



# Energy for the Future

## Session 1 – The Evolving Landcasp and Renewable Energy Sources

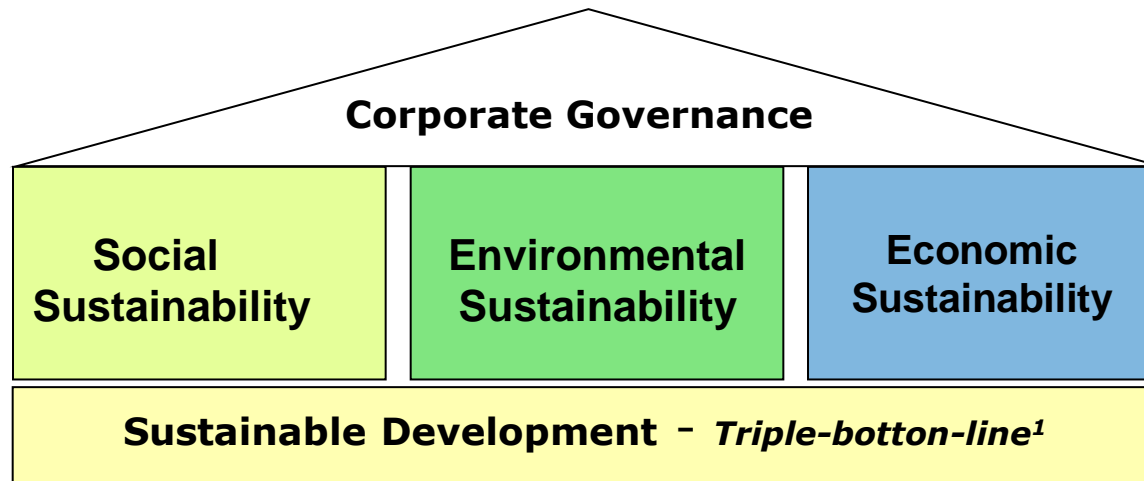
*"Renewable Energy  
Sources in Brazil and  
Integration Aspects"*

São Paulo, 21 September 2016

**Albert C. G. Melo**  
Director-General  
Electrical Energy Research Center - CEPEL

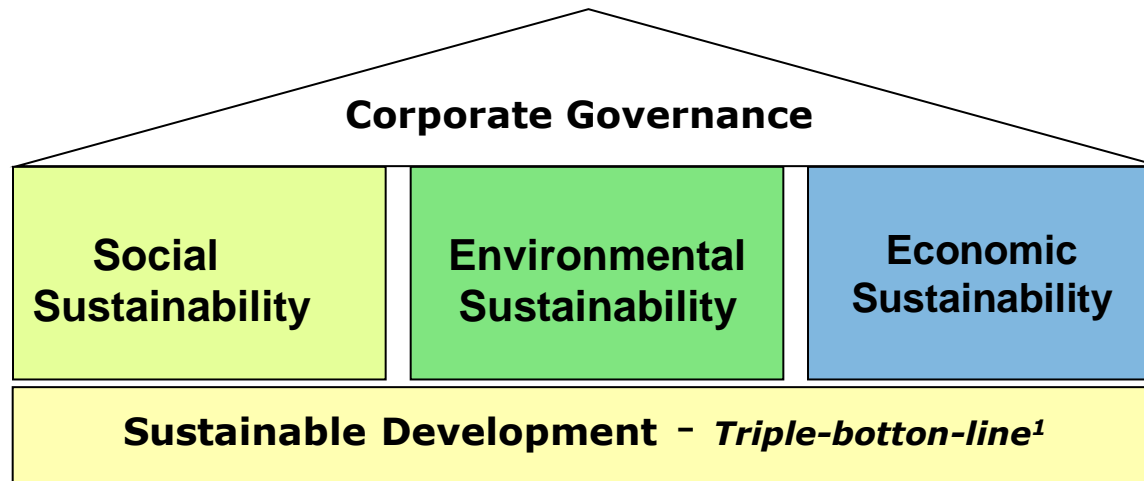
**There is no  
Sustainable Development  
without  
Sustainable Energy**

"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*



<sup>1</sup>John Elkington, 1998. *Cannibals with forks: The triple bottom line of 21st century business*

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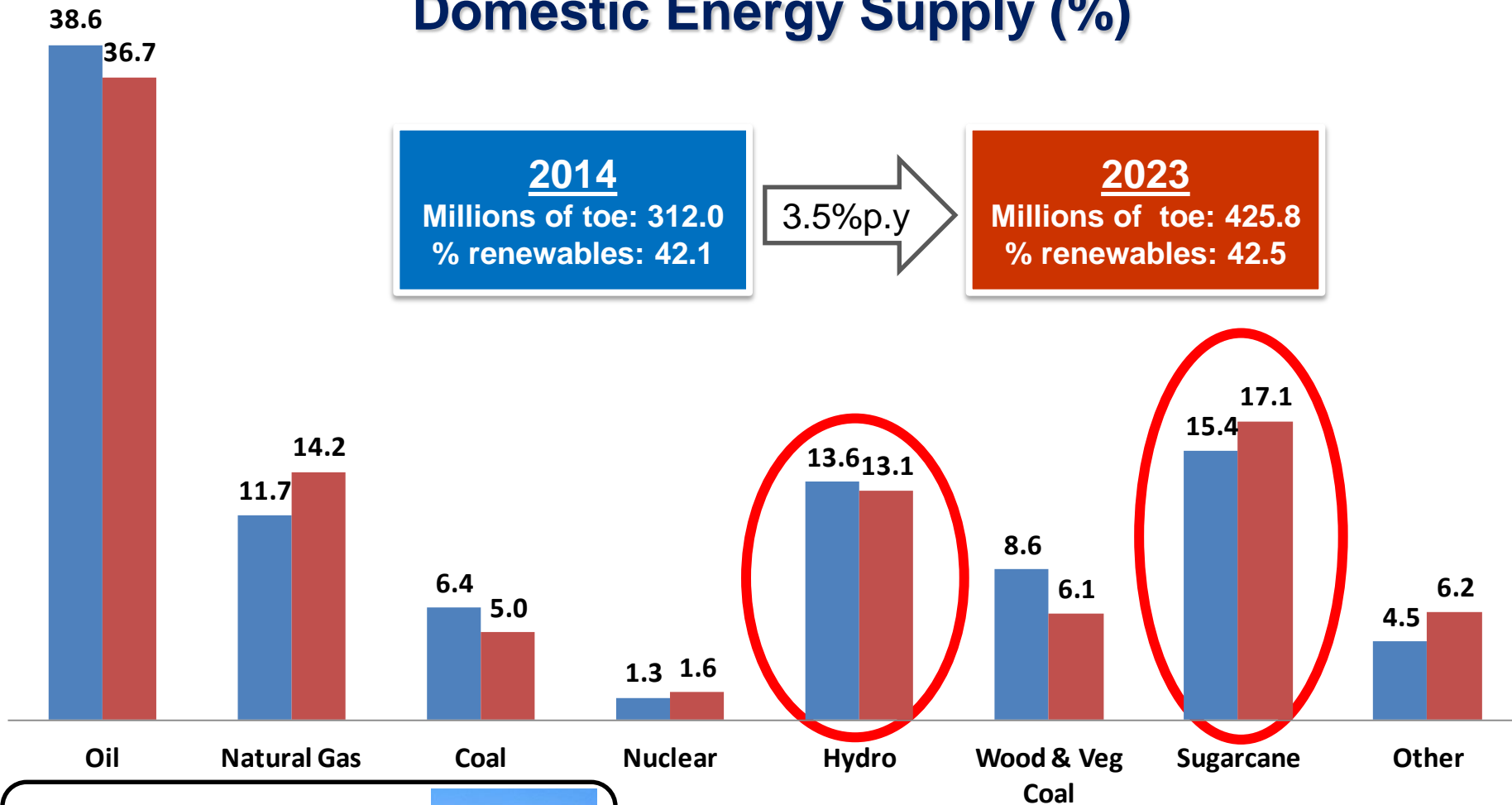


<sup>1</sup>John Elkington, 1998. *Cannibals with forks: The triple bottom line of 21st century business*

