Energy and New Technologies: How Can Systems Analysis Help Brazil Find Its Way in a 1.5ºC-2.0ºC World?

Prof. Roberto Schaeffer, CENERGIA/PPE/COPPE/UFRJ

Systems Analysis and the Americas,
Supported by CAPES, FGV, IIASA, and NAS

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This Presentation

• Brief introduction to our research team

• Our integrated modeling tools

• The role of Systems Analysis for devising low-carbon scenarios for Brazil

• Other interesting uses ... (if time allows)
Brief introduction to our research team
Energy Planning Program (PPE) - COPPE/UFRJ

• Created in 1979 within the Nuclear Engineering Program of COPPE

• 13 Full-time professors

• Every year we accept:
  • 20-25 new M.Sc. students
  • 20-25 new D.Sc. students

• PPE is part of a small group of D.Sc./M.Sc. Programs of “Excellency” in Brazil
  • Graded 6 (scale 1-7) by CAPES, from the Ministry of Education, in the “Engineering 3” Committee
  • Graded 6 during the last three four-yearly evaluations
Our integrated modeling tools
Cenergia’s Timeline

- Models Developed
- Scientific Production
- Relevant Studies
- International Cooperation
Cenergia’s Model Development Timeline

Start

1998

2003

2008

2013

2018
We are a member of the Integrated Assessment Modelling Community (IAMC)
Cenergia’s Current Integrated Modeling Tools

• Model Linkages and Integration:
  • TEA: Global CGE model
  • COFFEE: Global LP Opt. model
  • BLUES: National LP Opt. model
  • Plus some specific sectoral models
COFFEE Model

COmputable Famework F or E nergy and the E nvironment model

• Global model with 18 regions
• Time horizon: 2010 to 2100
• Includes both the Energy and the Land-use Systems
  • Completely integrated (hard-link)
  • Assessment of potential synergies/trade-offs in energy, environmental and climate policies
• Rochedo, P. “Development of a global integrated energy model to evaluate the Brazilian role in climate change mitigation scenarios”.
COFFEE Model

Africa
Australia & New Zealand
Brazil
Central America
Canada
Caspian

China
Eastern Europe
India
Japan
South Korea
Middle East

Rest of Asia
Russia
South Africa
South America
United States
Western Europe
COFFEE Model: The Energy System
COFFEE Model: The Land System (simplified)
BLUES Model

Brazilian Land-Use and Energy Systems model

- Originally known as Message-Brazil
  - MSB300 (until 2015) or MSB8000 (after 2015)
- 2017: incorporated the Land System using COFFEE’s approach
  - With enhanced regional and land-cover characterizations
  - Renamed as BLUES
- High-level technological details
  - Bottom-up model
  - With country-specific parameters (efficiencies and costs)
BLUES Model

- Time horizon: 2010 to 2050 in 5-year intervals
- Regions: 5 regions within Brazil
- Load curve with 12 months and 24 time-slices (1h)
- Demand-side is more technologically detailed than in COFFEE
  - Specific technologies for Brazil
The BLUES Model: Energy System - Demand

• Macroeconomic sectors (end-users)
  • **Transportation**
    • Service: Passenger-km (PKM) e Tonnage-km (TKM)
    • Passenger Options: LDV, bus, 2W, trains, planes and waterways
    • Freight Options: 6 types of trucks, trains, planes and waterways
  • **Industry: 11 sub-sectors**
    • Energy and non-energy consumption
    • Process modelling and end-use energy efficiency options
    • More detailed abatement options (such as Industrial CCS)
  • **Residential: 5 regions**
    • Detailed end-use energy efficiency options and on-site generation
  • **Services (Excluding Transportation)**
    • Detailed end-use energy efficiency options and on-site generation
  • **Municipal Solid Wastes (MSW)**
    • More specific and detailed characterization of available technologies
  • **Agriculture**
The BLUES Model: Land-use System (Köberle, 2018)

