


Eletrobras
Eletronuclear

# The Future of Nuclear Market in Brazil: Beyond the Grid

Innovations in Nuclear Technology 2012
Brazil: Challenges and Opportunities

December 10th & 11th, 2012

Leonam dos Santos Guimarães

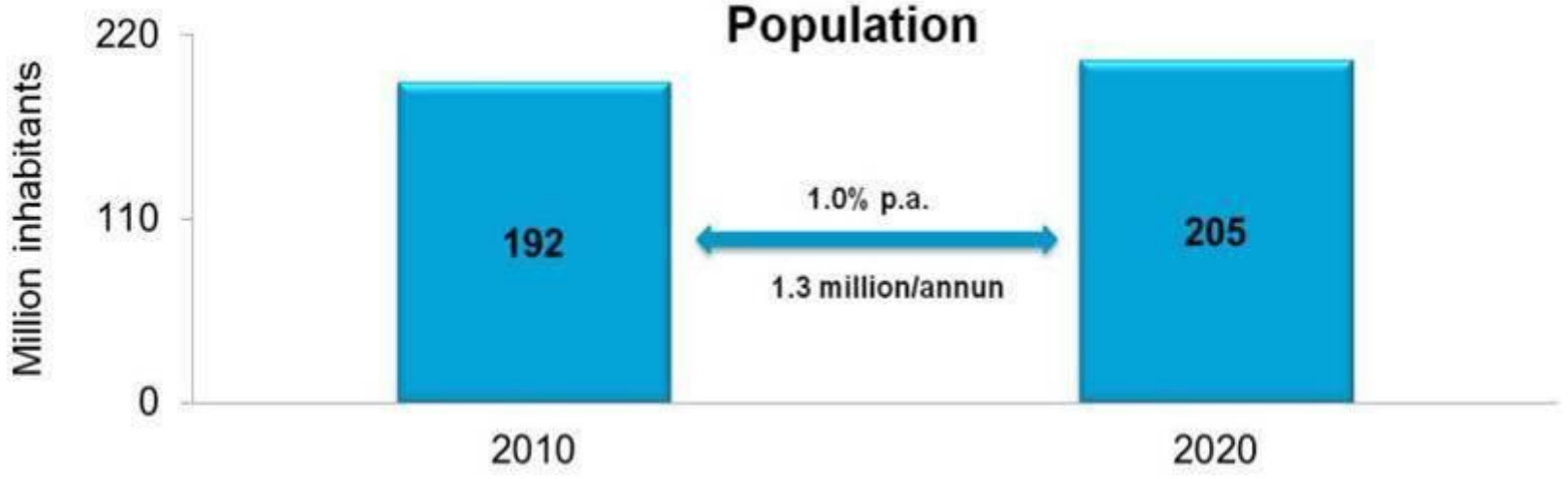
# BRAZIL
## GENERAL DATA

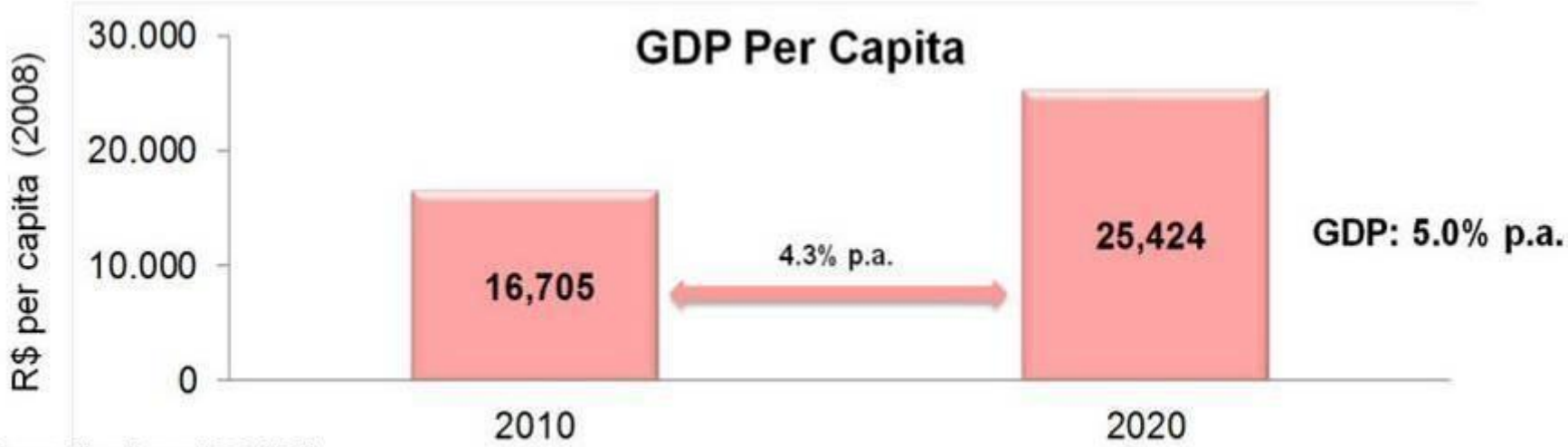
### National Interconnected System

| | | |
|---|---|---|
| Population | 192 million | 5th |
| Surface | 8.5 million km2 | 5th |
| GDP | US$ 1.98 trillion | 8th |
| GDP/capta | US$ 10,300/inh | 77th |
| HDI | 0.807 | 70th |
| Electric installed capacity | 102.6 GW | 9th |
| electricity production/year | 450 TWh | 10th |
| electricity consumption/capta | 2,400 kWh/inh | 90th |

# FORECASTS 2020

## Population and GDP per capita

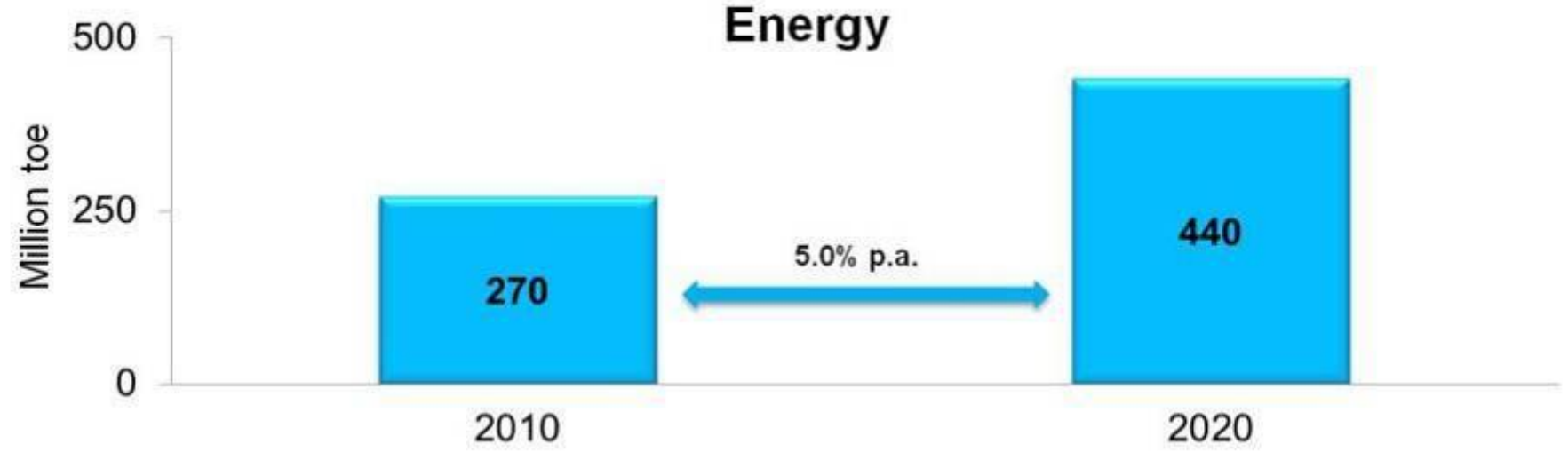


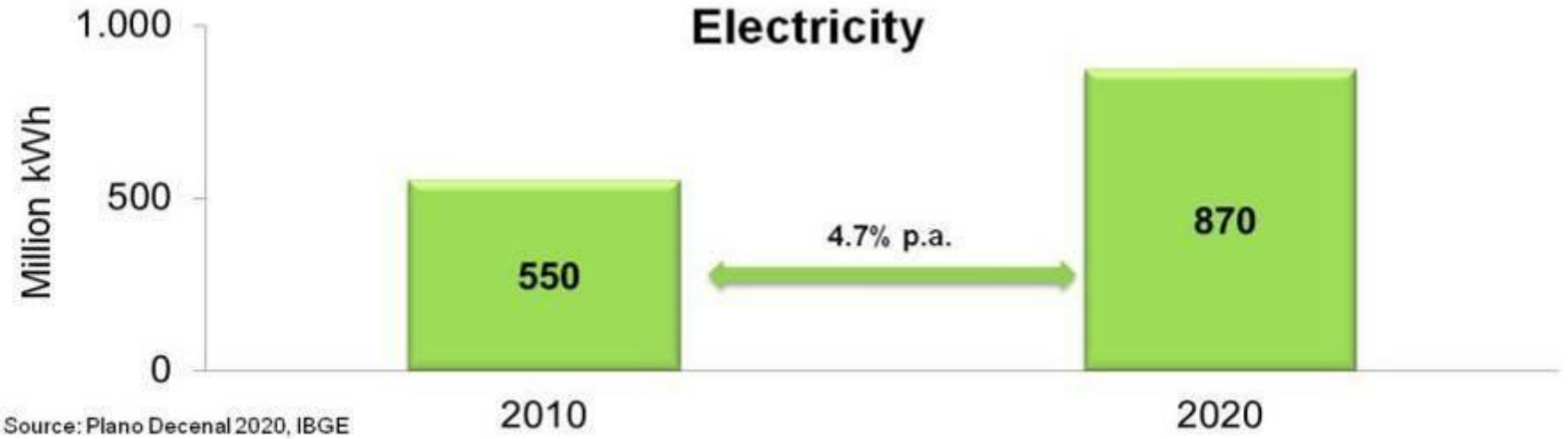




Source: Plano Decenal 2020, IBGE

# FORECASTS 2020

## Energy and electricity consumption

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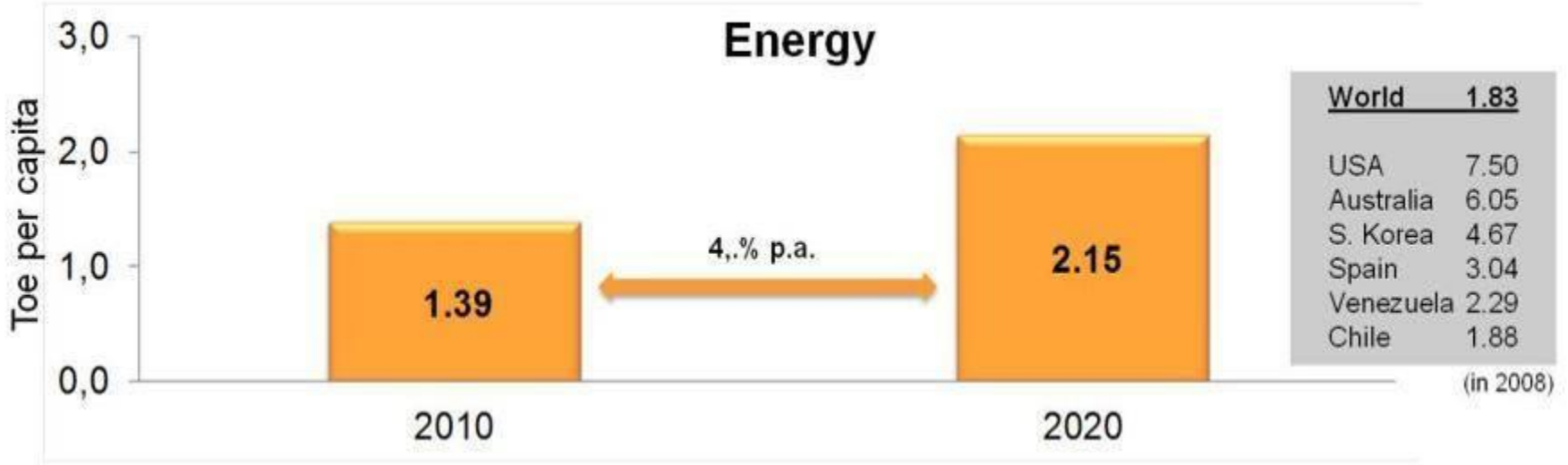
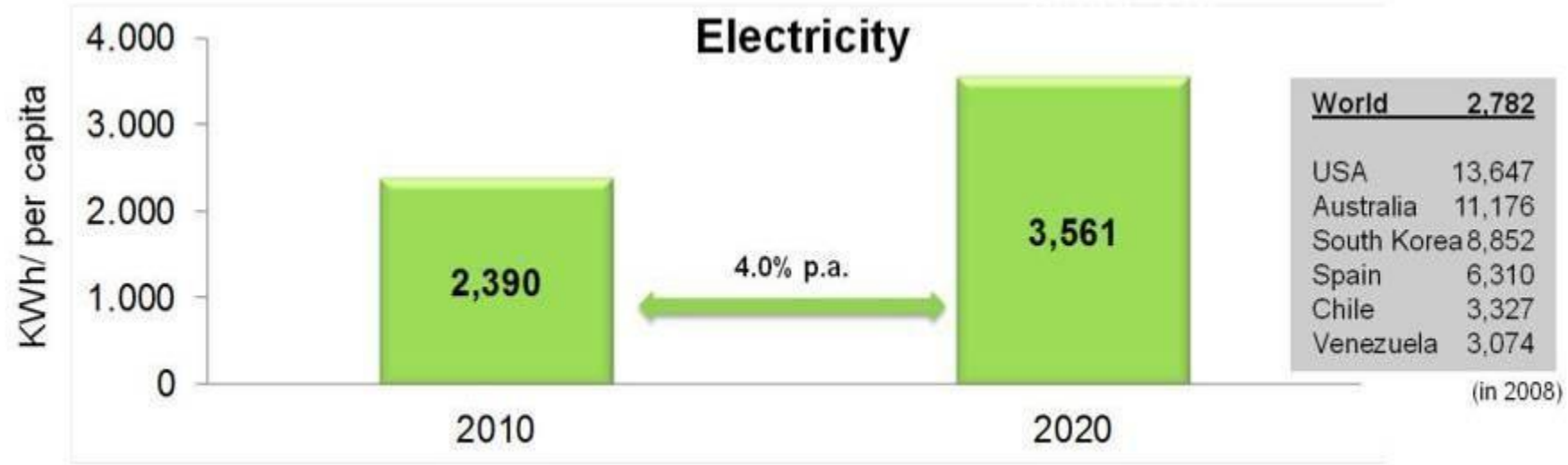
# FORECASTS 2020

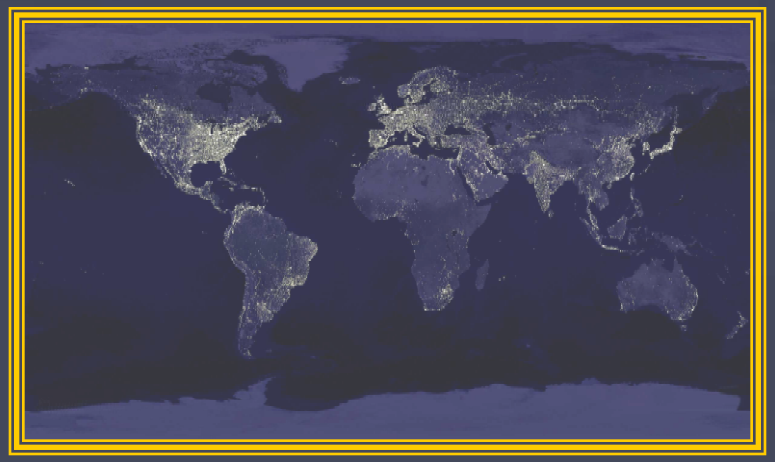
## Energy and electricity consumption per capita



