THE IRADe ACTIVITY ANALYSIS MODEL AND ITS CONTRIBUTIONS TO LOW-CARBON GROWTH PLANNING IN INDIA

Integrated Research and Action for Development
IRADe
Centre of Excellence (CoE)
Climate Change and Urban Development

ASIA LEDS PARTNERSHIP

MANY COUNTRIES IN THE ASIA-PACIFIC REGION have greenhouse gas (GHG) mitigation policies and initiatives to help address the causes of climate change and achieve sustainable development. The Government of India, in order to maintain its commitment to reducing poverty while at the same time being responsible stewards of the environment, pledged in its Intended Nationally Determined Contribution (INDC) to the United Nations to source 40% of its electricity from renewable and other low-carbon sources by 2030, and to reduce GHG emission intensity by 33-35% by 2030 compared to 2005, among other measures.

It is estimated that India will require major changes to its energy mix to lower carbon intensity per unit of GDP. The Planning Commission of the Government of India said in its *Final Report of the Expert Group on Low Carbon Strategies for Inclusive Growth*[1] that a low carbon growth strategy is "essential" for the country, and the Government of India has developed a series of climate-friendly development plans and polices.

In planning for a low-carbon economy, planners must explore and understand the full spectrum of low-carbon opportunities. Alternate development pathways require different policy and technology measures that have varying costs and benefits, and it is critical to identify the most cost-effective and locally appropriate policies and actions to achieve social, environmental and economic goals.

Several modeling tools have been developed to assist governments, researchers, and other stakeholders with this task. These include the 2050 Calculator, Energy Forecasting Framework and Emissions Consensus Tool (EFFECT), Long-range Energy Planning Alternatives (LEAP) tool, and Models for Energy Supply Strategy Alternatives and their General Environmental Impact (MESSAGE), among others. Some have been specifically developed for countries in Asia, such as the Asia-Pacific Integrated Model (AIM).This case study shows how one unique tool, the IRADe activity analysis model, has been used to assist with planning for low-carbon, climate-resilient growth in India.

WHAT ARE MODELS AND WHY USE THEM?

Models are tools that use mathematical methods to simulate interactions between numerous factors, such as the environment and the economy, and thus enable assessment of trends. Some models allow estimates of the impacts from different policy and technology options on economic growth, GHG emissions, and other social and economic indicators, and allow modelers to draw conclusions about possible strategies to overcome limitations and strengthen linkages.

At the same time, there are constraints inherent in modeling, and careful modelers are aware of the sensitivity of modeling results to various assumptions. While models help in understanding what may happen if certain actions are taken or not taken, the results are not forecasts but rather projections or scenarios based on underlying assumptions, some of which may involve uncertainties. These may be about oil prices, resource availability, or the price and availability of different technologies. To consider these uncertainties, modelers run many scenarios using different values of the uncertain variables. This process, called sensitivity analysis, is necessary to arrive at sound policy conclusions.

1 In January 2010, the Prime Minister of India constituted a 26-member Expert Group on Low Carbon Strategies for Inclusive Growth (LCSIG) to help develop a low-carbon growth strategy for India. The group included government, industry, academia, and civil society members. The group's final eport is available at http://www.scribd.com/doc/225451533/India-Climate-Policies.

