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Decarbonizing India's Power Sector

Preliminary Synthesis of Project Results from the U.S.-India Model Intercomparison

September 2015

Bo Liu
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U.S. DEPARTMENT OF ENERGY
Prepared for the U.S. Department of Energy
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Richland, Washington 99352

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Under the leadership of the United States Agency for International Development and the National Renewable Energy Laboratory, the Pacific Northwest National Laboratory has been working with partners in India to enhance energy modeling for policy analysis. Energy modeling is one of the three focus areas of the Sustainable Growth Working Group under the bilateral Energy Dialogue between the United States Government (USG) and the Government of India (GOI).

The authors are grateful for research support provided by the United States Agency for International Development, the United States Department of Energy and the National Renewable Energy Laboratory. The authors would like to thank our colleagues Kirit Parikh and Probal Ghosh at the Integrated Research and Action for Development (IRADe), Nihit Goyal and Amit Kanudia at the Center for Study of Science, Technology and Policy (CSTEP), Vaibhav Chaturvedi at the Council on Energy, Environment and Water (CEEW), Paul Friley and Vatsal Bhatt at the Brookhaven National Laboratory (BNL) for providing modeling results for the comparison and figures for visualizing their results. The authors also acknowledge the insights and support from Anil Jain and Rajnath Ram at the National Institution for Transforming India, Aayog (NITI Aayog), relevant ministries of GOI as well as other research institutions in India. The Pacific Northwest National Laboratory is operated for the United States Department of Energy by the Battelle Memorial Institute under contract DE-AC05-76RL01830.

Acronyms and Abbreviations

AgMIP	Agricultural Model Intercomparison and Improvement Project
BNL	Brookhaven National Laboratory
CBO	U.S. Congressional Budget Office
CCS	Carbon Capture and Storage
CDIAC	Carbon Dioxide Information Analysis Center
CEA	Central Electricity Authority of Government of India
CEEW	Council on Energy, Environment and Water
CMIP	Coupled Model Intercomparison Project
CSO	Central Statistical Office of Government of India
CSTEP	Center for Study of Science, Technology and Policy
EDGAR	Emissions Database for Global Atmospheric Research
EIA	U.S. Energy Information Administration
EMF	Energy Modeling Forum
GCAM	Global Change Assessment Model
GeoMIP	Geoengineering Model Intercomparison Project
GOI	Government of India
IEA	International Energy Agency
IESS	India Energy Security Scenarios
IMRT	India Multi-region TIMES Model
INCCA	Indian Network for Climate Change Assessment
IRADe	Integrated Research and Action for Development
NREL	National Renewable Energy Laboratory
PNNL	Pacific Northwest National Laboratory
SGWG	Sustainable Growth Working Group
UN	United Nations
USG	United States Government
WB	World Bank

Contents

Figures

Tables

1.0 Introduction

1.1 U.S.-India model intercomparison

Models are often used to simulate impacts of proposed policies, especially when dealing with complicated systems along with various scenarios. However, models are always associated with two types of uncertainty: model structure and input assumptions (McJeon et al., 2014). Model intercomparison has been a common practice used by the modeling community to deal with such uncertainty. Recent applications include the Coupled Model Intercomparison Project (CMIP), the Energy Modeling Forum (EMF), the Agricultural Model Intercomparison and Improvement Project (AgMIP), the Geoengineering Model Intercomparison Project (GeoMIP), to name a few (Energy Modeling Forum, 2001; Luderer et al., 2012; Meehl et al., 2005; Rosenzweig et al., 2013).

Energy modeling, which is critical to energy policy making and sustainable growth planning, has been identified as a focus area under the Sustainable Growth Working Group (SGWG) of the U.S.-India Energy Dialogue. The Government of India (GOI) and the United States Government (USG) have planned several steps in the near and medium term to enhance India's capacity in energy modeling, beginning with a combined energy data and modeling workshop held in Delhi in April 2014, which brought forth an agreement on the first round of model intercomparison for mutual model enhancement. The goal of the U.S.-India model intercomparison is to pull together multiple teams and multiple, complementary models, to focus on answers to a set of key questions. By bringing together collaborating teams, this project will both provide important insights about the driving policy questions and develop capability to answer similar questions in the future. It will also build the capacity of modeling teams as they share approaches, compare results, and improve data.

Five modeling teams participated in the first round of model intercomparison, including:

- Integrated Research and Action for Development (IRADe)

  IRADe is a research organization in India, providing policy analysis and decision support for sustainable development and effective governance (IRADe, 2015). The IRADe-Activity Analysis (AA) model is a linear programing model using the framework of activity analysis to model the linkages between the national economy and environment (Government of India, 2009).

- Center for Study of Science, Technology and Policy (CSTEP)

CSTEP is a multi-disciplinary research institution with focuses on energy, infrastructure, security studies, materials, climate studies and governance (CSTEP, 2015). CSTEP's India Multi-region TIMES Model (IMRT) is a 5-region TIMES model of the Indian power sector.

- Pacific Northwest National Laboratory (PNNL)

  PNNL is one of the ten national laboratories managed by U.S. Department of Energy's (DOE) Office of Science. PNNL's Global Change Assessment Model (GCAM), an integrated assessment tool for exploring the consequences of climate change and responses to it, is a dynamic-recursive model with technology-rich representations of economic, energy, land-use, water and climate systems (Calvin et al., 2014).

- Council on Energy, Environment and Water (CEEW)

  CEEW is an independent, not-for-profit policy research institution in India, addressing global challenges through an integrated approach (CEEW, 2015). Researchers from CEEW used a customized version of GCAM, GCAM-IIMA (the India Institute of Management, Ahmedabad version), to simulate policy scenarios in the exercise. GCAM-IIMA assumes different GDP and population trajectories and includes a more disaggregated buildings sector, compared to core GCAM (Chaturvedi and Shukla, 2014).

- Brookhaven National Laboratory (BNL)

  BNL is one of the ten national laboratories managed by DOE's Office of Science. The MARKAL family of models, a well-established tool for energy systems analysis, is used by BNL researchers for long-term integrated energy, environmental, and economic analysis (Brookhaven National Laboratory, 2015). The BNL modeling team ran the same scenarios using their ten-region U.S. model, not modeling the model intercomparison scenarios, but rather an illustration of impacts to the U.S. with the same policy explored in the exercise.

Model structure, data sources and input assumptions vary across the five models (Table 1), which provides the context for the model intercomparison.

Table 1 Date sources and input assumptions of participating models

Category \ Model	GCAM	IRADe-AA	IMRT	GCAM-IIMA	MARKAL
Basic characteristics					
Institution	PNNL/JGCRI	IRADe	CSTEP/KANORS	IIMA	BNL
Number of global regions	32	None	None	14	None
Number of India regions	1	1	5	1	10 US regions
Covered sectors	Energy, land use	All production & consumption sectors	Electricity generation, transmission and distribution	Energy, land use	Energy
Model base year	2010	2007	2010	2005	2010
Model time step (years)	5	1	5	5	5
Model of technology choice	Logit choice model	Linear programming	Linear programming	Logit choice model	Bottom-up optimization model
Covered gases	CO_2, CH_4, N_2O, HFC, PFC, SF_6	CO_2	CO_2	CO_2, CH_4, N_2O, HFC, PFC, SF_6	CO_2, CH_4, N_2O, SO_2, $PM_{2.5}$, PM_{10}
Sources of base-year data					
India population	UN	IRADe	IESS	UN	US Census
India GDP	WB & UN	CSO	IESS	GOI	CBO
India primary energy	IEA	CSO	N/A	IEA	EIA
India electricity production	IEA	CSO	CEA	IEA	EIA
India GHG emissions	IEA, EDGAR	INCCA	CEA	IEA, CDIAC	EIA
Expansion and share constraints for key technologies					
Coal-fired power	No constraints	Share constraint on sub critical coal	No constraints	No constraints	Soft growth constraints (allowing progressive capacity builds at a cost premium)
Natural gas fired power	No constraints	Fixed target for 2050	No constraints	No constraints	
Electricity with CCS	No constraints	N/A (no CCS)	N/A (no CCS)	No constraints	
Hydroelectric power	Fixed path	Share constraint	No constraints	Fixed path	
Nuclear	No constraints	Growth constraint	No constraints	No constraints	
Solar	Capacity model	No constraints	No constraints	Capacity model	
Wind	Capacity model	Fixed maximum capacity	No constraints	Capacity model	
Representation of key regional resources					
Solar power supply	Regional supply curves	No Limits	Regional supply curves	Regional supply curves	Regional supply curves
Wind power supply	Regional supply curves	Regional production limits	Regional supply curves	Regional supply curves	Regional supply curves

Category \ Model	**GCAM**	**IRADe-AA**	**IMRT**	**GCAM-IIMA**	**MARKAL**
Bioenergy	Endogenous land competition	Regional production limits	Regional production limits	Endogenous land competition	Regional supply curves
CO_2 storage supplies	Regional supply curves	N/A (no CCS)	N/A (no CCS)	No limits	Regional supply curves
Presence of restrictions on trade					
Bioenergy supply	No constraints	No import or export	No constraints	No constraints	No constraints
Coal supply	No constraints	Maximum import: 30% of total demand	No constraints	No constraints	No constraints
Oil supply	No constraints	Maximum import: 98% of total demand; minimum import: 70% of total demand	No constraints	No constraints	No constraints
Natural gas supply	No constraints	Maximum import: 70% of total demand	No constraints	No constraints	No constraints

Notes regarding acronyms: CBO (U.S. Congressional Budget Office), CDIAC (Carbon Dioxide Information Analysis Center), CEA (Central Electricity Authority of Government of India), CSO (Central Statistical Office of Government of India), EDGAR (Emissions Database for Global Atmospheric Research), EIA (U.S. Energy Information Administration), GOI (Government of India), IEA (International Energy Agency), IESS (India Energy Security Scenarios), INCCA (Indian Network for Climate Change Assessment), UN (United Nations), WB (World Bank).

