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

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Systems Analysis and the Americas,

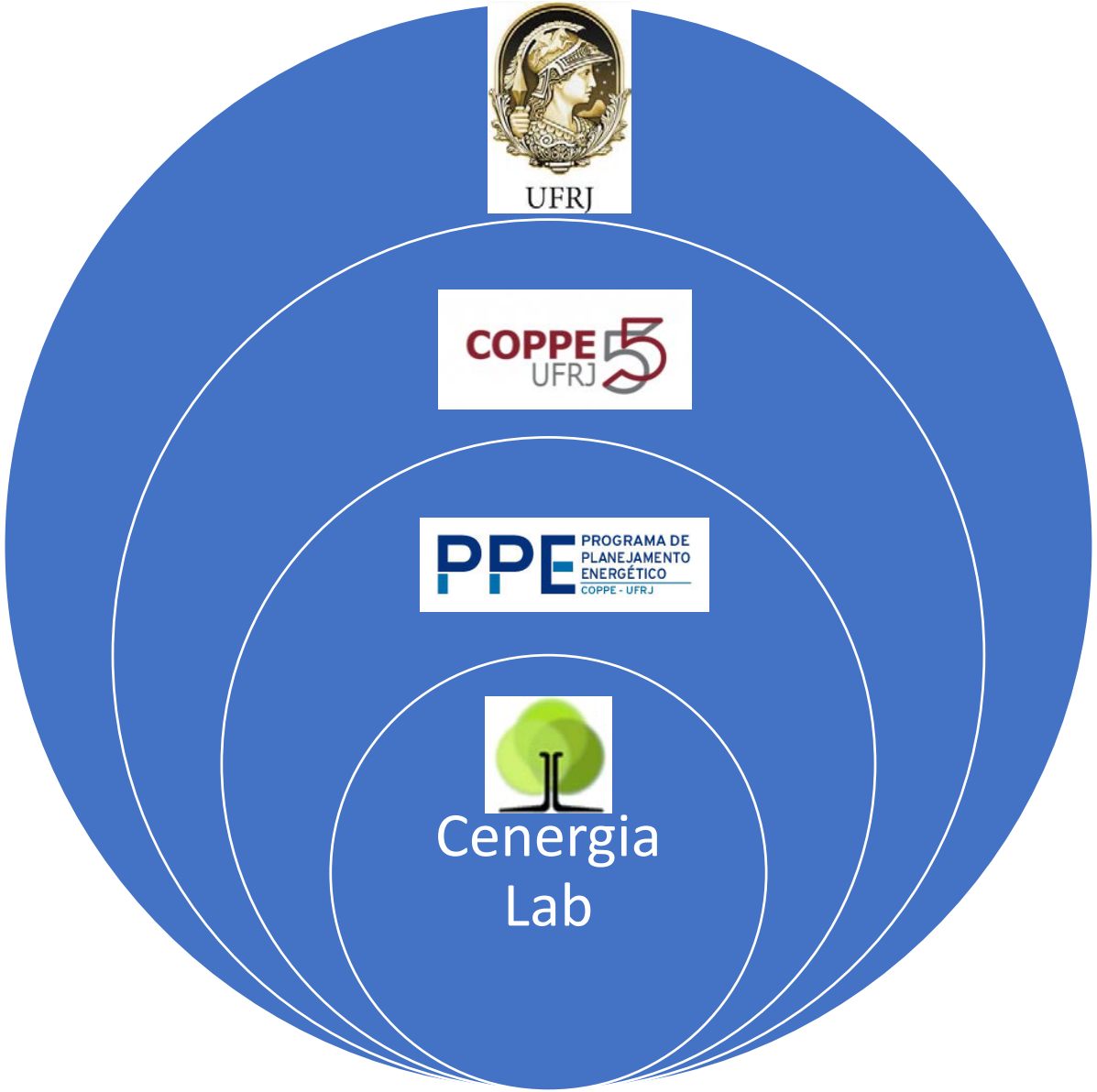
Supported by CAPES, FGV, IIASA, and NAS

Rio de Janeiro, 6 September 2019

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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COPPE
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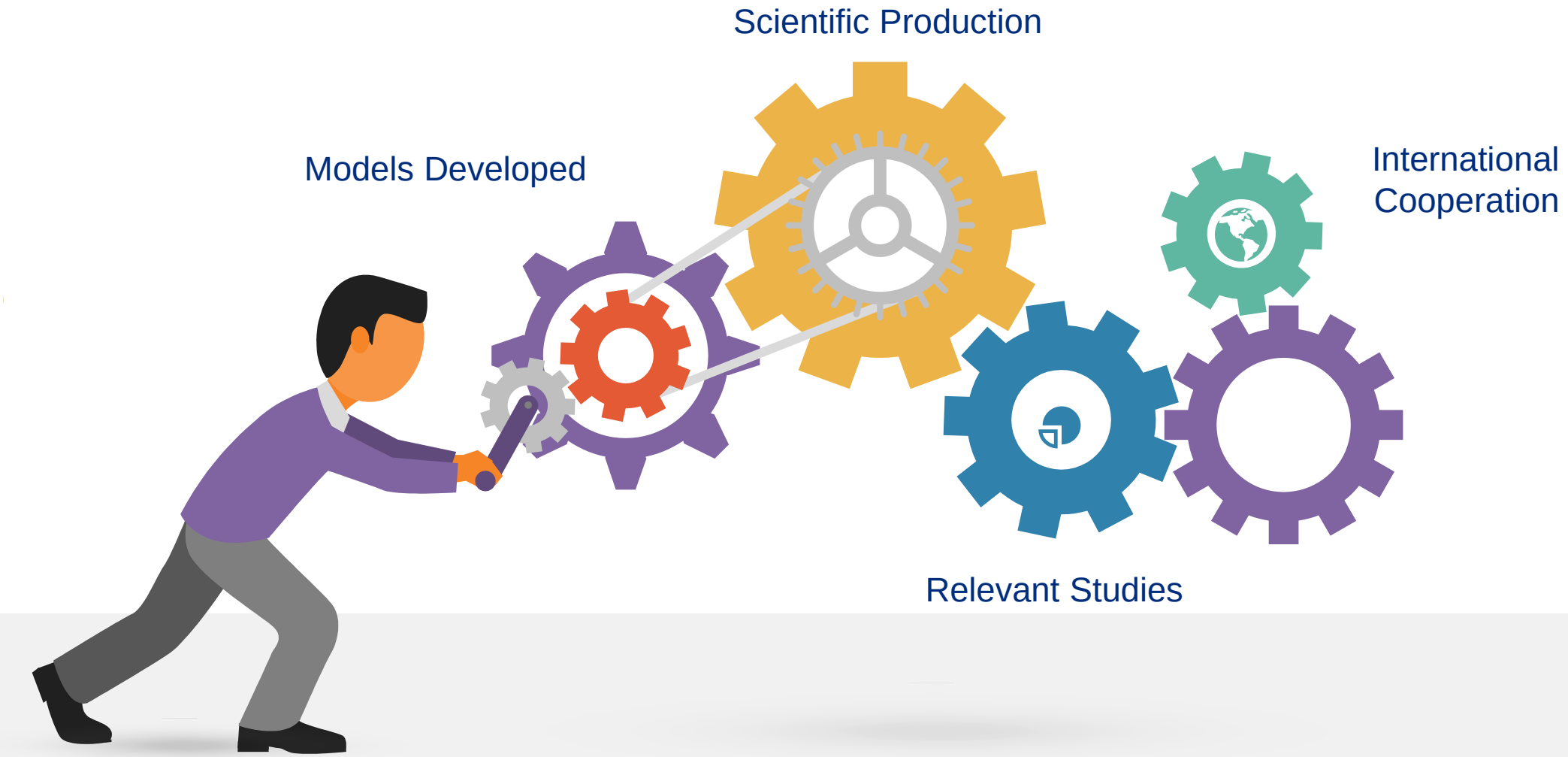
PROGRAMA DE
PLANEJAMENTO
ENERGÉTICO
COPPE - UFRJ
Cenergia
Lab

Energy Planning Program (PPE) - COPPE/UFRJ

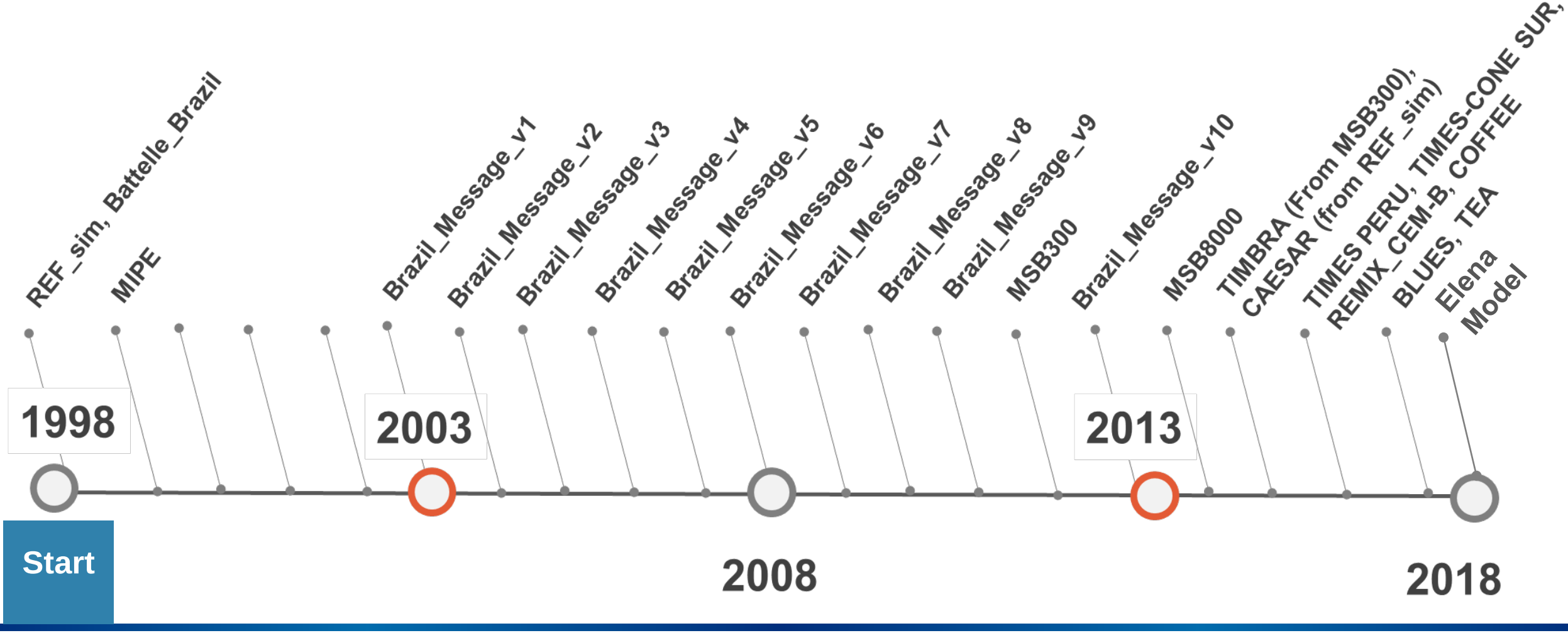
- Created in 1979 within the Nuclear Engineering Program of COPPE
- 13 Full-time professors
- Every year we accept:
  - 20-25 new M.Sc. students
  - 20-25 new D.Sc. students
- PPE is part of a small group of D.Sc./M.Sc. Programs of "Excellency" in Brazil
  - Graded 6 (scale 1-7) by CAPES, from the Ministry of Education, in the "Engineering 3" Committee
  - Graded 6 during the last three four-yearly evaluations

