26th AIM International Workshop

Theme: GHG Mitigation in Asia

Low Carbon Development Trends in India

Prof. Amit Garg

September 3-4, 2020

Development and Climate Change: SDG and NDC

India has been setting ambitious targets to achieved its development and Paris Agreement commitment by 2030

Development

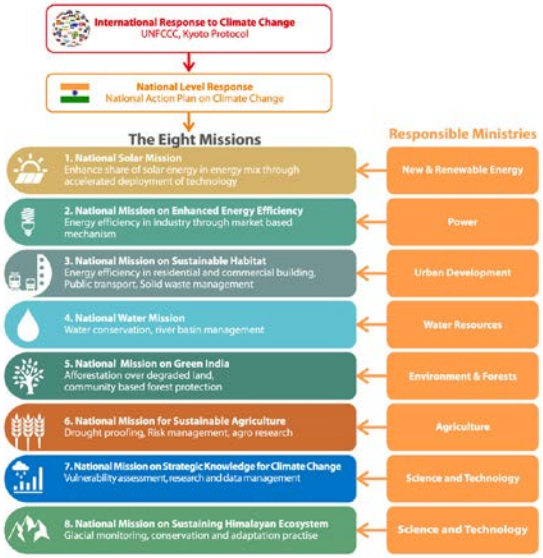
MDG (2000 – 2015)

Source: UN MDG 2000

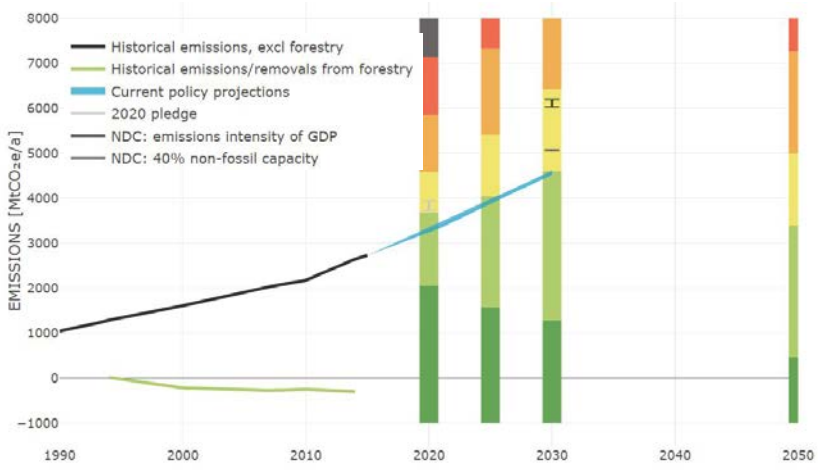
SDG (2015 -2030)

Source: UN SDG 2015

Climate Change



Source: NAPCC 2008



Source: https://climateactiontracker.org/countries/india/, 2020

Development and Climate Change: Future NDCs and LTS

4°C+ World	< 4°C World	< 3°C World	< 2°C World	< 1.5°C World	< 1.5°C World
CRITICALLY INSUFFICIENT	HIGHLY INSUFFICIENT	INSUFFICIENT	2°C COMPATIBLE	1.5°C PARIS AGREEMENT COMPATIBLE	ROLE MODEL
RUSSIA	ARGENTINA	AUSTRALIA	BHUTAN	MOROCCO	0 Countries
SAUDI ARABIA	CANADA	BRAZIL	COSTA RICA	THE GAMBIA	
TURKEY	CHILE	EU	ETHIOPIA	2 Countries	
UKRAINE	CHINA	KAZAKHSTAN	INDIA		
USA	INDONESIA	MEXICO	PHILIPPINES		
5 Countries	JAPAN	NEW ZEALAND	5 Countries		
	SINGAPORE	NORWAY			
	SOUTH AFRICA	PERU			
	SOUTH KOREA	SWITZERLAND			
	UAE	9 Countries			
	10 Countries				

PARIS2015 UN CLIMATE CHANGE CONFERENCE COP21·CMP11

Climate Action Tracker

CAT country ratings of Pledges & Targets

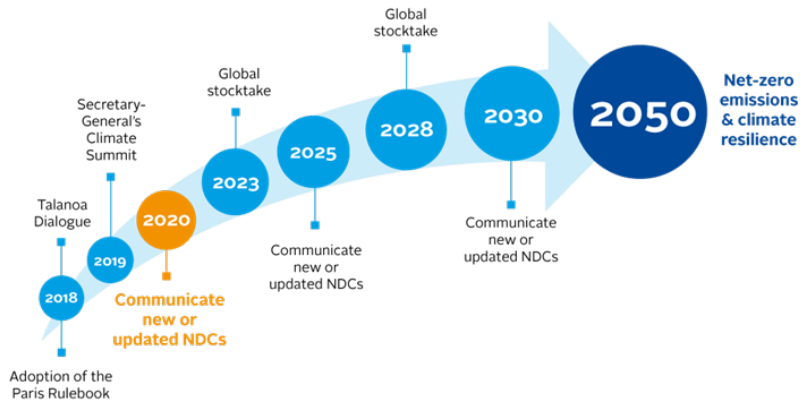
December 2018 update

India is the largest country that is on the pathway to achieve its Paris commitment

