Perspectives for Thorium Utilization in Nuclear Reactors – Brazil

Why Brazil does not have a Thorium Program?

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History and Scenarios

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Brief History: Nuclear Activities in Brazil

Nuclear Research in Brazil began in the years following World War II (39-45), São Paulo University – USP (S.P.) and Brazilian Center for Physics Research (R.J.)

The first unsuccessful attempts to establish the basis for using nuclear energy in Brazil date from the 50's, with Admiral Alvaro Alberto, then President of the National Research Council (CNPq)

The National Nuclear Energy Commission (CNEN) was separated from the CNPq in 1956 to execute the nuclear policy

A cooperation agreement with the United States was established (Atoms for Peace program): two research reactors were acquired and constructed: IEA-R1 (IEA, now IPEN/SP) and Triga IPR-R1 (IPR, now CDTN/BH). A third RR (Argonauta) was constructed in IEN/RJ – 1965.

The prevailing idea at that time was to build a power reactor with natural uranium (implying less dependency, avoiding enriched uranium monopoly)

CNEN opted for light water cooled/moderated reactor / enriched uranium - Angra I (PWR, 627 MWe, Westinghouse) – purchased and operated by Furnas (Eletronuclear)

Brief History: Nuclear Activities in Brazil

1973 World energy/oil crisis - United States suspended the security of enriched uranium supply to new reactors in Brazil

Americans opposed to the technology transfer to Brazil, especially nuclear fuel cycle

1975 Brazil-Germany Nuclear Agreement : jet nozzle enrichment process; fuel and reactor components fabrication; construction of 8 NPPs, 1.3 GWe each – in 15 years (until 1990)

Discussions during the dictatorship period criticizing the need of nuclear power on large scale in the country and exaggerated projection of the growth rate of electricity demand

Technical community (nuclear sector) not involved in the Agreement; questions concerning technical / economic feasibility of the jet nozzle process; confirmation that there was no effective transfer of technology in the Brazil-Germany Nuclear Agreement

Establishment of the Autonomous Nuclear Program (Parallel Program), which proposed domain: development of enrichment by ultracentrifugation; design and construction of IPEN-MB 01; design/construction of a small power reactor for naval propulsion (Labgene)

1990 – radical political changes in the Autonomous Nuclear Program: interruption of R&D activities, lack of resources, dispersion and retirement of specialists

National and International Nuclear Scenary

1988 - Brazilian Constitution states the banishment of nuclear weapons

1991- Brazil and Argentina implemented the ABACC, an agency for mutual inspections of nuclear facilities

1994 - Brazil ratified the Tlatelolco Treaty (1967), denuclearization of Latin America

1997 - Brazil signed the TNP – Non-Proliferation Treat

?-1997 – Nuclebras closure, nuclear sector restructuring, creation of Eletronuclear

2000 - Completion and operation of Angra II, project started in 1975

2002-10 – Beginning of INB's U enrichment, resumption of Angra-III, decision of construction of 4 new NPPs (PWR)

