Climate Action Tracker

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Decarbonising the Indian transport sector pathways and policies

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Contents

Executive Summary

To hold global average temperature increase to 1.5°C, global CO_2 emissions need to reach net-zero by 2050, with rapid decarbonisation in all sectors.

Global transport emissions have continued to steadily increase, with transport emissions accounting for 24 percent of direct CO_2 emissions from fuel combustion.

In this study we look specifically at how India can decarbonise its transport sector, its fastest-growing source of carbon emissions, mainly from oil combustion. Its transport sector is responsible for 13.5 per cent of the country's energy-related CO_2 emissions, with road transport accounting for 90 percent of the sector's final energy consumption.

India is the world's third largest global emitter of greenhouse gas emissions, and its domestic action will significantly impact global emissions, especially around transport, as its small vehicle fleet relative to its large population is expected to grow rapidly. India has emerged as a leader in renewable energy and can also become a leader in decarbonising transport, which needs to go hand in hand with decarbonised electricity generation.

Since 2010, the growing demand for internal combustion engine (ICE) vehicles has more than doubled the sector's energy consumption and related emissions. Further growth in transport emissions will also exacerbate air pollution and mortality, placing an increasing strain on an already overburdened public health system, as well as increasing traffic congestion.

High current and projected levels of population and GDP growth means that reversing the current trend in growing emissions will require a transformational approach.

This analysis explores Paris Agreement-aligned emissions reduction scenarios to zero emissions by 2050 for the Indian transport sector, in line with the magnitude and speed needed to be consistent with the Paris Agreement objective and that would bring benefits such as avoiding the air pollution that is causing high levels of mortality.

The scenarios explored aim for the highest plausible ambition level that can be achieved in India's transport sector – leaving aside the question of who pays for these ambitious endeavours. We define highest plausible ambition levels for all model levers based on what literature suggests can be achieved and at what speed. To the extent possible, interactions between these levers are taken into account within the model.

This study acknowledges that there is no single best solution to decarbonising the transport sector. Instead we explore two stylised pathways representing two paradigm shifts that could lead to a decarbonisation of the sector, neither of them exclusive:

 **Rail focused**	The "**Rail focused scenario**" explores a paradigm shift towards safe and reliant public transport, and shifting freight towards rail. This builds on the significant role that public transport already plays today, and addresses the congestion problems resulting from India's high population density that are also reflected in the large supressed demand in the sector.
 **Road focused**	The "**Road focused scenario**" explores a future reliant on road transport that is driven by a growth in personal vehicles and trucks. This builds on the ongoing trend towards increased personal transport modes and road freight routes that can be currently observed in India.

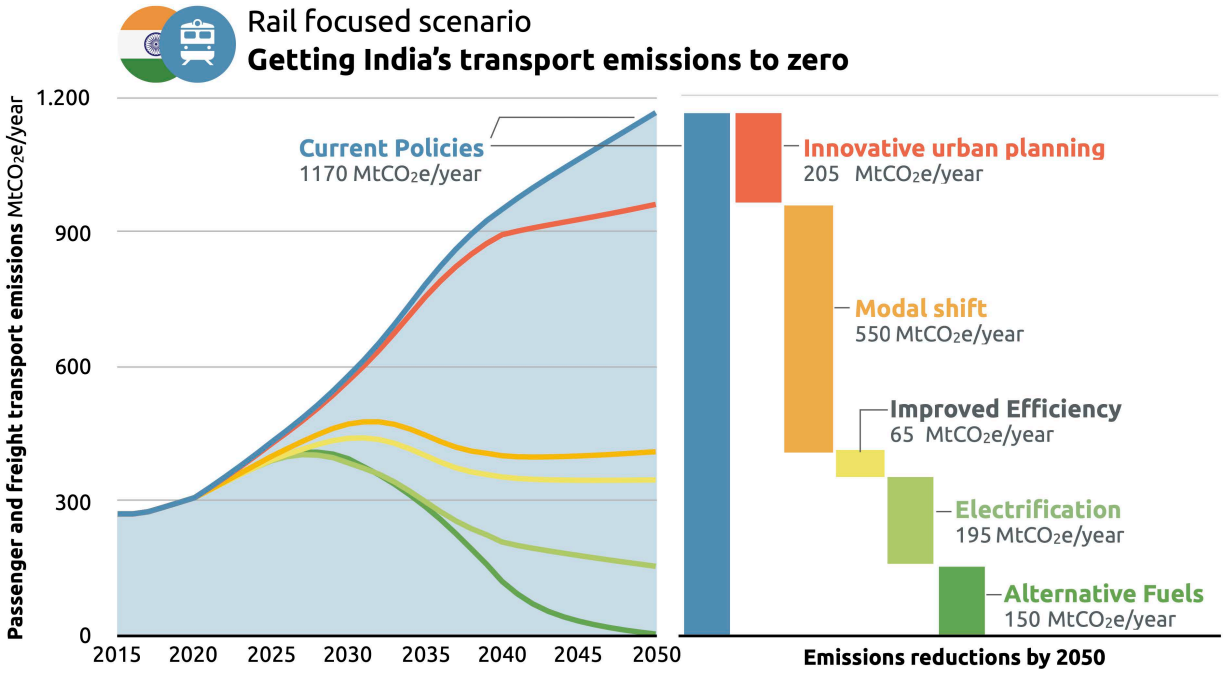

Figure 1. Annual emissions from the transport sector until 2050 – Rail focused scenario ($MtCO_2e$).

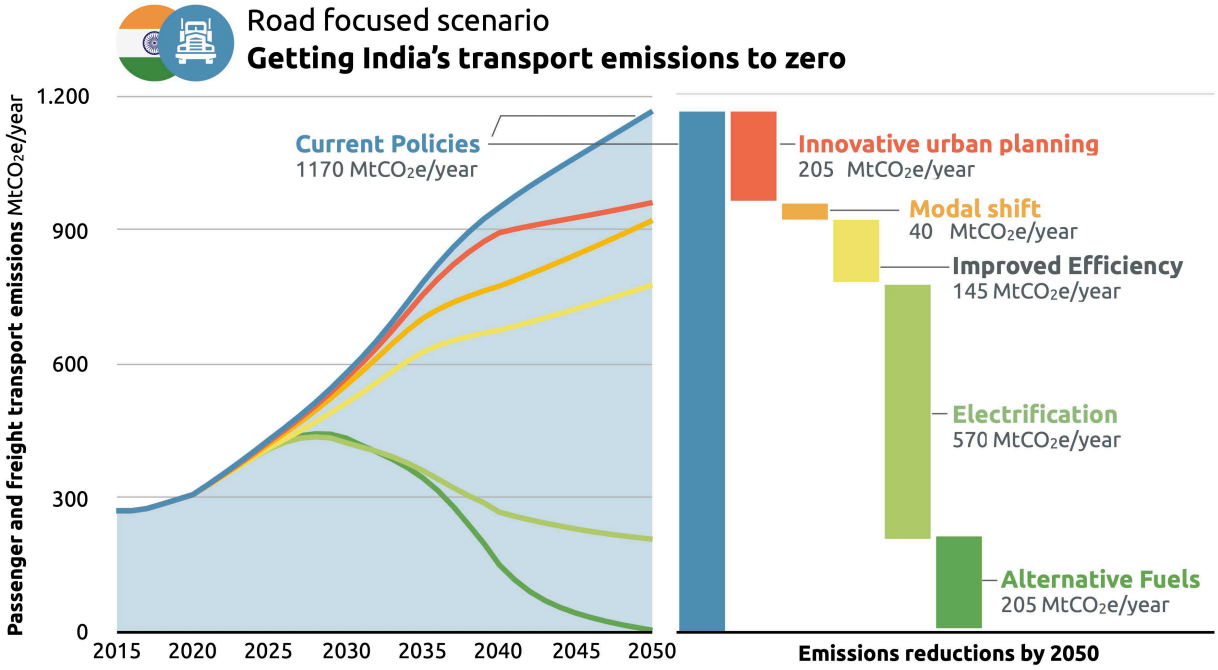

Figure 2. Annual emissions from the transport sector until 2050 – Road focused scenario ($MtCO_2e$).

The graphs above represent the emission reduction wedges compared to a Current Policies scenario, based on the avoid-shift-improve framework for the two scenarios used in this report. Each wedge represents the potential emissions reduction in each priority action area as defined in the report. The wedges build on each other: emissions are avoided through innovative urban planning, reduced by shifting transport demand to more efficient transport modes such as public transport, with the resulting vehicle fleet being electrified as far as technology allows, and lastly, modes that cannot be/are difficult to electrify (such as aviation or shipping) are shifted to run on bio and synthetic fuels. The order does not represent a prioritisation of action, but simply follows the model logic as described here.

The highest plausible ambition levels can only be reached with ambitious policy packages, and domestic or international financing. This report does not explore the issue of whether - or how much - international financial support would be required to support India's transition to these highest plausible ambition scenarios in its transport sector. Rather, we identify existing transport policies from a range of countries that achieve - or at least initiate - the necessary sectoral transformation in the various segments of the transport sector.

Example policies were primarily chosen based on the principle of highest plausible ambition. Since a large number of the policies identified according to this principle can be encountered in developed countries, likely due to the fact that these have more resources to implement such policies, we have tried, where possible, to also add examples from the developing world.

India can learn from these examples, if it carefully considers how they relate to national circumstances. While a policy implemented in another country cannot be used as a blueprint for policymakers in India, important lessons can still be learned. This study draws potential lessons from these examples, proposes a set of potential mid-term policy goals and immediate steps to be considered in the Indian context, and illustrates them with the two scenarios leading to a decarbonised transport sector by 2050.

Electrification is key

In any of the stylised futures explored, electrification plays an essential role in decarbonising the transport sector. Given the promising progress of electrification of this sector in recent years, India has an unprecedented opportunity to maximise the electrification of all modes of transport. Both the rail and road focused scenarios feature rates of close to 100 per cent electrification by 2050.

India's rail infrastructure is already largely electrified with a share of 54 per cent of conventional passenger demand and 65 per cent of freight transported on electrified trains. However, significant underinvestment over recent years has not enabled the full electrification of the network. Road transport, as is the case in almost all regions in the world, is only just beginning to electrify, with buses and two-wheelers showing the most significant trends in India.

Two and three-wheelers (2W & 3W) are the most important personal transport modes in India, with light duty vehicles (LDVs) increasingly replacing 2W & 3W in the recent past. A policy mix of financial, behavioural and charging infrastructure incentives has globally proven to be effective to get EVs off the ground, and India has already started to develop its own tailored approach with the Faster Adoption and Manufacturing of Electric Vehicles (FAME - II) scheme.

However, despite the commencement of this expanded scheme, EV sales in the 2019/20 financial year were only 156,000 units (97 per cent two-wheelers), while under both scenarios annual EV sales increase to between 1.6-2.9 million / year between 13.3 and 42.3 million/year in the next five and ten year respectively, leading to an end of sales of new internal combustion engines by 2035. Policies in China and California in particular could serve as role models here. Both regions have proven that the right policy mix can both support the uptake of EVs while simultaneously spurring the development of a nascent industry that can bring with it important industrial growth.

Decarbonising heavy duty vehicles (HDVs), and particularly long-range trucks, poses a much larger challenge. While studies have demonstrated that efficiency improvements already lead to cost savings today, the case for battery electric (BEV) or hydrogen fuel cell (FCEV) HDVs is currently not as compelling. Electric HDVs, primarily buses, have seen some growth in Indian cities for use in urban routes over shorter distances, but electric or hydrogen HDV use for medium to long distance has not seen any uptake.

While electric and hydrogen HDVs are expected to enter markets globally as early as 2021, a mix of financial, behavioural and infrastructure incentives is needed to develop them at the scale needed. A comprehensive HDV refuelling/charging network - for instance built around major freight corridors - could be developed throughout India, and concerted marketing campaigns put in place to help disseminate the technology.

Public transport and railways relieve pressure on roads: modal shift needed

Electrification, coupled with a decarbonisation of the power sector, is undeniably essential to reduce emissions but demand-side measures can play an important role in relieving the pressure on how much electrified transport is needed. A modal shift away from personal transport modes enable emissions reductions by avoiding the reliance on new technologies that are often costly and not available at commercial scale. Under the *Rail focused scenario,* demand for electrified 2W, 3W and LDVs is 88 per cent lower than under the *Road focused scenario*, whereas demand for electrified HDVs is 80 per cent lower.

Safe, seamless, reliable, and intermodal (public) transport services are key in urban areas to relieve the pressure on the use of private passenger vehicles. Congestion and low emission zones, as implemented in cities around the world, such as in London, can limit the number of vehicles in urban areas. As recently seen in times of Covid-19, support for safe and user-friendly walking and cycling infrastructure can be rapidly be rolled out and has a role to play.

Safe and reliable electric railways can especially help relieve the pressure on the road network. While the road network grew by 75 per cent between 2000 and 2015, India's rail network has largely remained the same for the last 60 years, with relatively limited investment. Policies have focused on electrifying railways but not their expansion and maintenance.

Electrified railway network extensions, especially along major routes such as the Golden Quadrilateral, could be prioritised, for example by building high-speed lines. Such measures should ensure that both passenger and freight transport can co-exist on the same network. With the right planning, the share of rail transport in freight could be increased to 40 per cent in 2050, as illustrated under the Rail focused scenario. Many elements of the policy framework needed to achieve this are already in place in India, but it would require strengthening to achieve the proposed measures.

Urban planning promotes sustainable transport

Sustainable urban planning and Transit Oriented Development (TOD), through regional and urban development policies, integrated transport and spatial planning, logistics optimisation and travel demand management can reduce the need for (motorised) passenger and freight transport and incentivise more environmentally friendly transport modes.

Urban areas where citizens have access to a wide range of services within reasonable distance and centred around a public transit station, can counteract ongoing urban sprawl in Indian cities. Our scenarios suggest the transport demand could increase more than threefold until 2050 compared to 2011/12 levels, 22 per cent lower than a current policy scenario.

India is already taking action by requiring municipalities to comply with TOD standards to be eligible for national support in developing metro lines. Such urban planning has high co-benefits such as reduced congestion and travel time, lowered traffic-related injuries and deaths, noise and air pollution reduction, and improved mobility and accessibility.

A decarbonised transport sector in India is possible but will require action in many areas. Strategic urban planning that minimises travel needs, meeting transport demand through reliable public transport and good walking and cycling infrastructure as the country urbanises, supporting the national rail network and electrifying road transportation can together lead to a strong, low carbon transportation network.

Box 1 | Supporting sustainable transformation of India's transport sector

The scale of the task facing India to rapidly decarbonise its transport sector is immense. To fully realise the opportunities outlined in this report, many of the options will require substantial financial investments, institutional development, knowledge sharing, technology transfer and capacity building.

Despite the many health co-benefits, reshaping the transport sector, particularly through major infrastructure projects, is likely to require high up-front investment costs that make such interventions too costly for India acting alone, without any form of support.

In accordance with the Paris Agreement's Article 4.5, developed countries should provide assistance in order to allow developing countries like India to raise its ambition on overall mitigation action. The Paris Agreement follows the effort-sharing principles that those countries with higher responsibility for past emissions and higher current capacities should not only reduce their domestic emissions as far as possible but also support other countries in reducing their emissions.

We outline possible pathways for India to secure such international support, including the development of a Paris compatible transport development strategy, engagement with other leaders, and through support from the GCF and development banks.

Paris Agreement alignment could transform India's emissions

Important in this is that a Paris Agreement-aligned sectoral pathway could significantly enable sustainable development benefits. Measures explored in this analysis may lead to economic development, particularly in urban areas, reduce congestion and travel time, lead to fewer traffic-related injuries and deaths, significantly reduce noise and air pollution, and improve mobility and accessibility.

While the proposed measures present many opportunities for India to lead and transform its transport sector, we note that this will require major investments in transport infrastructure to enable the transition to zero-emission mobility, particularly the expansion and improvement of India's railway (and metro) network.

