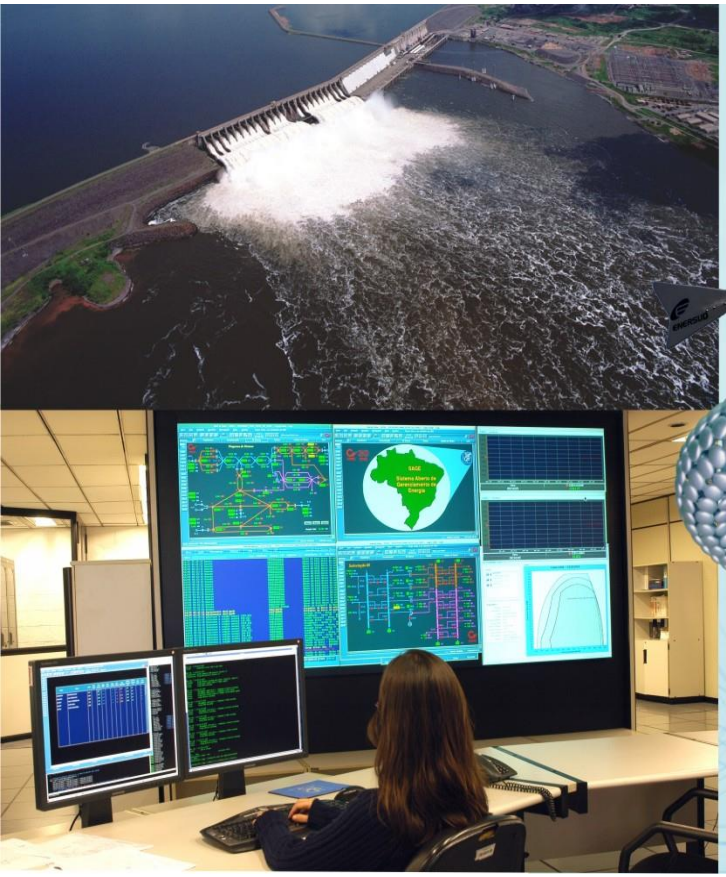
Electric Energy Research Center

Eletrobras Cepel



IEA & EPRI Workshop Electricity Market Design under Long-Term Decarbonisation: Challenges and Opportunities

"Experience in Brazil: how to design auctions in a low carbon power system"

Paris, 8 October 2014

Albert C. G. Melo

DIRECTOR-GENERAL
CEPEL

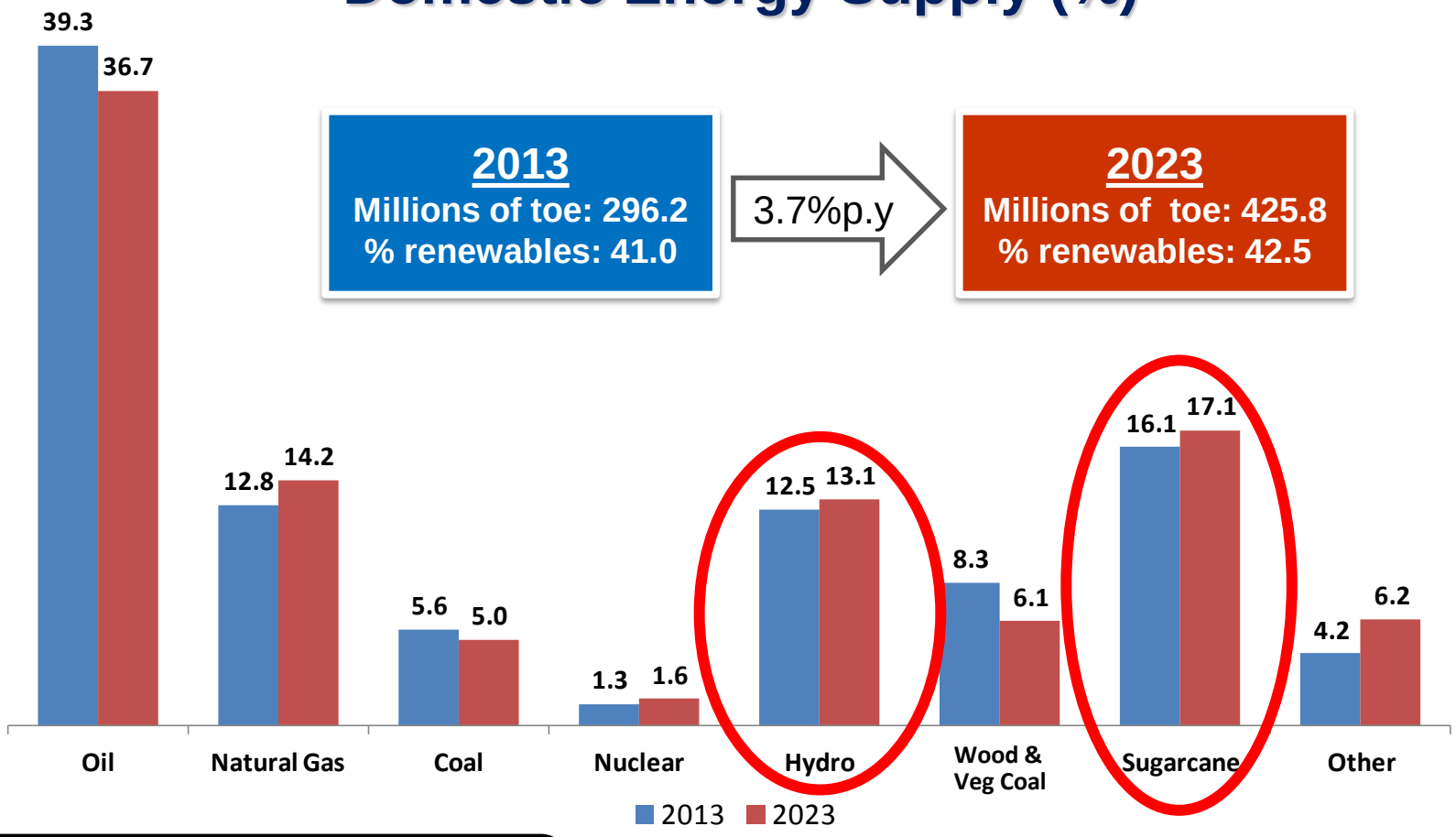
Brazilian Energy Matrix

Domestic Energy Supply (%)

2013
Millions of toe: 296.2
% renewables: 41.0

3.7%p.y

2023
Millions of toe: 425.8
% renewables: 42.5

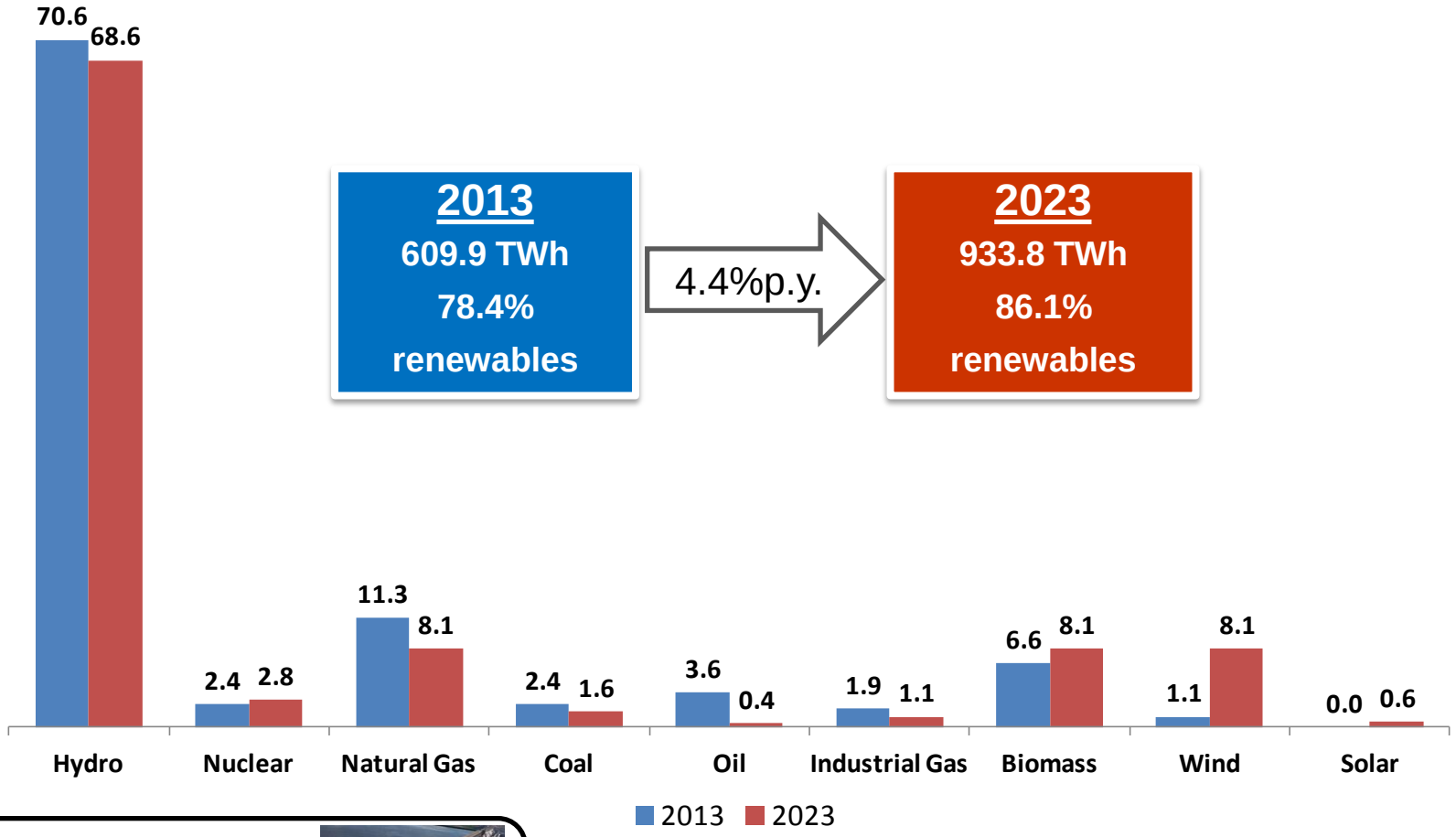


WORLD (2010)
RENEWABLES: 13%

Source: MME/EPE - PDE 2023

Brazilian Electricity Mix

Domestic Electricity Supply (%)



2013
609.9 TWh
78.4%
renewables

4.4%p.y.

2023
933.8 TWh
86.1%
renewables

WORLD (2010)
RENEWABLES: 19%

Source: MME/EPE - PDE 2023

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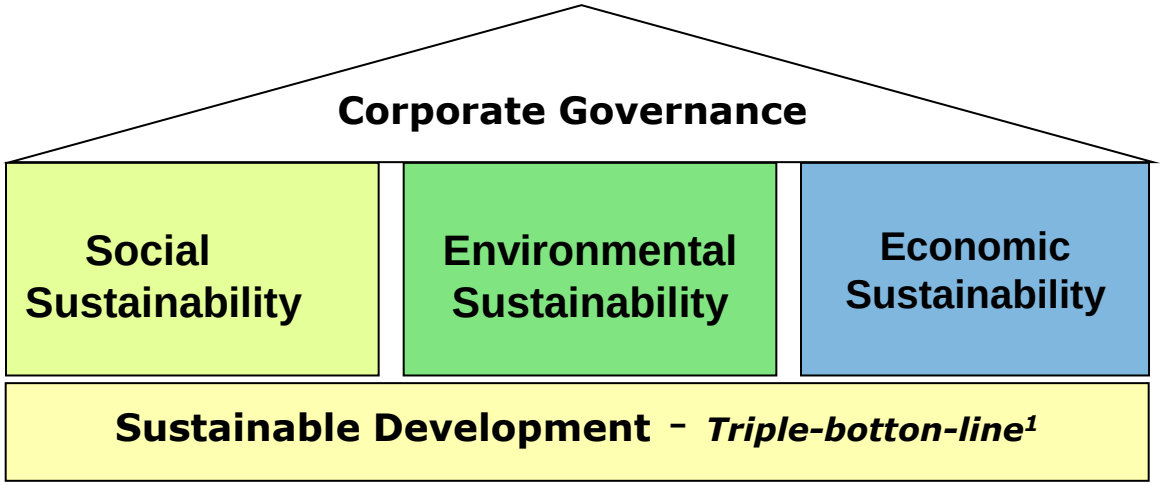
There is no
Sustainable Development
without
Sustainable Energy

Source: MME, EPE, 2010

Sustainability

"Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." ***World Commission on Environment and Development (WCED). Our common future. Oxford: Oxford University Press, 1987***



[1]John Elkington, 1998. Cannibals with forks: The triple bottom line of 21st century business