1.2 Policy scenarios and assumptions on GDP & population

At the April meeting and with follow-up discussions, modeling teams agreed on assessing three scenarios on carbon intensity reduction from the power sector with harmonized GDP and population assumptions (Table 2). The group picked the power sector because of the importance of this sector and since enough detail on the sector is included in each model allowing for intercomparison. Scenarios were structured as different levels of carbon intensity of the power sector by 2050. In particular, the group modeled a reference scenario and three policy scenarios with 10%, 30% and 50% decreases (referred below as Policy10, Policy30 and Policy50) in carbon intensity of power production by 2050, compared to the carbon intensity in 2010. Modeling teams used exponential pathways to construct these scenarios, with an annual decrease of 0.32%, 1.08% and 2.08% in carbon intensity of power production, respectively. In the policy scenarios, the reduction of carbon intensity was assumed to be first applied in 2018, the beginning of India's 13th Five-Year Plan. Some models may not explicitly use GDP as an input, meaning that adjustments to other parameters are required to match the GDP growth path. Models with different input years and time intervals were adjusted with GDP and population assumptions accordingly. Other input variables were not harmonized, which means models may have different assumptions and results regarding electricity demand, electricity technologies, and fuel prices, among other things.

Table 2 India GDP and population assumptions for the model intercomparison

Year	Population	Rural Households	Urban Households	GDP* (INR Cr)	GDP (INR Cr) per Capita
2007	1215947697	157158386	69186965	2,834,838	0.002331382
2012	1215947697	170870522	88647593	4,170,367	0.003429726
2017	1293560156	180524548	96982042	6,416,627	0.004960439
2022	1383591898	190098664	110266233	9,872,775	0.007135612
2027	1453466915	196706924	128540505	14,506,346	0.009980513
2032	1533937578	203582342	144162797	20,345,901	0.013263839
2037	1592149419	207261899	164673805	28,536,178	0.017923053
2042	1659579085	211390987	181948247	38,187,844	0.02301056
2047	1704172882	210603785	205571182	51,103,949	0.029987538
2052	1758022799	219761055	234312052	65,223,028	0.037100217

Note: *GDP has been calculated at factor cost at 1999-00 Prices and provisional value for 2011-12 has been taken from the Economic Survey. *Data Source:* NITI Aayog.

2.0 Key Results from Individual Models

2.1 AA/IRADe[1]

IRADe provided modeling results for the Policy30 and Policy50 scenarios. The analysis was based on the comparison between the two policy scenarios. With a more strict target (i.e. 50% reduction in carbon intensity), renewables, especially solar and hydro, tend to play a more important role in electricity generation (Figure 1 and Figure 2). The use of coal would decrease, but coal would still be the largest source for electricity generation in 2050. Compared to the Policy30 scenario, the capacity of solar energy under the Policy50 scenario would increase by 149% to 1324 GW in 2050 and it would be even higher than coal (Figure 2). In addition, the capacity of hydro in 2050 under the Policy50 scenario would be 2.6 times as much as it would be under the Policy30 scenario.

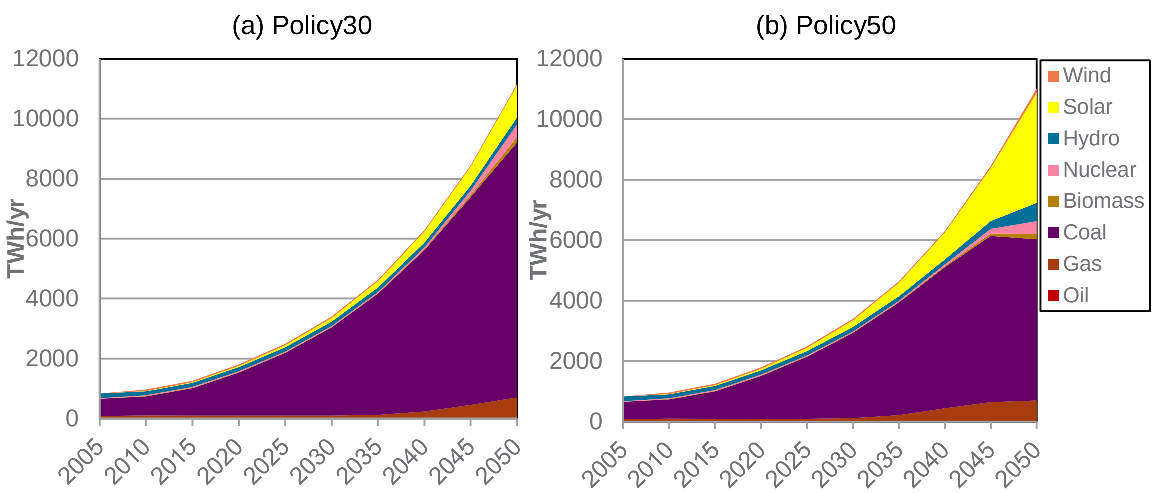

Figure 1 AA projections on annual electricity generation by fuel types under the Policy30 scenario (a) and the Policy50 scenario (b)

With the additional 20% more of reduction in carbon intensity in the power sector, there would only be a small decrease of 1.3% in overall electricity consumption in 2050 (Figure 3), including a decrease of 4.7% in the industrial sector, an increase of 0.2% in residential and commercial buildings, an increase of 0.4% in the transport sector, and a decrease of 0.2% in other sectors.

Emissions from the power sector in 2050 under the Policy50 scenario were projected to decrease by 35%, compared to the Policy30 scenario (Figure 4). However, there would be only 16 % less overall emissions across all sectors in 2050 under the Policy50 scenario, compared to the Policy30 scenario.

[1] Data were provided by IRADe and the actual analysis was done by PNNL.

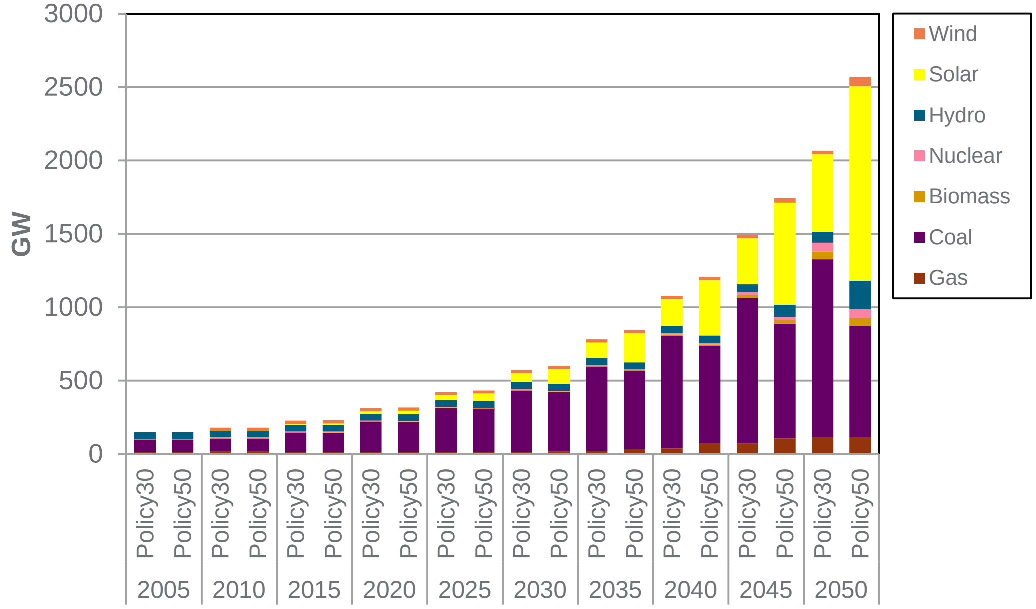

Figure 2 AA projections on installed capacity of electricity generation by fuel type under each policy scenario