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

# The Brazilian Approach

## Domestic Energy Supply (%)

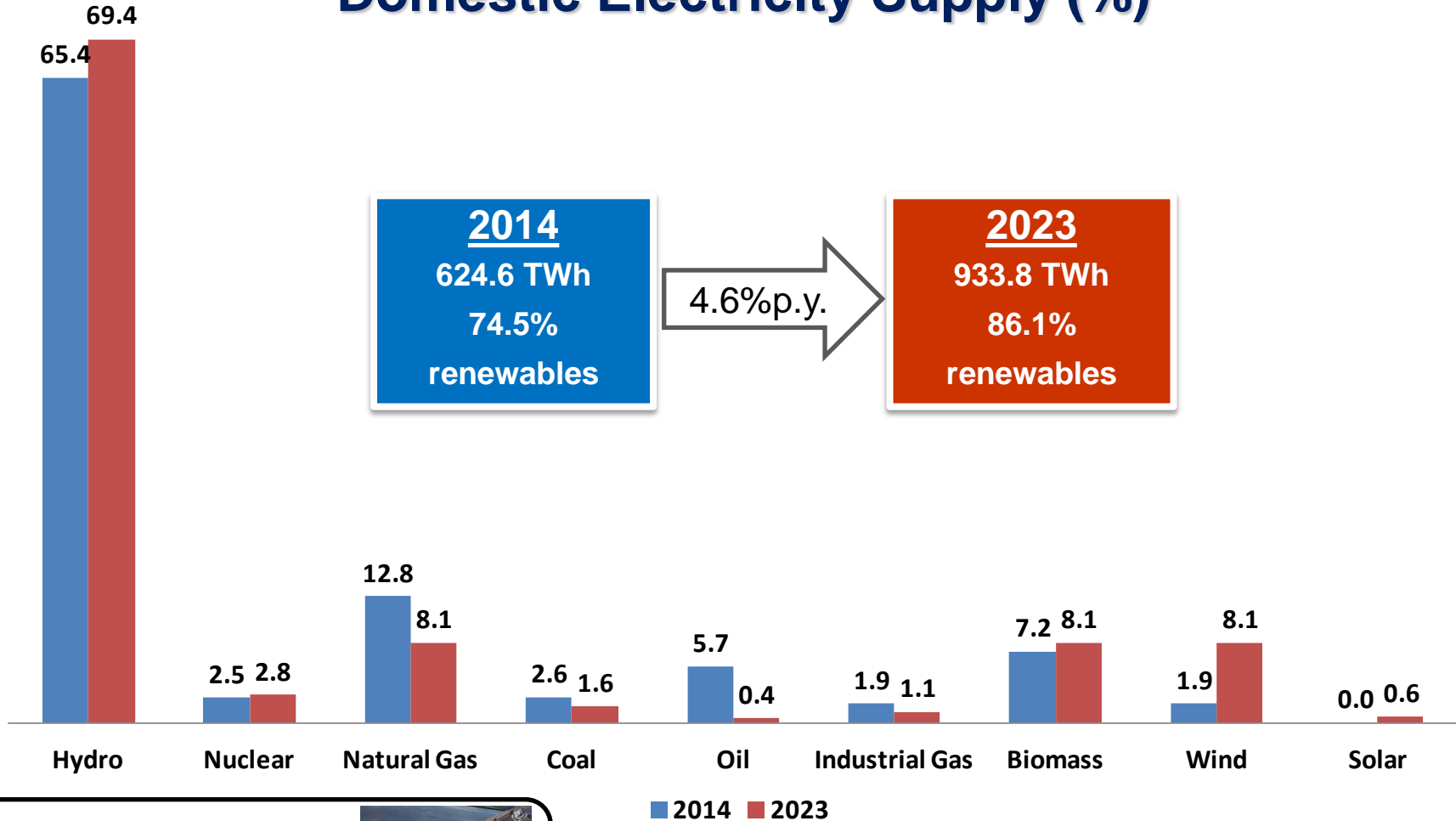


**WORLD (2010)  
RENEWABLES: 13%**



■ 2014 ■ 2023

## Domestic Electricity Supply (%)

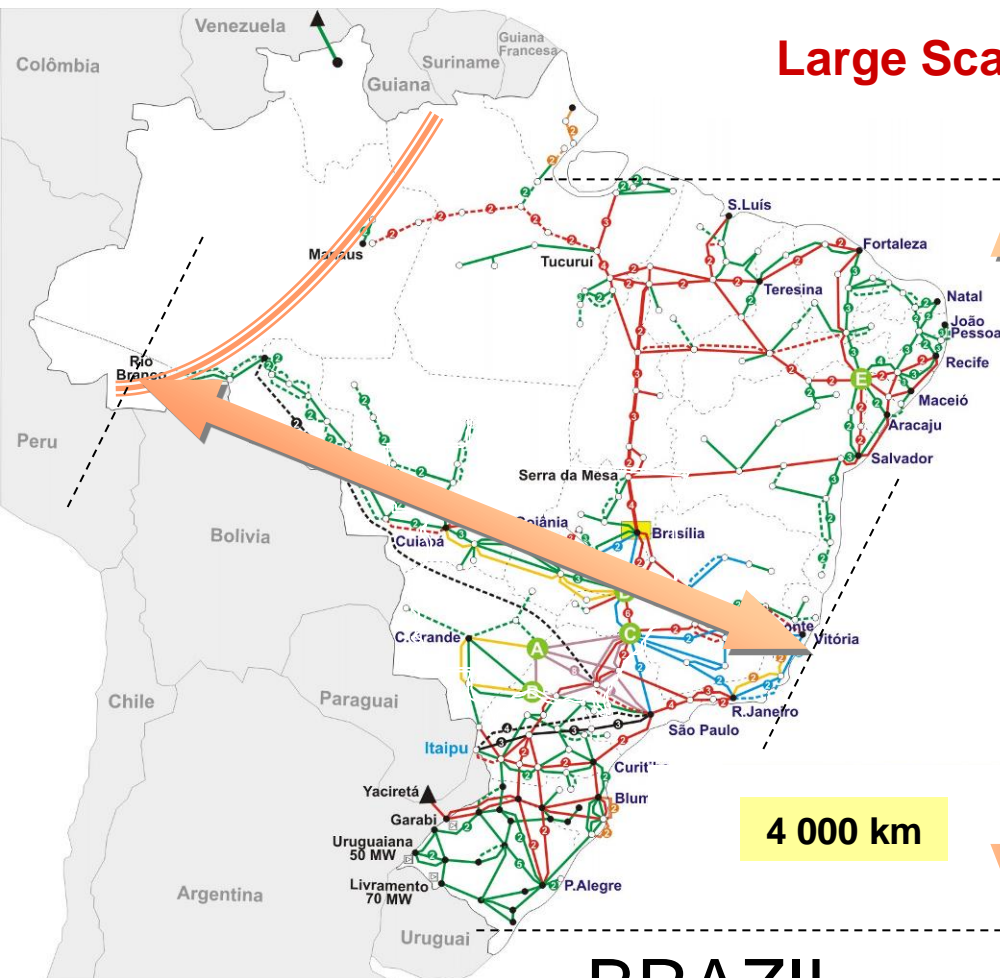


**WORLD (2010)  
RENEWABLES: 19%**

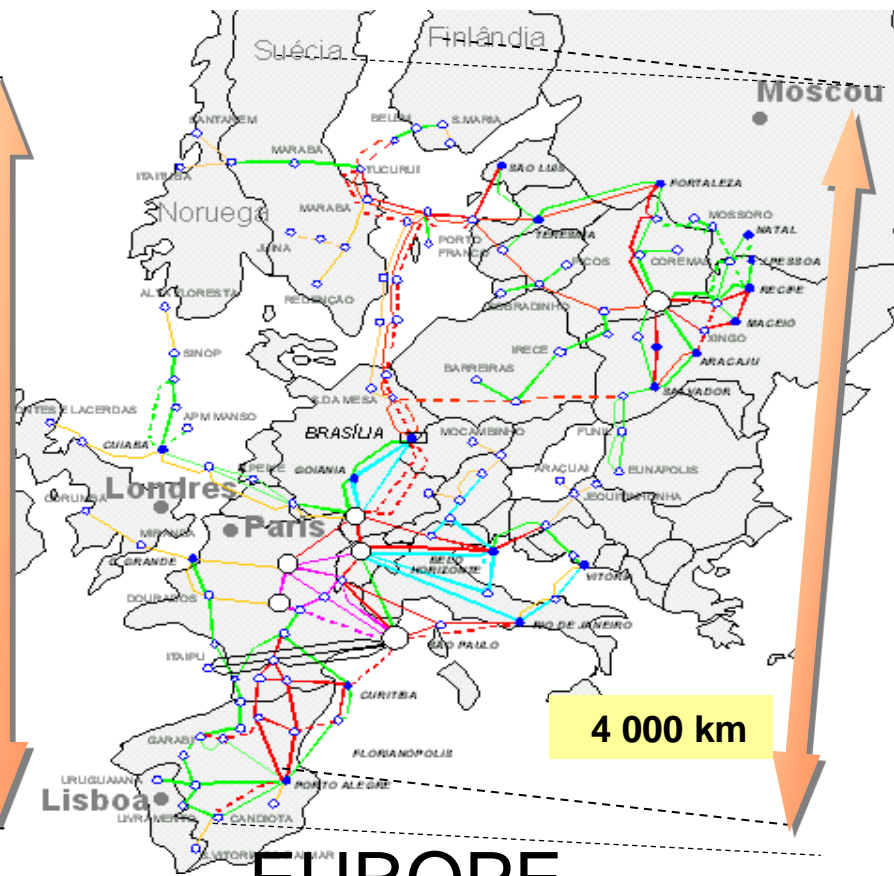


# Brazilian Transmission System

## Continental Dimension Large Scale Power System



**BRAZIL**



**EUROPE**

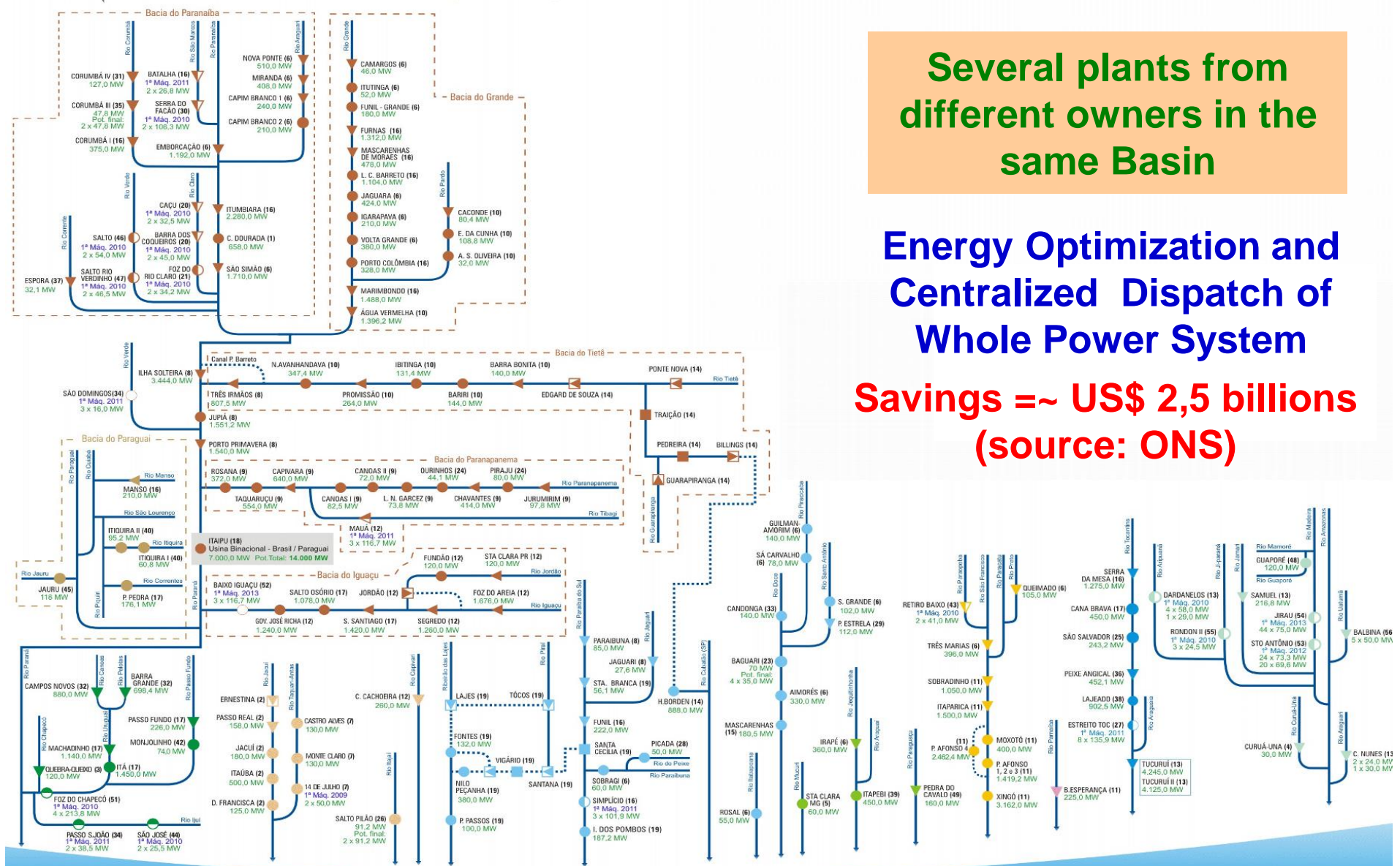