LONG-TERM CLIMATE STRATEGIES UNDER THE PARIS AGREEMENT

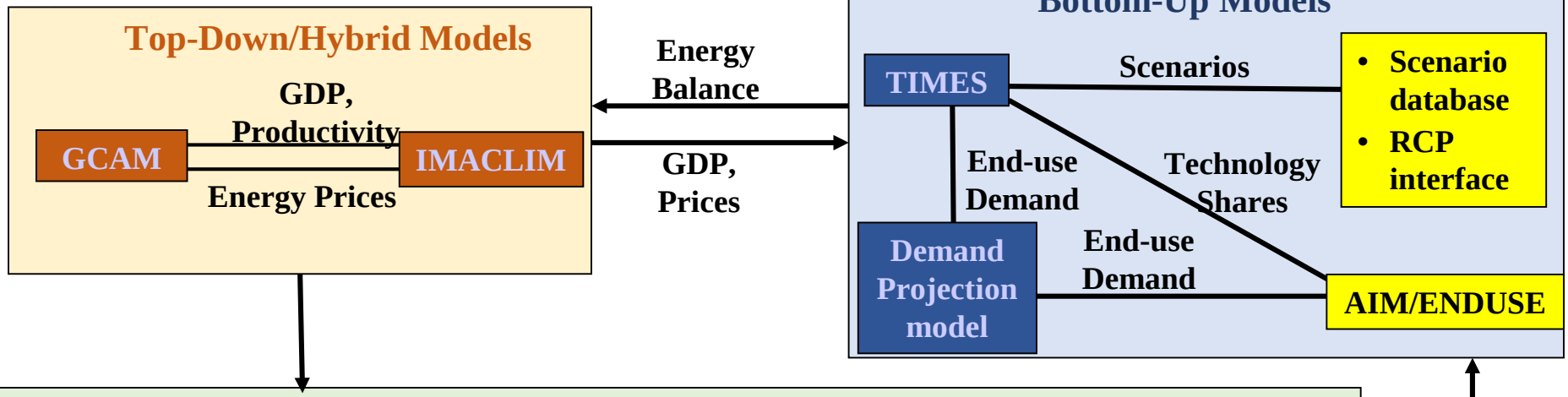
Additionally, India will submit its LTS and updated NDC in near future

AMBITION MECHANISM IN THE PARIS AGREEMENT



Source: wri.org/publication/NDC-enhancement-by-2020

Soft Linked Top-down, Bottom-up, Hybrid and GIS modeling System for India



GIS Based and Other Modelling

LPS and Area Sources
- CO_2
- Non CO_2 (9 gases)
- 1350 LPS, 641 districts
- Water Energy nexus – LPS level modelling

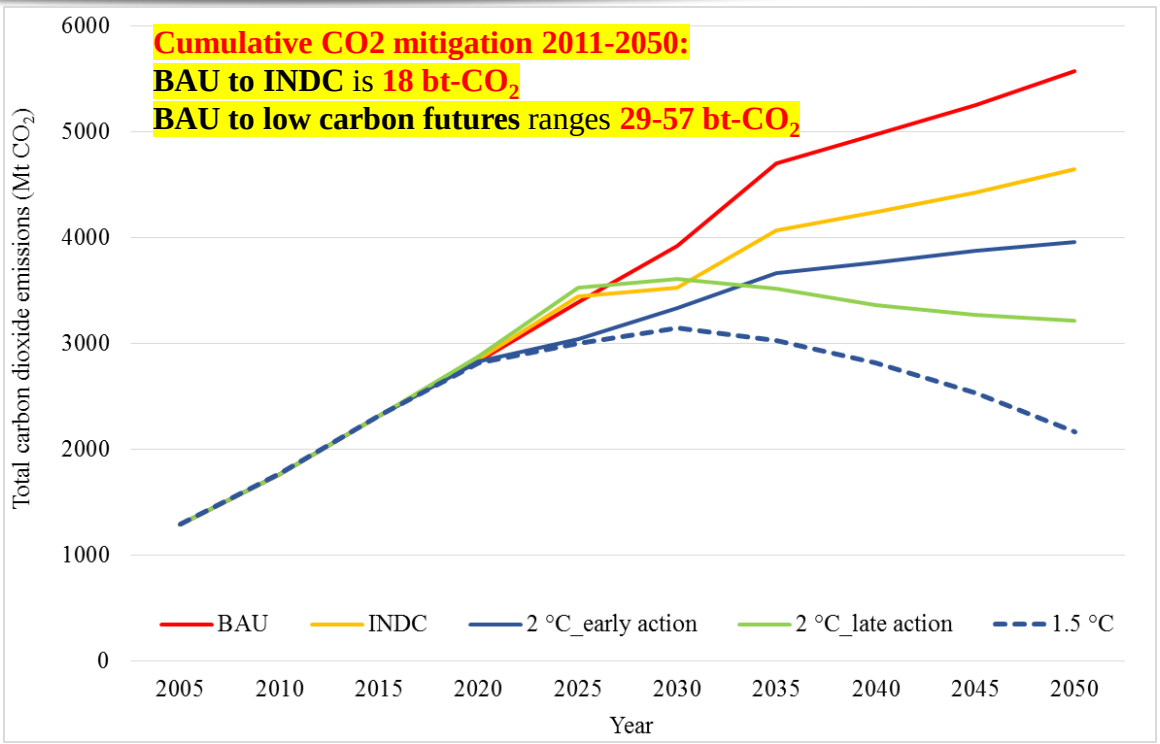
City level mitigation
- LPS + Area sources
- Energy efficiency
- Public transport, EV
- Rooftop Solar
- Waste management
- Landuse change
- Peri-urban agriculture

LULUCF
- 1 km x 1 km Land-use mapping for entire India
- Water flows from climate models
- District level Energy balance model
- Energy plantation modelling (District level 192 databases)
- Afforestation, Reforestation and Soil Carbon Sequestration modelling
- 47 cities landuse mapping and modelling (30 x 30 m) – linked with heat mortality, flooding
- Property pricing and climate extremes

CCUS
- Source-Sink match & Pipeline costing optimization
- BECCS model (coupled with EOR)

Industry/ Corporate level modelling (other)
- GREENEX with Bombay Stock Exchange
- Energy/Revenue, CO_2 /Revenue, share price and carbon

