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FUEL EFFICIENCY OF ROAD TRANSPORT

CONTENTS

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Asian Institute of Transport Development
13, Palam Marg, Vasant Vihar,
New Delhi-110 057 INDIA
Phone: +91-11-26155309
Telefax: +91-11-26156294
Email: asianinstitute.del@gmail.com

Introductory Note

The world today is beset with many uncertainties. But there is one thing that is not: the dependence on fossil fuels causing immeasurable harm to our planet. The blind pursuit of the consumerist model of economic growth has led to a disproportionate emphasis on the volume of output of goods within the borders of a country and the increase in global population has meant an equally disproportionate emphasis on the rate at which this output is growing. This, naturally, has raised concerns about sustainability.

Within this overall set of concerns about sustainability is the smaller (but not small by any means) subset of transport. Globally, the increase in vehicles and the growing demand and means to travel has meant an unsustainable level of usage by the transport industry—whether road, rail, ship or air. The transport industry is the source of 23 percent of the CO_2 emissions related to the burning of energy. This number is set to grow alarmingly—by almost 50 percent by 2030 and by more than 80 percent by middle of this century.

Another noteworthy aspect of the problem is that although until recently India was not a major contributor to this form of environmental pollution, as economic growth accelerates and people have become more prosperous, it could become one of the major polluters. Its vehicle population was around 11 million in 1985-86; it could go up to more than 350 million in the next 20 years. One estimate places this even higher at 430 million in 2030. As far as GHG emissions are concerned, India's Ministry of Environment estimates that the share of road transport in total GHG emissions in India at about 85 percent.

Apart from such global welfare considerations, India also faces an immediate problem: the issue of economic sustainability. It imports almost 80 per cent of its crude oil. In 2013 it paid $145 billion from its export earnings of $307 billion, or over 6 per cent of GDP. Without this oil bill, India would have had a current account surplus of over nearly 5 per cent of GDP.

To add to the problem, India's net energy imports are slated to more than double to $230-240 billion in the next decade because of growth revival. However, depending on world prices of crude oil, the share of the import bill will fluctuate around 5-6 per cent of GDP.

The role of transport in reducing this share will be crucial, especially that of personalized transport. The set of articles, included in this issue of Asian journal, is designed to throw light on the key issues relating to the problem of sustainable transport in general and vehicle energy efficiency in particular.

Anumita Roychowdhury argues that an integrated approach is required to minimise energy resource utilization in transport sector in India, as transport sector is likely to occupy centre-stage in quest for reducing energy intense growth process. The article, thus, delineates measures that can be taken specifically in car and truck transport that can improve energy efficiency by a significant amount, including tackling with the issues around the dwindling popularity of public transport in India.

João Aguiar Machado focuses on Europe which he says is very dependent on imported oil for its transport needs. It spends 2.5 percent of its GDP each year to meet its oil needs. For its energy security, the European Commission feels that Europe should reduce its oil dependency, thus protecting it from oil-price volatilities as well. The article therefore, brings out strategies/options and policies adopted by European Commission in order to reduce dependency on oil, which also include policies for opting alternative fuels.

Luke Tonachel, Mia Diawara & Nehmat Kaur discuss the state of motor vehicles industry in India and strategies adopted for fuel efficiency in the country. Their article brings out the experience of the US, having faced similar problem decades ago. The experience of the US is an important roadmap for India in this regard. The article suggests that the US has achieved considerable success in lowering its transport industry's share in carbon emissions and energy use and also average fuel economy, in the country, improved from around 6 kmpl in 1975 to 10 kmpl in 2013. Carbon pollution has dropped 18 per cent in the last decade.

In related research K L Thukral and M Absar Alam focus on the fuel efficiency parameters of vehicles and the issues associated with it. The paper summarises the standards adopted by various countries in the world. In India, so far discussions have been restricted to only car manufacturers and the government. Therefore, the article advocates participation of all stakeholders which is crucial for formulation and implementation of effective standards and also calls for periodical review of the regulatory standards.

Gopal Duleep, in his paper, shows via cross-country data of new light vehicle fleets of 10 countries that there is considerable diversity of local forces affecting the characteristics of the fleet. The most obvious lesson from the data is that policies aimed at improving fuel economy have to be tailored to the forces obtaining in each country and a single policy such as fuel economy standards cannot be uniformly effective across all nations.

Zifei Yang, Josh Miller and Anup Bandivadekar provide an account over the role of transport sector in reducing global CO_2 emissions and oil consumption with respect to light duty and heavy duty vehicles. The paper also summarises the efficiency standards, policies and strategies for on-road vehicles in major vehicle markets.

Finally, Akshima Tejas Ghate and Sanjivi Sundar, in their paper, give an outline of the methodology for estimating life cycle energy consumption and CO_2 emissions of transport sector projects in India with an objective to make informed choices addressing environmental and energy security concerns while formulating transport sector policies/planning. The paper outlines case studies of three intra-city transportation systems-urban roads, Bus Rapid Transit Systems (BRTS), and Metro Rail and two inter-city systems-National Highway (NH) and long-distance passenger railway.

Dr. Ajay Mathur
Guest Editor

Tame Fuel Guzzling

Anumita Roychowdhury*

INTRODUCTION

Explosive increase in vehicle numbers, growing demand for travel and dependence on personal vehicles, unprecedented expansion of road-based freight and neglect of other long range freight and passenger modes, make energy management in the transport sector very difficult. India cannot afford unrestricted oil guzzling when faced with crippling economic burden of oil imports, energy's insecure future, and challenge of climate mitigation.

Globally, transport accounts for a little over a quarter of the global final energy use, according to the World Energy Statistics 2013 of the International Energy Agency (IEA). This is also responsible for more than 23 percent of the energy related Carbon Dioxide (CO_2) emissions and this will continue to rise in the future. Both are expected to rise by nearly 50 percent by 2030 and more than 80 percent by 2050. Transport guzzles more than 60 percent of the petroleum products in OECD countries and about half in non-OECD countries. These estimates from the IEA are daunting, given the fact that the climate stabilisation goals of 2 degree C temperature rise would need deep cuts in emissions from this sector.

India mirrors this trend. Transport sector is the largest user of oil in India–close to half of the total consumption. India's Integrated Energy Policy of 2006 states that if India needs to sustain 8-10 percent economic growth rate over next 25 years to meet human development goals, primary energy supply must increase by 3-4 times from 2003-2004 levels. Ministry of Petroleum and Natural Gas's new vision aims to achieve energy independence by 2030. But this target can remain elusive as nearly the entire requirement of crude oil, as much as 94 percent, will have to be imported by 2030, says IEA.

Asian Development Bank (ADB) forecasts that the total fuel consumption of on-road vehicles in India in 2035 can be six times over that of 2005 level. Transport energy demand has grown at 1.2 times the GDP growth rate. Amongst the transport fuels, nearly 98 percent of the total petrol stock and nearly 62 percent of India's diesel fuel is used up by vehicles.

Transport energy management is not possible if all modes of freight and passenger travel are not addressed together. Action in one area can be undermined by guzzling and

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* Executive Director, Centre for Science and Environment, New Delhi.

neglect in another. The energy security and climate resilience policy demands a string of solutions – vehicle fuel efficiency improvement; reduction in vehicle miles traveled; and combined improvement of long range multi-modal freight and passenger transport including railways, waterways and aviation to cut ravenous appetite for energy. But each of these segments has unique challenges and potential.

ENERGY EFFICIENCY: MORE MILES PER LITRE

A spillover risk of motorisation is fuel guzzling that requires effective regulations to improve energy efficiency of vehicles. Regulations are rapidly taking shape globally for quicker uptake of energy efficient technologies to get more miles out of a litre of fuel burnt. In India, the Integrated Energy Policy 2006 has proposed improvement in vehicle fuel economy by 50 percent by 2030. This can go down by nearly 86 million tonnes by 2031-32. This amounts to 65 percent of total consumption in 2010 and in terms of carbon savings it is equal to removing 7 million of four-wheeled vehicles. This policy has catalysed the rule-making for energy efficient vehicles in India.

Yet, despite being one of the major vehicle producing regions of the world, India has not yet implemented fuel economy regulations for all vehicle segments. The fuel economy regulations have been notified for cars but these have not been implemented yet.

Car fuel efficiency: Future energy demand in India's transport sector will be largely driven by cars, after the heavy duty segment. The IEA estimates show that the total car fuel demand in 2030 will be more than the total road transport sector consumption in 2007.

India can avoid a lot of future fuel guzzling if it leverages the advantage of its baseline that is less carbon intensive than that of the industrialized world. This is largely because of predominance of small cars. The small cars could also have been more fuel efficient if fuel economy regulations were in place earlier. In 2010 India's average fleet wide fuel economy is reported to be 141 gm of CO_2/km as opposed to the European regulatory target of 140 gm CO_2/km for 2012. Yet, India is at serious risk of losing this advantage and this race over the coming decade.

The Indian market is shifting steadily towards bigger and heavier cars that guzzle more fuel. Between 2009-10 and 2012-13 the average weight and engine size has increased by 6 percent. On an average, every year, the weight and size of new vehicles is increasing at the rate of 2 percent. Due to these trends the fuel economy (km/litre) has stagnated and even declined by 1 percent during the same period. Earlier, the fuel economy was improving at 2.8 percent a year. But now it is stagnating. Unless tamed with stringent fuel economy standards, this shift can cause major fuel economy penalty.

The Corporate Average Fuel Consumption standards for cars that have been notified by the Bureau of Energy Efficiency in 2013 are scheduled to be implemented in stages in 2017 and 2022. The approved standards have laid down a target of 18.15 km/litre (or 129.8 gm of CO_2/km) in 2015 and 20.79 km/litre (or 113 gm of CO_2/km) in 2020, after adjusting for increase in the average weight of the car fleet. This is not effective enough to leverage the advantage of the baseline.

Though India and Europe were nearly neck-to-neck in terms of fleet average CO_2 emissions in 2010, Europe would nearly halve the emissions by 2025, while India would cut it barely by 25 percent. Europe will leapfrog to 95 gm/km in 2020. Europe has moved ahead to propose a target range of 68-78 g/km for cars in 2025 – which is what the Indian two-wheelers meet today.

The unique trend of dieselization of the car segment further complicates the fuel efficiency challenge in India. Even though diesel cars are comparatively more fuel efficient than petrol cars, dieselization can cause more fuel and carbon leakages. Dieselisation is increasing average weights of the car fleet. High petrol prices have kept the bulk of the petrol car sales-as much as 87 percent-below 1200 cc engine. But more than 40 percent of diesel cars are above 1500 cc. SUV segment has the highest growth rate. Estimates from the ongoing studies of International Council on Clean Transportation have shown that the current shifts towards bigger cars and Sport Utility Vehicles (SUVs) and growing dieselisation can lead to a cumulative loss of 6.5 mtoe of energy between 2010 and 2020. This equals the fuel use of all four-wheeled passenger vehicles in 2006 – around 6.6 mtoe.

Moreover, on a life cycle basis more energy intensive diesel refining will emit more CO_2. Cheaper and low-tax diesel can incite more driving and more CO_2 emissions. A litre of diesel fuel has more carbon content than a litre of petrol. If more diesel fuel is burnt more CO_2 will be emitted in the air.

Energy regulations for cars therefore need a wider set of measures-both regulatory and fiscal-to plug the leakages and ensure climate and public health co-benefits.

Trucks and buses: Heavy duty vehicles are the major fuel guzzlers. The IEA estimates that these consume about 30 percent of global transport energy-trucks alone consume 24 percent. Even in India trucks and buses consume close to 30 percent. For a long time regulatory intervention in this segment has been ignored globally on the premise that commercial operations are price sensitive and that ensures uptake of optimum fuel efficiency measures.

Globally, it has now been proven that quicker uptake of new technologies and operational efficiency measures are possible if fuel economy regulations are in place.

Japan has already taken the lead, whereas Europe, China and the US are developing these regulations. Regulations can accelerate rapid uptake of a range of technical solutions, including weight reduction, improvement in aerodynamics, use of hybrid technologies, and drag reduction techniques, among others, to enable significant fuel savings.

India has started the process of crafting these regulations. But quick decision is needed to ensure that the industry optimizes technical roadmap to meet the combined goals of lowering toxic emissions and efficiency improvement. Several emissions control systems are needed to comply with the Euro V and Euro VI emissions standards to cut local air pollution like the diesel particulate trap or NOx[1] control systems that can have fuel economy penalty. This requires equally stringent targets for both to avoid trade-offs between efficiency and emissions.

Heavy duty sector will also require improvement in truck operations to cut guzzling. Overloading and operational inefficiencies plague this sector. Operational efficiency, control on overloading and eco-driving strategies are needed to address this concern and prevent erosion of gains from technology improvement.

Fuel efficiency performance of public transport buses has drawn a lot of attention in Indian cities. Nearly, all bus transport corporations in India are reporting either stagnation or decline in fuel economy of their bus fleet. This is a serious concern as fuel cost can make overall cost of bus operation unaffordable and work against the goals of public transport solutions. One of the reasons is the shift towards heavier and bigger buses with higher torque that use more fuel than smaller and low-powered buses of the earlier times. The Bangalore Metropolitan Transport Corporation's analysis shows higher fuel use as bus technology changed through the successive stages of emissions standards of Euro II to Euro III and Euro IV. Though the new bus technologies are not directly comparable with the older generation technologies, these demand fuel economy standards to minimize fuel economy penalty while changing the genre of the bus technology.

The nature of bus operations can also influence fuel economy performance of the bus fleet. Frequent stop and go driving pattern in cities on congested streets can cause more fuel losses. A recent study by CAI-Asia[2] shows that by reducing idling by 10 minutes Bangalore Metropolitan Transport Corporations can save 100 litres per bus or

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1. NOx is a generic term for the mono-nitrogen oxides NO and NO_2 (nitric oxide and nitrogen dioxide).
2. Clean Air Initiative for Asian Cities (CAI-Asia) is a non-stock, non-profit organization based in Manila.

Rs 3 crore annually. Also, with the help of improved driver's training, and maintenance a saving of Rs 23 crore annually is possible.

Diverse range of heavy duty applications and their typologies complicate the effort to develop fuel economy regulations and monitor operational parameters. But not developing regulations is not an option for India and needs to be addressed on a priority basis.

MOBILITY AND FUEL SAVINGS

Overall energy and carbon intensity of the road transport sector does not depend only on the vehicle technology and fuels. Increased dependence on personal vehicles can also upset energy budget. Growing affluence and car-centric urban design is increasing automobile dependence and influencing energy use in the sector. According to the researchers of the Indian Institute of Technology (IIT), Kanpur, by 2030-31, on an average, Indians will travel thrice as many kilometers as they traveled during 2000-01. Modal share of this travel will determine the energy sustainability. This will increase fuel consumption manifold as on a per passenger basis a car uses six times more energy than a bus.

Even though India has an advantage in a sizeable ridership of public transport and non-motorised transport, this share is declining steadily. If no policy interventions are made to protect ridership of public transport, constant increase in passenger mobility will increase the share of personal vehicle trips in India.

A study of 30 Indian cities, carried out under the aegis of the Union Ministry of Urban Development, estimates that the share of public transport trips may drop from 75.7 percent in 2001-02 to 44.7 percent in 2030-31; personal motorised travel will gain about 20 percent additional modal share until 2031. This study has found that cars and motorised two-wheelers account for approximately 65-90 percent of the total carbon-dioxide emissions that is directly linked with the amount of energy burnt by all vehicles in mega cities. An assessment by the Department of Transport in Delhi shows that without any intervention the CO_2 emissions from transport sector will increase by 526 percent in 2030 from 1990 level. A lot of it will be driven by the personal vehicle segment.

If policies succeed in reversing the trend and increasing the use of public transport significant fuel saving is possible. A study carried out by the ADB shows that, in Bangalore, an increase in the share of bus trips from 62 to 80 percent can save equal to 21 percent of the fuel consumed, lead to 23 percent reduction in total vehicle numbers and free-up road space equivalent to taking off more than four lakh cars from roads. As a result, the CO_2 emissions can drop by 13 percent.

There is also a strong correlation between trip length and share of walking and cycling in cities that have bearing on fuel use. A Centre for Science and Environment (CSE) analysis in Delhi has shown that how after introduction of flyovers and signal-free corridors, the large number of zero emissions short-distance non-motorised trips get converted to carbon intensive motorized trips.

The message is clear – engineer policy change to bring people and jobs closer to public transport systems. Improve walking, cycling and para-transit access to public transport nodes. Discourage car-centric infrastructure (flyovers, signal free roads, foot overbridges, etc.) that obstruct and destroy movement patterns needed to promote walk, cycle and public transport. Urban design interventions will require car restraint policies like parking and fiscal measures to influence travel choices.

The National Habitat Mission Standard for transportation under the National Climate Action Plan has set guidelines for compact city, public transport and non-motorised transport along with pricing and taxation measures for car restraint. But cities will have to take steps to integrate such measures with land-use and transportation planning on ground.

LONG-RANGE MULTIMODAL TRANSPORT

The other piece of the transport energy jigsaw is the challenge of balance between on-road (trucks) and non-road freight and passenger movement (railways, waterways and aviation). This is a serious missing link in the energy policies today.

Foremost, the shift of freight from railways to trucks has added to the energy stress. Over the years, the share of railway freight has declined from 88 percent to 40 percent; but road freight has increased from 12 percent to 60 percent. Passenger trips by railways have also dropped from 68 percent to 20 percent. The medium and heavy duty vehicles are now increasing at 16 percent CAGR (Compound Annual Growth Rate).

The transportation energy demand can grow even faster than anticipated, if all of the new highway projects, currently under consideration, are completed and roadways continue to grow. A diesel truck consumes more than three times energy compared to rail on diesel per net tonne kilometer. Road based freight can lock up enormous amount of fuel and carbon.

There is no holistic vision yet to plan multi-modal transport spine of the country-road, rail, water, and air, to reduce energy impacts of the transport sector. Thus, several potential modes like waterways get neglected. Inland waterways have significant advantages over all other transportation systems. A barge can carry cargo equivalent of 15 rail wagons or 60 truckloads worth of goods. It is cheaper than railways and roadways. It is also more fuel efficient-a litre of diesel would carry 105 tonnes over a kilometre through waterways, 85 tonnes through railways and 24 tonnes through roadways. It emits much less-an inland transport water vessel emits less than 50 percent of carbon a lorry emits. The Indian Network on Climate Change Assessment estimates that inland navigation caused one percent of total transport Greenhouse Gas (GHG) emissions in 2007.

There is no clear revival plan for waterways. Poor navigability of rivers-fewer days of navigability, limits the transportation potential of the rivers. For instance, at Allahabad, navigability of the Ganga is restricted to 140 days for large vessels with the least available depth of 1.5 metres. This allows only low capacity barges on national waterways. The proposed Inland Vessel Building Subsidy Scheme for augmentation of vessel fleet and technological upgradation and other plans need to take off to facilitate river conservancy, including dredging and new irrigation-cum-navigation canals, among others.

The saga of the transport energy solutions will remain incomplete, if the aviation sector is not included in the transport energy management plan. Indian civil aviation sector has witnessed phenomenal growth rate of about 40 percent annually (2008-09 – 2009-10) when only 1 percent of the population boards planes. Consumption of Aviation Turbine Fuel has increased rapidly and GHG emission from aviation has more than trebled since 1994. The IEA (2010) estimates an exceptional increase in emissions of 165.7 percent between 1990 and 2008 in India, compared to the world average of 76.1 percent. High passenger occupancy and relatively younger fleets of the Indian private airlines allow more efficient operations.

In view of the future growth, a roadmap is needed to improve technology and operational practices; modification in climb, cruise and descent cycle of air planes; demand management; air transport management, airport management, and "Route Dispersion Guidelines" to minimise planes operating on routes with a low load factor among others.

SIGNPOST

India has not yet been able to put together all the pieces of the transport energy jigsaw for the big solution. Even as India prepares to meet its voluntary target to the United Nations Framework Convention on Climate Change (UNFCCC) to reduce energy intensity of its growth by as much as 25 percent by 2020, transport sector needs to occupy the centre-stage of this mitigation plan. India needs serious policy and technical preparedness for rule making and enforcement to find a low carbon and energy secure pathway.

The EU's Strategy for Reducing Emissions and Oil Dependency in Transport

João Aguiar Machado*

INTRODUCTION

Europe relies heavily on imported oil for its mobility and transport. The share of oil-based fuels in transport energy demand now stands at around 94 percent. Europe spends up to 1 billion euros per day on oil imports and burn more than half of this oil in transport vehicles, aircrafts and vessels. This equals approximately 2.5 percent of GDP and 7 percent of average household expenditure.[1] The European Commission thinks that European Union (EU) should not continue to expose itself to the risk of oil-price volatility and dependencies on some importers.

The EU's strategy to reduce the oil dependency of transport builds on a number of complementary initiatives, including (1) the introduction of alternative fuels, (2) encouraging greener and more sustainable urban transport, (3) making the best possible use of intelligent transport systems, (4) encouraging the use of a combination of different modes of transport (multimodality) (5) investing in research and innovation as well as (6) a charging policy.

THE CORNERSTONES OF THE EU STRATEGY

The 2011 European Commission White Paper on Transport sets out the Commission's transport policy for the current decade.[2] When the Commission adopted the White Paper on Transport, the goal was to define a strategy that would allow Europe to meet the challenges of growing congestion, increasing oil price and excessive emissions of Greenhouse Gas (GHG) emissions and local pollutants, while at the same time preserving people's mobility, business competitiveness and technological development.

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* Director-General for Mobility and Transport, European Commission.

1. European Environmental Agency, Expenditure on personal mobility (TERM 024) – Assessment published Jan 2011, available at: http://www.eea.europa.eu/data-and-maps/indicators/expenditure-onpersonal-mobility-2/assessment
2. "Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system", COM(2011) 144 final, 28.3.2011, http://ec.europa.eu/transport/themes/strategies/doc/2011_white_paper/white_paper_com(2011)_144_en.pdf

The European Commission is certainly ambitious, but it remains convinced that it is not unfeasible to transform the transport system in a way that meets all of the above concerns. The cornerstone of this transformation is the reduction of transport's oil dependence. If realized, the proposals contained in the Transport White Paper will dramatically reduce Europe's dependence on imported oil and cut carbon emissions in transport by 60 percent by 2050.

Key goals to be achieved by 2050 as set out in the White Paper include:

- Phasing out conventionally-fuelled cars in cities;
- 40 percent use of sustainable low carbon fuels in aviation; at least 40 percent cut in shipping emissions;
- A 50 percent shift of medium distance intercity passenger and freight journeys from road to rail and waterborne transport;
- All of which will contribute to a 60 percent cut in transport emissions by the middle of the century.

In line with this approach, the very recent Commission Communication "European Energy Security Strategy"[3] calls for reducing energy demand or switching to alternative fuels in the very short term.

In 2008, for the first time, a reduction was registered in transport GHG emissions. This positive new trend continued during the following years while economic activities recovered from the downturn. By 2030, we hope to bring emissions down by 20 percent from the 2007 peak, acting on two main levers: a more balanced use of all transport modes and the introduction of new technologies for energy efficiency and for the use of alternative fuels.

This is not an expensive whim for the sake of EU's environmental commitments, but a sound economic strategy. Transport activity is also growing fast in emerging economies and we are all facing similar constraints on energy use and emissions. The President of India, Shri Pranab Mukherjee, announced in his speech last June to the Parliament that cleaner fuels will be promoted to bring down pollution levels in Indian cities. In fact, the entire world will be asking for clean mobility technology and EU must be capable of providing it also for the sake of economic growth.

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3. Communication from the Commission to the European Parliament and the Council: European Energy Security Strategy, COM (2014) 330, 28.5.2014.

INTRODUCING ALTERNATIVE FUELS

The transport sector has a high priority for the introduction of alternative fuels substituting oil-based products, as motorised transport at present highly depends on oil as an energy source and as fuel. The 2011 White Paper on Transport specifically requested a sustainable alternative fuels strategy including also an appropriate infrastructure. Following this request, the Commission has set out a series of measures to reduce GHG emissions and consumption of transport fuels, including an alternative fuels strategy.

The objectives of introducing alternative fuels in the EU are primarily:

- Improvement in security of energy supply by source diversification and oil substitution;
- Reduction of GHG emissions on grounds of climate change concerns.

Energy savings, low emissions, better air quality, reduced congestion and technological leadership can all go hand-in-hand; and alternative fuels, together with increased transport efficiency, are an indispensable tool.

In early 2013, the European Commission adopted a proposal for a legislative package entitled "Clean Power for Transport". The cornerstone of the package is a Directive (EU legislation that has to be transposed into national law by all Member States) on the roll-out of alternative fuels infrastructure, which addresses the currently missing link to reach a sustainable transport sector. The legislative package putts in place a standardized recharging and refuelling infrastructure to allow EU-wide mobility with alternative fuel vehicles.

