UNPACKING

Getting India to Net-Zero

An assessment and interpretation of the 2022 modelling study by the Asia Society Policy Institute (ASPI)

The Climate Futures Project

BRIDGING CLIMATE POLICY AND MODELS

SUSTAINABLE FUTURES COLLABORATIVE

June 2026

Authors

Nikita Shukla
Aman Srivastava
Easwaran J. Narassimhan

Acknowledgements

Srishti Jain
Sonali Verma
Karthika J
Kartikeya Jain

Design

Kunal Agnihotri

Suggested Citation:
The Climate Futures Project. 2026. Unpacking Getting India to Net-Zero: An assessment and interpretation of the 2022 modelling study by the Asia Society Policy Institute (ASPI). New Delhi: Sustainable Futures Collaborative.

About The Climate Futures Project:
Models are powerful analytical tools that shape policy priorities, targets, and international negotiations on climate change. The Climate Futures Project is an initiative of the Sustainable Futures Collaborative, originally an independent initiative co-developed by the Centre for Policy Research and the Indian Institute of Technology Delhi, that aims to foster the informed and measured use of climate policy modelling studies by decision makers, scientists, journalists and concerned citizens. We apply a common framework to assess, compare, and interpret the assumptions and results of modelling studies.
www.climatefuturesproject.in

About SFC:
The Sustainable Futures Collaborative (SFC) is an independent research organisation analysing frontier issues in climate change, energy, and environment. We focus on the systemic changes required for India's transition to a sustainable, just, and resilient economy and society.

Highlights of the ASPI study

Purpose

The purpose of the study is to **provide guidance and advice to India on the net-zero transition**, by **identifying the impacts and benefits of decarbonisation** under various policy combinations and ambition levels and by considering the potential synergies and/or trade-offs between decarbonisation and development goals.

Key Merits

- The study offers a **detailed framework** that integrates the economy, energy systems, and environment, showing interactions between different components.
- The study **highlights GDP and employment gains, trade balance improvements, and energy savings** associated with the transition to net zero. It also **acknowledges co-benefits** such as air quality, biodiversity, health, and avoided damages.
- The study's scenarios were co-designed with local experts and benchmarked against India's 2030 and 2070 climate targets, ensuring relevance to policymakers. The **analysis goes beyond least-cost pathways to highlight economic opportunities and trade-offs** arising from India's decarbonisation.

Scope for Improvement

- There is **limited transparency** on both model inputs and outputs. Specific data sources and quantitative assumptions for technology costs, fossil fuel prices, and macroeconomic forecasts are not fully cited or made publicly accessible.
- Regional/state-level granularity (which is critical for India) is limited.
- **Just transition aspects** (e.g., social safety nets for affected workers) **are noted but not quantitatively assessed.** The analysis focuses on the socioeconomic costs of decarbonisation but does not quantify avoided climate damages (e.g., disaster costs) or health co-benefits (e.g., from reduced air pollution), which would strengthen the economic case for accelerated action.
- The study presents results (GDP, jobs, emissions) as **point estimates without sensitivity analyses.** It also lacks explicit discussion of uncertainties in macroeconomic growth, technology costs, or global policy shifts, which could affect outcomes.
- **The modelling horizon ends in 2060**, which **constrains assessment of a 2070 net-zero pathway**.

The Climate Futures Project

Models are powerful analytical tools that shape policy priorities, targets, and international negotiations on climate change. These models, however, can feature unclear and widely divergent assumptions, resulting in overly simplistic or conflicting recommendations about an uncertain future. It is imperative that the construct and results of these various studies be adequately understood and contextualised.

The Climate Futures Project (TCFP) is an independent initiative to foster an informed and measured use of such modelling studies by policymakers, scientists, journalists, and concerned citizens. We apply a common framework to assess, compare, and interpret the assumptions and results of modelling studies. This project is an initiative of the Sustainable Futures Collaborative, originally an independent initiative co-developed by the Centre for Policy Research and the Indian Institute of Technology Delhi.

About TCFP Model Factsheets

A model factsheet, such as this one, employs a common framework to assess, compare, and interpret the assumptions and results of current climate modelling studies. Each factsheet is structured to include:

1. An overview of the stated purpose of the model, key merits, and scope for improvement, model type and structure, and key scenarios included in the model.

2. An assessment of the modelling approach through an evaluation along five parameters.

3. The five parameters are as follows: transparency and credibility of model inputs, appropriateness of model structure to research objective, scenario construction process, approach to uncertainty, and transparency and validation of outputs.

4. Comparison of results: A summary table of results from the model, including core assumptions, emissions outcomes, energy and electricity projections, and projected costs and investments.

5. Outcomes of the model are interpreted along six categories of implications: development pathway, energy transition implications, emissions, investments, equity and resource impacts and energy security.

Access our earlier assessments and interpretations of climate models in this series here.

I. Introduction

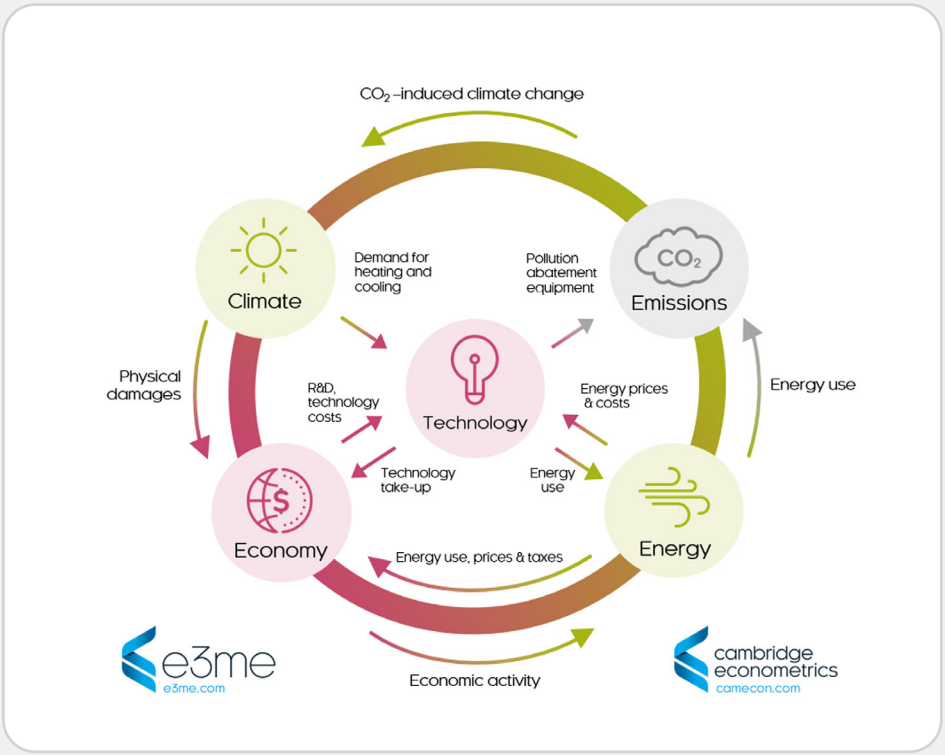
1.1 Purpose and model type

Purpose of the study: The purpose of the study is to provide economic analysis and modelling to identify the impacts, opportunities, trade-offs, and policy pathways for India to achieve its emissions reduction targets, including the 2030 updated NDC targets and the 2070 net zero target.

Citation: Asia Society Policy Institute. 2022. Getting India to Net Zero: A Report of the High-level Policy Commission on Getting Asia to Net Zero. The Asia Society, 2022. (Link)

Model used in the study:

The Energy-Environment-Economy Model of Europe and the World (E3ME) is a global macroeconometric model that is grounded in post-Keynesian and complex adaptive systems thinking. Unlike Computable General Equilibrium (CGE) models, E3ME is empirically based, meaning most relationships are derived from historical data rather than assuming market equilibrium.



Source: Cambridge Econometrics E3ME Model Manual

Model structure

E3ME links economic activity, energy use, and environmental emissions through over 30 sets of econometrically estimated equations. Key features include:

- Coverage of 71 countries, 44–70 sectors, 12 fuel types, and 24 power generation technologies.
- Feedbacks between consumption, investment, prices, trade, employment, energy demand, and emissions.
- Incorporation of technology diffusion mechanisms through sub-models for power, transport, steel, and heating sectors.
- Built on national accounts, ensuring consistency between physical (energy, emissions) and monetary units.

1.2 Key Scenarios

ASPI modelled the following policy pathways for India.

1

Pre-COP 26 policies (baseline):
This is the reference scenario representing the least ambitious pathway, including policies enacted before COP26.

2

Baseline+ 2030 targets:
This scenario enforces updated 2030 commitments without further ambition.

3

2070 net zero:
This scenario includes all COP26 commitments, including updated 2030 targets and the commitment to reach net zero emissions by 2070. Variants with different policy mixes (balanced, regulation-focused, market-based) are analysed to test differences in economic outcomes. The 2070 net zero target in the modelling is handled by extrapolating projections beyond the model's simulation horizon of 2060.

4

Accelerated coal phaseout:
This scenario involves India meeting its current targets plus additional efforts to phase out unabated coal power generation by 2040, including a no new coal construction policy from 2023.

5

2050 net zero:
In this more ambitious scenario, India adjusts climate policies to reach net zero by 2050. Measures include strengthened COP26 commitments, no new coal from 2023, and carbon pricing in non-energy-intensive sectors from 2031. Variants with regulatory or market-based focus add further policy flexibility.

