C3A Annual Symposium
December 2-6, 2024
World Bank Paris

Research Segment

SESSION 12

Climate Transition Policies in Emerging Economies: from subnational impacts to international cooperation

Nadia S. Ouedraogo
(UNECA)

Trocadero Room 4pm – 5:30pm

C3A, a program founded and hosted by WORLD BANK GROUP

OMEGA

AN OPEN-ECONOMY MULTI-SECTOR ENDOGENOUS-GROWTH ASSESSMENT MODEL FOR CLIMATE POLICY ANALYSIS IN AN EMERGING MARKET CONTEXT

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December 6th, 2024

Christian Schoder (World Bank)
Remzi Baris Tercioglu (World Bank)

Motivation

OMEGA is a large-scale, integrated framework for climate-economic policy analysis.

Open economy

A domestic country vs. the rest of the world including trade, financial flows, and foreign direct investment.

Multi-sector

Input-output structure of up to 10 value-added sectors and 4 final-good producers.

Endogenous growth

Long-term growth determined by human capital accumulation and learning-by-doing externalities.

Financial sector

Variety of financial instruments including equity shares, bonds, loans, and deposits with endogenous risk premia, borrowing constraints, and asset pricing. Short-term/long-term debt.

Market imperfections

Externalities, financial market imperfections, and a variety of nominal and real rigidities including monopoly power, staggered wage and price setting, and adjustment costs.

Policy interventions

Taxes, subsidies, tariffs, carbon markets, granular public investment in production and infrastructure, mandates, and green finance.

GHG emissions

Granular greenhouse gas emission from production activities, fossil-fuel combustion, and land use change.

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Motivation

Why the need for OMEGA?

No historical precedent of climate change

Accurate modelling is critical to assess climate action and climate impact because there are insufficient historical data to rely on statistical methods alone.

OMEGA is designed for policy analysis

Due to consistent micro-foundations, OMEGA can coherently trace and quantify the macroeconomic propagation of policy action and climate impacts.

Comparative advantage of OMEGA

Role of policy commitment/credibility for private sector mobilization.

Role of structural reforms.

Private sector incentives and carbon markets.

Motivation

A selection of questions OMEGA can answer.

STANDARD ANALYSIS

What are the macroeconomic effects of various climate, fiscal, and monetary policy interventions?

FORECASTING

What is the optimal policy mix to achieve emission targets under given feasibility constraints?

COUNTERFACTUAL SCENARIOS

What are the macroeconomic effects of policy interventions in counter-factual scenarios?

OPTIMAL POLICY

How to design optimal policy rules in the context of climate shocks and uncertainty?

POLICY CREDIBILITY

What are the effects of policy transparency and credibility on the net cost of the low-carbon transition?

STRUCTURAL REFORM

How can structural reforms contribute to the low-carbon transition?

Motivation

Related models

E-Quest (by European Commission; global model with focus on European Union)

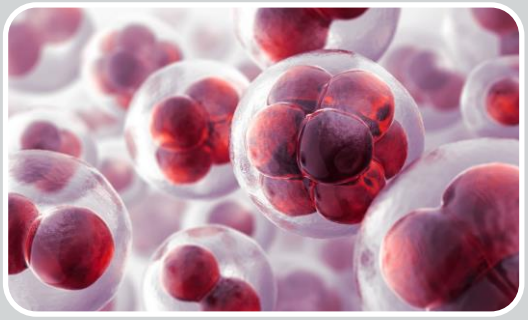
NAWM (by ECB; Euro Area and USA)

GMMAT (by IMF; global model)

-> No large-scale DSGE model for high-emitting developing countries.

Core Methodological Pillars

OMEGA utilizes state-of-the-art methodologies of macro-economic modelling, estimation, and simulation.



Micro-foundations

Economic behavior is characterized by micro-economic problems.

Forward-looking expectations

Expected future events affect current economic behavior.

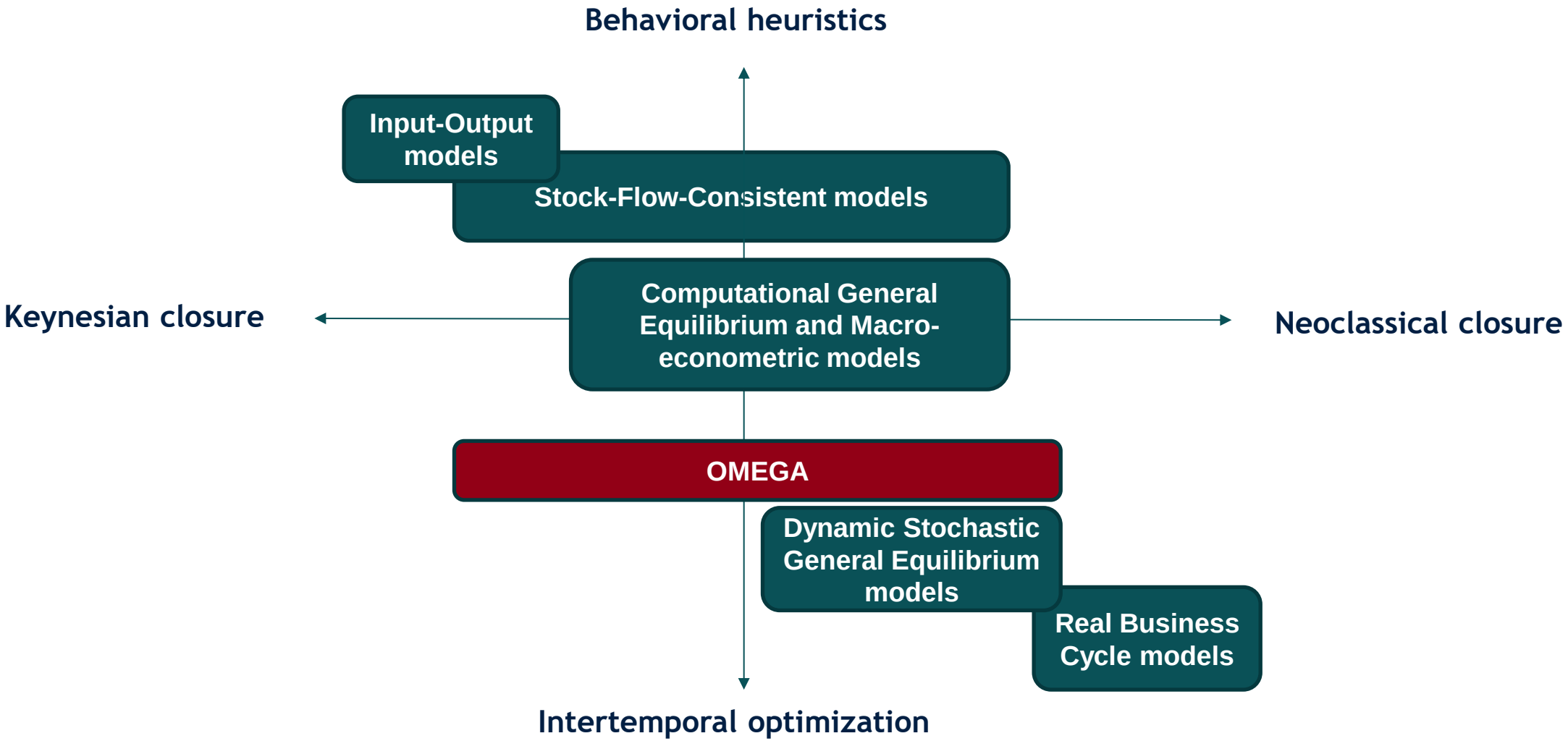
Bayesian estimation

The model is estimated using prior information and historical data.

Simulation

Starting from the current state of the economy, the model projects the future path of the economy.

Where to locate OMEGA?



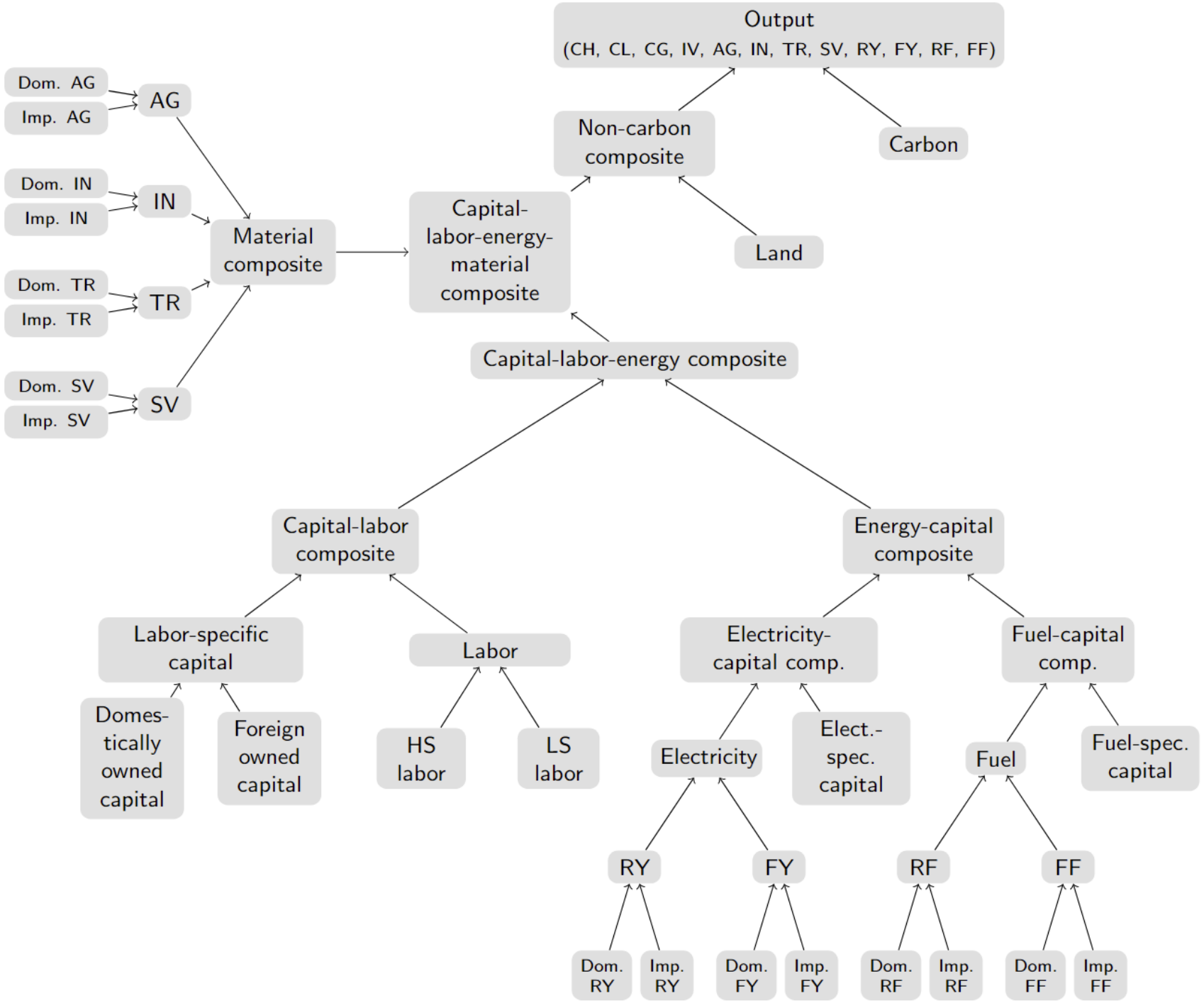
Core assumptions

Production structure

CH	High-skilled consumption goods
CL	Low-skilled consumption goods
CG	Government consumption goods
IV	Investment goods
AG	Agriculture
IN	Industry
TR	Transport
SV	Services
RY	Renewable electricity
FY	Fossil electricity
RF	Renewable fuels
FF	Fossil fuels
HS	High-skilled
LS	Low-skilled

Notes:

- The sector decomposition of the material composite can be modified according to GTAP but due to computational constraints the number is limited to 6 material sectors.
- Every node is a Constant-Elasticity-of-Substitution (CES) aggregate of 2 inputs except for the material composite which has 4 inputs.
- Carbon and land are natural resources.
- Capital is partly private and public. Public infrastructure is not part of productive capital but affects the productive capital's productivity (see below).



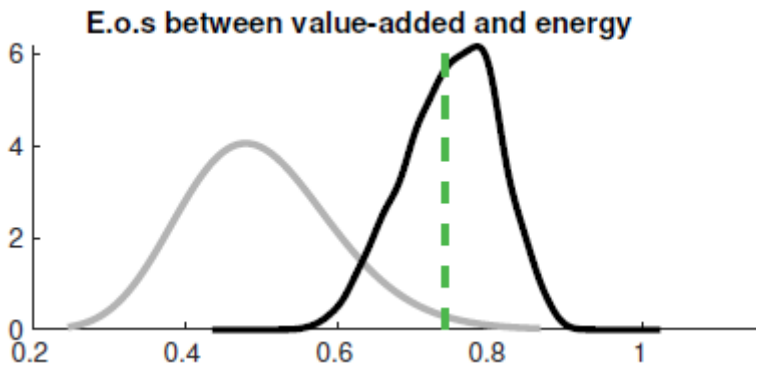
Application to Türkiye: Time series used to estimate the historical values

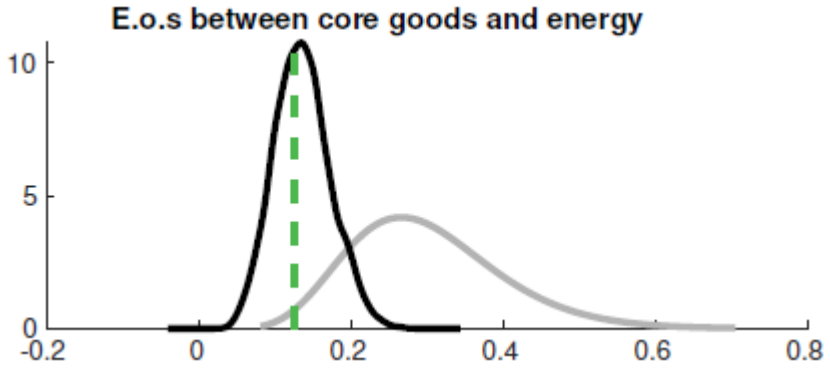
Quarterly
Gross Domestic Product (OECD)
Private consumption (OECD)
Government consumption (OECD)
Total fixed capital formation (OECD)
Exports (OECD)
Imports (OECD)
GDP deflator (OECD)
Private consumption deflator (OECD)
Government consumption deflator (OECD)
Investment good deflator (OECD)
Export deflator (OECD)
Import deflator (OECD)
Core good price deflator (TUIK)
Electricity price deflator (TUIK)
Energy price deflator (TUIK)
Retail electricity price deflator (TUIK)
Retail energy price deflator (TUIK)
Low-skilled wage deflator (TUIK)
Compensation of employees (OECD)
Money market rate (IMF)
Deposit rate (IMF)
Real effective exchange rate (OECD)
Unemployment rate (OECD)
Hours worked (OECD)
Core good production (TUIK)
Total electricity production (OECD)
Renewable electricity production (IEA)
Energy production (OECD)
Carbon production (TUIK)
Carbon price deflator (TUIK)
Oil price (OECD)
Foreign demand (OECD)
Money balances (TCMB)
Foreign interest rate (OECD)
Foreign GDP price deflator (OECD)

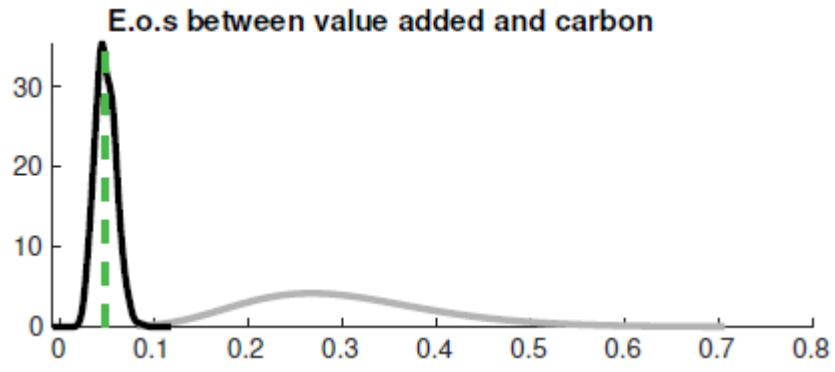
Annual
Education hours (UN)

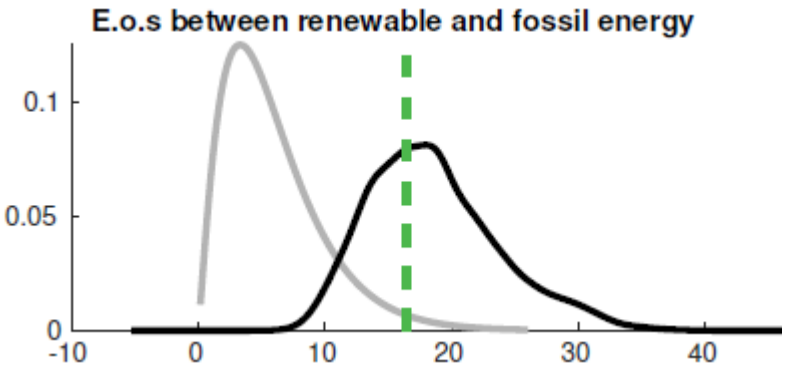
Applications: model estimation

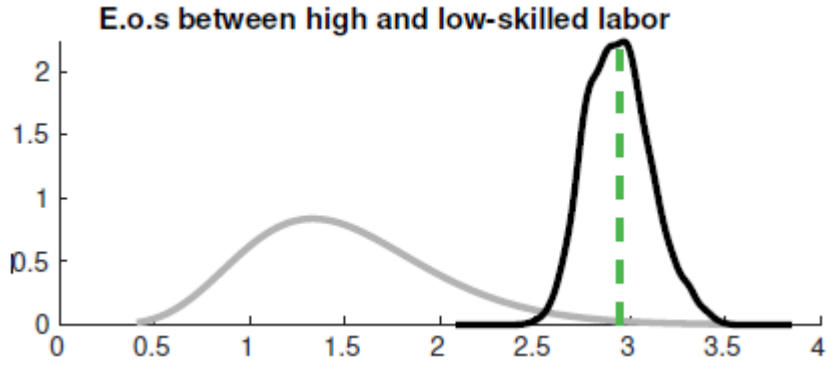
Important model parameters are estimated allowing OMEGA to characterize real-world economies. Here the plots of prior and posterior distributions for selected parameters estimated for Turkey (Schoder and Tercioglu 2023).











