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Climate Policy and Energy Transition

Nuclear Power Policy in Brazil

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Present Brazilian Nuclear Policy

- 2 nuclear power reactors in operation 1884 MW
- 1 in construction 1400 MW
- Nuclear submarine project
cooperation with France for shipbuilding
nuclear reactor prototype in construction by Brazilian Navy
- Multipurpose nuclear reactor – radioisotope production
in cooperation with Argentina
- Nuclear fuel cycle – uranium enrichment
ultracentrifugation demonstration plant working

THE CONTEXT

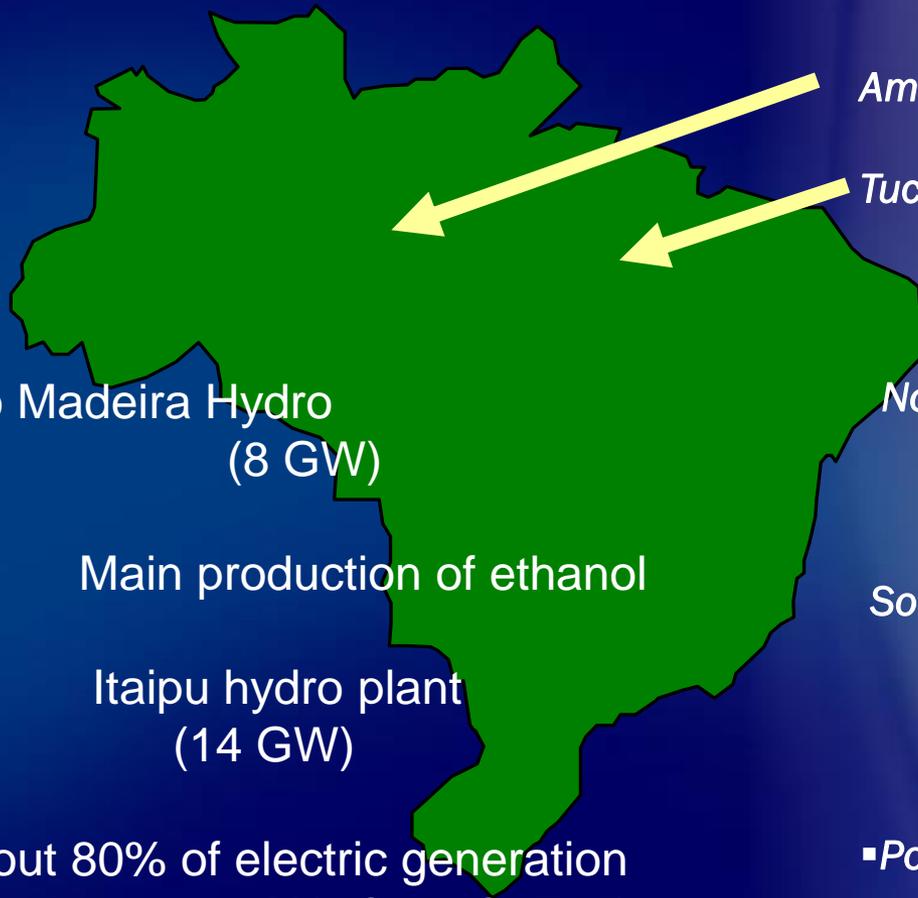
The background of the slide is a dark blue gradient. On the right side, there is a semi-transparent image of a woman's face, likely a portrait of a historical figure. In the foreground, there is a 100 Euro banknote, tilted slightly. The banknote features a detailed illustration of a fish, possibly a trout or salmon, and the number '100' is visible. The overall aesthetic is professional and academic.

Latin American and Caribbean Region



- 20 million km²
 - more than 500 m inhabitants
 - 13% of terrestrial surface
 - 26 inhabitants/km²
 - 34 countries
-
- Nuclear power plants
 - 2 in Brazil
 - 2 in Argentina
 - 2 in Mexico
 - In construction
 - 1 in Brazil
 - 1 in Argentina

Brazil



*Amazon Region - half of the Country area
rainforest low populated*

Tucuruí Hydro (8 GW)

Belo Monte Hydro (11 GW) in construction

*Northeast, high **populated and poorer***

*Southeast - Most industrialized and richer
Oil off shore production
Nuclear Power Plant*