All scenarios assume government financing for energy efficiency investments, low-carbon technologies, and compensation for stranded assets, with carbon revenues earmarked for transition costs. Technologies evolve based on historical costs, market shares, and technical constraints, especially for emerging solutions like carbon capture and green hydrogen.

II. Assessment of Approach

This section comprises an evaluation of the robustness and appropriateness of the modelling exercise along a set of parameters.

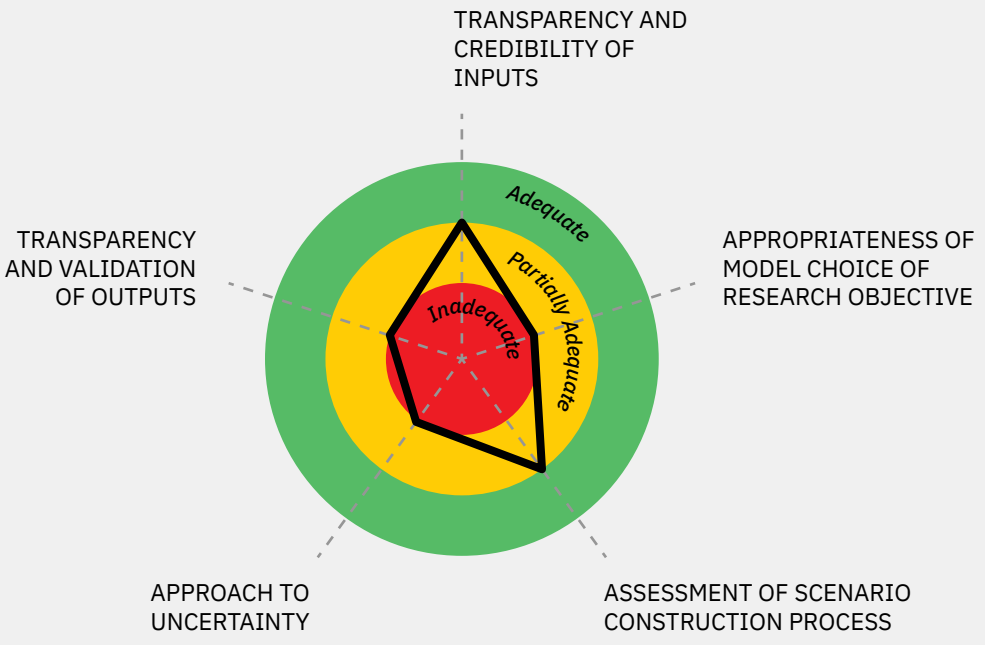
The TCFP framework for assessment employed in this section was developed based on studies of good practices for computational models which inform decision-making. A review of these papers indicated a few common themes: clarity of purpose, importance of model specification and the process involved, assessing data quality, dealing with uncertainty, and validation of the model and its results.

We arrived at the final indicators through an iterative process of applying the indicators to contemporary modelling studies, gauging their applicability and usefulness, and engaging in a peer review process for the framework. The five criteria used for assessment of the modelling approach are:

1. Transparency and credibility of inputs to the model
2. Appropriateness of model choice to research objective
3. Assessment of scenario construction process
4. Approach to uncertainty
5. Transparency and validation of outputs

The figure below provides a summary of how the ASPI modelling approach fares along the five criteria mentioned above. The following pages include a detailed description of each criterion and a rationale for the final score. They also include responses from the authors of the underlying study to the assessment.

Figure 1: Assessing ASPI modelling approach on five evaluation criteria



Source: Authors' analysis

1. Transparency and credibility of inputs to the model

Assessment of whether key inputs are transparent and have an adequate empirical basis.
Key inputs include:

- Techno-economic data (demand trends, costs of technologies, fuel costs, technology options)
- Socio-economic drivers, i.e., population and economic growth.

Overall Assessment Score: Partially adequate
Input data is not transparently described in the report, even though experts were involved in designing the scenarios for the study. Further, while the model methodology is documented, the model is proprietary.

Overall Assessment Criteria:
The study is:
Adequate: if all three parameters are met for both techno-economic data and socio-economic drivers
Partially adequate: if parameter 1 and 2 are met, but 3 is unmet for both techno-economic data and socio-economic drivers
Inadequate: otherwise.

Overall response from authors: E3ME is not open-source though the E3ME manual is accessible and contains more information on the model data.

Assessment Parameters	Detailed Assessments
1. Are data and data sources transparently stated and, where possible, based on multiple corroborating sources?	**No** The study does not fully disclose or cite datasets used in the modelling. While it refers to the E3ME model by Cambridge Econometrics, it does not list the exact input datasets, such as energy technology cost curves, fuel price assumptions, or macroeconomic forecasts. Further, there is no systematic referencing of corroborating sources (e.g., peer-reviewed studies, national data, or cross-model validation). The study notes that modelling assumptions are informed by "government announcements, expert advice, and academic literature", but actual sources are not cited.

Response from authors: The limitation of corroboration was due to practical constraints of the study. However, references that informed the scenario assumptions and the assumptions themselves have been included in the report. Additionally, a high-level validation of key conclusions/results against alternative studies was included.

2. Are the data up-to-date, with the bounds of data availability constraints?	**Yes** The model includes data up to 2019–2021, capturing post-pandemic adjustments and recent policy commitments (e.g., India's 2070 net-zero target and COP26 pledges). Scenarios also incorporate information up until December 2021.

Assessment Parameters	Detailed Assessments
3. Are inputs justified sufficiently through clear reasoning, particularly when they are based on projections? In particular (rated yes if any one of the sub-questions are true):	**Yes**
3.1. Is the basis for future projections explained and justified? For example, reasonable justifications include expert interviews and validation includes consistency checks.	**Yes** The basis for future projections is reasonably explained. The model uses historical data to simulate future technology costs and deployment, and scenario narratives are informed by government announcements, expert insights, and academic references. While expert validation is implied, interviews or sensitivity checks are not documented in detail. However, the approach of building scenarios around policy narratives reflects standard modelling practice.
3.2. Do inputs adequately reflect growing uncertainties over time?	**No** Key input assumptions are treated as single deterministic pathways within each scenario. The study does not specify ranges, alternative input trajectories, or time-varying uncertainty envelopes for these drivers. As a result, inputs do not explicitly reflect increasing uncertainty over longer time horizons even though such uncertainty is implicitly acknowledged in the narrative.

Response from authors: The assumptions were validated by local experts and ASPI through written communications and meeting discussions.

The study objectives did not include identification of uncertainty ranges, which could be the subject of follow-up analysis. E3ME as a simulation model will require running hundreds of sensitivities (which were not practically possible within the project) to inform this aspect.

2. Appropriateness of model choice to research objective

Assessment of whether the purpose of the study is aligned with the choice of model and whether this can be transparently assessed. This is important, as choice of model both enables the user to answer some types of questions and precludes users from answering others.

Overall Assessment Score: Inadequate
While the study's stated objective is broadly aligned with the general capabilities of the E3ME model, the appropriateness of the model choice cannot be assessed based on the information provided in the study. The study offers only a high-level description of the model and does not sufficiently explain key aspects of its structure, strengths, and limitations. As a result, readers are unable to clearly evaluate how the choice of model enables or constrains the analysis of policy impacts.

Overall Assessment Criteria:
The study is:
Adequate: if parameters 1, 2, and 3 are marked 'yes',
Partially adequate: if parameters 1 and 2 are marked 'yes',
Inadequate: otherwise.

Overall response from authors: The most important strengths and limitations of the modelling approach were included in the report. As a policy report aimed at a non-technical audience, the focus was on illustrating possible trajectories and details on the model had been kept to a concise summary.

Assessment Parameters	Detailed Assessments
1. Is the model structure transparent? (rated yes if at least 2 of the following are true)	**No**

Response from authors: As a policy report aimed at a non-technical audience, the focus was on illustrating possible trajectories and details on the model had been kept to a concise summary. Further information is available from the manual.

1.1. Has the model structure been described adequately through text and/or figures?	**No** The study uses the E3ME model by Cambridge Econometrics. There is a brief description about the structure, inputs, policies, structures etc. However, the study does not include detailed descriptions of model structure, equations, or schematic figures, nor does it explicitly link the publicly available E3ME Model Manual. As a result, while detailed documentation of the model exists externally, this information is not easily accessible to a reader based on the study alone, limiting transparency of model structure within the study.
1.2. Is the model itself open-source?	**No** E3ME is a proprietary model owned by Cambridge Econometrics. Although its conceptual design, methodology, and key equations are publicly available, the underlying code, database, and calibration files are not.

Assessment Parameters	Detailed Assessments
1.3. Is there sufficient description and accessibility to data and model structure to enable replication of the model?	**No** While the study provides a conceptual description of the E3ME modelling framework, it does not provide access to the underlying model code, calibration files, or input datasets required to independently reconstruct or run the model. Moreover, the E3ME model is proprietary, and full access is restricted to licensed users. As a result, the information provided in the study is insufficient to enable replication of the model itself by external researchers.
2. Is there adequate discussion of the strengths and weaknesses of the model structure, with respect to its fitness for purpose?	**Yes** There is extensive discussion about the strengths and limitations of the model in the study. Limitations include no quantification of avoided climate damages, exclusion of post-2060 dynamics, and limited data for some techs, among others.
3. Are key conclusions drawn based on the strengths of the model structure, and qualified for limitations of the model structure? **E.g., is the level of model detail appropriate for its conclusions? Is the model equipped to evaluate the impact of policy actions?**	**No** The conclusions of the ASPI study (such as the potential for net-zero pathways to enhance GDP and employment) are consistent with the strengths of E3ME. However, these findings are not adequately qualified by the model's limitations, particularly the absence of explicit uncertainty or sensitivity analysis when interpreting long-term macroeconomic and technology outcomes. Policy implications are discussed as robust outcomes, without sufficiently reflecting uncertainty in inputs or constraints inherent in the modelling framework.

