Eletrobras
Eletronuclear

Nuclear and Renewables:
Decarbonization in a Collaborative Model

Leonam dos Santos Guimarães

How much does it cost?

- It seems like a simple question. However, when it comes to competing power generation technologies, it is an **extremely challenging question.**

- Generation costs include many variables:
  - ***capital, fuel, location, waste disposal, environmental impact, interconnection, reliability, intermittency, and***
- other **external** and **systemic costs.**

- **No two technologies are alike.**

System Costs

- **Profile or Backup costs** refer to the increase in the generation cost of the overall electricity system in response to the variability of VRE output.

- **Balancing costs** refer to the increasing requirements for ensuring the system stability due to the uncertainty in the power generation (unforeseen plant outages or forecasting errors of generation).

- **Grid costs** reflect the increase in the costs for transmission and distribution due to the distributed nature and locational constraint of VRE generation plants.

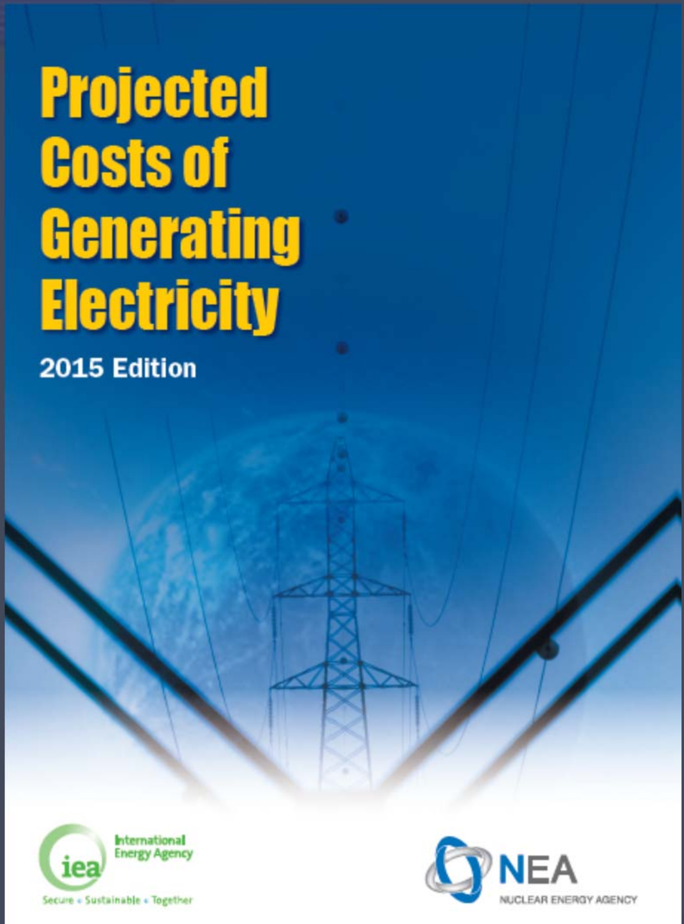
- **Connection costs** consist of the costs of connecting a power plant to the nearest connecting point of the transmission grid.

External costs

- Sum of three components:
  - **climate change damage costs** associated with emissions of greenhouse gases (CO_2 and others);
  - **damage costs associated with other air pollutants** (NO_x, SO_2, NMVOCs, PM10, NH_3) such as impacts on health, crops;
  - and **other non-environmental social costs** for non-fossil electricity-generating technologies.

- Environmental and social externalities are **highly site specific**
  - results will **vary widely even within a given country** according to the geographic location.

Levelized Cost of Electricity (LCOE)



- For decades, analysts have come up with an approach that attempts to **integrate some of the key cost variables** of generation technologies.

- **Levelized Cost of Electricity** (**LCOE**)
  - meeting internal costs, **including Capex and Opex**, until a plant is connected to the grid
  - **not take into account the system costs** that consumers would be required to pay
  - **not include environmental and social externalities**

- contradicts a **central point for clean energy** technologies:

the very impact of these externalities

Is MWh a commodity?

- **LCOE comparisons** of different generation technologies **treat** all generated **MWh as a commodity**, governed by a single price.
- The fundamental objection is: **cost does not measure value**
- Power **generation** occurs at **different times** and **in different places**, having **different values**
- It is like saying: **a car costs a lot more than a bicycle**, so we should all buy bicycles, disregarding that are providing **services of different natures.**