In these examples, the data is very informative about the parameters.

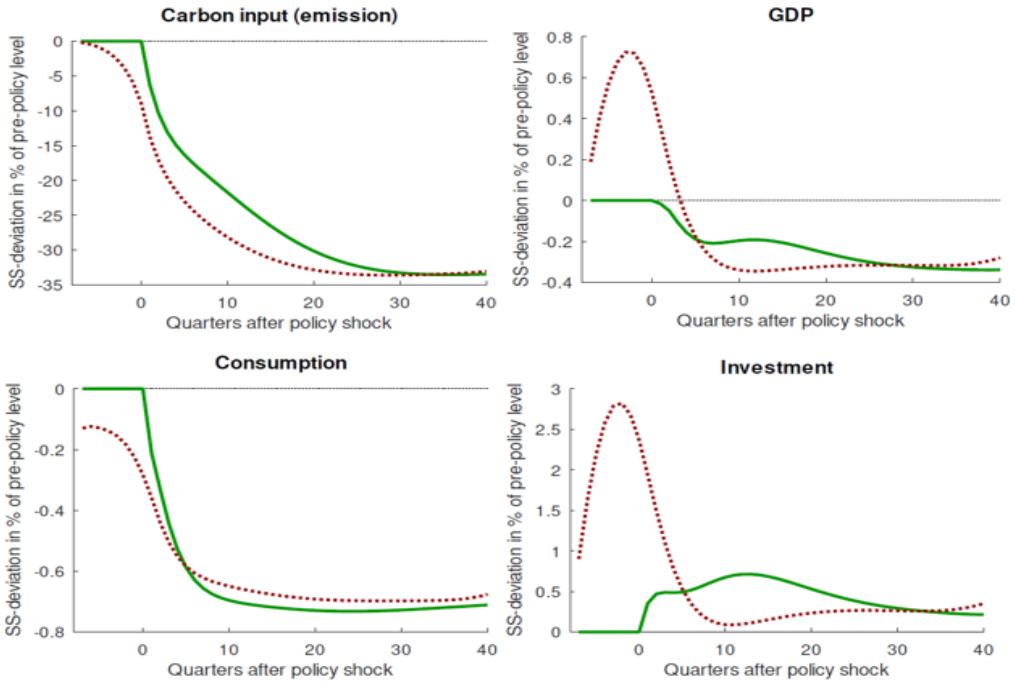
Posterior uncertainty can be accounted for in the simulation results.

Prior distribution (grey), posterior distribution (black), estimated mode (green – initialization of posterior simulation)

Applications: policy credibility

OMEGA can be used to quantify the role of policy transparency and commitment. Anchoring market expectations to the low-carbon transition can crowd in private sector engagement. Here, a simulation for Turkey.

Figure 6: Results from a preliminary forward-looking macro model



Note: Responses to a permanent increase of the carbon tax rate from $0 to $20/tCO2 when the policy change is not credible (green & solid) and when it is credible and announced 2 years before its implementation (red & dotted).

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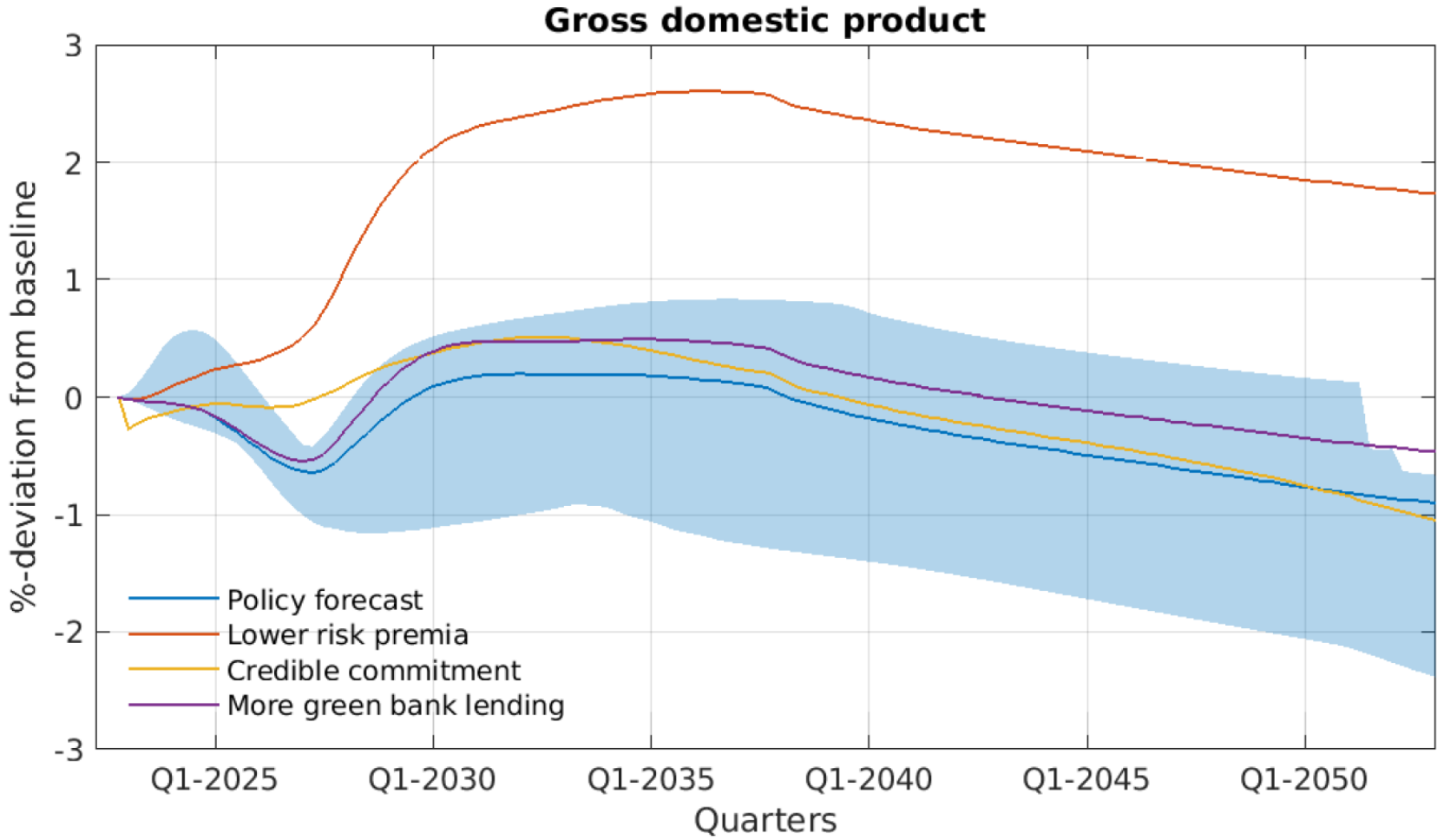
Applications: structural reforms

Since OMEGA features micro-foundations, counter-factual scenarios of structural reforms can easily be simulated. Here the potential of structural reforms in Turkey (Schoder and Tercioglu 2023).

The blue line is the net-zero policy forecast of GDP and the blue area is the 90% credible interval given posterior parameter uncertainty.

The red line is a counter-factual scenario in which, additionally, the risk premium in the renewable energy sector is reduced.

The purple line is a counter-factual scenario in which, additionally, the access to finance in the renewable energy sector is improved.



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THANK YOU!

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Raising Climate Ambition: Policies for Net Zero, Co-Benefits, Financing Needs, and the Role of a Global Climate Alliance

Leonardo Garrido

Contact: email address | LinkedIn profile

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Motivation

Engagement:

- Advanced as part of T20 activities that supported India G20 Presidency (2023);
- Fostering high-level discussions regarding the role of sub-global cooperation mechanism (climate clubs) to help overcome coordination problems that arise in international climate policy;

Research:

- Identify policies for Net Zero, co-benefits, costs, financing needs, and the role of international transfers + finance mechanisms ("Global North" to "Global South") to ease financing constraints.
- Case studies for Brazil, India and Indonesia, under a participatory modeling approach

Main messages

"Net Zero is Net Positive"

- Differential positive socio-economic outcomes from enhancing climate ambition relative to current commitments (NDCs, larger cumulative GHG reductions by 2050)

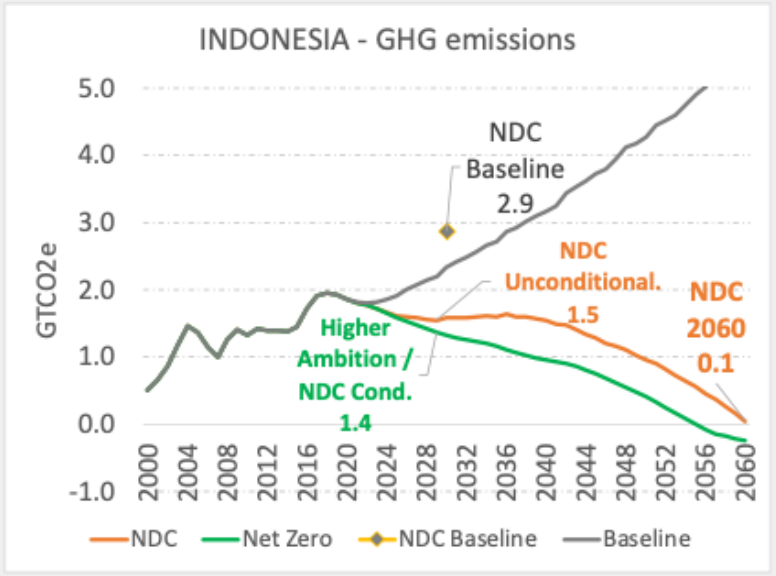
Financing constraint, Role of Climate Clubs

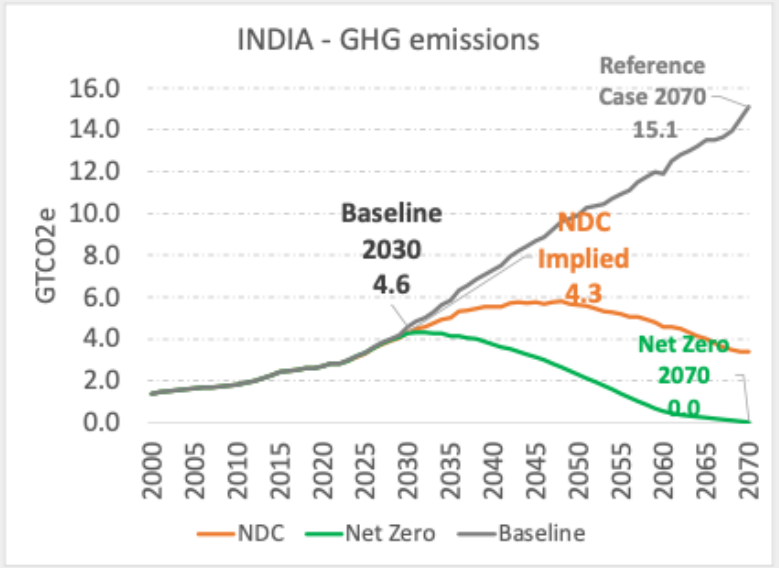
- Computed financing needs and how, in absence of substantive carbon market revenues and international financing, they'd yield unsustainable fiscal, debt paths
- Need for sub-global cooperation mechanisms with revenue recycling elements ("Global North – Global South")

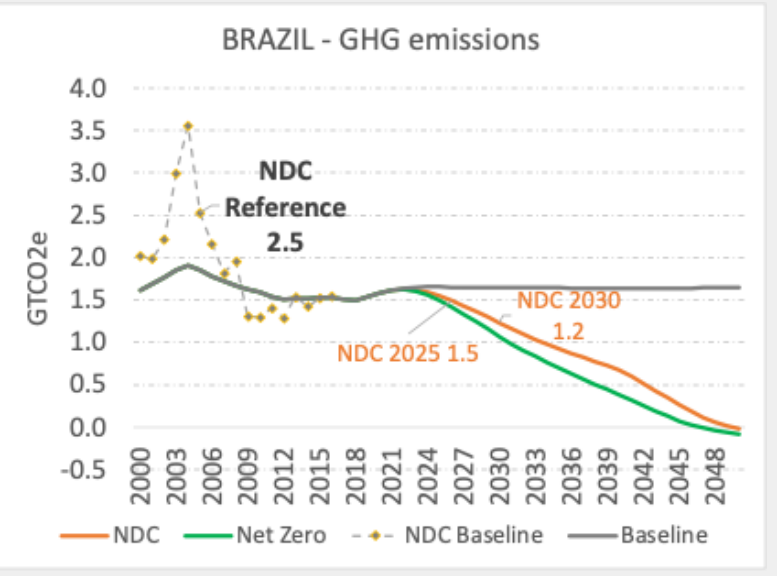
Climate considerations in fiscal policy

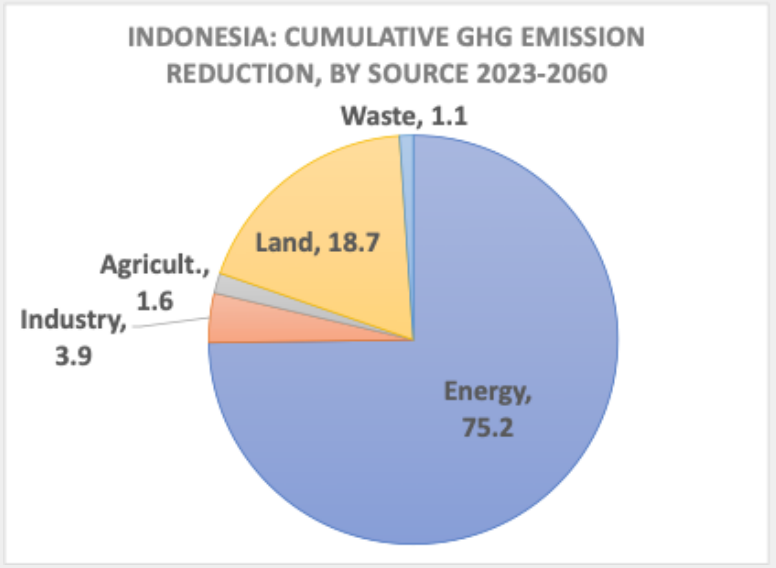
- Macro-fiscal analyses typically advanced (by Ministries of Finance) can no longer misrepresent, underrepresent climate impacts. These need to be fully incorporated in DSA, financial programming, etc.
- Method of engagement and participatory process *at least as important* as the incorporation of bio-physical elements that determine climate impacts an that allow for a sound appraisal of climate resilience and GHG mitigation policies.