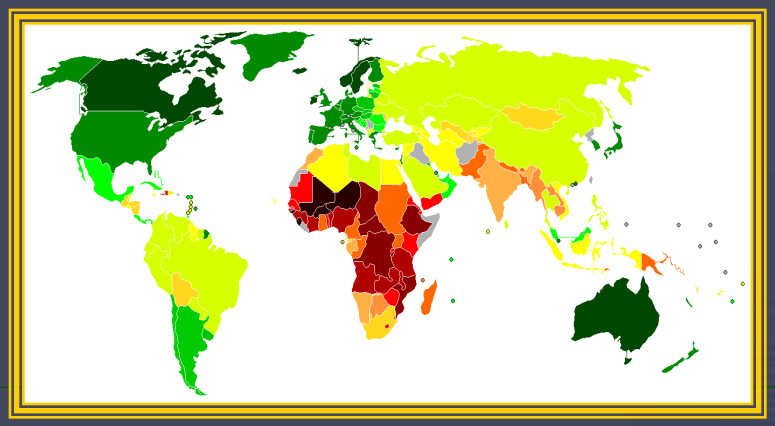



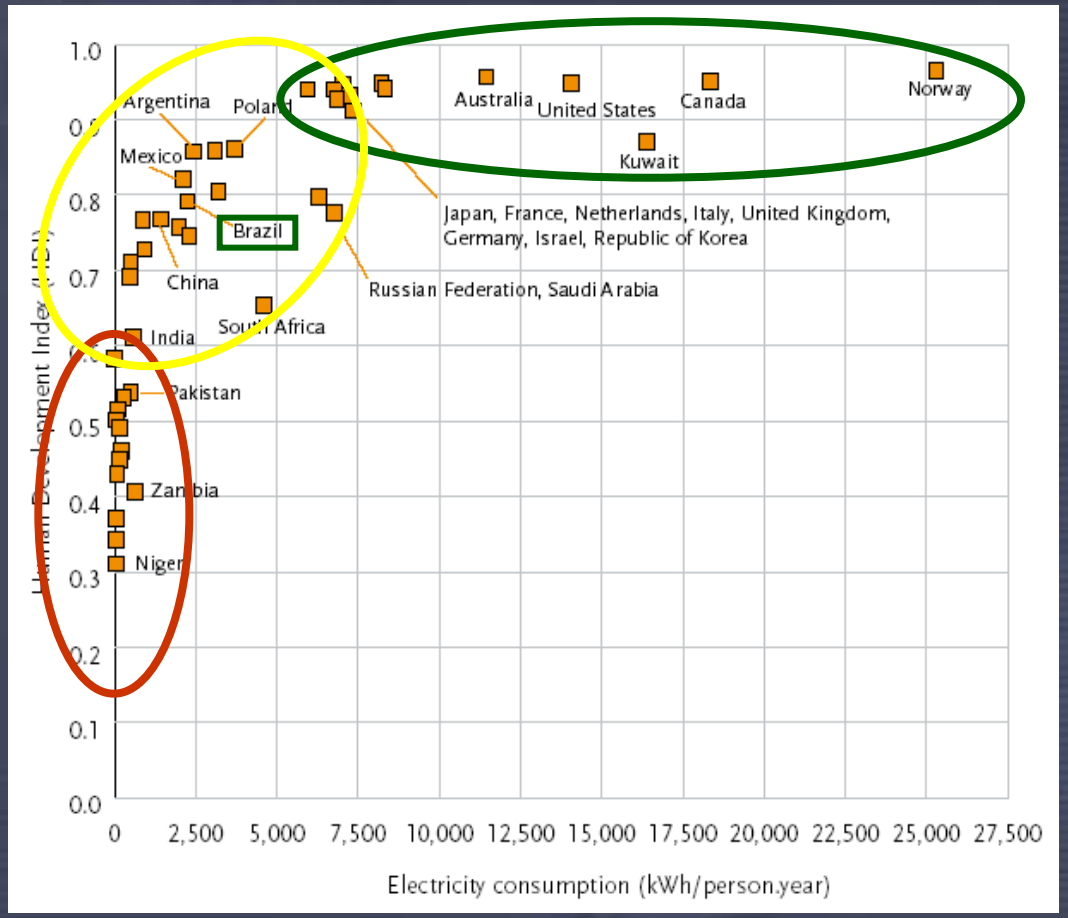
# HDI X ELECTRICITY CONSUMPTION

## BRAZIL: 90th place



## BRAZIL: 69th place

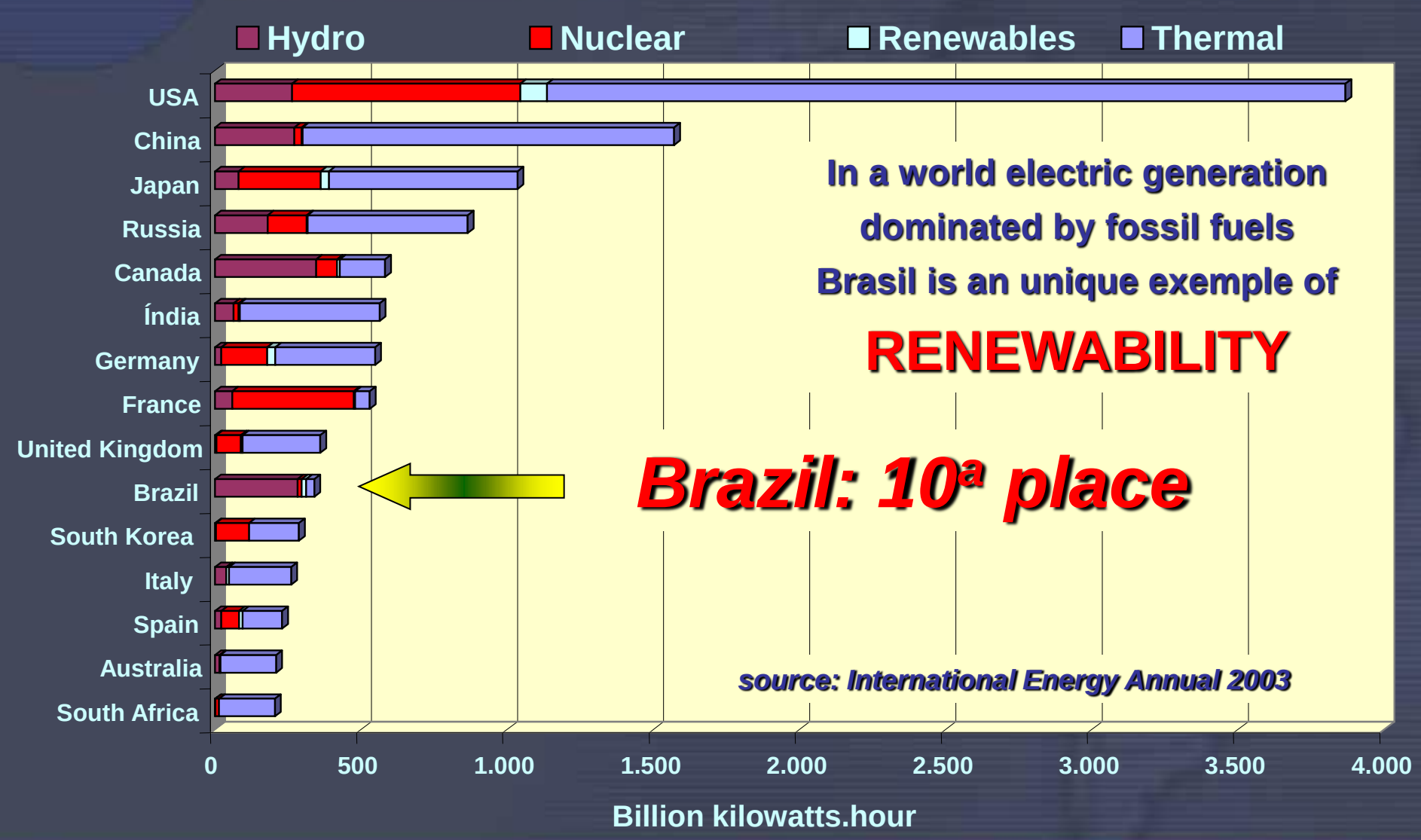





Fonte: Lighting the way, InterAcademy Council, 2007

# TOP 15 WORLD ELECTRIC GENERATORS

## BRAZIL IS ONE OF THE MAIN WORLD ELECTRICITY PRODUCERS



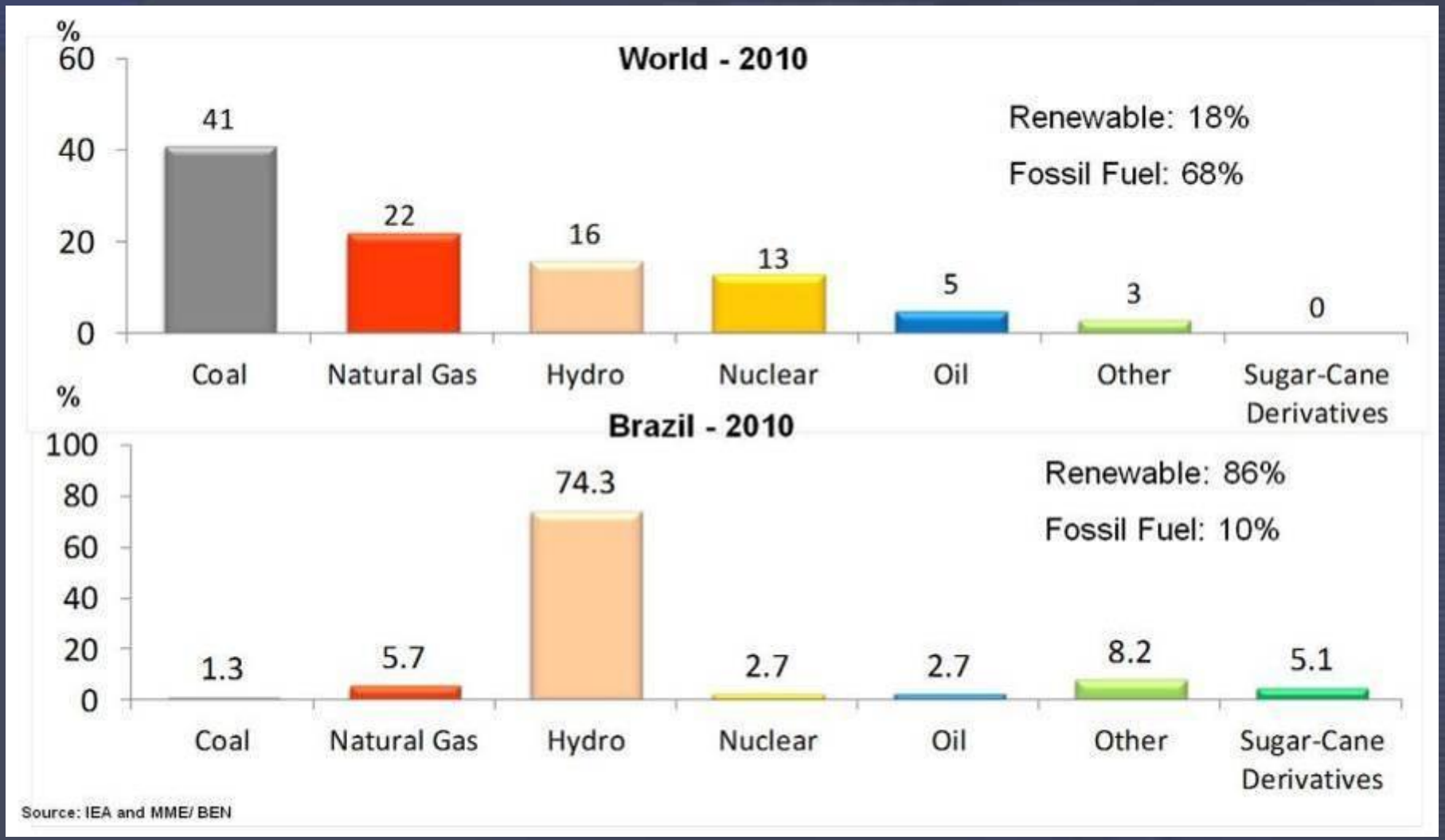

**In a world electric generation dominated by fossil fuels Brasil is an unique exemple of**

**RENEWABILITY**

***Brazil: 10ª place***

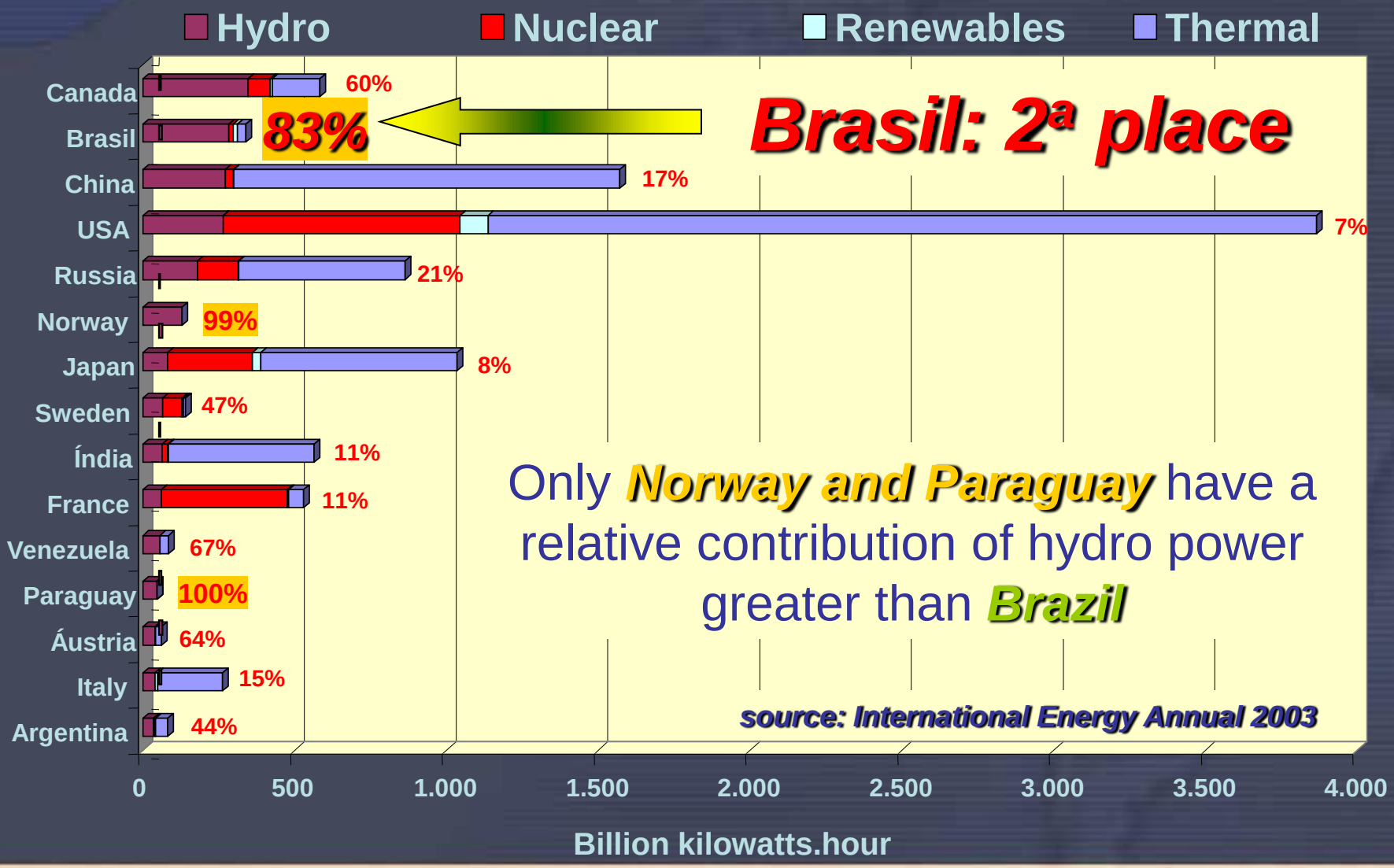
*source: International Energy Annual 2003*

# ELECTRICITY SUPPLY MATRIX
## WORLD x BRAZIL (%)



# TOP 15 WORLD HYDRO GENERATORS

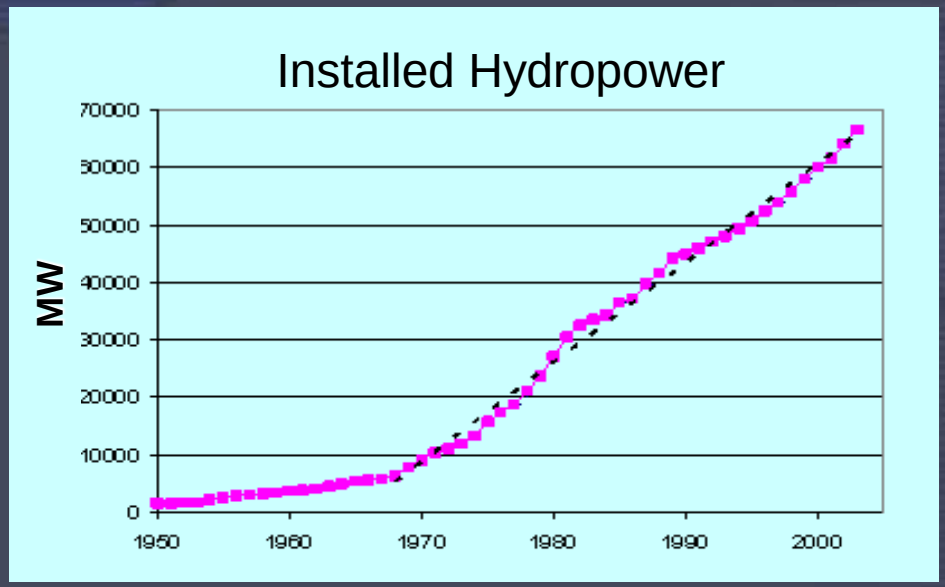
## *GREATEST CONTRIBUTION OF HYDRO POWER*



# HYDROPOWER REQUIRES SYSTEM INTEGRATION

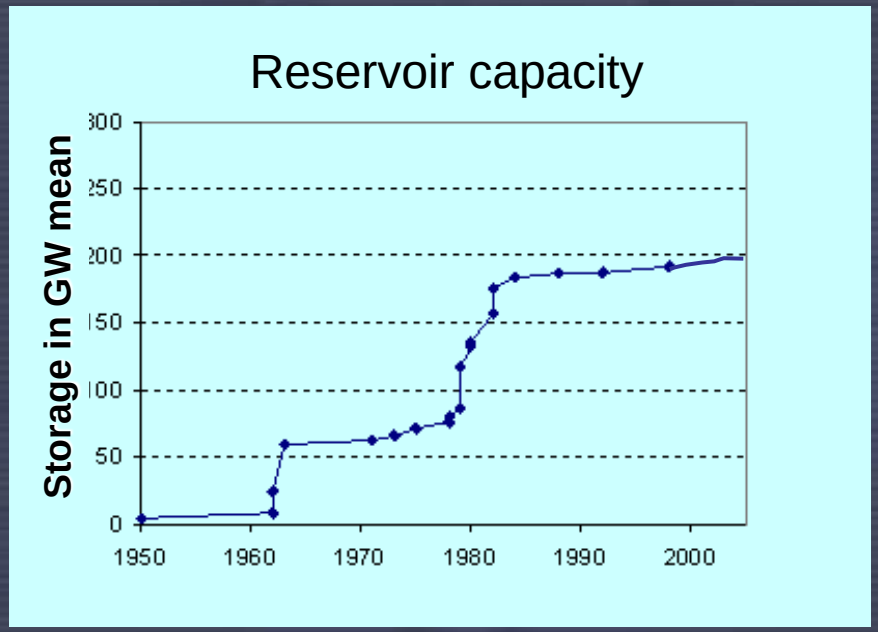
## HAVING CONTINENTAL DIMENSIONS EQUIVALENT TO EUROPE

