

# Unpacking ‘India: Transforming to a Net-Zero Emissions Energy System’

## *The Climate Futures Project*

*Bridging Climate Policy and Models*



THE CLIMATE FUTURES PROJECT

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**Date:** October 2022

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## Citation

The Climate Futures Project. 2022. Unpacking 'India: Transforming to a Net-Zero Emissions Energy System'. New Delhi: Centre for Policy Research and IIT Delhi. October 2022. Available at: [www.climatefuturesproject.in](http://www.climatefuturesproject.in)



## 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 independent initiative co-developed by the Centre for Policy Research and the Indian Institute of Technology Delhi 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](http://www.climatefuturesproject.in)

# THE CONSORTIUM



The Initiative on Climate, Energy and Environment at the Centre for Policy Research (CPR-ICEE) aims to stimulate an informed debate on the laws, policies and institutions shaping climate, energy and environmental governance in India. Our research focuses on an improved understanding of climate, development and environmental challenges – and pathways to improved outcomes – in three key areas: climate policy and institutions, the political economy of energy transition in India, and air quality governance. <http://cprindia.org/projects/initiative-climate-energy-and-environment>



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# Highlights

## **Purpose**

- *The stated purpose of the study is to **assess whether adequate solutions theoretically exist to fully decarbonise the energy sector.***

## **Key Merits**

- *The study offers a comprehensive ensemble of mitigation technologies and approaches across the energy sector.*

## **Scope for Improvement**

- ***Limited transparency in model data and structure constrains the** credibility of ensuing policy recommendations. Additionally, the study provides little insight on the extent to which uncertainties may influence recommendations.*
- ***These limitations are crucial** particularly with respect to technological breakthroughs, and potential alternative socio-economic — GDP and urbanisation — pathways.*
- *Finally, **the study does not quantify financial, equity, or energy security implications of the energy transition;** or the trade-offs between developmental and mitigation choices.*







# 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 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 co-developed by the Centre for Policy Research and the Indian Institute of Technology, Delhi.***

## 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 modelling approach through an evaluation along five parameters: 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*
- 3. 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.*
- 4. 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*

# I: Introduction

## 1.1. *Purpose and Type*

**Purpose of Study:** This study seeks to “examine whether adequate opportunities exist to fully decarbonise the energy sector” and to highlight the barriers for decarbonisation.

**Source:** TERI-Shell India, 2021. India: Transforming to a Net-Zero Emissions Energy System. TERI. ([Link](#))

**Model Type:** Insufficient information is available on the exact model type. However, [this note](#) offers a window into some implications of commonly employed model choices.

## 1.2. *Key Scenarios*

**TERI-Shell** report mentions two scenario sketches (though it presents implications of only one) and explores economic and energy transition development in India.

### 1. **Net-Zero Emissions (NZE) scenario:**

This scenario is the principal focus of the report, aiming to outline a pathway to a net-zero emissions energy system for India. It is a normative and ambitious scenario that identifies drivers for a rapid transition by 2050. The availability of required technology is assumed to overcome all social, infrastructural and behavioural barriers.

### 2. **Towards Net-Zero (TNZ) scenario:**

This scenario incorporates barriers to the NZE transition in limited areas (such as electrification, hydrogen, and bioenergy), assuming a delay in the transition of a decade or longer than in the NZE scenario.

# II: Assessment of Approach

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

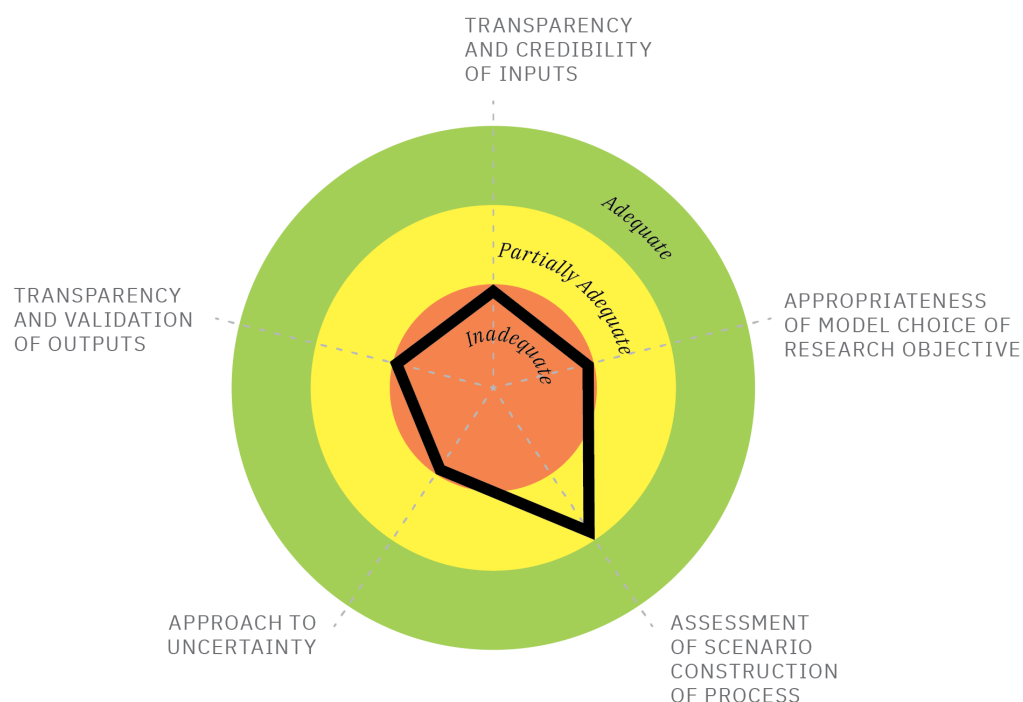
*The framework for assessment employed in this section was developed based on studies of good practices for computational models which inform decision-making. A review of these papers indicated a few common themes: clarity of purpose, importance of model specification and the process involved, assessing 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 **TERI-Shell 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.*