▪ *Population - 185 m*

*30 m recently did come out from poverty to
market economy → energy consumption*

*Rio Madeira Hydro
(8 GW)*

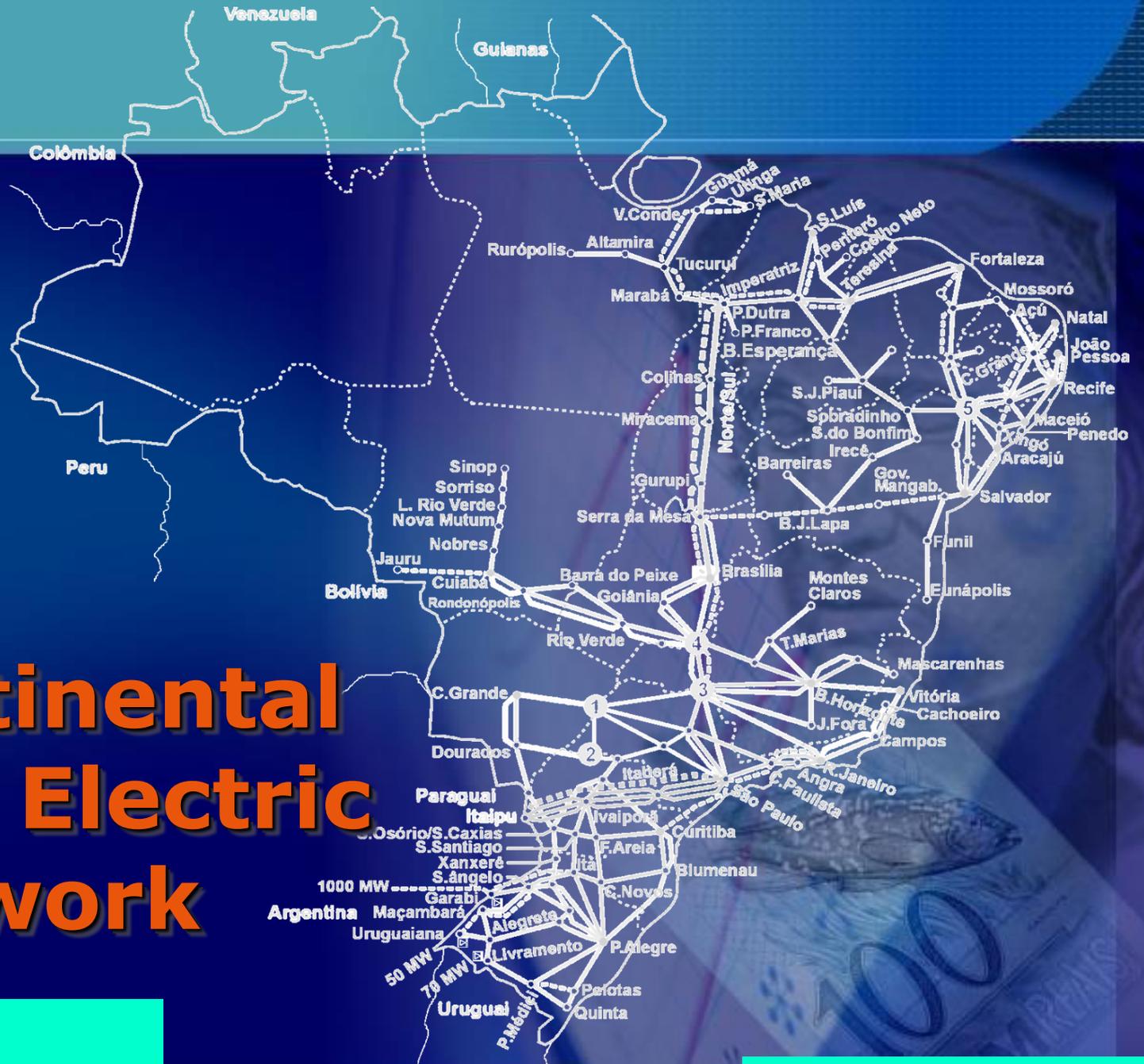
Main production of ethanol

*Itaipu hydro plant
(14 GW)*

*About 80% of electric generation