Response from authors: Uncertainty analysis was not within the scope of the study and could be explored as part of follow-on research.

3. Assessment of scenario construction process

Assessment of whether the scenario construction is transparently and well-designed to evaluate policy actions and outcomes across a range of high-impact, high-uncertainty contextual factors. Scenarios provide a way to explore alternative policy-relevant futures. However, these have to be developed in a manner that clearly lays out the underlying rationale for the scenario, and transparently explains the drivers of change under each scenario.

Overall Assessment Score: Partially adequate
The scenario construction process is relatively transparent and defined in the report. Policy assumptions are explained for each scenario. However, there is little information about the process and how these scenarios were chosen. Also, the scenarios do not explore alternative socio-economic pathways.

Overall Assessment Criteria:
The study is:
Adequate: if parameters 1, 2, and 3 are marked 'yes',
Partially adequate: if parameters 1 and 2 are marked 'yes',
Inadequate: otherwise.

Overall response from authors: The scenarios were informed by the study objectives and research questions put forward by ASPI and recommendations of Cambridge Econometrics (CE) and local experts. Alternative socio-economic pathways were not within the study's scope.

Assessment Parameters	Detailed Assessments
1. Is the rationale for alternative scenario 'storylines', appropriate to study purpose, adequately discussed and explained? (ranked yes if both of the following are true)	**Yes**
1.1 Is there an explanation of the rationale for each scenario and how different scenarios relate to each other?	**Yes** The study models 5 different scenarios which discuss short-medium- and long-term impacts of decarbonisation policies. It also clearly explains the rationale behind each scenario and how they differ in terms of ambition and policy instruments.
1.2 Are the scenarios well-designed to address the research question?	**Yes** The scenarios are well designed to address the research questions, and to assess short, medium and-long term impacts of decarbonisation policies. For example, the Accelerated coal phaseout scenario represents a pathway of additional policy implementation to phase out unabated coal power generation by 2040.
2. Is the process through which these storylines were developed explained? (ranked yes if at least 2 of the following are true)	**Yes**
2.1 Is the process transparent?	**Yes** Appendix D of the study summarises the policy assumptions modelled for all scenarios, which provides some transparency on how scenarios differ in terms of policy inputs.

Assessment Parameters	Detailed Assessments
2.2 Did the process involve users, notably policy-makers?	**Yes** The study notes that internal and local experts were involved in designing and reviewing scenarios, and the broader High-level Policy Commission[1] included prominent policymakers. However, it does not explicitly state that Indian government policymakers directly co-developed or validated the scenarios.
2.3 Was the process iterative?	**No** There is no mention of an iterative process such as feedback loops between policymakers and modelers, scenario refinement over multiple rounds, or updating scenarios based on feedback.

Response from authors: The final results presented in the report had undergone rounds of feedback and revisions within the project team (CE, ASPI and local experts). Engagement with additional stakeholders was led by ASPI.

3. Do the scenarios account for alternative socioeconomic pathways, in addition to technology development and adoption pathways? OR have the implications of not exploring those uncertainties on the results been discussed qualitatively?	**No** The study primarily varies technological and policy ambition pathways, rather than socioeconomic trajectories. While macroeconomic outcomes such as GDP growth and sectoral structure evolve endogenously across scenarios within the E3ME framework, they are not treated as alternative ex ante socioeconomic trajectories. Key drivers such as urbanisation, demographic trends, consumption behaviour, labour productivity, and income distribution are based on common baseline projections and are not varied across scenarios. The implications of not explicitly exploring these socioeconomic uncertainties are not discussed in the report.

Response from authors: Exploration of alternative socio-economic trajectories was not within the scope of the study. The focus of the research questions was on mitigation strategies and their macroeconomic impacts.

1 A regional body of recognised Asian leaders convened to advance a coherent, Paris-aligned vision for Asia's net-zero transition, with ASPI serving as the Commission's secretariat.

4. Approach to uncertainty

Assessment of the study's approach to addressing and communicating uncertainty across the various criteria identified above across:

- Economic growth
- Technology options
- Cost trajectories
- Any other uncertainties in input assumptions or model processes

Overall Assessment Score: Inadequate
The study only mentions that the modelling accounts for seasonal variation, implied demand for backup generation and storage and technological constraints. However, it does not elaborate on how any of these are defined or modelled.

Overall, the study does not include any uncertainty analysis for economic growth or technology cost trajectories. These inputs are treated as fixed within each scenario.

Overall Assessment Criteria:
The study is:
Adequate: if parameters 1, 2, and 3 are marked 'yes',
Partially adequate: if parameters 1 and 2 are marked 'yes',
Inadequate: otherwise.

Overall response from authors: Economic growth and technology costs are not fixed inputs but determined endogenously for each scenarios. Only baseline economic growth and historical technology costs are fixed inputs, in order to establish a starting point to which alternative scenarios can be compared to.

As mentioned before, modelling details had been intentionally kept concise in this report to favour more details on policy outcomes.

Assessment Parameters	Detailed Assessments
1. Have uncertainties in the input assumptions and results been analysed and presented transparently? Specifically, do figures include uncertainty bands, wherever reasonably quantifiable OR where not quantifiable, are qualitative explanations included? (E.g., does the study discuss contextual changes which may make trend-based projections less certain or conversely, account for insights or knowledge about future projections not present in historical data?)	**No** The study does not transparently analyse or present uncertainties associated with key input assumptions. Inputs such as macroeconomic growth trajectories, technology cost pathways, fuel prices, and policy effectiveness are specified as single deterministic assumptions within each scenario, without ranges or alternative parameterisations. While the study includes limited qualitative discussion of broader contextual uncertainties (e.g., data limitations or external shocks such as post-COVID economic conditions), these are not systematically linked to variations in input assumptions, nor are they reflected through uncertainty bands or alternative input pathways in the figures or tables.

Response from authors: As noted above.

Assessment Parameters	Detailed Assessments
2. Have uncertainties associated with the model's causal mechanisms through which inputs are translated into key outputs been analysed and presented transparently? Approaches include through modelling of alternative possible causal mechanisms, and their consequences on outputs, OR through discussion of alternative mechanisms?	**No** The study does not discuss the model inputs or its causal mechanisms in detail. Additionally, the study is not reflective of the uncertainties of the modelled causal mechanisms or its consequences on the outputs.
Response from authors: As noted above.	
3. Do the model results analyse and represent how uncertainty may change with time?	**No** The model results are presented as single-point projections extending to 2060, with no time-varying confidence intervals or formal treatment of how uncertainty compounds in the long term. Though the study acknowledges uncertainty qualitatively, it does not model or present its temporal evolution in a structured or transparent way.
Response from authors: As noted above, detailed uncertainty analysis was not possible within practical constraints of the study but can be explored in a subsequent study.	

5. Transparency and validation of outputs

Assessment of whether the key outputs are presented transparently and validated.

Overall Assessment Score: Inadequate
The appendices present a wide range of model outputs. However, there is little evidence to support the validity of the outputs. In addition, the study provides limited transparency on how specific input assumptions and model mechanisms translate into reported outputs, making it difficult to assess which drivers underpin changes in GDP, employment, or emissions. For example, while the study only discusses CO2 emissions, the appendix provides details about GHG emissions. There is a lack of uncertainty analysis which reduces the validity further.

Overall Assessment Criteria:
The study is:
Adequate: if parameters 1, 2, and 3 are marked 'yes',
Partially adequate: if parameters 1 and 2 are marked 'yes',
Inadequate: otherwise.

Overall response from the authors: The report provides non-technical explanations of drivers (inputs and mechanisms) for key results including GDP, employment and emissions.

Assessment Parameters	Detailed Assessments
1. Have outputs been presented in a manner that facilitates consideration of how they (outputs) are shaped by input assumptions, model mechanics, and scenarios?	**No** The study presents outputs transparently across key indicators: GDP, employment, investment, energy demand, and emissions for each scenario. Tables and graphs clearly distinguish results across the various pathways, helping readers infer how different assumptions shape outcomes. However, the linkages between specific input assumptions and quantitative outputs are not explicated. The model mechanics (e.g., econometric relationships, technology diffusion dynamics) are referenced but not unpacked in relation to each result.
Response from authors: As noted above, for a policy report aimed at a non-technical audience, priority had been given to explanations of key results and mechanisms rather than a full description for all results.	
2. Have the implications of uncertainties in inputs and model structure been considered in reporting of results and consequent policy implications?	**No** Although the study acknowledges some modelling limitations, it does not reflect these uncertainties in the conclusions or policy recommendations. Results are reported with strong assertions (e.g., "India can gain $371bn in GDP by 2036") without contextual uncertainty caveats.

Assessment Parameters	Detailed Assessments
3. Have results been validated with efforts at validation clearly presented? Forms of validation include: • **Expert validation** • **Peer review** • **Validation through literature** • **Empirical validation** • **Cross-country analysis**	**No** The study does not clearly present validation of key outputs (e.g., GDP, jobs, emissions) through empirical back-testing, benchmarking against historical trends, cross-model/cross-country comparison, or formal peer review. While the study draws on literature and notes engagement with experts (including through the broader commission process), these appear primarily to inform inputs and scenario framing rather than to validate model outputs.