These interventions are important to avoid further lock-in of carbon intensive infrastructure, such as highways, as soon as possible, which demands immediate policy action. Covid-19 presents a rare opportunity where many countries make huge investments to support economic recoveries, and India could use this opportunity to channel its resources towards a transformation of its transport sector.

This is the time for India to show leadership, by transforming its transport sector, and at the same time achieving sustainable development benefits such as reducing air pollution, climate change impacts, fossil fuel import dependency, contributing to economic development and the creation of jobs.

These benefits would also be supportive of many social and economic challenges faced by India. We acknowledge that it will not be possible to achieve these ambitious plans without international support.

1 Introduction

India is one of the countries that significantly contributes to global GHG emissions (7 per cent in 2016 (JRC, 2017)), but low on rankings per capita - well below the global average. Given its growing population and development needs, how India chooses to address its growing energy demand has important implications for the global efforts to achieve the Paris Agreement Long-Term Temperature Goal.

India is also extremely vulnerable to climate change, with high levels of poverty exacerbating this vulnerability. Limiting global warming to 1.5°C is important for the achievement of sustainable development benefits and would also substantially reduce climate impacts likely to affect India (Climate Analytics, 2019).

As a signatory to the Paris Agreement, India has committed to reducing the emissions intensity of its GDP by 33 to 35 percent below 2005 levels by 2030 (UNFCCC, 2015). Meeting the Paris Agreement temperature goal will require the world to reach net-zero CO_2 emissions by 2050 (Rogelj *et al.*, 2018), and this means governments will need to implement transformational policies in all sectors.

Decarbonisation of the electricity sector is a very important step and is essential for the decarbonisation of end-use sectors. India has already shown leadership in expanding renewable energy and could further build on this by shifting away from coal. This transformation of the power sector will achieve substantial benefits for sustainable development and pave the way for progress in all end-use sectors.

While India includes a sector-specific target for the power sector in its Nationally Determined Contribution (NDC), there is no such target for the transport sector, despite it being India's fastest-growing source of carbon emissions (SHAKTI, 2019). India has yet to publish a Long-Term Strategy to indicate how it intends to develop the transport sector in line with the Paris Agreement. A Long-Term Strategy is an opportunity to take a long-term integrated approach to achieving the Paris Agreement and Sustainable Development Goals.

The Indian transport sector is responsible for 13.5 per cent of India's energy-related CO_2 emissions, with road transport accounting for 90 per cent of the sector's total final energy consumption followed by rail and domestic aviation (both at 4 per cent) (IEA, 2020).

India's small vehicle fleet relative to its large population is expected to grow rapidly (SHAKTI, 2019; IEA, 2020). So far, the growing demand for internal combustion engine (ICE) vehicles has more than doubled the sector's energy consumption and related emissions since 2010 and more than tripled since 2000 (IEA, 2020).

Similarly, India has seen a fast growth in freight road transport (tenfold since the 1990s) largely based on ICE heavy duty vehicles (HDVs). This trend has resulted in increased fossil fuel demand for freight road transport, the highest globally (IEA, 2020). Despite the trend towards greater individual motorisation, mass transport modes, such as rail and buses, are important mobility modes in India.

Transport policy/planning in India is a concurrent function at all levels of government - national, state and municipal/city. Taxes are collected through the national and state governments, allowing them to redistribute funds and develop fiscal policies. Although cities do not have financial leverage, some decision-making happens within municipal jurisdictions, with financial support available from the state.

Transitional policies, such as India's Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) scheme, are often initiated and implemented at the national level. However, states and cities also have a significant role in influencing the necessary shift in the transport sector, as demonstrated by New Delhi's rapid ramp up of high-quality mass transit transport, and action taken by some states to encourage uptake of electric vehicles.

The state of Andhra Pradesh has established a target of one million electric vehicles on the road by 2024, Maharashtra has a production target of 500,000 electric vehicles in five years, and Tamil Nadu recently released

its EV strategy with a host of incentives, including land subsidies to set up EV charging infrastructure and tax exemptions to EV owners (Climate Action Tracker, 2019).

In addition to emitting greenhouse gases, the transport sector is also a major emitter of other, poisonous gases, such as Nitrogen Oxides (NOx), which cause local air pollution, resulting in a prevalence of adverse health effects and premature deaths. Twenty one of the world's 30 most polluted cities are located in India (World AQ Report, 2019). In 2015, approximately 1,800 premature deaths were attributed to noxious gases stemming from the transport sector in New Delhi alone, with 74,000 premature deaths registered across India (The International Council on Clean Transportation, 2019). Further growth in transport emissions will exacerbate this, placing an increasing strain on an already overburdened public health system.

Decarbonising the transport sector in India can help to substantially reduce these impacts and has several additional potential co-benefits, such as major improvements in public health, particularly in cities, improved fuel savings, reduced noise, and improved quality of life from reduced congestion and reducing individuals commuting time. Lower overall traffic levels also lead to increased utilisation of urban areas by pedestrians and cyclists. With regards to freight transportation, logistics optimisation can, for instance, lead to cost reductions as well as improved working conditions.

Under the Paris Agreement, 2020 is stipulated as the year when governments should strengthen their NDCs, as well as communicate mid-century, long-term low GHG emission development strategies (UNFCCC, 2020). In this context, we derive Paris Agreement-compatible scenarios for the transport sector in India to highlight opportunities for India to simultaneously address its sustainable development goals and Paris Agreement Commitments. Using a combination of good practice policy examples from around the world and quantitative modelling, we formulate scenarios and good-practice policy packages that can inform a Paris Agreement-compatible development strategy for the Indian transport sector.

2 A Paris Agreement-compatible future for India's transport sector

2.1 The concept of highest plausible ambition (Paris Agreement-compatible) emissions pathways

The stated goal of the Paris Agreement is to limit global temperature increase to well below 2°C and to pursue efforts to limit it to 1.5°C. The IPCC special report on 1.5°C stipulates that in order to limit warming to 1.5°C, global CO_2 emissions must reach net-zero by 2050, while global GHG emissions must reach net-zero by 2070 (Rogelj *et al.*, 2018). The current NDCs are not sufficient to achieve this goal, and therefore require countries to substantially increase their emission reduction targets and transition to low carbon economies and societies.

Ensuring that global net-zero emissions is achieved requires the speeding up and scaling up of action in a timely fashion. Drastic reductions in emissions are required now to keep within the global carbon budget. For this reason, policy decisions will be critical in determining whether India, like many other countries, will achieve the necessary level of climate action to play its role in achieving the Long-Term Temperature Goal (LTTG).

Global pathways consistent with the LTTG suggest the energy sector needs to be decarbonised by mid-century in order to avoid over-reliance on carbon dioxide removal (CDR) and to enhance synergies with sustainable development. To achieve the necessary emission reductions, all sectors need to be transformed. To date, the power sector has seen progress, especially in renewable electricity generation, and plays an important role in decarbonising end-use sectors such as transport, but transport-specific mitigation strategies are also needed.

In this regard, the concept of a 'highest plausible ambition level' helps define sectoral benchmarks and pathways. The approach builds on the robust findings from the IPCC Special Report on 1.5°C that all sectors need to achieve sectoral transformations as fast as possible (Masson-Delmotte *et al.*, 2018). These transformations are technically and economically feasible within the foreseeable future.

Specific benchmarks and pathways need to take into consideration country-specific circumstances, such as existing infrastructure and institutions. They push boundaries on all levels to increase our chances of collectively meeting the Paris Agreement temperature limit that is of crucial importance for sustainable development. In a previous report on Paris Agreement-compatible Sectoral Benchmarks (Climate Action Tracker, 2020b), we applied this approach and utilised economy-wide and sectoral analyses to determine Paris Agreement-compatible benchmarks in 2030, 2040, and 2050 for a number of key emitters and sectors, including India.

Such benchmarks and pathways for the coming decades can be used to guide the level of policy ambition that is needed across short, medium and long-term time horizons. The use of 2030 benchmarks provide an important reference point to inform Nationally Determined Contributions (NDCs) under the Paris Agreement. The benchmarks provide additional sectoral detail that elaborate on the overall emissions reduction targets and are useful for planning purposes. They outline domestic mitigation needs but do not specify who is financially responsible for the action. Based on equity and effort-sharing principles, some mitigation within India could be supported by other countries.

An important element of a strategy to achieve the transformation needed is to develop policies that aim at maximising synergies with sustainable development. Transport is an example where greenhouse gas emissions reductions can achieve substantial benefits, including for health and economic development, reducing air pollution and congestion. While high ambition benchmarks provide an indication as to what India could aim for in terms of real emissions reductions, they do not indicate how these transitions should be funded.

Given India's relatively low historical responsibility for emissions and its status as a developing country, considerable support from developed nations is necessary to assist it in achieving such ambitious climate action.

2.2 Approach

In the following chapters we outline options for developing India's transport sector in a way that both meets the needs of the population and is consistent with the Paris Agreement and sustainable development goals. Our analytical approach combines modelling and policy analysis that could support decision making. The modelling is based on an elaboration of the highest plausible ambition pathways outlined above. The policy analysis consists of an assessment of global good practice policies that can be replicated in India, building on scaling up existing policies and taking into account national circumstances.

This analysis follows a series of steps (Figure 1).

- First, we identify priority action areas in the Indian transport sector (see 2.2.1 Identifying) based on current emissions in the transport sector and options with high mitigation potential.
- Then, focussing on these priority action areas, we build pathways to full decarbonisation for the Indian transport sector (see 2.2.2 Modelling framework - CTI scenarios for India
- Using the CTI model (Pestiaux, J., Lalieu, S., Schobbens, Q., Monteith, S., Plechaty, D., Cronin, C. and Menon, no date). The CTI model is a bottom-up excel-based tool which estimates energy demand and emissions on a sectoral basis.
- We use the model to develop scenarios that demonstrate the mitigation potential of achieving the PA compatible benchmarks (Climate Action Tracker, 2020b) and link these to policies.
- These policies are identified through a rigorous evaluation process and are combined in a proposed aggregated policy package for each priority mitigation area (see 2.2.3 Policy analysis: Learning from global good practice policies).

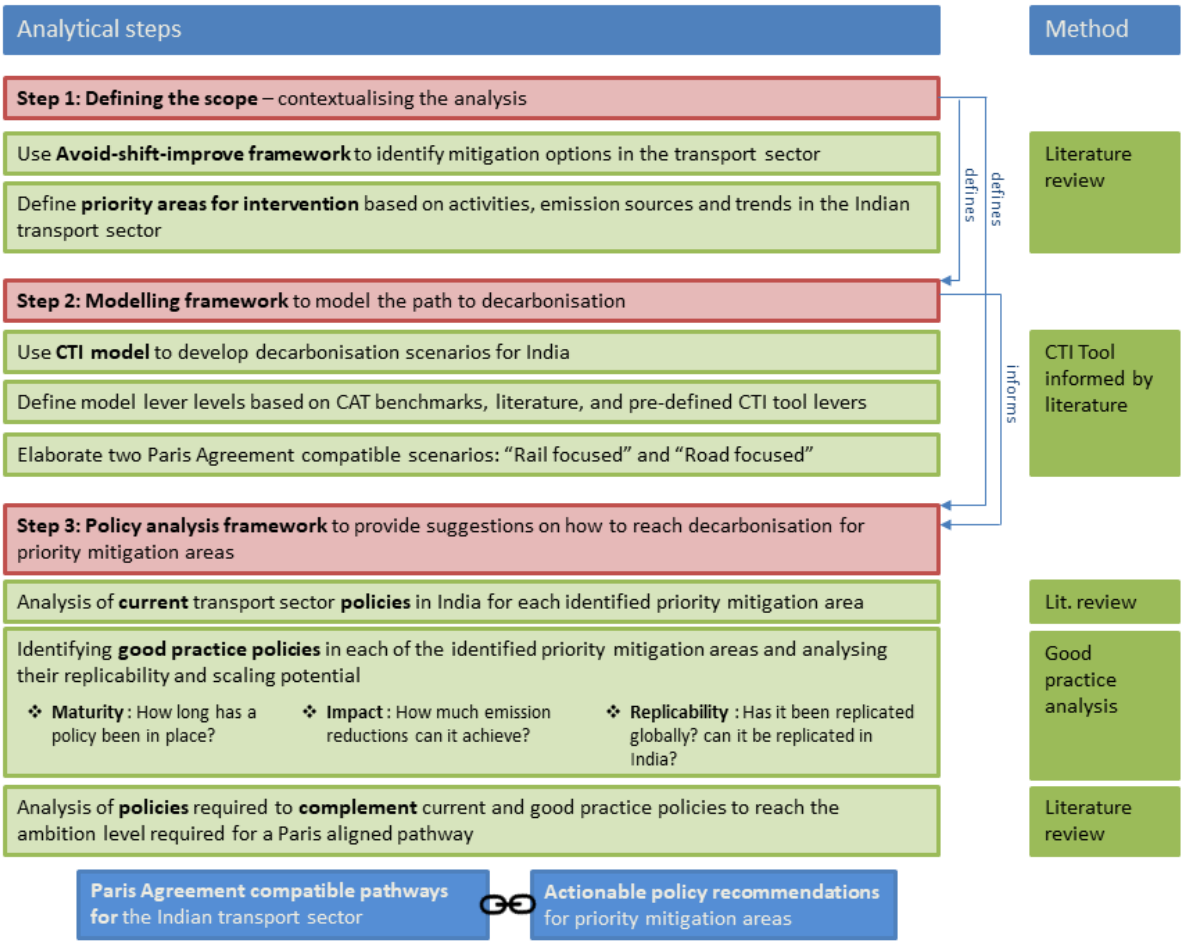

Figure 1: Overview of methodological approach

2.2.1 Identifying priority mitigation areas

Indian transport sector emissions stem mainly from road transport, which accounts for 90 per cent of the sector's total final energy consumption, followed by rail and domestic aviation (4 per cent each) (IEA, 2020). The transport sector's energy consumption and related emissions have doubled since 2010, and more than tripled since 2000, mainly due to a growing demand for internal combustion engine (ICE) vehicles for both passenger and freight road transport.

This trend is expected to continue until at least 2040 (IEA, 2020). In this assessment, we focus on policies to mitigate emissions from road transport, although we also consider rapidly rising emissions from other modes of transport, such as aviation or maritime transport. We categorise the drivers for rising ICE vehicle demand and related emissions into two categories (IEA, 2019; SHAKTI, 2019):

Growing demand for ICE vehicles in an urban context, due to urban sprawl and the demand for motorised (private) vehicles

Growing demand for ICE vehicles in a non-urban context, due to a shift away from rail transport and towards road transport

Mitigation action areas in the transport sector can be organised according to the nature of their impact using the Avoid-Shift-Improve (ASI) framework (SLoCaT, 2018).

Avoid	Shift	Improve
the need for (motorised) transport by, for example, improving logistics or improving urban planning.	to more environmentally friendly transport modes such as walking, cycling or public transport by, for example, improving public infrastructure and making public transport more attractive.	vehicles' energy efficiency and carbon intensities, for example through electric mobility.

The ASI framework can be applied in a different manner in India than in countries that have much higher rates of personal vehicle ownership, such as Europe. In India, the framework can help to guide development planning around minimising growth in the need for transport (avoid), ensuring that low carbon and efficient transport modes are supported (shift), and that new vehicles adhere to high efficiency standards (improve).

A well-balanced mix of measures in all areas is needed[1]. Based on the identified major emissions drivers in India, the avoid-shift-improve framework, decarbonisation options available for the transport sector and existing literature, we identify four priority action areas to mitigate emissions in the Indian transport sector. The order below does not suggest a prioritisation of one area over another.

