

Grid and Flexibility Services: An Overview of the Brazilian Interconnected Power System

CEPEL – Electric Energy Research Center



Eletrobras
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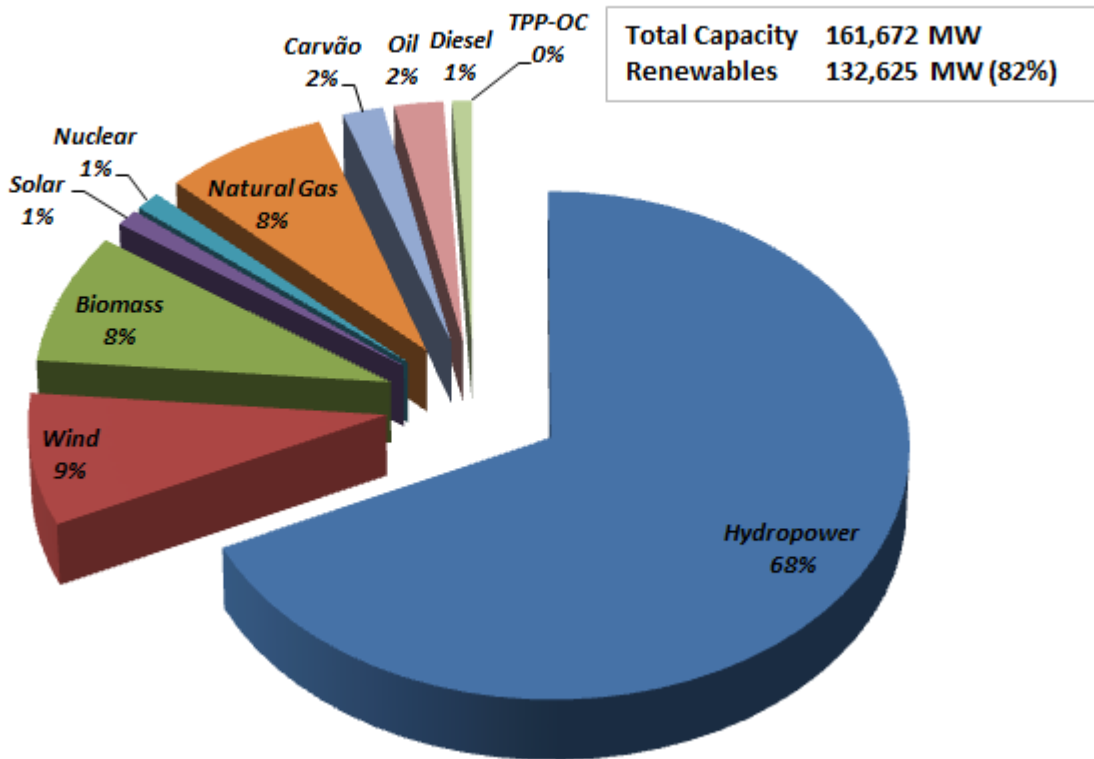
**IEA Hydro Annex IX Workshop: Valuing
Hydropower Flexibility in Evolving
Electricity Markets**

Rio de Janeiro, 03 June 2020

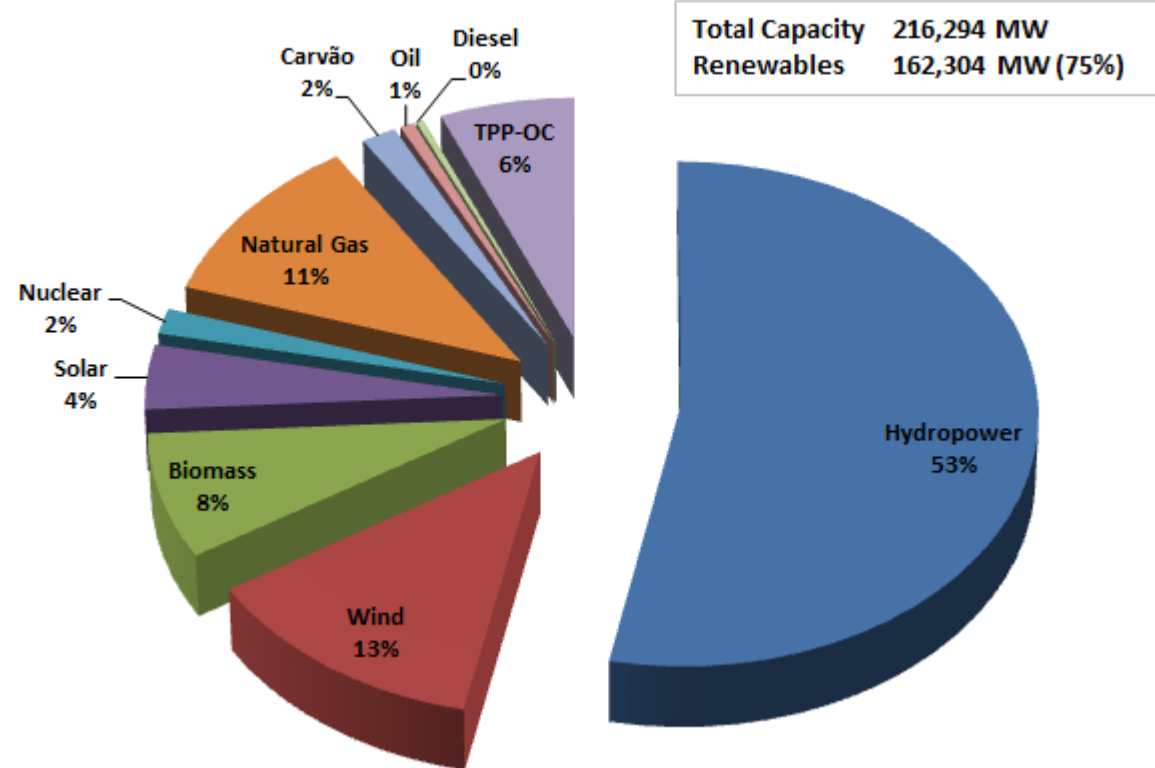
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Electricity Mix in Brazil