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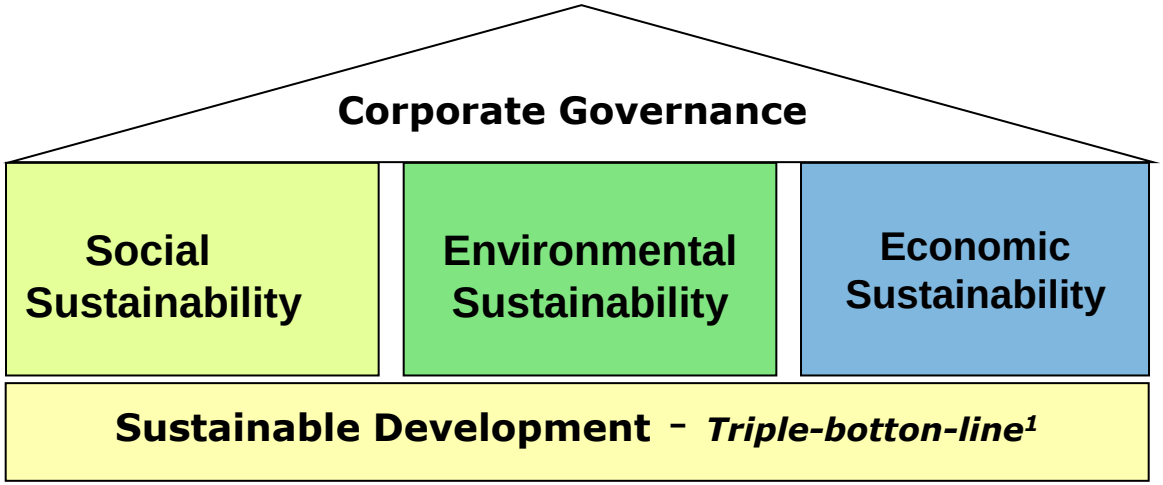

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Quadruple-Bottom-Line? (Policy Framework & Market Design)

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The Brazilian Approach

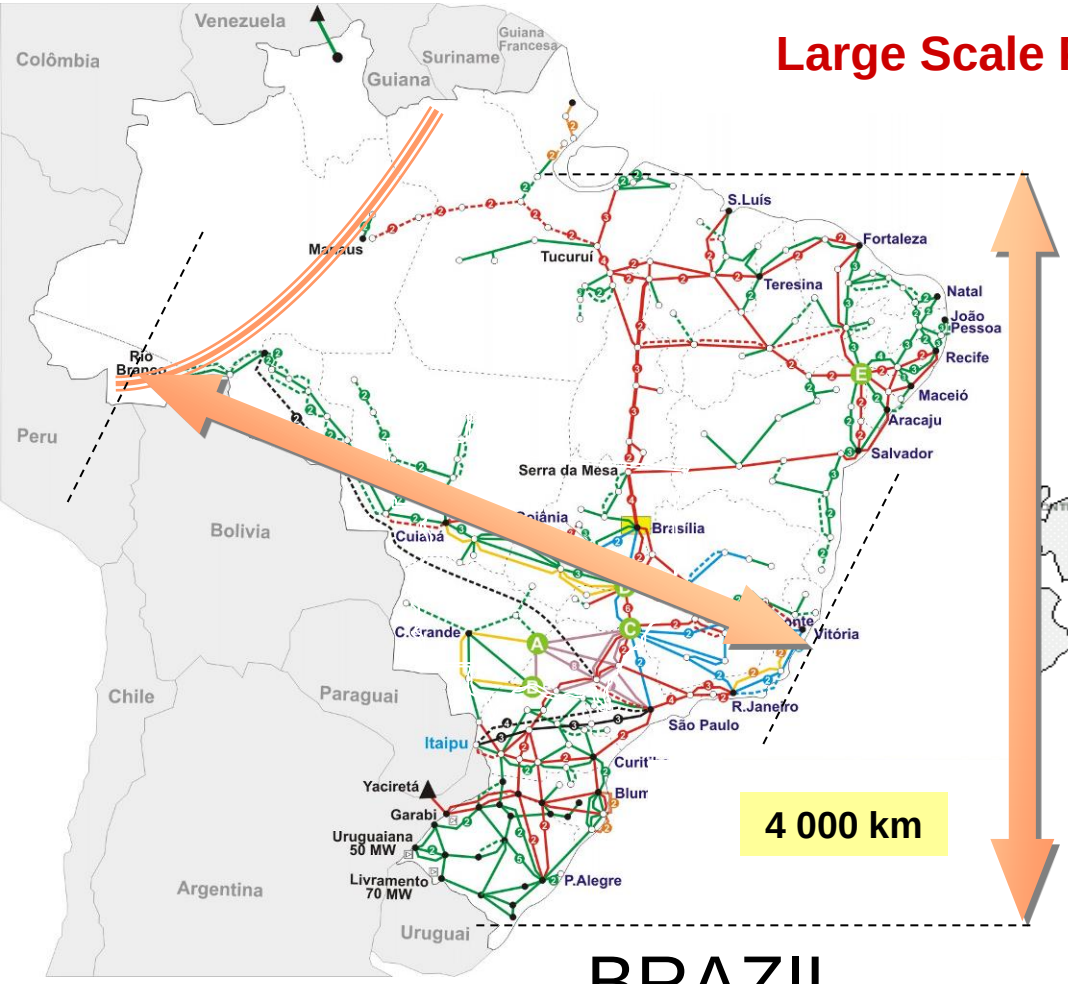
Policy Framework and Market Design

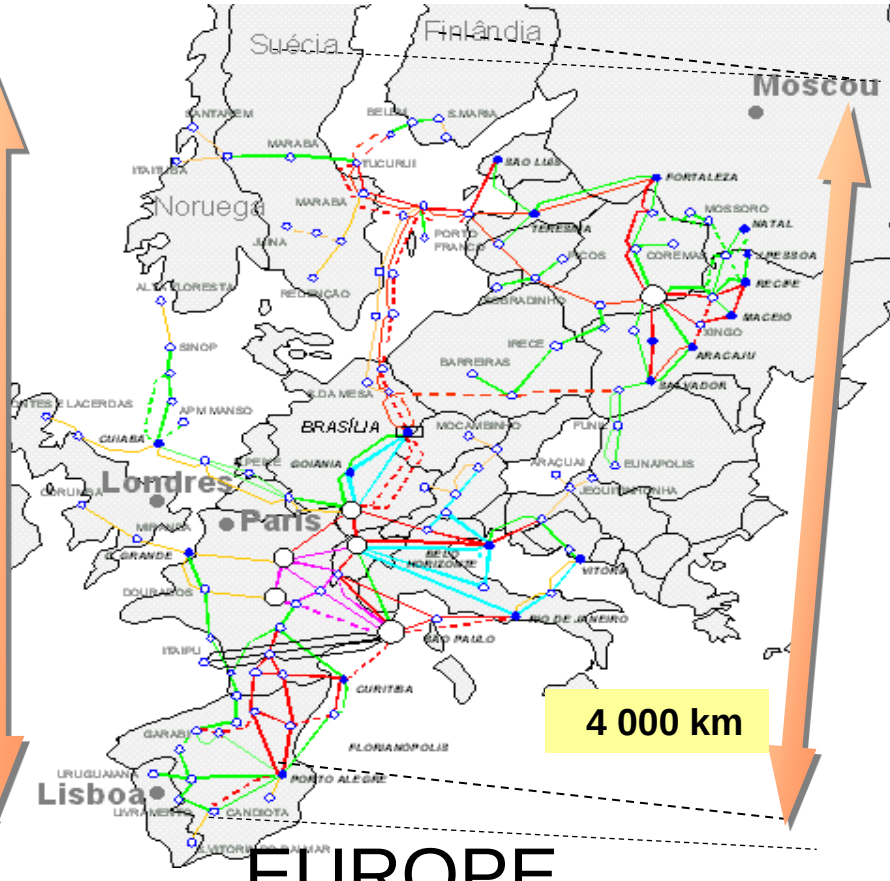
- **Should consider country circumstances**

Brazilian Transmission System

Continental Dimension

Large Scale Power System





BRAZIL EUROPE

Hydroelectric Interdependence

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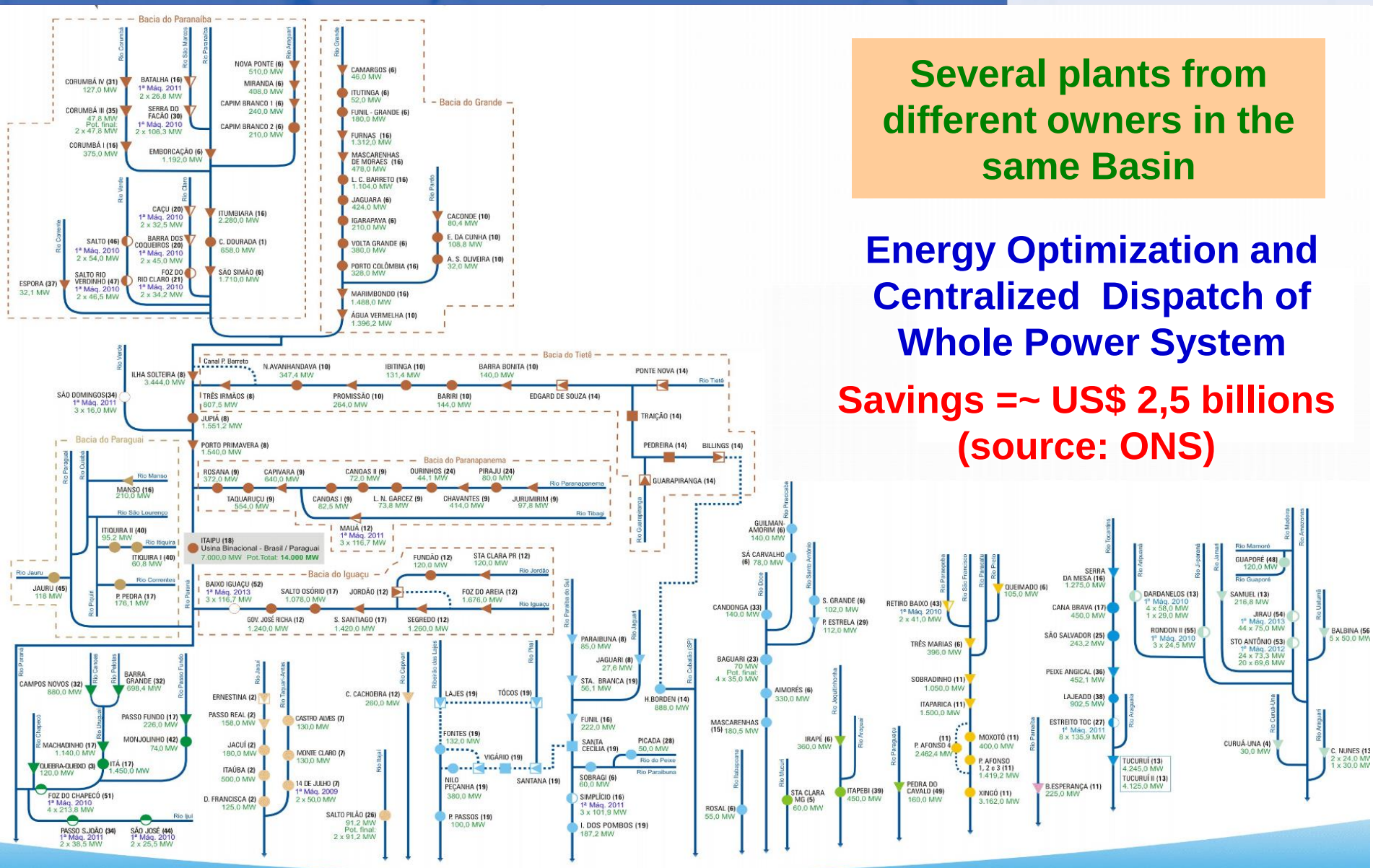

Several plants from different owners in the same Basin

Energy Optimization and Centralized Dispatch of Whole Power System

Savings =~ US$ 2,5 billions (source: ONS)