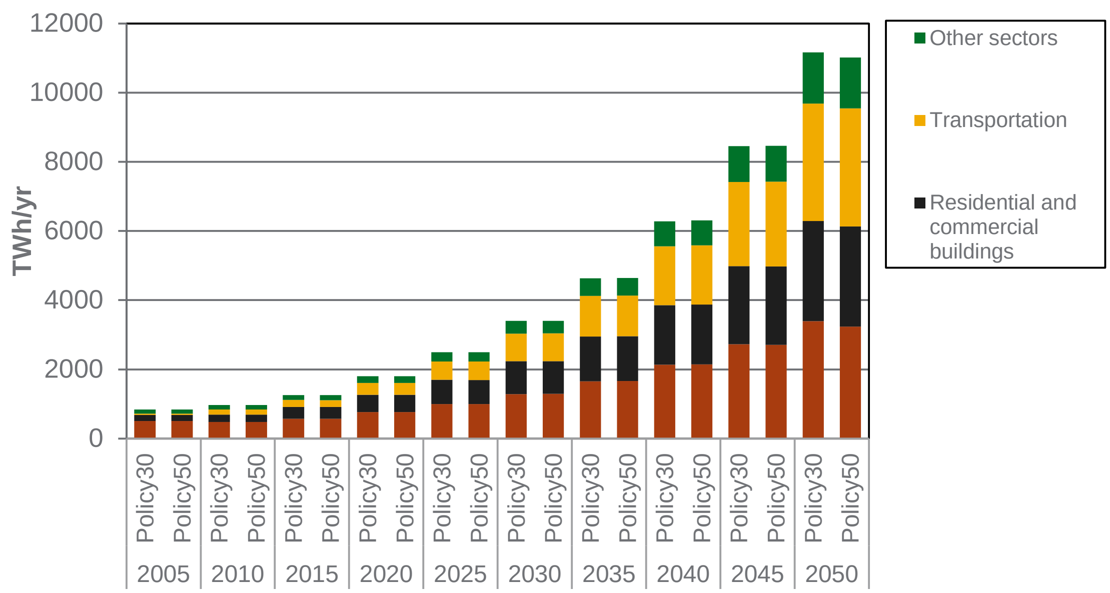

Figure 3 AA projections on annual electricity consumption by end-use sector under each policy scenario

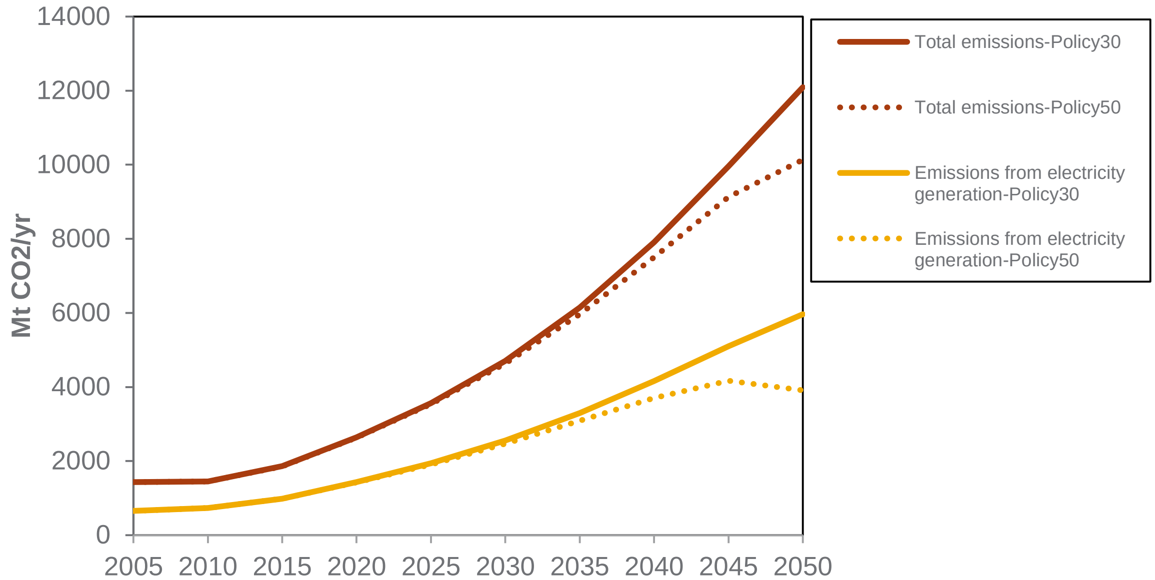

Figure 4 AA projections on total emissions and emissions from electricity generation under each policy scenario

2.2 IMRT/CSTEP

The reference scenario in IMRT already included a targeted reduction of 17.2% in the carbon intensity of the power sector, so only two policy scenarios (i.e. Policy30 and Policy50) were analyzed to compare to the reference scenario. Results from IMRT indicated that the total amount of electricity generation in 2050 would not differ among the three scenarios (Figure 5). However, more reduction in carbon intensity would end up with more electricity generation from gas and renewables, but less electricity generation from coal. As compared to the IRADe-AA model, wind and gas were projected by IMRT to have a more important role than solar resources in electricity generation of 2050 (Figure 6). Results from IMRT also suggested that targeted reduction of carbon intensity in the power sector would bring about 12% reduction in actual carbon emissions under the Policy30 scenario and 36% reduction in actual carbon emissions under the Policy50 scenario (Figure 7).

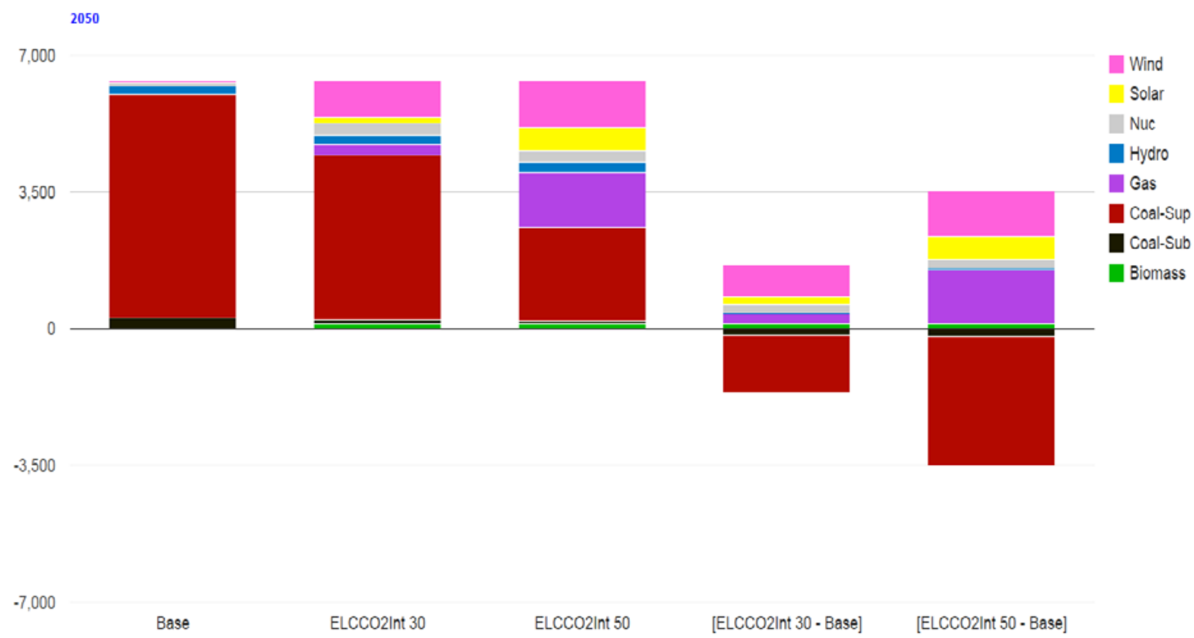

Figure 5 IMRT projections on electricity generation (TWh) in 2050 (Kanudia and Goyal, 2014)