• COFFEE’s methodology for modeling the Land-use System
• Enhanced regional and land-cover characterizations
  • 5 regions for Brazil (vs. 1 in COFFEE)
  • 8 kinds of land covers (vs. 5 in COFFEE)
  • Highlighting the role of agriculture and livestock in Brazil

Source: Köberle (2018)
The role of Systems Analysis for devising low-carbon scenarios for Brazil
A few of the Brazilian iNDC commitments (*Reference point: 2005*):

- ZERO illegal deforestation at 2030 and compensation of emissions from legal deforestation at 2030;
- Restore and reforest 12 millions hectares of forests till 2030, for multiple uses;
- Restoration of 15 millions of hectares in degraded pastures till 2030
- Participation of 45% renewable energy in the energy system at 2030
The COFFEE Model: Scenario Protocol

- **Global Current Policies (GCP or NPi):** based on current and indicated policies for all regions (energy, land and climate)

- **Global 2°C (G2D or NPi1000):** GCP + global budget of 1,000 GtCO₂

- **Global 1.5°C (G1.5D or NPi400):** GCP + global budget of 400 GtCO₂
COFFEE: Current Policies (GCP or NPi)

- **GHG Emissions (GtCO\textsubscript{2eq})**
  - Total GHG Emissions (GtCO\textsubscript{2eq})
  - Cumulative Emissions: 5,500 GtCO\textsubscript{2}

- **Primary Energy (EJ)**
  - Breakdown of energy sources:
    - Oil
    - Gas
    - Coal
    - Nuclear
    - Biomass
    - Hydro
    - Wind
    - Solar

- **Land Use Change (Gha)**
  - Change in land cover (Gha)
  - Forest, ForGrass, Grass, CropVeg, Crop, Flooded, Uns suited
COFFEE: 2°C Scenario (G2D or NPi1000)

GHG Emissions (GtCO$_{2eq}$)

Cumulative Emissions: 5,500 GtCO$_2$

Primary Energy (EJ)

Land Use Change (Gha)
COFFEE: 1.5°C Scenario (G1.5D or NPi400)

GHG Emissions (GtCO$_2$eq)

Cumulative Emissions: 5,500 GtCO$_2$

Primary Energy (EJ)

Renewables

Land Use Change (Gha)
COFFEE: Scenario Comparison

Global CO2 Emissions
COFFEE: National Budgets for Brazil

COFFEE’s CO₂ budgets for Brazil for the 2010-2050 period:
(to be used in the BLUES Model)

- **Global 2°C (G2D or NPi1000):** 23.6 GtCO₂ (out of 1,000 GtCO₂)

- **Global 1.5°C (G1.5D or NPi400):** 17.0 GtCO₂ (out of 400 GtCO₂)
The BLUES Model: Scenario Protocol

- **National Current Policies (NCP or NPi):** based on current and indicated policies for Brazil (energy, land and climate)

- **National 2°C (N2D or NPi1000):** NCP + national share of 2°C budget up to 2050 (23.6 GtCO$_2$)

- **National 1.5°C (N1.5D or NPi400):** NCP + national share of 1.5°C budget up to 2050 (17.0 GtCO$_2$)
BLUES: Current Policies (NCP or NPi)

GHG Emissions
BLUES: Current Policies (NCP or NPi)

Primary Energy Consumption
BLUES: 2°C Scenario (N2D or NPi1000)

GHG Emissions
BLUES: 2°C Scenario (N2D or NPi1000)

Primary Energy Consumption
BLUES: 1.5°C Scenario (N1.5D or NPi400)

GHG Emissions

[Graph showing GHG emissions from 2015 to 2050, with categories for CO2 | AFOLU, CO2 | Energy, CO2 | Process, CH4 | AFOLU, CH4 | Energy, N2O | AFOLU, N2O | Energy, and Total GHG.]
BLUES: 1.5°C Scenario (N1.5D or NPi400)

Primary Energy Consumption
BLUES: Scenario Comparison

Electricity Generation (TWh)
BLUES: Scenario Comparison

Power Sector Emissions (MtCO₂)