## TERI-Shell



## 1. Transparency and credibility of inputs to the model

Overall Assessment Criteria	Overall Assessment Score
<p><b>Transparency and credibility of inputs to the model</b></p> <p>Assessment of whether key inputs are transparent and have an adequate empirical basis. Key inputs include:</p> <ul style="list-style-type: none"> <li>• Techno-economic data (demand trends, costs of technologies, fuel costs, technology options)</li> <li>• Socio-economic drivers, i.e., population, and economic growth</li> </ul>	<p><b>Inadequate</b></p> <p>Input data sources have not been transparently stated, for the most part. The limited descriptions hamper independent assessments of credibility of key input assumptions. For example, the future cost assumptions of various technologies and assumptions regarding energy demand trends are not specified. Therefore it is difficult to ascertain how the outputs regarding projected parameters such as emissions, energy intensity etc., were arrived at.</p>

Sub-Criteria for Assessment	Sub-Criteria Scores
<p><b>Decision Rules to Aggregate Sub-criteria Scores:</b></p> <p><i>For this assessment criterion, the study is rated 'Adequate' if all three sub-criteria are met, 'Partially adequate' if any two sub-criteria are met, and 'Inadequate' otherwise.</i></p>	
Are data and data sources transparently stated and, where possible, based on multiple corroborating sources?	<p><b>No</b></p> <p>Some sources of data are mentioned as endnotes, and most sources for data in graphs are referred to as 'TERI Analysis'.</p> <p>However, individual data assumptions are often not specified, or linked to specific sources.</p>
Are the data up-to-date, with the bounds of data availability constraints?	<p><b>Yes</b></p> <p>Many figures (for e.g., 6 to 13) indicate historical data up to 2020.</p>
<p>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):</p> <ul style="list-style-type: none"> <li>• Is the basis for future projections explained and justified? For example reasonable justifications include expert</li> <li>• Do inputs adequately reflect growing uncertainties over time?</li> </ul>	<p><b>No</b></p> <p>Neither of the sub-criteria are met.</p> <ul style="list-style-type: none"> <li>• <b>No</b> Insufficient information on inputs, to make an assessment regarding their justification.</li> <li>• <b>No</b> Since only single trend-line projections are provided for most outputs (figures 6-13), uncertainties in input assumptions do not appear to have been accounted for.</li> </ul>

**Responses from study authors:** This is not a standalone report. This was just an extension and update of previous/ existing report. Hence, data sources etc. are not indicated in detail. But, as an internal reviewer we can confirm that all data was taken from various national and international public sources. However, some data when presented in the report, were mentioned as 'TERI analysis' because those are the final output. There was no clear scope or choice of model / inputs because this was just an extension / update of previous / existing study.



## 2. Appropriateness of model choice to research objective

Overall Assessment Criteria	Overall Assessment Score
<p><b>Appropriateness of model choice to research objective</b></p> <p>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.[1]</p>	<p><b>Inadequate</b></p> <p>There are no descriptions of model study used, therefore it is difficult to comment on the appropriateness of model choice to research objectives. Although the authors mention that this work is an extension of an earlier report “Energising India”, but, it is left to the reader to ascertain the specific manner in which the study was extended. There are also statements such as, “TERI developed a baseline case for India”, but no description of what the baseline case is, or how it was developed.</p>

Sub-Criteria for Assessment	Sub-Criteria Scores
<p><b>Decision Rules to Aggregate Sub-criteria Scores:</b></p> <p><i>For this assessment criterion, the study is rated ‘Adequate’ if all three sub-criteria are met, ‘Partially adequate’ if any two sub-criteria are met, and ‘Inadequate’ otherwise.</i></p>	
<p>Is the model structure transparent? (rated yes if at least 2 of the following are true)</p> <ul style="list-style-type: none"> <li>Has the model structure been described adequately through text and/or figures?</li> <li>Is the model itself open-source?</li> <li>Is there sufficient description and accessibility to data and model structure to enable replication of the model?</li> </ul>	<p><b>No</b></p> <ul style="list-style-type: none"> <li>No There is no description of model structure available</li> <li>No</li> <li>No</li> </ul>
<p>Is there adequate discussion of the strengths and weaknesses of the model structure, with respect to its fitness for purpose?</p>	<p><b>No</b></p> <p>There is no discussion regarding the model structure’s fitness for purpose.</p>
<p>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?</p>	<p><b>No</b></p> <p>There is insufficient information to comment.</p>

**Responses from study authors:** Suitability of the model is not discussed as it is well established in the field of energy modelling.

