



A multi-model assessment of energy and emissions for India's transportation sector through 2050

Anantha Lakshmi Paladugula^a, Nazar Kholod^{b,*}, Vaibhav Chaturvedi^c, Probal Pratap Ghosh^d, Sarbojit Pal^{e,1}, Leon Clarke^b, Meredydd Evans^b, Page Kyle^b, Poonam Nagar Koti^c, Kirit Parikh^d, Sharif Qamar^e, Sangeetha Ann Wilson^{e,2}

^a Center for Study of Science, Technology and Policy, Bangalore, India

^b Joint Global Change Research Institute, Pacific Northwest National Laboratory, USA

^c Council on Energy, Environment and Water, New Delhi, India

^d Integrated Research and Action for Development, New Delhi, India

^e The Energy and Resources Institute, New Delhi, India

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ABSTRACT

This paper focuses on comparing the framework and projections of energy consumption and emissions from India's transportation sector up to 2050. To understand the role of road transport in energy demand and emissions, five modeling teams developed baseline projections for India's transportation sector as part of inter-model comparison exercise under the Sustainable Growth Working Group (SGWG) of the US-India Energy Dialog. Based on modeling results, we explore the developments in India's passenger and freight road transport, including changes in the modal shift and the resulting changes in energy consumption, carbon dioxide (CO₂) and particulate matter (PM_{2.5}) emissions. We find significant differences in the base-year data and parameters for future projections, namely energy consumption by transport in general and by mode, service demand for passenger and freight transport. Variation in modeling assumptions across modeling teams reflects the difference in opinion among the different modeling teams which in turn reflects the underlying uncertainty with respect to key assumptions. We have identified several important data gaps in our knowledge about the development of the transportation sector in India. The results of this inter-model study can be used by Indian policy makers to set quantified targets in emission reductions from the transportation sector.

1. Introduction

The transportation sector in India plays an important role in economic growth, catering to passenger and freight transport demands, with infrastructure development improving connectivity to all regions. With increases in urban population, household incomes, and travel for various activities, the total volume of transport demand has also increased tremendously.

Currently, the road transportation sector contributes to about 3% of India's GDP (GOI, 2016b). In 2015, 210 million vehicles were registered in India (GOI, 2016b). Cities with a population over a million people account for about 32% of all registered vehicles. While the road vehicle fleet has been growing by 10% per year during the last decade, vehicle ownership in India is much lower than in developed countries. There were 167 vehicles of all types per 1000 people and only 19 passenger

cars per 1000 people in India in 2015 (GOI, 2016b). In contrast, there are 500–700 vehicles and 300–400 cars per 1000 people in Organization of Economic Co-operation and Development (OECD) countries.

Private car ownership will continue to grow with increases in personal income. For example, data from the Global Transportation Roadmap model, developed by the International Council on Clean Transportation (ICCT, 2015), shows that vehicle ownership will increase from 0.02 vehicle/capita in 2010 to 0.23 vehicle/capita in 2050. The share of two-wheelers in the on-road fleet increased from 9% in 1951 to 74% in 2015, while the share of buses decreased significantly from 11% in 1951 to just 1% in 2015 (GOI, 2016a). Such factors as safety, time, cost, attitudes, and investment into public transportation are important for understanding the reasons to own personal vehicles in India (Verma, 2015).

The transportation demand will continue growing very fast. The

* Correspondence to: 5825 University Research Court, Suite 3500, College Park, MD 20740, USA.

E-mail address: nazar.kholod@pnnl.gov (N. Kholod).

¹ Present address: Clean Energy Ministerial, Paris, France.

² Present address: Nagoya University, Nagoya, Japan.

National Transport Development Policy Committee (NTDPC) Planning Commission estimated that the freight demand would reach 13,000 billion tonne-kilometers in 2031–32, an increase by a factor of seven from 2000 billion tonne-kilometers in 2011–12. The passenger transport demand will increase to 169,000 billion passenger-kilometers in 2031–32 from about 10,000 billion passenger-kilometers in 2011–12 (GOI, 2014b). This growth in India's vehicle fleet has created and will continue to create significant problems in energy demand and exhaust emissions.

To understand the role of road transport in energy demand and emissions, five modeling teams – four from India and one from the United States – are developing baseline projections for India's transportation sector as a part of inter-model comparison exercise within the ambit of Sustainable Growth Working Group (SGWG), a joint India-USA platform hosted by the National Institution for Transforming India (NITI Aayog) in India. The choice of modeling teams was guided by their contribution and participation in the SGWG exercise. The five teams have been included in the SGWG exercise based on their expertise on energy modeling as well as energy policy analysis, and the teams are well cited for their work on energy and climate policy in India. Capability for energy modeling is very limited in developing countries, and though there are other strong modeling teams in India, our choice was constrained by their participation in the SGWG exercise which was voluntary. The SGWG platform is open to all modeling teams. In the future, as the number of Indian modeling teams on this platform grows, inter-model comparison exercises could include many more teams. We believe that this paper with contribution from four Indian modeling teams and the US modeling team is a very useful starting point on which future inter-model comparison exercises for energy policy analysis can be built. These projections explore how the developments in transportation will shape energy demand and emissions of CO₂ and PM_{2.5}. By using multiple models to explore these issues, this research aims to identify key areas of uncertainty, robust policy-relevant insights that emerge across teams and analyses, and important research needs in the transportation sector. The use of multiple models also provides a framework for comparing tools, making improvements to models, and clarifying which results may vary across different studies conducted by different institutions.