- **Sustainable and innovative urban planning** through regional and urban development policies, integrated transport and spatial planning, logistics optimisation and travel demand management can reduce the need for (motorised) passenger and freight transport and incentivise more environmentally friendly transport modes (SLoCaT, 2018). Planning can also reduce congestion and travel time, lead to fewer traffic-related injuries and deaths, may reduce noise and improve mobility and accessibility (Schiefer *et al.*, 2020).
- **High quality and safe non-motorised and mass-transit public transport infrastructure and services** provide a wide range of alternatives to private motorised vehicles. A previous study on the Indian road transport

[1] In reality, individual policies can have multiple impacts. We choose to include them in the area where they have the strongest link.

sector shows that such transport modes are a viable option for decarbonising road transport, reaching up to 90 per cent by 2050 (SHAKTI, 2019).

- **High quality railway infrastructure and services** provide a viable alternative to road transport in non-urban areas, where distances are longer. A recent IEA report identified the Indian railway network as a cornerstone to the country's transition. It highlights the development of the railway network in recent decades and its potential role in a pathway to full decarbonisation (IEA, 2019).
- **Electrifying all road transport vehicle fleets** is necessary to fully decarbonise the transport sector. Electric mobility has risen as an alternative to ICE vehicles for two and three- wheelers, public transport vehicles, LDVs and HDVs (SLoCaT, 2018). Electric vehicles are currently the most efficient technology compared to ICEs and other carbon neutral alternatives (e.g. synthetic fuels), in turn lowering the sector's energy needs. However, they also require an extensive deployment of renewable energy sources to be carbon neutral and thus cannot be the sole pillar to decarbonising the transport sector.

These priority mitigation areas form the structure of our scenario and policy analysis with mitigation options, potential and good practice policies being defined for each area and elaborated in chapters 3-6 below.

2.2.2 Modelling framework - CTI scenarios for India

In order to assess the mitigation potential related to the identified priority action areas, we model the Indian transport sector using the Carbon Transparency Initiative (CTI) model (Pestiaux, J., Lalieu, S., Schobbens, Q., Monteith, S., Plechaty, D., Cronin, C. and Menon, no date). The CTI model estimates transport sector energy demand and its related emissions from a bottom-up approach. Activity projections are based on population and GDP growth estimates and are developed for the passenger and freight sectors respectively.

The bottom up approach of the CTI model allows us to analyse the impacts of implementing a set of mitigation options, such as best available technologies (BAT), behavioural changes, and fuel mix, on overall emissions through time. It also allows us to analyse the implications from implementing such changes at different times and rates. By doing so, we can explore which of the available options could be defined as Paris Agreement-compatible.

Based on a set of levers linked to the ASI framework, see Table 1, we create a Paris Agreement-compatible scenario by parameterising the levers to comply with the CAT Paris Agreement-compatible benchmarks (Climate Action Tracker, 2020b), specifically relating to levers such as electrification of road-based transportation modes. In addition to the CAT benchmarks, we conduct a literature review that informs the parameterisation of other levers, such as energy efficiency, technology share of new vehicles and the modal shift towards public transportation modes, see Table 2. Finally, pre-defined CTI scenarios representing different ambition levels informed the development of the remaining levers.

Our Paris Agreement-compatible scenario sets the system boundaries in terms of what is needed to decarbonise the transport sector by 2050. Various different development routes that still lie within those boundaries, but differ in detail, can be taken. To explore examples of such routes, we develop two different scenarios through a sensitivity analysis on modal shift options.

One of those scenarios envisions a radical shift from private to public transportation modes in the passenger sector, and from road-based to rail-based transportation modes in the freight sector, see Figure 2 to Figure 5. This scenario is referred to as the *Rail focused scenario*.

The second scenario explores how a future in which private transportation modes (passenger) and road-based transportation modes (freight) are preferred, and electrification is pushed at a speed compatible with the "highest plausible ambition" paradigm laid out above. This scenario is referred to as the *Road Focused scenario*.

In order to estimate the mitigation potential of our resulting scenarios, we also develop a scenario representing a future in which current policies are not further improved, referred to as the *Current Policies scenario*. We develop the current policies scenario based on a pre-defined scenario in the CTI tool, which in many areas is similar to the Road Focused scenario (Pestiaux, J., Lalieu, S., Schobbens, Q., Monteith, S., Plechaty, D., Cronin, C. and Menon, no date).

The narratives behind both scenarios are described in Table 2 picturing two rather different futures. In both scenarios international marine remains unchanged, which is currently dominating the freight sector.

In this study we focus on transport areas that are under India's direct governance; international marine shipping should be addressed at the international level through the International Maritime Organisation (IMO). Pathways to full decarbonisation of international shipping have been identified (ETC, 2018) and rely on a combination of demand management, energy efficiency, and a shift toward zero carbon fuels, such as ammonia, hydrogen, biodiesel or synthetic fuels.

However, action to date has been limited and focused on energy efficiency only (Climate Action Tracker, 2020a). Further planned improvements to energy efficiency standards will only achieve some of the required reductions for either meeting the IMO's own targets or for the full decarbonisation of the sector required by the 1.5°C temperature limit so additional action is still needed. India could support that action on the international stage.

Table 1. CTI levers and corresponding sources in the scenario development.

CTI Lever		Unit	Source(s)
Avoid	Transport demand	pkm/cap; tkm/$ of GDP	Population and GDP growth according to Shared-Socio-economic Pathway (SSP) 1 (CTI)
Not applicable	Urban share	% share of total transport activity occurring in urban areas	CTI (Pestiaux, J., Lalieu, S., Schobbens, Q., Monteith, S., Plechaty, D., Cronin, C. and Menon, no date)
Shift	Modal share	% per mode	*Transformation of India's transport sector under global warming of 2 °C and 1.5 °C scenario* (Dhar, Pathak and Shukla, 2018); *Comparison of Decarbonisation Strategies for India ' s Land Transport Sector* (SHAKTI, 2019); *The Future of Rail* (IEA, 2019); *Pathways to deep decarbonisation in India* (Ribera and Sachs, 2015); India Energy Security Scenarios 2047 (Government of India, 2019)
Applicable to several [2]	Occupation rate	pkm/vkm; tkm/vkm	CTI (Pestiaux, J., Lalieu, S., Schobbens, Q., Monteith, S., Plechaty, D., Cronin, C. and Menon, no date)
Applicable to several	Utilisation rate	vkm/vehicle/year	CTI (Pestiaux, J., Lalieu, S., Schobbens, Q., Monteith, S., Plechaty, D., Cronin, C. and Menon, no date)
Improve	Life distance of new vehicles	Total vkm/vehicle	CTI (Pestiaux, J., Lalieu, S., Schobbens, Q., Monteith, S., Plechaty, D., Cronin, C. and Menon, no date)
Improve	Efficiency of new vehicles	kWh/vkm	CTI (Pestiaux, J., Lalieu, S., Schobbens, Q., Monteith, S., Plechaty, D., Cronin, C. and Menon, no date); *Energy efficiency in the Japanese transport sector* (Lipscy and Schipper, 2013)
Improve	Technology share of new vehicles	% of new vehicles/technology	CAT benchmarks (Climate Action Tracker, 2020b)
Improve	Fuel mix	%/fuel type	CAT; CTI (Pestiaux, J., Lalieu, S., Schobbens, Q., Monteith, S., Plechaty, D., Cronin, C. and Menon, no date)
Not applicable	Power sector emission pathway	g CO_2/kWh	CAT benchmarks (Climate Action Tracker, 2020b)

[2] The occupancy rate relates to more than just one ASI category. Improved occupancy rates may avoid vehicle demand which for example can have a positive effect on congestion. It also affects vehicle energy efficiency, in terms of energy used per pkm or tkm, which relates to improvement. The occupancy also affects the utilisation rate of a vehicle. An increased utilisation rate would trigger the renewal rate of the vehicle stock and so also the electrification rate, but it can also be seen as an improve lever referring to improved transportation systems with shared mobility, see Box 2.

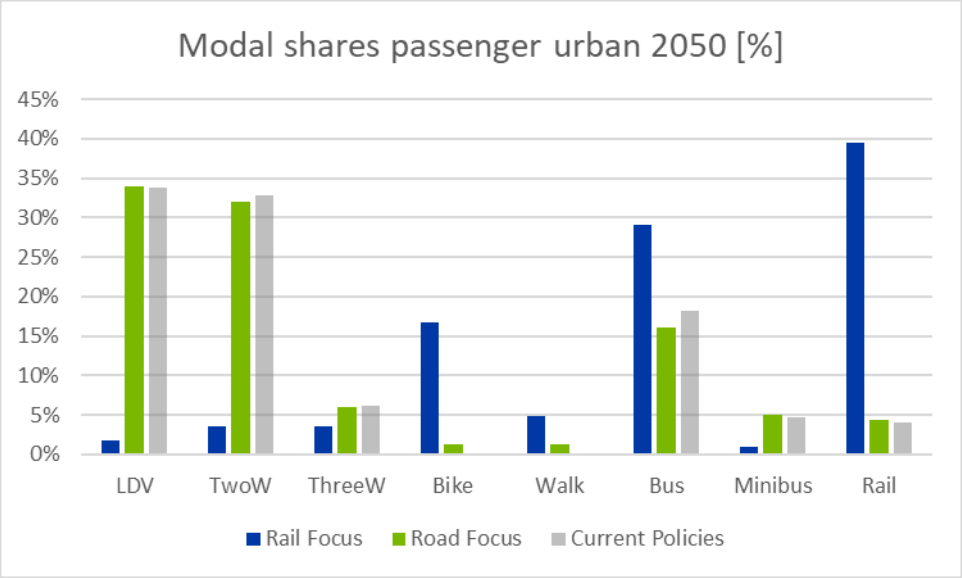

Figure 2. The modal split in urban passenger transport in 2050 in the Rail-, the Road Focused and Current Policies scenarios.

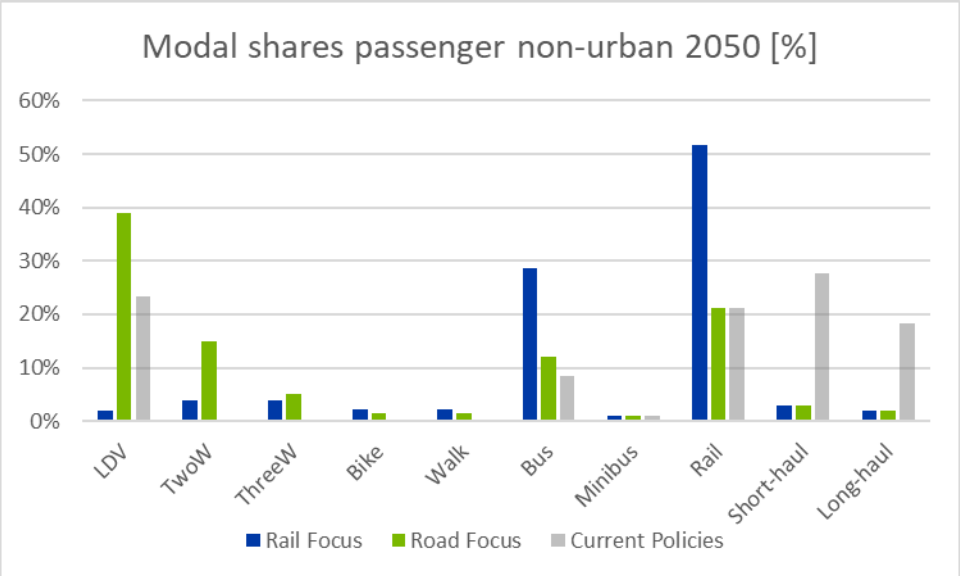

Figure 3. The modal split in non-urban passenger transport in 2050 in the Rail-, the Road Focused and Current Policies scenarios. Short- and long-haul refers to domestic aviation

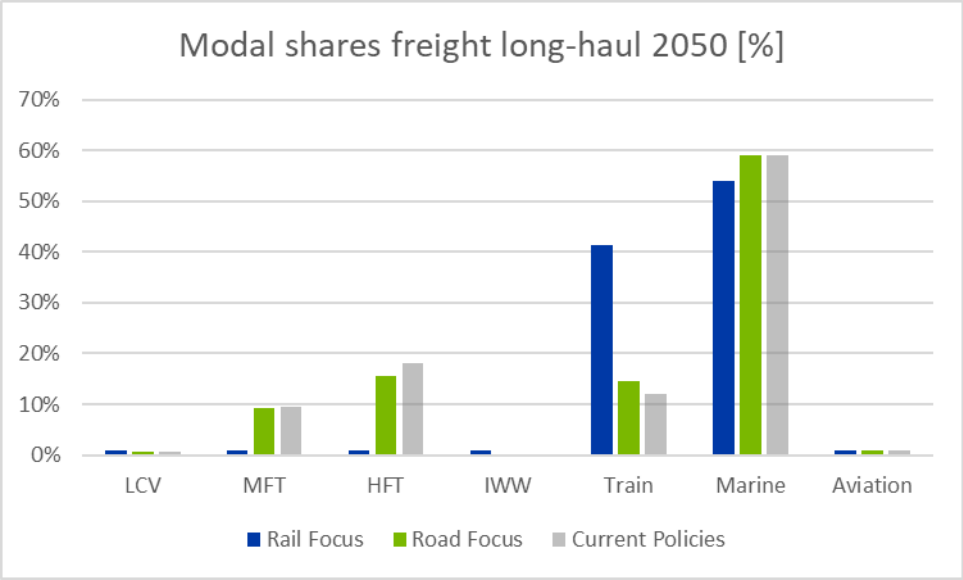

Figure 4. The modal split in long-haul freight transport in 2050 in the Rail-, the Road Focused and Current Policies scenarios.

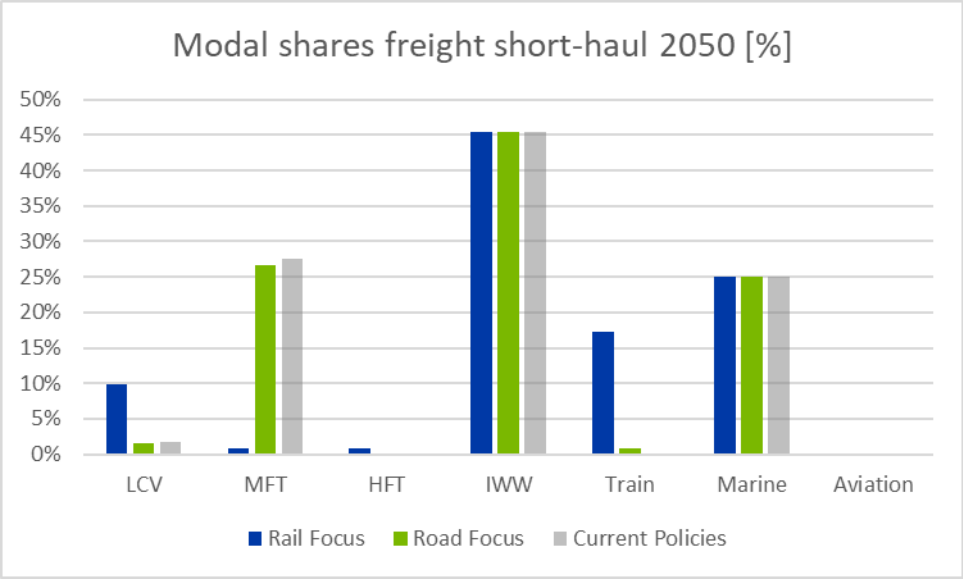

Figure 5. The modal split in long-haul freight transport in 2050 in the Rail-, the Road Focused and Current Policies scenarios.

Table 2. Descriptions of the Rail- and Road focused scenarios.