Indian CO_2 Emissions



Scenario	Budget	CO2/capita (2050)
BAU (NPi**)**	165	3.2
INDC	147	2.7
2 °C_early action (NPi2020_high**)**	136	2.3
2 °C_late action (INDC2030_low**)**	128	1.9
1.5 °C (NPi2020_verylow**)**	108	1.2

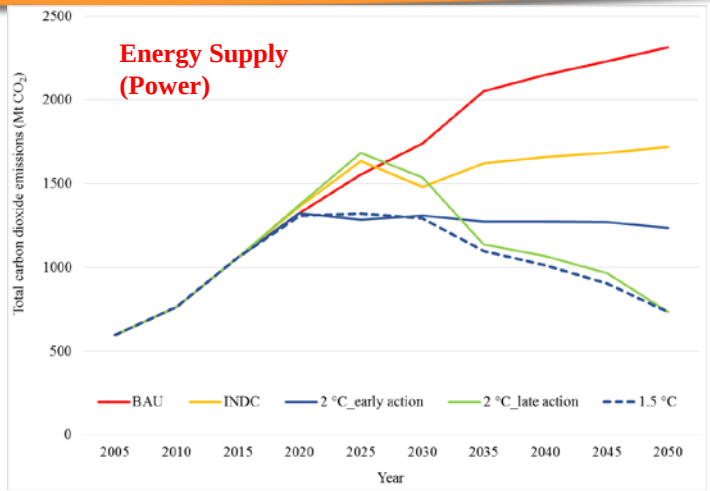
Notes:
Carbon budget 2011-2050 in billion ton-CO_2
(scenario name) denote CDLINKS name

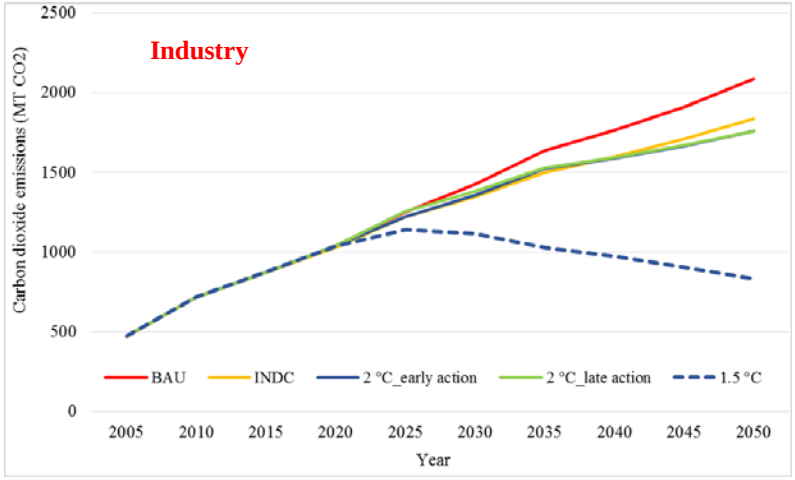
Scenarios	Bt-CO_2 (% reduction)	Energy Efficiency (bt-CO_2)	Renewables (bt-CO_2)	Demand Reduction (bt-CO_2)	CCS (bt-CO_2)
BAU to INDC	18 (11%)	10	7	1	0
INDC to 2 °C	11-19 (8-13%)	1-2	3-5	3-4	4-8
INDC to 1.5 °C	39 (27%)	4	6	6	23

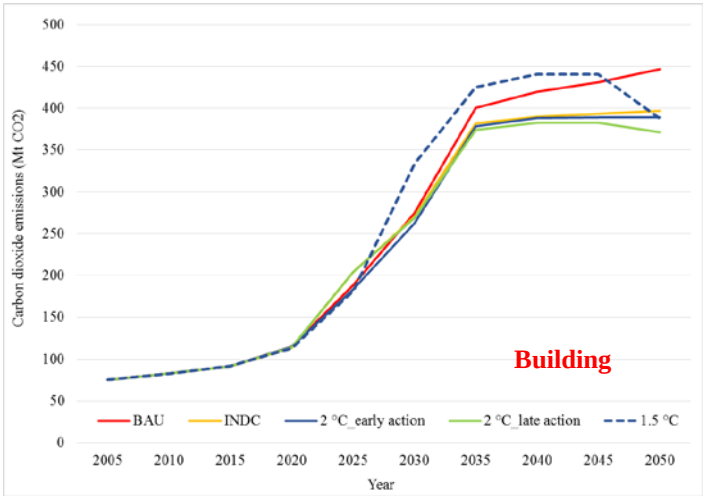
Cumulative CO_2 budget: India needs room for development, results within higher range of global models.

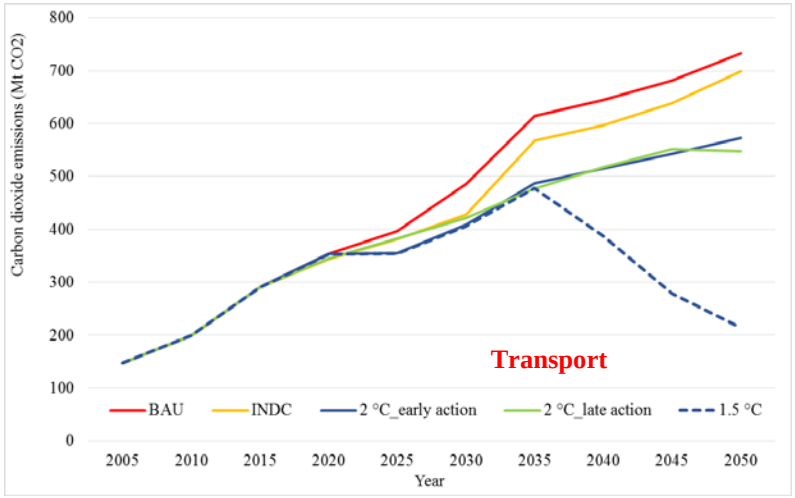
Source: Vishwanathan, S.S., Tiwari, V., Garg, A. and Shukla, P.R. (2018)