EU Member States will have to take necessary measures so that the Directive can start taking effect from 2020. The Directive mandates the build-up of infrastructure for the alternative fuels that are most promising in reducing both oil dependence and emissions: electricity, natural gas and hydrogen.

Even with the current EU energy mix an electric vehicle emits 30 percent less CO_2 than a vehicle with a combustion engine.[4] The increasing use of renewable energy will further reduce the environmental impact of electro-mobility. A lot of progress has indeed

4. CO_2 emissions can be significantly reduced by replacing internal combustion engine vehicles using petrol or diesel by electric vehicles. On the basis of the CO_2 intensity of the European electricity grid of 430 g CO_2 /kWh (JEC study), CO_2 emissions are reduced by 30 percent, Report of the European Expert Group on Future Transport Fuels, January 2011, http://ec.europa.eu/transport/themes/urban/cts/doc/2011-01-25-future-transport-fuels-report.pdf

been made in the recent past regarding electric cars and manufacturers are in the process of bringing to the market an increasing offer of plug-in hybrid and full-electric cars.

Natural gas is a mature and readily available technology for both road and waterborne applications. There are a number of cars and vans available in the market right now and it is the most promising alternative for trucks, as well as maritime and inland waterway vessels.

Liquid Natural Gas (LNG) is an important element in the effort to comply with sulphur emission reduction legislation: 0.1 percent in Sulphur Emission Control Areas as of 1 January 2015 and 0.5 percent in all EU waters as of 1 January 2020.

Alternative fuels – Project examples

- The 11 industrial partners of the Blue Corridor demonstration project for LNG will put 100 LNG trucks on the road and open 14 LNG refuelling stations.
- The Costa project aims at developing the framework conditions for the use of LNG for ships in the Mediterranean, Atlantic Ocean and Black Sea areas. If Costa's policy recommendations are implemented, it is expected that CO_2 emissions from shipping could drop by 25 percent in 2020 and by 50 percent in 2050. Considering air pollutants, the use of LNG would eliminate SOx and reduce NOx by 90 percent.

Hydrogen is a very promising alternative fuel. It can be produced from any primary energy source, decoupling the vehicle fuel from the energy source. Its production through electrolysis or other renewable sources can contribute significantly to the decarbonisation of transport and, when used in fuel cells, it delivers a clean, energy efficient, zero-emission and low noise fuel. Several EU Member States have extensive deployment plans even if the build-up of a hydrogen refuelling infrastructure is intended to stay voluntary in the Directive on the roll-out of alternative fuels infrastructure, and several car manufacturers plan to market fuel-cell electric vehicles as of 2015.

Biofuels, in particular 2nd and 3rd generation, are another option for the long-term substitution of oil in transport. They could technically substitute oil in all transport modes and are compatible with already existing power train technologies and re-fuelling infrastructures. Therefore, EU-wide research and development is giving high priority to the development of advanced biofuels. They have a more favourable GHG balance, use less land, and can be blended with petrol or diesel at any blending ratio. This is the only solution for aviation at this stage.

In order to improve the use of alternative fuels, the ongoing revision of EU legislation on maximal weights and dimensions of lorries will open up the possibility to manufacturers to design greener vehicles with more aerodynamic shapes and a length extension, permitting the introduction of fuel saving systems like waste energy recovery.

MAKING URBAN TRANSPORT GREENER AND MORE SUSTAINABLE

Public transport continues to play a very important role in our transport policies. Indeed, urban mobility figures prominently in the 2011 White Paper on Transport which calls for achieving essentially CO_2-free city logistics in major urban centres by 2030, and for phasing out the use of conventionally-fuelled cars in cities by 2050. This requires a transformation in the use of vehicles, more efficient and lower impact city logistics, and a reduction in urban road congestion, combined with a broad take up of cleaner vehicles powered by alternative fuels and drive trains.

The European Commission is stepping up its support to towns and cities with a package of measures on urban mobility[5], adopted in December 2013. These measures are about reinforcing the exchange of best practice between cities in different countries, providing targeted financial support and investing in research and development, in particular:

- ***Sharing experience and show-casing best practices:*** The Commission will set up in 2014 a European platform for sustainable urban mobility plans. This platform will help cities, planning experts and stakeholders to plan for easier and greener urban mobility;
- ***Providing targeted financial support:*** Through the European structural and investment funds, the EU will continue to support urban transport projects, in particular in the less-developed regions of the EU;
- ***Research and Innovation:*** Initiatives in the framework of the Horizon 2020 research programme will allow cities, companies, academia and other partners to develop and test novel approaches for urban mobility.
- ***Involving the Member States:*** The Commission calls on Member States to create the right conditions for towns and cities to develop and implement their sustainable urban mobility plans;
- ***Working together:*** The Commission puts forward specific recommendations for coordinated action between all levels of government and between the public and the private sector in the following four areas;

5. Communication from the Commission: "Together towards competitive and resource-efficient urban mobility", COM(2013) 913 final, 17.12.2013

Urban logistics; urban access regulation; deployment of intelligent transport system (ITS) solutions; and urban road safety.

INTELLIGENT TRANSPORT SYSTEMS

Intelligent transport systems (ITS) contribute significantly to decarbonisation by mitigating consumption, improving road safety and reducing congestion consequences. The deployment of ITS services is estimated to bring about a reduction of 10 to 15 percent of GHG emissions. To define and harmonise the interoperable deployment and use of ITS in road transport and interfaces with other modes across Europe, the ITS Action plan[6] and the ITS Directive[7] define priorities and actions to take. I would like to highlight two areas of concrete decarbonisation potential of ITS:

Consumption: traffic information (for example real-time information on dynamic road signs or onboard navigation systems) and eco-driving services (such as automatically stopping engines) contribute to reducing energy use.

Urban mobility – Project examples

- The ZeEUS project (Zero Emission Urban Bus System) aims at extending the use of fully electric buses to a wider part of the urban bus network. Developing electric vehicles of large capacity and creating an infrastructure able to provide the required charging energy will facilitate the market up-take of electric buses in Europe. ZeEUS covers innovative electric bus solutions with different electric power train systems to be demonstrated in 8 major European cities.
- The FREVUE project (Freight Electric Vehicles in Urban Europe) aims to demonstrate to industry, consumers and policy makers how electric freight vehicles can provide a solution to many problems of urban logistics.

These projects contribute to closing the link between electro-mobility and public transport and between private mobility and freight transport. They will make important contributions to the market take-up of electro-mobility solutions across different modes of transport.

Congestion: advanced traffic management systems include real time traffic information, multimodal travel information services, infrastructure to vehicle communication and vehicle to vehicle communication, dynamic speed limits, dynamic

6. Communication from the Commission: Action Plan for the Deployment of Intelligent Transport Systems in Europe, COM(2008) 886 final, 16.12.2008
7. Directive 2010/40/EU of 7 July 2010 on the framework for the deployment of Intelligent Transport Systems in the field of road transport and for interfaces with other modes of transport

traffic light synchronisation, green waves, slot management and freight trip planning systems.

MULTIMODALITY

Multimodality is the combination of different modes of transport to travel or to transport goods from A to B. Supported by ICT applications, it will allow a better exploitation of the capacity and relative advantages of the overall transport system.

Multimodal transport supports the aims of less congestion, fewer emissions, road traffic safety and energy savings especially in countries with heavy road traffic by directing a considerable amount of long distance transport away from the road, be it to rail, inland waterways or short-sea shipping. As a matter of fact, multimodal transport is one of the main ways to achieve the aim of the White Paper to reduce 50 percent by the medium-long distance road transport by 2050.

Multimodal transport is advantageous in terms of better capacity and infrastructure utilisation, but per definition makes transport chains more complex and interdependent with possible negative impacts on costs, timing and reliability. Multimodal transport also has an 'image' problem, meaning shippers do not consider it as an alternative to road transport. We are addressing these issues from different angles: increasing technical interoperability, raising awareness, and providing incentives for investment, for example by pooling private and public resources for research, like in the recently launched Shift2Rail initiative.

INVESTING IN TRANSPORT INFRASTRUCTURE

Multimodal transport is also addressed from an infrastructure point of view. The revised guidelines for the Trans-European Network for Transport (TEN-T)[8] foresees enhanced multimodal infrastructures in combination with intelligent management systems and the establishment of corridors in which freight moves on key axes using modern technologies and integrated transport chains in an efficient and environmentally friendly way. Likewise, the revised TEN-T guidelines require that the network shall enable the decarbonisation of all transport modes by stimulating energy efficiency as well as by the introduction of alternative propulsion systems and provision of corresponding infrastructure. Thirdly, the guidelines require that core inland and sea ports, airports and roads provide for the availability of alternative clean fuels.

8. Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network and repealing Decision No 661/2010/EU, http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32013R1315

The Connecting Europe Facility (CEF)[9]-providing EU budget for the period from 2014 to 2020 to invest in transport, energy and ICT infrastructures – is the funding instrument. On top of offering EU grants, the CEF is also designed to attract and guarantee private sector involvement. For the European core network, the CEF makes the deployment of these new technologies and innovation, including infrastructure for alternative clean fuels, eligible for grants.

RESEARCH AND INNOVATION

New technologies, such as electric, natural gas or fuel cell vehicles open up new perspectives and create growth opportunities for the automotive and transport industry, so important for the well-being of our economies. Alternative fuels therefore contribute to the overall ambition of growth and jobs. That is why the Commission will continue supporting research and demonstration for alternative fuels in the Horizon 2020 programme[10] and the European Clean Vehicles Initiative[11].

From the outset the Horizon 2020 programme – the new research and innovation programme of the European Commission – has devoted attention to alternative fuels. In its work programme 2014-15 the section "Green Vehicles" focuses specifically on research, technological developments, innovation and demonstration in support of improvements in energy efficiency of road transport vehicles and the use of new types of non-conventional energies in road transport. The scope of the activities includes advanced power-train technologies and new vehicle architectures, as well as the interfaces between the vehicles and the recharging infrastructure, which will also need to be taken into account when developing standards.

ROAD CHARGING

Road charging is another way of providing incentives to users to purchase cleaner vehicles. Existing road charging schemes in the EU charge for the cost of infrastructure usage and charges vary according to the Euro-class (emission classification) of vehicles. However, charging users for external costs (pollution, noise and congestion), in addition to infrastructure costs is a more effective instrument, in combination with distance-based charges, to incentivise the use of cleaner vehicles. The Commission currently envisages tabling a new proposal on road charging with renewed emphasis on these points.

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9. Regulation (EU) No 1316/2013 of the European Parliament and of the Council of 11 December 2013 establishing the Connecting Europe Facility, amending Regulation (EU) No 913/2010 and repealing Regulations (EC) No 680/2007 and (EC) No 67/2010, http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:32013R1316
10. Horizon, 2020, European Commission, http://ec.europa.eu/programmes/horizon2020/en
11. European Green Vehicle Initiatives, http://www.egvi.eu/

CONCLUSION

All these initiatives and in particular the Directive on the roll-out of alternative fuels infrastructure show the political will at the European Commission, the European Parliament and EU Member States to go forward with reducing our dependence on oil for transport, whilst at the same time making our transport greener and more sustainable. The measures that we are taking create a favourable regulatory framework to provide manufacturers, investors and consumers with the necessary confidence that alternatives to oil which are available are not only to stay but will become increasingly important over the years and decades to come.

US Fuel Efficiency Standards: History, Benefits and Implications for India

Luke Tonachel[1], Mia Diawara[2] and Nehmat Kaur[3]

FUEL EFFICIENCY STANDARDS IN INDIA

Vehicle sales in India have skyrocketed in recent years, rising from 10 million vehicles sold in 2007 to nearly 16 million sold in 2012. The total number of vehicles on India's already congested roads will reach a whopping 250 million by 2025, more than double from the number of vehicles that can be seen today. The growth of the country's light duty vehicle (LDV) fleet, which excludes lorries, but includes both small and large four-wheeled passenger vehicles, will usher in a variety of impacts—both local and international. These range from increased air pollution levels involving potential health risks to rising carbon dioxide (CO_2) emissions that will impact the environment on a global level.

Although India's LDV fleet is small relative to both its population and also to the fleets of other countries, it currently remains the largest fleet in the world without efficiency or CO_2 emission standards in place, and India stands alone as the only car manufacturing country without such regulations. With the current passenger vehicle averaging only 16 kilometers per litre (kmpl) of fuel (~37.63 miles per gallon (mpg), there are great improvements to be made to the Indian vehicle fleet, and the institution of fuel efficiency standards can catalyze the innovation and development necessary not only to lower CO_2 emissions, but also to ensure that India remains competitive in the global automobile market and to protect Indian consumers from the volatility of petroleum prices.

India took the first step towards instituting fuel efficiency and carbon emission standards in February of 2014 when the country's Bureau of Energy Efficiency (BEE) proposed new norms regarding fuel use in passenger vehicles. The standards, referred to as Corporate Average Fuel Consumption (CAFC), mandate a 15 percent reduction in vehicle fuel consumption by 2020 for LDVs, which would lead to an average mileage of 18.2 kmpl (42.8 mpg) by 2016-2017 and 22 kmpl (51.74 mpg) by 2021-2022 (Pal, Chauhan

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1. Senior analyst and director of Clean Vehicles and Fuels Project, The Natural Resources Defense Council, New York.
2. Summer MAP Fellow, The Natural Resources Defense Council, New York.
3. India Representative, India Initiative, The Natural Resources Defense Council, New York.

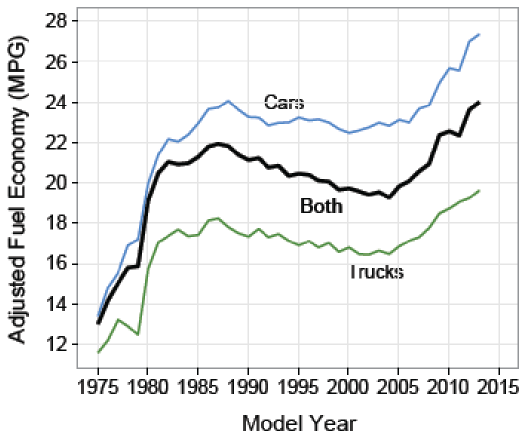
2014). A star-based labeling system will assign an efficiency rating (from one to five) to cars in eight different weight categories. It is projected that these measures will save around 20 million tons of fuel (~ 400,000 barrels per day) by 2025, decreasing petroleum demand by about 7 percent and simultaneously cutting India's CO_2 emissions significantly (Bandivadekar, 2014).

The United States (US) implemented similar fuel efficiency standards several decades ago, and since then, the country has witnessed the contribution of such measures to decreased CO_2 emissions, economic stimulation, and innovation in the automotive industry. Prior to the development of the first set of standards in 1975, the US found itself in a position similar to that in which India finds itself today as more and more families started purchasing their first vehicles, and the number of automobiles on the road skyrocketed, along with consumption of petroleum. The US' progress in the realm of energy efficiency, and the path the country took to arrive at where it is today provides lessons and practices that India can modify and implement itself.

UNITED STATES: FUEL ECONOMY CONTINUES TO RISE

The US fuel economy has seen tremendous growth over the past few years. New cars and trucks are poised to continue to set new records in fuel efficiency according to the latest Fuel Economy Trends report from the US' Environmental Protection Agency (EPA). EPA, which is the official keeper of automotive fuel economy and emissions data for regulatory compliance, gathers automaker submissions and reports automotive efficiency trends annually. The most recent report "Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 through 2013" provides a comprehensive history and highlights recent advancements. The report states that unadjusted laboratory average fuel economy values have risen from 13.1mpg (5.57 kmpl) in 1975 to 24 mpg (10.2 kmpl) in 2013 (see Figure 1). This value is a record high since the agency first began to keep track of such data several decades ago (Alsonet al. 2013).

Figure 1: New Vehicle Fleet Average Fuel Economy (Adjusted to real-world driving)



Source: United States Environmental Protection Agency

Carbon pollution has also been significantly reduced with the introduction of new, more efficient automobiles to the fleet, having dropped 18 percent since the 2004 model year[4] (Alson et al. 2013). Such improvements are projected to continue well into the future, as automakers innovate to meet stronger clean car and fuel economy standards that roughly double fuel efficiency by 2025. It can be expected that the number of fuel-efficient vehicles that will be made available to consumers will grow in quantity and variety.EPA finds that there are more and more fuel-efficient conventional vehicles, and that this increase has been accompanied by a doubling in the number of hybrids since 2007.

Making such progress was a slow and deliberate process, and in order to fully understand the developments that have been made in the fuel economy of the US LDV fleet, it is important to understand the motivations and history that guided them.

BRIEF HISTORY OF FUEL EFFICIENCY IN THE UNITED STATES

The US' efforts to improve the fuel economy of its LDV fleet began long before such noticeable changes, as those witnessed over the past few years took place. The first standards were implemented in 1978 under the Energy Policy Conservation Act, which established the Corporate Average Fuel Economy (CAFE) standards for passenger vehicles and light-duty trucks. The Act came in response to the 1973 oil crisis, which resulted from the embargo put in place by the Organization of Arab Petroleum Exporting Countries (OAPEC) that caused petroleum prices to triple in about 1 year from $4 (Rs. 240) to $12 (Rs. 720) per barrel. The Energy Policy Conservation Act had a near term goal of doubling the fuel economy of new cars from their 1974 measurements of 13.6 mpg (5.78 kmpl) to 27.5 mpg (11.69 kmpl). Many car companies rose to the occasion, making staggering changes in the fuel efficiency of their vehicles, and the fuel efficiency of each model year rose until the 1985 near term benchmark (DieselNet, 2013).

Unfortunately, after 1985, improvements in fuel efficiency got stalled significantly, and for the next two and a half decades, the US LDV fleet's fuel economy was stagnant, fluctuating slightly but not exhibiting any prominent growth trends. Gas-guzzling sport utility vehicles (SUVs), which were classified as trucks and held to low-fuel economy standards, became popular and drove down the overall light-duty fleet average. Meanwhile, constant lobbying by automakers kept away the federal government from raising fuel economy standards.

Recognizing the energy security impacts of the US' heavy and growing reliance on oil, policymakers finally took action. The 2007 Energy Independence and Security Act

4. The model year of a product is a number used worldwide, but with a high level of prominence in North America, to describe approximately when a product was produced. The model year and the actual calendar year of production rarely coincide.

mandated that federal regulations adopt the first increase in passenger car fuel economy in decades. Federal regulatory agencies also recognized the initiatives of states, led by California, to set greenhouse gas (GHG) emissions standards on new cars and light trucks. In 2010, the United States Department of Transportation (US DOT) and EPA jointly set new fuel economy and GHG emissions standards for model years 2012 through 2016 that raised the new car and light truck fleet average to 34.1 mpg (14.5 kmpl). The 2012-2016 standards broke the streak of stagnancy in fuel efficiency, and the 2012 model year was a landmark, introducing unprecedented progress to the 2012 fleet.

A GAME-CHANGING BREAKTHROUGH: THE 2012 MODEL YEAR

The 2012 model year brought significant changes in automobile fuel efficiency, not only for fleet-wide average fuel economy, but for the sales of hybrids and plug-in electric vehicles (EVs) as well. Automobile dealers' showrooms began to feature a previously unprecedented variety of fuel-efficient cars and light-duty trucks for consumers to choose from. Just as had been intended, as the federal clean car and fuel economy standards began to take root, they worked to spur automaker investment in fuel-efficiency, decreasing petroleum demand and helping consumers cope with rising fuel prices.

According to the EPA's latest trends report, model year 2012 fuel economy measurements reached 23.6 mpg (10.03 kmpl), which is 1.2 mpg (.51 kmpl) higher than the previous record of 22.4 mpg (9.52 kmpl) for model year 2011. For 2012, the first year of the national clean car and fuel economy program, automakers exceeded the expectations of the federal regulators. In the CAFE compliance laboratory test cycle, model year 2012 vehicles averaged 29.0 mpg (12.33 kmpl), topping the 28.7 mpg (12.20 kmpl) level projected by the US Department of Transportation (DOT) and EPA.

These changes saved US consumers a tremendous amount of money that would have otherwise been spent on purchasing fuel. If 2012 vehicles had stagnated at the 2007 efficiency level of 20.6 mpg (8.76 kmpl), for instance, drivers would have spent another $8 billion (Rs. 48,000 crore) a year to buy over 2 billion gallons of additional fuel annually. Not only did the improvements ensure that consumers saved money, but, according to University of Michigan researchers Michael Sivak and Brandon Schoettle, they also helped reduce carbon pollution from cars by 25 million metric tons in 2012-a quantity equivalent to the emissions of 6 US coal-fired power plants over a year.

Automobile market analyst Alan Baumhas deduced that the fuel economy increase of model year 2012 was unique compared to past instances because the associated average efficiency increase was not primarily driven by an increase in small car sales. While new small car offerings like the Chevy Cruze were very popular at the time, improved mid-size vehicles (which grew 0.8 percent points from 2011) were also strong contributors to a better fuel efficiency average. Baum compared the number of popular fuel-efficiency models available today to those that were offered in 2009 (Table 1) and found that the number of vehicles with improved efficiency demonstrated increases in all three LDV categories (compact/subcompact, midsize and crossovers).

Table 1: Number of Popular Nameplates with Improved Efficiency*

	Model Year 2009	**Model Year 2013**
Compact/Subcompact > 30 mpg	5	17
Midsize > 25 mpg	6	9
Crossovers > 20 mpg	17	35
Total	**28**	**61**

Source: Baum and Associates
* "Popular" nameplates are defined as having sales of at least 30,000 units annually. Fuel economy levels are combined city and highway window sticker values based on EPA ratings.

The 2012 model year also saw a huge growth in offerings of fuel-efficient hybrids and EVs. According to Baum, model year 2012 hybrid sales climbed 55 percent from model year 2011. Importantly, the number of hybrid models available to consumers increased by 8 in one year, reaching 41 in 2012, which is nearly double the number, offered just three years earlier in 2009. Model year 2012 was just the second year of availability of mass-marketed EVs including the Nissan Leaf and Chevy Volt and sales were three times those of the prior year.

As will be discussed in greater detail in a later section of this paper, EVs are poised for strong growth because they not only reduce CO_2 emissions, but also offer consumers an economically feasible option—as the gasoline equivalent to electricity prices is about US$1 per gallon. We can look forward to record-breaking years of green cars through the decade ahead.

Indeed, 2012 was a year of many changes, and paved the way for even more stringent standards in fuel efficiency that have led to even greater improvements in the US vehicle fleet. Finalized standards for 2025 were reached just recently, and they take the progress made in 2012 to even a higher level.

THE UNITED STATES' MOST RECENT FINALIZED STANDARDS

In August of 2012, US DOT and EPA finalized new automobile standards that reach the equivalent of 54.5 mpg (23.17 kmpl) in 2025. A historic achievement, the full impact of these standards has yet to be witnessed, but they will undoubtedly lead to a variety of benefits for consumers, the US' oil dependence, the environment, and jobs.

The standards for model years 2017 to 2025 extend the LDV National Program that ramped up fuel economy and cut GHG emissions for model years 2012 to 2016. The National Program applies to light duty cars and trucks in two phases, 2012-2016 and

2017-2025, and includes both LDV CAFE and GHG emissions standards. Under the finalized standards, new fleet average fuel efficiency improves by about 4.5 percent per year. Starting from a 2016 baseline of 34.1 mpg (14.5 kmpl), the CAFE standard is 35.0 mpg (14.88 kmpl) in 2017 and 49.7 mpg (21.13 kmpl) in 2025.The GHG emissions standard starts from a 2016 baseline of 250 grams CO_2 per mile (g/mi) and ramps down to 243 g/mi in 2017 and 163 g/mi in 2025. If all emissions reductions are achieved through technologies that improve fuel economy and reduce fuel consumption, then the fleet would achieve 54.5 mpg (23.17 kmpl) in 2025.

According to the agencies, a fleet that meets the model year 2025 clean car and fuel economy standards will achieve about 40 mpg (17 kmpl) in real-world driving. Today, the fleet of vehicles on the road average about 22 mpg (9.4kmpl), so the efficiency of new vehicles will roughly double.

As far as technological developments go, 2025 is expected to bring the widespread deployment of improvements to gasoline internal combustion engine vehicles including downsized, turbocharged engines with direct injection and sophisticated valve controls; cooled exhaust gas recirculation; eight-speed dual clutch transmissions; fuel-efficient tires; improved aerodynamics; improved air conditioning systems; and greater use of light-weight, high-strength steel, aluminum and magnesium parts.

