Brazil's Energy Plans and Strategies: challenges related to climate change

Andre F P Lucena

Energy Planning Program – Graduate School of Engineering Federal University of Rio de Janeiro

PPE/COPPE/UFRJ

andrelucena@ppe.ufrj.br

Research Team

- Energy Planning Program
  Graduate School of Engineering
  Federal University of Rio de Janeiro
  (PPE/COPPE/UFRJ – www.ppe.ufrj.br)
- Professors
  - Roberto Schaeffer
  - Alexandre Szklo
  - André Lucena
  - Bruno Borba (UFF)
- M.Sc., D.Sc. and Post-Doc researchers

Summary

- The Brazilian Energy System
- Case Studies:
  - Economics of Climate Change in Brazil (impacts and adaptation)
  - Low Carbon Scenarios for Brazil (mitigation)
- Other projects and work at JGCRI

The Brazilian Energy System

- The Brazilian energy system is highly dependent on renewable energy, especially hydropower.
- Renewable energy accounted for 44% of total primary energy in 2011 (EPE, 2012):
  - Hydropower provided 82% of electricity supply;
  - Sugar cane ethanol accounted for15% of fuel consumption in the transportation sector;
  - The Brazilian wind power generation potential is estimated in 1.26TW, enough to provide 3000TWh/year (Dutra. 2007).

Producers of Hydro – World

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Producers	TWh	% of world total
People's Rep. of China	722	20.5
Brazil	403	11.5
Canada	352	10.0
United States	286	8.1
Russian Federation	168	4.8
Norway	118	3.4
India	114	3.3
Japan	91	2.6
Venezuela	77	2.2
France	67	1.9
Rest of the world	1 118	31.7
World	**3 516**	**100.0**

2010 data

Installed capacity	GW
People's Rep. of China	171
United States	100
Brazil	79
Canada	75
Japan	47
Russian Federation	47
India	37
Norway	30
France	25
Italy	21
Rest of the world	331
World	**963**

2009 data
Sources: IEA, United Nations.

Country (top-ten producers)	% of hydro in total domestic electricity generation
Norway	94.7
Brazil	78.2
Venezuela	64.9
Canada	57.8
People's Rep. of China	17.2
Russian Federation	16.2
India	11.9
France	11.7
Japan	8.1
United States	6.5
Rest of the world**	15.4
World	**16.3**

2010 data

*Includes pumped storage.
**Excludes countries with no hydro production.

Source: IEA Key World Energy Statistics 2012

Primary Energy Supply (2011)

RENEWABLES – 120 ktoe (44.1%)

Sugarcane
15.7%

Hydraulic (electricity)
14.7%

Wood and Charcoal
9.7%

Others
4.1%

NON-RENEWABLES – 152 ktoe (55.9%)

Oil
38.6%

Natural Gas
10.2%

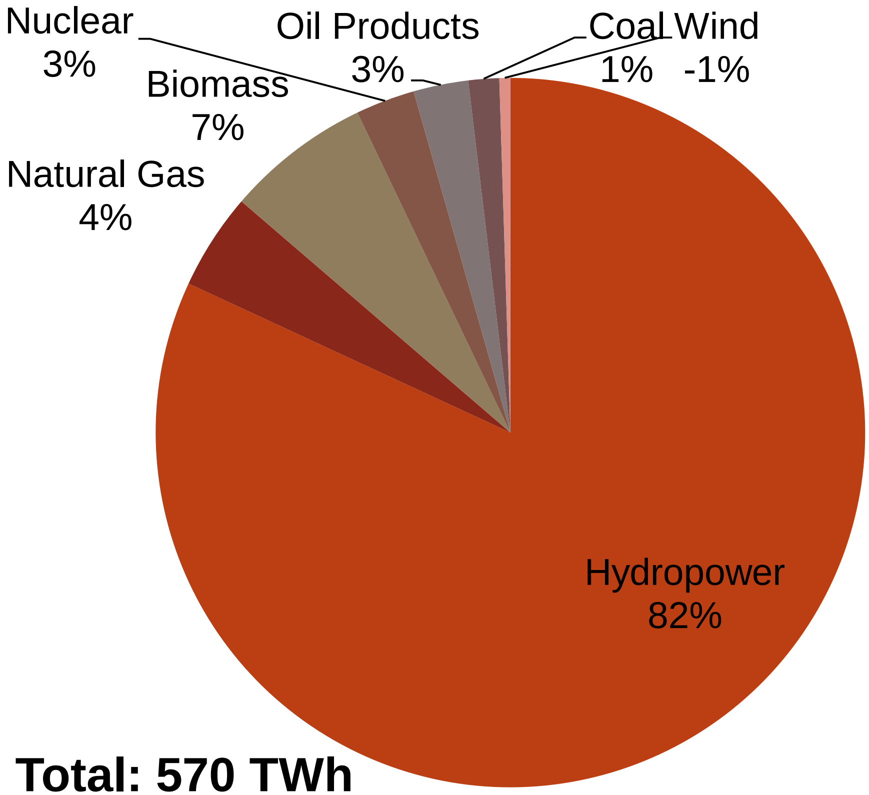
Coal
5.6%

Uranium
1.5%

Source: EPE (2012)

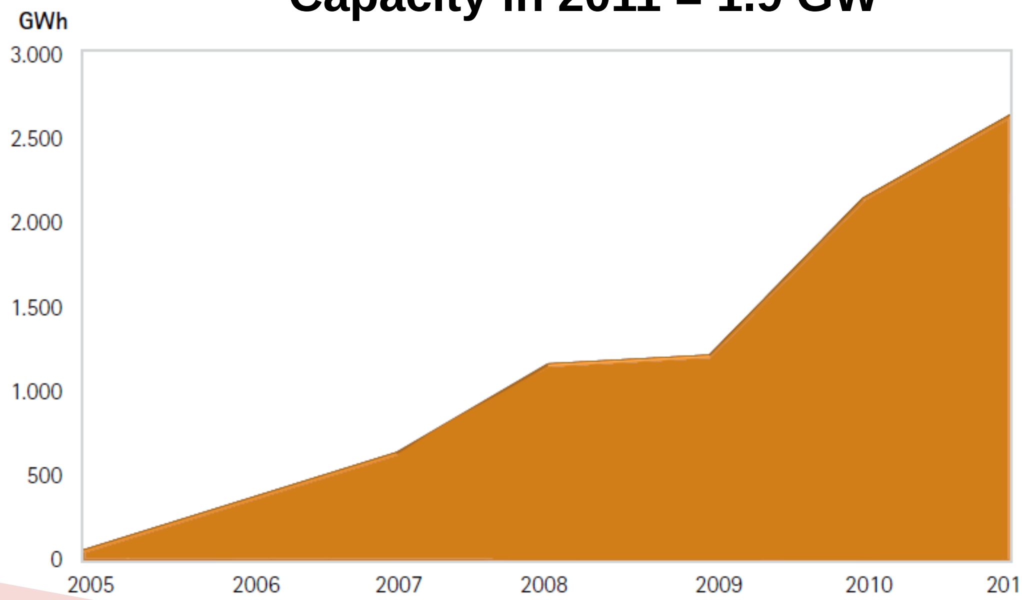
Electricity Generation (2011)

Installed Capacity in 2011 = 130 GW



Total: 570 TWh
88.9% Renewable

Wind Power Generation Capacity in 2011 = 1.9 GW

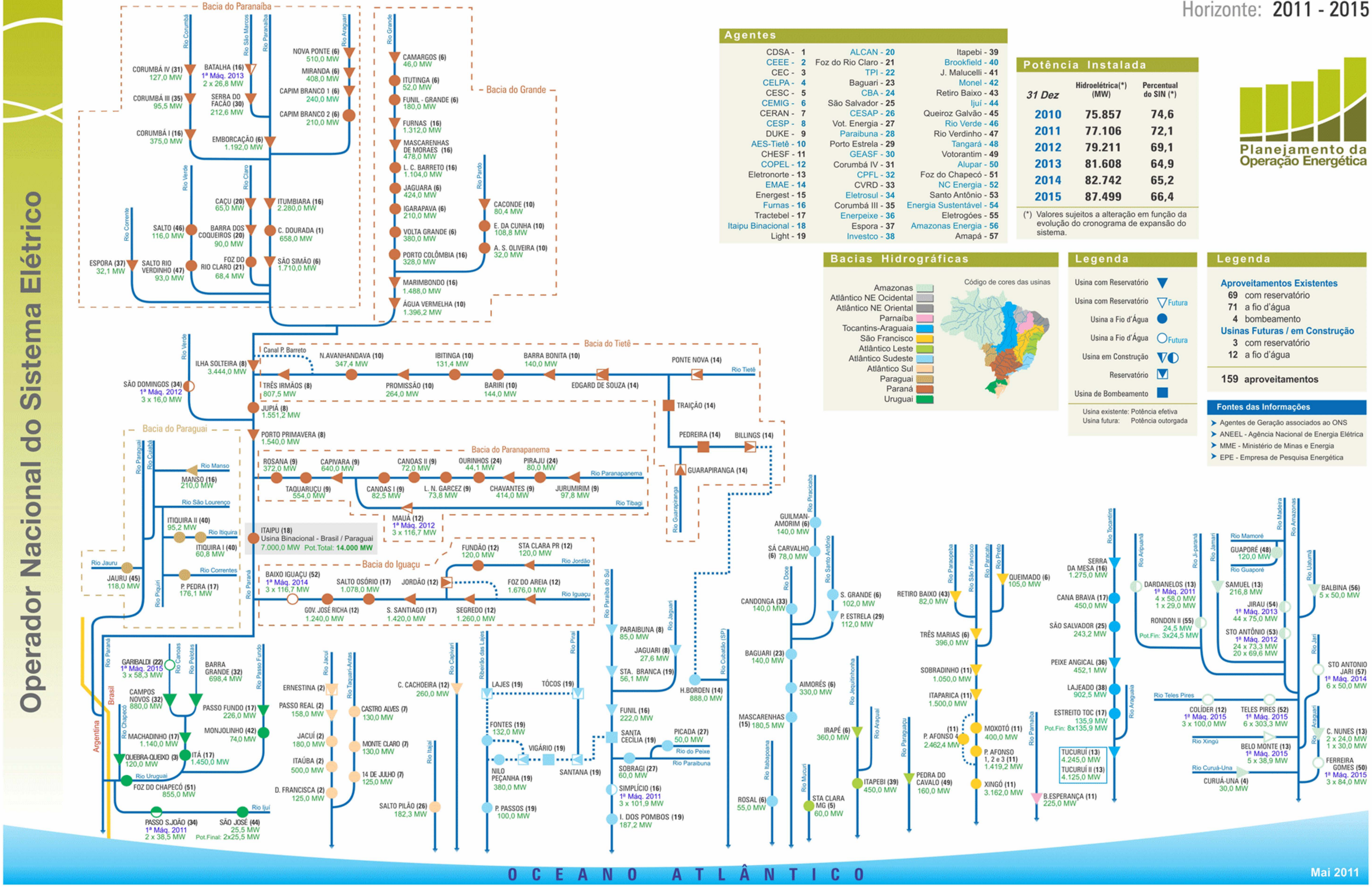


Source: EPE (2012)

