Simulations with E3-India model

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The E3-India is a macroeconomic policy impact model developed by Cambridge Econometrics to help foster effective engagement around policy at the state level in India. The model is being developed as a tool and at present is at an advanced stage of development, sufficient for us to demonstrate its potential for simulation and analysis of policy impacts. Data gaps will be filled, and we hope that the growth of local knowledge over time will help the model realise its full potential.

The analysis presented below helps to demonstrate the flexibility and use of the model in three ways. First, the model is flexible with respect to geographic scale. It can be used to demonstrate policy impacts at different geographic resolutions (regions) that span one or more states and territories. Second, the model is flexible with respect to technology. It can be used to reveal the impacts of policy scenarios that are differentiated by energy technology (like feed-in tariffs, or FiTs, for example, to demonstrate impacts on greenhouse gas [GHG] emissions) by region. Third, the model is tightly woven among energy, environment, and the economy (the three e's in 'E3'). Consequently, the model permits its users to understand impacts of policy both within the sector and beyond. We can, for example, use the model to understand the impacts of technology transition scenarios with key economic parameters such as state-level GDP, investments, and consumer expenditure for state-level or economy-wide E3 simulations.

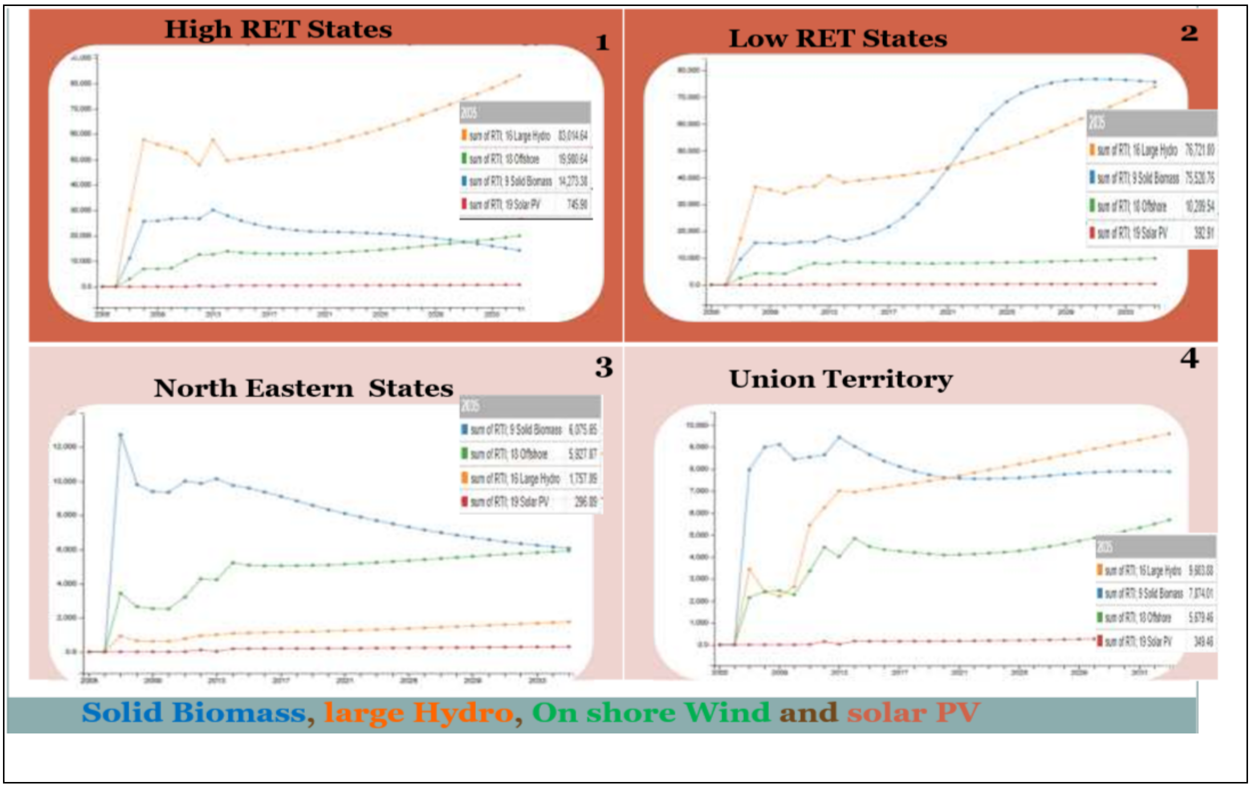
The latest version of the E3-India model, the Beta 3 (B3) version, is now available. This version of the model incorporates certain default "scenario" and "assumption" files along with "idiom" files that provide users flexible tools to run policy simulations. All three of these text file groupings are in text files that can be manipulated by the model user. The scenario and assumption files are preconstructed tables to allow for relatively simple policy simulations by users. The idiom files represent a tool for advanced users to simulate policies using a fairly basic programming language developed by Cambridge Econometrics (CE) for the model.