# ELECTRIC SYSTEM EVOLUTION IN THE 90´s
## NEED FOR THERMAL REGULATION



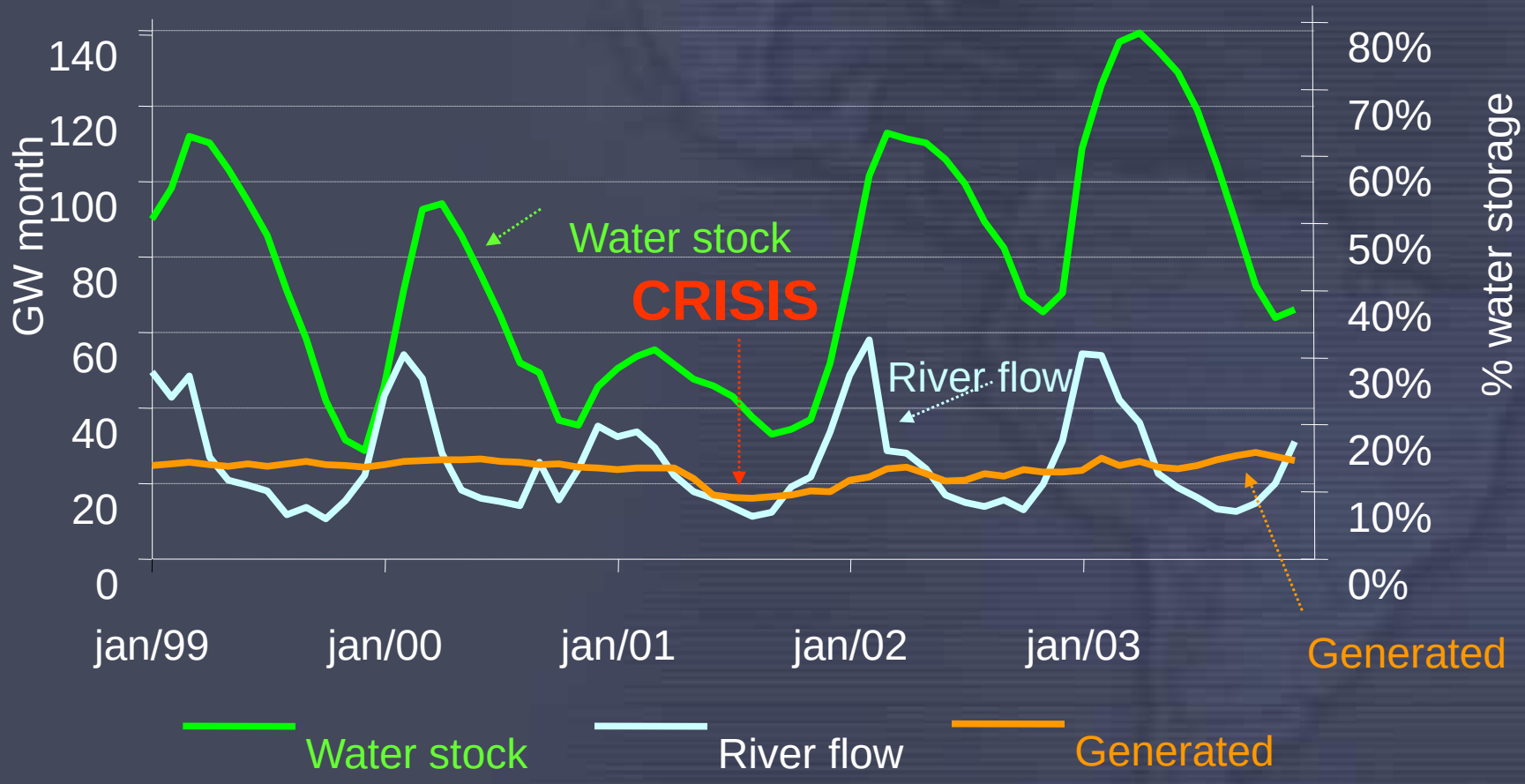

***installed hydro capacity increasing …***

***… but without a proportional increase in the water stock***



# ELECTRIC SYSTEM EVOLUTION
# NEED FOR THERMAL REGULATION

## root cause of 2001 supply crisis



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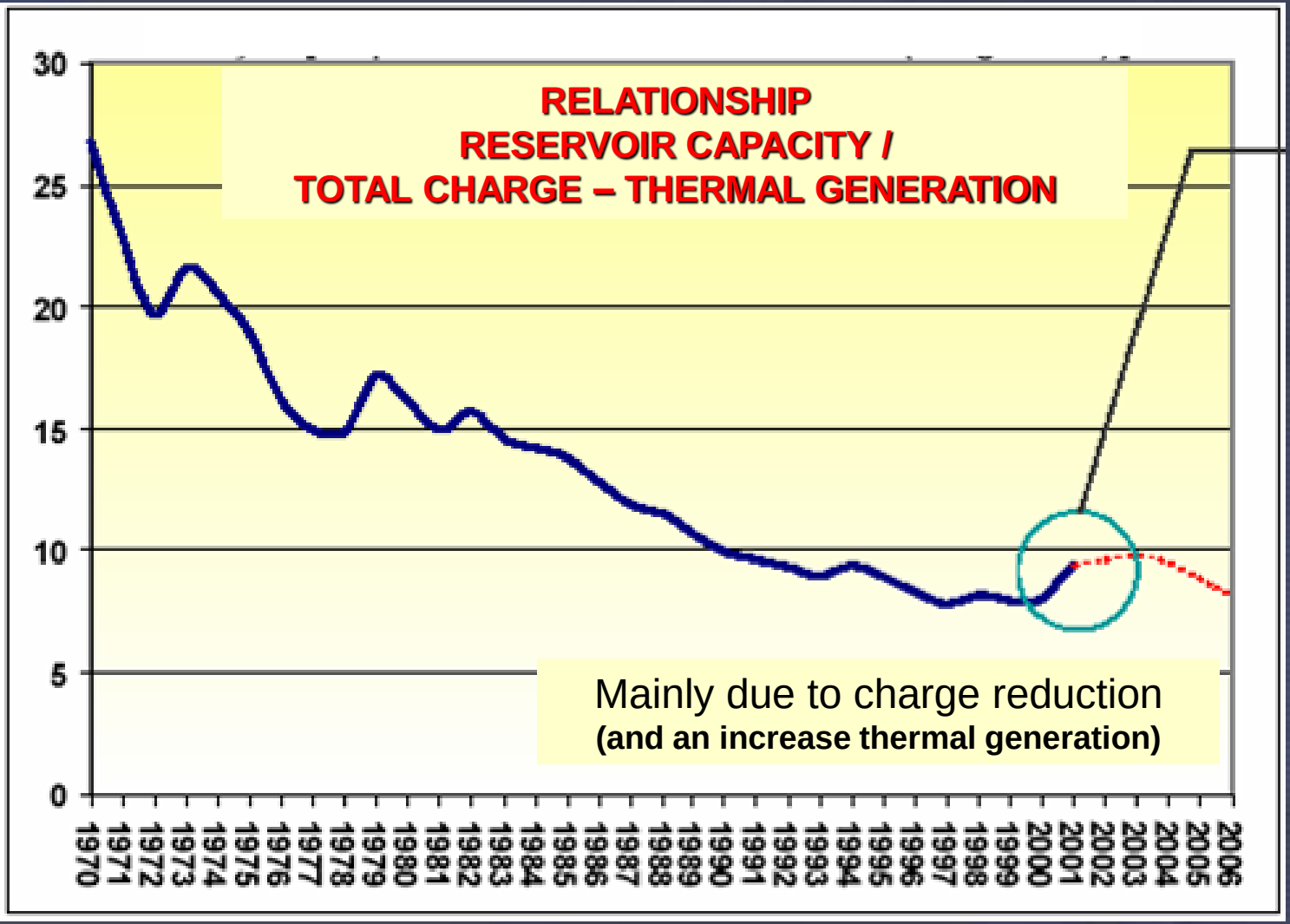
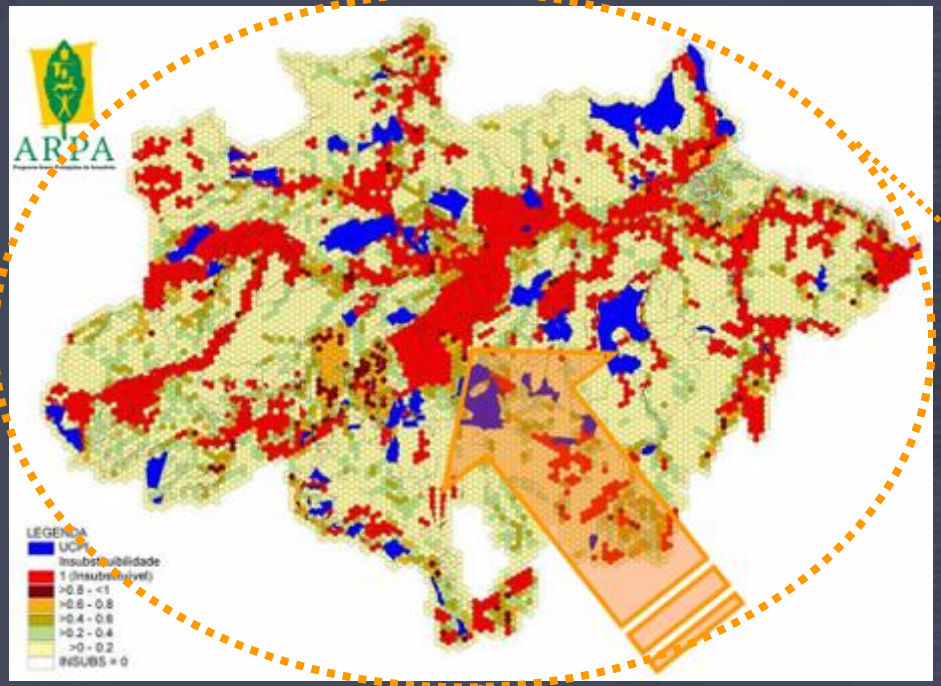


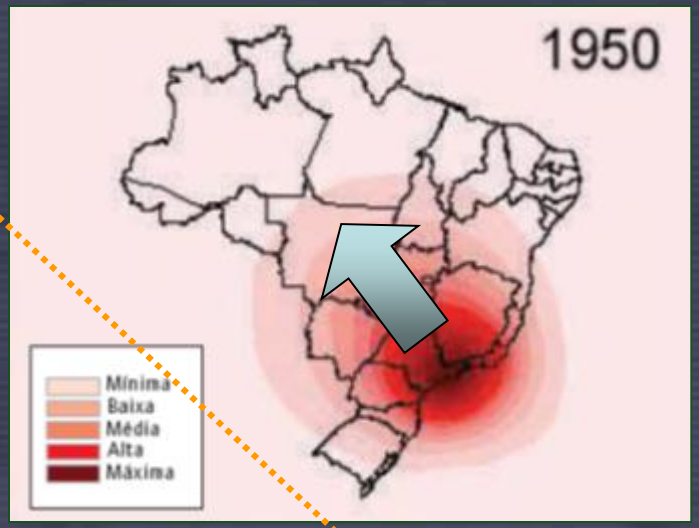

**2001**

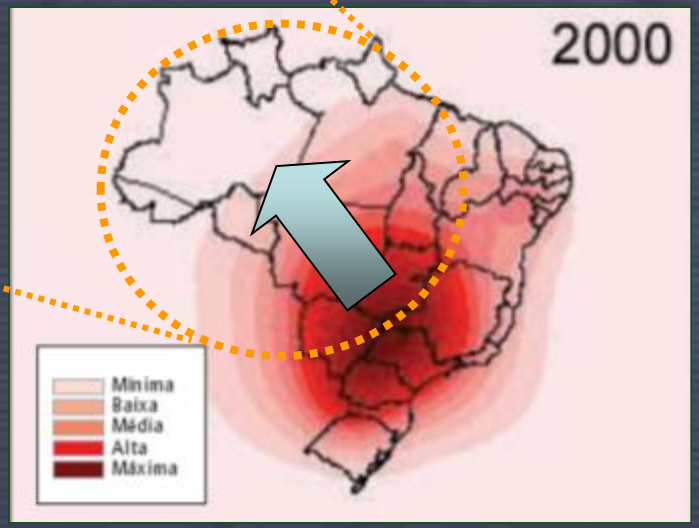
**SUPPLY CRISE**

# ELECTRIC SYSTEM EVOLUTION IN THE 90´s

## "DAM CULTURE" CHANGE



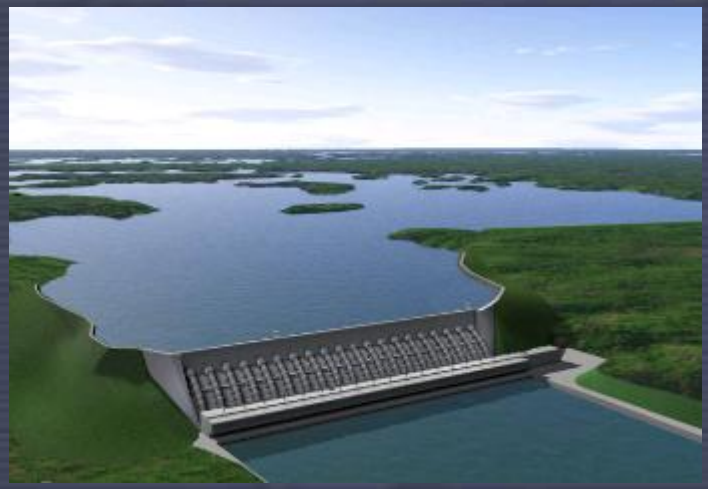

*small reservoirs to avoid flooding large surfaces*

# ELECTRIC SYSTEM EVOLUTION IN THE 90´s
# "DAM CULTURE" CHANGE


***This tendency will be amplificated by new projects in Amazon Bassin***

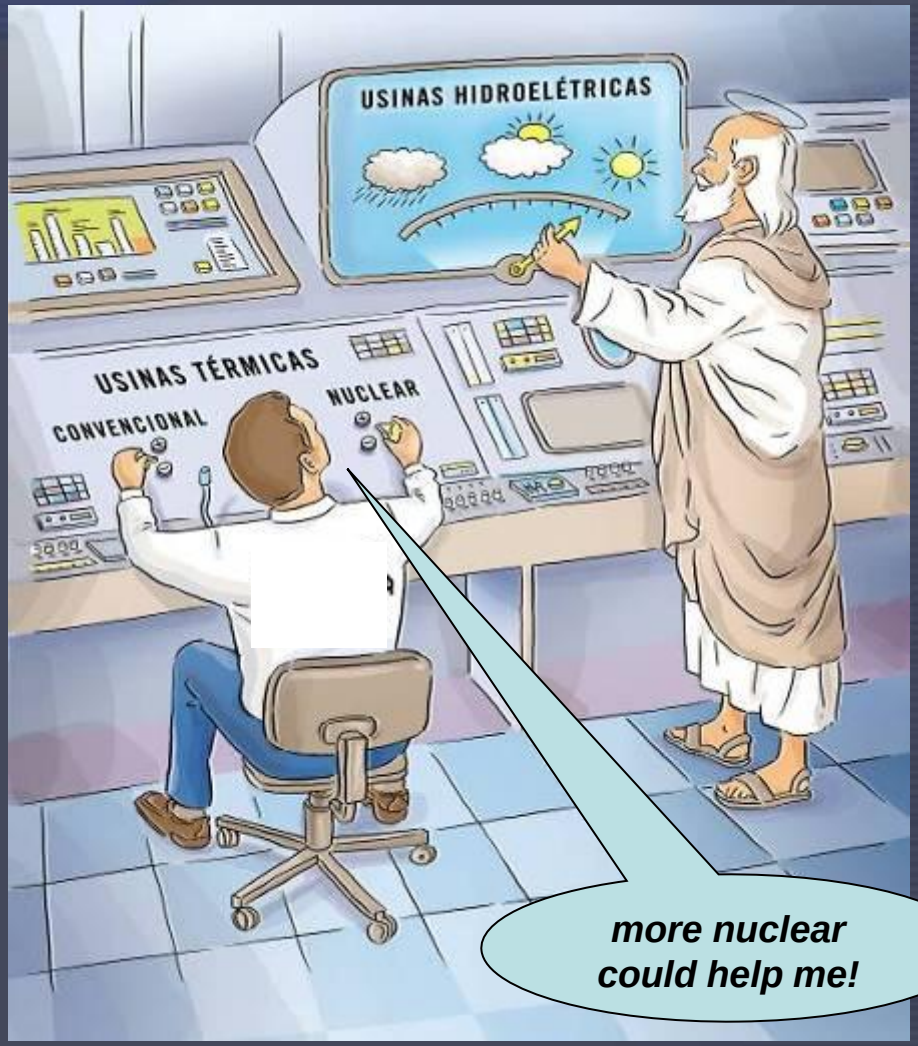

- Current average hydro capacity factor: **55%**
- Future average Amazon hydro capacity factor: **40%**

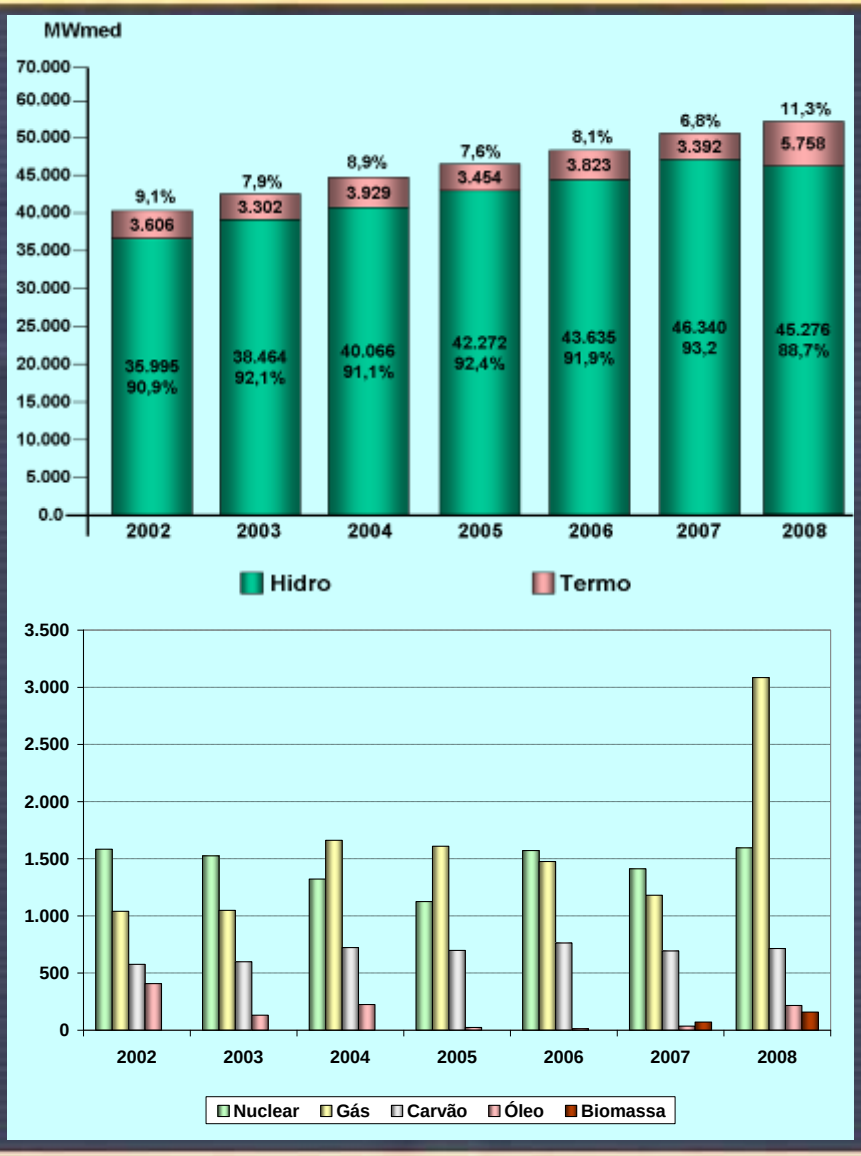
Project AHE MADEIRA 6.500 MW



Project AHE BELO MONTE 11.000 MW

# ELECTRIC SYSTEM EVOLUTION IN THE 90´s
## NEED FOR THERMAL REGULATION



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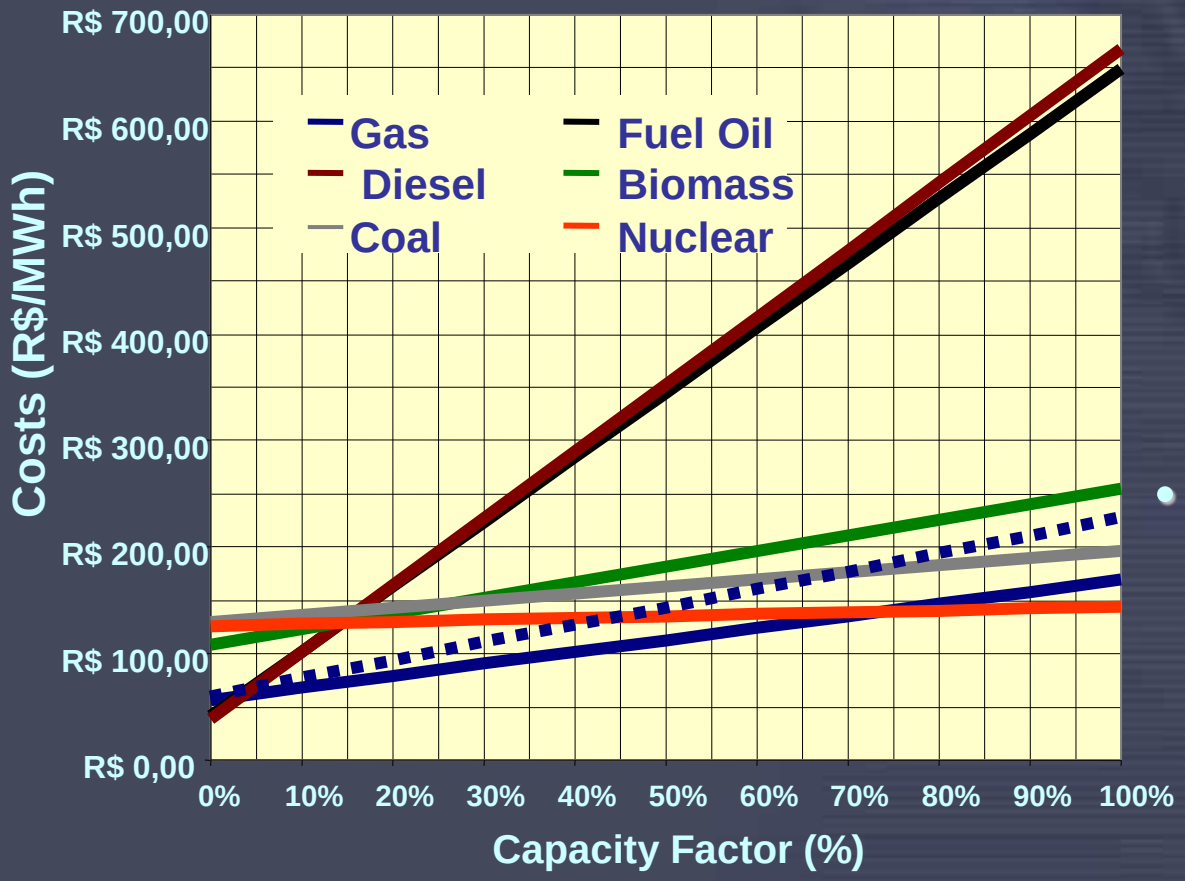


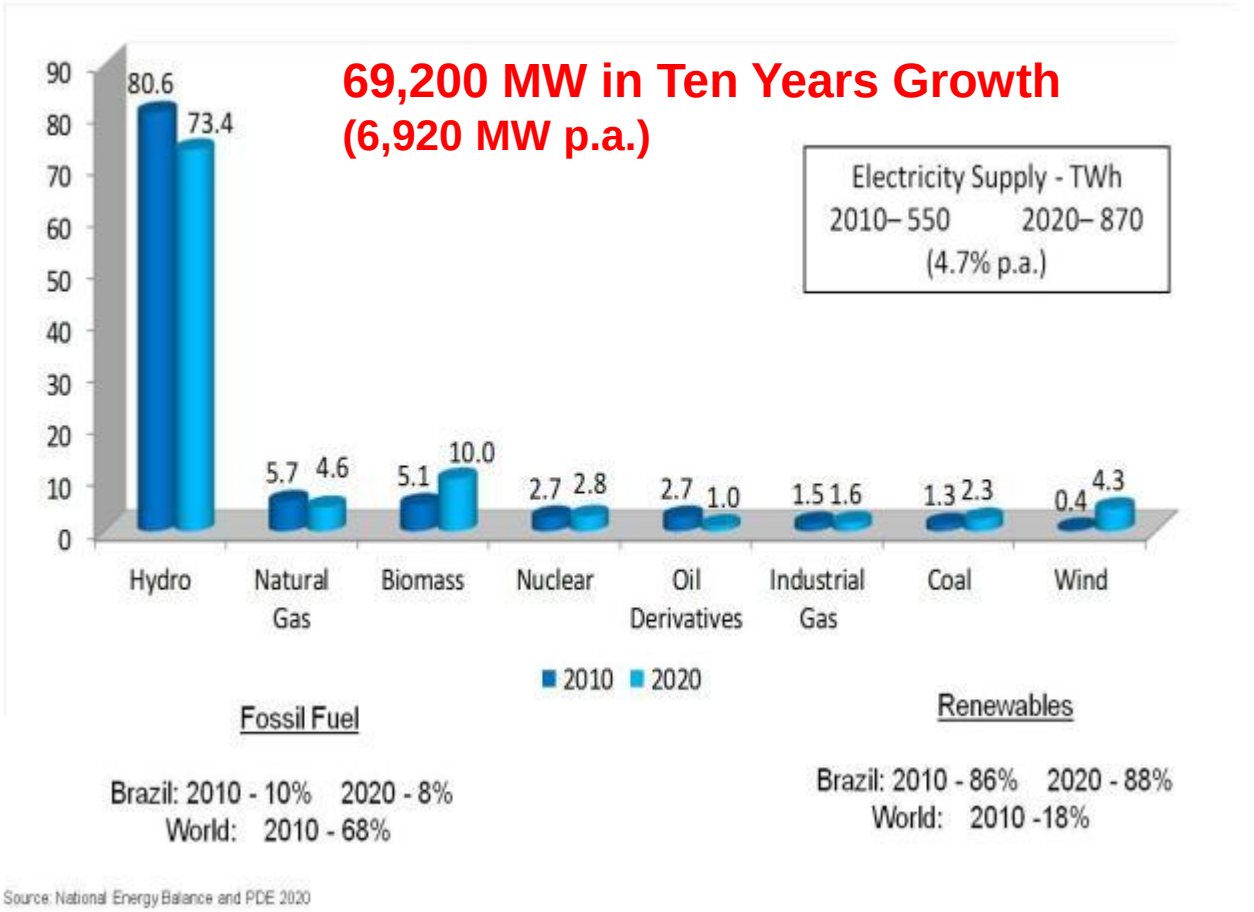

- There will be a place for all thermal options
  - Minimum cost according capacity factor range
- But costs are not the only decision factor:
  - ❑ *Price volatility*
  - ❑ *Assurance of supply*

must be considered too

# ELECTRICITY SUPPLY MATRIX
## FORECASTS 2020

| Year | 2010 | 2020 |
|---|---|---|
| MW | 112,400 (80,600 hydro-71%) | 181,600 (115,600 hydro-64%) |

| Source | MW | % | |
|---|---|---|---|
| Hydro | 35,000 | 49.1 | 81.3% |
| Wind | 10,600 | 14.9 | |
| Biomass | 12,300 | 17.3 | |
| Oil | 4,100 | 5.8 | |
| Natural Gas | 2,200 | 3.1 | |
| Coal | 1,800 | 2.5 | |
| Industrial Gas | 1,800 | 2.5 | |
| Nuclear | 1,400 | 2.0 | |
| **Total** | **69,200** | **100.0** | |