Environmental Conservation and Indigenous Areas in the Brazilian Amazon

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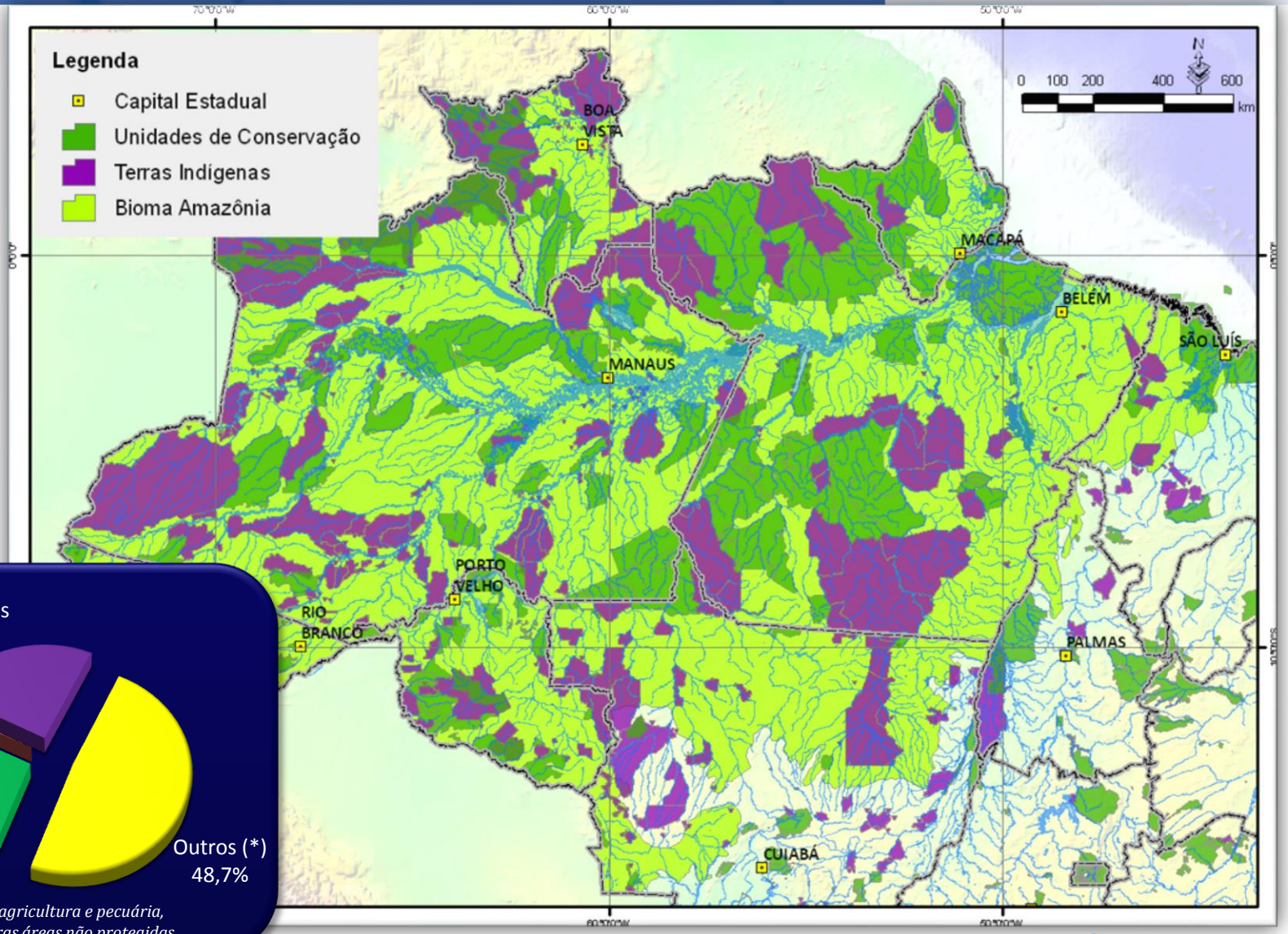

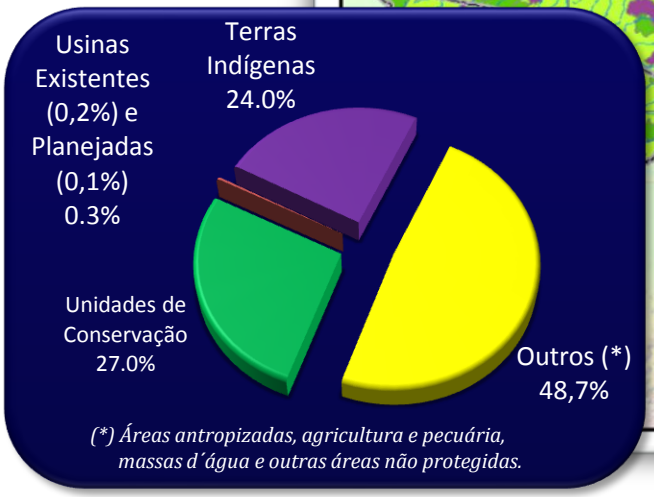

(*) Áreas antropizadas, agricultura e pecuária, massas d´água e outras áreas não protegidas.

Source: EPE

Policy Framework and Market Design

- **Should consider country circumstances**
  - Brazil main features
    - Territorial Extension 8,514,876 km²; Population (2014) : 200.2 million
    - GDP 2013 US$ 2.3 trillion
  - Installed capacity (Sep 2014) 131 GW
    - Hydro: 67 % (Capacity); 75-90% (Power production)
    - Thermal: 30 %
    - Wind: 3 %
    - will double in the next 15 years
  - Transmission lines 110,000 km
  - Consumption (2014 est.) 530 TWh
    - Load growth rate: 4% to 5% per year

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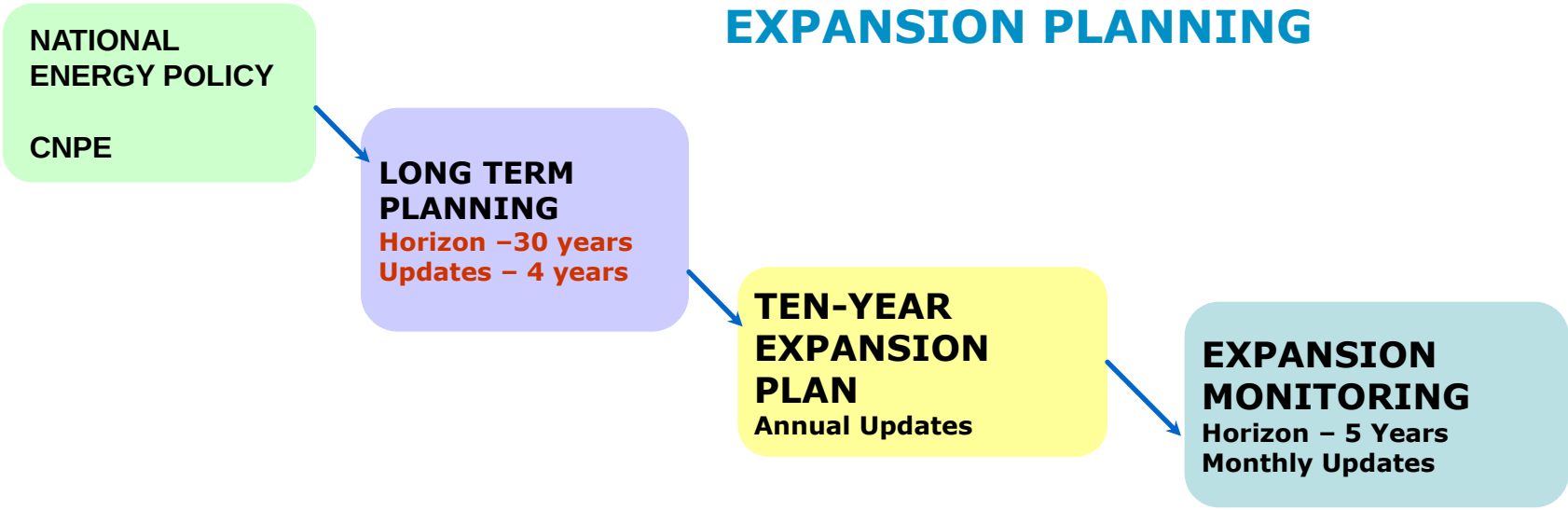
➔ Continental country
➔ Large renewables potential
➔ Hydro-dominated
➔ Rapidly expanding

  - Importance of tools for
    - Expansion Planning
    - Hydrothermal centralized dispatch, considering hydrological diversity

Policy Framework – Stages for Coordinated Expansion Planning

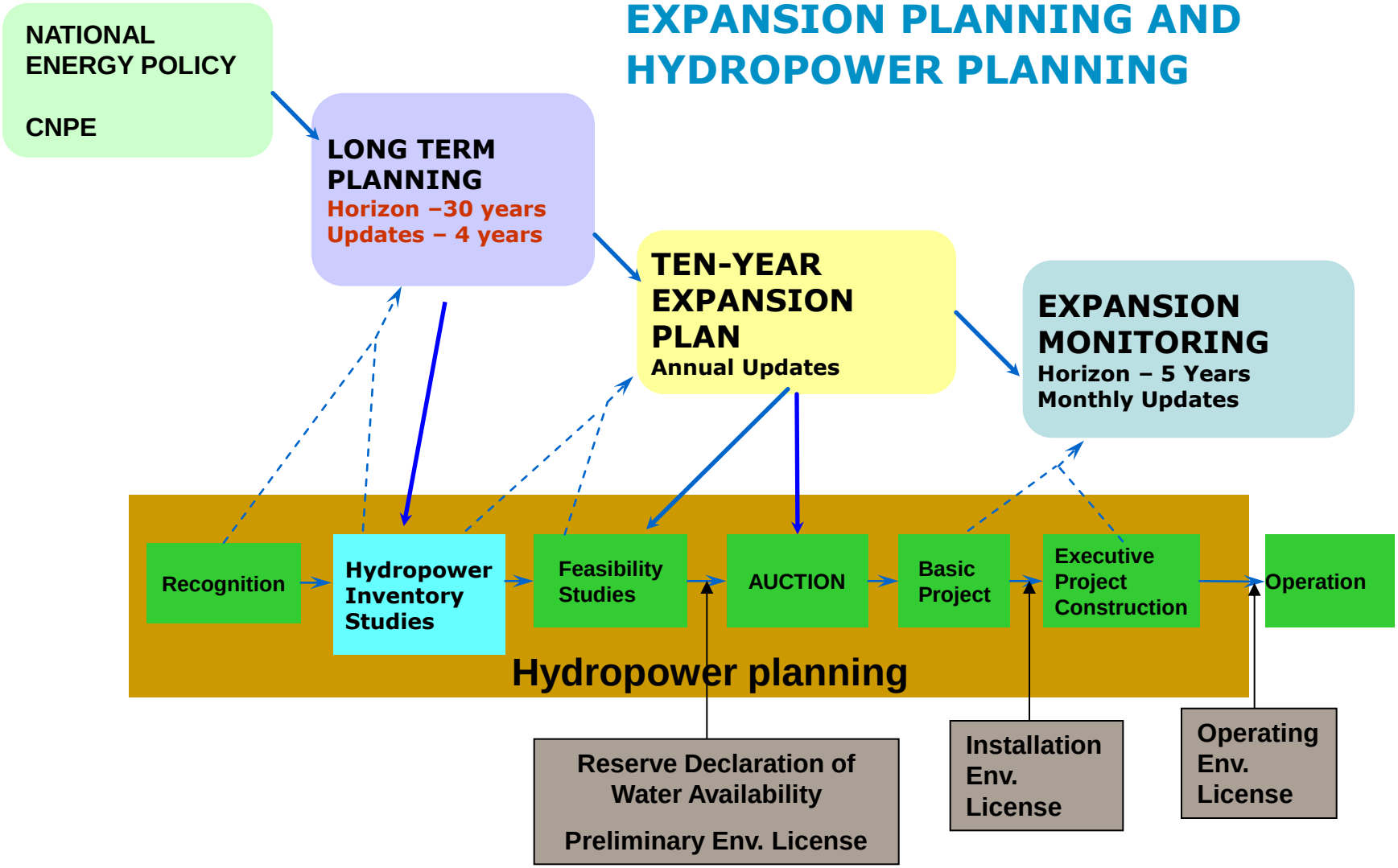
BRAZILIAN NATIONAL POWER SYSTEM EXPANSION PLANNING



Policy Framework – Stages for Coordinated Expansion Planning and Sustainable Hydropower Development