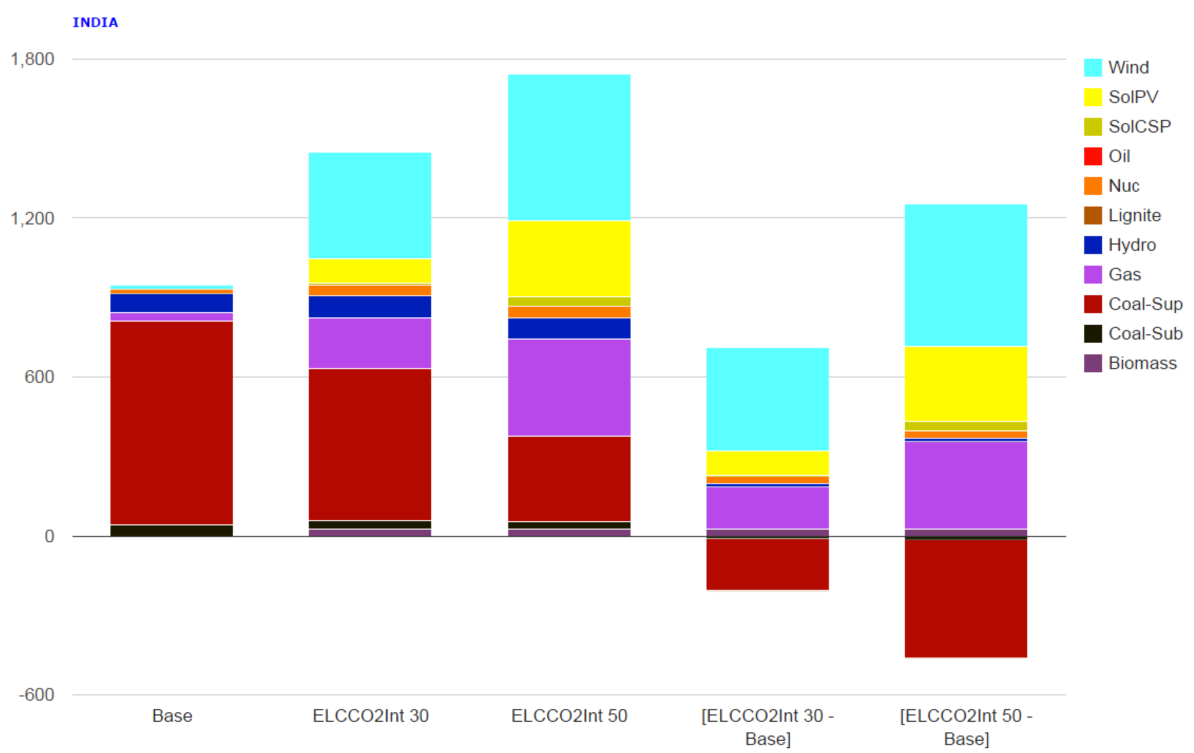

Figure 6 IMRT projections on installed capacity (GW) in 2050 (Kanudia and Goyal, 2014)

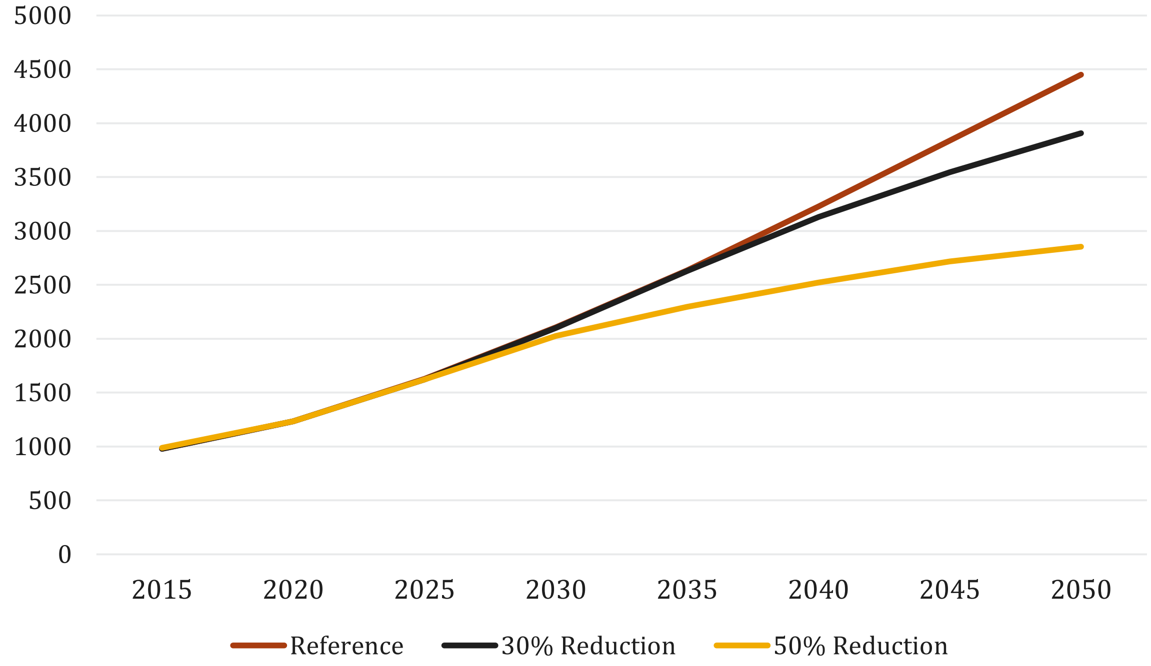

Figure 7 IMRT projections on emissions ($MtCO_2$/year) from electricity generation (Kanudia and Goyal, 2014)

2.3 GCAM/PNNL

The reference scenario in GCAM recognizes a reduction of 38% in the carbon intensity of the power sector in India, so only the Policy50 scenario was considered as an option for the analysis. To achieve the policy target, GCAM modelers set a CO_2 emissions cap which forced the use of lower emitting and more expensive technologies in the power sector (Figure 8). This resulted in the increase in electricity price. Electricity prices were projected to decline by 10% by 2050 in the reference scenario while prices were projected to increase sharply in the policy scenario and could be as high as 30% more than the electricity price in 2010 (Figure 9). Higher electricity prices would cause a decrease of 24% in electricity demands especially in the industrial sector and the buildings sector (Figure 10) and encourage the substitution to other energy technologies. Taking the industrial sector as an example (Figure 11), electricity demand was projected to decrease by 29% in 2050 while demand for non-electricity energy would increase. Similar patterns were found in the projections for the buildings sector and the transport sector. In the transportation sector, increase in demand for refined liquids and gas was projected to be 10 times greater than the decrease in electricity demand.

In 2050, emissions from the power sector under the policy scenario were projected to be 40% less than the reference scenario and the actual difference was projected to be about 700 metric tons of carbon (Figure 12). Total emissions in 2050 were projected to decrease by 16% and about 500 metric tons of carbon. Some of the emissions reductions are offset by substitution to other non-electricity energy sources. The policy could only decrease total emissions intensity (as total emissions divided by total primary energy) in 2050 by 10% comparing to 2010.

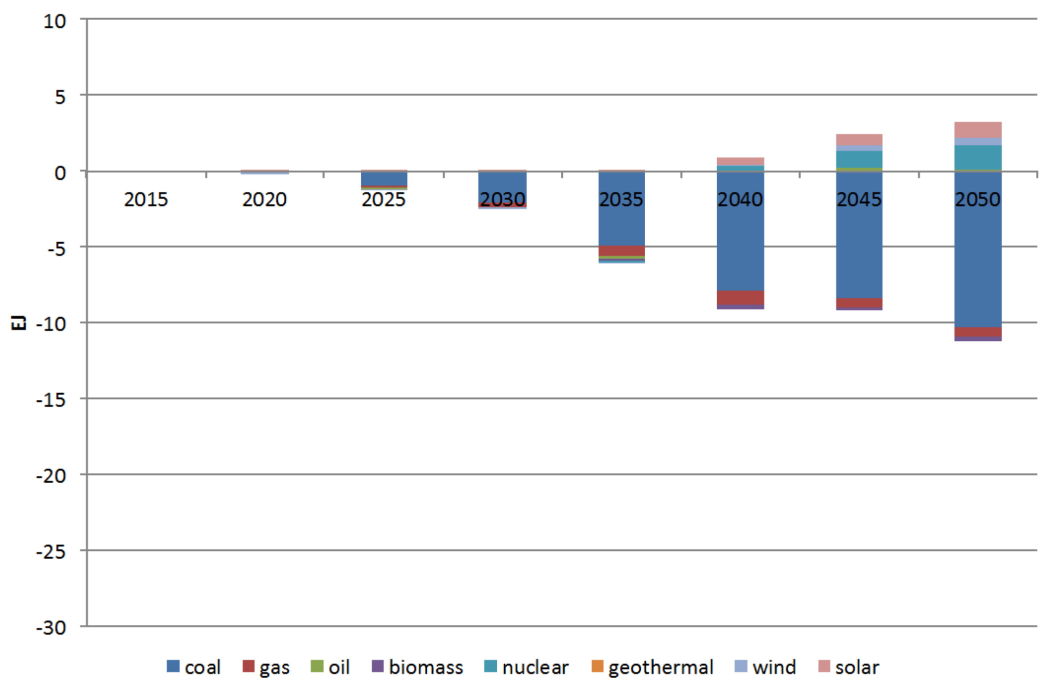

Figure 8 GCAM projections on changes in electricity generation by fuel type under the Policy50 scenario, comparing to the reference scenario (Waldhoff and Kyle, 2014)

