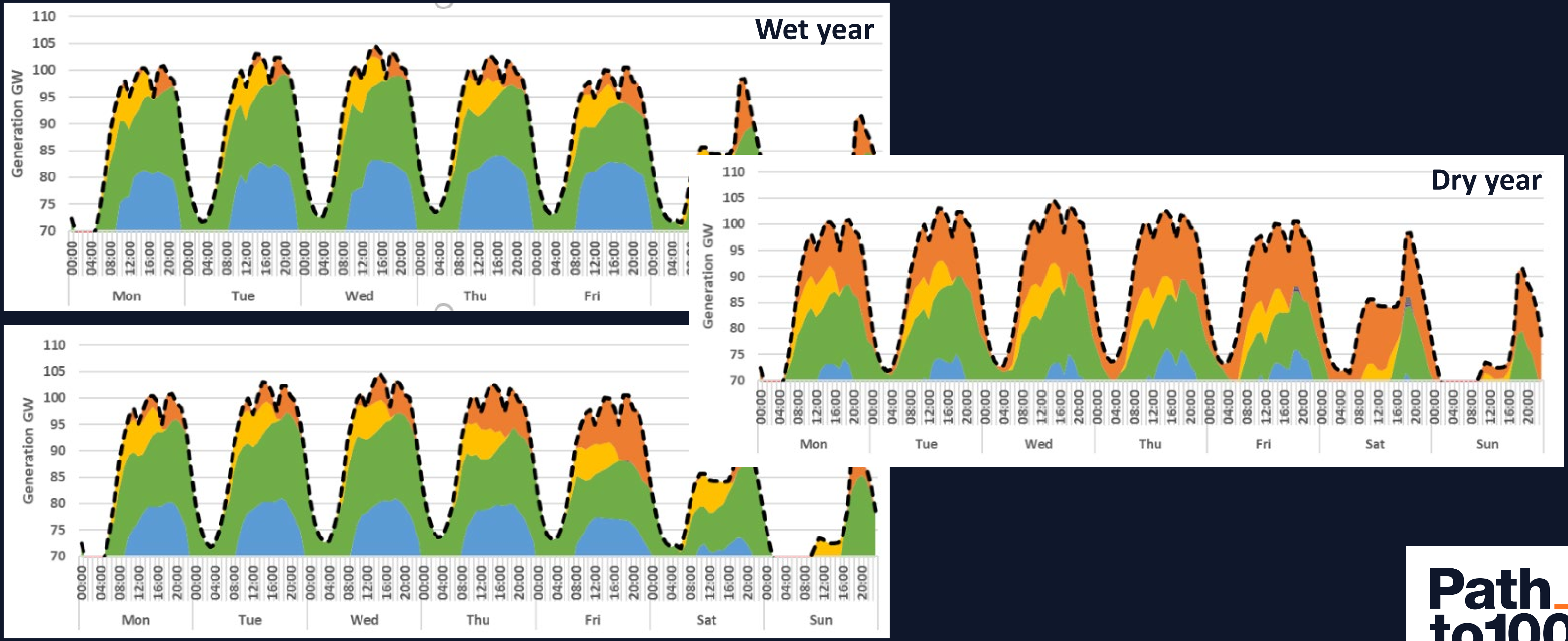
How the flexibility serves the grid?