Our integrated modeling tools

Cenergia's Timeline



Cenergia's Model Development Timeline



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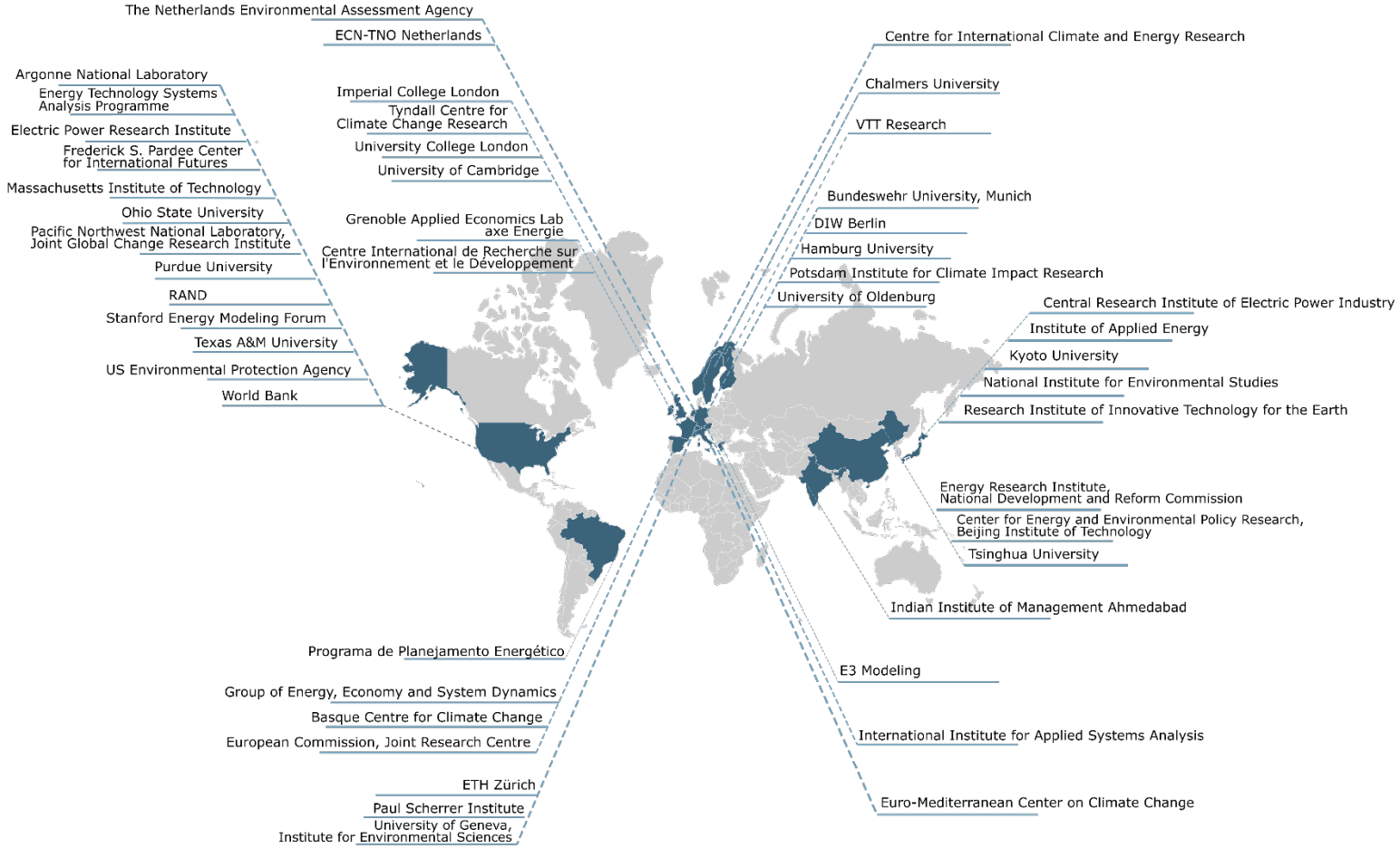
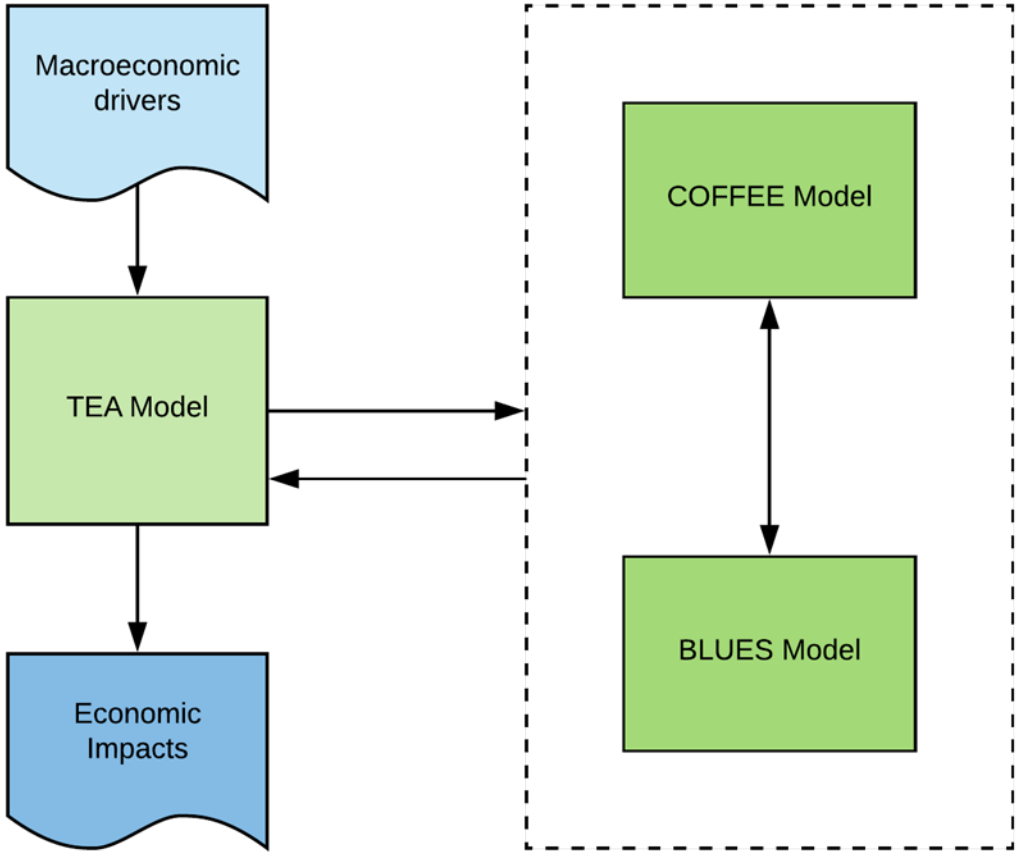
We are a member of the the Integrated Assessment Modelling Community (IAMC)



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

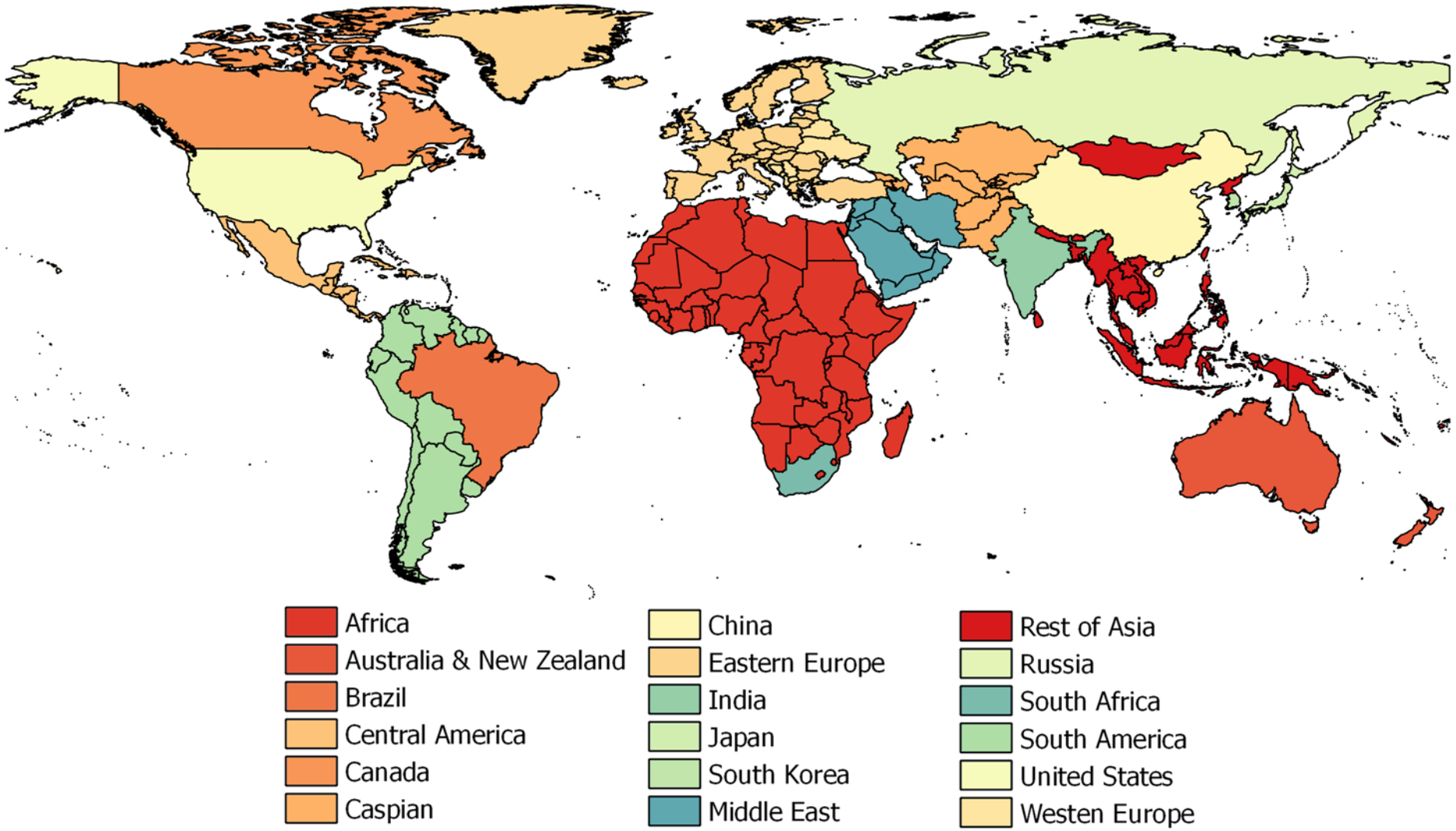


COFFEE Model

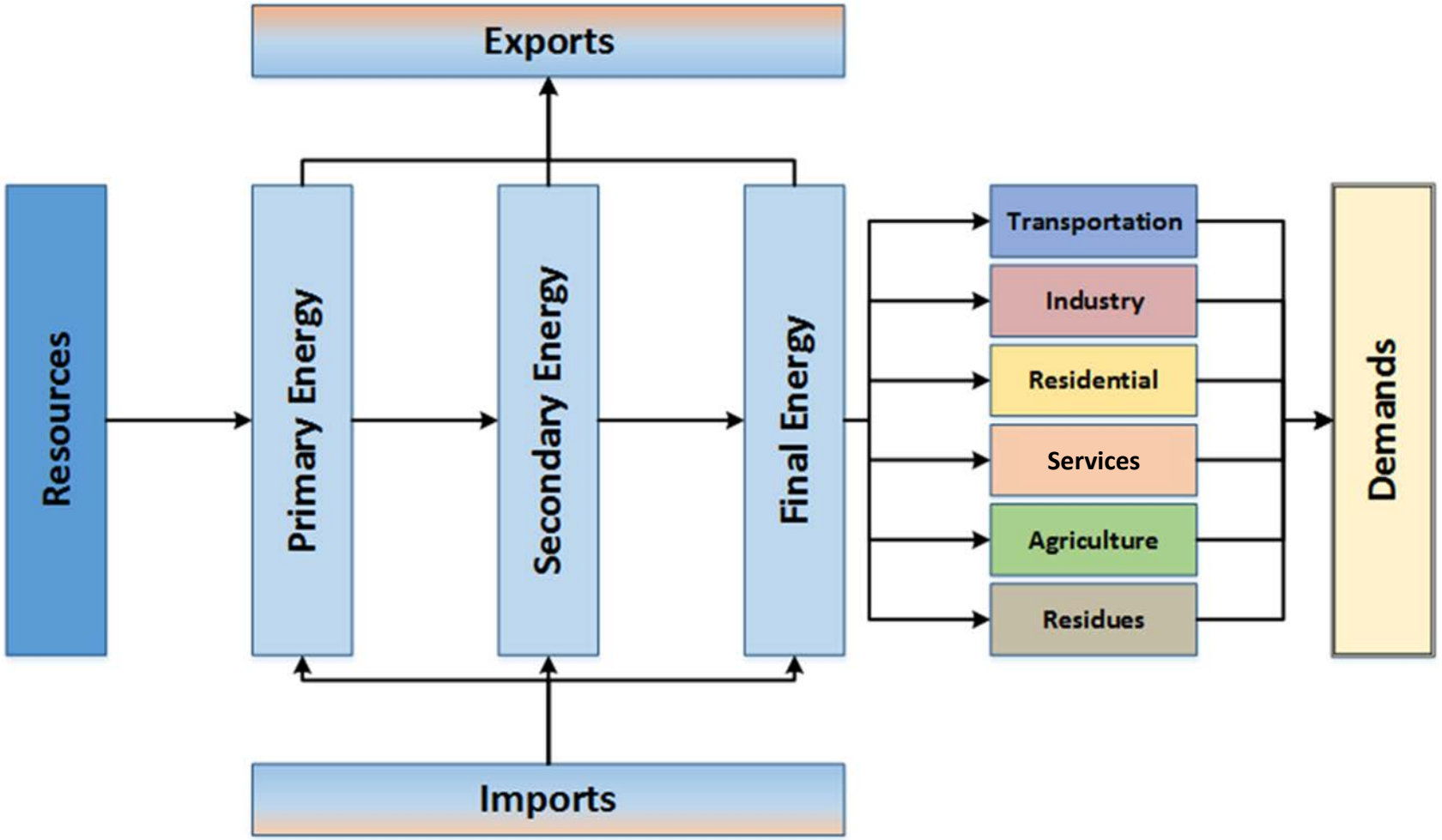
COmputable **F**ramework **F**or **E**nergy and the **E**nvironment model