Electricity Mix (MW) - 2018



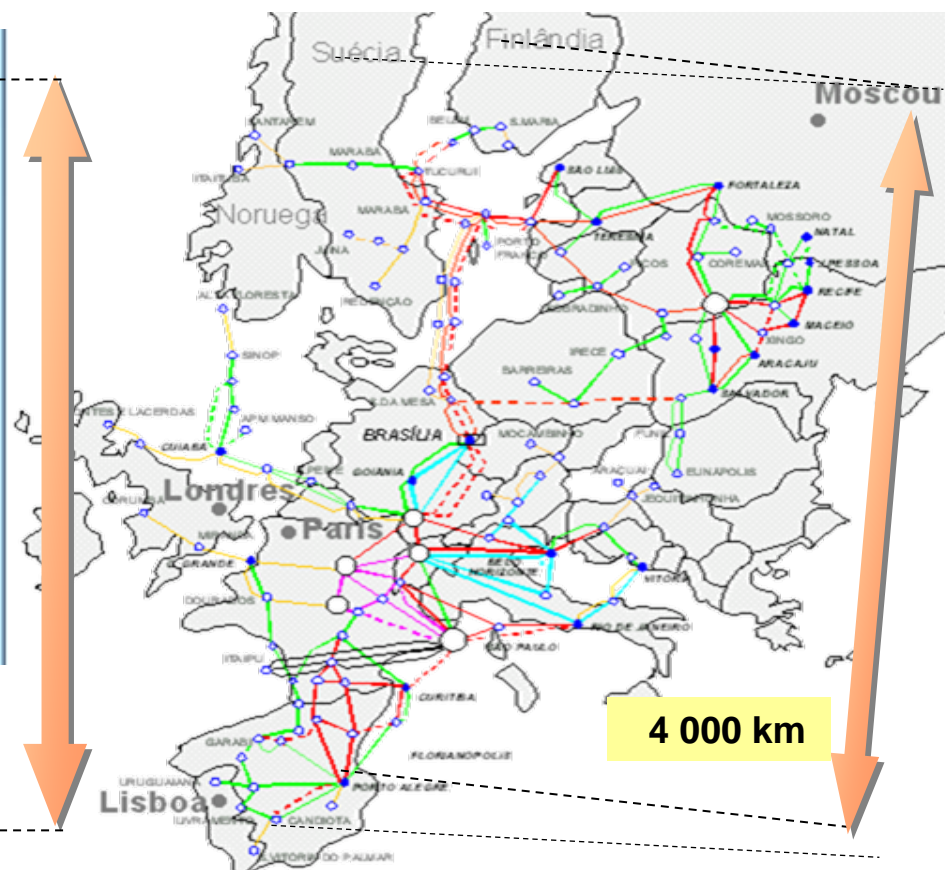
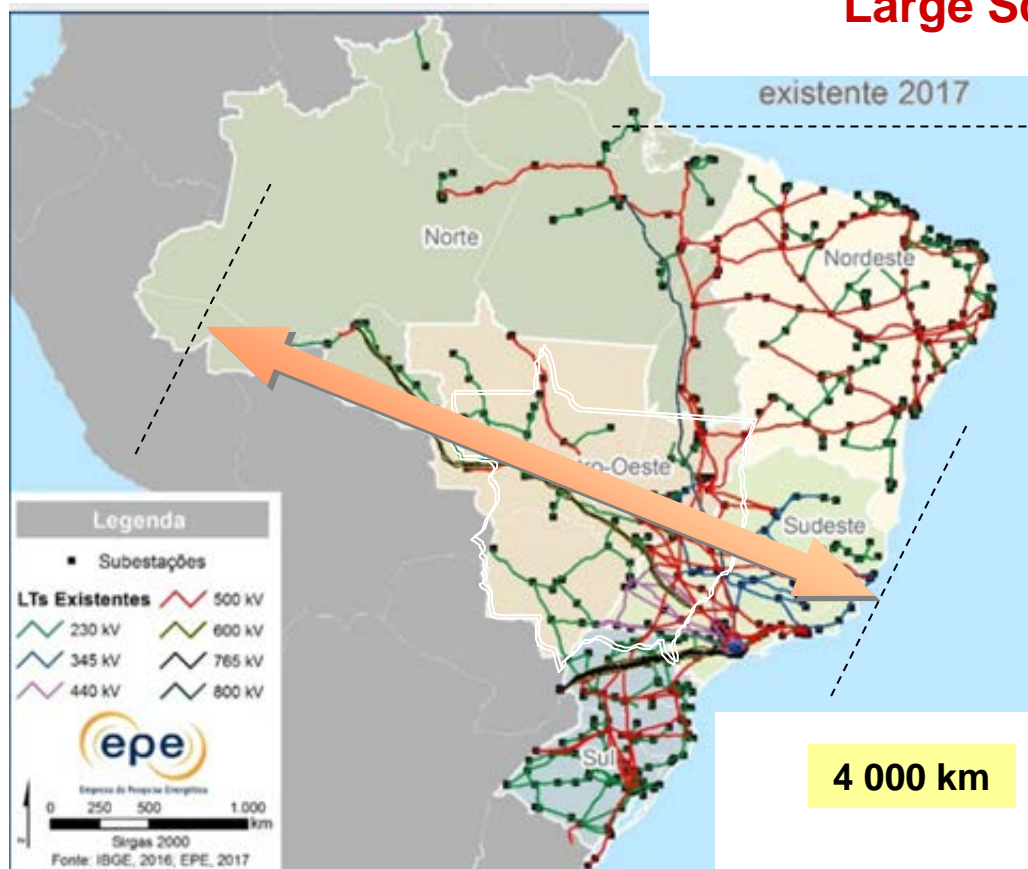
Electricity Mix (MW) - 2027



