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IAEA
International Atomic Energy Agency

**2061-1**

# Joint ICTP/IAEA Workshop on Alternative Response Actions to Climate Change and Energy Options

***5 - 9 October 2009***

## Greenhouse Gas Mitigation Strategies and the Energy Options for the Brazilian Power Sector

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Centro Clima
CENTRO DE ESTUDOS INTEGRADOS SOBRE MEIO AMBIENTE E MUDANÇAS CLIMÁTICAS

# Greenhouse Gas Mitigation Strategies and the Energy Options for the Brazilian Power Sector

*Amaro Pereira - André Pereira - Prof. Emílio La Rovere*

Workshop on Alternative Response Actions to Climate Change and Energy Options

# Introduction

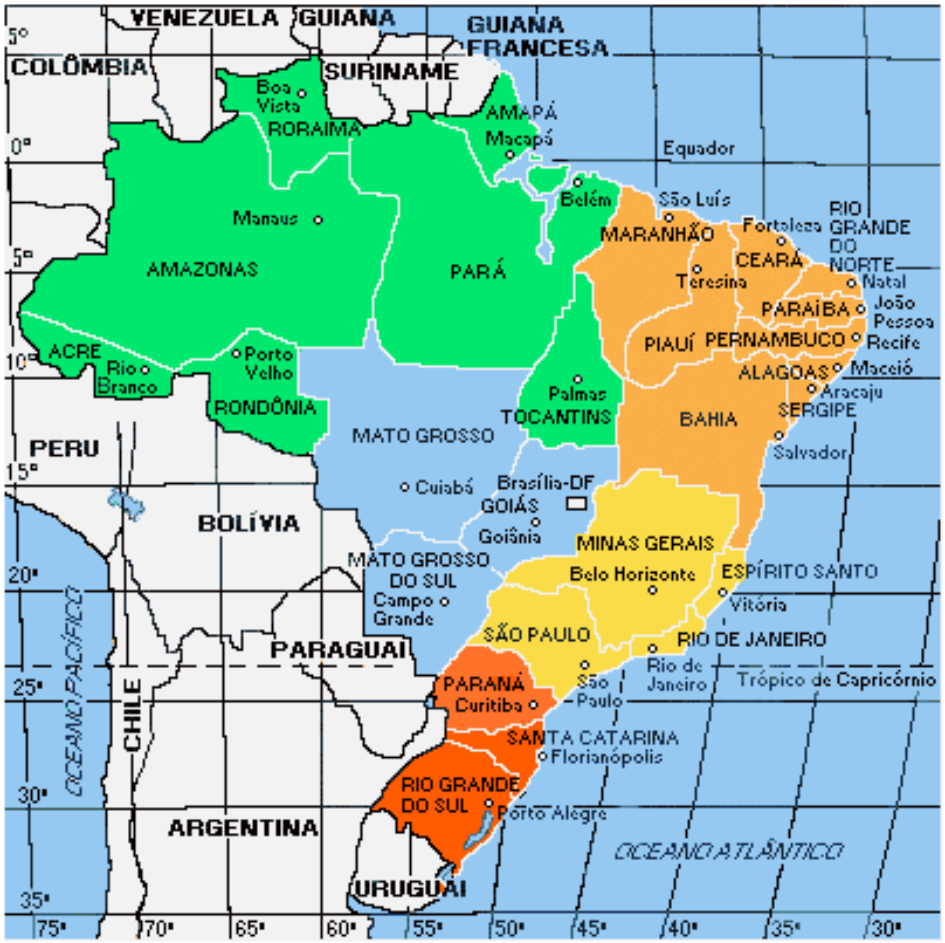
- Availability of Energy Resources
- Commitments for Post-Kyoto ?
- Brazilian Proposal
- National Plan of Climate Change:
  - To maintain the high share of renewable energy in the electricity sector, thus maintaining the outstanding position that Brazil has always occupied in the international sphere

# Objective

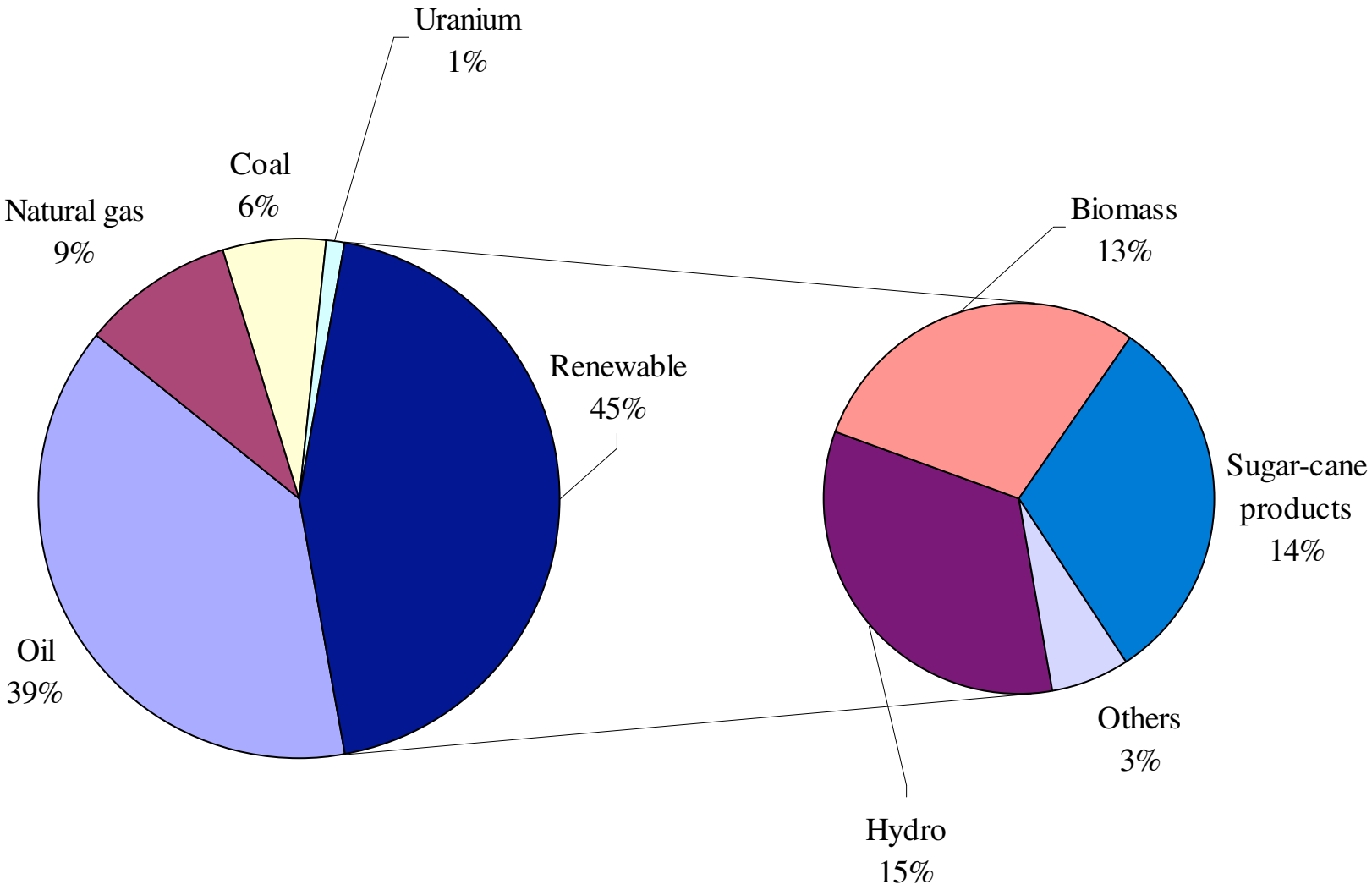
- To assess the strategies to mitigate greenhouse gas emissions in the Brazilian power sector, based on recent researches that CentroClima was involved in:
- Development First: Linking Energy and Emission Policies with Sustainable Development – UNEP RISOE Centre, 2007;
- Cost Assessment for Sustainable Energy Systems (CASES) – European Commission, 2008; and
- Energy Compensation Mechanism – Government of Rio de Janeiro State, 2008.

# Major Features of the Brazilian Economy - 2005

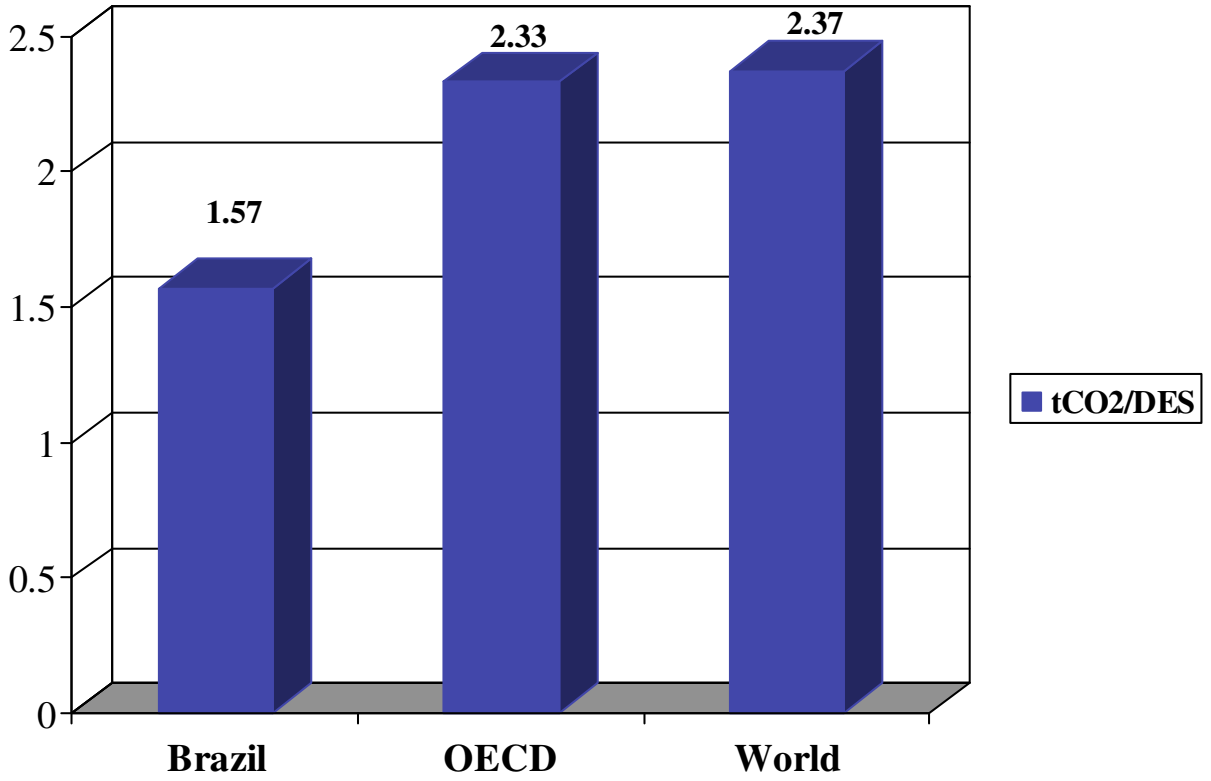
- GDP of US$ 880 billion
- Population of 184 million inhabitants
- GDP/cap of US$ 4.800
- Land Area of 8.5 million km$^2$