THE IRADE ACTIVITY ANALYSIS MODEL

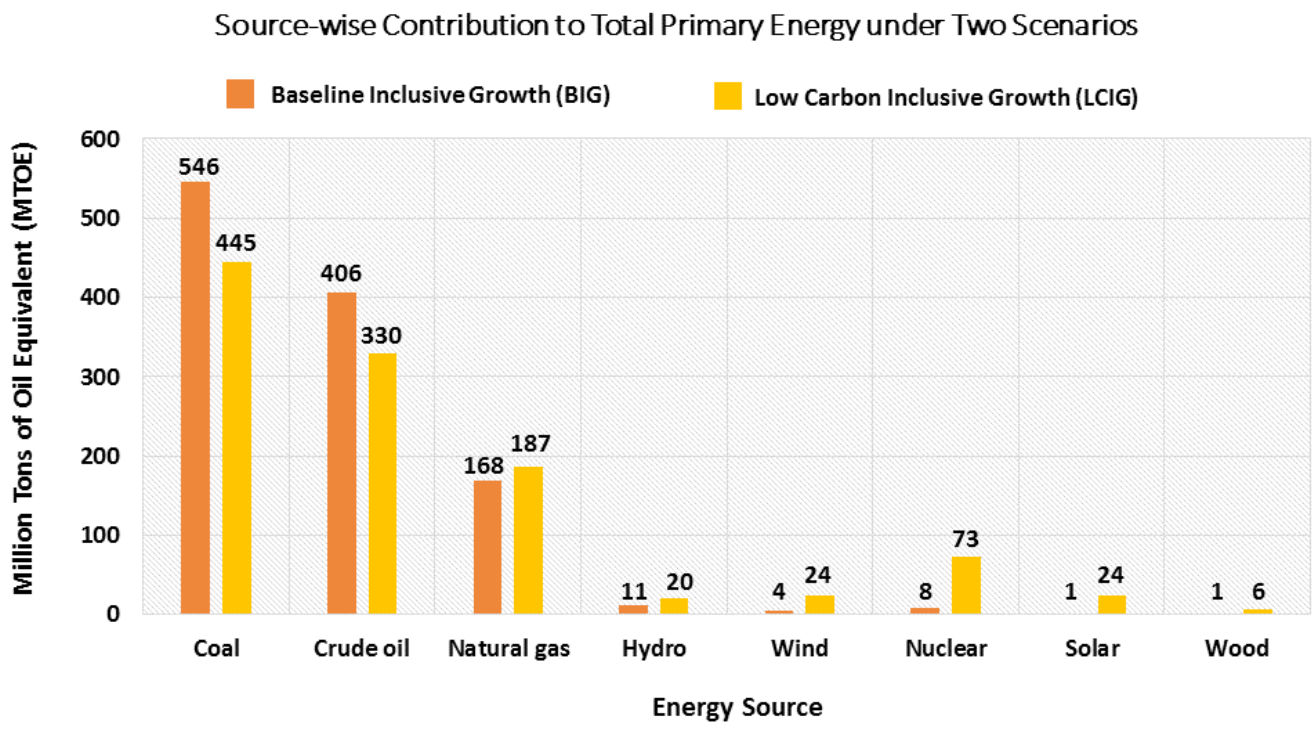
Objectives of Model Development

The Integrated Research for Action and Development (IRADe), an institute based in New Delhi, India, has developed a unique modeling tool to examine the impacts of various climate change and CO_2 emissions mitigation policies on India's economic development, in particular the implications of these policies for the poor. The IRADe activity analysis model was first developed during 2006-2009 in support of the Ministry of Environment and Forests' analysis of climate policy options up to 2030, with subsequent enhancements to better respond to emerging policy questions.

The process of model development included a series of meetings and stakeholder consultations organized by IRADe where model design, assumptions, and interim analysis results from model simulations were presented to a national-level committee of administrators, NGO representatives, and technical experts from various ministries. The stakeholders contributed input to improve the model's relevance to the economic and policy context – such as the suggestions to provide more realistic assumptions and to tailor outputs to more directly answer questions faced by decision makers.

New versions of the model are now capable of carrying out analysis of many types of policy and technology changes in an economy-wide context. For example, it has been adapted to help policymakers develop strategies for national low-carbon pathways and to assess economic growth scenarios based on different mixes of energy sources. The results have helped policy makers to understand the implications of various scenarios for GHG emissions, economic growth, food security, and other priority issues.

FIGURE 1: PROJECTED ENERGY MIX BY 2030 IN INDIA'S LOW CARBON INCLUSIVE GROWTH SCENARIO VERSUS A BASELINE SCENARIO, AS MODELED BY THE IRADE ACTIVITY ANALYSIS TOOL

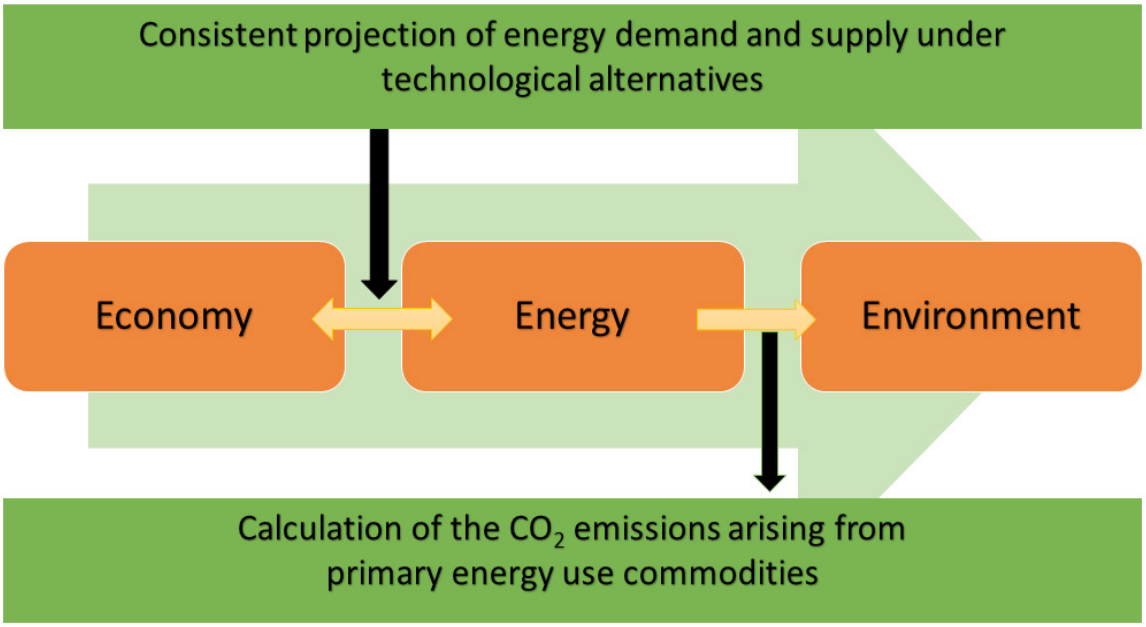


BRIEF DESCRIPTION OF THE MODEL

THE IRADE ACTIVITY ANALYSIS TOOL MODELS LINKAGES between energy use and the economy, the wellbeing of different socio-economic groups, and the environment, with a particular focus on impacts from production and consumption "activities" on CO_2 emissions and poverty. It analyzes the resources available to the economy over a long period of time and the various technological possibilities for using them to help identify the best alternative approaches to maximize private consumption and mitigate GHG emissions.