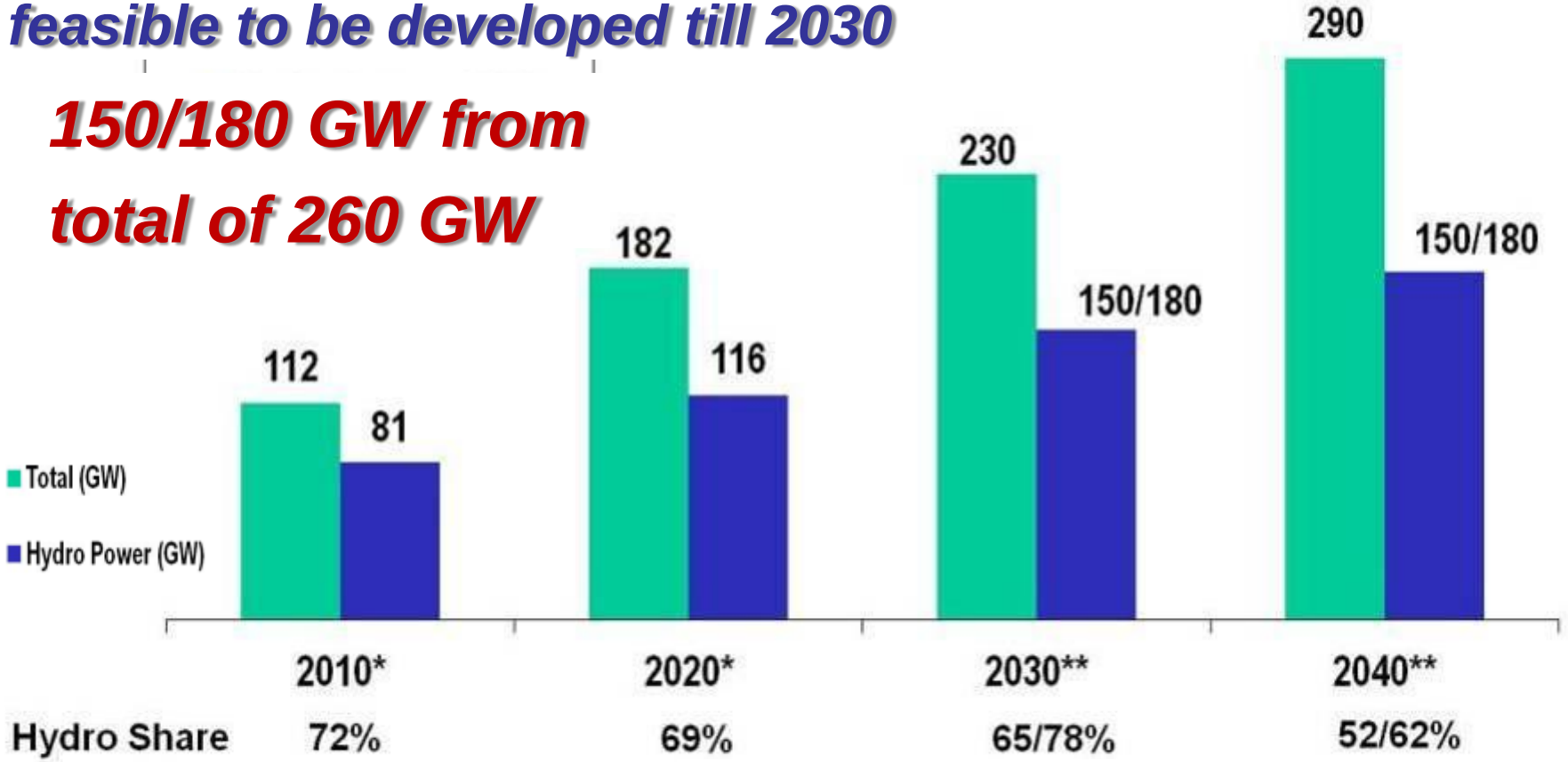



Source: National Energy Balance and PDE 2020

# ELECTRICITY SUPPLY MATRIX
## HYDROPOWER POTENTIAL RESSOURCES

***technical, environmental and economically feasible to be developed till 2030***

***150/180 GW from total of 260 GW***

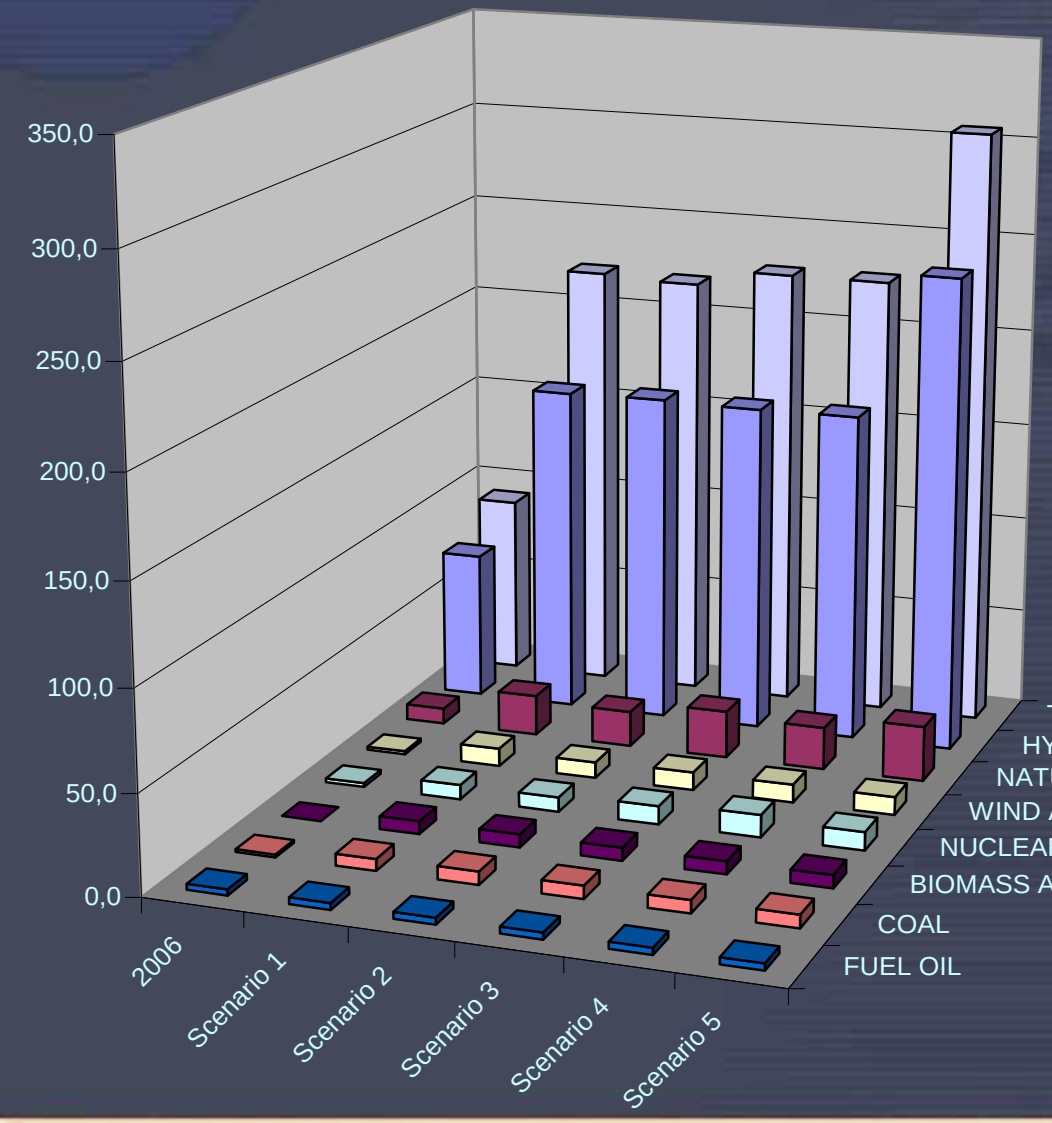



* PDE 2020
** MME/SPE –2050 Prospective Studies

***CONTINUOUS DECREASE IN HYDRO SHARE AFTER 2020***

# NUCLEAR RENAISSANCE IN BRASIL

## PROJECTIONS FROM NATIONAL ENERGY PLAN 2030




| | HYDRO | NATURAL GAS | WIND AND OTHER RENEWABLES | NUCLEAR | BIOMASS AND WASTE | COAL | FUEL OIL | TOTAL |
|---|---|---|---|---|---|---|---|---|
| 2006 | 75,6 | 8,1 | 1,6 | 2,0 | 0,1 | 1,4 | 2,9 | 91,6 |
| Scenario 1 | 167,8 | 20,6 | 9,1 | 7,3 | 6,5 | 5,9 | 3,3 | 220,5 |
| Scenario 2 | 168,8 | 18,1 | 8,0 | 7,3 | 6,5 | 6,5 | 3,3 | 218,5 |
| Scenario 3 | 168,2 | 24,1 | 9,1 | 9,3 | 6,5 | 6,5 | 3,3 | 227,0 |
| Scenario 4 | 168,7 | 21,6 | 9,1 | 11,3 | 6,5 | 6,5 | 3,3 | 227,0 |
| Scenario 5 | 243,3 | 28,1 | 9,1 | 9,3 | 6,5 | 6,5 | 3,3 | 306,1 |

**A greater growth rate for renewables**

# NUCLEAR RENAISSANCE IN BRASIL

## PROJECTIONS FROM NATIONAL ENERGY PLAN 2030

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| | 2007-2015 | 2016-2020 | 2021-2025 | 2026-2030 | 2016-2030 |
|---|---|---|---|---|---|
| REFERENCE | 1.405 MW<br>Angra 3 | 1.000 MW<br>NE 1 | 1.000 MW<br>NE 2 | 2.000 MW<br>SE 1+SE 2 | 4.000 MW |
| MEDIUM | 1.405 MW<br>Angra 3 | 1.000 MW<br>NE 1 | 2.000 MW<br>NE 1+NE 2 | 3.000 MW<br>SE 1+SE 2+NE 3 | 6.000 MW |
| HIGH | 1.405 MW<br>Angra 3 | 2.000 MW<br>NE 1+NE 2 | 3.000 MW<br>SE 1+SE 2+NE 3 | 3.000 MW<br>SE 3+SE 4+NE 4 | 8.000 MW |

# ELECTRIC SYSTEM EVOLUTION
## NUCLEAR CAPACITY INSTALLED - 2030

*Thermal based Electric systems*

| | High Scenario Adicional MW | Low Scenario Adicional MW |
|---|---|---|
| BRASIL | 9.360 | 5.360 |
| RÚSSIA | 33.760 | 26.760 |
| ÍNDIA | 32.160 | 16.260 |
| CHINA | 43.830 | 24.830 |

# BRAZILIAN NUCLEAR INDUSTRY

## MONOPOLY ESTABLISHED BY CONSTITUTION



**ENERGY**

- NUCLEAR POWER PLANTS
- NUCLEAR FUEL

**DEFENSE**

- NAVAL PROPULSION
- NUCLEAR FUEL

**Applications**

- MEDICINE
- INDUSTRY
- AGRICULTURE & ENVIRONMENTAL
- RESEARCH & DEVELOPMENT

**WASTE MANAGEMENT**

# BRAZILIAN NUCLEAR INDUSTRY

## MONOPOLY ESTABLISHED BY CONSTITUTION

MINISTRY OF MINES AND ENERGY

MINISTRY OF SCIENCE & TECHNOLOGY

MINISTRY OF DEFENSE

ELETROBRÁS (holding)

BRAZILIAN NUCLEAR ENERGY COMMISION
CNEN

RESEARCH INSTITUTES
NAVY — CTMSP
AIR FORCE — CTA/IEAv
ARMY — CTEx/IEA

ELETRONUCLEAR

NUCLEAR FUEL INDUSTRY
INB

CONVENTIONAL UTILITIES
Furnas, Chesf, ...

NUCLEAR HEAVY EQUIPMENT
NUCLEP

*NUCLEAR SAFETY AUTHORITY*

RESEARCH INSTITUTES
IPEN, CDTN, IEN, IRD, CRCN

# ELETROBRAS

## 10th. WORLD UTILITY

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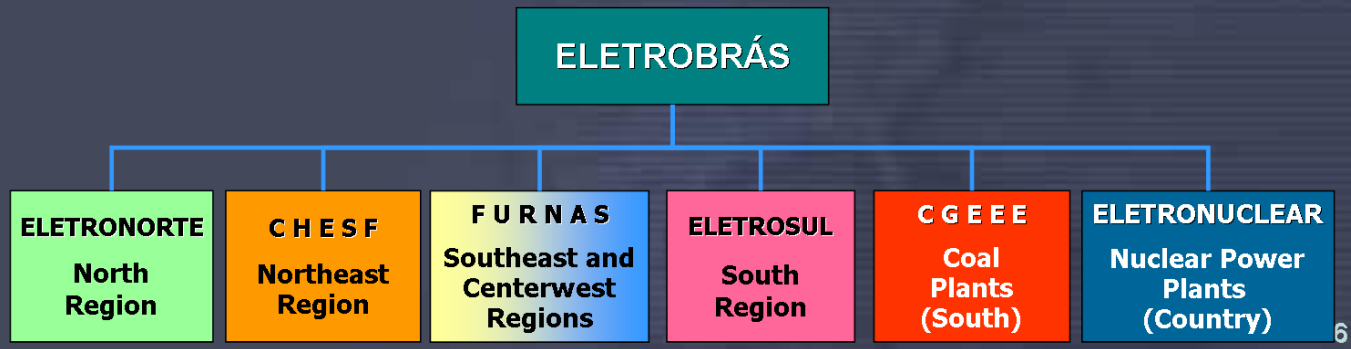


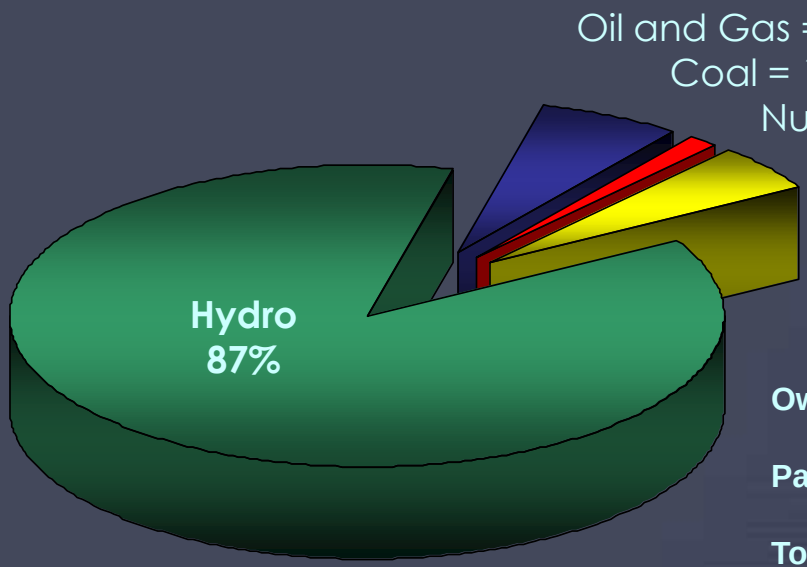


- ✓39,434 MW in operation
- ✓37% of Brazil Installed Capacity
- ✓59.000 km of transmission lines
- ✓56% of Brazil total transmission

| | FURNAS | Chesf | Eletronorte | ITAIPU BINACIONAL | ELETRONUCLEAR | CGTEE | Total |
|---|---|---|---|---|---|---|---|
| Own | 8,137 | 10,618 | 10,203 | 7,000 | 2,007 | 490 | 38,455 |
| Partnerships | 968 | - | 11 | - | - | - | 979 |
| Total | 9,105 | 10,618 | 10,214 | 7,000 | 2,007 | 490 | 39,434 |

# MISSION
## WORKING ON 3 TIME FRAMES

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1. *TODAY : Operation & Maintenance*
   - *Angra 1 :1985 (Westinghouse PWR 657 MW)*
   - *Angra 2: 2001 (Siemens-KWU PWR 1350 MW)*
2. *TOMORROW: Engineering, Procurement, Construction & Commissioning*
   - *Angra 3: 2015 (AREVA NP PWR 1405 MW)*
3. *FUTURE: Research & Development*
   - *4 to 8 New NPP: 2015-2030 (national configuration PWR concept)*

# ADMIRAL ÁLVARO ALBERTO
## NUCLEAR POWER STATION

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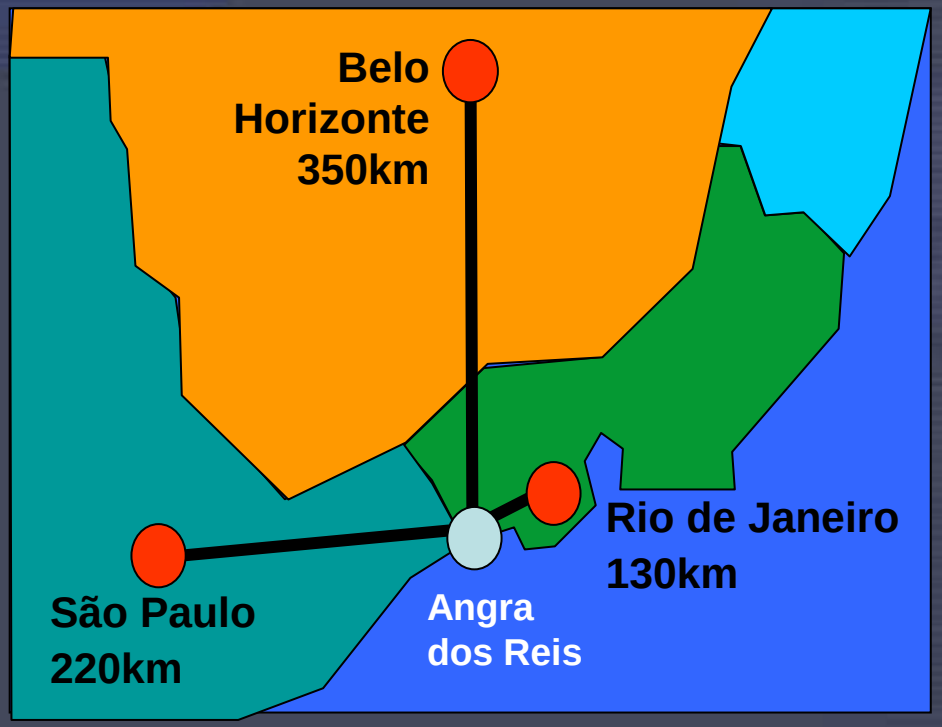