Diagrama Esquemático das Usinas Hidroelétricas do SIN

Usinas Hidroelétricas Despachadas pelo ONS na Otimização da Operação Eletroenergética do Sistema Interligado Nacional

Horizonte: 2011 - 2015



Agentes

CDSA - 1	ALCAN - 20	Itapebi - 39
CEEE - 2	Foz do Rio Claro - 21	Brookfield - 40
CEC - 3	TPI - 22	J. Malucelli - 41
CELPA - 4	Baguari - 23	Monel - 42
CESC - 5	CBA - 24	Retiro Baixo - 43
CEMIG - 6	São Salvador - 25	Ijuí - 44
CERAN - 7	CESAP - 26	Queiroz Galvão - 45
CESP - 8	Vot. Energia - 27	Rio Verde - 46
DUKE - 9	Paraibuna - 28	Rio Verdinho - 47
AES-Tietê - 10	Porto Estrela - 29	Tangará - 48
CHESF - 11	GEASF - 30	Votorantim - 49
COPEL - 12	Corumbá IV - 31	Alupar - 50
Eletronorte - 13	CPFL - 32	Foz do Chapecó - 51
EMAE - 14	CVRD - 33	NC Energia - 52
Energest - 15	Eletrosul - 34	Santo Antônio - 53
Furnas - 16	Corumbá III - 35	Energia Sustentável - 54
Tractebel - 17	Enerpeixe - 36	Eletrogóes - 55
Itaipu Binacional - 18	Espora - 37	Amazonas Energia - 56
Light - 19	Investco - 38	Amapá - 57

Potência Instalada

31 Dez	Hidroelétrica(*) (MW)	Percentual do SIN (*)
2010	75.857	74,6
2011	77.106	72,1
2012	79.211	69,1
2013	81.608	64,9
2014	82.742	65,2
2015	87.499	66,4

(*) Valores sujeitos a alteração em função da evolução do cronograma de expansão do sistema.

Planejamento da Operação Energética

Bacias Hidrográficas

Código de cores das usinas

- Amazonas
- Atlântico NE Ocidental
- Atlântico NE Oriental
- Parnaíba
- Tocantins-Araguaia
- São Francisco
- Atlântico Leste
- Atlântico Sudeste
- Atlântico Sul
- Paraguai
- Paraná
- Uruguai

Legenda

- Usina com Reservatório
- Usina com Reservatório – Futura
- Usina a Fio d'Água
- Usina a Fio d'Água – Futura
- Usina em Construção
- Reservatório
- Usina de Bombeamento

Usina existente: Potência efetiva
Usina futura: Potência outorgada

Legenda

Aproveitamentos Existentes

- 69 com reservatório
- 71 a fio d'água
- 4 bombeamento

Usinas Futuras / em Construção

- 3 com reservatório
- 12 a fio d'água

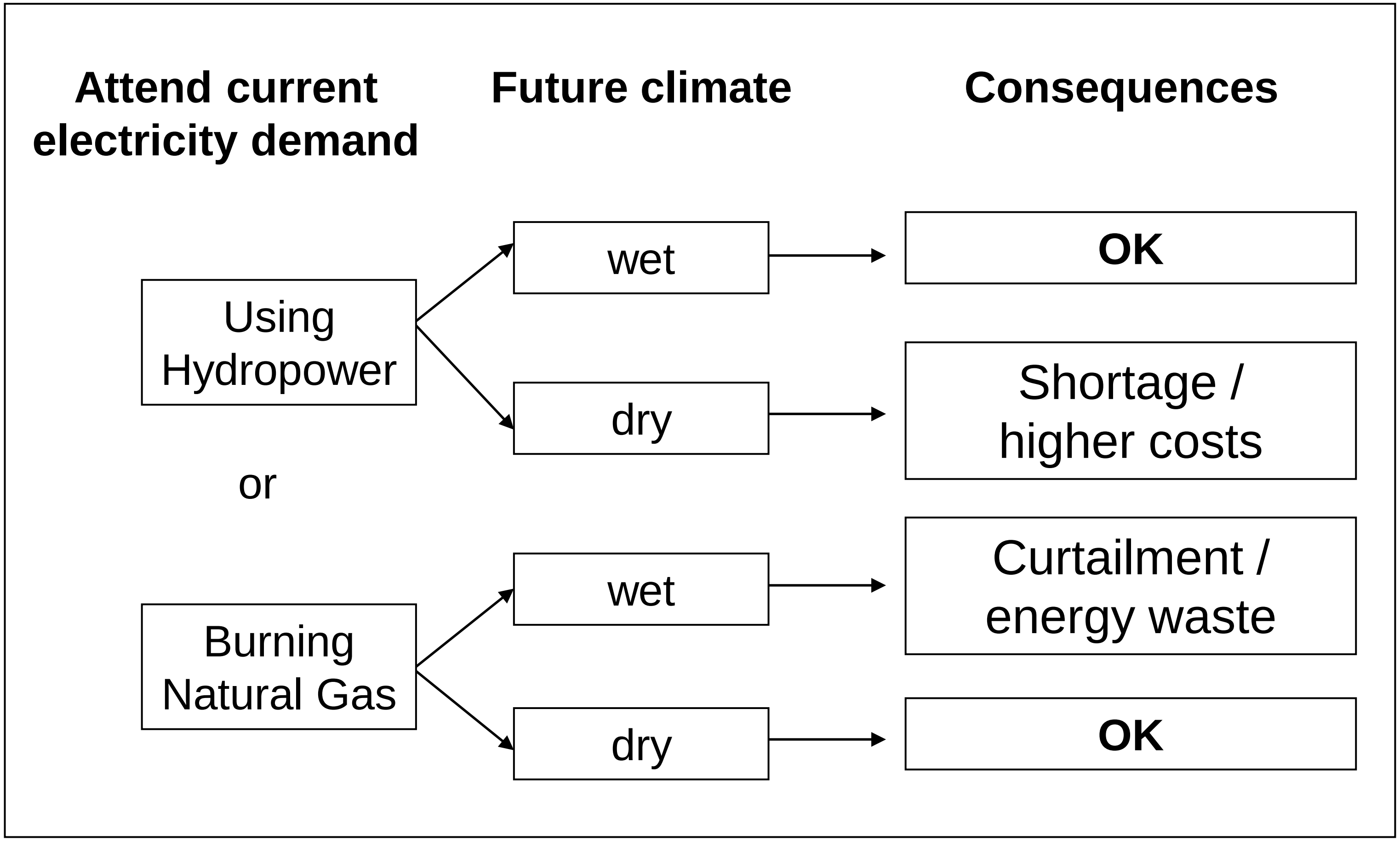
159 aproveitamentos

Fontes das Informações

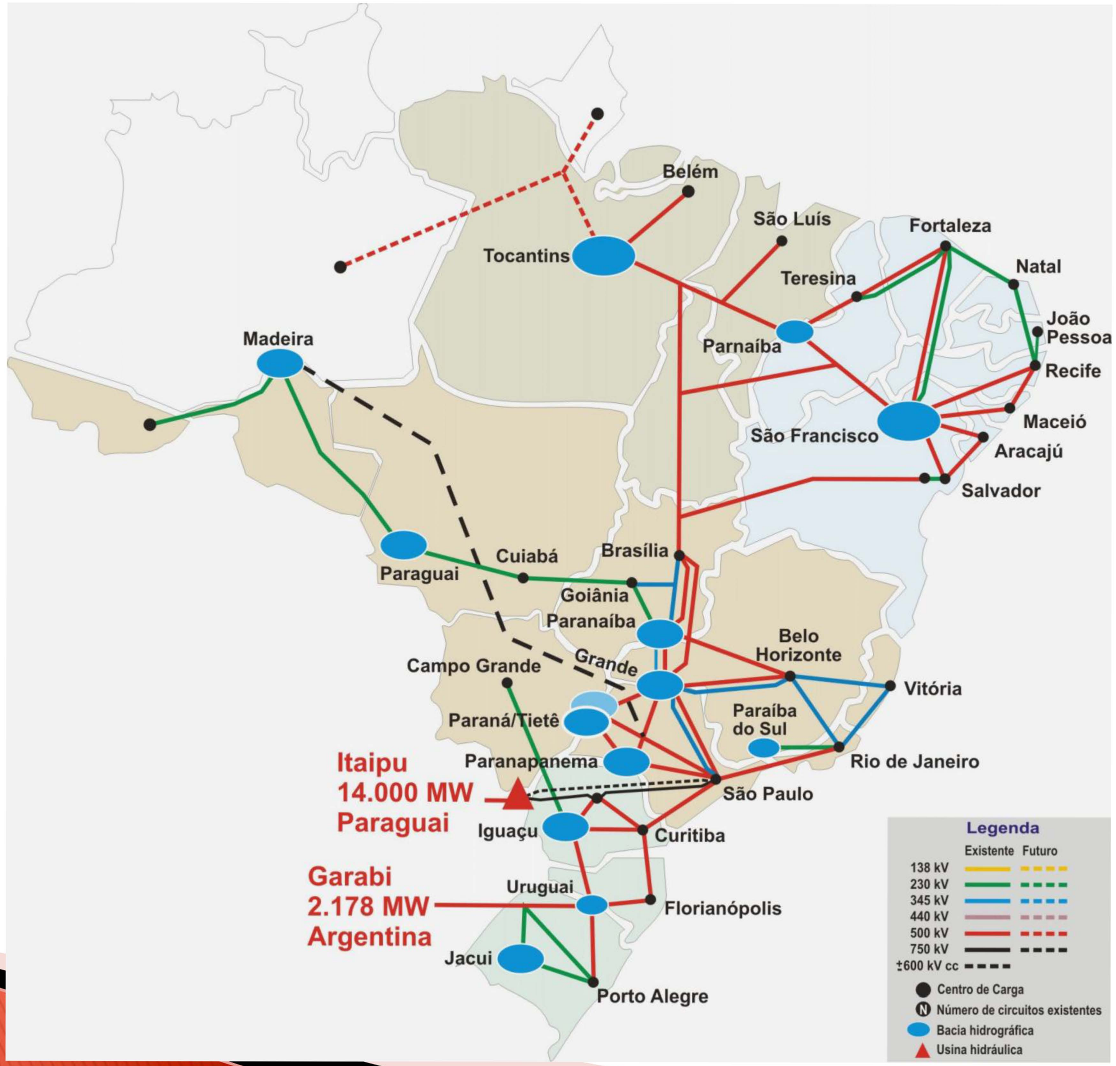
- Agentes de Geração associados ao ONS
- ANEEL - Agência Nacional de Energia Elétrica
- MME - Ministério de Minas e Energia
- EPE - Empresa de Pesquisa Energética