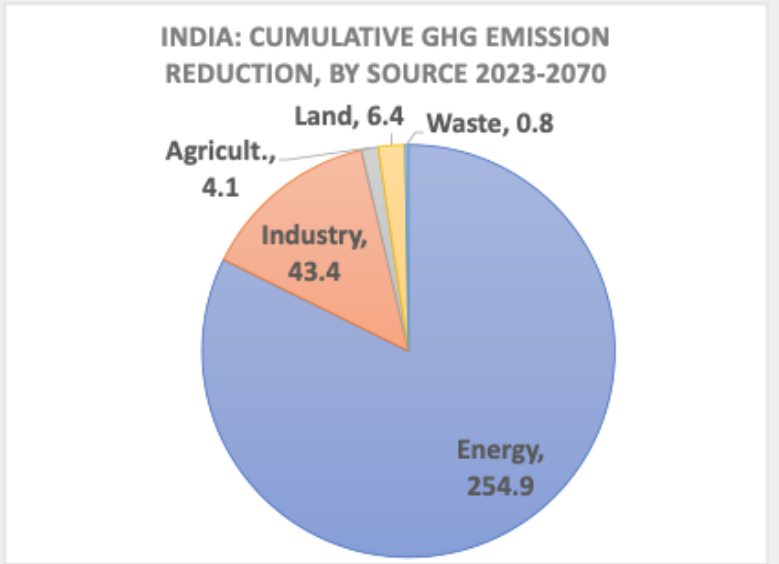
Model results: GHG Emission Paths

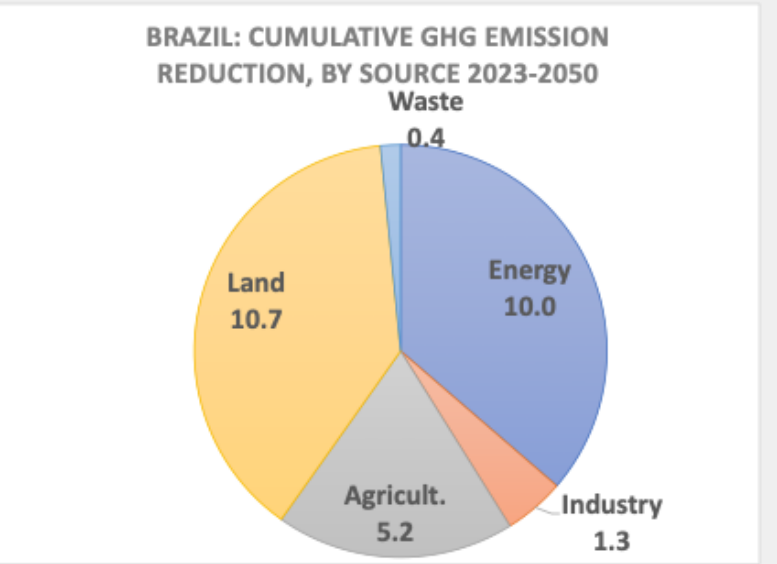




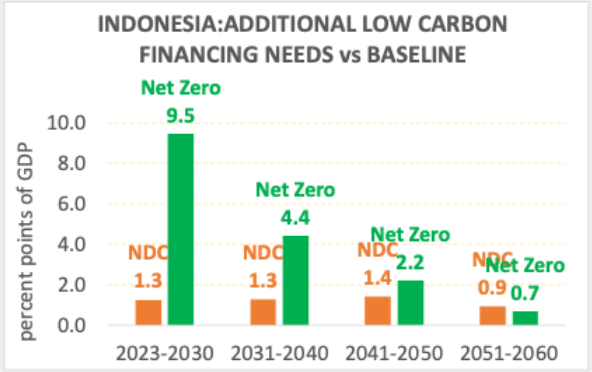


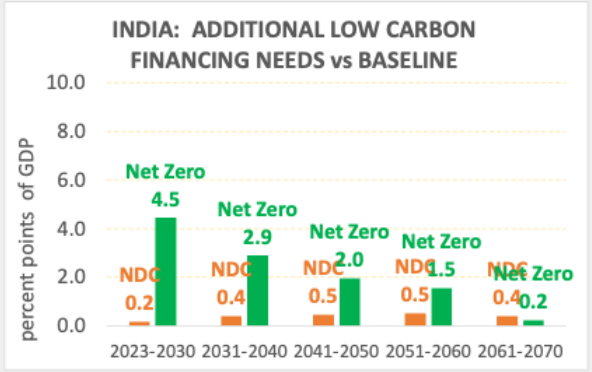


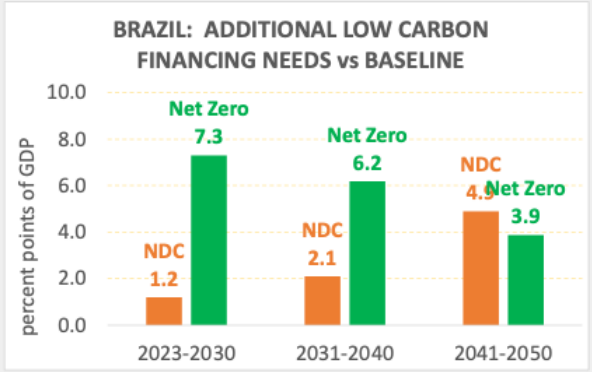


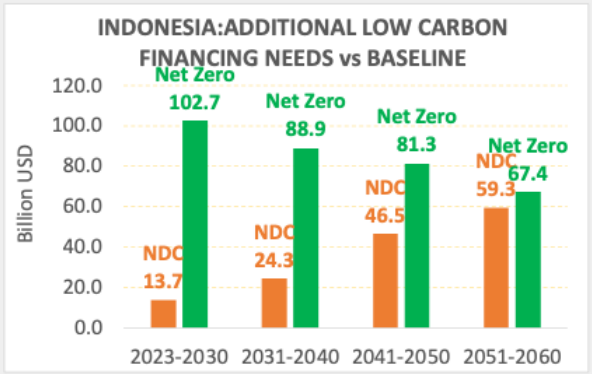


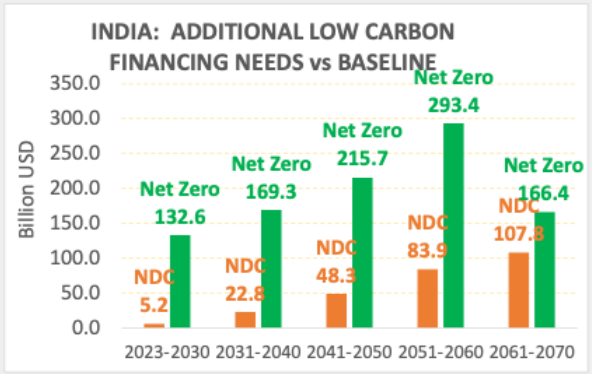
Model Results: Financing Needs and impacts on fiscal balances

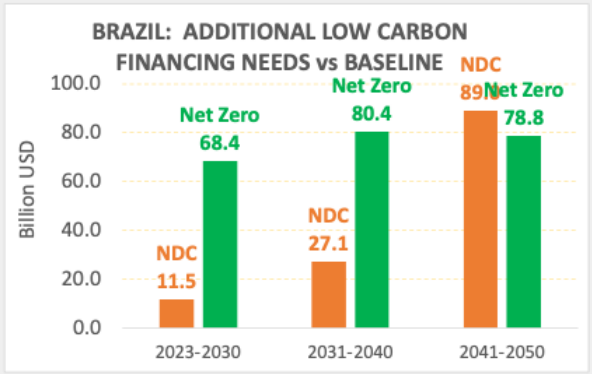


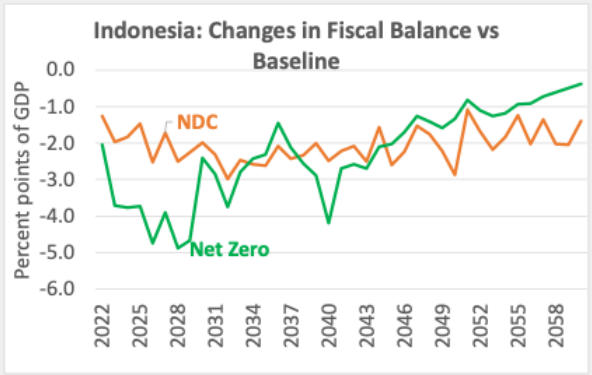


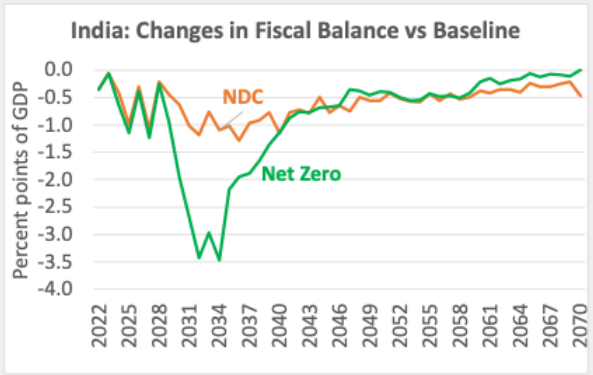


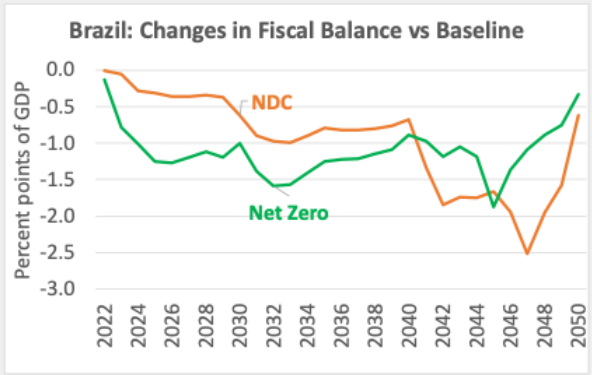












Method of work

Participatory framework

- Participatory modeling (consultations with stakeholders) - *limited in the GCA exercise*
- Model customization (country specific characteristics, including the biophysical elements that determine climate impacts and affect policy)
- Embeddedness (identifying opportunities and constraints for policy) - *not in the GCA exercise*
- Capacity building - *not in the GCA exercise*
- Links to stakeholders' models and tools building - *not in the GCA exercise*
- Feeding into national climate /green policy document / initiative - *not in the GCA exercise*

Modeling Approach

System Thinking Based / System Dynamics Tools

- Amenable to foster participatory modelling and for model customization (“white box”)
- Core System Dynamics modelling features suitable for representing climate impacts and the role of policy (GHG mitigation and and climate resilience and adaptation) under an integrated framework
- Stock flow representation; feed backs; non linearities; delays
- Integration with other tools feasible (soft / hard linkages)
- Suitable for capacity building

Method of work - Considerations for country support in the context of C3A

- Significant effort in terms of embeddedness
- Not a short-term project: Consider the time for country-specific tool development and for capacity building
- Three pronged support:
  - Policy design (e.g. carbon market based mechanisms, sustainable agriculture, waste)
  - Capacity building and engagement (macro modeling, environmental project analysis)
  - Implementation (e.g. developing green taxonomies, project support -concept notes, financing)

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Thank you

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ECONOMIC EFFECTS OF THE CLIMATE TRANSITION POLICIES OF BRAZIL

APPLICATION OF THE OMEGA MODEL TO EVALUATE THE ECOLOGICAL TRANSFORMATION PLAN OF THE BRAZILIAN MINISTRY OF FINANCE

First Annual C3A Symposium
Paris, France
12/6/2024

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Christian Schoder (World Bank)
Roshen Fernando (World Bank)
Cornelius Fleischhaker (World Bank)
Joao Gabriel De Araujo Oliveira (World Bank)

Ecological Transformation Plan

Type of Intervention	Policies
Investments and Investment Incentives	**Investments** **1. Public infrastructure investment in electricity and low-carbon transport** **Green Finance** **2. Derisking renewable electricity and biofuels** **3. Removal of free-market finance premium on electricity-specific investments** **4. Conditioning the concessional lending rate on low-carbon practices in agriculture**
Taxes and Subsidies	5. Increasing fossil fuel taxes 6. Phasing out fossil fuel subsidies 7. Phasing in renewable electricity subsidy
Carbon Markets	**8. An Emission Trading System (ETS) with varying annual cap reductions** 9. Increasing global demand for reforestation-backed carbon offsets
Regulations	**10. Restrictive policy stance on deforestation** 11. Increasing efficiency of the land inputs

Design of the ETP Policies: Emissions Trading System (ETS)

Emissions cap:

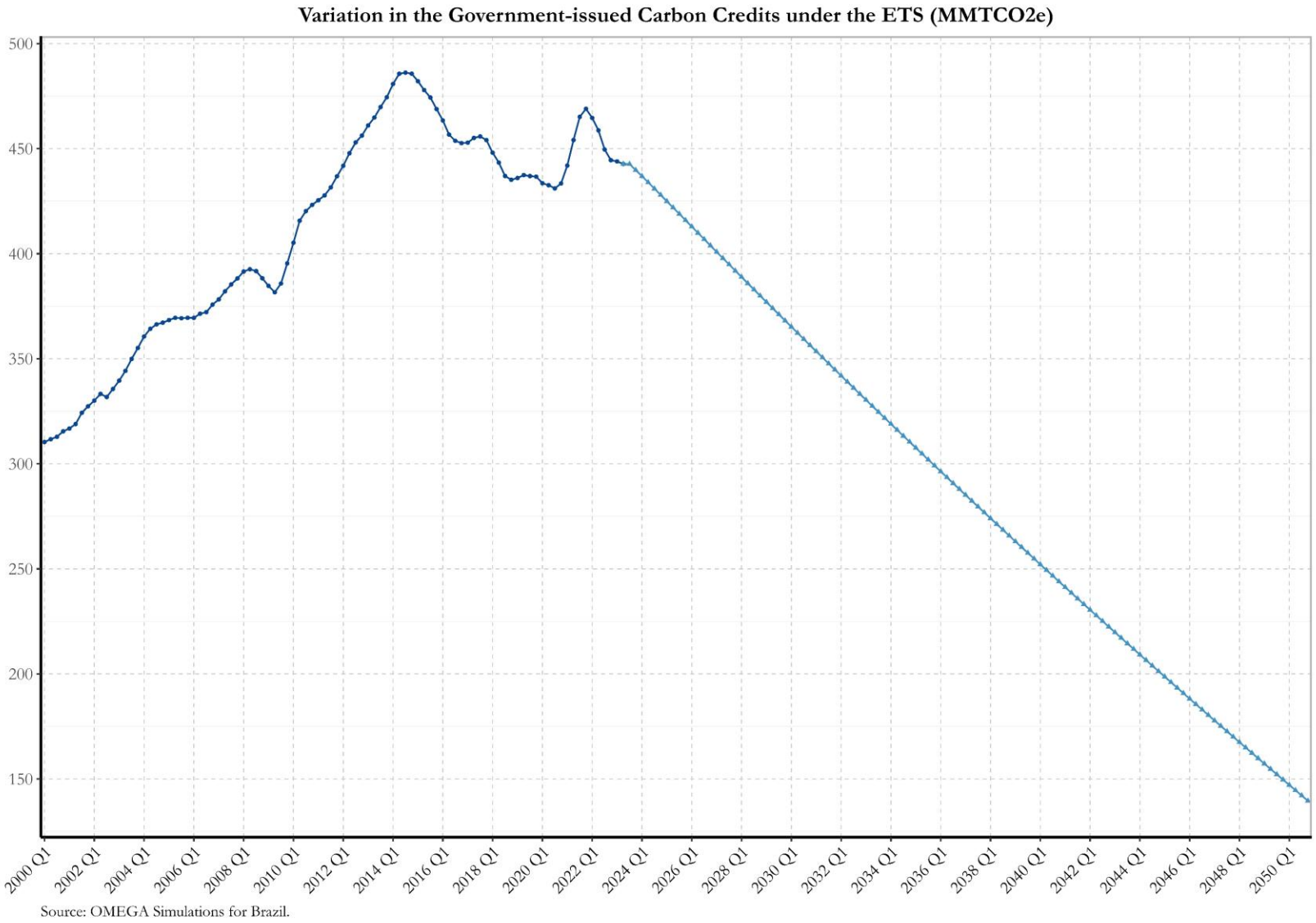
Initially set to the current level of emissions and is reduced by 2.1% per annum.

Supply of carbon credits:

- Free government-issued carbon allowances decrease from 100% to 0% over 20 years.
- Abatement-backed carbon credits – 5%
- Reforestation-backed carbon credits – 5%

Sector coverage:

- AGR: 0%
- IND: 80%
- TRA: 50%
- SVC: 50%
- RELC: 0%
- RFL: 0%
- FELC: 70%
- FFL: 90%



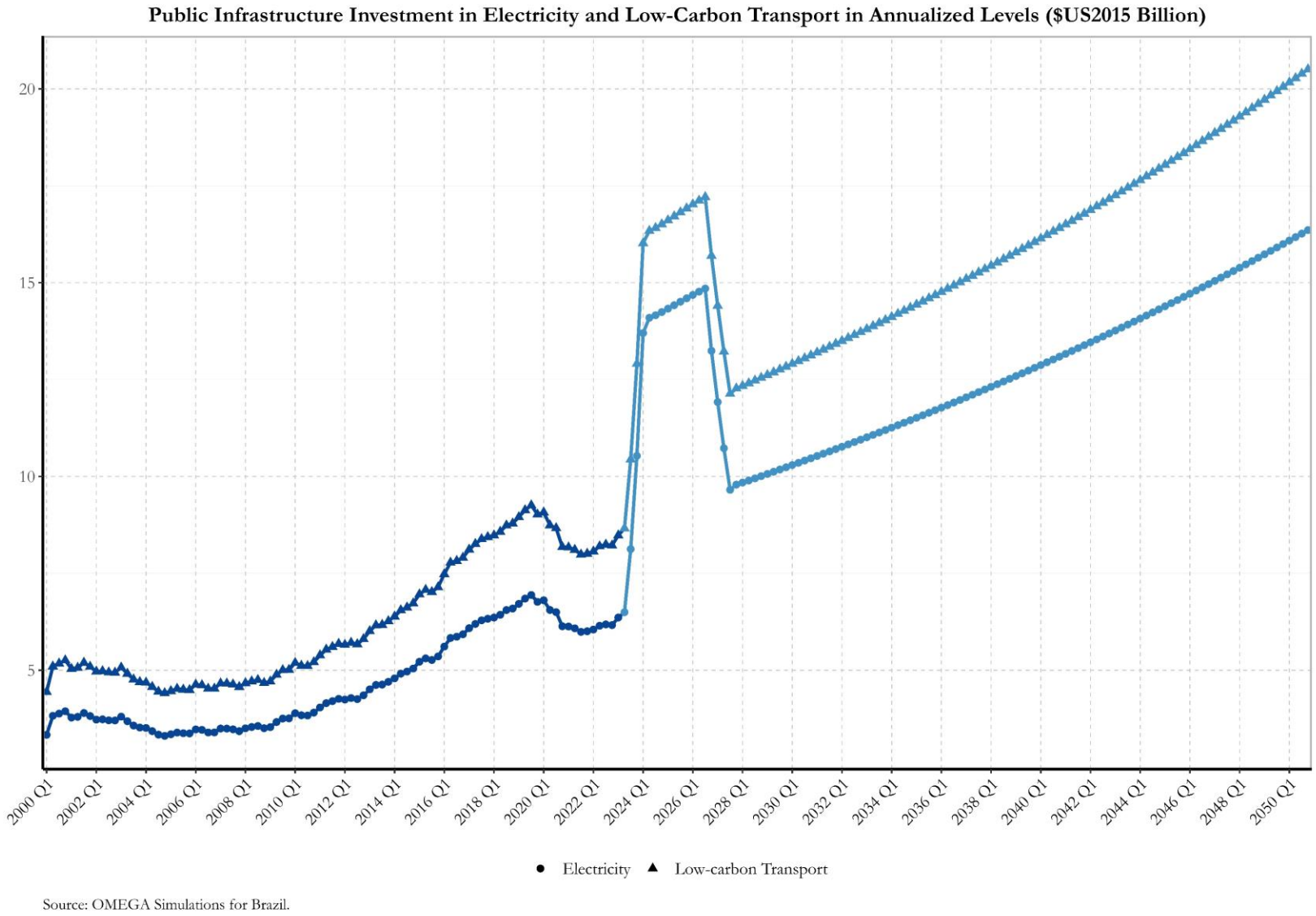
Design of the ETP Policies: Public Infrastructure Investment

Public Infrastructure Investment Package: 2.1% of 2023 GDP

Timing: Phased in over 16 quarters

Sectoral Coverage:

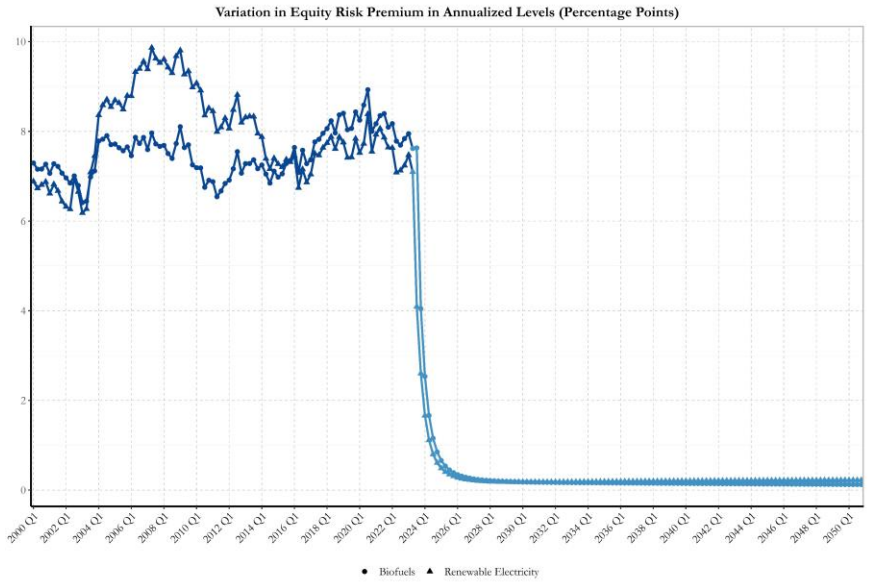
- Electricity-specific Investment (such as power grid and storage capacity)
- Low-carbon Transport (such as railways)



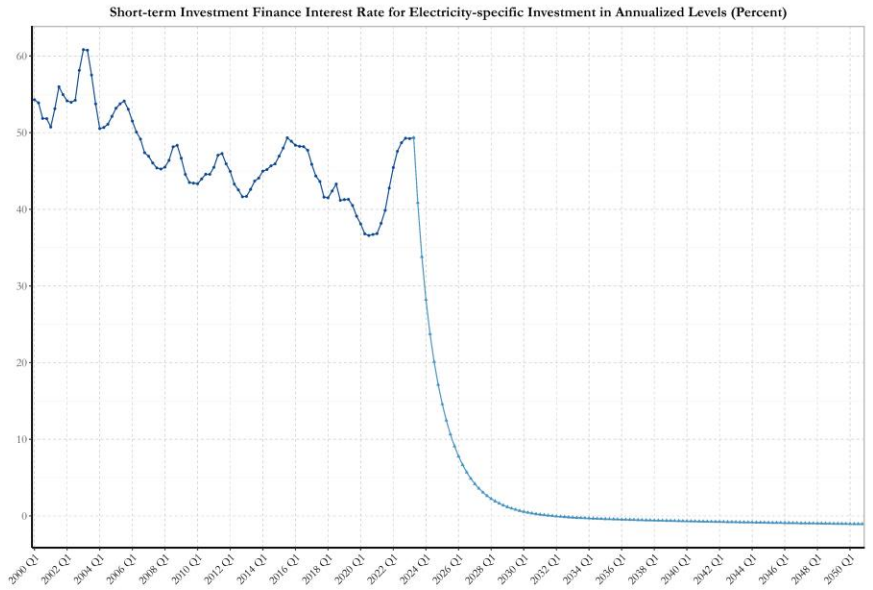
Source: OMEGA Simulations for Brazil.

Design of the ETP Policies: Green Finance

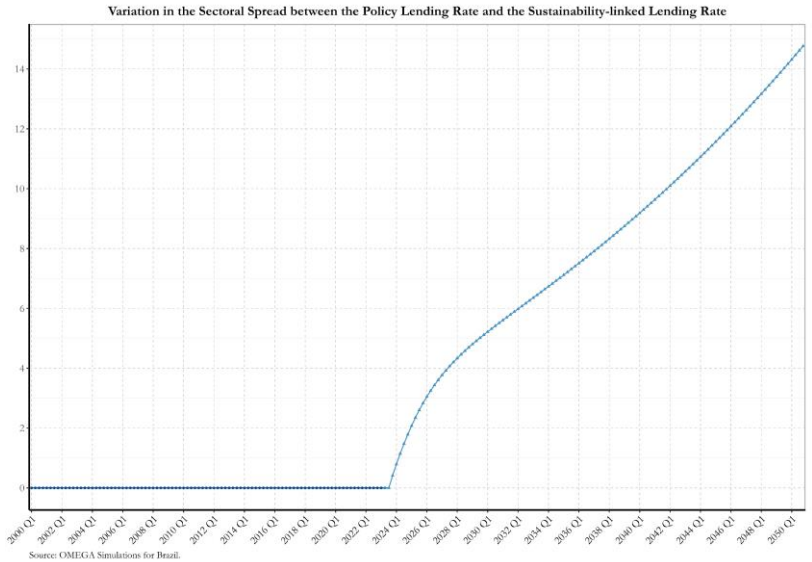
Derisking Renewables



Removal of Free-market Finance Premium for Electricity-specific Investments



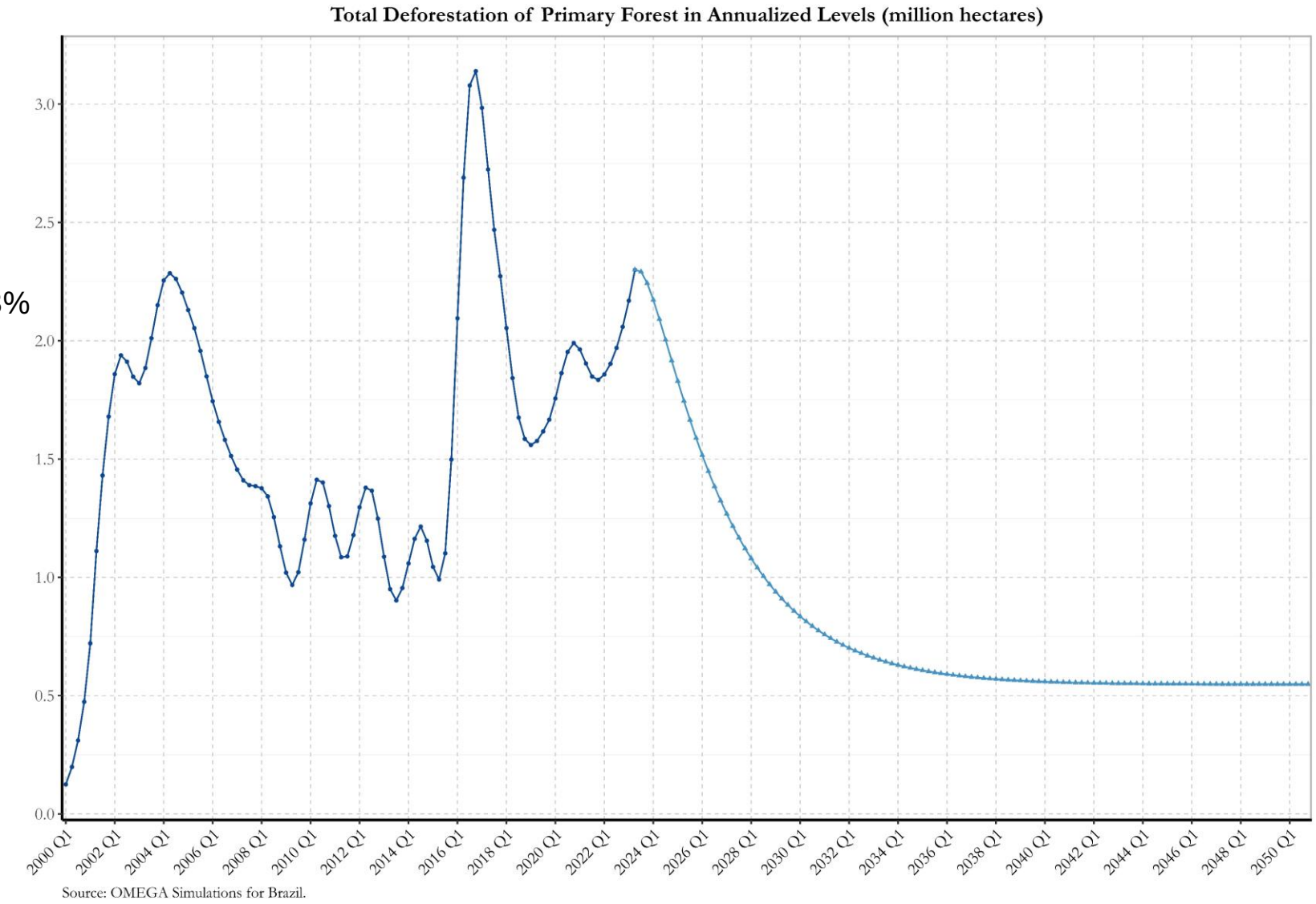
Conditioning the Regulated Interest Rate in Agriculture based on Emission Performance



Design of the ETP Policies: Restrictive Stance on Deforestation

Deforestation:

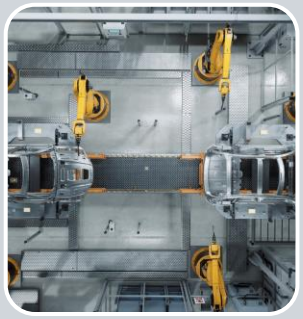
- Baseline: Phase out quarterly at 1%
- Scenario: Phase out quarterly at 7.3%



The OMEGA Model: Core Model Features

Open Economy

A domestic country vs. the rest of the world including trade, financial flows, and foreign direct investment



Multiple Sectors

Input-Output structure of 8 value-added sectors and 4 final-good producers

Endogenous Growth

Long-term growth determined by human capital accumulation and learning-by-doing externalities

Financial Sector

Variety of financial instruments including equity shares, bonds, loans, and deposits with endogenous risk premia, borrowing constraints, and asset pricing

Market Imperfections

Externalities, financial market imperfections, and a variety of nominal and real rigidities including monopoly power, staggered wage and price setting, and adjustment costs

Policy Interventions

Taxes, subsidies, tariffs, carbon markets, granular public investment in production and infrastructure, mandates, and green finance

GHG Emissions

Granular greenhouse gas emission from production activities, fossil-fuel combustion, and land use change

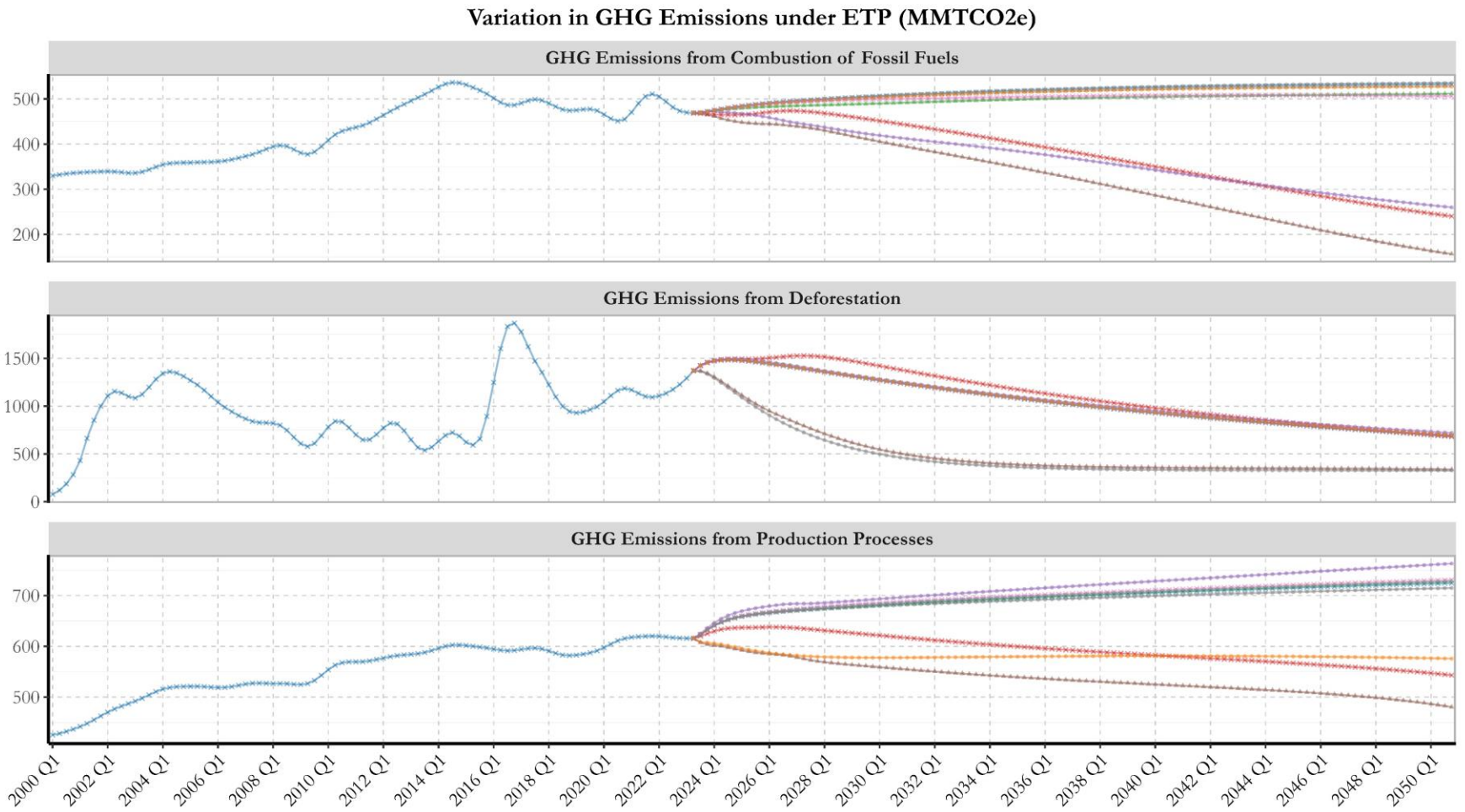
Simulations: Baseline Assumptions

- An annual autonomous energy efficiency improvement of 2%.
- An annual renewable electricity productivity improvement of 1% (roughly equivalent to an annual decrease in renewable electricity costs of 1%).
- An annual process emission intensity reduction of 2%.
- Phasing out deforestation beyond sustainable levels at a quarterly rate of 1%.

Simulations: Indicator Variables with Simulation Results

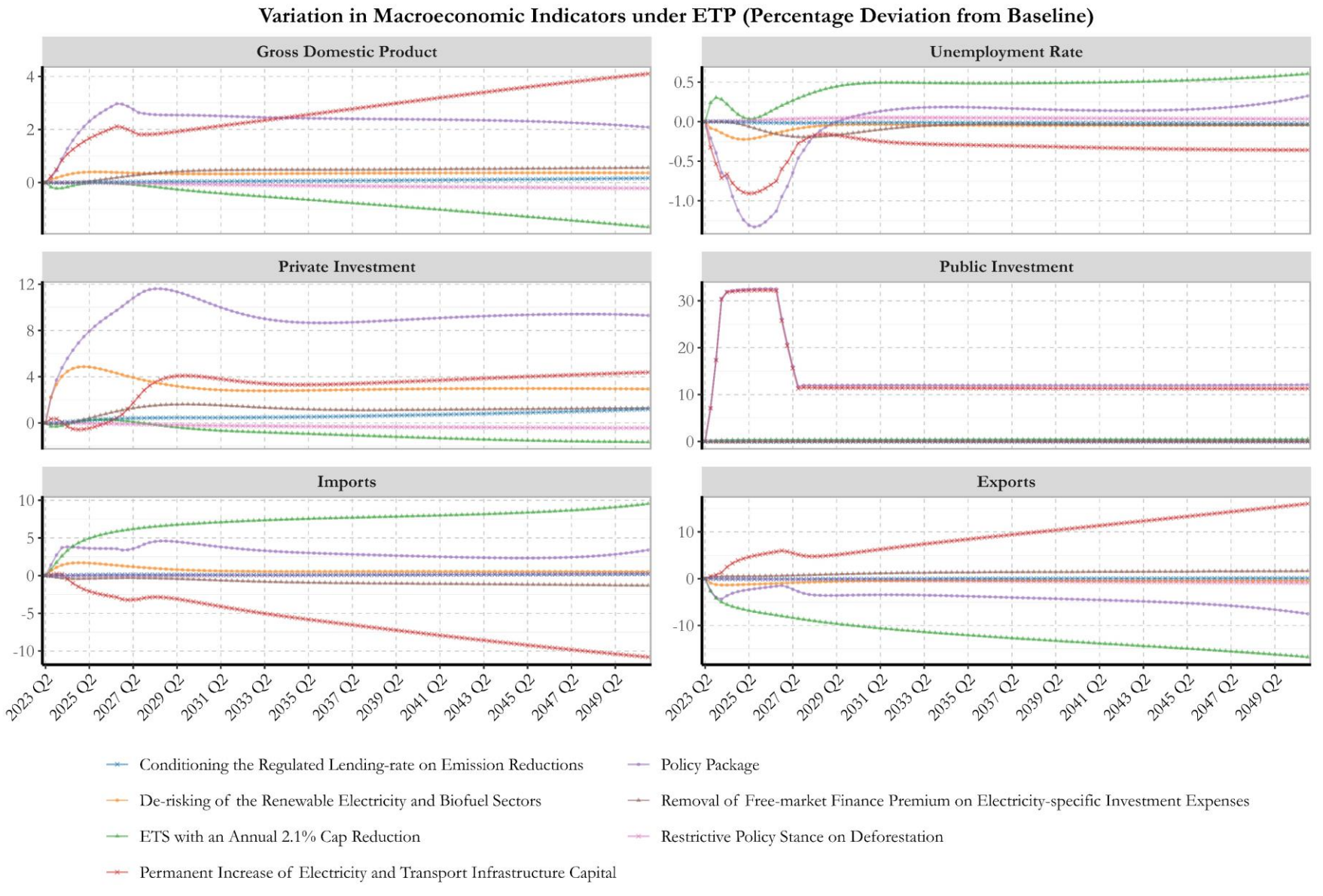
- Macroeconomic Variables
  - Real GDP
  - Private and Public Consumption and Investment,
  - Exports and Imports
- Fiscal Variables
  - Tax Revenues
  - Primary Surplus
  - Government Borrowing
  - Government Debt Servicing Payments
  - Public Debt to GDP Ratios
- Sectoral Output and Employment
- Sectoral Capital and Investment
  - Labor-, Electricity-, and Fuel-specific Capital and Investment
  - Public Capital Investment in Infrastructure
  - Sectoral Equity Risk Premia
- Aggregate and Sectoral Emissions
  - Emissions from Combustion, Processes, and Land-use Changes
- Carbon Markets
  - Government-issued Carbon Credits and Prices
  - Abatement-backed Carbon Credits and Prices
  - Reforestation-backed Carbon Credits and Prices
- Prices
  - Consumer Price Inflation
  - Policy Interest Rates
  - Short-term Finance Rates
  - Exchange Rates