To further drive technological innovation, the standards include incentives to promote more rapid development and deployment of new, advanced technologies. For a limited period while the market develops, plug-in electric vehicles receive extra fuel economy and emissions credits. Limited credits are also awarded for technologies that reduce fuel consumption and emissions during real-world operation but are not demonstrated on laboratory regulatory compliance test cycles. Examples of so-called "off-cycle" technologies include engine idle start-stop, active aerodynamic improvements like grill shutters, high efficiency exterior lights, solar panels, waste heat recovery and active transmission warm-up. And while it is improvements in conventional vehicle technology that the governing agencies foresee playing the largest part in the achievement of the standards (the 2025 fleet is expected to be made up of over 90 percent internal combustion engine vehicles), both hybrids and EVs are projected to contribute to the fleet as well, and will likely gain more and more market penetration as the years go on.

Recently, several US states including (but not limited to) California, New York, Massachusetts and Oregon have banded together with the goal of accelerating the adoption EVs, aiming to put 3.3 million new electric vehicles on the country's roads by 2025. Such an action would contribute significantly to a reduction in CO_2 emissions in the transportation sector, and would set a precedent that other states, and perhaps other countries, might follow.

With particular regard to India, electric vehicles present an environmentally sustainable, economically viable option with the potential to contribute significantly to the country's LDV fleet. However, the vehicles themselves are not a standalone technology, and in assessing their contribution to a sustainable energy future, it is important to consider how the electricity they are consuming is generated. EVs are inextricably linked to the energy grids that supply them electricity, and if those grids are still powered by pollution-intensive processes, the potential benefits of electric vehicles can never be realized fully.

OBSERVED AND PROJECTED BENEFITS OF UNITED STATES FUEL EFFICIENCY STANDARDS

Benefits to Consumers

Under the finalized fuel efficiency standards of the National Program, consumers can expect to save $1.7 trillion (Rs. 1,00,00,000 crore) in fuel expenditures. Drivers of an average 2025 model year vehicle could save over $10,600 (Rs. 6,37,000) in fuel over the life of their vintage vehicle, compared to a typical 2010 vehicle. According to EPA and DOT, the incremental cost of the technology to meet the 2025 standards compared to today's vehicles will be about $2560 (Rs. 1,53,000). (It will cost about $720 (Rs. 43,290) to reach the 2016 standard and then about $1840 (Rs. 1,10,000) to reach the 2025 standard). Therefore, offering net savings of $8,000 (Rs. 4,80,000) or more.

If a consumer were to purchase a new car with a loan, he would save money immediately, because the savings in fuel are greater than the increase in the loan payment for the fuel-saving technologies. Used car buyers will see a very quick return on their investment, as most of the incremental cost of fuel-saving technology will not be included in the price of a 5 or 10-year-old vehicle and yet the buyer will get the benefit of improved efficiency with fewer trips to the petrol pump. In fact, EPA and DOT estimate that a 5-yr-old 2025 vehicle will have a payback of about a year compared to a 2016 vehicle.

Benefits to Environment and Energy Security

When combined with the 2012-2016 standards, the new 54.5 mpg (23.17 kmpl) standards will result in the biggest action ever taken by the U.S. to cut carbon pollution and oil dependence.

This action is imperative, as the latest BP annual review of energy statistics reported that US oil consumption in 2013 grew by 400,000 barrels per day (bpd) (19.9

million tonnes per year) to 18.9 million bpd (9.4 billion tonnes per year). This was the sharpest consumption gain globally, surpassing China's increase of 390,000 bpd (19.4 million tonnes per year) (BP 2014). This shows a longstanding trend of exceptionally high oil consumption in the US. In 2012, the US consumed roughly 18.5 million bpd (9 billion tonnes per year)—nearly that consumed by China, which came in at second place (EIA, 2014).

Such high consumption, of course, correlates with very high GHG emission levels—especially relative to other countries with much larger populations. While such emissions have decreased over the past several years as a result of fuel efficiency measures and a shift toward cleaner methods of electricity generation, CO_2 levels are still very high, totaling 6,526 million metric tons in 2012 (EPA, 2014).

Fortunately, the 2012-2025 standards could cut US oil imports by one-third in 2030, because the program avoids consumption of 3.1 million barrels of oil per day (1.5 billion tonnes per year). Annual carbon pollution in 2030 will be reduced by about 570 million metric tons of CO_2, which is equivalent to the pollution from 85 million of today's US vehicles or 140 US coal-fired power plants. The 2017-2025 standards alone will cut oil consumption by 1.5 million bpd (74 million tonnes per year)—a figure that exceeds current US imports from Saudi Arabia (about 1.33 million bpd or 66 million tonnes per year)—and reduce carbon pollution by about 270 million metrics tons.

Benefits to Job Market and Innovation in the Automobile Industry

The connection between fuel efficiency standards and job creation may not seem obvious, but it is supported by two main rationales: (1) improving automobile efficiency requires the addition of new technologies, which are designed and manufactured by adding workers in the auto industry and (2) money saved on gasoline by drivers will be spent on other goods and services, increasing jobs across the economy.

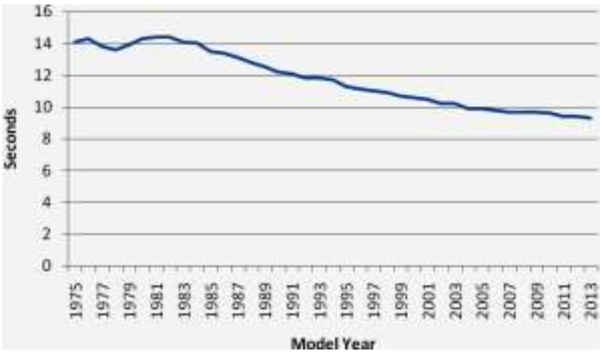
Fuel efficiency standards are critical because they establish long-term predictability in a world of highly uncertain petroleum prices. Automakers use the certainty from the standards to guide investments in fuel-saving technologies years before they hit the showroom floor. The investments drive job growth as new workers are needed to manufacture the new parts. Job growth resulting from more efficient cars is confirmed in a new study "*Gearing Up: Smart Standards Create Good Jobs Building Cleaner Cars*" by the BlueGreen Alliance and the American Council for an Energy Efficient Economy (ACEEE) [Busch et al. 2014]. The study finds that 570,000 jobs will be created across the United States by 2030 as automobile efficiency ramps up. This is because by buying less gasoline, drivers of more efficient vehicles are able to save more money to spend on other items. The study finds that within the auto industry itself, 50,000 jobs are expected to be created because more content is added into each vehicle.

The BlueGreen Alliance – ACEEE study forecasts jobs based on the Obama Administration's proposal to strengthen automobile fuel economy and carbon pollution standards for model years 2017 to 2025 to the equivalent of 54.5 mpg (23.17 kmpl). Researchers used the fuel savings estimated by the US DOT and EPA for the standards as inputs to a macroeconomic model to calculate jobs created in 15 sectors of the economy. In the study, the baselines include the existing 2012-2016 standards, meaning that a jobs analysis that covers the full set of existing and proposed standards from 2012 to 2025 would likely find numbers to be even higher than those discussed above.

In fact, jobs in the U.S. automobile industry are *already* on the rise. The BlueGreen Alliance – ACEEE report notes that since a seasonally-adjusted trough in June 2009, the auto manufacturing and sales industry has added 219,000 jobs, about one third of which are related to auto dealers. Economic growth and job creation are not the only benefits that US consumers and manufacturers are experiencing. Fuel efficiency standards promote innovation and creativity in the automobile industry, and have raised the bar globally for LDVs.

The EPA has kept track of several statistics regarding vehicle performance and finds that with recent and on-going innovations in engines, electric motors and lightweight materials, automakers are maintaining driver expectations for acceleration while improving efficiency. Figure 2 depicts a graph of the time taken to accelerate from 0 to 60 miles per hour (0 to 96.5 kilometers per hour), in seconds, for vehicles from 1975 until 2013. The steady decrease in acceleration time over the years demonstrates that performance need not be sacrificed in the name of improving fuel efficiency but, rather, innovations in both areas of vehicle functioning can occur simultaneously and lead to an altogether superior fleet of automobiles.

Figure 2: Acceleration Time (0-60 miles per hour) for Model Years 1975 to 2013. Data source: EPA Fuel Economy Trends



Such innovation has propelled US' car industry forward, catalyzing development that may not have happened had there not been improvement in efficiency standards. Standards drive innovation, and can introduce important modernizations to a vehicle fleet. They are critical to ensuring global competitiveness in the automobile market, and continuing the industry's progress overall. India made a great decision in implementing its first fuel efficiency standards, and is likely to see the positive results of such standards in the coming several years—not just in lower carbon dioxide emissions, but in the growth of the industry and economy as well.

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In Quest for Fuel Economy and Efficiency Standards

K. L. Thukral and M. Absar Alam*

INTRODUCTION

More than a century and a half ago, Karl Marx started his Communist Manifesto with the words, "A spectre is haunting Europe, the spectre of Communism. All the powers have entered into a holy alliance to exorcise this spectre."

Today, another spectre is haunting not just Europe but the whole world – that of global warming caused by greenhouse gas (GHG) emissions. A major contributor to this is global transport which burns billions of gallons of petrol and diesel every year.

Thus, according to the IEA, the transport alone sector accounted for 37 percent of carbon dioxide (CO_2) emissions from oil consumption in 2005 and it is projected to increase to 58 percent in 2030. The world vehicle population crossed the one billion mark and is still growing.

In short, earth has a major problem on its hands.

Until recently, India was not a major contributor to this form of environmental pollution. But as economic growth has accelerated and people have become more prosperous, there has been a manifold increase in the number of vehicles in India. The vehicle population increased from 10.6 million in 1985-86 to 141.9 million 2010-11. The Asian Development Bank (ADB) has estimated India's vehicle population at 373 million in 2035. The International Council of Clean Transportation (ICCT) places this at 430 million in 2030.[1] India's Ministry of Environment, meanwhile, has estimated the share of road transport in total GHG emissions in India at about 85 percent. It is obvious that India has to take firm action in this regard with a view to reducing its contribution to global warming.

Apart from such global welfare considerations, India also faces a practical problem: the issue of economic sustainability. It imports almost 80 percent of its crude oil. In 2013, it paid $145 billion from its export earnings of $307 billion, or over 6 percent of GDP. Without this oil bill, India would have had a current account surplus of over nearly 5 percent of GDP.

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* Authors are with Asian Institute of Transport Development (AITD), New Delhi.

1. Report of the National Transport Development Policy Committee (NTDPC), Planning Commission, Government of India

To add to the problem, India's net energy imports are slated to more than double to $230-40 billion in the next decade because of growth revival. However, depending on world prices of crude oil, the share of the import bill will fluctuate around 5-6 percent of GDP. The role of transport in reducing this share will be crucial, especially that of personalized transport.

This paper focuses on what can be done towards this end. Many countries have taken steps to launch and enforce fuel economy regulations which India must also do. Standards have generally been evolved for Light Duty Vehicles (LDVs) in the first instance as improvements in fuel consumption and emissions work best for this class of vehicles. The objectives of regulation include reducing fuel consumption.

MEASURES TO IMPROVE FUEL EFFICIENCY

Fuel economy standards may be based on voluntary or mandatory targets. The former was popular during the last two decades of the 20^{th} century when there was no great urgency to save fuel or/and reduce CO_2 emissions. The European Union (EU), Canada, Australia, Japan and Korea adopted such measures. Their experience however, showed the ineffectiveness of the voluntary measure; consequently, these countries have either switched or are switching over to mandatory regulation (See Table 1). There are three main methods for setting standards of fuel efficiency of which most popular is Minimum Energy Performance Standards (MEPS) system. These are set out in the Box No. 1.

United States had introduced the fuel efficiency standards for LDVs in 1975; Japan followed suit in 1998. China introduced standards for passenger cars in 2004 followed up by Korea in 2005. The structure of fuel economy and GHG standards vary greatly across the countries. In EU and Australia, CO_2 emission standards are based on fleet average. However, in EU, it is expressed as gm/km and in Australia it is expressed as L/100 km. US, Canada have fuel economy standards for cars and light duty trucks (LDTs) that are expressed in miles per gallon (mpg). In California, CO_2 emission standards are set for personal cars and LDTs and expressed as g/mile.

In addition, some countries have set the standards based on test weight and vehicle footprint as well. Considering test weight, Japan and China have set the standards for 9 and 16 weight classes respectively. It is expressed in Japan as km/L and in China as L/100km. Taiwan and South Korea follow fuel economy standards based on engine size and expressed as km/L. The table below describes the measures adopted by the European Union and several other countries:

Table 1: Fuel Economy and GHG Standards for Vehicles

Country/ Group	Mandatory standards	Voluntary targets	Type of regulation	Vehicle tax differentiation	Status
European Union	Planned	Implemented	Fleet average CO_2 emissions to be met by the Industry Associations	EU states have Tax system in place; action has been initiated by European Commission to bring about harmonization of the systems	Implemented and average CO_2 emissions/km has decreased to 132.2 g CO_2/km
Japan	Implemented		Fuel economy standards	Implemented	Implemented and achieved average fuel efficiency of 16.2 km/l for passenger vehicles.
United States	Implemented		Corporate average fuel economy	Implemented	Implemented and CO_2 emissions from both LDV and Passenger cars dropped by 14% and 13% respectively.
Canada	Planned	Implemented*	Fuel economy standards; GHG emissions targets		Implemented and fuel efficiency increased from 31.8 mpg in 2005 to 34.6 mpg in 2011.
China	Implemented		Fuel economy standards	Implemented	Implemented and fuel efficiency yet to be achieved.
Korea	Implemented	Implemented	Fuel economy standards		Implemented and efficiency has increased from 30.7 mpg in 2005 to 37.3 mpg in 2011.
Australia		Implemented	Fuel economy standards		Implemented

**As in EU, voluntary targets in Canada relate to GHG and not to fuel efficiency.*
Source: International Council for Clean Transportation, Global Passenger Vehicles Standards

Improving fuel efficiency of transport vehicles is crucial since consumers these days are less responsive to hikes in gasoline prices than they were in the past. There is scope for development and marketing of more efficient propulsion systems-engines and transmissions, vehicle weight reduction, use of alternative fuels to reduce petroleum consumption. Besides, opportunities exist to improve the operating efficiencies of these vehicles through strategies such as eco-driving, improved maintenance, higher loading, use of improved tyres, reduced idling of vehicles and better traffic management.

Thus, there is considerable potential for saving energy in the transport sector. According to an estimate, there is potential of fuel economy improvement of 50 percent in new vehicles by 2050, if technology up-gradation is maximized and fuel economy losses due to increase in vehicle size, weight and power are minimized (IEA, 2008).

Box 1: Comparison of Methods to Regulate Energy Efficiency

There are three main methods for setting energy efficiency standards for machinery and equipment. The first is a minimum standard value system, under which machinery and equipment covered by the system are required to exceed a certain level of performance. The second is an average standard value system, under which the average performance of machinery and equipment products are required to exceed standard values. The third is called a maximum standard value system (Top Runner Standard). Under this system, target performance levels are set, based on the value of the most energy-efficient products on the market at the time of the target-setting process.

The most popular minimum standard value system is MEPS. Under MEPS, the target machinery and equipment products must exceed a minimum performance standard (or be subject to sanctions such as suspension of product shipments) with essential process of evaluation.

The second system, the average standard value system, was introduced in Japan in 1979 as an equipment energy consumption efficiency value system. Target values are determined considering potential technical improvements and potential impact of categorical improvements that may contribute to overall improvements, information provided by manufacturers, etc. Under this system, designated machinery and equipment products are required to achieve a weighted average efficiency performance by a target fiscal year. The system provides flexibility to manufacturers, but on the other hand may have less impact on energy conservation than expected, since the establishment of standard values is partly dependent on manufacturer's provision of good information.

The Top Runner System uses, as a base value, the performance of the most energy-efficient product on the market to set future standards taking into account potential technological improvements. As a result, target standard values are extremely high compared to the other approaches described above. Manufacturers are required to achieve targets using weighted average values is the same as the average standard value system; that is, the system is meant to give manufacturers flexibility to develop energy-efficient equipment. An advantage of the system is that negotiation of the targets can proceed smoothly in a shorter period.

Source: The Energy Conservation Centre, Japan, 'Developing the World's Best Energy-Efficient Appliances (Japan's "Top Runner" Standard)' http://www.eccj.or jp/top_runner/index_contents_e.html

FUEL ECONOMY OF VEHICLES IN INDIA

In India, law requires measurement of fuel consumption of domestically produced vehicles. Under the notification issued in 2004 by the Ministry of Road Transport, Highways and Shipping, it became mandatory for the manufacturers to get the vehicles produced on or after 1 April 2005, tested for fuel consumption. However, there is no requirement to maintain such information collected during the type approval tests of vehicles.

In the absence of any reliable data on fuel consumptions of vehicles and the need to conserve fuel in the country, the Government of India asked the Bureau of Energy Efficiency (BEE) under the Ministry of Power to develop and notify the fuel efficiency standards for passenger transport vehicles. After long deliberations, the BEE has developed and notified fuel efficiency norms for passenger cars on 30^{th} January, 2014.

The standards are in terms of sales weighted corporate average CO_2 emissions (in mileage terms, km/litre). It is CO_2 emissions which will measure fuel economy. Manufacturers would have to take a weighted average of fuel consumption of all cars it sells during a year and it should be less than the Corporate Average Fuel Economy (CAFÉ) standards for that year. Indian industry has already achieved fleet-wide CO_2 emissions of 141 gm/km in 2009-10 and 138-139 gm/km in 2010-11.

The government wants the car industry to improve km/litre by at least 20 percent from the current average of 16.6 km/litre spread over in two phases. In the first phase, it will be raised to 18.1 km/litre by reducing CO_2 emissions by a car to 129 gm/km. In the second phase, fuel consumption will be reduced by achieving 20.79 km/litre through reducing CO_2 emissions to 113 gm/km. The first phase was to be launched from 2015 and second phase by 2020.[2] After the objections of the Industry, voiced by the Ministry of Heavy Industry and the Ministry of Road Transport and Highways (MoRTH), the nodal Ministry of Power agreed to delay the implementation of standards to 2017 and 2022 respectively.

NORMS FOR HEAVY DUTY VEHICLES (HDVs)

It may be mentioned that several countries have begun to develop and implement standards for HDVs. Japan implemented the first mandatory HDVs fuel economy standards in 2005 followed by USA in 2011. China is developing mandatory fuel consumption standards for these vehicles. In India, the government has recently formed a

2. Live Mint, October 27, 2013, Fuel Efficiency Notification to Car Makers, Neha Sethi and Amrit Raj

committee to look into the norms for HDVs. This would help improve mileage and curtail fuel consumption of these vehicles.

The automobile industry would be working with various agencies to evolve efficiency parameters for HDVs that consume bulk (about 37 percent) of auto fuel. The committee is expected to submit the report in 15 months time.

Fuel efficiency policies deliver valuable fuel savings in relatively less time. These policies are related to setting standards, providing financial incentives and making available the requisite information for the use of the consumers. These are discussed hereafter.

SUPPORTIVE MEASURES IN THE FORM OF LABELLING AND FINANCIAL INCENTIVES

Generally, countries are empowered by their Energy Conservation Law to ask the manufacturers for a labelling scheme for their vehicles. Label may provide information for the consumers about the likely fuel efficiency range expressed in litres/100 km or miles per gallon, CO_2 values, fuel price, estimated annual fuel cost based on a given number of miles/km to be performed and comparison of performance of similar vehicles. The label is pasted on the window of each new vehicle model. Some countries bring out annually a Fuel Economy Guide to help the buyers choose the most fuel-efficient vehicle.

Financial incentives/ disincentives may take various forms. It may be a tax deduction based on fuel efficient performance, a fee for less fuel efficient vehicle or a "feebate" that combines rebates for fuel efficient cars and the fees for less fuel efficient ones. The details of rebates and penalties in USA and Canada are set out in Box No. 2.

Japan's success in implementing fuel efficiency standards (80 percent of cars achieved the 2010 standards in 2004 itself) are due to package of measures to encourage customers to buy fuel-efficient cars. In China, vehicle purchase tax has two components: excise tax levied on manufacturers and sales tax charged from buyers of vehicles. While the latter is fixed at 10 percent, excise tax varies with engine size. Excise on small engines is charged at a lower rate; its rate is higher for large engines.

In addition to taxes related to vehicles, fuel tax is another method to implement such policies as tax incentives affect only consumer choice of vehicles. Vehicle tax does not necessarily lead to change in consumer driving behaviour. Fuel tax directly affects reducing consumption of fuel.

Box 2: Improving Fuel Efficiency for Existing Vehicles: Examples of Rebates and Penalties

The United States government allows tax credits for the purchase of energy efficient vehicles. Tax credit is calculated on the basis of the vehicle's fuel economy and energy savings. After a vehicle meets the eligibility criteria, the automaker applies to the Internal Revenue Service for official certification of the incentive. Above a certain level, the tax credit amount decreases until it eventually phases out.

The state of California developed a 'feebate' system (fee as penalty and rebate as reward). Such a system could be designed to be revenue neutral or to yield a certain pre-specified ratio of total fees to total rebates. For this policy, issues to be considered include (i) the effect of gradual reduction in energy efficiency of vehicles over time. So scheme parameters pivot point(s) and rate-need to be adjusted periodically to maintain overall revenue neutrality. (ii) There can be significant administrative cost, depending on the complexity of the scheme. The purchase of old vehicles which tend to be fuel inefficient and the production of fuel inefficient cars are penalized in certain countries. At the federal level in the US, the Gas Guzzler Tax is a disincentive established by the 1978 Energy Tax Act to discourage the production and purchase of fuel inefficient vehicles.

The Car Allowance Rebate System (CARS), colloquially known as "Cash for Clunkers", a $3 billion U.S. federal programme, established in 2009, provides economic incentives to residents to purchase a new, more fuel-efficient vehicle when trading in a less fuel-efficient vehicle. The programme was promoted as providing stimulus to the economy by boosting auto sales, while putting safer, cleaner and more fuel-efficient vehicles on the roadways.

In Canada, the ecoAUTO programme provides rebates for purchase or long-term lease of efficient cars and light trucks, and Green Levy-an excise tax-penalises those who purchase certain types of energy inefficient cars.

Source: Report of the National Transport Development Policy Committee, 2014

In the EU, member states are encouraged to adopt taxation policies that promote the purchase of fuel-efficient cars. These countries levy tax both on vehicle as well as fuel consumption. Table 2 presents fiscal measures taken to improve CO_2 emissions.

UK has taken a number of measures including lower rate of vehicle excise duty on vehicles with engine size of 1549 cc or less, graduated vehicle excise duty for new cars based primarily on their level of CO_2 emissions, vehicle tax on company car given for private use of employee related to its CO_2 emissions. Further, during 2006, a zero rate of excise duty has been introduced for cars with the lowest carbon emission and a new top band for the most polluting cars. In France, a higher rate of registration tax has been introduced for vehicles with CO_2 emissions above 200g/km.

Table 2: CO_2 Based Motor Vehicle Taxes in Select Countries

Country	Incidence	Type of Tax	Feature of the tax
Austria	One time	Fuel consumption tax at the time of first registration of car	The deduction amounts to €350 for diesel vehicles €450 for petrol vehicles and €600 for hybrid and other alternative fuel vehicles. Electric vehicles are exempt. The malus amounts to €20 for each g/km emitted in excess of 250 g/km.
Germany	Annual	Circulation tax for car registered with effect from 1, July 2009	It consists of a base tax and a CO_2 tax. The base tax is €2 per 100 cc (petrol) and €9.50 per 100 cc (diesel) respectively. The CO_2 tax is linear at €2 per g/km emitted above 95g/km. Cars with CO_2 emissions below 95 g/km are exempt from the CO_2 tax.
Sweden	Annual	Annual circulation tax	The tax consists of a base rate (360 Swedish Kroner) plus SEK 20 for each gram of CO_2 above 117 g/km. In case of diesel cars this sum is multiplied by 2.33. For alternative fuel vehicles, the tax is SEK 10 for each gram above 117 g/km.
UK	Annual	Annual circulation tax with effect from March 2001.	Rates range from £0 (up to 100 g/km) to £490 (for cars over 255 g/km) (alternative fuels receive a £10 discount where a rate is paid). A first year rate of registration applies since 1 April 2010. Rates vary from £ 0 (upto 130 g/km) to £1,055 (more than 255 g/km).

Source: European Automobile Manufacturer Association. http://www.acea.be/industry-topics/tag/category/co2-taxation

TECHNOLOGICALLY ADVANCED VEHICLES

USA and the Europe have witnessed technological up-gradation of vehicles aimed at improving vehicle emissions and fuel efficiency. Advanced vehicle technologies have been developed in these markets with stringent fuel economy targets. Improved technical features include shift from mechanical injection to electronic injection systems, introduction of direct injection system in diesel cars replacing the hitherto indirect injection system etc. India has lagged behind in technology up-gradation in the absence of fuel economy regulation.