Sectoral Emissions







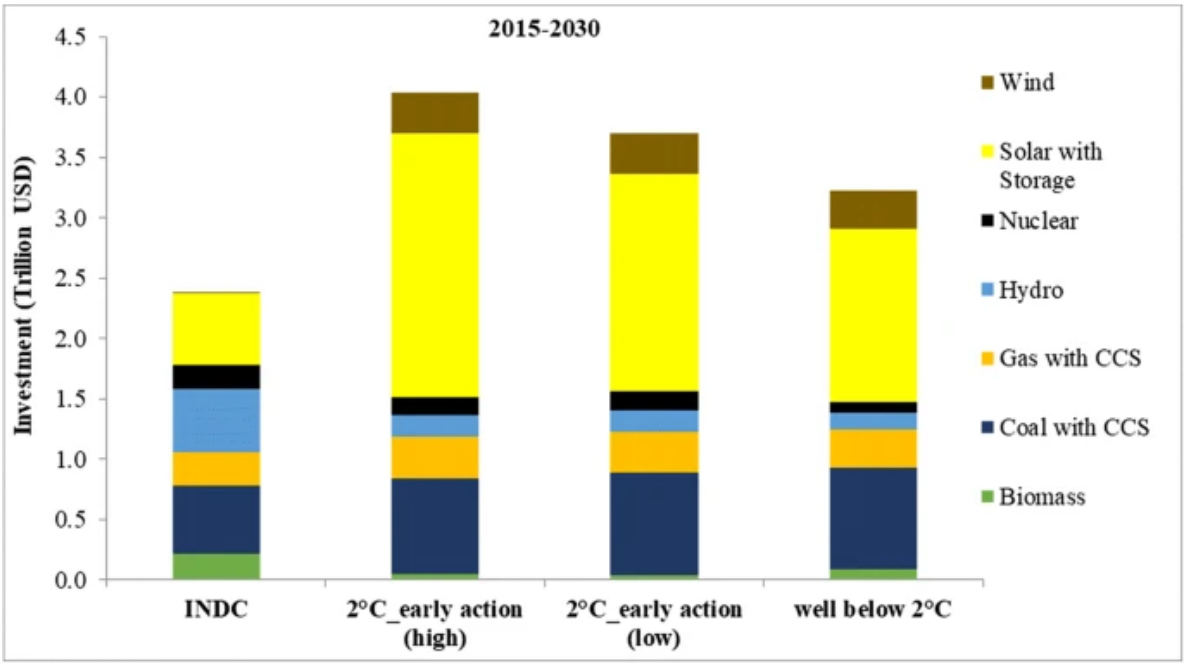


Power, Industry and Transport mainly responsible for reduction in emissions in low carbons scenarios

Source: Vishwanathan, S.S., Tiwari, V., Garg, A. and Shukla, P.R. (2018)

Energy Transformation: Investments

These transformations will likely need investments of **US$ 6–8 trillion** between 2015 and 2030 across various scenarios



39–52% shared by power sector

13–17% shared by transport sector

19–25% shared by industry sector

11–14% shared by building sector

Source: Vishwanathan and Garg (2020)

Sustainable Development : Macroeconomic Assessment

Low carbon pathways and sustainable development can co-exist with policy alignments

World Development 123 (2019) 104623

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World Development

journal homepage: www.elsevier.com/locate/worlddev

Achieving sustainable development in India along low carbon pathways: Macroeconomic assessment

Dipti Gupta [a,*], Frédéric Ghersi [b], Saritha S. Vishwanathan [c], Amit Garg [d]

[a] Public Systems Group, Indian Institute of Management, Ahmedabad, Gujarat 380015, India
[b] CNRS, CIRED, 45 bis, avenue de la Belle Gabrielle, 94736 Nogent sur Marne CEDEX, France
[c] Faculty Room 12, Indian Institute of Management, Ahmedabad, Gujarat 380015, India
[d] Wing 16, Public Systems Group, Indian Institute of Management, Ahmedabad, Gujarat 380015, India

ARTICLE INFO

Article history:

Keywords:
India
Energy-economy modelling
Low carbon pathways
2°C
Sustainable development

ABSTRACT

Achieving fast and inclusive economic growth concurrently with greenhouse gases (GHG) emission control could have wide-ranging implications for the Indian economy, predominantly fuelled by fossil energies. India faces high income inequality with the bottom 50% of its population owning only 2% of total national wealth. Other developmental challenges include 304 million people living in poverty, 269 million without access to electricity, 92 million without access to safe drinking water, and around 2 million homeless. Despite such challenges, India has committed to reduce the GHG emission intensity of its GDP 33–35% below its 2005 level by 2030, including via turning 40% of its power-generation capacity away from fossil sources. To explore the macroeconomic consequences of achieving development along low-carbon pathways, we use a hybrid modelling architecture that combines the strengths of the AIM/Enduse bottom-up model of Indian energy systems and the IMACLIM top-down economy-wide model of India. This hybrid architecture stands upon an original dataset that reconciles national accounting, energy balance and energy price statistics. With this tool, we demonstrate that low carbon scenarios can accommodate yearly economic growth of 5.8% from 2013 to 2050 i.e. perform close to if not slightly higher than our business-as-usual scenario, despite high investment costs. This result partly stems from improvement of the Indian trade balance via substantial reduction of large fossil fuel imports. Additionally, it is the consequence of significant shifts of sectoral activity and household consumption towards low-carbon products and services of higher value-added. These transitions would require policies to reconcile the conflicting interests of entrenched businesses in retreating sectors like coal and oil, and the emerging low-carbon sectors and technologies such as renewables, smart grids, electric vehicles, modern biomass energy, solar cooking, carbon capture and storage, etc.

