

Mitigation strategies for transitioning towards 'net-zero' energy systems in India – an application of the TIMES model

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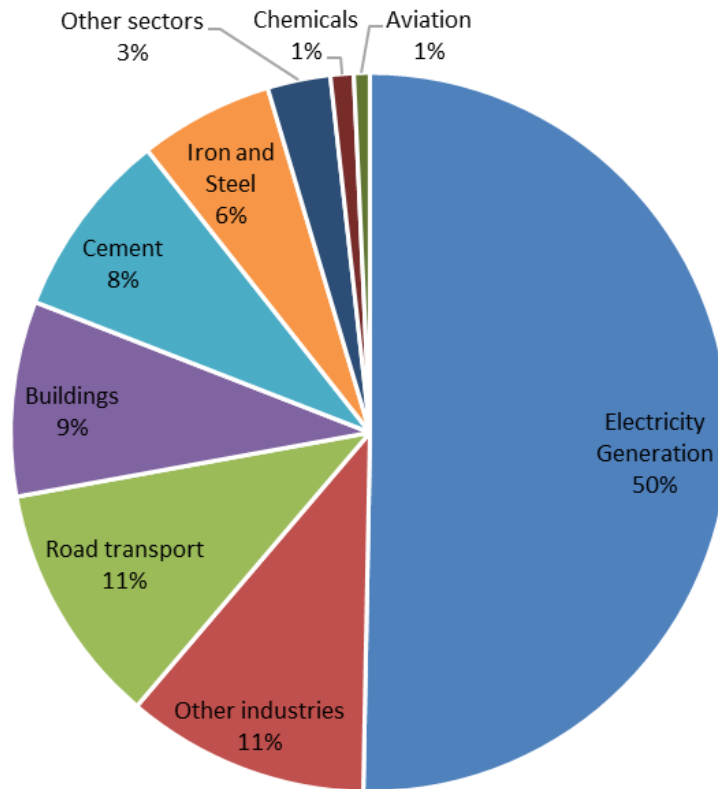
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Outline

1. Background and Motivation
2. Research Objectives
3. Methods and Data
4. Results and Discussions
5. Conclusion and Policy Implications

Energy System Emissions in India