After the introduction of economic reforms in the country, there was induction of new technology which was, however, limited to personal transport modes such as scooters/motor bikes and cars; its application to commercial vehicles has been slow. It may be noted that the improved technologies of the US and Europe may not be suitable for India due to high cost involved and low benefits due to high congestion and low speeds of vehicles. There are good prospects of induction of conventional low cost technology, discussed below, that may yield fuel savings to the vehicle users and help Indian automobile industry to gear up exports with immense benefits.

Use of low cost technology

Cost effectiveness of technology for improving fuel efficiency and reducing GHG emissions, is important for India as well as other countries. Several low cost technologies are available for this purpose. Energy demand can be reduced through measures such as weight reduction, drag and rolling resistance reduction, idle-stop-start driving system and improving engine technologies; these can yield 25 percent to 30 percent reduction in fuel consumption over the next 10 years. The estimated benefits will be reduced in case of delay by manufacturers to adopt the new technology; consumers may also neutralize the technology benefits by resorting to larger and energy intensive vehicles.[3]

Spark Ignition (SI) technology improvements are far more cost effective than alternatives like hybrids. The latter are costly and are not suited for cargo handling. Their benefits decline in extreme climates; this technology may have potential in the long term. Incentives for technology improvement will work better in developing countries. Promotion of electric vehicles is yet another possibility to achieve the requisite objectives.

TASK AHEAD IN INDIA

The purpose of fuel economy standards is to provide the fuel economy performance of vehicles that can help the consumers to make a choice between different models and help the industry to set benchmarks and improve vehicle technology if warranted by on-road performance. This cannot brook any delay in the light of rapid growth of road transport and rising burden of oil imports in India.

A host of agencies are concerned with the fuel efficiency standards in India. These include Ministries of Power, Petroleum & Natural Gas, Road Transport & Highways, vehicle-testing agencies such as Automotive Research Association of India (ARAI) and vehicle manufacturers. So far discussions have been restricted to only car manufacturers and the government. Participation of all stakeholders and taking note of their concerns is crucial for formulation and implementation of effective standards. Further, the regulatory standards would need to be periodically reviewed and strengthened.

One way for reducing the consumption of fossil fuels by vehicles is by the use of alternative fuels including bio-fuels, CNG and LPG; these are environment friendly and are in use in many countries though their limited supply cannot replace fossil fuels. This was substantiated by the report of Integrated Energy Policy (2006) in India which

3. Fuel Economy Technology: KG Duleep, Chennai, 2007, Presentation

enjoined that no economic substitutes of fuel are obvious for transport sector till 2031-32. Hence, manufacture of energy efficient vehicles and deployment of mass transport have to have high priority. Further, research has made available flexi-fuel, hybrid vehicles though these are still expensive compared to petrol/diesel driven vehicles. Research is on for the use of hydrogen for running the vehicles; these will be zero pollution vehicles. Though, automakers have been dabbling in hydrogen powered cars for quite some time, a mass produced car that runs on hydrogen was always a decade away. The position will change next year when Hyundai starts selling a SUV powered by a hydrogen fuel cell. It will be the first mass market vehicle of its type to be sold /leased in the US. However, commercialization of hydrogen will take time since several issues including the setting up of filling stations would need to be resolved.

It may be noted that though bio-fuels reduce GHG emissions, but these have large effect on land use, water use as well as food prices. These issues need to be carefully examined before taking any decision on the massive utilization of these fuels for vehicle operations.

The success of fuel efficiency is contingent on restraining the industry from shifting the production to large, heavy and fuel inefficient vehicles. In India, for example, the government has also to check the unbridled growth of diesel cars. Dieselization will push the market towards bigger cars and SUVs. It is reported that close to 40 percent of diesel cars are above 1500cc. This will increase the average weight of fleet and worsen fuel efficiency performance.

Empirically, the Indian industry has shown annual improvement of 1 percent in fuel economy of cars. Fuel efficiency standards should help improve the CO_2 emissions /fuel savings further. Key vehicle producing countries are continuously tightening the standards. For example, Europe has proposed 95 gm/km in 2020 against 145 gm/km in 2010. US has proposed to improve it from 187 gm/km to 121gm/km. China will bring it down to 117 gm/km from 179 gm/km during the same period. According to available information, India is expected to reach 113 gm/km from 140 gm/km in 2010. The proposed started 113 gm/km to be achieved on the implementation of the standards in India is pegged at a low level, compared to other countries. In the context of strong public expectation of substantial results from implementation of the standards, the industry and other stakeholders have to decide whether fuel deficient India may be left behind in the race for fixing effective targets.

It is also essential that countries enforcing fuel efficiency standards should come out with the implementation strategy. In countries implementing sales weighted corporate average standards, the regulator will have to assess the actual number of cars sold by model and make and calculate average CO_2 /fuel economy levels to verify compliance. This requires reporting of fuel economy data as well as exact number of cars sold for each make and model in a year. Only a few countries have a system in place to collect and verify sales; the system depends on self reporting by car industry. In India, therefore, Ministry of Road Transport & Highways need to put that system in place, frame the strategy for compliance as well as the penalty for non-compliance during the year. It is necessary to create independent system to generate the requisite data.

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Analysis of Differences in Light Vehicle Fuel Economy across Nine Countries and Their Policy Implications

K. G. Duleep*

INTRODUCTION

Improving light duty vehicle (LDV) fuel economy[1] is a major objective for most nations, due to the need for reducing oil consumption as well as Greenhouse Gas (GHG) emissions. While most OECD (Organisation for Economic Cooperation and Development) countries report the average fuel economy of new light vehicles (typically defined as vehicles under 4000 kg gross weight) in each year, such information is generally not available publicly for most developing countries. In general, developing country fleets have large percentages of small cars that has led many to conclude that the fleets are fuel efficient. Through a detailed analysis of data, not only can the average fuel economy of new cars be measured with better accuracy, but other statistics of interest can also be assessed, such as fuel economy across market/size class and the presence of various technologies on vehicles (and the fuel economy effects of these technologies). A key question that this analysis seeks to answer is the extent of the gap in fuel economy between developing and OECD countries that is associated with the employment of more fuel efficient technology in the latter countries. A large fuel economy gap between OECD and developing country vehicles of the same size and performance indicates a significant technology gap that could be addressed with policy measures or fuel economy regulations.

The new light vehicle fleets for model year 2010 in five emerging market, non-OECD countries relative to the new vehicle fleets in the United States (US), Australia, Germany and France, as four example developed countries were examined in detail. The developing countries include Russia, India and China, as well as Malaysia and South Africa. This analysis updates an earlier analysis performed for the International Energy Agency (IEA) using 2008 data, to also include 2010 data, which allows for some examination of time trends (Duleep, 2013). The US, France and Germany have enacted regulations with stringent requirements for fuel consumption reductions, while Australia has no specific regulations aimed at reducing fuel consumption. Among the developing countries, only China had adopted fuel consumption related regulations as of 2010. The

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* President, H-D Systems, Washington D.C.

1. The term “fuel economy” is used to denote travel distance per unit of fuel consumed (km/L) while the term “fuel consumption” is used to denote the inverse of fuel economy or fuel consumed per unit distance (L/100km).

other developing countries, considered in this analysis, are in the process of developing and adopting standards but none has adopted requirements as of mid-2014.

The vehicles sold in the nine countries not only include some common models as identified by nameplate but also include many models that are unique to specific countries. Moreover, the most obvious and visible difference is the size mix of vehicles sold; the sample includes the US with the largest size mix in the world to India, which has the smallest size mix among major countries. The vehicle technology mix differs but outside of diesel engine penetration, this is certainly less obvious. Diesel engine penetration does vary widely, with France having one of the highest levels of diesel penetration in the world at about 75 percent of all new vehicles, while diesel penetration in the US and China is less than 1 percent of the new vehicle fleet in 2010. Hence, we have assessed the fleet both from a "top-down" viewpoint of aggregate data analysis and a bottom-up viewpoint of examining individual high sales volume models in each country. Table 1 summarizes some of the major features of each market in 2010. It should be noted that CO_2 emissions are directly proportional to fuel consumption for a given fuel type.

Table 1: Selected Characteristics of the 2010 Light Duty New Vehicle Fleet

	Sales (millions)	**FC (NEDC) L/100KM**	**Diesel Share**	**Lt. Truck share**	**High Sales Classes**
USA	10.51	9.31	0.6%	44.6%	C, D, M-TRK
Germany	2.80	6.44	44.4%	25.4%	B, C, D
France	2.35	5.57	74.7%	28.0%	B, C, C-TRK
Australia	0.87	8.74	24.1%	39.1%	B, C, M-TRK
China	11.40	7.69	1.3%	31.9%	B, C, C-TRK
India	2.42	6.07	35.8%	28.1%	A,B, S-TRK
Russia	1.51	8.02	5.5%	29.0%	B, C, C-TRK
Malaysia	0.50	7.09	7.7%	15.5%	B, C, D
South Africa	0.55	7.69	19.3%	39.5%	B, C, M-TRK
(M-TRK, C-TRK and S-TRK refer to medium size, compact and small trucks which include SUV, van and pickup truck models, see below for class definitions)					

DATA SOURCES AND METHODOLOGY

In order to provide statistics on a comparable basis across countries, LDVs were classified into size or market classes using the European notation system that is approximately consistent with the US market class system. In this system, cars are grouped into five classes: A class cars which are 'entry' level very small cars with engines of 1 litre or smaller displacement, B class cars which are classified as sub-compacts in the

US, C class cars are classified as compacts in the US and are the most popular size in Northern Europe, Japan and China and D class cars are classified as midsize in the US and are the largest part of the market there, but are generally regarded as large cars in the rest of the world. Large (US) cars and sport cars are classified as E and F class respectively and are a small fraction of sales in most countries except in North America.

Vans, sport utility vehicles (SUVs) and pickup trucks are collectively referred to as light trucks, which have always been a major part of the North American market and have only recently increased in popularity in other parts of the world. We have classified them into 4 sizes, labeled small, compact, mid size and large. The large models are sold in significant quantities only in North America, Russia and some parts of the Middle East.

In addition, sales were also allocated to engine type. The vast majority of vehicles in most countries are gasoline or diesel powered and the data indicated that less than 0.5 percent of new vehicles in any of the countries were powered by other fuels, except in India and Australia. India has 3.5 percent of its new vehicle sales that are fueled by Compressed Natural Gas (CNG) in 2010, largely concentrated in 2 models used in taxi fleets. Australia has 1.4 percent of its new car fleet fueled by Liquefied Petroleum Gas (LPG), although this figure reflects only new LPG car sales – another 6 to 7 percent are converted to LPG in the after-market, and these are not accounted for in this analysis. We have used fuel economy on a gasoline equivalent basis for alternate fuel vehicles (AFVs) in India and Australia.

Hybrid vehicles were not sold in India in 2010 and had very low sales in Europe and China (a few thousand units sold amounting to less than 0.1 percent of sales). Hybrid vehicles are rapidly increasing in popularity in the US and sales were nearly at 2.5 percent of the fleet in 2008, and 3.5 percent in 2010. On the other hand, diesels are well represented in France, where penetration stood at about 80 percent in 2008 and 75 percent in 2010, and in India where penetration is at 31.5 percent in 2010. As noted, diesels are less than 1 percent of light vehicle sales in China and the US. In the instances where alternative fuel types account for less than 2 percent of the fleet, we have not analyzed any of their specific efficiency characteristics.

Commercial vehicles are defined as those vehicles which are primarily intended for cargo transport. In Europe as well as most of the other countries examined in this study, the van body vehicle is the most dominant light commercial vehicle type, while in the US and Australia, the pick-up truck is the largest seller. Many light cargo vehicles share their body and drive-train with a passenger vehicle (often with the same name) and we have also classified commercial vehicles into the same four classes as passenger light trucks. In this case, many European large vans are included in the same size as the large pickups common in the US. Since the US does not have a separate "commercial" category, we created one for this analysis by reclassifying all pickup trucks and cargo vans as commercial for the US.

Development of the data set to permit detailed comparisons of fuel economy was a major part of the effort. However, it should be noted that vehicle models in the European Union (EU) and China (defined as a unique combination of nameplate, engine size, power and transmission type) encompass many hundreds of different types and it was not possible to develop detailed technology data on so many models. Rather, we selected the highest sales volume models in most countries to provide the comparisons required. This subset of 25 to 50 models usually accounts for 70 to 80 percent of all sales in each country.

Engine technology data available in the data set include engine size, layout (OHV/OHC), number of cylinders, compression ratio, aspiration, valve lift and timing control (presence/absence) and fuel injection type (port/direct). Data on transmission type and number of gears, drive type (2wd/4wd) and vehicle curb weight are also available. No data on aerodynamic drag or rolling resistance is available, but we do have data on the use of fuel efficient electric power steering. This data was used for a reference set to be obtained for select high sales volume vehicles in other countries.

Detailed sales data at the nameplate/ engine/ transmission level was not publicly available for many countries, and we used the registration data for calendar year 2008 and 2010 obtained from R. L. Polk by IEA. Data on vehicle fuel economy and on vehicle technical specifications were not included in the Polk database, and because of the relatively complex layout of the database, it was not easy to match the registration data to any database containing vehicle technical specifications. IEA obtained data on vehicle weight, Horse Power (HP) and fuel economy for models that constitute approximately 80 to 85 percent of sales in each country, or for about half the models in the database. In addition, some effort was made to obtain representation of vehicles in all classes, including the low sales volume classes. This method resulted in the fleet-wide averages being not affected significantly; for example, the computed CO_2 emissions for the French fleet was 138 g/km while the official figure was 140 g/km. The small under-estimate is due partially to the fact that many high fuel consumption cars are sold at low volumes and are, hence, not included in the data.

As noted, the data on fuel economy and vehicle specifications were available for only 70 to 80 percent of all vehicles depending on the country. However, there were also other important fields in the Polk data set that were incomplete. The fuel type field was blank in about 6 percent of records for India, but was missing in 15.5 percent of records in both China and Russia, which was considered unacceptably large. In Russia and China, diesel sales in light vehicles are very small (0.5 to 1 percent of all sales) and hence, we reclassified all vehicles with fuel type unspecified in these three countries to gasoline. In India, diesel penetration in the light vehicle market is about 35 percent of sales with the result that a uniform shift was not possible; a model-by-model analysis was used, but this resulted in most unclassified models being moved to gasoline. The US sample is complete at 100 percent since we are using the official dataset used to determine compliance with fuel economy standards.

The first step in this analysis was a detailed qualitative assessment of the fleet of new cars in terms of manufacturers, vehicle sizes, model availability, and vehicle pricing. Second, a quantitative analysis of the differences in the fleet in terms of mix by size class, weight engine size, power and fuel economy was developed. The quantitative analysis relies on a mathematical decomposition of the differences to several selected variables such as performance, diesel penetration, automatic transmission penetration and weight differences within the class. Third, a detailed difference analysis is documented, with the results illustrating the actual causes of differences in fuel economy between countries, especially to examine if there are substantial technology differences contributing to fuel economy. Finally, a "bottom-up" analysis of individual models is used to examine the results of the difference analysis and lend substance to the policy conclusions.

The official fuel economy test from which the fuel economy numbers are derived varies across the four countries. The US utilizes the Federal Test Procedure which has city cycle with an average speed of 31.5 km/h and a highway cycle with an average speed of 77.6 km/h. Europe, Australia and China used the "New European Driving Cycle" or NEDC which is a stylized cycle consisting of 4 repeats of a city cycle with an average speed of 18.7 km/h and a highway cycle with an average speed of 62.6 km/h and a maximum speed of 120 km/h. For an average car, studies have determined that the US fuel consumption multiplied by 1.13 equals the fuel consumption as measured on the EC test (Feng, et. al, 2007). We have used this correction factor to adjust the US fleet fuel consumption value to NEDC values.

India also uses the NEDC but modifies it for Indian conditions by limiting the maximum cycle speed to 90km/h. There are also some other procedural changes to the test protocol that make the Indian test somewhat different. No specific study is available to estimate the effect of the Indian procedure relative to the NEDC procedure. As a result, we compared the reported fuel economy of 'identical' vehicles for Europe and India. The vehicles are identical in terms of published specifications, but there may be engine calibration differences and tire differences that could affect fuel economy but are unknown. The comparison yielded a figure which suggested that fuel consumption measured in India is 2.75 percent higher than the NEDC, which is a reasonable difference, given that the changes to the drive cycle are relatively modest.

ANALY SIS RESULTS

The data for 2008 and 2010 were utilized for a detailed mathematical decomposition analysis. The decomposition analysis allocates the differences in fuel consumption of the fleet between two countries to:

- Differences in the mix of size classes sold
- Diesel penetration differences
- Differences in consumer preference for options and performance (engine size)
- Differences in the preference for automatic transmissions
- Differences in fuel efficiency technology adoption

The effect of each of these factors is examined holding all other factors constant, so that the partial effect is measured accurately and the sum of all of the above effects explains the entire difference in fuel consumption.

ANALYSIS OF OECD COUNTRY DIFFERENCES

Tables 2 shows the analysis of fuel consumption differences in 2010 between the other OECD countries and Germany, which is used as the reference benchmark. The results for each country are discussed below.

Table 2: Allocation of Fuel Consumption Differences Relative to Germany for 2010

2010		Size Mix	Diesel	Performance and Trim	Transmission	Technology	Total
USA	DELTA FC	-1.208	-0.985	-0.548	-0.282	0.153	-2.870
	% FC	-18.76%	-15.30%	-8.51%	-4.38%	2.38%	-44.56%
AUSTRALIA	DELTA FC	-0.665	-0.676	-0.240	-0.115	-0.560	-2.256
	% FC	-10.33%	-10.50%	-3.72%	-1.78%	-8.69%	-35.02%
FRANCE	DELTA FC	0.208	0.515	0.230	0.027	-0.150	0.830
	% FC	3.23%	8.00%	3.56%	0.43%	-2.33%	12.88%

(Negative numbers are fuel consumption increases from German consumption values)

The differences between the US and Germany remained relatively consistent between 2008 and 2010 with US consumption about 45 percent higher than the German new fleet fuel consumption. The size mix differences accounted for almost 19 percent of the 45 percent, diesel for about 16 percent, higher option content and larger engines for about 9 percent and the use of automatic transmissions for about 4.5 percent. The remaining difference is only in the range of 2 to 4 percent that is associated with fuel economy technology, showing that there is hardly any difference in the technology content between the two countries (the small positive difference for the US is partly due to higher hybrid vehicle sales in the US). This is a surprising finding since fuel prices are much higher in Germany than in the US, suggesting that regulatory drivers rather than fuel prices are constraining technology requirements in both countries.

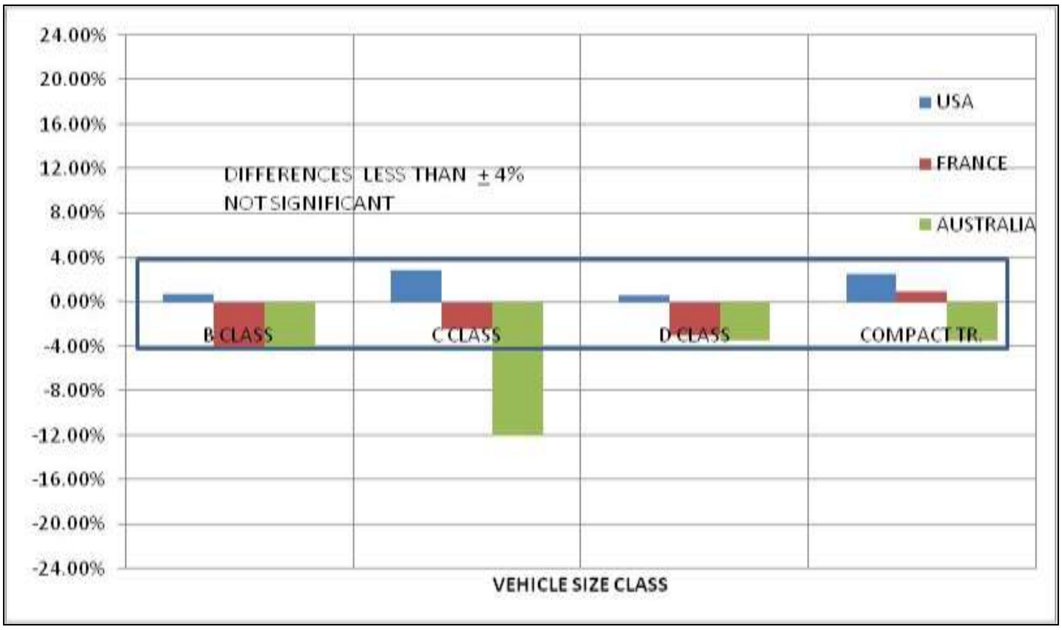
While new fleet fuel consumption was lower in France than in Germany by 16 percent in 2008 and 13 percent in 2010, most of the difference can be explained by the smaller size mix in France (2 to 3 percent), higher diesel penetration (7 to 8 percent) and the lower option content and performance of French cars (1.5 to 3.5 percent). However, it is notable that the technology effect went from about +5 percent in 2008 to -2 percent in 2010 relative to Germany. A more detailed analysis at the size class level showed that many French models from Peugeot, Citroen and Renault in the A, B and C class made special efforts to have very low CO_2 emissions in 2008 due to the introduction of the "Bonus Malus" fee and rebate program in France that was effective in promoting low fuel consumption cars. By 2010, the German manufacturers had essentially caught up and even surpassed the French manufacturers due to strong pressure from the EU on complying with the light vehicle CO_2 standards. A similar effect is seen in Australia. It is noteworthy that the economic fee and rebate program was successful not only in motivating customers to move to smaller vehicles, but also affecting technology supply by motivating manufacturers to "pull ahead" technology introduction.

Australia lies between the US and Germany in many of its light vehicle fleet characteristics, but Australia imports most of its cars from Japan and the EU. Sales of domestic vehicles (that are uniquely Australian models) had declined to less than 20 percent of the fleet by 2008 and to about 15 percent of the fleet in 2010. While the Australian fleet had 35 percent higher FC than Germany in both 2008 and 2010, the difference could be attributed to size mix (10.3 percent in both years), diesel penetration (10.5 percent and 11.5 percent), higher option content and engine size (4 to 5 percent), and higher automatic transmission penetration (2 to 3 percent) which still left a technology difference that accounted for about 6 percent difference in 2008 and widened to 9 percent in 2010. A detailed analysis of differences showed that about 3 percent is attributable to the different certification levels between the EU and Australia on average for ostensibly identical vehicles, possibly due to tire and trim differences.

The similarity of fuel consumption at the size class level (after adjustment for diesel penetration and performance differences) is shown in Figure 1. The significant difference in Australian C class vehicle fuel economy was found to be due to the high fuel consumption of 2 popular models in Australia that were replaced with more fuel efficient models in 2011/12.

The widening gap between Australia and Germany from 2008 to 2010 appears to be a temporary effect since new technology introduction appears to lag by a year or two between the EU and Australia possibly due to the timing of model introductions. Bottom-up analysis of Australian data for 2011 and 2012 confirmed additional reduction of the technology gap between Germany and Australia.

Figure 1: Size class specific fuel consumption differences relative to Germany



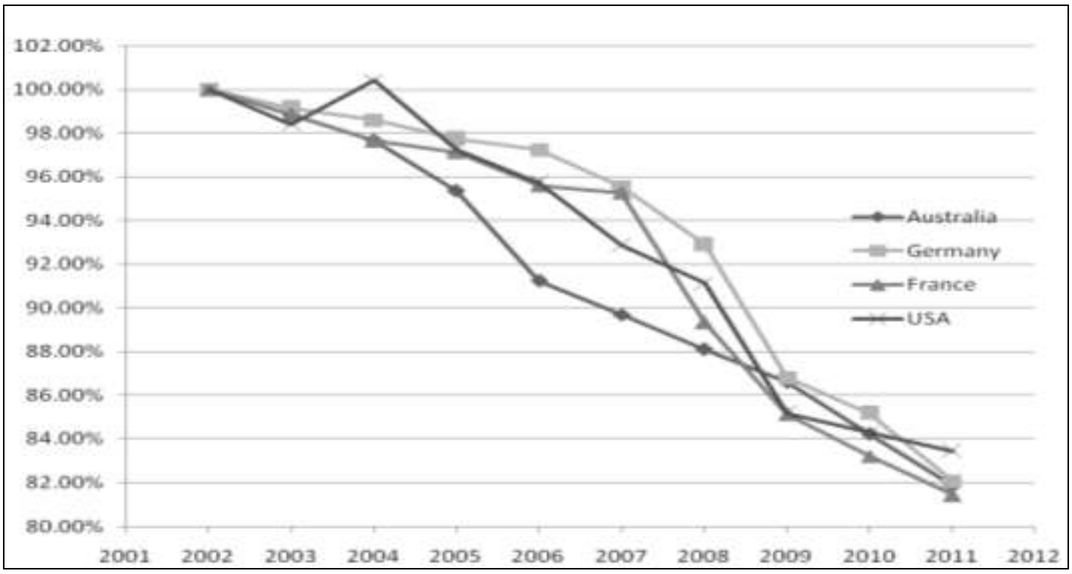
(adjusted for diesel penetration, weight and performance; negative percentages indicate worse FC)

COMPARISON TO OFFICIAL ESTIMATES

The "macro" data of fleet average fuel economy or CO_2 emissions published by the regulatory agencies also confirms that fuel consumption reduction in the OECD countries appears to be remarkable consistent in percent reductions over time, although there are small year-to-year movements. Figure 2 shows the rate of decline in the four countries examined in this report using the official statistics on fuel consumption or CO_2, normalized to the 2002 value at 100 percent.