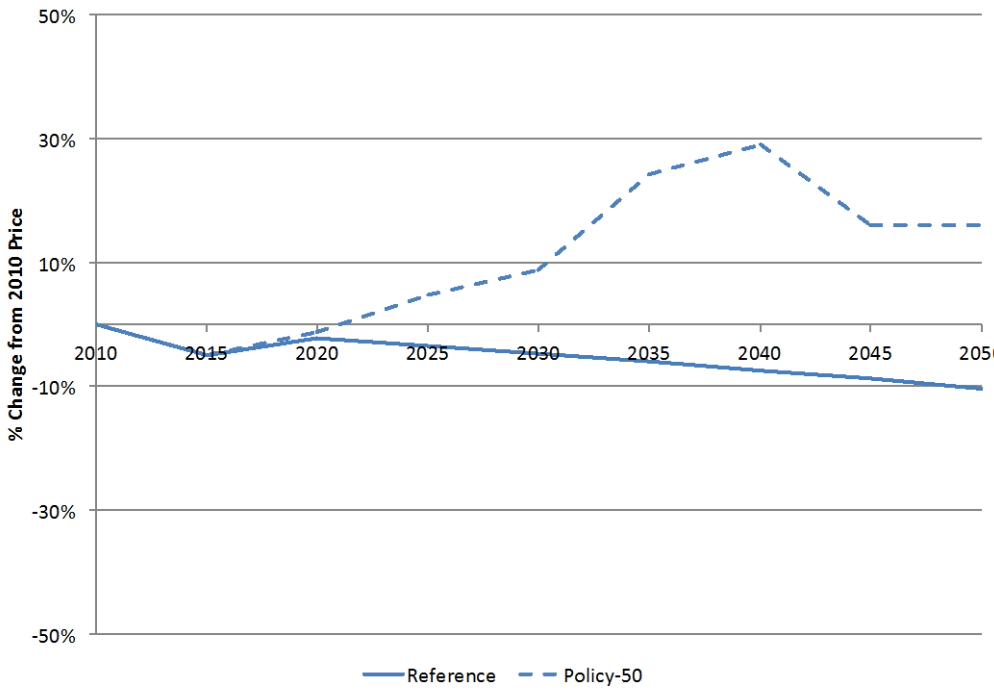

Figure 9 GCAM projections on electricity prices under the reference scenario and the Policy50 scenario (Waldhoff and Kyle, 2014)

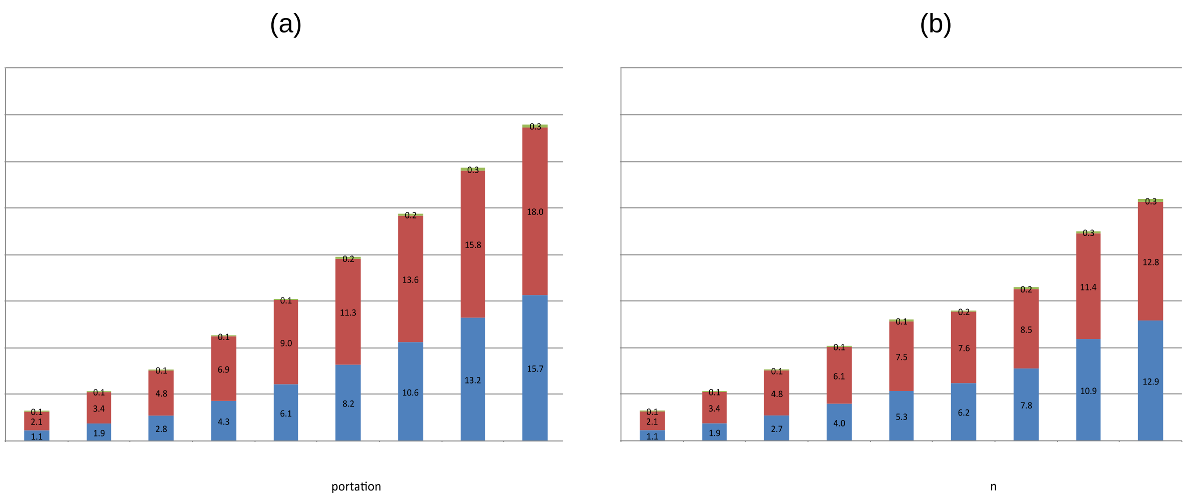

Figure 10 GCAM projections on electricity demand under the reference scenario (a) and the Policy50 scenario (b) (Waldhoff and Kyle, 2014)

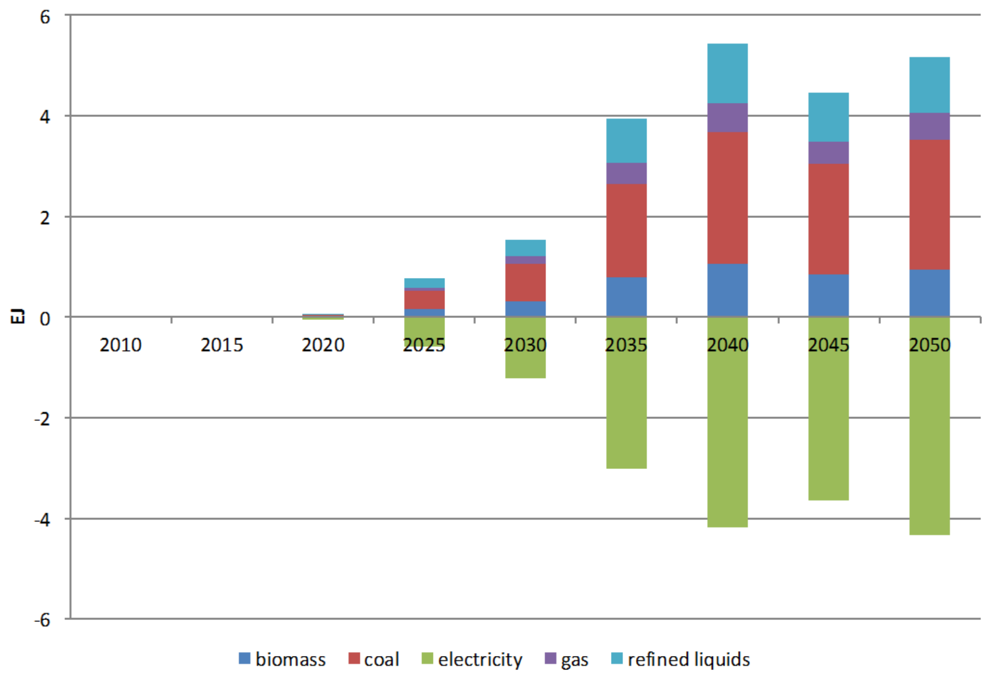

Figure 11 GCAM projections on changes in industrial energy demand by fuel type under the Policy50 scenario, comparing to the reference scenario (Waldhoff and Kyle, 2014)

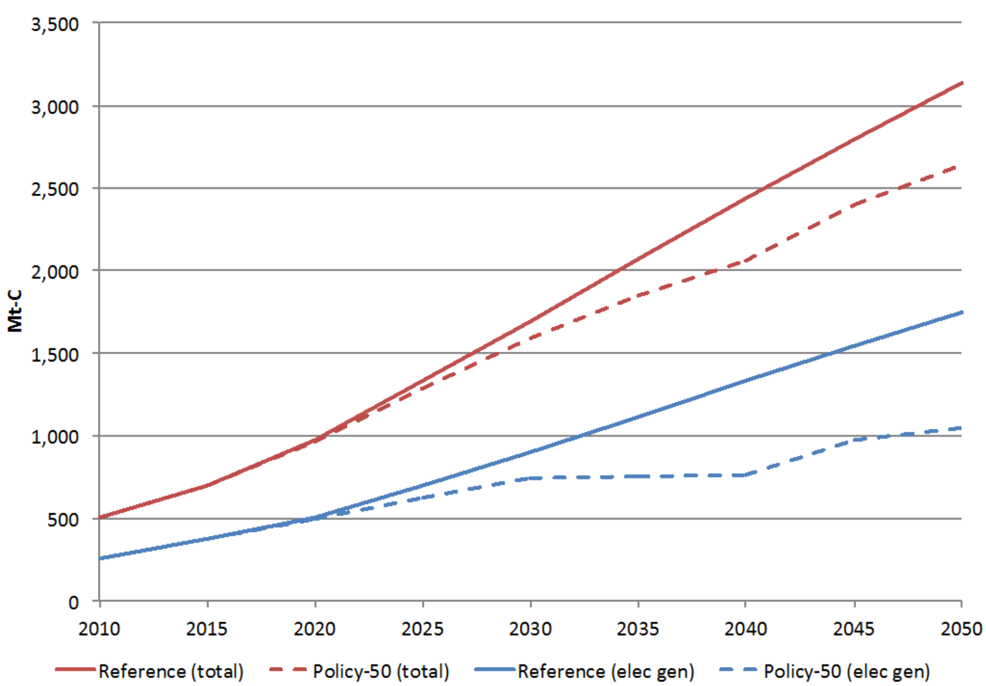

Figure 12 GCAM projections on total emissions and emissions from electricity generation under the reference scenario and the Policy50 scenario (Waldhoff and Kyle, 2014)