Carbon generation targets first

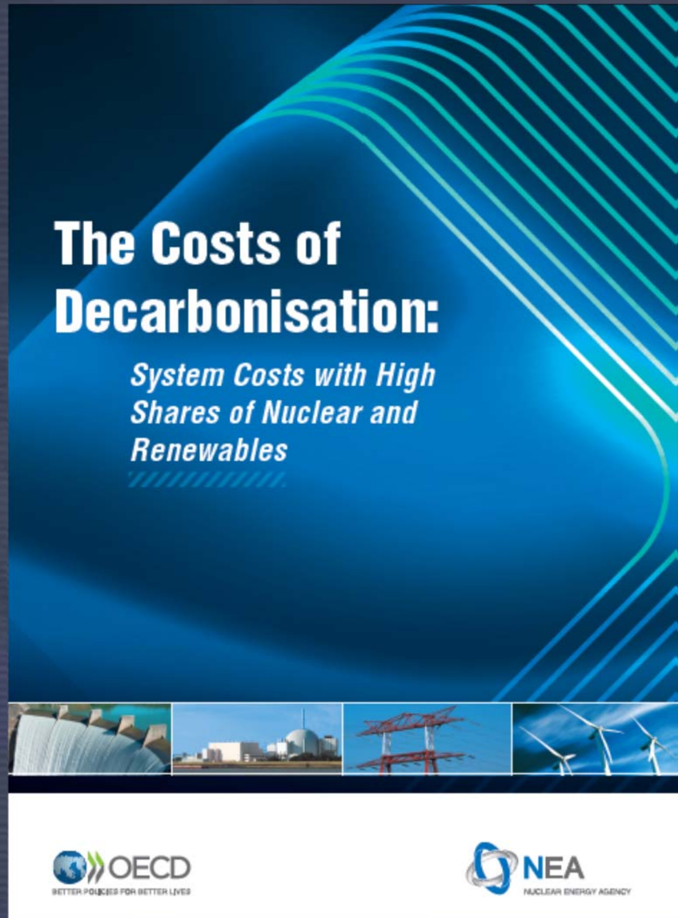
- There is clear evidence that **in addition to hydroelectric power with large reservoirs, nuclear is the only low-carbon dispatchable technology**, and it is essential, along with VRE, to obtain a decarbonized electrical system.

- Rather than developing public policies that set targets for VRE participation, which will require network capacity, flexibility and infrastructure, it would be preferable

to set carbon generation targets first and then identify which electrical system would provide the best cost-benefit

True costs of decarbonisation

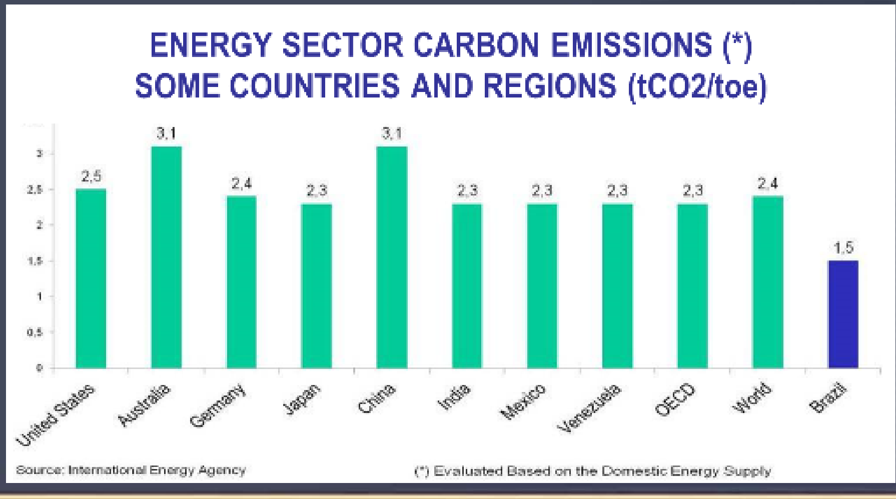
- Main considerations when assessing **choices** that would effectively **achieve deep decarbonization** of the future electricity system (*lower than 50gCO2/kWh*):
  - What is the **most cost-efficient mix** to achieve a decarbonization target with a given share of VRE?
  - Which **technologies** are **available**, what are their reasonably **expected costs** and what are their effects on the **overall reliability** of the electricity system?
  - What **policies** will lead to the **long-term investments** that deep decarbonization requires?