1. Introduction

The developing Indian economy faces multiple challenges echoing key dimensions of the Sustainable Development Goals (SDGs) of the United Nations. It thus counts around 269 million people living in poverty (Planning Commission, 2013), approximately 500 million deprived of clean cooking fuel, 304 million having no access to electricity (NEP, 2017), 163 million without access to safe drinking water (WaterAid, 2018), close to 1.7 million people homeless (Census, 2011) and 48% of rural households lacking basic socio-economic services (SECC, 2011). Moreover, post-2020 climate commitments outlined in India's Nationally Determined Contribution (NDC) under the Paris agreement of the United Nations Framework Convention on Climate Change (UNFCCC) envision development along low-carbon emission pathways. India's enormous developmental needs therefore have to be balanced with emission reduction targets. The fact that coal produces nearly three fourth of electricity generated in India points at potentially high costs of emission control. In such conditions, achieving rapid economic growth and GHG mitigation targets concurrently can have substantial macroeconomic implications. Though climate action can help redress the trade unbalance via reduction of large fossil fuel imports, the transition to non-fossil fuels could be costly.

India has been growing at a remarkable GDP growth rate of 7–8% annually since economic liberalization in 1991. The share of agriculture in GDP has gone down from 42% in 1970 to 17% in 2015, and continues to decline. In 2016, services and industry sec-

* Corresponding author at: Dorm34, Room18, Public Systems Group, Indian Institute of Management, Ahmedabad, Gujarat 380015, India.
E-mail addresses: diptig@iima.ac.in (D. Gupta), ghersi@centre-cired.fr (F. Ghersi), sarithasv@iima.ac.in (S.S. Vishwanathan), amitgarg@iima.ac.in (A. Garg).

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RESEARCH ARTICLE

OPEN ACCESS Check for updates

Macroeconomic assessment of India's development and mitigation pathways

Dipti Gupta[a], Frederic Ghersi[b], Saritha S. Vishwanathan[a] and Amit Garg[a]

[a]Public Systems Group, Indian Institute of Management, Ahmedabad, India; [b]CIRED, AgroParisTech, CIRAD, CNRS, EHESS, Ecole des Ponts ParisTech, Univ Paris-Saclay, Nogent-sur-Marne, France

ABSTRACT

Although a rapidly growing economy, India faces many challenges, including in meeting the Sustainable Development Goals of the United Nations. Moreover, post-2020 climate actions outlined in India's Nationally Determined Contribution (NDC) under the Paris Agreement envision development along low-carbon emission pathways. With coal providing almost three-quarters of Indian electricity, achieving such targets will have wide-ranging implications for economic activity. Assessing such implications is the focus of our research. To do so, we use a hybrid modelling architecture that combines the strengths of the AIM/Enduse bottom-up model of energy systems and the IMACLIM top-down economy-wide model. This hybrid architecture rests upon an original dataset that brings together national accounting, energy balance and energy price data. We analyse four scenarios ranging to mid-century: business-as-usual (BAU), 2°C, sustainable 2°C and 1.5°C. Our 2°C pathway proves compatible with economic growth close to the 6% yearly rate of BAU from 2012 to 2050, at the cost of reduced household consumption but with significant positive impact on foreign debt accumulation. The latter impact stems from improvement of the trade balance, whose current large deficit is the primary cause of high fossil fuel imports. Further mitigation effort backing our 1.5°C scenario shows slightly higher annual GDP growth, thereby revealing potential synergies between deep environmental performance and economic growth. Structural change assumptions common to our scenarios significantly transform the activity shares of sectors. The envisioned transition will require appropriate policies, notably to manage the conflicting interests of entrenched players in traditional sectors like coal and oil, and the emerging players of the low-carbon economy.

Key policy insights

- Low carbon pathways are compatible with Indian growth despite their high investment costs
- Moving away from fossil fuel-based energy systems would result in foreign exchange savings to the tune of $1 trillion from 2012 to 2050 for oil imports.
- Achieving deep decarbonization in India requires higher mobilized capital in renewables and energy efficiency enhancements.
- Phasing out fossil fuels would, however, require careful balancing of interests between conventional and emerging sector players through just transitions.

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KEYWORDS
India; energy-economy model; sustainable development; 2°C; 1.5°C; climate policy

CONTACT Dipti Gupta diptiguptaeiiml.ac.in Indian Institute of Management Lucknow, Chintan faculty room no. 235, IIM Road, Lucknow, Uttar Pradesh 226013, India
This article has been republished with minor changes. These changes do not impact the academic content of the article.

Source: Gupta et. al 2019; Gupta et. al 2019

Low-Carbon Developments in Indian Transport Sector

Transportation Research Part D 85 (2020) 102474

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journal homepage: www.elsevier.com/locate/trd

Sustainable development and carbon neutrality: Integrated assessment of transport transitions in India

Dipti Gupta[a,*], Amit Garg[b]

[a] Indian Institute of Management Lucknow, Chintan Faculty Room no. 235, IIM Road, Lucknow, Uttar Pradesh 226013, India
[b] Indian Institute of Management Ahmedabad, Public Systems Group, Wing 16, Indian Institute of Management Ahmedabad, Gujarat 380015, India

ARTICLE INFO

Keywords:
Modal transitions
Deep decarbonization
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Carbon neutrality
Modal shift
Energy-economy modelling

ABSTRACT

Dependence on crude oil imports, high correlation with economic growth, and contribution to air pollution cause the transformations in transport sector in India to have significant ramifications. Moreover, these transitions are to be steered through the global and domestic sustainable development and carbon neutrality goals. In this paper, we determine the energy-environment-economy implications of transport sector dynamics by undertaking an integrated analysis using a novel methodological approach involving two main aspects: soft-coupling the IMACLIM-IND and AIM/Enduse models; and back-casting approach with long-term benchmarks. We examine four scenarios: business-as-usual (BAU), development first (DEVF), carbon neutrality (CNT) and synchronous (SYNCH). Our synchronous scenario pathway reduces the crude oil and natural gas imports by 68% for the year 2050 compared to 2012 in the BAU scenario, leading to foreign exchange saving of 5.8 trillion US$ during 2013–2050. The envisioned transitions necessitate formulation of strategic policies which provide equitable access of transportation to all.