The model covers the entire economy and incorporates data from multiple economic sectors (including transport, power generation, industry, agriculture and services), while ensuring intersectoral consistency (i.e., ensuring that projections are consistent with the production of goods and services and the expected growth of other sectors in addition to energy). The model optimizes dynamically over a long time horizon, meaning resources are allocated and technologies are chosen taking anticipated future needs and priorities into account.

FIGURE 2: OVERVIEW OF IRADE'S ACTIVITY ANALYSIS MODEL



The modeling describes the relationships between past, present and future conditions and accounts for the behavioral responses of economic agents (such as consumers and producers) to changes in policy at a selected time point and also over time. This permits analysis of existing and/or alternative technologies in different sectors projected into the future in order to provide a comprehensive profile of expected GHG emissions and possible policies to help in reduction of GHG emissions and emission intensity, in keeping with stated objectives or voluntary pledges.

In principle, each version of the model can be used to construct scenarios up to a target year – such as 2030 or 2050 – keeping in view resource availability, intersectoral consistency, technological potentials and the importance of sectoral productivity, while also ensuring that selected pathways achieve social and environmental indicator targets. (For a more detailed explanation of the model, see Annex 1)

KEY QUESTIONS ANSWERED BY THE MODEL

To date IRADe has used the activity analysis model to respond to a wide variety of questions and requests for inputs to policymaking in India. Examples of typical questions that the IRADe tool has been used to address include:

- What might be the GHG profile of India in 2030 or 2050?
- What are the costs to the economy to undertake a low-carbon pathway?
- What would be the energy transition required for India up to 2050 under different considerations of climate change and energy security?
- What would be the welfare implications of a GHG mitigation strategy (e.g., impacts on poverty)?
- What would be the impact of a technological change, higher energy efficiency and/or falling costs of renewable technologies?

SCENARIOS THAT CAN BE RUN USING THE LATEST IRADE MODEL WITH SOME EXTENSIONS

- GDP projections including sectoral outputs, investment, commodity consumption and sector GHG emissions up to 2050.
- A carbon-constrained, low-carbon scenario.
- A carbon tax and carbon trade scenario.
- A scenario to achieve reduction in GHG emission growth while achieving human development indicator targets.
- Interventions in the power, transport and household appliances sectors.
- Rural to urban migration and the impacts of urbanization.
- Impacts of current government targets in schemes such as the Jawaharlal Nehru solar mission NAPCC targets, nuclear plans, etc.
- Trade-offs between food security and energy needs in the case of growing bio-energy crops.

Photos: Thermal power plant in Rajastan: "STPS" by Bhuvantoo; "220kV tower near Ennore" by Nikhilb239 ; "Chennai skyline" by Vineeshkoomully; all own work. Licensed under CC BY-SA 3.0 via Commons.

SUMMARY OF APPLICATIONS

The table below lists the primary applications of the IRADe activity analysis model over the past decade. This is followed by brief summaries of how several versions of the model have been applied to proposed scenarios in order to assist Indian decision makers with planning and policy making.

TABLE 1: IRADE MODELING PROJECTS AND THEMES ADDRESSED

MODEL	FUNDED BY	THEME(S) ADDRESSED	YEAR
IRADe-AA30	Ministry of Environment and Forests (MoEF)	India's GHG Emissions Profile: Results of Five Climate Modeling Studies	2006-2009
IRADe-ET50	Technology Information, Forecasting and Assessment Council (TIFAC)	India's Energy Transition till 2050 in the Global Context	2010-2013
IRADe-AG40	Centennial Group	Study on Indian Agriculture, 2040	2009-2011
IRADe-EQ30	SouthSouthNorth (SSN)	Impact of Mitigation and Poverty Alleviation	2012
IRADe-LCSD	World Wide Fund for Nature-India (WWF-India) and other partners	Low-Carbon Development Pathways For a Sustainable India	2012-14
IRADe-LCSIG	Planning Commission of India	Study on Economy-wide Model for Low Carbon Strategy for Inclusive Growth	2013-2014
IRADe-NEG50*	Ministry of Environment, Forest & Climate Change (MoEF & CC)	Modelling Studies on Greenhouse Gas Emissions and Emission Intensity of the Indian Economy	2014-15
IRADe-SARI35**	United States Agency for International Development (USAID)	South Asian Regional Initiative for Energy Integration	2012-17

** This is a ongoing project in which the model provides inputs by constructing scenarios for various pathways for the INDC of India..*

*** IRADe is developing a model for Nepal along similar lines to asses the economic benefits from cross border electricity trade.*

IRADe-AA30: This model was first developed under the project *Developing a CGE Model with Activity Analysis for Climate Policies for India* with funding from the Ministry of Environment and Forests (MoEF), Government of India, during 2006-2009. The model was used to project India's CO_2 emissions up to 2030 under various assumptions of technological progress and energy efficiency.