Is hydro – only 2% IS NUCLEAR*

4.000 kms

A Continental Size Electric Network

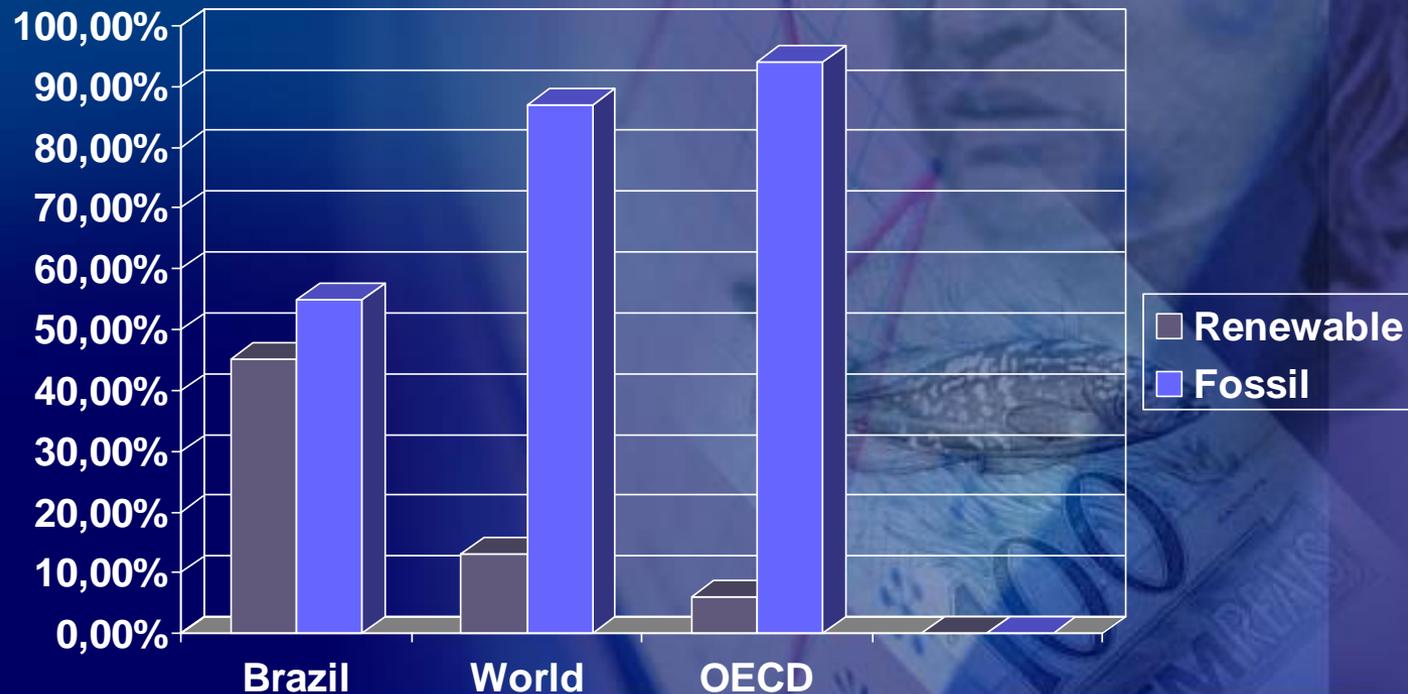


Brazilian Comparative Advantages

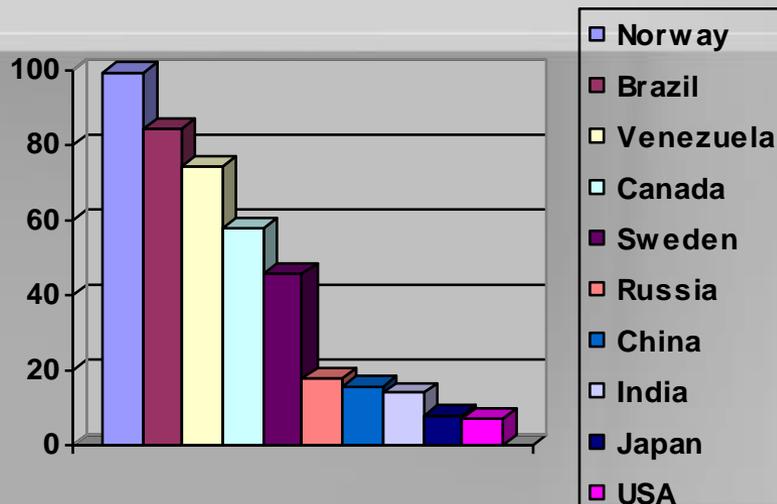


Brazil has great component of renewable energy in the energy matrix:

hydroelectric energy,
biofuels

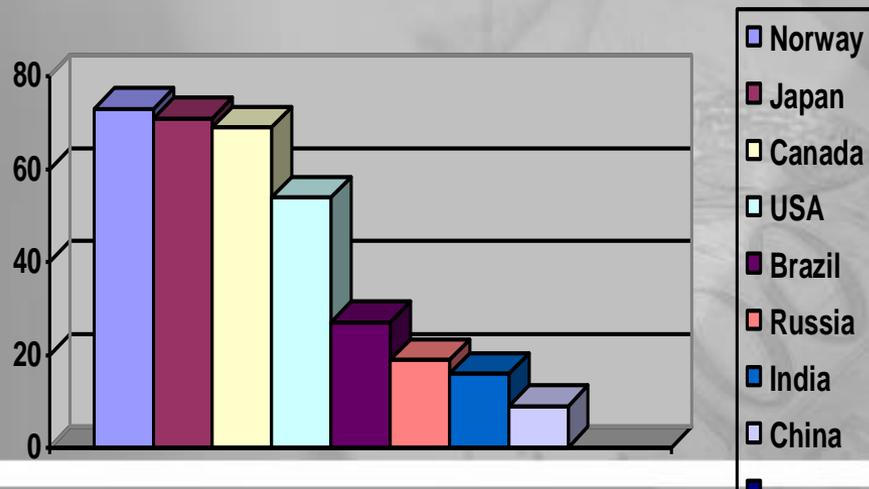


Top countries with the highest percentage of hydropower in their electricity generation (%)



Source: IEA, 2006

Percentage of economic hydropower potential that is currently utilized in selected countries



Origin of Nuclear in Brazil

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PAST



The Pre-history

- Brazil had a project of nuclear technology based on natural uranium like Argentina to avoid uranium enrichment dependence.
- A Thorium Nuclear Reactor Project started based in natural uranium reactors, but it was abandoned.
- Brazilian military government shifted to uranium enriched reactors to buy Angra I from Westinghouse.
- There was no need of nuclear energy for electricity.

Difference between Argentina and Brazil Nuclear Choices

Reactor Technology

Argentina = Natural Uranium + Heavy Water

Siemens and Candu Medium Size Units

Brazil = Enriched Uranium + Light Water

Westinghouse → Siemens Big Reactor

Uranium Enrichment Technology

Argentina = Gaseous Diffusion

Brazil = from Jet Nozzle to Ultracentrifugation

Debate on Nuclear Energy in Brazil different aspects:

- **Electric Energy Generation**
- **Environmental Risks**
- **Military Uses**
- **Technology**



Problems of Angra I – The first power reactor

- The Angra I nuclear reactor had technical difficulties of operation, but they are now solved.
- One of the problems was the corrosion of the steam generator, due to a mistake in the metal alloy (inconel) used by Westinghouse.
- Angra I steam generators had been replaced recently with very high cost.
- Good performance now = high capacity factor

The Brazil-Germany Nuclear Agreement

- The areas of cooperation were:
 - Prospecting, mining and processing uranium - OK
 - Producing nuclear reactors – 8 plants planned and about 50 forecasted → only one reactor built
 - Enriching uranium – jet nozzle did not work
 - Fabricating nuclear fuel rods - OK
 - Reprocessing spent fuel – never implemented

The Agreement triggered a broad reaction

- Never a decision by military government faced so strong civilian opposition.

The Brazilian Physical Society (SBF) pointed out environmental risks of nuclear technology:

Costs and need of nuclear power X hydropower

Safety of nuclear reactors

The radioactive wastes

Some years later there were the nuclear reactors accidents of TMI and Chernobyl as well as the radioactivity accident with Cs 137 in Brazil

Parallel Nuclear Program

- Last military government implemented a Parallel Nuclear Program to develop the technology not transferred by the Nuclear Agreement with Germany.
- This Parallel Programme included uranium enrichment by ultracentrifuge technology and a nuclear reactor for nuclear-propelled submarine.