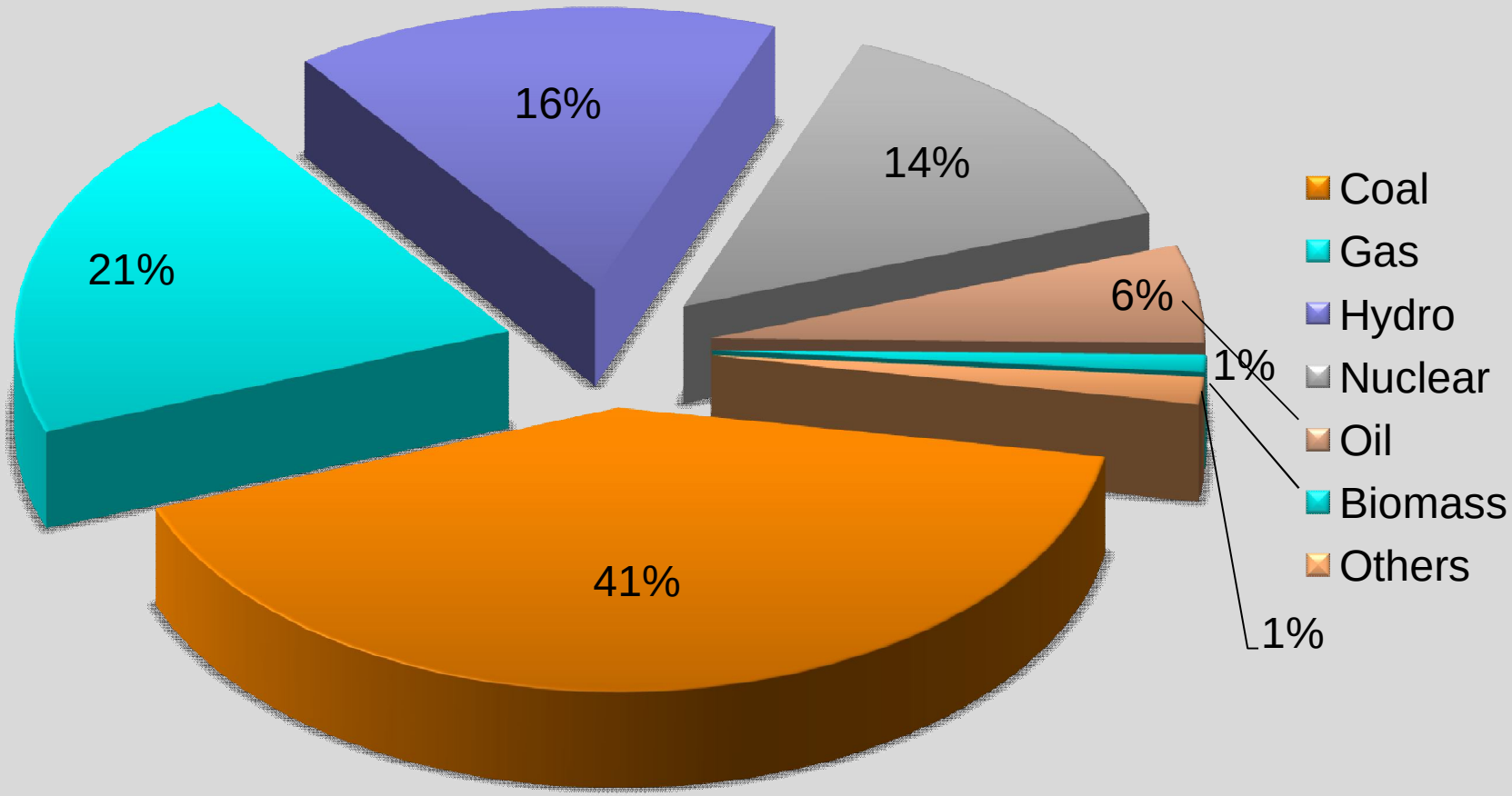
80's – Three Mile Island and Chernobyl accidents, reduction in the world nuclear energy growth rate