The model was also used to assess impacts of a carbon tax and carbon trade on the economy and its emissions profile, and welfare implications such as impacts on poverty. The model showed that GHG mitigation measures can result in higher poverty rates.

The results from the study were used to guide MoEF in formulating its position for the UNFCCC COP meetings at Poznan and Copenhagen. The results from the model also were used by the Ministry in the report *India's GHG Emissions Profile.*

IRADe-ET50: The IRADe-AA30 model was modified to project India's energy pathways up to the year 2050. This was done with the support of the Technology, Information Forecasting and Assessment Council (TIFAC), Department of Science and Technology of the Government of India, in collaboration with the Austrian International Institute for Applied Systems Analysis (IIASA), during 2010-2012.

The model provided insights for TIFAC regarding the energy transitions required in the power sector up to 2050, and the associated costs and impacts on GDP to achieve the transitions required for three alternative scenarios: (i) the reference scenario; (ii) a scenario incorporating the Government's policies on energy efficiency (in the National Action Plan on Climate Change) and the Ministry of New and Renewable Energy's policies for wind, small hydro and solar; and (iii) a scenario based on adopting carbon cuts in the power sector consistent with the Global Energy Assessment (GEA) scenario of IIASA for achieving a 2 degree Celsius global temperature reduction target.

IRADe-EQ30: This model was used in 2012 to analyze Poverty Alleviating Mitigation Actions (PAMAs). The organization SouthSouthNorth (SSN) in South Africa supported the study *Impacts of Mitigation and Poverty Alleviation* which analyzed potential impacts of developmental measures on GHG emissions and addressed the question of how mitigation actions impact poverty and economic growth. The model results showed that expenditures on basic development measures did not have a large carbon footprint, but that GHG mitigation measures increased poverty.

IRADe-LCSD: The challenge of low-carbon development was further addressed in this study supported by a consortium of partners – the World Wide Fund for Nature-India (WWF-India), Centre for Environment Education (CEE), LAYA, Welthungerhilfe and Church's Auxiliary for Social Action (CASA)) – during 2012-2014. The IRADe model was extended to incorporate development parameters – such as life expectancy, infant mortality, mean years of schooling, and access to sanitation, clean water, electricity and clean cooking fuel – as functions of economic growth. The Human Development Index (HDI) values of developed countries were used to specify targets for the development parameters to be achieved by 2050. This included cash transfers and higher expenditures on education and health to achieve faster eradication of poverty and to attain the targeted levels of development while still adhering to a stringent low-carbon pathway specified by a carbon budget. Two carbon budgets were used allowing for 156 GT and 133 GT of CO_2 emissions during the period 2010-2050.

The analysis results showed the technological changes needed in power generation, energy efficiency measures and transport demand management in order to adhere to the carbon budgets while still being able to achieve the HDI levels of developed countries. The results were used as a communication tool to inform the civil society debate and the Government's view and understanding of these issues in the context of developmental aspirations and climate commitments.

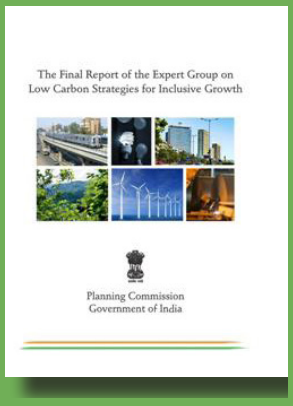
Photo: Skyline at Rajiv Chowhk (Delhi, India), Kabi1990, own work. Licensed under CC BY-SA 3.0 via Commons.

FEATURED: THE IRADE-LOW CARBON STRATEGY FOR INCLUSIVE GROWTH (IRADE-LCSIG) MODEL

The IRADe-LCSIG is the latest version of the model. For this version, the IRADe-LCSD model was updated for a new base year and converted from a 5-year interval simulation model to an annual simulation model, in order to provide input to India's Expert Group on Low Carbon Strategies for Inclusive Growth under the Government's Planning Commission. The expert group, in its interim report and in sectoral studies, had outlined various low-carbon measures in different sectors of the economy.

The IRADe-LCSIG model was used to incorporate all the policies together into a macroeconomic framework to ensure consistency across all sectors and to assess the net impact of the policies across the economy and on major macro parameters. The model analyzed the likely loss in national income growth, higher investment costs, and any increase in the incidence of poverty due to various low-carbon policies.

The model also estimated the incremental costs of abating CO_2 emissions and quantified the additional inflows of foreign finances required to compensate for the welfare losses incurred from abatement.



