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

Amaro Pereira
Associated Researcher – CentroClima/COPPE/UFRJ

Joint TERI ETSAP Workshop Energy Modeling Tools & Techniques to address Sustainable Development & Climate Change
Session n. 1: Climate Change and Mitigation
Introduction

- Availability of Energy Resources
- Commitments for Post-Kyoto?
- 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
Gradual Incorporation of Commitments

Source: Figueres et al, 2005
Objective

- To assess the strategies to mitigate greenhouse gas emissions in the Brazilian power sector, based on recent researches that CentroClima was involved in.

- Reference scenario – No mitigation measure

- Scenario alternative 1 – Carbon tax scheme

- Scenario alternative 2 – Energy compensation mechanism
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 km²
Domestic Energy Supply - 2005

Natural gas: 9%
Coal: 6%
Biomass: 13%
Renewable: 45%
Uranium: 1%
Oil: 39%
Sugar-cane products: 14%
Hydro: 15%
Others: 3%
CO$_2$ Emissions per Domestic Energy Supply (DES) - 2005

- Brazil: 1.57 tCO2/DES
- OECD: 2.33 tCO2/DES
- World: 2.37 tCO2/DES
Electricity Generation - 2005

- Hydro: 83%
- Nuclear: 2%
- Natural gas: 5%
- Biomass: 3%
- Wind: 0%
- Oil: 2%
- Coal: 2%
- Other: 2%
Installed Capacity (GW) - 2005

- Hydro: 80 GW
- Thermal: 10 GW
Sub-systems and Connections

Non-grid systems

North

Northeast

Southeast

South
Hydro Power Potential

112 GW 43%
35 GW 14%
26 GW 10%
45 GW 17%
43 GW 16%
Oil Resources

Refineries
Natural Gas
Coal Resources

MAPA DAS PRINCIPAIS OCORRÊNCIAS DE CARVÃO MINERAL, LINHITO E TURFA DO BRASIL

Uranium Resources

Pitinga: 150,000 t

Itataia: 70,000 t

Lagoa Real: 70,000 t

Pitinga: 160,000 t

Itataia: 160,000 t

Lagoa Real: 120,000 t

Pitinga: 80,000 t

Lagoa Real: 30,000 t

Lagoa Real: 120,000 t

Lagoa Real: 80,000 t
Sugar Cane Production

Areas of promising sugar cane expansion
Wind Potential

Região Norte
12,8 GW
26,4 TWh/ano

Região Nordeste
75,8 GW
144,3 TWh/ano

Região Centro-Oeste
3,1 GW
5,4 TWh/ano

Região Sudeste
29,7 GW
54,9 TWh/ano

Região Sul
22,8 GW
41,1 TWh/ano

BRASIL
143,5 GW
272,2 TWh/ano
Promoting Renewable Energy in Brazilian Power Sector

- Several studies show that, until 2030, electricity consumption should grow more than 3% a year.
- The additional installed capacity required is 100 GW.
- PROINFA (2002) – Feed-in tariff
- Energy Auctions
## Results of PROINFA and Energy Auctions (MW)

<table>
<thead>
<tr>
<th>SOURCE</th>
<th>PROINFA</th>
<th>2005</th>
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<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>TOTAL</th>
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<td>685</td>
<td>245</td>
<td>426</td>
<td>542</td>
<td>2 489</td>
<td>45</td>
<td>4 432</td>
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<td>-</td>
<td>-</td>
<td>-</td>
<td>1 806</td>
<td>3 229</td>
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<td>73</td>
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<td>1 628</td>
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<td>5 700</td>
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<tr>
<td>Oil</td>
<td>-</td>
<td>117</td>
<td>992</td>
<td>2 207</td>
<td>5 050</td>
<td>-</td>
<td>8 366</td>
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<tr>
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<td>-</td>
<td>6 663</td>
<td>6 332</td>
<td>5 533</td>
<td>3 650</td>
<td>-</td>
<td>22 178</td>
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<tr>
<td>TOTAL</td>
<td>3 299</td>
<td>9 490</td>
<td>9 409</td>
<td>9 934</td>
<td>13 177</td>
<td>1 857</td>
<td>47 166</td>
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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 (exc. 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)

<table>
<thead>
<tr>
<th>Year</th>
<th>Coal</th>
<th>Oil</th>
<th>Natural Gas</th>
<th>Hydro</th>
<th>Nuclear</th>
<th>Biomass</th>
<th>Wind</th>
<th>Total</th>
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<td>2010</td>
<td>2.42</td>
<td>1.43</td>
<td>13.50</td>
<td>78.74</td>
<td>1.97</td>
<td>6.44</td>
<td>0.65</td>
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<td>2015</td>
<td>2.42</td>
<td>1.43</td>
<td>17.50</td>
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<td>10.44</td>
<td>1.35</td>
<td>130.23</td>
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<td>2020</td>
<td>2.42</td>
<td>1.93</td>
<td>18.00</td>
<td>121.60</td>
<td>3.31</td>
<td>13.44</td>
<td>1.85</td>
<td>162.55</td>
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<tr>
<td>2025</td>
<td>3.42</td>
<td>1.93</td>
<td>20.00</td>
<td>150.06</td>
<td>3.31</td>
<td>13.44</td>
<td>2.85</td>
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<td>2030</td>
<td>3.42</td>
<td>2.43</td>
<td>22.00</td>
<td>169.82</td>
<td>3.31</td>
<td>15.44</td>
<td>2.85</td>
<td>219.27</td>
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Comparison with Other Studies (GW)

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<tr>
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<td>28.38</td>
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<tr>
<td>Total</td>
<td>219.27</td>
<td>224.9</td>
<td>180.00</td>
<td>205.00</td>
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### Scenario Alternative 1

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

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<th>2020</th>
<th>2025</th>
<th>2030</th>
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<td>(\text{CH}_4)</td>
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<td>441</td>
<td>441</td>
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<td>6510</td>
<td>6510</td>
<td>7130</td>
<td>9300</td>
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Source: CASES Project
## Alternative Scenario (GW)

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<th>Oil</th>
<th>Natural gas</th>
<th>Hydro</th>
<th>Nuclear</th>
<th>Biomass</th>
<th>Wind</th>
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<tr>
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<td>1.93</td>
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Total Cost of the GHG Emission Abatement

Average Abatement Cost 26 US$/tCO$_2$
Impacts on the Tariff
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.
## Scenario Alternative 2

### Factor of Energy Compensation (FCE)

<table>
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<th>FCE</th>
<th>Renewable (FCE1)</th>
<th>Energy Efficiency (FCE2)</th>
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</tr>
<tr>
<td>Oil</td>
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<td>4%</td>
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</tr>
<tr>
<td>Natural Gas</td>
<td>3%</td>
<td>2%</td>
<td>1%</td>
</tr>
</tbody>
</table>
## Expansion ECM (GW)

<table>
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<tr>
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</table>
Total Cost of the GHG Emission Abatement

Average Cost of Abatement 46 US$/tCO$_2$
Impacts on the Tariff
Carbon Tax Scheme vs. Energy Compensation Mechanism

Gradual Incorporation

- Emission reduction targets
- Limiting emission growth
- Adoption of climate friendly policies
- No mitigation commitments

TIME

CAPABILITY
Thanks, for your attention!

Amaro Pereira
amaro@ppe.ufrj.br
++ 55 21 3512 3182