INTEGRATED GREENHOUSE-GAS-EMISSION MITIGATION SCENARIOS FOR BRAZIL TO 2050

This material is based on partial and preliminary results of the project "Mitigation Options of Greenhouse Gas (GHG) Emissions in Key Sectors in Brazil". The integrated low-carbon scenarios were developed for use in this project exclusively. Thus, they do not represent the official view of the government on this issue.

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+ 84 researchers

Energy System

Contents

- Context
- MESSAGE tool
- Sectoral models
- Integration of sectoral results with the MESSAGE energy optimization model
- Integrated scenarios of the energy sector
- Final considerations and activities currently underway

Context

Scenarios

- Reference (REF): "the past helping to explain the future"
  - Less influence from premises
  - Less technical effort to elaborate
  - Generally conservative
- Mitigation / Low Carbon (LC): scenarios with efforts to reduce GHG emissions
  - Represent alternative scenarios (Low-carbon and Low-carbon with Innovation)

Energy Model Optimization

- Optimal solution: find the "best" solution
- Low-cost solutions for the energy system
- Efficient allocation of resources
- Main constraint: demands have to be met
  - Additional restrictions may represent physical, technological, economic or market limitations
  - Restrictions also serve to make possible solutions more realistic
- Disadvantages:
  - Corner solutions, failure to detect market shortcomings (although the use of restrictions could help to deal with this issue)

MESSAGE tool

MESSAGE

Model for Energy Supply Strategy Alternatives and their General Environmental Impacts

- Linear programming **optimization**
- Originally developed by IIASA (Austria)
- Applied to national and global energy sectors for decades
- Applicable for energy and/or mass balances

Instrument	Detailing	Computational procedure	Balance	Geographical area	Timeframe
MESSAGE	***Bottom-up***	***Optimization***	***Partial***	***Global/ national/***	***Medium and long term***

MESSAGE MSB8000 – Some details

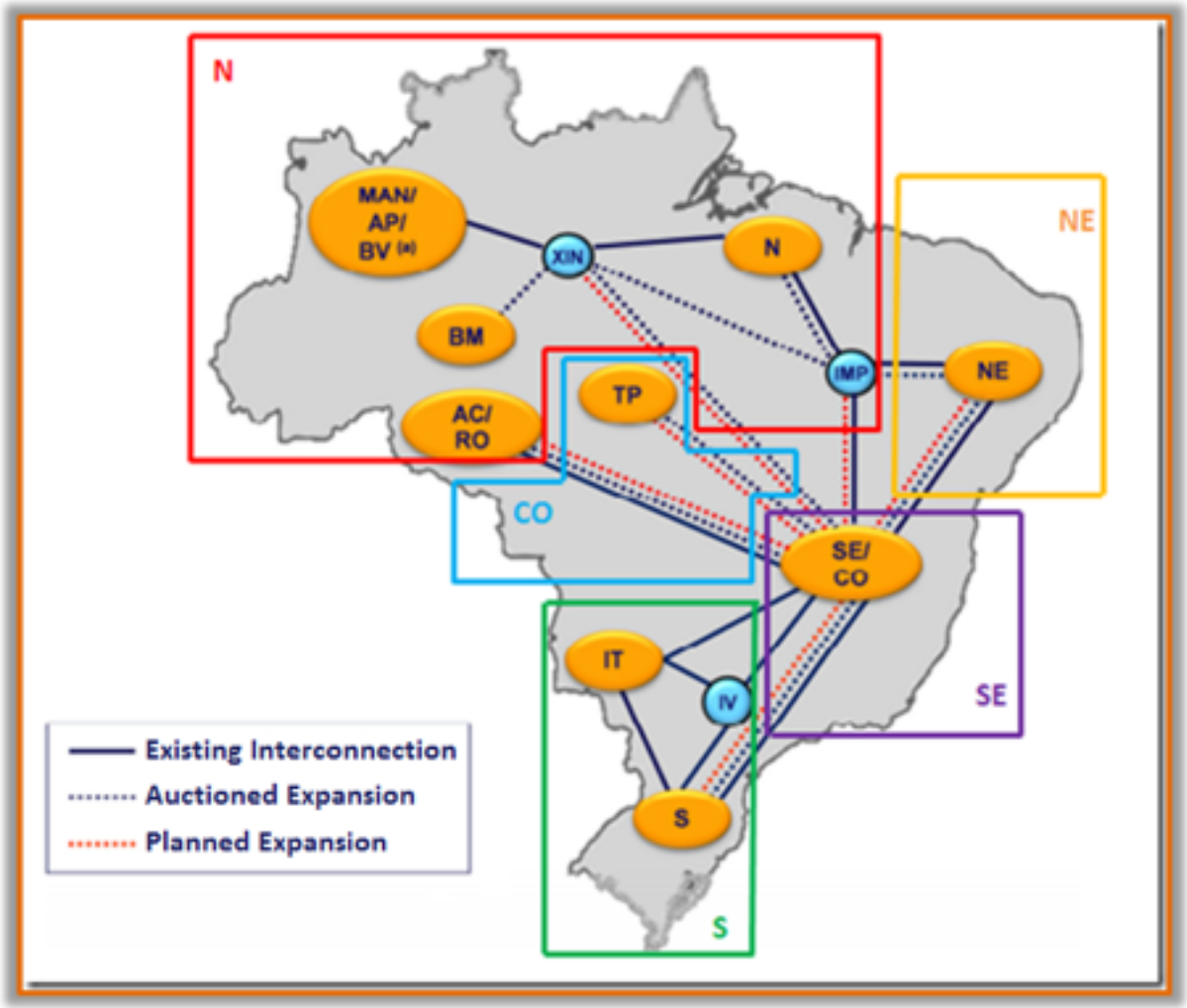
Analysis timeframe:
2010 - 2050
5-year intervals

Seasonality:
12 months

Daily load curve:
24 hours

6 regions
(transport of electricity and gas)

Approximately 8,000 technologies
(> 400 LC technologies)



MSB8000: Abatement measures

- Division:
  - Conversion: fuel substitution, increased efficiency (furnaces, boilers)
    - Converting an energy source into a utility (heat, steam, electricity)
  - Consumption: reducing consumption (ex: insulation of lines, replacement of motors/electrical equipment)
    - No new inputs
    - Product is limited by the potential, determined by application of the measure (year to year)
  - Process: substitution of processes
    - Competition to meet product demand

Optimization: restrictions

- Restrictions on installed capacity
- Restrictions on capacity being built
- Restrictions on the use of a technology
- Restrictions on balance and share:
  - For example, 30% renewable energy on electricity
- Informative restrictions:
  - For example, using or not using technologies with CCS
- Environmental restrictions
- Financial constraints: CO_2 emissions

Sectoral Models

Sectoral Models

- Main Objective: Represent the behavior of agents
- Typical results: Demand for energy services, emissions, potential and abatement costs

Procedures:

1 – Description and characteristics of the sector

- Principal agents
- Production profile and socioeconomic data
- Energy consumption and GHG emissions profile
- Technological routes: equipment, processes, inputs
- Detailed technical data: efficiency, costs, restrictions

Sectoral Models - Procedures

2 – Starting the model structure

- Database and tools
- Representation of the historical period
- Adjust coefficients, efficiency, shares and assumptions

3 – Use model to construct sectoral scenarios

- Identification of key variables for the evolution of the sector (GDP, population, ...)
- Construction of the structure of the model
- Determination of the set of assumptions