The modelling framework provides considerable flexibility for users to modify model input variables and then to view the impacts of those modifications on an extensive list of outputs. In order to manage the long list of variables, CE has created a high-level organizational structure that can be viewed through the model interface. There are three major groups of simulation variables: i) energy, environmental, and economic (E3) variables available by region; ii) E3 variables available by sector (within each region); and iii) energy technologies, referred to as future technology transition (FTT,) variables. The requisite regional resolution for analysis is selected using either individual states or union territory or aggregates as demonstrated in Theme I.

Theme I: Applying the E3-India Model in Different Geographic Regions

The Renewable Energy Technology (RET) transition scenario is based on existing renewable capacities associated with individual states and the trajectory of renewable growth as forecasted by the model. The RET transition scenario was studied among four different groups of Indian states categorised and aggregated as follows: i) high-RET (i.e., "high" with respect to installed capacity) states; ii) low-RET states; iii) remote Northeastern states; and iv) Union Territories. The growth trends for four renewable energy technologies (solid biomass, large hydro, onshore wind, and solar photovoltaic technology [PV]) from 2005 to 2035 were analyzed in terms of annual electricity generation (GWh/year). The results indicate that states with high-RET capacity would be the forerunners in solar and wind installations until 2035. Solid biomass and large hydro would account for a significant share of renewables in all of the categories. The promotion of solar PV would be more aggressive in Union Territories than in Northeastern states or low-RET states. Thus, within the same national boundaries, the pathway of the Renewable Energy Transition would be significantly different for the four regional categories analysed. The simulated trajectory of renewable generation for either individual states or aggregated groups can effectively inform policy choices, regulatory actions, and utility decisions for better management and infrastructure planning for energy capacity addition in each region. The vertical axis shows the trend of electricity generation by technology represented in GWh/year.

High-RET states	**Low-RET states**	**Remote Northeastern states**	**Union Territories**
1	2	3	4
Maharashtra, Madhya Pradesh, Gujarat, Rajasthan, Tamil Nadu, Karnataka, Chhattisgarh	Bihar, Jharkhand, Uttarakhand, Haryana, Odisha, Himachal Pradesh	Assam, Tripura, Meghalaya, Arunachal Pradesh, Manipur, Nagaland , Mizoram	Goa, Delhi, Chandigarh, Pondicherry, Andaman Nicobar