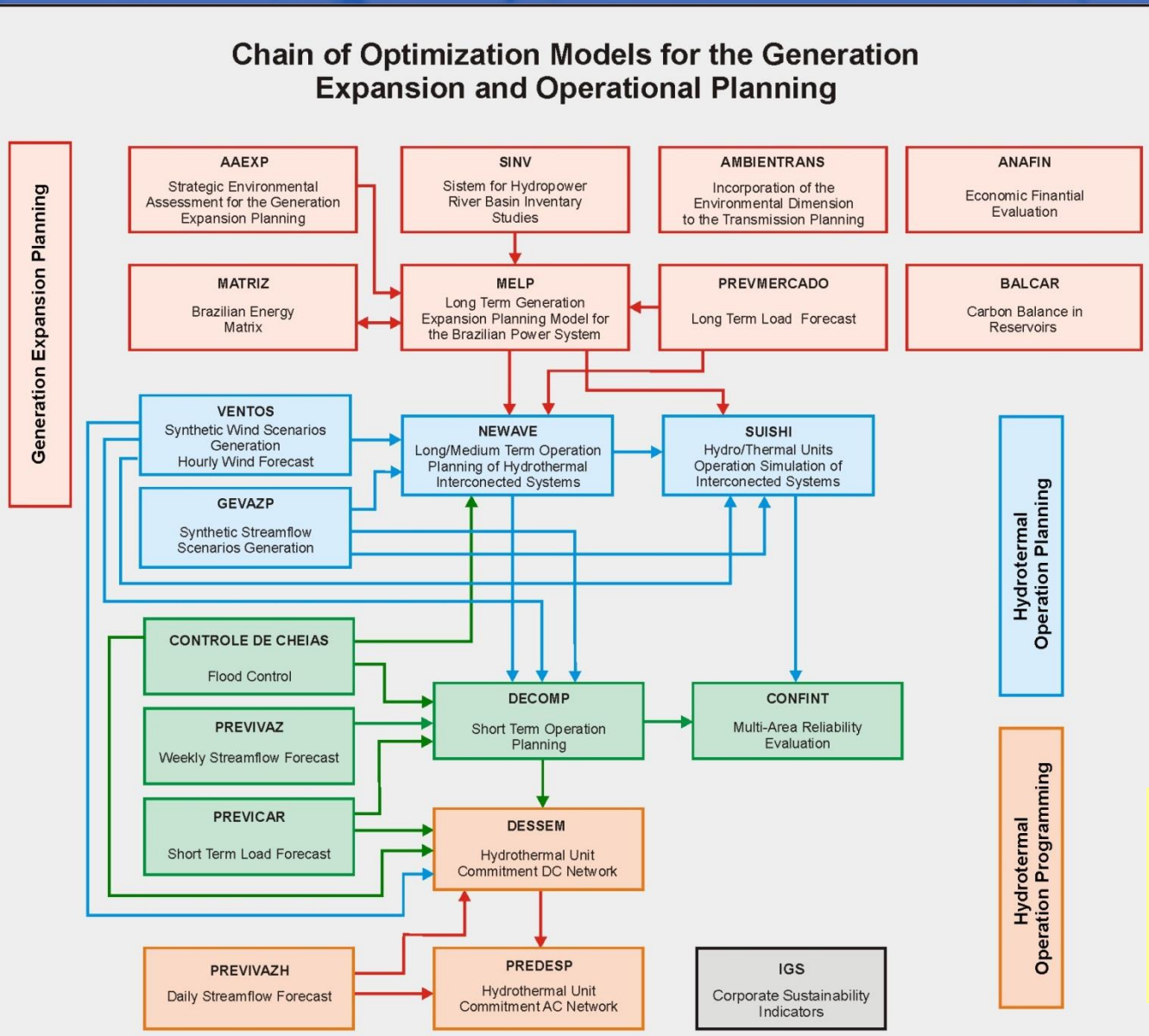
Eletrobras Cepel

BRAZILIAN NATIONAL POWER SYSTEM EXPANSION PLANNING AND HYDROPOWER PLANNING



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

Eletrobras Cepel

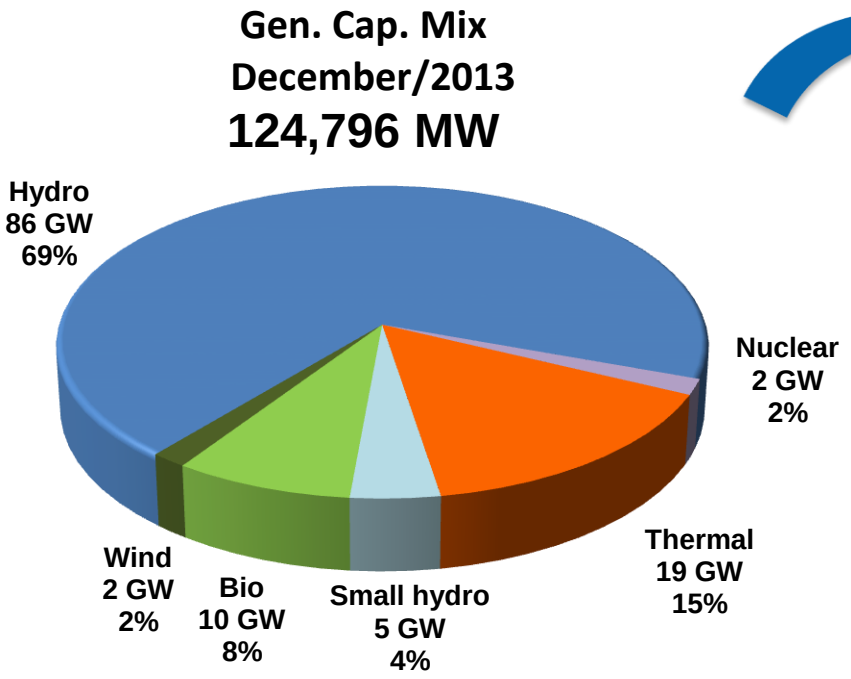


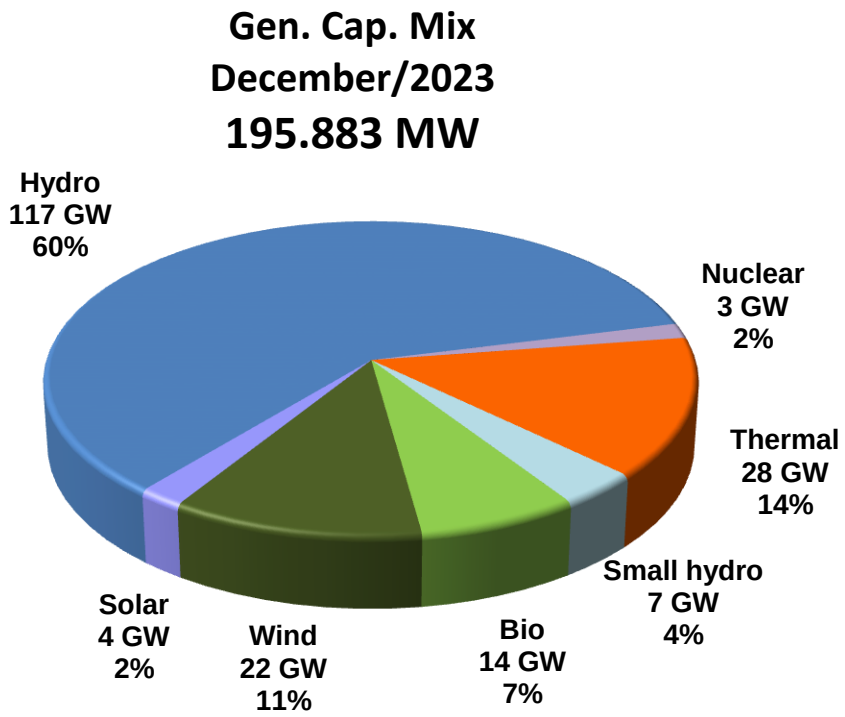
Energy Optimization and Centralized Dispatch of the Whole Interconnected Hydrothermal System:

20% More Energy Production

Need of capturing synergies in planning and operation stages

Ten-Year Expansion Planning of the Generation Capacity (GW)





Note1: Includes import
Note2: Excludes self-production

Source: MME/EPE - PDE 2023

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The Brazilian Auctions Mechanism

Previous Environment (Until 2003)

- **The development of a hydropower project was granted to that one that offered to the Government the largest monetary value for this**
  - He assumed the obligation to seek " loads ", ie, distributors and free consumers
  - to establish a long-term contract for the purchase of energy (PPA)
- **However, in a system with predominantly hydroelectric production**
  - most of the time, the operation marginal costs are low
  - if the loads had established PPAs with generators , they would have to pay higher long-term prices
- **The loads decided to act as "free-riders"**
  - and to not establish PPAs with generators
  - once there was no real obligation to be the long-term contracted
- **With no PPAs**
  - generators were unable to obtain financing for the implementation of the plants
  - the expansion of generation capacity required to meet the demand growth did not materialize.
- **This structural imbalance was a Key issue that led to the electricity rationing in 2001/2002**

A Key Feature of the 2004 Electrical Sector Reform

- Introduction of competition for the Long-Term market
- Electricity Contracting Environments

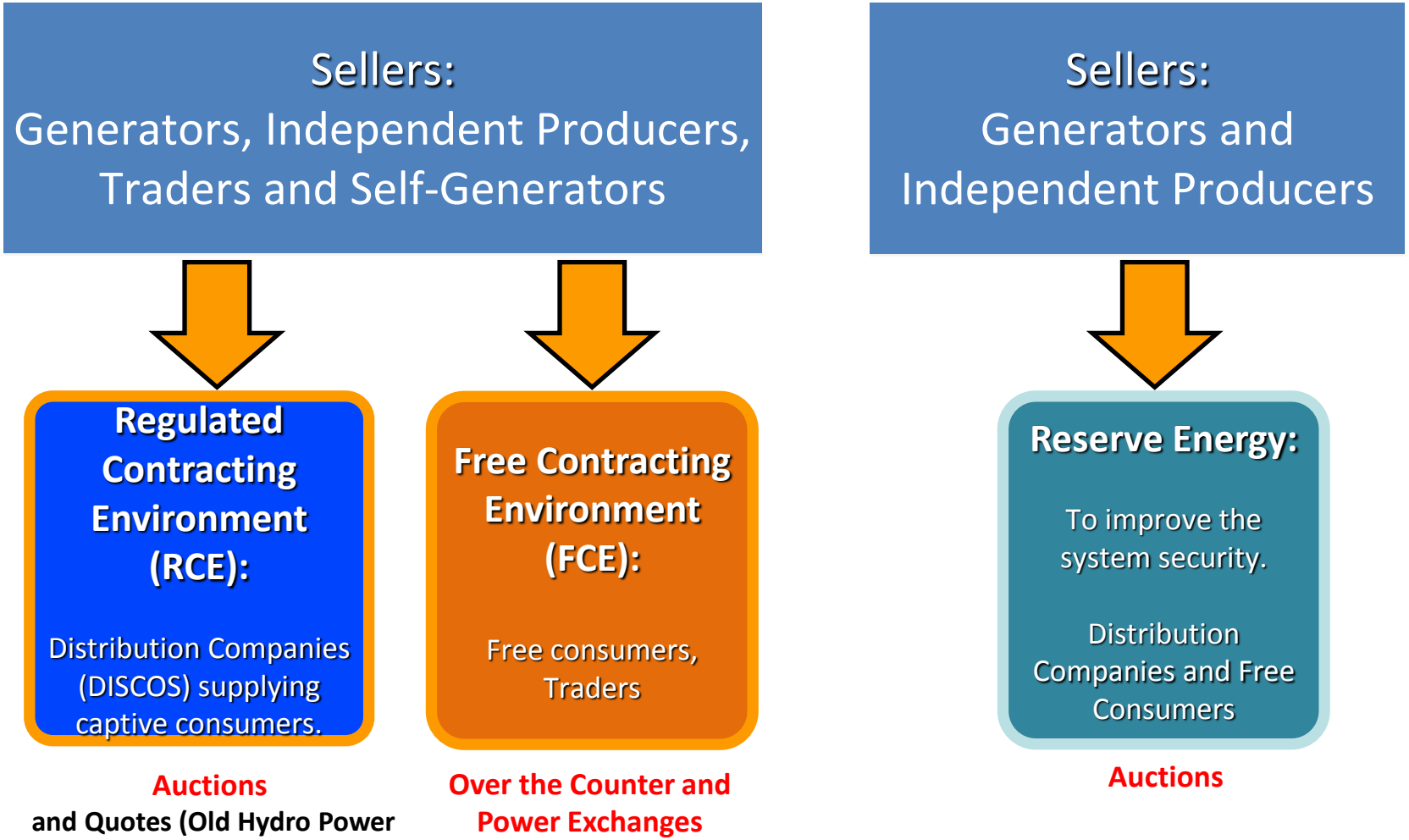

Figure - Source: CCEE

A Key Feature of the 2004 Electrical Sector Reform

- Introduction of competition for the *Long-Term* market
- Loads have now to be 100 % contracted
  - Regulated (captive) consumers, supplied by Discos
  - Free consumers

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Eletrobras Cepel

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- All contracts, which are financial instruments, must be covered by real power production capacity
  - defined by a "plate number" called *Assured Energy Certificate – AEC*
  - need to present *Fuel Supply Purchase Agreement*

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- Public auctions were introduced as a procurement mechanism for purchasing energy for captive consumers
  - the winner in auctions is the one that offers the lowest price per kWh
  - in exchange, all distributors have an obligation to enter into Long-Term PPAs with each auction winner
  - this future cash flow can be used to obtain loans from banks
  - hydros need the Preliminary Environment License to go to Auctions
  - role of the Brazilian National Development Bank (BNDES)
  - dedicated auctions for *Structuring Projects* or *Specific Technologies* is allowed

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  - role of the Brazilian National Development Bank (BNDES)
  - dedicated auctions for *Structuring Projects* or *Specific Technologies* is allowed
- Free consumers can procure their energy needs as they please
  - as long as they remain 100% contracted

Public Auctions

- Auction prices are then passed on to electricity tariffs

- In the Regulated Contracting Environment there are separate auctions to
  - procure new energy or
  - renew existing contracts (from existing power plants)

Public Auctions

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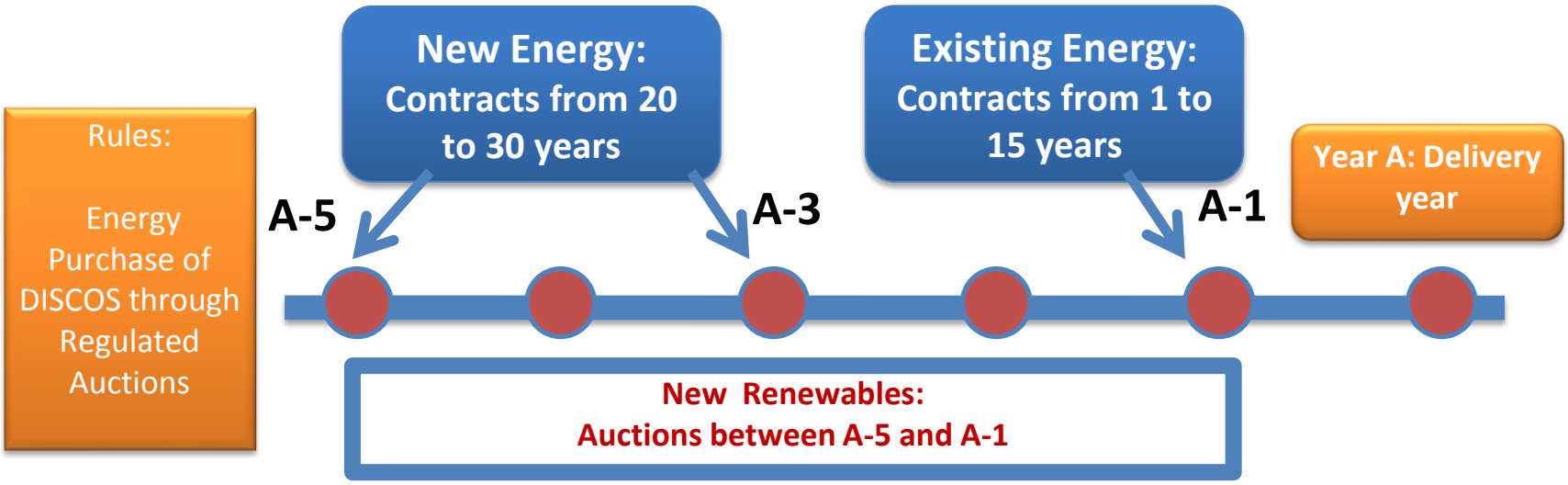
- There are two types of contracts: quantity or availability
  - Quantity: It is a standard financial forward contract, where generators bid an energy price of R$/MWh for their AECs
    - generators bear all the risks from the coordinated operation of the hydrothermal generation system
  - Availability: It is a typical call option, where generators receive an option premium in R$/year (paid in 12 monthly installments) to remain available to the dispatch.
    - the captive consumers bear the hydrological risk pay the operational cost every time the generator is dispatched
    - this operational cost works as an energy strike price