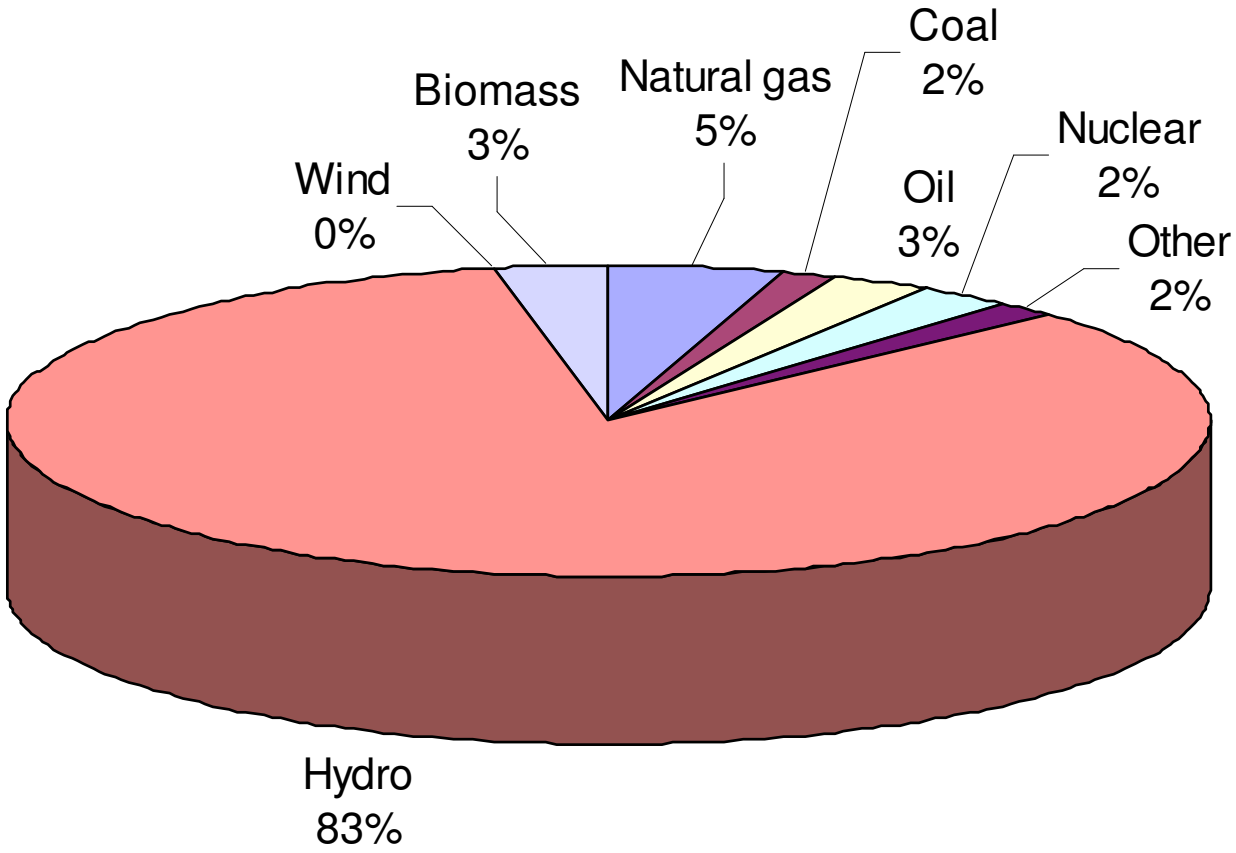
# Domestic Energy Supply - 2005



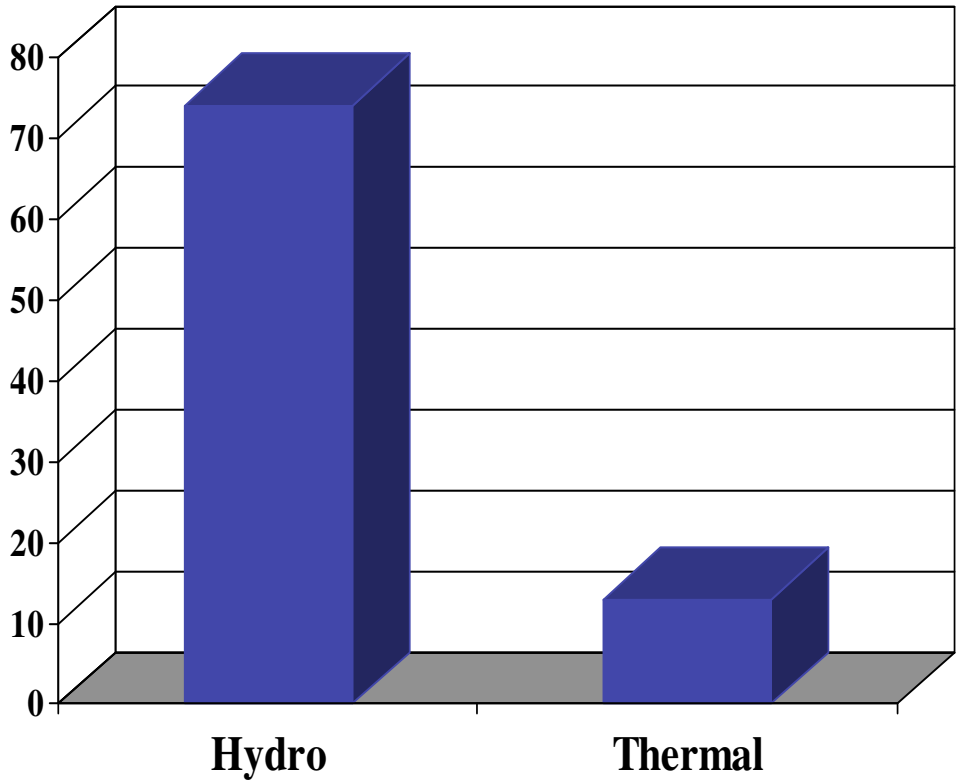
# $CO_2$ Emissions per Domestic Energy Supply (DES) - 2005