http://www.ons.org.br/

Brazilian's Power System Operator's Dilema

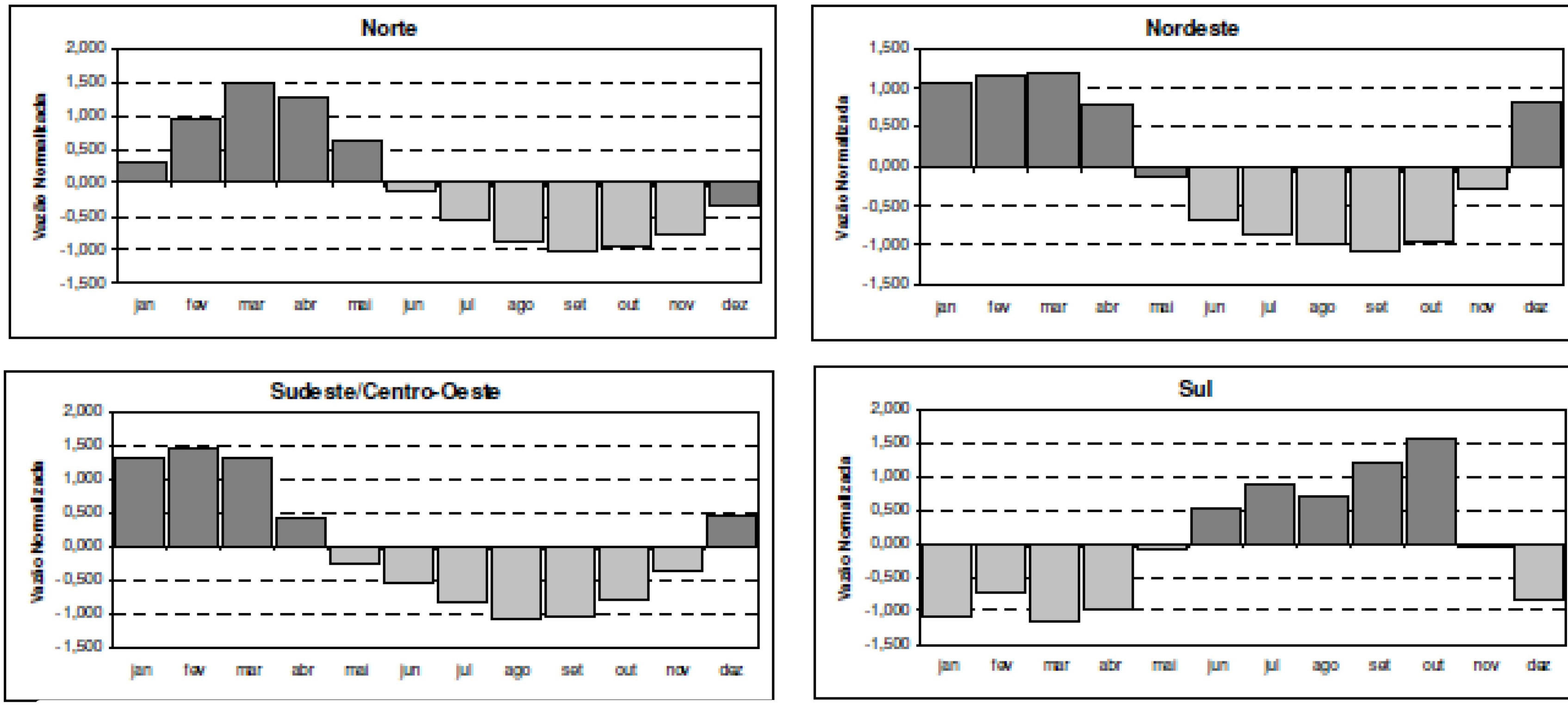


National Interconnected System (SIN)



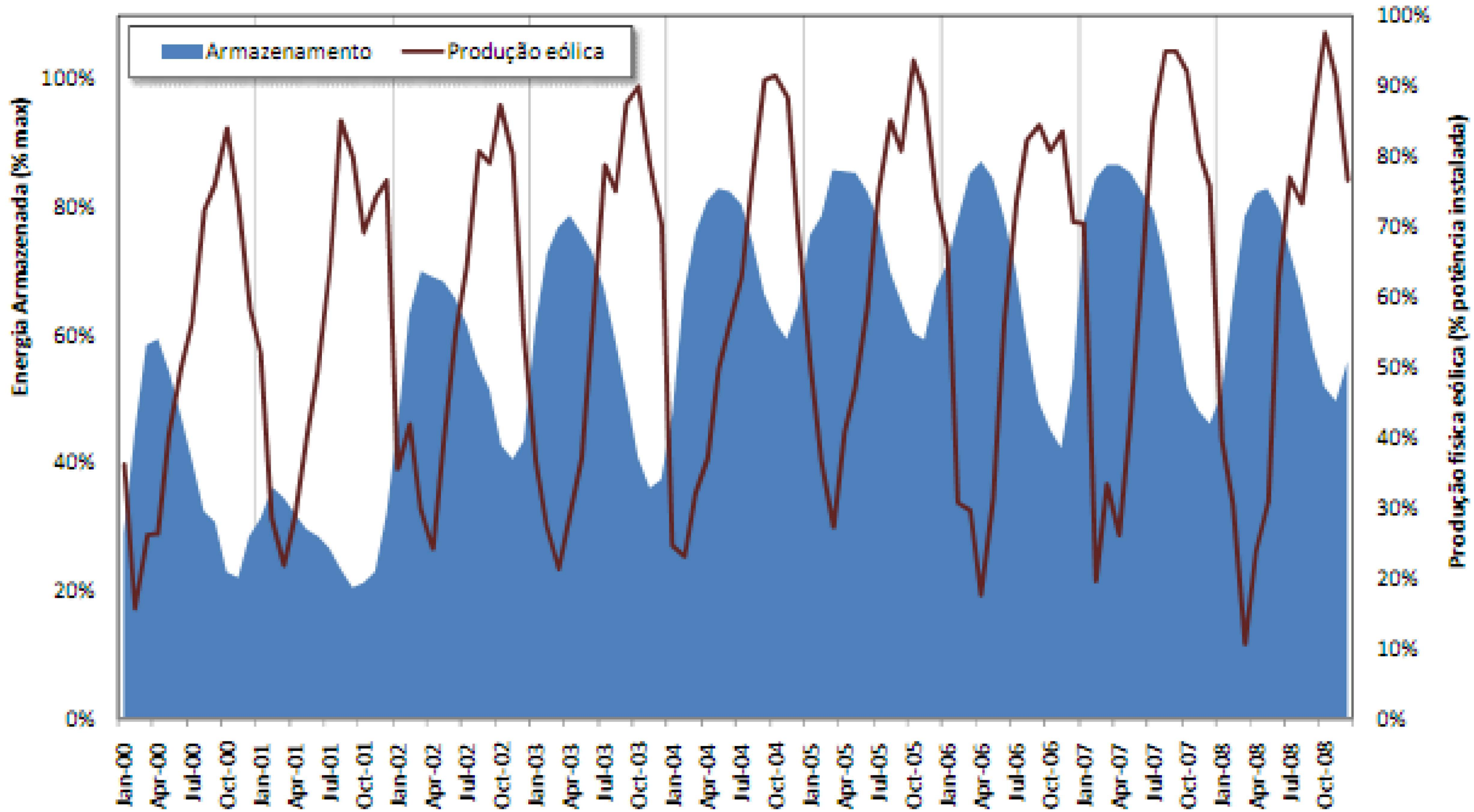
http://www.ons.org.br/

Hydrological Seasonality in Brazil



ONS (2008)

Wind x Hidro Energy – Northeast Brazil

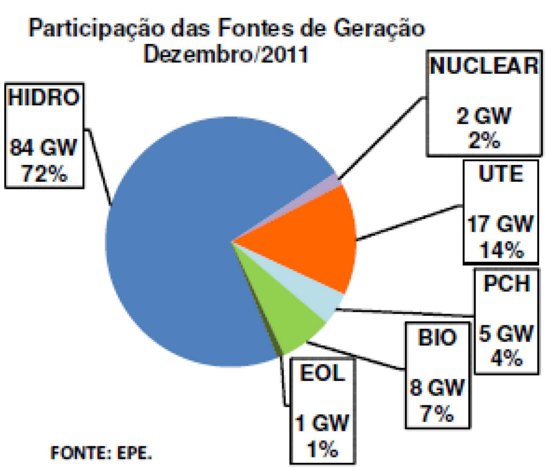


Energy stored in hydropower reservoirs (% max) *versus* wind energy generation % installed capacity)

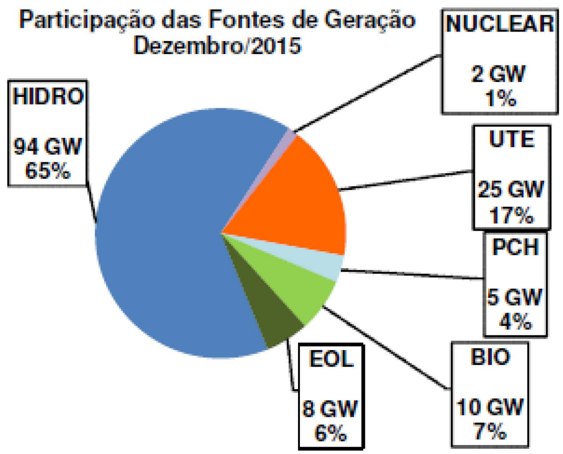
Simões (2010)

