Assurances of Supply

Brazilian utility perspective

Rio de Janeiro, October 30th 2009

Leonam dos Santos Guimarães
SUMMARY

1. Nuclear power in Brazilian Electric System
   • Brazilian nuclear industry and ELETRONUCLEAR
   • unique role: complementing hydro power

2. The future of nuclear power in Brazil
   • assuring electric system Renewability & Reliability

3. Brazilian nuclear fuel industry current status
   • fortunate combination of uranium and technology
   • full application of NPT regime: a unique case

4. Assurance of supply and non-proliferation
   • future of Brazilian nuclear fuel industry
   • Brazilian contribution for IAEA policies
BRAZILIAN NUCLEAR INDUSTRY
MONOPOLY ESTABLISHED BY CONSTITUTION

MINISTRY OF MINES AND ENERGY
ELETROBRÁS (holding)
ELETRONUCLEAR
CONVENTIONAL UTILITIES Furnas, Chesf, ...
NUCLEAR SAFETY AUTHORITY

MINISTRY OF SCIENCE & TECHNOLOGY
BRAZILIAN NUCLEAR ENERGY COMMISSION CNEN

MINISTRY OF DEFENSE
RESEARCH INSTITUTES
NAVY CTMSP
AIR FORCE CTA/IEAv
ARMY CTEX/IEA

NUCLEAR FUEL INDUSTRY INB
NUCLEAR HEAVY EQUIPMENT NUCLEP
RESEARCH INSTITUTES IPEN, CDTN, IEN, IRD, CRCN
ELETRONUCLEAR MISSION
WORKING ON 3 TIME FRAMES

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)*
100 MILLION MWH GENERATED
MILESTONE REACHED ON FEBRUARY 2006

1997-2008
Availability factors:
Angra 1: 82,44%
Angra 2: 82,97%
TOP 15 WORLD ELECTRIC GENERATORS
BRAZIL IS ONE OF THE MAIN WORLD ELECTRICITY PRODUCERS

Brazil: 10ª place

source: International Energy Annual 2003
TOP 15 WORLD ELECTRIC GENERATORS
but its consumption per inhabitant is very low

<table>
<thead>
<tr>
<th>Country</th>
<th>Kilowatts.hour per inhabitant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>16.531</td>
</tr>
<tr>
<td>USA</td>
<td>12.574</td>
</tr>
<tr>
<td>Australia</td>
<td>10.170</td>
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<tr>
<td>Japan</td>
<td>7.413</td>
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<tr>
<td>France</td>
<td>7.205</td>
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<tr>
<td>South Korea</td>
<td>6.359</td>
</tr>
<tr>
<td>Germany</td>
<td>6.188</td>
</tr>
<tr>
<td>United Kingdom</td>
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<td>Russia</td>
<td>5.665</td>
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<td>Spain</td>
<td>5.631</td>
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<td>Italy</td>
<td>5.262</td>
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<tr>
<td>South Africa</td>
<td>4.383</td>
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<td>Portugal</td>
<td>4.375</td>
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<tr>
<td>Brasil</td>
<td>2.081</td>
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<tr>
<td>China</td>
<td>1.281</td>
</tr>
<tr>
<td>India</td>
<td>487</td>
</tr>
</tbody>
</table>

Brasil: 90ª place

Source: International Energy Annual 2003
HDI X ELECTRICITY CONSUMPTION

BRAZIL: 90th place

BRAZIL: 69th place

Fonte: Lighting the way, InterAcademy Council, 2007
TOP 15 WORLD HYDRO GENERATORS
GREATEST CONTRIBUTION OF HYDRO POWER

Brasil: 2ª place

Only Norway and Paraguay have a relative contribution of hydro power greater than Brazil.

source: International Energy Annual 2003

Billion kilowatts.hour

Canada: 60%
Brasil: 83%
China: 17%
USA: 7%
Russia: 21%
Norway: 99%
Japan: 8%
Sweden: 47%
Índia: 11%
France: 11%
Venezuela: 67%
Paraguay: 100%
Áustria: 64%
Italy: 15%
Argentina: 44%
ELECTRICITY GENERATION IN BRAZIL

an unique renewable matrix

Installed capacity

Total Generation

Thermal Generation

- Hydro
- Fuel Oil
- Nuclear
- Biomass
- Gas
- Wind
- Coal
- Import

Rio, 30/10/2009

Não Proliferação e Desarmamento

Leonam dos Santos Guimarães
CO2 emissions avoided in Brazil

2000 – 2006

**HYDRO POWER:**
1.677 million tons

**BIO ETHANOL:**
165 million tons

**NUCLEAR POWER:**
63 million tons

38%
HYDROPOWER REQUIRES SYSTEM INTEGRATION
HAVING CONTINENTAL DIMENSIONS EQUIVALENT TO EUROPE

4,000 km

Rio de Janeiro, São Paulo, Belo Horizonte, Brasília, Manaus, Fortaleza, Recife, Salvador, Porto Alegre, Angra NPPs, Itaipu
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 IN THE 90’s
NEED FOR THERMAL REGULATION