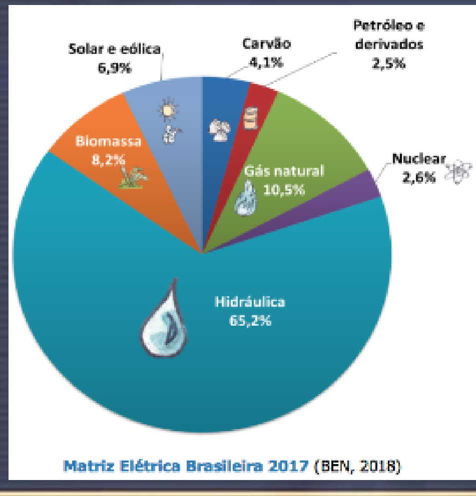


A cost-effective low carbon system

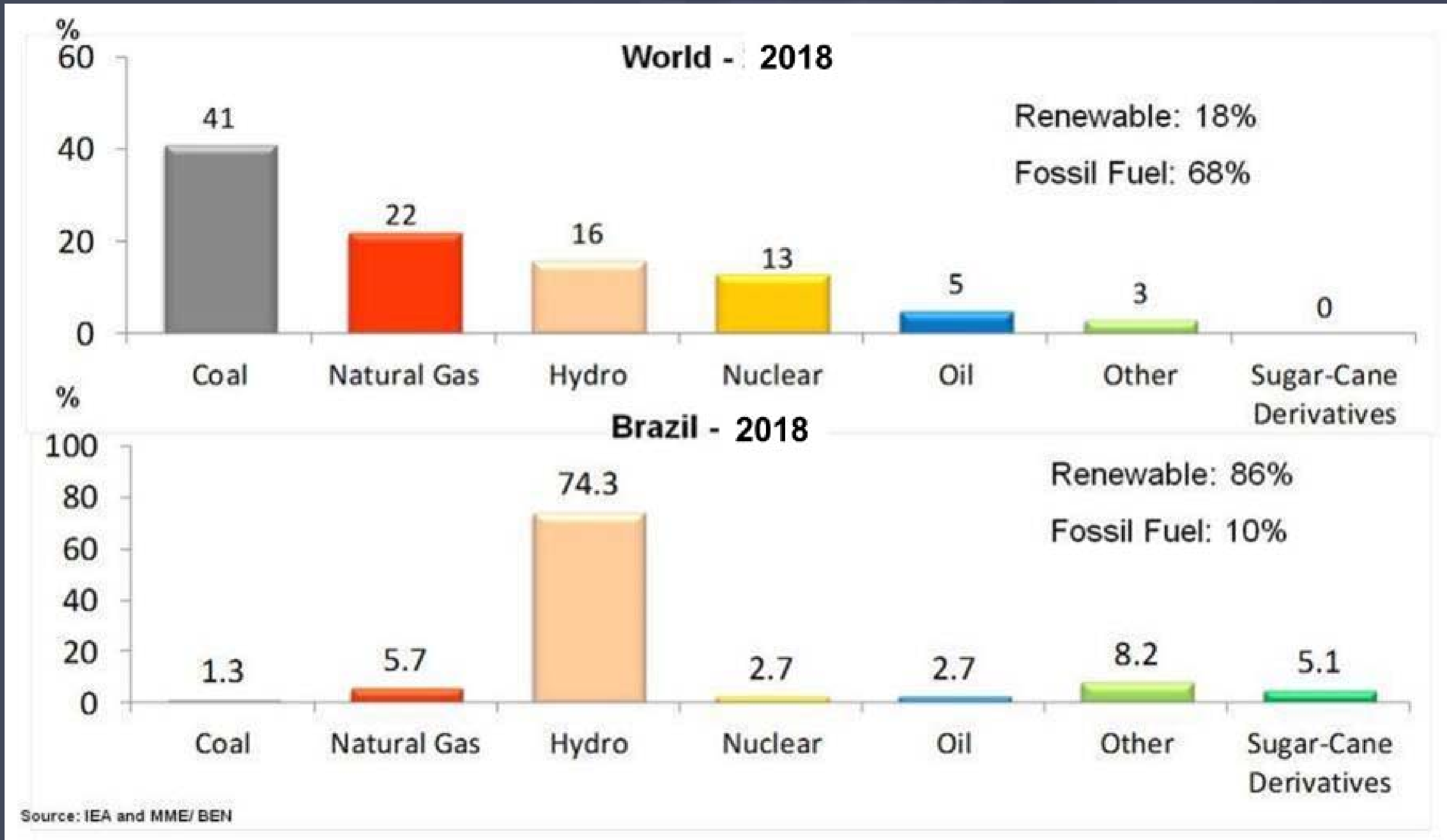
- sizeable share of VRE,
- sizeable share of dispatchable zero carbon technologies, as nuclear energy and hydroelectricity with large reservoirs.
- complementary amount of gas-fired capacity for additional flexibility, alongside storage, demand side management and interconnections

The Brazilian system seems to go in that direction, already having some of these attributes.