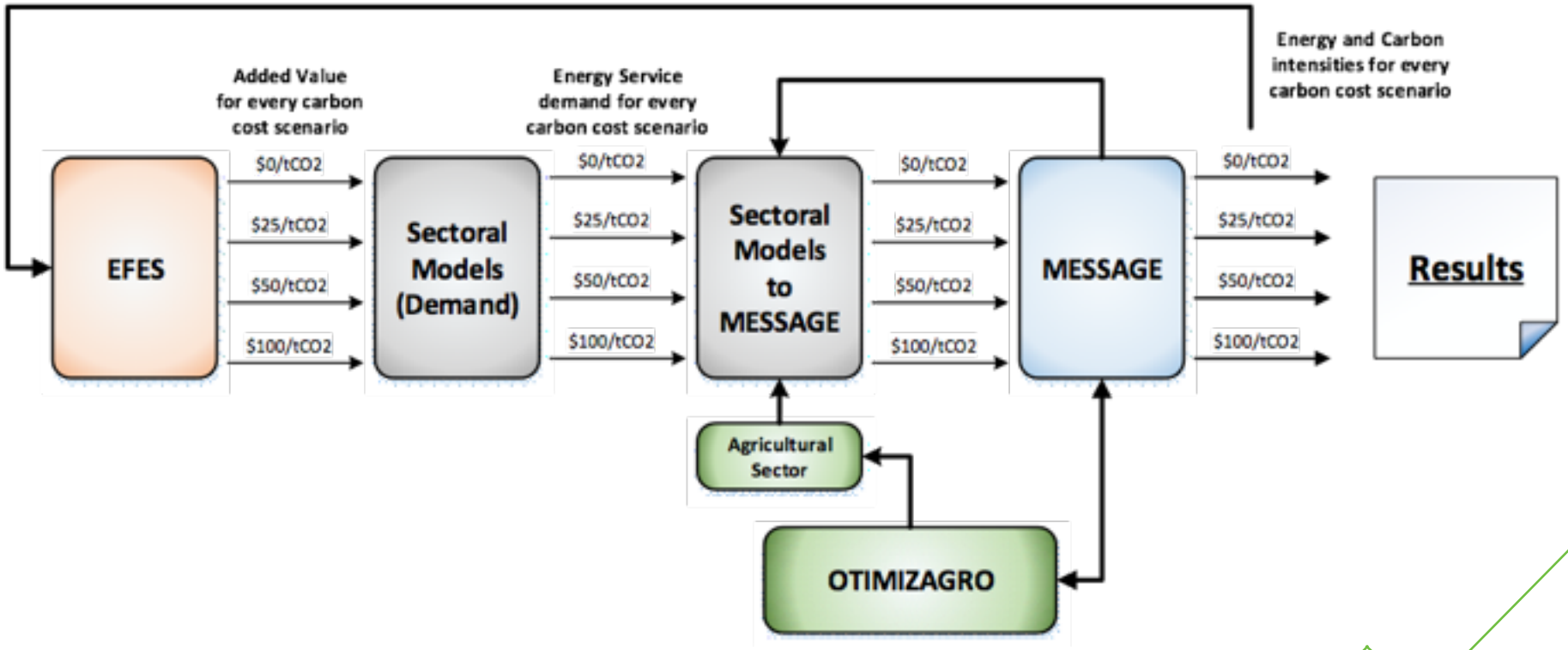
Integration of sectoral results with the MESSAGE energy optimization model

Model Integration

- Objective: To ensure macro-economic and sectoral consistency; to measure the added potential of GHG emissions mitigation
- Sectoral information serves as input to the MESSAGE model
- Need for convergence between models
- Importance of keeping consistency between sectoral modeling and representation of the sector in the optimization model of the energy system

Model Integration

Iterative modeling procedure considered in the project



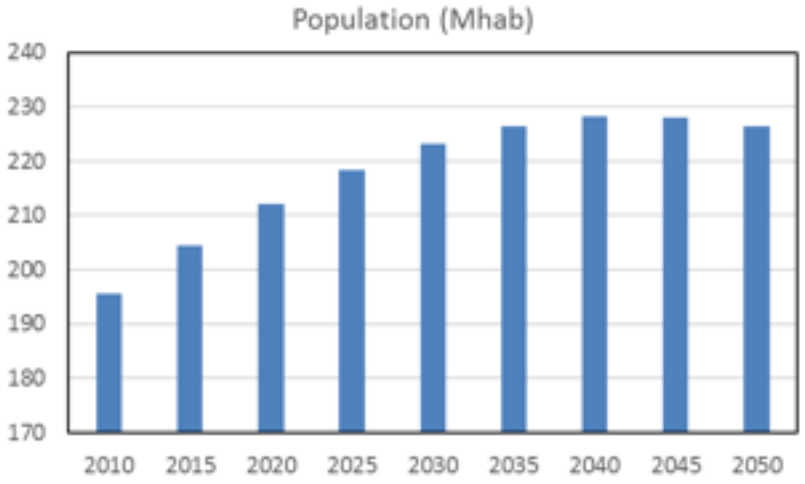
Model Integration

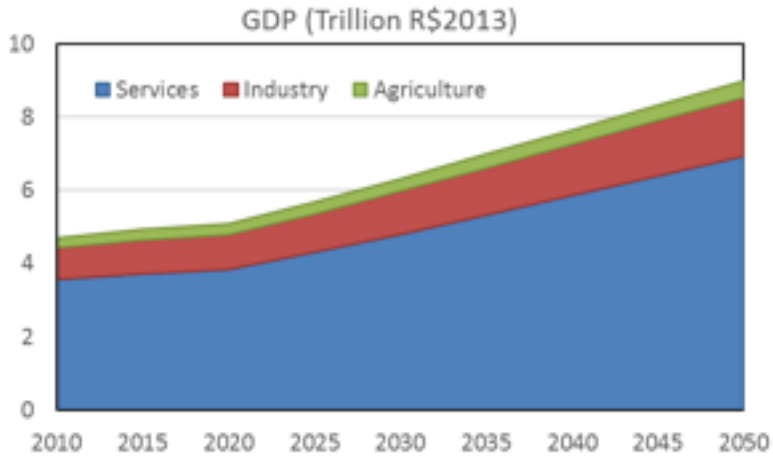
- In this way model integration can capture effects:
  - Elasticity-price: changes in demand due to energy costs
  - Intensity: GDP reduction
  - Structural: sectors are affected differently
  - Energy efficiency
  - Technology: supply curve in more detail (especially for the electricity sector)
- Energy model can provide different kinds of information:
  - Energy consumption and energy intensity
  - Sectoral emissions and carbon intensity
  - Energy sector growth
  - Cost of energy inputs
  - Estimated investments for the expansion and operation of the energy system

Integrated scenarios for the energy system

Exogenous data

- "Macro" data
  - ✓ Details on household spending and π_L : impact on buildings and transport
  - ✓ Aggregated VA and VA sector growth
  - ✓ Population growth, economic active population etc





Basic Modeling Data

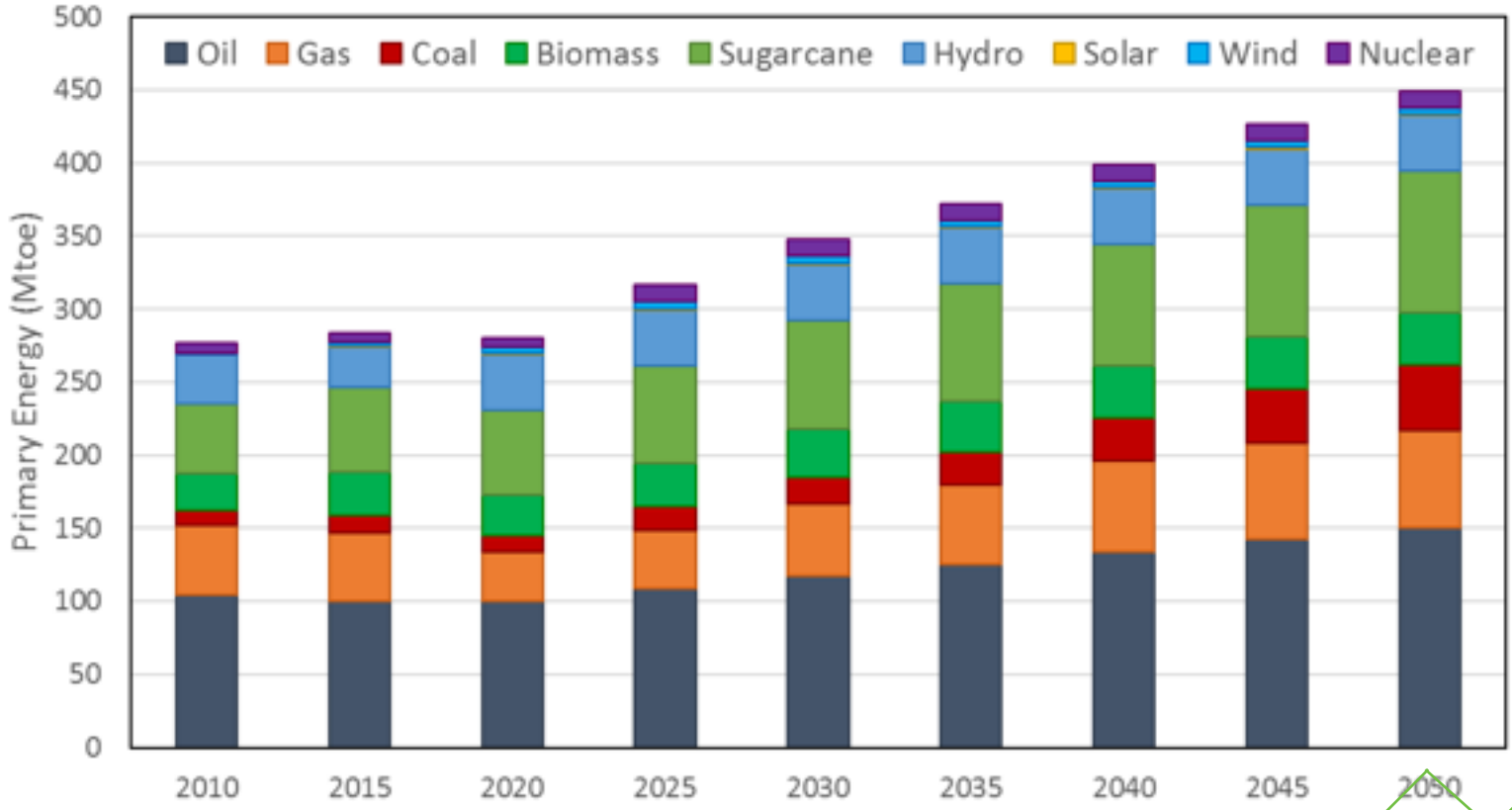
- ✓ Light sweet crude (Brent type) follows a moderate path reaching more than 70 US$/bbl only after 2030 (oil price scenario in 2050 reaches 76 US$/bbl)
- ✓ Prices of derivatives defined according to Δ Brent (FOB basis) - COPPE analysis
- ✓ Oil supply curves were modelled using field database for discovered resources (bottom-up aproach) and using curve-fitting for EOR and non-discovered resources (top down approach) - COPPE analysis
- ✓ Detailed refining modeling (CAESAR model) - COPPE analysis
- ✓ Potential biomass production curves - CSR/UFMG analysis
- ✓ Energy services demand and efficiency options