By 2011, all four countries showed a 17 + 0.7 percent reduction relative to 2002, which is remarkably similar given the differences in local fuel prices, vehicle taxes, fleet composition and the vehicles covered by regulation. One explanation is that the developed country markets are being supplied by the same set of major global auto-manufacturers, who are responding to regulatory pressure by adopting similar technology for all developed country markets (and, as shown in the next section, for many developing country markets).

Figure 2: New Vehicle Fleet CO_2 Emissions Decline Relative to 2002, OECD Countries



The figure also shows that Australian fuel consumption decline occurred earlier than in the other OECD countries with a steep decline in the 2003 to 2006 period when other OECD countries were showing modest or no declines. Our analysis showed that in this period, the Australian consumers abandoned the large car and large SUV models manufactured domestically and moved to smaller international models as the tariff barriers against imports were lowered over the period. Similarly, the steep reduction in French fleet fuel consumption between 2007 and 2009 is evident and this corresponds to the introduction of the fee and rebate regime. Hence, both local factors and international technology adoption trends explain the short term trends in fuel consumption and the relative differences between countries.

DEVELOPING COUNTRY FLEETS

The analysis uses the same methodology as the decomposition analysis for the OECD countries, with Germany as the reference country for benchmarking. Table 3 shows the details of the decomposition analysis for the 2010 developing country fleets, with the German fleet used as the reference for comparison.

Table 3: Decomposition Analysis of the 2010 Fleet Relative to the German Fleet

2010		Mix	Diesel	Performance	Transmission	Technology	Total
China	DELTA FC	0.174	-0.912	0.420	-0.082	-0.846	-1.246
	% FC	2.70%	-14.16%	6.5%	-1.28%	-13.13%	-19.34%
India	DELTA FC	0.480	0.161	0.525	0.020	-0.838	0.348
	% FC	7.45%	2.49%	8.16%	0.31%	-13.01%	5.41%
Russia	DELTA FC	-0.290	-0.822	0.311	-0.070	-0.712	-1.582
	% FC	-4.50%	-12.76%	4.83%	-1.09%	-11.06%	-24.58%
South Africa	DELTA FC	-0.481	-0.587	0.083	-0.199	-0.068	-1.253
	% FC	-7.47%	-9.12%	1.28%	-3.09%	-1.06%	-19.46%
Malaysia	DELTA FC	0.198	-0.697	0.608	-0.210	-0.535	-0.636
	% FC	3.07%	-10.83%	9.45%	-3.26%	-8.31%	-9.87%

China

In 2010, the Chinese fleet fuel consumption was about 19.3 percent higher than German FC, in spite of the smaller average vehicle size that should have provided a 2.7 percent benefit. The net -22 percent size adjusted (i.e., 19.3 + 2.7) differential can be explained by lower diesel penetration which accounted for 14.1 percent, higher use of automatics (about 1.5 percent) and lower vehicle technology which accounted for a 13.1 percent differential, offset somewhat by lower vehicle weights and performance levels which accounted for a positive 3.35 percent. The 2008 data was quite similar, but the vehicle technology differential increase was only 10.7 percent, indicating that German vehicle fuel efficiency technology adoption was occurring at a faster rate than in China.

A detailed decomposition by size class showed that the A, B and C classes as well as the small truck class have significantly higher fuel consumption than German models of equal size and performance, and the differentials are in the 13 to 16 percent range for the cars and 24 percent for the micro-van in 2010. Larger car classes have a lower technology based differential of 8 to 10 percent. In addition, the technology differentials in all classes have increased from 2008 to 2010, suggesting that German models in all classes have adopted more technology in the 2 years (the increase in differences between 2008 and 2010 are on the order of 3 to 4 percent but are present in all classes).

The differentials in the smaller car and truck classes is due to the existence of many local manufacturer's models in these classes and these models often employ older lower cost designs to enable a cheap product. As an example, the popular Wuling van is based on a Mitsubishi van design from the late 1970s although the power-train was modernized in the 1990s using Suzuki engines. Even so, the technology employed is at least 15 years old, but the price of the van is under $6000, which is less than half the price of a similar size vehicle in Germany. These low cost vehicles are still popular and explain much of the differential in technology for smaller vehicles. China also has a very large number of joint venture manufacturers that manufacture modern international designs of vehicles in China. Our analysis suggests that these vehicles are technologically nearly identical to OECD models but the latest technology historically moved to China with a modest time lag of 2 to 3 years. This could explain the increased technology differential in 2010, due to the rapid change in German technology in the 2008-2010 period.

India

The Indian fleet had 5.4 percent lower fuel consumption than the German fleet, in contrast to the fleet fuel consumption in China which was 19 percent higher. The fleet average size mix was also smaller than the German mix which should alone have provided a 7.5 percent advantage in fuel consumption if Indian vehicle technology was on par with Germany. Higher diesel penetration in the smaller size classes, and significantly lower vehicle performance levels along with the mix should have resulted in the Indian fleet being 18.4 percent more efficient rather than only the 5.4 percent in actuality. The 13 percent differential is due to the lower technology of the Indian fleet. It is remarkable that the technology differential in 2010 between the Indian and German fleets is virtually identical to the technology differential between the Chinese and German fleets.

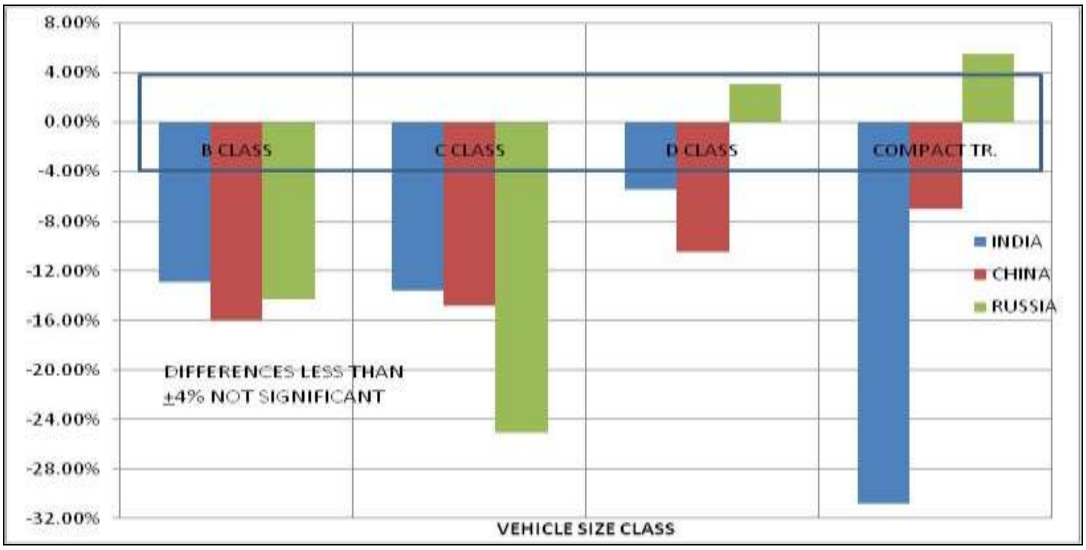
However, many of the same underlying forces are responsible for the technology differential. India has only a limited number of "domestic" vehicle designs in production but there are several popular low cost models that have older designs, notably Maruti 800, Hindustan Ambassador and Premier (these models have become less popular in the post-2010 time frame). The domestic designs include Tata Nano, which is an ultra-low cost model with relatively basic technology. These vehicles sell for less than $5000 but given their size and performance, the fuel consumption is about 13 percent higher than German models in the B and C classes and 26 percent in the A class (where the Nano and Maruti 800 are popular models). The micro truck class has a similar 27 percent technology differential due to the unique characteristics of the Tata Ace with a 16 HP engine that has no real equivalent in the EU market. In the D and E classes, all of the cars are imported, and again, the decomposition analysis shows that in these classes, the technology difference is in the 0 to 5 percent range, with any difference associated only with the time lag between model introduction in the EU and India. Much like Chinese vehicles, the technological gap between Indian and German vehicles for fuel economy increased between 2008 and 2010, but rose more sharply because some vehicles like the Nano were introduced in 2010. The common findings between India and China are encouraging in that low cost vehicle technology is similar globally and is approximately at the 1990-2000 level of OECD technology.

Russia

The Russian fleet had 24.6 percent higher fuel consumption than the German fleet in 2010, and is the only one among "developing" countries to have a larger average size of vehicle than Germany. Of course, Russia embodies a mix of developing country and developed country characteristics. The size adjusted differential in fuel consumption is 20.1 percent and the technology specific difference between Russian and German vehicles is 11 percent, which is comparable to but slightly smaller than the 13 percent differential in China and India.

Russia has one major "domestic" car manufacturer, Lada, which produces several versions of an old design Fiat model that dates from the 1970s, but these variations have the virtues of ruggedness and ease of repair, as well as relatively low cost. Most models continued to use older design 2 valve petrol engines to 2010, and are in the B and C classes. Lada accounts for about half of all cars produced in Russia, while the other 50 percent are local assembly of major OECD manufacturers' models. The detailed class specific analysis shows the influence of the Lada cars as the B and C class vehicles have a technology gap of 14 percent and 25 percent respectively while the technological gap in the other classes in of the order of 0 to 6 percent. Hence, Russia shares some of the same factors that explain the technological gap in India and China, in having a significant percentage of its fleet comprised of low technology content, older design, and inexpensive vehicles. The similarity of effects in China, India and Russia is illustrated in Figure 3.

Figure 3: Size class specific fuel consumption differences relative to Germany



(adjusted for diesel penetration, weight and performance; negative percentages indicate worse FC)

More recently, Lada has signed a major agreement with Renault-Nissan, and is replacing the old models with modern designs sourced from its new partners. In addition, Russian driving conditions and population density are more akin to those in Western Europe, and it is anticipate that the Russian market will gradually evolve to being technologically much closer to the EU market. In this sense, the Russian new vehicle fleet will be similar to the one in Australia where larger and more rugged vehicles have a higher sales mix than in the EU, but technological differences will be limited.

South Africa

The South African fleet had 19.5 percent higher fuel consumption than the German fleet in 2010. Interestingly, the average vehicle size in South Africa is larger than the average German vehicle, and this accounts for 7.5 percent of the 19.5 percent difference. Low diesel penetration and higher trim/option content of cars in South Africa account for 9 percent and 3 percent of the fuel consumption difference respectively and together, the three factors explain the difference completely. Hence, there are virtually no technological differences between the South African and German fleet.

Of course, the result has to be expected given that the South African industry only assembles vehicles exported from the EU and Japan, and the models assembled in South Africa are not specially designed for the region. The larger vehicle size and option content is due to the unusual mix in South Africa, where the class with the highest sales is the midsize truck class that includes pickup and SUV models and accounts for over 25 percent of the total sales. This class is also relatively highly dieselized (over 50 percent diesel). It should be noted that the reference German midsize truck class is principally composed of diesel cargo vans with the result that fuel economy comparisons are not between like models in this class. In spite of these differences, it is clear that one advantage of importing or simply assembling OECD vehicle models is access to the latest technology and hence, the highest fuel efficiency vehicles.

Malaysia

The Malaysian fleet was almost 10 percent less fuel efficient than the German fleet in 2010, in spite of a smaller mix of vehicles, with lower average performance and weight in each class than the German fleet. The mix and weight adjusted differential of 21.1 percent is explained by the lower diesel penetration which accounts for 10.8 percent of the 21.1 percent difference, the high automatic transmission penetration which accounts for 3.3 percent and a net technology differential of 7 percent. The 2008 data, which would not include some model updated by the two major domestic manufacturers (Proton and Perodua) indicated a technology differential of close to 10 percent.

The data at the size class level shows that the technology differential is largely in the A and B class vehicles as well in the medium truck class, all of which are dominated by the older design domestic models that are 15 to 20 percent less fuel efficient than a European model of the same size and performance level. In other classes where imports are dominant, there appears to be little or no technology differential. Hence, the Malaysian fleet has characteristics similar to the Indian, Chinese and Russian fleets where domestic producers have continued production of old vehicle designs, and sell these vehicles as entry level low priced vehicles in their home market.

As in the other countries, these older designs appear to be fading from the market, perhaps in response to the sharp increase in world oil price since 2008. Both Proton and Perodua are rapidly updating their products and it is expected that by 2015, the technology gap may be narrowed considerably.

TECHNOLOGICAL IMPROVEMENTS

Many studies have been conducted by regulatory agencies in the EU, US and Japan on the technological potential to improve vehicle fuel economy while maintaining consumer desired attributes of space, convenience and performance, and their findings are quite consistent, suggesting that a doubling of fuel economy (i.e., a halving of fuel consumption) is possible relative to 2008 baseline. In general, fuel economy improvement can be realized by reducing the energy required to move the vehicle, and by improving the efficiency with which fuel is converted to shaft power by the engine and drivetrain. The energy required to move the vehicle is affected by the weight of the vehicle, the rolling resistance of the tires and the aerodynamic drag of the body. Improvements in all these three areas are being pursued, but drag reduction may have limited benefits in developing country environments where traffic speeds are low. Technologies to provide engine efficiency gains for both petrol and diesel vehicles have emerged rapidly in the last decade, surprising many analysts who believed that these technologies were mature and offered modest prospects for significant improvement. Available studies indicate that about 35 percent of the fuel consumption reduction could come from the drivetrain, and 15 percent from weight, drag and rolling resistance reduction.

Two major pathways have emerged for petrol engine efficiency improvement. The first is by downsizing the engine but maintaining power by the use of direct fuel injection and turbo-charging with inter-cooling. Engine displacement reduction of up to 50 percent is possible now and further reduction may be possible in the future. In conjunction with advanced 7 to 10 speed transmissions, engine efficiency gains of about 20 percent are possible. This technological path has been widely adopted by manufacturers in the EU. A second pathway is by the use of very high compression ratio engines coupled with the use of over-expanded cycles like the Miller cycle or Atkinson cycle. The pathway has emerged more recently in Japan and though its ultimate potential is not completely clear it is likely to be as effective as the downsized and turbocharged pathway. Post-2020, both pathways could adopt lean combustion to provide an additional 10 to 12 percent benefit in fuel economy. Engine idle stop is another low cost technology with very good potential especially in congested urban driving conditions where fuel economy benefits can be as large as 10 percent. Hybrid engine-electric pathways still appear quite expensive for developing country applications, but lower cost "mild" hybrid solutions providing an additional 15 to 20 percent fuel economy benefit may emerge by the end of this decade.

The latest EU technology of using downsized, turbo-charged engines may not be well suited to low speed developing country driving conditions, and the official test result based fuel economy may not see the decline in technology differentials if the EU technology proves less transferable to developing countries. The Japanese path may also have some issues in developing countries if fuel quality and octane requirements are very stringent, but initial indications suggest that lower quality fuels could be accommodated with engine optimization and some reduction of compression of ratio.

CONCLUSIONS AND POLICY IMPLICATIONS

The analysis of vehicle specification and fuel economy data from the new light vehicle fleets of 10 countries shows the considerable diversity of local forces affecting the characteristics of the fleet. The most obvious lesson from the data is that policies aimed at improving fuel economy have to be tailored to the forces obtaining in each country and a single policy such as fuel economy standards cannot be uniformly effective across all nations.

The comparison across four OECD countries provides the following lessons:

- First, vehicle fuel efficiency technology is very similar across all developed countries in spite of significant differences in fuel prices and incomes, showing that fuel economy regulations rather than economic forces control manufacturer technology introduction plans.
- Second, economic instruments such as fees and rebates (feebates) based on vehicle fuel efficiency can have significant market effects by drawing consumers to the most efficient vehicles, even when there are stringent fuel economy standards. There is also some evidence that manufacturers subject to fee-bates may "pull ahead" technology introduction to take advantage of the market response, based on France's experience with the fee and rebate system called Bonus Malus.

- Third, developed nations like Australia that rely on imported vehicles for most or all of their vehicle fleet enjoy a free rider effect of having the latest fuel economy technology since most vehicles are imported from the EU, Japan and Korea. Fuel economy technology may lag the level in the EU or Japan by a modest one to two years due to the lag in the timing of new model introduction.

In the context of developing countries, there are additional specific findings

- In countries where most of the vehicles are imported or simply assembled from knock-down kits, the same free rider effect of obtaining the latest fuel efficiency technology from the EU and Japan is observed, as in South Africa. Here again, there is a modest time lag in technology introduction.
- The situation in countries with significant domestic production and/or restriction of imports, the situation is more complex. Products manufactured locally by global auto-manufacturers generally employ new technology but with a somewhat larger time lag of 4 to 5 years relative to OECD countries in many cases, but not always, depending on the local market's competitiveness.
- Products manufactured by purely domestic manufacturers, typically feature older technology and are 15 to 25 percent less fuel efficient relative to their OECD counterparts of equal size and performance. However, these products are usually smaller, low performance vehicles and their fuel economy may be good on an absolute scale.
- A major factor inhibiting the adoption of new technology in the older design vehicles manufactured domestically is that these products are usually very low price models sold to the most cost sensitive buyers, at prices that are less than half the price of similar size vehicles sold in the OECD. The old technology models may also be perceived as easier to maintain and repair in a developing country environment.

The above findings are based on the 2008 and 2010 data, but the steep increases in global fuel price since 2009 is changing the picture. Sales of these older design models appear to be fading and it is possible that technology in developing countries will converge to the technology used in the OECD in the future with a modest time lag as consumer demand for more efficient products grows in developing countries.

A separate issue is the applicability of new technology being introduced in OECD countries to the developing country environment. The EU manufacturers have adopted the technology of using downsized direct injection turbocharged gasoline engines as a primary method of meeting future fuel consumption or CO_2 standards, but the technology is better suited to high speed driving. Other technology solutions such as high compression ratio engines may be better suited to low speed driving conditions prevalent in developing countries, and it is possible that the technologies may diverge significantly between the EU and the developing world in the post-2015 time frame.

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Global Impact of Light-Duty and Heavy-Duty Vehicle Fuel Efficiency Standards

Zifei Yang, Josh Miller and Anup Bandivadekar*

INTRODUCTION

The world has over 1.5 billion vehicles today, and this global vehicle fleet will continue to expand in the coming years, especially in developing countries. Given the number of vehicles and the growth trend, reducing carbon dioxide (CO_2) emissions and energy use in the area of transportation has become a priority in many countries. Governments have adopted a variety of policy measures in pursuit of these aims. These include promotion of non-motorized as well as public transport, improving traffic and speed management, establishment of fuel efficiency or CO_2 emission standards for new vehicles, and facilitation of technology research and development. Although all of these policy measures contribute in important ways to achieve needed reductions in global vehicle CO_2 emissions, this paper focuses exclusively on efficiency/CO_2 standards and their impact. In the past decade, regulatory action on fuel efficiency for new light-duty (LDVs) and heavy-duty vehicles (HDVs) has accelerated. Setting of vehicle efficiency standards, combined with other measures, could make a significant dent in transport-related oil consumption and CO_2 emissions worldwide. This paper provides a brief overview of the transport sector's role in global CO_2 emissions and oil consumption, summarizes efficiency/CO_2 policies for on-road vehicles in major vehicle markets, and evaluates the short- and long-term impact of adopted and proposed policies on global CO_2 emissions.

TRANSPORTATION SECTOR OIL CONSUMPTION AND GREENHOUSE GAS (GHG) EMISSIONS

Transportation Sector Oil Consumption

Petroleum accounts for 97 percent of transportation energy use (US EIA, 2011; IEA, 2012). In 2011, the transportation sector directly consumed an estimated 46 million barrels of oil per day, equivalent to over half of oil consumed by all sectors. On-road transportation—two- and three-wheelers, LDVs (cars, sport utility vehicles, minivans) and HDVs (trucks, buses)-accounted for over three-fourths of transportation sector oil consumption, equivalent to 35 million barrels per day globally (Figure 1).

Transportation Sector GHG Emissions

The combustion of oil products in the transport sector results in about 7 billion metric tonnes of carbon dioxide ($GtCO_2$) emissions per year, nearly a quarter of global

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* Authors are with The International Council on Clean Transportation (ICCT), San Francisco.

CO_2 emissions (Figure 2). On-road vehicles contribute three-quarters of CO_2 emissions from transport. While the carbon intensity per unit of distance traveled is much higher for HDVs than LDVs, and commercial vehicles tend to be driven more than passenger vehicles, the light-duty fleet accounted for 3.5 $GtCO_2$ emissions in 2010, as opposed to 3.0 $GtCO_2$ from the heavy-duty fleet, due to the greater number of passenger transport vehicles.

Figure 1: Transportation Sector Global Oil Consumption

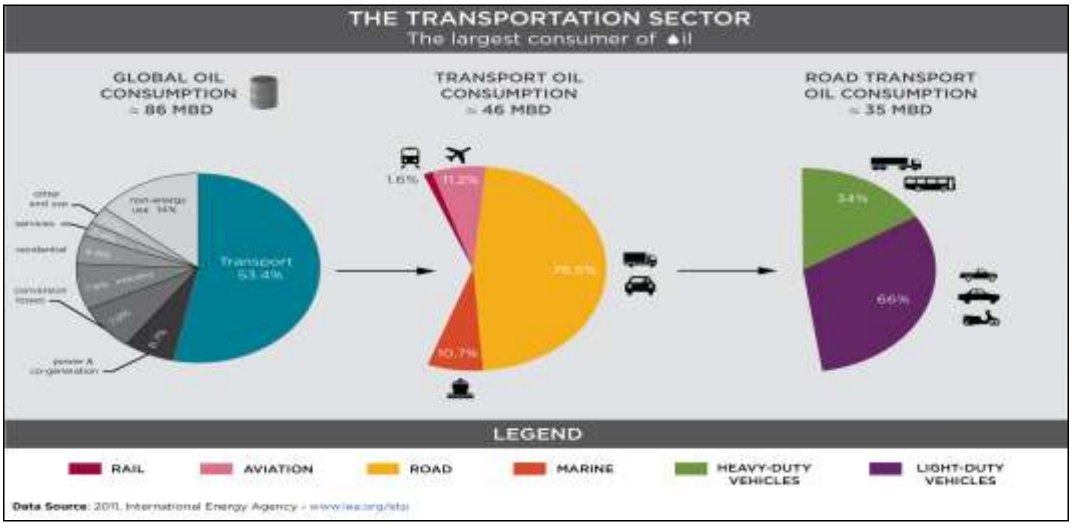
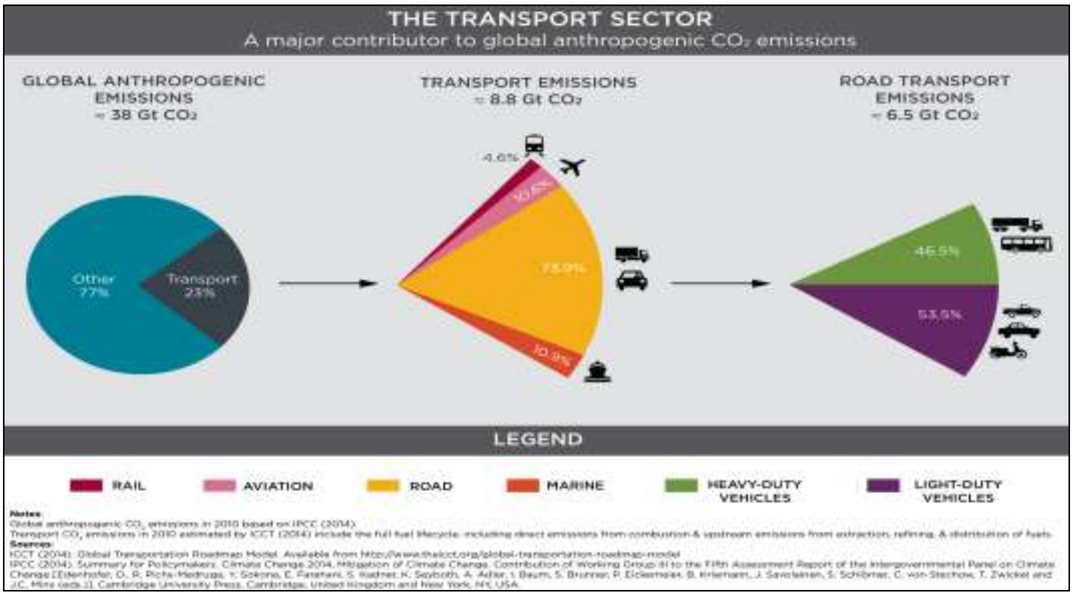


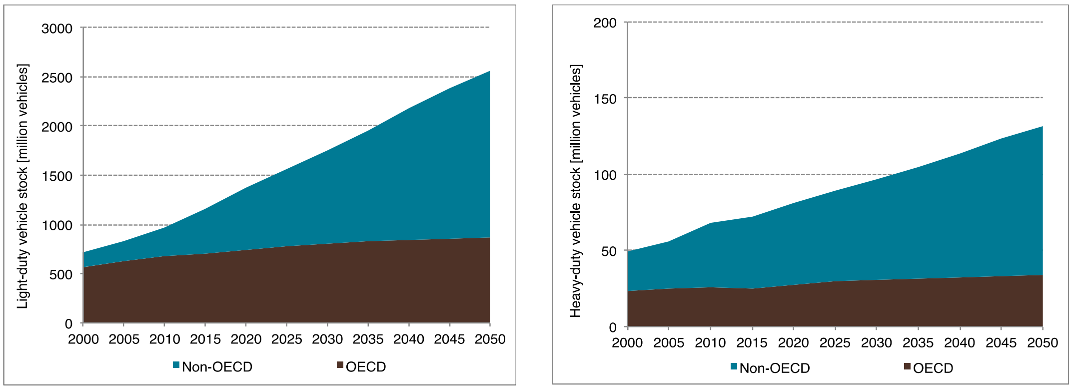
Figure 2: Transportation Sector Global CO_2 Emission



Expanding Role of Transportation Sector

The impact of the transport sector on energy use and climate will intensify as the on-road vehicle fleet grows. The global vehicle stock could triple between 2005 and 2050, with almost all growth accounted for by low-and-middle-income countries. The stock of LDVs, which include passenger cars and light-commercial vehicles, is projected to grow more rapidly than HDVs (Figure 3). Under adopted policies, from 2010 to 2035, the transportation oil demand is estimated to rise from 34 million barrels per day to 59 million barrels per day and well-to-wheel CO_2 from on-road vehicles could rise from roughly 6.5 $GtCO_2$ to 12.7 $GtCO_2$.[1] The anticipated growth in vehicle activity and concomitant increase in oil use and CO_2 emissions calls for a strong policy response for energy security and to mitigate climate change impacts.