Scenario	Characteristics	Sources
 **Rail focused**	For passenger transportation, rail expands at the expense of private transport modes, assuming current plans on metro expansion are followed through and replicated in most large urban areas. Bus transportation increases significantly as less people experience the need for a personal vehicle. Efforts to expand and improve the current non-urban railway system reverts the current declining trend for rail-based freight in India, resulting in a significant increase in terms of modal share for rail-based long-haul freight. The increase almost completely eliminates any need for road-based transportation for long-haul freight.	*Transformation of India's transport sector under global warming of 2 °C and 1.5 °C scenario* (Dhar, Pathak and Shukla, 2018); *Comparison of Decarbonisation Strategies for India ' s Land Transport Sector* (SHAKTI, 2019); *The Future of Rail* (IEA, 2019); *Pathways to deep decarbonisation in India* (Ribera and Sachs, 2015);
 **Road focused**	Current trends in private vehicle ownership continue in a similar manner as in a current policies scenario, expanding the need for road infrastructure. Apart from international marine trade, the freight transport continues to be dominated by road-based transportation modes, while the rail-based freight stays similar to current modal shares.	*India Energy Security Scenarios 2047* (Government of India, 2019); CTI (Pestiaux, J., Lalieu, S., Schobbens, Q., Monteith, S., Plechaty, D., Cronin, C. and Menon, no date)

External parameters and model assumptions

The model results are sensitive to several external input parameters which are not modelled in CTI. Transport activity is mainly driven by population and GDP growth, Table 2. These are assumed to develop according to the *Shared Socio-Economic Pathways* first scenario (SSP1). We use the same population and GDP projections in all scenarios as we aim to analyse the implications of the proposed mitigation measures only.

The SSP scenarios explore five different futures in which societal choices strongly affect population and GDP growth. SSP1 represents a sustainable scenario, with strong commitments to achieving the Sustainable Development Goals (SDGs). This leads to reduced inequality, stimulating education and low material consumption (Riahi *et al.*, 2017).

Another important parameter, given the high electrification rates in our analysis, is the decarbonisation rate of the power sector. The power sector emissions intensity is an input parameter to the modelling and is derived from CAT Paris Agreement-compatible benchmarks, in which the Indian power sector is fully decarbonised by 2050 (Climate Action Tracker, 2020b).

Box 1 | The role of biofuels and synthetic fuels

As communicated by our Paris Agreement-compatible scenarios, electrification will be an essential part of decarbonising the transport sector. But given the technological challenges in electrifying certain transport modes, mainly water and air-based travel modes, relying on electrification will not be enough. Pairing electrification with alternative low-carbon fuels has the potential to ensure net-zero emissions in the transport sector is achieved. Some major low-carbon fuel options are available, all with different level of advancement in terms of technical and economical maturity.

Biofuel blending is already being practiced across the globe, but faces significant challenges related to the limitations in producing sufficient quantities of sustainable biomass, particularly as there is an increasing demand for sustainable biomass in other sectors, such as the heavy industry and power sectors. Demand reduction and energy efficiency measures (avoid and shift) would enable the available sustainable biomass to satisfy a higher share of the non-electrified fuel demand.

Several ongoing research projects are looking at the production of synthetic fuels, where fuels with similar chemical characteristics as those of conventional fossil fuels are produced using electricity.

Synthetic fuels can typically be categorised into two sub-sectors: (i). Hydrogen produced from electricity and water, and (ii). Hydrocarbons produced from carbon captured from the atmosphere and electricity. There are several points worth noting related to the production of synthetic fuels.

Firstly, for the synthetic fuels to be classified as carbon neutral from a life-cycle perspective, the electricity used in the production of the fuels must be generated from clean sources.

Secondly, as for all processes which include a shift in energy carrier, there will be losses, meaning that synthetic fuels will always be more energy intensive compared to using electricity directly in a vehicle. Electric vehicles should therefore be the preferred choice where possible.

Lastly, in the case where synthetic fuels are produced from carbon captured from the atmosphere, the carbon neutrality aspect of the fuel becomes questionable, since that carbon will be combusted and eventually recycled into the atmosphere again. That said, this is still a better option than that of burning fossil fuels.

In our analysis, we assume that hard-to-electrify transport modes are fed from a mix of biofuels and synthetic fuels (Figure 6 and Figure 7). The same assumption is made for the remaining non-electrified fleet. The majority of the non-electrified energy demand originates from international water-based freight transportation. We recognise the substantial advancements in technology development and investments needed in R&D for such advancements to take place, however, we also emphasise that this is an international issue that requires an international approach.

We find that alternative synthetic fuels have a potential to mitigate up to around 2.200 $MtCO_2e$ between 2020 and 2050 in the road focused scenario, equivalent to 70 $MtCO_2e$ on average per year and 150 $MtCO_2e$ in 2050.

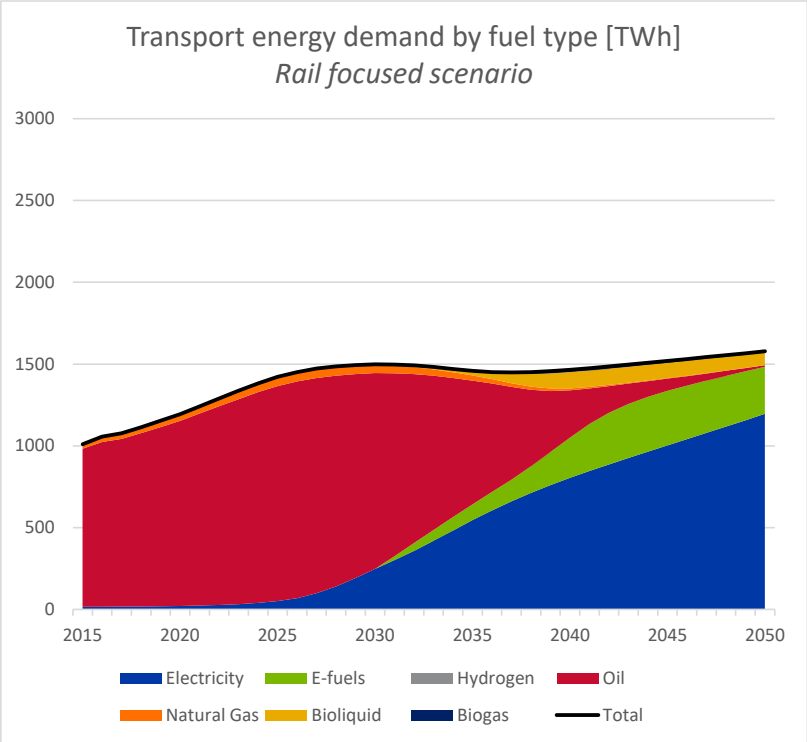

Figure 6. Total energy demand by fuel type in the Rail focused scenario.

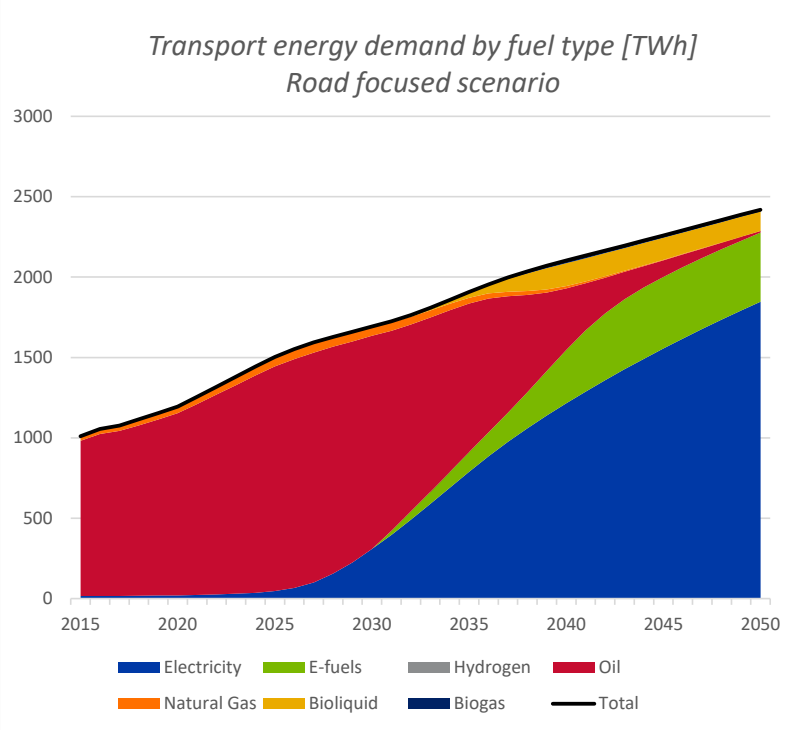

Figure 7. Total energy demand by fuel type in the Road Focused scenario.

2.2.3 Policy analysis: Learning from global good practice policies

Emissions in the Indian transport sector are rising and are expected to grow further, despite the policies in place (IEA, 2020). For India to reach the highest plausible emission pathways put forward in this study, new, more ambitious policies will need to be implemented in all areas of the transport sector.

A way to identify possible policies that India could consider to scale-up its climate action is to learn from good practice policies implemented in other countries (Roelfsema et al., 2018). Good practice policies provide concrete policy examples in a particular context that have led to a transformation in a particular mitigation area. Any policy, however, has to be embedded in, and adjusted to, national, regional or municipal circumstances. Hence it is equally important to understand how the current policy framework in the context works in order to learn from these good practice policies. This way, actionable lessons can be drawn from the good practice policies that apply to the particular context in the country.

Against this background we have split our policy analysis into three different parts:

First, we review the current policy landscape in India's transport sector. We identify the main drivers in the sector and describe how policies have shaped these. This is done for each identified priority mitigation area.

Second, we identify global good practice policies that have enabled a transition of the transport sector in their respective context and can be used to draw important lessons for India. The search for these polices was organised around the identified action areas (Section 2.2.1) and further guided by a global policy assessment of the transport sector by the Partnership on Sustainable, Low Carbon Transport (SLoCaT, 2018). These policies were identified on the basis of a literature review and build on the methodology developed in an earlier study on decarbonising the European transport sector by 2040 (Climact & NewClimate Institute, 2020).

The policies were primarily chosen based on the principle of highest plausible ambition, in line with the approach used for scenario development. Since a large number of the policies identified according to this principle can be encountered in developed countries, likely due to the fact that these have more resources to implement such policies, we have tried, where possible to also add examples from the developing world or, at a minimum, carefully caveated the applicability of the policies to India.

To better understand how these policies could serve as examples for the Indian context, the policies identified are evaluated using three indicators:

- The *maturity indicator* assesses how long a policy or set of policies have been in place and investigates whether the policy has had the intended effect. Essentially, the indicator assesses the degree of certainty to which a policy will do what it is drafted to do, based on how proven the policy is;
- The *impact indicator* assesses the emissions mitigation potential the policy or set of policies has or could have. The indicator is also informed by the historic performance of the policy, where such information is available;
- The *replicability indicator* assesses whether the identified policy has already been replicated in other areas/countries, as well as the extent to which the policy could be replicated in India – while taking into consideration legislative and socio-economic context.

The assessment shows the scale of performance for each of the three indicators from low to medium to high. We apply a "traffic light" colour-coding to each indicator.

In a final step, we propose actionable policy recommendations per identified priority mitigation area. These recommendations bring together the analysis of current policies, providing an idea of what is feasible, and the existing good practice policies to develop policy suggestions for the Indian context. The stringency of the policy

recommendations is, where possible, guided by the results from the modelling work, especially if a direct policy-modelling link can be established. The policy recommendations include key overarching medium-term mitigation goals and concrete and policy recommendations.

3 Sustainable and modern urban planning to counter-act urban sprawl

The Indian population is projected to reach 1.6 billion inhabitants in 2050, with half of its population living in urban areas and generating three quarters of the national income. To date, urbanisation has been coupled with inadequate public infrastructure, which most often leads to overcrowding, congestion and poor traffic conditions.

Towards the outskirts of the country's typically densely-populated cities, new buildings have rather low density, exacerbating urban sprawl development patterns. Public infrastructure and basic public services have not been able to support this rate of urbanisation. Such conditions have led to a rapid growth in private motor vehicle ownership, reinforcing the negative impacts of urban sprawl through, for example, congested traffic, long commuting, and local air pollution (Tewari, Godfrey and et. al., 2016). The rise in private motor vehicle ownership is also a social issue with many Middle-income households preferring to have a personal motor vehicle when their income can support it.

India has no overarching national policy intended to limit increasing urban sprawl and motorised transport demand. On the contrary, current policies such as land registry systems and construction permits tend to encourage urban sprawl. In 2006 the Ministry of Urban Development developed the National Urban Transport Policy (NUTP) - a national framework for sustainable urban development but was never anchored into law and thus has had no or very limited impact, despite its 2014 revision.

To complicate this situation more, plans, strategies and initiatives centred around sustainable urban planning exist at various governance levels (IEA, 2020). However, it is worth noting that there are many other initiatives that in some way relate to urban planning. While often coordinated at the national level, these initiatives are scattered, limited in their reach and lack a coordinated approach. These include the 100 Smart Cities and Atal Mission for Rejuvenation (AMRUT), which includes the preparation of Master Plans, the elaboration of State Annual Action Plans or the establishment of Urban Development Authorities (Government of India, no date; Singh, 2016); and India's Ministry of Housing and Urban Affairs' Smart City Mission to support sustainable urban development while giving cities the freedom to choose their own approach (Ministry of Heavy Industries & Public Enterprises, 2020).

3.1 Paris Agreement-compatible transport demand reductions

Sustainable long-term urban planning leading to compact spatial and transit-oriented development (TOD), in which neighbourhoods provide a full range of services and better transport management centred around public transport, can counter-act urban sprawl and reduce the need for transport. Measures in this area can be effective if designed to be holistic in their approach in transport planning and encompass sustainable urban mobility plans.

Under a Paris Agreement-aligned scenario, passenger transport demand is 22 per cent lower in 2050 than under a current policy scenario, see Figure 8. The corresponding decrease for freight transport is 11 per cent in 2050, see Figure 9. In 2011/2012 the average annual passenger demand per capita in India was 3,100 pkm per year, which in a current policies scenario would increase to 12,900 pkm per year, representing a fourfold increase in terms of intensity. In a Paris Agreement-compatible scenario, the corresponding increase would only be 3.3 times higher than the 2011/2012 levels, reaching an annual per capita intensity of about 10,100 pkm per year. Such reductions in passenger demand can be achieved through behavioural changes and improved infrastructure systems.

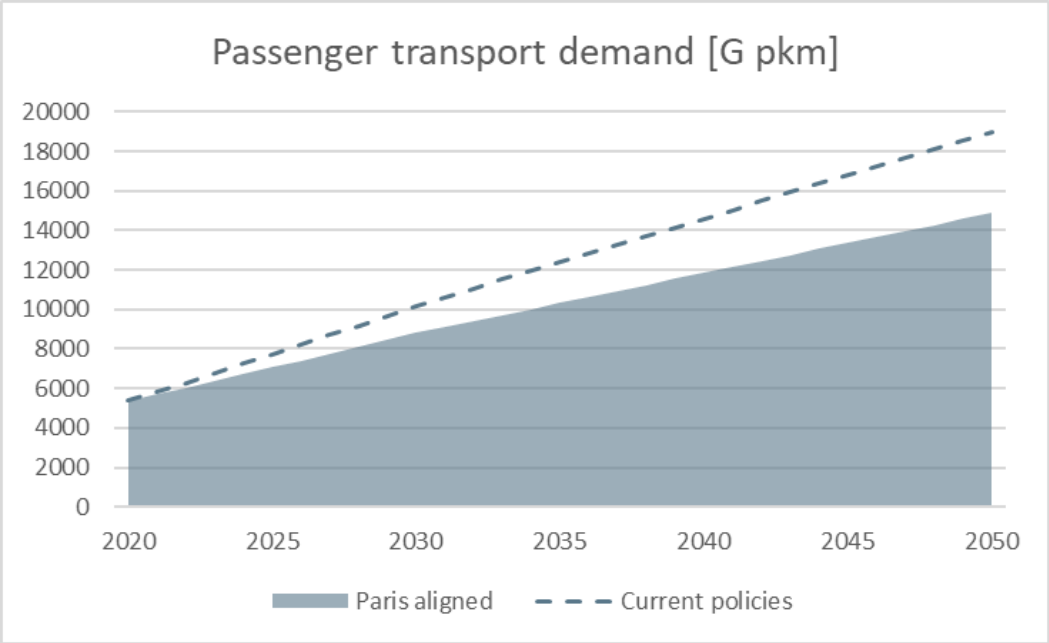

Figure 8. In a Paris Agreement-aligned scenario, overall passenger transport demand is reduced by 22 per cent in 2050 relative to the current policy scenario (Giga pkm).