Reference scenario (REF)

- Assumptions:
  - Expansion at minimal cost
  - Available technologies
  - Only current mitigation policies, and no additional ones
  - Sectoral perspective dominates the modeling
  - Restrictions guarantee BAU trajectory in the short term

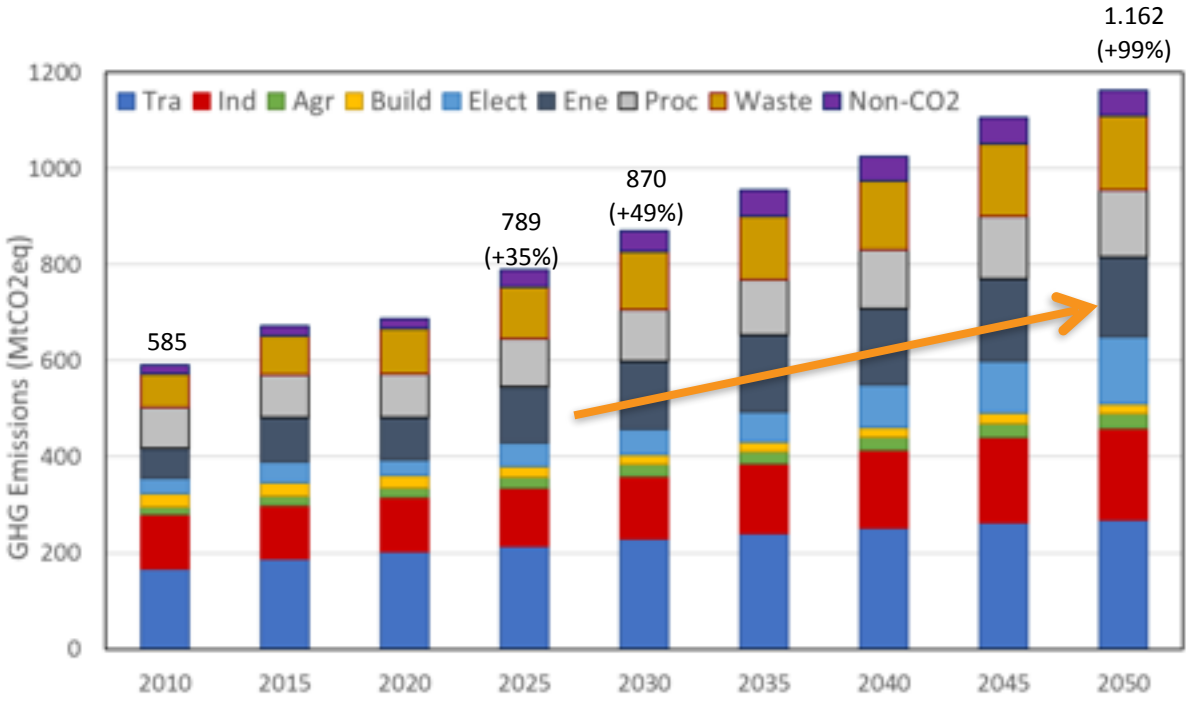
Results – REF Scenario

Primary Energy Consumption



Results – REF Scenario

GHG emissions by sector ($MtCO_2e$)

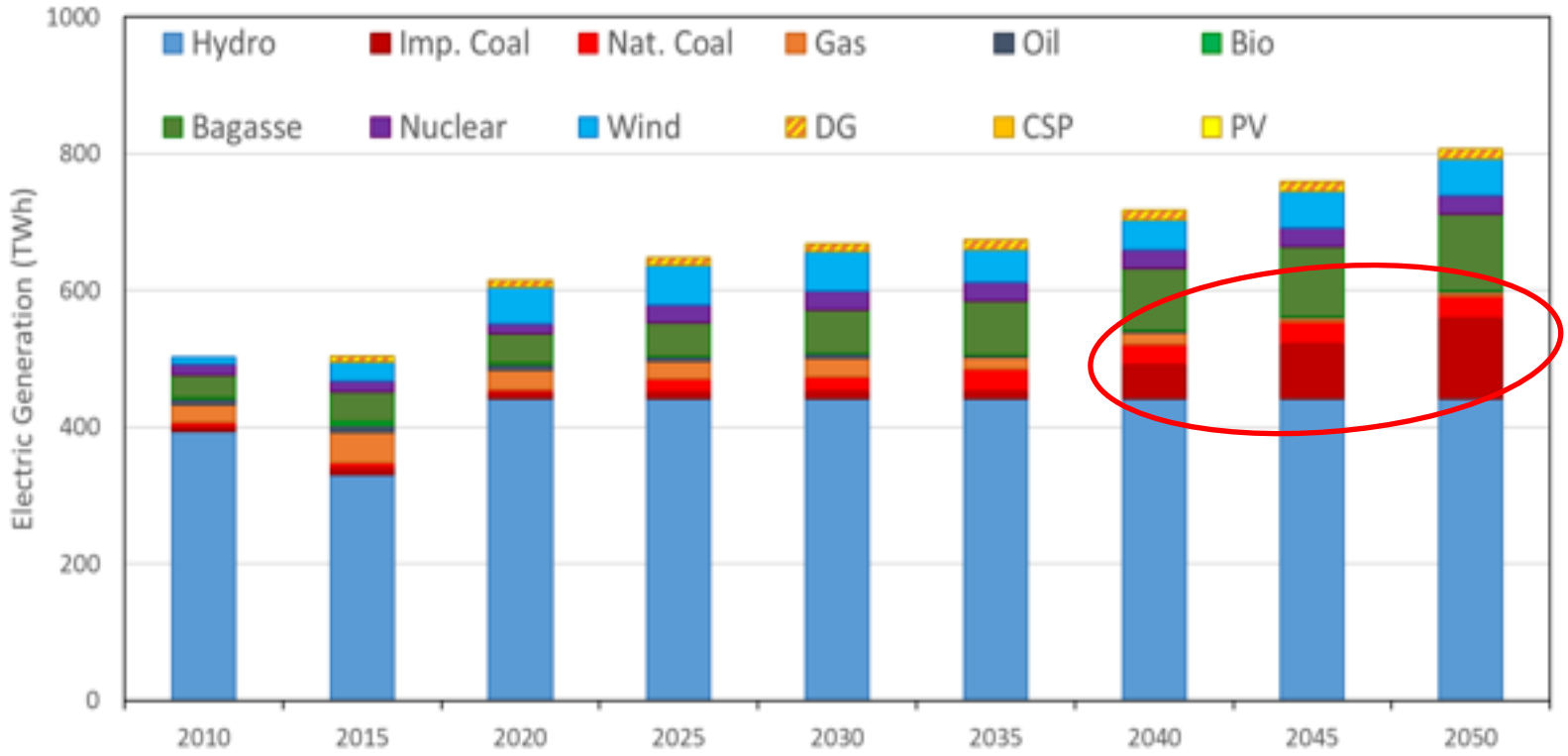


Combustion emissions, waste treatment, processes (energy and industrial facilities) and fugitive emissions of CH4. Not including emissions associated with land use.

Legend: Tra = Transport; Ind = Industry; Ene = Energy; EE= Electricity; Agr = Agriculture; Build = Buildings; Proc = Industrial Processes; Waste = Waste; Non-CO2 = Non-CO2 emissions.