**LOCATED NEAR FROM THE 3 BRAZILIAN MAIN METROPOLITAN REGIONS**

# ADMIRAL ÁLVARO ALBERTO
## NUCLEAR POWER STATION

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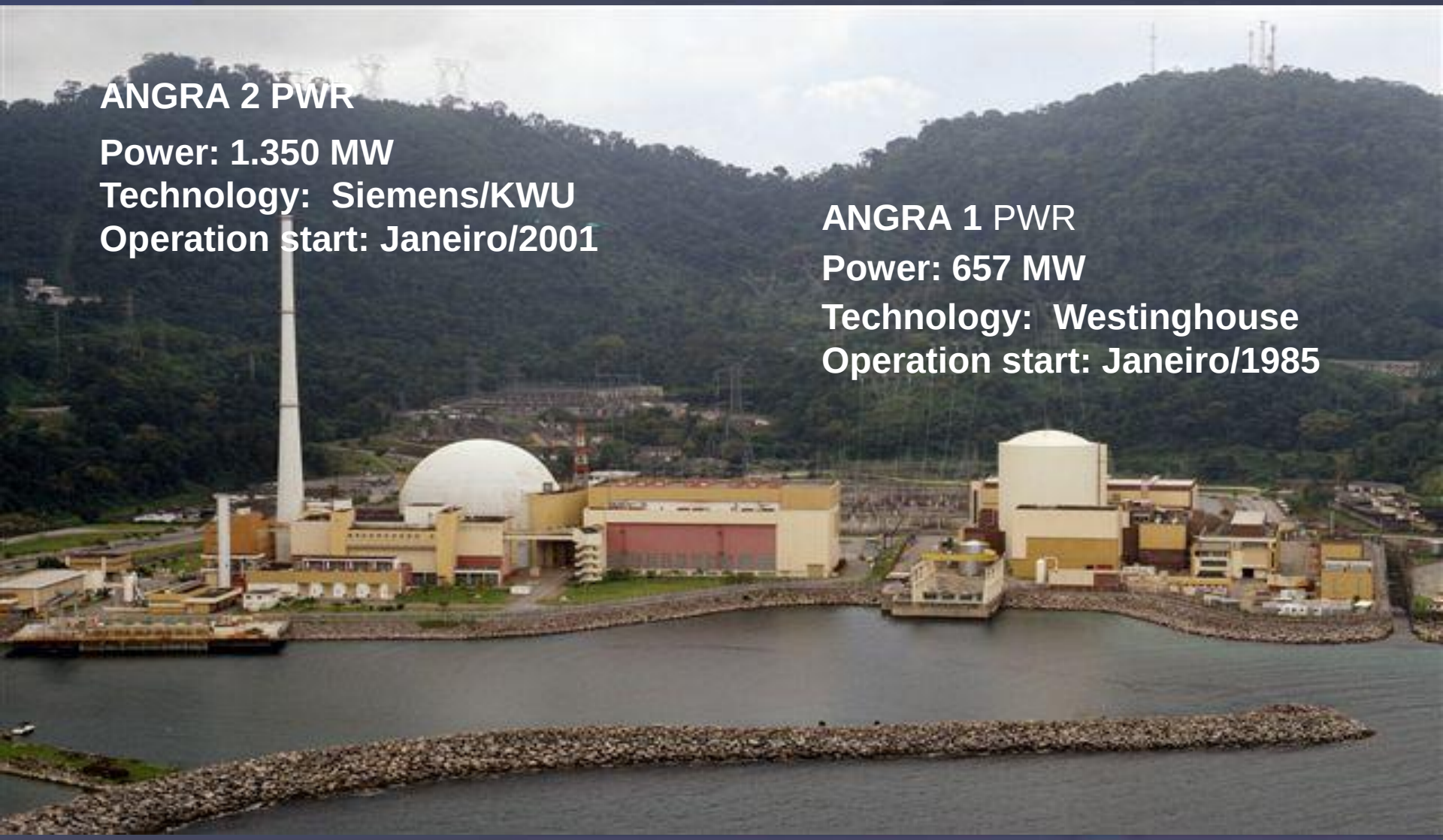
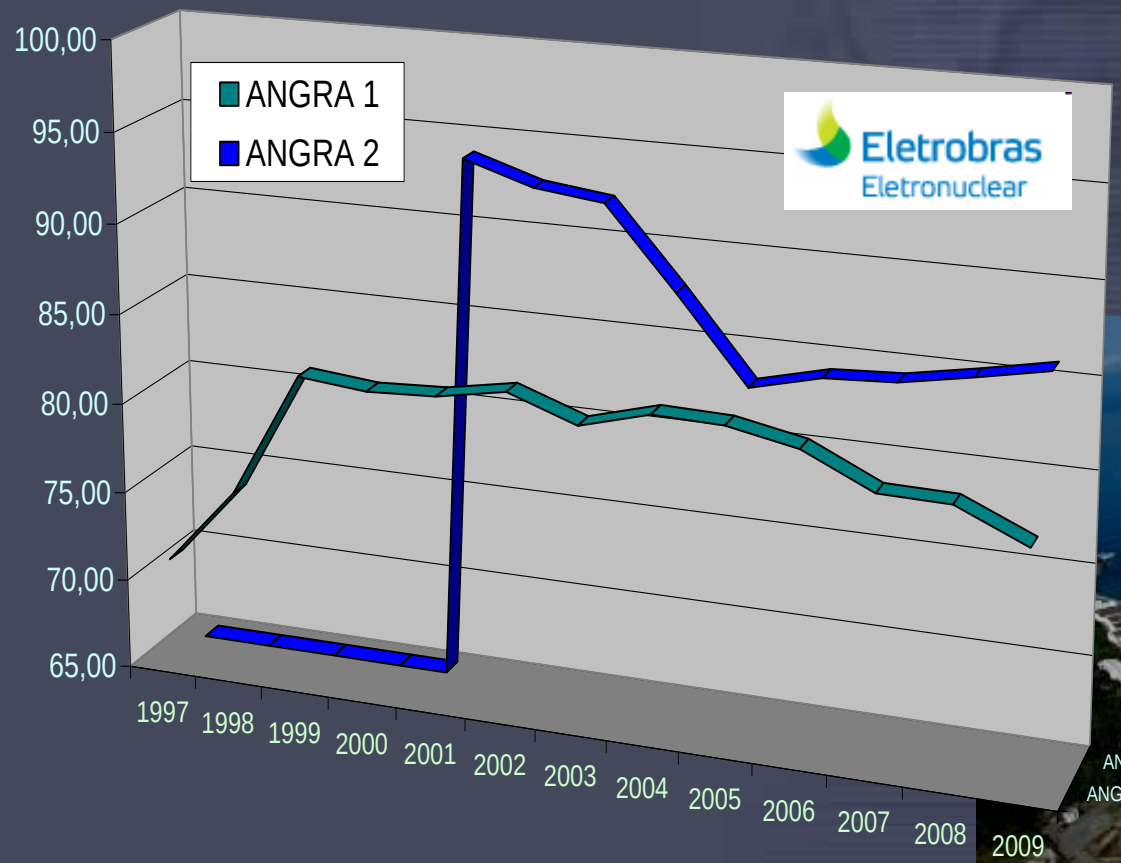
Eletronuclear



# ANGRA 1 AND ANGRA 2 OPERATION

## Availability factors:




## 1997-2010
## Cumulative

**Angra 1: 78,04%**

**Angra 2: 85,87%**

# ANGRA 1 AND ANGRA 2 OPERATION

GENERATION TILL 2011: 182.450.141 MWh

***GENERATION RECORD 2011: 14,4 TWh****

** Itaipu record: 94 TWh*

***Availability***

***1997-2011***

***Angra 1: 78,75%***

***Angra 2: 88,03%***

# NUCLEAR EXPANSION IN BRAZIL

## ANGRA 3

**FIRST CONCRETE POURED 2010**

**TO BE CONNECTED 2016**

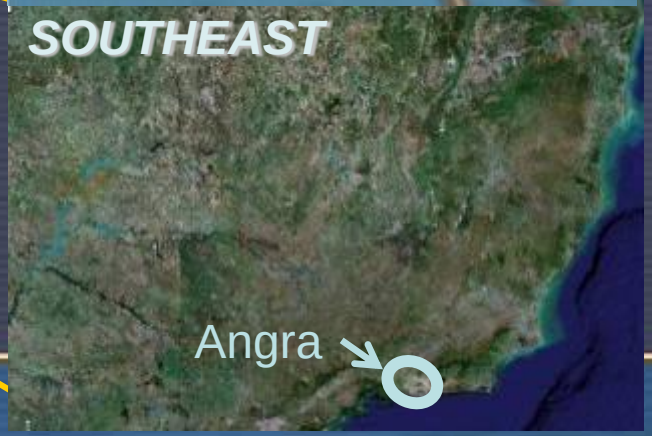
# NUCLEAR EXPANSION IN BRAZIL

## ANGRA 3 + 4-6 x 1.000 MW NUCLEAR STATIONS

# AFTER ANGRA 3:

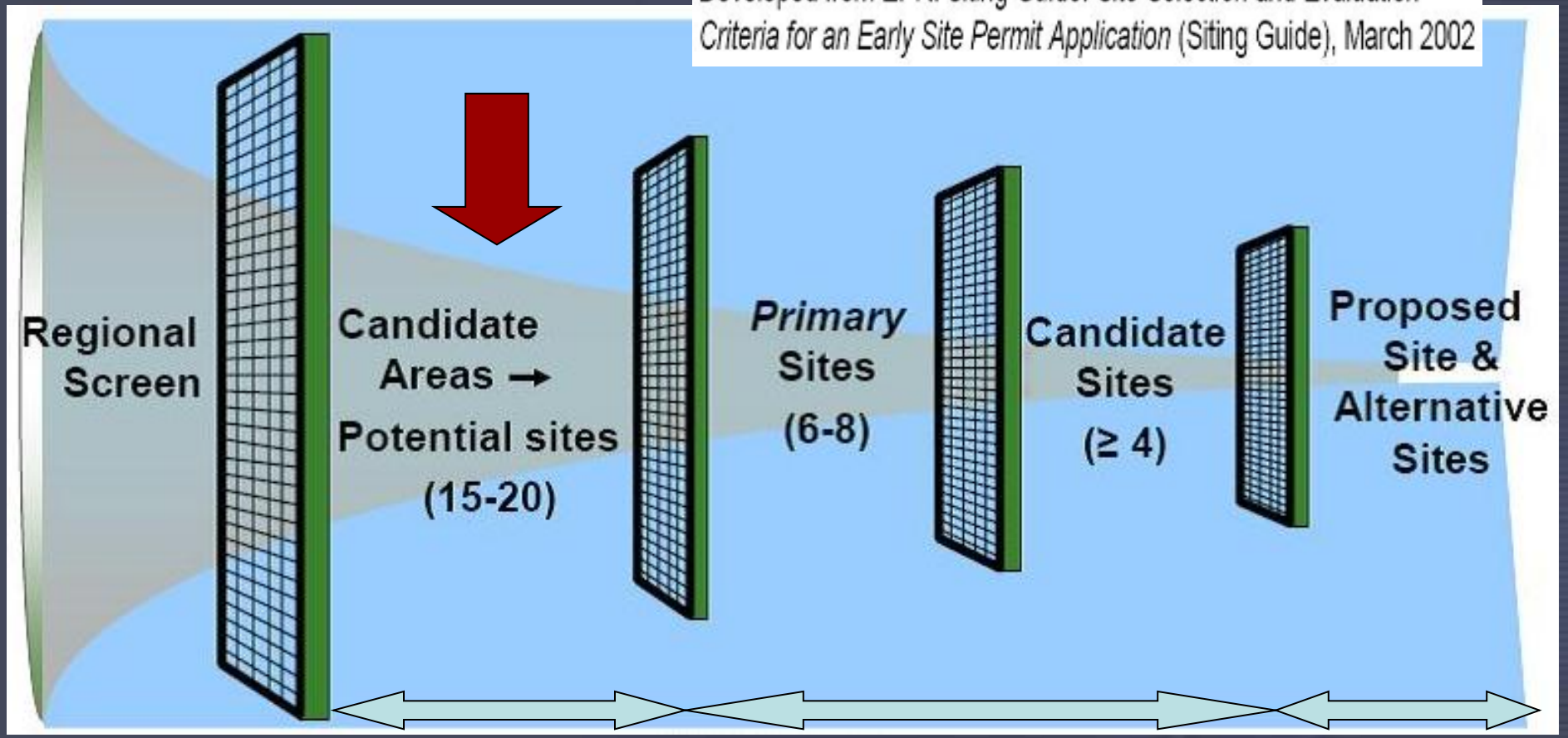
## 4-6 x 1.000 MW NUCLEAR POWER STATIONS





# NUCLEAR EXPANSION IN BRAZIL

## SITE SELECTION PROCEDURE

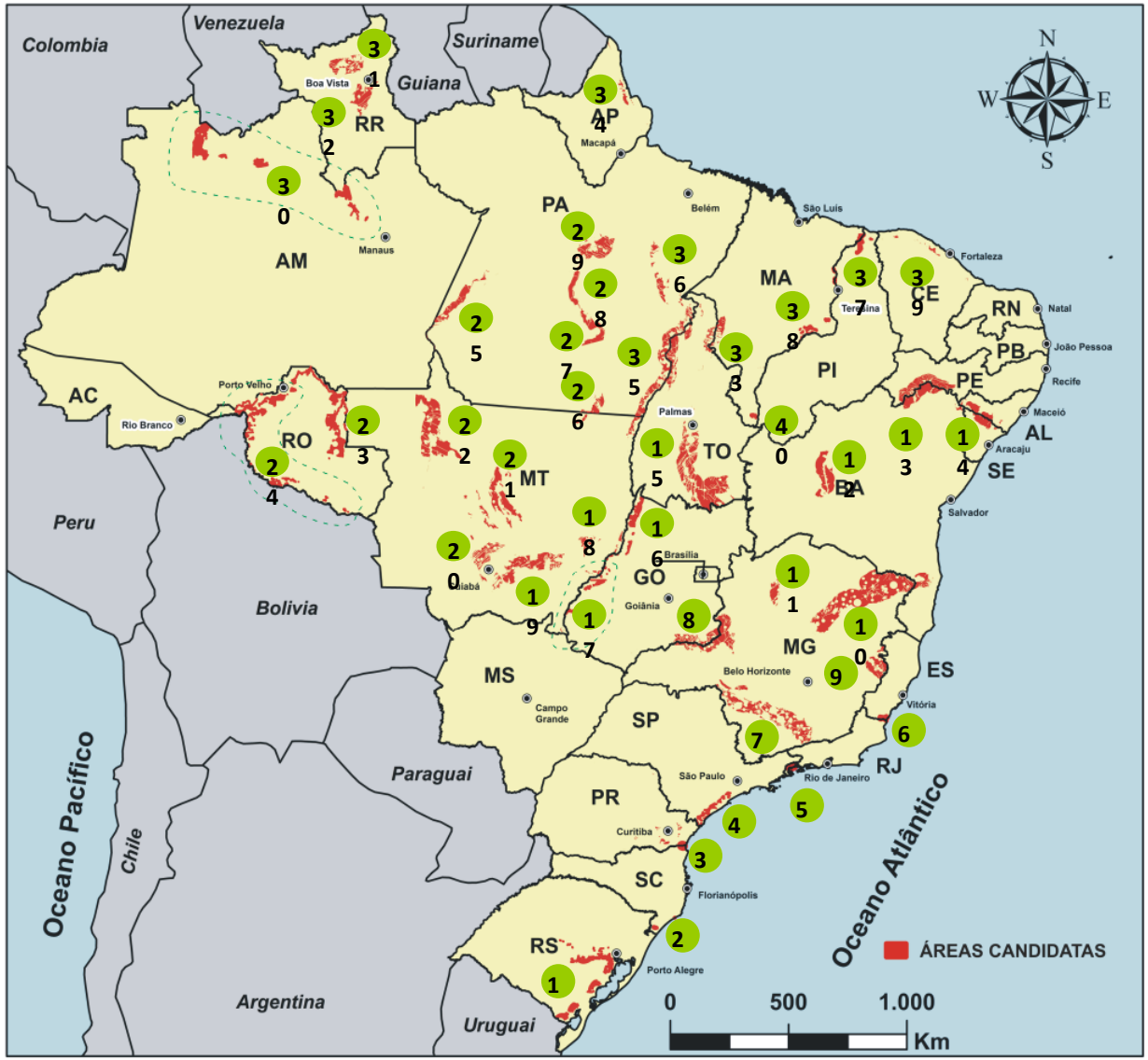


# NUCLEAR EXPANSION IN BRAZIL

## SITE SELECTION PROCEDURE: NATIONWIDE SCREENING

**BRAZILIAN NUCLEAR POTENTIAL ATLAS**

**40 CANDIDATE AREAS**



# NUCLEAR EXPANSION IN BRAZIL

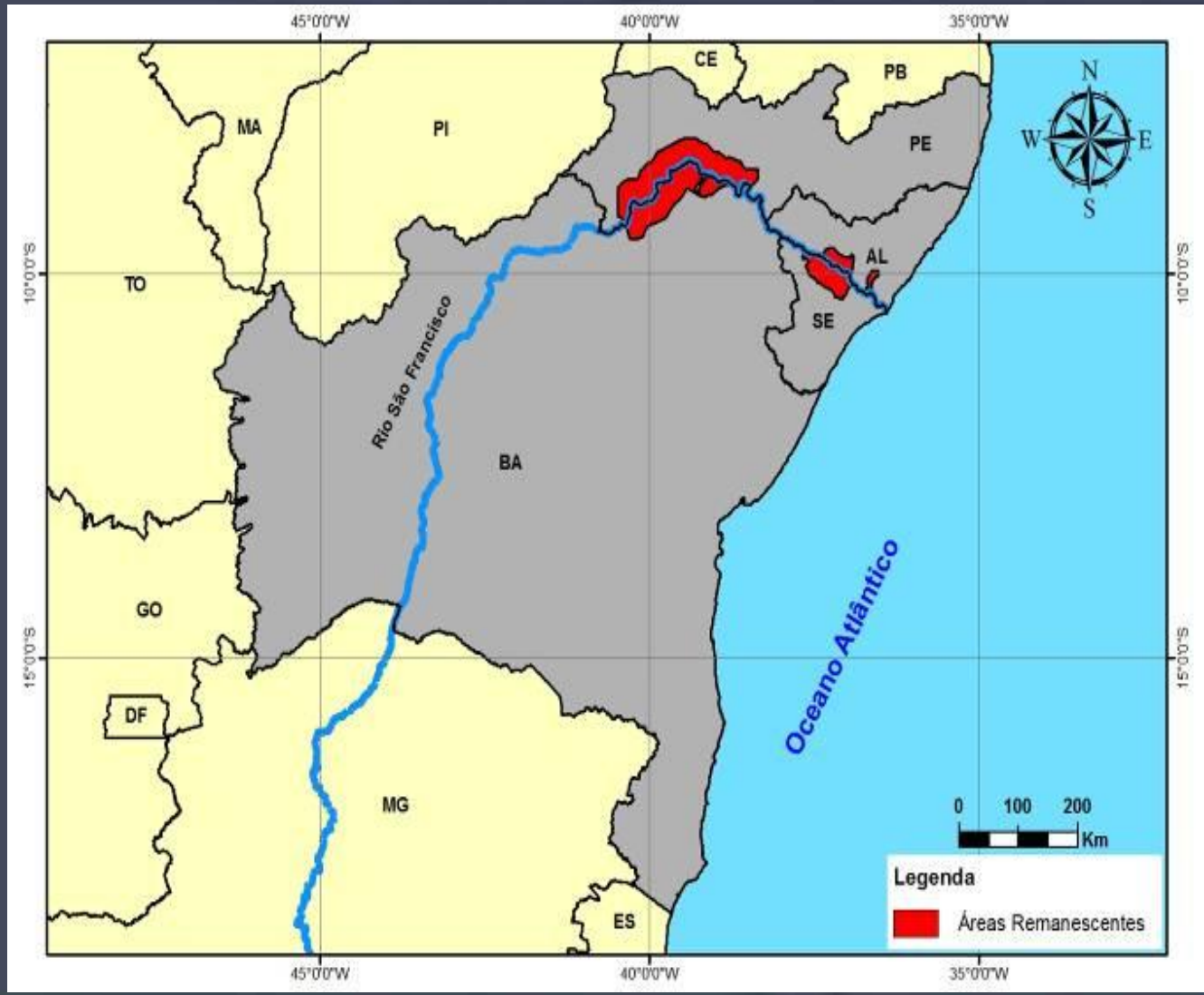
## REGIONAL SCREEN IN 4 NORTHEAST STATES