1. Introduction

Transport sector plays a pivotal role in improving regional connectivity and facilitating movement of individuals, and trade of goods across the country. Rapid economic growth and urbanization, since the end of the nineteenth century, have led to an unprecedented increase in the demand for mobility services (NITI Aayog and Rocky Mountain Institute, 2018). With the share of manufacturing sector in GDP poised to grow up to 25% by the year 2022 from 17% in 2018 (MoCI, 2018), freight transport demand is expected to rise quickly. On the one hand, the large scale growth in passenger traffic (from around 3000 BPMK in the year 1995 to over 10,000 BPKM in 2017) led to rise in the private vehicle ownership rather than public transport system, and on the other, growth in freight traffic (from around 1000 BTKM in 1995 to over 2500 BTKM in 2017) was accompanied by the dominance of road transport in total traffic share compared to rail (Fig. 1). These transformations and future possibilities along with government-led reform measures can have certain co-benefits and trade-offs for energy systems, environment, and domestic economy, which we set out to investigate in this paper.

Transport sector accounts for 9.4% share of domestic final energy consumption amounting to 52.3 Mtoe (CSO, 2019), and 47% of total refined petroleum products consumption which amounts to 82.5% of fuels consumed by transport services. Further, it accounts for 47% of the petroleum products' consumption in the country (IEA, 2015). Given the dependence on imports for meeting the crude oil demand (PPAC, 2019), it plays a critical role in the country's energy security dynamics. Further, it accounts for 13.3% of total energy CO_2 emissions with road transport dominating the mix with 90.1% share of total transport emissions followed by air (5.6%),

* Corresponding author at: Faculty room no. 235, Indian Institute of Management Lucknow, Lucknow, Uttar Pradesh 226013, India.
E-mail addresses: dipti.gupta@iiml.ac.in (D. Gupta), amitgarg@iima.ac.in (A. Garg).

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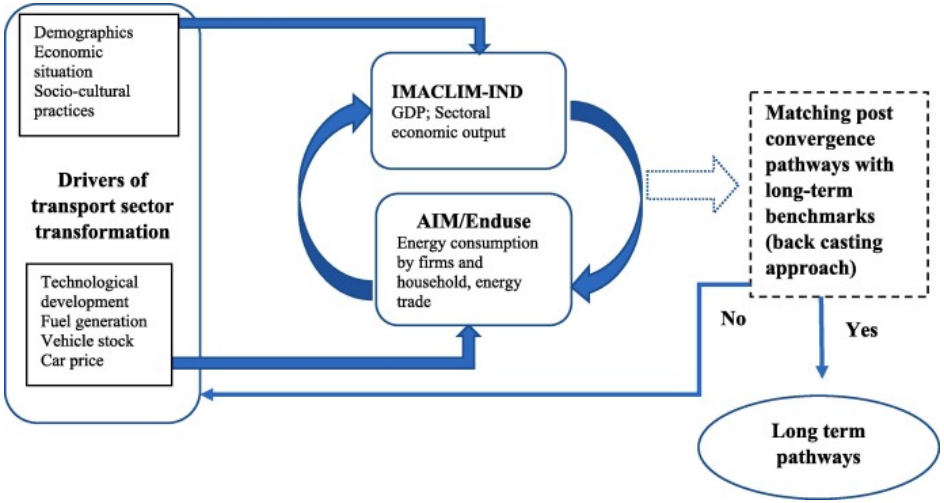
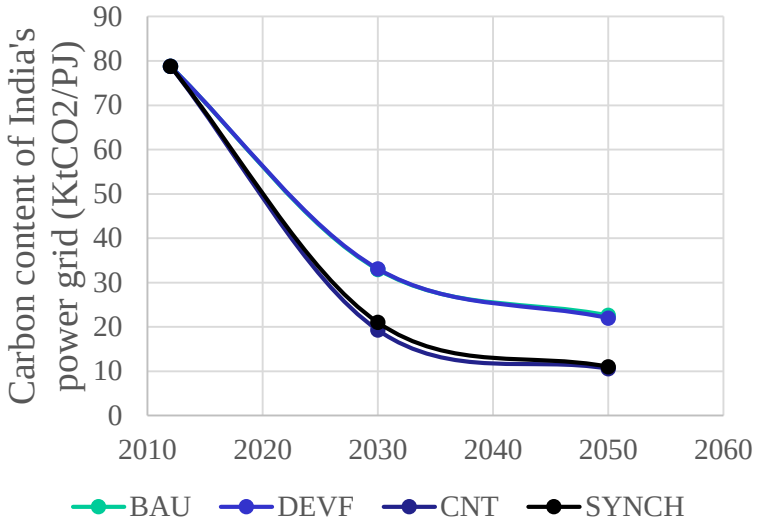
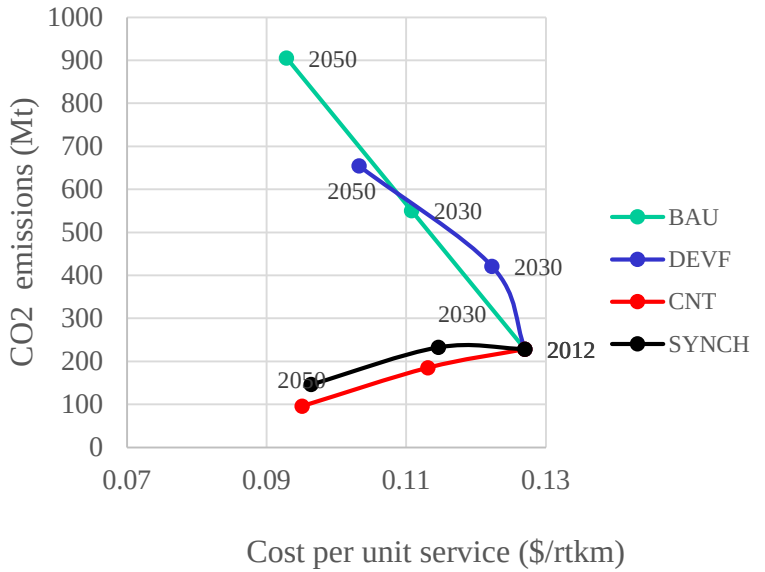
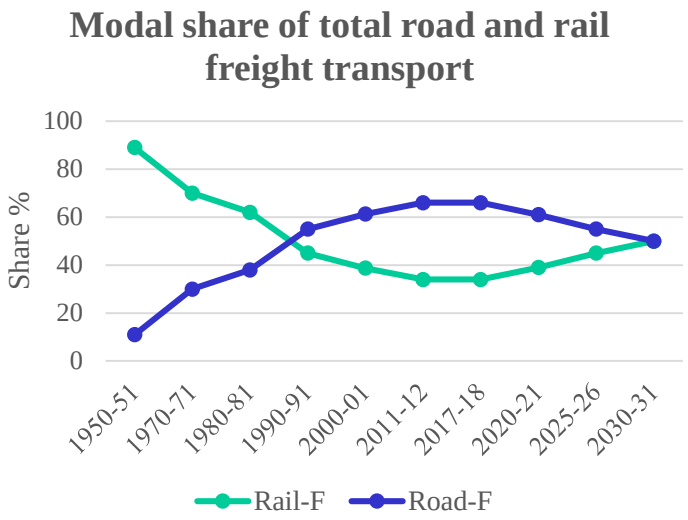