Brazilian Transmission System

Continental Dimension

Large Scale Power System



4 000 km

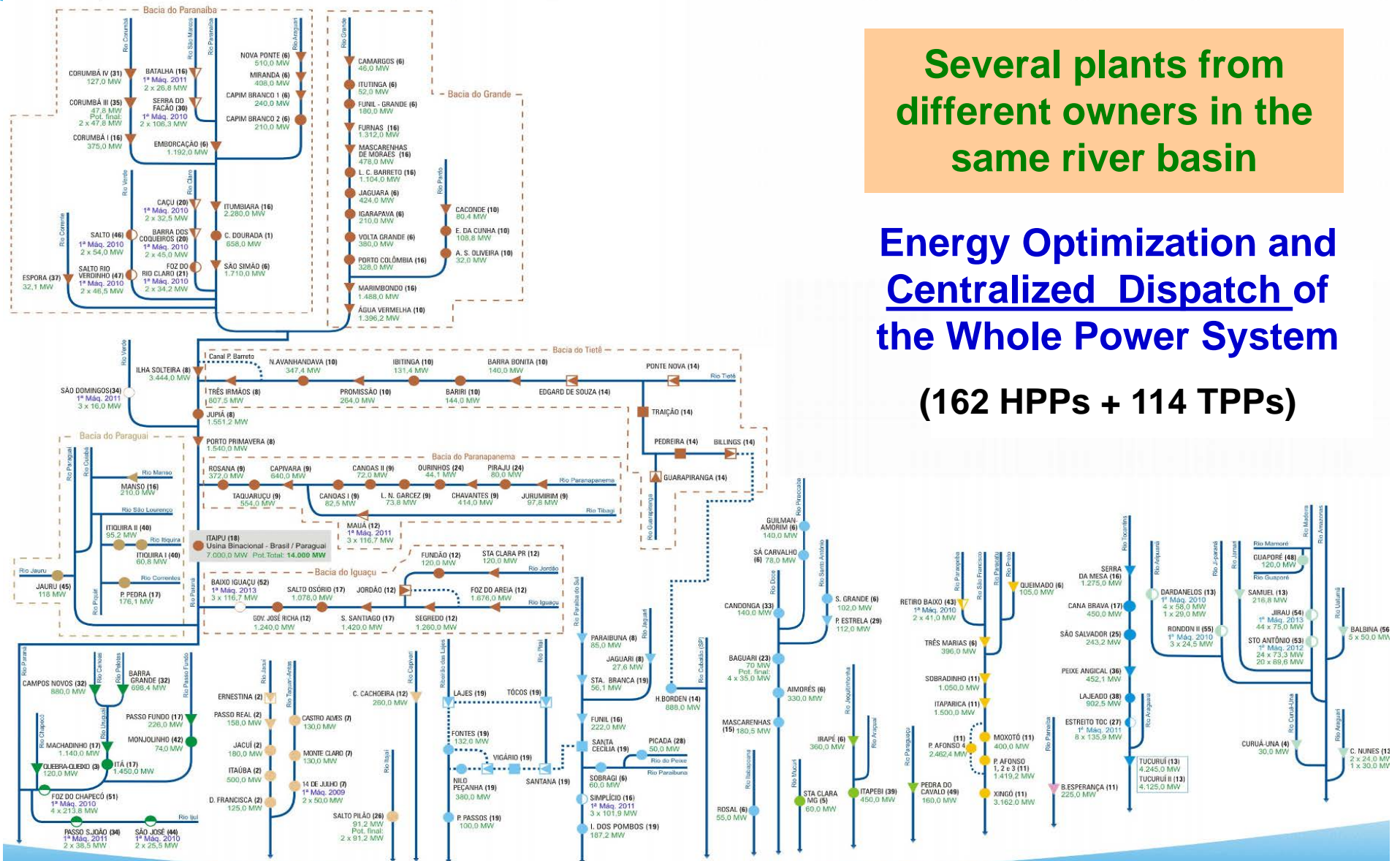
4 000 km

BRAZIL

EUROPE

- Territorial Extension : 5,514,876 km²
- Population: 210 million (2019)
- GDP: USD 1.9 trillion (2018)

Hydropower Plants Configuration



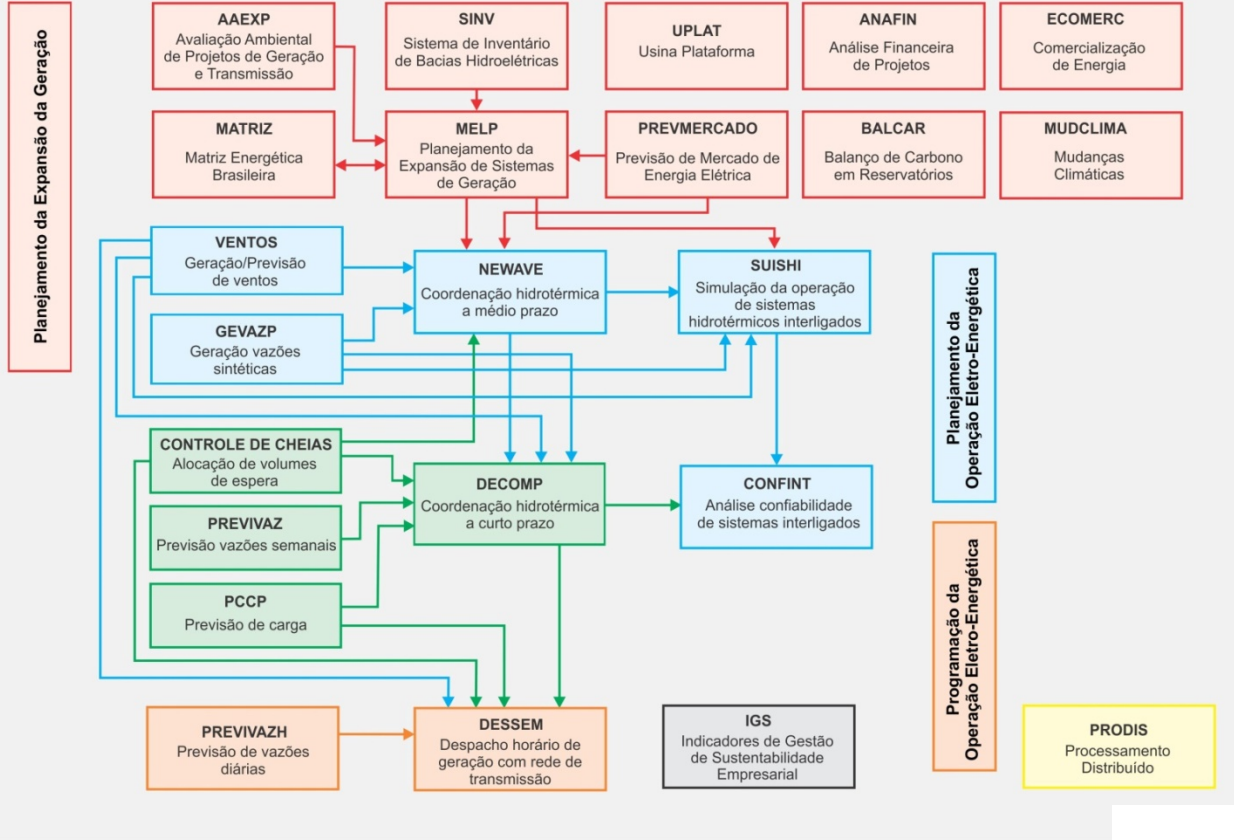
Several plants from different owners in the same river basin

Energy Optimization and Centralized Dispatch of the Whole Power System

(162 HPPs + 114 TPPs)

CEPEL's Chain of Optimization Models for the Generation Expansion and Operational Planning of the Brazilian Interconnected System

Cadeia de Modelos para o Planejamento da Expansão da Geração e da Operação Energética



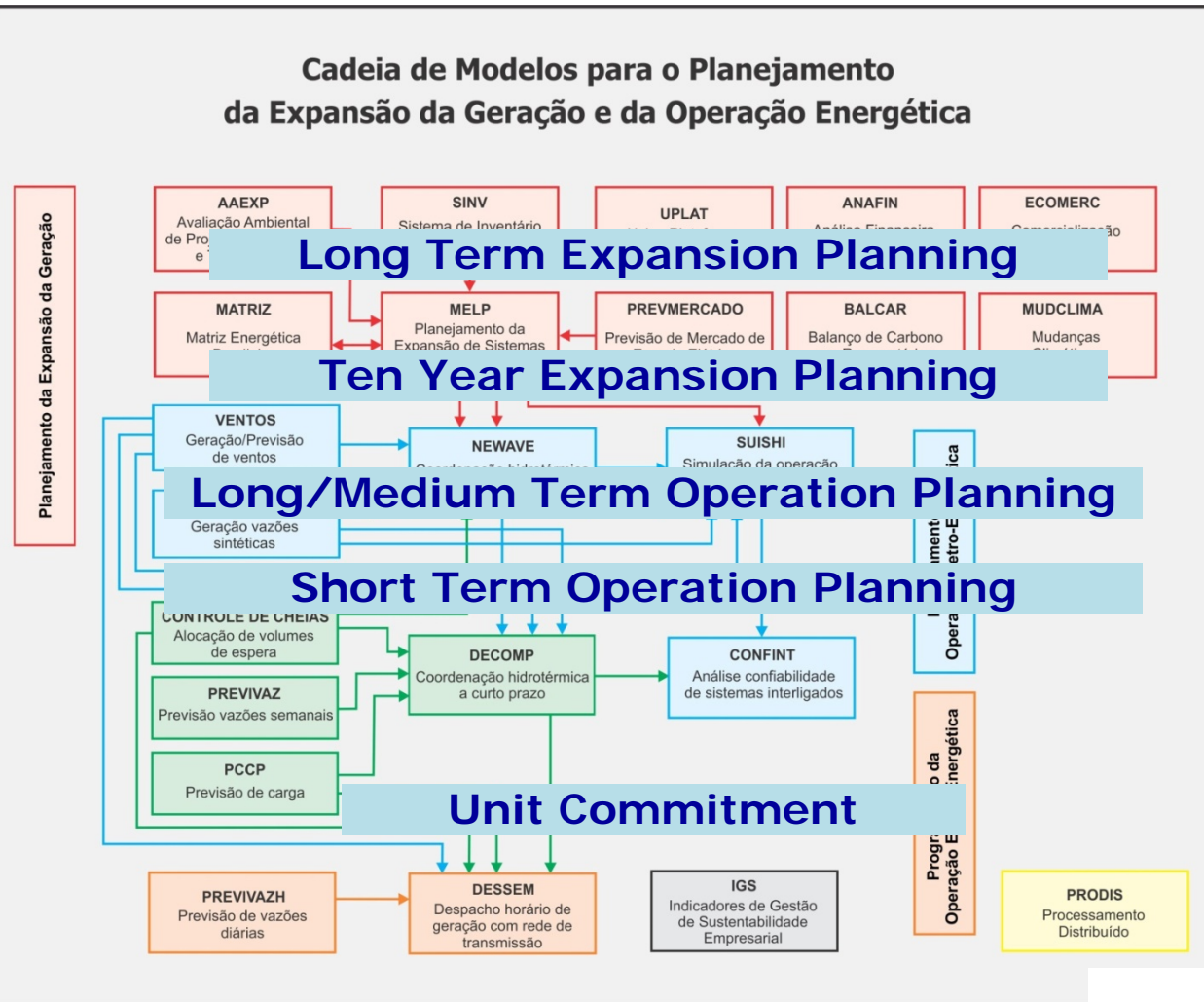
Energy Optimization and Centralized Dispatch of the Whole Interconnected Hydrothermal System