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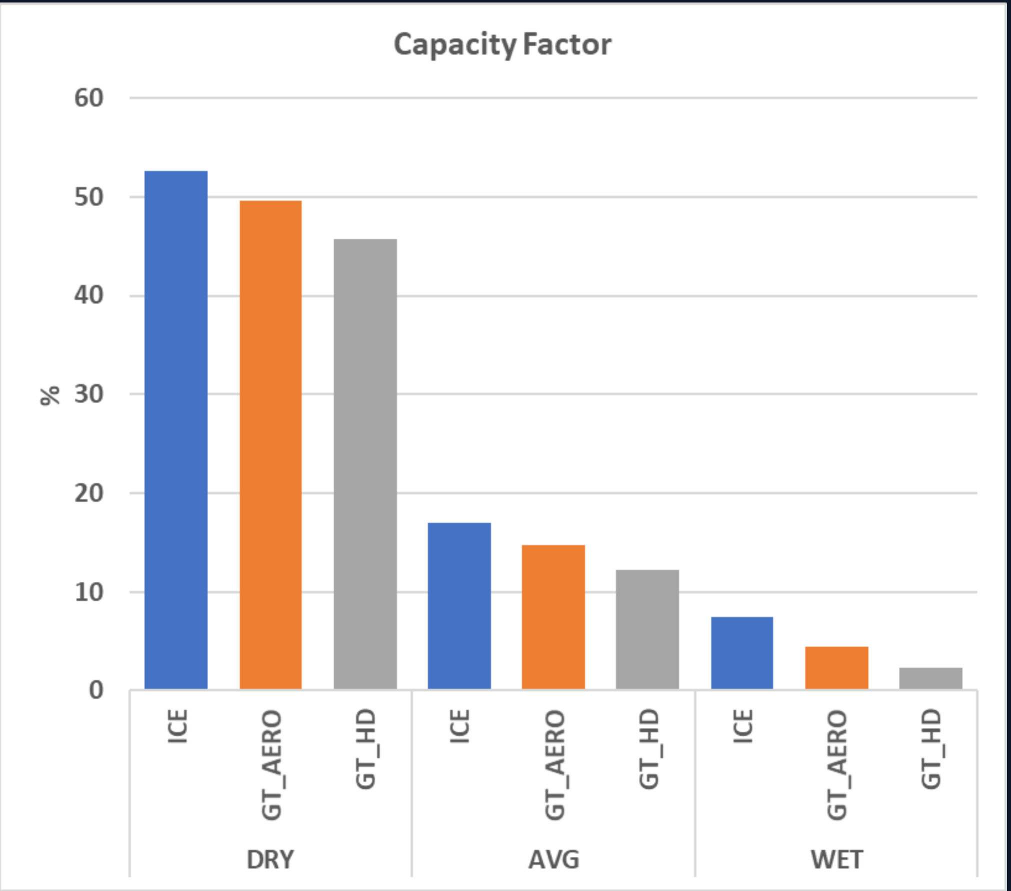
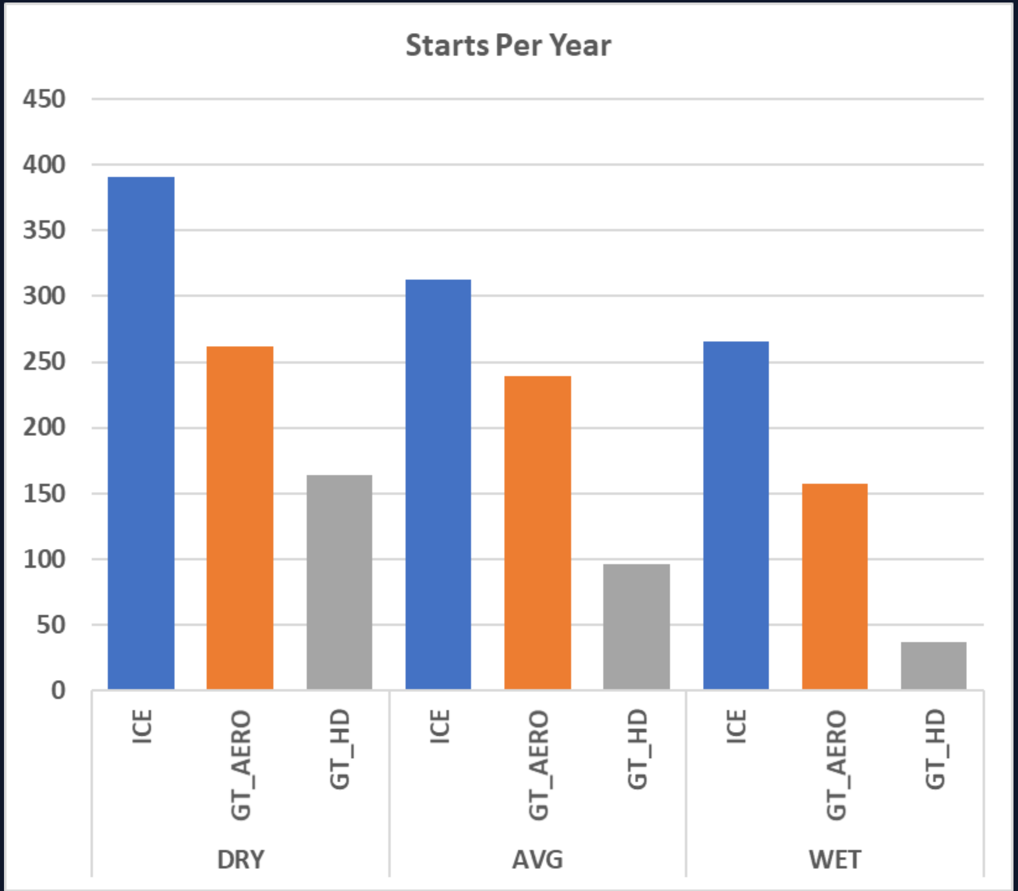
How the flexibility serves the grid? An interesting point.





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Final Takeaways

1. **High Renewables Grids are the new normal**
    - Drivers are very low-cost variable renewables: solar PV and wind energy
    - Variable renewables are ONLY compatible **system flexibility**
    - Power sector of today provides only little flexibility
    - Dispatchable renewables (hydro dams, bioenergy) are very valuable
    - Power sector requires some **flexible and fast ramping thermal capacities, based on thermal plants**
    - Flexibility is the new king: **fast ramping thermal plants, energy storage (hydro or chemical), DSM, etc.)**
2. **What’s not part of a long-term solution**
    - Old fossil and inflexible plants.
    - Nuclear energy: it’s high-cost and inflexible
3. **Suggestions for the future of the Brazilian System**
    - New flexible generation is required to maintain system reliability and avoid periods of unserved energy.
    - Encourage the procurement of flexibility for times of low renewable generation, including hydro.
    - Flexibility to be procured on system level, considering the most economical options.
    - It is important to consider the dispatch uncertainty in the procurement of flexibility.

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Q&A

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