Official 10-year Plan

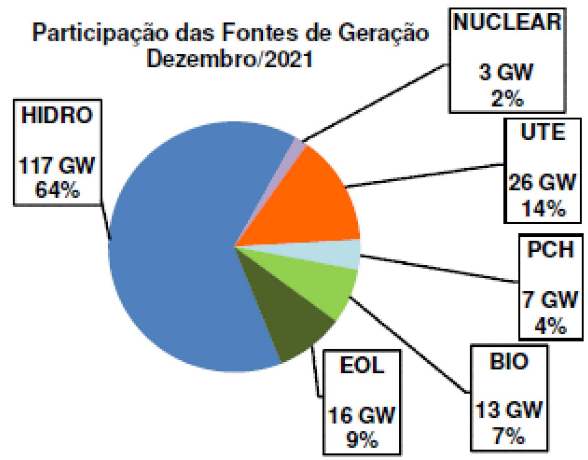
2011



2015



2021



Source: EPE – http://www.epe.gov.br/PDEE/Forms/EPEEstudo.aspx

Some Energy Modeling Studies

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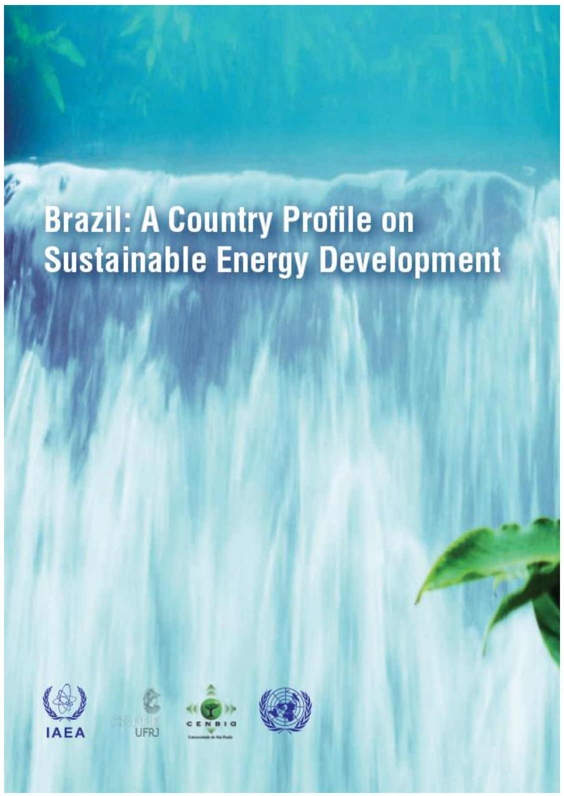
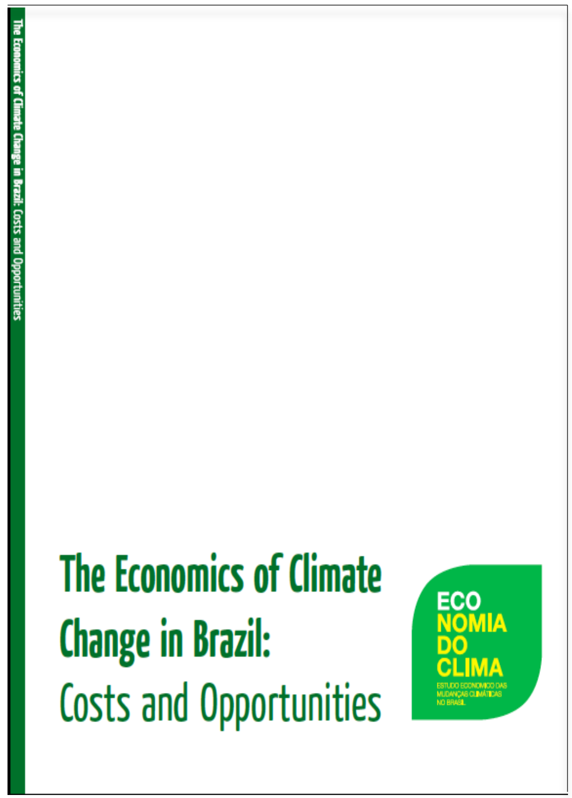
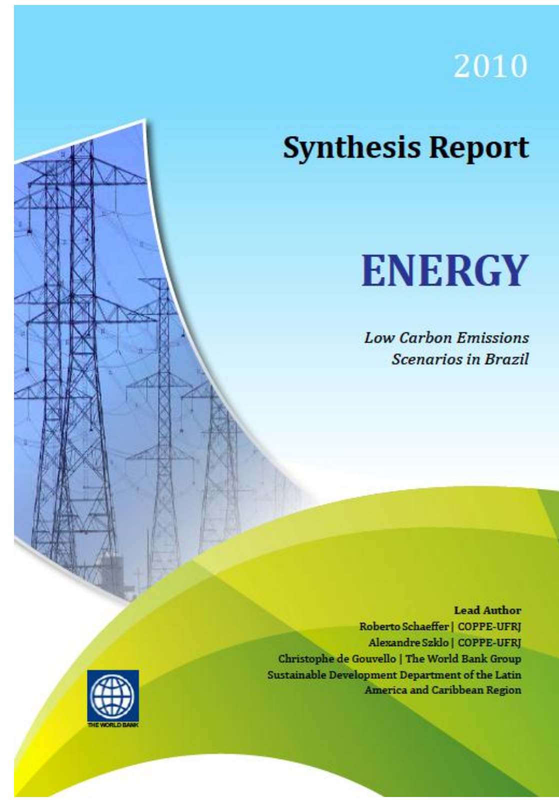


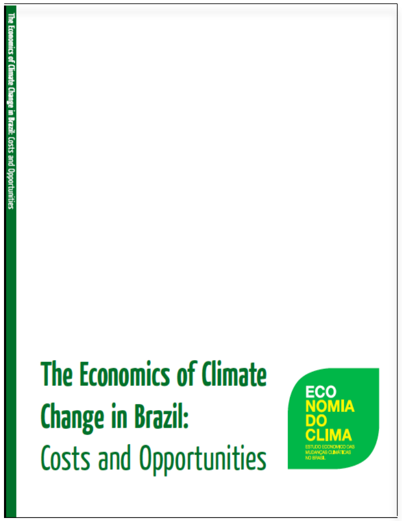
2006



2008



2010



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Climate Change Impacts and Adaptation in the Brazilian Energy Sector

(Economics of Climate Change in Brazil)

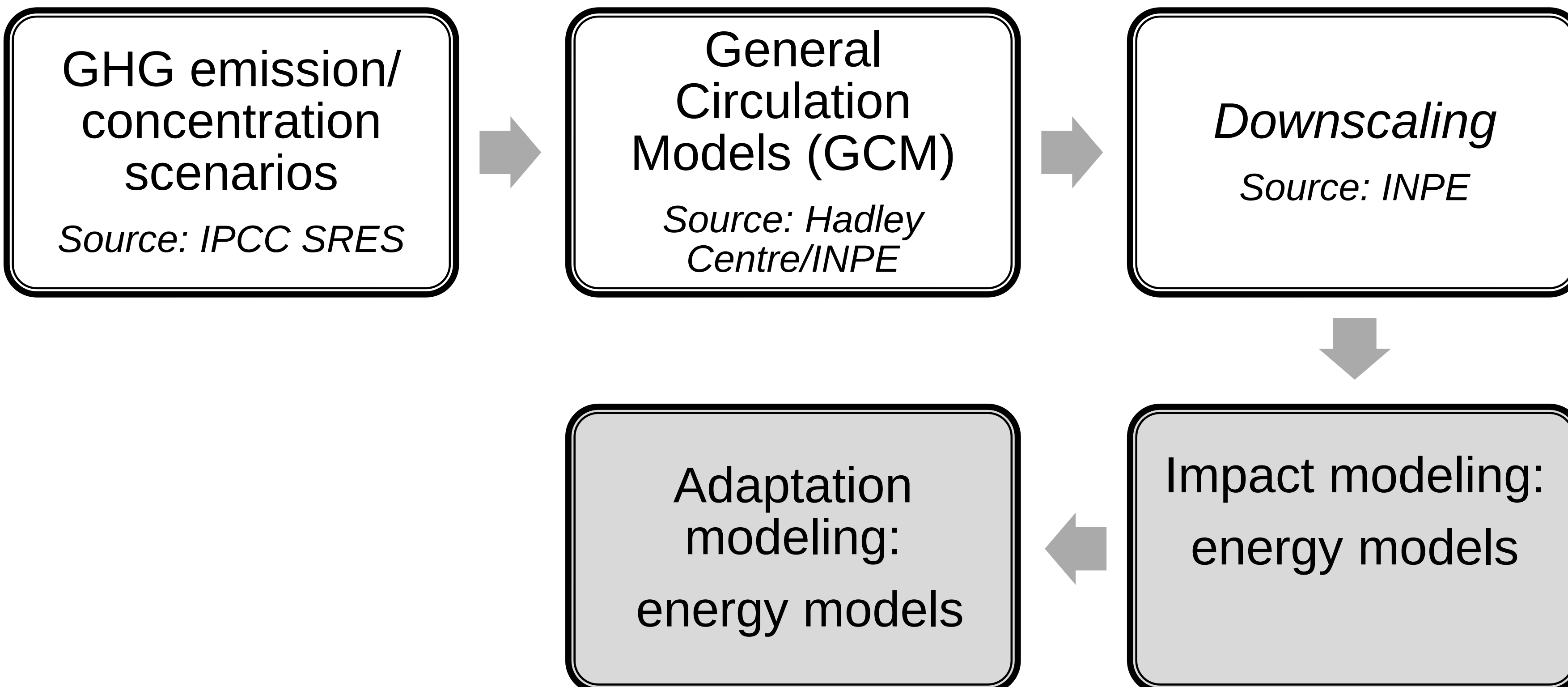
Introduction

- Human and natural systems can be affected by climate change
- Changes in climate conditions can affect the production and consumption of energy
  - Renewable
  - Non-renewable
- System operation and expansion are planned under uncertainties regarding:
  - Fuel availability and prices, future demand, technological improvements. future costs, etc.
  - Climate uncertainty: temperature, precipitation, river flow, wind speed, etc.
- Conventional energy planning assumes that climate variables are stationary.

→ need to evauate the impacts of climate change and adaptation measures

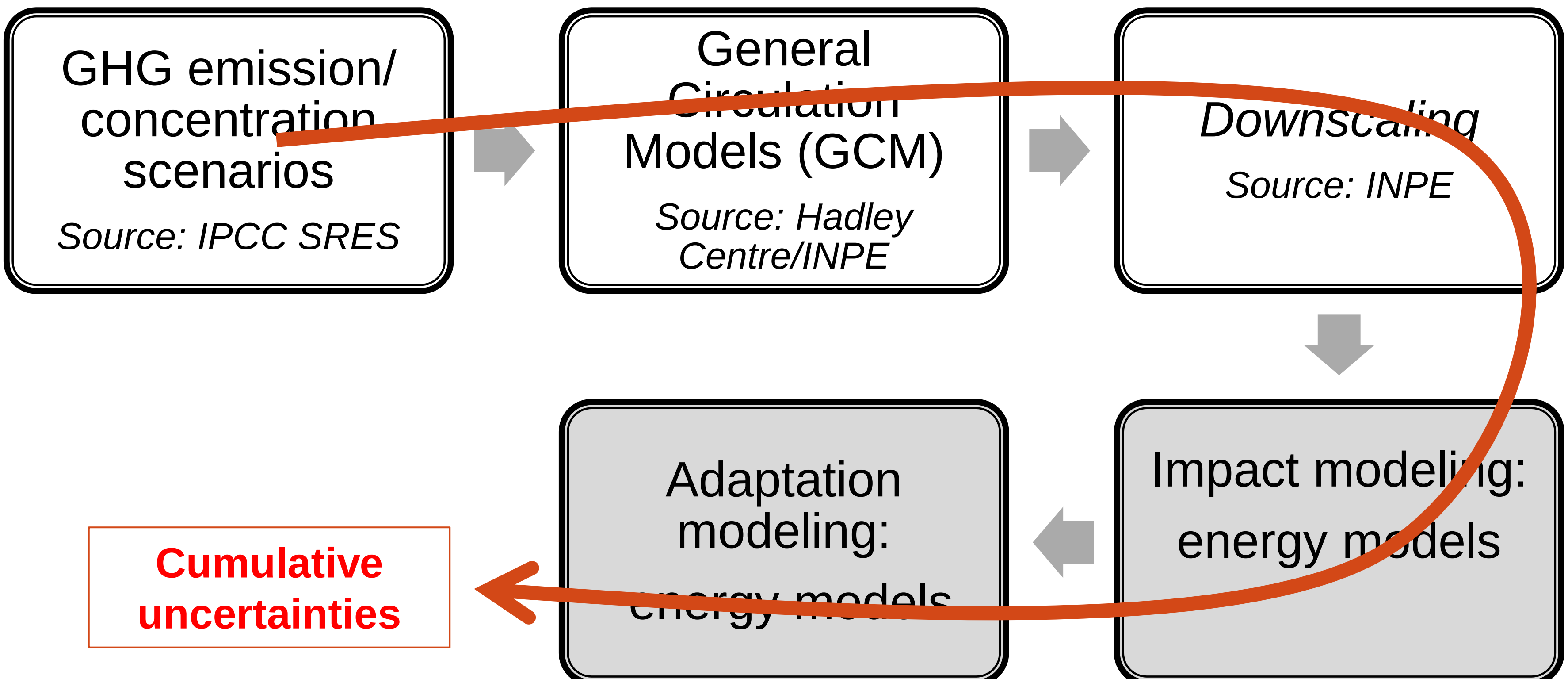
Methodological Procedure for Climate Change Impact Projections – Energy