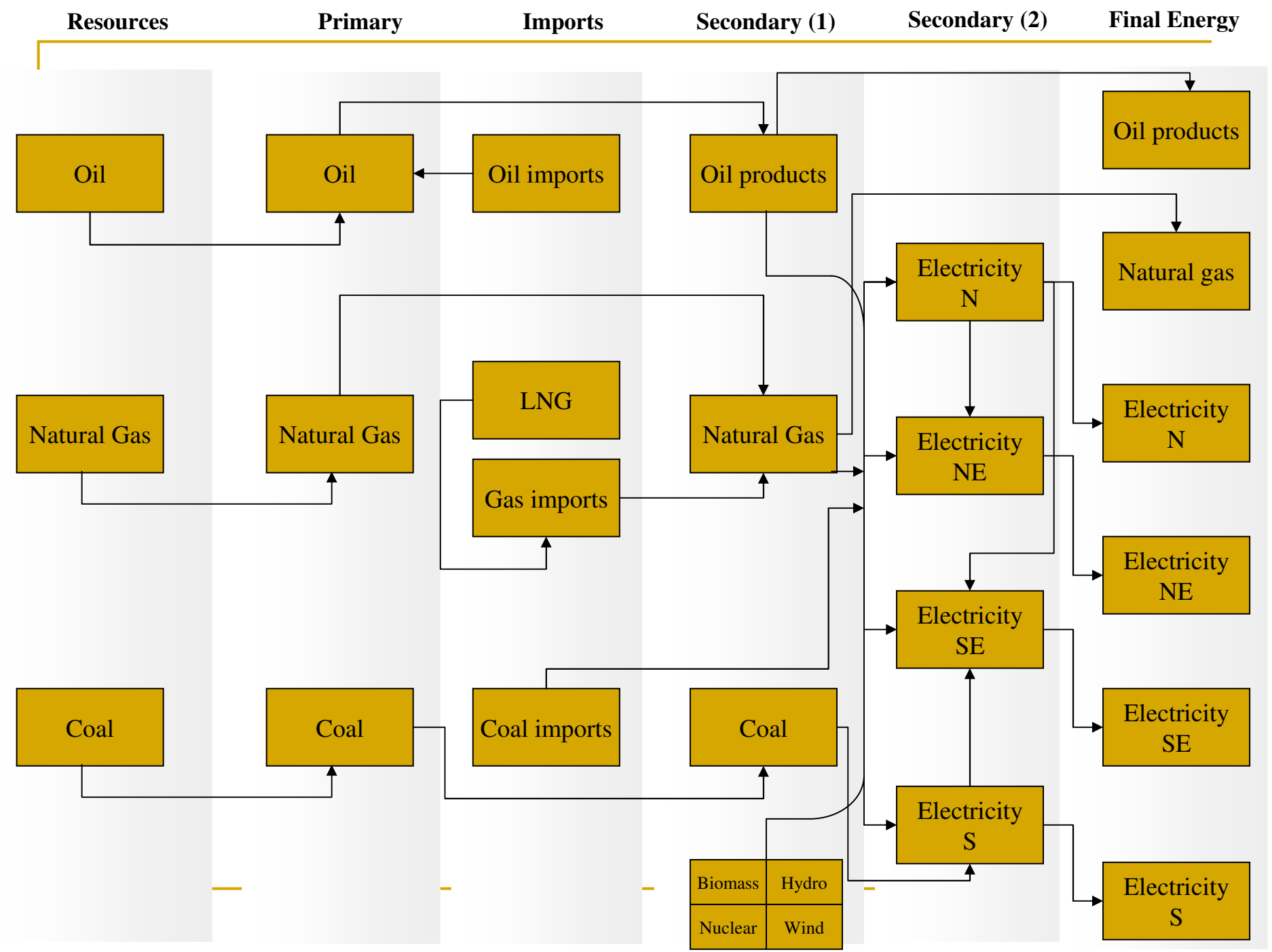


# Electricity Generation - 2005

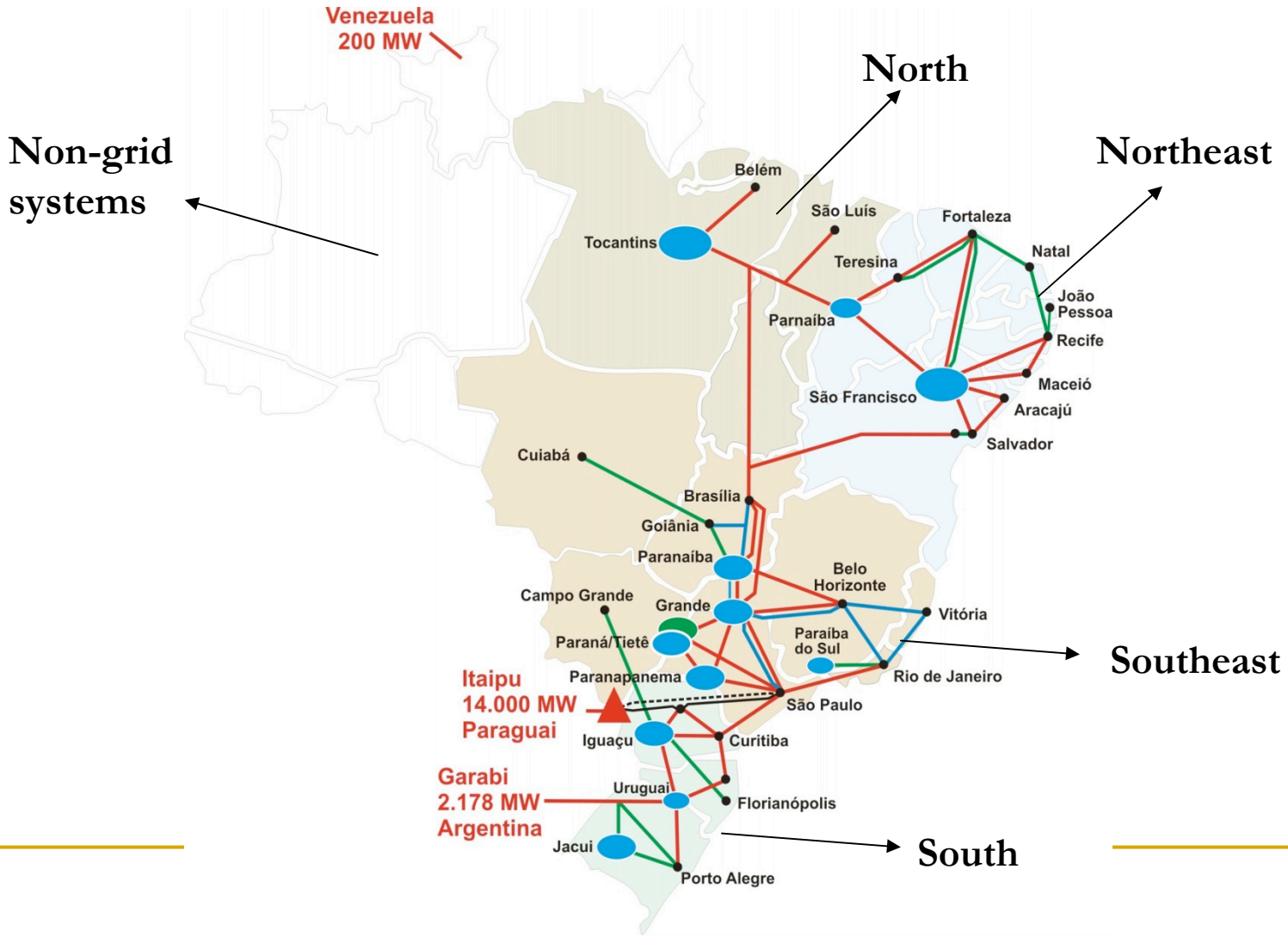


# Installed Capacity (GW) - 2005

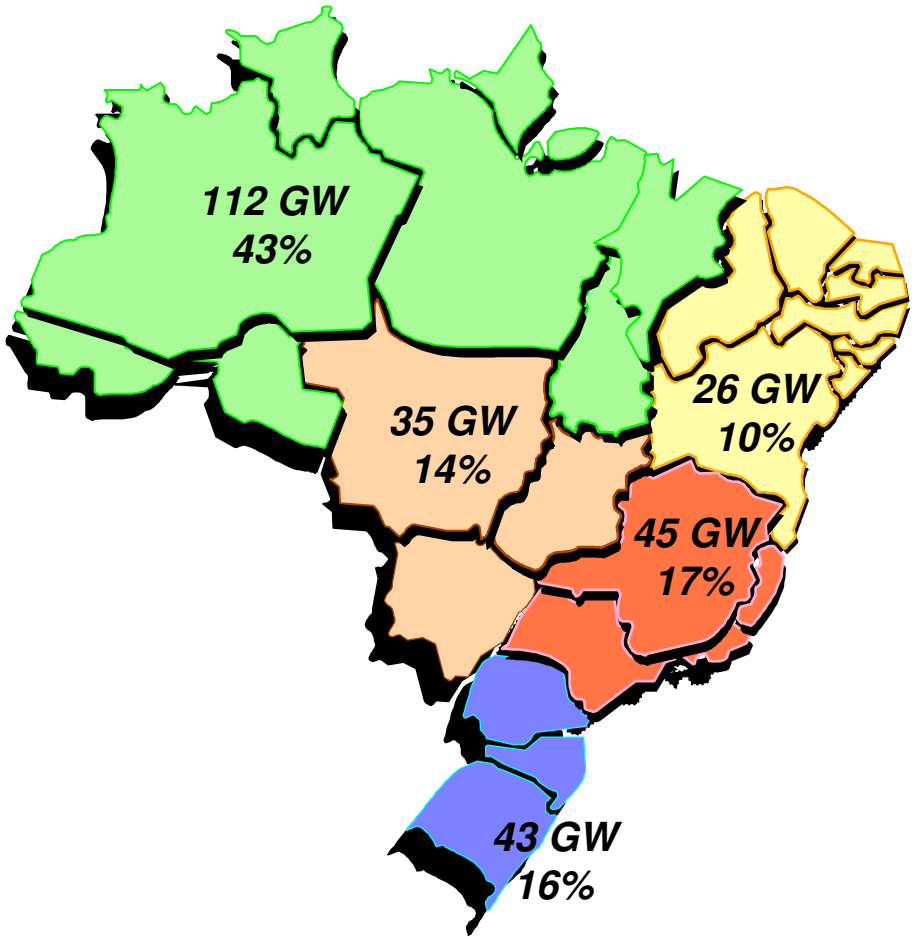



Resources
Primary
Imports
Secondary (1)
Secondary (2)
Final Energy
Oil
Oil
Oil imports
Oil products
Oil products
Natural Gas
Natural Gas
LNG
Natural Gas
Gas imports
Natural gas
Coal
Coal
Coal imports
Coal
Biomass
Hydro
Nuclear
Wind
Electricity N
Electricity NE
Electricity SE
Electricity S
Electricity N
Electricity NE
Electricity SE
Electricity S