Figure 3: Projected numbers of light-duty and heavy-duty vehicles in OECD and non-OECD regions



Source: IEA World Energy Outlook 2012 model, extracted on June 9, 2014

STATUS OF GLOBAL FUEL-EFFICIENCY STANDARDS

Fuel-efficiency/CO_2 standards are among the most cost-effective measures to reduce transport CO_2 emissions and accelerate the commercialization of vehicle efficiency technology (Harvey & Segafredo, 2011). Nine regions, including the United States (U.S.), European Union (EU), Canada, Mexico, China, Japan, India, Brazil, and South Korea, have already established fuel-efficiency or CO_2 emission standards (or their equivalents) for LDVs. Some of them have also set standards for HDVs. This section summarizes the status of these efficiency standards. [2]

1. ICCT's Global Transportation Roadmap model, http://theicct.org/global-transportation-roadmap-model.
2. Some countries have also established fuel-efficiency standards for two- and three-wheelers, although these are not discussed here. For more information, please see Posada et al, 2011; Lyer, 2012.

LDV Fuel-Efficiency Standards

In the last decade, governments in the major vehicle markets have made significant efforts to improve passenger vehicle efficiency. Fuel-efficiency standards are in effect in nine of the top 15 markets, with regulatory time horizons ranging from 2015 to 2025. These standards cover 90 percent of global passenger vehicle sales.[3] The US is the only country that has set fuel-efficiency standards as far out as 2025. India has set targets for 2021, and the EU and Japan for 2020. Some regions have already made commitments or proposed further standards. For example, Canada and Mexico have expressed their intent to align with the US LDV 2017–2025 fuel-economy program, and China has proposed standards for 2020 (Hui & Yang, 2014). However, these commitments require follow-up actions if they are to enter into practical effect.

Early evidence suggests that long-term standards (i.e., for 2020 and beyond) are effective in incentivizing technology development (EPA, 2013; EPA, 2014a; Tietge &Mock, 2014; Rutherford, 2014).The implication is that markets in which the final efficiency target is set before 2020 would benefit from an extended regulatory time horizon. Fewer markets have efficiency standards for light-commercial vehicles (LCVs) than for passenger vehicles (category M1 vehicles in the EU).[4] Six regions (EU, U.S., Canada, Mexico, Japan, China) have set efficiency targets for LCVs. China has announced plans to develop more stringent standards to replace the current standards.[5]

It may be noted that the market segmentation of LCVs varies across the world. In North America, vehicles that would be categorized as LCVs elsewhere (some pickup trucks, vans, and SUVs) are instead categorized as light trucks. Chinese LCVs include not just light pickup trucks and small vans (category N1 vehicles) but also passenger vehicles categorized as M2 that can carry more than nine passengers. The EU LCV regulation on the other hand is restricted to N1 category vehicles. Table 1 compares the fleet-wide emissions target and target year of each region's latest adopted passenger vehicles (PV) or LCV standard, and indicates opportunities for additional commitments. Although the targets are established for different years and rely on different test procedures, using an established conversion methodology it is possible to compare the stringency of these standards on an equal footing (Yang & He, 2014). Figures 4 and 5 show that comparison.

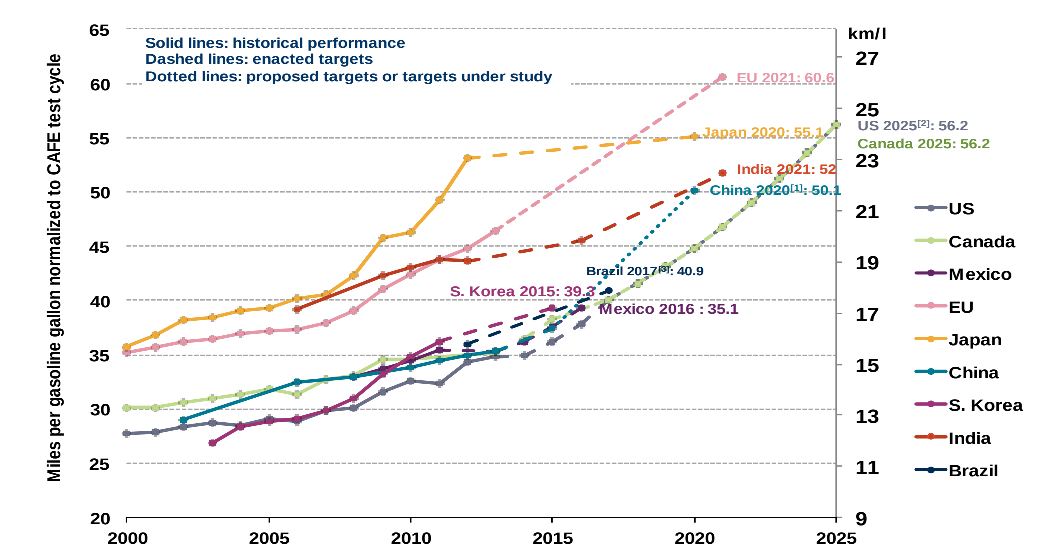
3. 2012 Wardsauto sales database
4. M1 refers to passenger vehicles with maximum 9 seats weighing less than 5000 kg; M2 to passenger vehicles with more than 9 seats weighing less than 5000 kg; N1 to cargo vehicles with maximum designed gross weight less than 3500 kg.
5. News release from China Ministry of Industry and Information Technology (January 3rd, 2014): Launch the revision of light-commercial vehicle fuel consumption standards. http://www.miit.gov.cn/n11293472/n11293832/n11293907/n12246780/15820369.html

Table 1: Light-duty vehicle fuel efficiency/CO2 standards in major markets

Country/ Region	Light-duty vehicle type	Target Year	Unadjusted Fleet Target/Measure	Next steps and opportunity for additional commitments
EU	Passenger car	2015 2021	130 gCO_2/km 95 gCO_2/km	Propose post-2020 CO_2 standards in 2015 and finalize in 2016
	Light commercial vehicle	2017 2020	175 gCO2/km 147 gCO_2/km	
U.S.	Passenger car	2016 2025	36.2 mpg [i] or 225 gCO_2/mi 56.2 mpg [i] or 143 gCO_2/mi	Midterm review in 2017–2018
	Light truck	2016 2025	28.8 mpg [i] or 298 gCO_2/mi 40.3 mpg [i] or 203 gCO_2/mi	
Canada	Passenger car	2016 2025 (proposed)	217 gCO_2/mi [ii] N/A [iii]	Proposed to aligning with the US LDV fuel economy program (2017 – 2025)
	Light truck	2016 2025 (proposed)	293 gCO_2/mi [ii] N/A [iii]	
Mexico	Passenger car	2016	39.3 mpg or 140 g/km	Committed to aligning with the US LDV fuel economy program (2017 – 2025)
	Light truck	2016	29.7 mpg or 185 g/km	
Japan	Passenger car	2015 2020	16.8 km/L 20.3 km/L	3.5% reduction in fuel consumption per year from 2020 to 2030
	Light commercial vehicle	2015	15.2 km/L	
China	Passenger car	2015 2020 (proposed)	6.9 L/100km 5 L/100km	Phase 4 (2020) standards adopted in 2014
Brazil	Passenger car	2017	1.82 MJ/km[iv]	Proposal in agency work plan for the end of 2014, development might possibly extend to 2015
India	Passenger car	2016 2021	130 g/km 113 g/km	Additional technical potential could be capture by further standards
South Korea	Passenger car	2015	17 km/L or 140 gCO_2/km	3.5% reduction in fuel consumption per year from 2015 to 2030

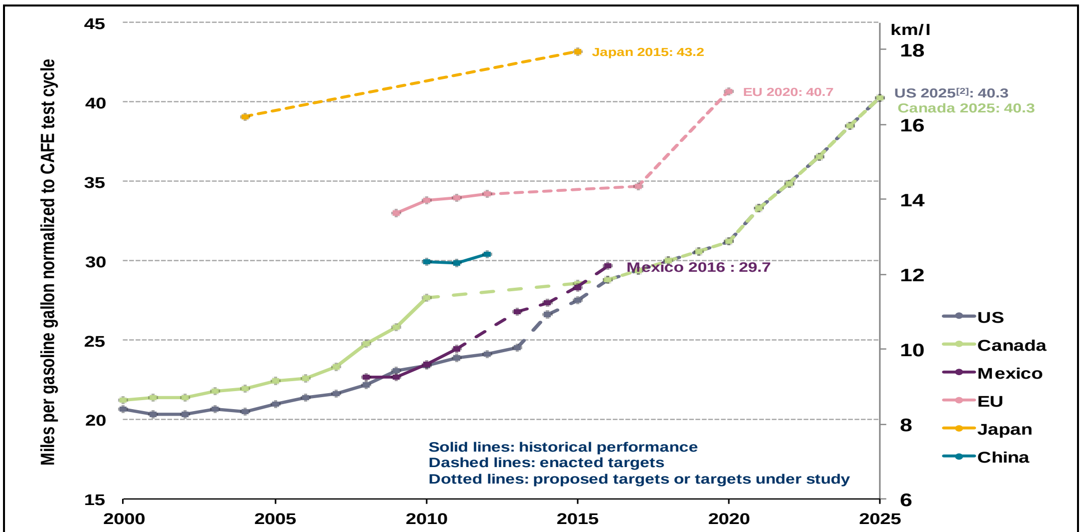
- Fuel economy standard by NHTSA assuming manufacturers fully use A/C refrigerant credit.
- In April 2010, Canada announced a target for light-duty vehicle fleet of 246 g/mi for MY2016. The separated targets for car and light truck fleet are estimated by ICCT based on the overall target.
- Canada follows the US standards in the proposal, but the final target value would be based on the projected fleet footprints.
- The 1.82 MJ/km target corresponds with the implementation of Inovar-Auto program, a fiscal instrument that incentivizes passenger vehicles to improve new fleet efficiency by 12-19 percent between 2013 and 2017.

Figure 4: Global comparison of passenger vehicle fuel-efficiency standards



1. China's target reflects gasoline vehicles only. The target may be higher after new energy vehicles are considered.
2. The U.S standards are fuel economy standards set by NHTSA, which is slightly different from GHG standards due to A/C credits.
3. Gasoline in Brazil contains 22 percent of ethanol (E22), all data in the chart have been converted to gasoline (EOO) equivalent.
4. Supporting data can be found on the website of ICCT

Figure 5: Global comparison of light-commercial vehicle fuel-efficiency standards



Presently, most regions are on track to meet their respective targets. In fact, Japan and the EU have met their 2015 targets two years ahead of the regulatory deadline. Japan's passenger car fleet is fast approaching the 2020 target due to rapid market penetration of hybrid vehicles.[6] Some regions, such as the EU, China, Brazil, have started to develop longer-term targets that would extend beyond their existing policies (EC, 2014).

HDV fuel-efficiency standards

Fuel-efficiency regulations for heavy-duty vehicles are a more recent development compared to the LDV efficiency standards. Today, only U.S., Canada, China, and Japan have established efficiency standards, covering 25 percent of global truck and bus sales. Other regions are working toward HDV efficiency standards. The EU is developing a regulatory proposal for its HDV GHG certification program. Mexico has committed to harmonize with the US and Canada heavy-duty efficiency regulation (Blumberg, 2014), as it has already done with U.S. light-duty standards. Though Mexico has not committed to a specific timeframe for implementation, a delay of several years is anticipated. Other regions, such as Brazil, India, and South Korea, are considering developing standards by conducting technical assessments to convey a sense of the impact such developments could have.[7] These markets accounted for two-thirds of heavy-duty freight activity (tonne-km) and energy use in 2010 (Façanha, et al. 2012).

Unlike LDV regulations, none of the existing HDV standards extend to 2020, let alone beyond that date. Only the U.S. and Canada have begun to work on GHG and efficiency standards that would apply to model year 2019 and later HDVs. Technical potential for further efficiency improvement of HDVs exists; however, realizing this potential will require regulatory measures (Roeth, et al, 2013) as well as complementary voluntary programs (EPA, 2014b). Table 2 summarizes the status of HDV fuel-efficiency/CO_2 emission policies by region and indicates opportunities for further commitments.

Impact of fuel-efficiency standards on new-energy vehicles

As demonstrated by the recent increase in regulatory action to improve vehicle efficiency, there is still significant potential to reduce the emissions of conventional vehicles. But as efficiency standards become more stringent, the promotion of electric-drive vehicles (EVs) will become increasingly important to achieving deep cuts in on-road CO_2 emissions.

6. See Rutherford, 2014 for detail.
7. For example, India set up a heavy-duty vehicle efficiency standards committee on 1 July 2014. See http://petroleum.nic.in/steer.pdf

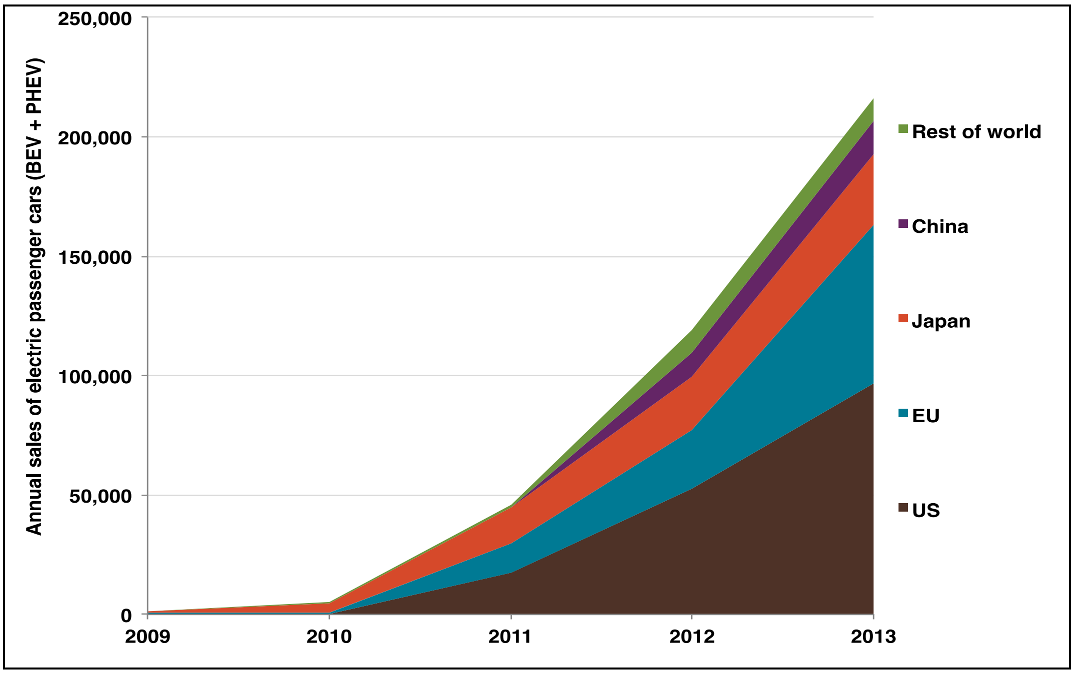
Many efficiency standards provide special credits for EVs. However, given the current high cost of electric-drive vehicle technologies, fuel-efficiency standards alone may not provide sufficient near-term incentive to rapidly expand the market share of EVs. Strong complementary fiscal incentives have contributed to a doubling of the EV market share and quadrupling of sales in the past three years (2011–2014), as shown in Figure 6.Yet even with this direct and indirect support, EVs still account for less than 1 percent of new vehicle sales in major markets around the world. Notable exceptions to this pattern are Norway and the Netherlands, which have among the strongest incentives for EVs in the world (Mock & Yang, 2014). While the market share of EVs is not yet large enough to significantly impact fleet-wide fuel efficiency, policy support for EVs is critical since these vehicles offer a long-term pathway for deep reductions in oil use and CO_2 emissions.

Table 2: Heavy-duty vehicle GHG and fuel-efficiency standards in major markets

Country/ Region	Policy/program	Status	Next steps and opportunity for additional commitments
United States	Phase 2 HDV efficiency standard	Announced in February 2014	Proposal and adoption expected by the end of 2015
Canada	Phase 2 HDV efficiency standard	Align with the US program	Proposal and adoption expected in the 2015-2016 timeframe
China	Phase II HDV fuel consumption standards for 2014 (new types) and 2015 (existing types)	Proposed in 2012	Implementation plan expected to be adopted in 2014. An additional phase of standards starting in 2020 would provide additional benefits
Japan	Phase I standards	Mandatory implement starting MY 2015, fiscal incentives for early compliance are in effect	Potential for a second phase applicable from model year 2020
Mexico	Phase 1 HDV GHG standards	In February 2014, committed to harmonize with US	Potential proposal and adoption expected in the 2015-2016 and alignment with adopted Phase 2 US program
Brazil	Green freight program/ regulatory options	Public and private stakeholders are pursuing the development of a green freight program	Potential for green freight program and HDV efficiency standards
Europe	HDV GHG certification program	Developing a regulatory proposal for the program	Certification proposal expected in late 2015. HDV CO_2 standards are expected by experts following the process, but not announced.
India	HDV labeling and standards	Steering committee to develop HDV efficiency standards established in July 2014	Potential for green freight program and HDV efficiency standards
Korea	HDV standards		Potential for a standard applicable from model year 2020

Evaluating the carbon savings from fuel-efficiency/CO_2 standards measures the effectiveness of such programs. This paper uses ICCT's Roadmap model (Façanha, 2012) to forecast the CO_2 emission reductions achieved by adopted fuel-efficiency/CO_2 standards and potential future actions. Overall, the fuel-efficiency standards adopted to date will slow the increase in CO_2 emissions driven by rapid growth in vehicle activity. However, these effects are not strong enough to stabilize long-term CO_2 emissions from on-road transportation.

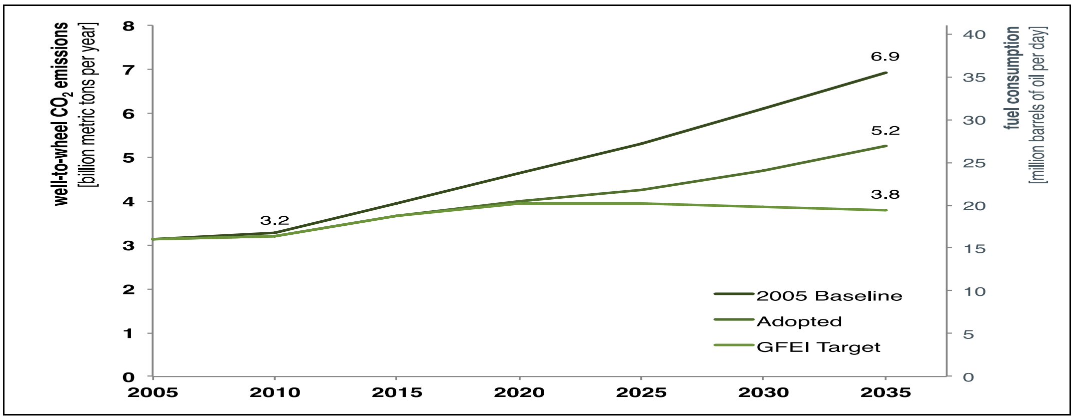
Figure 6: Global sales of electric vehicles (passenger cars), 2009–2013



Impact of current fuel-efficiency programs and additional policy actions on GHG emissions from road transport

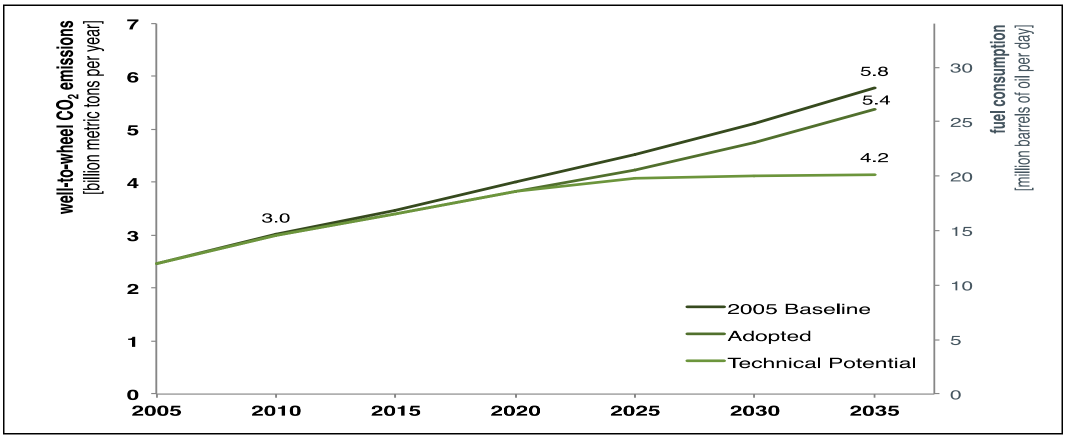
Figure 7 illustrates LDV CO_2 emissions under three scenarios: a baseline with vehicle efficiency held constant at 2005 levels, a scenario with adopted fuel-efficiency/CO_2 standards, and a scenario with achievement of Global Fuel Economy Initiative (GFEI) goals. Adopted regulations to improve LDV efficiency are forecast to cut nearly 1.7 Gt CO_2 emissions in 2035 alone compared to the baseline. However, since the size of the global LDV fleet is expected to double by 2035 from its 2005 level, CO_2 emissions would keep rising after 2020 in the absence of further policy actions.