# Hydroelectric Interdependence

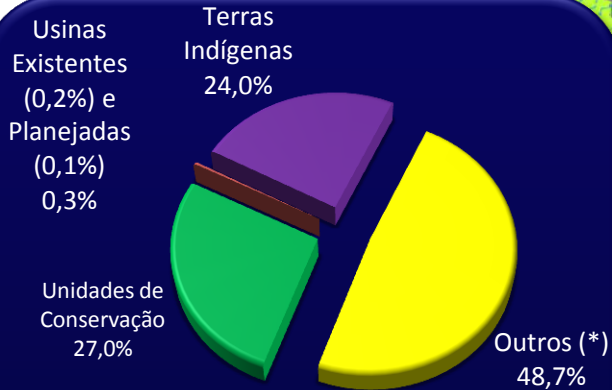
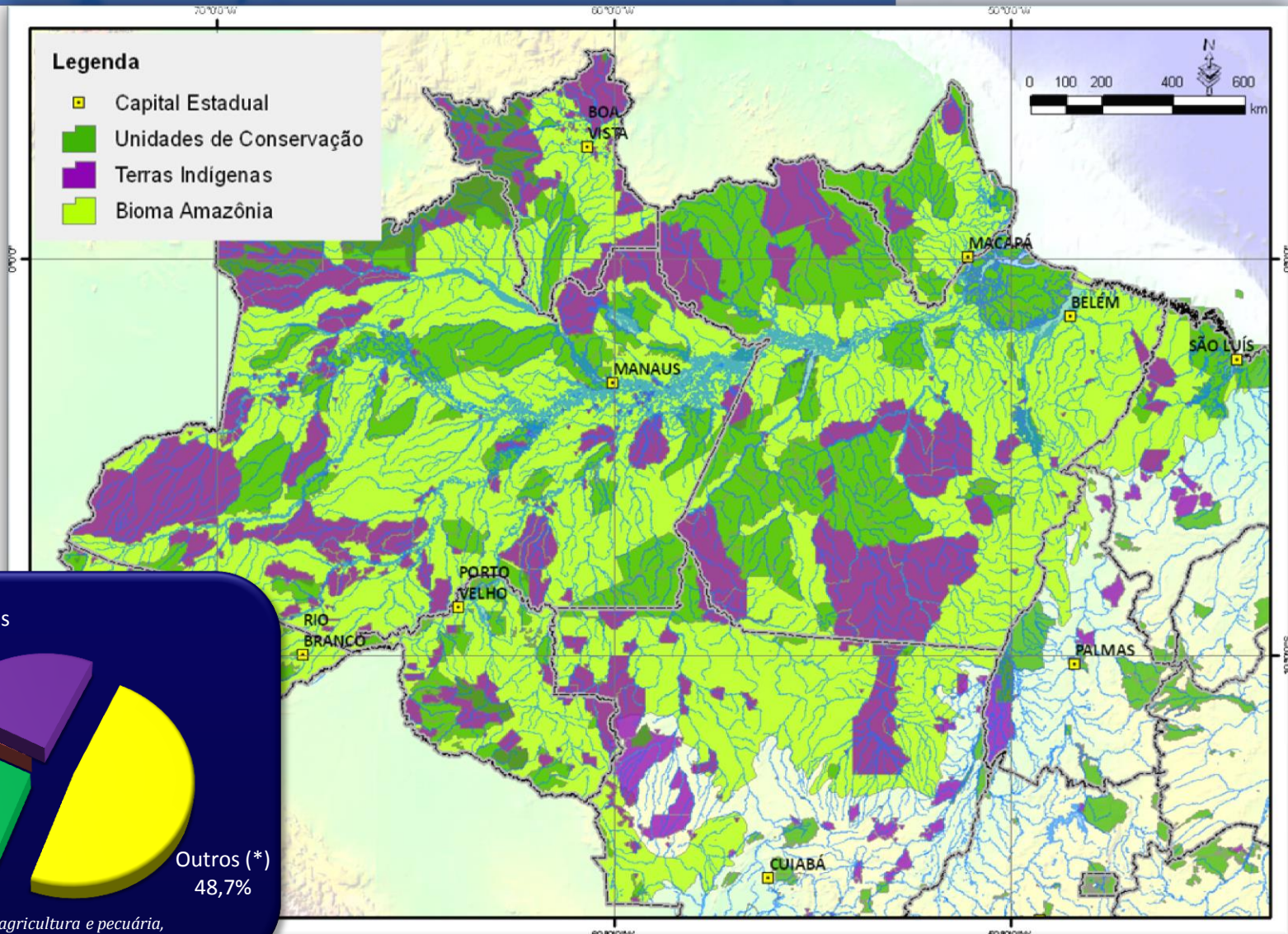
Several plants from different owners in the same Basin

Energy Optimization and Centralized Dispatch of Whole Power System

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



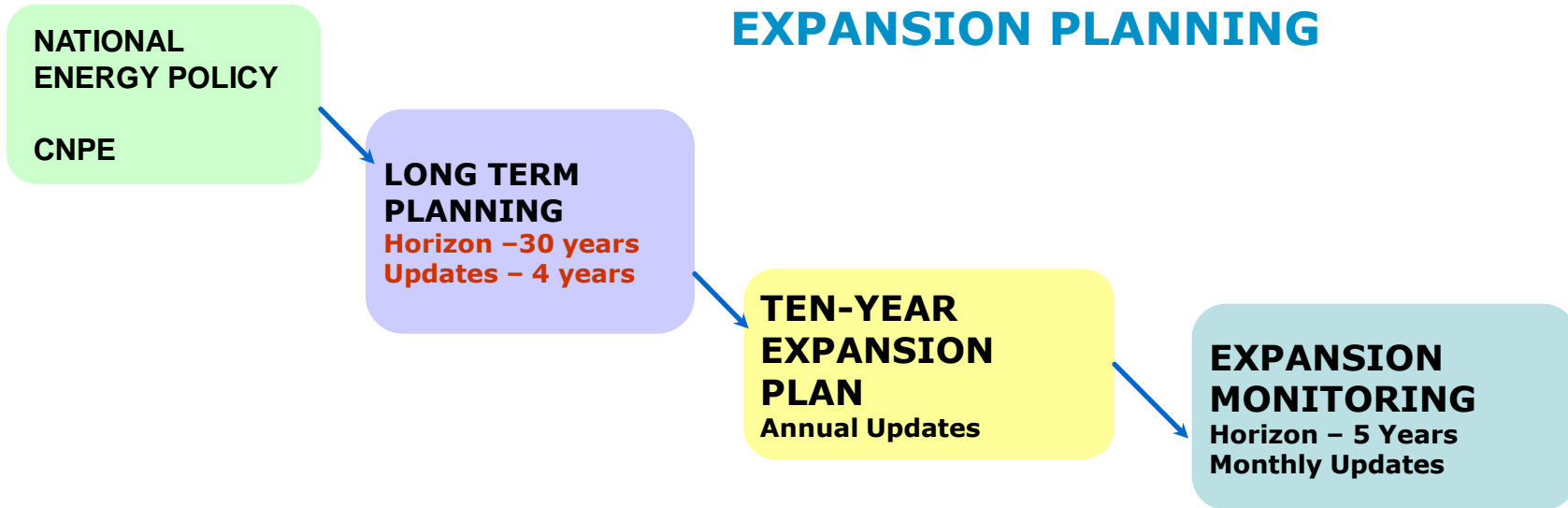
# Environmental Conservation and Indigenous Areas in the Brazilian Amazon