RELATIONSHIP
RESERVOIR CAPACITY /
TOTAL CHARGE – THERMAL GENERATION

Mainly due to charge reduction
(and an increase thermal generation)

Rio, 30/10/2009
ELECTRIC SYSTEM EVOLUTION
NEED FOR THERMAL REGULATION

root cause of 2001 supply crisis

- Water stock
- River flow
- Generated

GW month

jan/99 jan/00 jan/01 jan/02 jan/03

0% 10% 20% 30% 40% 50% 60% 70% 80%

% water storage

CRISIS
ELECTRIC SYSTEM EVOLUTION IN THE 90’s
“DAM CULTURE” CHANGE

small reservoirs to avoid flooding large surfaces
ELECTRIC SYSTEM EVOLUTION IN THE 90’s
NEED FOR THERMAL REGULATION

This tendency will be amplified by new projects in Amazon Bassin

- Current average hydro capacity factor: 55%
- Future average Amazon hydro capacity factor: 20-25%

Project AHE MADEIRA 6.500 MW
Project AHE BELO MONTE 11.000 MW
ELECTRIC SYSTEM EVOLUTION IN THE 90’s
NEED FOR THERMAL REGULATION

more nuclear could help me!
ELECTRIC SYSTEM EVOLUTION IN THE 90’s
NEED FOR THERMAL REGULATION

BRAZILIAN THERMAL OPTIONS

The main thermal fuels available in the country:

1. Coal
2. Biomass
3. Natural Gas
4. Crude Oil
5. Uranium
ELECTRIC SYSTEM EVOLUTION IN THE 90’s

NEED FOR THERMAL REGULATION

- 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
### A greater growth rate for renewables

#### PROJECTIONS FROM NATIONAL ENERGY PLAN 2030

<table>
<thead>
<tr>
<th>Scenario</th>
<th>HYDRO</th>
<th>NATURAL GAS</th>
<th>WIND AND OTHER RENEWABLES</th>
<th>NUCLEAR</th>
<th>BIOMASS AND WASTE</th>
<th>COAL</th>
<th>FUEL OIL</th>
<th>TOTAL</th>
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<tr>
<td>2006</td>
<td>75,6</td>
<td>8,1</td>
<td>1,6</td>
<td>2,0</td>
<td>0,1</td>
<td>1,4</td>
<td>2,9</td>
<td>91,6</td>
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<td>Scenario 1</td>
<td>167,8</td>
<td>20,6</td>
<td>9,1</td>
<td>7,3</td>
<td>6,5</td>
<td>5,9</td>
<td>3,3</td>
<td>220,5</td>
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<td>Scenario 2</td>
<td>168,8</td>
<td>18,1</td>
<td>8,0</td>
<td>7,3</td>
<td>6,5</td>
<td>6,5</td>
<td>3,3</td>
<td>218,5</td>
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<td>Scenario 3</td>
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<td>24,1</td>
<td>9,1</td>
<td>9,3</td>
<td>6,5</td>
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<td>3,3</td>
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<td>Scenario 4</td>
<td>168,7</td>
<td>21,6</td>
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<td>11,3</td>
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<td>Scenario 5</td>
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<td>28,1</td>
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<td>9,3</td>
<td>6,5</td>
<td>6,5</td>
<td>3,3</td>
<td>306,1</td>
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</table>

**Note:** The table shows projections for different energy sources across various scenarios, with specific emphasis on the growth rate for renewable energy sources.
## NUCLEAR RENAISSANCE IN BRASIL
### PROJECTIONS FROM NATIONAL ENERGY PLAN 2030

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<tbody>
<tr>
<td><strong>REFERENCE</strong></td>
<td>1.405 MW</td>
<td>1.000 MW</td>
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<td>2.000 MW</td>
<td>4.000 MW</td>
</tr>
<tr>
<td></td>
<td>Angra 3</td>
<td>NE 1</td>
<td>NE 2</td>
<td>SE 1+SE 2</td>
<td></td>
</tr>
<tr>
<td><strong>MEDIUM</strong></td>
<td>1.405 MW</td>
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**ELECTRIC SYSTEM EVOLUTION**