- 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”.
  - D.Sc. thesis, Programa de Planejamento Energético, COPPE/UFRJ, RJ (2016)

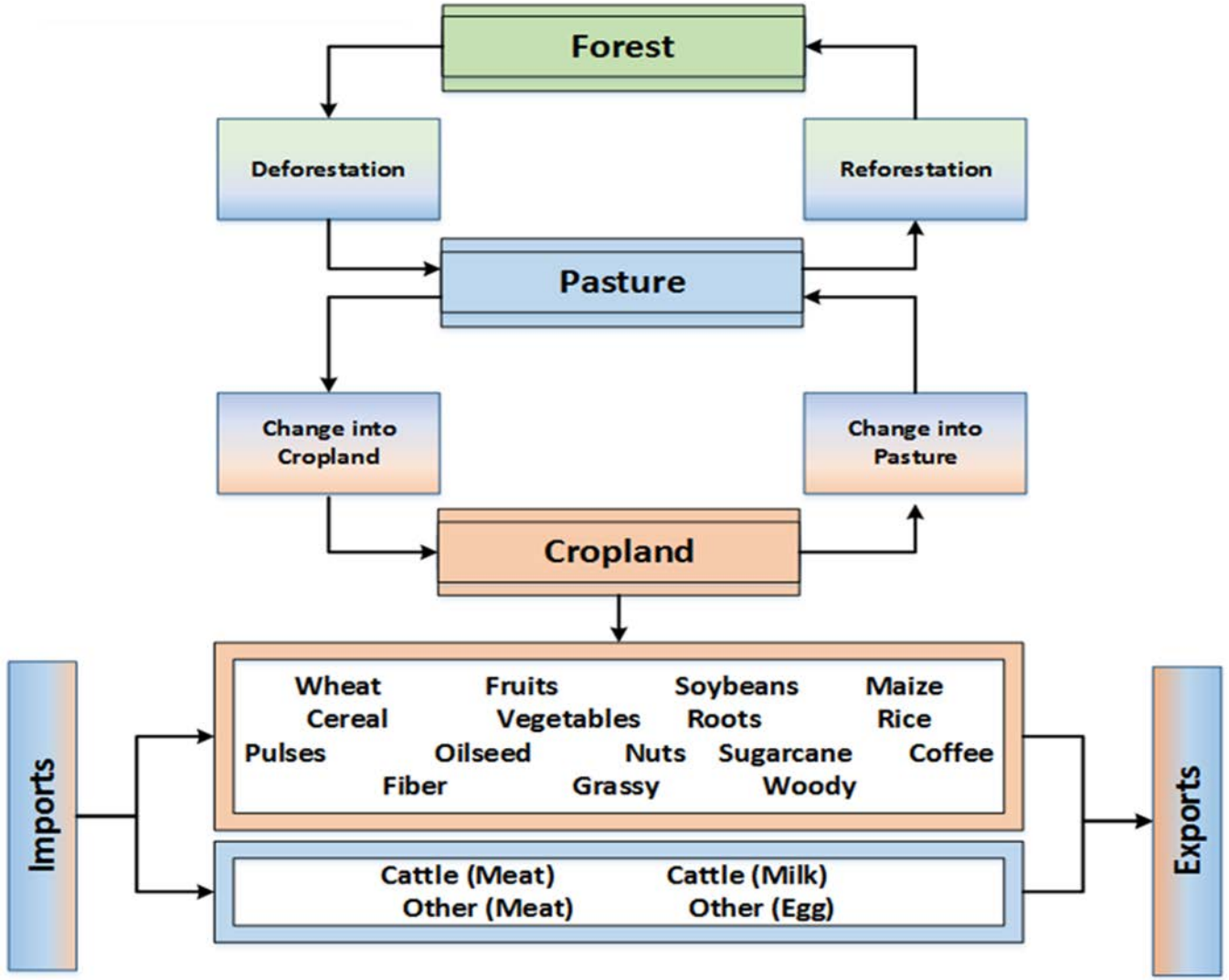
COFFEE Model



COFFEE Model: The Energy System



COFFEE Model: The Land System (simplified)



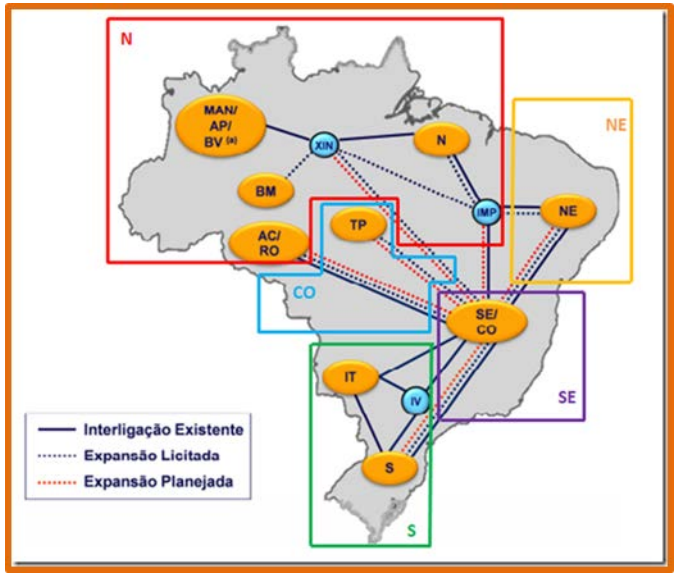
BLUES Model

Brazilian **L**and-**U**se and **E**nergy **S**ystems 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)
- Koberle, A. "Implementation of Land Use in an Energy System Model to Study the Long-term Impacts of Bionergy in Brazil and Its Sensitivity to the Choice of Agriculture Greenhouse-gas Emission Factors"
  - D.Sc. thesis, Programa de Planejamento Energético, COPPE/UFRJ, RJ (2018)

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

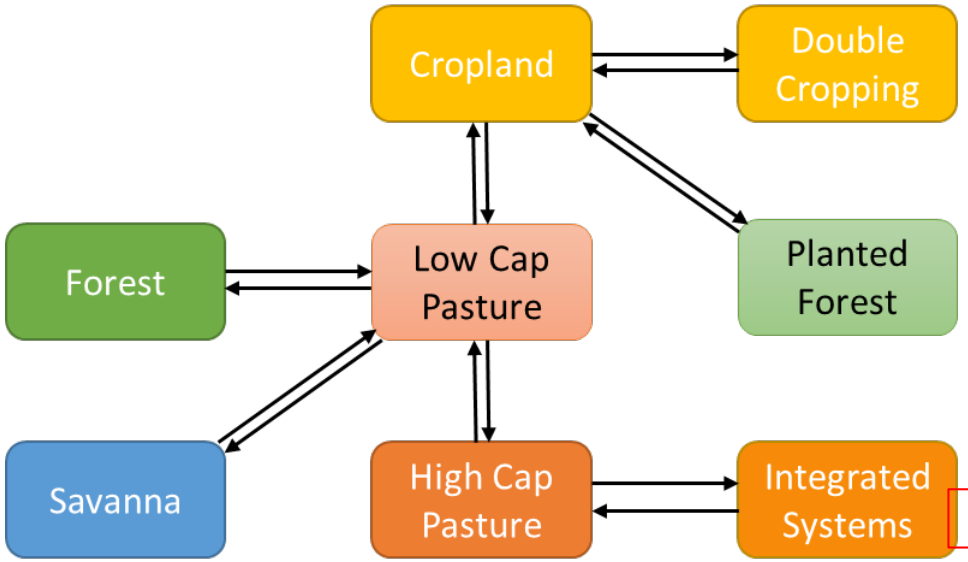


The BLUES Model: Energy System - Demand

- 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

Brazilian iNDC

Emissions reductions in 2025	Reduction in 2030
37%	**43%**

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 $GtCO_2$

- **Global 1.5°C (G1.5D or NPi400)**: GCP + global budget of 400 $GtCO_2$

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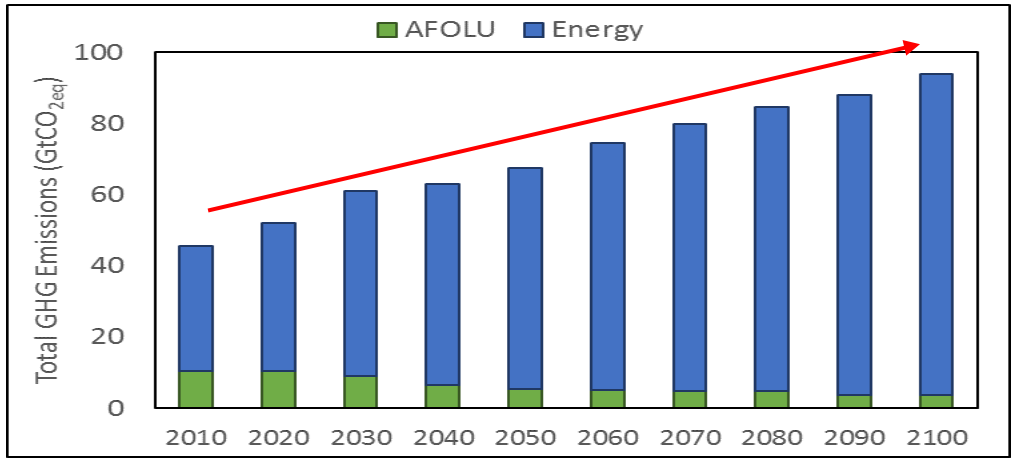
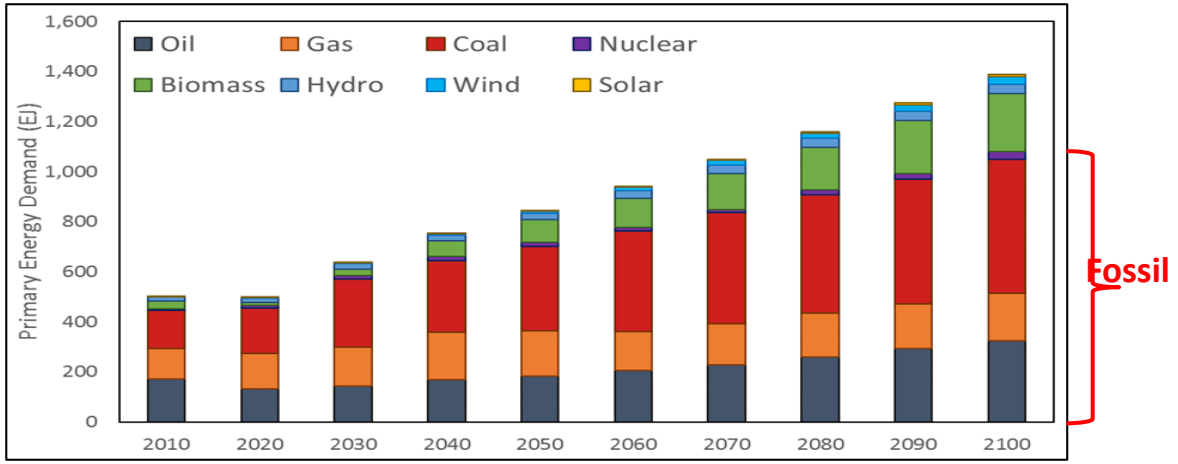
COFFEE: Current Policies (GCP or NPi)