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

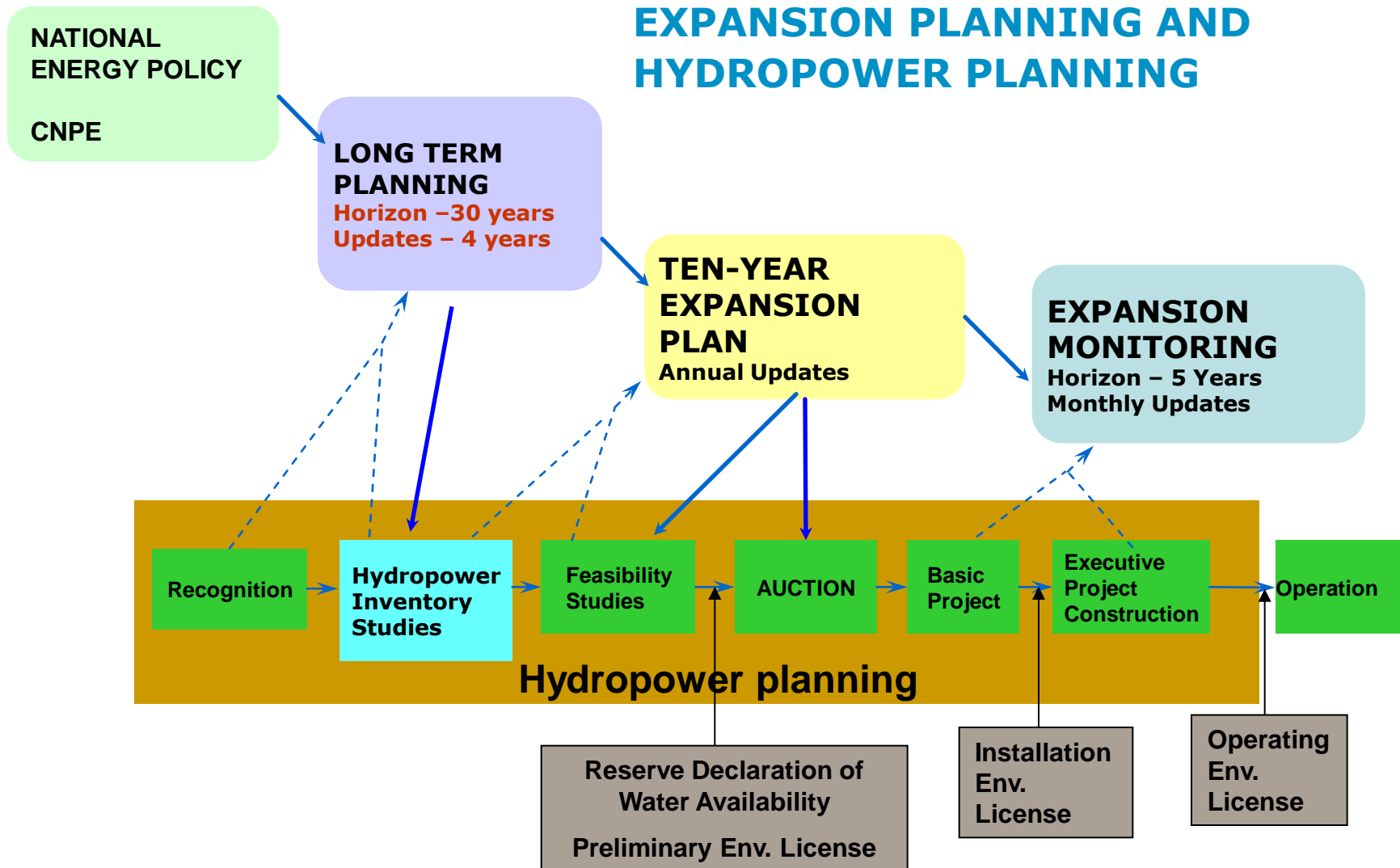
Source: EPE

## BRAZILIAN NATIONAL POWER SYSTEM EXPANSION PLANNING



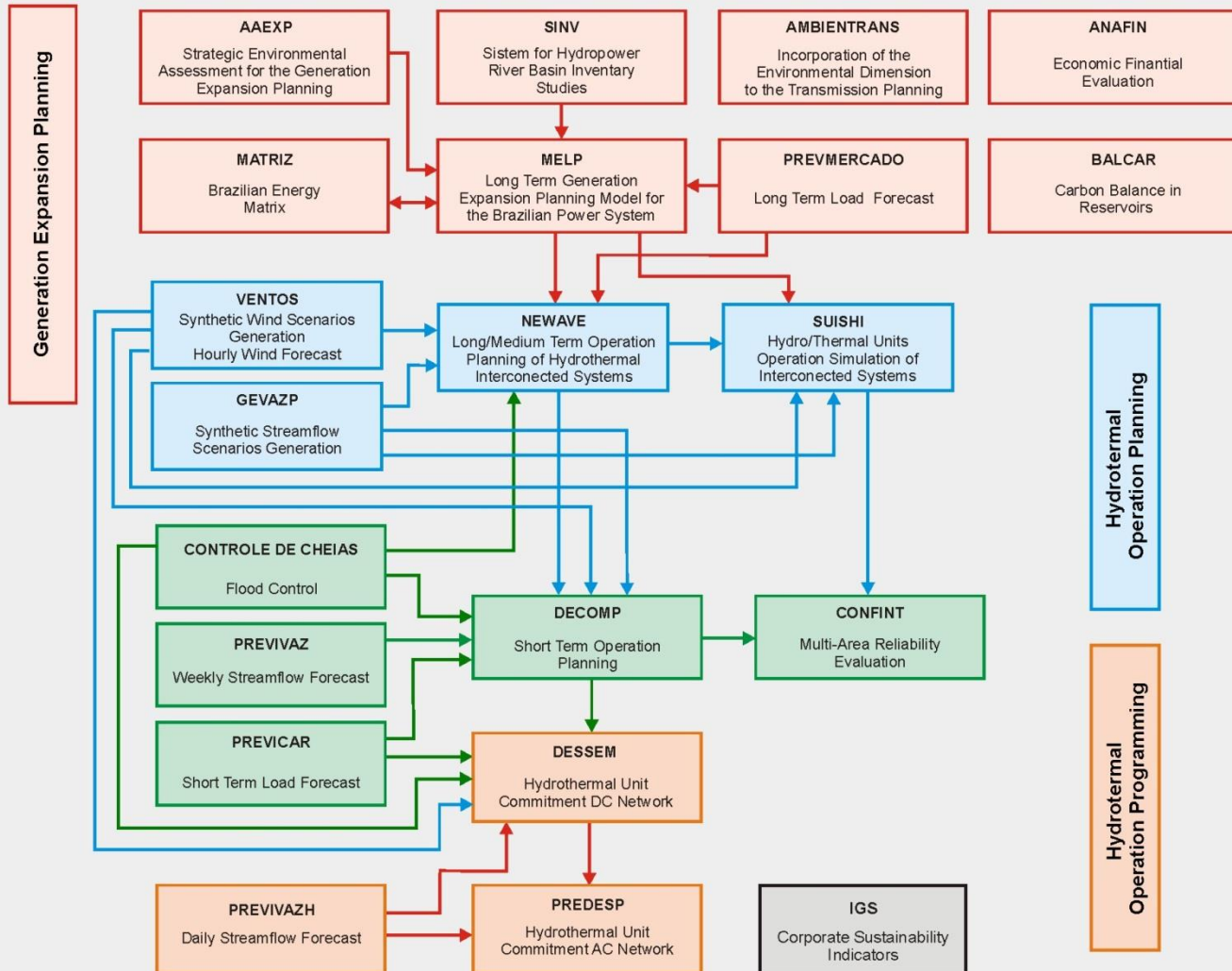
# Policy Framework – Stages for Coordinated Expansion Planning and Sustainable Hydropower Development