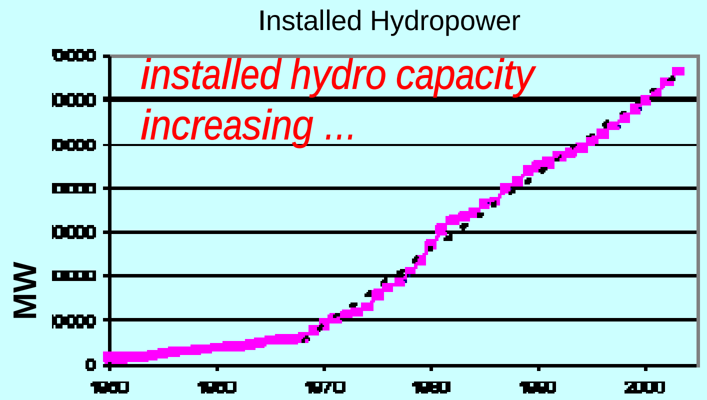


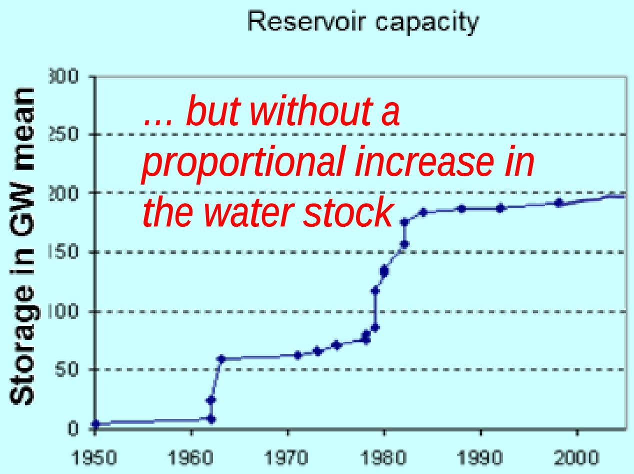


ELECTRICITY SUPPLY MATRIX
WORLD x BRAZIL (%)



ELECTRIC SYSTEM EVOLUTION IN THE 90´s
HYDROTHERMAL TRANSITION



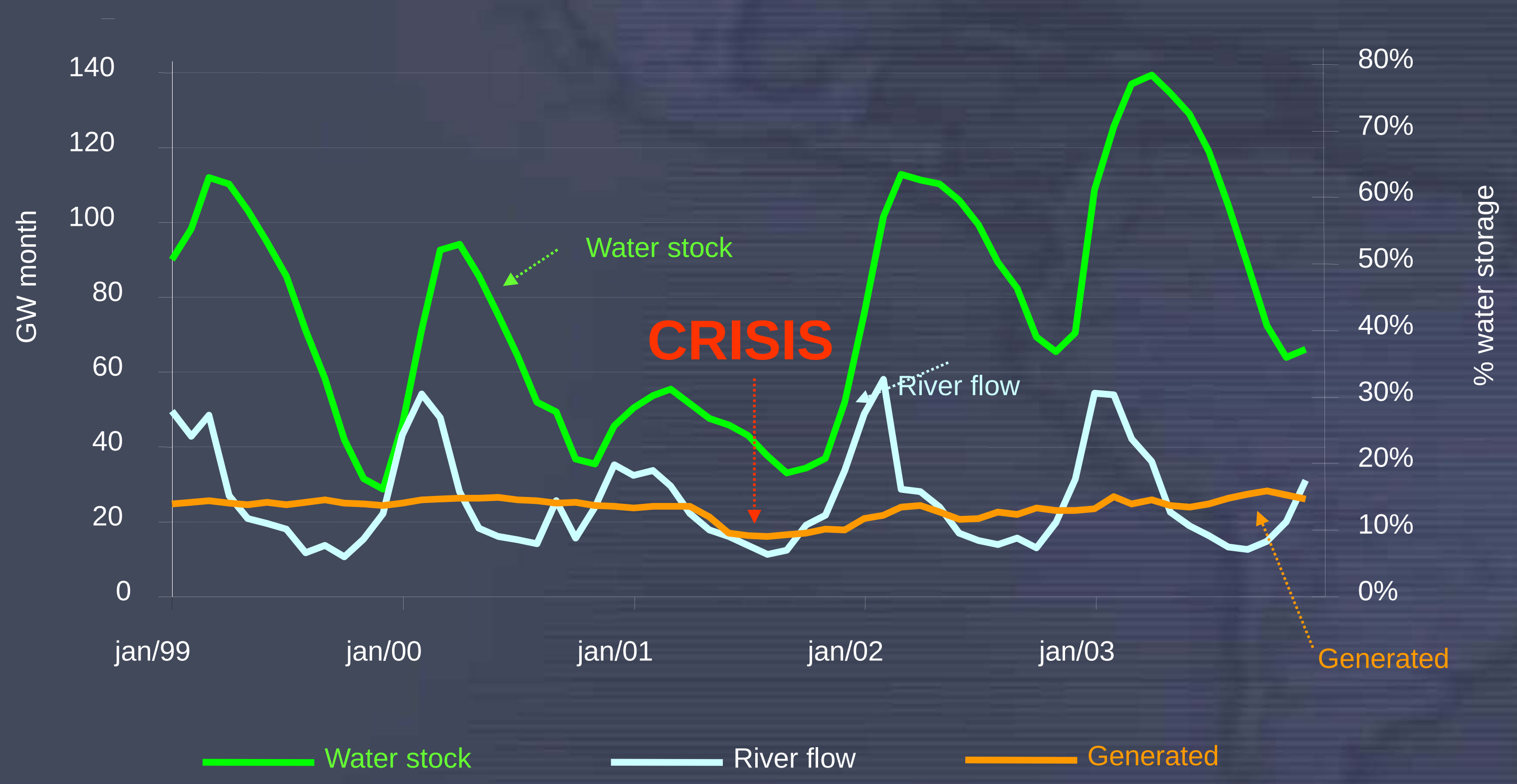


The expansion of a large interconnected power system, with significant predominance of hydro renewable primary source now requires an increasing thermal contribution,