GHG Emissions ($GtCO_{2eq}$)

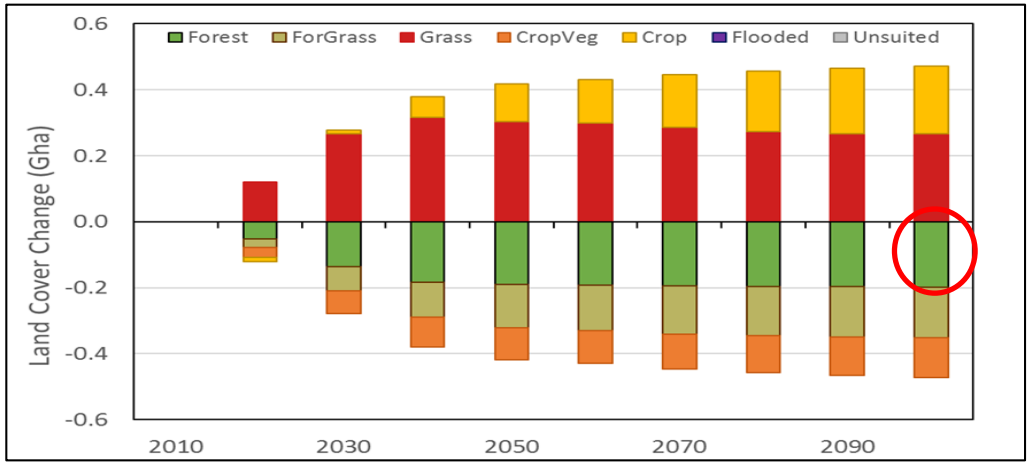


Cumulative Emissions: 5,500 $GtCO_2$

Primary Energy (EJ)



Land Use Change (Gha)



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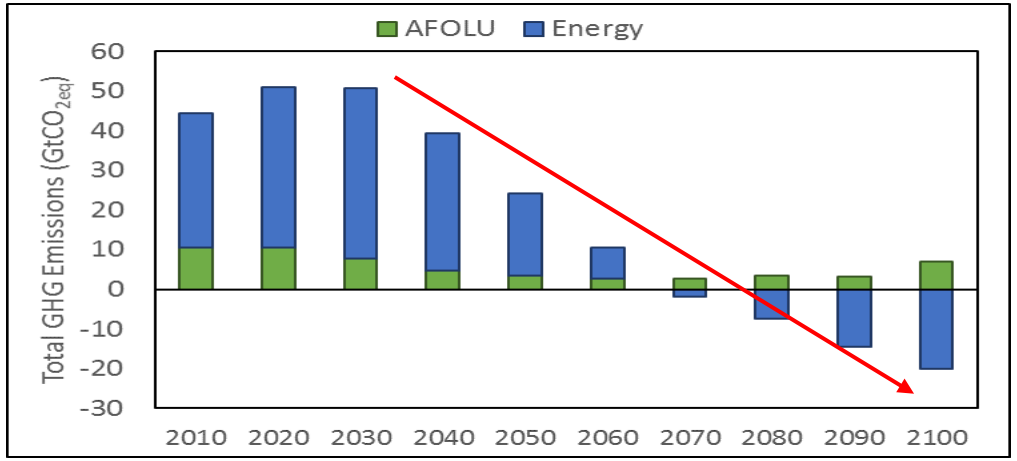
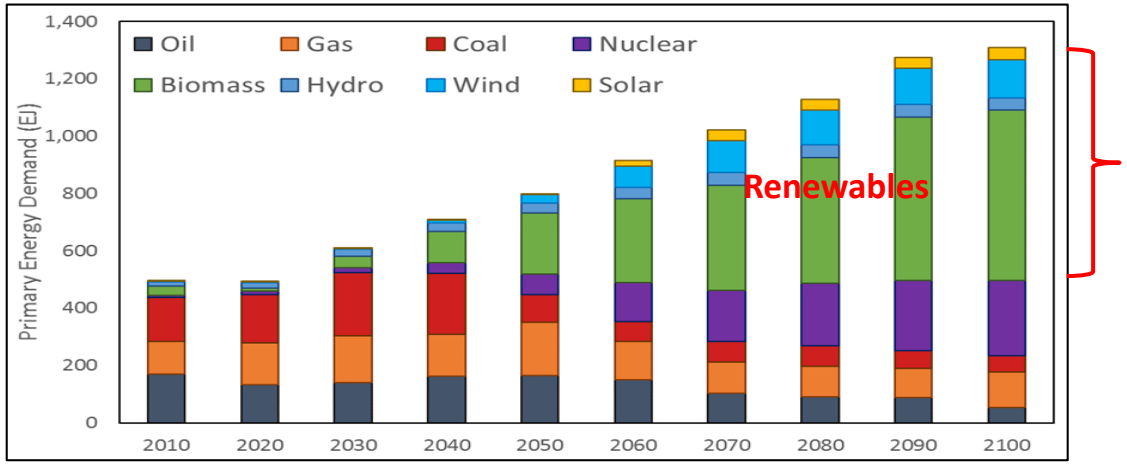
COFFEE: 2°C Scenario (G2D or NPi1000)

GHG Emissions ($GtCO_{2eq}$)



Cumulative Emissions: 5,500 $GtCO_2$

Primary Energy (EJ)



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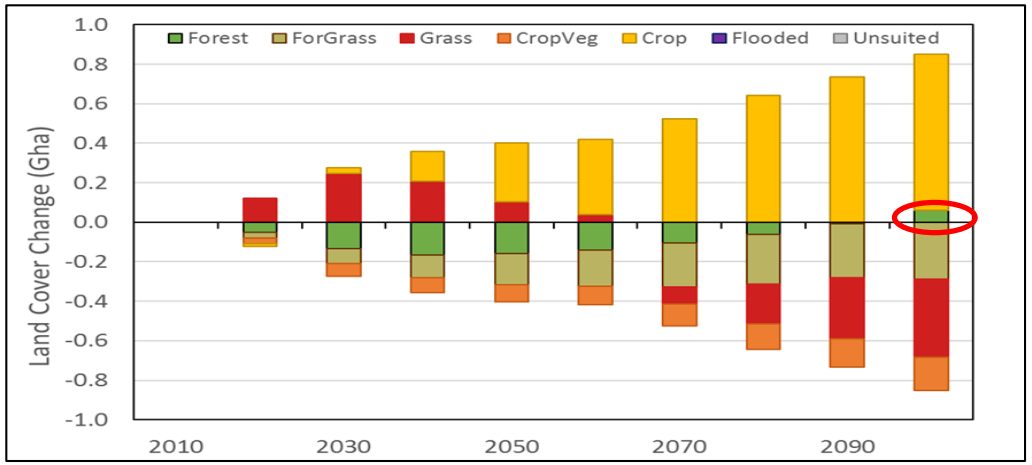

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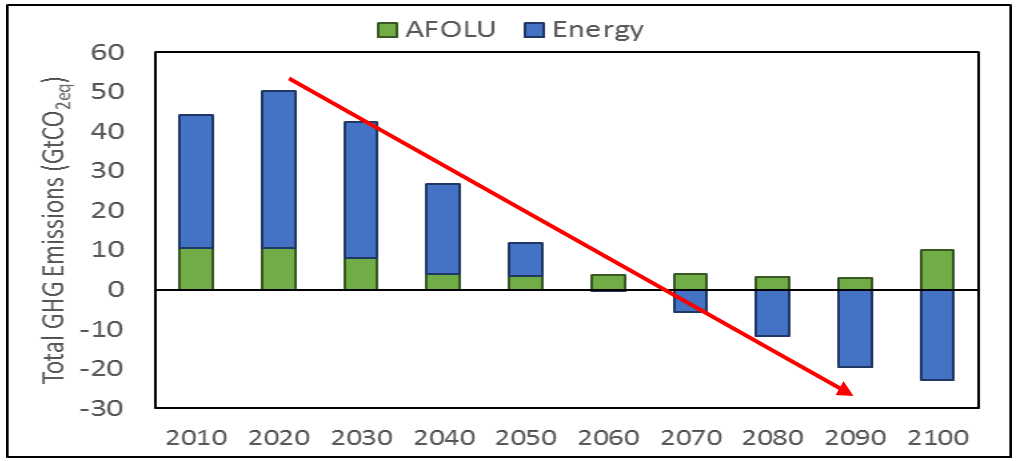
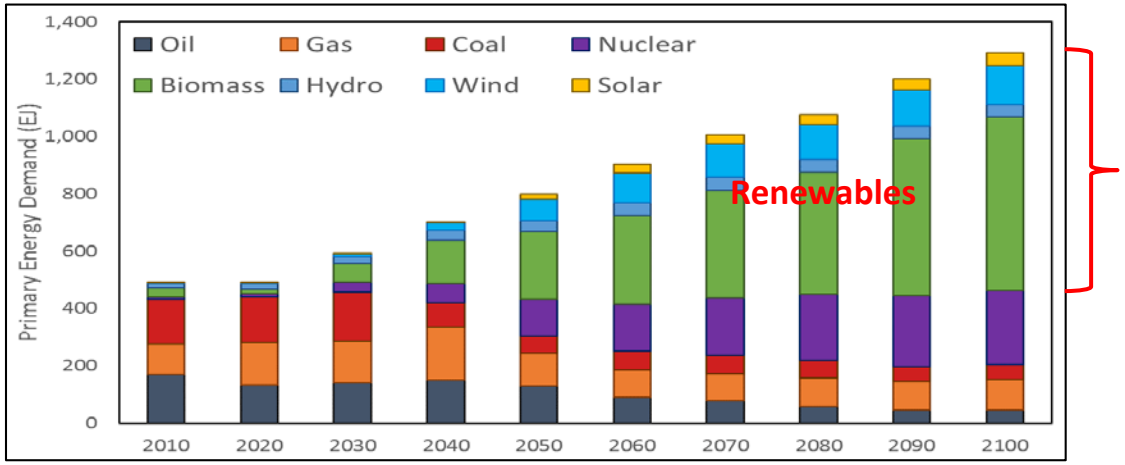
COFFEE: 1.5°C Scenario (G1.5D or NPi400)

GHG Emissions ($GtCO_{2eq}$)



Cumulative Emissions: 5,500 $GtCO_2$

Primary Energy (EJ)



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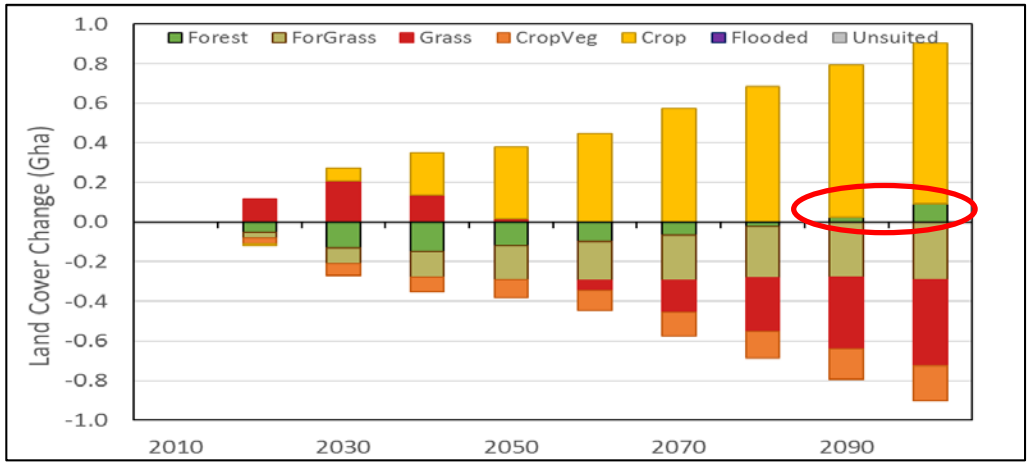