In the first civilian government it was revealed the existence of a deep shaft drilled in an Air Force Base

A report issued by the Brazilian Physical Society (SBF) concluded that it had all the characteristics and dimensions required to test a nuclear bomb of 10 kilotons

This conclusion prompted many denials by government.

In the 1990s, the government acknowledged the existence of an underground nuclear explosion facility, and sealed this shaft

The background is a blue-tinted image. On the right side, there is a fisherman's net with a fish inside. Above the net, there is a portrait of a man with a beard and a hat. The word "PRESENT" is written in large, white, bold, sans-serif capital letters across the center of the image.

PRESENT

Argentina Brazil Agreement

- Argentina and Brazil ratified the Treaty of Tlatelolco on the denuclearisation of Latin America .
- Created ABACC, an agency for mutual inspections of nuclear facilities in Brazil and Argentina with IAEA.
- Argentina and Brazil signed the Non-Proliferation Treaty .

Angra II and III reactors from Germany Agreement

- The Angra II nuclear reactor was completed after more than 20 years, despite costs that soared from an initial estimate of US\$ 500/kW to US\$ 4000/kW.
- The Brazilian Government has decided to go ahead with the second reactor from the Nuclear Agreement with Germany: Angra III with 1400 MW.
- US\$ 700 million of its components were imported from Germany and are stored in Brazil .
- To conclude Angra III nuclear power plant a further US\$ 5 billion are needed, partly financed by France (Areva - Siemens).

- The cost of Angra III is too high: $5.7 + 5 = 10.7$ US\$ bi
- $5.7 \text{ bi} / 1400 \text{ MW} = 4071 \text{ US\$} / \text{kW}$
- A study by COPPE compared nuclear power costs with hydro and thermo plants.
- Hydro-power proved the least expensive, followed by natural gas thermo-power and then nuclear power.
- The comparison between the two latter options indicates a marked sensitivity to the rate of return.
- Present debate on power plants in Brazil put the focus not in nuclear power, but on hydro plants because of Amazon forest and Indian lands
- New hydro plants have small reservoir – run of river to avoid large impact

Environment and Hydroelectric Power

Reduction of Reservoir Area → Run of River Hydroplants

Reservatório Antigo



Reservatório Atual



FUTURE



Problems to be solved

- The electric power in Brazil was moving from hydroelectricity to thermoelectricity → It means higher greenhouse gas emissions.
- Present debate on new hydro plants → the case of Madeira River and Belo Monte.
- Run of river hydro without reservoir → need of complementation: fossil fuel, biofuel, wind or nuclear.
- Wind energy is growing in Brazil with decreasing costs – present installed capacity is almost equal to nuclear
- Proposal of nuclear to operate in the base because the capacity factor is high.

Nuclear power offers now the argument that it does not emit greenhouse gases

- Although hydro-power plants emissions are rated as negligible, measurements started by COPPE show that hydro reservoirs have CH₄ and CO₂ emissions, although generally at levels far lower than thermo-power plants.
- Brazil shall cut between 36% and 39% of estimated emissions in 2020 → voluntary commitment in Copenhagen Conference
- Most of the Brazilian emissions did come from deforestation until now, but with the reduction of deforestation energy is becoming important