In this article, we analyze energy demand and emission trends from passenger vehicles (two-wheelers [2W], three-wheelers [3W], passenger cars, or light-duty vehicles [LDV], and buses [Bus]) and from freight transport (light heavy-duty trucks [LHDT], medium heavy-duty trucks [MHDT], and heavy heavy-duty trucks [HHDT]) under the reference scenario. In other words, we estimate trends in India's road transportation sector assuming no policy changes in the future.

The article is structured as follows: Section 2 provides an overview of historical energy consumption and emissions in the transportation sector in India. Section 3 describes the framework for the model comparison and key inputs. Next, we present the results of the model projections for energy consumption by types of vehicles, CO₂, and PM_{2.5} emissions. Finally, we provide our conclusions for policy implications and discuss data gaps in transport modeling in India.

2. India transportation: energy consumption and emissions

Transport is the third-largest energy consumer in India after buildings and industry (IEA, 2015a). Energy consumption in the transportation sector is growing faster than in other sectors of the economy, and this growth is expected to continue. For example, the International Energy Agency (IEA) projects that transport will consume 22% of India's energy in 2040 compared to 14% in 2013 (OECD/IEA, 2015).

The transportation sector in India consumes about 70% of diesel and 99.6% of petrol in the country (PPAC, 2013). The demand for petroleum products has increased by more than 4% per year from 2010 to 2015. In 2015, India consumed about 185 million metric tonnes (Mt) of petroleum products, and the road transportation sector consumed about

19 Mt of petrol and 47 Mt of diesel.

India is the third-largest importer of crude oil in the world, and the level of oil import dependency reached 75% in 2015. The country has relatively modest oil resources and relies on import of crude oil (while also being a significant net exporter of refined products) (IEA, 2015c). The Indian government is concerned about its growing energy insecurity. Some efforts to reduce energy dependency include promotion of alternative fuels, such as biofuel (biodiesel and bioethanol) use in the transportation sector as stipulated in the National Policy on Biofuels (MNRE, 2015).

India's transportation sector contributes about 10% of total national greenhouse gas (GHG) emissions (GOI, 2015b), and road transportation contributes about 87% of the total emissions in the sector. In the urban context, the Central Pollution Control Board (CPCB) monitored 85 cities for the National Air Quality Index during June 2015. Of the 1898 values observed, 28% indicated good air quality, and 36% indicated satisfactory air quality (CPCB, 2015). However, according to the World Health Organization (WHO), India is home to 20 of 40 of the most polluted cities in the world as measured by particulate matter (PM_{2.5}) concentrations (WHO, 2016). The Global Burden of Disease study found that ambient particulate matter pollution caused about 590,000 premature deaths in India in 2013 (GBD, 2016). The number of premature deaths from exposure to PM_{2.5} emissions has increased by 50% from 1995.

With rapidly growing transportation demand being a major source of PM_{2.5} emissions in cities, air-quality problems will be even more critical in the future. Similarly, continued growth in GHG emissions from transport will increase the challenges India faces in meeting long-term climate-mitigation goals.

The results of our study can help understand key trends in passenger and freight transport developments and provide important insights for Indian policy makers as they try to decrease oil dependency, improve energy efficiency in the transportation sector, and reduce emissions from vehicles.

3. Methodology and data

3.1. Models used in the analysis

The five teams used a variety of models to project energy consumption and CO₂ emissions from road transport in India by 2050. The teams included the Center for Study of Science, Technology and Policy (CSTEP), Integrated Research and Action for Development (IRADe), The Energy and Resources Institute (TERI), Council on Energy, Environment, and Water (CEEW), and Pacific Northwest National Laboratory (PNNL). Note that different kinds of models have respective strengths and weaknesses; for a detailed comparison of the implications of different modeling types and structures, see Clarke et al. (2012).

CSTEP uses the India Multi Region TIMES model, a bottom-up energy system model (TIMES-The Integrated MARKAL EFOM System). The model uses a hybrid approach to supply-side and demand-side sectors; the transportation sector follows an accounting framework (Byravan et al., 2017). The transportation sector was considered as one of the demand-side sectors (CSTEP, 2015b). CSTEP's transport activity model is based on the India Energy Security Scenarios (IESS) 2047, a tool developed by NITI Aayog (GOI, 2015c).

IRADe uses the Activity Analysis model, which is a macroeconomic model that employs a social accounting matrix of 2007–08. The 130 sector economy from the social accounting matrix for 2007–08 (Pradhan et al., 2013) is aggregated to 28 sectors depending on their significance for energy consumption. The transportation sector in this model is represented by five sectors – railways, road transport, water transport, air transport, and other auxiliary supporting activities. The model is based on the input-output framework, and is useful in making macroeconomically and sectorally consistent demand projections.

TERI has developed an Excel-based national macro-model tool to

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