2.4 GCAM-IIMA/CEEW

The reference scenario in GCAM-IIMA already assumed a decrease of 35.4% in the carbon intensity of the power sector, so only the Policy50 scenario was analyzed and compared to the reference scenario. GCAM-IIMA results showed that electricity generation from coal would account for about half of the overall electricity generation in 2050 without any new policy being implemented, but the share of coal would decrease to less than one third with the carbon policy considered (Figure 14). Comparing to other models, GCAM-IIMA also projected similar patterns for renewables: increased shares in electricity generation. Electricity generation was projected to decline, but the installed capacity in 2050 would be almost the same (Figure 15).

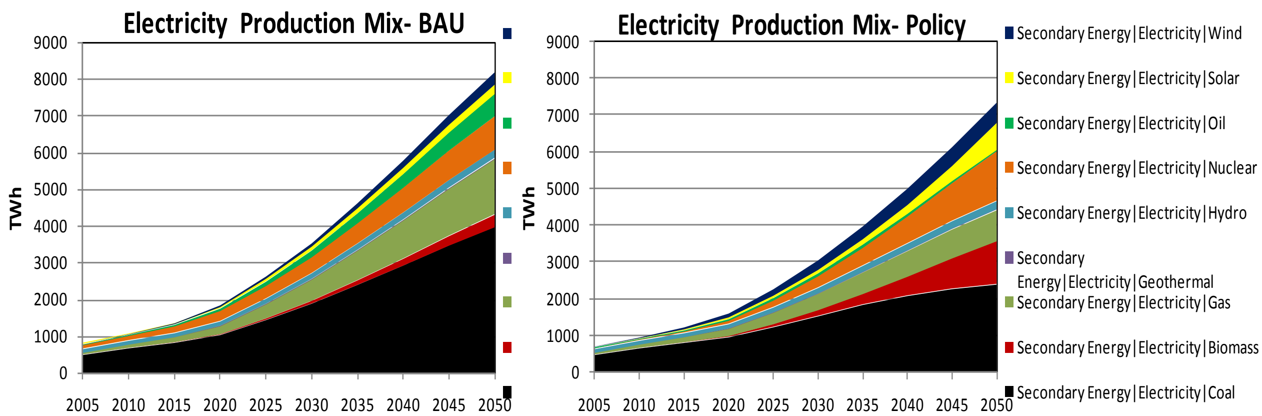

Figure 13 GCAM-IIMA projections on annual electricity generation by fuel types under the reference scenario (BAU) and the Policy50 scenario (Chaturvedi, 2014)

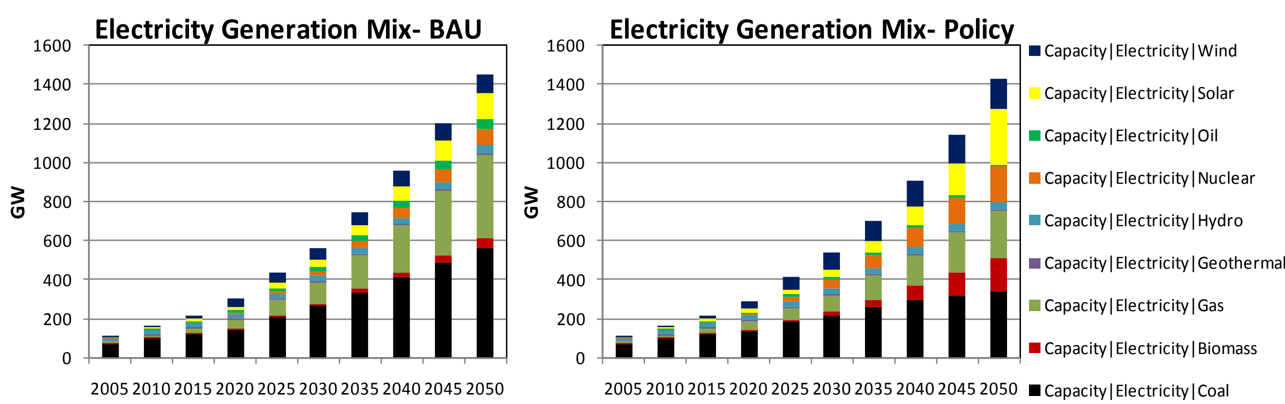

Figure 14 GCAM-IIMA projections on installed capacity of electricity generation by fuel type under the reference scenario (BAU) and the Policy50 scenario (Chaturvedi, 2014)

Emissions from electricity generation were projected to decline by 23.9% in 2050 (Figure 15). However, there would really be no impact on emissions from other sectors. Contrary to the projections by GCAM, electricity price was projected by GCAM-IIMA to increase by 36.6% in 2050 under the reference scenario and decrease by 12.3% in 2050 under the policy scenario, comparing to the electricity price in 2010 (Figure 16). The electricity price under the policy would decline because the carbon tax/subsidy component was not included in the electricity price. If the tax/subsidy was passed through, the electricity price would be higher compared to the reference scenario, which is consistent with the GCAM projections.

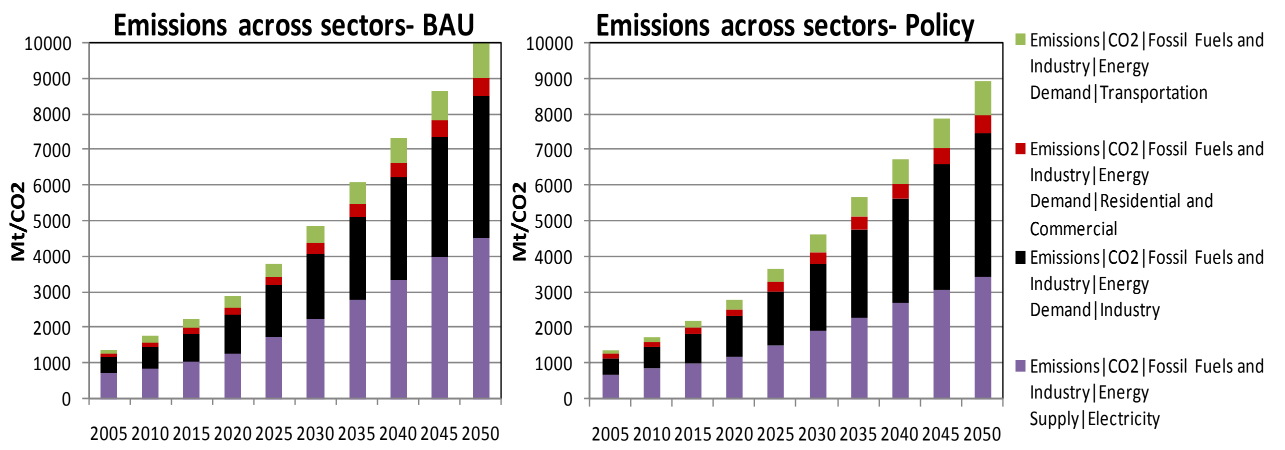

Figure 15 GCAM-IIMA projections on emissions across sectors under the reference scenario (BAU) and the Policy50 scenario (Chaturvedi, 2014)