**NATIONAL ENERGY PLAN 2030 PRIORITY REGION**

**5 CANDIDATE AREAS**

**12 POTENTIAL SITES SELECTED FOR FURTHER STUDIES**

***3 PER STATE***



# NUCLEAR EXPANSION IN BRAZIL

## NORTHEAST NUCLEAR POWER STATION

**EXPLORATORY STUDY: SITE PE-1 (artistic view)**

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# NUCLEAR EXPANSION IN BRAZIL

## NORTHEAST NUCLEAR POWER STATION

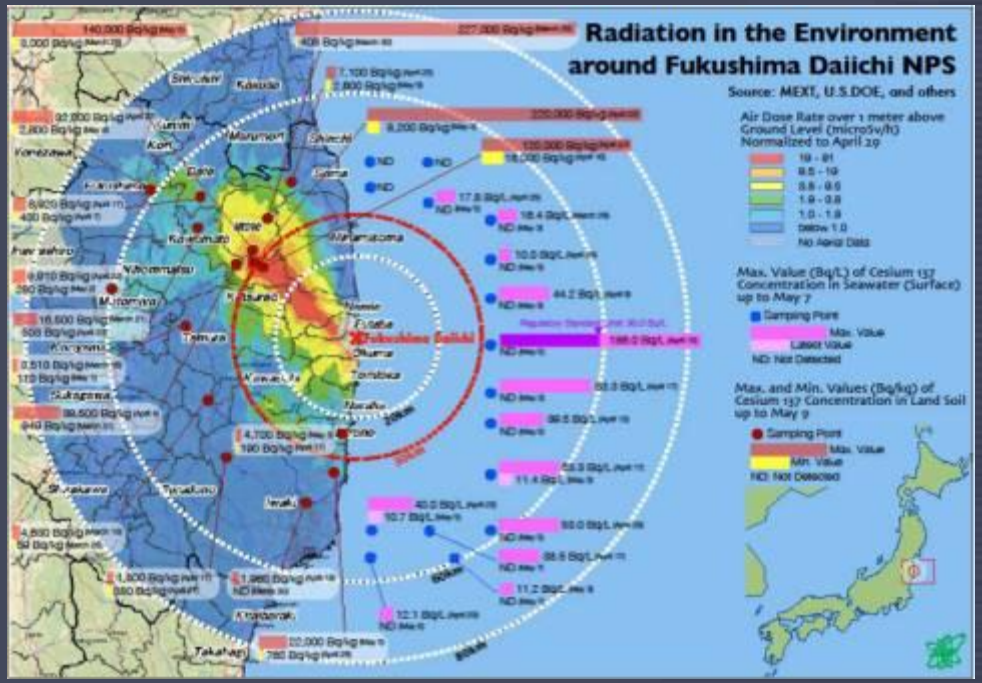
**INSPIRED ON TVA ROADMAP**


**A ROUTE TO DEVELOPMENT**

# FUKUSHIMA BRINGS 2 NEWS

## FOR WORLD NUCLEAR INDUSTRY

*A BAD ONE*



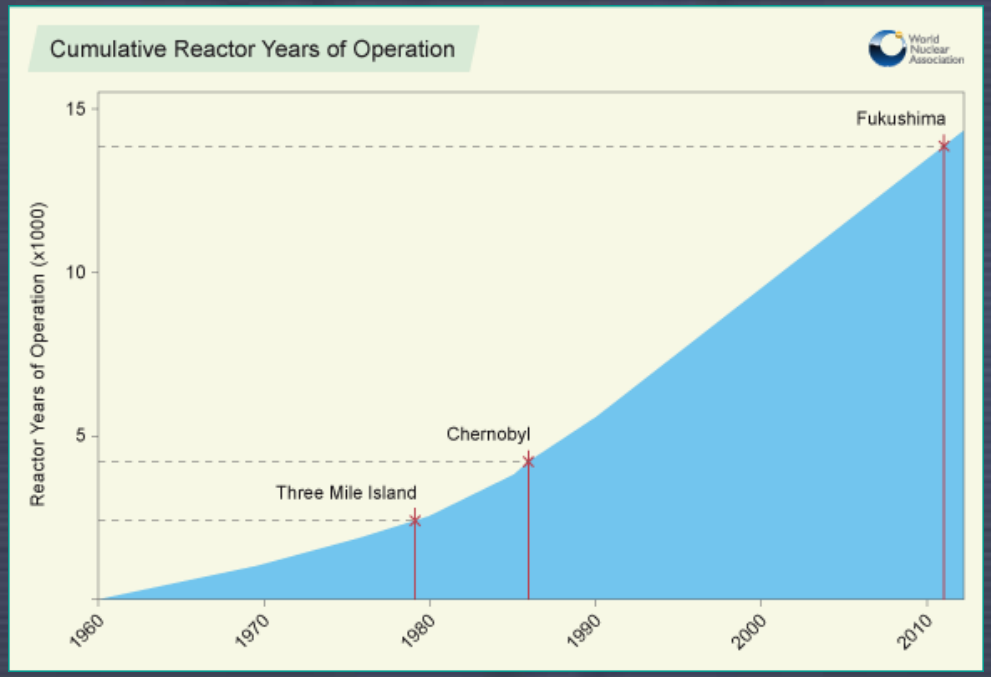

*OTHER*
*NOT SO BAD*

# FUKUSHIMA BRINGS 2 NEWS

## THE BAD NEWS

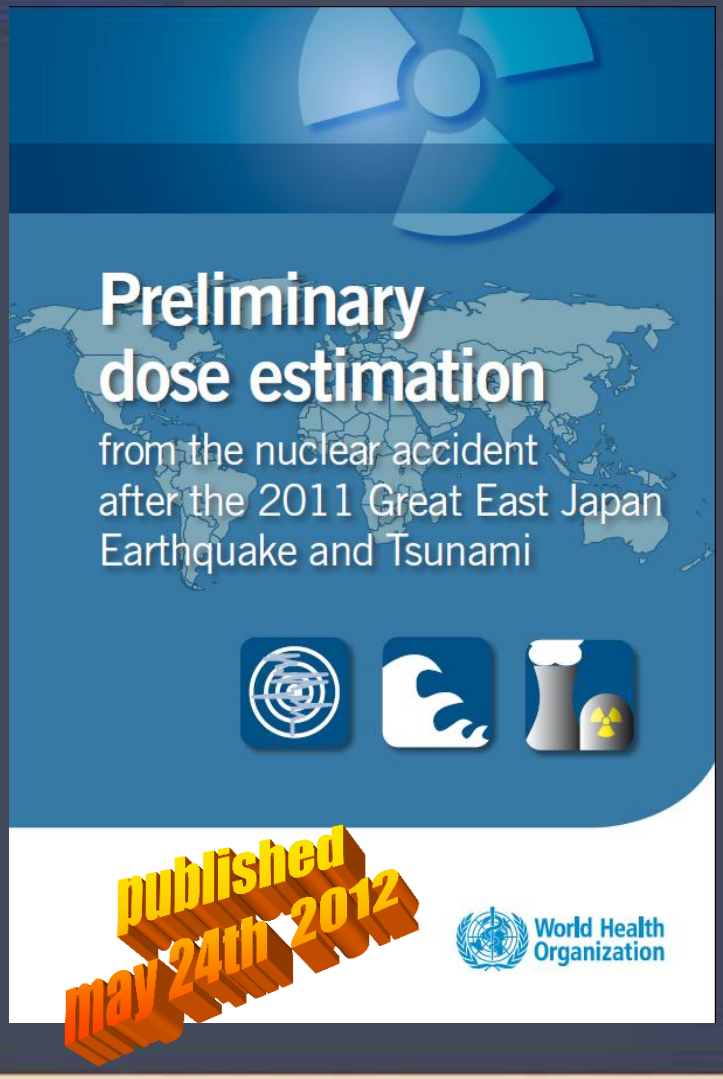
***SEVERE ACCIDENTS HAPPEN***

***EVEN AFTER ALL POST-TMI, POST-CHERNOBYL AND OPERATIONAL EXPERIENCE FEEDBACK COUNTER-MEASURES***



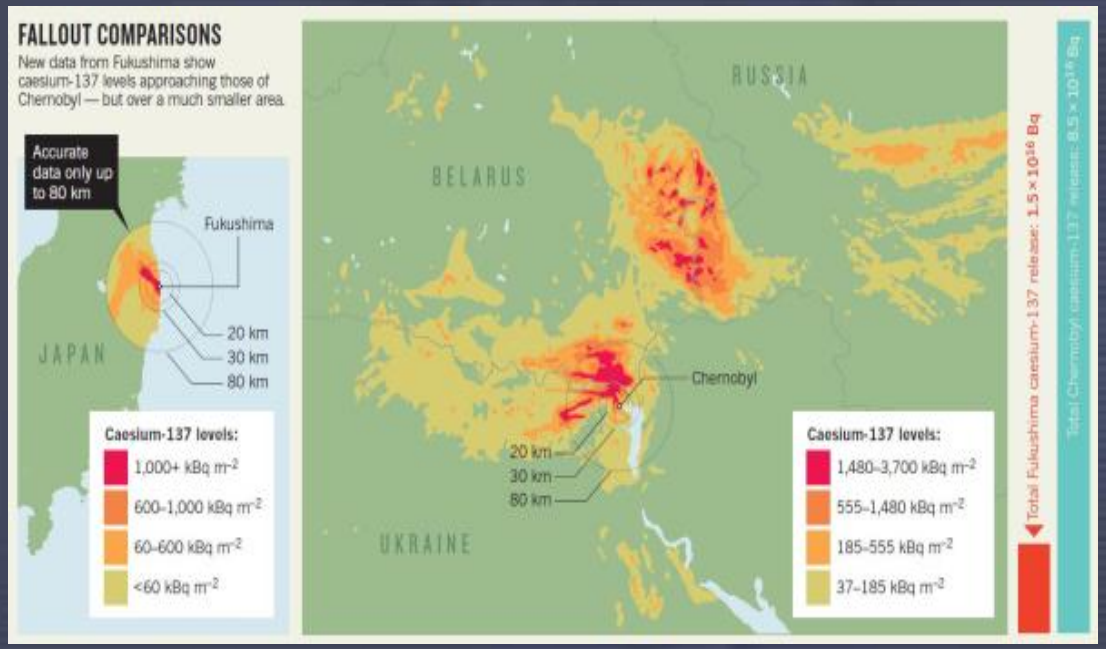
# FUKUSHIMA BRINGS 2 NEWS

## THE NOT SO BAD NEWS



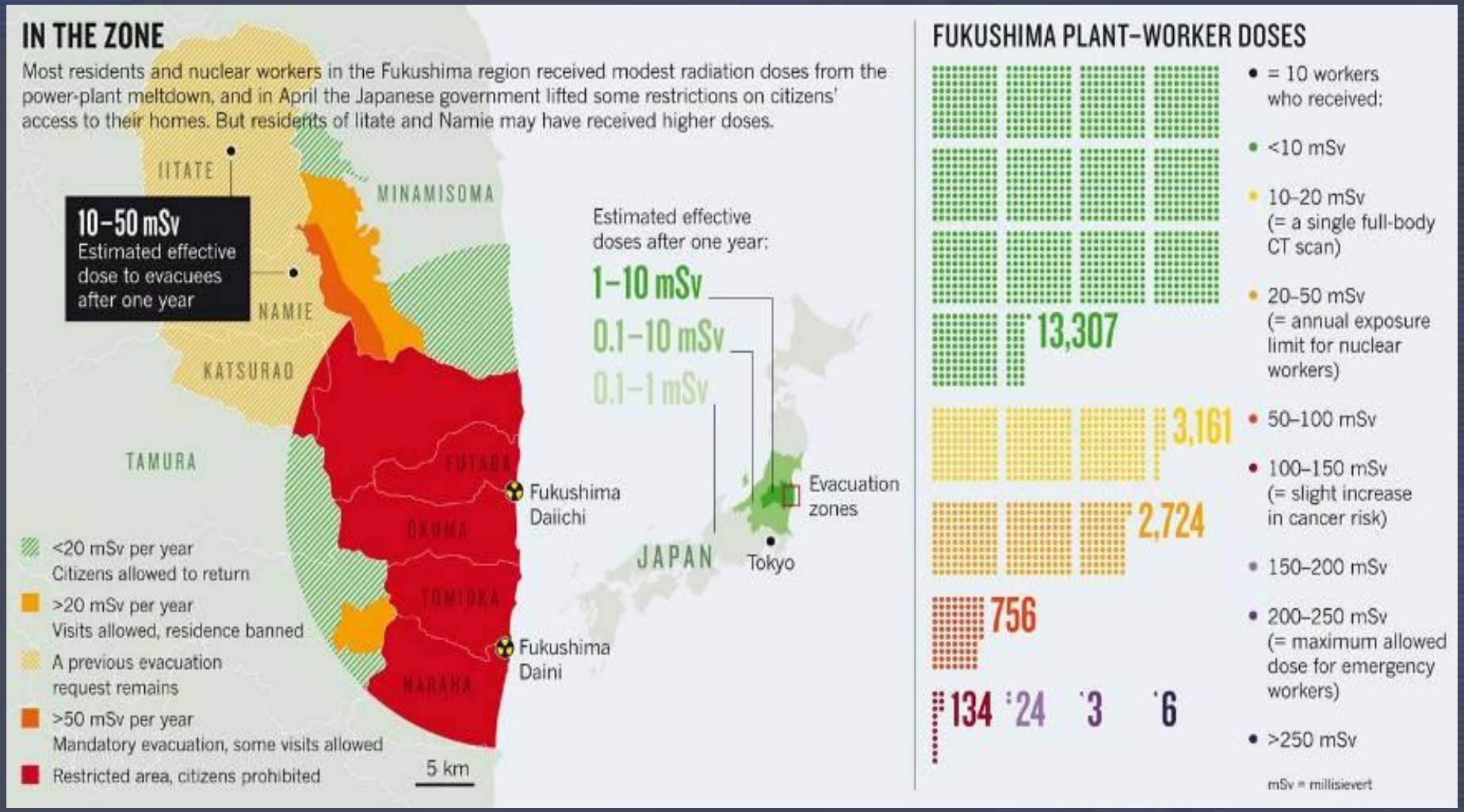

***THEY ARE NOT SO "CATHASTROFIC"***

***THE OBJECTIVELY MEASURED HARM FOR PUBLIC AND ENVIRONMENT CAUSED DOES NOT ADHERE TO THE HYPERBOLIC LANGUAGE OFTEN USED***



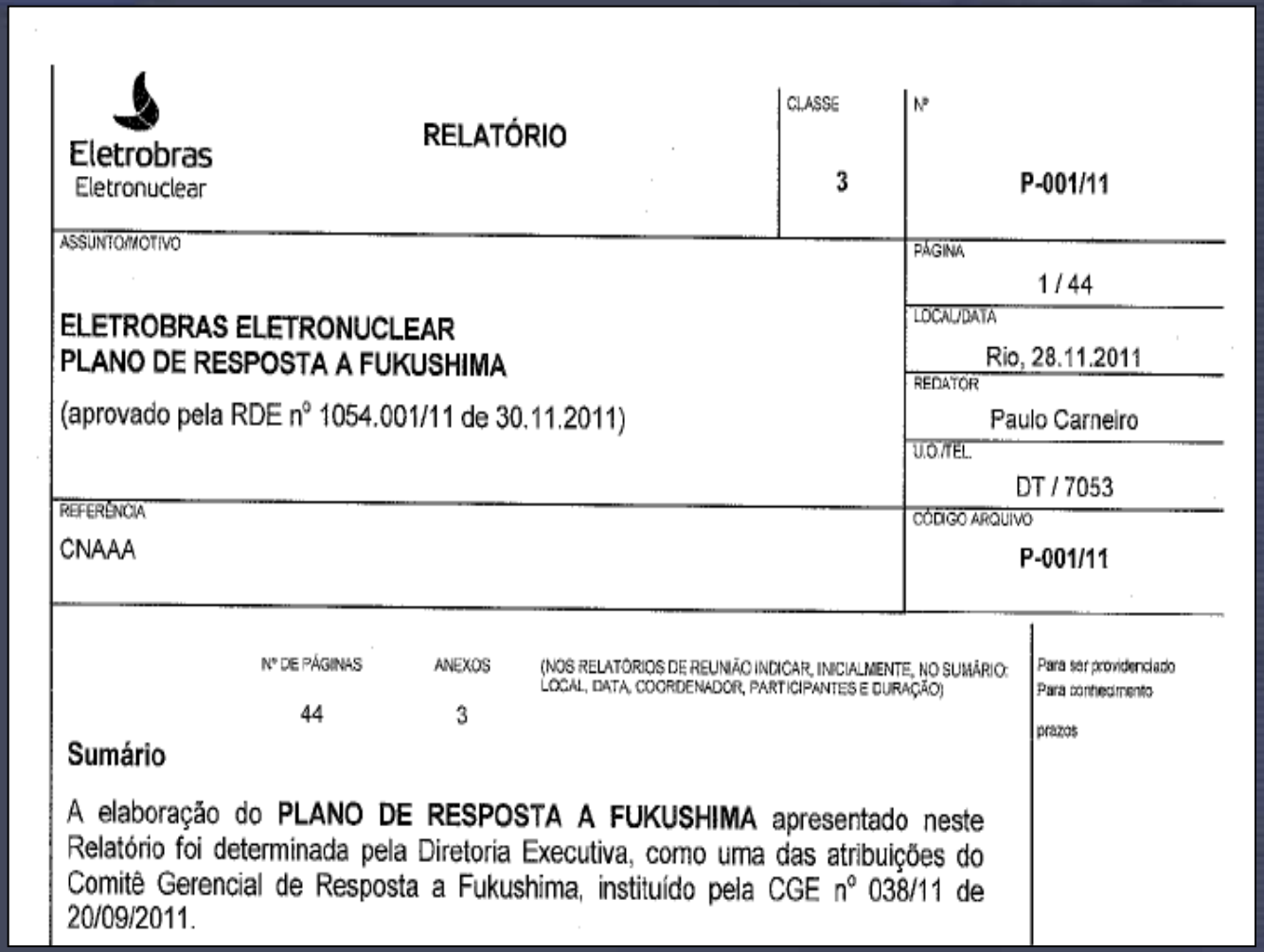
# FUKUSHIMA BRINGS 2 NEWS

## THE NOT SO BAD NEWS



# Fukushima Response Plan

## (submitted to Brazilian Nuclear Authority in December 2011)



Eletrobras
Eletronuclear

RELATÓRIO

CLASSE: 3

Nº: P-001/11

ASSUNTO/MOTIVO

**ELETROBRAS ELETRONUCLEAR**
**PLANO DE RESPOSTA A FUKUSHIMA**

(aprovado pela RDE nº 1054.001/11 de 30.11.2011)

PÁGINA: 1 / 44

LOCAL/DATA: Rio, 28.11.2011

REDATOR: Paulo Carneiro

U.O./TEL.: DT / 7053

REFERÊNCIA: CNAAA

CÓDIGO ARQUIVO: P-001/11

Nº DE PÁGINAS: 44

ANEXOS: 3

(NOS RELATÓRIOS DE REUNIÃO INDICAR, INICIALMENTE, NO SUMÁRIO: LOCAL, DATA, COORDENADOR, PARTICIPANTES E DURAÇÃO)

Para ser providenciado
Para conhecimento
prazos

**Sumário**

A elaboração do **PLANO DE RESPOSTA A FUKUSHIMA** apresentado neste Relatório foi determinada pela Diretoria Executiva, como uma das atribuições do Comitê Gerencial de Resposta a Fukushima, instituído pela CGE nº 038/11 de 20/09/2011.