## 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

## Chain of Optimization Models for the Generation Expansion and Operational Planning



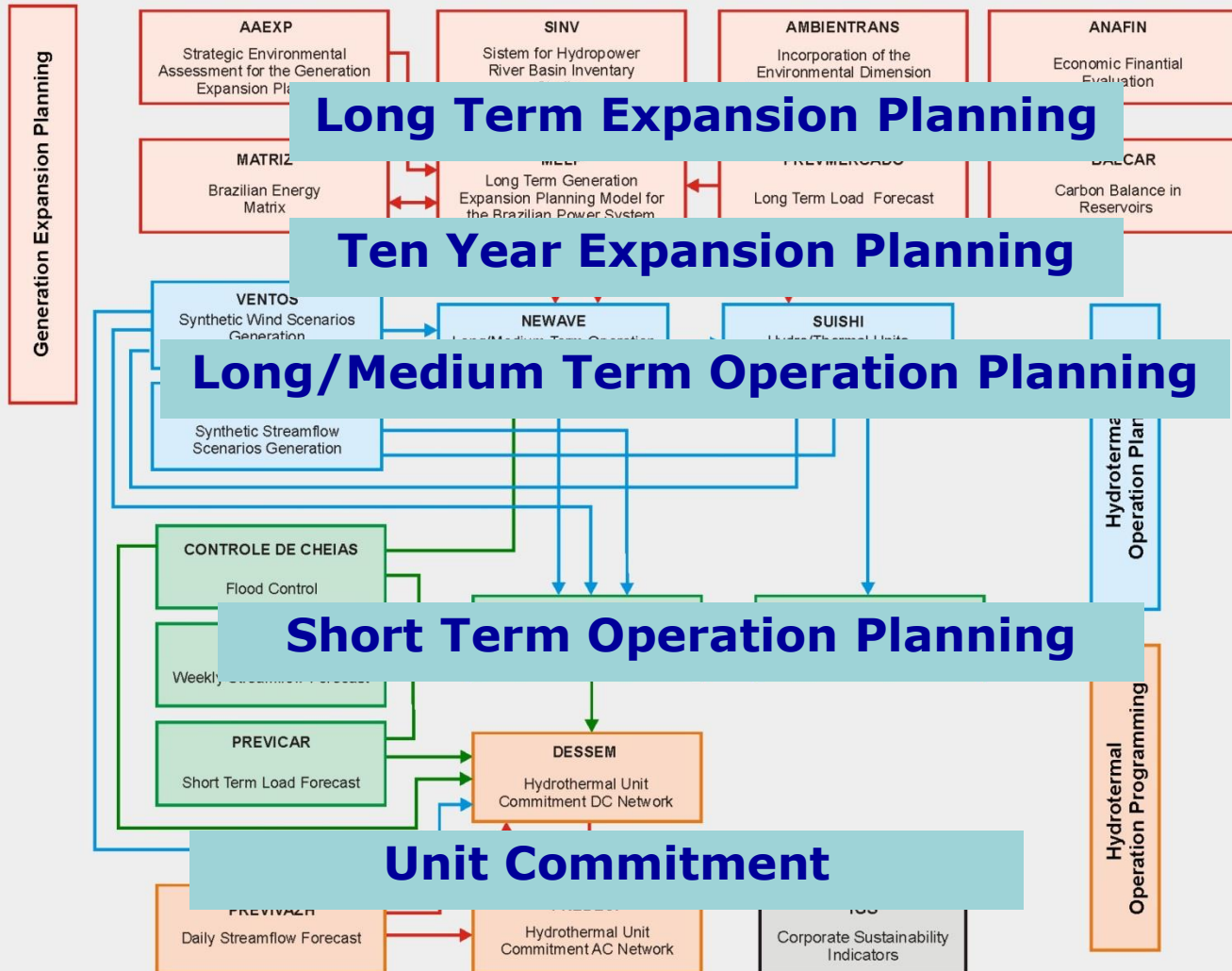
**Energy Optimization and Centralized Dispatch of the Whole Interconnected Hydrothermal System:**

**20% More Energy Production**

**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 System

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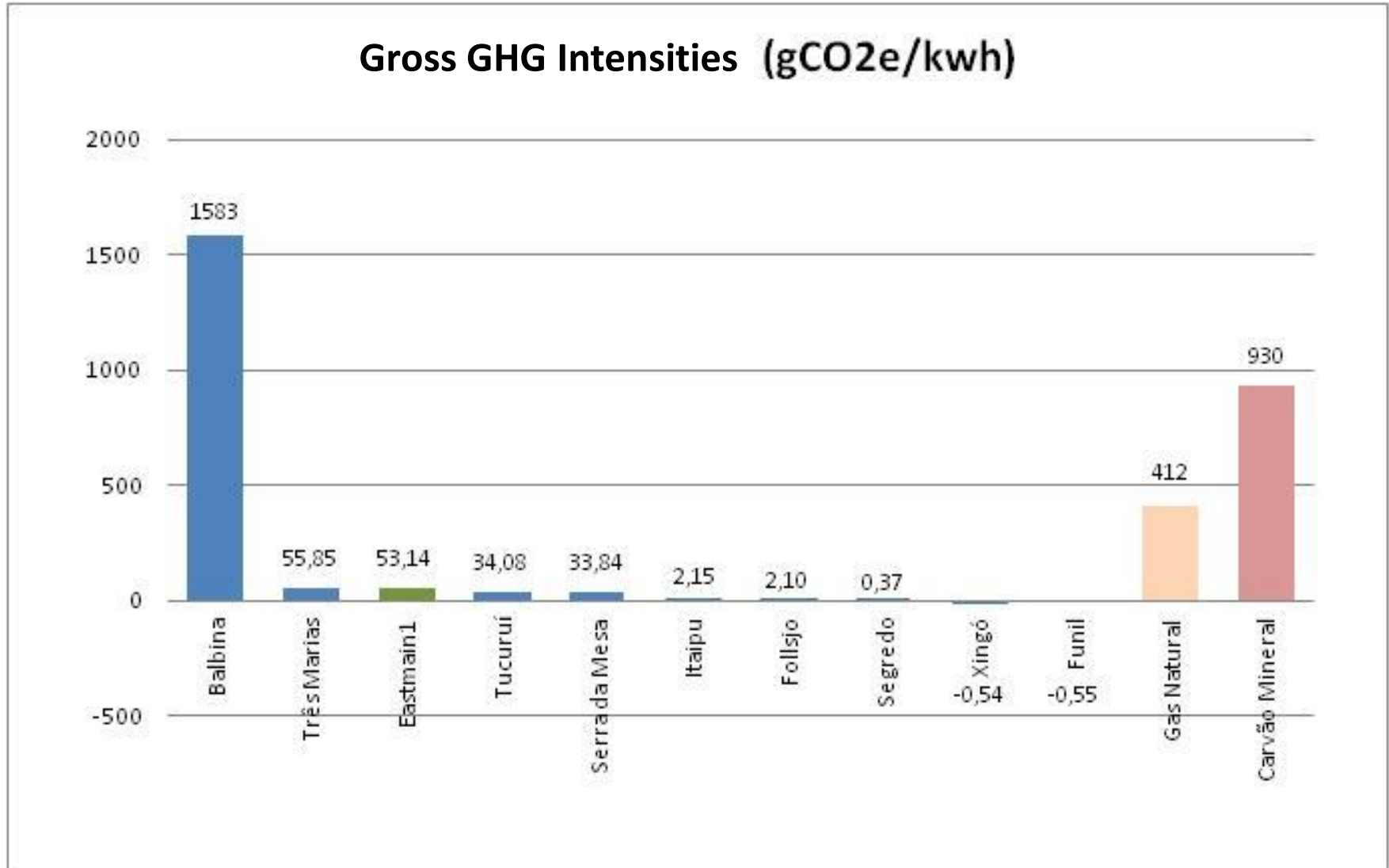


**Energy Optimization and Centralized Dispatch of the Whole Interconnected Hydrothermal System:**

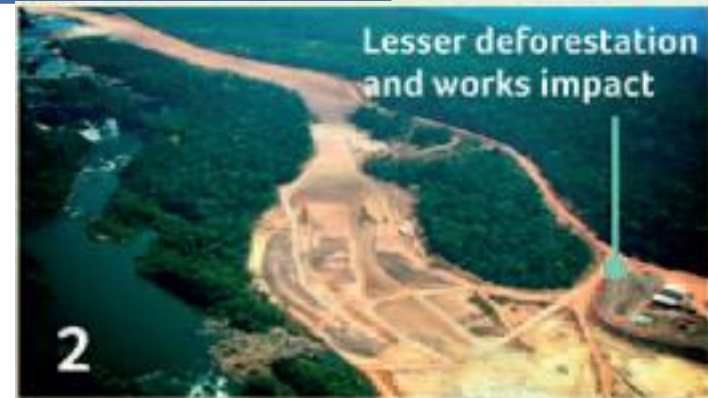
**20% More Energy Production**

**Need of capturing synergies in planning and operation stages**

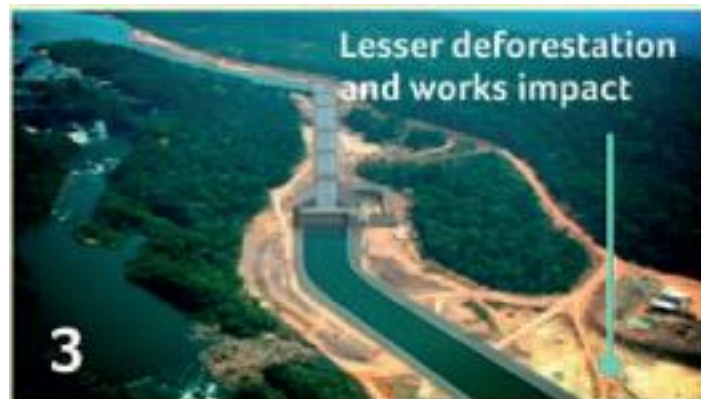
# GHG Emissions in Hydropower Plants Reservoirs Project - Field Measurements