### 3. Assessment of scenario construction process

Overall Assessment Criteria	Overall Assessment Score
<b>Assessment of scenario construction process</b>  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.	<b>Partially adequate</b>  There are two scenarios mentioned: Towards Net Zero (TNZ), and Net Zero Energy (NZE). However, only the NZE scenario is explained and examined. The rationale for such a normative scenarios is also briefly discussed. This scenario construction process is justified for the stated purpose of the report, “to assess whether adequate solutions exist to fully decarbonise the sector, and/or examine the level to which each of the sectors could theoretically move to Net Zero emissions by 2050”. There is value in this report, as it includes a list of mitigation technologies across sectors, and timelines corresponding to their deployment. However, the report is limited in that it is not designed to shed light on the choices and trade-offs involved in achieving the normative goal. However, the report does highlight some trade-offs with regard to biomass and biofuels as an interim energy source, even with this single scenario framework.

Sub-Criteria for Assessment	Sub-Criteria Scores
<b>Decision Rules to Aggregate Sub-criteria Scores:</b> <i>For this assessment criterion, the study is rated ‘Adequate’ if all three sub-criteria are met, ‘Partially adequate’ if any two sub-criteria are met, and ‘Inadequate’ otherwise.</i>	
Is the rationale for alternative scenario ‘storylines’ appropriate, adequately discussed and explained (ranked adequate if both of the following are true)?  <ul style="list-style-type: none"> <li>Is there an explanation of the rationale for each scenario and how different scenarios relate to each other</li> <li>Are the scenarios well-designed to address the research question?</li> </ul>	<b>Yes</b> Since both sub-criteria are met.  <ul style="list-style-type: none"> <li><b>Yes</b> The rationale for the TNZ scenario is clearly discussed.</li> <li><b>Yes</b> The scenario is designed to address the research question.</li> </ul>
Is the process through which these storylines were developed explained? (ranked adequate if at least 2 of the following are true)  <ul style="list-style-type: none"> <li>Is the process transparent?</li> <li>Did the process involve users, notably policy-makers?</li> <li>Was the process iterative?</li> </ul>	<b>No</b> Because there is insufficient information to comment
Do the scenarios account for alternative socio-economic pathways, in addition to technology development and adoption pathways? OR have the implications of not exploring those uncertainties on the results been discussed qualitatively?	<b>Yes</b> While the scenarios do not account for alternative development pathways (growth rates, urbanisation), the study does highlight the limitations of certain assumptions. For e.g., “hydrogen... is highly anticipated but technology development at scale is only just emerging.” (Pg. 35)

Responses from study authors: No response

## 4. Approach to uncertainty

Overall Assessment Criteria	Overall Assessment Score
<p><b>Approach to uncertainty</b></p> <p>Assessment of the study's approach to addressing and communicating uncertainty across the various criteria identified above. Across:</p> <ul style="list-style-type: none"> <li>• Economic growth</li> <li>• Technology options</li> <li>• Cost trajectories</li> <li>• Any other uncertainties in input assumptions or model processes?</li> </ul>	<p><b>Inadequate</b></p> <p>Outputs primarily indicate singular trends, without specifying ranges, or the uncertainties they may be subject to. Uncertainties related to inputs and model structure are also not examined. The report emphasizes barriers, constraints, and statements which indicate uncertainty regarding the transition. For example, there are statements such as, "India's pathway to a NZE system will require unprecedented co-operation"(Pg. 31), "...hydrogen at scale is only emerging... still a nascent industrial process" (Pg. 35). Therefore, while there is some consideration of uncertainty, such considerations are not systematically related to the model's assumptions or causal mechanisms. It is hard to comment on when these uncertainties may influence policy outcomes, and to what extent.</p>

Sub-Criteria for Assessment	Sub-Criteria Scores
<p><b>Decision Rules to Aggregate Sub-criteria Scores:</b></p> <p><i>For this assessment criterion, the study is rated 'Adequate' if all three sub-criteria are met, 'Partially adequate' if any two sub-criteria are met, and 'Inadequate' otherwise.</i></p>	
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?)	<p><b>No</b></p> <p>Uncertainties in inputs are not explicitly discussed or examined</p>
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?	<p><b>No</b></p> <p>Since the model's causal mechanisms are not described, uncertainties related to the model structure are also not analysed or presented.</p>
Do the model results analyse and represent how uncertainty may change with time?	<p><b>No</b></p> <p>Outputs (e.g.: emissions, energy demand) primarily indicate singular trends, without specifying ranges, or the uncertainties they may be subject to.</p>

**Responses from study authors:** Long run estimation is itself uncertain given the fast pace of change in energy innovation and technology development. So, no other specific assumptions were taken to incorporate 'uncertainty'.