Public Auctions



Buyers: Distribution Companies

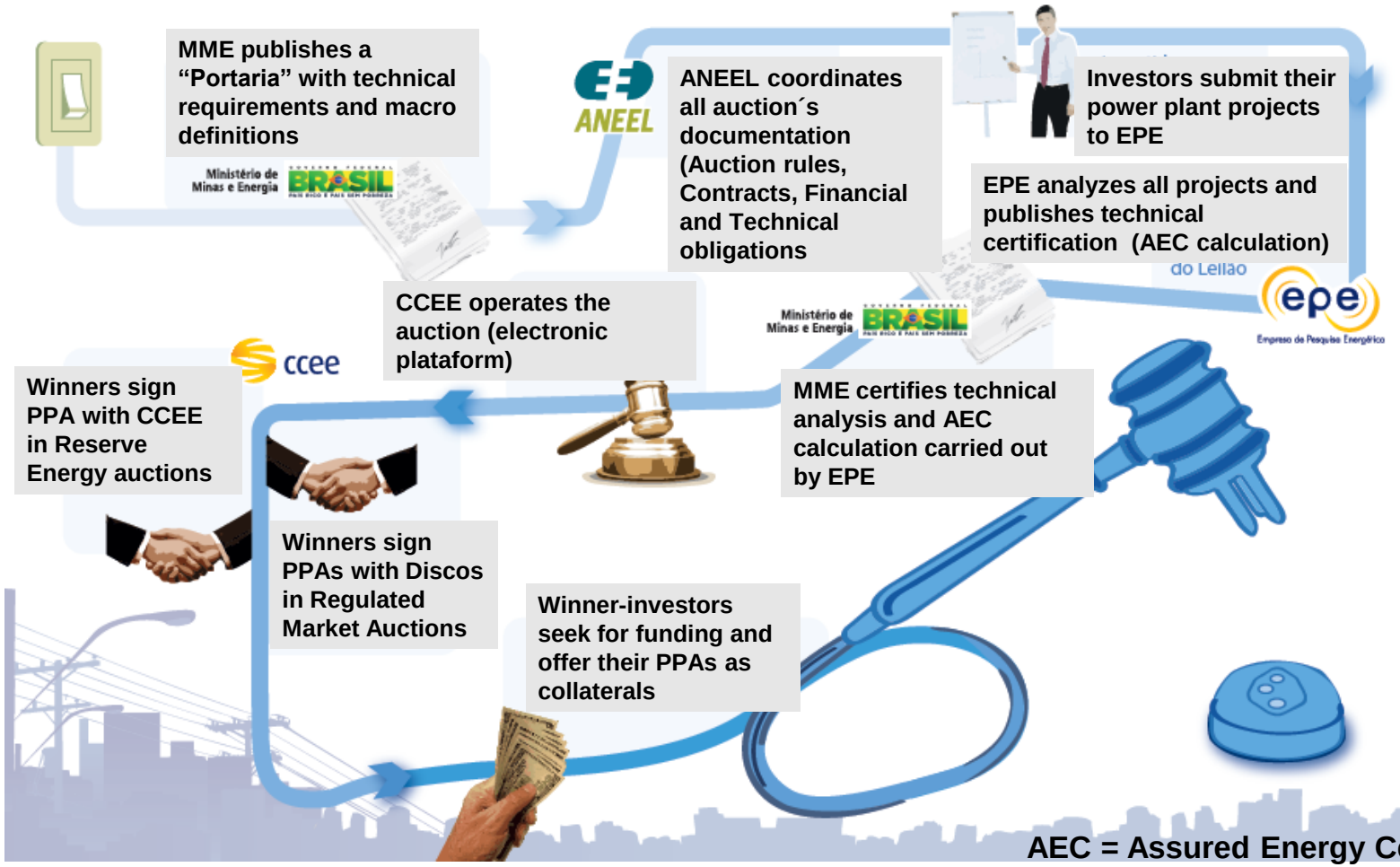
- Auction works centralized with DISCOS declaring their needs to cover the load.
- Obligation to cover 100% of the load

Sellers: Generators technically qualified by EPE or ANEEL

- Hydro: Contracts of 30 years
- Thermal, Wind, PV and Biomass: Contracts of 20 or 25 years

Public Auctions

How auctions are operated?

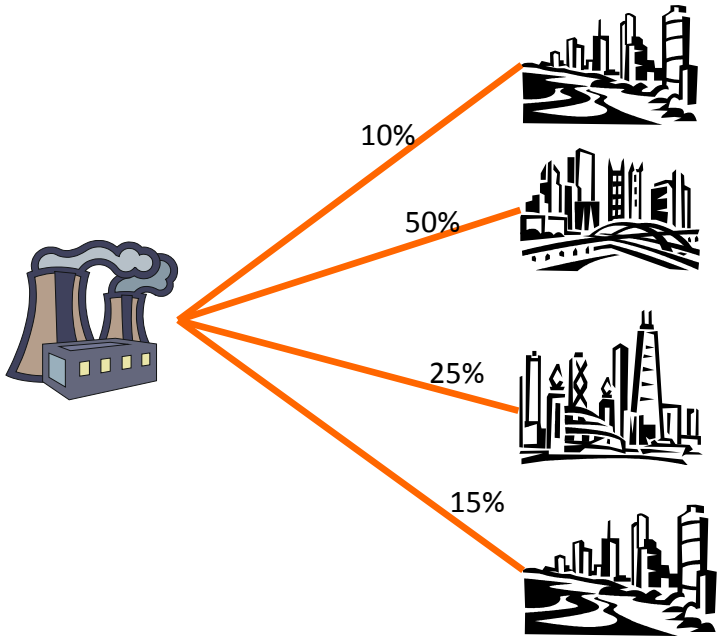


AEC = Assured Energy Certificate

Source: CCEE

Public Auctions – Contracts Guarantees

- Winners sign direct bilateral contracts with the Discos, despite of the centralized auction
  - in proportion to their declared load forecasts (Pool Contracting scheme)
  - small Discos benefit from economy of scale of the centralized auction scheme
  - *Portfolio* approach



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Eletrobras Cepel

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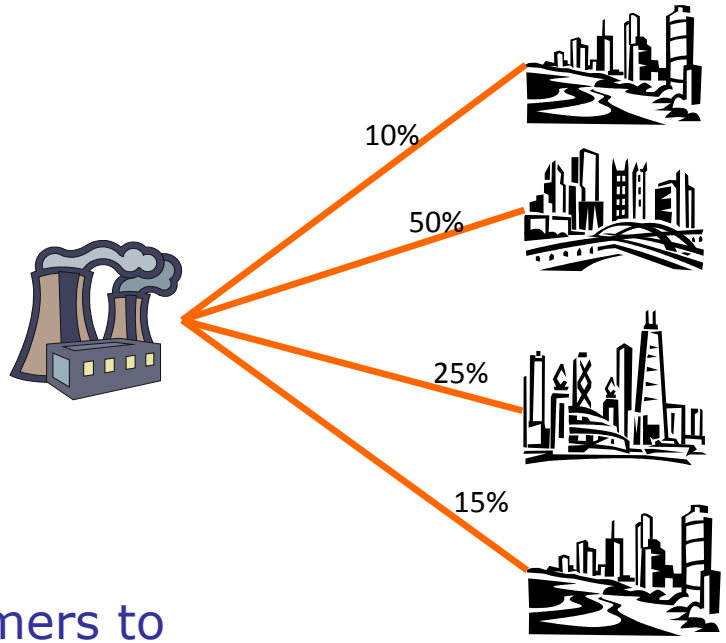
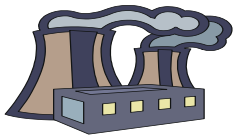


- There is another contract attached which is called *Guarantee Linked Contract (CCG)*
  - it transfers the money from end-Customers to Generator
  - avoids the Discos of making discretionary payment
  - minimizes the default risk of Generators


Generator

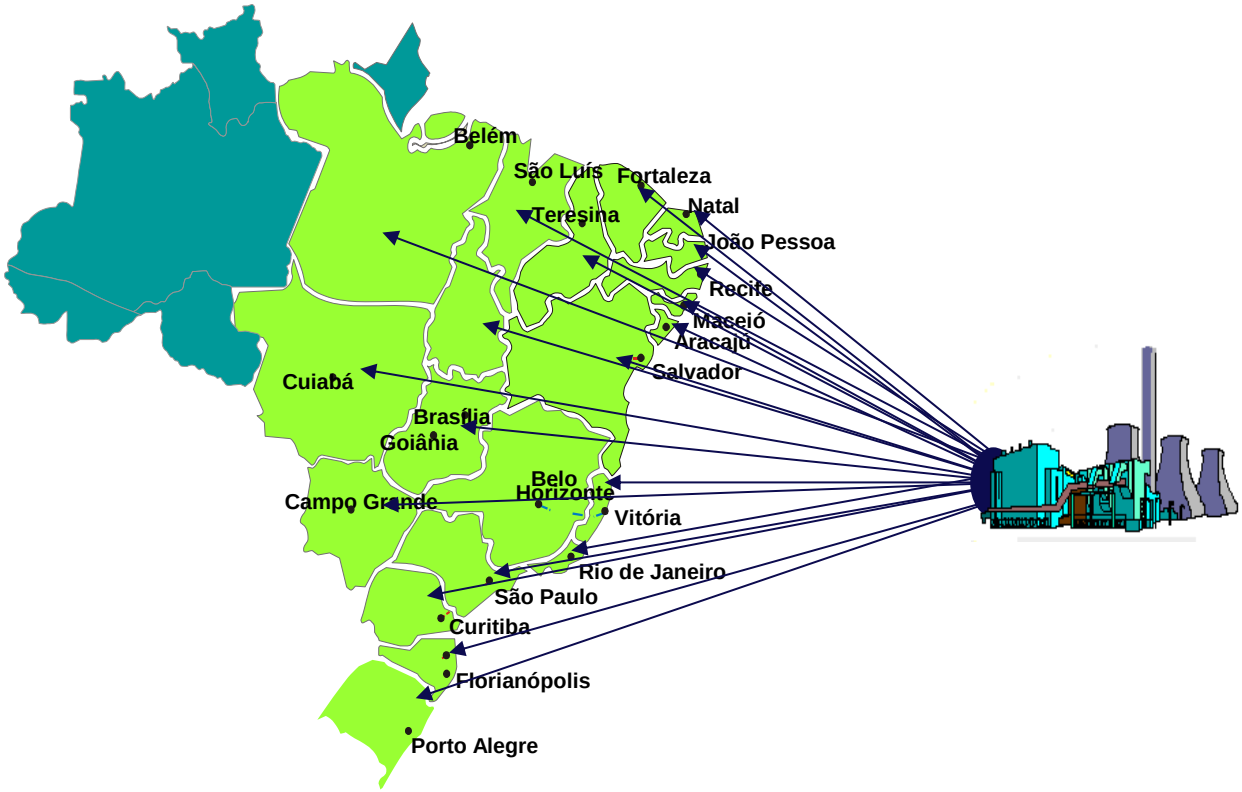

Distributor


Customers

Public Auctions – Contracts Guarantees

- Government
  - does not interfere with the demand forecasts, which are directly declared by distribution companies
  - nor does it take ownership for the energy contracts
  - nor provides payment guarantees

- It is not a typical single buyer model



Auction Mechanism

- Brazil has mainly used two different hybrid design formats for electricity auctions
  - Sealed-bid and Continuous
  - Descending clock and pay-as-bid (discriminatory auction)

- Sealed-bid and Continuous
  - is used to competition for concession rights of *Medium/Large Hydro Plants*

- Descending clock and pay-as-bid
  - is normally used to contracting of Small Hydro Plants, Winds, Solar, Biomass, Gas, Oil and Coal

- The majority of Brazilian auctions are done electronically by internet

Public Auctions

- Auctions act as the main driver to promote efficient purchases by distribution companies when acting on behalf of captive consumers

- Since 100% of the load needs to be contracted, the *spot market* serves to settle (positive or negative) differences between
  - a plant's actual production, scheduled by the System Operator, and its energy Assured Energy Certificate
  - a load actual consumption and its contracted energy

- The cleared price in the Spot Market is the *short run marginal cost*

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The Brazilian Auctions Mechanism