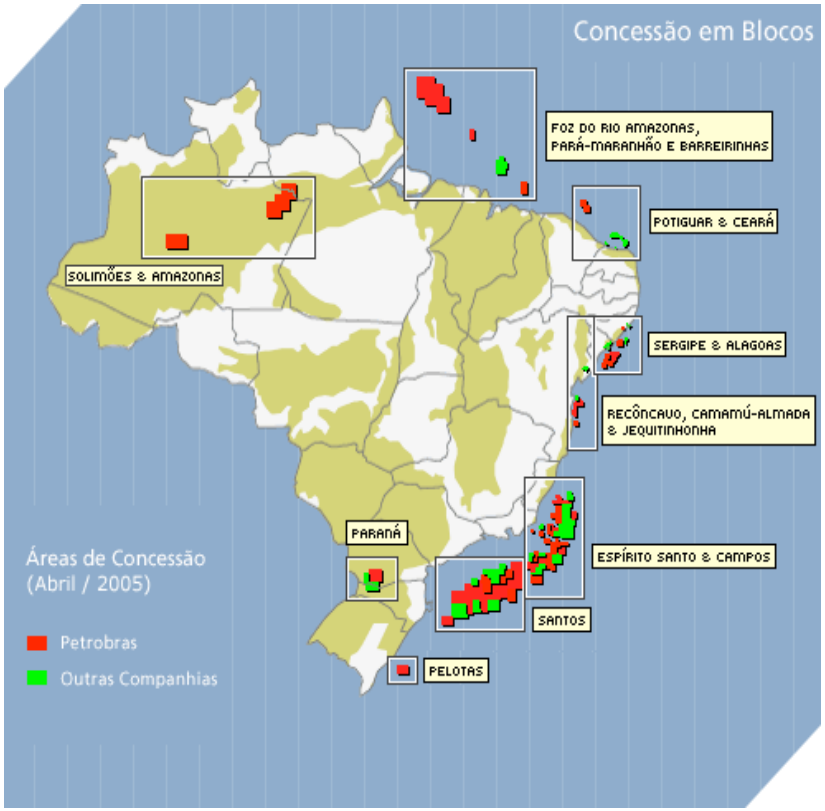
# Sub-systems and Connections



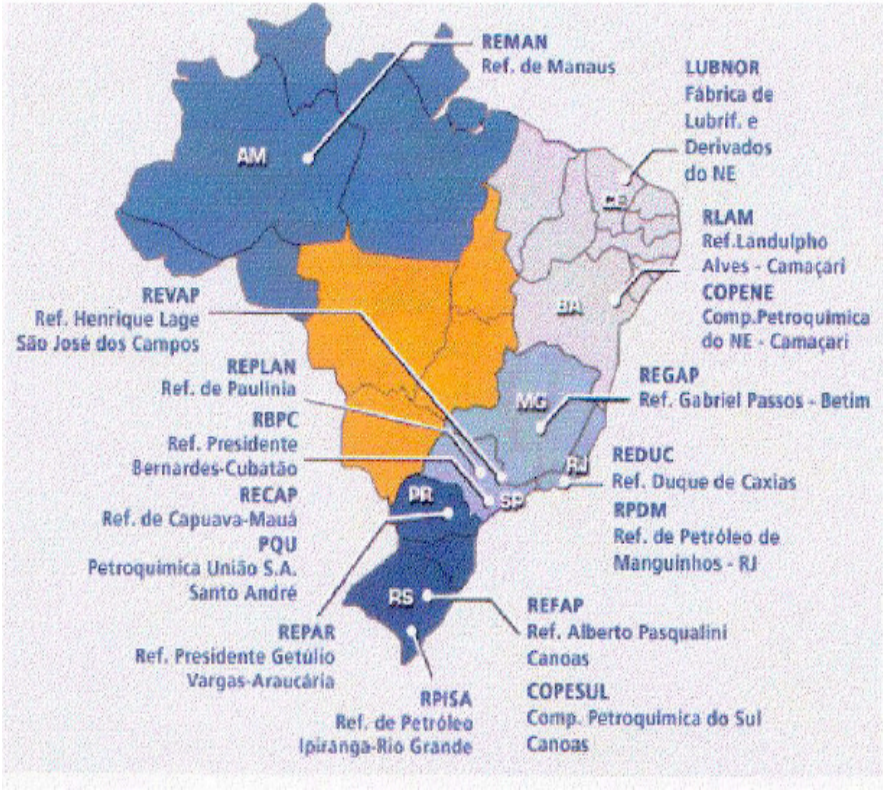
# Hydro Power Potential




# Oil Resources



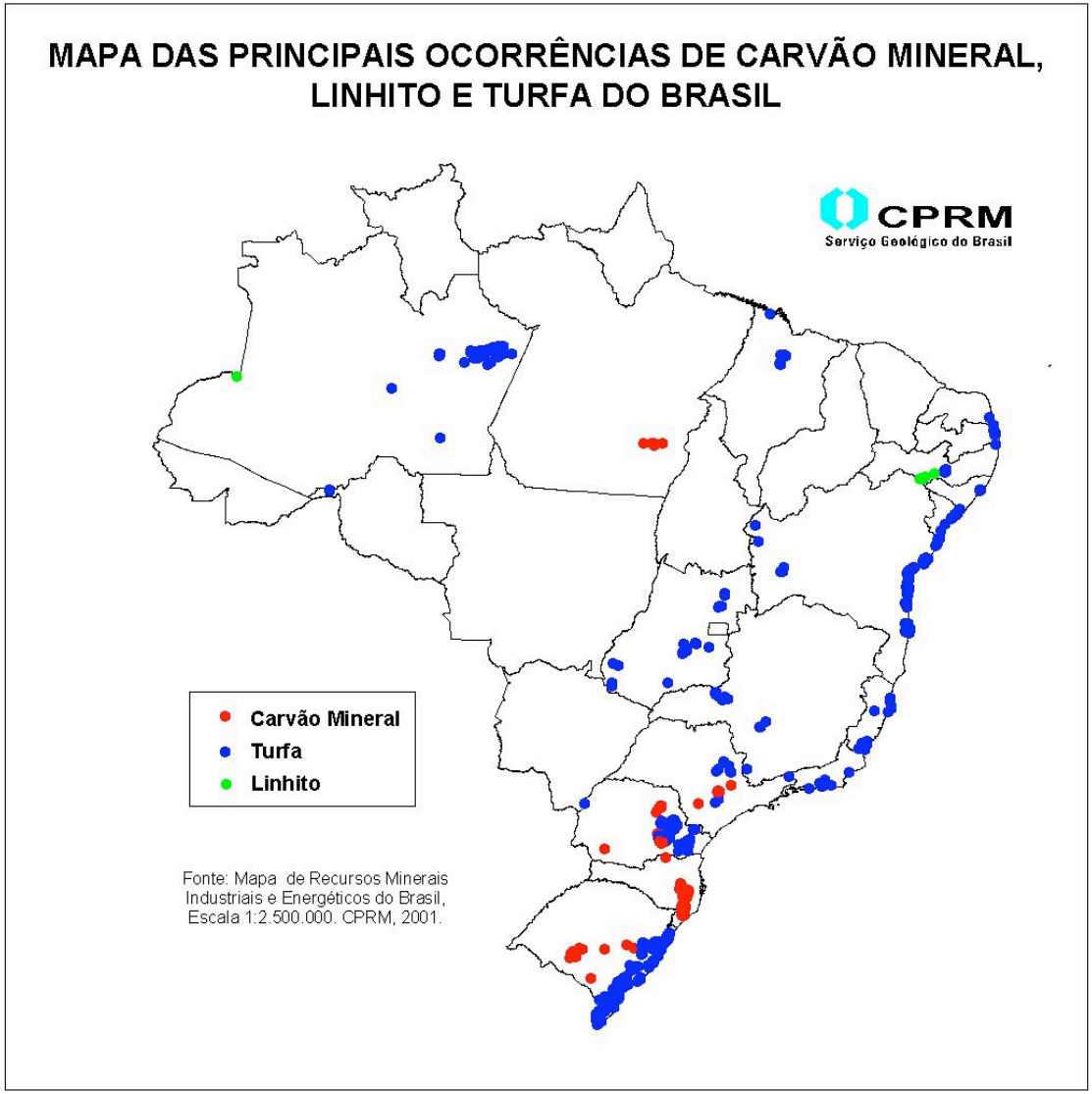

# Refineries



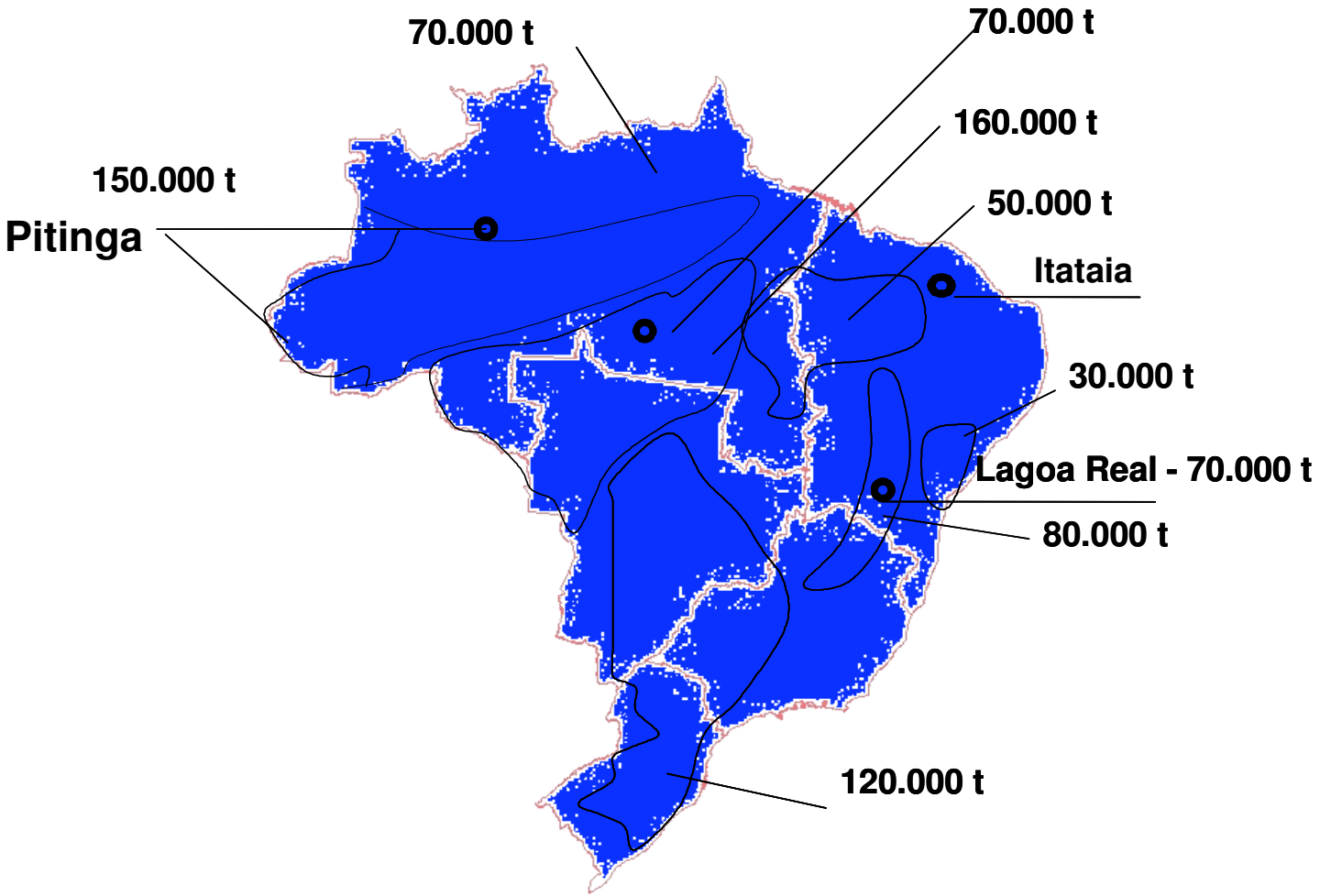
# Natural Gas


CARACAS
Trinidad Tobago
Maracaibo
Sta. Bárbara
VENEZUELA
Boa Vista
Macapá
Belém
São Luís
Manaus
Guamaré
Fortaleza
Juruá
Urucu
Coari
Mossoró
Natal
Carauari
João Pessoa
Teresina
Recife
Porto Velho
Palmas
Maceió
Rio Branco
BRASIL
CAMISEA
Feira de Santana
Aracaju
Salvador
PERU
BOLÍVIA
BRASÍLIA
Cuiabá
BOOMERANG
Goiânia
SANTA CRUZ
Campo Grande
Belo Horizonte
R. GRANDE
S. ANTÔNIO
Corumbá
Ribeirão Preto
Varginha
Betim
Vitória
OCEANO PACÍFICO
S. ALBERTO
PARAGUAI
Dourados
Campinas
RJ
Campos
REDUC
RAMOS
ASSUNÇÃO
SÃO PAULO
Curitiba
Joinvile
ARGENTINA
Itajaí
Florianópolis
Paso de los Libres
Uruguaiana
Criciúma
Alegrete
Porto Alegre
OCEANO ATLÂNTICO
SANTIAGO
Aldea Brasilera
URUGUAI
CONCEPCIÓN
BUENOS AIRES
MONTEVIDEO
CUENCA NEUQUINA
LEGENDA
GASODUTOS
EM OPERAÇÃO
EM CONSTRUÇÃO
EM ESTUDO
PROJETADOS
BOLÍVIA/BRASIL
RESERVAS DE GÁS
Fonte:Petrobrás