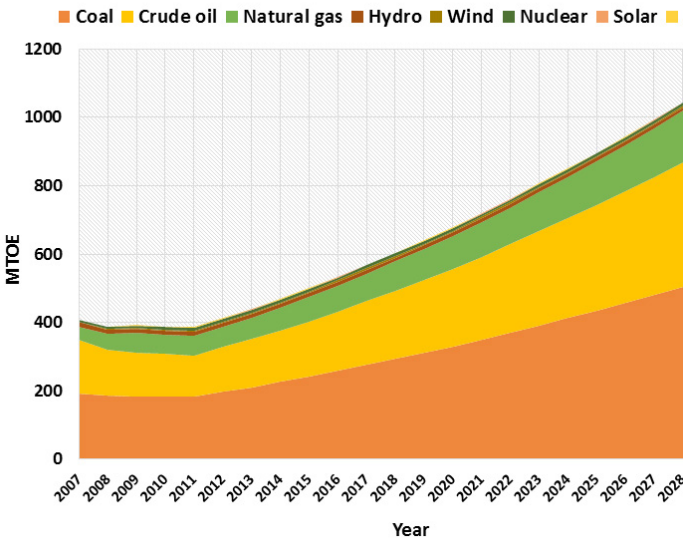
The report of the expert group was widely quoted by civil society and used as a reference document for government policy making. More specifically, to address the question posed by India's Expert Group on Low Carbon Strategies for Inclusive Growth, the IRADe-LCSIG model was applied and the output was summarized in two very different scenarios:

1. **Baseline, Inclusive Growth (BIG)**. This scenario incorporated inclusive growth policies and served as the reference scenario.
2. **Low Carbon Strategy for Inclusive Growth (LCIG)**. This scenario incorporated low-carbon strategies while maintaining the inclusive growth interventions as introduced in the BIG scenario.

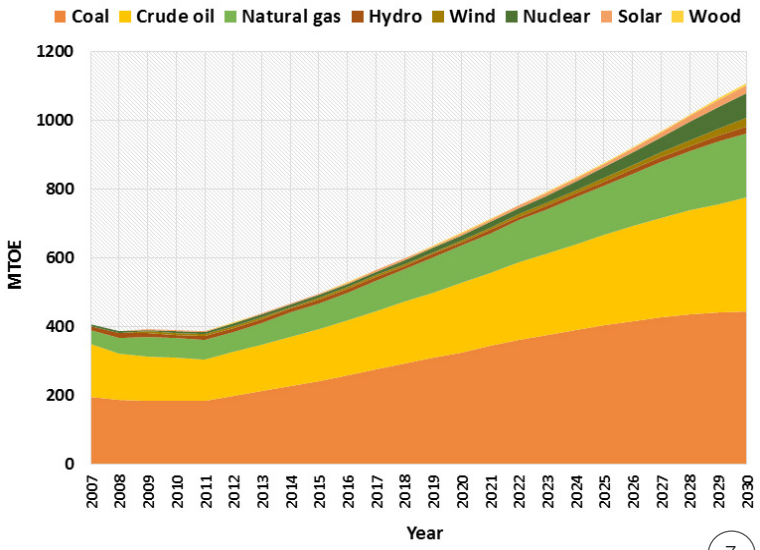
The inclusive actions were mandatory for both the scenarios while the two scenarios covered the entire range of possible low carbon pathways.

The following graphs summarize key results from the application of the IRADe-LCSIG model to address questions requested by India's Expert Group on Low Carbon Strategies for Inclusive Growth. As can be seen in **Graphs 1A and 1B**, the energy mix changes from predominantly a coal-based economy in the BIG scenario to a more renewable-based generation (with 33% of energy from non-fossil fuel-based sources) in the LCIG scenario.