Figure 7: Global LDV CO_2 emissions with and without adopted fuel efficiency/CO_2 standards and GFEI programs



The GFEI target trajectory evaluates the effects of additional regulations that come into place to achieve GFEI targets, which are to double the efficiency of the global new passenger vehicle fleet by 2030 and double the efficiency of all passenger vehicles on road by 2050. The implementation of additional fuel-efficiency standards consistent with these targets could cut CO_2 emissions by 1.4 Gt CO_2 in 2035 compared to adopted policies, and 3.1 Gt CO_2 compared to the baseline. Such policies could begin to reduce absolute global LDV emissions as early as 2020. Similarly, Figure 8 illustrates HDV CO_2 emissions under three scenarios: a baseline with vehicle efficiency held constant at 2005 levels, a scenario with adopted fuel efficiency/CO_2 standards, and a scenario with consideration of further technical potential. In the baseline scenario, HDV CO_2 emissions would nearly double from 2010 to 2035.

Figure 8: Global HDV CO_2 emissions with and without adopted fuel-efficiency/ CO_2 standards and technical potential



Source: ICCT's Global Transportation Roadmap model

In the second scenario, under the influence of just the four regions that have adopted efficiency standards to date, the forecast emission reduction would be 0.4 $GtCO_2$ by 2035even though the HDV stock is expected to double from 2005 to 2035.That reduction is far less than what is achieved by LDV policies, which are more widespread and tend to require faster rates of improvement than the HDV policies adopted to date. More progressive actions to improve HDV efficiency are needed to counter act expected growth in vehicle activity by trucks and buses. The technical potential scenario assumes that new HDV standards would improve fuel consumption by 3.5 percent annually starting in 2020 in the top eleven vehicle markets, and in 2025 in the rest of the world. Such an approach could stabilize CO_2 emissions by roughly 2025, avoiding emissions of 1.2 Gt CO_2 in 2035 compared to what is forecast under adopted policies. The introduction of additional policies pushing HDVs towards this technical potential will play a crucial role in reducing the carbon footprint of the global HDV fleet.

CONCLUSION

Overall, fuel-efficiency or CO_2 standards have been proven by policymakers around the world to be a cost-effective way to reduce fuel use and CO_2 emissions from on-road transportation. Based on this review of trends in transport sector fuel use, the impacts of fuel-efficiency policies adopted to date, and the potential impacts of additional policy action, following conclusions can be drawn.

- The transportation sector, especially on-road transportation, is a major oil consumer and contributor to global CO_2 emissions. Given the forecast expansion of the vehicle fleet, especially in low- and middle- income countries, improving the efficiency of on-road vehicles is vital if global CO_2 emissions are to be reduced.

- In the past decade, a great deal of progress has been made globally in fuel efficiency and CO_2 standards for both LDVs and HDVs. LDV efficiency standards are better developed than those for HDV. Nine regions, including the U.S., EU, Canada, Mexico, China, Japan, India, Brazil, and South Korea, have established standards or equivalent policies, covering 90 percent of the global LDV market. Only the U.S., Canada, Japan, and China have adopted HDV efficiency standards, covering 25 percent of HDV markets. Moreover, while some regions have adopted LDV efficiency standards that will apply over a long timeframe (2020 to 2025), all HDV efficiency standards adopted to date target near-term improvements (2014 to 2018).

- As more and more regulators in top vehicle markets recognize the importance of fuel-efficiency standards, a larger fraction of vehicle sales will be regulated with more stringent, long-term standards. There remains vast potential for additional policy action, particularly in emerging markets.

- Adopted fuel-efficiency standards for LDVs and HDVs are forecast to reduce 2.1 Gt CO_2 in 2035 compared a baseline scenario featuring no improvements to vehicle efficiency after 2005. However, the current policies are not strong enough to counteract the expected increase in CO_2 emissions driven by growth in vehicle activity. To stabilize and reduce CO_2 emissions in the long run, additional policies will be needed in the next two decades to harness the technical potential of improved efficiency from conventional vehicles and incentivize the development and commercialization of new-energy vehicles and efficient vehicle technology.

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Life Cycle Energy Consumption and CO_2 Emissions of Different Transport Systems in India

Akshima Tejas Ghate* and Sanjivi Sundar*

INTRODUCTION

Transport infrastructure promotes and supports economic growth of the country and economic growth, in turn, generates transport demand. The construction of transport infrastructure and the use of that infrastructure to meet transport demand results in the use of energy and emission of CO_2 and criteria pollutants. Investment decisions on transport infrastructure as in the case of other investment decisions are based on techno-economic feasibility analysis; they are in addition subject to environmental impact analysis (EIA). EIA usually assesses the impact of the construction and use of infrastructure on natural resources and air quality.

However, given the importance of energy conservation in a country like India which is highly dependent on imports of energy and given also the importance of containing CO_2 emissions, it is essential to take note of the energy consumption and CO_2 emissions during the entire life of a project i.e. construction, maintenance, and operations (Chester and Horvath, 2009a; Chester et al., 2010; and Facanha and Horvath, 2007). This becomes all the more important when massive investments are being made in transport infrastructure by way of construction of highways, regional railways, airports, ports, metro railways, bus rapid transit projects and urban roads. It is estimated that an amount of nearly 130 billion USD will be spent on building transport infrastructure during the period 2012-17 (Planning Commission, Government of India, 2013).

There are no comprehensive studies on the life cycle inventory of energy consumption and CO_2 emissions from transport modes in India. Such studies should be routinely carried out following well-established methodologies when investment decisions are taken on major transport projects. This paper aims to establish a methodology for such an assessment and demonstrate its use. The transport modes selected for this study include three intra-city transportation systems-urban roads, Bus Rapid Transit Systems (BRTS), and Metro Rail and two inter-city systems-National Highways (NH) and long-distance passenger railway.

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* Authors are with the Energy and Resources Institute, New Delhi.

FRAMEWORK AND SCOPE OF THE LIFE CYCLE ENERGY CONSUMPTION AND CO_2 EMISSIONS INVENTORY

2.1 Framework

ISO 14000 framework[1] for Life Cycle Analysis (LCA) and several papers on methodology/application of LCA for transport sector were reviewed before drawing up a framework for carrying out the life cycle inventory of energy consumption and CO_2 emissions of different transport systems in India. The key features of the framework developed by the authors are discussed below.

The life cycle inventory framework drawn up by the authors is in line with the ISO 14000 framework for carrying out LCA studies. Most of the reviewed LCA methodologies for transport sector follow the ISO 14000 framework for LCA (Birgisdóttir, 2005; Mroueh et al., 2000; Mazri et al, 2005). The system boundary/scope of the inventory has been defined/limited by the authors as it was observed that all LCA methodologies that were reviewed define the system boundaries and limit the scope of LCA in order to ensure that it is doable (Treloar et al., 2004; Mroueh et al., 2000; NTUA, 2006). The system boundaries defined by the authors limit the scope of life cycle inventory to specific life stages and sub-stages of transport projects; the life stages/sub-stages considered by the authors are in consonance with the typical LCA methodologies for transport sector. Authors have considered construction, maintenance and operations life stages and their key sub-stages.

The key stages that are included are:

- Raw material extraction, processing, transport and manufacture
- Transportation of construction materials/waste to and from construction site
- On-site energy usage
- Consumption of materials for annual and periodic maintenance
- Material and energy consumption for manufacture and maintenance of rolling stock
- Direct energy consumption for rolling stock operations

The material and energy consumption for manufacturing/constructing capital assets like the machinery used for construction, trucks used for transportation of materials, factories/industries/retail facilities used for manufacture/sale of construction materials, etc. are not included in the inventory scope on account of their expected insignificant contribution to a single project. The same is in line with the ISO 14000 framework and other LCA methodologies reviewed that also exclude such capital assets; none of the reviewed LCA methodologies included capital assets.

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1. http://www.iso.org/iso/home/standards/management-standards/iso14000.htm

Demolition stage is not considered in the life cycle inventory as infrastructure projects in India are hardly demolished. This is in line with the methodologies followed in various papers:

- Demolition stage is not included in Mroueh et al. (2000) and NTUA (2006)
- Inclusion of demolition stage is optional in Birgisdóttir (2005)
- While Stripple (2001) indicates inclusion of disposal/reuse of the road at the end of the life cycle, it also indicates that most roads have no final end. Instead, they are reconstructed or replaced by a new road while the old road remains in operation.

The framework developed by the authors follows a bottom-up approach, wherein life cycle inventory is carried out for specific projects by carrying out extensive data collection. Typical projects for all selected modes have been selected and studied in order to estimate the life cycle impacts. Due to limited time period for this study, authors could not select a large sample of projects per mode to estimate the life cycle impacts. Hence, one typical project was selected per mode. Authors defined 'typical' projects as projects that do not have unusual features e.g. road and rail projects selected are in flat terrains, do not pass through forested areas, etc. Many international papers on LCA of transport also select typical projects to estimate life cycle impacts (Mroueh et al., 2000; Birgisdóttir, 2005; NTUA, 2006; Mroueh et al., 2001, etc.).

In most of the LCA applications reviewed (Birgisdóttir, 2005; Stripple, 1995; Stripple, 2001; Mroueh et al., 2000; Mroueh et al., 2001; Treloar et al., 2004), country-specific spread sheet models/software programs have been developed to carry out the LCA. Authors have also developed their own India-specific spread sheet model to carry out the life cycle inventory for transport systems in India.

Conversion factors, specifically embodied energy and CO_2 values of materials and fuels and tailpipe CO_2 emission factors of fuels, are very critical for LCA analysis. India-specific values have primarily been used by the authors to estimate energy and CO_2 impacts of material and fuel consumption. In case India-specific values were not available, international values were used.

The study recognizes that technological and efficiency changes will take place in future which could reduce energy consumption and CO_2 in construction processes, materials production and transportation of materials. However, such efficiency improvements are not accounted for while estimating the energy and CO_2 impacts for the project life; it is assumed that the same level of efficiency will prevail during the project life.

2.2 Scope

Ideally, a life cycle inventory should include all the stages in the life of a project. However, time and resource constraints could make it difficult to collect data on all the stages and it may become necessary to exclude some stages from the scope of the life cycle inventory. In case such exclusions are made, they should be clearly spelt out. As stated in section 2.1, in this study also, certain stages in the life of projects studied have been excluded and these have been clearly spelt out as discussed below.

Construction of the transport corridor/fixed infrastructure

Embodied energy and CO_2 in construction materials: Construction of any transport corridor involves consumption of materials. The production of most construction materials is an energy intensive process that also generates CO_2 emissions; this energy that is used for the manufacture of materials is referred to as the ‘embodied energy’ of materials, and the resultant CO_2 as the ‘embodied CO_2’.Embodied energy and CO_2 of materials, however, do not typically include the embodied energy and CO_2 of manufacturing units producing these construction materials, as these manufacturing units are capital assets that produce materials for several projects/purposes. The embodied energy and CO_2 of only the construction materials is taken into account in this study and not of the manufacturing units producing these materials. To the extent possible, India-specific embodied energy and CO_2 coefficients for materials were used to estimate total embodied energy and CO_2 of materials consumed per km of infrastructure construction and maintenance (AEI, 2009). In case India-specific embodied energy and CO_2 coefficients were not available, they were derived from international sources (Hammond and Jones, 2008).

Transportation of construction materials/waste and labour to and from the construction site: The materials produced are then transported to the construction sites, usually by motorized modes like trucks, tractor-trailers, etc. Additionally, motorized modes are also used for transporting construction wastes from the site. There are, thus, two types of energy consumptions in these transport activities – direct energy consumption by vehicles used to transport the materials and waste and indirect energy consumption in the manufacture and maintenance of vehicles. While the direct energy consumption and CO_2 in the transportation of materials is included, the indirect energy consumption and CO_2 i.e. embodied energy and CO_2 of trucks, tractor-trailers, etc. are not included because these vehicles are capital assets that are re-used for several other construction projects and non-construction activities. The direct energy consumption and CO_2 due to transport of construction labour to and from the construction site is also included in the inventory; the embodied energy and CO_2 of vehicles transporting labour, however, are not included for the reasons stated earlier.

On-site energy usage during construction: On-site construction processes require energy to run construction machinery, hot mix plants, etc. Diesel, electricity and fuel oil are the most common fuels consumed on-site. On-site energy consumption for construction processes and CO_2 impact due to this are included in the scope of this inventory. Indirect energy consumption and CO_2 in the manufacture of construction machinery and equipment, however, is not included as these are also capital assets and their embodied energy and CO_2 cannot be attributed to a single transport project.

Direct and indirect energy consumption for rolling stock operations and maintenance

Operations on transport corridors involve movement of rolling stock. Direct energy consumption and CO_2 due to movement of rolling stock is included in the inventory. For direct energy consumption, well-to-wheel embodied energy coefficients and CO_2 emission factors have been considered. India-specific indirect energy consumption in the manufacture and maintenance of rolling stock should ideally have been used in the inventory, but such data was not available. Therefore, the data was sourced from international literature on the assumption that the rolling stock's embodied energy and CO_2 will not vary substantially due to standard/common processes and materials used in rolling stock manufacture globally. Besides, the vehicle manufacturers in India are all global manufacturers of vehicles and are expected to follow similar practices.

It is recognized that future research and development (R&D) into materials and engines would lead to improved energy efficiency of rolling stock; however, as this cannot be predicted or anticipated, improvements in energy efficiency on account of technological advances have not been considered (Akerman, 2011). The efficiency levels of rolling stock are therefore, assumed to remain unchanged during the life period of the project.

Maintenance of the transport corridor/fixed infrastructure

Energy and CO_2 impacts of annual routine maintenance and periodic maintenance/ renewal have been considered in the study. In estimating the energy consumption and CO_2 emissions in the maintenance stage, only the energy consumption and CO_2 emissions of the material used during maintenance have been considered; energy consumption in on-site maintenance activities such as operating hot mix plants and in the transport of materials and labour, though important, could not be included due to lack of data. Also, additional energy consumption and CO_2 emissions due to disruption/congestion of traffic on account of maintenance works, are not included in the inventory.

3. DATA AND METHODOLOGY

A bottom-up approach was adopted to carry out the life cycle inventory of the selected transport modes within the boundaries discussed in section 2. Within the intra-city and inter-city transport systems referred to in section 1, specific projects were selected and in respect of these projects, primary data was collected to estimate the energy consumption and CO_2 emissions during their full life subject to the exclusions made above. The projects that were selected were typical projects and did not have any unusual features e.g. road and rail projects selected were in flat terrains and did not pass through forested areas, hilly areas, etc.

3.1 Construction stage- primary data

Following data was collected to estimate energy consumption and CO_2 emissions during construction of physical infrastructure.

- Quantity of all key construction materials consumed per kilometre (km) construction
- Total fuel consumed for transportation of materials required for per km construction
  - Quantities of materials transported and average leads for all materials
  - Mode of transportation (truck, dumper, tractor, transit mixer, rail, etc.) and its fuel efficiency
  - Average loading (per vehicle) and number of trips to transport materials
- Total energy consumed on-site (for per km construction)
  - Electricity consumption
  - Consumption of petroleum products

The projects for which the above listed data was collected are listed in Table 1. These projects were under construction at the time the study was carried out.

Table 1: Selected transport projects for which construction data was collected

Mode	Projects for which construction data was collected
National highway	Four laning of Rohtak-Bawal national highway, Haryana state (Bituminous road)
Long-distance passenger rail	Construction of Rewari-Rohtak new passenger rail line, Haryana state (single line)
Metro rail	Construction of New Ashok Nagar-Sector 32, Noida section of Delhi metro rail (elevated track and elevated station)
BRTS	Construction of Pirana-Naroda section of Ahmedabad BRTS, Gujarat state (BRTS corridor and one station)
Urban road	Construction of Ring Road (arterial road) in Delhi

3.2 Operations stage - Secondary data

Table 2 lists the sources from which data was collected to estimate energy consumption and CO_2 emissions in the operations of rolling stock. As for the data on embodied energy and CO_2 of rolling stock, India-specific data on energy consumption and CO_2 emissions in the manufacture and maintenance of rolling stock was not forthcoming for reasons of commercial confidentiality; the data was obtained from Chester (2008) and Chester and Horvath (2009b). They have put together data for the United States (US) on the assumption that the manufacturing processes are by and large similar and would not vary significantly for India.

Table 2 Data and data sources used for estimation of energy consumption and CO_2 emissions in the operations of rolling stock

Mode	Data collected	Data source
Long-distance train	Energy consumption for passenger services by Indian Railways	Annual Statistical Statements of Indian Railways (2010-11), Ministry of Railways (GoI, 2012)
Long-distance bus	Energy consumption by long-distance buses of State Road Transport Undertakings (SRTUs)	Data published by Ministry of Road Transport and Highways (GoI, 2011)
Metro rail (train)	Energy consumption by Delhi Metro for traction and stations	PDD (Project Design Document) submitted by Delhi Metro Rail Corporation (DMRC) to UNFCCC in 2011 (to get carbon credits for Phase-2 of Delhi Metro)[2]
BRTS	Energy consumption data for Ahmedabad BRTS	Data obtained from the Project Management Cell of Ahmedabad BRTS
Car	Average fuel efficiency and occupancy of cars (petrol, diesel and CNG car)	Data obtained from the Society of Indian Automobile Manufacturers

3.3 Maintenance stage - primary data

For the purpose of assessing the embodied energy and CO_2 consumption at the maintenance stage, a few projects that had been completed and were in operation were chosen. These are listed in Table 3. In respect of these projects, data on material consumption for annual and periodic maintenance activities was collected for the latest year for which such data was available with the concerned agencies.

The energy consumption and CO_2 emissions on account of annual maintenance activities were estimated for a period of 30 years; it was assumed that the nature of the annual maintenance activity will remain unchanged during all the 30 years. In the case of

2. Report available at http://cdmloanscheme.org/sites/default/files/pdd3.pdf, last accessed on 13 Nov, 2013.

road projects (national highway, BRTS and urban road), periodic maintenance in addition to annual maintenance was carried out. This involved adding a renewal coat to the wearing course at a predetermined frequency. Data on one periodic renewal (consumption of materials only) in respect of the selected projects was collected and then used to estimate the material consumption for the total number of periodic maintenance activities during the 30-year period. In the case of rail projects (long-distance rail and metro rail), the periodic renewal activities during the 30 year period like replacement of sleepers, replacement of rails, through screening of ballast, etc. were identified in consultation with the railway authorities; the data in respect of the materials used was collected and used for calculating the materials consumed for periodic maintenance during the entire project period.

As noted earlier, technological and efficiency changes will take place in future which could reduce energy consumption and CO_2 emissions in the construction and maintenance processes and in the production and transportation of materials. However, such efficiency improvements are not accounted for in estimating the energy and CO_2 impacts in the maintenance activities during 30 years, as these are not known. Therefore, it is assumed that the level of efficiency will remain unchanged during the 30 year project life.

Once the data was collected, a spread sheet model was developed to estimate the energy consumption and CO_2 emissions at various life stages of the selected projects. As would be noted, drawing up life cycle inventories calls for considerable amount of data. Such data is not usually collated and maintained by the agencies involved in construction/operations of transport systems. In order to carry out comprehensive life cycle inventories in future, it is critical to collect, collate and maintain good quality data on energy consumption and materials used during the life stages of transport projects. This should be carried out as a matter of routine ideally in respect of all transport projects, and if this is not possible, at least in respect of projects above a certain cost threshold. The authors would be happy to provide a typical list of data required for life cycle inventory of transport projects.

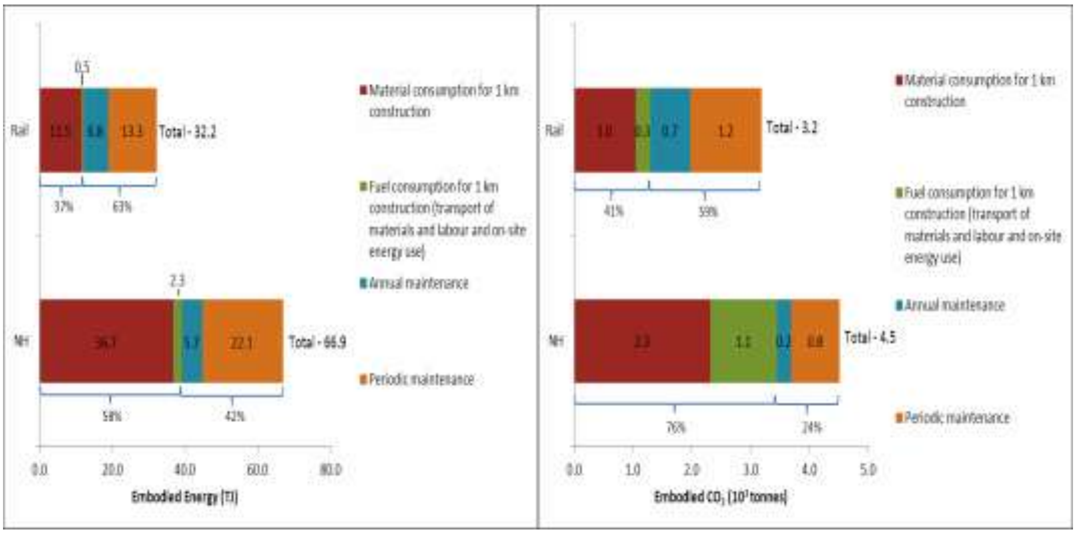
4. RESULTS

The results of this study, discussed below, should be treated as indicative and not conclusive. For one, certain stages in the life cycle have been excluded for good reason as indicated at the outset. For another, it has not been possible to obtain all the data required from sources in India and some data like the one for embodied energy in vehicles had to be obtained from international sources.

4.1 Inter-city modes - National highway and Railway

Construction and maintenance

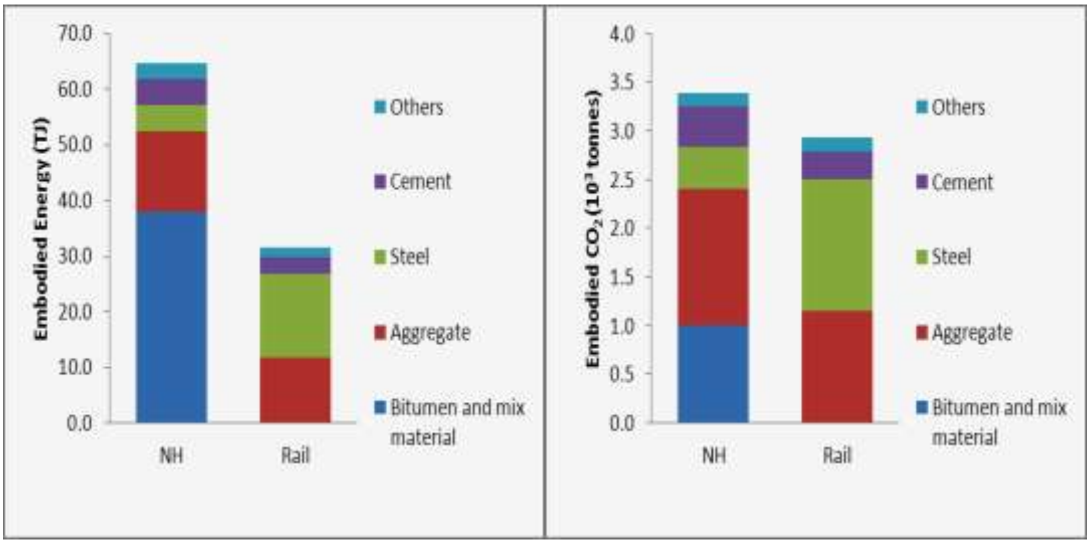
Figure 1: Inter-city modes: Energy consumption and CO_2 emissions on account of construction and maintenance activities for a period of 30 years



National highways have more embodied energy and embodied CO_2 as compared to railways on account of construction and maintenance activities for a period of 30 years (Figure 1).This is primarily due to the use of more quantities of some energy and carbon intensive materials such as aggregates and cement in the construction and maintenance of 1 km of national highway as compared to 1 km of rail, and the use of bitumen in road construction and maintenance (Figure 2).

Energy consumption on account of on-site activities and transportation of materials, waste and labour is not very high in the full life cycle of either of the projects (Figure 1). However, it is higher for national highway projects as compared to rail projects. This is due to the use of more machinery driven by fossil fuels in highway construction in India as compared to railway construction.

Figure 2: Inter-city modes: Contribution of construction materials to embodied energy and CO_2 emissions of construction and maintenance activities for a period of 30 years



Interestingly, the results show that the use of materials which are less-energy and CO_2 intensive could significantly reduce the energy and carbon intensity in the construction and maintenance of transport infrastructure. A life cycle inventory will thus be useful not only to see whether one transport mode is more energy and CO_2 intensive than another but also to explore how the energy intensity of any one mode can be reduced by the use of different materials. Given the massive investment program on road construction in India, there is need for research to find alternative materials that are less energy and CO_2 intensive.

It is also evident that energy consumption and CO_2 emissions in on-site activities during construction and maintenance can be reduced by using efficient construction machinery and alternative sources of energy to run them. The use of locally-available materials, thereby avoiding the need for transportation and optimized logistics for transport of materials, waste and labour when unavoidable to and from construction/maintenance sites can also help reduce energy consumption and CO_2 emissions. These are all areas for research.