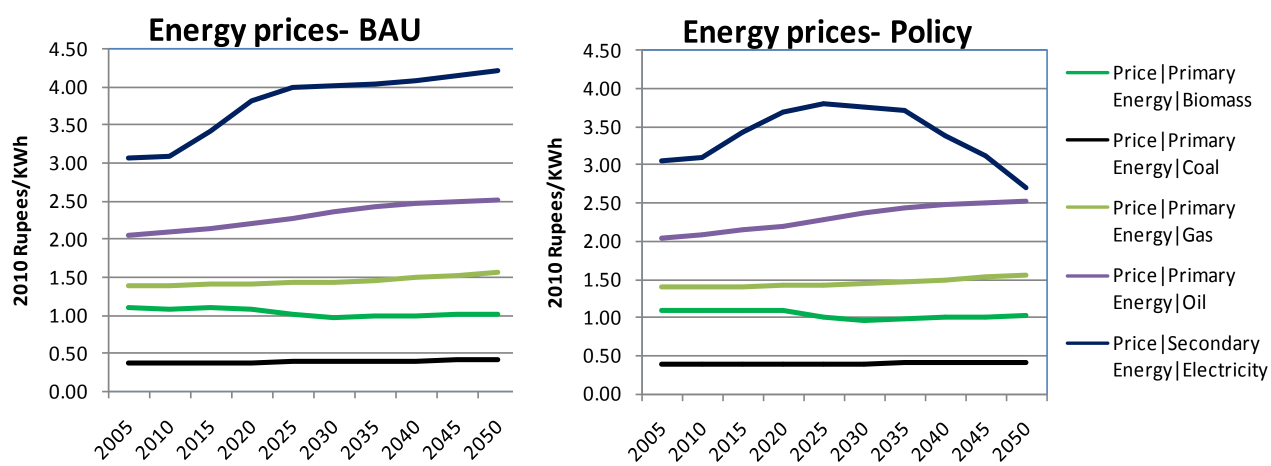

Figure 16 GCAM-IIMA projections on energy prices under the reference scenario (BAU) and the Policy50 scenario (Chaturvedi, 2014)

2.5. MARKAL/BNL

Results from the MARKAL analysis revealed that policies restricting emissions from the power sector have similar impacts in the U.S. in terms of fuel switching and reduction in electricity generation (Figure 17). Such similar patterns can be briefly described as: 1) the policy would cause fuel switching to lower-emission sources such as gas, solar, wind and nuclear, and the electricity price would increase; 2) demand and production for electricity would decline; 3) emissions from electricity generation would dramatically decline.

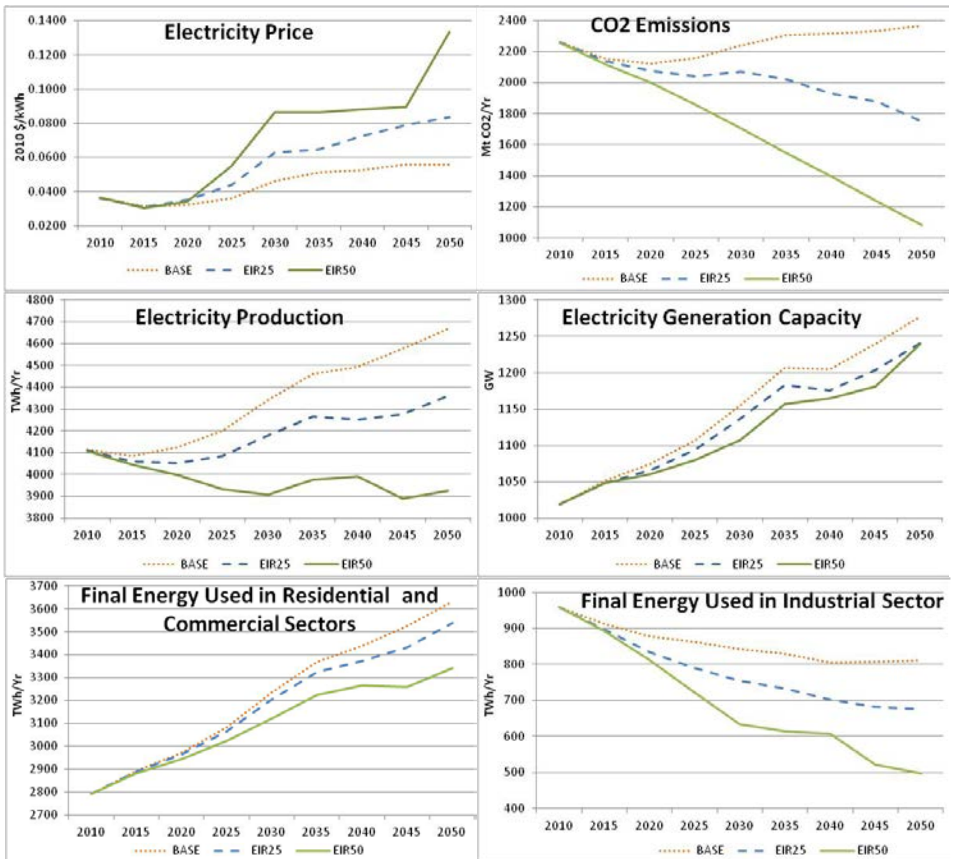

Figure 17 MARKAL projections for the U.S. under the reference scenario, the Policy25 scenario and the Policy50 scenario (Bhatt, 2014)

3.0 Key Results and Policy Implications from the Model Intercomparison

3.1 Carbon intensity

Base-year carbon intensity of power production across models ranged from 0.76 to 0.98 Mt CO_2 per TWh of electricity produced (Figure 18a). Differences in base-year data can be common, and the variation can be caused by different methodologies for region aggregation, various ways of adjustment to the time-value of economic output, and different sources for historical data among models (Chaturvedi et al., 2012). Base-year differences need to be reconciled in future exercises to reduce uncertainty, and this is because values would not match even if a standardized methodology was used by modelers to deal with base-year data from various sources. Irrespective of the base-year differences, most models projected reduced carbon intensity without any explicit long-term climate policy (Figure 18b).

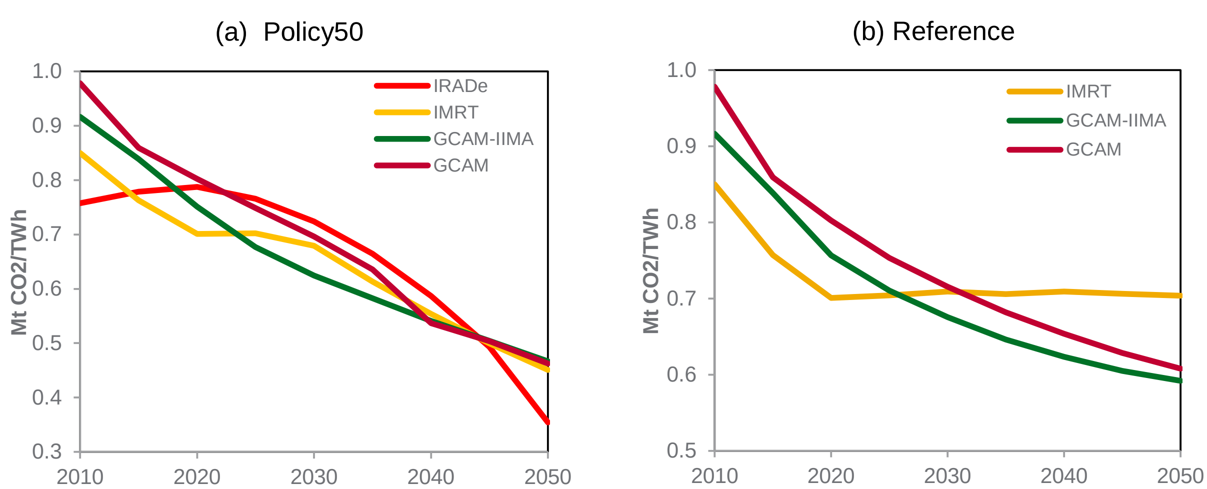

Figure 18 Carbon intensity of power production in India under the Policy50 scenario (a) and under the reference scenario (b)

3.2 Electricity generation and emissions reduction

Projected electricity generation varied across models (Figure 19a). This is due to various assumptions about electrification in each model, for instance, GCAM includes substantial electrification in the buildings sector, as well as transportation. However, regardless of the total amount, all models projected that electricity generation would decarbonize by increasing the efficiency of coal-fired generation, incorporating additional gas-fired generation, and increasing the use of low-carbon energy technologies such as renewables, nuclear, and fossil energy with CCS (Figure 19b). Technologies selected by models varied, which was brought about by various constraints that each type of technology was given in different models. For example, in the IRADe-AA model, the maximum wind capacity was constrained while no constraints were put on solar energy, and this resulted in a dramatic increase of solar energy in 2050 under the policy scenario. Institutional variances in treating nuclear would also be a source of differences in various modeling projections.