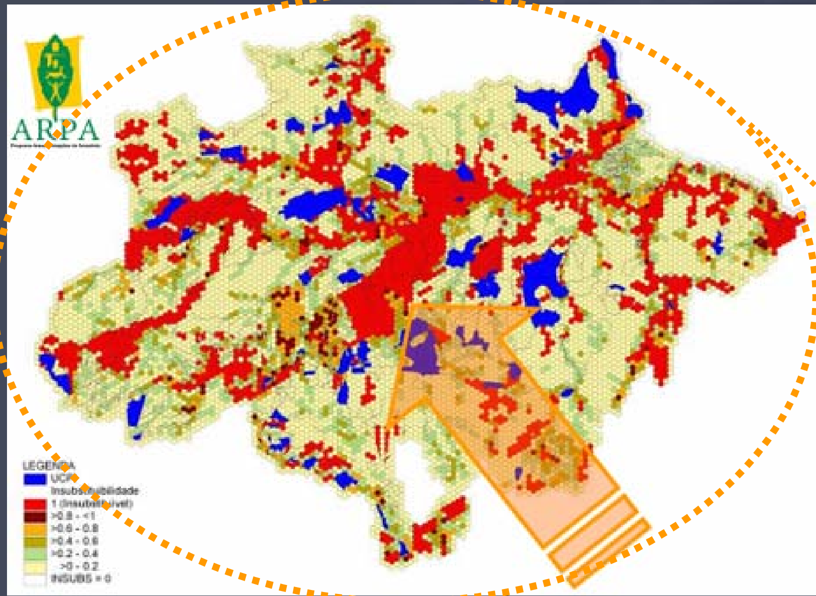
- by gradual exhaustion of the economic and environmentally feasible hydro potential and/or
- loss of autoregulation capacity due to lower water storage capacity in reservoirs in relation to the system load growth.

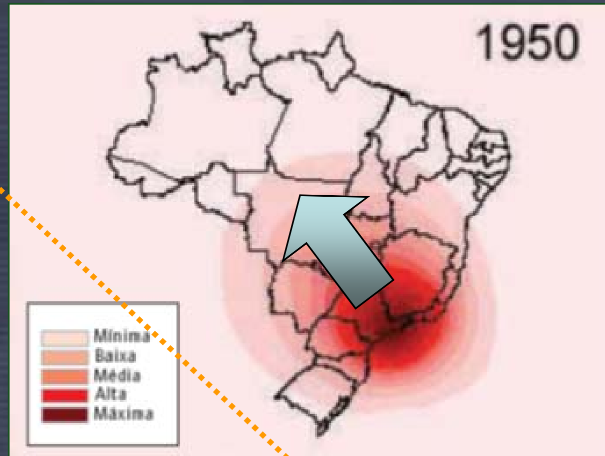
ELECTRIC SYSTEM EVOLUTION
NEED FOR THERMAL REGULATION

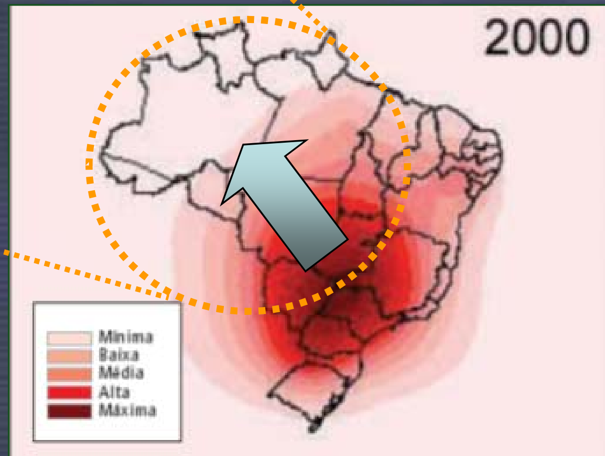
root cause of 2001 supply crisis



ELECTRIC SYSTEM EVOLUTION
“DAM CULTURE” CHANGE



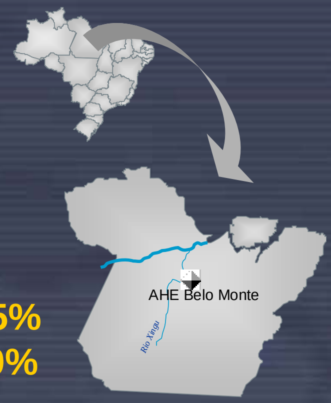




small reservoirs
to avoid flooding
large surfaces

ELECTRIC SYSTEM EVOLUTION
"DAM CULTURE" CHANGE

This tendency are amplificated by new projects in Amazon Bassin



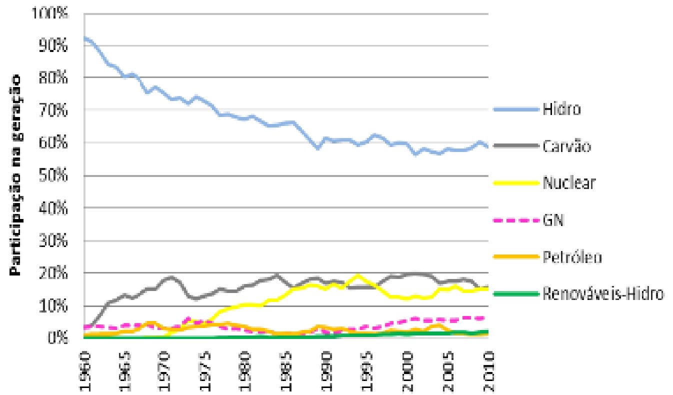
- **Current average hydro capacity factor: 55%**
- **Future average Amazon hydro capacity factor: 30-40%**