162 HPPs
114 TPPs

Need of capturing synergies in planning and operation stages



CEPEL's Chain of Optimization Models for the Generation Expansion and Operational Planning of the Brazilian Interconnected System



Energy Optimization and Centralized Dispatch of the Whole Interconnected Hydrothermal System

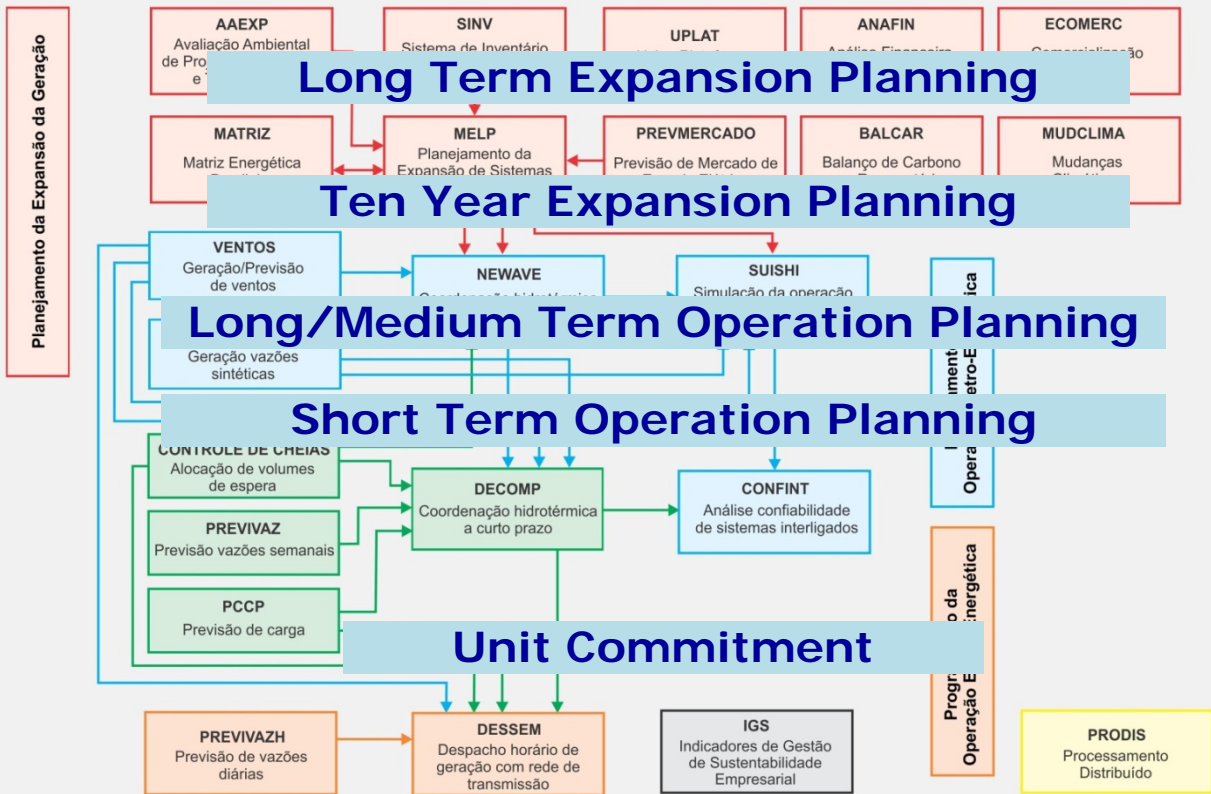
**162 HPPs
114 TPPs**

Need of capturing synergies in planning and operation stages

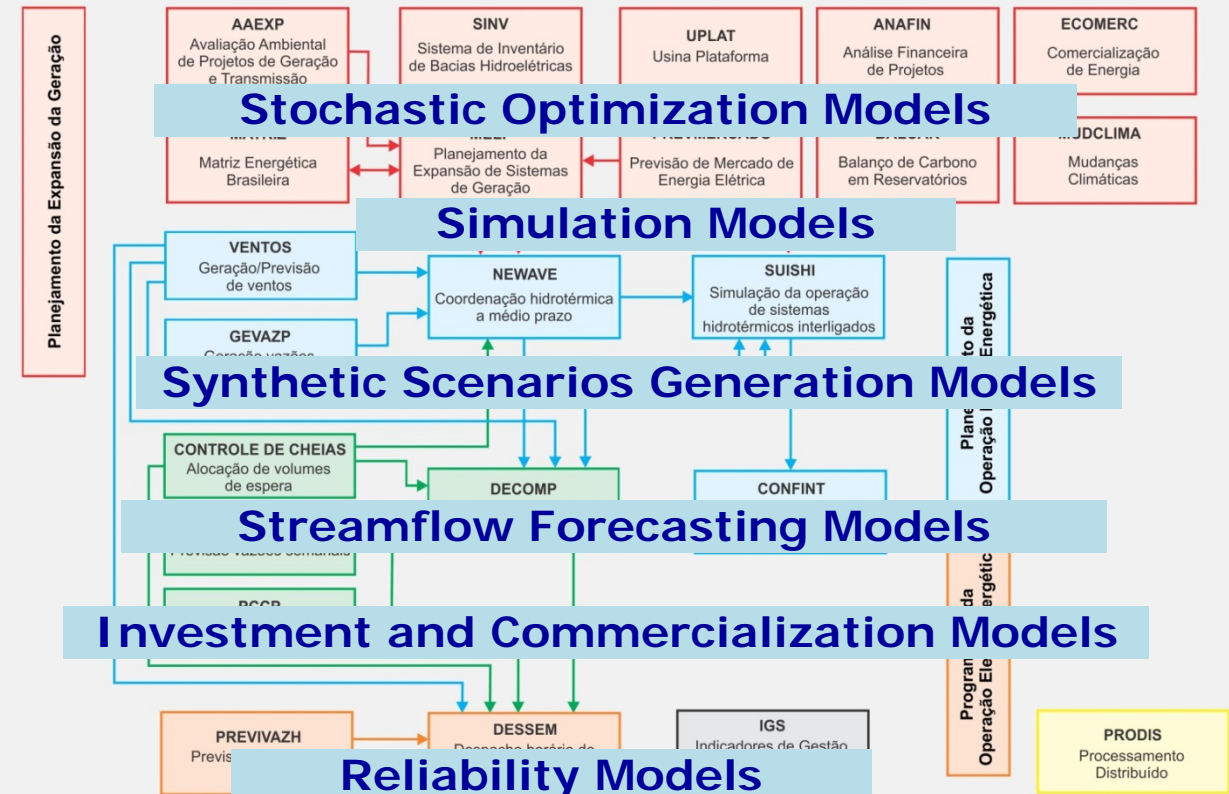


CEPEL's Chain of Optimization Models for the Generation Expansion and Operational Planning of the Brazilian Interconnected System

Cadeia de Modelos para o Planejamento da Expansão da Geração e da Operação Energética



Cadeia de Modelos para o Planejamento da Expansão da Geração e da Operação Energética



Ancillary Services in Brazil

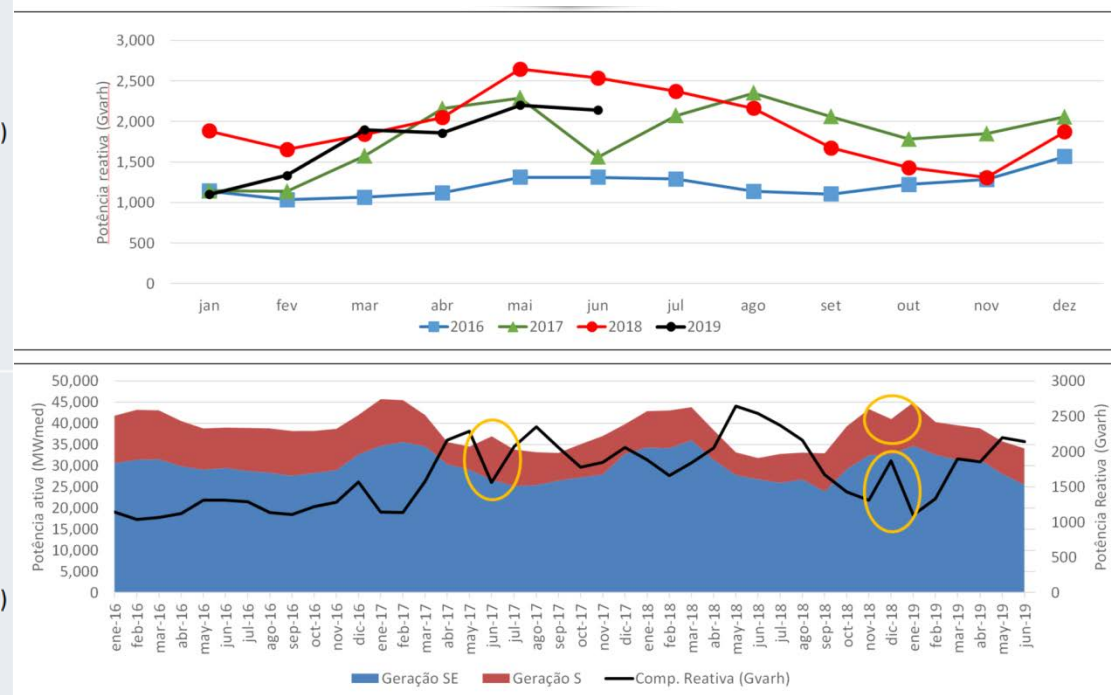
Current Ancillary Services in Brazil

1. Reactive power support / voltage control
2. Reactive power support -Synchronous Compensator
3. Special Protection Systems (SPS)
4. Primary Frequency Control
5. Secondary Frequency Control / AGC
6. Black-Start capability
7. Complementary dispatch to maintain the SR/AGC
8. Demand Response - pilot program

Short-Term: Milliseconds to Seconds

Flexibility services and products	How are procured?	Are these services compensated?	HPP ?	How much is normally procured
<p>1. Reactive power support / voltage control</p> <p>1.(a) - generating units that are providing active power</p> <p>1.(b) - generating units that operate as synchronous compensators</p> <ul style="list-style-type: none"> - reactive support in dynamic regime - aggregation of inertia - increase in short-circuit levels 	<p>1.(a) - automatically, by all generating units that are providing active power.</p> <p>1.(b)</p> <ul style="list-style-type: none"> - the ONS (National Electric System Operator) demonstrates the need and endorses the technical and economical feasibility of providing it, according to Grid Procedures - requires authorization by the Regulator (ANEEL) - the Ancillary Service Provision Contract (CPSA) must be signed between the ONS and the generator - must be provided whenever requested by ONS 	<p>1.(a) - No</p> <p>1.(b) Yes</p> <ul style="list-style-type: none"> - recovering fixed costs (installation of equipment) - remunerated through the Ancillary Services Tariff - AST, as a function of the MVA_{rh} generated or absorbed - to recover the additional operation and maintenance costs - the active energy consumption when operating as a synchronous compensator are accounted as system losses. 	Yes.	<p>1.(b)</p> <p>R\$ 163 million (US\$ 41 million) in 2019.</p>