Response from authors: Validation of key results against alternative studies from the grey literature is included in the report though being somewhat constrained by the level of details available in such studies. The results were validated within CE, as well as with ASPI and local experts. Within practical constraints of the project, a full validation exercise using methods listed here was not possible.

III. Summary of Outputs

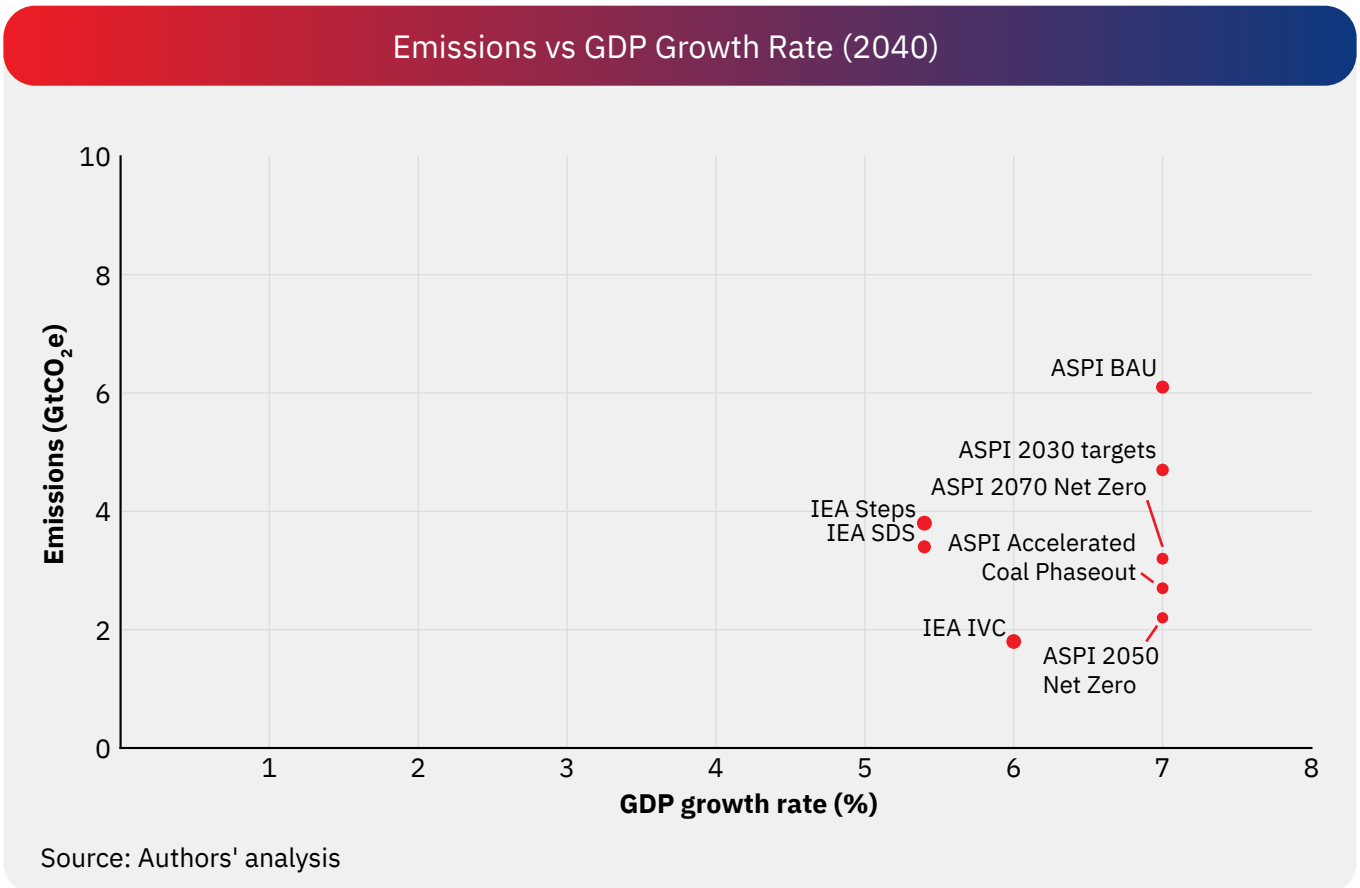
Key findings across studies

This section presents key projections related to emissions, GDP growth, final energy demand, installed capacity, and energy supply for the years 2040, 2050, 2060, and 2070.

We summarise these results graphically across all studies assessed, and in tabular form for this study.

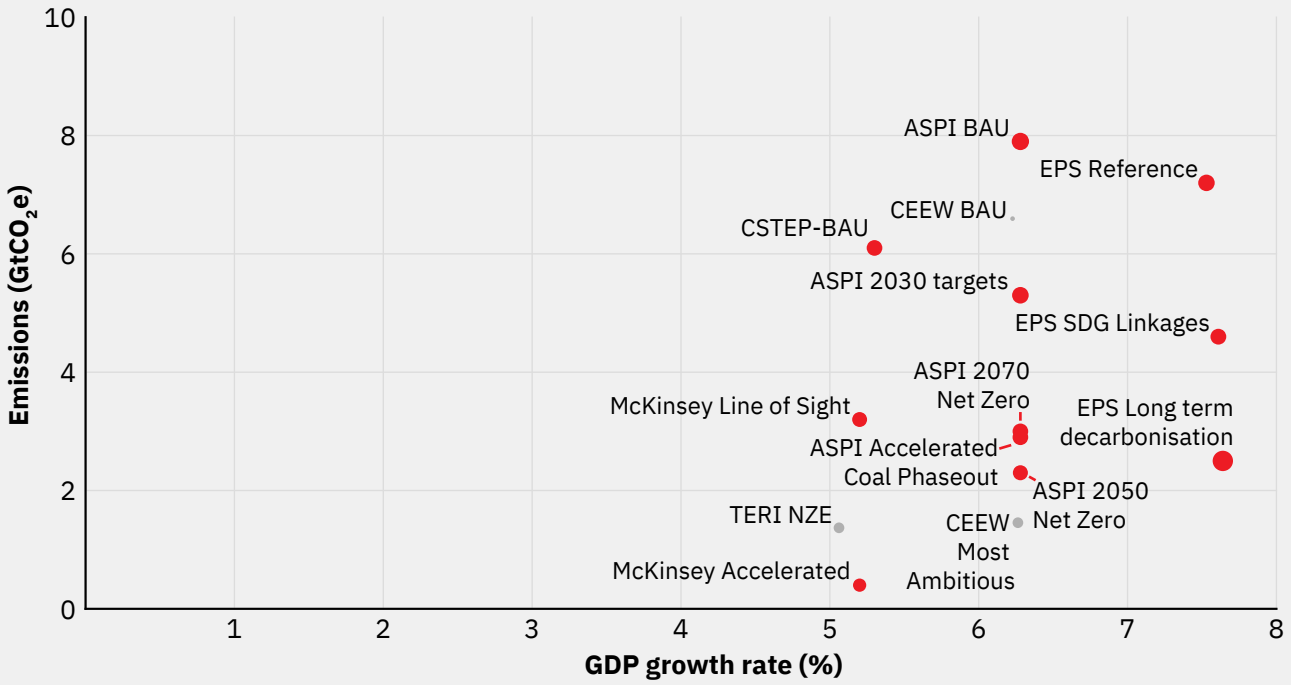
Figure 2: Annual GHG emissions in end-year vs. average GDP growth rate from base year

Notes: TERI-Shell and CEEW estimates are not adjusted for CCUS and carbon sinks, which are included in their scenarios to enable net-zero emissions; CEEW figures represent averages of four scenarios within respective net-zero years; Figures adjacent to the points represent primary energy demand in megatonnes of oil equivalent (Mtoe).



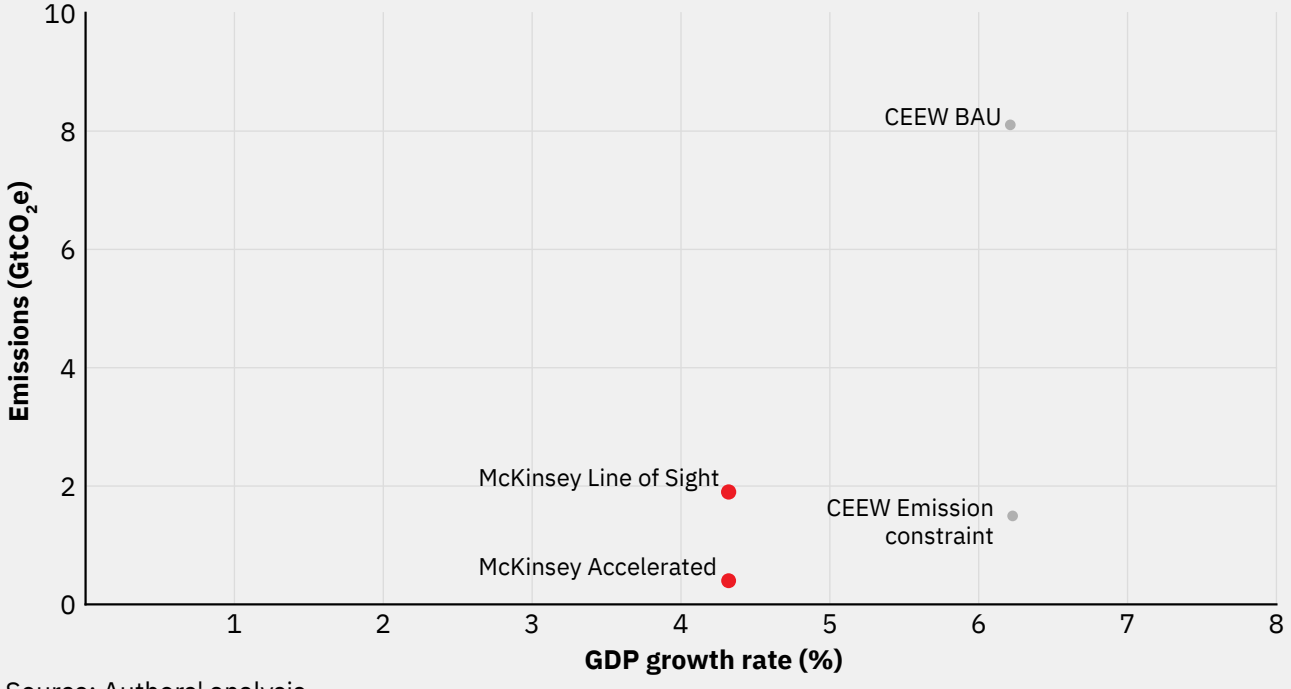
Source: Authors' analysis

Emissions vs GDP Growth Rate (2050)