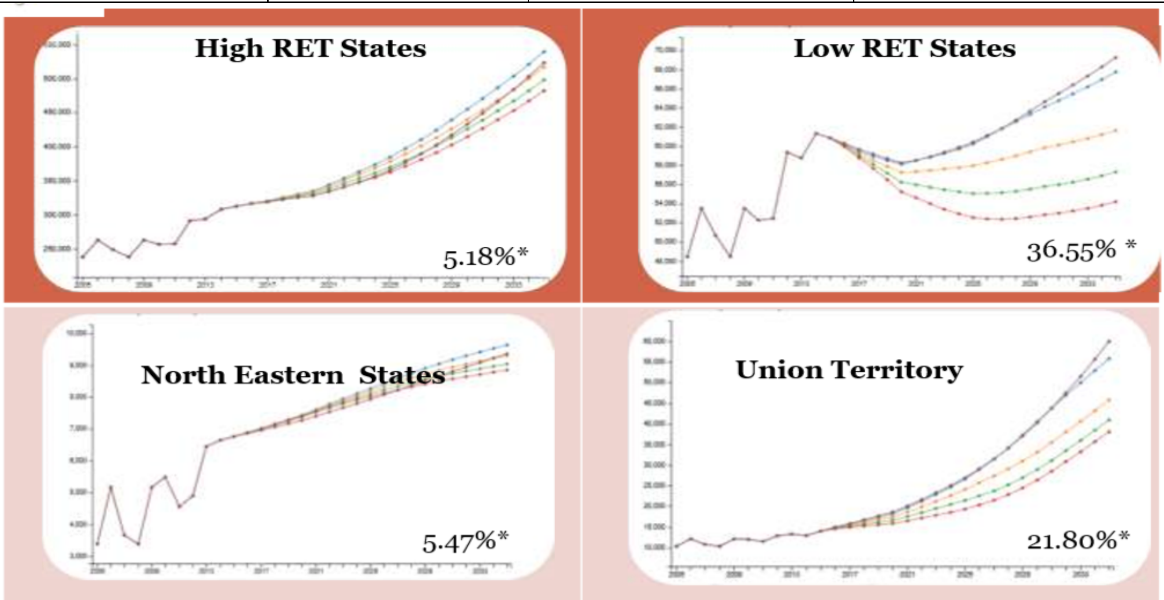


Theme II: Feed-in tariff (FiT) scenario for renewables by technology and assessment of low-GHG trajectory pathways for the aggregated state categories in India

FiTs are wholesale price or "standard offer" prices that are awarded to technologies that meet the eligibility requirements for any given generation technology. FiTs typically include a price premium (above market-base or cost-based prices) to encourage the development of newer technologies.

The analysis performed required modifications to the "idiom" files described earlier. The code in the file was modified to establish greater FiT-based incentives for solid biomass, large hydro, offshore wind, and solar PV. The analysis includes four different levels of FiTs in terms of the percentage premium above the electricity price to establish a new levelised wholesale FiT-based price available to the technologies listed. The baseline scenario (9) has FiT levels set at 1.1 (meaning that the FiT is 110 percent of the base price). New idiom scenario files named with changes to the code were modified and given new text file names: F1, F2, F3, and F4. The FiTs were set at 1.6, 2.1, 2.6, and 3.1 (to establish price premiums of 60 percent, 110 percent, 160 percent, and 210 percent, respectively). An assessment of carbon emissions associated with above energy pathways of RETs for the four categories of Indian states was performed.
The results are illustrated below.

FCO2: User emissions of carbon dioxide (CO_2), thousand tons carbon (thTC)

High-RET states	Low-RET states	Remote Northeastern states	Union Territories
 Fbase , F1, F2, F3 , F4			
Percent Emissions Change (positive values reflect a reduction)			
5.18%	21.80 %	5.47%	36.55%

Fit1: sum of RTI: 1 Power generation　FIT2: sum of RTI: 1 Power generation
Fit3: sum of RTI: 1 Power generation　Fit4: sum of RTI: 1 Power generation
FITbase: sum of RTI: 1 Power generation　FIT: sum of RTI: 1 Power generation

The above analysis demonstrates that higher FiT rates in high-RET states or remote Northeastern states do not show a significant reduction in CO_2 emissions. However, a similar incentive for low-RET states or Union Territories such as Delhi and Chandigarh led to a fairly large reduction in carbon intensity of 21.8 percent and 36.55 percent, respectively. This analysis is indicative of the role that RET policies for Union Territories or late movers' states can play in GHG reductions for India. This type of analysis becomes critically important with India's ratification of The Paris Agreement, in which India has proactively committed to reductions in the carbon emissions intensity of its GDP of 33-35 percent below 2005 levels by 2030.