Total CO₂ emissions without LULUCF = 2231 Mt-CO₂



Source: Third BUR to UNFCCC, MoEFCC, 2021

LULUCF: Land Use, Land-Use Change and Forestry

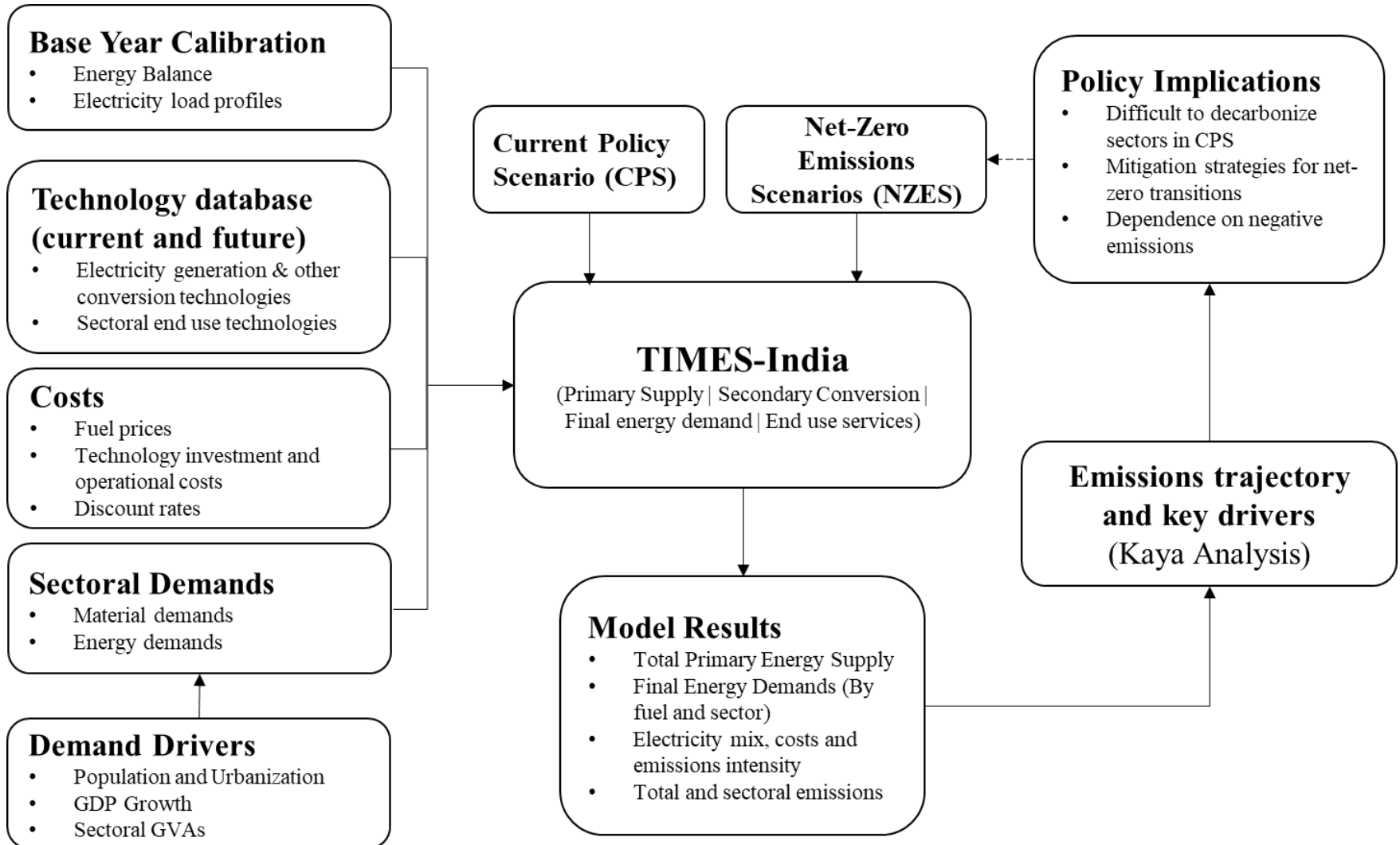
- Paris Agreement and goals for net-zero energy systems
- Energy sector responsible for 93% of total CO₂ and 75% of GHG emissions
- Coal dependent, fast growing economy
- Low per capita energy consumption and emissions per capita
- NDCs reflect the need to balance climate goals and developmental priorities