(Sequential Approach)

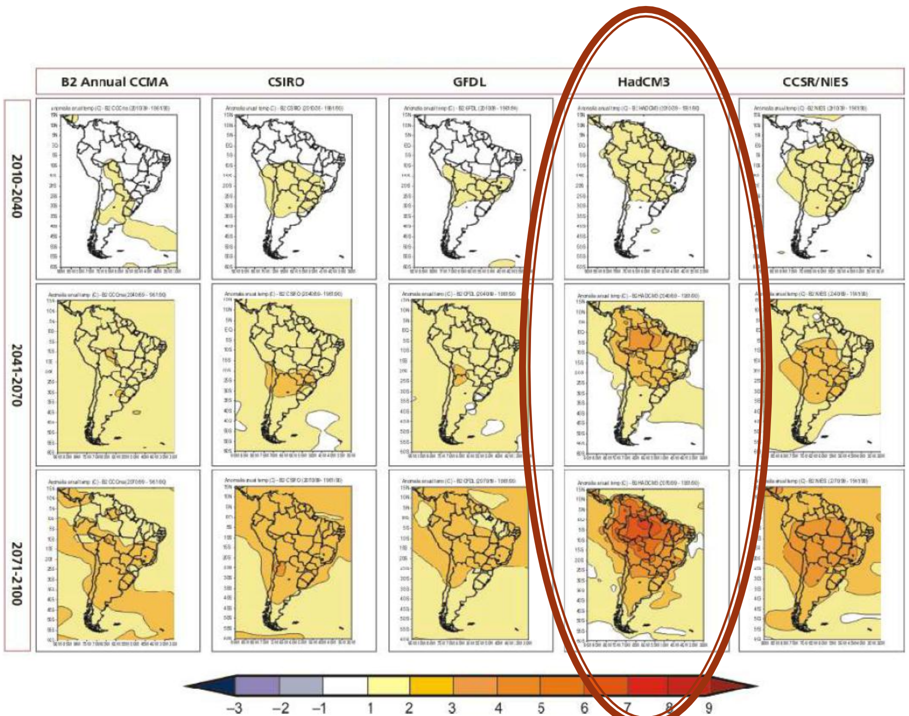


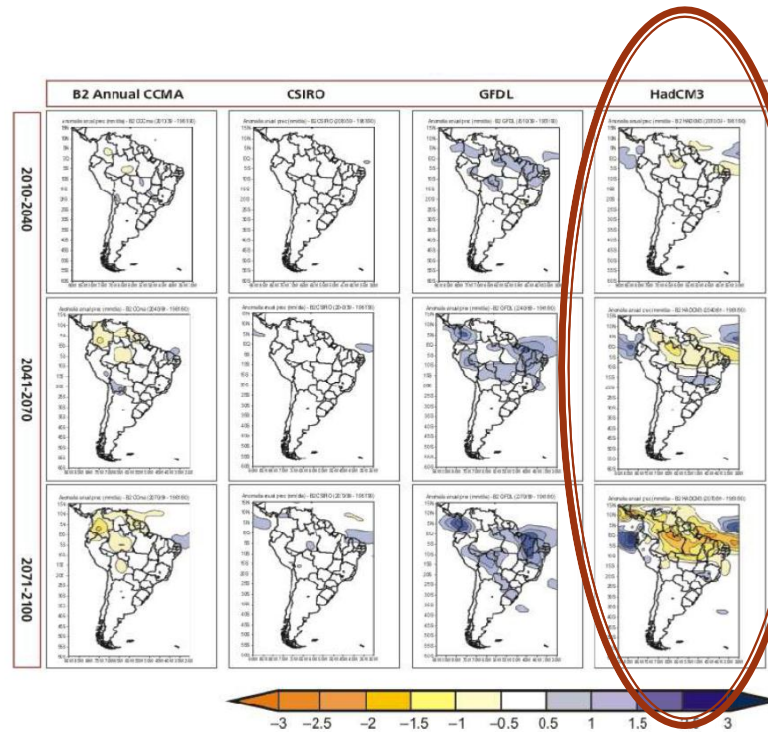
Methodological Procedure for Climate Change Impact Projections – Energy

(Sequential Approach)



Climate model uncertainty: Temperature (°C) and Precipitation (mm/day)





INPE (2007)

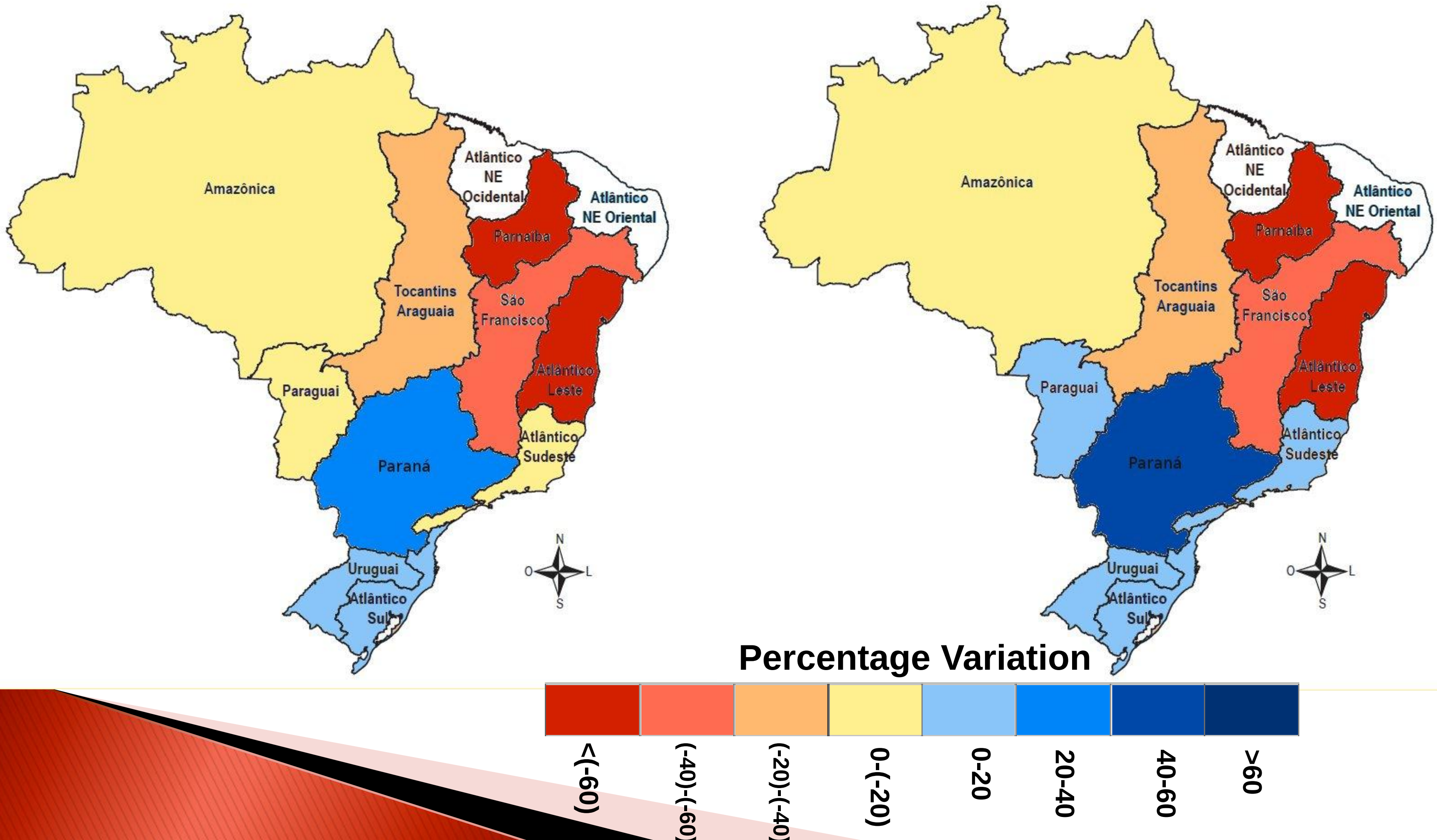
- Climate Modeling:
  - GCM HadCM3 (UKMO)
  - Dynamic dowscaling using the PRECIS model (INPE)

Modeling Climate Change Impacts on Hydropower Production

- Hydrological Model
  - Mixed approach: water balance & statistical
- Hydropower Model
  - *Modelo de Simulação de Usinas Individualizadas* (SUISHI-O) developed by CEPEL
    - Firm Energy → Capacity Factor
    - Average Energy

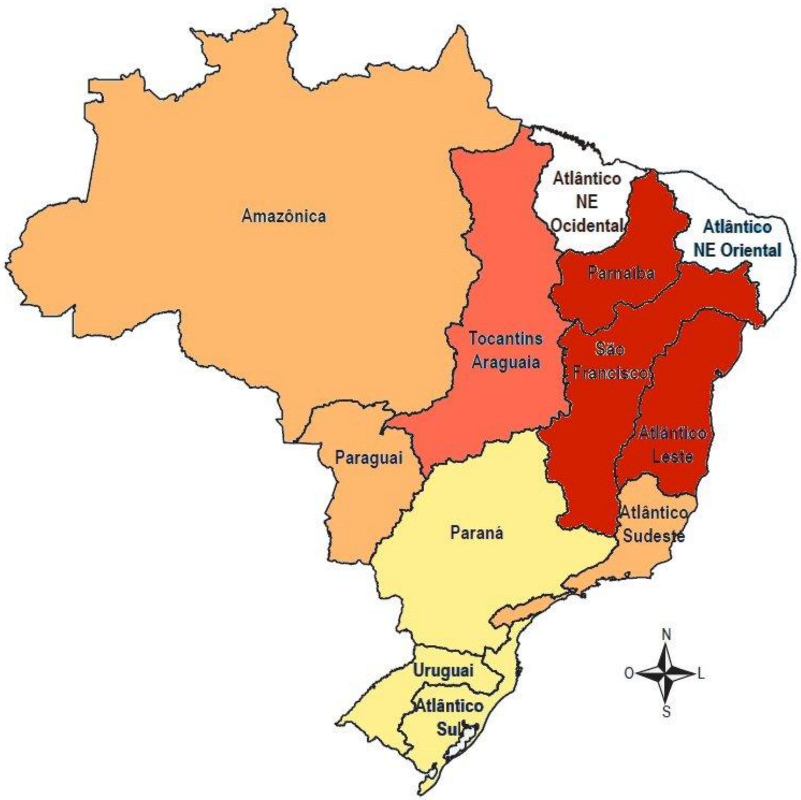
Climate Change Impacts on Hydropower Production: Average Energy