90's – growing concerns about global warming

2000's – "renaissance" of nuclear energy in the world

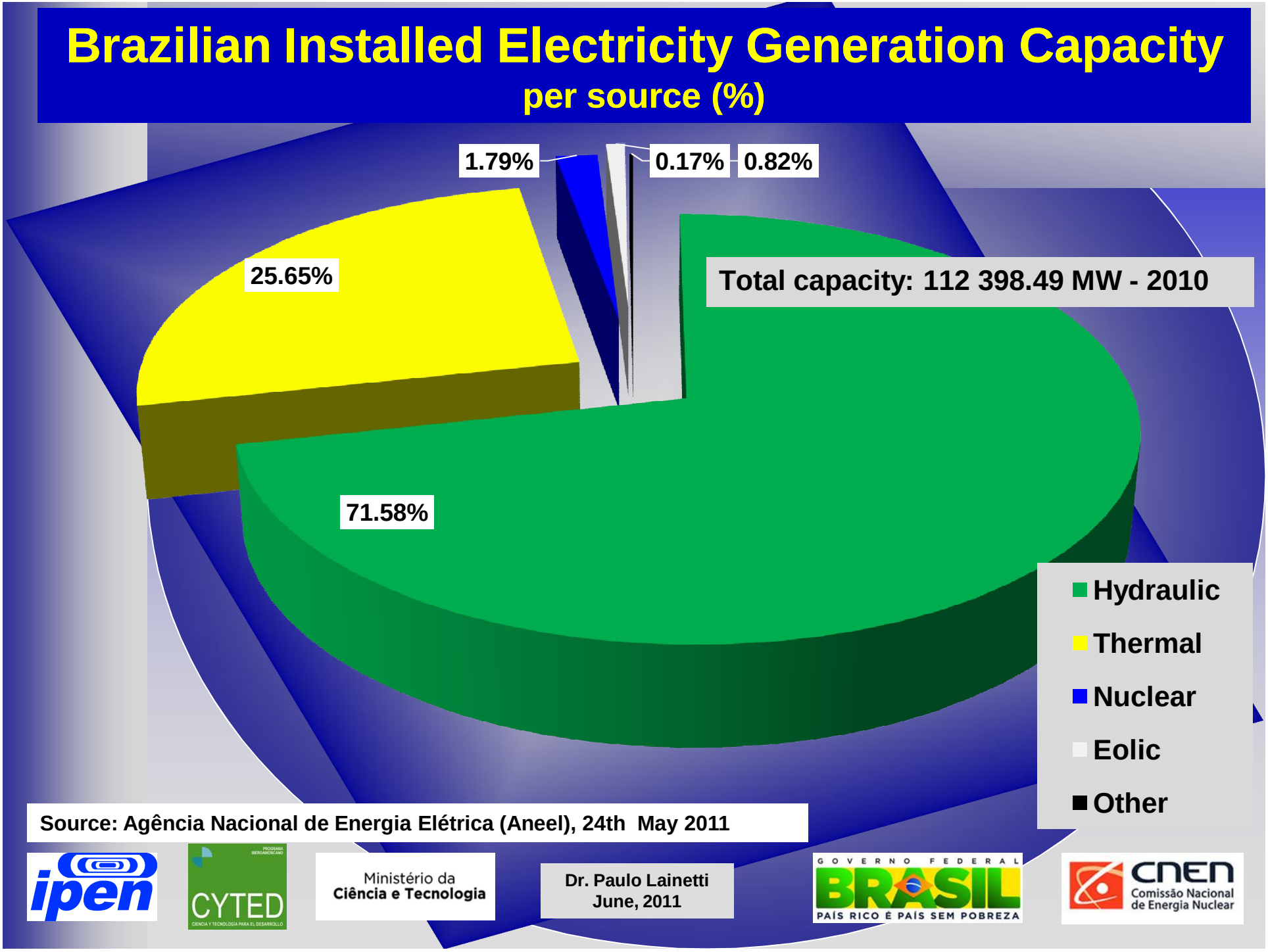
2011 – Fukushima accident

Share of Electric Generation - World



Source: IEA 2007

Brazilian Installed Electricity Generation Capacity
per source (%)