<p>2. Special Protection Systems (SPS): automatic control and protection systems, comprising</p> <ul style="list-style-type: none"> - Emergency Control Schemes - Security Control Schemes - reducing the occurrence and coverage of major disturbances 	<ul style="list-style-type: none"> - ONS identifies the need to install new SPEs, as well as the revision or uninstallation of the existing ones, according to Grid Procedures - need of authorization by the Regulator (ANEEL) - the Ancillary Service Provision Contract (CPSA) must be signed between the ONS and the generator 	<p>Yes</p> <ul style="list-style-type: none"> - The generating plants with satisfactory performance in relation to the activities in the SPS in the previous year, as assessed by ONS, will receive annually the revenue for a special protection system. 	Yes.	<p>SPS + AGC + Black-Start:</p> <p>R\$ 62 million (US\$ 16 million) in 2019.</p>

Reactive support from Synchronous Compensators



Source: ONS

(* SPS in the transmission system are paid through the TUOS charge

137 generating units from HPPs

Short-Term: Seconds to Minutes

Flexibility services and products	How are procured?	Are these services compensated?	HPP ?	How much is normally procured	Possible developments
<p>1. Primary Frequency Control: control carried out by means of automatic speed regulators of the generating units, to limit the frequency variation when there is an imbalance between the load and the</p>	<ul style="list-style-type: none"> - provided automatically by all generating units - requirements are defined by ONS through the Grid Procedures 	No	Yes		
<p>2. Secondary Frequency Control: carried out by generating units participating in the Automatic Generation Control - AGC, aimed at restoring the system frequency and/or the active power interchanges between subsystems to the programmed values.</p>	<ul style="list-style-type: none"> - ONS points out the need and technical viability in accordance with the Grid Procedures - need of authorization by the Regulator (ANEEL) - the Ancillary Service Provision Contract (CPSA) must be signed between the ONS and the generator - whenever requested by ONS, a generator participating of the AGC must provide this service 	<p>Yes</p> <ul style="list-style-type: none"> - The generating plants with satisfactory performance in relation to AGC in the previous year, as assessed by ONS, will receive annually the revenue for the Secondary Frequency Control. 	Yes	<p>SPS + AGC + Black-Start:</p> <p>R\$ 62 million (US\$ 16 million) in 2019.</p>	Discussion about changing the remuneration methodology to encourage greater service availability.