- Some Results

Results – New Energy Auctions

Date	Period of Supply	Source	Installed Capacity (MW)	Energy (TWh)	Average Price		Average Current Price		Current Financial Allocation	
					(R$/MWh)	(US$/MWh)	(R$/MWh)	(US$/MWh)	(R$ Billion)	(US$ Billion)
16/12/2005	2008 - 2022 2009 - 2023 2010 - 2024 2008 - 2037 2009 - 2038 2010 - 2039	B, NG, DO B, C, NG, DO C, NG H H H	13,020.9	564.0	121.20	60.60	189.71	94.86	107.0	53.5
29/06/2006	2009 - 2023 2009 - 2038	B, NG, FO, DO H	7,049.7	356.3	128.95	64.48	198.79	99.40	70.8	35.4
10/10/2006	2011 - 2025 2011 - 2040	B, NG, FO, DO H	3,151.5	220.0	128.90	64.45	197.17	98.59	43.4	21.7
26/07/2007	2010 - 2024	FO	1,791.4	171.5	134.67	67.34	199.74	99.87	34.3	17.1
16/10/2007	2012 - 2026 2012 - 2041	C, NG, FO H	4,616.0	398.0	128.73	64.37	189.12	94.56	75.3	37.7
17/09/2008	2011 - 2025	NG, FO	1,935.4	141.5	128.42	64.21	178.10	89.05	25.2	12.6
30/09/2008	2013 - 2027 2013 - 2042	B, C, NG, FO H	5,566.5	426.8	141.78	70.89	196.63	98.32	83.9	42.0
27/08/2009	2012 - 2026 2012 - 2041	B H	70.5	1.6	144.50	72.25	192.52	96.26	0.3	0.2

Source: Brazilian Ministry of Mines and Energy; Brazilian Chamber for Commercialization of Electrical Energy
Reference date for current values: august/2014 (IPCA)
Exchange rate: 2 R$/US$

Results – New Energy Auctions

Eletrobras Cepel

Date	Period of Supply	Source	Installed Capacity (MW)	Energy (TWh)	Average Price		Average Current Price		Current Financial Allocation	
					(R$/MWh)	(US$/MWh)	(R$/MWh)	(US$/MWh)	(R$ Billion)	(US$ Billion)
30/07/2010	2015 - 2044	H	808.9	67	99.48	49.74	126.90	63.45	8.5	4.3
17/12/2010	2015 - 2044	H	2,928.9	340.6	67.31	33.66	83.58	41.79	28.5	14.2
17/08/2011	2014 - 2044 2014 - 2034	H B, W, NG	2,744.6	285.5	102.07	51.04	121.38	60.69	34.7	17.3
20/12/2011	2016 - 2046 2016 - 2036	H B, W	1,211.5	104.5	102.18	51.09	119.14	59.57	12.5	6.2
14/12/2012	2017 - 2047 2017 - 2037	H W	574.3	66.2	91.25	45.63	100.52	50.26	6.7	3.3
29/08/2013	2018 - 2048 2018 - 2043	H B	1,265.5	165.2	124.97	62.49	133.43	66.72	22.0	11.0
18/11/2013	2016 - 2036	W	867.6	58.3	124.43	62.22	130.62	65.31	7.6	3.8
13/12/2013	2018 - 2048 2018 - 2043 2018 - 2038	H B W	3,507.4	325.6	109.93	54.97	114.34	57.17	37.2	18.6
06/06/2014	2017 - 2047 2017 - 2037	H W	968.6	80.6	126.18	63.09	127.01	63.51	10.2	5.1

Source: Brazilian Ministry of Mines and Energy; Brazilian Chamber for Commercialization of Electrical Energy
Reference date for current values: august/2014 (IPCA)
Exchange rate: 2 R$/US$

Total Energy Traded in the New Energy Auctions: **3,773 TWh**

Results – Dedicated Renewable Sources Auctions

Date	Period of Supply	Source	Installed Capacity (MW)	Energy (TWh)	Average Price		Average Current Price		Current Financial Allocation	
					(R$/MWh)	(US$/MWh)	(R$/MWh)	(US$/MWh)	(R$ Billion)	(US$ Billion)
18/06/2007	2010 - 2024 2010 - 2039	B H	549.1	30.5	137.32	68.66	204.16	102.08	6.2	3.1
26/08/2010	2013 - 2042 2013 - 2032	H B, W	1,685.6	129.4	135.48	67.74	172.76	86.38	22.4	11.2

Source: Brazilian Ministry of Mines and Energy; Brazilian Chamber for Commercialization of Electrical Energy
Reference date for current values: august/2014 (IPCA)
Exchange rate: 2 R$/US$

Total Energy Traded in the New Energy Auctions and Renewable Sources Auctions: **3,933 TWh**

Results – Structuring Projects Auctions

Date	Period of Supply	Source	Installed Capacity (MW)	Energy (TWh)	Average Price		Average Current Price		Current Financial Allocation	
					(R$/MWh)	(US$/MWh)	(R$/MWh)	(US$/MWh)	(R$ Billion)	(US$ Billion)
10/12/2007	2012 - 2041	H	3,150.4	379.2	78.87	39.44	114.59	57.30	43.5	21.7
19/05/2008	2013 - 2042	H	3,300.0	348.6	71.37	35.69	100.78	50.39	35.1	17.6
20/04/2010	2015 - 2044	H	11,233.1	794.9	77.97	38.99	99.90	49.95	79.4	39.7

Source: Brazilian Ministry of Mines and Energy; Brazilian Chamber for Commercialization of Electrical Energy
Reference date for current values: august/2014 (IPCA)
Exchange rate: 2 R$/US$

Total Energy Traded in the New Energy Auctions, Renewable Sources Auctions and Structuring Projects Auctions: **5,456 TWh**

Results – Energy Reserve Auctions

Date	Period of Supply	Source	Installed Capacity (MW)	Energy (TWh)	Average Price		Average Current Price		Current Financial Allocation	
					(R$/MWh)	(US$/MWh)	(R$/MWh)	(US$/MWh)	(R$ Billion)	(US$ Billion)
14/08/2008	2009 - 2023 2010 - 2024	B B	2,383.9	71.2	58.84	29.42	81.82	40.91	5.8	2.9
14/12/2009	2012 - 2031	W	1,805.7	132	148.39	74.20	195.16	97.58	25.8	12.9
25/08/2010	2011 - 2025 2012 - 2026 2013 - 2042 2013 - 2032 2013 - 2027	B B SH W B	1206.6	72.0	125.07	62.535	159.48	79.74	11.5	5.7
18/08/2011	2014 - 2034	B, W	1,218.1	80.7	99.61	49.81	118.46	59.23	9.6	4.8
23/08/2013	2015 - 2035	W	1,505.2	118.4	110.51	55.26	117.71	58.86	13.9	7.0

Source: Brazilian Ministry of Mines and Energy; Brazilian Chamber for Commercialization of Electrical Energy
Reference date for current values: august/2014 (IPCA)
Exchange rate: 2 R$/US$

Total Energy Traded in the Energy Reserve Auctions: **474 TWh**

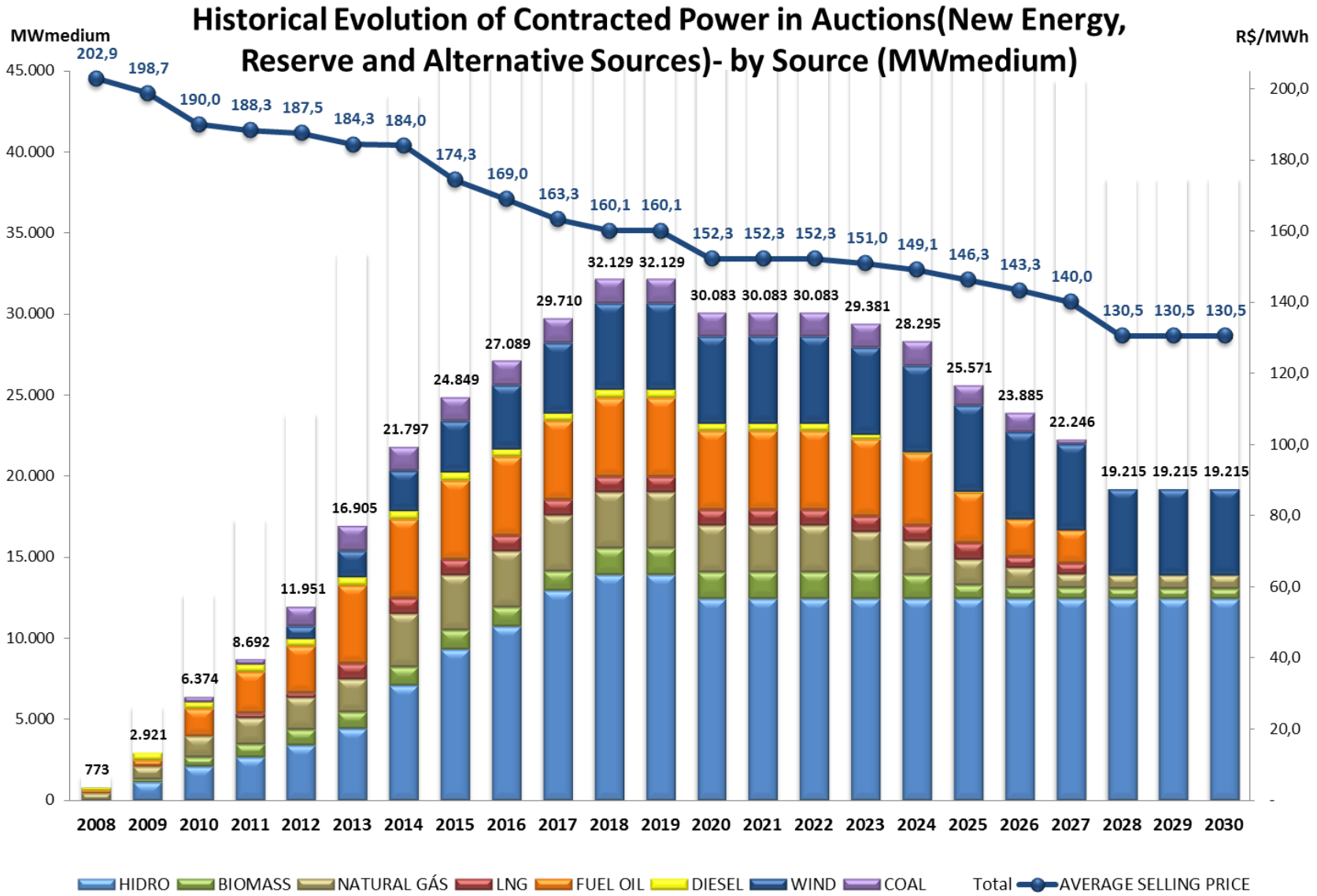
Consolidated Results

Auction Type	Qt	Added Capacity (MW)	Energy (TWh)	Current Financial Allocation (R$ Billion)	Current Financial Allocation (US$ Billion)
Existing Energy	30	-	1,550	187	93
New Energy	19	52,079	3,706	600	300
Renewable Sources	2	2,235	160	29	14
Structuring Projects	3	17,684	1,523	158	79
Reserve Energy	5	8,120	474	76	38
TOTAL	**59**	**80,117**	**7,413**	**1,049**	**525**

Source: Brazilian Ministry of Mines and Energy; Brazilian Chamber for Commercialization of Electrical Energy
Reference date for current values: august/2014 (IPCA)
Exchange rate: 2 R$/US$

Auctions´ Results

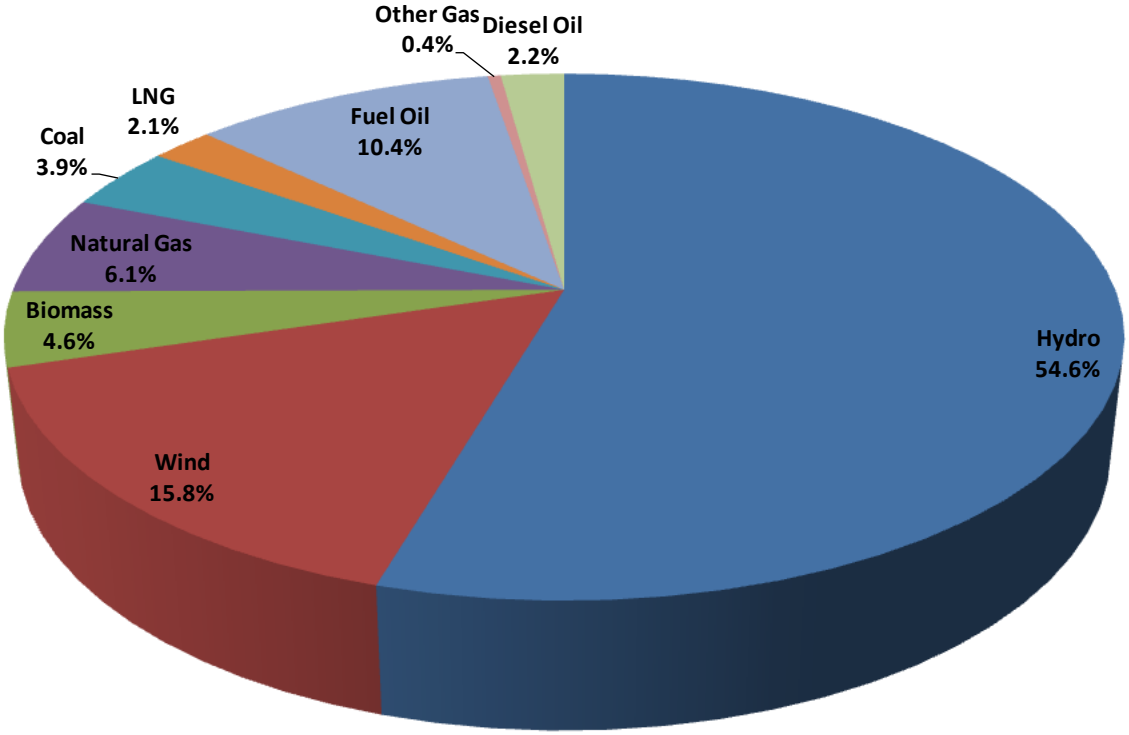
Auctions' Results



Source: CCEE

Consolidated Results

Total Energy Traded – 5,930 TWh



75% of the Energy Traded and Added to the System comes from Renewables

Source: Brazilian Ministry of Mines and Energy; Brazilian Chamber for Commercialization of Electrical Energy