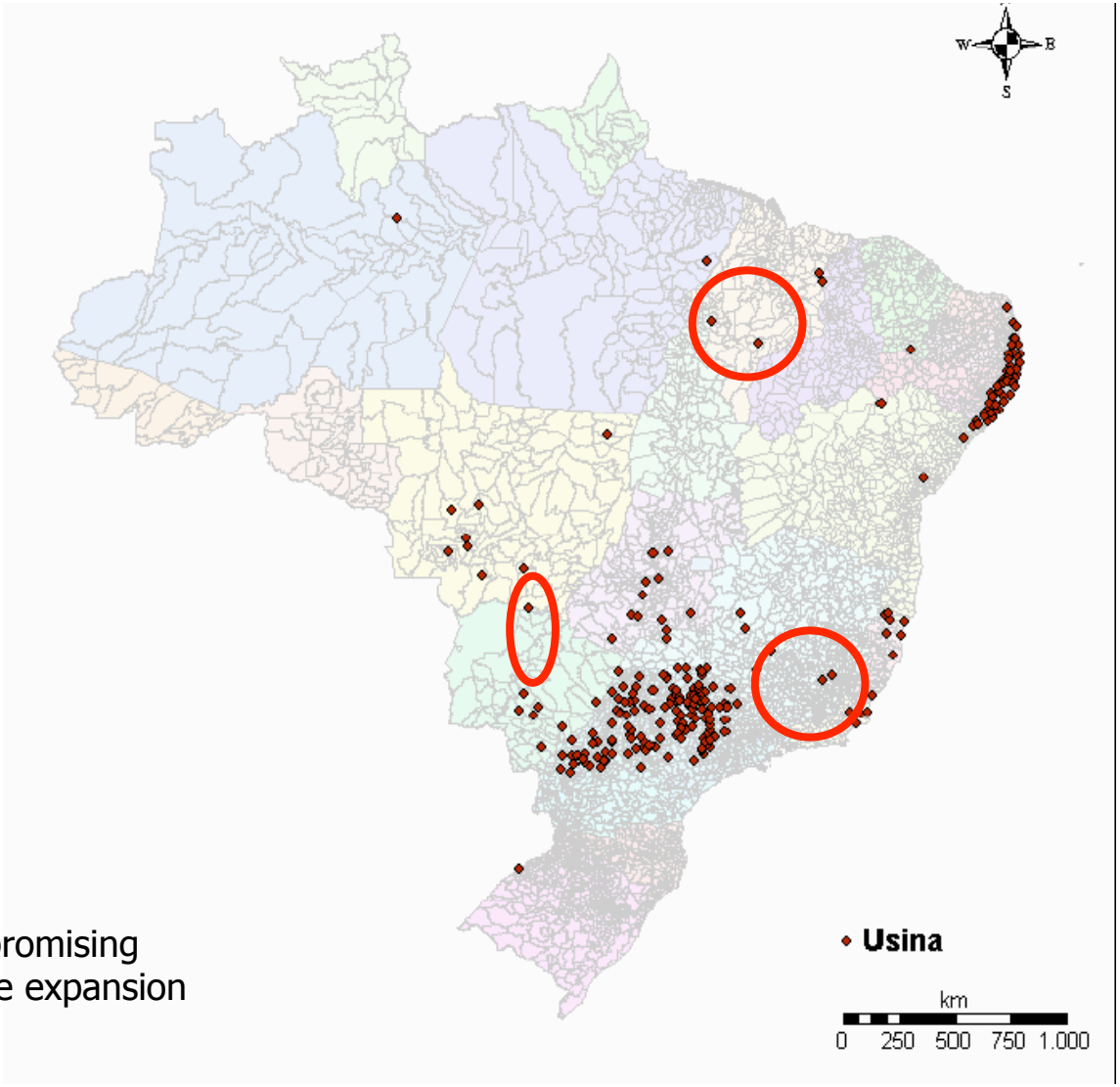
# Coal Resources



# Uranium Resources

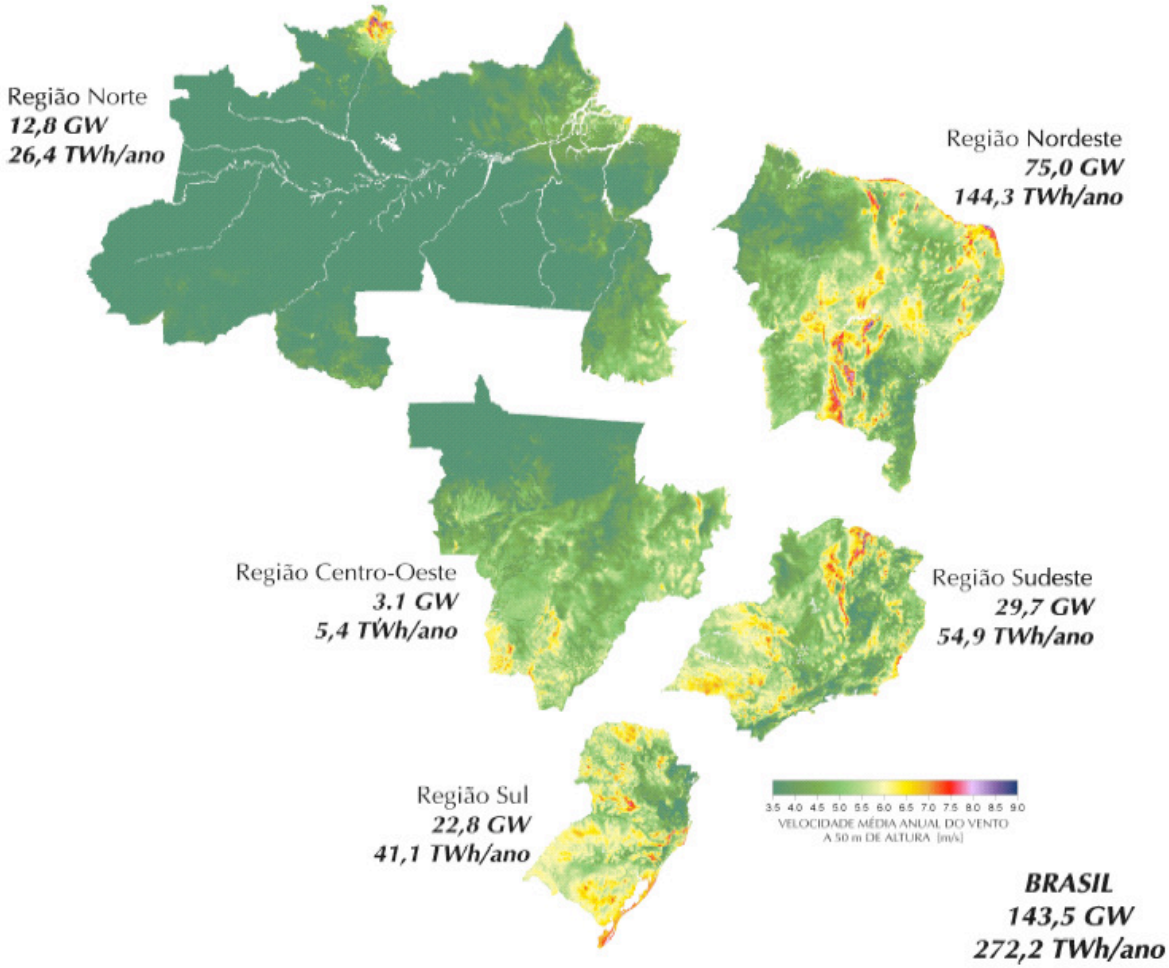


# Sugar Cane Production




Areas of promising sugar cane expansion

# Wind Potential



# Promoting Renewable Energy in Brazilian Power Sector

- Various studies show that, until 2030, electricity consumption should grow more than 3% a year
- The additional installed capacity required is 100 GW
- PROINFA
- Energy Auctions

# Results of PROINFA and Energy Auctions

| SOURCE | PROINFA | Auctions | | | | TOTAL |
|---|---|---|---|---|---|---|
| | | 2005 | 2006 | 2007 | 2008 | |
| **Biomass** | 685 | 245 | 426 | 542 | 2 489 | 4 387 |
| **Wind** | 1 423 | - | - | - | - | 1 423 |
| **Small Hydro** | 1 191 | 73 | 129 | 102 | - | 1 495 |
| **Coal** | - | 350 | - | 1 050 | 360 | 1 760 |
| **Natural Gas** | - | 2 042 | 1 530 | 500 | 1 628 | 5 700 |
| **Oil** | - | 117 | 992 | 2 207 | 5 050 | 8 366 |
| **Hydro** | - | 6 663 | 6 332 | 5 533 | 3 650 | 22 178 |
| **TOTAL** | 3 299 | 9 490 | 9 409 | 9 934 | 13 177 | 45 309 |

# Reference Scenario

Main Assumptions:

- Brazil's GDP – an annual average growth of 4%;
- Population – an average annual growth of 1.09%;
- Energy demand growth rate:
  - Electricity: 4.0%
  - Natural gas (excl. power generation): 6.8%
  - Oil products: 3.8%
- Costs of new power plants
  - "Brazil: A Country Profile on Sustainable Energy Development" (IAEA, 2006)
  - "Future electric power technology choices of Brazil: a possible conflict between local pollution and global climate change" (Schaeffer & Szklo, 2000)