Figure 1 also indicates that energy consumption and CO_2 emissions on account of annual and periodic maintenance of infrastructure are important in a life cycle inventory. Maintenance activities over a period of 30 years account for 63 percent of the total embodied energy and 59 percent of the total CO_2 emissions in the rail project and 42 percent of the total embodied energy and 24 percent of the total CO_2 emissions in the case of a national highway project. Periodic maintenance has a significant share in embodied energy and CO_2. If periodic maintenance requirements can be reduced by better construction and good routine annual maintenance, the time between periodic renewal/maintenance can be lengthened, thereby reducing the number of periodic renewals and consequently the energy consumption and CO_2 emissions.

Operations

As indicated in Table 2, operational energy consumption of long-distance passenger buses was estimated by using data on physical performance of State Road Transport Undertakings (SRTUs). Average energy consumption and CO_2 of the 16 SRTUs for which data was available was estimated to be around 221.9 kJ/passenger km (PKM) and 17.9 g/PKM, respectively in 2010-11 (Table 3).

Table 3: Selected transport projects for which maintenance data was collected

Mode	Projects for which maintenance data was collected
National Highway	Delhi-Agra National Highway
Long-distance rail	Delhi-Bathinda rail line
Metro rail	Phase I and Phase II operational network of Delhi metro rail
BRTS	Pirana-Naroda section of Ahmedabad BRTS
City road	Ring Road (arterial road) in Delhi

Operational energy consumption for Indian Railways was estimated by using fuel consumption data contained in the Annual Statistical Statement, 2010-11 published by Indian Railways. For 2010-11, operational energy consumption for Indian Railways was about 107.6 kJ/PKM for diesel traction and 50.7 kJ/PKM for electric traction (Table 4). CO_2 per PKM was 8.7 g/PKM and 11.4 g/PKM for diesel and electric tractions, respectively (Table 4).

Table 4: Inter-city modes: Operational energy consumption and CO_2 emissions

Year	Rail		NH
	Diesel traction	Electric traction	Long-distance diesel bus
Energy consumption (kJ/PKM)			
2009-10	109.8	52.2	225.6
2010-11	107.6	50.7	221.9
CO_2 emissions (g/PKM)			
2009-10	8.8	11.7	18.2
2010-11	8.7	11.4	17.9

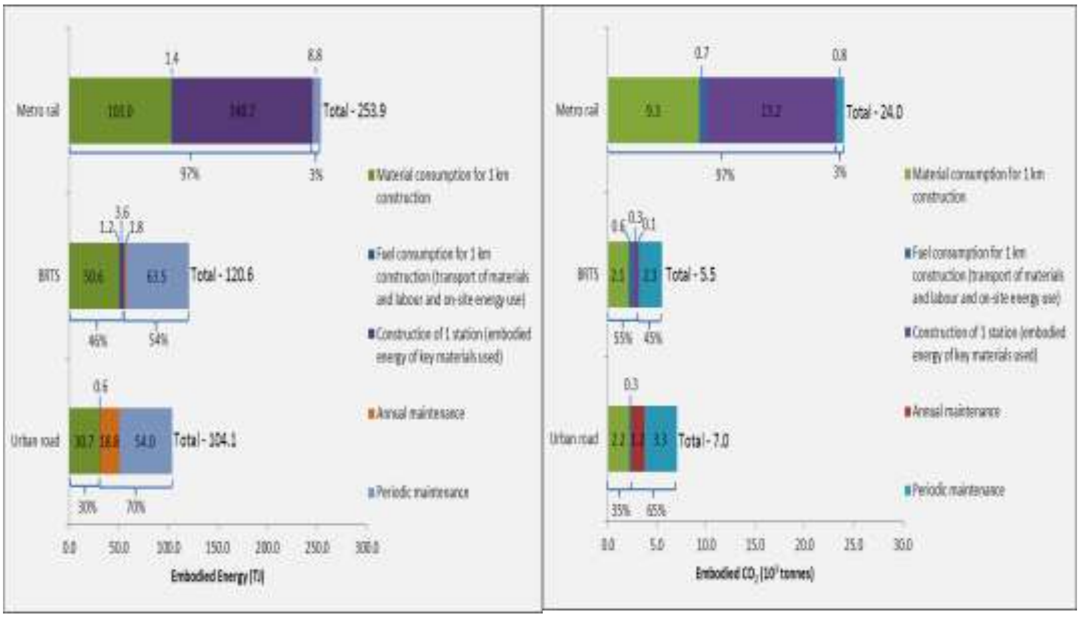
Sources for deriving the efficiency and CO_2 emissions numbers-Annual Statistical Statements of Indian Railways (2010-11), Ministry of Railways (GoI, 2012), Data published by Ministry of Road Transport and Highways (GoI, 2011).

The operational energy consumption and CO_2 emissions presented in Table 4 do not include embodied energy and CO_2 of rolling stock i.e. energy consumption and CO_2 in the manufacture and maintenance of rolling stock over the given life of rolling stock, as such data was not available. It is important to generate this data in India and make it available for future work on life cycle inventory.

4.2 Intra-city modes

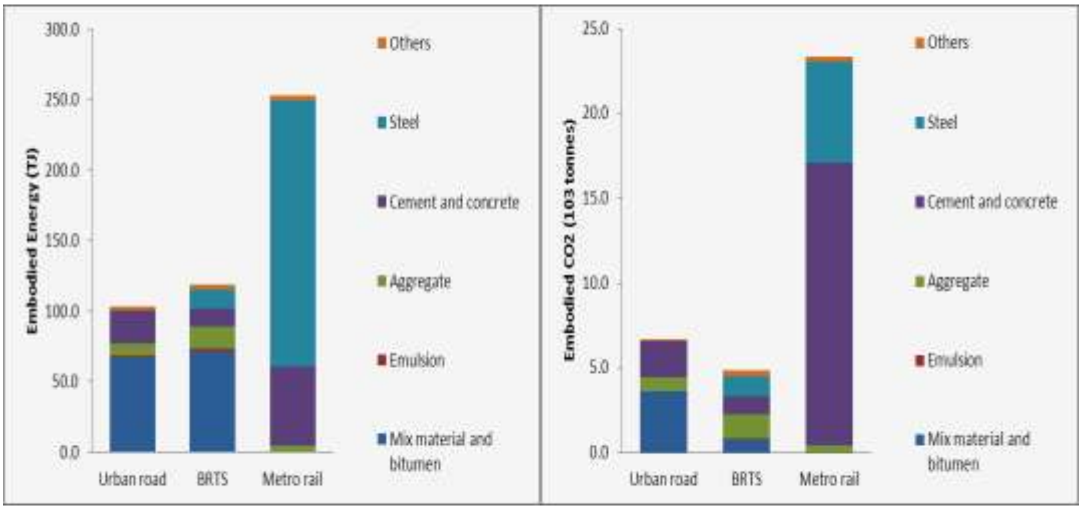
Construction and maintenance

Figure: 3 Intra-city modes: Energy consumption and CO_2 emissions on account of construction and maintenance activities for a period of 30 years



As for construction, metro rail project is the most energy and carbon intensive mode of transport amongst the intra-city transport modes (Figure 3). Embodied energy on account of construction activities (track and station) in a metro rail project is four times more than that of BRTS and about eight times more than that of urban road projects; embodied CO_2 is more than seven times higher than that of both BRTS and urban road projects. This is because the construction of metro rail tracks and stations entail the use of highly energy and carbon intensive materials, namely, steel and cement in large quantities (Figure 4). Within the metro rail system itself, the construction of stations is more energy and CO_2 intensive as compared to the construction of tracks.

Figure: 4 Intra-city modes: Contribution of construction materials to embodied energy and CO_2 emissions of construction and maintenance activities for a period of 30 years



As for maintenance over a period of 30 years, road-based intra-city transport modes i.e. BRTS and urban road have more embodied energy and CO_2 as compared to metro rail. Annual and periodic maintenance contribute 54 percent and 70 percent embodied energy in the case of BRTS and urban road respectively, as compared to 3 percent in case of metro rail; embodied CO_2 due to maintenance activities is also higher in road based modes.

Maintenance activities account for more embodied energy and CO_2 as compared to construction activities in the case of road-based modes. Within maintenance, periodic maintenance on account of the need to renew the wearing course is more energy and CO_2 intensive. As argued earlier, better construction and good annual maintenance would lengthen the time between periodic renewals over a given life span of the project, thereby reducing energy consumption and CO_2 emissions.

Operations

Results for operational energy consumption and CO_2 emissions for different intra-city modes are presented in Table 5. On a passenger km (PKM) basis, metro rail is the most energy efficient mode of intra-city transport. As for CO_2 emissions, non- Air Conditioned (AC) intra-city buses perform the best. However, it must be noted that the embodied energy and CO_2 emissions in the manufacture and maintenance of rolling stock are not included in these operational energy and CO_2 emissions estimates and their inclusion could alter the findings.

Table 5: Intra-city modes: Operational energy consumption and CO_2 emissions

	Energy consumption (kJ/PKM)	CO_2 emissions (g/PKM)
Metro rail	86.4	19.7
Urban bus (Non-AC)	206.1	16.6
BRTS bus (AC)	554.1	36.9
BRTS bus (Non-AC)	215.6	17.4
Two wheeler	467.5	36.5
Petrol car	1870.0	146.0
Diesel car	2343.3	188.6
CNG car	2293.3	138.1

Sources for deriving the efficiency and CO_2 emissions numbers - PDD (Project Design Document) submitted by Delhi Metro Rail Corporation (DMRC) to UNFCCC in 2011 (to get carbon credits for Phase-2 of Delhi Metro), Data obtained from the Project Management Cell of Ahmedabad BRTS, Data obtained from the Society of Indian Automobile Manufacturers

4.3 Application of results of life cycle inventory

It would be interesting to see as to how the energy consumption and CO_2 estimates, both direct and indirect, arrived at on a unit basis in sections 4.1 and 4.2 can be used to estimate the full life cycle energy and CO_2 intensity of inter and intra city modes of transport. Using the unit values derived from this study, an attempt has been made to carry out full life cycle energy and CO_2 estimation in respect of the two intra-city transport systems, the Ahmedabad BRTS and the Delhi metro rail. Ideally, we would have liked to carry out life cycle comparisons of two inter-city modes, say a highway and an inter-city rail as well. Unfortunately, the necessary data to make this analysis could not be collected as part of the study. The key assumptions and data used for this estimation are discussed below.

Ahmedabad BRTS

- Total life of the fixed infrastructure i.e. the bus lanes and bus stops is 30 years
- Total life of the rolling stock i.e. the buses is 15 years. As stated in section 3.2, India-specific data on embodied energy and CO_2 of rolling stock was not available; USA-specific data from Chester (2008) and Chester and Horvath (2009b) was used.
- Calculations have been done for the entire planned BRT corridor length of about 129 kms having 249 bus stops although the length operational so far is only about 67 kms.
- Once the BRTS is fully functional, 737 AC buses will be plying per day.

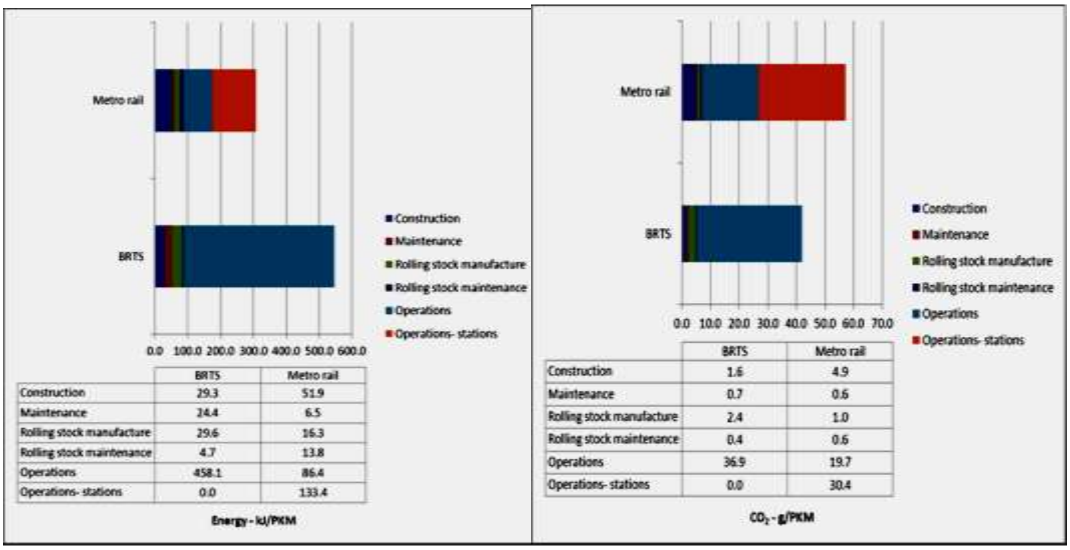
- Passenger km is estimated based on the design capacity of the Ahmedabad BRTS system i.e. 1.03 million passengers per day.

Delhi Metro

- Total life of the fixed infrastructure i.e. the viaduct and stations is 100 years
- Total life of the rolling stock i.e. the trains is 30 years. As stated in section 3.2, India-specific data on embodied energy and CO_2 of rolling stock was not available; USA-specific data from Chester (2008) and Chester and Horvath (2009b) was used.
- Calculations have been done for phase I and II of Delhi metro i.e. track length of 189.7 km having 142 stations.
- 208 trains ply per day on phase 1 and phase 2 network.
- Passenger km (PKM) is estimated based on the current average ridership of the phase I and II i.e. 1.5 million passengers per day.

The results are presented in Figure 5.

Figure 5: Life cycle inventory: Results for Delhi metro rail and Ahmedabad BRTS projects



	BRTS	Metro rail
Construction	29.3	51.9
Maintenance	24.4	6.5
Rolling stock manufacture	29.6	16.3
Rolling stock maintenance	4.7	13.8
Operations	458.1	86.4
Operations- stations	0.0	133.4

Energy - kJ/PKM

	BRTS	Metro rail
Construction	1.6	4.9
Maintenance	0.7	0.6
Rolling stock manufacture	2.4	1.0
Rolling stock maintenance	0.4	0.6
Operations	36.9	19.7
Operations- stations	0.0	30.4

CO_2 - g/PKM

Figure 5 shows that on the basis of full life cycle energy intensity, the Delhi metro rail is less energy intensive on a per passenger km basis as compared to Ahmedabad BRTS. However, it is more CO_2 intensive primarily on account of the high carbon intensity of electricity in India, which is largely produced by coal and gas based power plants. Electricity consumption for running trains and in stations are major components of energy consumption in the life of a metro rail project.

These life cycle results give more comprehensive insights into the energy and emissions intensity of different modes as opposed to conclusions arrived at only on the basis of fuel consumed in operations and tailpipe emissions. In the popular perception, high capacity public transport systems like metro rail are clean modes as they have zero emissions at the tail-pipe. However, an evaluation based on life cycle indicates that a metro system generates more CO_2 emissions/PKM as compared to a BRT system. The same metro system, however, is more energy efficient (on a per PKM basis) for its full life period, when compared to a BRT system (Figure 5). Life cycle impact analyses is, therefore, necessary to enable decision makers to make considered choices of transport projects based not only on economic and financial viability and environmental impact but also on energy and CO_2 intensity.

The results of LCA could vary if the assumptions made regarding some of the basic parameters like ridership, operational energy consumption for both the rolling stock and fixed infrastructure, the source of electricity produced in India vary. It is, therefore, important that these assumptions are made carefully.

CONCLUSIONS

Developing countries like India which are making massive investments in transport infrastructure should, as argued above, draw up life cycle energy and CO_2 emission inventories of different modes of transport and take these into account in making investment decisions. Developing countries should also use these inventories to reduce energy and CO_2 emissions in construction and maintenance by identifying and using less-energy and carbon intensive materials and processes. Efficient construction machinery and alternative sources of energy to run them can also help reduce energy and CO_2 impacts during construction and maintenance.

Maintenance activities are usually not given adequate attention in India. Life cycle inventory shows that maintenance accounts for a significant portion of embodied energy and CO_2 over a given life period of infrastructure projects, especially road-based infrastructure projects. Periodic maintenance activities, in particular, have a high share in embodied energy and CO_2 emissions indicating the need to reduce the requirement for periodic maintenance through good construction and good routine maintenance.

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- **Extracts Relating to Efficiency from the Report of the Expert Group on Low Carbon Strategies for Inclusive Growth (2014)**

- **Recommendations Relating to Fuel Efficiency from the Report of the National Transport Development Policy Committee (2014)**

Report of the Expert Group on Low Carbon Strategies for Inclusive Growth (2014)

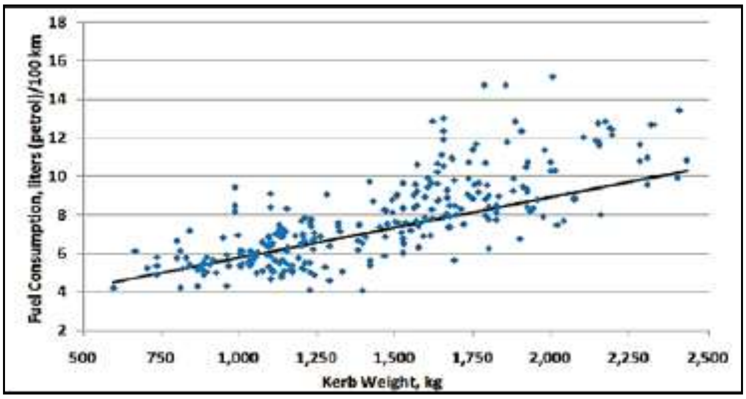
Extracts relating to efficiency norms for the automobile industry

A two pronged approach has been put in place in the country in order to accelerate the reduction in average fuel consumption of new cars introduced in the Indian market, which are;

1. Medium and Long term fuel efficiency standards for new cars which would provide a regulatory signal to manufacturers to continuously reduce the average fuel consumption of cars sold by them over the next 10 year period.
2. Labelling of new cars that are sold in the market with the labels providing the consumers with information on fuel consumption of the car model and the relative fuel consumption of the model compared to other models in the same weight class.

This strategy which combines a "supply push" with a "demand pull" could enable a large scale transformation in the automobile market. However, these measures need to be taken up as soon as possible for both passenger and commercial vehicles for best results.

Figure 1: Fuel Consumption and Kerb Weight of Vehicle Models



India has also been aggressively pursuing fuel emissions standards since the Auto Fuel Policy of 2002. Although these emissions standards which are built on the European format are focused on the standard and quality of the fuel that is used to drive road vehicles, increasing fuel emissions standards also require advancements in engine technologies to use these fuels. Therefore aggressive implementation of fuel norms also has additional benefits of increased efficiencies. Keeping these in mind the efficiency of vehicles in road transport sector is accordingly expected to improve every year in the low carbon scenario.

Table 1: Description of Low Carbon Scenarios

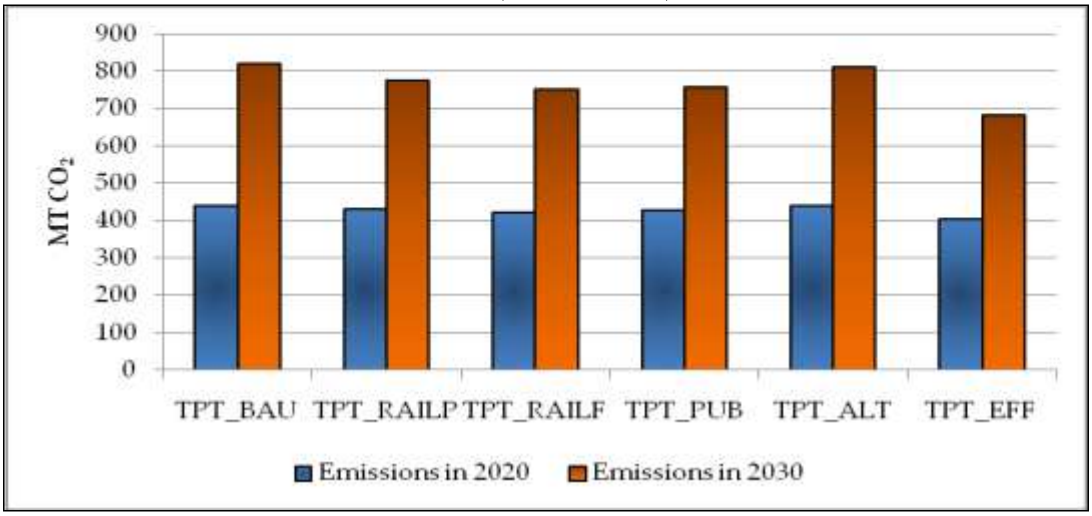
Scenario	Overview	Details
TPT_RAILP	Increase in share of passenger kilometre by rail in total passenger kilometre	Share of rail in total passenger movement by road, rail and air (domestic) is assumed to become 25% by 2031/32
TPT_RAILF	Increase in share of freight tonne kilometre by rail in total freight tonne kilometre – shift from road to rail transport	Share of rail in total freight movement by road, rail and air (domestic) is assumed to become 50% by 2031/32
TPT_PUB	Increase in share of public transport - Shift from private vehicles to buses	Share of passenger movement by buses in total passenger movement by road is assumed to increase to 75% by 2031/32 (shift from cars)
TPT_ALT	(i). Increase in share of CNG cars	Share of passenger kilometres by CNG cars in total passenger kilometres by cars is assumed to become 15% by 2031/32
	(ii). Increase in share of CNG buses	Share of passenger kilometres by CNG buses in total passenger kilometres by buses is assumed to become 10% by 2031/32
	(iii). Increase in share of electric cars	Share of new sales of electric cars in total new sales of cars is assumed to become 10% by 2031/32
	(iv). Increase in share of electric 2 W	Share of new sales of electric 2 Wheeler in total new sales of 2 Wheelers is assumed to become 30% by 2031/32
	(v). Increase in share of CNG Taxies	Share of passenger kilometres by CNG taxies in total passenger kilometres by taxies is assumed to become 10% by 2031/32
	(vi). Increase in share of CNG 3 W	Share of passenger kilometres by CNG 3W in total passenger kilometres by 3W is assumed to become 17% by 2031/32
	(vii). Electrification-Railways - Passenger	Share of passenger kilometres on electric traction-assumed to become 60% by 2030
	(viii). Electrification-Railways - Freight	Share of tonne kilometres on electric traction assumed to become 60% by 2030
TPT_EFF	**Improving efficiency of vehicles - road transport**	**Improvement in efficiency - road transport by 1% every year**

Table 2 and figure 2 below show the impact of the above mentioned scenarios relating to CO_2 emissions in the time horizon 2020 and 2030.

Table 2: CO_2 Emissions by Transport Sector in Various Scenarios (Million Tonne)

Scenarios	Emissions in 2020 (MT CO_2)	Emissions in 2030 (MT CO_2)	Percentage drop over 2020 BAU	Percentage drop over BAU 2030
TPT_BAU	441	820	-	-
TPT_RAILP	430	776	3%	5%
TPT_RAILF	423	752	4%	8%
TPT_PUB	428	757	3%	8%
TPT_ALT	440	812	-	1%
TPT_EFF	**403**	**684**	**9%**	**17%**

Figure 2: CO_2 Emissions by Transport Sector in Various Scenarios (Million Tonne)



The above depictions show that the largest impact relating to CO_2 emissions from (TPT EFF) will come from increasing the efficiency of the overall vehicle stock and by moving to electric traction, with an emissions reduction potential of almost 17 percent over 2030 Business as Usual(BAU) levels.

Report of the National Transport Development Policy Committee (NTDPC) (2014)

Recommendations relating to fuel efficiency

1. 50 ppm sulphur fuels should be mandated nationwide by the middle of this decade, and 10 ppm sulphur fuels should be mandated nationwide by 2020.

2. Bharat IV fuel quality standard should be implemented nationwide by the middle of this decade, with a target to reach Bharat VI by 2020.

3. India should make world-harmonised test cycles optional when Bharat IV regulations go into force nationwide and mandatory when Bharat V regulations come into force.

4. A new Auto Fuel Policy Committee should be formed five years after each previous one completes its work.[1]

5. A National Automobile Pollution and Fuel Authority responsible for setting and enforcing vehicle emission and fuel quality standards should be set up.

6. India needs to establish a robust Inspection and Certification (I&C) regime to ensure safety, road worthiness and emission performance of in-use vehicles.

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[1] In 2003, the Mashelkar Auto Fuel Policy committee had recommended a review of the auto fuel policy every five years. A new Auto Fuel Policy Committee was formed in January 2013. The committee has the authority to recommend reforms through the year 2025.