Results – REF Scenario

Electricity Generation (TWh)



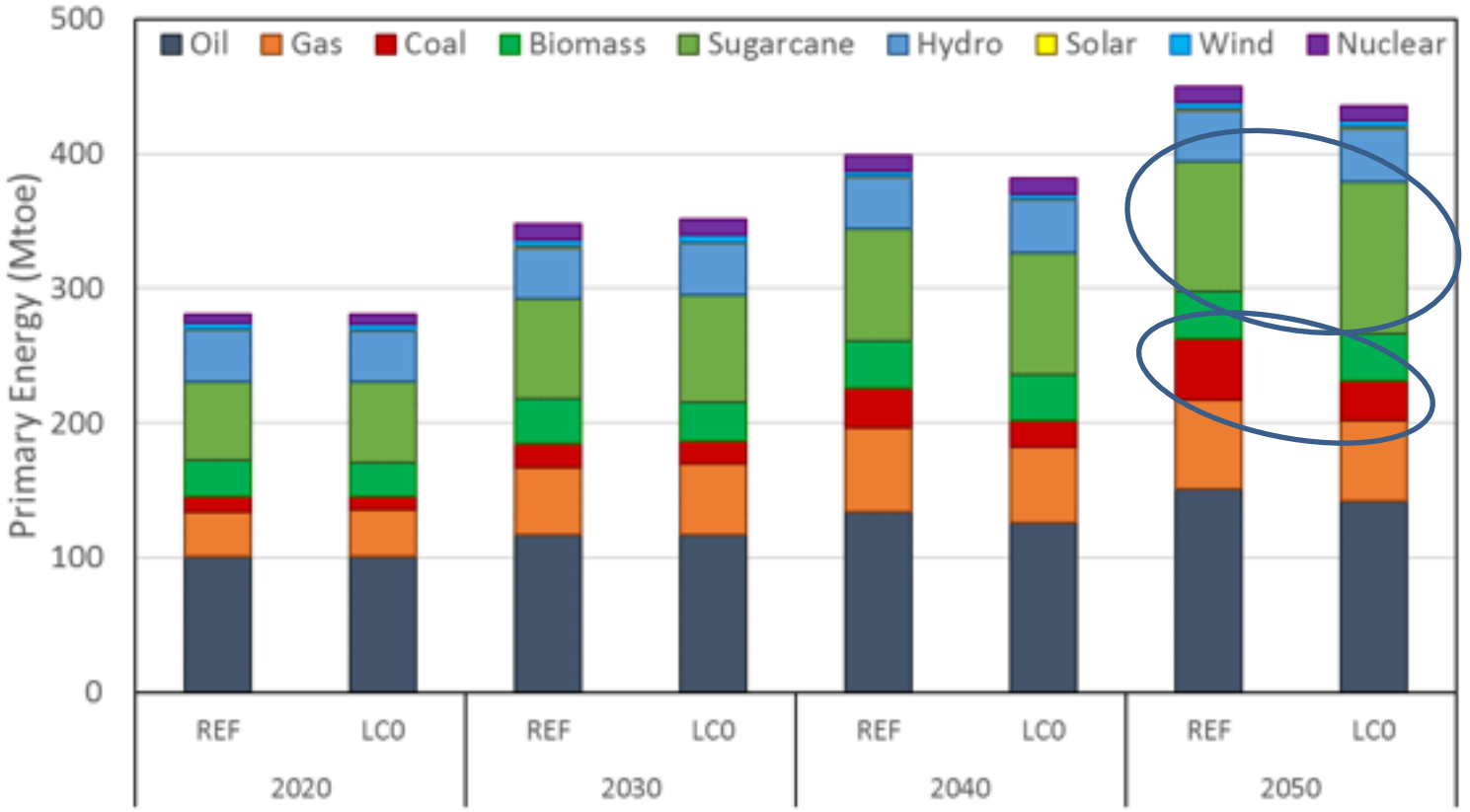
Low-Carbon Scenarios (LC)

- Low-carbon assumptions (LC_x):
  - Best Available Technology (BAT)
  - Diverse energy-efficiency measures and low-carbon production processes (≅ 400 low-carbon technologies)
  - Less restrictions in relation to the technological profile
  - Model has greater optimization flexibility
  - LC_0 = No carbon value
    - Options that would be economically viable potentially, but are not implemented due to market barriers
    - Set of "no regrets" options

Results – LC_0

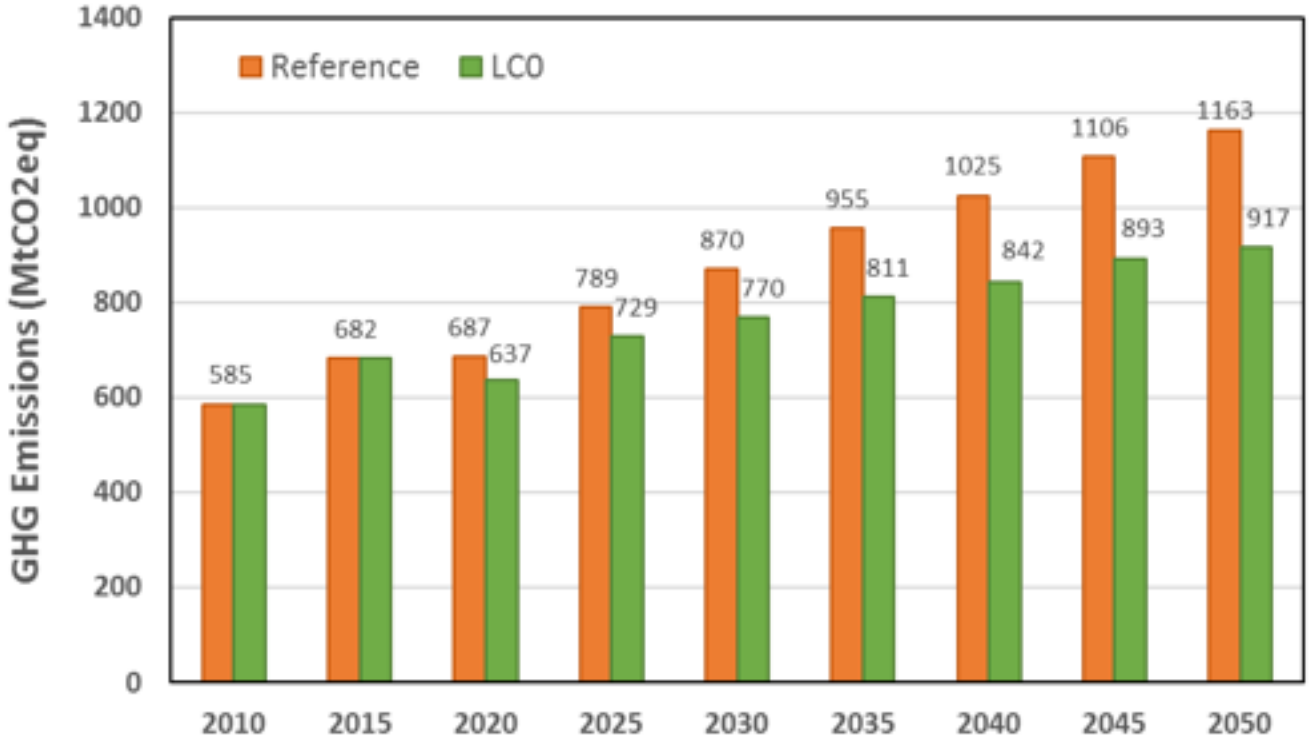
Primary Energy (Mtoe)