Note: Industrial and refinery CHP excluded
BLUES: Scenario Comparison

Liquid Biofuel Production (PJ)
BLUES: Scenario Comparison
Transport Sector – Passenger Energy Use

![Chart showing energy use by sector](chart_image)
BLUES: Scenario Comparison

Transport Sector – GHG Emissions

- NCP
- N2D
- N1.5D

Transport Sector Emissions (MtCO₂)

- 2015
- 2020
- 2025
- 2030
- 2035
- 2040
- 2045
- 2050

Peak
Other interesting uses for Systems Analysis
Rochedo et al, 2018

• In exchange for political support, the Brazilian government has been signaling landholders to increase deforestation in Amazônia and Cerrado

• The (former) President of Brazil has signed provisional acts and decrees lowering environmental licensing requirements, suspending the ratification of indigenous lands, reducing the size of protected areas and facilitating land grabbers to obtain the deeds of illegally deforested areas

• Using the BLUES model, we explored 2 °C-compliant scenarios estimating the effort needed in other sectors of the economy to compensate for the weakening of environmental governance
Rochedo et al, 2018

- What is the role of Brazil in a 2°C world?
  - CO₂ budget from 2010 to 2050
  - Defined by literature review and available data (n=22)

<table>
<thead>
<tr>
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<th>Menor</th>
<th>P25</th>
<th>Mediana</th>
<th>P75</th>
<th>Maior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Budget Nacional de 2010 a 2050 (GtCO₂)</td>
<td>4.7</td>
<td>16.5</td>
<td>23.8</td>
<td>35.5</td>
<td>41.0</td>
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</tbody>
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- COFFEE’s CO₂ budget for Brazil is 23.6 GtCO₂
Based on past records, we defined three environmental governance scenarios, which led to different deforestation rates and CO₂ emissions

- **Weak (WEG)** – 23.1 GtCO₂
  - 27,772 km²/y in the Amazon in 2030
- **Interm. (IEG)** – 16.3 GtCO₂
  - 17,377 km²/y in the Amazon in 2030
- **Strong (SEG)** – 9.6 GtCO₂
  - 3,920 km²/y in the Amazon in 2030
Rochedo et al, 2018

• LULUCF CO2 emissions hinders other sectors
  • Power, oil and gas, industry, transportation, etc
Rochedo et al, 2018

- Need for additional investments
- High economic impacts on other sectors (not land-related)

### Table S4 – Total costs across scenarios

<table>
<thead>
<tr>
<th>Sector</th>
<th>SEG (10⁹ US$₂₀₂₀)</th>
<th>IEG (10⁹ US$₂₀₂₀)</th>
<th>WEG (10⁹ US$₂₀₂₀)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Investment</td>
<td>O&amp;M</td>
<td>Investment</td>
</tr>
<tr>
<td>Fuels¹</td>
<td>622</td>
<td>381</td>
<td>1,132</td>
</tr>
<tr>
<td>Power</td>
<td>367</td>
<td>86</td>
<td>641</td>
</tr>
<tr>
<td>Industrial</td>
<td>48</td>
<td>52</td>
<td>49</td>
</tr>
<tr>
<td>Others</td>
<td>164</td>
<td>136</td>
<td>167</td>
</tr>
<tr>
<td>Penalty</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>1,201</td>
<td>654</td>
<td>1,989</td>
</tr>
</tbody>
</table>

Note: 1 – Fuels Sector include primary energy production, oil refineries, biofuel production and energy-related CCS infrastructure; 2 – Values relative to median, 25th and 75th percentile of the carbon price (respectively). See Figure S1.
The experience over the years with the integrated models we developed in-house (with great support from IIASA) has proved the power of Systems Analysis to solve important energy, land-use and climate mitigation problems in Brazil.
Thanks!

Contact
- roberto@ppe.ufrj.br
- +55 21 3938-8777
- +55 21 3938-8760
Rio de Janeiro
Brazil
CENERGIA
Center for Energy and Environmental Economics
PPE/COPPE/UFRJ, Brazil