# Power Expansion (GW)

| Year | Annual Electricity Capacity (GW) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Coal | Oil | Natural Gas | Hydro | Nuclear | Biomass | Wind | Total |
| 2010 | 2.42 | 1.43 | 13.50 | 78.74 | 1.97 | 6.44 | 0.65 | 105.15 |
| 2015 | 2.42 | 1.43 | 17.50 | 95.13 | 1.97 | 10.44 | 1.35 | 130.23 |
| 2020 | 2.42 | 1.93 | 18.00 | 121.60 | 3.31 | 13.44 | 1.85 | 162.55 |
| 2025 | 3.42 | 1.93 | 20.00 | 150.06 | 3.31 | 13.44 | 2.85 | 195.01 |
| 2030 | 3.42 | 2.43 | 22.00 | 169.82 | 3.31 | 15.44 | 2.85 | 219.27 |

# Comparison with Other Studies (GW)

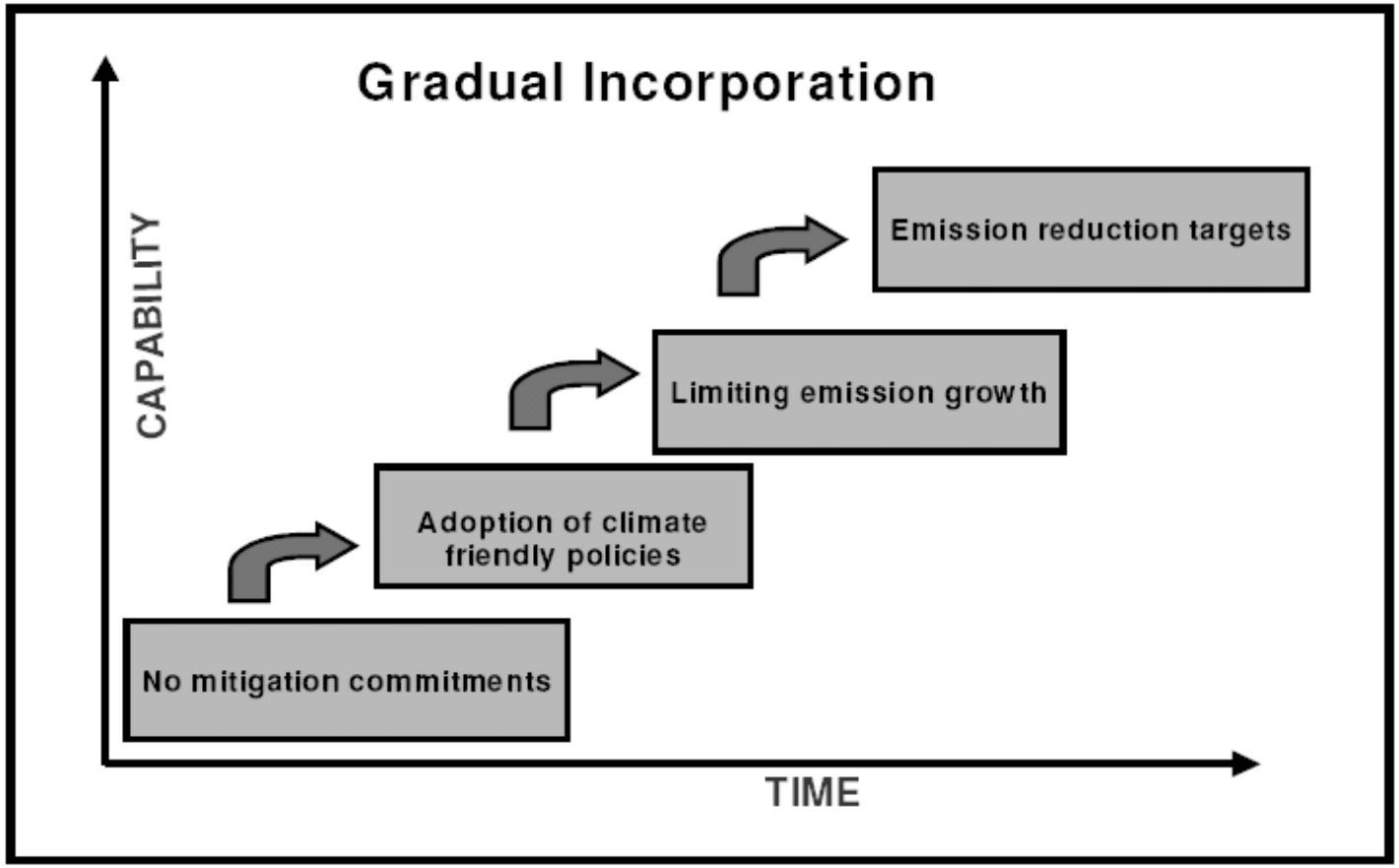
| Technology | Development First | PNE | WEO | WETO |
|---|---|---|---|---|
| Hydro | 169.82 | 156.3 | 128.12 | 114.00 |
| Natural Gas | 22.00 | 21.03 | 11.50 | 53.00 |
| Oil | 2.43 | 5.50 | 12.00 | 4.00 |
| Coal | 3.42 | 6.01 | - | 10.00 |
| Others | 21.60 | 36.08 | 28.38 | 24.00 |
| Total | 219.27 | 224.9 | 180.00 | 205.00 |

# The CASES Project as an Alternative Scenario

Marginal Cost of Avoided Emission (Euro-2005/ton)

| | 2010 | 2015 | 2020 | 2025 | 2030 | 2040 | 2050 |
|---|---|---|---|---|---|---|---|
| $CO_2$ | 21 | 21 | 21 | 23 | 30 | 46 | 61 |
| $CH_4$ | 441 | 441 | 441 | 483 | 630 | 966 | 1281 |
| $N_2O$ | 6510 | 6510 | 6510 | 7130 | 9300 | 14260 | 18910 |