## 5. Transparency and validation of outputs

Overall Assessment Criteria	Overall Assessment Score
<b>Transparency and validation of outputs</b> Assessment of whether the key outputs are presented transparently and validated.	<b>Inadequate</b> Explanation for assessment: There is little discussion on the input assumptions, model mechanisms, and how they inform emission outputs; therefore, it is unclear to what extent the policy recommendations are based on the model results or separate analysis. There is no discussion on validation of the study, model structure, or model results either. Further discussion: However, the report does reflect on possible socio-economic impacts of the energy transition such as impact on UN SDGs, regional shifts in economic activity, potentially disproportionate costs to low-income groups etc. (Pg. 41). A discussion comparing the recommendations of this report to other similar studies would have helped improve credibility in the results.

Sub-Criteria for Assessment	Sub-Criteria Scores
<b>Decision Rules to Aggregate Sub-criteria Scores:</b> <i>For this assessment criterion, the study is rated 'Adequate' if all three sub-criteria are met, 'Partially adequate' if any two sub-criteria are met, and 'Inadequate' otherwise.</i>	
Have outputs been presented in a manner that facilitates consideration of how they (outputs) are <b>shaped by input assumptions, model mechanics, and scenarios</b> ?	<b>No</b> Since there is limited discussion of the input assumptions or model mechanics.
Have the implications of <b>uncertainties</b> in inputs and model structure been considered in reporting of results and consequent policy implications?	<b>No</b> Although there is little discussion on the input assumptions, model mechanisms, there is some reflection of uncertainties. Acknowledgement of uncertainties translate directly to normative statements.
Have results been <b>validated</b> with efforts at validation clearly presented? Forms of validation include: <ul style="list-style-type: none"> <li>• Expert validation</li> <li>• Peer review</li> <li>• Validation through literature</li> <li>• Empirical validation</li> <li>• Cross-country analysis</li> </ul>	<b>No</b> Insufficient information regarding validation efforts.

**Responses from study authors:** It was not a standalone study. It was just an extension and updating of previous/ existing study.

The input assumptions were not discussed in detail. The output was validated with expert consultation (indicated in acknowledgement section).



# III. Summary of Outputs

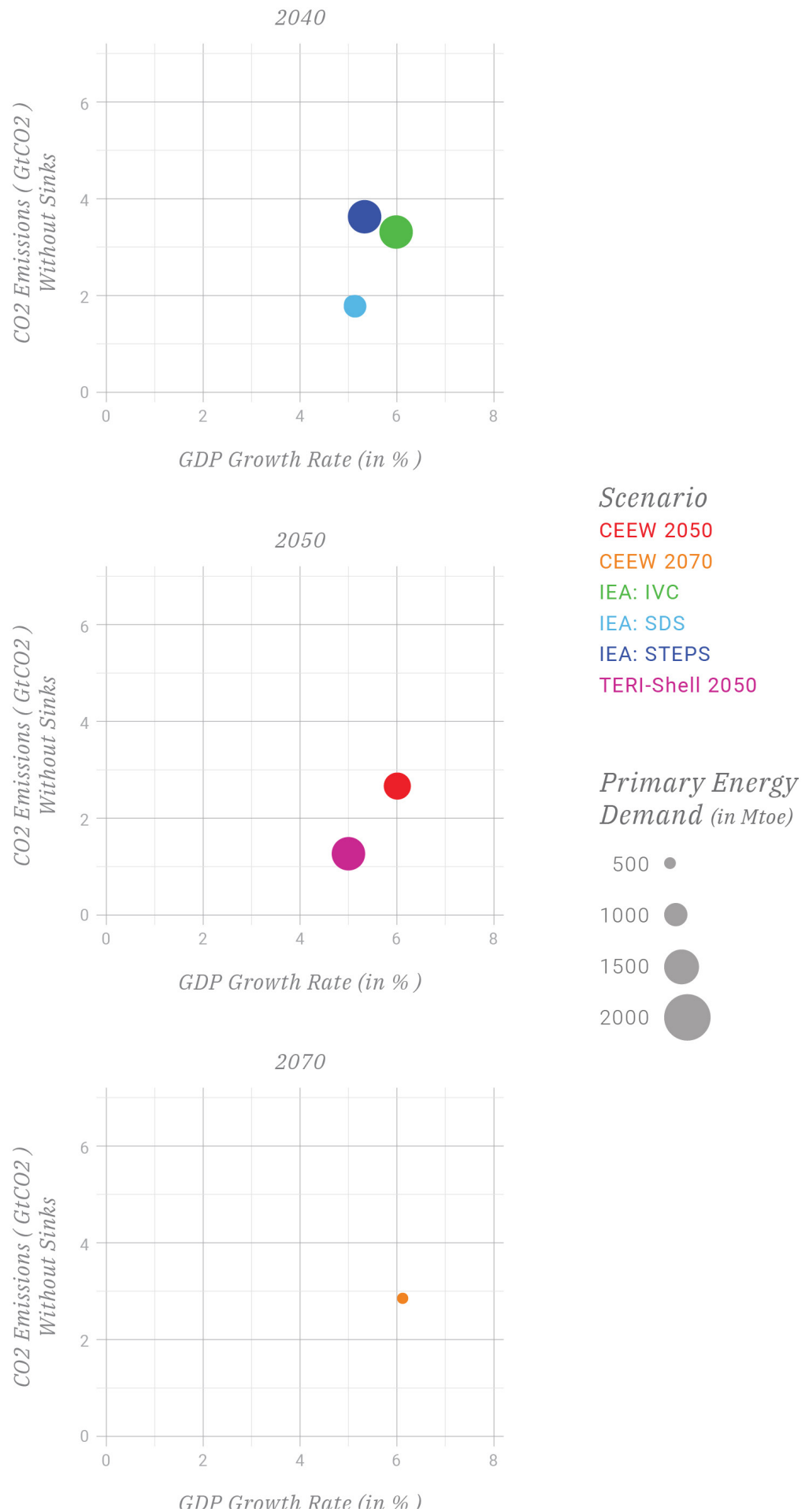
*In this section, we present key mid-century projections related to emissions, GDP growth, final energy demand, and energy supply, across studies. We summarise these results graphically across all studies\* assessed, and in tabular form for this present study.*