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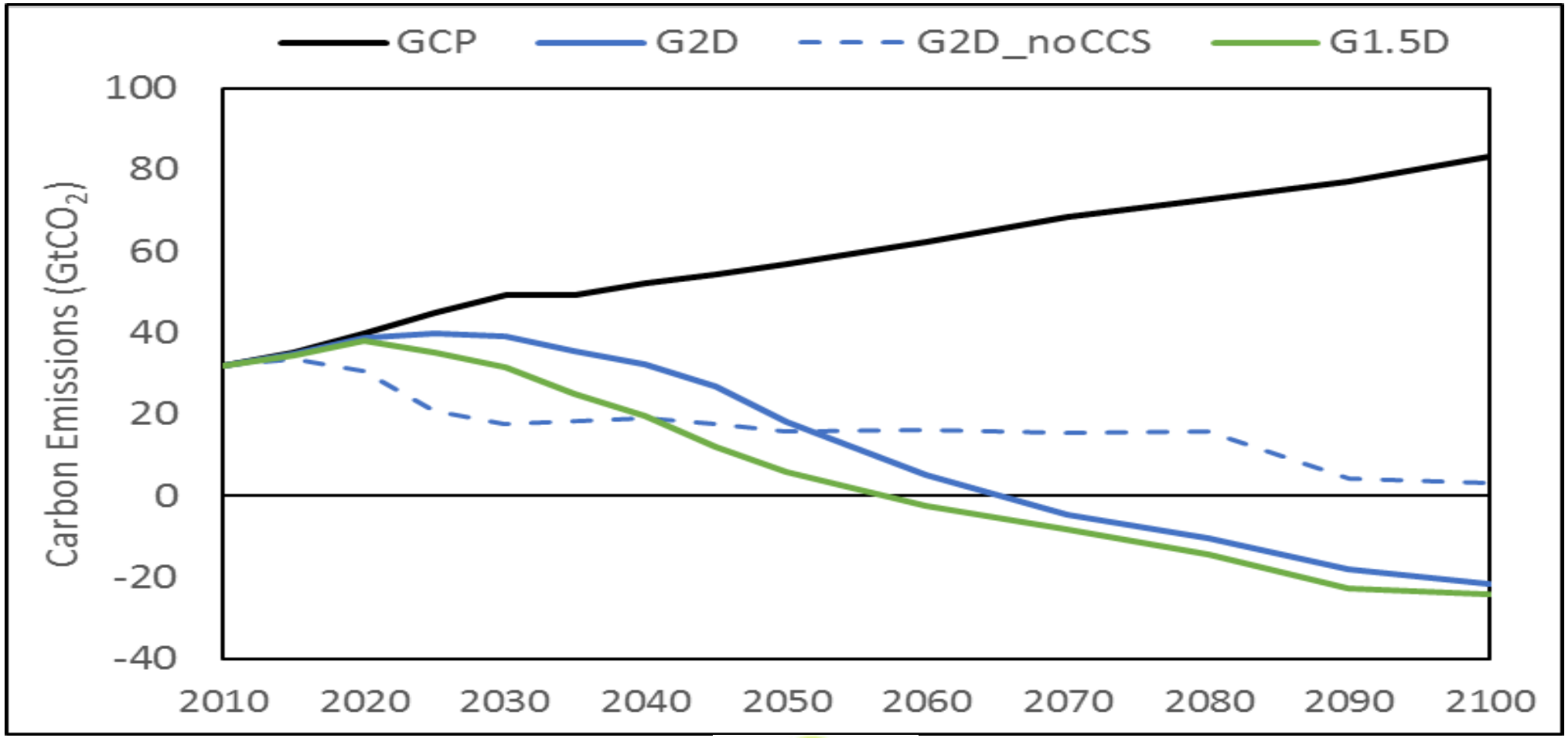
COFFEE: Scenario Comparison

Global CO2 Emissions



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COFFEE: National Budgets for Brazil

COFFEE's CO_2 budgets for Brazil for the 2010-2050 period:
(to be used in the BLUES Model)

- **Global 2°C (G2D or NPi1000)**: 23.6 $GtCO_2$ (out of 1,000 $GtCO_2$)

- **Global 1.5°C (G1.5D or NPi400)**: 17.0 $GtCO_2$ (out of 400 $GtCO_2$)

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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 $GtCO_2$)

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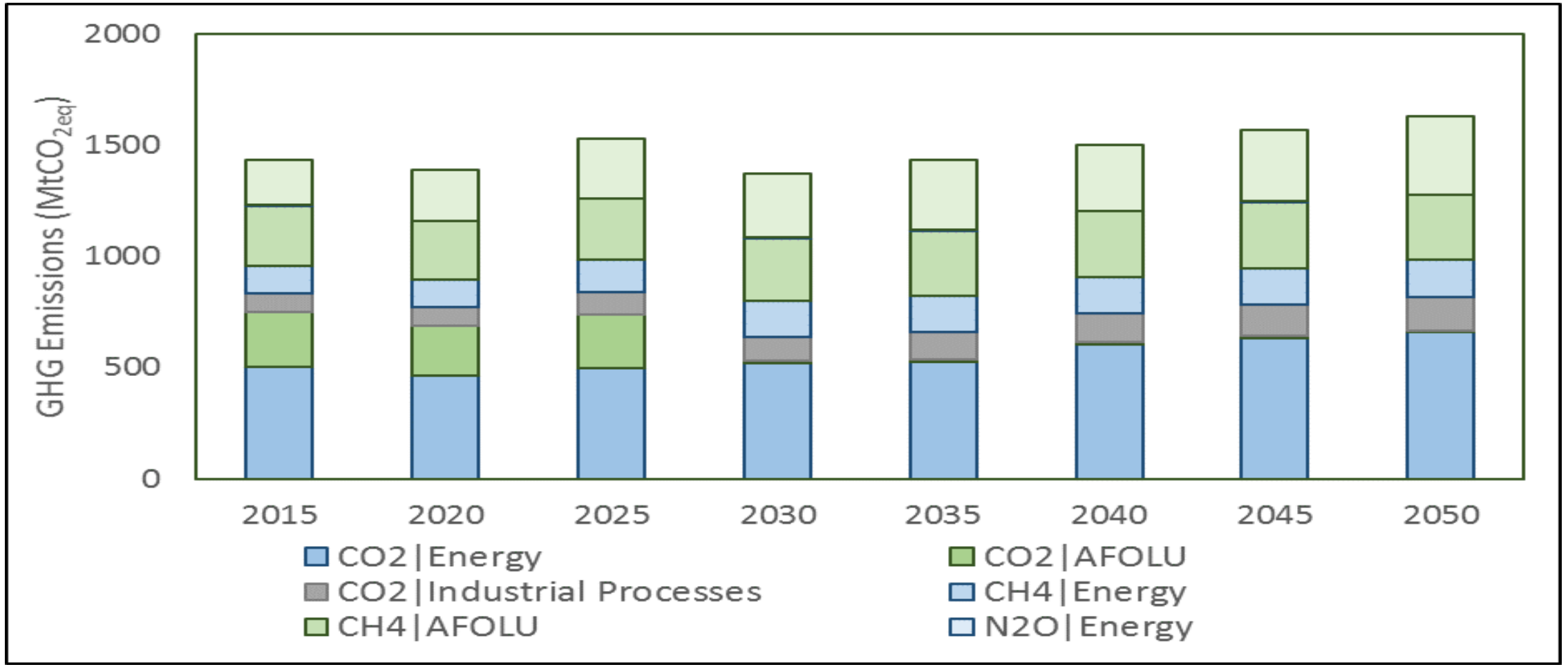
BLUES: Current Policies (NCP or NPi)

GHG Emissions



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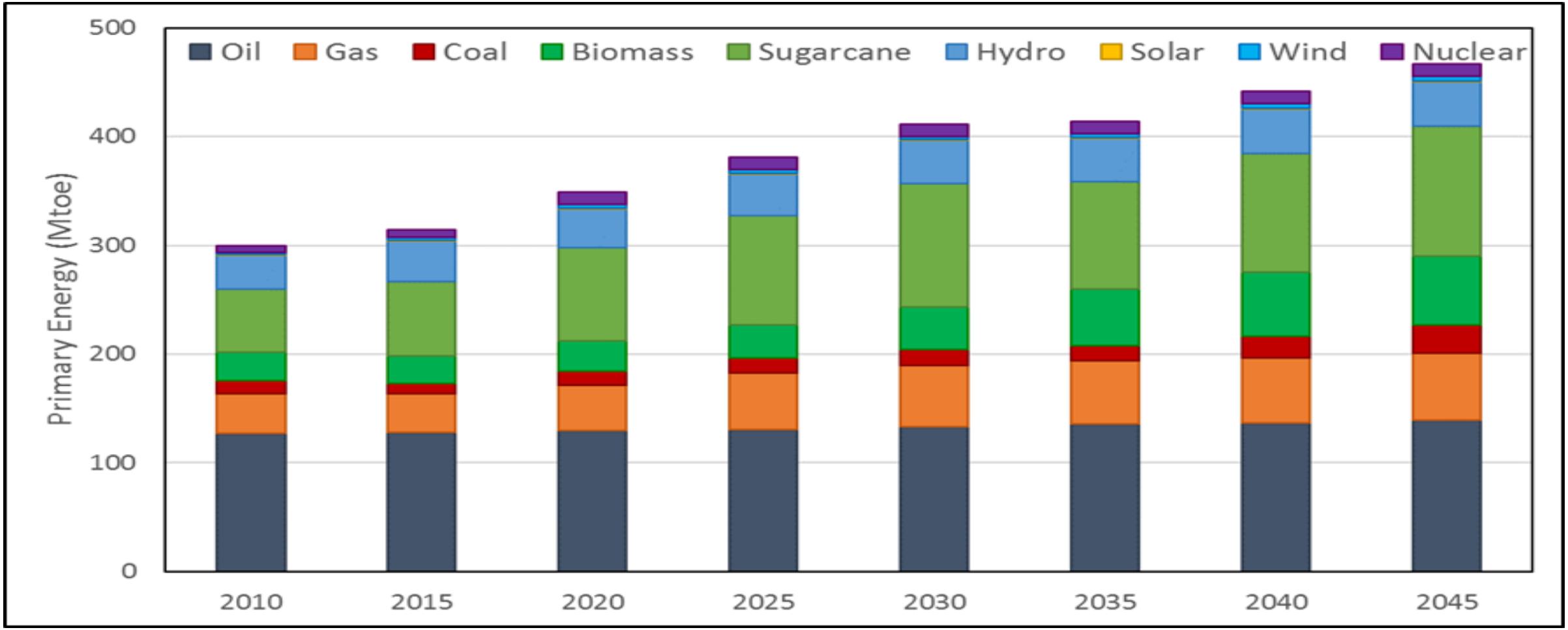
BLUES: Current Policies (NCP or NPi)