Project AHE MADEIRA 6.500 MW

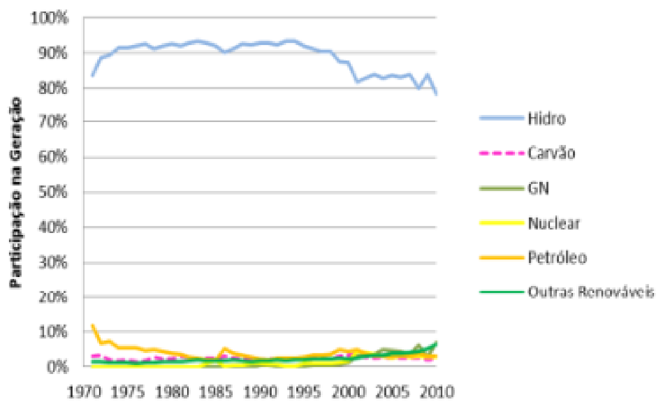
Project AHE BELO MONTE 11.000 MW

ELECTRIC SYSTEM EVOLUTION
HYDRO-THERMAL TRANSITION IS NOT NEW

ELECTRICITY GENERATION IN CANADA



ELECTRICITY GENERATION IN BRAZIL

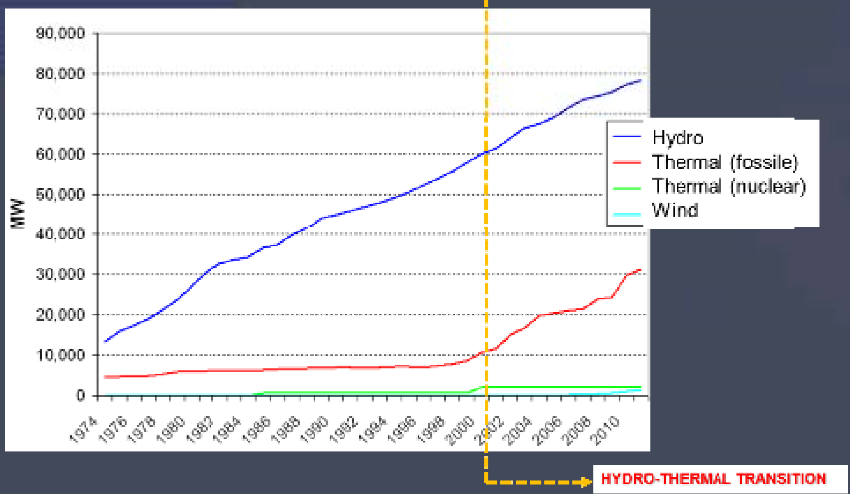


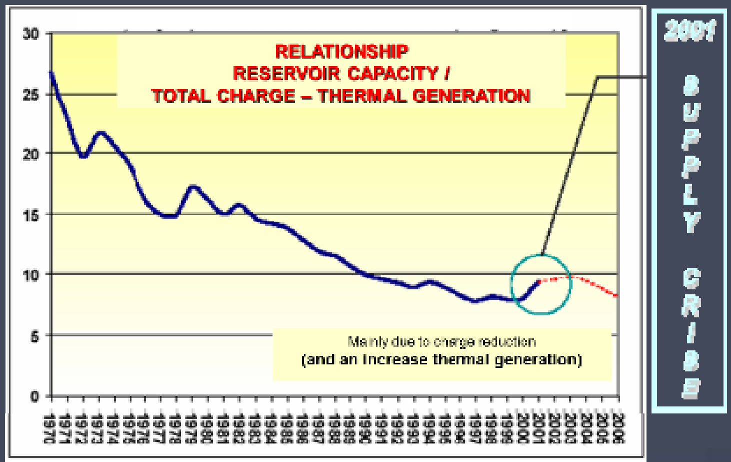
The evolution of the Canadian electrical system in 50 years holds many similarities with the situation of the Brazilian electrical system in last 20 years.

•From a contribution of over 90% in 1960, the share of hydroelectricity in Canada declined steadily until 1990, when it stabilized at around 60%.