## 3.1 *Key Findings Across Studies*

*\*Apart from TERI-Shell 2021, the other studies we include in the graphics below are*

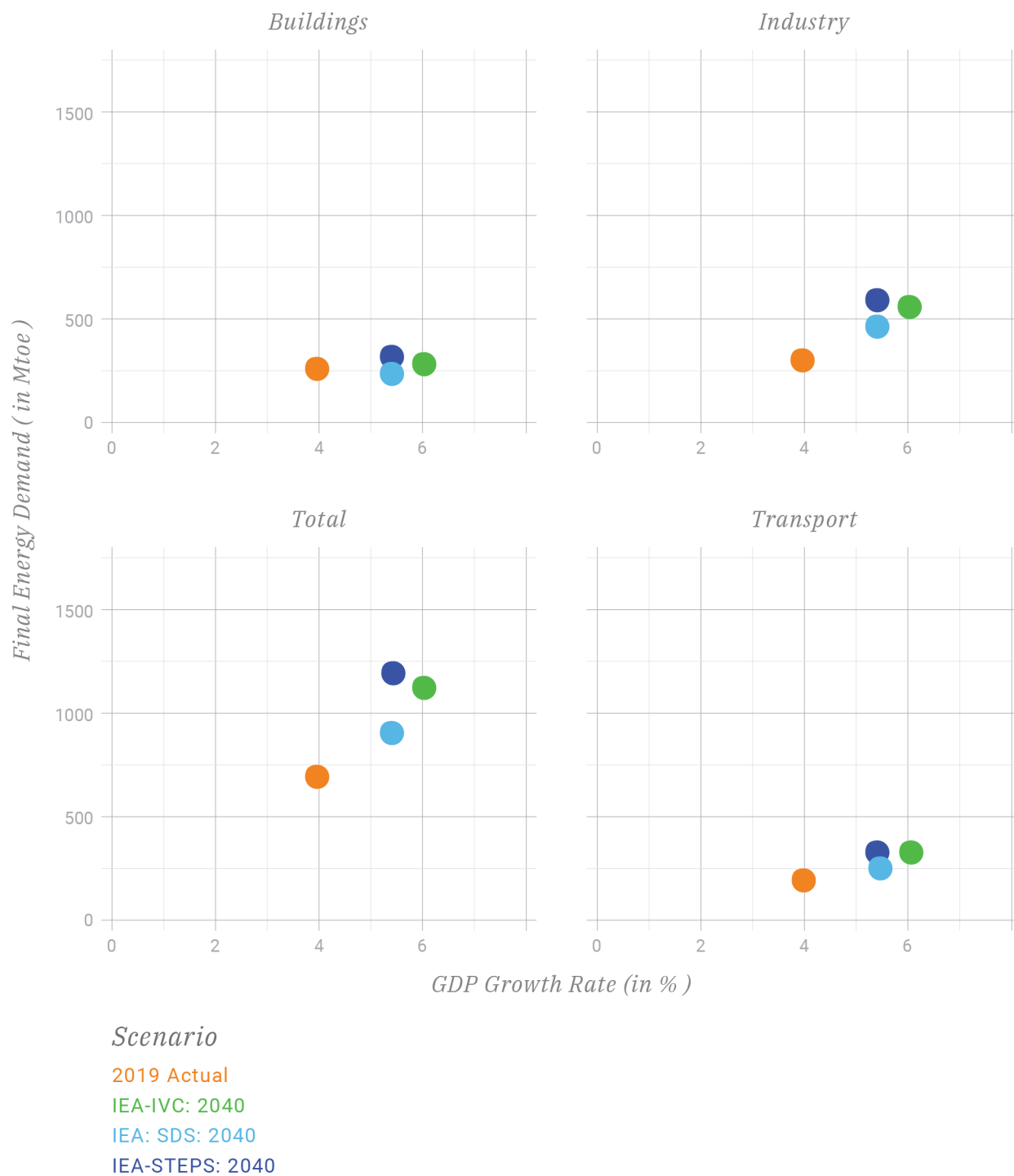
*(i) Chaturvedi, V. and Malyan, A., 2021. Implications of a Net-Zero Target for India's Sectoral Energy Transitions and Climate Policy. Council on Energy, Environment and Water (CEEW); and*