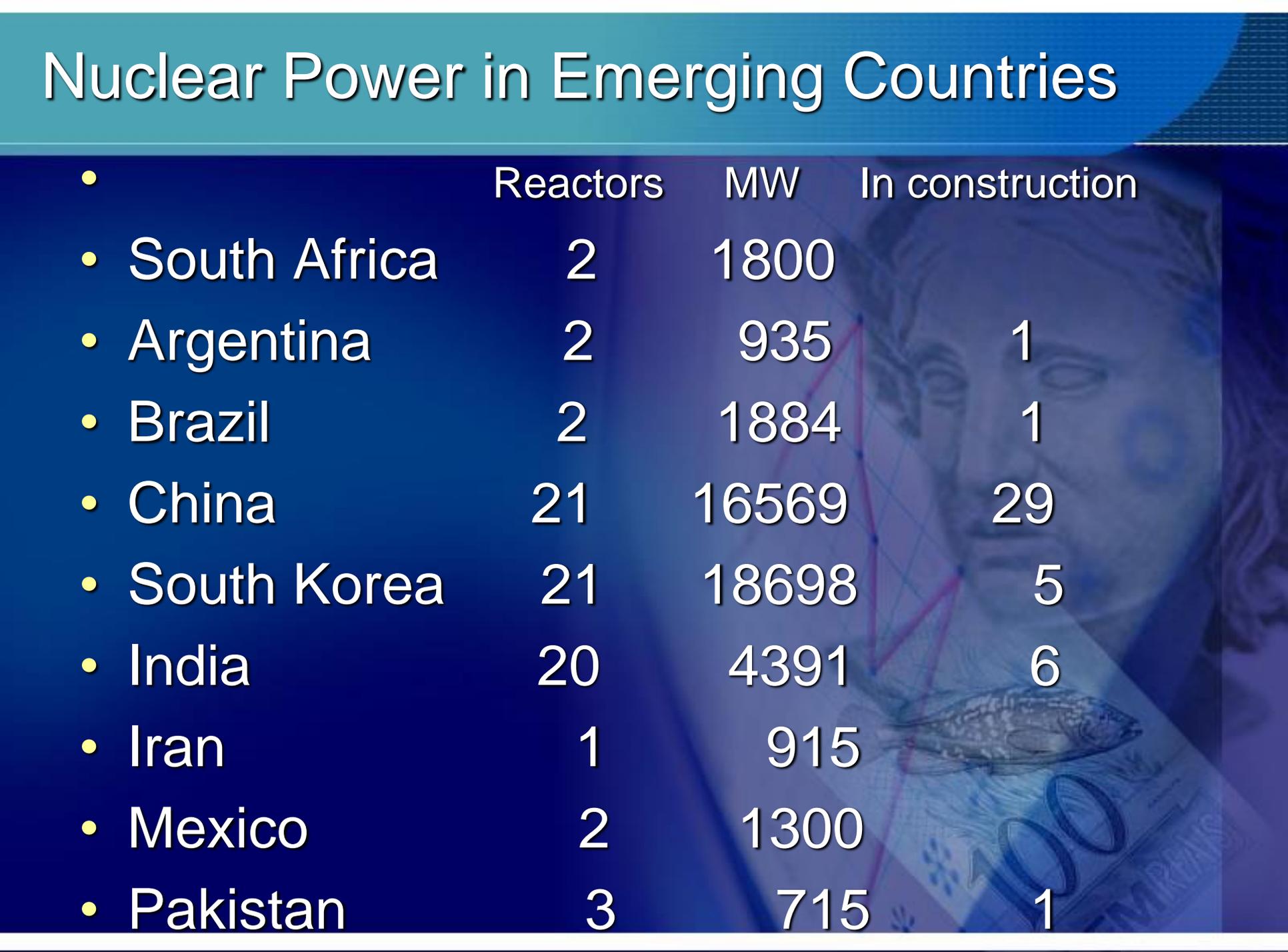
There was a plan of more 4 nuclear power reactors in 2030

The plan did include 4 new reactors of 1000 MW besides Angra III operating in 2030.

That means more 5300 MW of nuclear power = Angra III (1300 MW) + 4x1000 MW (?)

Under discussion after FUKUSHIMA accident

Nuclear Power in Emerging Countries



	Reactors	MW	In construction
• South Africa	2	1800	
• Argentina	2	935	1
• Brazil	2	1884	1
• China	21	16569	29
• South Korea	21	18698	5
• India	20	4391	6
• Iran	1	915	
• Mexico	2	1300	
• Pakistan	3	715	1

Possible Cooperation Argentina + Brazil/ Reactor Technology

The Argentina's company NASA is finishing Atucha II while the Brazilian company Eletronuclear did retake Angra III work.

Both reactors use Siemens technology (with Areva)

Problem : Atucha II = natural uranium reactor
while Angra III = enriched reactor (PWR)

Argentina produces small research reactors, exported to Peru, Egypt and Australia

Brazil has three small reactors for research/ and there is a project to build a new one for radioisotope production.

Cooperation of Argentina for the Brazilian Multipurpose Reactor

What about nuclear proliferation?

- The Brazilian technology for uranium enrichment by ultracentrifugation works well and it is currently being transferred to a civilian industry, the INB.
- This technology developed by the Brazilian Navy for nuclear-propelled submarine project will be used to civilian power reactors.
- This uranium enrichment project is not intended to endow Brazil with the capacity to produce nuclear weapons.
- Brazil has not agreed with the additional protocol proposed in NPT to control nuclear technology.