Primary Energy Consumption



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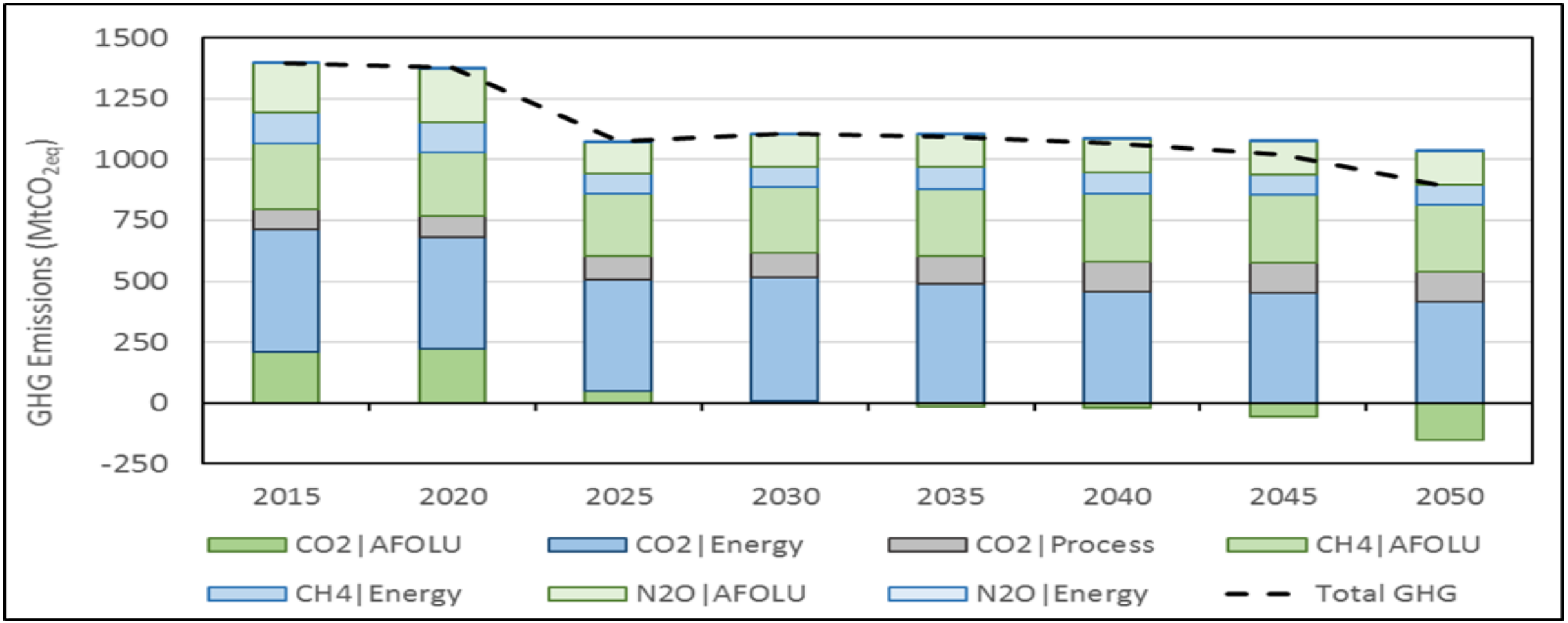
BLUES: 2°C Scenario (N2D or NPi1000)

GHG Emissions



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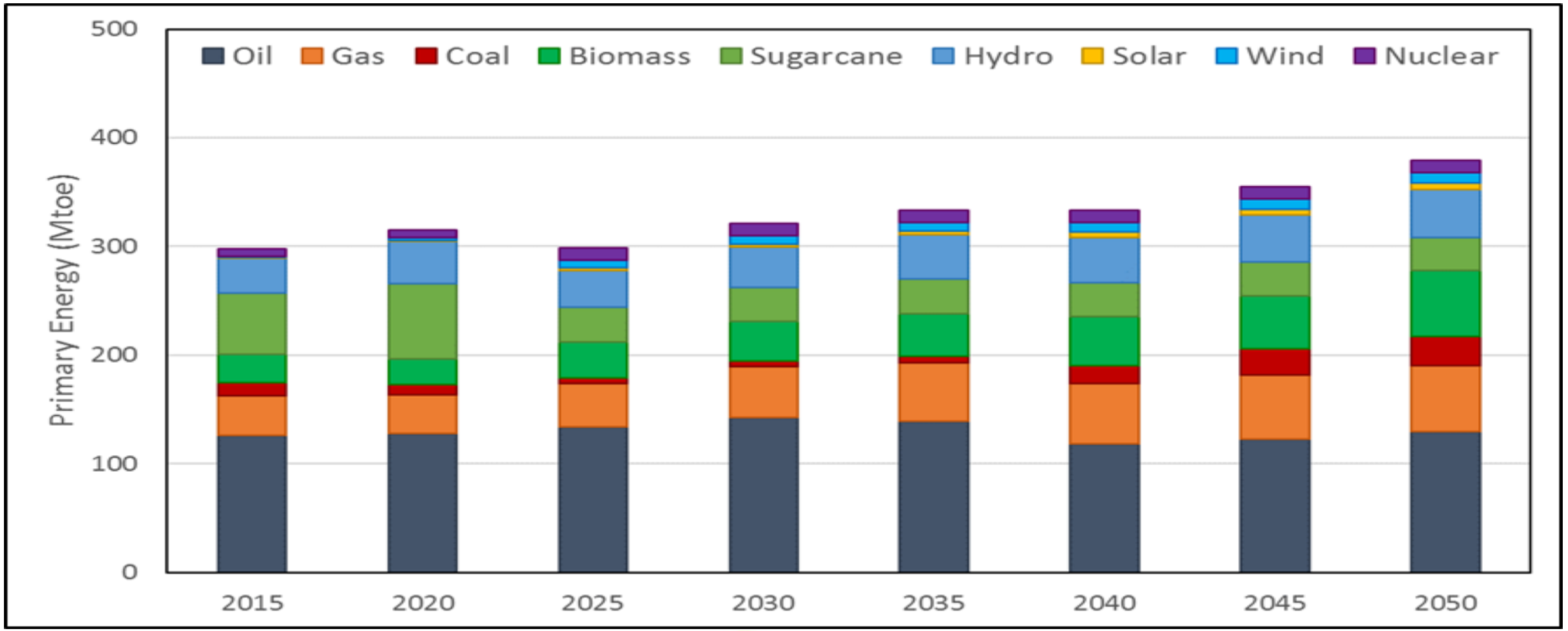
BLUES: 2°C Scenario (N2D or NPi1000)

Primary Energy Consumption



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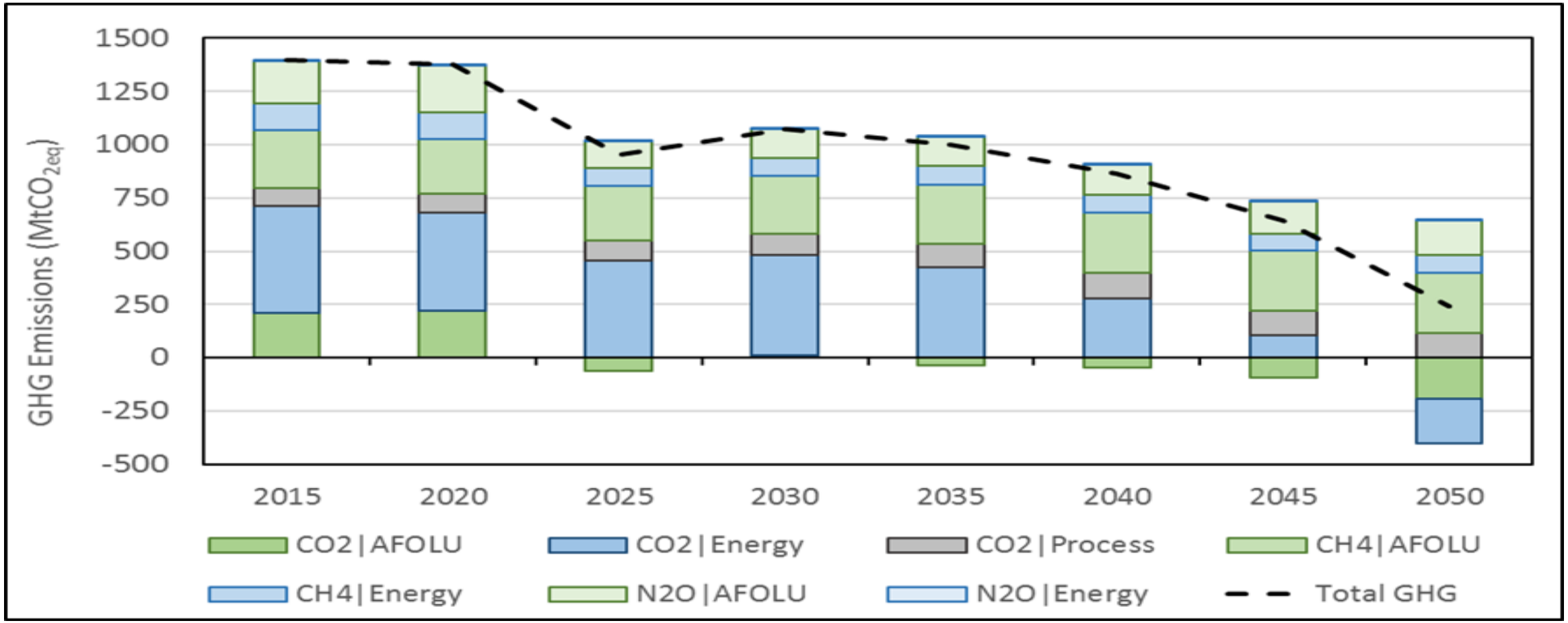
BLUES: 1.5°C Scenario (N1.5D or NPi400)

GHG Emissions



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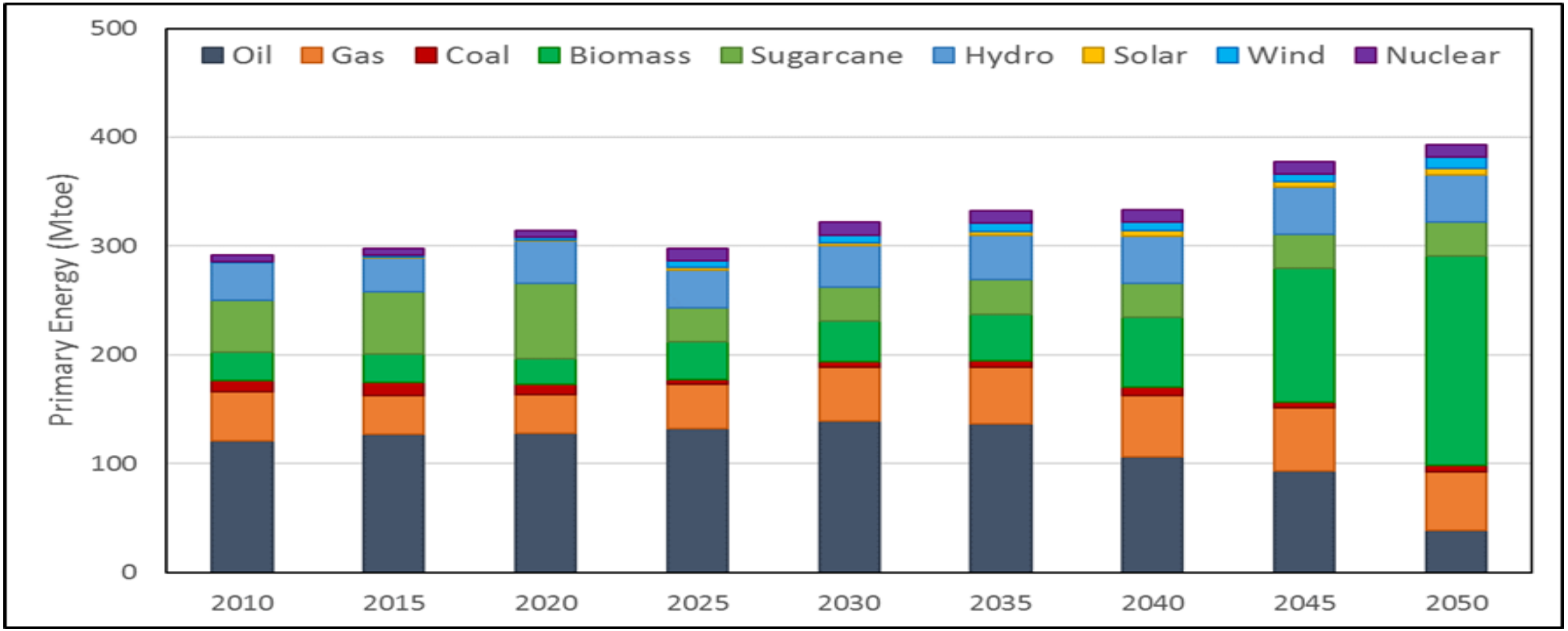
BLUES: 1.5°C Scenario (N1.5D or NPi400)