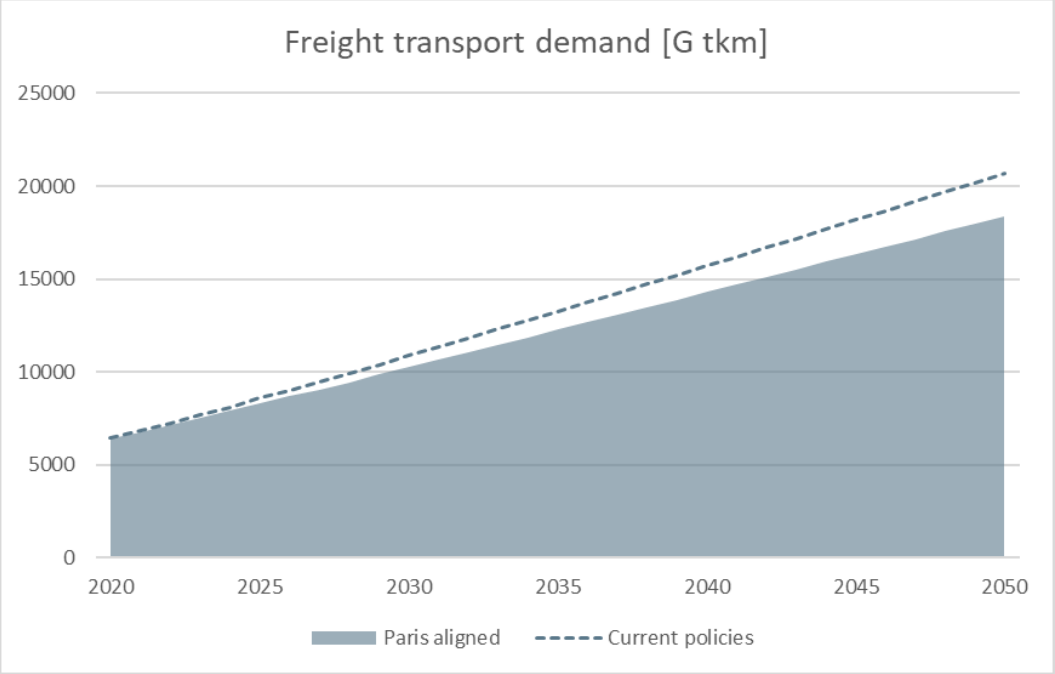

Figure 9. In a Paris Agreement-aligned scenario, overall freight transport demand is reduced by 11 per cent in 2050 relative to the current policy scenario (Giga pkm).

The high urbanisation rate in India is assumed to result in a shift of passenger activity from non-urban areas into urban areas. By 2050, it is assumed that 70 per cent of all passenger demand will be centred in urban areas, compared to the current rate of about 50 per cent. Such an aggressive increase, along with an overall increase in per capita activity, will require an efficient and reliable urban transport system.

It is clear that transport demand will increase in India. But as already discussed, limiting that increase through strategic approaches that are consistent with sustainable development can still be considered. In terms of emissions, that could contribute to a 17.5 per cent (205 MtCO2e/year) reduction in 2050 compared to a current policies scenario (Figure 10).

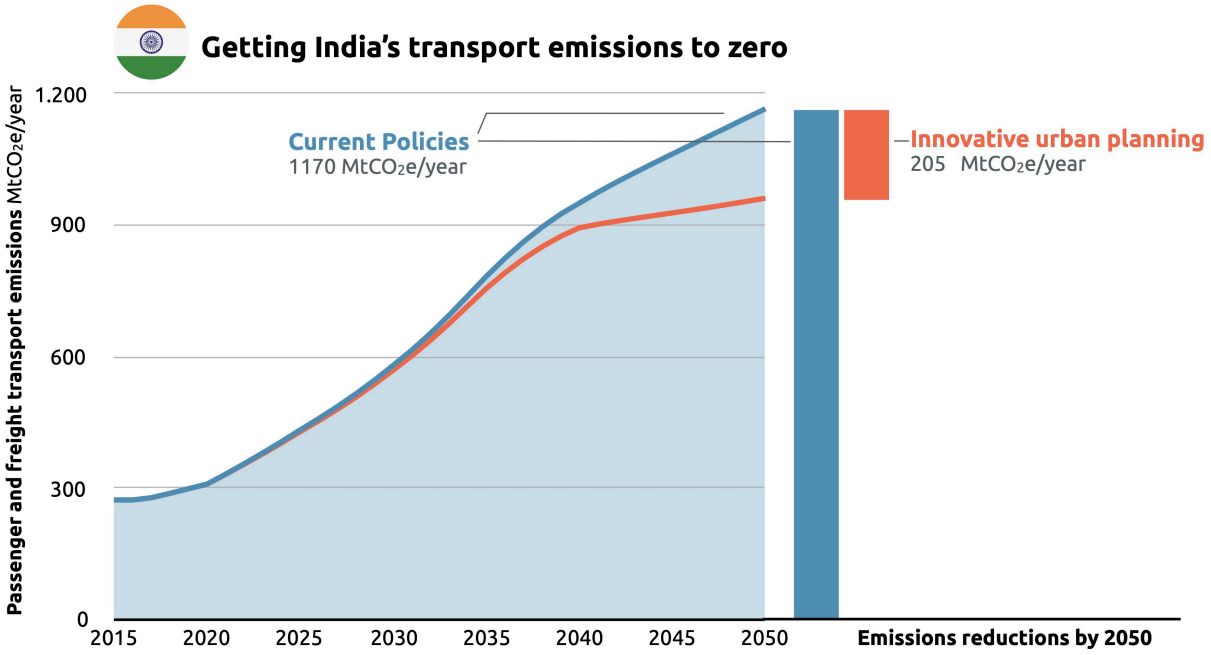

Figure 10. The impact of innovative urban planning to limit the increase in demand compared to a current policies scenario on transport emissions.

In addition to reducing the growth in passenger activity demand, the distance travelled by individual vehicles can also be minimised. In our modelling exercise, we do so through the two parameters of occupation rate and modal shift. By increasing the number of passengers per vehicle, the total distance driven by each vehicle is reduced by satisfying a higher number of passengers per vehicle kilometre (vkm). In the Paris Agreement-compatible scenario, the average occupation rate reaches 3.2 pkm/vkm in urban areas by 2050, compared to a current average of 2.6 pkm/vkm. The increase in occupation rate is driven by improved car-sharing systems which coincides with a reduced demand for privately owned vehicles.

3.2 Good practice policies implemented in other countries to move toward Paris Agreement compatibility

Lessons can be learned from some good practice urban transport policies that other countries have implemented and have been impactful in reaching the desired effect. Denmark developed an urban planning policy at the national level that mandates sustainable urban planning, called the national planning directive.

Here we focus on the policies developed in the Copenhagen area. Copenhagen acts as a role model for the development and implementation of urban planning policies and demonstrates that policy-making in this area is more effective at a city-level.

Policy area	Good practice policy	Governance level
Sustainable and innovative urban planning	Copenhagen's "five-finger" urban development plan that ensures transport-oriented development in Greater Copenhagen embedded in Denmark's national urban planning policy.	City / municipal (embedded in national)

POLICY AREA 1 - SUSTAINABLE AND INNOVATIVE URBAN PLANNING

EXAMPLE OF GOOD PRACTICE POLICY: COPENHAGEN'S URBAN DEVELOPMENT PLAN AND CURITIBA'S MASTER CITY PLAN

Copenhagen's five-finger plan is focused around metropolitan train lines (170 km) that spread like fingers on a hand from the "palm" of central Copenhagen, with green spaces in between and neighbourhoods planned around train stations.

The plan ensures that integrated urban development takes place with enhanced mobility and green living spaces available for urban living, which avoids unnecessary travel. This ensures that focus on public transport services and cycling infrastructure, are not lost during urban development (Danish Ministry of the Environment, 2015). The plan also enables easy connection with neighbouring cities and sub-urban areas.

Overall, Copenhagen's plan avoids the need for private passenger cars within the city and when commuting from further afield. The city's urban plan also encompasses strategies for freight transport through consolidation centres at the city's borders, to limit freight traffic into and within Copenhagen (Baster *et al.*, 2014).

Maturity: Copenhagen began implementing the five-finger plan around 70 years ago, in cooperation with neighbouring municipalities. Denmark introduced national planning guidelines in 1974 and reinforced the framework in 2007 through its national Planning Act, explicitly supporting and strengthening Copenhagen's urban planning framework (Ministry of the Environment, 2007).

Impact: Greater Copenhagen (3.000 km^2) is dense and well-connected with core economic areas within a walking distance of up to 500-600m of popular stations. The Metropolitan area also offers many green and cycling friendly areas and paths.

Despite the Plan, private cars still make up a 26 per cent modal split and kilometres travelled by car slightly increased between 1995 and 2005 but have since been decreasing (Danish Ministry of the Environment, 2015; Deloitte Insight, 2018; Kommune København, 2018). In a survey undertaken by the city in 2015 to understand how citizens feel about urban planning, 82 per cent felt it was easy to get around, but that figure declined to 69 per cent in 2017. The vast majority of cyclists reported they felt safe, and traffic accidents involving cyclists have been declining since 2013 (Kommune København, 2018).

Replicability in India: Urban planning processes are long and complicated, and are influenced by the economic, social, political and ideological contexts. While the context-specificity represents a barrier to replicating such processes, the fact that similar transit-oriented urban plans were implemented in multiple cities around the world shows they can be adjusted to suit the local context.

Another good-practice policy example for urban planning is Brazil's city of Curitiba's Master City Plan. Curitiba's Bus Rapid Transit (BRT) model based on the transit-oriented development (TOD) concept has inspired more than 150 cities to develop similar models (EcoMobility, 2016).

With the same groundwork as Copenhagen, Curitiba's plan, adopted in 1966, builds around a "radial linear-branching pattern" with five transport corridors that direct traffic away from the city centre and protects green areas by encouraging industrial development along radial axes.

Curitiba institutionalised the TOD principle in its 1971 Mass Transit Terminal Plan, which requires mixed-use urban developments along bus rapid transit (BRT) corridors as well as pedestrian networks. The local government acquired land along the planned corridors for low-income housing and adjusted zoning laws to increase housing density by the corridors (Bräuninger *et al.*, 2012; EcoMobility, 2016). For instance, high activity areas (e.g. shopping centres or residential skyscrapers) are planned next to public transportation stations.

In Curitiba, the increased level of accessibility through sustainable urban planning has counter-acted urban sprawl and a shift to passenger cars, with a share of passenger cars of 22 per cent (EcoMobility, 2016). Compared with Copenhagen, Curitiba relies on non-electric buses instead of electrified light-rail as a core transport mode of its TOD development, which is less space and energy efficient and has led to overcrowded public transport in recent years. A sad development is that the Curitiba Plan has lost prominence over the years, so that some parts of the city, particularly newly-built suburbs, are not well-integrated and connected, leading to inhabitants having to rely on private motorised vehicles (Halais, 2012).

These examples show that, while very context-specific, the general approach to sustainable urban planning can be replicated in multiple contexts, from smaller municipalities to large metropolitan areas. As India further urbanises, it is important that city expenditure takes into account sustainable urban development into consideration. An emphasis could be placed on integrated urban development around enhanced mobility, and green living spaces available for urban living. Coupled with the TOD concept, such urban development can avoid unnecessary travel.

3.3 Policy recommendations for sustainable and modern urban planning

While India has urban planning initiatives, it lacks scale and coordinated national and state-level legislation to ensure sustainable urban planning and infrastructure. Measures could include:

Mid-term policy **goal**	Intermediate **Steps**
Mandatory incorporation of Transport Oriented Development in city planning, ideally planned around corridors	Support municipalities in developing, monitoring and reporting on Sustainable Urban Mobility Plans, which could be incorporated into State Annual Action Plans as proposed by the Atal Mission for Rejuvenation
	Incentivise Transport Oriented Development in public infrastructure projects, as currently done for metro projects
	Support municipalities through dedicated national and state public budget lines to support the implementation of urban transport-oriented development
	Reform land registry systems and construction permits to favour the purchase of smaller, more central urban parcels for (re)development and allow the construction of taller buildings

4 High-quality and safe non-motorised and public transport infrastructure and services

Many Indian metropolitan areas already have high shares of walking, cycling, and public transport. Together, these three modes can reach shares as high as 90 per cent of the entire modal split in selected Indian cities (ITDP, 2020). Yet motorised two and three-wheelers, largely fossil-fuel based, are the favoured transport modes in urban India (OECD/ITF, 2020). Due to a lack of safe transit infrastructure in many cities, the majority of India's workforce works from home, walks or depends on private transport[3], and only a fifth of the population uses public transport to get to work (Singh, 2016). Out of around 8,000 cities in India, only 65 have some kind of formalised public transport (SHAKTI, 2019).

Overall, India lacks overarching legislative and regulatory frameworks that would provide a coherent structure for all transport modes (GADEPALLI *et al.*, 2018), and as a result the policy framework is fragmented and ineffective. For example, metros are planned on a national level without coordination and interaction with other transport modes, which are often coordinated at a state or city level. This is reflected in the Metro Rail Policy 2017, which provides a framework for planning, development, financing and standardisation of metro systems, which supports the rapid ramp-up of metro systems in India's largest cities and reflects the effectiveness of a clearly defined policy framework (IEA, 2020). However, this is not in any way linked to other transports modes, preventing the creation of an integrated transport system.

On a more positive note, India has the National Urban Transport Policy (NUTP), which provides a policy framework and focuses on planning and investments in public transport and non-motorised transport systems in cities (Mani, Pai and Aggarwal, 2012). However, the NUTP has not been very impactful as it does not have the necessary regulatory support and funding required to make it effective. This is a gap that needs to be addressed in order to expand high-quality, safe mass-transit in Indian cities to meet growing transport demand in a low-carbon manner.

4.1 Paris Agreement-compatible non-motorised and public transport shares

The development of the modal split significantly influences the path a country takes towards decarbonisation of the transport sector. Modal shift to environmentally friendly transport modes such as walking and cycling are typically space and cost-efficient and require relatively low infrastructure and capital investment (ITDP, 2020; Schwedhelm et al., 2020). Like many low carbon interventions, walking and cycling also come with several co-benefits, mainly related to health but also to employment (SLoCaT, 2018; IEA/IMF, 2020). India used to have lots of walking and cycling activities in the 90s, but this has declined, mainly due to lack of infrastructure upgrade and maintenance.

Public transport vehicles such as buses and light-trains have much higher occupancy rates than LDVs, so more passengers can be pooled in one vehicle, which in turn reduces per capita emissions from mobility as well as congestion, urban space requirements, and noise. Proper investments and urban planning towards high-quality and safe mass-transit systems are necessary to offer a proper alternative to passenger cars (SLoCaT, 2018).

Intermodal systems are necessary in enabling seamless transport chains and supporting high-quality and reliable transport services. An example is the use of a metro line for a longer distance and a shared bike for the "last mile"

[3] Government's Census 2011 published in March 2016

of a given journey. Facilitating inter-modality can be achieved through monthly transport passes incorporating all transport services as well as regulations enabling cooperation among different transport operators (public and private companies), which could involve a metropolitan or regional transport authority as an effective central institution (compare (SLoCaT, 2018). Planning for the shift from passenger cars to public transport vehicles should include just transition considerations to ensure affordability, access and safety support.