# «Platform Hydropower Plant» Concept



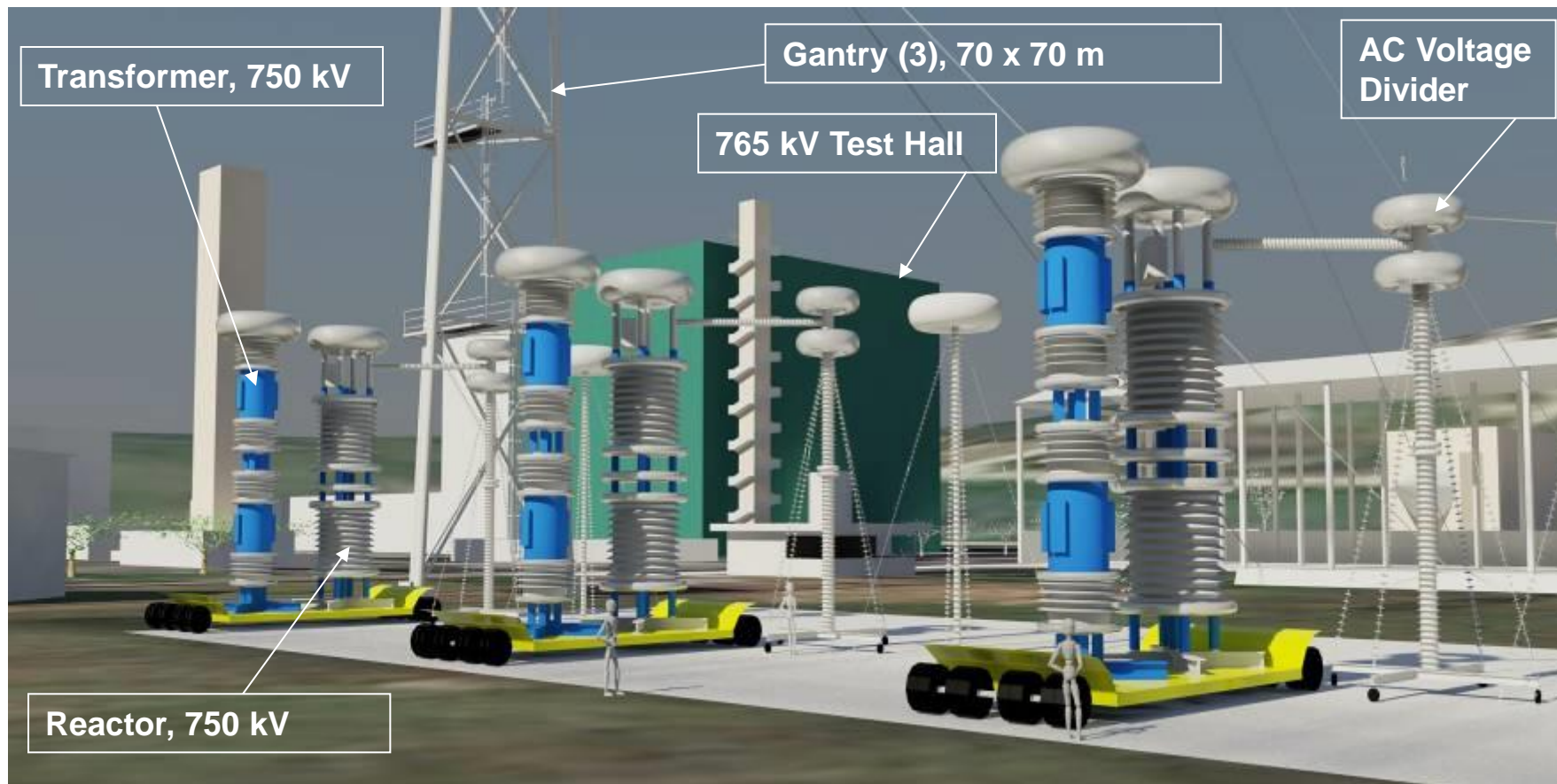
- Under development in Brazil, funded by WB and MME
- Objective: aims to limit the impacts of construction in areas with no or low anthropogenic activity, so the Platform HPP will be an enabler of permanent environmental conservation





# New Cepel's UHV Outdoor Test Facility

Under construction



AC: 750 kV 3 Phases, 1500 kV e 2250 kV Single Phase

DC: 800 kV bipole and 1600 kV Single pole.

Voltage Impulse: 6.4 MV and 2 MV

UHV AC or DC in the same test area

# UHV Laboratory - Outdoor



MME, Eletrobras, FINEP/MCTI, BIRD

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# UHV Laboratory - Outdoor



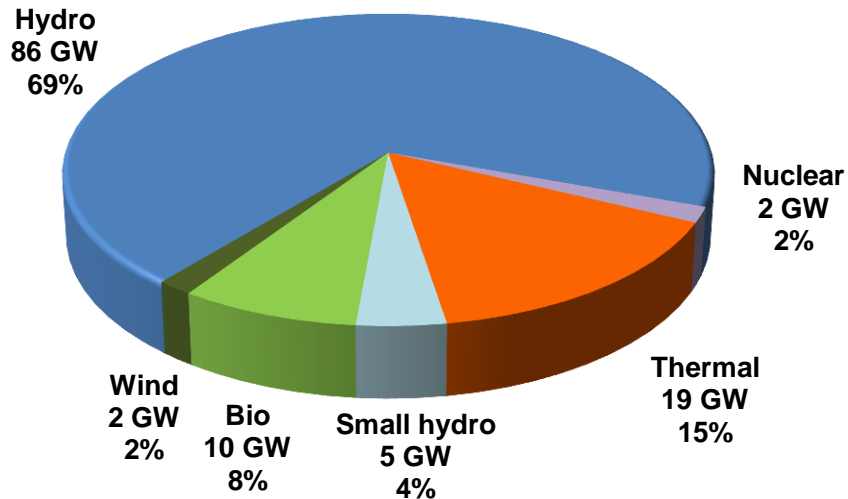
# UHV Laboratory - Outdoor



MME, Eletrobras, FINEP/MCTI, BIRD

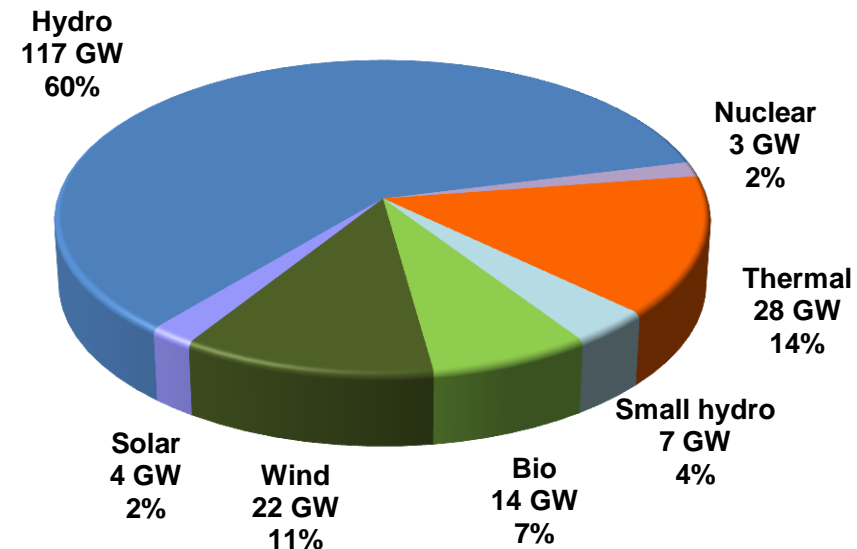
# Ten-Year Expansion Planning of the Generation Capacity (GW)

**Gen. Cap. Mix  
December/2013  
124,796 MW**



**Added  
Capacity  
2014-2023  
71,087 MW**

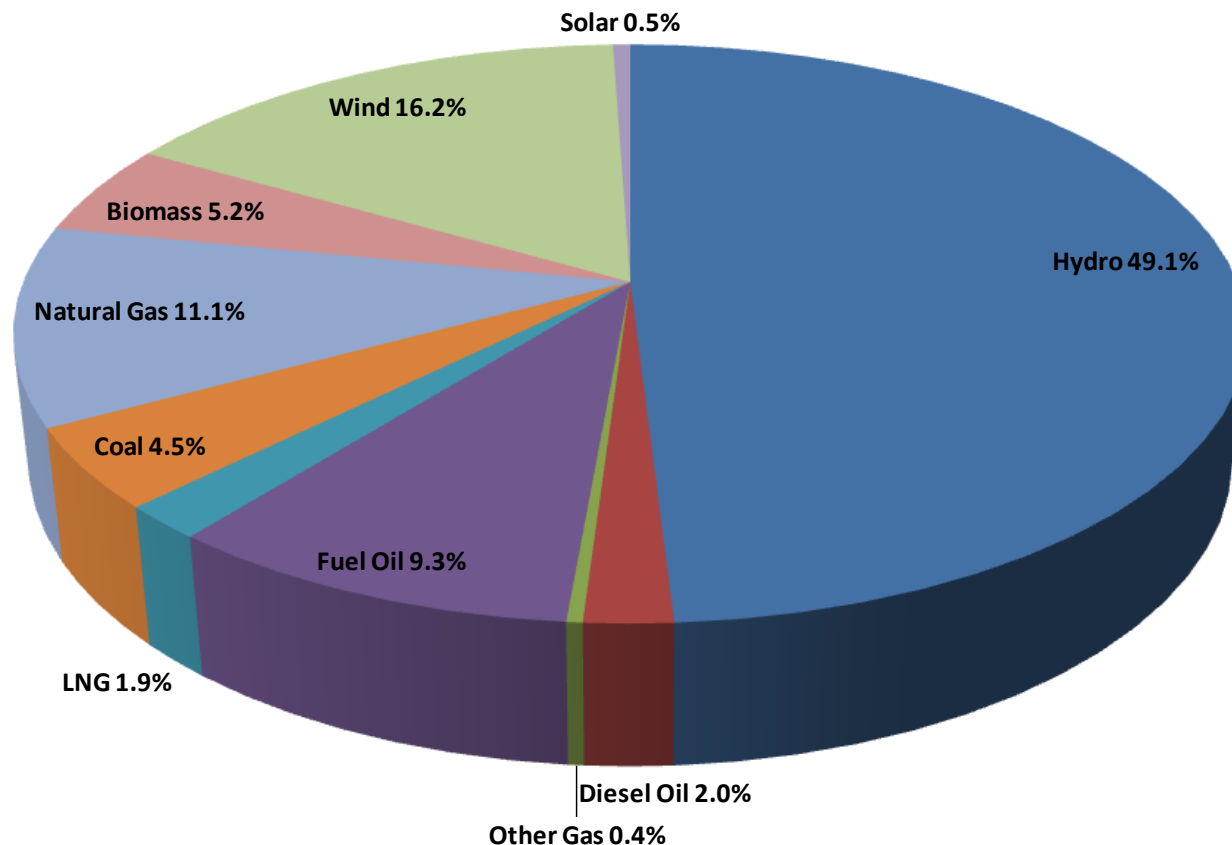
**Gen. Cap. Mix  
December/2023  
195.883 MW**