•This reduction of hydro share was compensated by the growth of nuclear and coal – and the transition was successful

ELECTRIC SYSTEM EVOLUTION
HYDRO-THERMAL TRANSITION



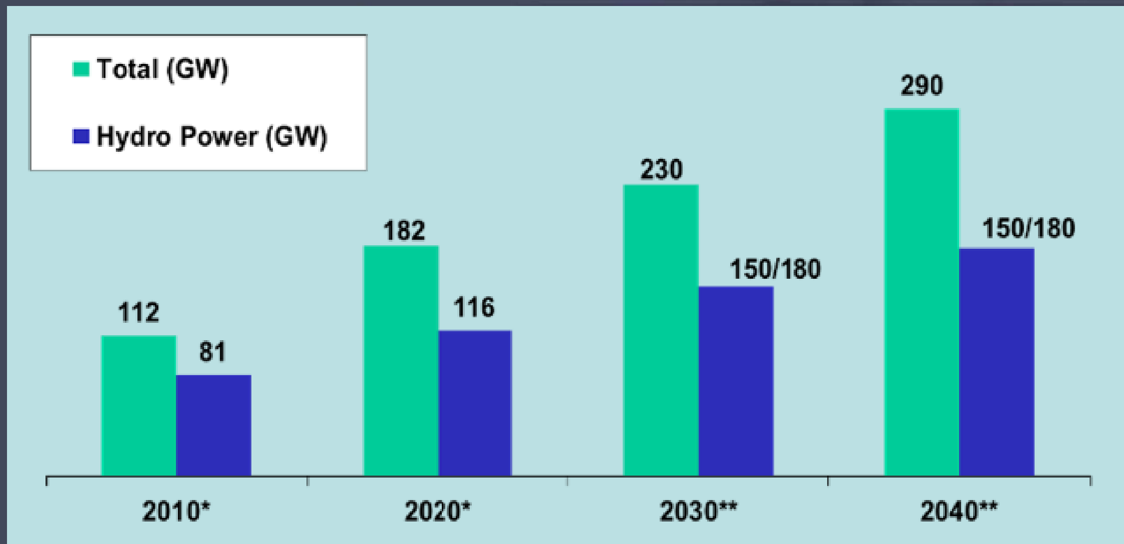


- Hydrothermal transition requires a long-term strategy for diversification of primary sources of electricity generation.
  - The role of new renewables in a Brazilian hydrothermal transition nowadays is much more important than was in Canadian transition, decades ago.
  - The installed capacity of these new sources increased spectacularly from almost 0% in 2000 to 22% in 2018.

ELECTRIC SYSTEM EVOLUTION
BRAZILIAN TRANSITION IS NEW

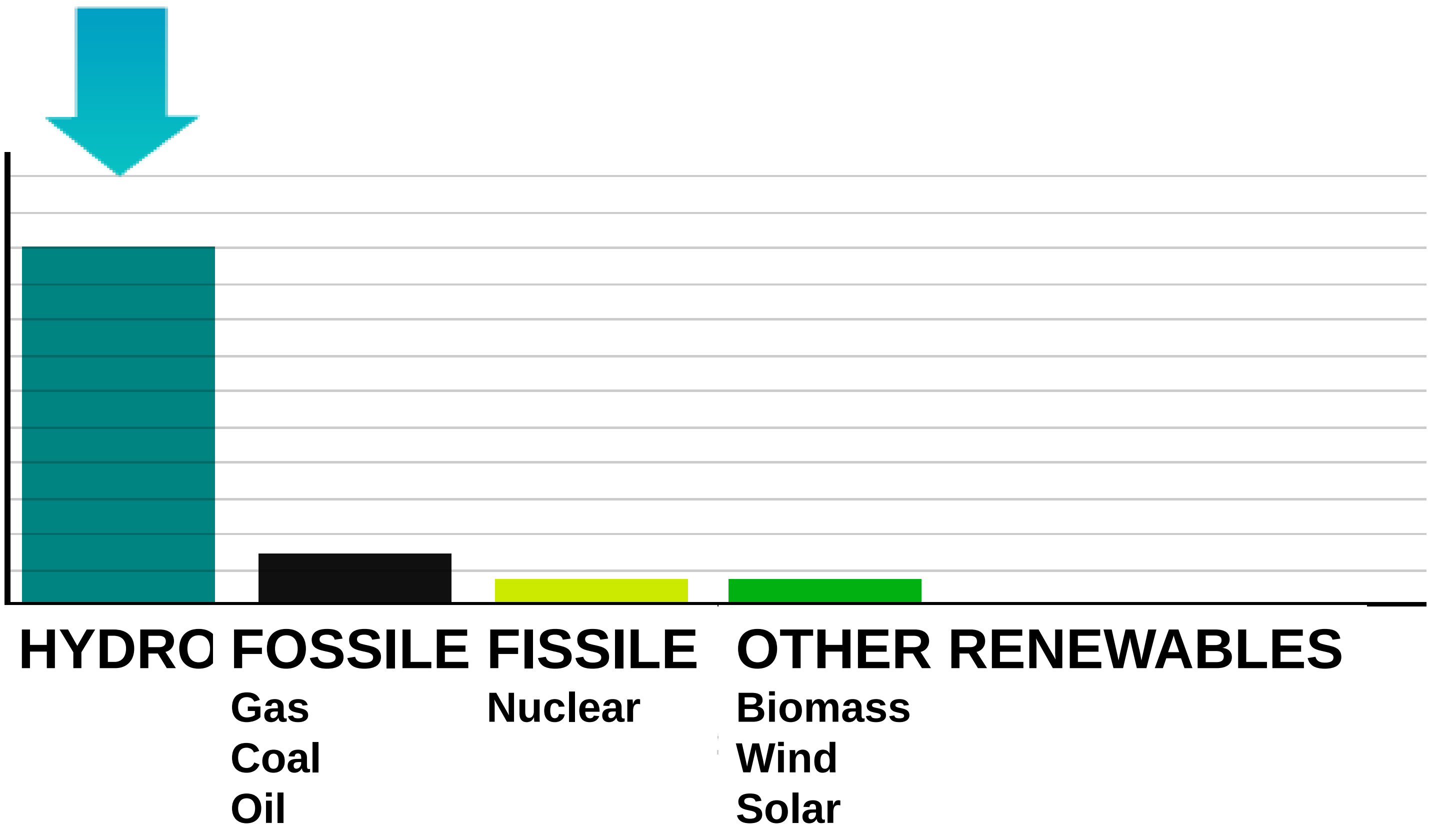
- New renewables have unique competitive advantages in Brazil for two complementarities:
  - **wind-hydro (high wind in dry season) and**
  - **wind-solar (high wind in high insolation places)**