Research objectives

- To study and quantify the impacts of NDCs and other current policies on the energy supply and demands, sectoral technology-fuel mix and emissions trajectory in the near (2030) to medium term (2050)
- To understand the drivers of CO₂ emissions in the current policy scenario (CPS) and the share of difficult to decarbonize sectors in the CPS
- To develop a net-zero emissions scenario for the energy systems (NZES) and compare the CPS and NZES in terms of emission trajectories and their drivers, cumulative emissions, technology-fuel mix and mitigation strategies to inform the policy discussions on the long-term strategies (LTS) as part of the Paris agreement

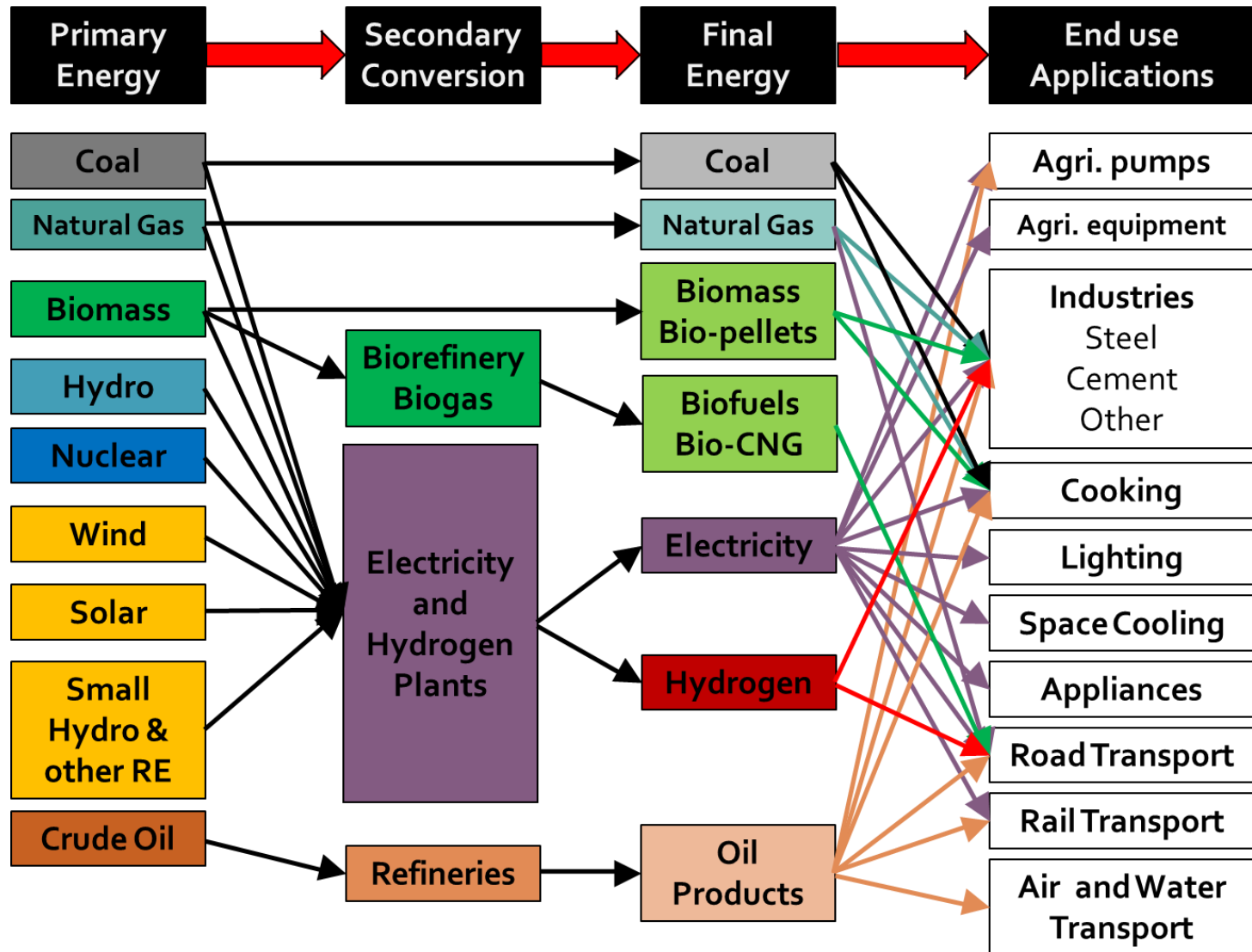
Methods and Data

Modelling framework for the national energy system



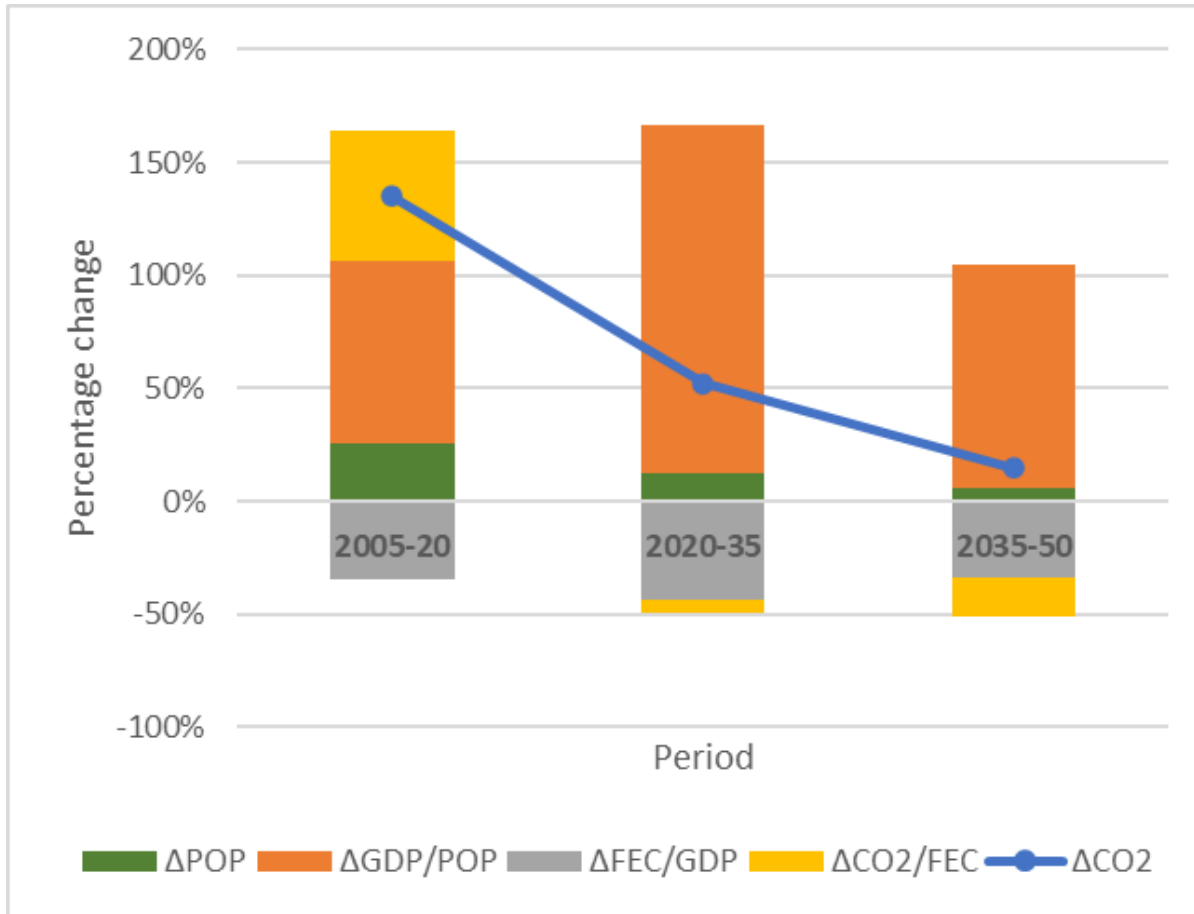
Methods and Data

TIMES-India Reference Energy System (RES)



Results and Discussion - CPS

Energy System CO₂ emissions

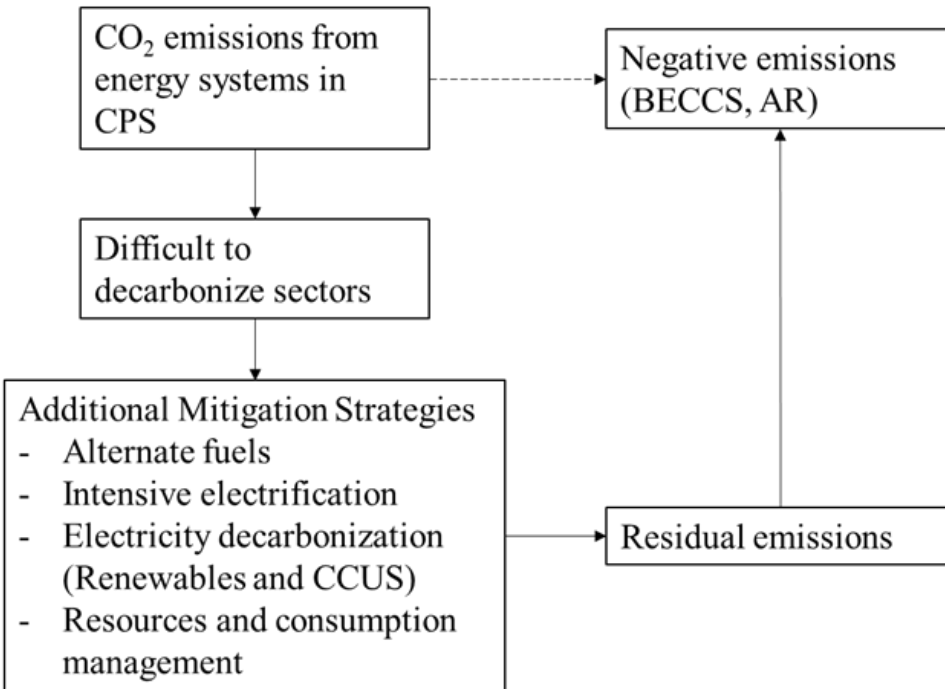


- Emissions go up from 1.9 Gt-CO₂ in 2015 to about **3.8-4 Gt-CO₂ in 2050**
- Cumulative emissions between 2015 to 2050 are around **105-110 GtCO₂**

Notes: Analysis based on **Kaya Identity**: $CO_2 = POP * (GDP/POP) * (FEC/GDP) * (CO_2/FEC)$

POP: Population; GDP: Gross Domestic Product (USD); FEC: Final Energy Consumption (PJ); CO₂: CO₂ emissions (Giga grams Gg)