*Note1: Includes import*  
*Note2: Excludes self-production*

Source: MME/EPE - PDE 2023

## Total Energy Traded – 6,614 TWh



71% 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

# Expansion of New Renewables



# Expansion of New Renewables – Driven Forces

## ⇒ Policy Framework & Market Design

- ⇒ Planning
- ⇒ Public Auctions
- ⇒ Financing mechanisms
- ⇒ Incentives

## ⇒ Brazil's iNDC at COP 21

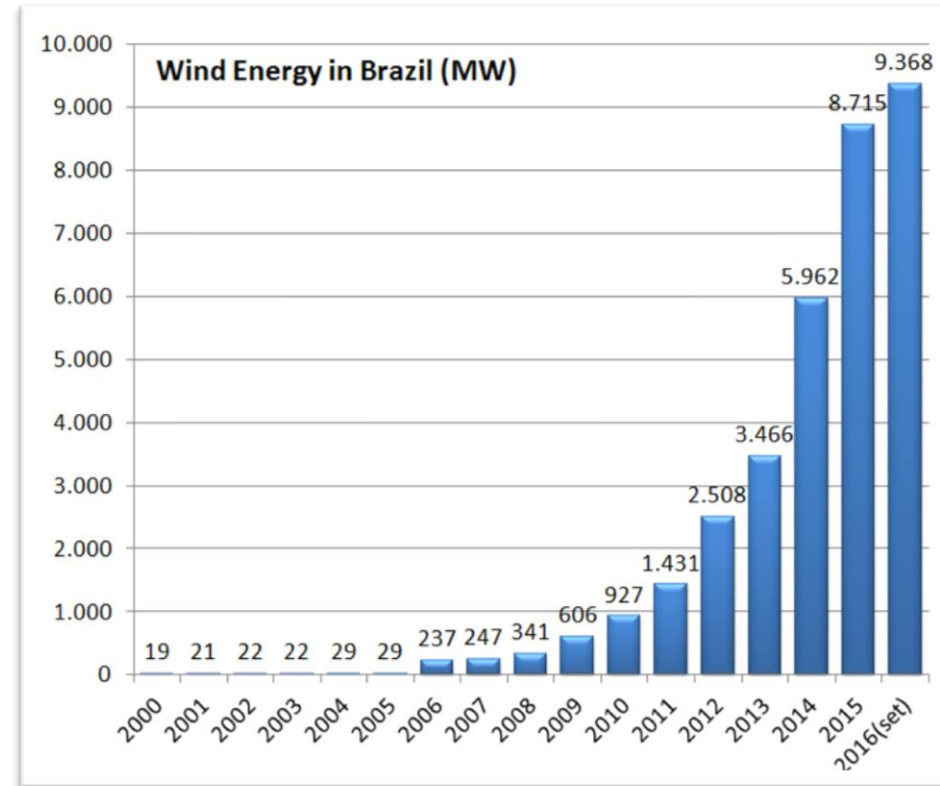
## ⇒ Distributed Generation


- ⇒ Net Metering (Res ANEEL 482/2012 e 687/2015)
- ⇒ ProGD – Distributed Power Generation Development Program

- ⇒ Reduce greenhouse gas emissions below 2005 levels
  - ⇒ by 37% in 2025
  - ⇒ By 43% in 2030 (indicative)
  
- ⇒ Maintain 45% of renewables in the *energy* mix by 2030
  
- ⇒ Expanding the use of renewable energy sources other than hydropower in the total *energy* mix to between 28% and 33% by 2030
  
- ⇒ Increasing the share of renewables (other than hydropower) in the *electricity* mix to at least 23% by 2030, including by raising the share of wind, biomass and solar
  
- ⇒ Achieving 10% *efficiency* gains in the electricity sector by 2030

# Wind Energy in Brazil - installed capacity in 2016

State	Power MW (set/2016)	Wind Farm # (set/2016)
Bahia	1.718,1	68
Ceará	1.353,2	49
Paraíba	69,0	13
Paraná	2,5	1
Bahia	595,4	28
Ceará	777,6	28
Rio de Janeiro	28,1	1
Rio Grande do Norte	2.994,1	110
Rio Grande do Sul	1.553,8	67
Santa Catarina	242,5	15
Sergipe	34,5	1
<b>Total</b>	<b>9.368,6</b>	<b>381</b>





**Electric Energy Compensation System**  
Res #482/2012  
Res #687/2015

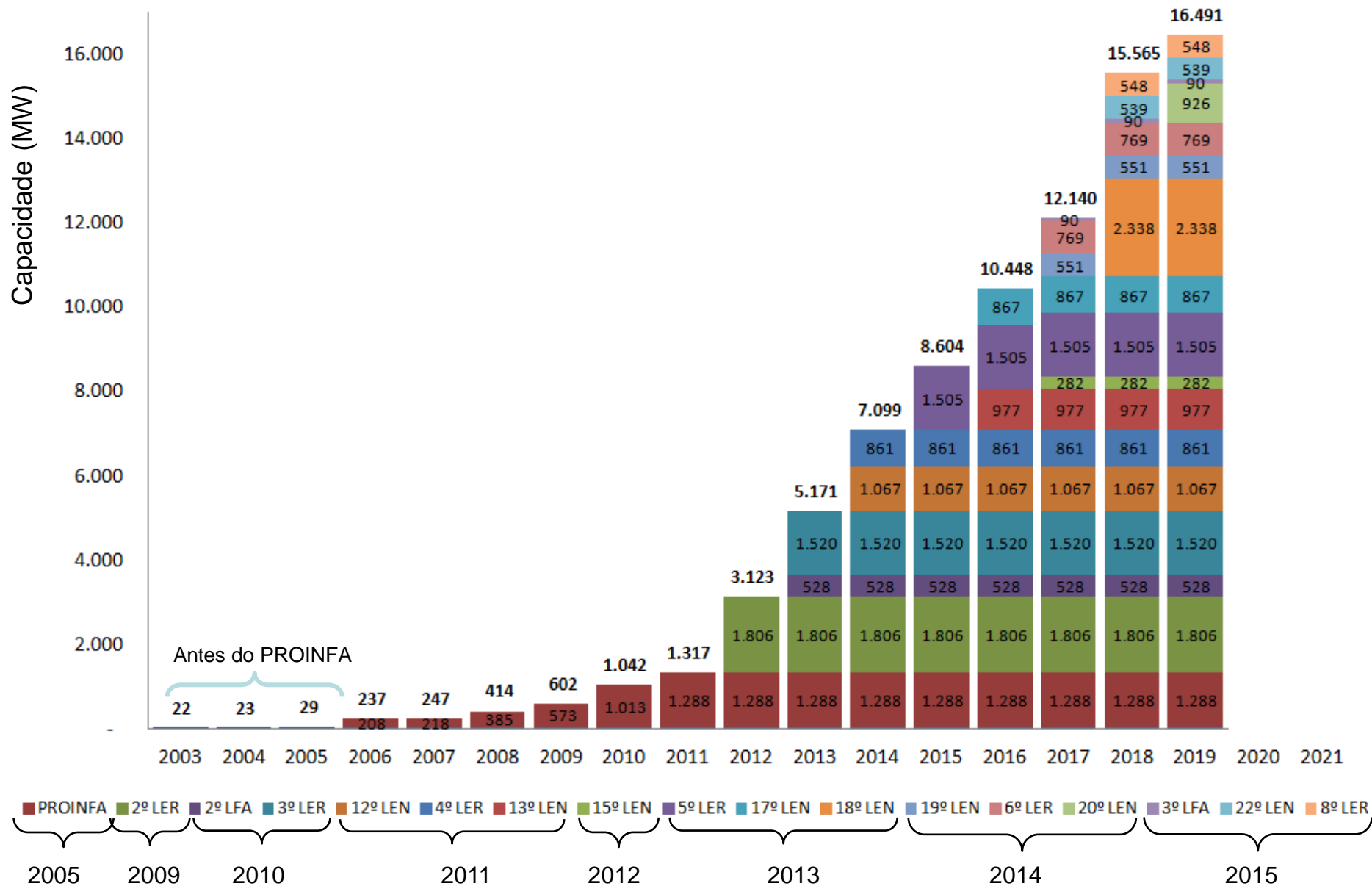
➔

Distributed microgeneration & minigeneration to the grid:  
239 kW (62 units)

(Source: ANEEL, 2016. *Banco de Informações de Geração*. Disponível em: <http://www.aneel.gov.br>)

(Source: GWEC, 2016. *Global Wind Report 2015*. Disponível em: [http://www.gwec.net/wp-content/uploads/vip/GWEC-Global-Wind-2015-Report\\_April-2016\\_22\\_04.pdf](http://www.gwec.net/wp-content/uploads/vip/GWEC-Global-Wind-2015-Report_April-2016_22_04.pdf))