Graph 1A: Energy Mix in BIG Scenario

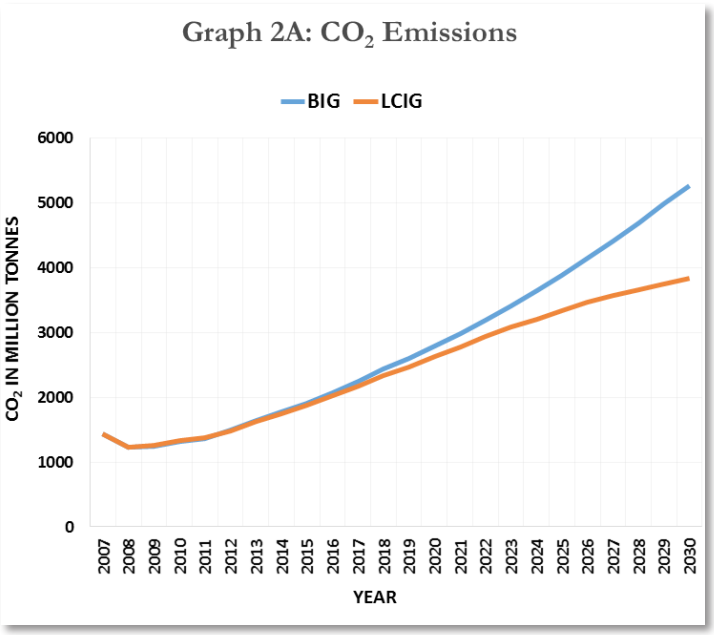


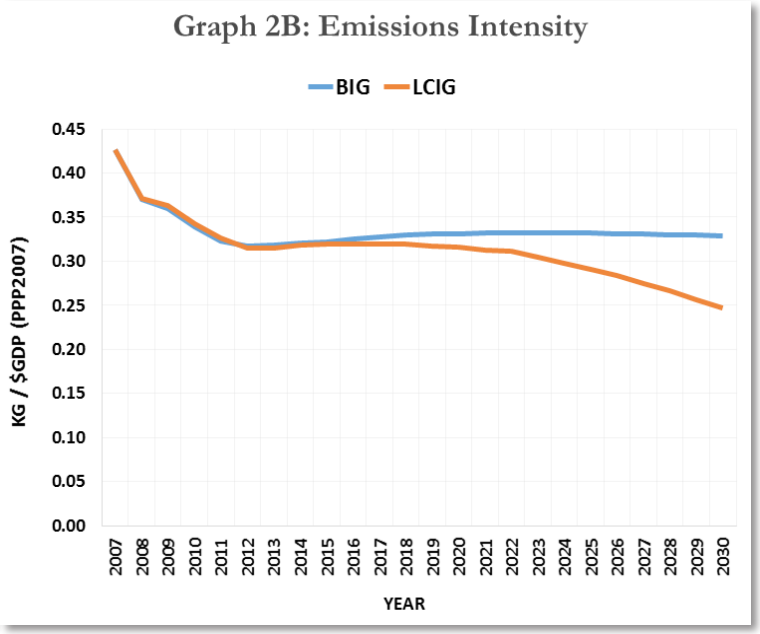
Graph 1B: Energy Mix in LCIG Scenario



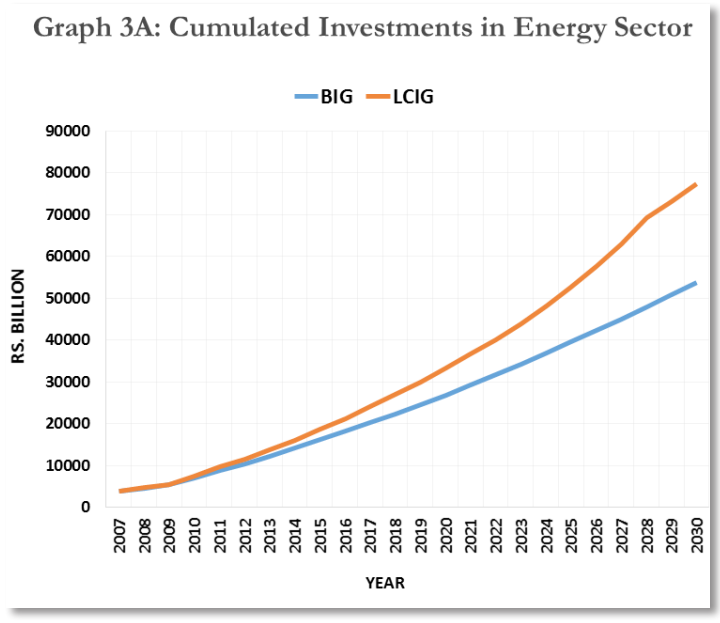
FEATURED: IRADE-LOW CARBON STRATEGY FOR INCLUSIVE GROWTH (IRADE-LCSIG) MODEL

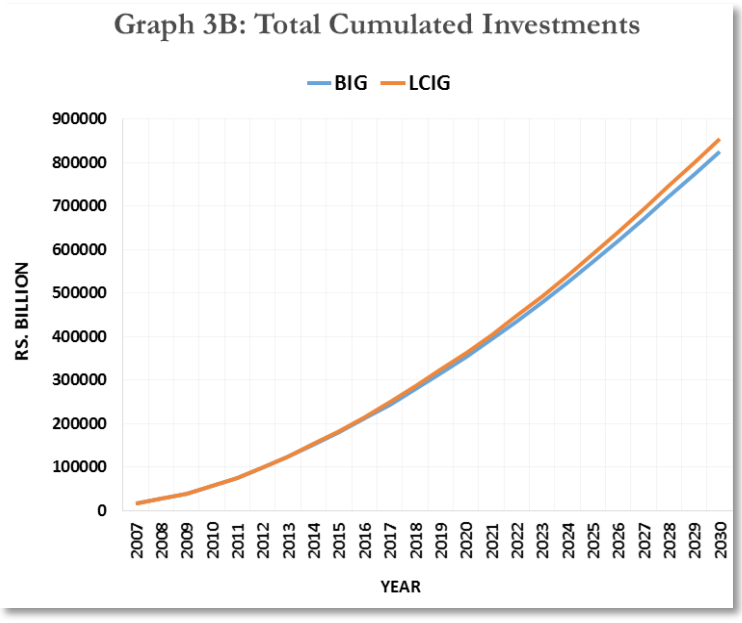
Graphs 2A and 2B show the impacts on CO_2 emissions from a 40% reduction in CO_2 emissions intensity in the LCIG scenario.