# Gradual Incorporation of Commitments

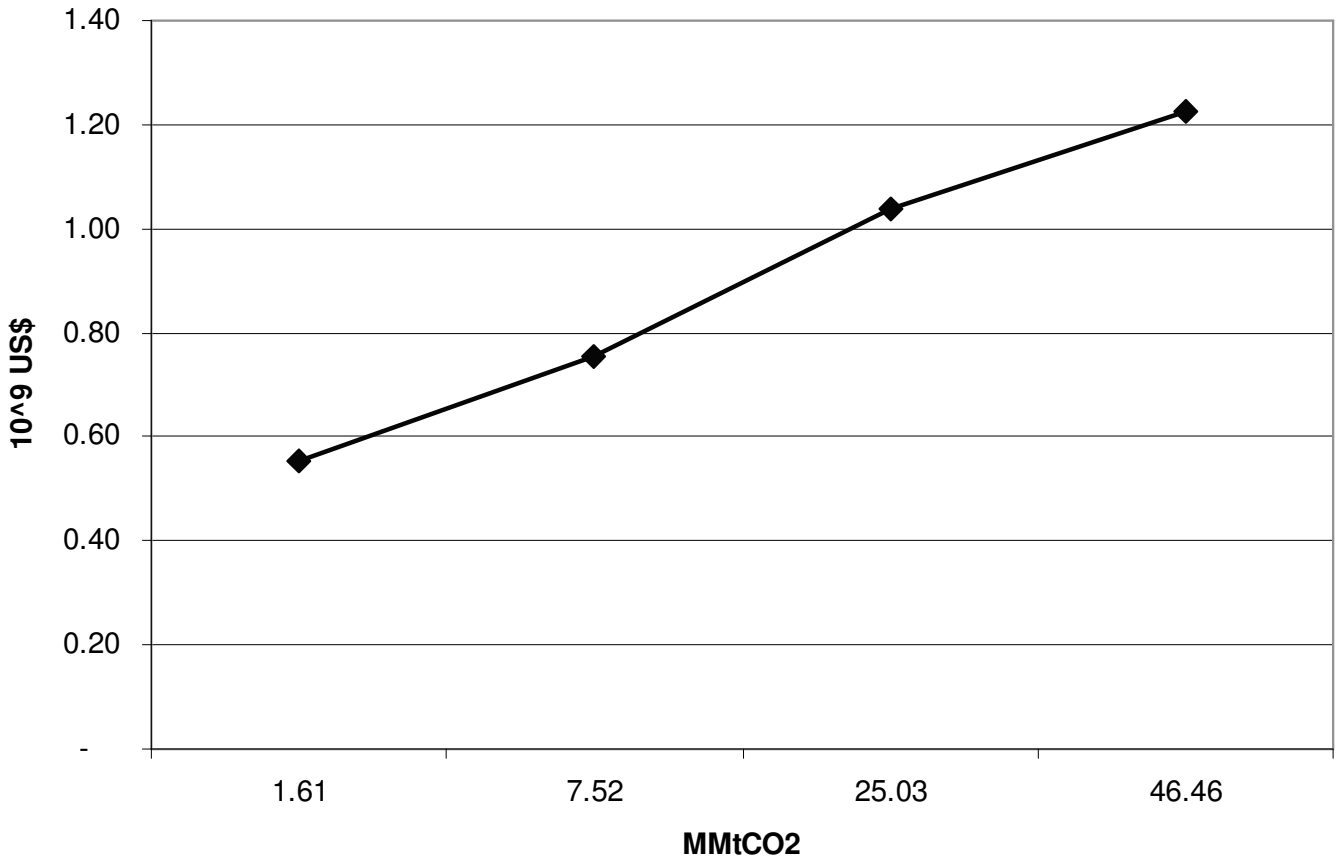



Source: Figueres et al, 2005

# Alternative Scenario (GW)

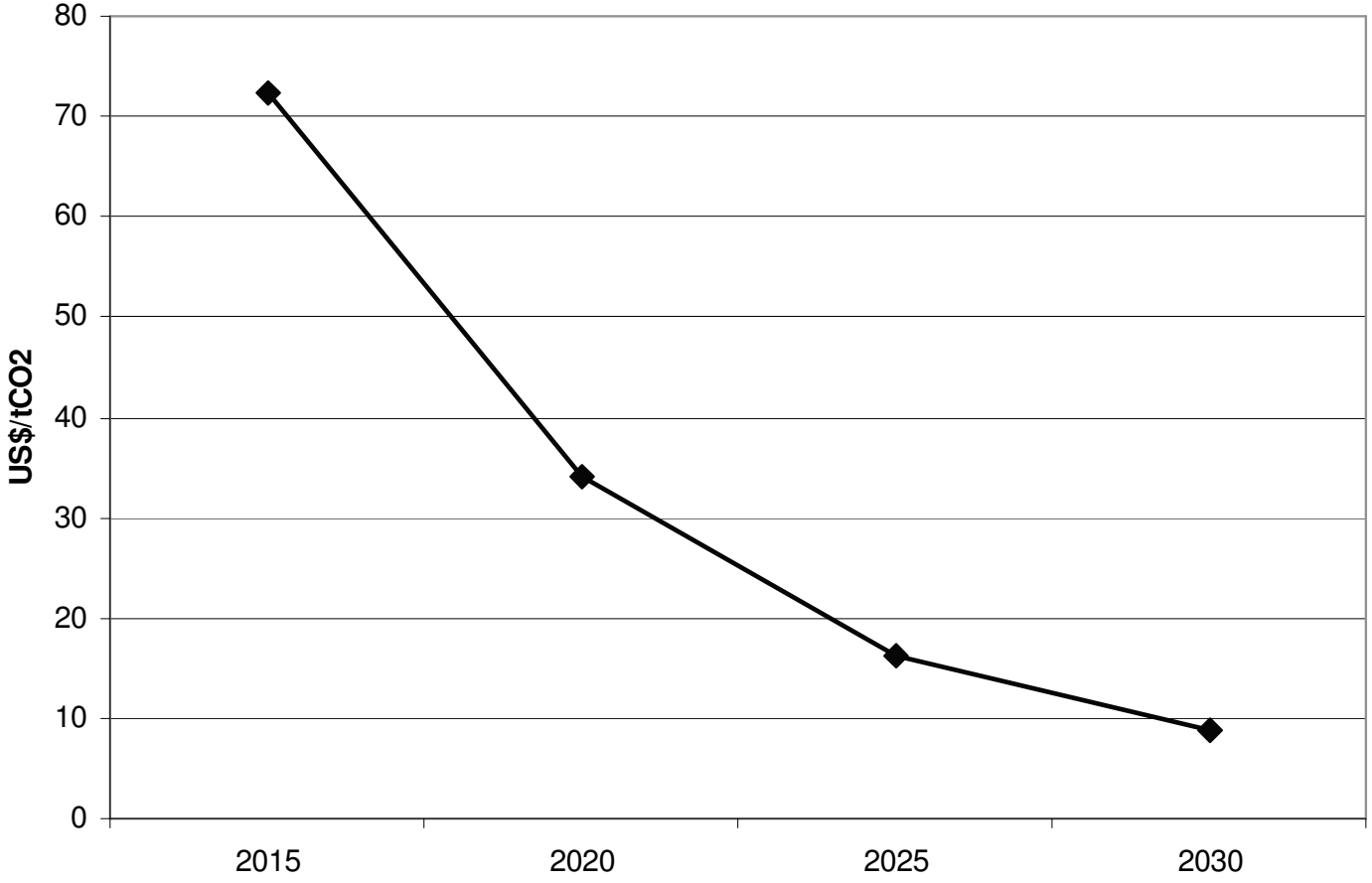
| Year | Coal | Oil | Natural gas | Hydro | Nuclear | Biomass | Wind | Total |
|---|---|---|---|---|---|---|---|---|
| 2010 | 2.42 | 1.93 | 13.50 | 78.74 | 1.97 | 6.44 | 0.65 | 105.65 |
| 2015 | 2.42 | 1.93 | 15.50 | 98.13 | 1.97 | 10.44 | 1.35 | 131.73 |
| 2020 | 2.42 | 1.93 | 15.50 | 126.60 | 3.31 | 13.44 | 1.85 | 165.05 |
| 2025 | 2.42 | 1.93 | 15.50 | 160.06 | 3.31 | 13.44 | 2.85 | 199.51 |
| 2030 | 2.42 | 1.93 | 16.50 | 178.38 | 4.31 | 15.44 | 3.85 | 222.83 |

# Total Cost of the GHG Emission Abatement

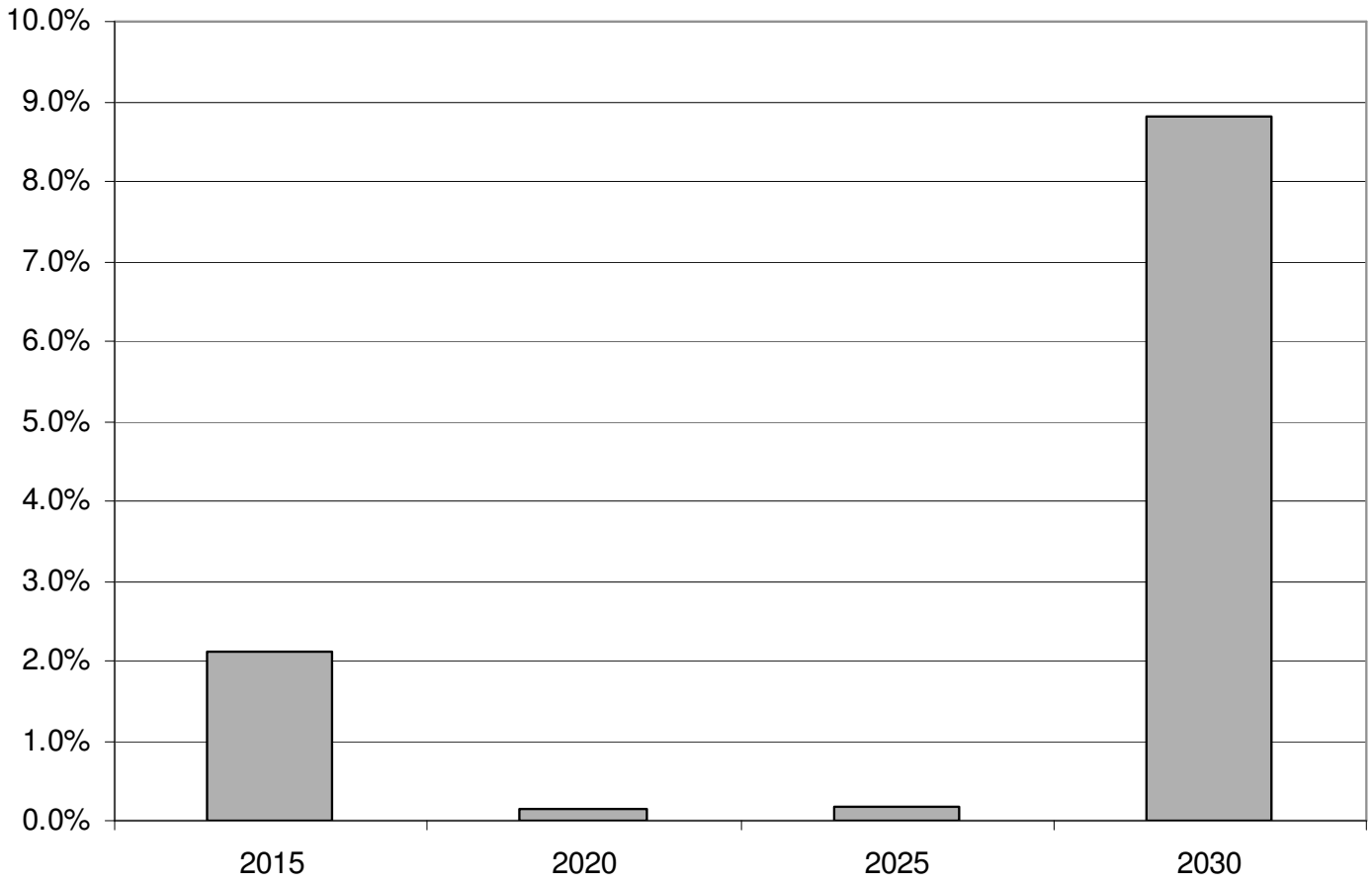



Average Abatement Cost 26 US$/$tCO_2$

# Marginal Abatement Cost Curve



# Impacts on the Tariff



# Energy Compensation Mechanism (ECM)

- The proposal, published in La Rovere (2008), was directed to the government of the State of Rio de Janeiro and suggested that new fossil-powered thermal plants should be required to invest in renewable resource based electric power generation when requesting an environmental license
- The idea was to choose a level of energy compensation for thermal plants without excessively raising the total price of electric power sold by the producer, considering the sum of electricity generated by fossil and renewable sources
- The level of compensation proposed was 179 kWh/tCO2, and in order to prevent the impact on the producer's final selling price from being greater than 1%, its calculation was based on the selling price for new energy established by the 2007 auction.

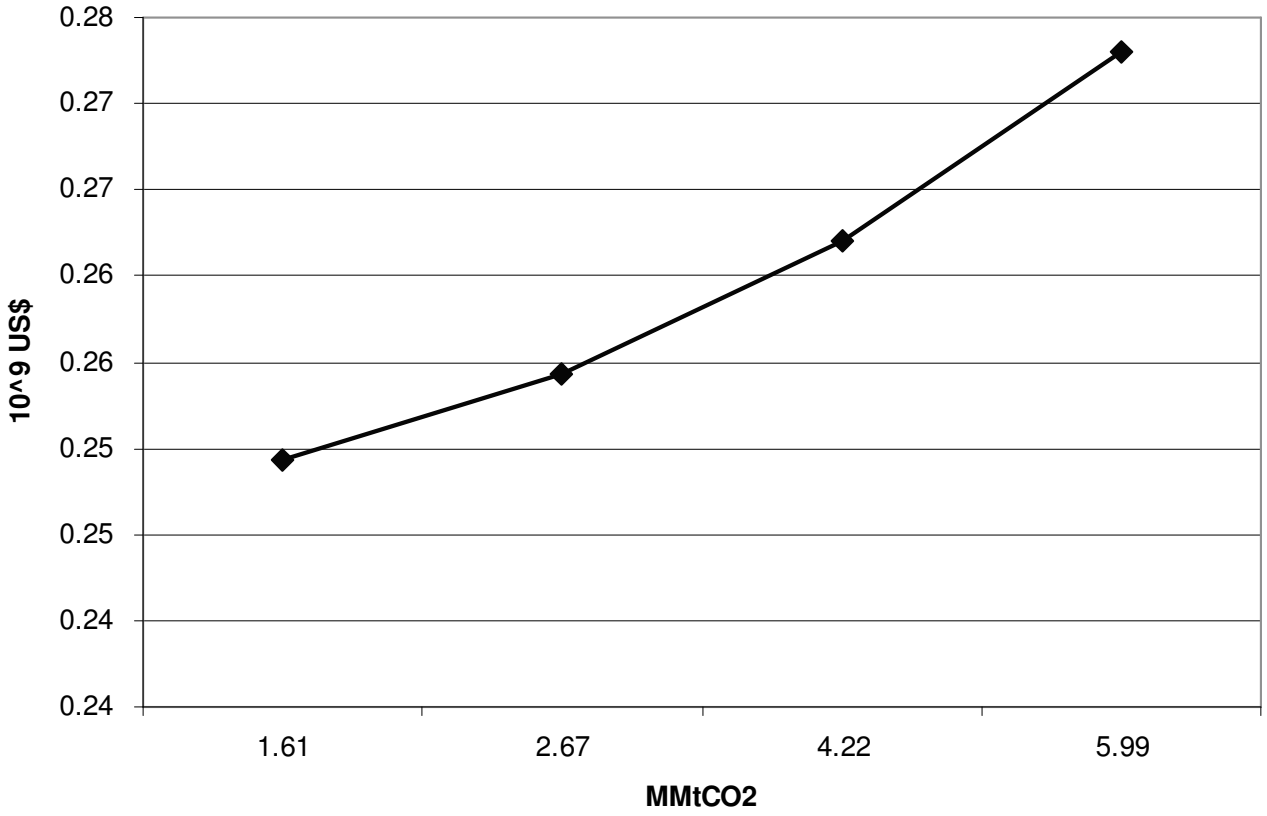
# Factor of Energy Compensation (FCE)

| | FCE | Renewable (FCE1) | Energy Efficiency (FCE2) |
|---|---|---|---|
| Coal | 5% | 4% | 1% |
| Oil | 5% | 4% | 1% |
| Natural Gas | 3% | 2% | 1% |