*(ii) International Energy Agency, 2021. India Energy Outlook 2021. OECD.*



**Figure 2: Annual CO<sub>2</sub> emissions in end-year vs. average GDP growth rate from base year**

\* Notes: TERI-Shell and CEEW estimates are not adjusted for CCS 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)



**Figure 3: Final energy demand versus per capita GDP in end-year, faceted by end-use sector**

\* Notes: 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

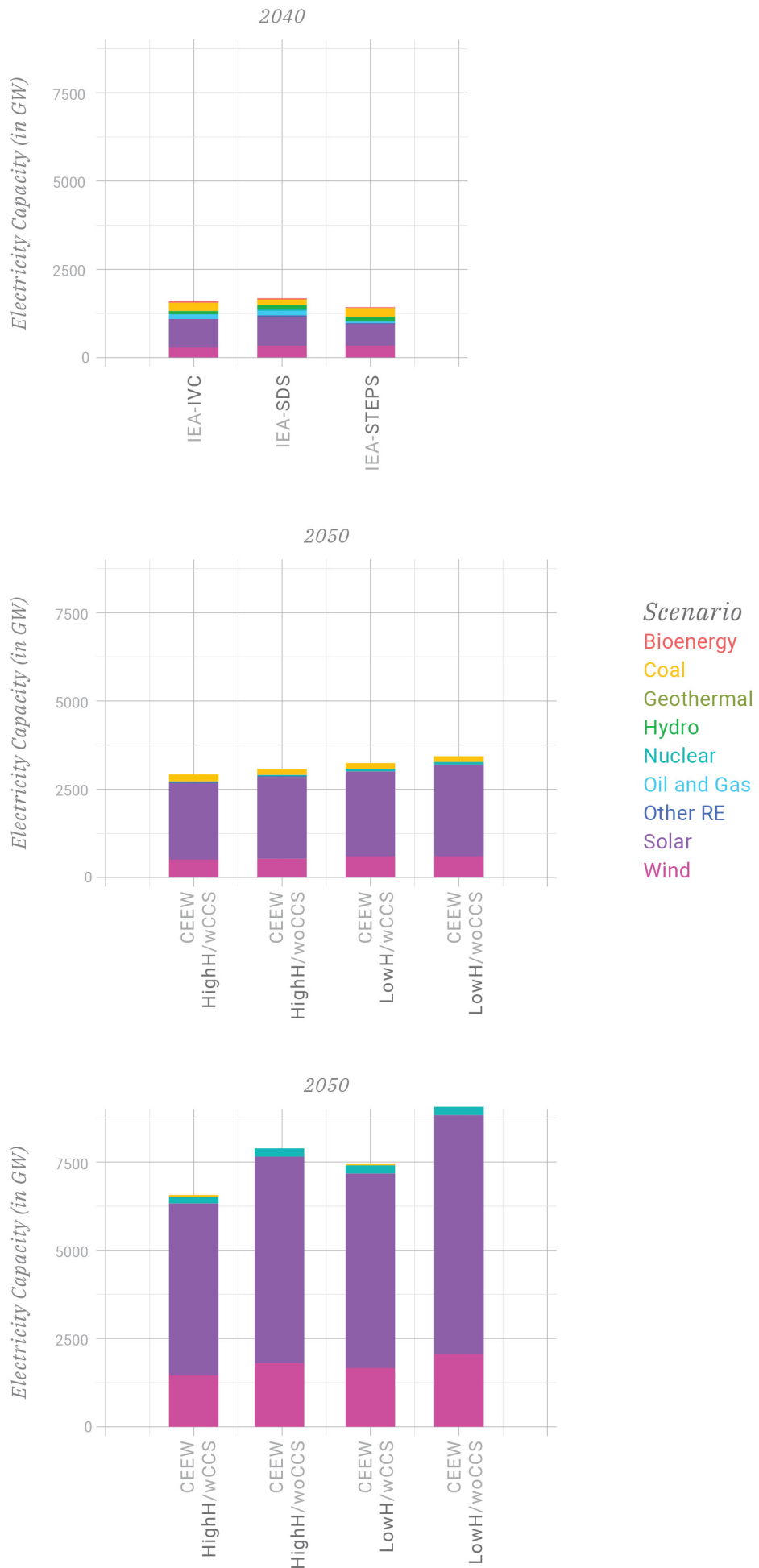


Figure 4: Installed electricity capacity (GW) in end-year





**Figure 5: Electricity generation by fuel source in end-year**  
 \* Notes: Studies for which data was not available are not represented