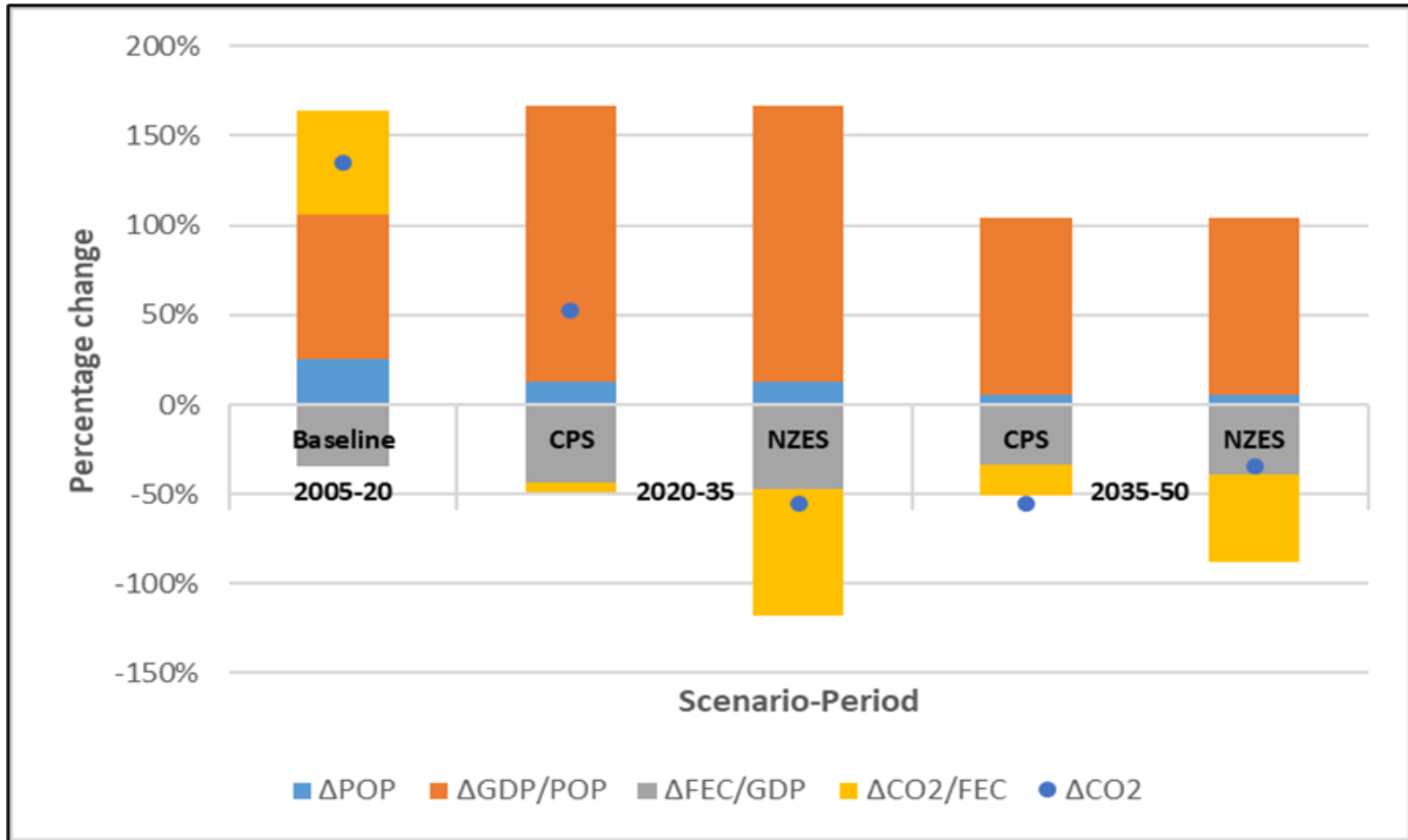
Transitioning from CPS to NZES



- **Net-Zero Emissions Scenario (NZES) ensemble**
- Policy alternatives to decarbonize the difficult to decarbonize sectors
- Electricity Sector variants (E1-E4)
 - **NZES-E1:** Maximum growth assumed for solar and wind with battery storage, All remaining coal and gas retrofitted with CCUS
 - **NZES-E2:** Coal and gas plants shares assumed to remain high but retrofitted with CCUS
 - **NZES-E3:** Next generation nuclear shares increase to reduce the share of solar and wind in E1
 - **NZES-E4:** Same as E1 but all remaining coal capacity replaced with next generation nuclear

Results and Discussion

Key transformations in NZES as compared to the CPS



Conclusion and policy implications

- In NZES, **CO₂ emissions in 2050** could be reduced to around **600-800 Mt-CO₂** without the deployment of negative emission technologies
- NZES also reduces the **cumulative emissions by over 50 per cent** as compared to the CPS; reduces dependence on CCUS and NETs in the latter half of the century
- **Per capita electricity consumption improves** by around 13% and the **emission intensity of electricity production goes below 10 gCO₂/kWh** in 2050 (NZES-E4) with **little impact on the cost of electricity** as compared to the CPS
- The incremental investments in power sector to realize the NZES could be met with an average **carbon price of USD 10-20/tCO₂** between 2015-50
- Policy implications for NZES
 - **Affordable financing** alternative for pilot stage technologies (nuclear, CCUS, new battery chemistries, advanced biofuels)
 - **Early investments** in alternate fuels and carbon management technologies
 - **Consultations with wider set of stakeholders** to address the socio-cultural and political concerns

Thank you

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