Source: Authors' analysis

Emissions vs GDP Growth Rate (2070)



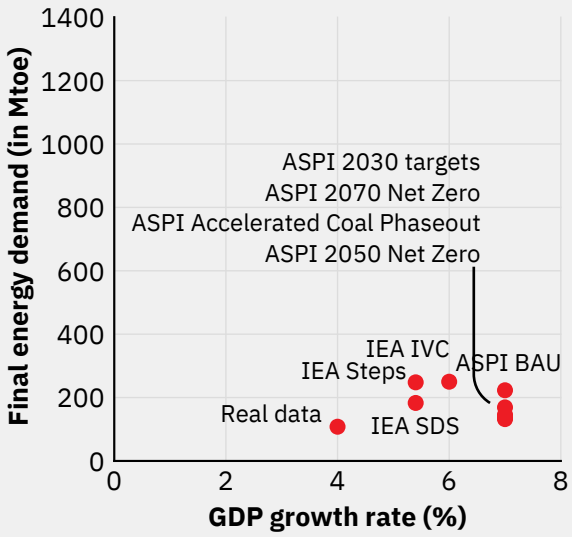
Source: Authors' analysis

Figure 3: Final energy demand versus GDP growth rate in end-year faceted by end-use sector

Notes: Real 2019 data is sourced from IEA, in which building energy consumption includes traditional biomass use; Studies for which data was not available are not represented. IEA data is for 2040.