Source: Agência Nacional de Energia Elétrica (Aneel), 24th May 2011

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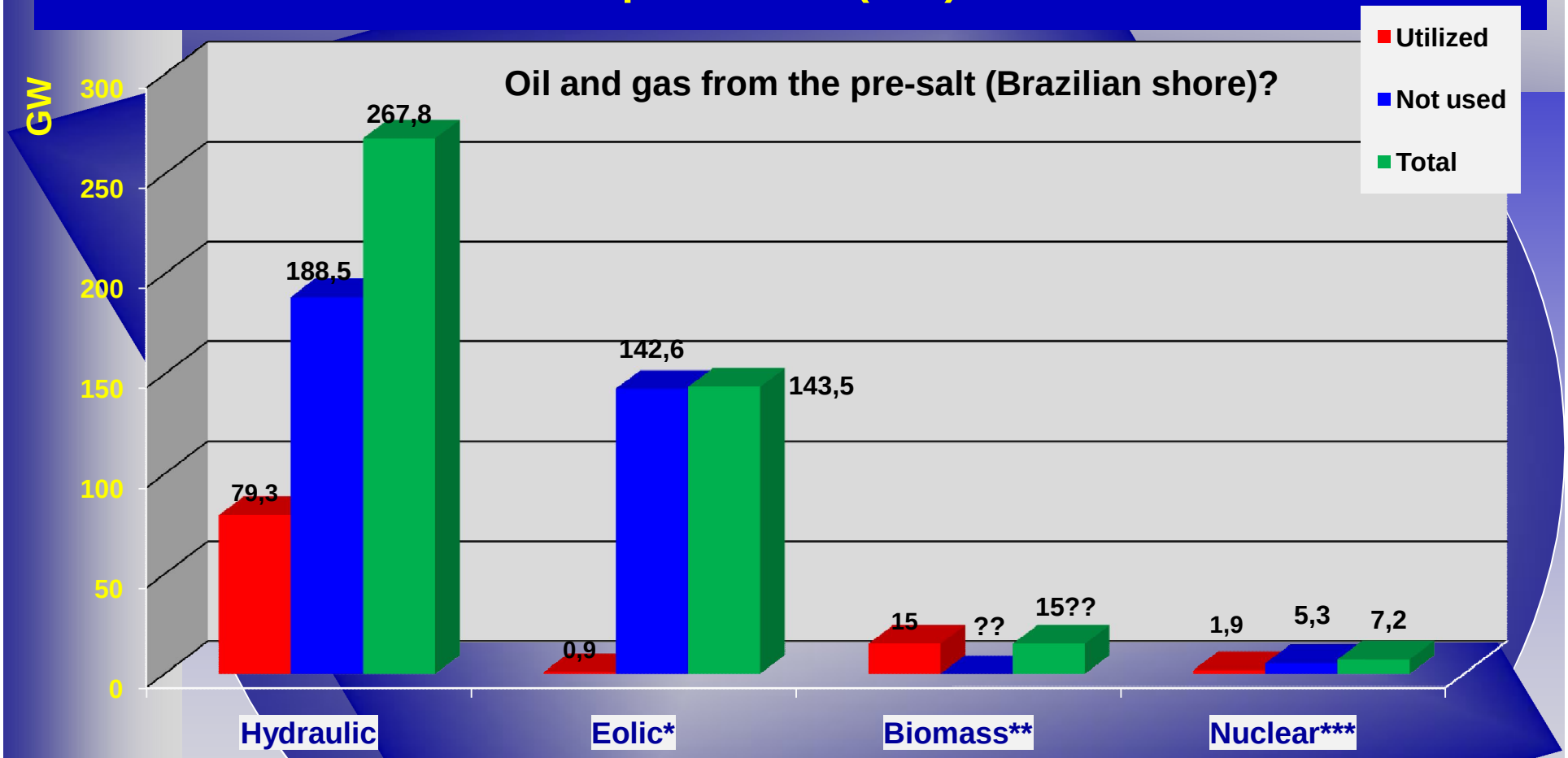
Electricity Generation Capacity: Utilized, Potential, Total
per source (GW)



* Measured 10 years ago (may be higher with new technologies)
** 15 GW in 2012 (mainly from sugar cane bagasse - ethanol production)
*** Considering Angra III conclusion and 4 new 1000 Mwe NPPs until 2020

Source: Carvalho, J.F., Sauer, I.J. da Ciência, 13/05/2011

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Brief History: Thorium Activities in Brazil

1886: beginning of monazite exploitation for gas lighting Prado-Ba

1948 Monazite processing - ORQUIMA SA –SP

60's: teoretical studies for a kind of reactor with natural uranium, which would allow subsequently the use of thorium as fertile material : natural U graphite moderated reactor (Amaral and Nevares /CNEN); Heavy water moderated and cooled pressurized reactor (J. Mello and S. Brito - Group of Thorium, IPR/BH

60's and 70's - experimental studies: purification of Th compunds, obtaining of metallic Th from ThF_4, production of ThO_2 /ThO_2-UO_2 pellets (*Abrão, Costa, Ikuta, Freitas, Haydt, Cintra, Gentile, Capocchi, S. Santos* **– IEA/SP - IPEN)**

80's - Utilization of mixed oxides (Th,U)O2 in LWR reactors (79-88) (*Pinheiro, Carneiro, Lameiras, Ferreira, Ferraz, Dias, Soares, Andrade, Mascarenhas, dos Santos, Pinto, Santos, Filgueras, Lopes* - CDTN/Nuclebras in cooperation with Siemens KWU, Nuken, KFA-Jülich)