# Wind Power Auctions (MW)

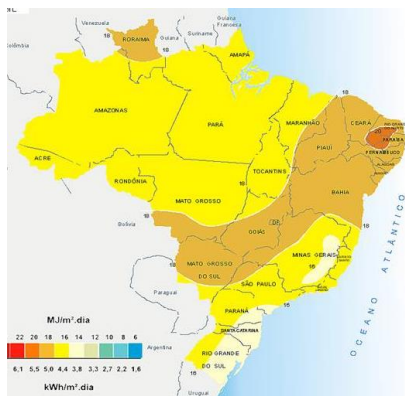


# Solar Photovoltaic Energy in Brazil

## Installed capacity in 2016 & forecast

**(September/2016)**

**Auctions**



Solar Photovoltaics  
40 Power Plants  
26,9 MWp

6º LER (2014)  
31 Power Plants  
889,6 MWp

10/2017

7º LER (2015)  
30 Power Plants  
833,8 MWp

08/2017

8º LER (2015)  
33 Power Plants  
929,3 MWp

11/2018



**Electric Energy  
Compensation  
System**  
Res #482/2012  
Res #687/2015

Distributed microgeneration  
& minigeneration to the grid:  
32,3 MW (4.054 units)

**Total (september/2016):**

- 4.094 units
- 59,2 MWp

**Total (end of 2018):**

- 134 PV power plants
- 2.679,6 MWp

# Biomass and SHP power generation in Brazil (September/2016)



SHP:  
446 Power Plants  
4.854,8 MW



Thermopower by  
Biomass:  
528 Power Plants  
13.822,8 MW



Electric Energy  
Compensation  
System  
Res #482/2012  
Res #687/2015



Distributed microgeneration  
& minigeneration to the grid:  
2,5 MW (5 units)

**Total (september/2016):**

- 451 Units
- 4.857,3 MW

Distributed microgeneration  
& minigeneration to the grid:  
3,2 MW (21 units)

**Total (september/2016): :**

- 549 Units
- 13.826,0 MW

(Source: ANEEL, 2016. *Banco de Informações de Geração*. Available at <http://www.aneel.gov.br>)

(Source: MME, 2016. PROINFA. Available at <http://www.mme.gov.br/programas/proinfa/>)

# Incentives for Distributed Micro and Minigeneration

**RN ANEEL #482/2012 was revised in 2015 according RN #687:**

<b>Power capacity</b>	Micro-DG: $P \leq 75$ kW (before up to 100 kW); Mini-DG: $75$ kW $< P < 5.000$ kW (before $< 1.000$ kW).
<b>Credit use period</b>	The deadline for the consumer to use the energy credits rises from 3 to 5 years.
<b>“Remote consumption”</b>	The consumer can use the energy credits to other properties whose account is under his/her ownership.
<b>Condominium</b>	Residents of a condominium can use their energy credits jointly.
<b>Consortium group</b>	Shared generation: consumers, in different places, come together in a consortium or cooperative and share the energy credits, similar to a condominium.

# ProGD - Distributed Power Generation Development Program



**ProGD** – Distributed Power Generation Development Program, was created by the Ministry of Mines and Energy (MME Act #538, of 12/15/2015)

## Goals:

- I - to promote the expansion of distributed power generation based on renewable energy sources and cogeneration;
- II - to encourage the deployment of distributed generation for:
  - a) public buildings such as schools, universities and hospitals;
  - b) commercial, industrial and residential buildings.



# CEPEL's PMU and SmartGrid Labs

# Cepel's Smart Grid Lab (under development)

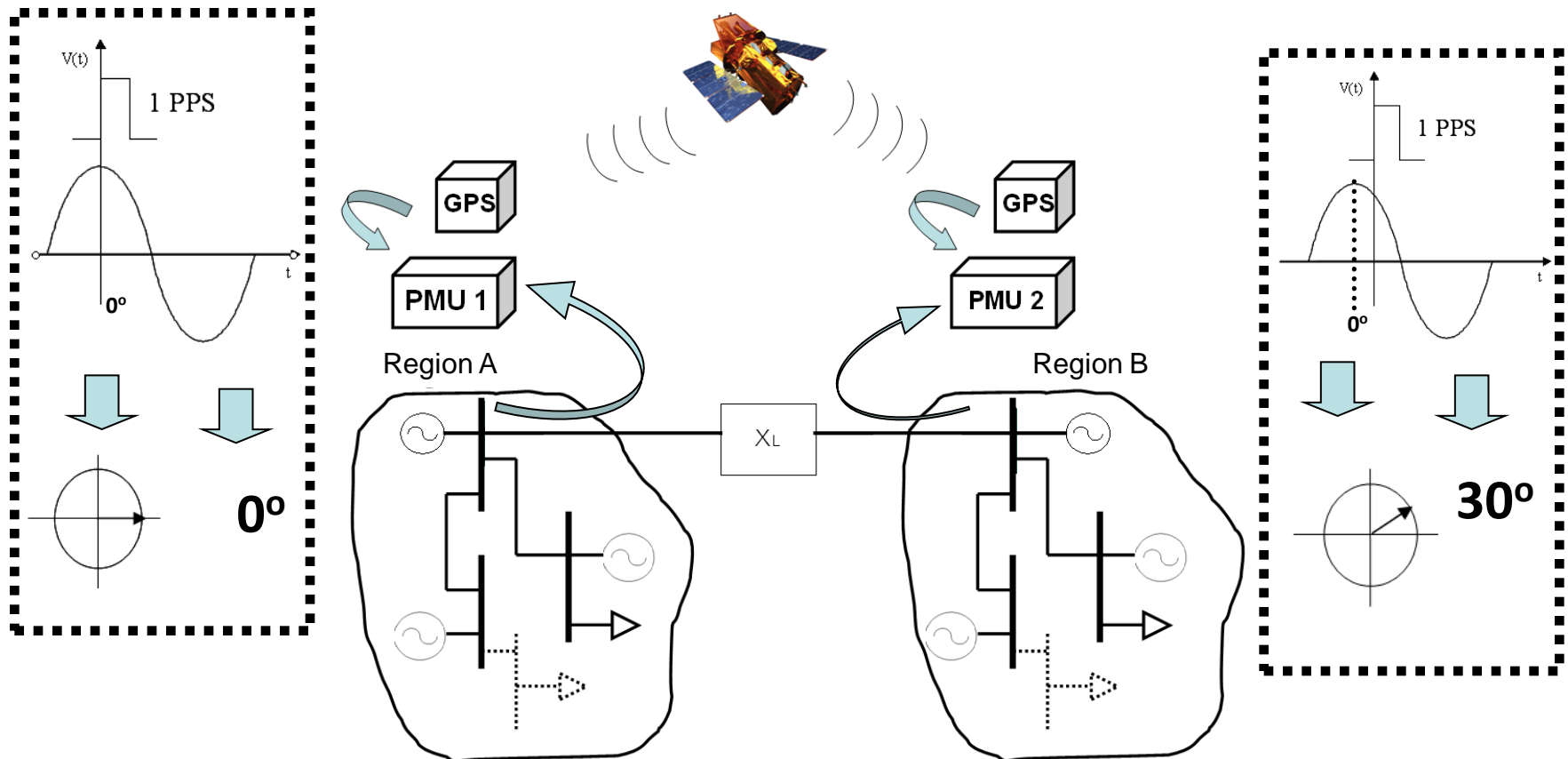
*Testbed* for Distribution Utilities, Manufacturers and Infrastructure for R&D Activities

- Reference Tests or Compliance Tests of devices and systems before their connection to the grid;
- Interoperability of devices & systems;
- Experimental MV and LV feeder for microgrid tests and emulation of an integrated Smart Grid facility;
- Tests of microgrids controls using Distribution Energy Resources (DER) and storage;
- Disturbance Tests;
- Control and Demonstration Room



CEPEL Adrianópolis

**Phasor Measurement Units** measure with great accuracy, magnitude and angle at power system buses, allowing the evaluation of angles between electric bars located at great distances from each other, using GPS's signal as reference.



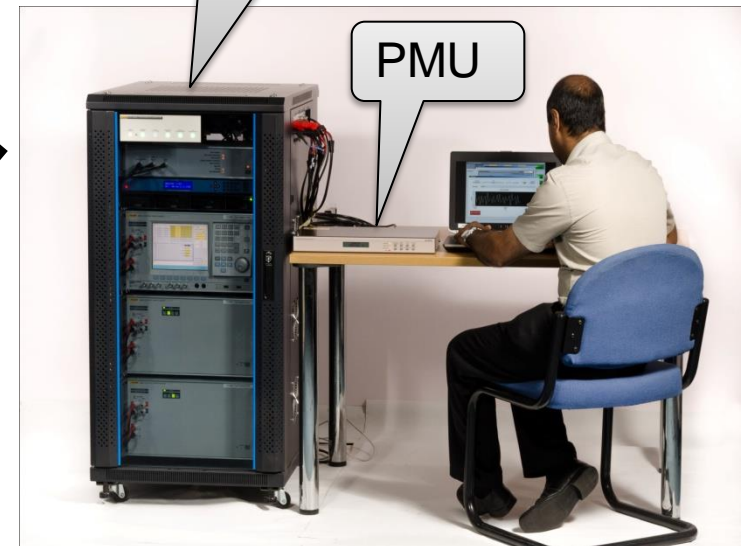
# Reference Tests of PMUs



## LabPMU

Calibrator

PMU



**Test bed to assess PMUs regarding compliance with International Standard IEEE-C37-118.1**



**Thank You !**

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