A2 Scenario **B2 Scenario**

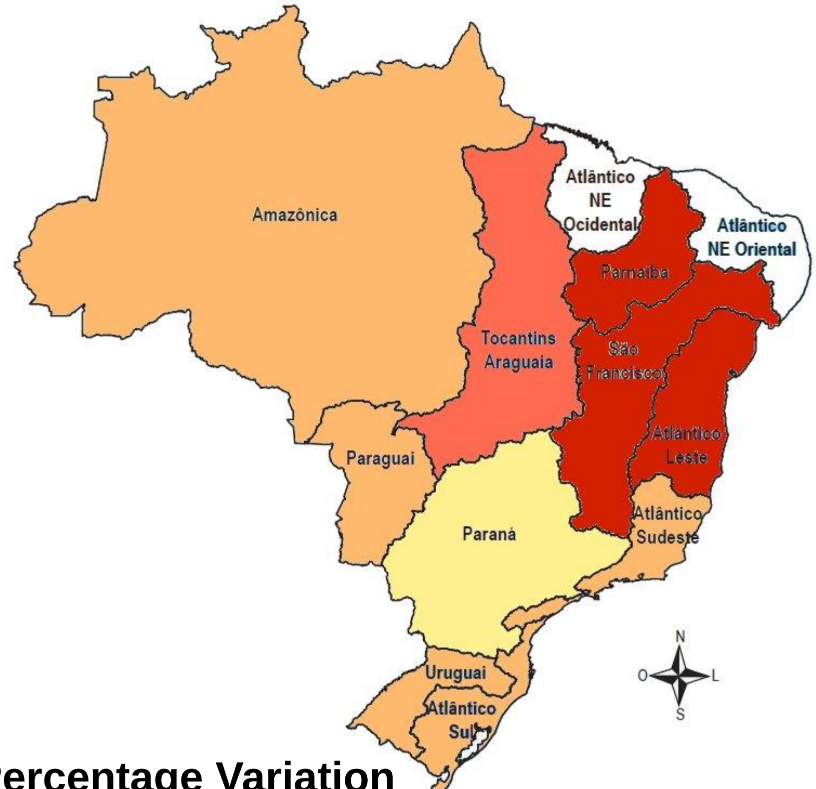


Climate Change Impacts on Hydropower Production: Firm Energy

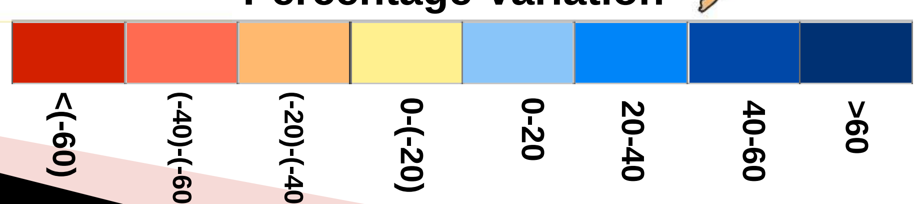
A2 Scenario



B2 Scenario



Percentage Variation



Climate Change Impacts on Hydropower Production

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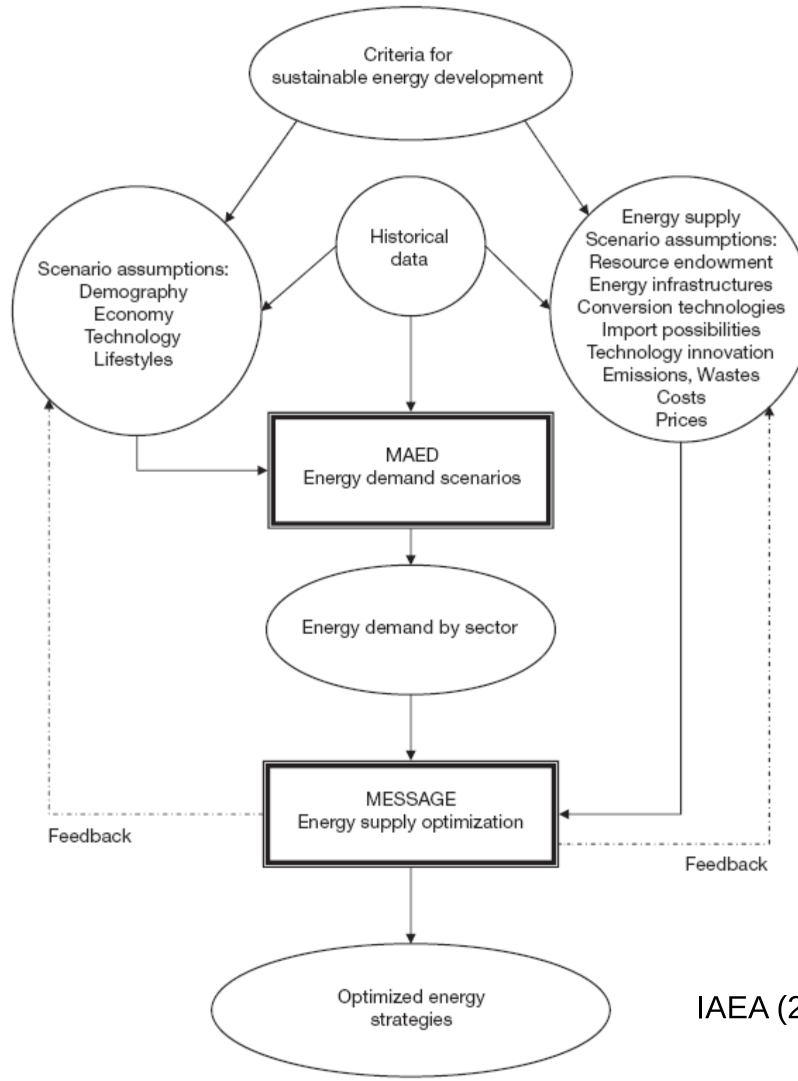
Basin	Historical MWyr		Variation from reference estimates			
			A2		B2	
	Firm Energy	Average Energy	Firm Energy	Average Energy	Firm Energy	Average Energy
Amazonas	9425	10628	-36%	-11%	-29%	-7%
Tocantins Araguaia	7531	10001	-46%	-27%	-41%	-21%
São Francisco	5026	5996	-69%	-45%	-77%	-52%
Parnaiba	236	293	-83%	-83%	-88%	-82%
At. Leste	496	565	-82%	-80%	-82%	-80%
At. Sudeste	1937	2268	-32%	1%	-37%	-10%
At. Sul	1739	2037	-26%	8%	-18%	11%
Uruguai	1715	1996	-30%	4%	-20%	9%
Paraguai	375	426	-38%	4%	-35%	-3%
Paraná	22903	29038	-8%	43%	-7%	37%
TOTAL	**51382**	**63247**	**-31.5%**	**2.,7%**	**-29.3%**	**1.1%**

Modeling Least-cost Adaptation Options

- **MAED** (*Model For Analysis of Energy Demand)*: *bottom-up* energy demand simulation model

- **MESSAGE** *(Model for Energy Supply Systems and their General Environmental Impacts)*: integrated optimization model for energy supply



IAEA (2006)

Modeling Least-cost Adaptation Options

- Approach:
  - Comparison between scenarios *with* and *without* projected climate change impacts on hydropwer production

  → Least-cost adaptation
- Direct financial burden
- Integrated energy modeling

  → Direct and indirect repercussions of decreased hydropower availability

Least-cost Adaptation Scenarios

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A2
- Business as Usual Scenario
- Differentiated discount rates for power generation options

→ A2-1: no impacts

→ A2-2: impacts on capacity factor of hydropwer plants

Difference between scenarios
=
Least cost adaptation options

B2
- Alternative Scenario
- Greater incentive to energy eficiency and conservation

→ B2-1: no impacts

→ B2-2: impacts on capacity factor of hydropwer plants

Difference between scenarios
=
Least cost adaptation options

Least-cost Adaptation: A2 Scenario

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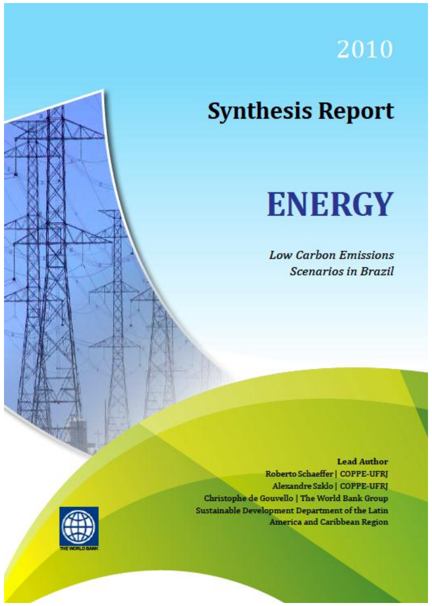
	Energy		Installed Capacity
	TWh	var %	GW
Hydropower			
Small(<30MW)	**-12 (↓)**	**-30% (↓)**	**0.0**
Medium (>30MW; <300MW)	**-63 (↓)**	**-36% (↓)**	**0.0**
Large (>300MW)	**-87 (↓)**	**-28% (↓)**	**0.0**
Sugar Cane Biomass			
CP 22 bar	0	0%	0.0
CP 42 bar	0	0%	0.0
Cascade Cogeneration	**-20 (↓)**	**-57% (↓)**	**-3.7 (↓)**
CEST	**99 (↑)**	**143% (↑)**	**13.2 (↑)**
BIG-GT	0	0%	0.0
Municipal Solid Waste	0	0%	0.0
Wind Power	**21 (↑)**	**39% (↑)**	**10.0 (↑)**
Natural Gas	**128 (↑)**	**129% (↑)**	**31.7 (↑)**
Nuclear	**24 (↑)**	**31% (↑)**	**3.2 (↑)**
Coal	0	0%	0.0
Diesel	0	0%	0.0
Fuel Oil	0	0%	0.0

Least-cost Adaptation: B2 Scenario

	Energy		Installed Capacity
	TWh	var %	GW
Hydropower			
Small(<30MW)	**-12 (↓)**	**-30% (↓)**	**0.0**
Medium (>30MW; <300MW)	**-61 (↓)**	**-35% (↓)**	**0.0**
Large (>300MW)	**-80 (↓)**	**-26% (↓)**	**0.0**
Sugar Cane Biomass			
CP 22 bar	0	0%	0.0
CP 42 bar	0	0%	0.0
Cascade Cogeneration	**-12 (↓)**	**-100% (↓)**	**-2.3 (↓)**
CEST	**77 (↑)**	**49% (↑)**	**10.3 (↑)**
BIG-GT	0	0%	0.0
Municipal Solid Waste	0	0%	0.0
Wind Power	**24 (↑)**	**26% (↑)**	**11.5 (↑)**
Natural Gas	**99 (↑)**	**117% (↑)**	**23.8 (↑)**
Nuclear	0	0%	0.0
Coal	**53 (↑)**	**134% (↑)**	**8.6 (↑)**
Diesel	0	0%	0.0
Fuel Oil	0	0%	0.0

Adaptation – discussion

- Decreased Hydropower availability leads to a loss of 162TWh/yr and 153 TWh/yr in 2035, in the A2 and B2 scenarios, respectively.
- Built capacity to replace that would cost 51 billion dollars (A2) / 48 billion dollars (B2), most of which using natural gas.
- Greater demand for natural gas in power sector takes up from the industrial sector, being replaced by fuel oil.