Simulations: ETP: Aggregate Emissions



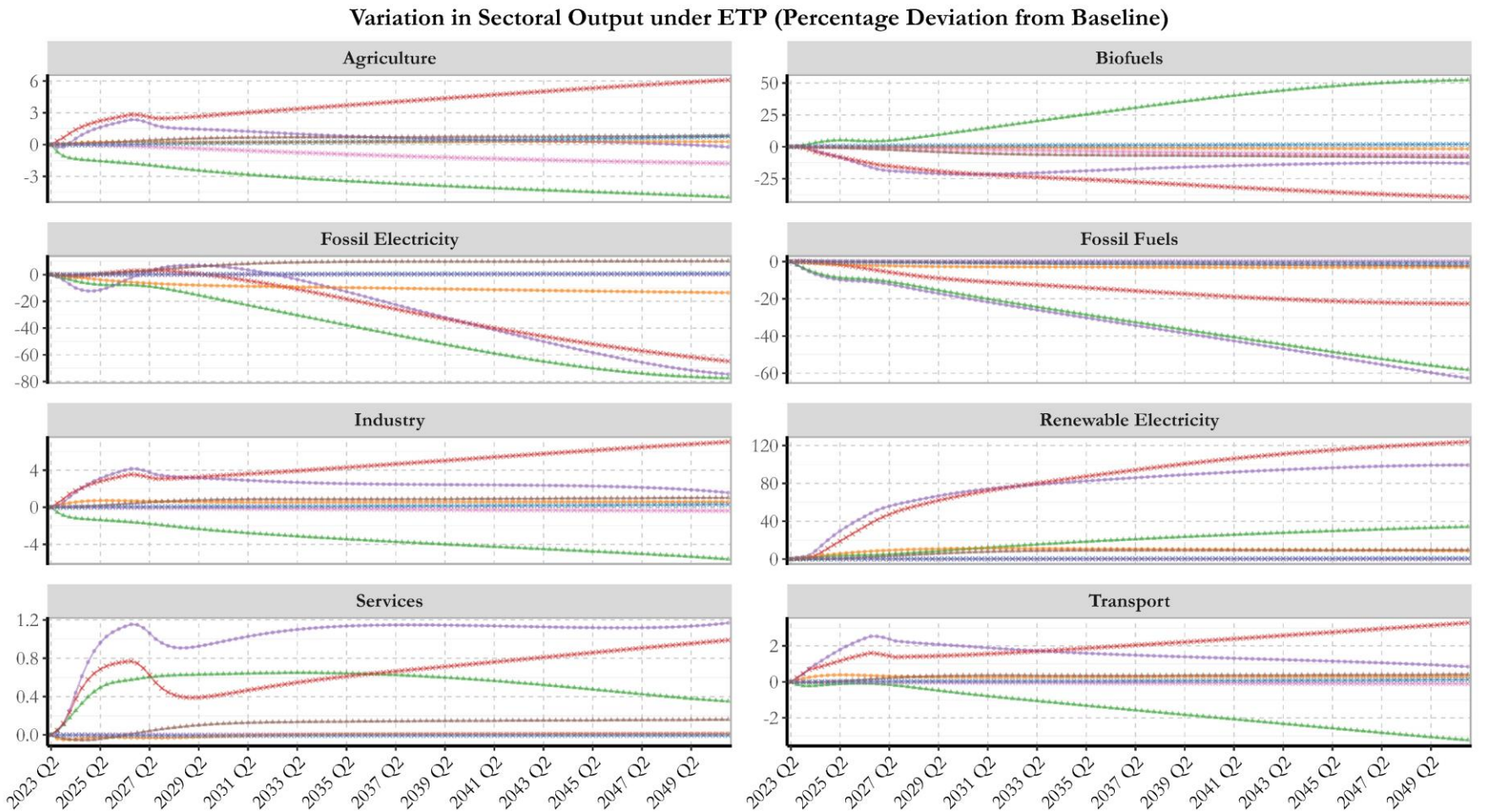
Source: OMEGA Simulations for Brazil.

Simulations: ETP: Macroeconomic Effects



Source: OMEGA Simulations for Brazil.

Simulations: ETP: Sectoral Output



Source: OMEGA Simulations for Brazil.

Summary of Results: ETP

- GHG Emissions
    - Emissions (excluding deforestation and reforestation) will reduce by 8% by 2050 compared to 2005.
    - Fossil fuel emissions will be 40% lower in 2050 compared to 2005.
    - Process emissions will be 10% higher in 2050 compared to 2005.
    - Emissions from deforestation will be about 50% lower compared to 2005.
    - Carbon sequestration will be about 30% higher compared to 2005.

- Macroeconomic Indicators
    - GDP is about 2% higher throughout compared to the baseline.
    - Private investment is about 20% of GDP by 2050.
    - Exports decrease by about 3.5% in the short-run and increase by about 1.5% by 2050 compared to the baseline.

Link to Dashboard with Results:
https://datanalytics.worldbank.org/omegabrazilresults/

C3A Annual Symposium
December 2-6, 2024
World Bank Paris

Research Segment

Session 12: Climate Policy and Structural Change

Chair of session:Nadia S. Ouedraogo (UNECA) and Tatiana Vasconcelos Fleming Machado (C3A/WB)

Friday, December 6

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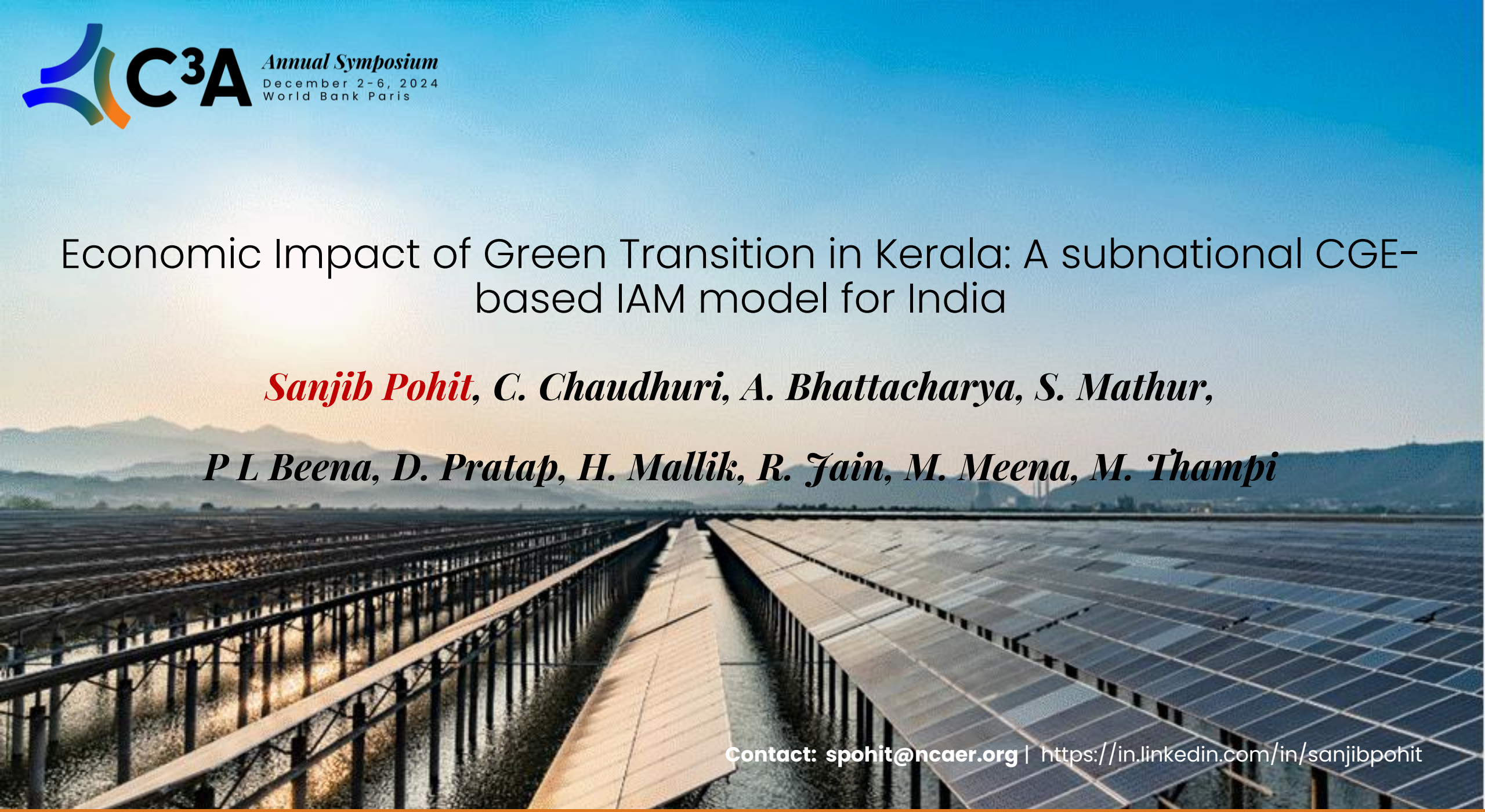
Economic Impact of Green Transition in Kerala: A subnational CGE-based IAM model for India

***Sanjib Pohit*, C. Chaudhuri, A. Bhattacharya, S. Mathur,**

P L Beena, D. Pratap, H. Mallik, R. Jain, M. Meena, M. Thampi



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Introduction

India, aspires to achieve the target of **net-zero emission by 2070**.

NDC for India included reduction in **emission intensity as a share of GDP by 45% by 2030**, from **2005 level**; and achieving **50%** cumulative electric power **installed capacity from non-fossil fuel**-based energy resources by **2030**

But **presently** the share of renewables in power generation in India is only **12%** , coal still dominant

India still depends heavily on fossil fuel as source of energy in power & other sectors, with variability across region

The impact of the **adoption of green fuels** will have **different impact on different states**. In this study, we want to explore the effect of adoption of low carbon pathway at a sub-national level, for the state of **Kerala**

To understand **feasible policy choices** and **financial implications** for adopting the right policy interventions for transition towards a low carbon pathway in Kerala

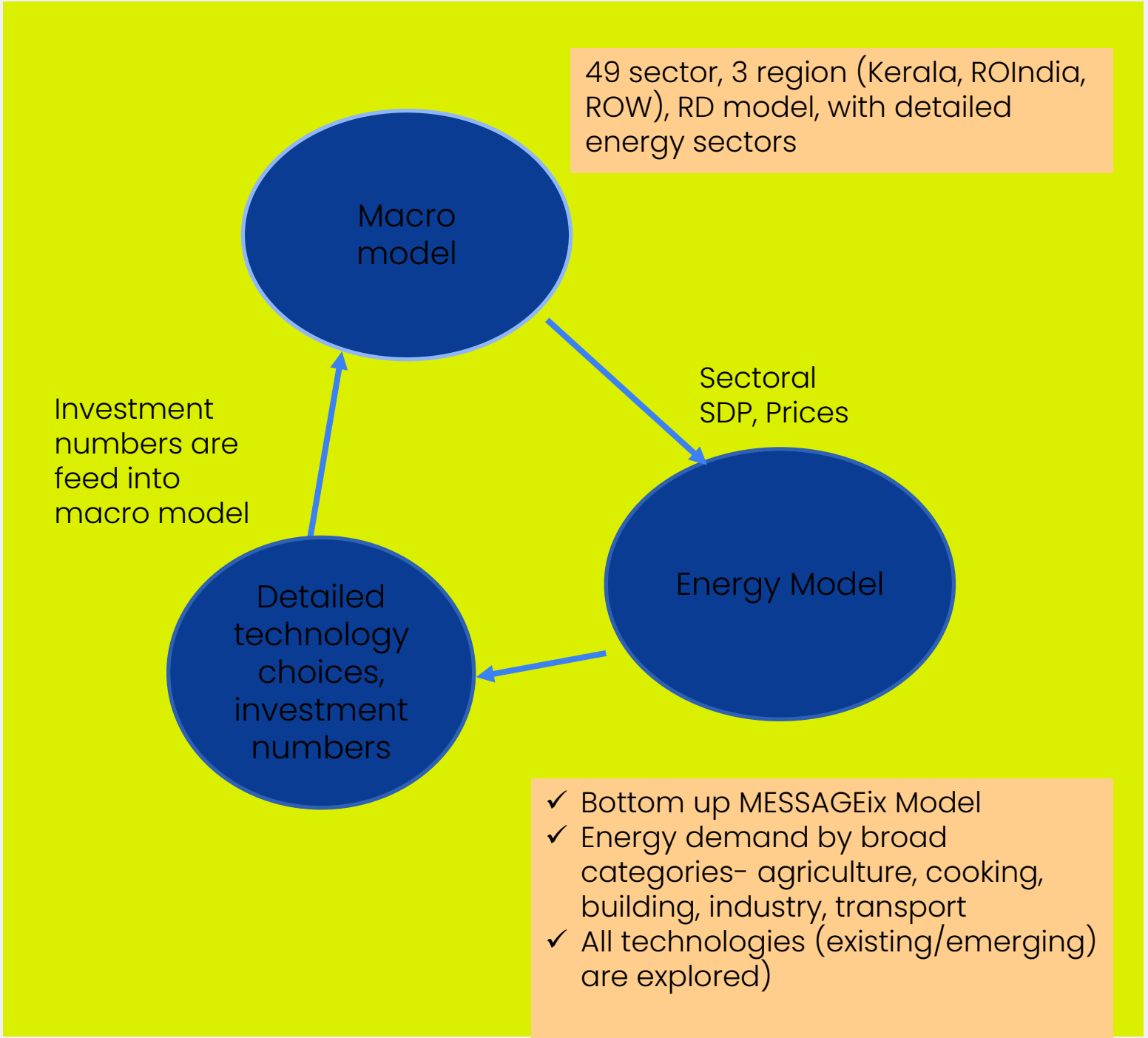
Kerala economy: An overview

- Kerala ≈ About **1.2%** of the **geographical area** of India, **3% of India's population**
- **Service sector** has the highest **output share (64%)** followed by industry (27%) and agriculture sectors
  Low emission in Kerala ≈ Low share of power generation sector in total emission.
- **Kerala meets its energy demand by purchasing power from other states**
- When all the states adopt a low carbon pathway, the **availability of cheap power** from the neighboring states may not be a reality
- Adopting low carbon pathway implies not only **augmenting capacity of non-fossil-based power use**, but also **increasing energy efficiency** across economy ≈ Lower carbon footprint
- **Our focus - Mitigation strategies**
  - ✓ It mainly involves sectors like power, transport, industries, and agriculture, which cumulatively contribute to 80 per cent of the emission in the state
  - ✓ Analysis to some extent needs to take into accounts happenings in the rest of the world

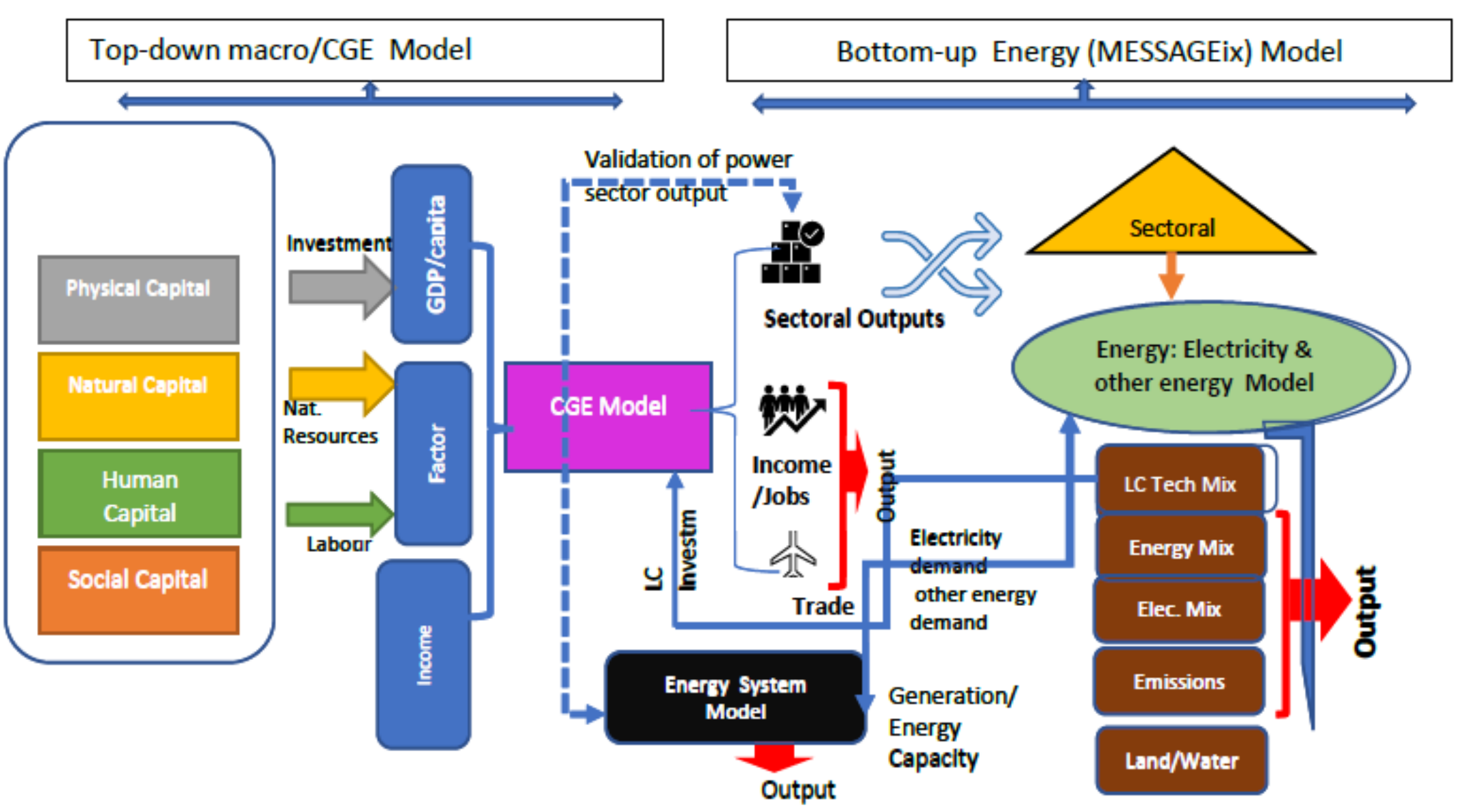
An Integrated Approach

Energy demands derived from macro model will reflect the impacts on sectors and their energy demand considering the whole network of economic interlinkages in a complete equilibrium state