Short-Term: Minutes to Hours

Flexibility services and products	How are procured?	Are these services compensated?	HPP ?	How much is normally procured	Possible developments
<p>Black-Start: the capacity of a generating plant to move from a condition of total stop to an operating condition, regardless of an external source to supply its auxiliary services, contributing to the process of restoring the electrical system, based on the number of generating units defined by the National Electric System Operator (ONS).</p>	<ul style="list-style-type: none"> - ONS points out the need and technical viability in accordance with the Grid Procedures - need of authorization by the Regulator (ANEEL) - the Ancillary Service Provision Contract (CPSA) must be signed between the ONS and the generator - whenever requested by ONS, a generator has signed a CPSA for Black-Start must provide this service 	<p>Yes</p> <ul style="list-style-type: none"> - The generating plants approved in the tests carried out by the ONS in the previous year will receive annually the Black-Start revenue aiming to recover the additional operation and maintenance costs for the provision of this AS 	<p>Yes</p>	<p>SPS + AGC + Black-Start:</p> <p>R\$ 62 million (US\$ 16 million) in 2019.</p>	<p>Discussion about how to increase the incentive to avoid failures in real situations</p>

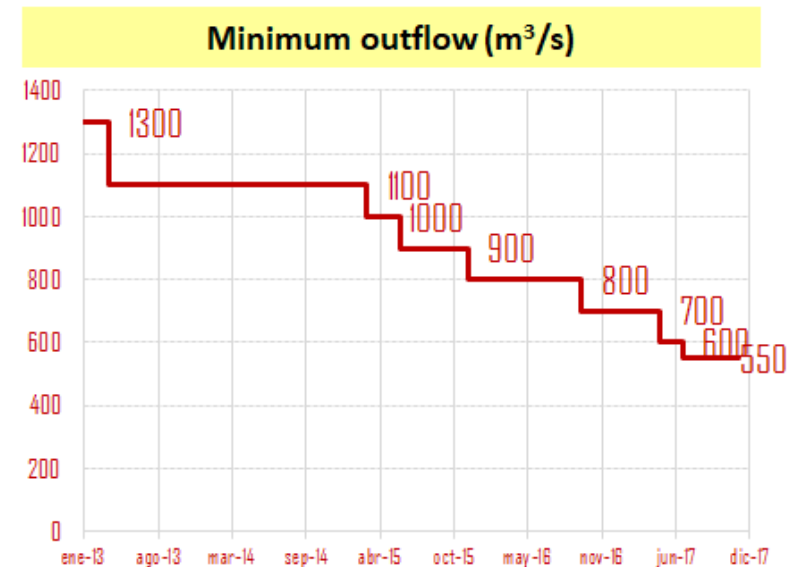
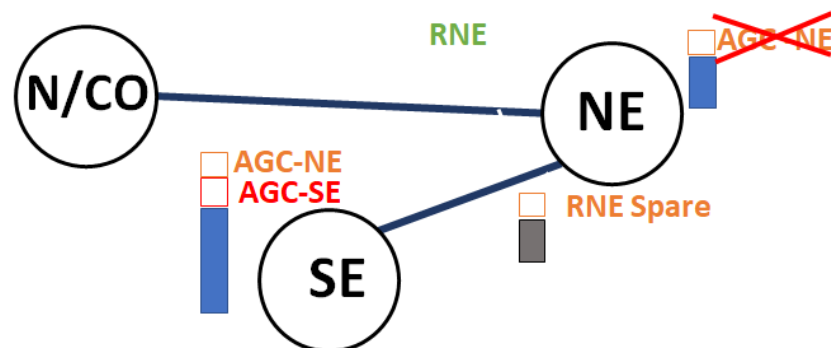
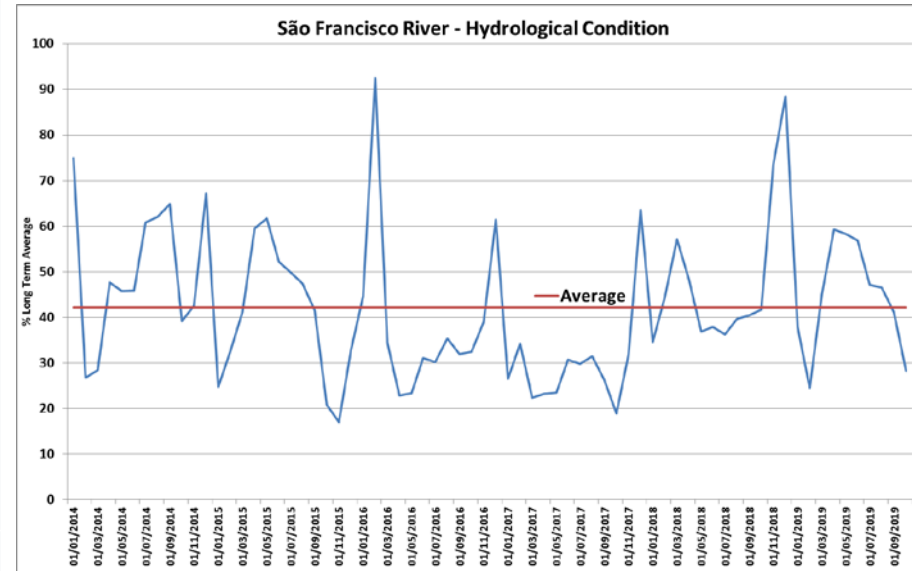
71 HPPs currently with contracts

Medium-Term: Hours to Days

São Francisco River Basin



Flexibility services and products	How are procured?	Are these services compensated?	HPP ?	How much is normally procured
<p>1. Complementary dispatch to maintain the spinning reserve: dispatch of generating units of thermal power plants aiming to preserving the spinning reserve in the hydropower generating units participating in the AGC</p>	<p>Day-Ahead Market</p> <ul style="list-style-type: none"> - The generator must inform the ONS, in the week of operation prior to dispatch, the price offer and operational constraints valid for the following week. - The prices bid must be limited to 130% of the variable operating costs - ONS procures this product daily when elaborating the operating schedule for the following day 	yes	No	R\$ 696 million US\$174 million in 2019
<p>2. Pilot program for a new product: Demand Response - proposed by the Regulator in 2017 (extended in 2019)</p>	<p>Intra-Day and Day-Ahead Market</p> <p>The demand reduction will be valued, for each participant, considering the price of his winning bid and the spot price in each hour of the product offered.</p>	Yes	No	