Our two scenarios differ considerably in terms of public versus private transportation modes in the passenger transportation sector and the role of non-motorised and public transport.

The *Rail focused scenario* demonstrates how metro and railway expansion, in combination with other public transportation services such as bus lines, can reduce the demand for private vehicle ownership significantly. Such a shift leads to less crowded roads, rendering cycling more attractive in return. In our scenario this leads to 77 per cent of the passenger transport activity in urban areas being carried out through public transportation modes (Figure 11), and when walking and cycling area included this reaches 94 per cent. The picture is the same in non-urban areas, where the share of public transportation alone reaches 94 per cent in the *Rail focused scenario*.

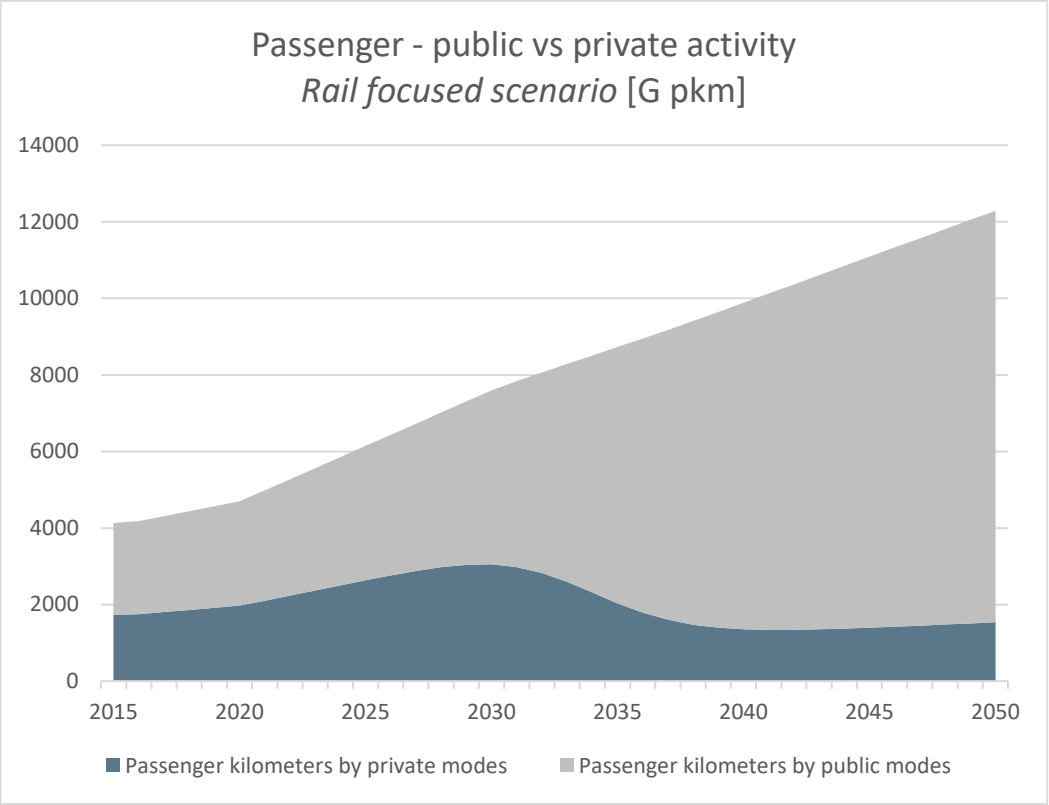

Figure 11. Activity carried by public versus private modes in the Rail focused scenario (Giga pkm).

In the *Road Focused Scenario*, the trend follows the opposite direction. Growing demand in passenger transport activity is mainly met by private vehicles, while slow advancement in public transportation systems are observed. In terms of modal shares, the picture looks similar as in a current policies scenario. By 2050, private vehicles account for 74 per cent of passenger transport activity (LDVs, two wheelers and three-wheelers) (Figure 12).

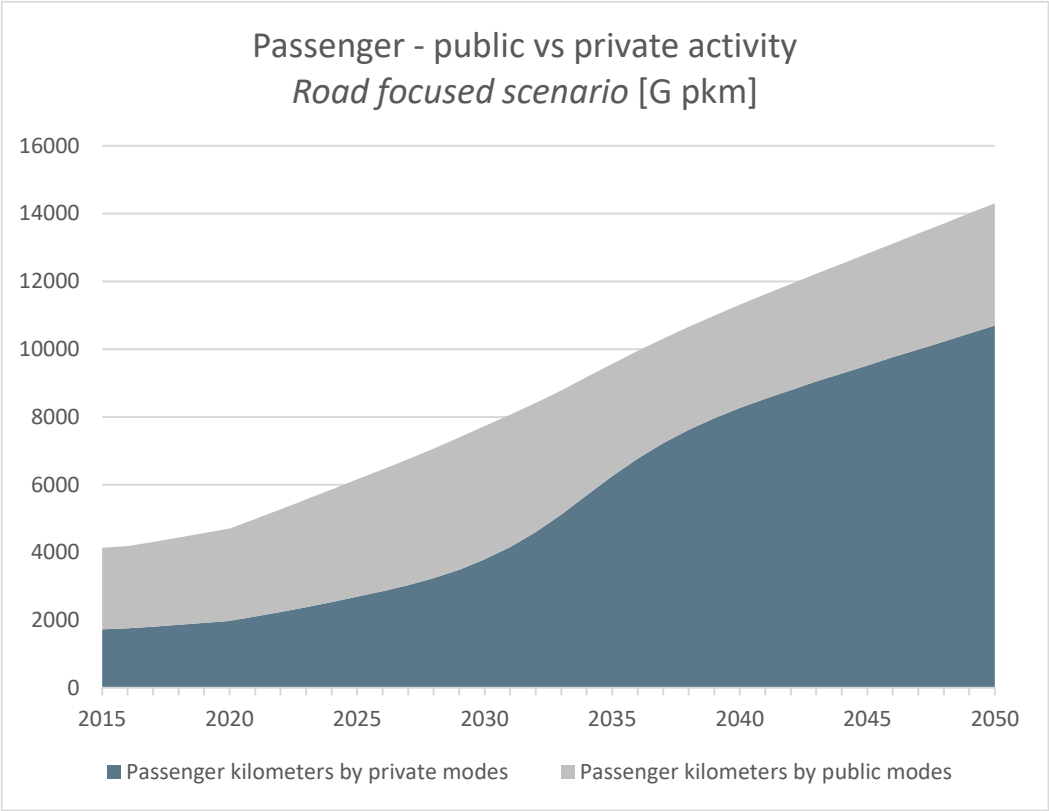

Figure 12. Activity carried by public versus private modes in the Road Focused scenario (Giga pkm).

When looking at effects the two modal shift strategies have on emissions, the difference observed is substantial. In the *Rail focused Scenario*, modal shift alone contributes to cutting more than half of emissions, see Figure 13. In the *Road Focused Scenario*, the corresponding emissions reduction is minimal, see Figure 14. This means that the required emission reductions that need to be achieved through other mitigation options, mainly electrification and low-carbon fuels, are considerably larger in the latter case.

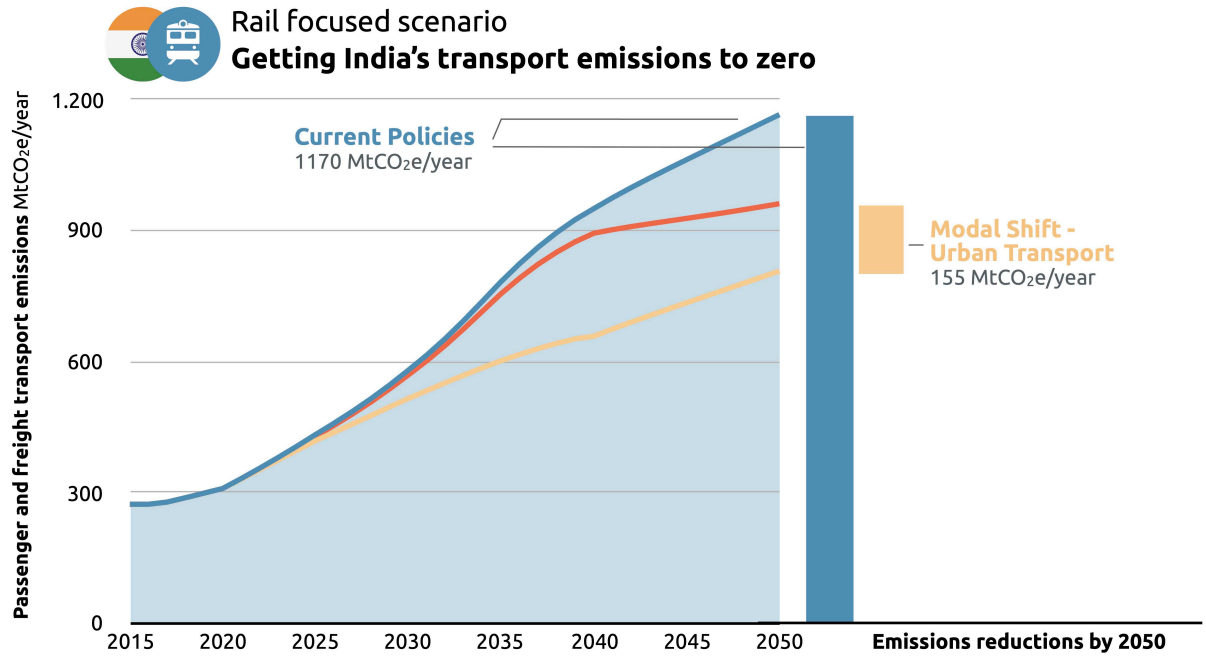

Figure 13.Emissions from passenger and freight in the Rail focused scenario, showing emission reductions obtained from urban modal shift.

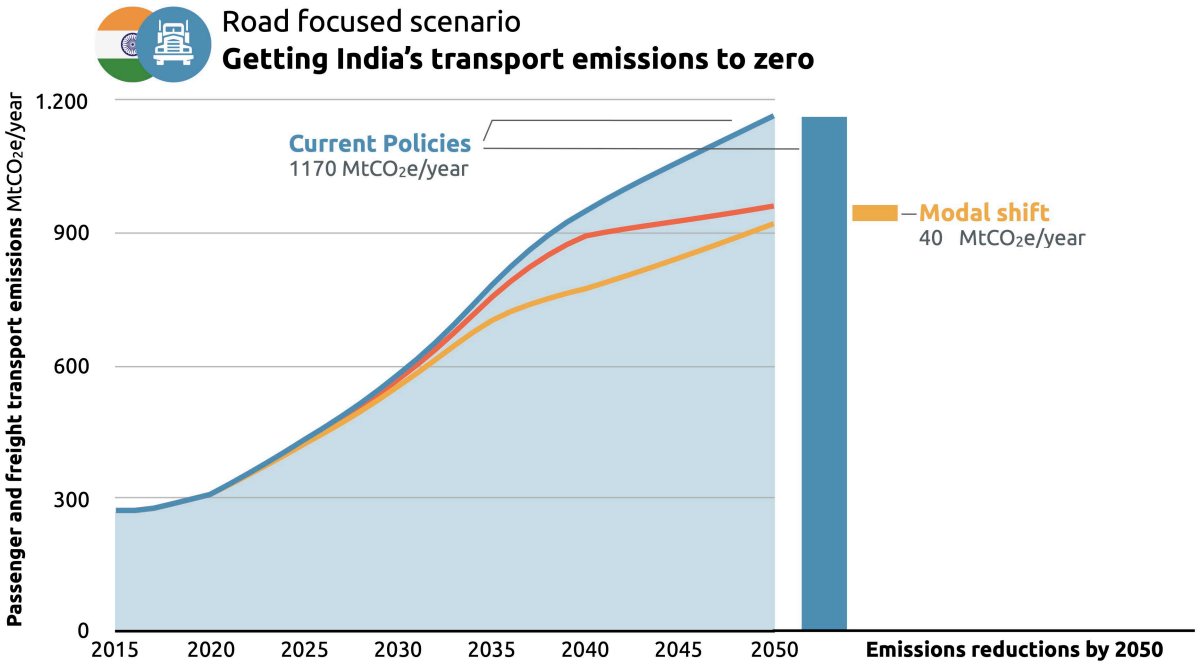

Figure 14. Emissions from passenger and freight in the Road Focused scenario, showing emission reductions obtained from modal shift (urban and non-urban).

4.2 Good practice policies implemented in other countries to move toward Paris Agreement compatibility

There are many policies supporting non-motorised and public transport, yet very limited good practice policies that can help achieve the modal shift needed under the highest plausible scenarios proposed here, especially the *Rail focused scenario*.

Policy area	Good practice policy	Governance level
Shift away from passenger cars and freight trucks in cities	London's ultra-low emission zone (ULEZ) and congestion charge limit the use of motorised vehicles in cities.	City / municipal
Offer integrated transport services and encourage the use of public and shared services	The Finnish Act on Transport Services enables coordinated, seamless, reliable and inter-modal public transport services.	National
Improving walking infrastructure	Singapore' walking and cycling plan prioritises non-motorised transport modes	National
Improving cycling infrastructure	Bicycle infrastructure planning in the Netherlands showcases that cycling can be a viable transport mode when it is taken into account in urban planning	National
Funding and developing affordable public transport	Funding affordable public transport in the Paris metropolitan region through a cost efficient and collaborative tax scheme enables public transport ticket subsidies.	City / municipal

POLICY AREA 2 - SHIFT AWAY FROM PASSENGER CARS AND FREIGHT TRUCKS IN CITIES

EXAMPLE OF GOOD PRACTICE POLICY: LONDON'S CONGESTION AND ULTRA-LOW EMISSION ZONES

Since 2003, London has had a congestion zone imposing an entrance fee for all vehicle entering the zone during working hours. The fee started at £5/day in 2003 and has risen to £11.50/day today (Badstuber, 2018). In April 2019, London also launched an ultra-low emission zone (ULEZ) for part of the city. It imposes a fee, based on the vehicle and emissions type, on top of the regular congestion charge (The Guardian, 2019).

Maturity: The policy has been in place since 2003, is well-established and widely enforced.

Impact: The policy has successfully reduced the number of cars and pollution in London with positive mitigation impact. Between 2000 and 2018, the modal share of passenger cars decreased by 15 per cent. Within the first six months after the introduction of the ULEZ, nitrogen dioxide concentrations at roadside locations decreased by almost 30 per cent, and all air quality

monitoring stations placed within the ULEZ recorded a decrease. Carbon dioxide emissions decreased by around four per cent within six months and around 15 per cent when comparing to 2016 levels (TfL, 2019). Its main success lies in shifting away from passenger cars, as the policy does not require vehicles to be fully decarbonised. Comparing London's modal split to other cities (see Copenhagen above) shows that there is still significant potential to increase the policy's stringency over time and to allow even fewer personal vehicles(Badstuber, 2018; Transport & Environment, 2019b).

Replicability in India: The policy in itself is easily replicable, yet a city would also need to provide proper public transportation and/or cycling and walking infrastructure to allow for a modal shift. For instance, over 250 European cities have introduced low emissions zones.

In Asia, Singapore's electronic road pricing (ERP) system was designed to reduce congestion as early as the 1960s and in 2013, Beijing released the Beijing Clean Air Action Plan 2013–2017, as well as its Work Plan for Vehicle Emissions Control 2013–2017 (Wang *et al.*, 2017).

Severe air quality issues in Indian cities and first attempts to reduce vehicle traffic on polluted days, such as forbidding trucks to enter city boundaries, further hint towards a high replicability in the Indian context (The Economic Times, 2019a). In Delhi, the government has put in place first initiatives to counter-act growing LDV traffic and related pollution, demonstrating interest in the type of measure. This includes for instance, the implementation of an environment pollution charge of one per cent on the registration of diesel vehicles with engines greater than 2L or the Environmental Pollution Authority's 2017 "Graded Response Action Plan" which allows agencies to restrict truck traffic or raise parking fees (ICCT, 2019). This could be strengthened and replicated in other parts of India.