Role of price is built into the system in future period depending on demand/supply situation



Integrated Model Framework



Policy Scenarios

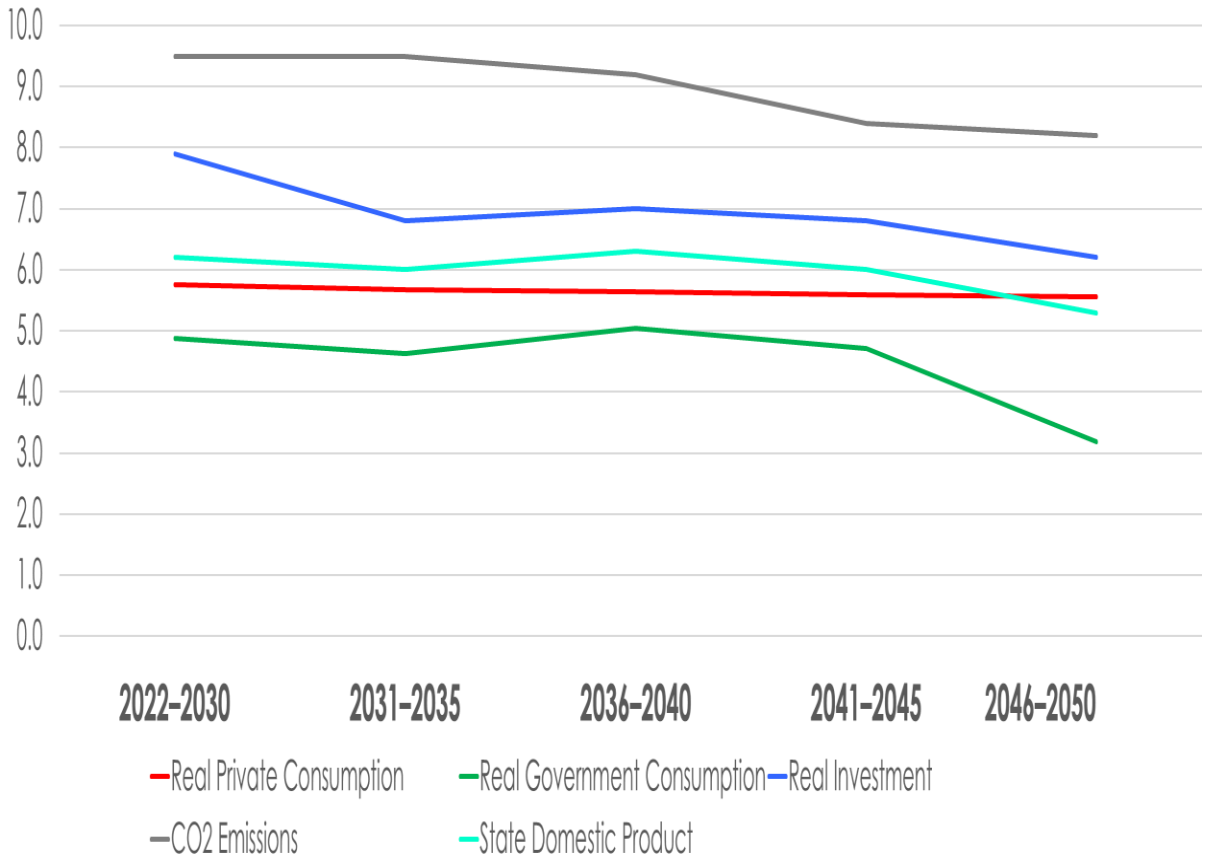
- Scenario 1: Restriction of fossil electricity from the rest of India (Rest_F_Elec)

- Scenario 2: Scenario 1 + capacity augmentation of renewable electricity (Aug_R_Elec)
  - ✓ 50% of the existing potential of renewable electricity by various modes is achieved in Kerala and rest of India by the terminal year of our model run (2050)
  - ✓ Fund of investment is not a constraint.

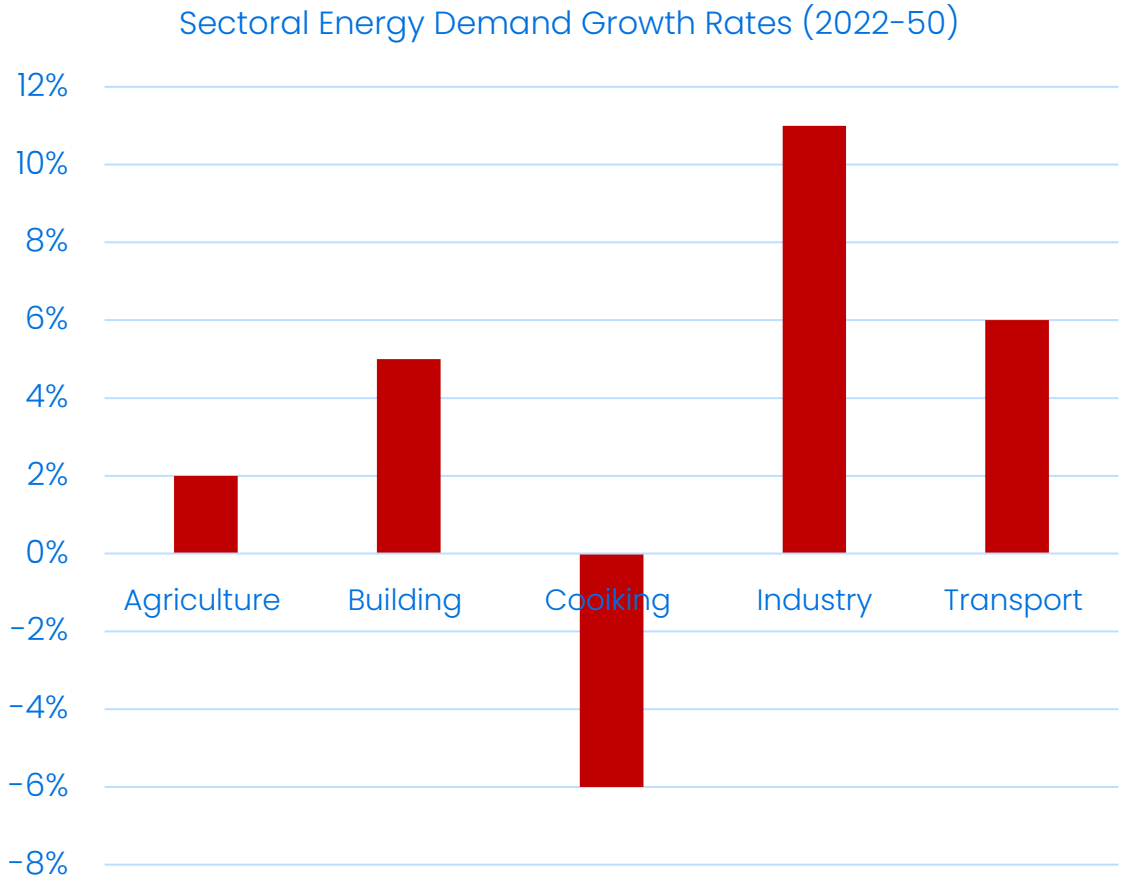
- Scenario 3: Scenario 2 + increased energy efficiency (Incr EE)
  - ✓ Increased energy efficiency to the tune of 2.5% per annum
  - ✓ Assumed 1% total productivity growth per year in all sectors
  - ✓ This range of total factor productivity (TFP) growth has been achieved in the past in the Indian context

Base Line Scenario

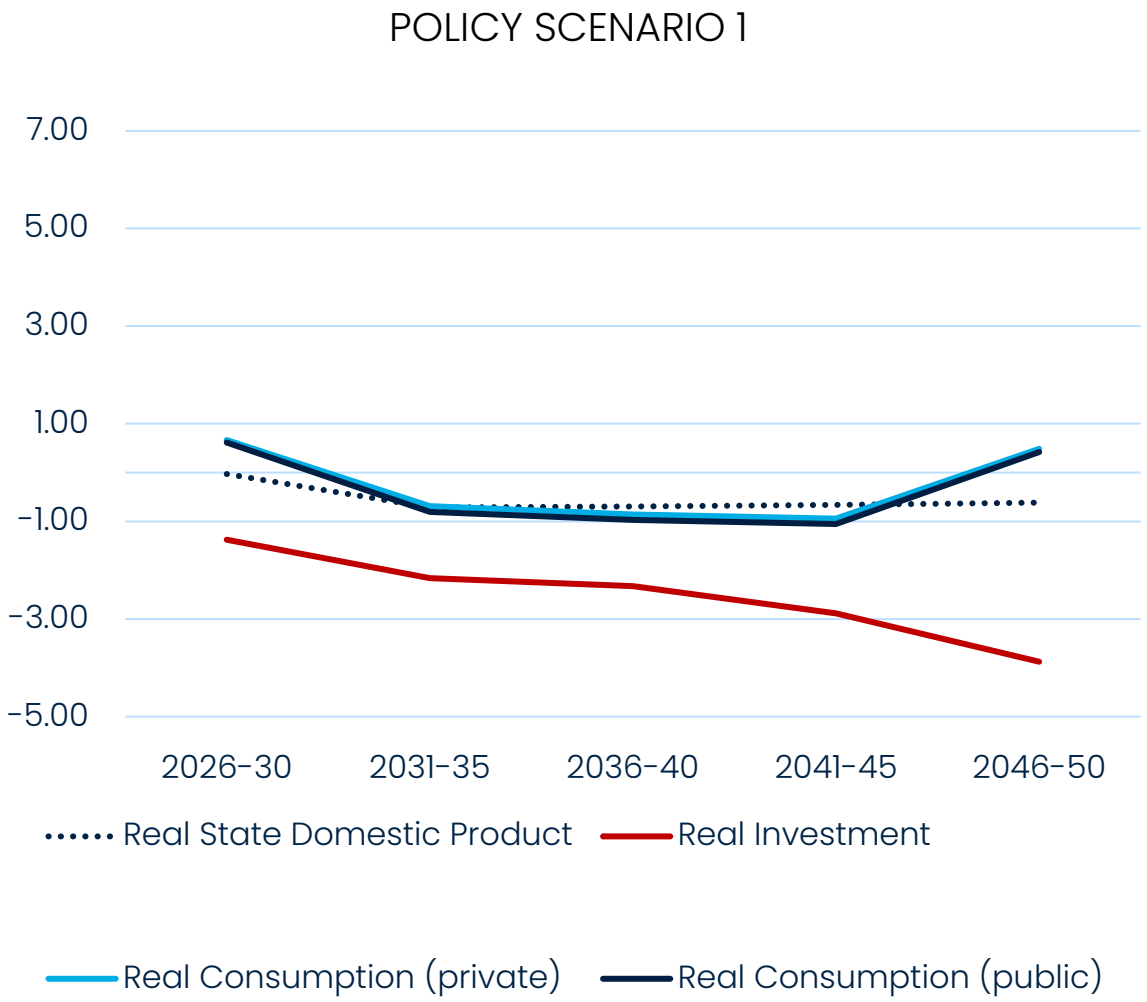
MACROECONOMIC GROWTH OF KERALA (%)