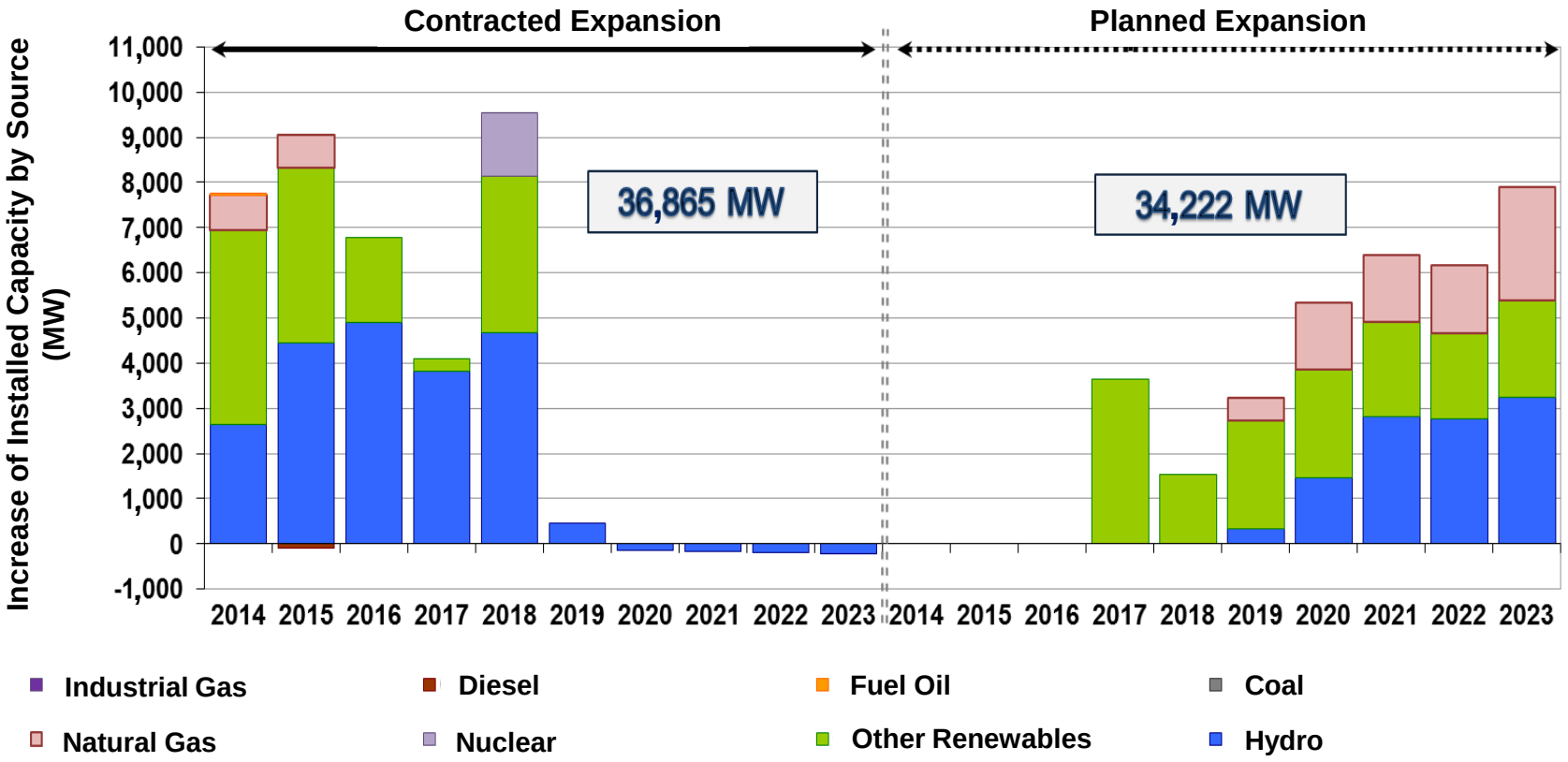
Includes New Energy Auctions, Renewable Sources Auctions, Structuring Projects Auctions and Reserve Energy Auctions

Brazilian Interconnected System Contracted Power (GW)

Eletrobras Cepel

INCREASE OF INSTALLED CAPACITY

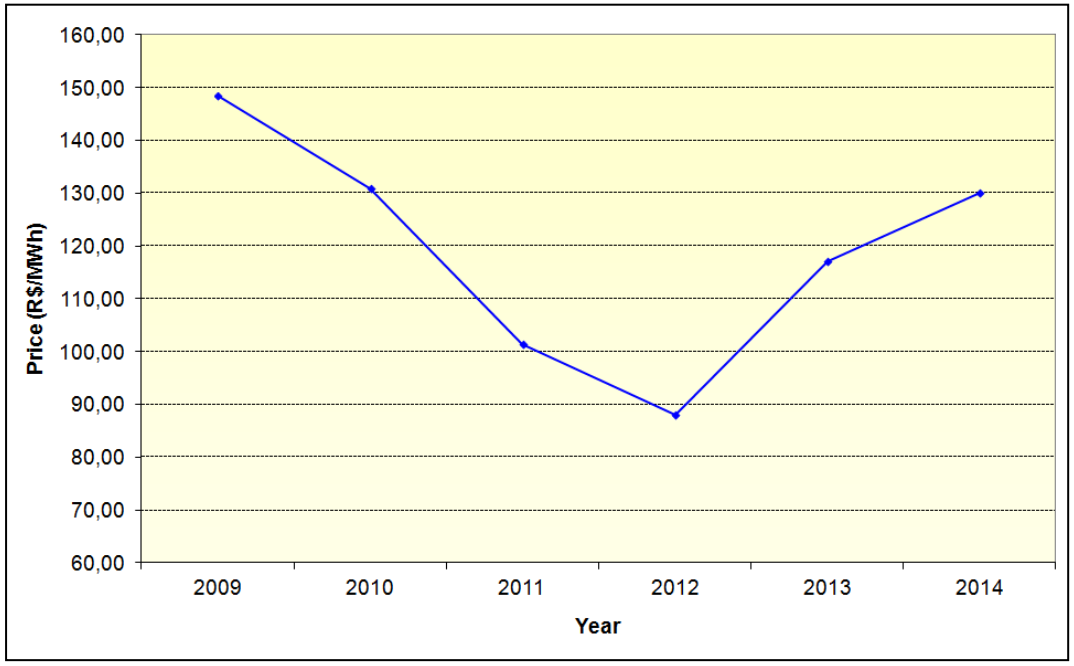
71,087 MW



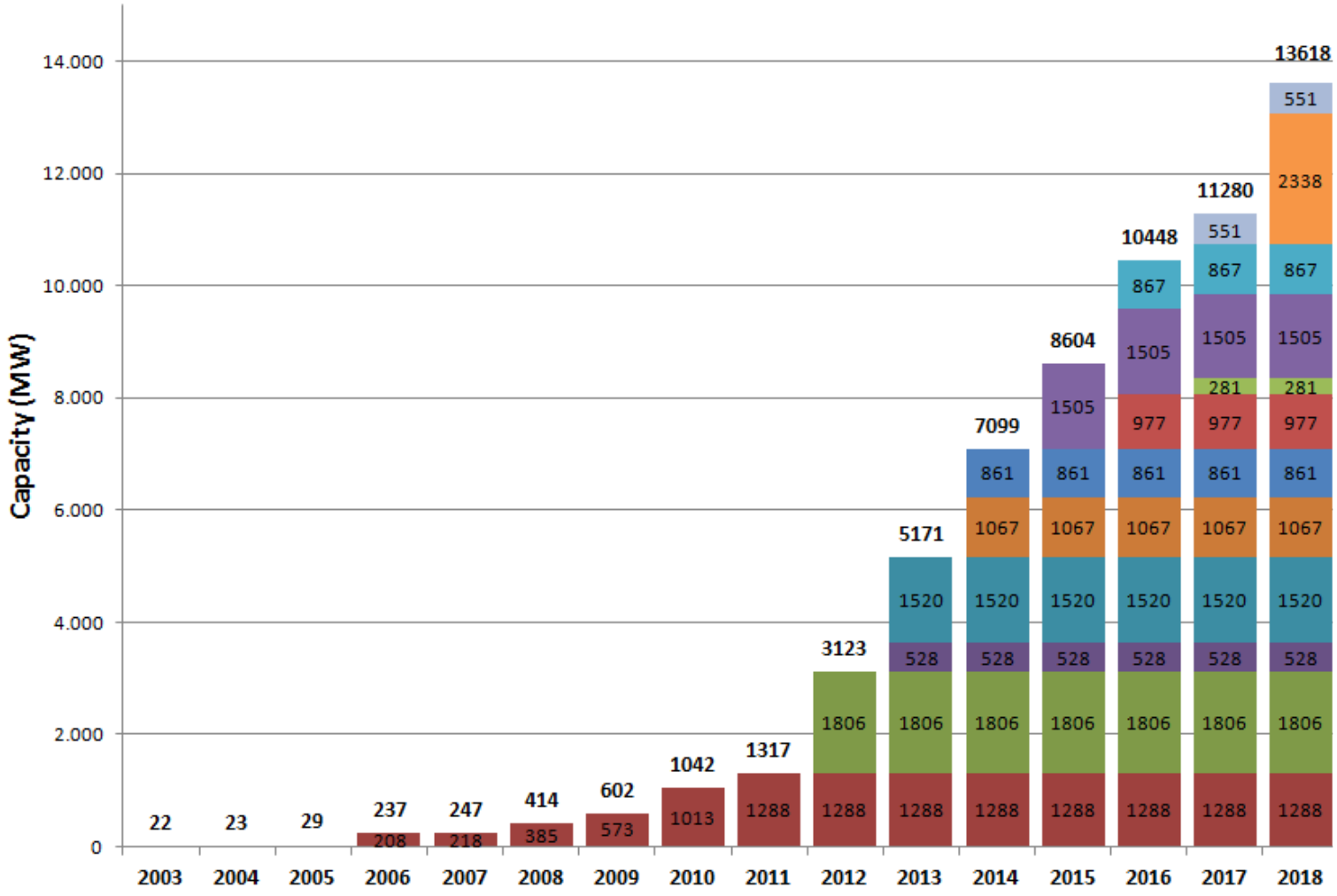
Fonte: EPE

Wind Projects Auctions

Year	Qualified Projects		Contracted Projects			
	Nº	MW	Nº	MW	Price R$/MWh	Price US$/MWh
2009	339	10.005,00	71	1.805,70	148,39	84,79
2010	320	8.304,00	70	2.047,80	130,86	73,93
2011	240	6.052,00	117	2.905,30	101,47	54,85
2012	484	11.879,00	10	281,90	87,94	42,20
2013	539	13.287,00	202	4.710,60	117,21	49,12
2014	248	6.159,00	21	551,00	130,01	57,94



Wind Projects Auctions (MW)



Source: EPE 2014

Next Energy Reserve Auction (6th)

Eletrobras Cepel

Oct. 31st, 2014
PPA: 20 years

Source	Number of Registered Projects	Capacity (MW)	Initial Price (R$/MWh)	Initial Price (US$/MWh)
Biomass	8	151	169.00	70.42
Wind	626	15,356	144.00	60.00
Solar photovoltaic	400	10,790	262.00	109.17
TOTAL	**1,034**	**26,297**	-	

Source: Brazilian Ministry of Mines and Energy
Exchange rate: 2.4 R$/US$

Biomass using municipal solid waste, biogas from landfills, biodigestors from vegetable or animal waste, sludge from sewage treatment plants

Next New Electric Energy Auction ("A-5") – 20th

Source	Number of Registered Projects	Capacity (MW)	Initial Price (R$/MWh)	Initial Price (US$/MWh)
Wind	763	18,760	137.00	57.08
Solar - PV	224	6,068	137.00	57.08
Solar - CSP	8	240	137.00	57.08
Hydro	9	1,261	158.00	65.83
Small hydro	30	526	158.00	65.83
Biomass	32	1,917	197.00	82.08
Coal	10	4,490	197.00	82.08
Natural Gas	39	20,607	197.00	82.08
TOTAL	**1,115**	**53,869**	-	