Primary Energy Consumption



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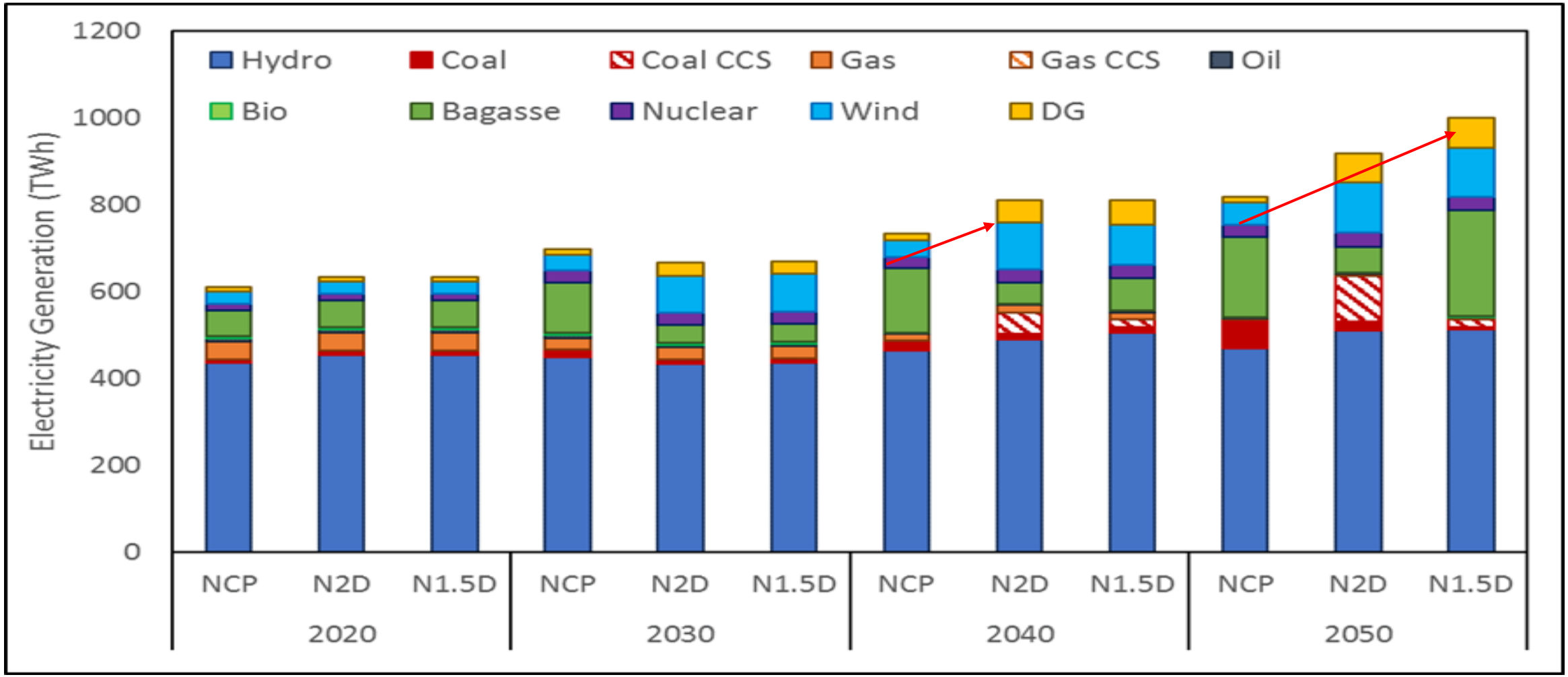
BLUES: Scenario Comparison

Electricity Generation (TWh)



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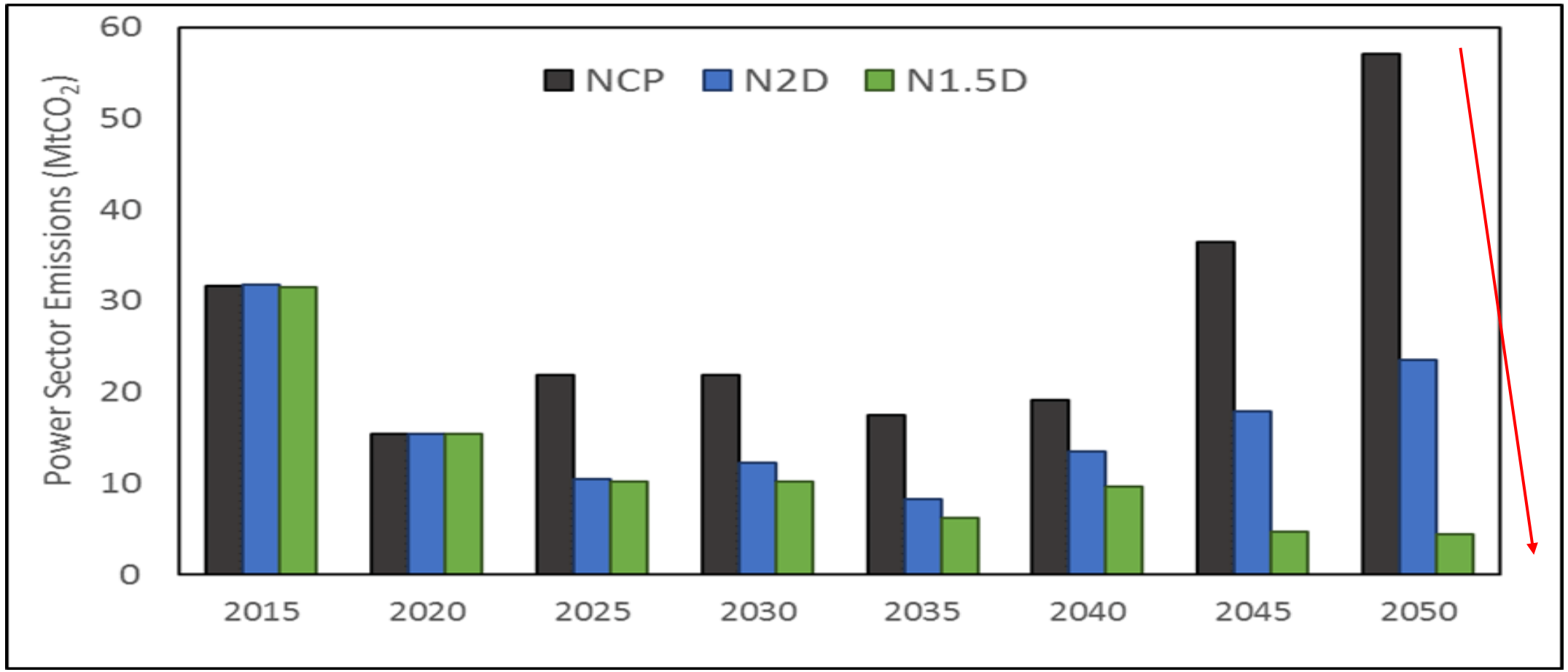
BLUES: Scenario Comparison

Power Sector Emissions ($MtCO_2$)

Note: Industrial and refinery CHP excluded



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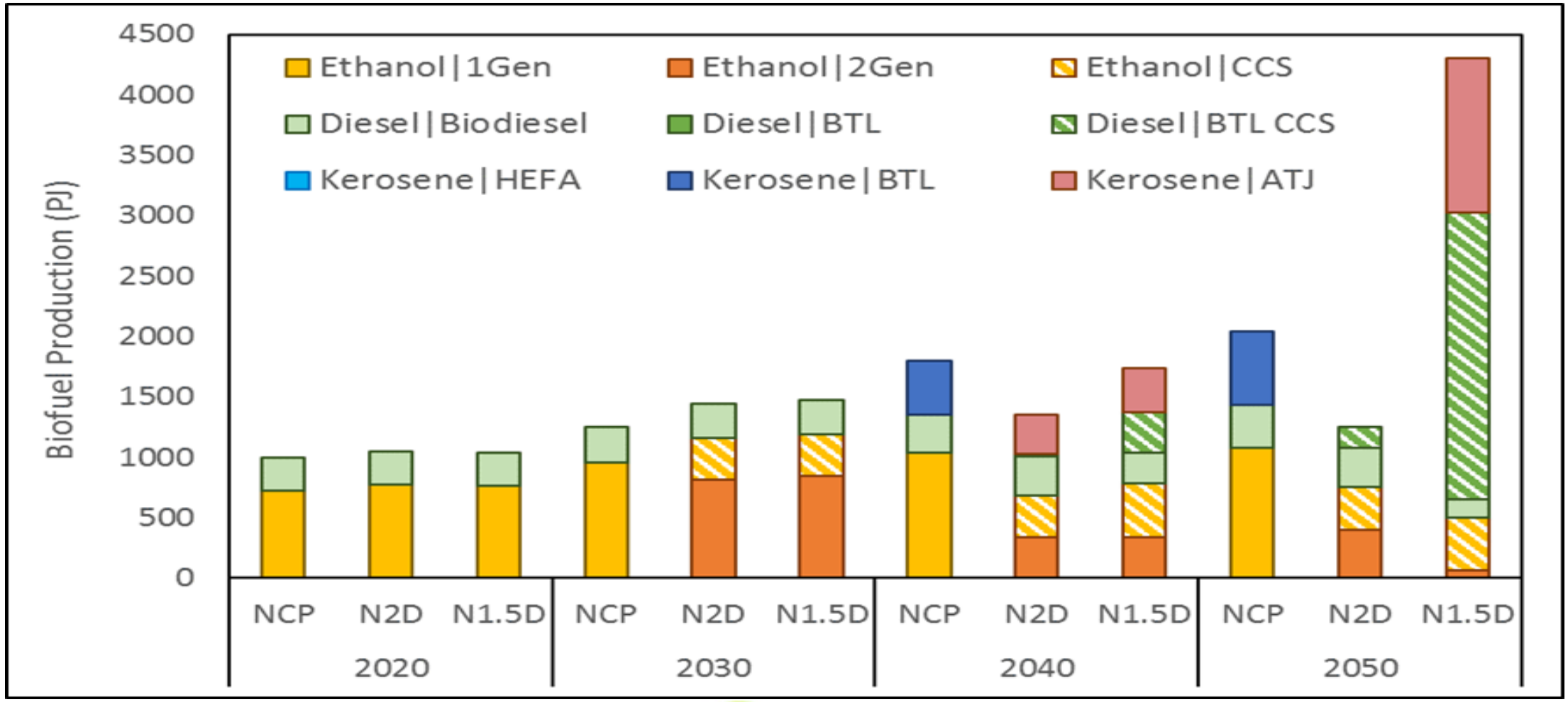
BLUES: Scenario Comparison

Liquid Biofuel Production (PJ)



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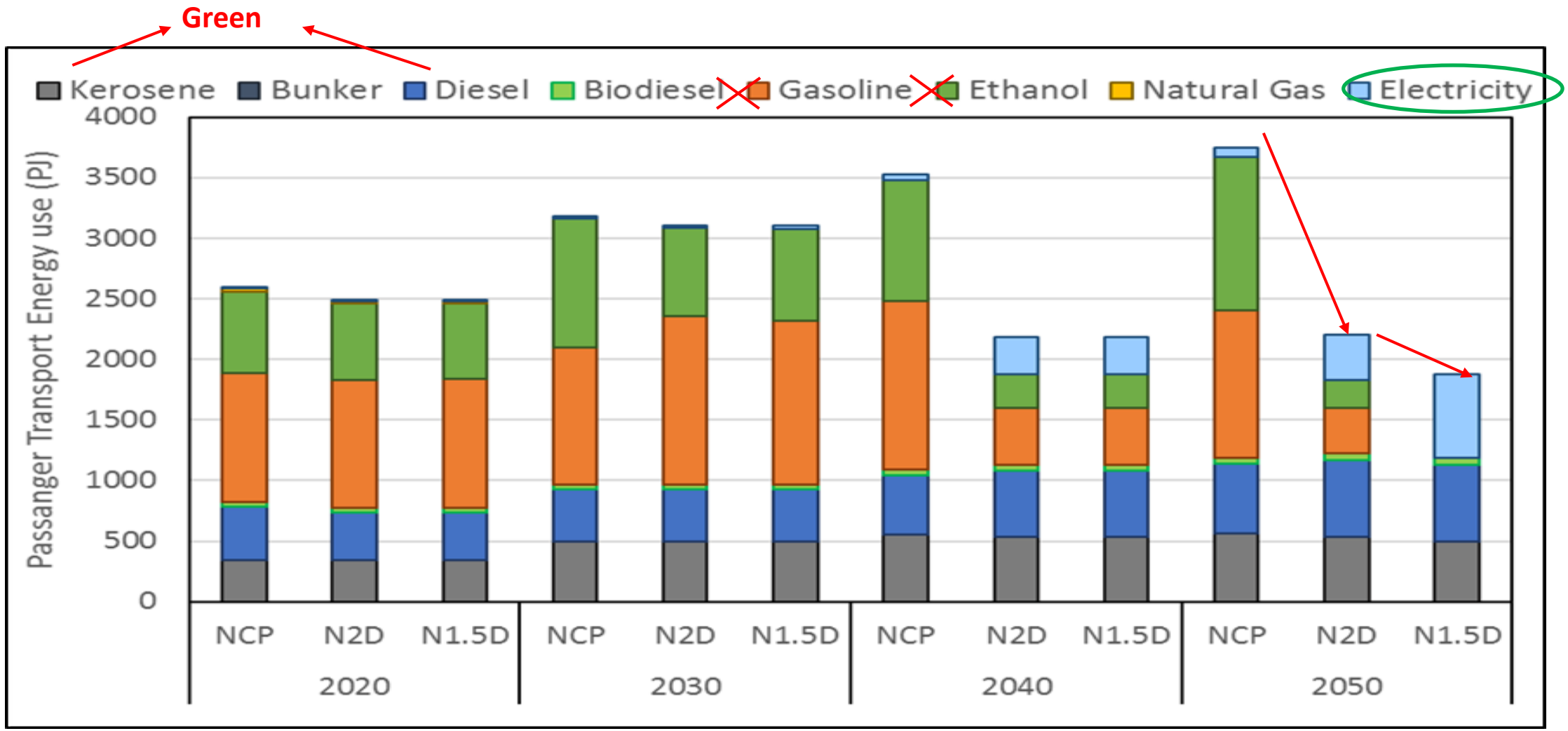
BLUES: Scenario Comparison