POLICY AREA 3 - OFFER INTEGRATED TRANSPORT SERVICES AND ENCOURAGE THE USE OF PUBLIC AND SHARED SERVICES

EXAMPLES OF GOOD PRACTICE POLICY: FINLAND AND SEOUL, SOUTH KOREA

Finland's Act on Transport Services specifically targets "interoperability of data and information systems" and "intelligent transport systems" to ease the use of public transport and shared services through "seamless, multimodal travel chains". To achieve this, Finland approaches the transport sector as a single entity, requiring transport service providers to share essential information on routes, stops, timetables, prices, availability and accessibility and provide information and services to end-users through compatible search, booking and payment systems (Finland Governement, 2017; LVM, 2017).

Maturity: The Finnish Act on Transport Services only came into force in 2018 but has the support of various national agencies, transport companies and cities, as well as regions (Finnish Transport Agency, 2018).

Impact: Creating a sound policy framework around inter-modality is key in the transport transition to enable flexibility, digitalisation and new business models, yet inter-modality relies on the parallel development of high-quality and safe public transport and shared services in the Indian context (Finland Ministry of Transport and Communications, 2018). As the policy is recent, there are no numbers supporting a possible impact on modal shift.

Replicability in India: India is a technology friendly country yet such a policy framework requires the availability or creation of a central coordinating agency. (GADEPALLI *et al.*, 2018). The Indian government could enforce a national regulation to set up a coordinating authority similar to the Finnish Act on Transport Services, at the national or state level. This authority could coordinate all transport modes and gather transport services onto one platform that end consumers could access through a standardised application. Transport services planning and coordination is currently very scattered across modes: passenger road transport is regulated through the recently amended Motor Vehicles Bill, both at national and state level, but taxi services are separately regulated by the Ministry of Road Transport and Highways; public transport by bus is coordinated on a state level, but many Indian cities provide city bus services under Public Private Partnerships (PPP); metro infrastructure planning is coordinated through the national "Metro Railways (Construction of Works) Act' but railway services are coordinated by the state-owned railway company Indian Railways.

Another example of successful public transportation policy implementation comes from Seoul, South Korea, a city with a metropolitan area population of 25 million, roughly half the total population of South Korea. Seoul implemented a wide-ranging public transportation reform in 2004, which included a "quasi-public operation system", leading to greater coverage of the bus network on routes that were deemed unprofitable by the private firms that previously operated these routes (Seoul Metropolitan Government, 2006). The bus network was also redesigned for seamless integration with the subway system, while an integrated public transport fare system removed unfair transfer fees for many who transferred on short commutes. This reversed a downward trend in bus commuting numbers and led to an increase in overall profitability of the public transport system.

An increased reliance on technology has increased the efficiency and convenience of commuting, with the Seoul Transport Operation and Information Services (TOPIS) monitoring over 9,000 buses and leveraging this data to improve services (Ko and Lee, 2016). The creation of virtual supermarkets in the subway and bus network, whereby commuters can photograph bar codes of various products and order them for same day delivery, ensures the commuting experience is practical and convenient (Lawson, 2012). These innovations and reforms led to a mass transit modal share of 65 per cent in Seoul in 2013, and with the expansion of light rail across Seoul, this is expected to increase to 75 per cent by 2020 (Seoul Metropolitan Government, 2016).

POLICY AREA 4 - IMPROVING WALKING INFRASTRUCTURE

EXAMPLE OF GOOD PRACTICE POLICY: SINGAPORE' WALKING AND CYCLING PLAN

Singapore's walking and cycling plan aims for safer, more direct and comfortable walking (and cycling) paths. The legislation affects all construction projects. Its main pillars include the connectivity to key public transport nodes and measures to minimise conflicts between pedestrians, cyclists, and vehicles (Land Transport Authority, 2017).

Maturity: Singapore's first Walking and Cycling Plan (WCP) came into effect in 2016 and was amended in 2018 to strengthen requirements. Both the amended WCP and the Active Mobility Plan requirements have been in force since 2016 and 2017 respectively.

Impact: No data is available to show the impact of this plan to date. A recent study forecasts a significant shift to walking and cycling in Singapore over the next ten years, although in absolute terms both modes are somewhat minimal (Tan, 2020). It is important to note that although walking is, in many cases, not a viable, stand-alone transport mode, it is an important complementary transport mode to public transport.

Replicability in India: Coordinated walking planning has already been a proven instrument outside Asia (especially Europe) for decades, and examples such as the city of Vienna (Austria) have proven to lead to significant increase in the share of walking (City of Vienna, 2018). Developing an infrastructure conducive to walking requires public investment that is relatively low compared to other modes of transport. Many elements of such a plan, such as preferred traffic signals, are relatively easily replicable. Walking as a transport mode is particularly suitable for urban areas with high population density and public transport services, as is the case in India. To avoid a shift to personalised vehicles, the policy needs to be complemented with high-quality and safe public transport services, which needs to be developed in parallel.

There are examples in India: Chennai, India's sixth largest city, implemented a Non-Motorised Transport Policy in 2014, which aims to increase the modal share of non-motorised transport by providing safe and reliable infrastructure (Corporation of Chennai, 2014). These could be replicated to other cities. It is also worth noting that there used to be fair amount of walking and cycling in Indian cities in the 90s, but due to lack of infrastructure upgrade and maintenance this has now declined.

POLICY AREA 5 - IMPROVING CYCLING INFRASTRUCTURE

EXAMPLE OF GOOD PRACTICE POLICY: BICYCLE INFRASTRUCTURE IN THE NETHERLANDS

The Netherlands can be considered the cycling infrastructure leader of the world, having the largest share of bikes per capita (Mark Wagenbuur, 2018; Landelijk Fietsplatform, 2019). Bicycles play a major role in urban transport settings, largely supported by policymaking at the city level that has prioritised bicycles over other modes for decades. Utrecht, for instance, modified streets to accommodate bikes over cars, developed a comprehensive bike-parking infrastructure, made public bikes widely available and designed cycleways in a way that led to more direct access routes to the city. As a result, cycling has, for most routes, become the city's fastest mode of travel (City of Utrecht, 2019).

In 2018, the Netherlands presented plans to also make bicycles a more attractive mode for intra-urban travel. An additional three billion cycling kilometres will be built, including high-speed bicycle routes and bicycle parking facilities. The plan aims to shift 200,000 commuters from private vehicles to cycling (Dutch Government, 2017).

Maturity: The Netherlands, particularly cities such as Utrecht or Delft, but also other European cities such as Munster (Germany) or Copenhagen (Denmark), have prioritised cycling since the 70s.

Impact: Although by kilometres travelled, in the Netherlands cycling has an eight per cent modal share nationwide, in urban areas it can go up to a 50 per cent share, surpassing that of cars. The modal shift is currently stronger for short to medium distance trips of up to seven kilometres and is stronger in urban areas, yet the latest cycling policies might also increase this for rural/ intra-urban traffic (Kennisinstutuut voor Mobiliteitsbeleid, 2018; Jonkeren, Wust and Haas, 2019).

Replicability in India: Improving cycling infrastructure is quite simple but needs to be adjusted to the country and city context. For instance, US cities such as Portland opt for introducing bicycle lanes as part of roads, whereas in the Netherlands these are often separate lanes. The dense urban context in India, approximately as dense as the Netherlands (World Bank, 2019), suggests that safe bicycle infrastructure could incentivise a significant number of people to shift to bicycles.

As demonstrated in national lock-down circumstances during the Covid-19 outbreak, cycling has proved to be a viable transport mode that the public sector can support in a fast, straightforward and cost-effective manner (ITDP, 2020; Schwedhelm *et al.*, 2020). Since Covid-19, the Ministry of Housing and Urban Affairs has recommended measure to support walking and the development of cycling infrastructure in India (Chandran, 2020). While we don't recommend replicating exactly the same cycling infrastructure as the Netherlands, the urban planning policies and the support of safe and efficient cycling routes can certainly be a source of inspiration in the Indian context.

Box 2 | The role of shared mobility

Shared mobility, new mobility services, or Mobility-as-a-Service (MaaS) offer users access to shared transport modes on an 'as-needed' basis. Examples of such services are shared mobility, bike and car sharing, ride sharing, ride-sourcing / transportation network companies (TNCs), microtransit (such as electric scooters) or shared, and eventually autonomous, vehicles.

Shared mobility and MaaS, if done right, could become a key piece of the puzzle in decarbonising the transport sector, but due to the potential negative effects, we do not address it here as a policy area as such. Indeed, MaaS can lead to more efficient use of vehicles and infrastructure through a better matching of supply and demand, improving reliability and accessibility of transport services and reducing the number of cars and the number of rides (higher occupancy and utilisation rates). Nevertheless, such mobility services can also have adverse effects, such as shorter vehicle lifetimes, increased transport demand, congestion, noise and air pollution. The balance of positive and adverse effects has two key variables:

- *passengers shift from private car use to shared vehicles, reducing the size of the vehicle fleet;*
- *passengers shift from public transport to ride sharing, increasing traffic and the size of the vehicle fleet* (adapted from Jung and Koo, 2018).

Ride-hailing or autonomous driving in particular can shape a future sustainable transport sector, especially in areas where public transport cannot play such a strong role. Studies have shown that carsharing often results in a decrease of vehicles on the road, car ownership and even reduced transport demand to some extent (SLoCaT, 2018). Nevertheless, emissions may not decrease in the case of a monomodal use (autonomous fleets or ride-hailing fleets substitute public and non-motorised transport), as has occurred in some US cities (Agora Verkehrswende, 2017; Bliss, 2017; SLoCaT, 2018).

Policies could act to maximise the positive impacts of MaaS and minimise potential negative effects, for example by providing the required infrastructure and coordinating transport services for transport alternatives to passenger cars. Shared services should have a fiscal advantage over ownership and have clear and harmonised operation and data protection rules, including for shared bikes and scooters (see Transport & Environment, 2019a). In order to maximise their contribution to reducing emissions, ideally shared service vehicles would be zero emissions vehicles. We address the need for coordination and integration of such services in "Policy area 3 - Offer integrated transport services and encourage the use of public and shared services".

Example of good practice policy: Hangzhou' Public Bicycle Sharing programme is the largest digitalised shared bicycle service programme in the world, with 89,600 bicycles and 473,000 daily rides as of 2018 (Zhejiang Daily Online, 2018). The city ranks seventh in the Global Bicycle Cities Index (Coya, 2019). Given high demand, and docks being filled quickly, bluetooth geofencing devices were implemented on 1,000 sites and 10,000 bikes by 2018, allowing bikes to be parked beside docks and reducing the need for redistributing bikes, also reducing costs (Urban Sustainablity Exchange, no date; Zhejiang Daily Online, 2018). On a national level, China leads the world in public bike share programmes, with 170 programmes across the country. Bike sharing has known success in several cities worldwide (e.g. Paris' Vélib' or Mobike in China).

POLICY AREA 6 - FUNDING AND DEVELOPING AFFORDABLE PUBLIC TRANSPORT

EXAMPLE OF GOOD PRACTICE POLICY: FUNDING AFFORDABLE PUBLIC TRANSPORT IN THE PARIS METROPOLITAN REGION

The Paris metropolitan region is a good practice policy on the funding models for public transport, as the city offers high-quality mass transit transport at relatively affordable prices, based on a shared burden finance model. The public transport network is mainly financed through the transport tax ("versement transport") collected as a tax through employers and by subsidies in the form of statutory contributions from the Paris metropolitan region and its municipalities (French Government, 2019; Conseil d'administration, 2020).

Maturity: The Paris metropolitan region and national law have encouraged public transport subsidies for decades: the transport tax has been anchored in national law since as early as 1996 (French Government, 2020).

Impact: In Paris, public transport financing led to modern affordable public transport (including shared bike infrastructure investments), where ticket fares cover only 28 per cent of total investment and operations costs (2016 estimates). As such, the city has been able to shift away from the use of cars, reducing its modal share to 13 per cent since 2013 (Île-de-France Mobilités, 2020). In the Paris metropolitan region around half of working citizens use public transport; in Paris itself this is as high as 70 per cent (Insee, 2017). Although inhabitants still rely on passenger cars, especially in the outskirts of the capital, the number of cars in the city has slowly reduced over the last decade[4].

Replicability in India: In India, some cities take the lead in setting affordable high-quality mass-transit public transport, and this could be expanded and strengthened. For example New Delhi has made major investments in the metro system, leading to reliable but still relatively expensive public transport services that are still not accessible to a large part of the population (Alam, 2013; Aggarwal and Jain, 2016; Deloitte, 2018).

The New Delhi example of high-quality service throughout the broader metropolitan region has inspired other cities to replicate the approach so that ten cities now have an operating metro system (Kolkata, Delhi, Bengaluru, Gurgaon, Mumbai, Jaipur, Chennai, Kochi, Lucknow and Hyderabad) (IEA, 2019). Similarly, although not relying on a metro network, Kerala has a well-organised bus rapid transit in place supported by the public sector (e.g. Kerala State Road Transport Corporation). Mumbai currently operates Bus-Rapid-Transit (BRT) lines, but also plans metro lines.

[4] It is important to note that the modal shift is not solely impacted by public transport subsidies, but other policies such as traffic management (e.g. congestion zones) also influence modal split.

4.3 Policy recommendations to maintain high modal split of public and non-motorised transport

Mid-term policy **goal**	Intermediate **Steps**
Reduce motorised passenger and freight traffic in cities	Low emissions zones can reduce air pollution from ICE cars and trucks
	Congestion zones de-incentivise the use of passenger cars
Safe and user-friendly walking and cycling infrastructure	A national and/or state-level body supporting cities in implementing safe and user-friendly walking and cycling infrastructure could facilitate the exchange of good practise
	City level plans for walking and cycling and allocate funding to implement them are key to supporting these transport modes. These plans could include dedicated safe walking and cycling paths and adapted traffic signalling amongst other things.
Ensure seamless, reliable and intermodal transport services	A coordinating agency (e.g. Public Transport Authority), that could be affiliated with the governing existing authorities can ensure coordinated, reliable and user-friendly public transport. A role of the agency could also be to monitor private transport services such as private bike sharing or ride-hailing services.
	A platform that serves as an integrated transport services hub and is coordinated by a public agency could enable the booking of all, or a wide range of, public and private transport services and include information on availability of vehicles, shared services, timetables. Ideally such a platform integrates walking and cycling information in route suggestions.
Public transport remains affordable and is supported through public budget	National budget and state budgets could be allocated to subsidise the cost of public transport (and potentially non-motorised infrastructure and services)
	A fiscal scheme could be setup to redirect funds (e.g. through corporate taxes) and to minimise the fiscal burden and redistribute the costs to those who benefit (e.g. employers as employees have shorter commutes or can commute to work at all)

5 High quality railway infrastructure and services

Railways are well-developed in India, and are the main transport mode for inter-city travel and major freight goods. Between 2000 and 2017 passenger railway demand tripled while freight railway demand increased 2.5 times (IEA, 2020). At the same time, road transport and aviation have grown even more significantly, effectively leading to a decrease in the modal share of rail transport (IEA, 2020). Railways are easier to decarbonise than other modes, as rail is largely electrified: 54 per cent of the conventional passenger demand and 65 per cent of freight are moved through electrified trains. It's also worth noting that light rail, such as metros, is fully electrified (IEA, 2019).

Although railway infrastructure exists in India, the biggest challenges are that it is congested, slow and unsafe as it lacks adequate funding for network expansion and modernisation. Maintenance activities on the congested network are often difficult to implement. Nevertheless, accidents have decreased significantly since 2000 (IEA, 2019).