- Increase in sugarcane
- Decline in coal, oil and gas



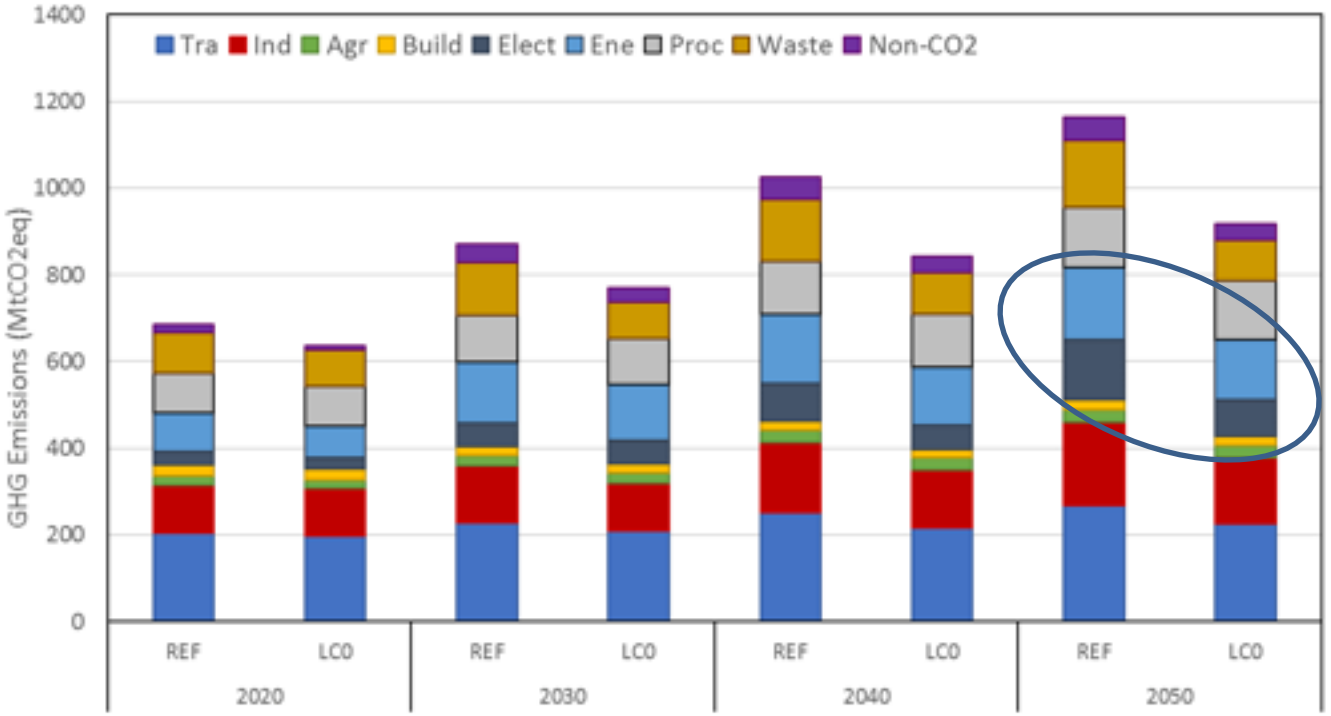
Results – LC_0

/// Reduction of emissions: 22% in 2050



Results – LC_0

Emissions by sector

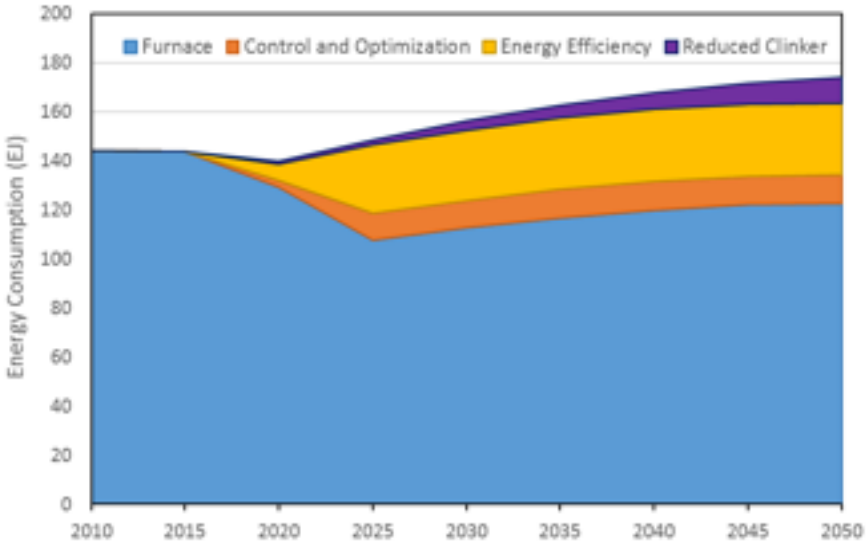


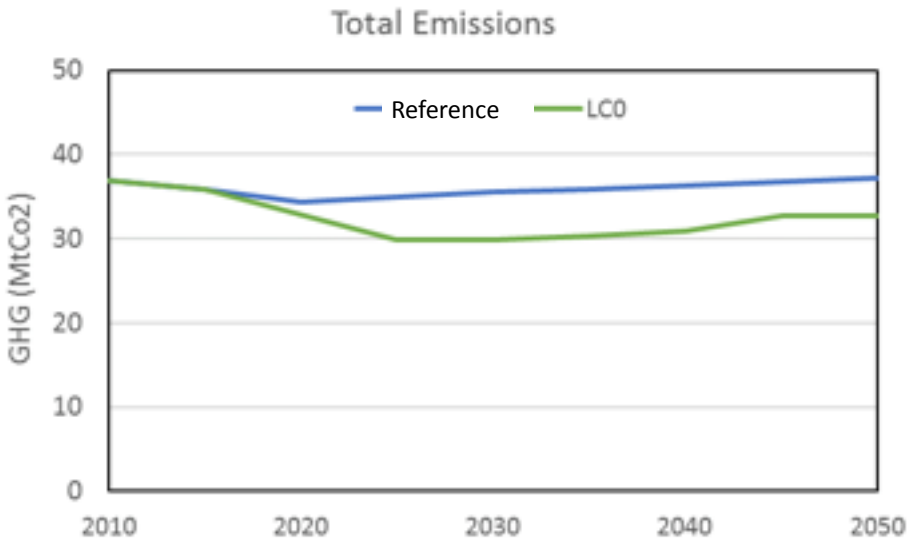
Legend: REF: Reference Scenario; LC0 = No Regret Low-Carbon Scenario; Tra = Transport; Ind = Industry; Ene = Energy; Elect = Electricity; Agr = Agriculture; Build = Buildings; Proc = Industrial Processes; Non-CO2 = Non CO2 emissions.

Industrial - some results

LC_0 – Industrial - Cement

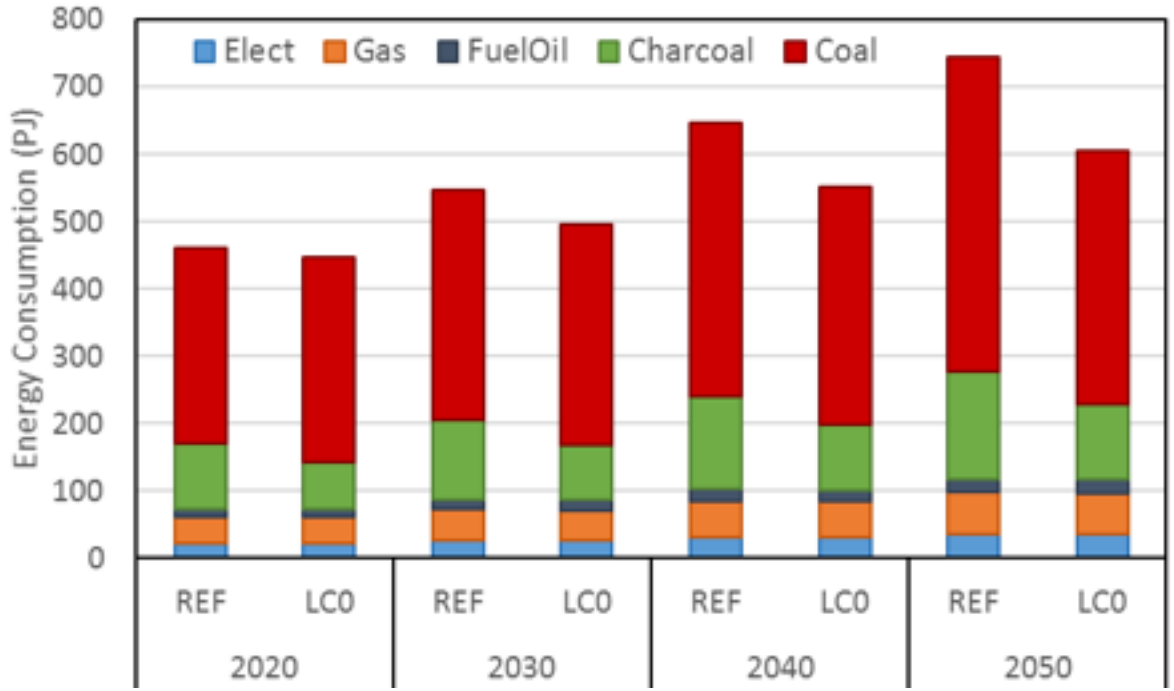
Energy Efficiency (ex: Heat) and Emissions