**56 initiatives (studies and projects)**

**Performance of Stress Tests**

**Around US$ 250 million to be applied from 2011 to 2015**

**High priority inside the organization**

# Stress Tests for Angra 1 and 2


According to specification issued by Iberoamerican Forum of Regulatory Bodies, Nuclear and Radiological (request from CNEN in January 2012)

**Compliance with WENRA Specification for Stress Tests**

European Commission

**Submitted to CNEN on April 2nd, 2012**

# OPERATING PLANTS
## Scope of Analysis

| External Events Design Basis Re-evaluation | Reeavaluation of Plant means for control of Beyond Design Basis events | Definition of Additional External Means to Mitigate Natural Disasters | Re-evaluation of the Internal and External Emergency Planning |
|---|---|---|---|
| Seismic Threat | Reactor Cooling | Means of transportation and accesses for moving people, equipment and materials | Alternative means for Evacuation ( by sea) |
| Slope stability | Containment Integrity | Additional Power supply Equipment | Main road conditions |
| High Waves | In-Plant Electric Power Supply | Additional Water Supply | Transportation Means conditions |
| Heavy Rain (Flooding) | Post-accident Instrumentation | Miscellaneous equipment and supplies | Sheltering conditions |
| High Intensity Winds (tornedos, hurricanes, etc...) | Spent fuel pool Cooling | | Emergency Centers |
| | Procedures and Personnel Training | | |

# DECENIAL ENERGY PLAN 2021

## No changes for Angra 3, but no new build

ANGRA 3: 1.405 MW AREVA PWR

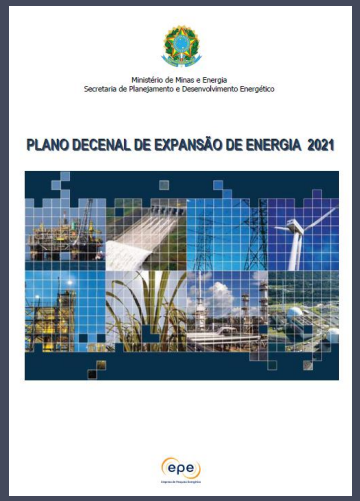


**ANGRA 3**
**1.405 MW**
**2016**

# DECENIAL ENERGY PLAN 2021

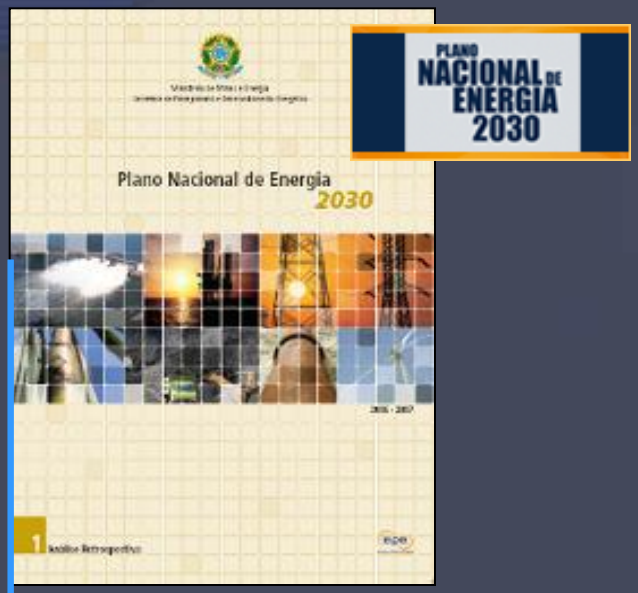
## No changes for Angra 3, but no new build


Launched Set 24




- *The fact that the expansion of nuclear power generating facilities with have been restricted to Angra 3 is **basically the time needed to deploy new plants**.*
  - *These periods are of the order of ten years counted from the definition of the site for the nuclear localization and the decision to commence effective measures for its implementation.*
- *It is noteworthy that are in development **studies for selection of sites** favoring the deployment of nuclear power plants in the **Southeast / Midwest, South and Northeast**.*
  - *Thus, considering the time of maturation of a nuclear project, the probable date for the effective participation in the expansion of this power generation system beyond the horizon of this Plan.*
- *However, following the development of new projects and the deployment of new plants around the world, with prospects of technological advances that lead to the reduction of time and cost of deployment, must continue so that **this source might be considered indicative plans in future.***

# NATIONAL ENERGY PLAN 2030

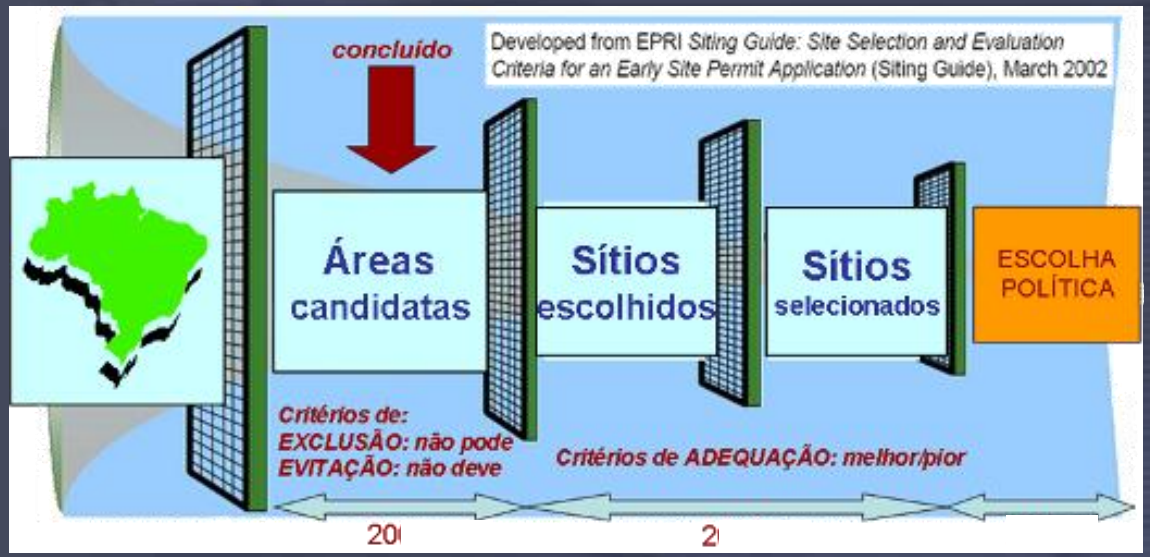



1) Northeast
2.000 MW

2) Southeast
2.000 MW

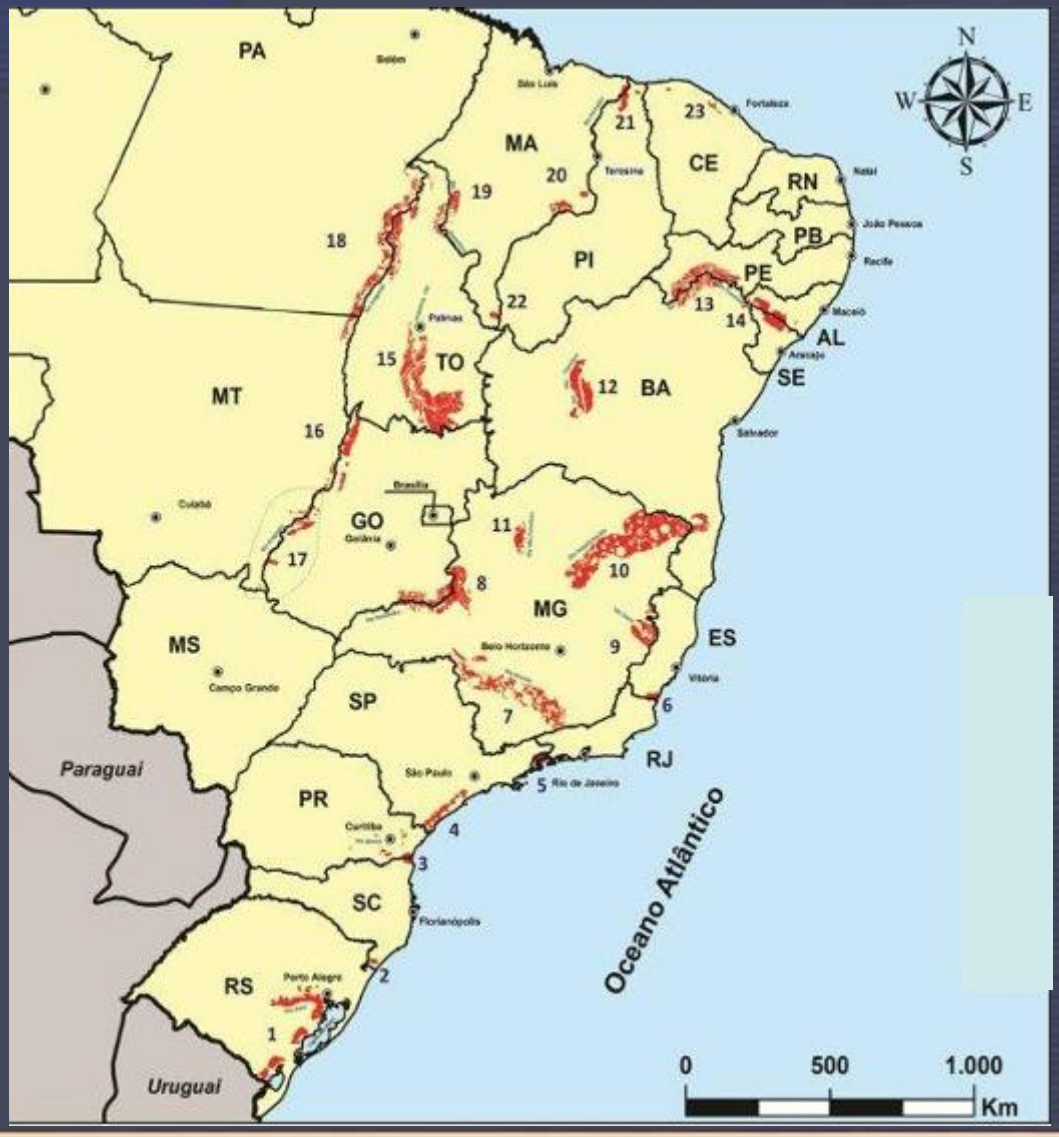
**STARTING OPERATION:**
**2022 - 2030**

## EPRI SITTING CRITERIA
## GEOPROCESSING APPLIANCES




## NUCLEAR POTENCIAL ATLAS OF BRASIL

# BRAZILIAN NUCLEAR POTENCIAL ATLAS






# NATIONAL ENERGY PLAN 2030

## 1 - 2 year delay minimum

1. **Update 2035 (more nuclear?)**
   - Was not be presented in 2011, as planned – only this year (?)
2. **Candidate areas National Atlas**
   - Would be presented May 2011
   - Will not be presented in 2011, as planned – only in 2012 (?)
3. **Site selection field works**
   - Would be started end 2011
   - Delayed (2013?)

**NUCLEAR POTENTIAL ATLAS**

*40 CANDIDATE AREAS*


PLANO NACIONAL DE ENERGIA 2030

| 2016-2020 | 2021-2025 | 2026-2030 | 2016-2030 |
|---|---|---|---|
| 1.000 MW NE 1 | 1.000 MW NE 2 | 2.000 MW SE 1+SE 2 | 4.000 MW |

1) Northeast 2.000 MW

2) Southeast 2.000 MW

# OPERATING PLANTS

## Investment Plan

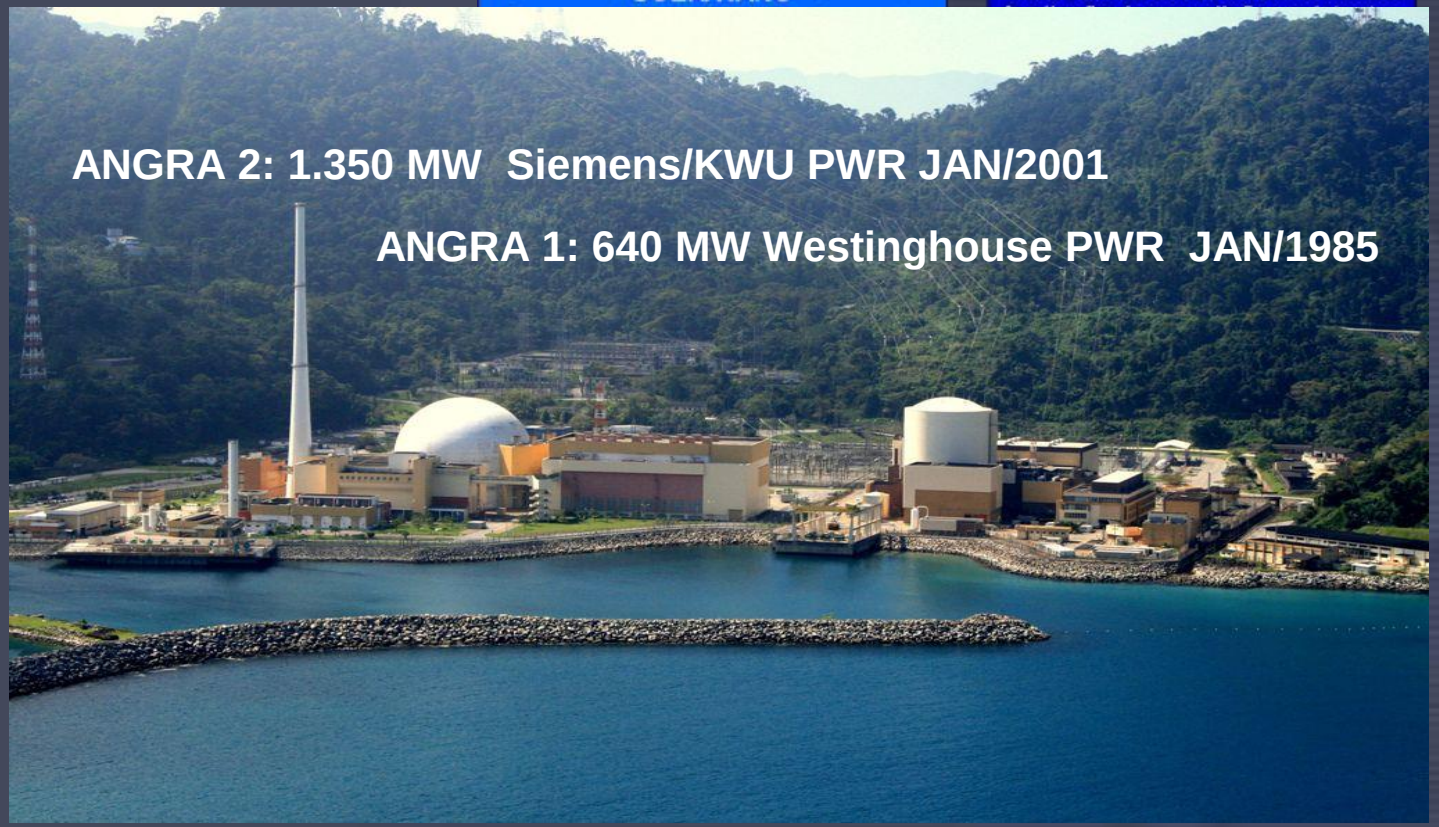
***US$ 250 million till 2015***

WANO

EU

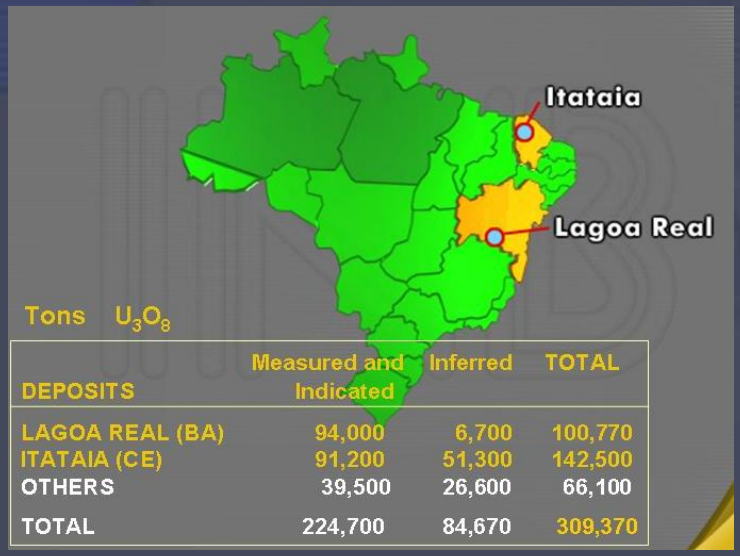
SOER/WANO

Stress Test



# BRAZILIAN URANIUM RESOURCES

## ONE OF THE MAIN RESERVES IN THE WORLD




Tons $U_3O_8$

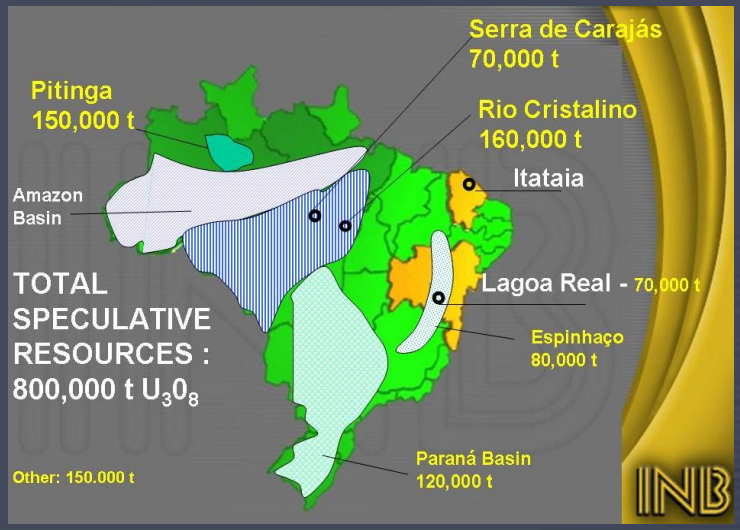
| DEPOSITS | Measured and Indicated | Inferred | TOTAL |
|---|---|---|---|
| LAGOA REAL (BA) | 94,000 | 6,700 | 100,770 |
| ITATAIA (CE) | 91,200 | 51,300 | 142,500 |
| OTHERS | 39,500 | 26,600 | 66,100 |
| TOTAL | 224,700 | 84,670 | 309,370 |

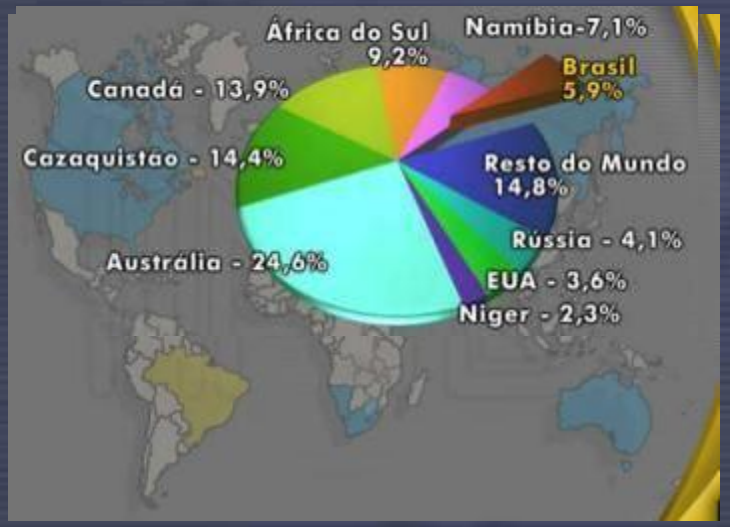
**Prospected area:**

***only 30% of national territory***

**up to 100 meters deep**

***6th. WORLD RESERVE***

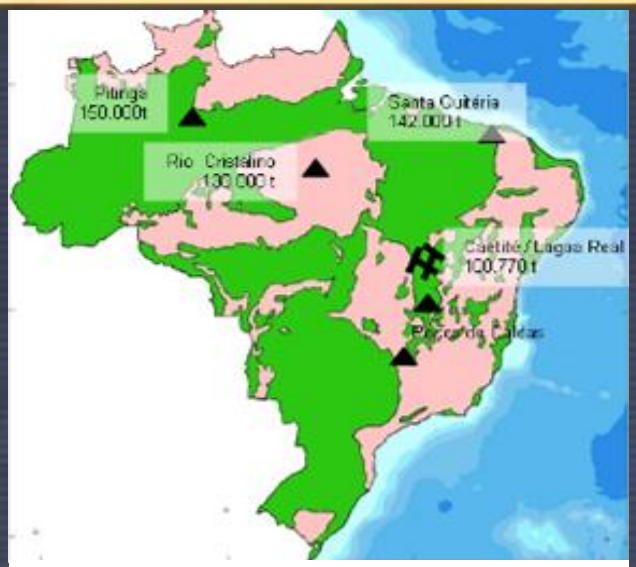


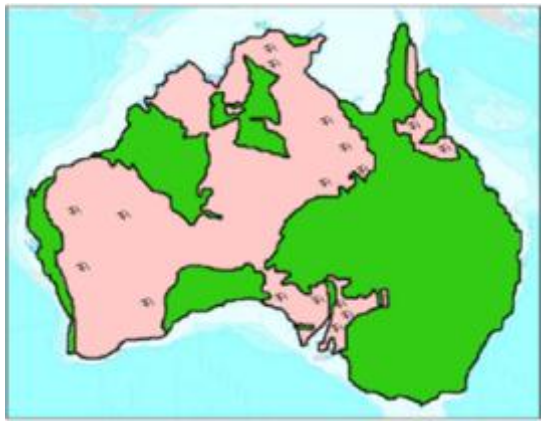
# BRAZILIAN URANIUM RESOURCES

## ONE OF THE MAIN RESERVES IN THE WORLD

**After prospected all the national territory, probably *Brazil should be among the 2 MAJOR WORLD RESERVES***

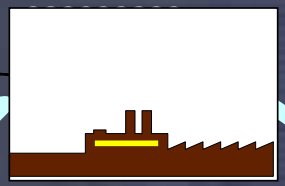



**Pré-cambrian soils**
**Brasil 3.400.000 km2**
**Austrália 3.800.000 km2**



# NUCLEAR FUEL INDUSTRY IN BRAZIL
## URANIUM + TECHNOLOGICAL CAPABILITIES

USEXA - NAVY
(CONSTRUCTION)