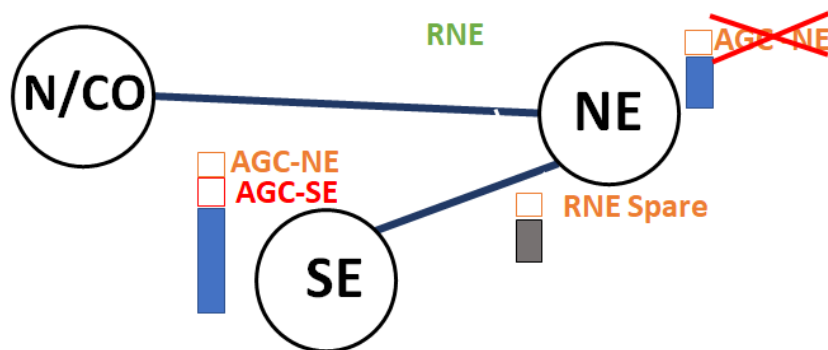
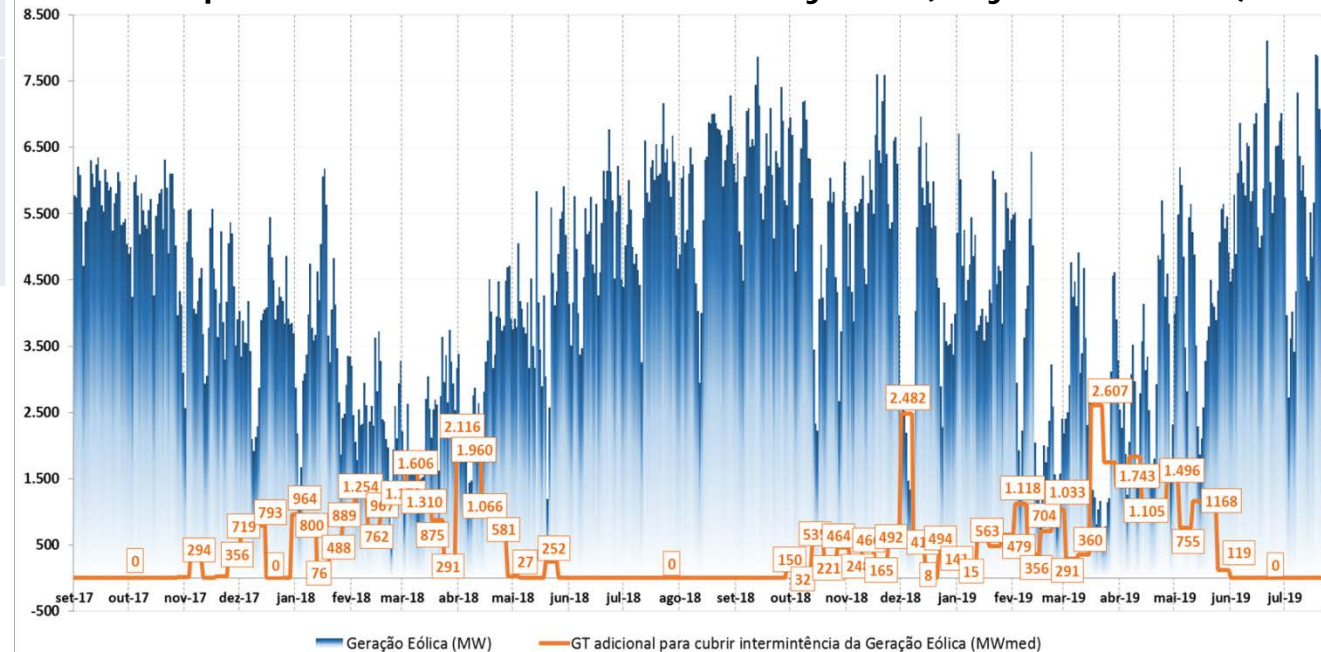
Medium-Term: Hours to Days

São Francisco River Basin



Flexibility services and products	How are procured?	Are these services compensated?	HPP ?	How much is normally procured
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Wind power vs Thermal power complementary dispatch to keep AGC in HPPs - Northeast subsystem (May-17 to Jul-19)

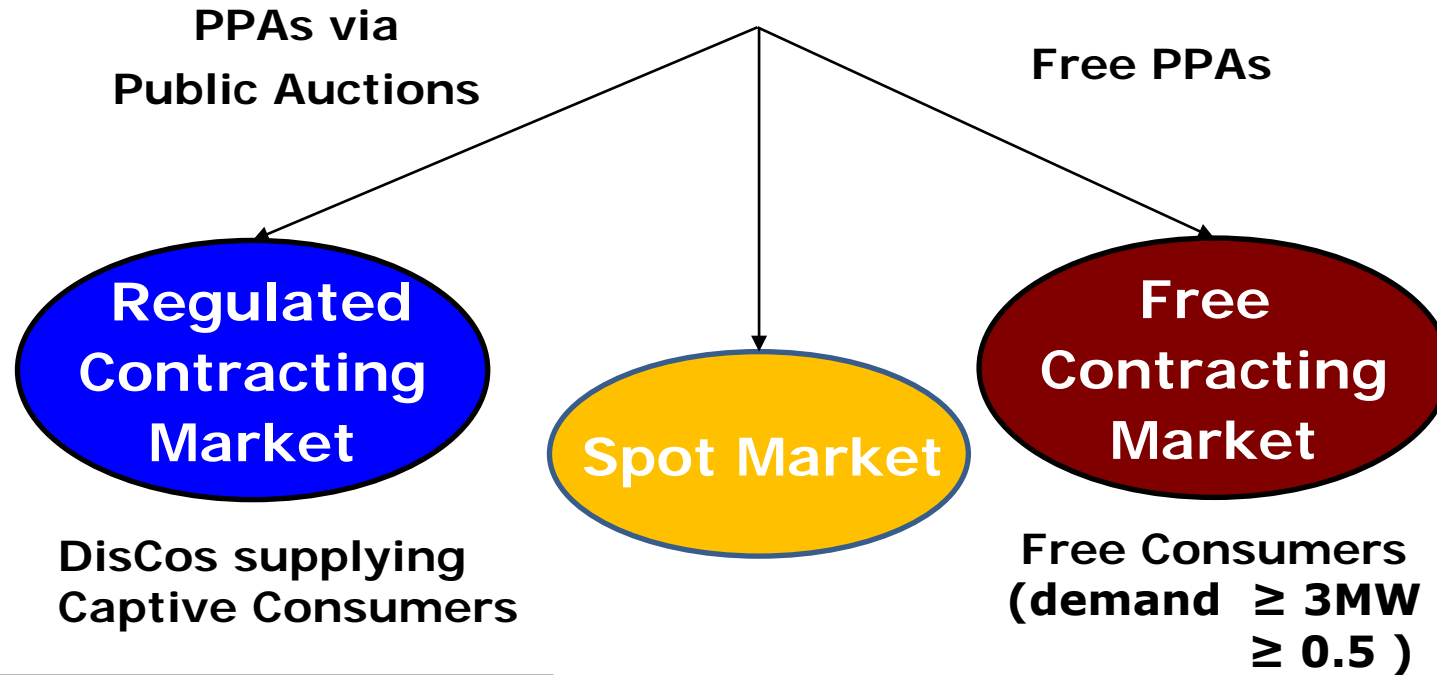


Long-Term: Months to Years

- ❑ Environments for Electricity Trading in Brazil
- ❑ Competition for the long-term market