LC_0 – Industrial – Pig Iron and Steel

Energy Consumption



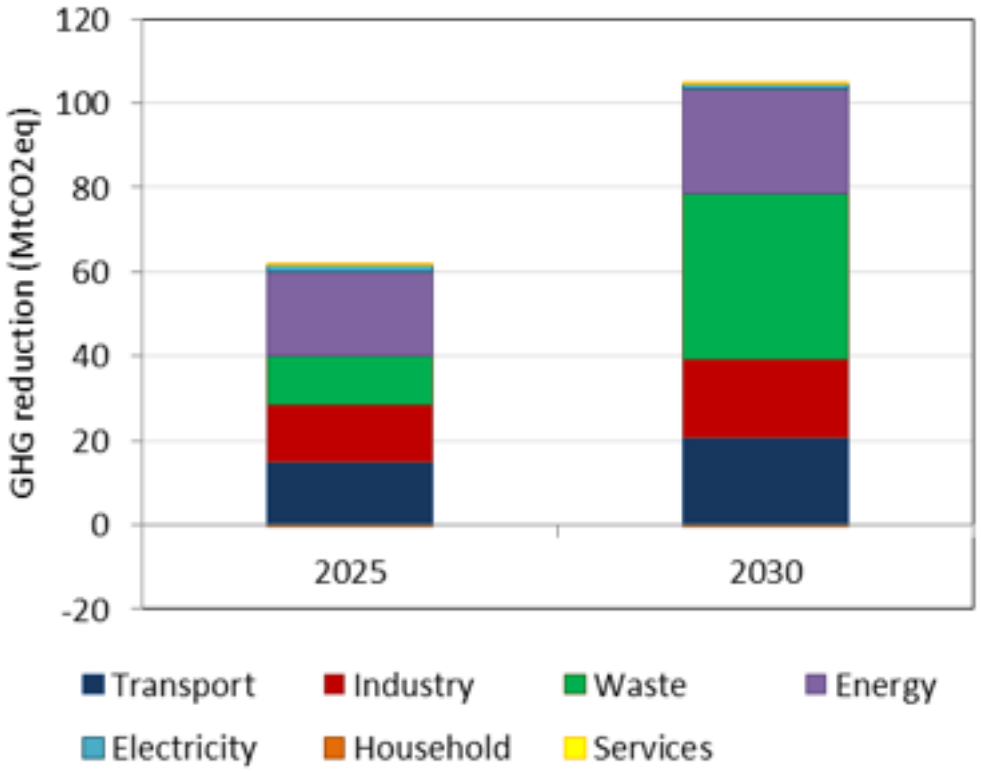
LC_0 - summary

LC_0 – Summary

- Gains in electricity efficiency in buildings and industry → less need for expansion of coal- and natural-gas-fired thermal power plants
- Efficiency gains in the conversion of thermal energy in industry and refining:
  - Measures with virtually no fixed cost, such as proper burn control
  - Measures with low fixed cost, especially when considering the replacement of equipment near the end of its useful life
- From 2030, increase in share of HEVs in fleet of light vehicles; and PHEV and BEV vehicles from 2040 onwards

LC_0 – Summary

/// Mitigation by sector



Energy: energy efficiency, especially in upstream

Waste: controlled landfill, methane recovery in landfills, composting, biodigestion and incineration efficiency.

Industry: fuel substitution, heat and steam efficiency. Main subsectors: iron and steel, chemical and cement.

Transport: modal shift.
Passenger: airplanes, motorcycle and cars are replaced with buses and light commercials.
Freight: road transportation is replaced with rail and hydro transportation.

Electricity: hydro repowering, cogeneration from sugarcane and lower coal-fired generation.

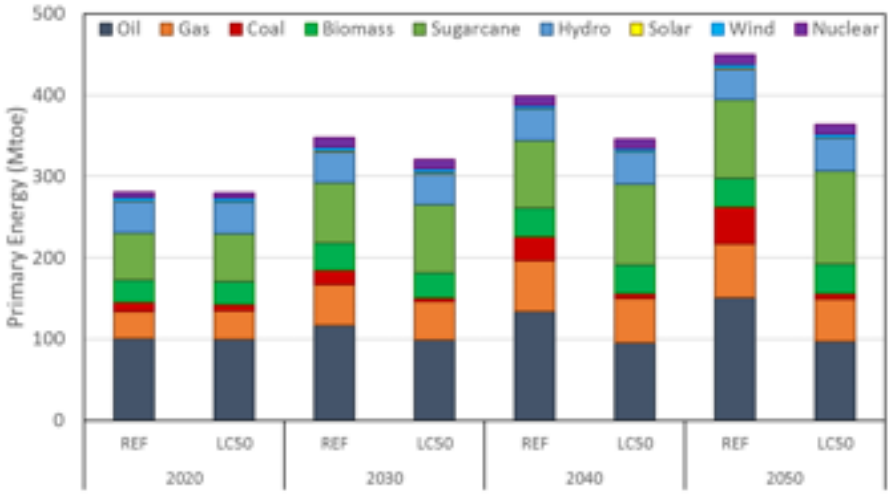
Services: fuel substitution natural gas for cooking generation, replacing petroleum liquefied gas.

Low-carbon Scenarios

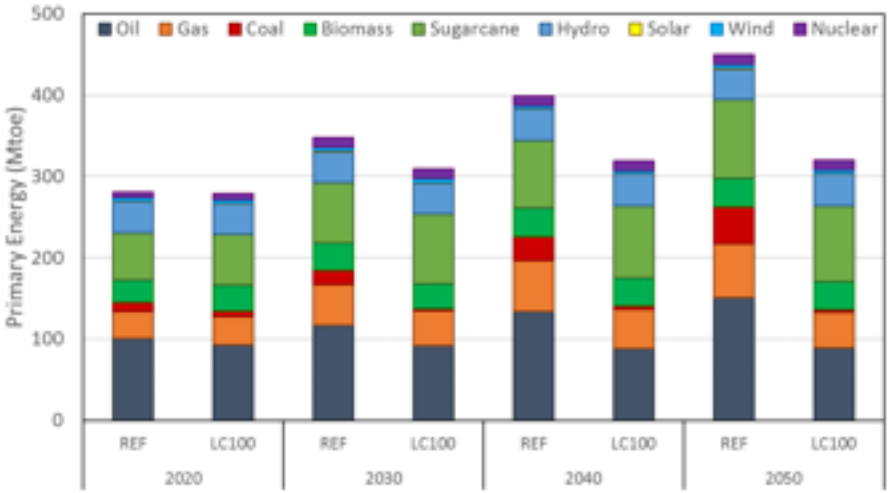
- LC_x:
  - Same degree of technological freedom as LC_0
  - Where "x" represents the cost range of low-carbon measures (this is not a carbon tax)
    - For example, LC25 (the set of measures with abatement costs that are negative, zero and up to US$ 25/tCO_2)
  - Scenarios were developed with emission reduction costs up to US$ 200/tCO_2

LC_x Results

Primary Energy (Mtoe)



LC_{50}

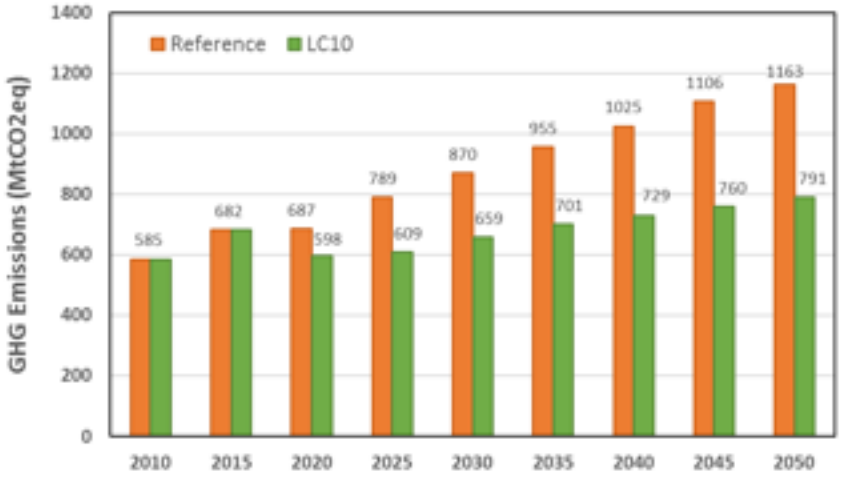


LC_{100}

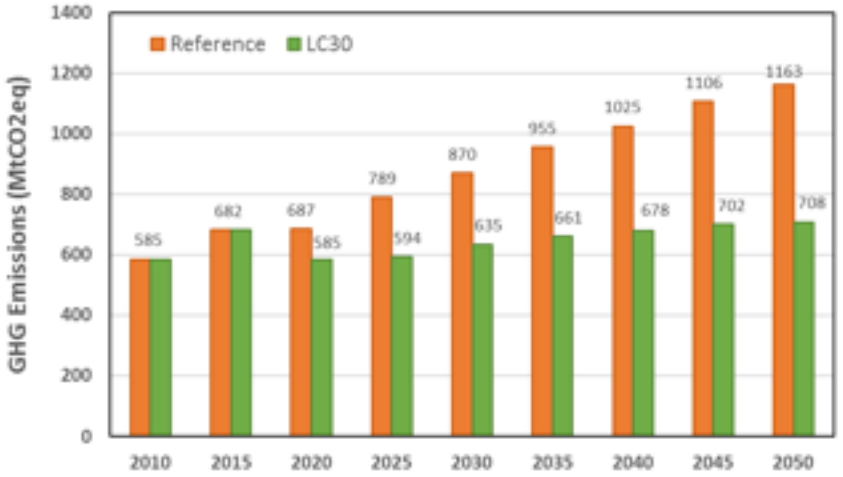
Consistent growth of sugarcane, given the limits of land use and productivity