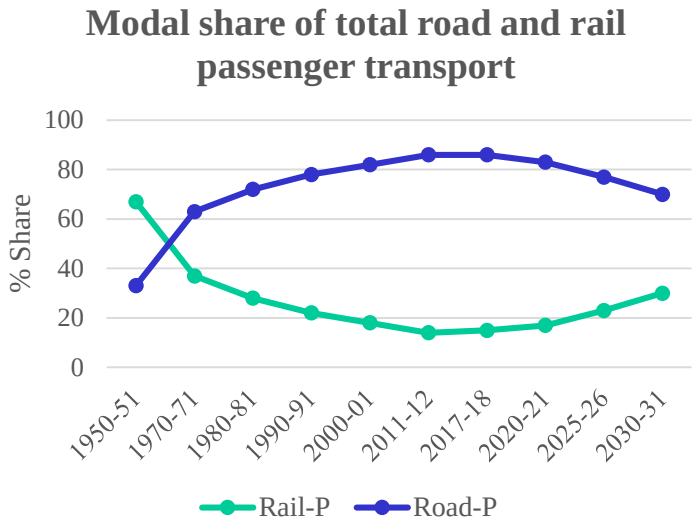
Source: Gupta and Garg 2020

Integrating Transport & Power sector transitions



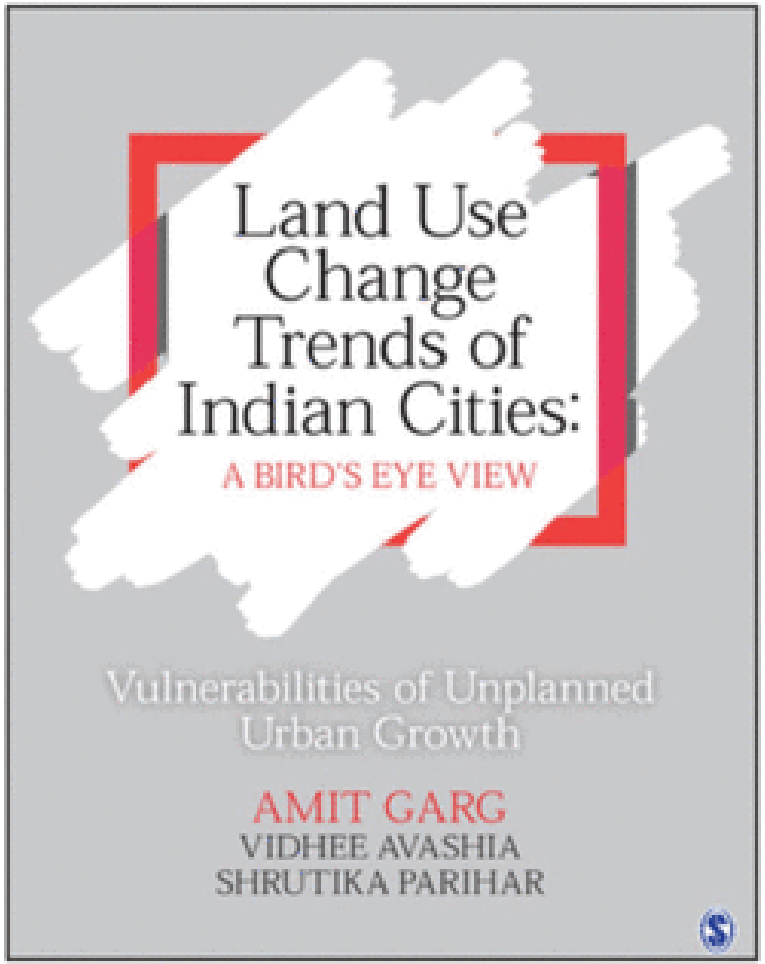






Source: Gupta and Garg 2020

Development, Vulnerability, Adaptation : Indian Cities



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Urban commons service generation, delivery, and management: A conceptual framework

Arpit Shah [a], Amit Garg [b]