⇒ System Resource Adequacy

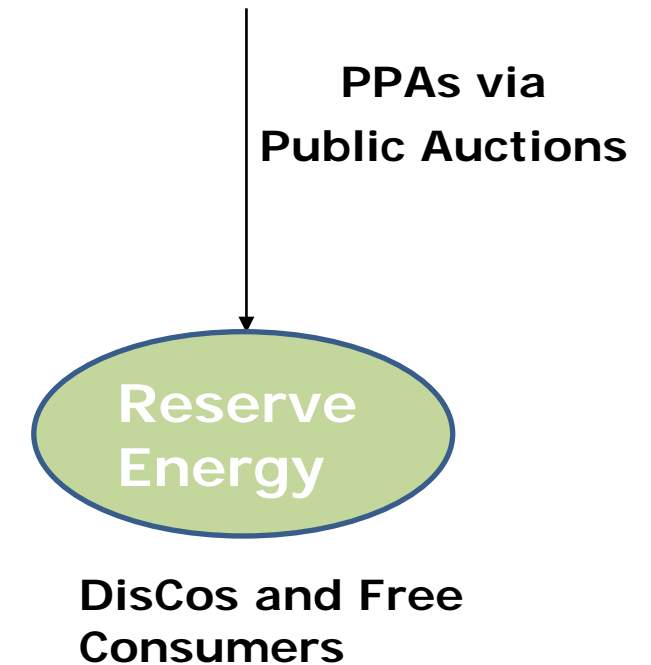
GENERATORS



Public Auctions in which the electrical energy is negotiated through long-term regulated PPAs (15 - 35 years)

Supply and Demand are free to negotiate the terms of PPA

GENERATORS

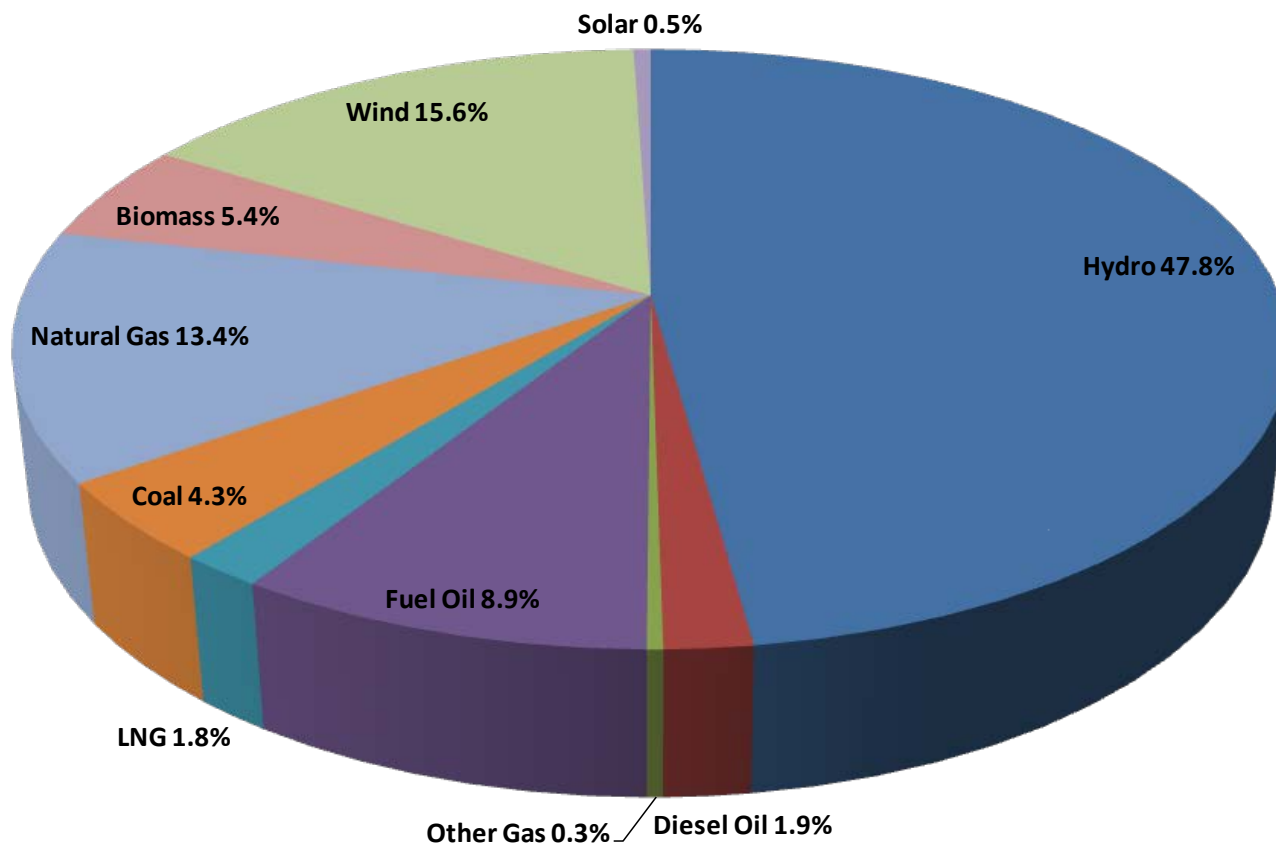


To improve the system security

Results of Public Auctions: 2008 - 2015

- ❑ Environments for Electricity Trading in Brazil
- ❑ Competition for the long-term market

⇒ System Resource Adequacy



Total Capacity Added:
65,479 MW

Financial Allocation:
US\$ 613 billion

70% of the
Energy Traded
and Added to
the System
comes from
Renewables

Source: Brazilian Chamber for Commercialization of Electrical Energy

Includes New Energy Auctions, Renewable Sources Auctions,
Structuring Projects Auctions and Reserve Energy Auctions

Concluding Remarks

Type of Ancillary Service	Need of Sign CPSA	Types of Compensated Costs			Price Bids	By HPP ?
		Fixed Costs	Variable Costs			
			O&M	Active Losses		
Reactive power support / voltage control	No	-	-	-		Yes
Reactive power support - Synchronous Compensator	Yes	x	x	x		Yes
Special Protection Systems (SPS)	Yes	x	x	-		Yes
Primary Frequency Control	No	-	-	-		Yes
Secondary Frequency Control / AGC	Yes	x	x	-		Yes
Black-Start capability	Yes	x	x	-		Yes
Complementary dispatch to maintain the SR/AGC	Yes	-	-	-	x	No
Demand Response - pilot program	Yes	-	-	-	x	No

Hydropower

- provides most of the ancillary services
- is remunerated for the costs incurred instead of the opportunity costs

A Bill on the commercial model of the electric sector is under analysis in the Brazilian Congress

Two key issues regarding Ancillary Services:

- separation between capacity and energy in two products with different prices (currently they are commercialized as a single product)
- introduction of a price bidding procedure in the short-term market (currently, spot prices are calculated based on stochastic optimization models developed by CEPEL)

If approved, room will be opened for the definition of new products for the provision of ancillary services

Thank you!

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Eletrobras
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CEPEL – Centro de Pesquisas de Energia Elétrica
DEA – Energy Optimization and Environment Department