Source: Brazilian Ministry of Mines and Energy
Exchange rate: 2.4 R$/US$

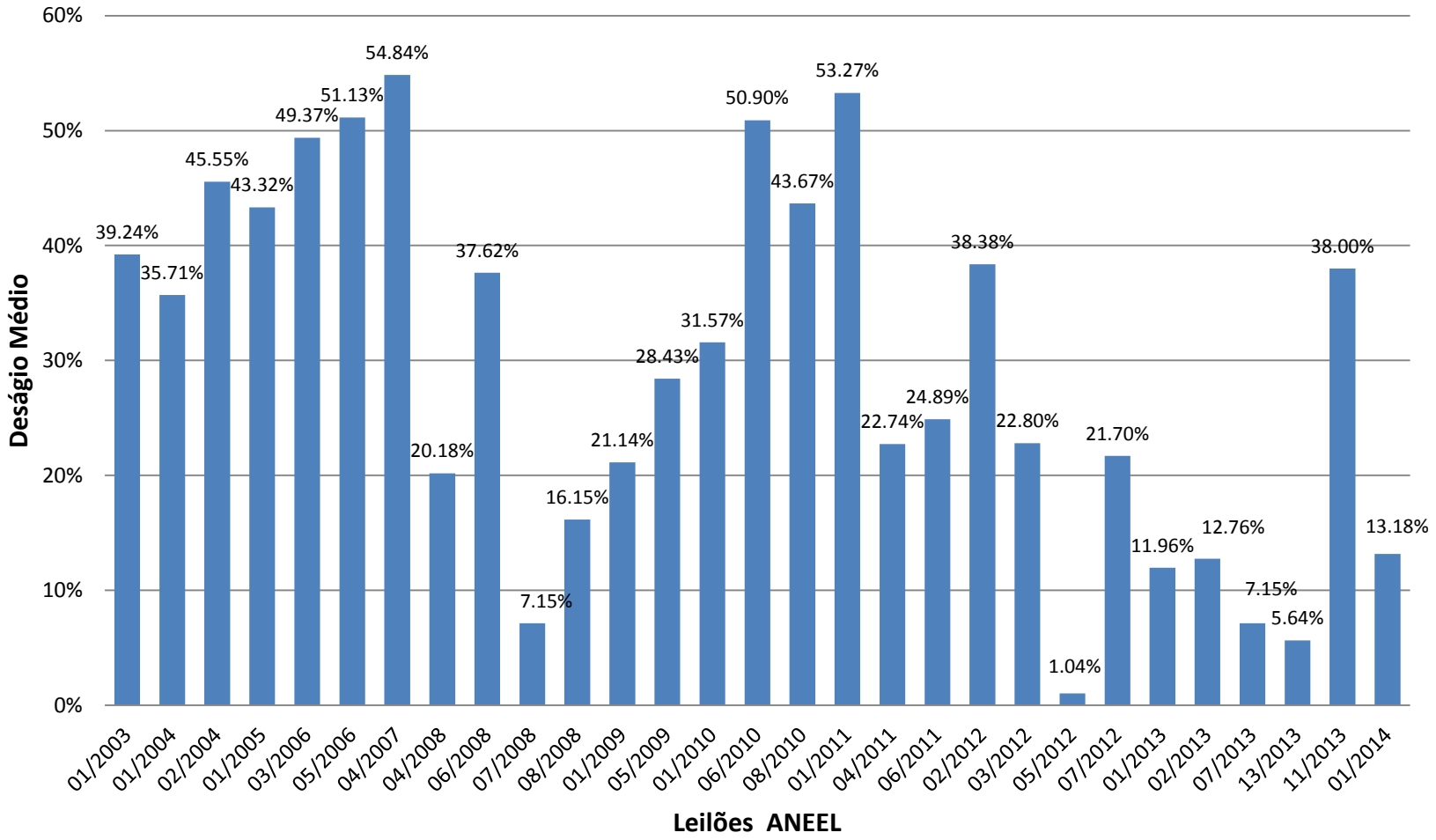
Eletrobras
Cepel

Transmission System Auctions

Transmission System Auctions

Eletrobras Cepel

Main Grid – Average disccount from the Ceiling Prices by year



Eletrobras
Cepel

The Role of the Brazilian National Development Bank - BNDES

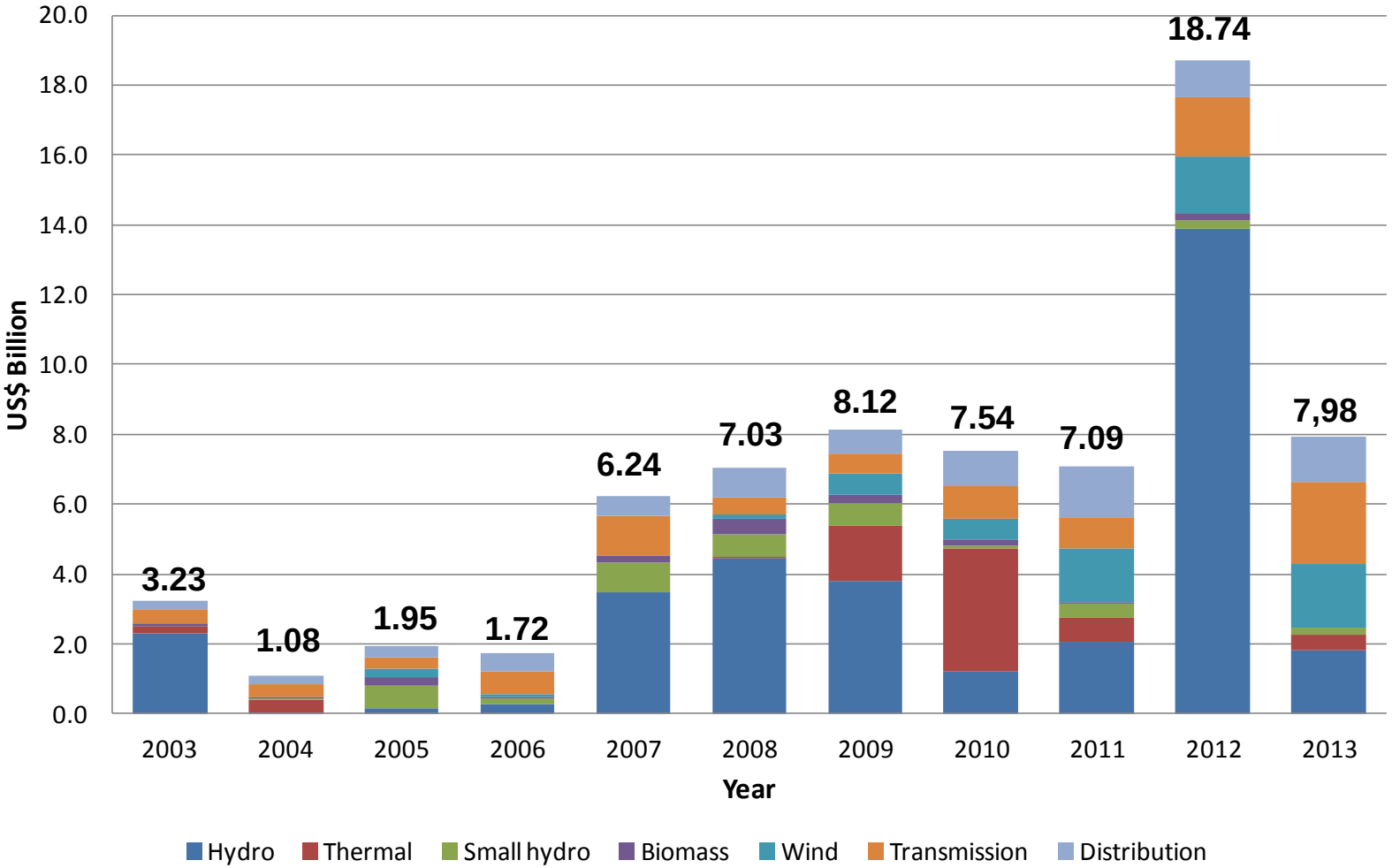
Operations with Credit Approved by BNDES (2003 – 2014)

Eletrobras Cepel

Activity	Capacity	Number of Projects	BNDES Funding		Associated Investment	
			(R$ mil)	(US$ mil)	(R$ mil)	(US$ mil)
1. Generation	**50,130.03 MW**	**436**	**103,137,002**	**51,568,501**	**168,464,786**	**84,232,393**
Hydro	33,525.42 MW	51	63,788,018	31,894,009	102,759,798	51,379,899
Thermal	6,578.24 MW	18	13,612,858	6,806,429	25,255,198	12,627,599
Small hydro	2,340.09 MW	122	7,788,698	3,894,349	12,125,407	6,062,704
Biomass	1,958.90 MW	44	3,421,617	1,710,809	4,610,389	2,305,195
Wind	5,727.38 MW	201	14,525,810	7,262,905	23,713,994	11,856,997
2. Transmission	**31,061 km**	**109**	**19,608,041**	**9,804,021**	**39,072,007**	**19,536,004**
3. Distribution		**93**	**16,648,892**	**8,324,446**	**29,077,061**	**14,538,531**
4. Efficiency		**23**	**221,648**	**110,824**	**302,116**	**151,058**
TOTAL		**661**	**139,615,583**	**69,807,792**	**236,915,970**	**118,457,985**

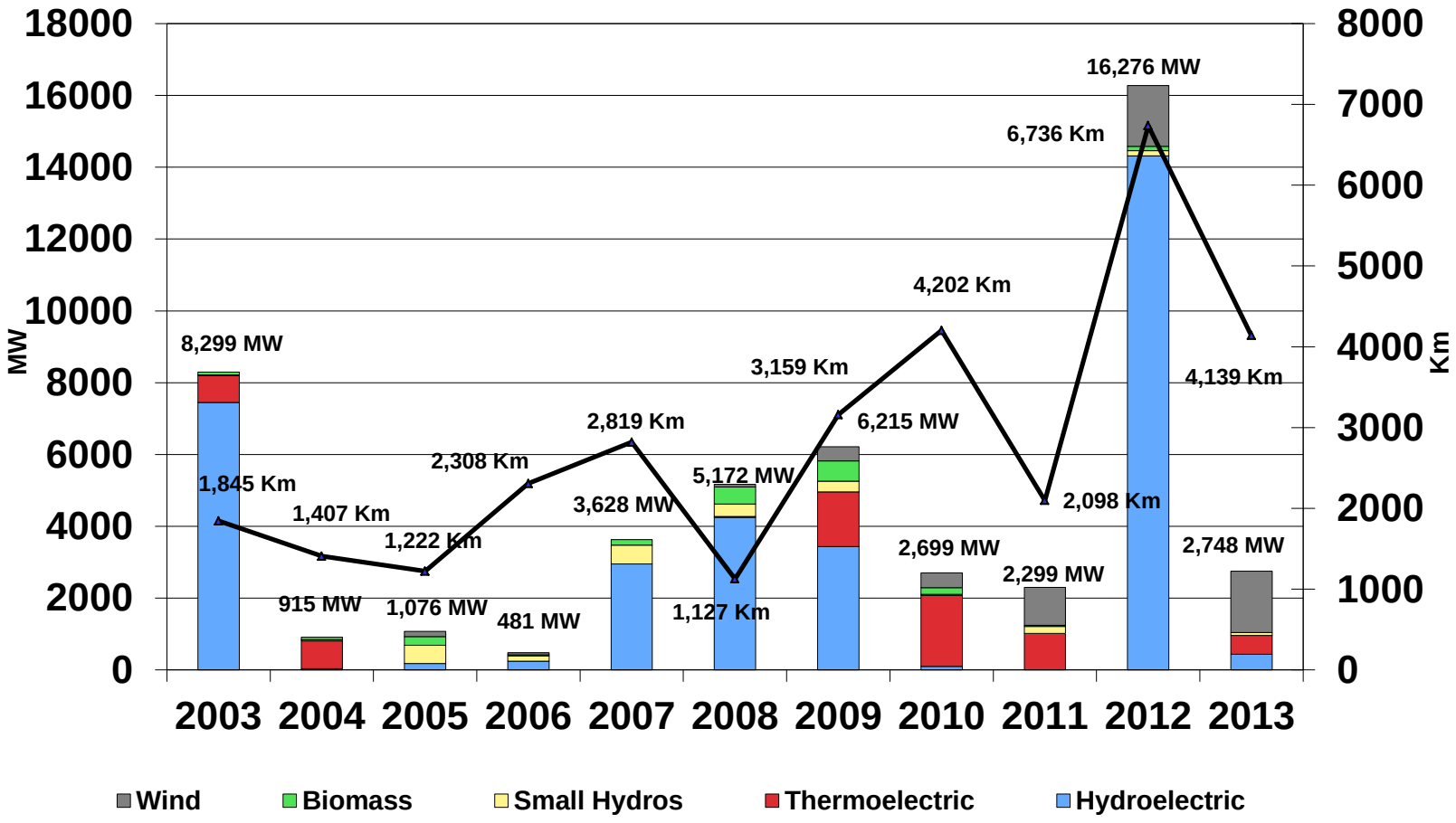
Exchange rate: 2 R$/US$

Credit Aproved by BNDES
(2003 - 2013)



Exchange rate: 2 R$/US$

Appprovad Operations - 2003 a 2013 (Capacity Indicators)



Exchange rate: 2 R$/US$

Thank you !

albert@cepel.br

Ministério de Minas e Energia

GOVERNO FEDERAL BRASIL PAÍS RICO É PAÍS SEM POBREZA