80's Manufacturing first core IPEN-MB 01*(Riella, Gomes, Urano, Fogaça, Lainetti* IPEN-MB*)*

80's and 90's – Separation/purification of thorium and rare earths; production of sol-gel microspheres, routine production of thorium nitrate (170 t); microwave denitration, separation $^{232}Th/^{233}U$ THOREX, Proposal for new core $(Th,U)O_2$ 1996 for the IPEN-MB 01 reactor (*Abrão, Freitas, Ikuta, Seneda, Nakamura, Camilo , Carvalho, Moreira, Abe, Figueiredo, Lainetti* - CTM-SP/MB and IPEN-CNEN/SP)

World Distribution of Uranium Resources

Australia	**1 679 000**	**26.6%**
Kazakhstan	**832 000**	**13.2%**
Russia	**565 000**	**9.0%**
Canada	**544 000**	**8.6%**
United States	**472 100**	**7.5%**
South Africa	**295 600**	**4.6%**
Namibia	**284 200**	**4.5%**
Brazil*	**278 700****	**4.4%**
Niger	**275 500**	**4.3%**

***1/3 of the Brazilian territory prospected**
****** 310 000 t in accordance with other sources**

Brazil can export U (natural and enriched) in the future.

With 7 reactors (~7.2 GW) installed until 2020, Brazilian U known resources enough >200 years

IAEA /OECD NEA Uranium 2009: Resources, Production and Demand

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World and Brazilian Thorium Resources

Country	RAR	EAR
Australia	19 000	-
Brazil	606 000	700 000
Canada	45 000	128 000
Greenland	54 000	32 000
Egypt	15 000	309 000
India	319 000	-
Norway	132 000	132 000
South Africa	18 000	-
Turkey	380 000	500 000
United States	137 000	295 000

Estimated thorium reserves (tonnes of Th metal)

RAR - Reasonably Assured Reserves
EAR - Estimated Additional Reserves

In the RAR category, the deposits in Brazil, Turkey and India are in the range of 0.60, 0.38 and 0.32 million tonnes respectively.
The thorium deposits in India has recently been reported to be in the range 0.65 million tonnes.
Source: OECD/NEA, Nuclear Energy, "Trends in Nuclear Fuel Cycle", Paris, France (2001) cited in ***IAEA TECDOC-1450 Thorium fuel cycle — Potential benefits and challenges May, 2005.***

Country	Reserves	Reserve base
United States	160,000	300,000
Australia	300,000	340,000
Brazil	16,000	18,000
Canada	100,000	100,000
India	290,000	300,000
Malaysia	4,500	4,500
Norway	170,000	180,000
South Africa	35,000	39,000
Other countries	90,000	100,000
World total	1200000	1400000

Source: U.S. Geological Survey, Mineral Commodity Summaries, January 1998

Data in metric tons of thorium oxide (ThO_2) equivalent

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Proposal for Th Use in the IPEN / MB - 01

From 1985 until 2002, the IPEN's Thorium Pilot Plant produced over 179 t of high purity thorium nitrate (Pilot Plant partially decommissioned in 2003-04)

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Proposal for Th Use in the IPEN / MB - 01

IPEN's UO_2 Fuel Pellets Pilot Plant produced over 43000 fuel pellets (4.3% ^{235}U enriched) for the first core of IPEN/MB-01 (Pilot Plant decommissioned in 2007)

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Large Nuclear Projects in Progress in Brazil

- Construction of Angra-III – 1300 Mwe
- Definition of the localization - new nuclear power plants
- Design of the Multipurpose Research Reactor
- Design of the radioactive waste repository
- Expansion of the capacity of the ultracentrifugation plant
- Construction of the Labgene (land prototype/propulsion)
- Navy conversion facilities

Thorium project has to compete for budget and personnel

Conclusion

- Probably, thorium constitutes the largest Brazilian energy reserve, supplanting much oil (despite the pre-salt reserves) and uranium
- In spite of the different alternatives available in Brazil for electricity generation, the future importance of thorium in the world is undeniable, and is of strategic importance to keep a research program

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