# Expansion ECM (GW)

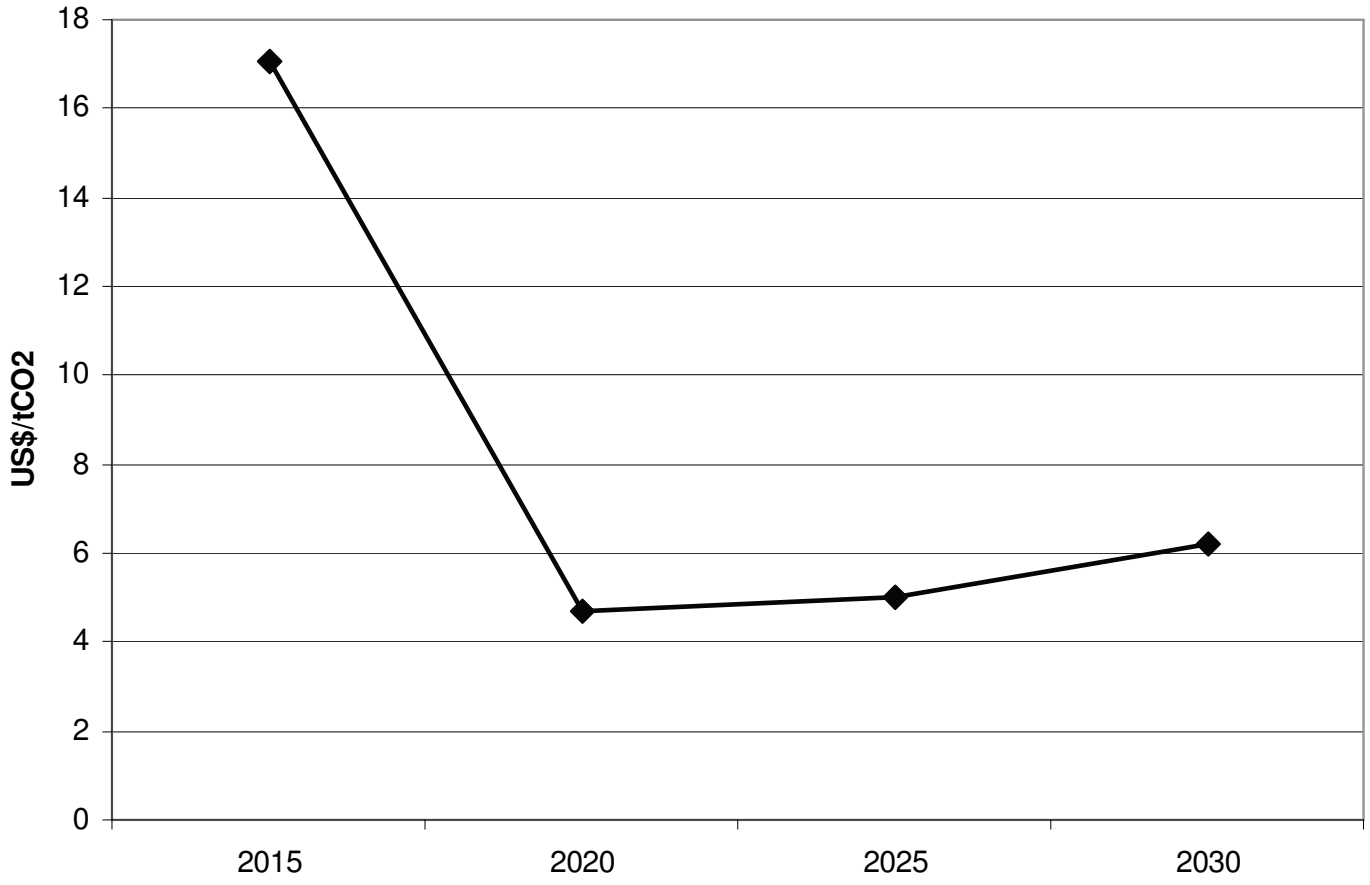
| Year | Coal | Oil | Natural gas | Hydro | Nuclear | Biomass | Wind | Energy Efficiency | Total |
|---|---|---|---|---|---|---|---|---|---|
| 2010 | 2.37 | 1.43 | 13.37 | 78.74 | 1.97 | 6.44 | 0.78 | 0.06 | 105.15 |
| 2015 | 2.37 | 1.43 | 17.25 | 95.13 | 1.97 | 10.44 | 1.56 | 0.10 | 130.23 |
| 2020 | 2.37 | 1.91 | 17.73 | 121.60 | 3.31 | 13.44 | 2.09 | 0.11 | 162.55 |
| 2025 | 3.32 | 1.91 | 19.67 | 150.06 | 3.31 | 13.44 | 3.17 | 0.14 | 195.01 |
| 2030 | 3.32 | 2.38 | 21.61 | 169.82 | 3.31 | 15.44 | 3.23 | 0.16 | 219.27 |

# Total Cost of the GHG Emission Abatement

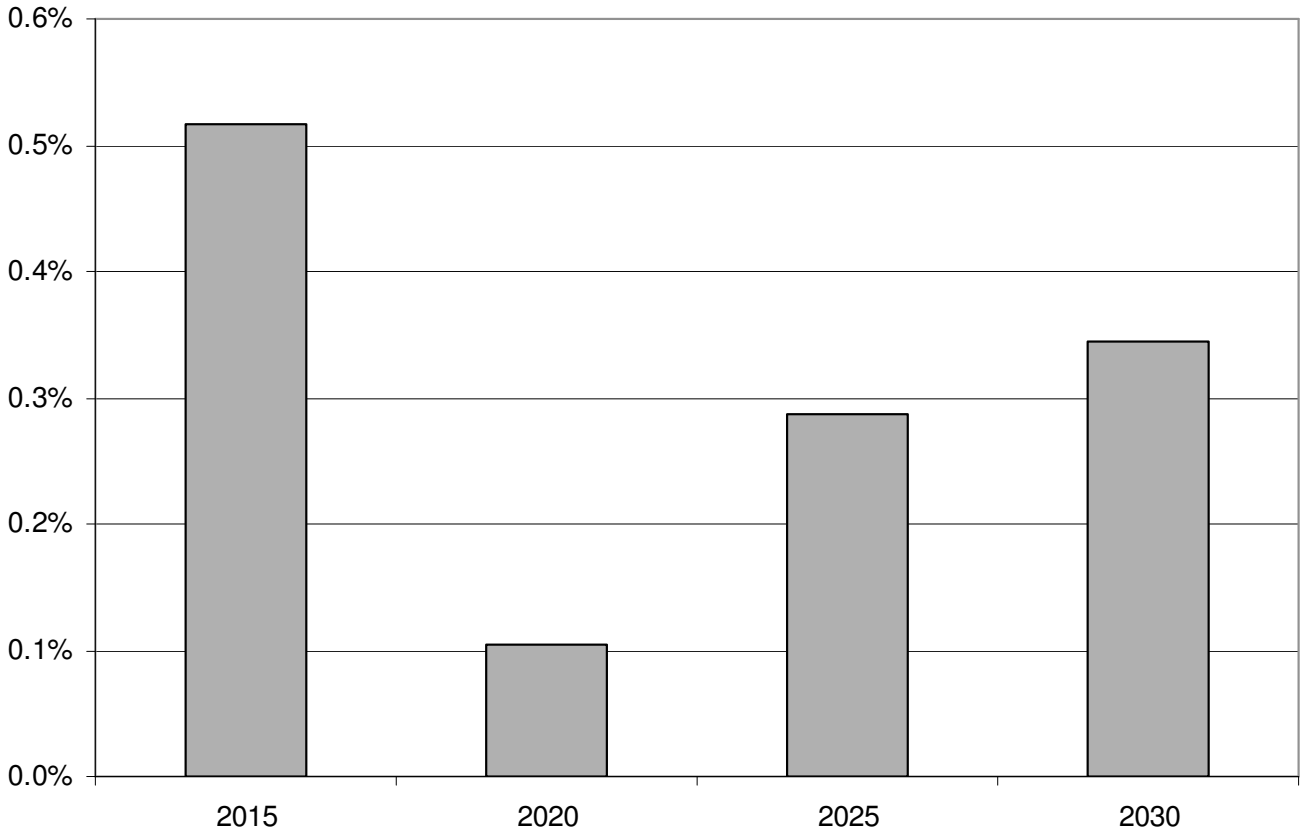



Average Cost of Abatement 46 US$/$tCO_2$

# Marginal Abatement Cost Curve



# Impacts on the Tariff



# Final Remarks

- CentroClima Experience
- Nation Plan of Climate Change
- Penalties x ECM
- Finally, it should be highlighted that although Brazil, as it is not a member of Annex 1 of the Climate Convention, is not formally committed to limiting greenhouse gas emissions, is fully engaged in the struggle against global warming

# Thanks, for your attention!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