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Mitigation Potential and Marginal Abatement Costs (Brazil Low Carbon Scenario Study)

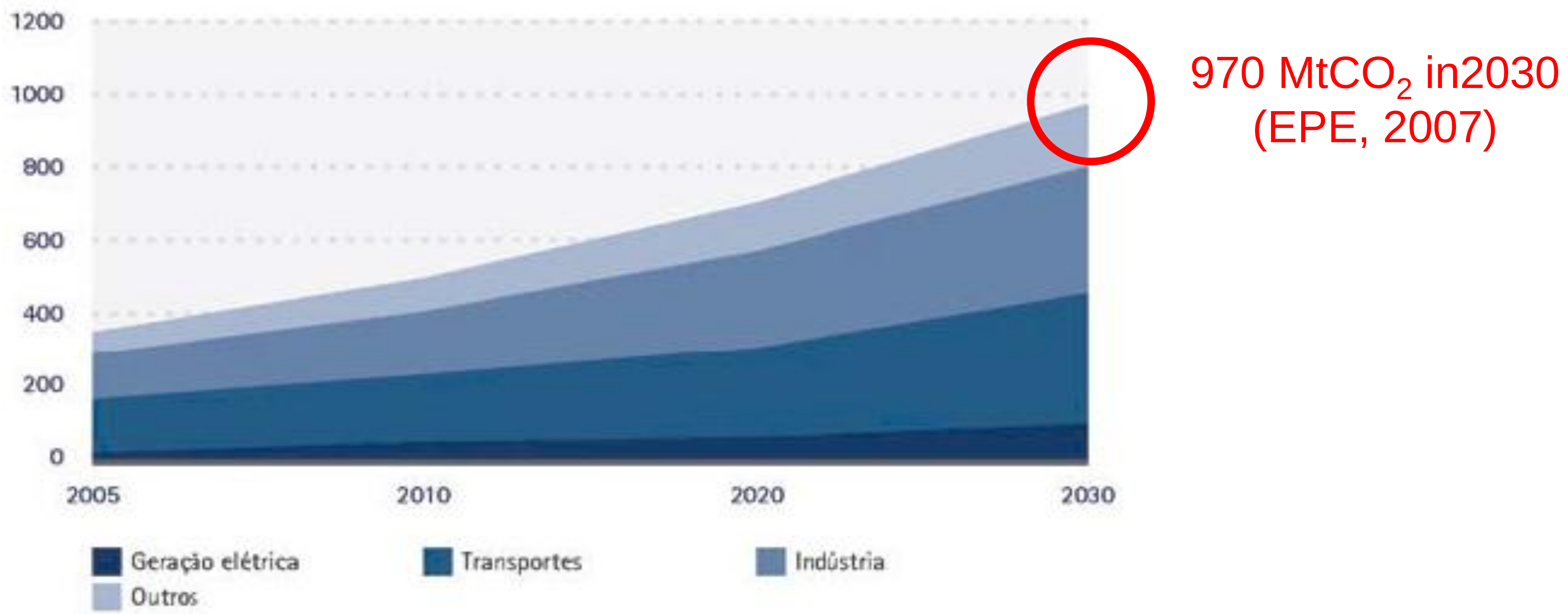
Objective

- Compare two energy related emission scenarios up to 2030:
  - Reference Scenario – PNE 2030 (EPE. 2006)
  - Low Carbon Scenario – mitigation alternatives not included in the PNE 2030

- Calculate the country's mitigation potential and the marginal abatement cost for the energy sector

Methodology

- Approach based on “wedges”
- Reference case emissions (EPE, 2007)

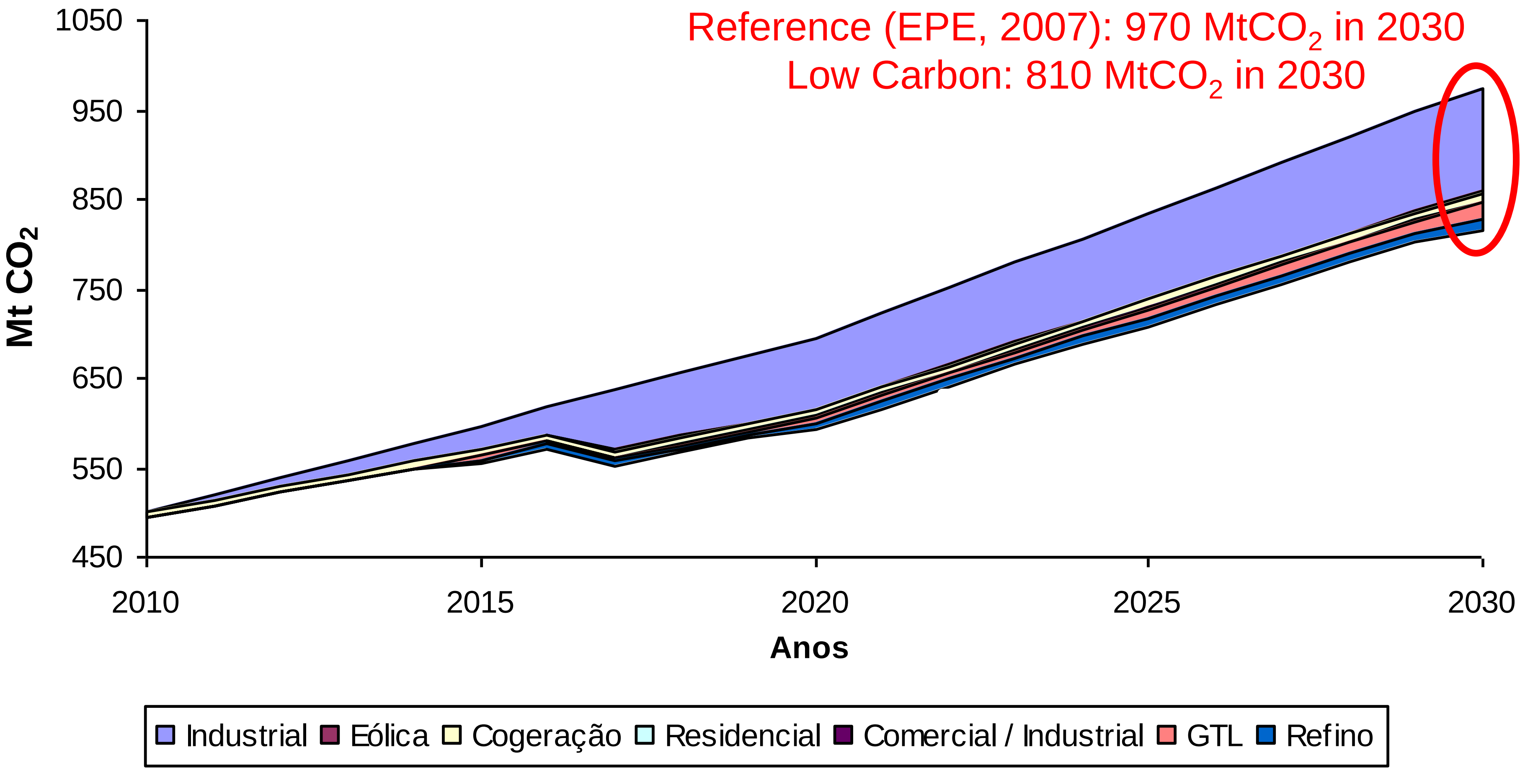


Total Emission Reduction Potential (2010-2030)

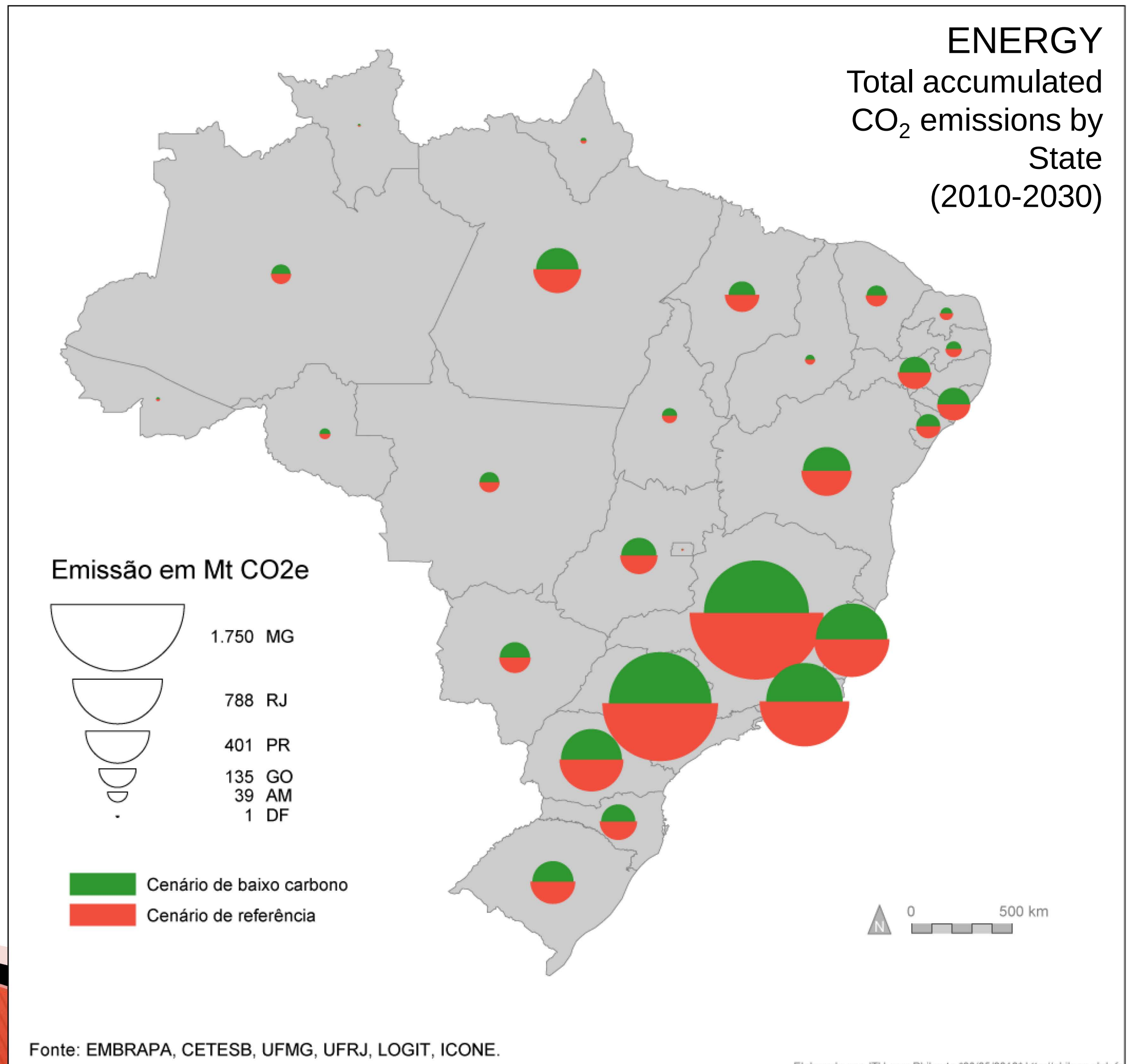
Sector	**Acumulated emission Reductions (tCO_2 2010-2030)**
Industrial Sector	1,378,915,782
Household Sector	18,159,757
Wind Generation	19,289,551
Cogeneration	156,682,872
Comertial / Industrial (Electricity)	3,657,216
GTL	128,150,069
Oil Refining	117,979,882
Total	**1,822,835,101**

Total estimated accumulated emission reduction potential up to 2030 in the energy sector of around 1.8 billion tons of CO_2