## 3.2

### *Key Results in Current Study*

Scenario	Net zero emissions (NZE)
<b>Macro-Structural Variables (2050)</b>	
Annual GDP Growth (%)	Unclear, approximately 5%
GDP	Data not listed
Population	Data not listed
Urbanisation (%)	Unclear, approximately 50%
Job Growth Outcome	Data not listed, but job increases expected in renewables
<b>Emissions</b>	
Peaking Year	2025 (Energy sector)
Emissions in Peaking Year (GtCO <sub>2</sub> e)	3 GtCO <sub>2</sub> e
Net Zero Year	2050 (Energy sector)
Energy Emissions in Net Zero Year (GtCO <sub>2</sub> e)	Residual emissions of 1.3 GtCO <sub>2</sub> e
Per Capita Emissions (tCO <sub>2</sub> e/ person/ year)	Data not listed
<b>Energy and Electricity (2050)</b>	
Primary Energy Demand (Mtoe)	Approx. 2,200 Mtoe
Installed Generation Capacity (GW)	Data not listed
Electricity Demand (TWh)	8,800 TWh
RE Share in Electricity Generation and in Primary Energy (%)	90%
	Data not listed
<b>Costs and Investments</b>	
Energy Investment Required	Data not listed

Table 1: Summary of key variables

# IV: Interpretation of Results

*This section qualitatively interprets model outcomes along a set of parameters, in order to aid understanding of policy relevant insights. Through an **iterative and consultative process**, we have identified six policy priorities against which we interpret the outcomes. These are:*

1. Development pathway
2. Energy transition pathway
3. Emissions
4. Investments
5. Equity and resource impacts
6. Energy security

*For each parameter, **the section offers a brief description and the justification for the assessment**. It also includes responses from the authors of the underlying study to the interpretation.*

Policy Parameter	Interpretation	Responses by Study Authors
<b>Development Pathway</b> <ul style="list-style-type: none"> <li>How does the model determine macro-structural assumptions (such as urbanization, growth, jobs, total and sectoral energy demand, and electrification)?</li> <li>What do macro-structural assumptions imply for patterns of development and how do they diverge from current trends?</li> </ul>	<p><b>The study assumes single estimates for select development indicators such as sector shares of GDP or consumption patterns, and thus does not consider alternative development pathways. Further, these singular estimates are not detailed, thereby making it difficult to assess their feasibility or implications for India's development.</b></p> <p>With a single scenario, the study only assumes a single annual growth rate, level of urbanisation, and levels of appliance ownership. Justification for these estimates is not clearly provided. Within these estimates, the study does not discuss the possible sectoral shares of GDP or their likelihoods, listing instead the government's stated goals for - among others - a USD 5 trillion economy by 2025, a 25% share of manufacturing in GDP by 2025, and doubling agricultural incomes by 2024. It is unclear how these goals are realised in the study, or how they interact with each other. The study highlights the role of potential modal shifts – in passenger rail and freight transport – in reducing emissions, without discussing their feasibility from the supply and demand sides. The reference to 90% appliance ownership suggests consumption patterns that replicate those seen in developed countries. The scenario does not discuss other development indicators, such as sectoral shares of energy, passenger mobility, or total and regional employment. It is thus difficult to infer the development patterns implicit in the scenario and to explore whether they differ from current trends.</p>	No response