Transport Sector – Passenger Energy Use



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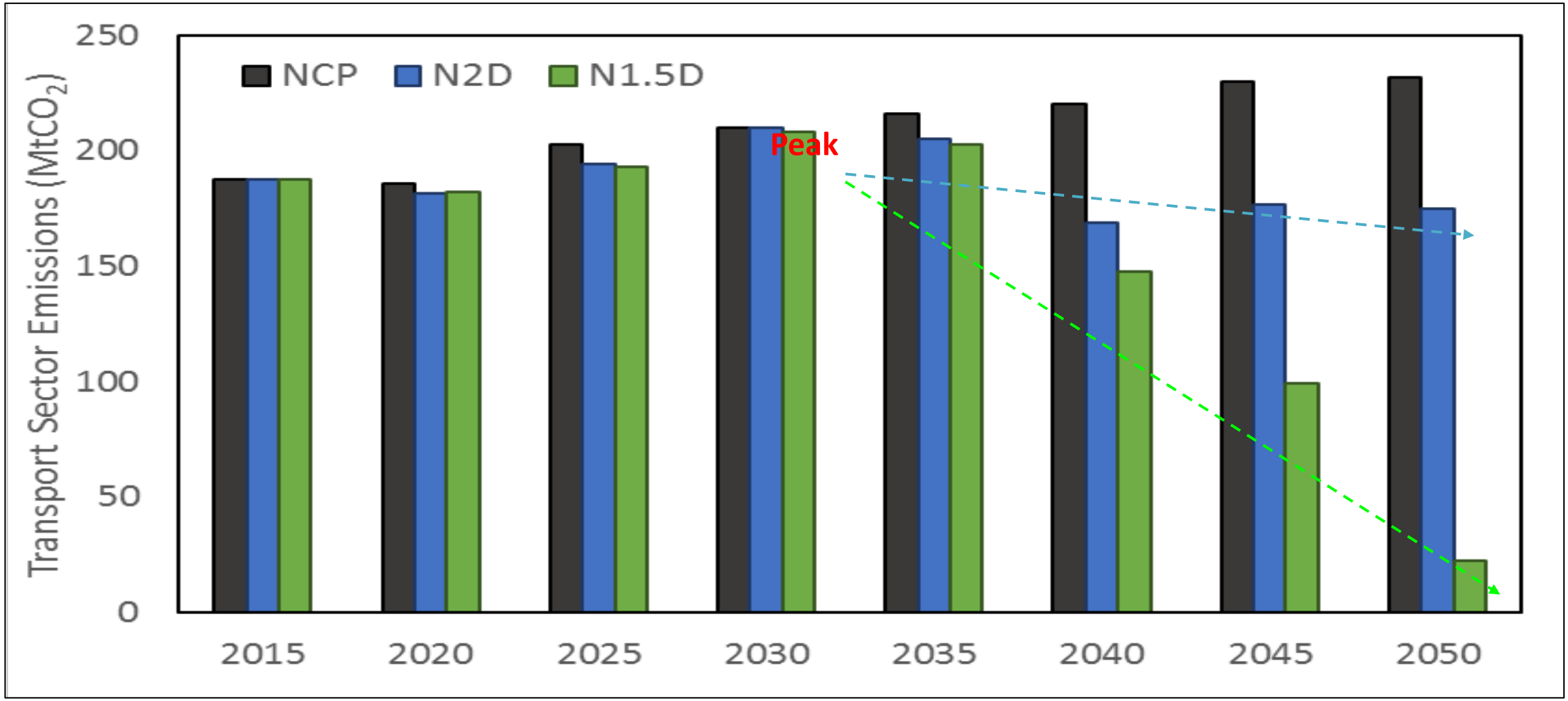
BLUES: Scenario Comparison

Transport Sector – GHG Emissions



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Other interesting uses for Systems Analysis

Rochedo et al, 2018

nature climate change
LETTERS
https://doi.org/10.1038/s41558-018-0213-y

The threat of political bargaining to climate mitigation in Brazil

Pedro R. R. Rochedo[1], Britaldo Soares-Filho[2], Roberto Schaeffer[1]*, Eduardo Viola[3], Alexandre Szklo[1], André F. P. Lucena[1], Alexandre Koberle[1], Juliana Leroy Davis[2,4], Raoni Rajão[4] and Regis Rathmann[1]

- 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 provisionary 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 2ºC world?
  - CO_2 budget from 2010 to 2050
  - Defined by literature review and available data (n=22)

Budget Nacional de 2010 a 2050 ($GtCO_2$)				
Menor	**P25**	**Mediana**	**P75**	**Maior**
4.7	**16.5**	**23.8**	**35.5**	**41.0**

- COFFEE's CO2 budget for Brazil is 23.6 $GtCO_2$

Rochedo et al, 2018

- Based on past records, we defined three environmental governance scenarios, which led to different deforestation rates and CO_2 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

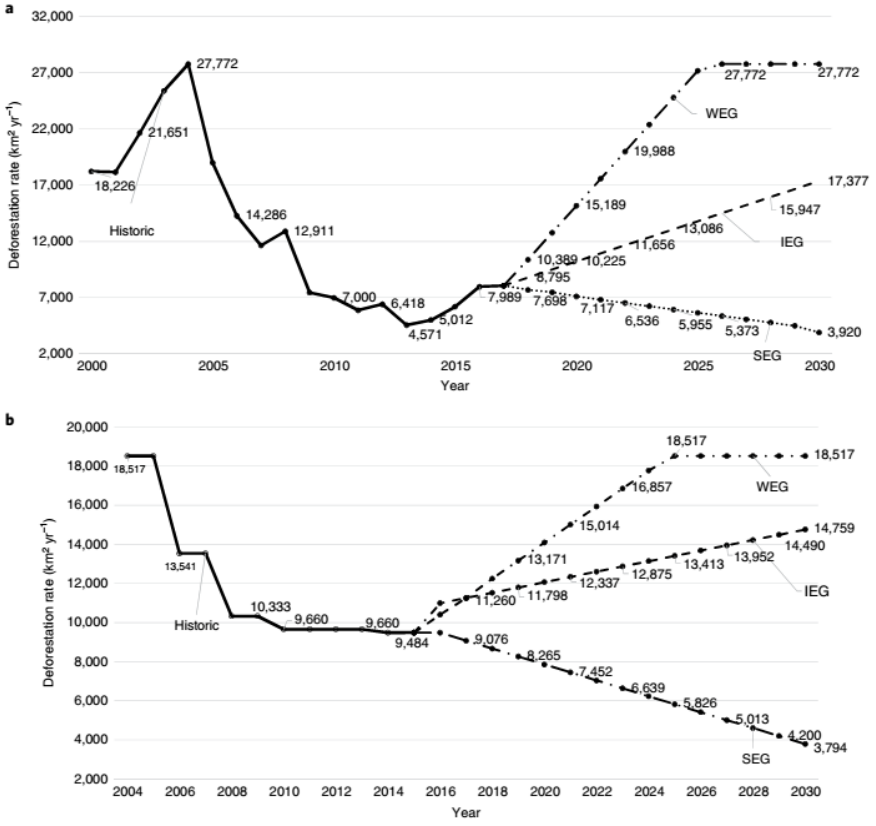

Fig. 1 | Deforestation rates. a,b, Deforestation rates for the Amazon (**a**) and Cerrado (**b**) biomes.

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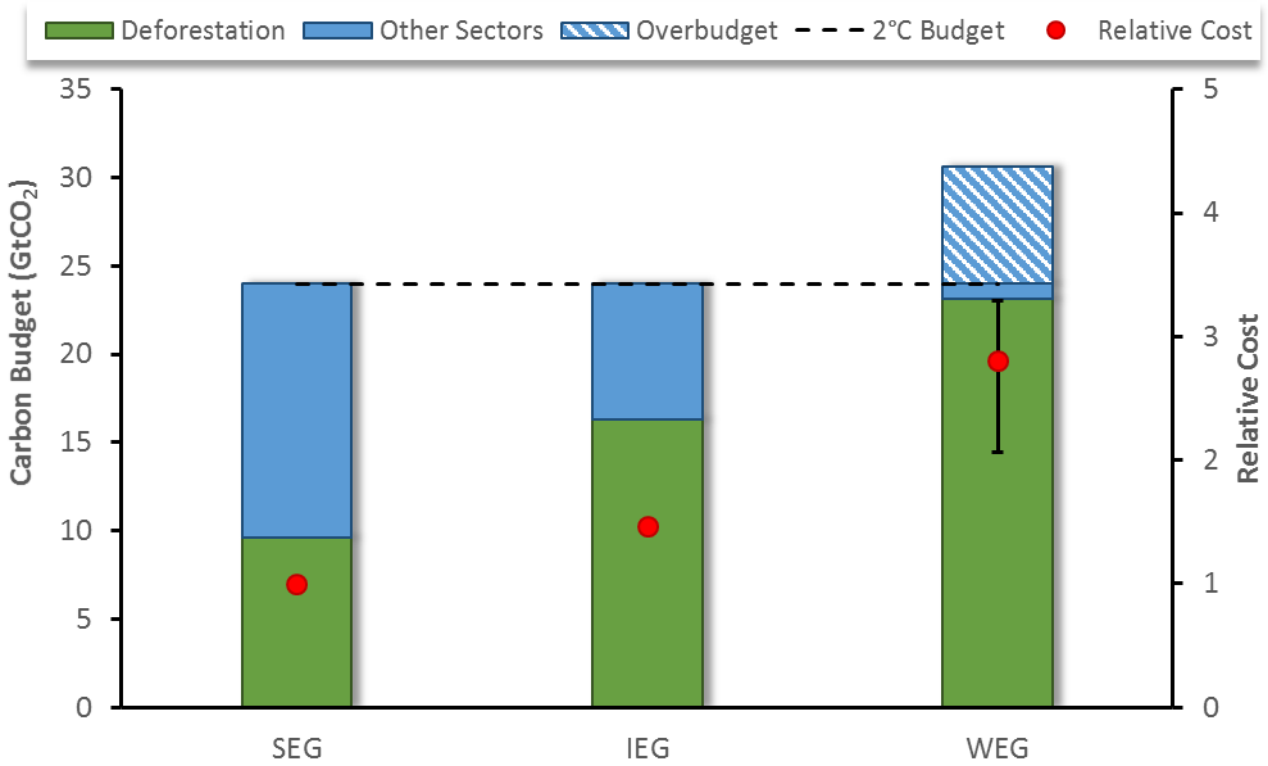
Rochedo et al, 2018

- LULUCF CO_2 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

Sector	SEG (10^9 US$_{2010}$)		IEG (10^9 US$_{2010}$)		WEG (10^9 US$_{2010}$)	
	Investment	O&M	Investment	O&M	Investment	O&M
Fuels[1]	622	381	1,132	418	1,142	417
Power	367	86	641	109	675	109
Industrial	48	52	49	65	49	65
Others	164	136	167	137	167	138
Penalty	-	-	-	-	-	2,440 (1,069-3,333)[2]
Total	1,201	654	1,989	729	2,033	3,169 (1,798-4,062)[2]

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!

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