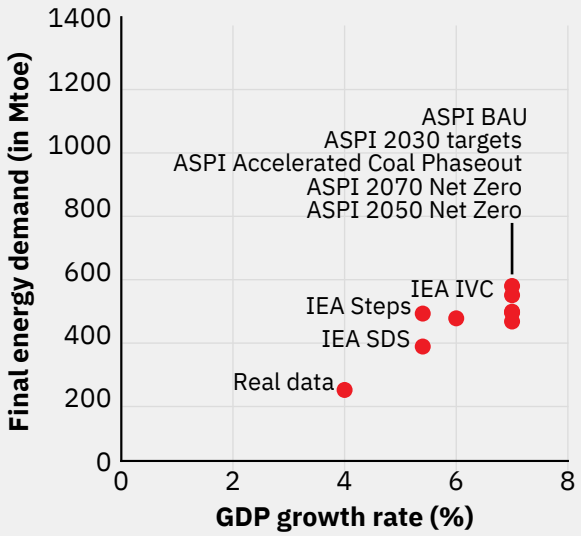
2040

Transport



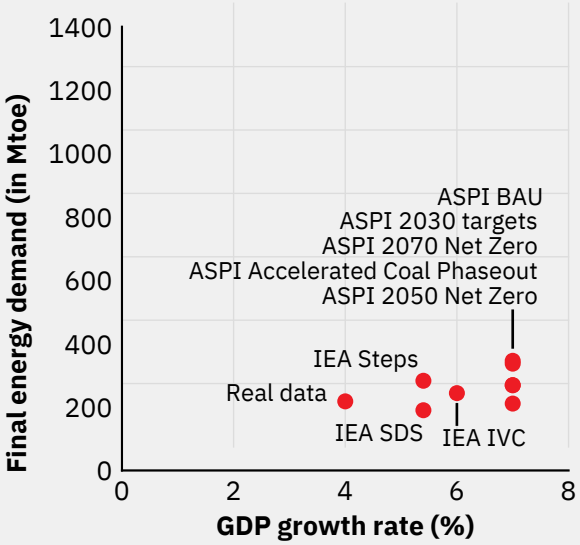
Source: Authors' analysis

Industry



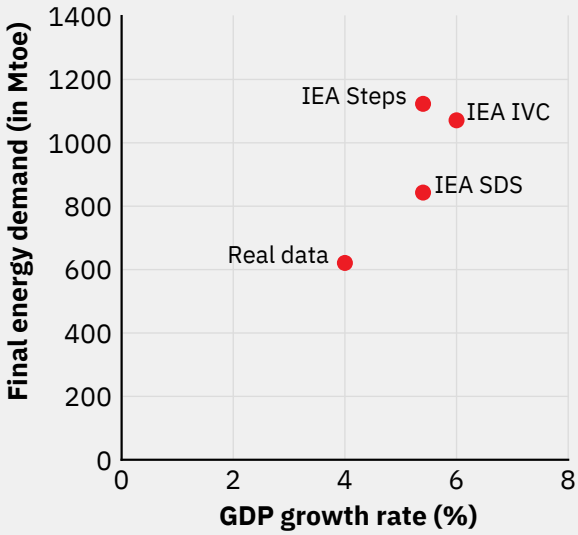
Source: Authors' analysis

Building



Source: Authors' analysis

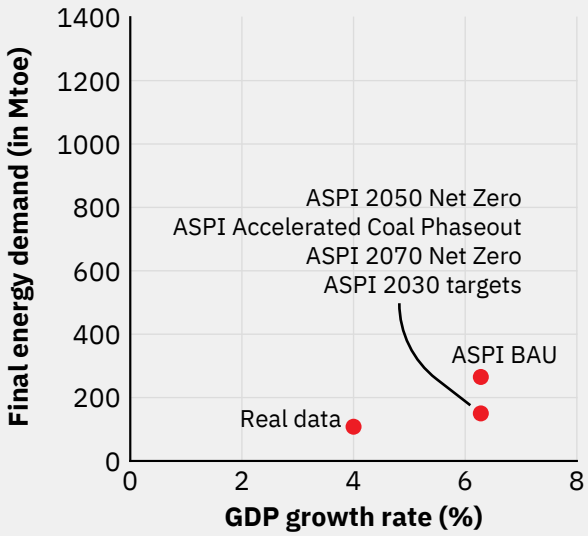
Total



Source: Authors' analysis

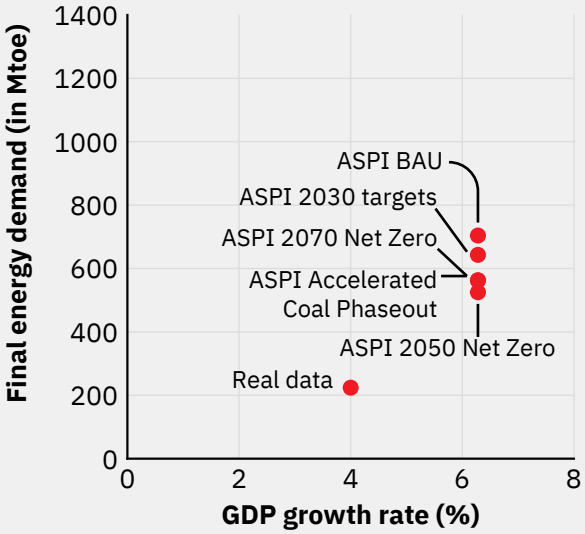
2050

Transport



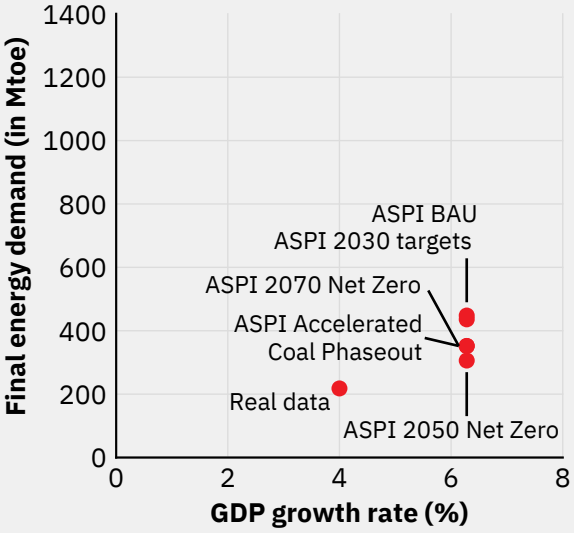
Source: Authors' analysis

Industry



Source: Authors' analysis

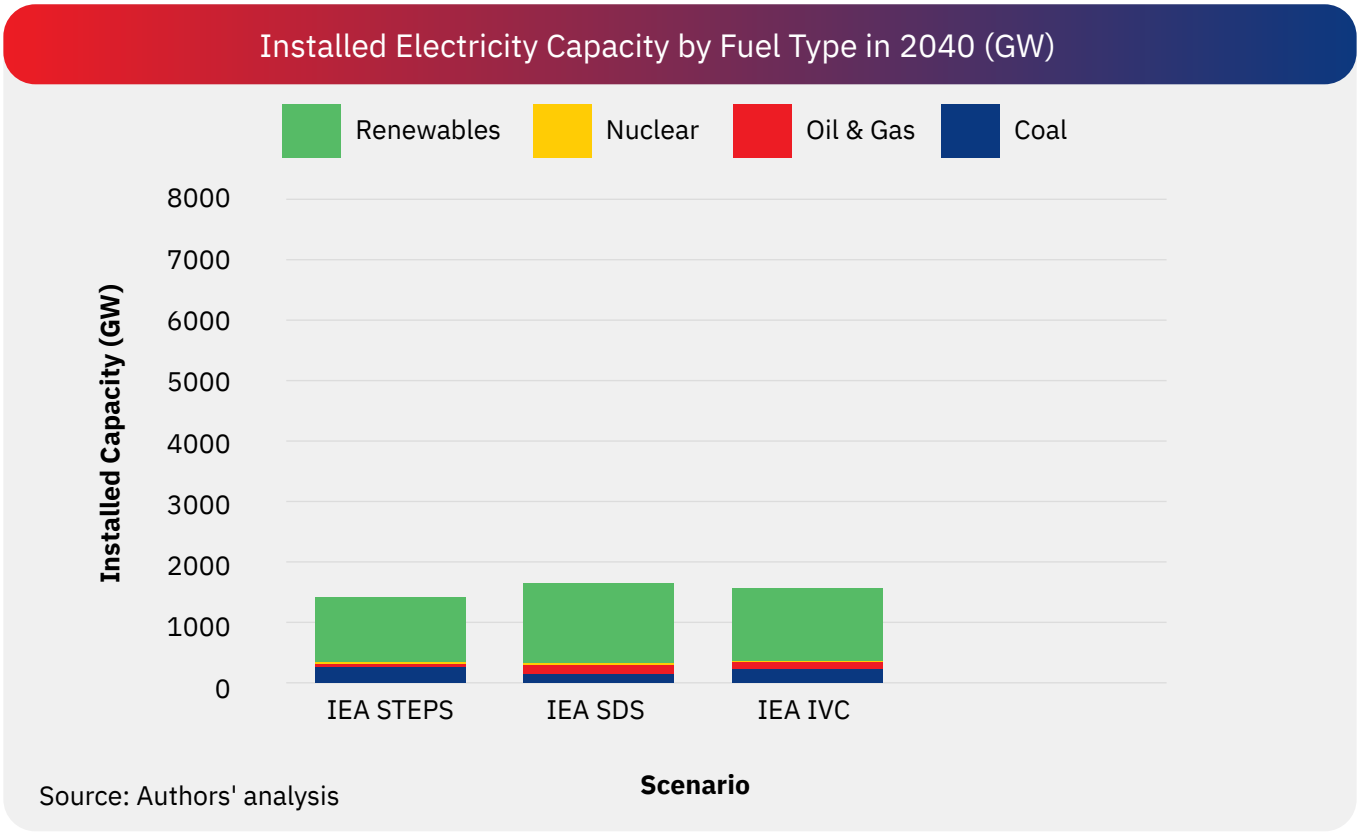
Building



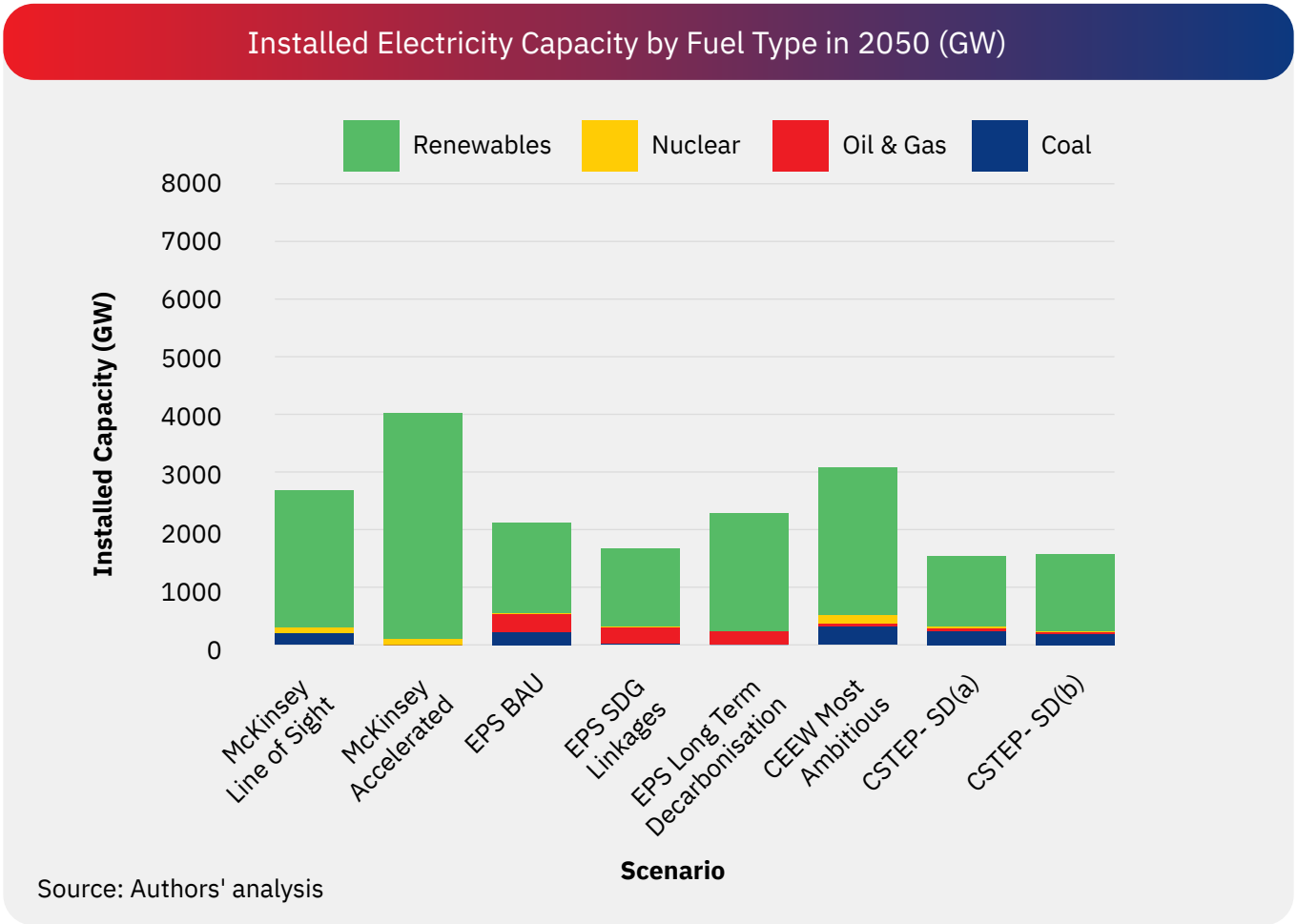
Source: Authors' analysis

Figure 4: Installed electricity capacity (GW) in end-year

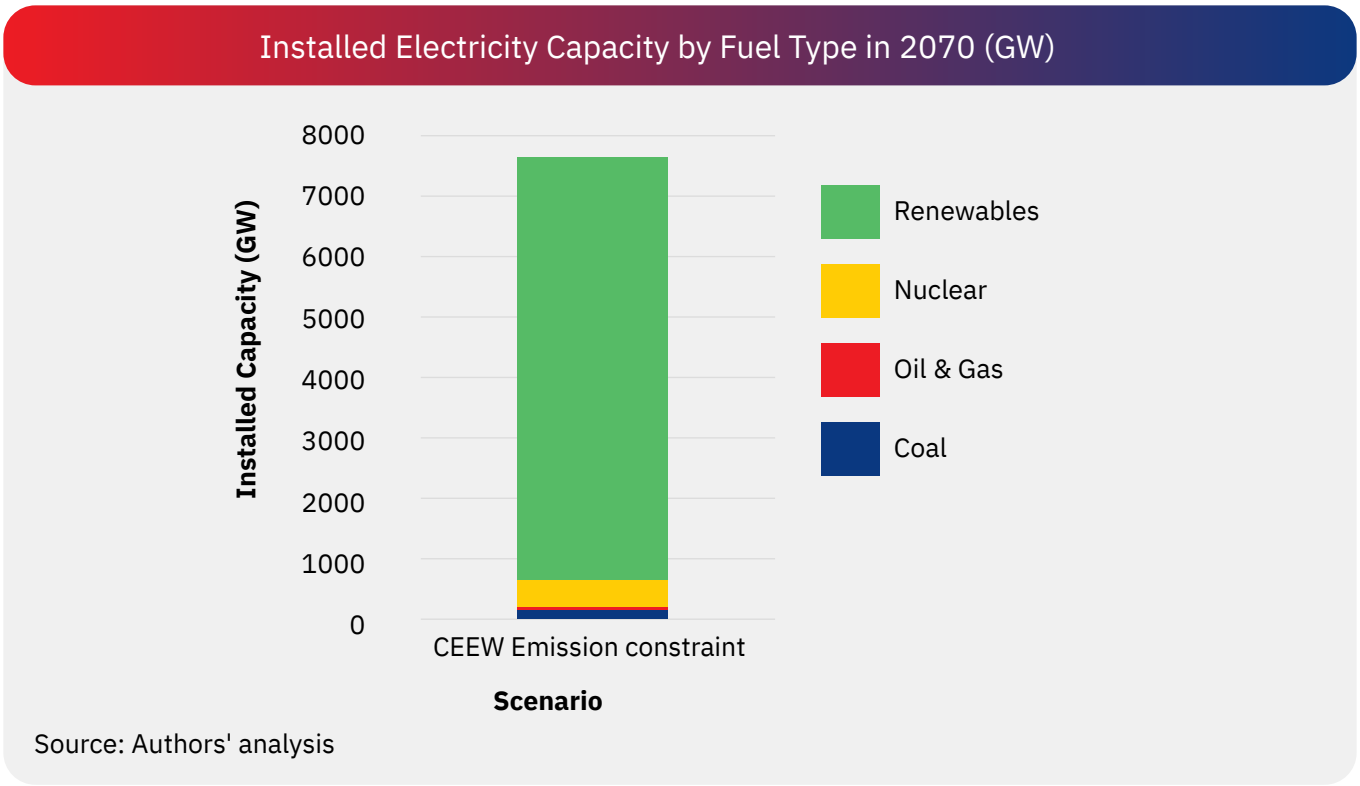
** Notes: Studies for which data was not available are not represented.*