Policy Parameter	Interpretation	Responses by Study Authors
<p><b>Energy Transition Pathway</b></p> <ul style="list-style-type: none"> <li>• 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)?</li> <li>• What are the technological implications of the study, and how are these expected to be realized?</li> </ul>	<p><b>Energy demand is assumed to be driven by growth and urbanisation, but the study does not discuss its likelihood or variability, its distribution across sectors, and the role of efficiency gains. Shares of generation capacity and utilisation factors are not clear, and uncertainties in technological breakthroughs are not discussed. It is thus difficult to fully understand the energy transition pathway implicit in the study.</b></p> <p>Expectations of energy demand are primarily based upon economic growth and urbanisation. The narrative is built upon significant clean energy deployment and electrification, with support from cleaner fuels including hydrogen. The study notes the importance of enabling infrastructures such as grid connectivity and storage. However, it considers a single estimate of energy demand, without discussing the likelihood of its realisation, its distribution across sectors or regions, how it might vary with economic growth and urbanisation, and how energy efficiency gains might moderate demand. It is difficult to infer energy needs and supply adequacy, or plan for sectoral energy transitions, from this information.</p> <p>The study states that nearly 90% of the generation comes from renewables in 2050. The implications for generation capacity and assumed utilisation factors are not clear. Emerging technologies such as storage and hydrogen are also subject to significant uncertainties in feasibility; the study does not analyse these uncertainties, rendering it difficult to understand the likelihoods of their realisation, or explore alternative energy transition pathways. This is noteworthy since, for instance, the study states that businesses will “...need to take their decisions on hydrogen before the mid-2020s...”</p>	<p>No response</p>
<p><b>Emissions</b></p> <ul style="list-style-type: none"> <li>• Are emissions projected (to explore feasibility based on policies), or back-calculated (to assess policy needs) from an end-goal?</li> <li>• How complete is the coverage: are any sources of emissions not reflected?</li> <li>• What do technological and demand trends imply about robustness of emissions estimates, where projected?</li> </ul>	<p><b>The scenario is a back-calculation exercise to assess policy needs, and thus is not designed to discuss likelihoods of emissions estimated. Non-energy emissions are not included, and the study does not discuss sources of emissions and emissions reductions, or the impacts of alternative patterns of energy demand and supply.</b></p> <p>The scenario assesses how the energy sector may reach net-zero emissions by 2050; as such, it is set up as a back-casting exercise to discuss what policies, technologies, and energy trends are needed. It presents an estimate for gross emissions, as well as the amounts that must be absorbed through sequestration and CCU/CCS, although it is not clear how these amounts were determined or whether they are feasible. The scenario does not discuss the sectoral shares of emissions, nor does it quantify the sources of emissions reductions. It also does not assess the impact on the estimates of unrealized assumptions of technological deployment and energy supply, or to alternative patterns of energy demand. It is thus not possible to infer how robust these estimates are, how they may be achieved, or what alternative emissions scenarios India is likely to face. Given the scope of the study, non-energy emissions are not included.</p>	<p>No response</p>



Policy Parameter	Interpretation	Responses by Study Authors
<b>Investments</b> <ul style="list-style-type: none"> <li>What lessons does the study offer for investments, based on technological choices, cost assumptions, sectoral coverage, and avoided expenses?</li> <li>Are investments factored as inputs or outputs within the modelling process?</li> <li>How do investment estimates relate to cost and growth assumptions?</li> </ul>	<p><b>The study does not quantify domestic investment needs, either cumulative or annual, and does not explicate technological cost assumptions.</b></p> <p>It quotes another study that estimates the transition will have a modest impact on GDP, and separately states that much of the investment will be redirected, rather than being additional. However, it does not clarify how much, what is included, where investments will need to be directed, or how they will be sourced. Without clarity on investment estimates and allocations, it is difficult to gauge the impacts of different economic growth rates, unrealized technology cost assumptions, or alternative scenarios relating to different energy transition pathways.</p>	No response
<b>Equity and Resource Impacts</b> <ul style="list-style-type: none"> <li>If feasible, how does the study explore variations in economic outcomes across socioeconomic classes, sectors, or regions?</li> <li>How do macro-structural inputs account for the roles of the informal economy and employment?</li> <li>How does the study consider the natural resource implications of technology deployment?</li> </ul>	<p><b>The study notes India's development challenges, but does not detail co-benefits or resource impacts, discuss distributive impacts, or capture discussions on resilience and the informal economy.</b></p> <p>The study recognizes India's development challenges, noting that investment in the energy transition can create jobs and improve air quality, and that digitalisation can create further opportunities in energy services delivery. These are however noted in qualitative discussion and are not quantified. The study does not expand on for instance the quantity or quality of jobs created, and does not further discuss the distributive impacts of the transition. Statements on appliance ownership and modal shifts to high-speed rail are partly contingent on the level and distribution of income and demand patterns; this is not discussed. The study does recognize the potentially uneven spread of impacts, the risks to lower income groups, and the need for reskilling and retraining, but doesn't explain how or the extent to which this can be mitigated. Gender impacts are only briefly noted, from the perspective of air quality effects on health and fertility. The informal economy is not explicitly discussed. Per the information provided in the scenario, it is difficult to get a clear picture of how inclusive and just the transition outlined will be.</p>	No response
<b>Energy Security</b> <ul style="list-style-type: none"> <li>Does the study factor fuel and material import dependence into its energy capacity and investment estimates?</li> </ul>	<p><b>The study acknowledges greater resultant self-sufficiency and macroeconomic stability, but does not quantify reductions in energy imports, potential import dependence for natural gas and solar PV components, or impacts of potential supply shocks.</b></p> <p>The study acknowledges that the transition to a low-carbon system can increase self-sufficiency and thereby reduce the risk of macroeconomic instability. It however does not define how much energy imports might be reduced or what their impacts might be, and does not discuss the potential import dependence of cleaner energy and transition fuels, such as natural gas and solar PV manufacturing. It also does not account for shocks that might affect fuel prices and/or supply, and their impacts on energy security goals.</p>	No response