Graphs 3A and 3B show the estimated impacts on energy investments and investments in other sectors in the BIG and LCIG scenarios.





ANNEX I: TECHNICAL DETAILS OF THE IRADE ACTIVITY ANALYSIS MODEL

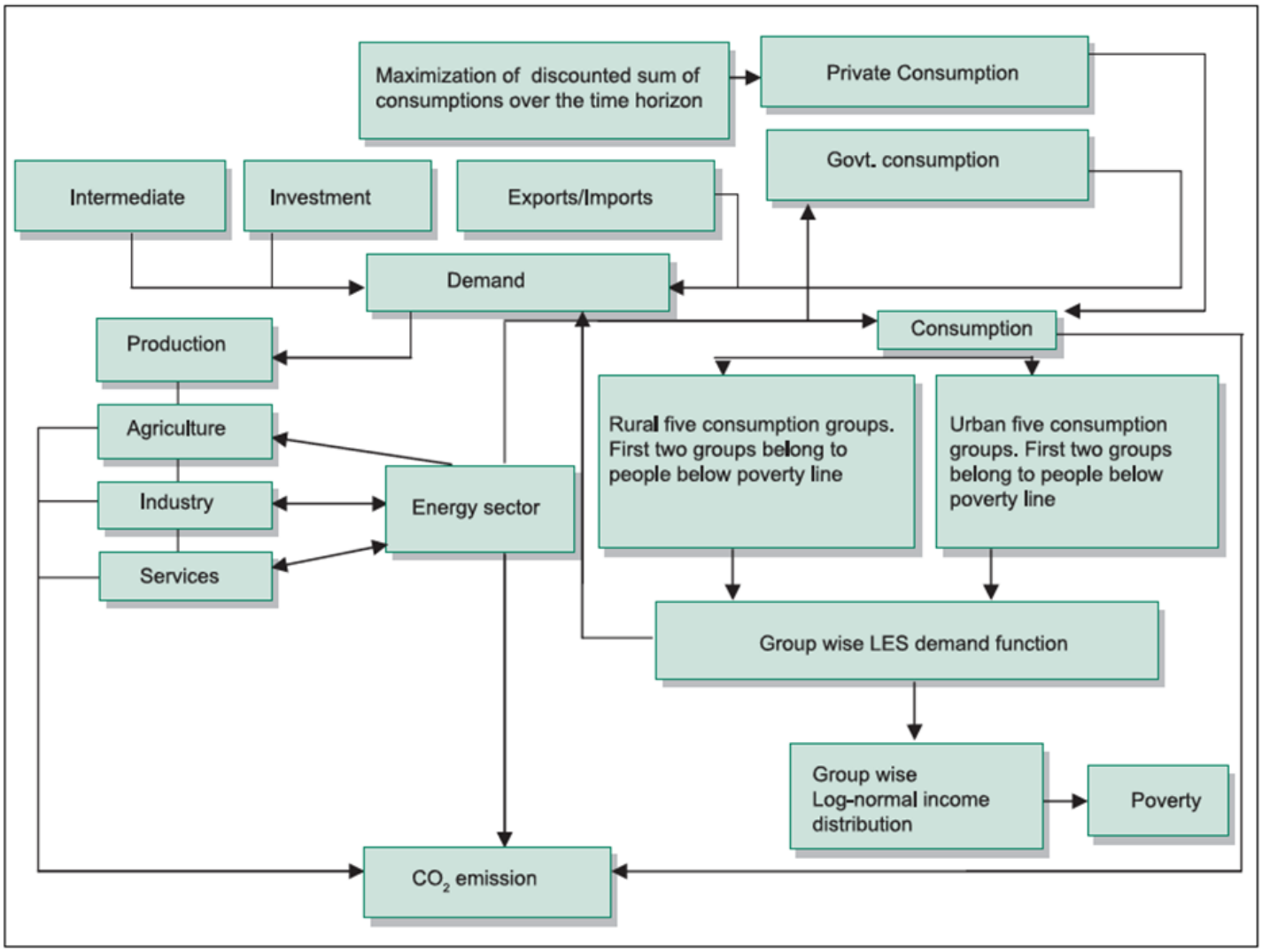
The IRADe activity analysis model is a dynamic multi-sectoral, intertemporal, linear programming activity analysis tool based on an input–output framework. It uses a mathematical method to solve practical problems (such as the allocation of resources) where the variables involved are subject to certain constraints. The model is able to analyze the total consumption streams across the entire planning horizon.

As illustrated in Figure A1, the model computes and matches the supply and demand of each commodity.

On the supply side, the model uses the input-output relationships as provided in the national social accounting matrix (SAM). The input-output matrix for a particular year gives the flow of material inputs and services used in each production activity and the output levels of the production activity.