- This allows **low-cost storage of intermittent energy in hydro reservoirs**, saving water and increasing the capacity of hydroelectric make regulation of demand.

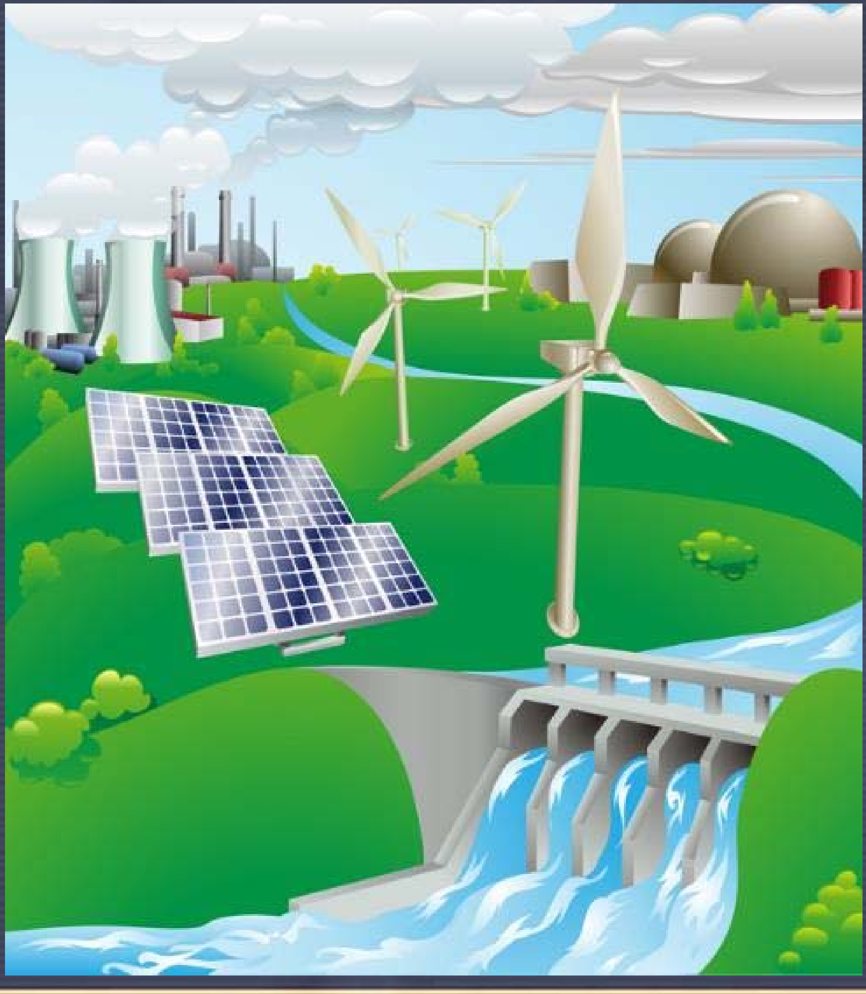


Hydro Share 72% 64% 65/78% 52/62%

ELECTRIC SYSTEM EVOLUTION
BRAZILIAN TRANSITION IS NEW



- **Nuclear power is a reliable partner of VRE through a collaborative model.**
  - A **technical complementarity** could be achieved through the development of a larger flexibility in reactor operating, in order to palliate VRE variable power production.
  - A **systemic complementarity** could be achieved through innovative technologies in fields like cogeneration, heat and hydrogen production, demand management or interconnection of ultra large power grids.
  - Last, but not the least, a **strategic complementarity** for building the future decarbonized energy mix.



THANK YOU!

Leonam dos Santos Guimarães leonam@eletronuclear.gov.br

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