Source: Authors' analysis



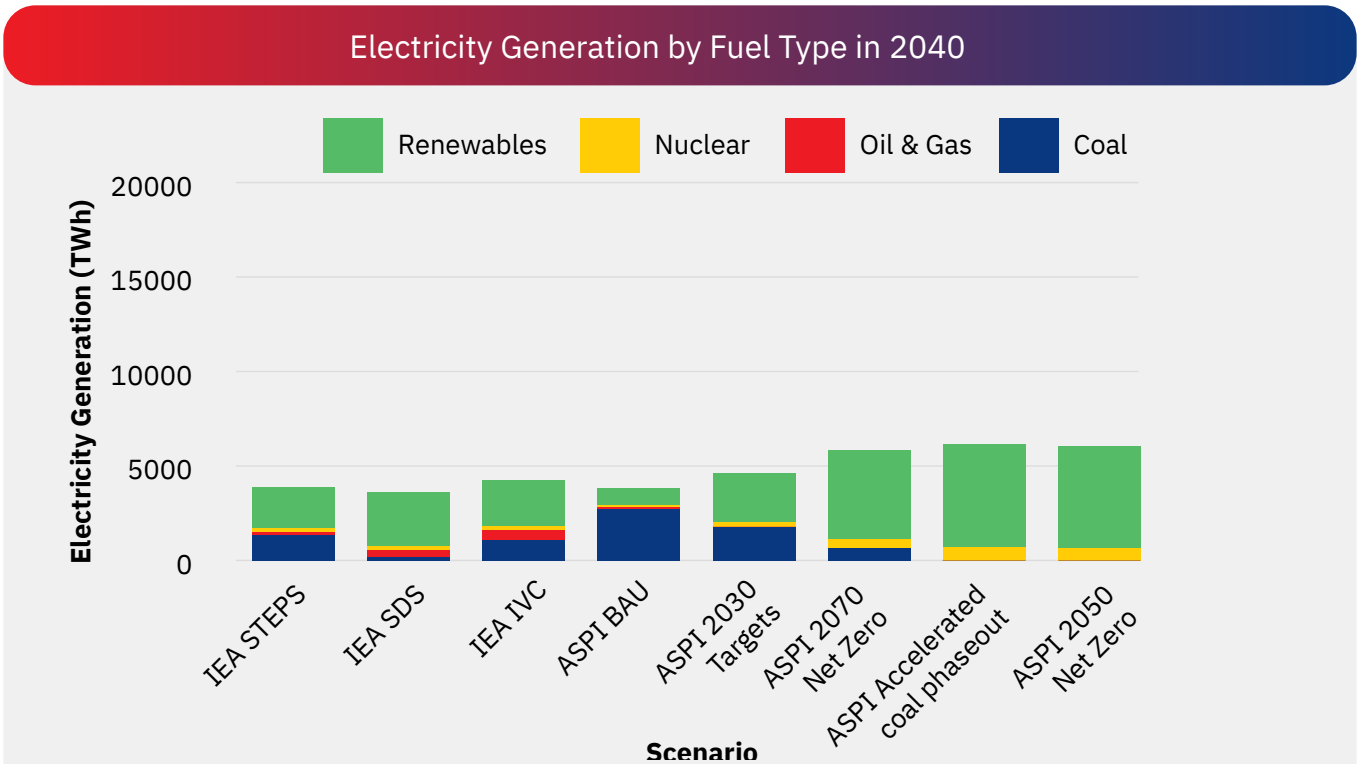
Source: Authors' analysis



Source: Authors' analysis

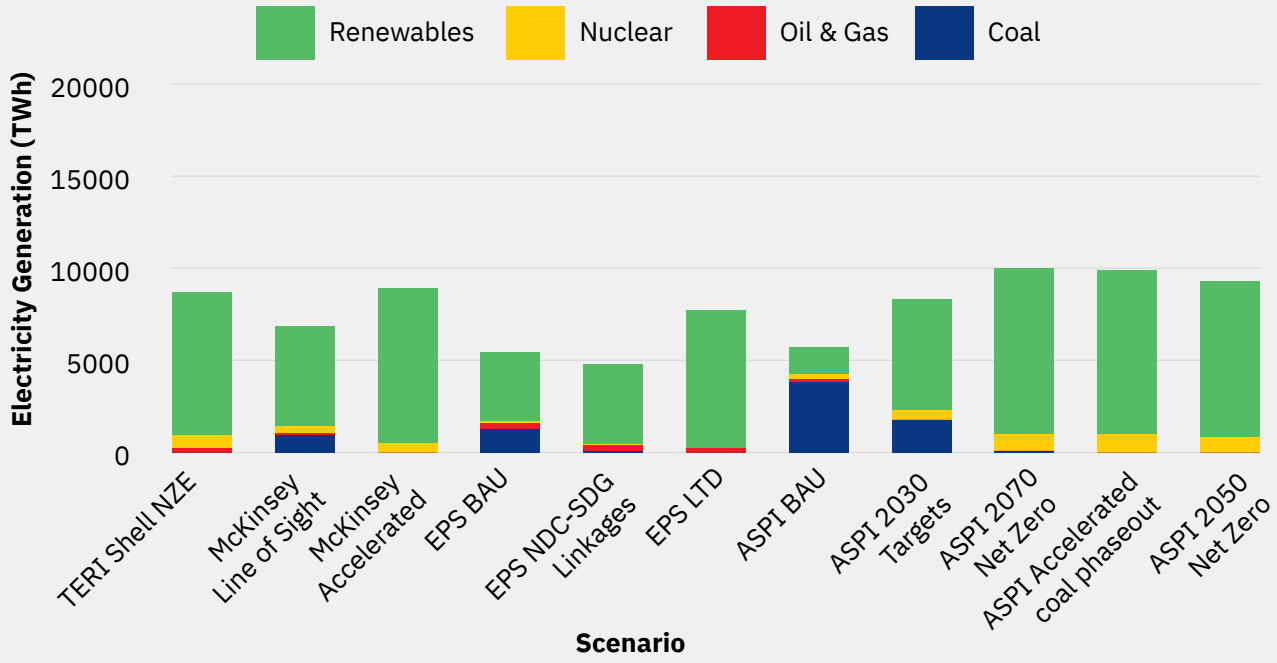
Figure 5: Electricity generation by fuel source in end-year

** Notes: Studies for which data was not available are not represented*
For ASPI, Renewables includes Biomass, Wind, Solar and Hydro
For IEA, Renewables includes Hydro, Bioenergy, Wind, Geothermal, Solar PV and CSP and Marine
For McKinsey, Nuclear includes hydro, biomass and nuclear (cannot be separated).



Source: Authors' analysis

Electricity Generation by Fuel Type in 2050



Source: Authors' analysis

Key results in current study

Table 1: Summary of key variables

Scenario	Baseline	2030 Targets	2070 Net Zero (balanced policy mix)	Accelerated Coal Phaseout	2050 Net Zero (balanced policy mix)
Macro-Structural Variables (2060)					
Annual GDP Growth (%)	6.28	6.28	6.28	6.28	6.28
GDP (2021 trillion USD)	NA	NA	NA	NA	NA
Population (billion)	NA	NA	NA	NA	NA
Urbanisation (%)	NA	NA	NA	NA	NA
Job Growth Outcome (additional jobs)	*NA*	NA	12 million	NA	13 million

Scenario	Baseline	2030 Targets	2070 Net Zero (balanced policy mix)	Accelerated Coal Phaseout	2050 Net Zero (balanced policy mix)
GHG Emissions					
Peaking Year	NA	2030	2030	2025	2025
Emissions in Peaking Year ($MtCO_2e$)	NA	4020	3530	3147	2988
Net Zero Year	NA	Does not assume a net-zero target	2070	2065	2050
Energy Emissions in Net Zero Year ($MtCO_2e$)	NA	NA	NA	NA	NA
Per Capita Emissions (2050, tCO_2e/ capita)	NA	NA	NA	NA	NA
Energy and Electricity (2060)					
Primary Energy Demand (Mtoe)	1804	1602	1424	1424	1424
Installed Generation Capacity (GW)	2381	5710	7601	7520	7520
Electricity Demand (TWh)	8605	13181	15886	15803	15803
RE Share in Electricity Generation	26%	77%	93%	93%	93%
Costs and Investments (2060)					
Energy Investment Required	NA	$5.6trn	$10.1trn	$10.4trn	$13.5trn

Source: Authors' compilation

IV: Interpretation of Results

This section comprises an interpretation of model outcomes along a set of parameters, in order to aid understanding of policy relevant insights.