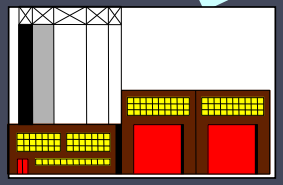


INB

CONVERSION
(PROJECT)

LEI and USIDE - NAVY
(OPERATION)

INB



URANIUM MINNING
AND MILLING

LAGOA REAL
(OPERATION)

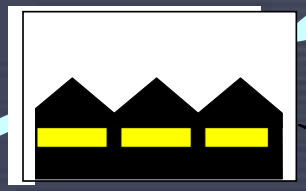
*One of the few countries having both:*

1. *large uranium reserves*
2. *full technological capability for local fuel production*

INB

ENRICHMENT
RESENDE
(CONSTRUCTION)

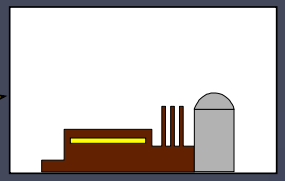
INB



FUEL FABRICATION
RESENDE

(OPERATION)

ELETRONUCLEAR



ANGRA 1/2/3
PWR

LABGENE
NAVY
(CONSTRUCTION)

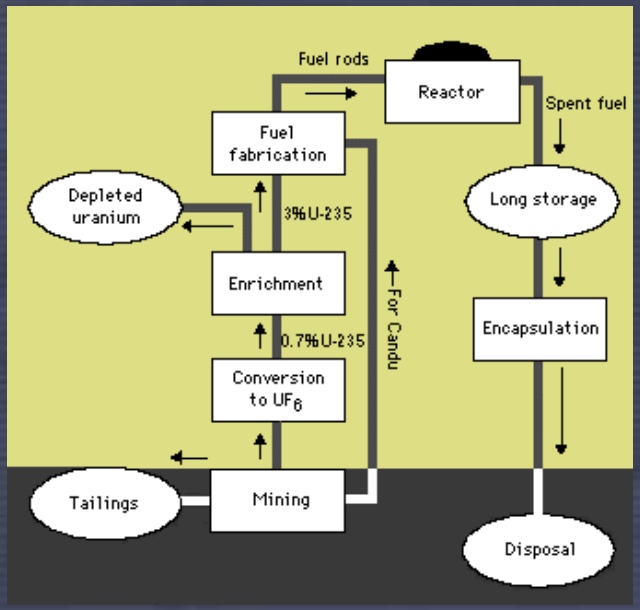
LABMAT and LADICON
NAVY
(OPERATION)

# NUCLEAR FUEL INDUSTRY IN BRAZIL

## LONG TERM VISION

### Continental integration

1. Mercosur
2. South America
3. Latin America




### Assuring regional supply

1. Uranium supplier
2. Integral nuclear fuel services supplier (open cycle)

**FULL SCOPE SAFEGUARDS**

# NON PROLIFERATION IN BRAZIL
## UNIQUE SUCCESS EXPERIENCE


- ***Brazilian Constitution proscribe all non-pacific uses of nuclear energy***
  - ***Member of NPT***
  - ***Member of Tlatelolco Treaty***

- **All nuclear installations fully safeguarded**
  - **Multilateral agreements (1990 + 1994) (Brazil – Argentina – ABACC) + IAEA**
    - *ABACC – bilateral regional agency*
  - **IAEA full escope (NPT - 1997)**

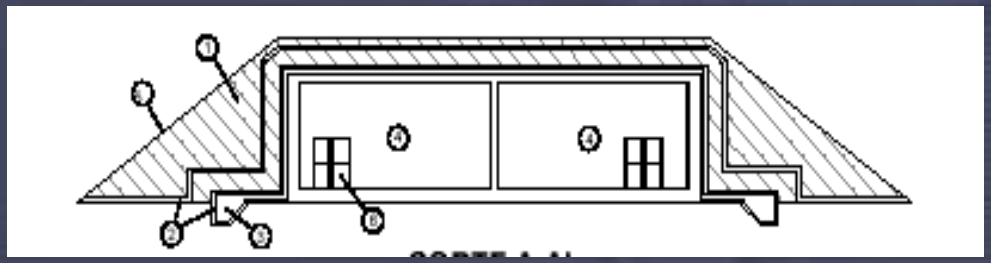
***A remarkable record of more than 25 years without technical deviations or suspicious events***

# NON PROLIFERATION IN BRAZIL

## UNIQUE SUCCESS EXPERIENCE


- ✓ As Japan, Germany and Netherlands, has 2+1 enrichment plants fully safeguarded
- ✓ Brazilian centrifuge program was never suspected being “proliferant” neither part of any international “black-marketing”
- ✓ **Has produced 20% batches for research reactor fuel under full scope safeguards**

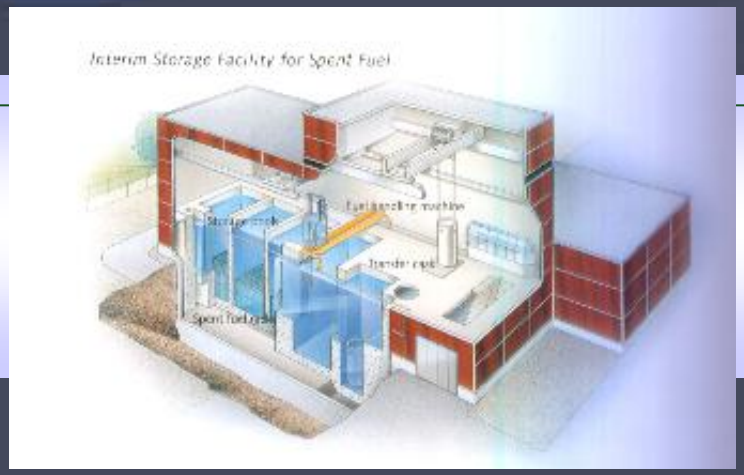

# LOW AND MEDIUM LEVEL WASTE
## FINAL DISPOSAL

# SPENT FUEL LONG TERM STORAGE

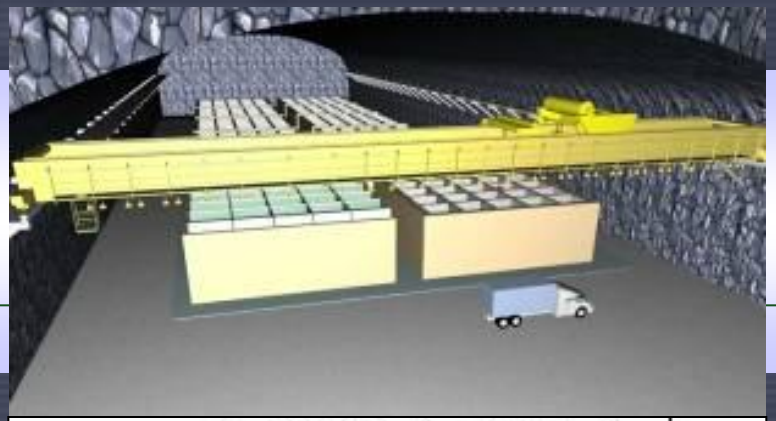
## BRAZILIAN SOLUTION

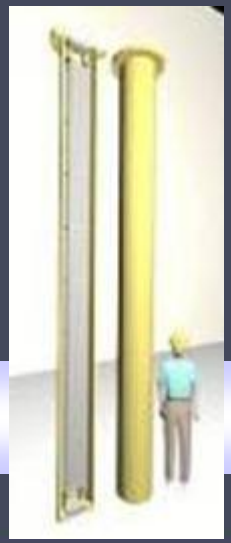
External pool (2020)

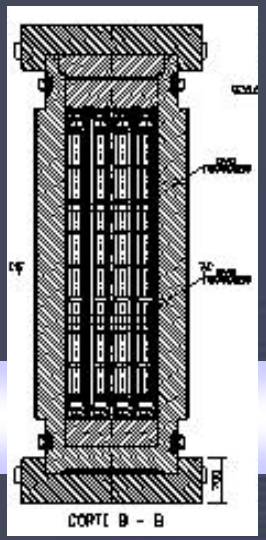


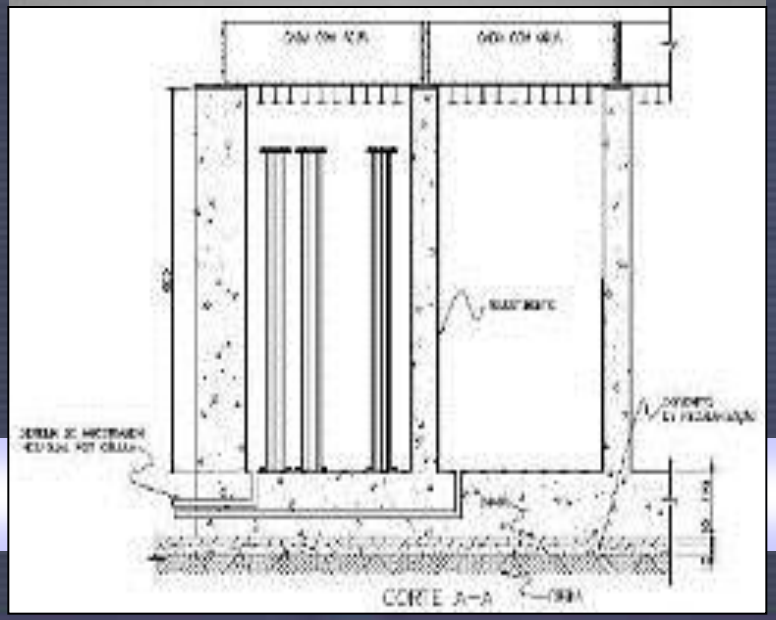

Designed for 500 years

Long Term Interim Storage (2035)

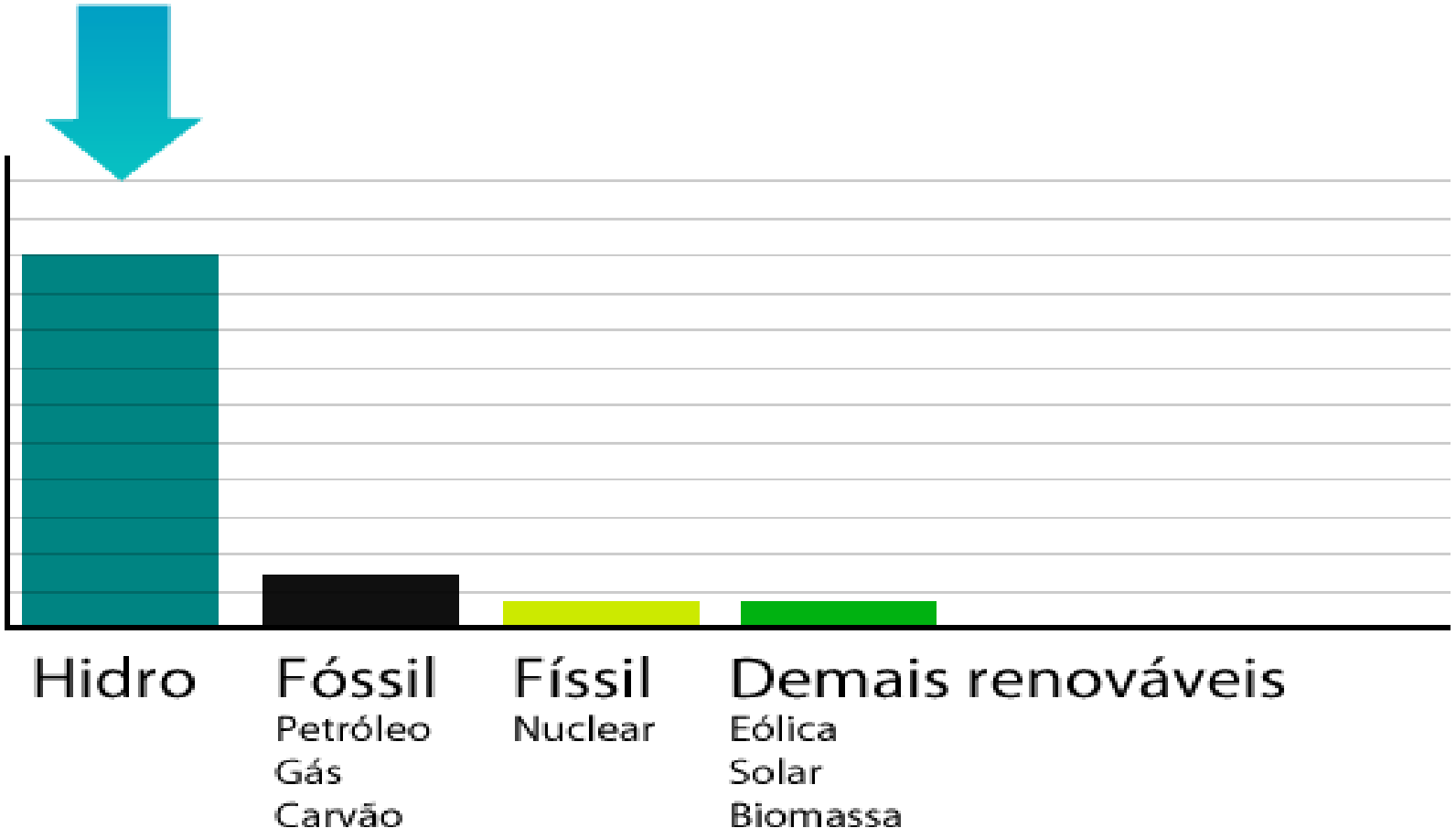




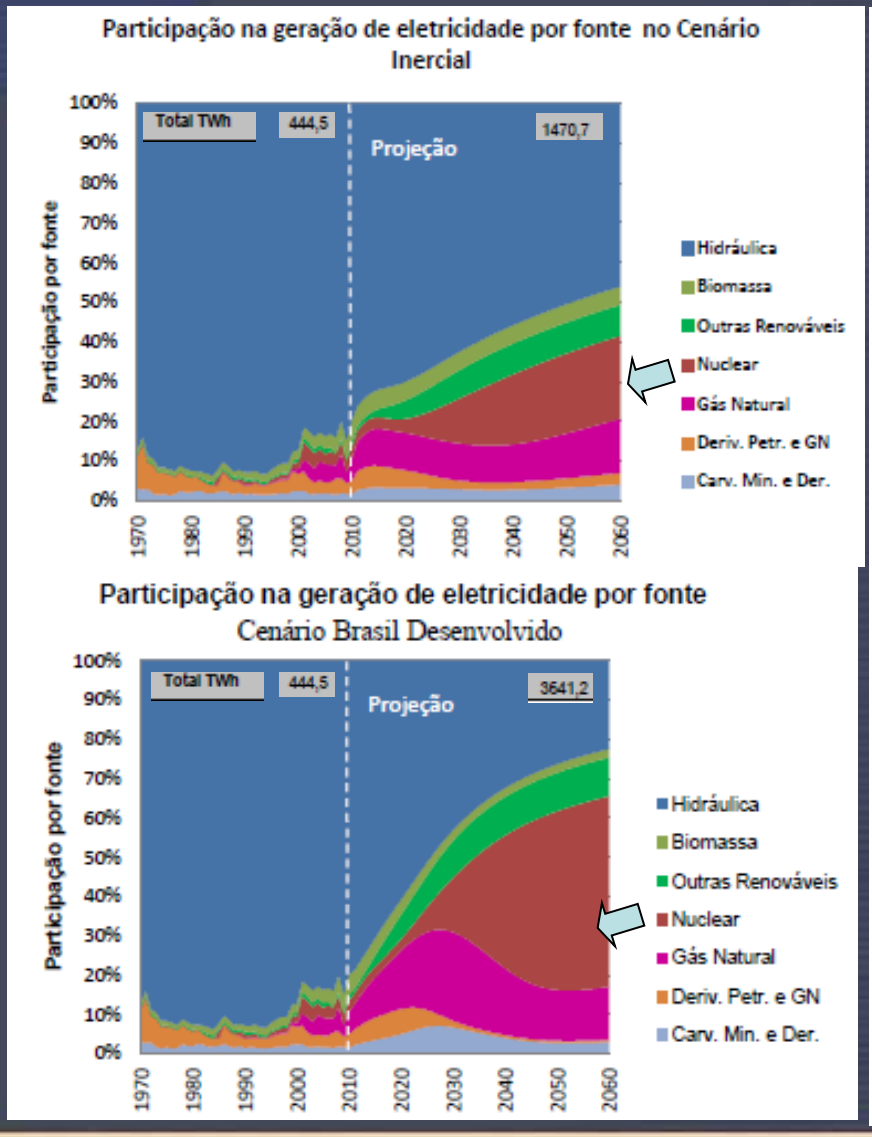


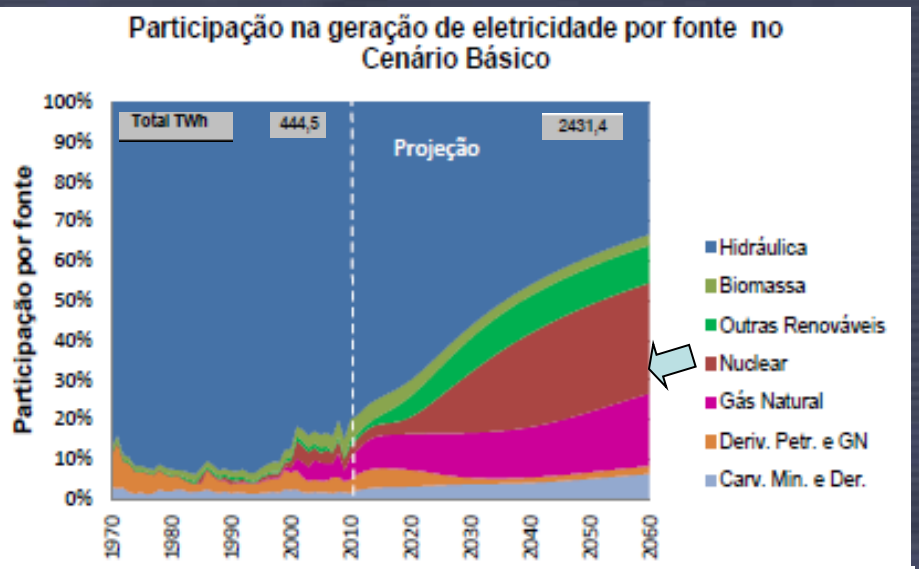



# SOPHIAS´S CHOICES



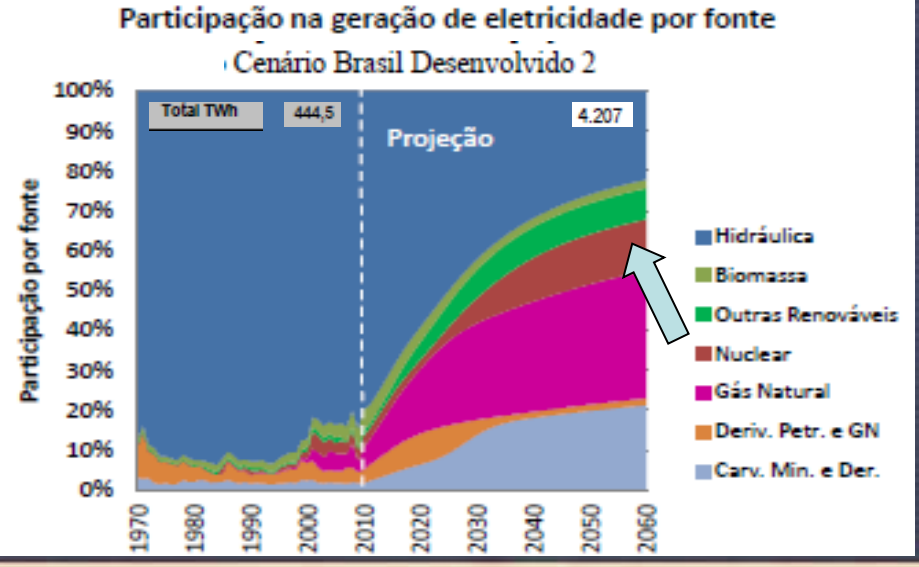
# SOPHIAS´S CHOICES










# Thank you!

Eletrobras
Eletronuclear

Innovations in Nuclear Technology 2012
Brazil: Challenges and Opportunities

December 10th & 11th, 2012

Leonam dos Santos Guimarães