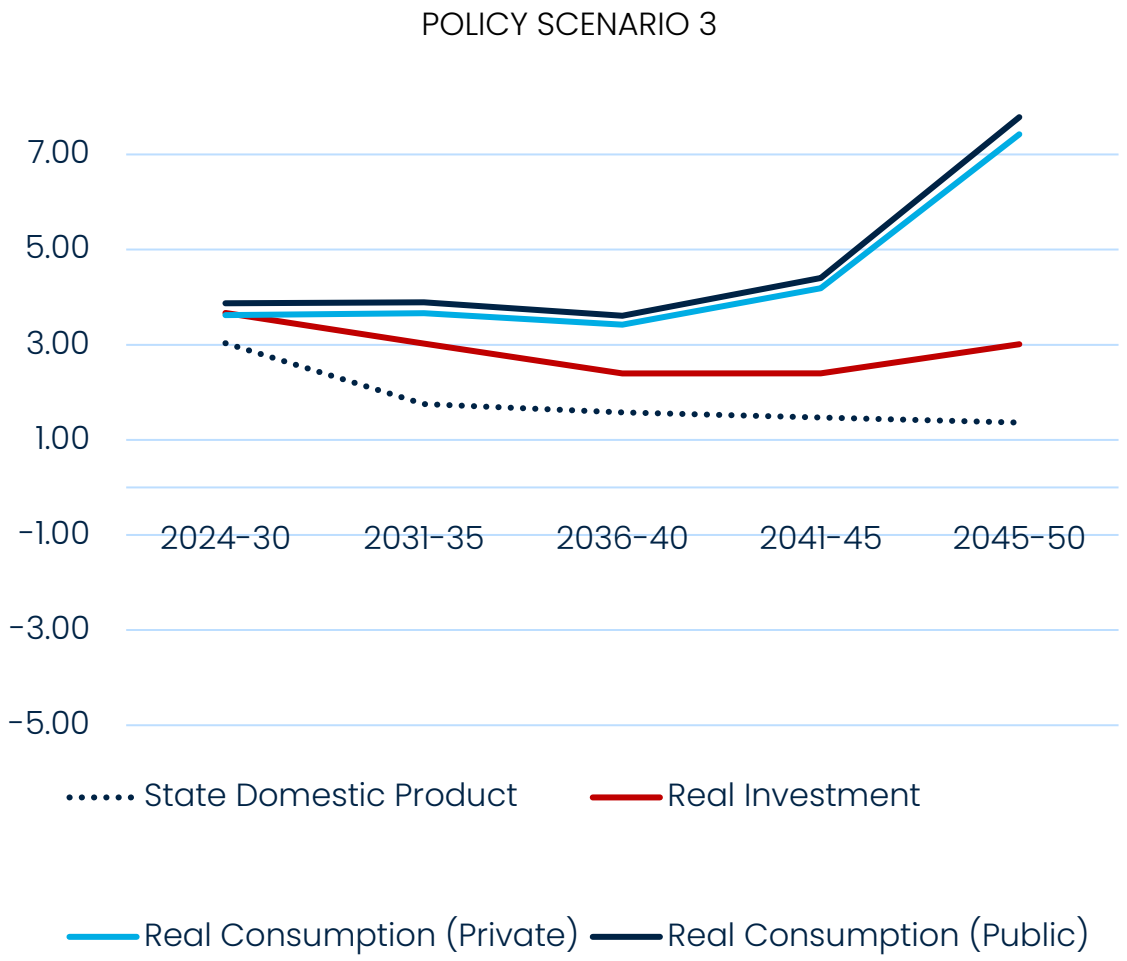


ENERGY DEMAND GROWTH RATES IN KERALA (BTW 2022-2050

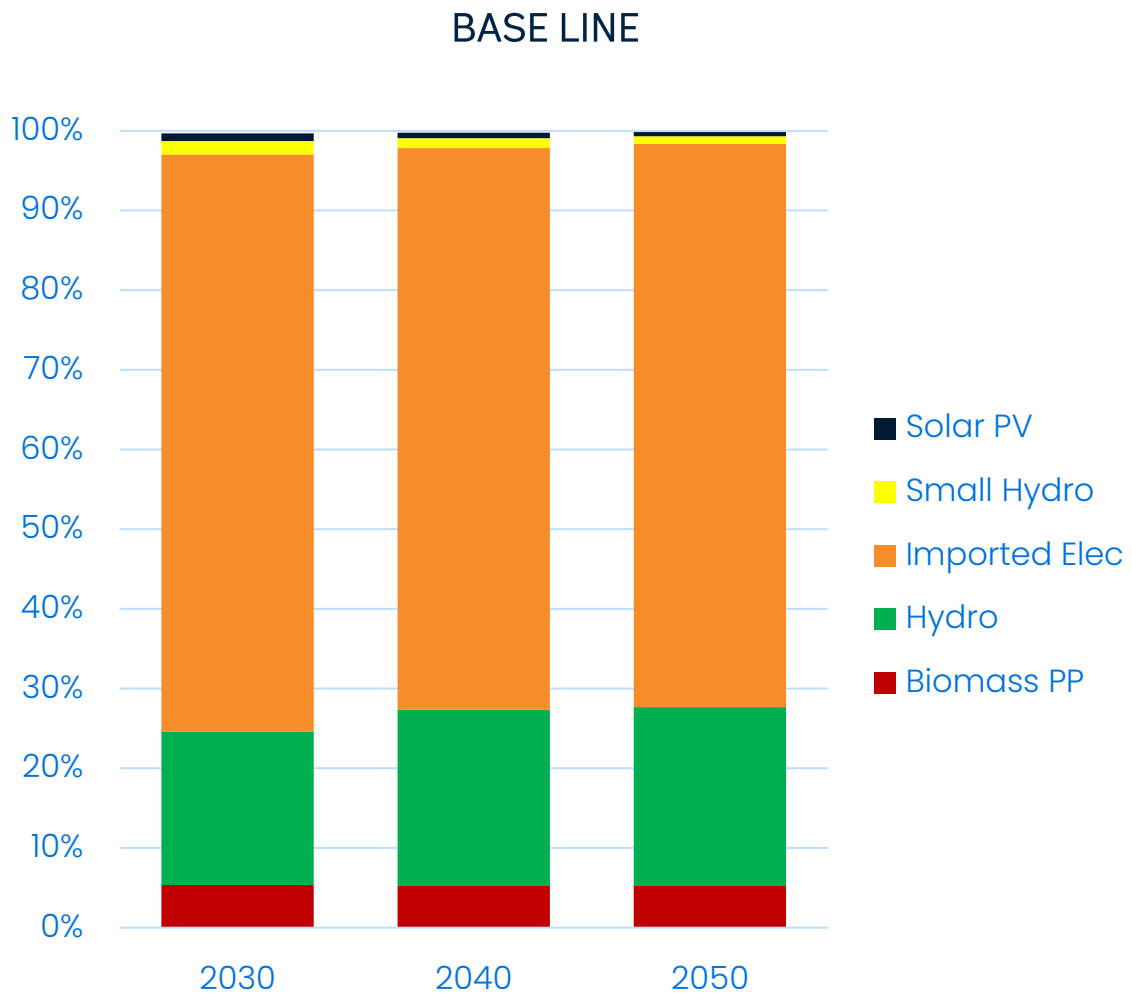


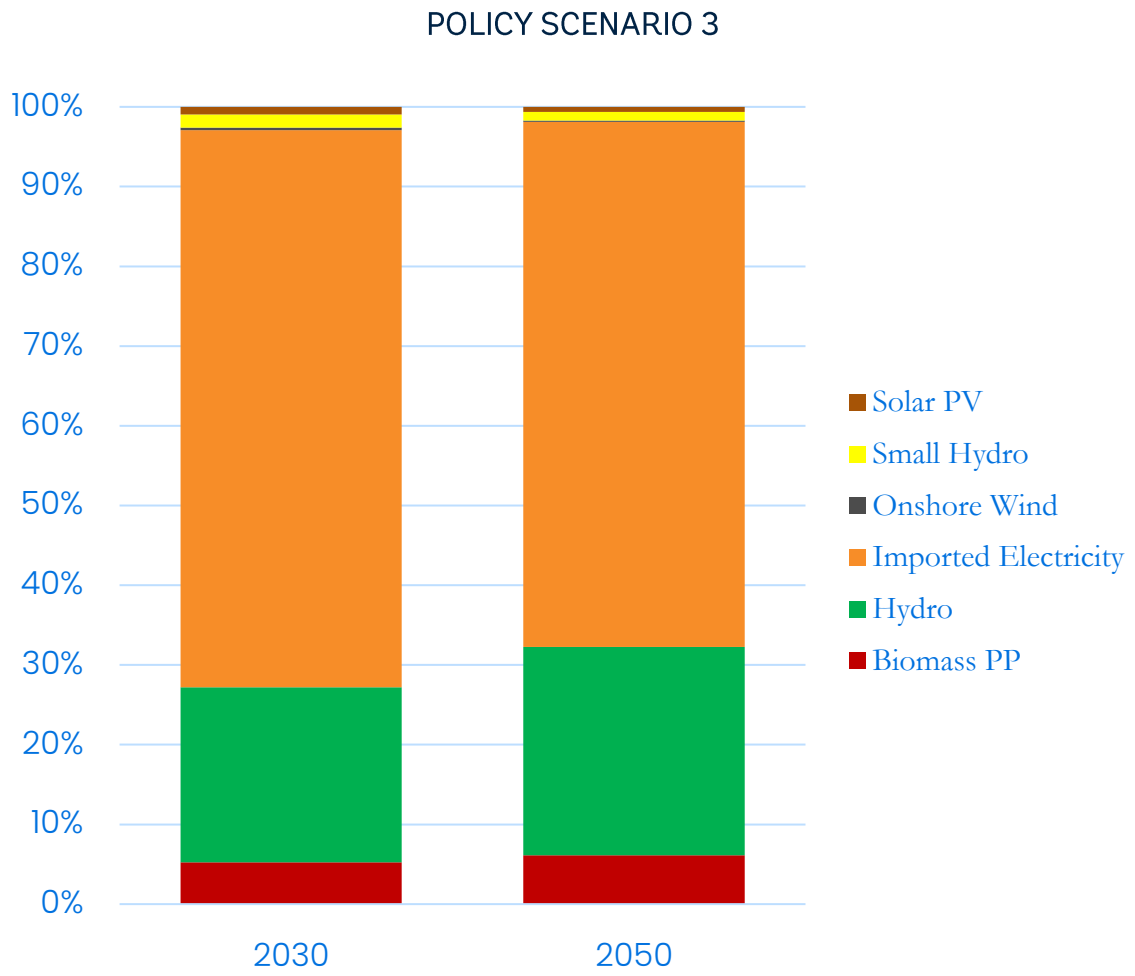
Macroeconomic indicators of Kerala (Percentage derivation from baseline)