LC_x Results – GHG Emissions

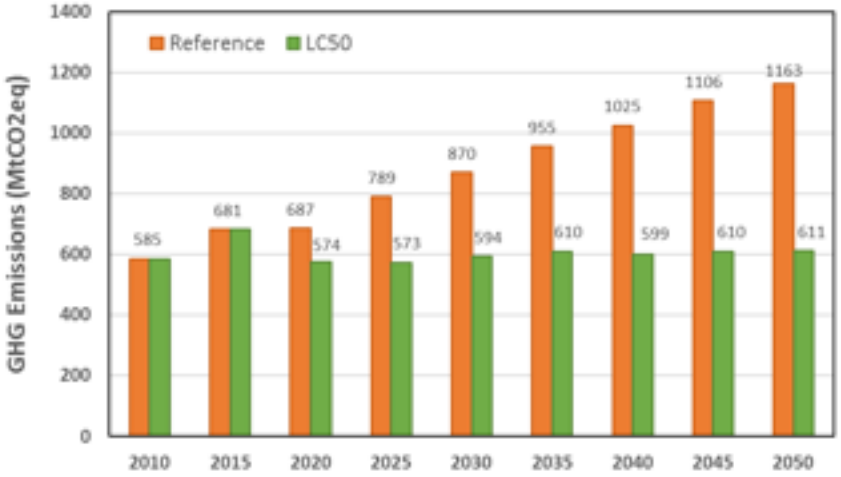
LC_{10}



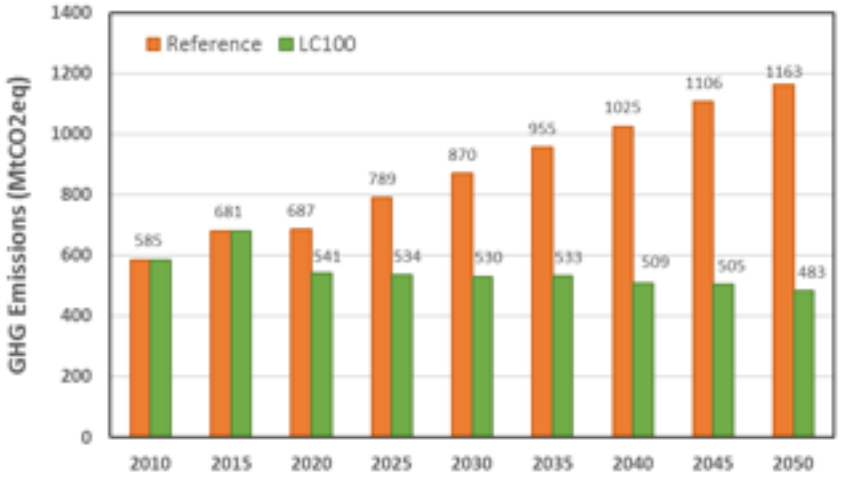
LC_{25}



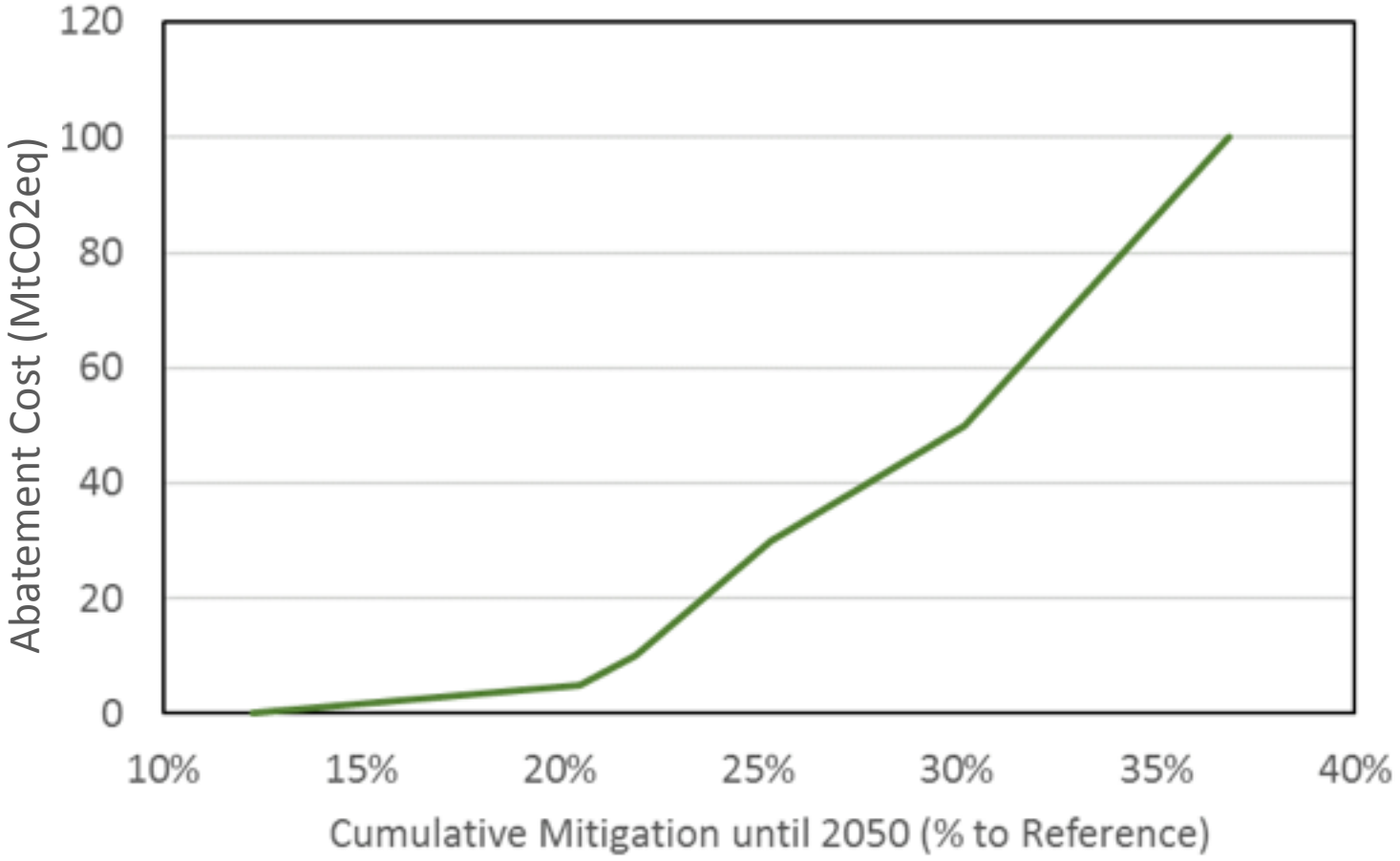
LC_{50}



LC_{100}

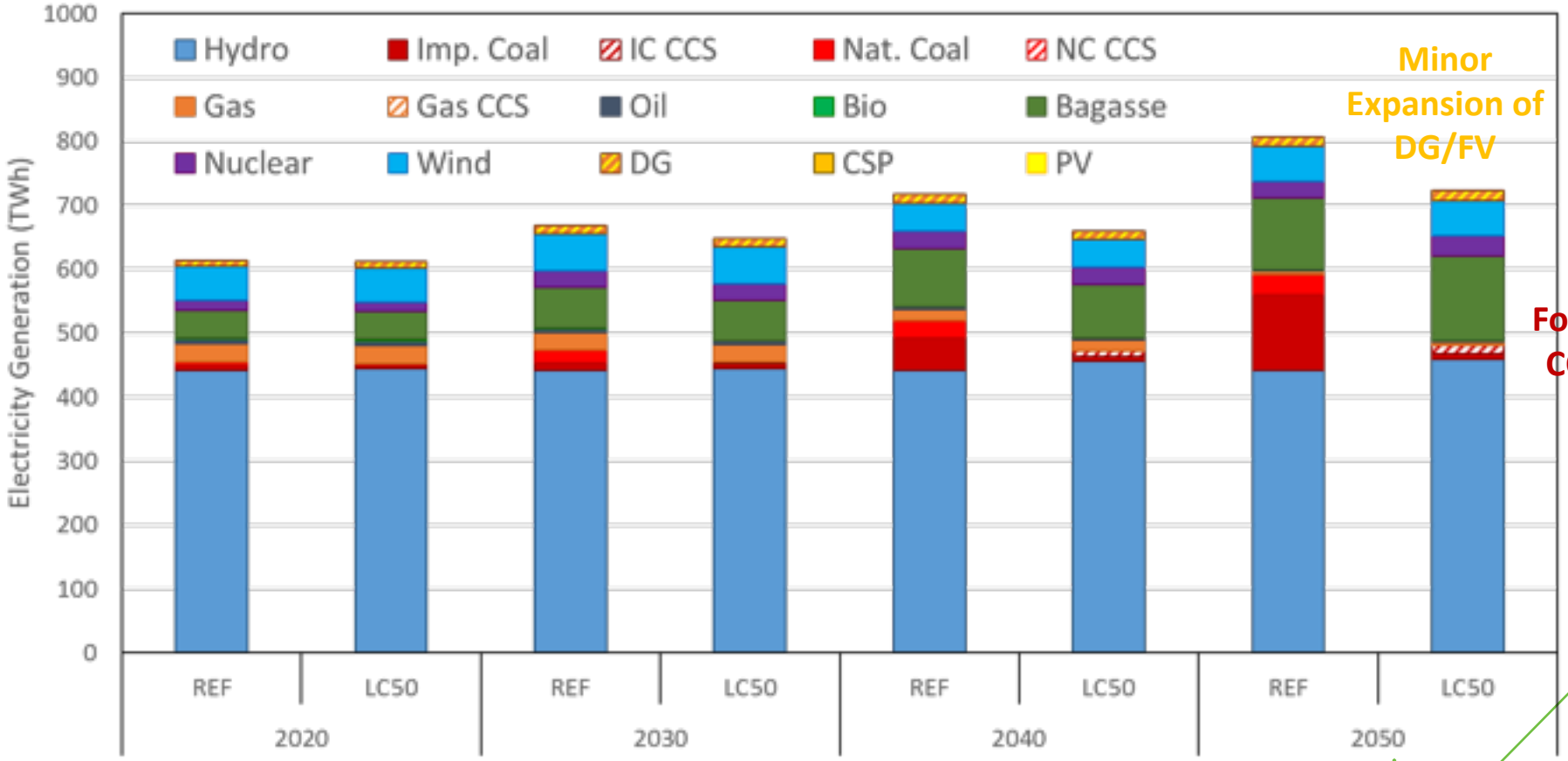


LC_x Results up to 2050



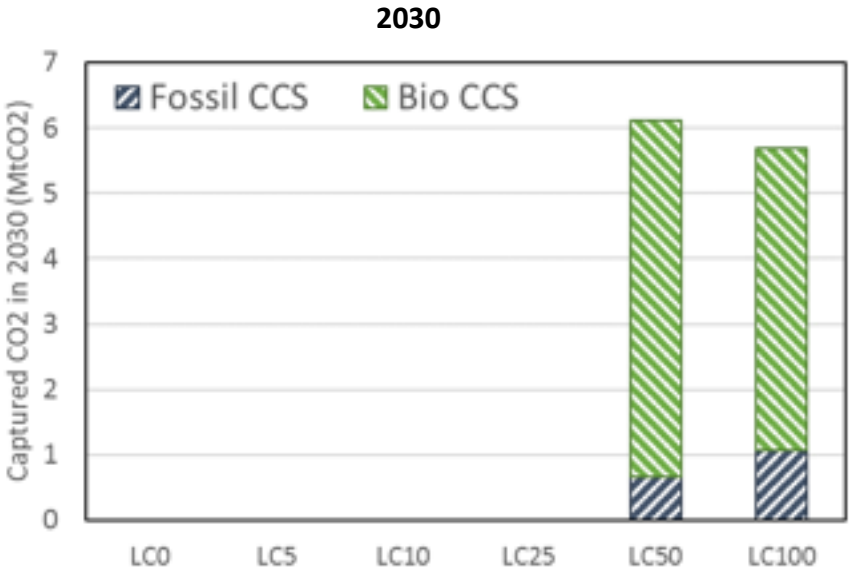
LC_{50} Results

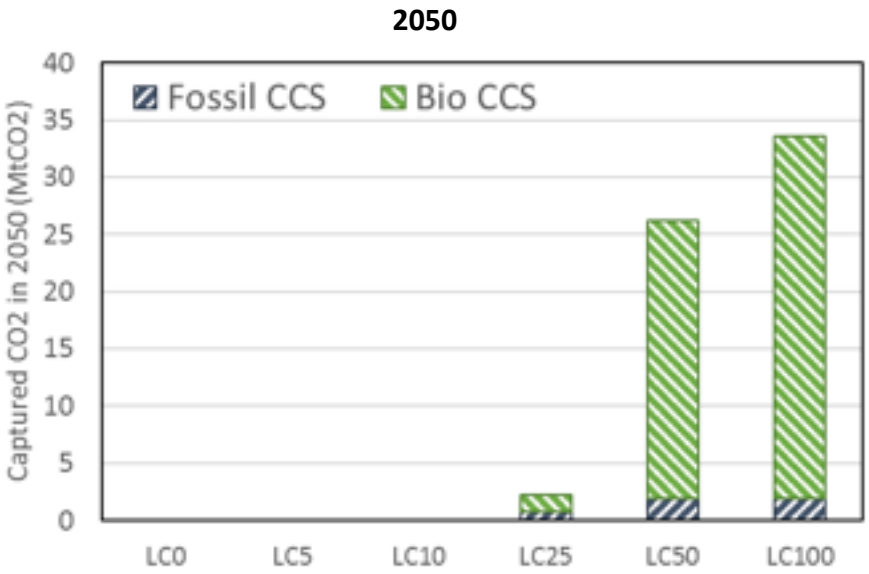
Electricity Generation: CCS starts at 40 US$/$tCO_2$



LC_X Results – Bio CCS

- The importance of BECCS





Will Brazil have the CO_2 transport capacity needed in 2030?

Commercial scale + regulatory aspects + transaction costs

Final considerations

Final considerations

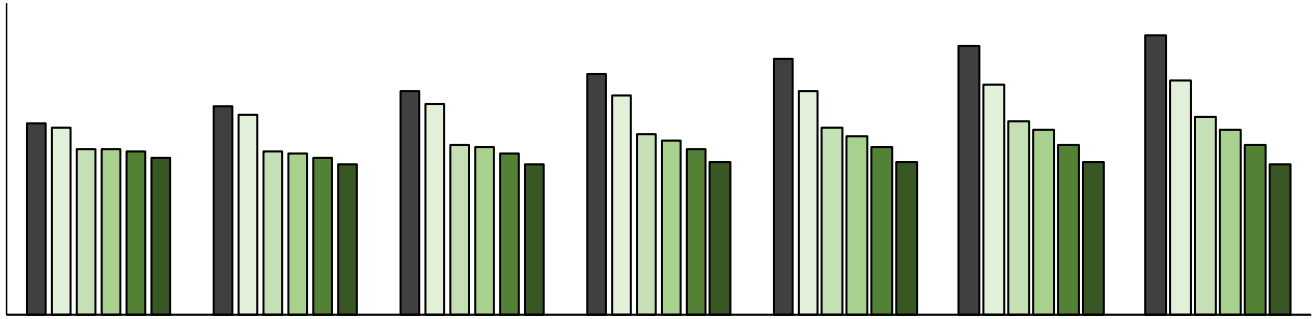
- The availability, or lack, of CCS technology is quite relevant to very stringent CO_{2eq} scenarios

- In 2030, in the REF scenario, emissions reach 870 MtCO2e. In the LC_0 scenario, emissions reach 770 Mt CO_{2eq}

- Comparing our results with the Brazilian NDC…

Total Emissions – Energy and Land systems

(A)



(A) Cenários de emissão até 2050, referência (REF) e baixo carbono (BC) com faixas de valor de carbono de US$ 0 a US$ 100/tCO_2e.
(B) Cenários de emissão de 2025 e 2030, referência (REF) e baixo carbono (BC) com faixas de valor de carbono de US$ 0 e US$ 10/tCO_2e.

Próximos passos

Análises de sensibilidade

- Efeitos do contexto macroeconômico atual para o cumprimento das políticas existentes (afetam, sobretudo, o cenário referencial do setor de AFOLU).
- Efeito de incertezas críticas no sistema energético (tempo de construção dos empreendimentos; entrada ou não do CCS; limite técnico de painéis FV na geração elétrica; venda exclusive de veículos elétricos a partir de 2030; …).

Subsídios para a formulação de instrumentos de política visando a implementação dos cenários de baixo carbono

- Barreiras e instrumentos.