**NUCLEAR CAPACITY INSTALLED - 2030**

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<tr>
<th>Country</th>
<th>High Scenario Adicional MW</th>
<th>Low Scenario Adicional MW</th>
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<tbody>
<tr>
<td>BRASIL</td>
<td>9.360</td>
<td>5.360</td>
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<tr>
<td>RÚSSIA</td>
<td>33.760</td>
<td>26.760</td>
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<td>ÍNDIA</td>
<td>32.160</td>
<td>16.260</td>
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<tr>
<td>CHINA</td>
<td>43.830</td>
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Thermal based Electric systems
NUCLEAR EXPANSION IN BRAZIL
ANGRA 3 + 6 x 1.000 MW NUCLEAR STATIONS

ANGRA 3 CONNECTED IN 2015
NUCLEAR EXPANSION IN BRAZIL
ANGRA 3 + 6 x 1.000 MW NUCLEAR STATIONS

ANGRA 3
WORKS ON SITE
ANGRA 3
WORKS ON SITE

08/09/2009
A greater growth rate for renewables
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ANGRA 3 CONNECTED IN 2015
NUCLEAR EXPANSION IN BRAZIL
ANGRA 3 + 6 x 1.000 MW NUCLEAR STATIONS

ANGRA 3 WORKS ON SITE
ANGRA 3
WORKS ON SITE

08/09/2009
NUCLEAR EXPANSION IN BRAZIL
SITE SELECTION

Developed from EPRI Siting Guide: Site Selection and Evaluation
Criteria for an Early Site Permit Application (Siting Guide), March 2002

Regional Screen

Candidate Areas → Potential sites (15-20)

Primary Sites (6-8)

Candidate Sites (≥ 4)

Proposed Site & Alternative Sites

19 SITES SELECTED

2009  2010  2011
SPENT FUEL LONG TERM STORAGE
BRAZILIAN SOLUTION

External pool (2020)

Long Term Interim Storage (2050)

Designed for 500 years
BRAZILIAN URANIUM RESOURCES
ONE OF THE MAIN RESERVES IN THE WORLD

Prospected area: only 30% of national territory up to 100 meters deep

6th. WORLD RESERVE

<table>
<thead>
<tr>
<th></th>
<th>Measured and Indicated</th>
<th>Inferred</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>LAGOA REAL (BA)</td>
<td>94,000</td>
<td>6,700</td>
<td>100,700</td>
</tr>
<tr>
<td>ITATAIA (CE)</td>
<td>91,200</td>
<td>51,300</td>
<td>142,500</td>
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<tr>
<td>OTHERS</td>
<td>39,500</td>
<td>26,600</td>
<td>66,100</td>
</tr>
<tr>
<td>TOTAL</td>
<td>224,700</td>
<td>84,870</td>
<td>309,370</td>
</tr>
</tbody>
</table>
After prospected all the national territory, probably Brazil should be among the 3 MAJOR WORLD RESERVES.

**BRAZILIAN URANIUM RESOURCES**

**ONE OF THE MAIN RESERVES IN THE WORLD**

*TOTAL SPECULATIVE RESOURCES: 800,000 t $U_3O_8$*

- **Pitinga** 150,000 t
- **Serra de Carajás** 70,000 t
- **Rio Cristalino** 160,000 t
- **Itataia**
- **Lagoa Real** - 70,000 t
- **Espinhaço** 80,000 t
- **Paraná Basin** 120,000 t
- **Other** 150,000 t
One of the few countries having both:
1. large uranium reserves
2. full technological capability for local fuel production
**Lagoa Real** mine assures supply for Angra NPPs and NPPs planned for 2030

**Itataia** mine (*phosphate and uranium production*) could be developed for international markets
The profits obtained through Itataia should be invested in industrial development:

1. Prospecting
2. Conversion
3. Enrichment

Aiming to achieve

1. auto-sufficiency
2. added value exports
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
"We must abandon the unworkable notion that it is morally reprehensible for some countries to pursue weapons of mass destruction, yet morally acceptable for others to rely on them for security - and indeed to continue to refine their capacities and postulate plans for their use."

(Mohamed ElBaradei)

- **Over and above this paradox, Brazil is making an irreprehensible “homework” in non proliferation issues**
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 Holland, 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
CONCLUDING REMARKS
“PEPPERING” THE DISCUSSION

1. Any solution envisaging to limit access of some countries to technology will mean assuming the “bankruptcy” of international non-proliferation regime

   • Unfortunately: in technical grounds, it can work very well
   • Brazilian example shows it clearly
CONCLUDING REMARKS
TRYING TO ANSWER THE “DISCUSSION PAPER”

2. Having large uranium reserves, technology and fully safeguarded industrial facilities for all open fuel cycle steps

• Brazil could play an important role in future IAEA assurance of supply mechanisms

– as a regional production center