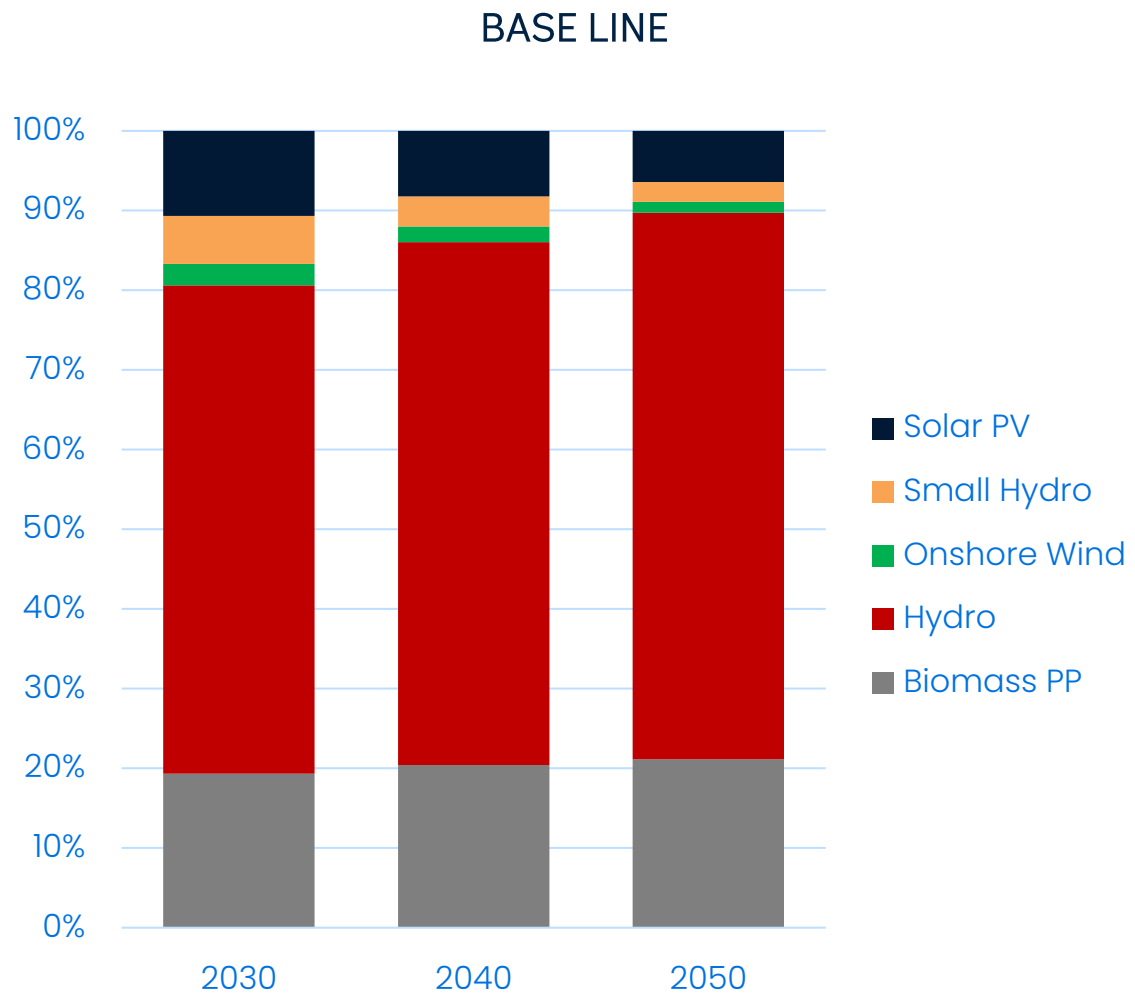


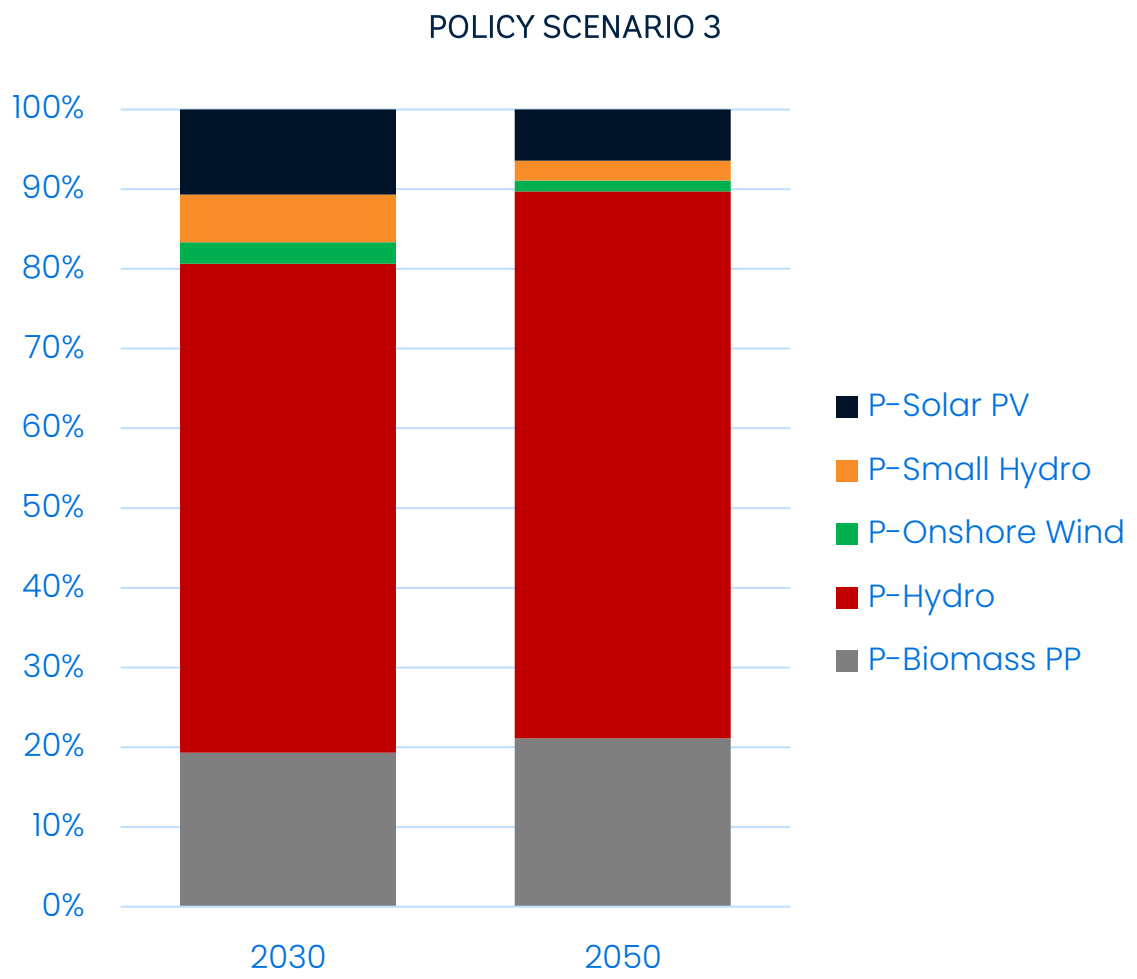
Share of Electricity Generation in %



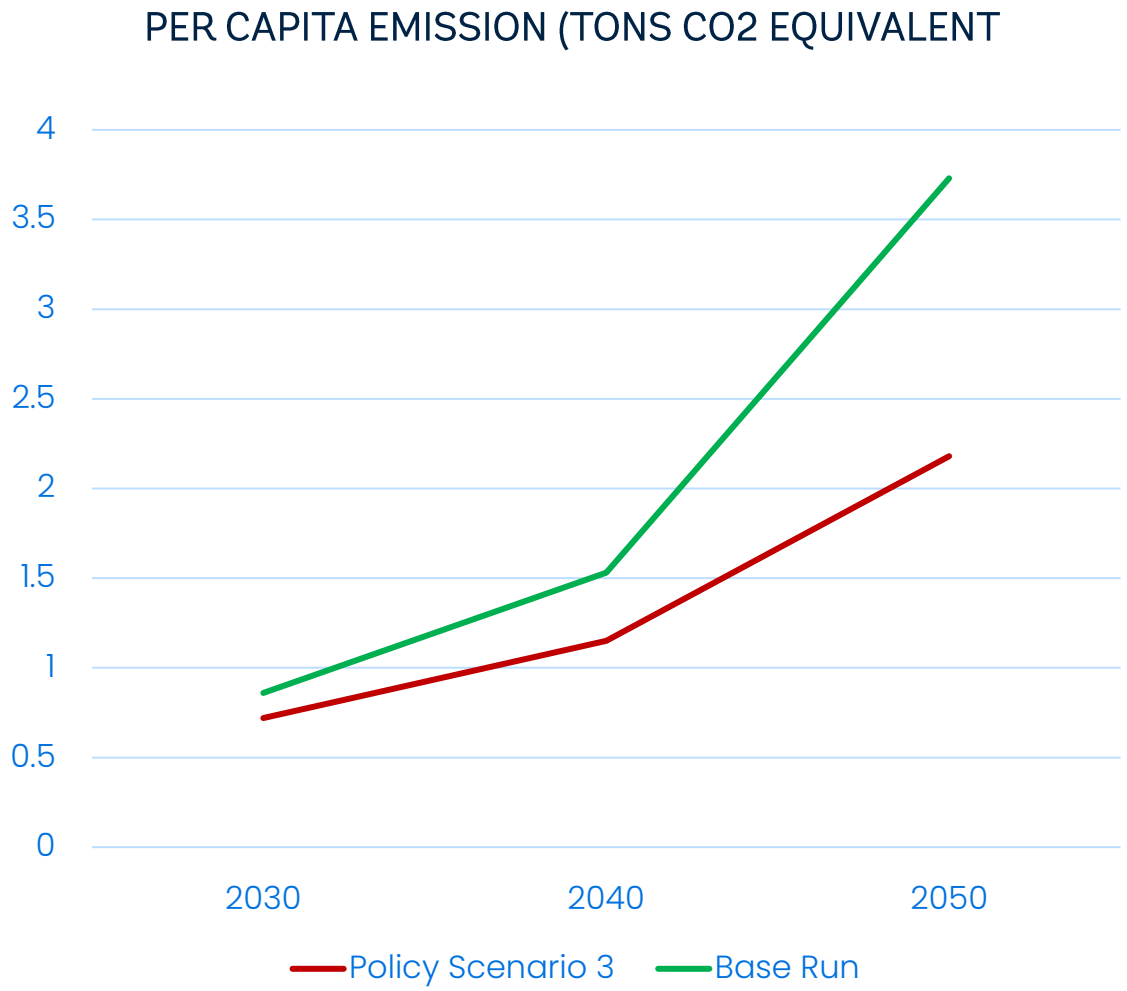


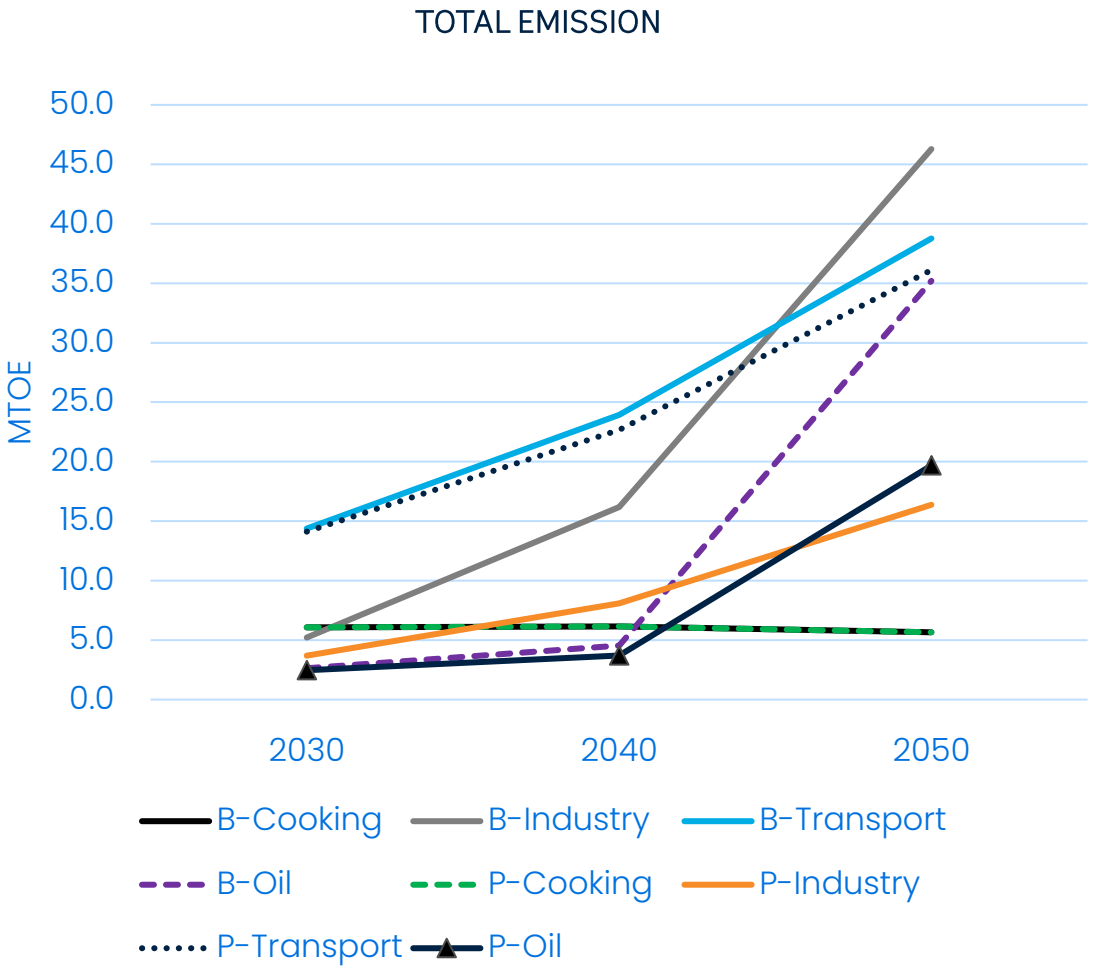
Share of Electricity Capacity Mix in %





Emission profile

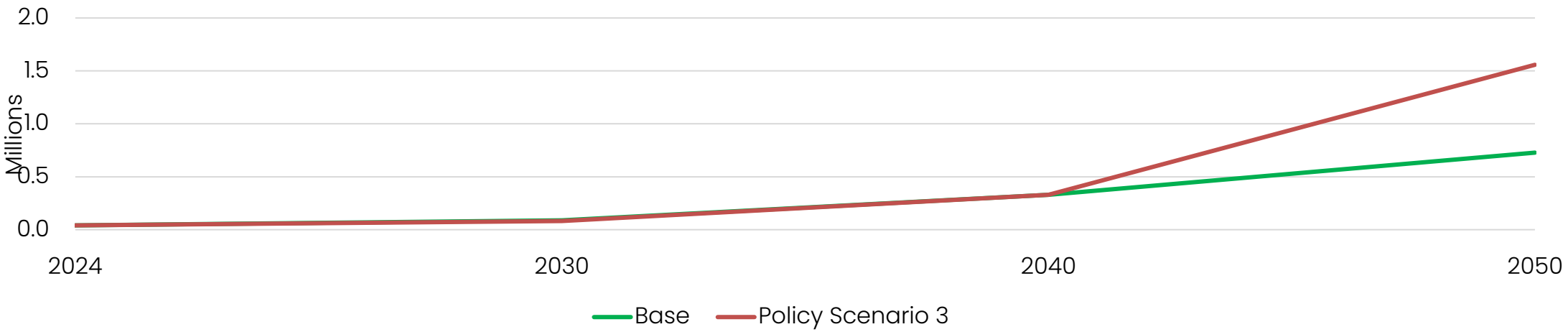




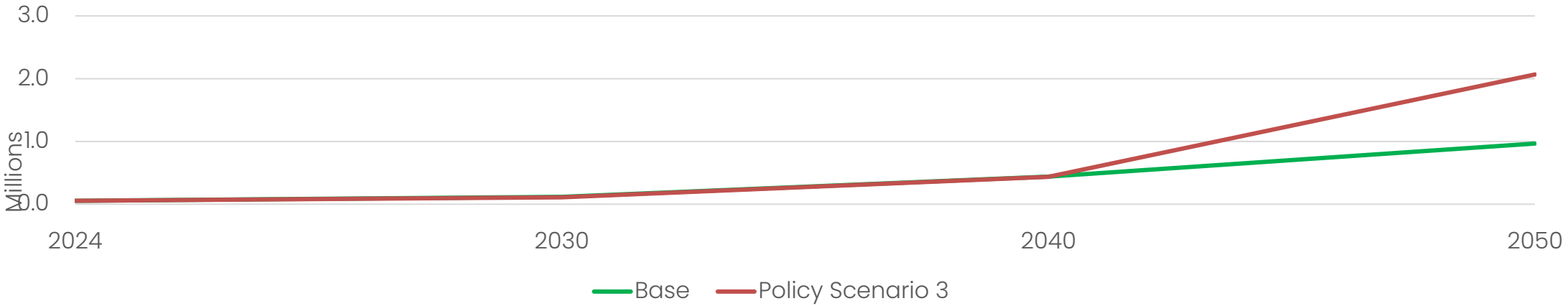
Cumulative Investment (US $ million) requirement for green transition

Sector	Base Run		Policy Scenario 3		Additional Investment required	
	2025-30	2025-50	2025-30	2025-50	2025-30	2025-50
Agriculture	241	626	241	626	0	0
Biofuel	66	154	63	129	-3	-25
Buildings	1131	4733	1131	4733	0	0
Cooking (Rural)	87	230	87	230	0	0
Cooking(U)	502	1855	502	1855	0	0
Domestic (Resource)	753	5079	568	3551	-185	-1528
Electricity	1958	26152	1958	26152	0	0
Gas	7	38	7	33	0	-5
Industry	188	3075	130	1223	-58	-1852
Transport (Freight)	11489	53638	11033	48842	-456	-4796
Transport (Passenger)	31852	166834	28835	143291	-3017	-23543
Biogas	5	40	5	35	0	-5
Green hydrogen	22	58	0	54	-22	-4
Total	48301 (3.6% of cumulative SDP)	262512 (0.83% of cumulative SDP)	44560 (3% of cumulative SDP)	230754 (0.36% of cumulative SDP)	-3741	-31758

Direct Employment in Energy Sector

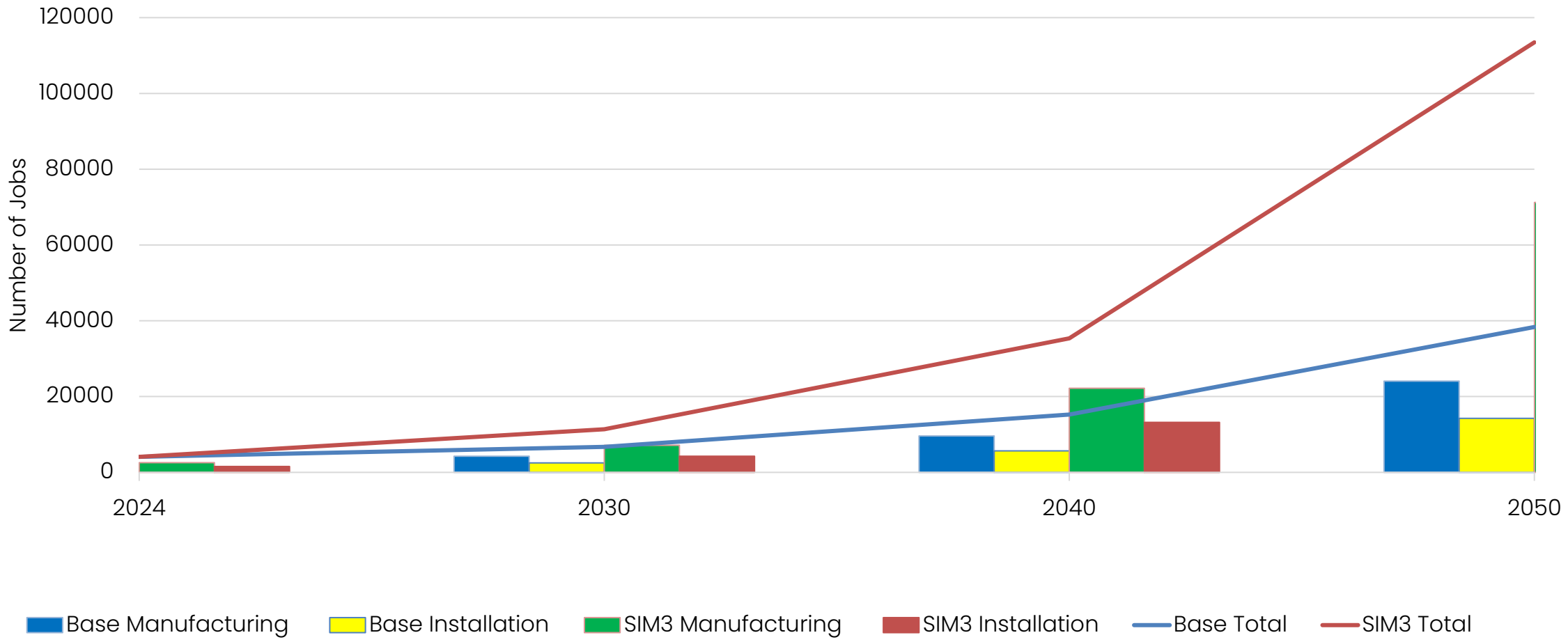


Total (Direct, Indirect and Induced Together) Employment in Energy Sector

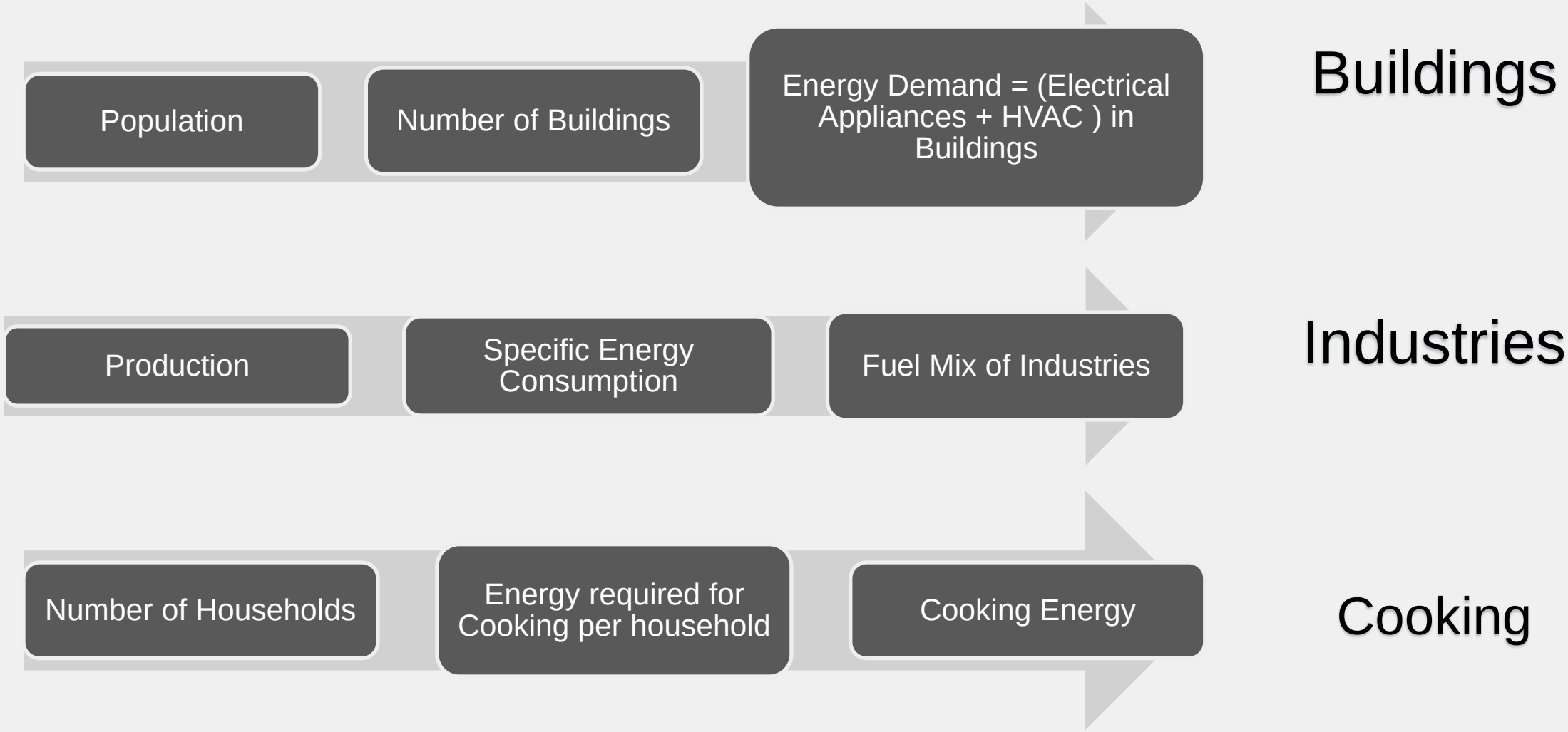


**employment from Operation and Maintenance*

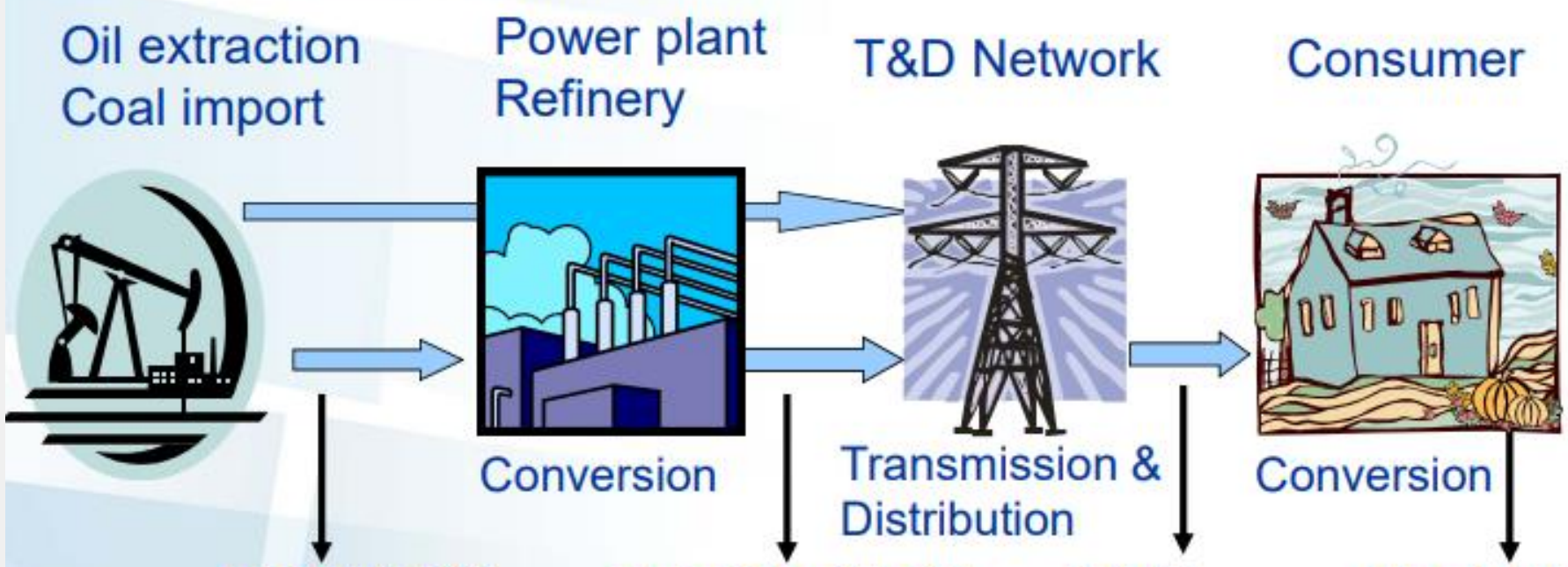
Employment in Manufacturing and Installation of New Renewable Power Plants



Linking approach and methodology



MESSAGE$_{ix}$ Energy System



PRIMARY
- crude oil
- natural gas
- coal
- uranium
- water
- wind

SECONDARY
- diesel
- kerosene
- gas
- electricity
- coal
- heat

FINAL
- diesel
- kerosene
- gas
- electricity
- coal
- heat

USEFUL
- heat
- light
- mechanical energy

Conclusion & *key messages*

Analysis of Mitigation strategies for energy transition based on Integrated modelling Approach

- Business as usual scenario indicates
    - Per capita emission will rise from 0.7 tons CO2e in 2025 to 3.73 tons CO2e in 2050
    - Imported electricity will still play an important role in BAU
- Policy run indicates that restriction on import/production of fossil-based electricity, without any policy intervention specific to renewable energy capacity enhancement, will not lead to augmentation of the capacity of renewable electricity
    - Kerala's State Domestic Product (SDP) contracts as all sectors to face contraction due to reduced supply of electricity and higher price of electricity
    - A market-based approach with tax/subsidies performs better in limiting the SDP loss during the transition along with augmentation of renewable energy capacity
- Results improve significantly in terms of restricting emission without hampering economic growth, if the assumption on increased energy efficiency along with productivity growth is incorporated into the model for energy transition.

Conclusion & *key messages*

- Results improve significantly in terms of restricting emission without hampering economic growth, if the assumption on increased energy efficiency/productivity growth is incorporated
    - An energy efficiency to the tune of 2.5% concomitant with productivity growth of 1% per annum will lead to only a rise of per capita emission by 2.18 ton CO2e in 2050 versus 3.73 ton CO2e in 2050 in the base run
- Prudent to augment capacity of renewable electricity
- Results show that direct employment from operation and maintenance of power plants would be significantly more than the baseline employment projection from 2040 onwards, and the policy scenario 3 (aggressive use of renewable energy, increased energy efficiency, and productivity growth) is expected to provide 0.8 million more direct employment in the energy sector in Kerala as compared to the baseline scenario.
- Investment in renewable energy also increases employment in manufacturing/installation of new power plants.

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Thank you