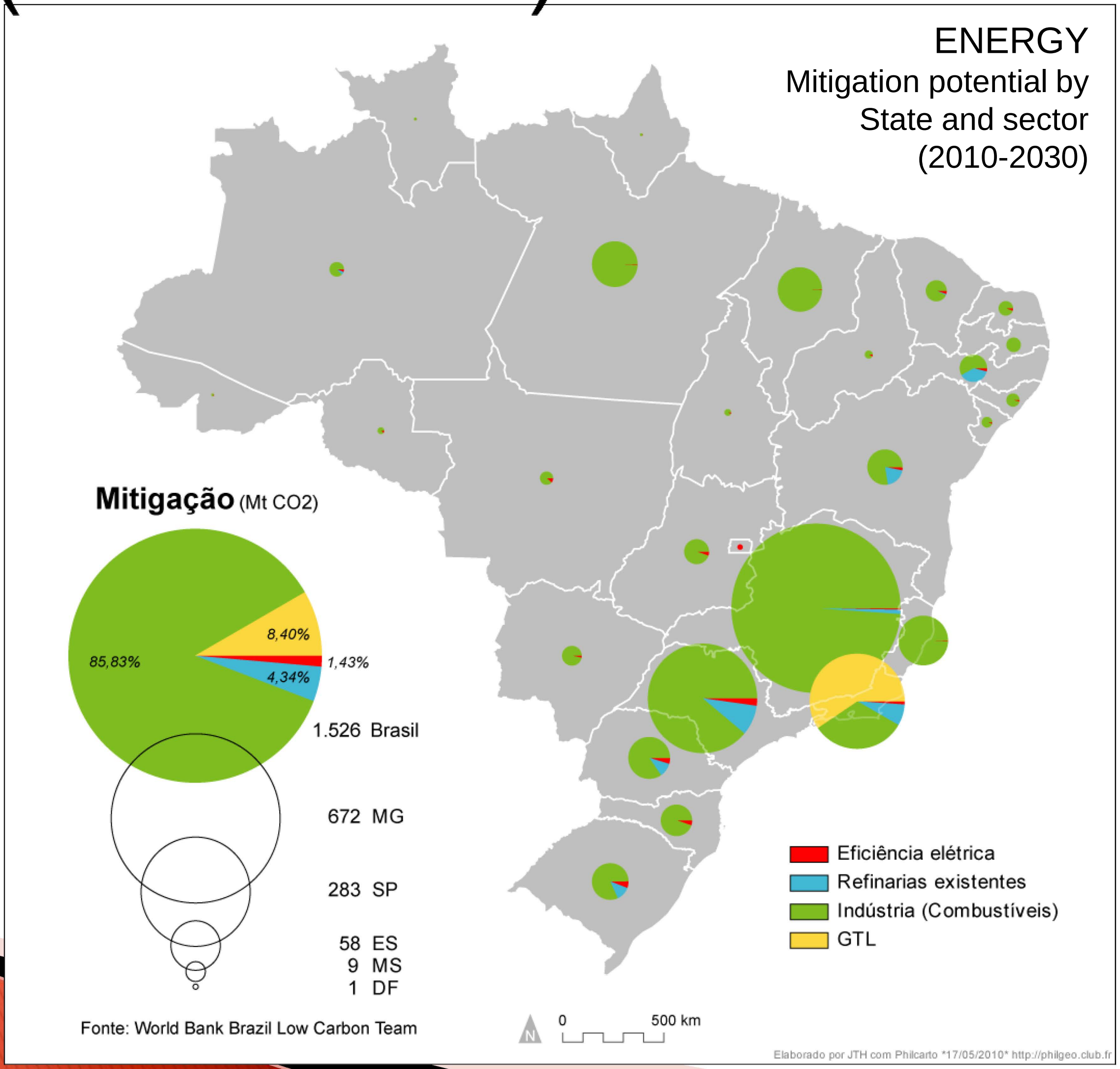
Total Emission Reduction Potential (2010-2030)



Total Emission by State (2010-2030)



Total Emission Reduction Potential by Sector and State (2010-2030)



Estimated Abatement Costs

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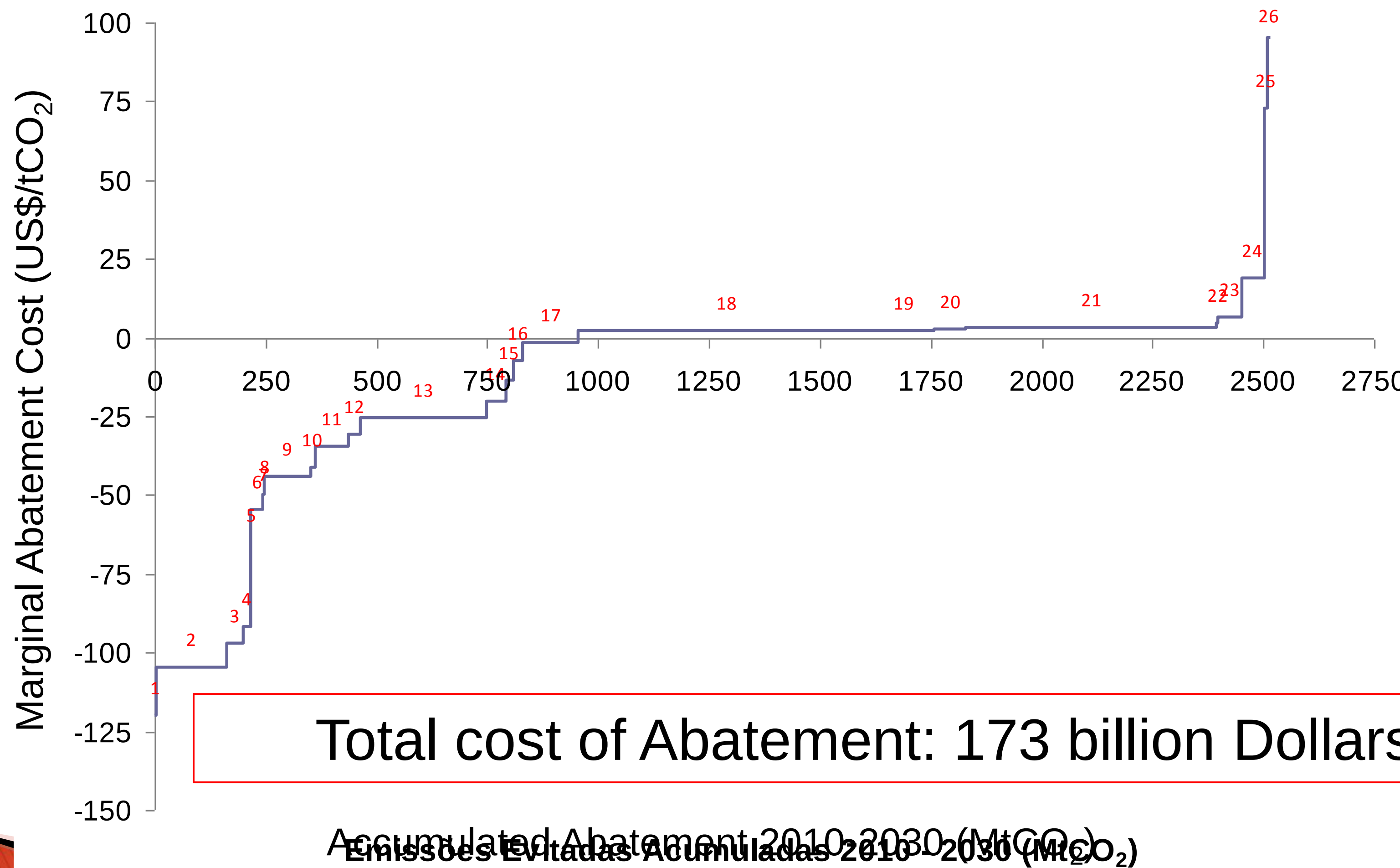
Nº	Sector	Mitigation Alternatives	Emission Reduction ($MtCO_2$)	Marginal Cost of Abatement ($US\$/tCO_2$) (disc. rate 8%)	Sector's Estimated IRR	Break Even Carbon Price ($US\$/tCO_2$)
1	Industrial	Improving combustion	105.2	-44.1	15%	n/a
2		Heat recovery	19.0	-91.7		n/a
3		Steam recovery	37.3	-97.0		n/a
4		Heat recovery in kilns	283.0	-25.6		n/a
5		New processes	135.4	2.1		173.6
6		Other efficiency improvement measures	18.3	-13.5		n/a
7		Solar Heating	25.8	-54.7		n/a
8		Recycling	74.8	-34.5		10.4
9		Fuel substitution (for natural gas)	43.7	-20.2		68.9
10		Fuel substitution (for renewable biomass)	69.2	2.8		41.8
11		Eliminating non-renewable biomass	567.0	2.9		41.8
12	Wind Power	Wind Power	19.3	-7.6	15%	98.5
13	Cogeneration	Cogeneration	157.9	-248.2	18%	34.0

Estimated Abatement Costs

Nº	Sector	Mitigation Alternatives	Emission Reduction ($MtCO_2$)	Marginal Cost of Abatement (US$/$tCO_2$) (disc. rate 8%)	Sector's Estimated IRR	Break Even Carbon Price (US$/$tCO_2$)
14	Houshold Sector	Solar water heating	3.0	161.8	79%	1.397.6
15		Efficient air conditioning	2.6	516.6		2.807.3
16		Lighting	3.1	-119.7		n/a
17		Efficient Refrigerators	9.5	41.8		547.5
18	Comertial / Industrial	Motors	1.5	-49.8	15%	72.3
19		Industrial lighting	0.6	-65.0		n/a
20		Comercial lighting	1.5	-52.3		n/a
21	GTL	GTL offshore plant	128.2	-1.5	25%	33.9
22	Oil Refining	Changing Design of New Refineries	51.8	19.1	15%	106.1
23		Improving Energy Use of Existing Refinery Units (Heat Integration)	52.3	6.6		74.8
24		Improving Energy Use of Existing Refinery Units (Fouling Mitigation)	7.0	72.9		208.5
25		Improving Energy Use of Existing Refinery Units (Advanced Control)	7.0	95.1		431.5
		Total Potential	**1.823**			

Marginal Abatement Cost Curve (8% discount rate)



Total cost of Abatement: 173 billion Dollars

Current Studies Using Energy Models PPE/COPPE/UFRJ

- Estimating abatement cost curves for industrial facilities in the state of Rio de Janeiro;
- Integrating plug-in hybrid electric vehicles (PHEV) in the electric power grid: using PHEV to cope with wind power intermitency;
- Testing different alternatives for introducing solar power generation in the Brazilian grid;
- Analysis of the impacts of climate policy on industrial competitiveness using an input-output model;
- Carbon Capture and Storage (CCS): estimating Learning Curves and Life Cycle Analisys;
- Integrated analysis of Distributed Electricity Generation Options;
- Assemssent of climate change impacts on Amazonian energy systems;
- Integrated Modeling of Latin America energy systems;
- Estimating MAC for Brazil and analysis in integrated modeling framework.

Work at JGCRI

- Break up Brazil in GCAM
- LAMP – Latin America Modeling Project
- Make connections!

Thank You

Andre Lucena

andrelucena@ppe.ufrj.br

Programa de Planejamento Energético

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