[a] Indian Institute of Management, Ahmedabad, Public Systems Group, Dorm 29, Room 30, New Campus, IIM Ahmedabad, Vastrapur, 380015, Ahmedabad, Gujarat, India
[b] Indian Institute of Management, Ahmedabad, Public Systems Group, Wing 16B, Main Campus, IIM Ahmedabad, Vastrapur, 380015, Ahmedabad, Gujarat, India

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Land Use Policy
journal homepage: www.elsevier.com/locate/landusepol

Implications of land use transitions and climate change on local flooding in urban areas: An assessment of 42 Indian cities

Vidhee Avashia*, Amit Garg

Indian Institute of Management Ahmedabad, Vastrapur, Ahmedabad, 380 015, Gujarat, India

Journal of the Indian Society of Remote Sensing (June 2020) 48(6):877–908
https://doi.org/10.1007/s12524-020-01122-7

RESEARCH ARTICLE

Evaluation of Classification Techniques for Land Use Change Mapping of Indian Cities

Vidhee Avashia[1] · Shrutika Parihar[2] · Amit Garg[1]

Received: 4 October 2019 / Accepted: 30 May 2020 / Published online: 20 June 2020

Source: Garg et al. 2018; Shah and Garg 2017; Avashia and Garg 2020; Avashia et al. 2020

Selected Recent Past and Ongoing Projects

INTERNATIONAL

- Exploring National and Global Actions to reduce Greenhouse gas Emissions (**ENGAGE** funded by H2020) (2019-2023)
- Deep Decarbonization Pathways Project (**DDPP BIICS** funded IKI and BMUB) (2018-2021)
- Linking Climate and Development Policies – Levering International Networks and Knowledge Sharing (**CD-LINKS**) (2015-2019)
- Modelling and informing low-emission strategies (**MILES**) (2014-2017)
- Low climate impact scenarios and the implications of required tight emission control strategies (**LIMITS**) (2012-2014)
- Assessment of climate change mitigation pathways and evaluation of the robustness of mitigation cost estimates (**AMPERE**) (2011-2014)
- United States India Joint Center for Building Energy Research and Development: Grid responsive buildings (**CBERD**) (2012-2017)

NATIONAL

- Development of a prosumer driven integrated SMART grid (2018-2021)
- Risk and uncertainty assessment for Critical Railway Infrastructure due to impacts of Climate change (2018- 2019)
- Estimating Energy Sector GHG Emissions from Unorganized sectors (2016-2018)
- Coordination of Energy Sector Inventory (2011-2018)

MITIGATION: SECTOR/TECHNOLOGY ASSESMENT

- Electric Vehicles: Indian Market Study (2017-2018)
- Energy plantations: Integrating land-use, water, energy and sustainable development at local level (2013-2015)
- Techno-economic Assessment of CO2 Capture and Storage Potential in India: A Policy Perspective (2013-2015)
- Study of Energy Balance of Rural India Using Geospatial Inputs (Energy and Mass Exchange in Vegetative Systems) (2013-2015)

STATE

- Revision of Gujarat's State Action Plan on Climate Change (SAPCC) (2019-2020)

CITY

- Can Peri-Urban Agriculture help to feed "hungry cities" (funded by GiZ) (2020-2021)
- Economic cost of impacts and adaptation to extreme rainfall event induced flooding for selected Indian cities (2016- 2018)
- Linking GHG and local air pollution in Delhi (2018) – video case study
- Solar rooftop in India: Sky is the limit (2020) - video case study

Future Projects – Discussion for AIM Family

I. Modelling Non-CO_2 gases in all sectors (in Asian countries)

- In most of the past and current literature, the focus has been on CO_2 emissions.
- Non-CO2 emission also contribute a significant amount to the warming.
- Presently, agriculture and livestock related emissions contribute above 65% of Indian CH_4 emissions and above 90% of N_2O emissions.
- We can work on proposal to model non-CO2 gases in Asia to contribute towards Global Stocktake 2023.

Selected references on the work published in past:

Garg, A., Shukla, P.R. and Upadhyay, J. (2012). N_2O Emissions of India: An Assessment of Temporal, Regional and Sector Trends. *Climatic Change, 110 (3),* 755-782. doi: 10.1007/s10584-011-0094-9.

Garg, A., Kankal, B., and Shukla, P.R. (2011). Methane emissions in India: Sub-regional and sectoral trends. *Atmospheric Environment, 45,* 4922-4929. doi: https://doi.org/10.1016/j.atmosenv.2011.06.004.

Garg, A., Shukla, P. R., and Kapshe, M. (2006). The sectoral trends of multigas emissions inventory of India. *Atmospheric Environment, 40,* 4608-4620. doi: https://doi.org/10.1016/j.atmosenv.2006.03.045.

Garg, A., Shukla, P. R., Kapshe, M., and Menon, D. (2004). Indian methane and nitrous oxide emissions and mitigation flexibility. *Atmospheric Environment, 38 (13),* 1965-1977.

Garg, A., Shukla P. R., Bhattacharya S. and Dadhwal V.K. (2001). Sub-region (District) and Sector Level SO_2 and NO_x Emissions for India: Assessment of Inventories and Mitigation Flexibility. *Atmospheric Environment 35(4),* 703-713. doi: https://doi.org/10.1016/S1352-2310(00)00316-2.

II. Climate Change Mitigation: Mega-cities in Asia

- Cities produce 70 per cent of anthropogenic global carbon dioxide emissions.
- The 50 largest cities together emit greenhouse gases equivalent to 2,600 megatons of carbon dioxide per year. That is more than some countries. For instance, Russia emits about 2,200 MT and Japan about 1,400 MT per year.
- We can work on policy assessment towards mitigation in selected mega-cities in AIM partner Asian countries.

Thank you

amitgarg@iima.ac.in

Webpage: https://www.iima.ac.in/web/faculty/faculty-profiles/amit-garg