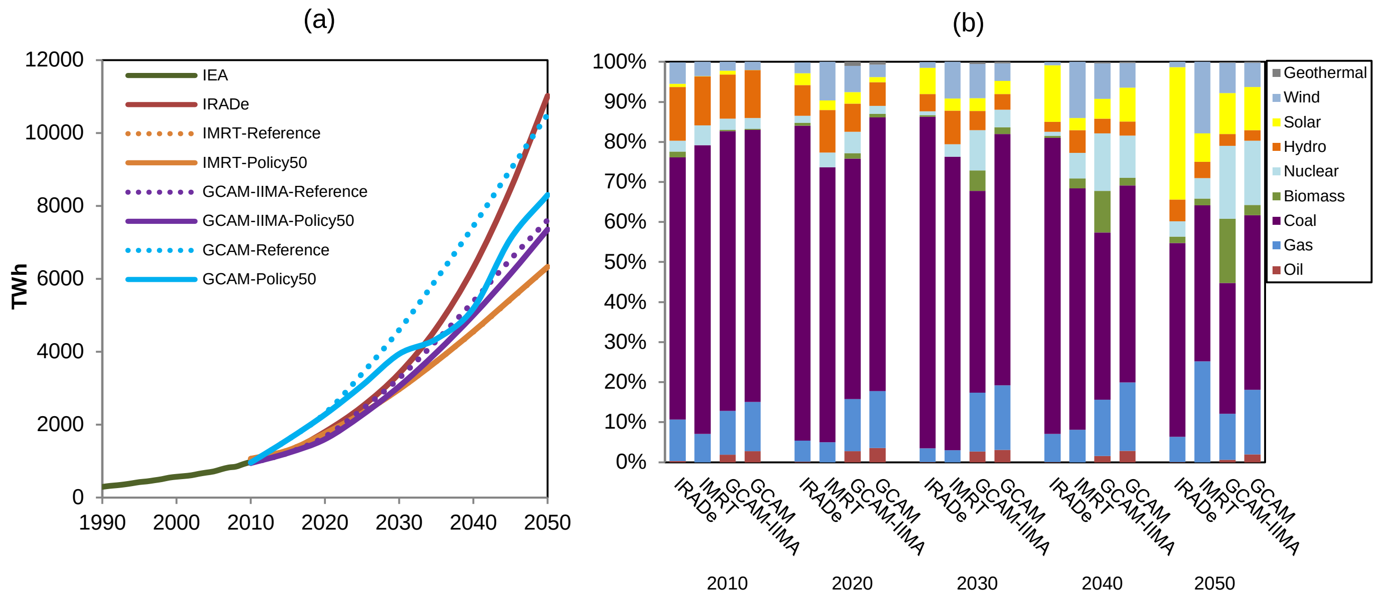

Figure 19 Historical and projected electricity generation (a) and share of electricity generation by fuel type under the Policy50 scenario (b)

In addition, models coincidently projected that although emissions from the power sector would decrease when the carbon policy was considered, the policy would not be effective in overall emissions reduction. Higher electricity price could reduce demands in electricity, cutting emissions in the power sector. However, the policy only focuses on the power sector and would encourage fuel switching to cheaper primary energy sources like gas for end use. It would also have adverse impact on the electrification of the transport sector. Results indicated that carbon policy targeting the power sector alone is more costly than the economy-wide carbon policy.

3.3 Variation in input parameters: an example of GDP

Past studies have found important differences in base-year GDP numbers based on the way that exchange rates are applied (Chaturvedi et al., 2012). For example, there are two alternative methods for converting GDP in 2005 local prices to GDP in 2010 USD prices (Figure 20). One can use the annual average exchange rate in 2005 and then inflating to 2010 prices using the GDP deflator for USD between 2005 and 2010. Alternatively, one can inflate GDP first using the local currency deflator between 2005 and 2010 and then apply the annual average exchange rate for 2010 USD. However, results obtained from the two methods may vary a lot (Figure 20).

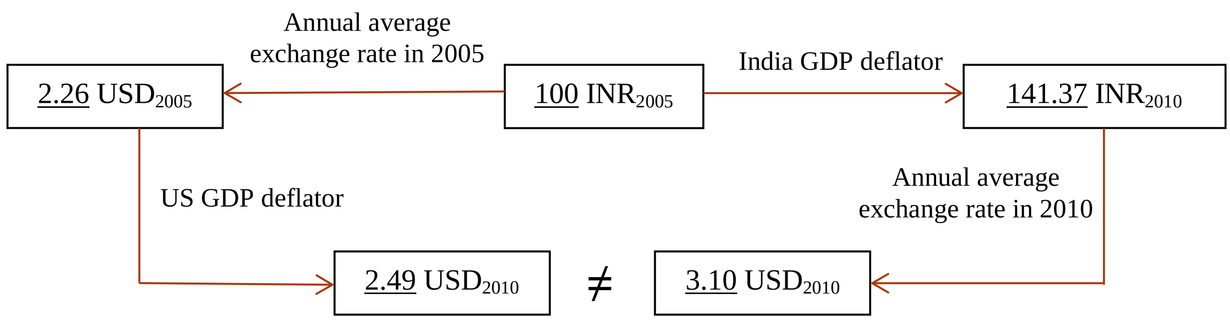

Figure 20 An example of converting 100 2005 INR to 2010 USD using both methods

In this model intercomparison exercise, IRADe used their own GDP assumptions and other teams used projections provided by NITI Aayog. However, these projections differed from what has been used in the core version of GCAM. As explained above, the differences may come from the conversion method used for currency exchange. In addition, historical GDP, especially the base-year GDP, and future growth rates may vary across different sources. In GCAM, it is the rate of future growth that really matters for the scale of the energy system.

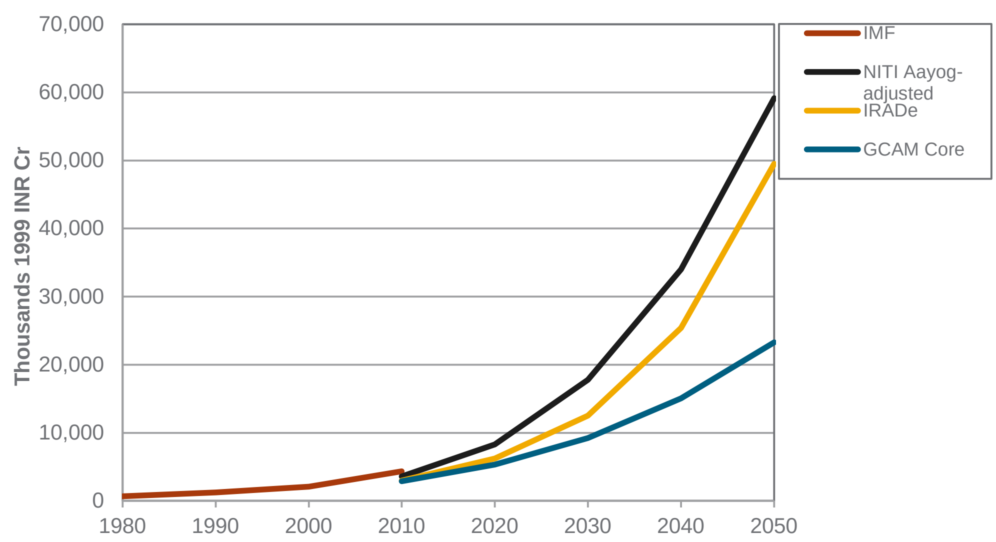

Figure 21 GDP trajectories from various sources

4.0 Key Insights and Recommendations for Next Steps

Although GDP and population assumptions were harmonized in this round of model intercomparison, some key model inputs like the base-year data and the representation of current policies differ in these models. Some key insights from this round of model intercomparison can be summarized as:

- All models project reduced carbon intensity without any explicit long-term climate policy, and irrespective of base-year differences.
- Models decarbonize by increasing the efficiency of coal-fired generation, additional gas-fired generation, and increased low-carbon energy such as renewables, nuclear, and fossil energy with CCS.
- The increase in electricity prices can potentially reduce electricity demands and cause fuel switching to cheaper primary energy sources, which would cut total emissions reductions and be more costly than economy-wide carbon policy.
- Past studies have found important differences in base-year GDP numbers based on the way that exchange rates are applied. However, it is the rate of future growth that matters for the scale of the energy system.
- Base-year differences can be common, but need to be reconciled.

From this round of model intercomparison, we have made great strides in establishing an infrastructure for collaboration and analysis. There has already been learning in this process and decision-relevant insights. This will lay a good foundation for future collaboration on model intercomparison between modelers from both countries. Looking forward, some potential topics for future modeling exercises include:

- Examining the role of renewable energy in the low-carbon growth;
- Expanding the model intercomparison to other sectors such as end-use sectors;
- Comparing and harmonizing base-year data and assumptions;
- Air quality and transportation: reducing diesel subsidies, or assuming a lower emissions factor from vehicle fleet because of regulation ;
- 100 GW solar PV: required subsidies linked to possible achievement dates;
- Energy-water nexus: extent to which policies to promote certain energy technologies may stress water resources.

Future areas of collaboration should be clearly linked to stakeholders' priorities. Topics for next rounds of model intercomparison should be decided by NITI Aayog and relevant stakeholders (e.g. line ministries of the Government of India and participating teams). As an important component for model intercomparison, collection of comparable background information from each modeling team is required as a basis for future activities.

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