Policy Parameter	Description
Development Pathway • How does the model determine macro-structural assumptions (such as urbanisation, growth, jobs, total and sectoral energy demand, and electrification)? • What do macro-structural assumptions imply for patterns of development and how do they diverge from current trends?	**The study provides limited coverage of macro-structural development assumptions (e.g., urbanisation, sectoral composition, demand drivers, and electrification) and therefore offers limited insight into how development patterns may evolve beyond the policy-ambition differences captured in the scenarios.** The study does not present alternative ex ante GDP-growth pathways; instead, it reports that GDP levels in net-zero scenarios are approximately 3.4–5% higher than the baseline around mid-century. Patterns of urbanisation are not discussed. Investments in energy efficiency, carbon sink potentials, and the power sector are projected to be the largest drivers of GDP. These are assumed to be funded only by additional taxes, which lower household consumption, disposable income, and purchasing power. A redistribution of jobs is projected across scenarios, although skills aren't discussed. The impacts of additional jobs on growth are also not discussed. The study does not explore alternative development pathways. The focus remains on the assumption that decarbonisation responses will be principally determined by strengthening of policy targets and ambitions across scenarios.

Response from authors: The study's main focus is mitigation strategies. Alternative decarbonisation pathways are not within the scope of the model and the study.

Impacts of additional jobs on growth are discussed in the section on household consumption results. Skills assessment was not within the scope of the study.

Policy Parameter	Description
Energy Transition Pathway • What does the study imply for sectoral energy needs, the composition of the energy mix, its adequacy, and other enabling considerations (e.g., complementary infrastructure, utilisation, resource adequacy)? • What are the technological implications of the study, and how are these expected to be realised?	**The study outlines broad sectoral energy and technology shifts under net-zero scenarios but provides limited discussion of system adequacy, enabling infrastructure, and the feasibility of key technologies and demand-side measures.** According to the study, electricity remains the dominant form of energy demand across scenarios, met primarily by solar generation. Industry and construction are seen to be the sectors with highest demand. Even though the study recognises additional capacity needs to meet the higher demand, there is no discussion on enabling factors such as investment, labour, grid connectivity, or storage capacity required for it. Biofuel mandates and carbon pricing are also seen to drive the energy transition but biofuel adoption is seen to be low due to land use requirements. However, there is no discussion on land needs for solar, wind etc. The viability of off-grid solar is also not discussed. In the net-zero 2050 scenario, decarbonisation of the power sector is driven by a combination of rapid coal phase-down in the near term, followed by full coal phaseout, the introduction of carbon pricing, and early procurement of carbon capture technologies in the medium term. The study discusses the requirement to invest in R&D for low carbon technologies such as carbon capture and storage, and hydrogen but only very briefly, rendering it difficult to understand the likelihood of their realisation. The study also refers to improvements in energy efficiency, particularly in industry and buildings, as contributing to reduced energy demand under net-zero pathways. However, these efficiency gains are not discussed in terms of specific policy instruments, implementation mechanisms, or demand-side management strategies, and the role of DSM (such as load shifting or behavioural demand reduction) is not explicitly analysed.

Response from authors: As a macroeconomic assessment, detailed analysis of energy systems feasibility and conditions was not within the study scope. They were under consideration when designing the scenarios and internally validating results.

Policy Parameter	Description

Emissions

- Are emissions projected (to explore feasibility based on policies), or back-calculated (to assess policy needs) from an end-goal?
- How complete is the coverage: are any sources of emissions not reflected?
- What do technological and demand trends imply about robustness of emissions estimates, where projected?

The study projects emissions outcomes through a mix of forward policy simulation and net-zero-constrained pathways, but focuses primarily on CO_2 emissions and provides limited detail on sectoral sources, drivers of emissions reductions, and the feasibility of key mitigation technologies.

The study uses a combination of forward policy simulation and target-oriented pathways to assess emissions outcomes. In the Baseline, 2030 Targets, and Accelerated Coal Phaseout scenarios, emissions trajectories are projected forward based on specified policy packages and assumptions. In contrast, the 2070 Net Zero and 2050 Net Zero scenarios are defined by explicit end-goals, with policies calibrated to achieve these objectives within the modelling horizon.

Emissions coverage in the study is limited primarily to CO_2, with other greenhouse gases not comprehensively modelled in the main analysis. As a result, while the estimates provide insight into CO_2 mitigation under different policy pathways, they are less comprehensive with respect to total GHG emissions. The scenarios also provide limited discussion of sectoral emissions shares, sources of emissions, or the specific drivers of emissions reductions.

Although the study notes that "the evolution of different technologies is determined within the model," it does not clearly articulate how future demand trends and technology uptake translate into economy-wide emissions outcomes. References to mitigation options such as carbon capture and green hydrogen are brief, and their feasibility and contribution to emissions reductions are not examined in detail.

Response from authors: As a macroeconomic assessment, detailed analysis of emissions reduction potentials and feasibility was not within the study scope. They were under consideration when designing the scenarios and internally validating results.

Policy Parameter	Description
Investments • What lessons does the study offer for investments, based on technological choices, cost assumptions, sectoral coverage, and avoided expenses? • Are investments factored as inputs or outputs within the modelling process? • How do investment estimates relate to cost and growth assumptions?	**The study highlights the scale and direction of investment needs under net-zero pathways, but presents deterministic estimates without uncertainty analysis or sufficient detail on timing, financing instruments, sources, or distributional impacts.** The study treats investments both as a driver of growth and as an outcome of policy ambition, with projected investments in non-fossil power generation, transmission and distribution infrastructure, and enabling systems for carbon pricing. Additional investments are assumed to be financed domestically through higher prices and taxes or increased private borrowing, with investment trajectories broadly tracking GDP impacts and front-loaded in the early 2030s. However, in the absence of explicit uncertainty analysis around technology costs, macroeconomic growth, financing conditions, or policy effectiveness, these investment estimates appear over-specified. The study does not disaggregate investments by timing, financing instruments, or sources, nor does it assess distributional impacts, limiting insights into investment feasibility and equity implications.

Response from authors: As a macroeconomic assessment, detailed analysis of investment feasibility and equity was not within the study scope. They were under consideration when designing the scenarios and internally validating results.

The cost burden of the transition is explicitly discussed in the report.

Equity and Resource Impacts • If feasible, how does the study explore variations in economic outcomes across socioeconomic classes, sectors, or regions? • How do macrostructural inputs account for the roles of the informal economy and employment? • How does the study consider the natural resource implications of technology deployment?	**The study acknowledges aggregate employment shifts and selected resource constraints but does not systematically analyse equity, informal economy dynamics, regional or socio-economic distributional impacts, or the broader natural resource implications of large-scale technology deployment.** The study acknowledges significant losses in the fossil fuel sector (coal, oil and gas). Although it mentions the need for investments to reskill and upskill displaced workers to be able to work in other sectors, it does not quantify the investment required. Neither does it include any discussion on specific policies required for the same. Due to no discussion on patterns of urbanisation, it is difficult to gauge the impacts of decarbonisation and policy implications across socio-economic classes, sectors and regions. There is no systematic discussion of the informal economy, beyond brief references to informal employment in coal-related activities. It briefly discusses the impact and feasibility of biofuel mandates as it is projected that it would compete for available land with agriculture and forestry sectors but there is no discussion on land use implication of renewable energy (solar or wind), on hydrogen and water use. Additional co-benefits

Policy Parameter	Description
	of decarbonisation, such as better air quality, improved biodiversity, and other health benefits are discussed but not across socio-economic classes or regions. Neither does it discuss gender impacts.

Response from authors: These topics were considered to be outside the immediate scope of the study and can be the subject of follow-on analysis.

Energy Security

- Does the study factor fuel and material import dependence into its energy capacity and investment estimates?

The study links net-zero pathways to reduced fossil fuel import dependence and improved energy security, but does not assess emerging import dependencies for clean energy technologies or examine how improved energy security translates into reliable and equitable energy access.

The study suggests that reduced dependence on imported coal, oil, and gas under higher policy ambition scenarios—including the 2030 Targets and 2070 Net Zero pathways—improves energy security relative to the baseline. The study argues that greater reliance on domestically produced renewable energy enhances energy security by reducing exposure to global fossil fuel supply disruptions, though this claim is not supported by a detailed assessment of system reliability, variability, or balancing requirements. The analysis does not consider emerging import dependencies associated with the energy transition, such as reliance on imported solar PV modules, batteries, critical minerals, or rare earth materials. While improved energy security from domestic generation is presented as beneficial for energy access, the study does not examine historical or projected trends in energy demand, affordability, or access, nor does it assess how gains in system-level security translate into improved access for different socio-economic groups.

Response from the authors: The modelling assumes that patterns of trade remain unchanged for all sectors. Thus, the results reflect potential reliance on imported materials to support domestic renewable energy production. Energy demand and costs (including affordability) were discussed in the report.

Analysis of detailed energy systems and energy access was not within the immediate scope of the study.

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/sustainable-futures-collaborative

/sustainablefuturescollab

@SFC_India

/sustainablefutures

hello@sustainablefutures.org

A-16, First Floor, Qutab Institutional Area
Aruna Asaf Ali Marg, New Delhi (110067)