The information from the input-output matrix is then used to compute technical relationships between production levels desired and the inputs demands they generate.

FIGURE A1: FLOW CHART SHOWING ECONOMIC LINKAGES IN IRADE ACTIVITY ANALYSIS MODEL STRUCTURE



ANNEX I: TECHNICAL DETAILS OF THE IRADE ACTIVITY ANALYSIS MODEL

For example, to analyze the "activity" of power generation, the model uses national data on "inputs" used to generate electricity such as fuel, material inputs and services like transportation, and the "output" of electricity to compute a technological relationship for the production of power and material inputs and services required (i.e. operating costs).

This information is then used to forecast a likely supply/generation of power given the availability of fuel, material inputs, and transportation and services infrastructure over a long-term planning horizon of 50 years.

On the demand side, the SAM matrix also gives the intermediate demand (the input demand from production) and final demand for each commodity that is met by total supply (domestic production and additional supply through imports). The final demand consists of household demand, government consumption demand, investment demand and export demand. Each of these demands is projected consistently by relating them to income generation occurring in the economy through macroeconomic theoretical relationships.

Changing household tastes and preferences due to rising income drive structural change in sectoral production, and this is captured in the model in a consistent manner over 30-50 years.

SECTORAL BREAKUP IN THE MODEL

As an economy-wide model covering the interaction of all economic sectors with the energy sector, the input costs for each sector and the demand for each sector's output need to be computed to make projections for the specified time horizon. In India, the Central Statistical Organisation of India (CSO) tracks and publishes this information for 130 economic activities that cover all production-related economic activity that takes place in the economy. For use in the IRADe activity analysis model, these data are aggregated into 25 "commodity" groups produced using 38 types of "production activities" (the difference in these numbers is due to the aggregation of 13 types of activities used to generate electricity into the power sector).

Theoretically, any technological intervention can be introduced for any sector, but typically broad technological interventions are introduced for the major sectors where technology/policy interventions can be modeled:

- **Energy** – fossil fuels like coal, crude petroleum, petroleum products and natural gas;
- **Power** – power generated from various technologies including renewables (13 electricity producing activities based on coal, nuclear, biomass, etc.);
- **Industry** – includes sectors like cement and steel;
- **Transport** – railways and other transport (including road transport);
- **Services** – includes education, health services and other public and private services;
- **Household consumption** – of energy in rural and urban areas;
- **Forestry sector** – emissions as well as sequestration from forests; and
- **Buildings** – includes all commercial buildings; considers ECBC-compliant buildings.

ANNEX I: TECHNICAL DETAILS OF THE IRADE ACTIVITY ANALYSIS MODEL

IMPORTANT OUTPUTS FROM THE MODEL

- Sectoral outputs of, and investments in 38 production activities.
- Household consumption of selected commodities, government consumption, investment, intermediate demand, exports and imports.
- Total and commodity consumption expenditure, population in both rural and urban areas.
- Poverty at each time period, in rural and urban areas.
- GHG emissions from each production activity.
- Total investment demand, foreign investment flows.
- GHG emissions by households from consumption of fossil fuels and appliance demand.

FUTURE APPLICATIONS

Although IRADe developed the activity analysis tool for use in India based on Indian data, the tool can be applied to situations in other countries by replicating the methodology.

For more information on the IRADe model and other potential applications, please contact Dr. Probal Ghosh, Senior Research Analyst, IRADe: pghosh@irade.org.

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IRADe is an independent advanced research institute which aims to conduct research and policy analysis to engage stakeholders such as government, non-governmental organizations, corporations, and academic and financial institutions. Energy, climate change, urban development, poverty, gender equity, agriculture and food security are some of the challenges faced in the 21st century. Therefore, IRADe research covers these, as well as policies that affect them. IRADe's focus is effective action through multi- disciplinary and multi-stakeholder research to arrive at implementable solutions for sustainable development and policy research that accounts for the effective governance of techno-economic and socio-cultural issues.

IRADe networks with the government, ministries/ departments, international organizations, public and private sectors, academic experts, NGOs, and consultants to work on projects awarded by them. The ministries include Ministry of Environment and Forests and Climate Change, Ministry of New and Renewable Energy, Niti Aayog (formerly Planning Commission), Ministry of Power, Ministry of External Affairs, and others for many national level projects.

At the international level, IRADe has worked with multilateral organizations and IRADe has collaborated with private sector and multinational organizations and NGOs. IRADe has also developed strategic partnerships and is part of global networks.

IRADe has carried out some pioneering work in the field of state level energy planning, city level climate resilience planning, other climate change studies and livelihood studies in agriculturally vulnerable flood prone areas.

For more information, visit: ***http://www.irade.org*** or contact:

IRADe
C-80, Shivalik, Malviya Nagar
New Delhi - 110017
Tel: +91 11 2668 222

ASIA LEDS PARTNERSHIP | Advancing low-emission, climate-resilient development across Asia

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This case features IRADE, an Asia LEDS Partnership member