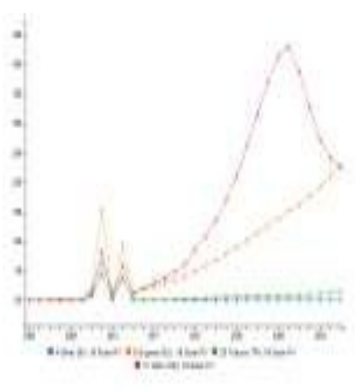
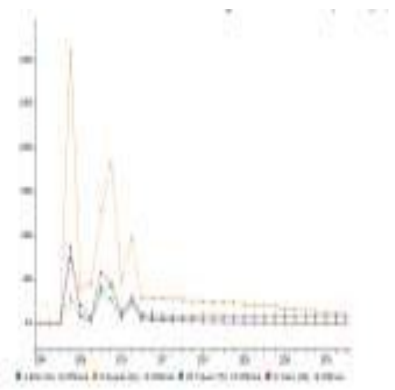
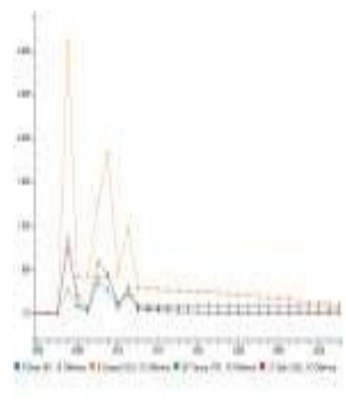
Of course, other dimensions of the impacts, including impacts on electric rates and the economy, should also be considered in such an analysis. Such analysis would allow policymakers to consider the alternative pathways and their respective impacts on carbon reduction, consumers, and the economy.

The E3-India modeling framework provides a closed (self-consistent) framework for evaluating the potential impacts. The third theme helps to demonstrate these capabilities within the E3-India model.

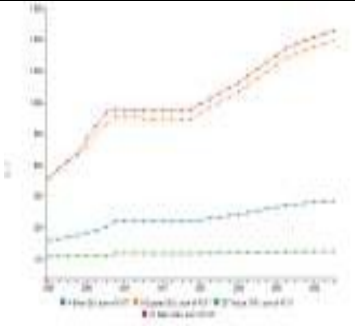
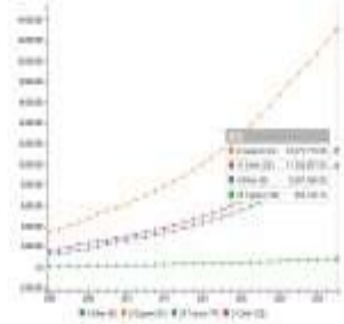
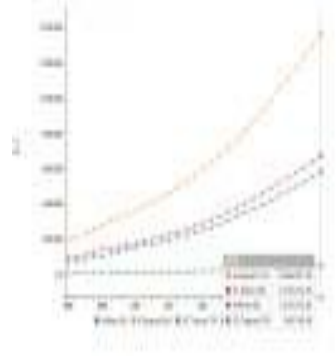
Theme III: Integration of the technology transition scenarios with key economic state-level parameters

This section looks at using the E3-India model for analysing some key state-level parameters, such as power sector investments, consumer spending, and total investments, and ascertaining their impact on key economic outcomes such as changes in GDP. The first set of graphics shows the investment categories and levels that are needed to meet the RET targets in different regions. The second set of graphics shows the impacts of these investments on key economic outputs, including GDP and consumer expenditures.

I) MWIY: Investment in new generation capacity (M2000$) for representative high- and low-RET states, remote Northeastern states, and Union Territories

PV	Onshore wind	Solid biomass
		

II) GDP trends measuring expenditure at market price, regional total consumption expenditure, and regional total investment spending are traced in the figure below for the four categories of states studied.

GDP measure at market price (2005-2035)	**Regional total consumption expenditure (2005-2035)**	**Regional total investment spending (2005-2035)**
		

The trend indicates high investments in earlier years, followed by constant low investments for onshore wind and solid biomass. Investments for solar PV show a greater positive investment trajectory over time. The GDP trends for the four categories of states show higher GDP generation for high-RET states and Union Territories, followed by low-RET states and remote Northeastern states. The regional consumption expenditure and investments increase with time but the trajectory differs among the categories of states, with high-RET states and Union Territories being the leaders.