A lack of public funding for rail infrastructure due to a shift of public budget towards road transport has led to a marginal expansion of the track network of five per cent over the last 60 years. In comparison, the road network expanded by 75 per cent between 2000 and 2015.

Instead, the electrification of railways (see above) has been a policy priority over recent decades. Indian policies have only recently shifted toward the expansion of the rail network. A number of high-speed passenger rail lines are under planning and construction. India aims to create high-speed rail corridors connecting the four largest cities of India, the Golden Quadrilateral (IEA, 2019). The Indian state-owned railway company Indian Railways has recently conducted operational and technological improvements to its diesel train fleet such as replacing passenger short route trains by diesel-electric multiple units (DEMU) or blending biodiesel.

The government plans to set itself a target of a 50-55 per cent share of rail in freight transport by 2025 and promoting multi-modal infrastructure (Ministry of Commerce and Industry, 2019). To achieve this, India has put in place a set of policies, including the construction of two dedicated freight corridors (DFCs), advanced signalling to increase efficiency and safety, and the Dedicated Freight Corridor Corporation of India (DFCCIL).

Although dominated by the state-owned company Indian Railways, the market for container rail transport is partially privatised, to foster competition and increase container traffic by rail. However, a major barrier to reaching higher shares is that freight has to compete with passenger transport, both physically on a congested network, and financially, through India's current tax / subsidy scheme for freight transport by rail. One of the main goods transported by rail in India is coal, which is highly taxed, with the revenue used to subsidise passenger train tickets (IEA, 2019).

National policies supporting domestic and international air travel counteract these initiatives to support railway transport. India's National Civil Aviation Policy (NCAP 2016) specifically aims to increase the country's air travel market to trigger economic growth (Ministry of Civil Aviation India, 2016).

While India has domestic fuel taxes and has been phasing out subsidies on domestic kerosene (The Economic Times, 2020), policies promoting aviation, such as the Regional Connectivity Scheme (RCS), which requires states to reduce the tax on aviation fuel if they want an airport built, are counteracting these efforts (Ministry of Civil Aviation India, 2016). For freight transport, the National Air Cargo Policy launched at the beginning of 2019, seeks to make India a major air freight market (Ministry of Civil Aviation Economic Regulation Division, 2019; The Econo

mic Times, 2019b).

5.1 Paris Agreement-compatible railway shares

Increasing the share of electrified rail can make a significant contribution towards decarbonising India's transport sector. There are a number of factors as to why this could be a feasible path forward. First, electrified railways are already a proven mode of transport in India, unlike electric passenger vehicles. The institutional framework already exists and rail transport is widely-used across the country.

Second, the high population density lends itself to diversified road and rail networks. And finally, the energy consumption per kilometre travelled is lower than for other modes, including those that are electrified. While for passenger transport, vehicle occupancy rate and load factors determine which mode of transport is more efficient, the energy consumption of freight rail transport is indisputably lower than that of road transport (IEA, 2019). Externalities and emissions per person kilometre are a lot lower than for road transport (SLoCaT, 2018).

In our *Rail focused scenario,* rail-based infrastructure in the urban context expands significantly to reach a share of 40 per cent by 2050. The non-urban rail-based transportation share for passengers in India has historically been quite high (52 per cent) but has been decreasing in recent years. Maintaining the current modal share is expected to be an ambitious task given the expected rise in overall transport demand.

In terms of freight, rail-based transportation is expected to advance rapidly under the Rail focused scenario at the expense of road-based transportation modes. That is particularly the case for long-haul freight where the vast majority of transportation will be rail-based, apart from international marine freight transport. A certain demand for road-based transport is still expected to remain for short-haul freight, where rail only contributes to about 17 per cent of activity in 2050. As observed in Figure 15, Figure 16 and Figure 17, the improved rail shares contribute to a 34 per cent lower energy demand in 2050 compared to our Road Focused scenario. The Rail based scenario results in a mitigation potential from modal shift in a non-urban context of 395 Mt CO2e /year in 2050 (see Figure 18).

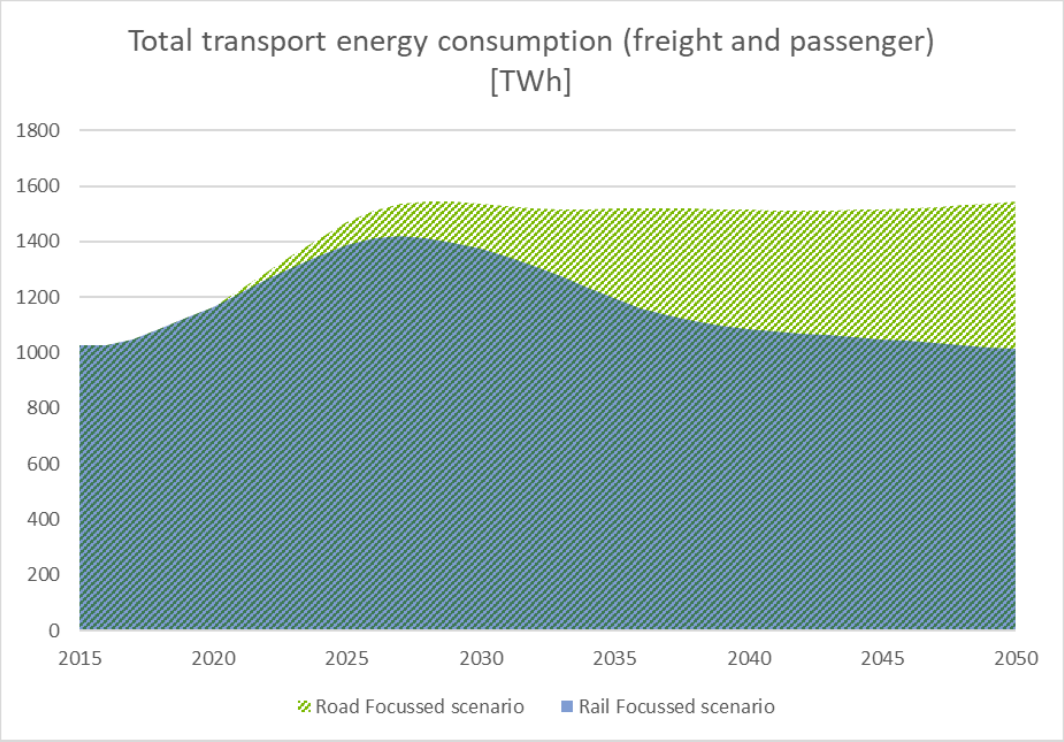

Figure 15. Total energy consumption from freight and passenger transportation in India, Rail- and Road Focused scenarios compared.

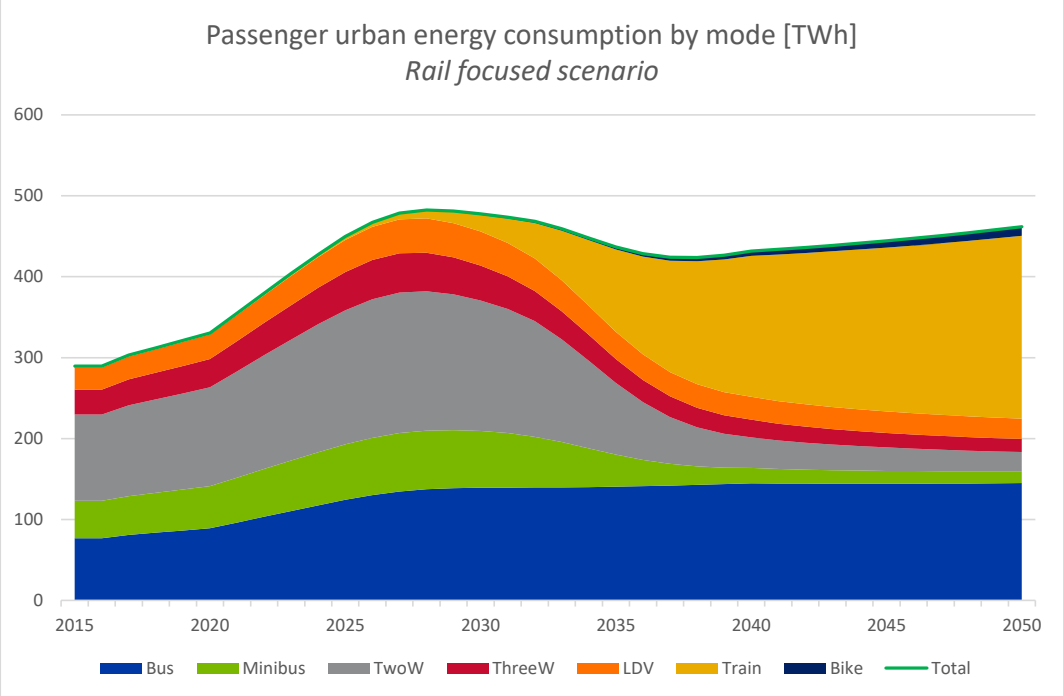

Figure 16. Passenger urban energy consumption by mode in the Rail Focus scenario.

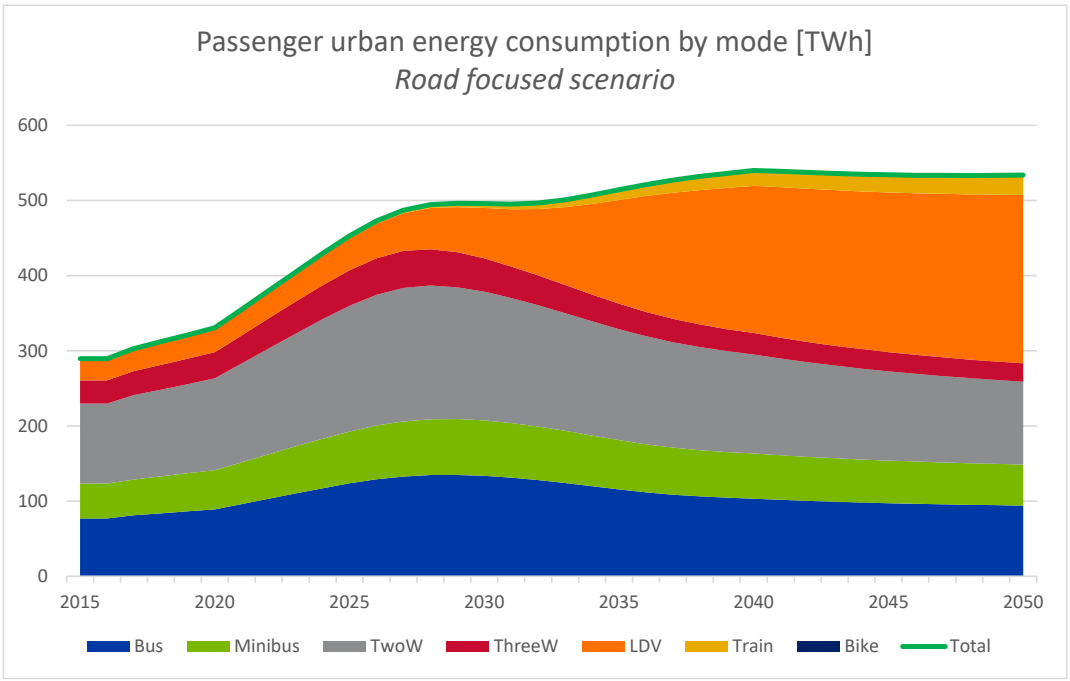

Figure 17. Passenger urban energy demand by mode in the Road Focused scenario.

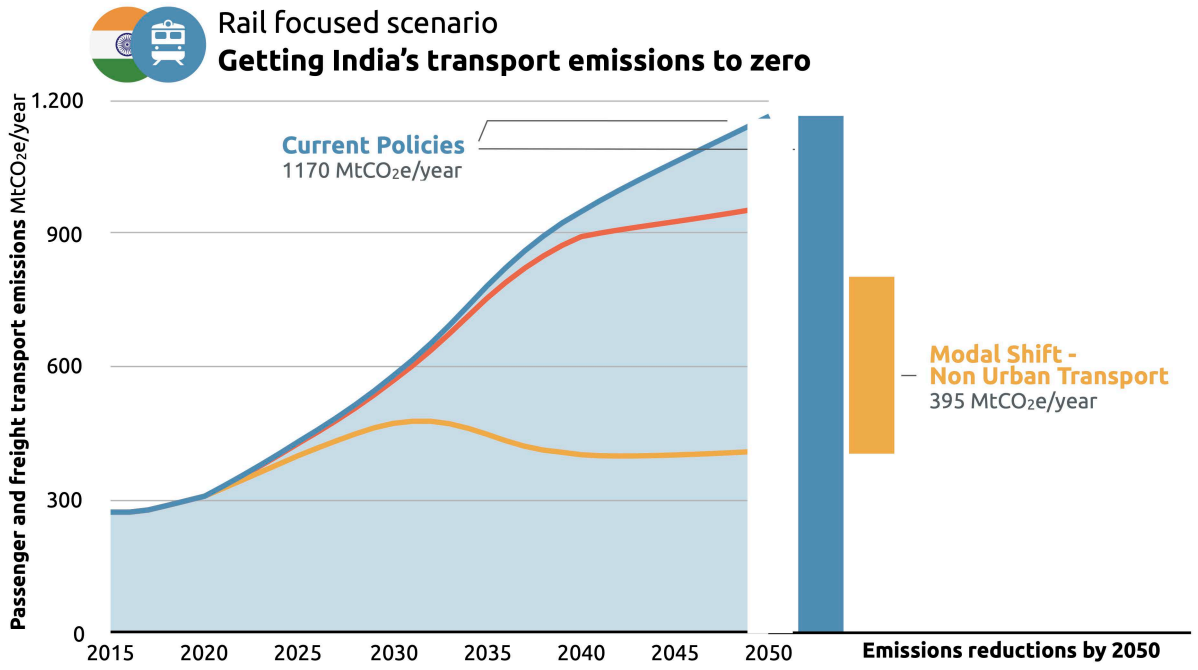

Figure 18. Emissions from passenger and freight in the Rail focused scenario, showing emission reduction obtained from non-urban modal shift.

5.2 Good practice policies implemented in other countries to move toward Paris Agreement-compatibility

Railway and general transport infrastructure is often planned and regulated at a national level. As such we find three good practice policies that support a shift toward railway transport and away from other transport modes.

Policy area	Good practice policy	Governance level
Develop and support railway infrastructure and services	Japan's railway system is made up of public and private railway services, ensuring competition and mobilisation of private funds as well as affordable prices.	National
Establish a level-playing field and tax air travel to limit an exponential growth of air travel	The UK's innovative air travel tax scheme which can be useful as an instrument to create a level playing field for rail by imposing a tax on air travel to avoid exponential and polluting air travel and so indirectly encouraging the use of trains.	National

POLICY AREA 7- DEVELOP AND SUPPORT RAILWAY INFRASTRUCTURE AND SERVICES

EXAMPLE OF GOOD PRACTICE POLICY: JAPAN'S RAILWAY SYSTEM

Japan's railway system is organised along geographical lines, yet avoids regional monopolies. The country significantly invested in railway infrastructure and developed the notorious Shinkansen high-speed train in the 1960s and in 1987 reformed the railway system to partly privatise railway services.

Today, private companies and the publicly-owned company JR Railways run lines in the same area, interlaced with each other and in competition, offering choices to consumers and ensuring financial self-sufficiency. In Japan, the Ministry of Transport sets an upper boundary on JR railways ticket fares, which are based on current market prices, influenced by private sector competitors.

If ticket fares become too expensive, the government can subsidise them through JR railways, thus indirectly driving market prices. Overall fares have increased less than the country's inflation rate. Public funding and commercial competition are coupled with ever-expanding high-speed train lines (Shinkansen, up to 320 km/h), punctual departures and a modern and user-friendly payment system (Marc, 2016; Rail Delivery Group, 2018; Financial Times, 2019).

Maturity: Significant public investment in Japan's railways happened as early as 1950, several reforms and the continuous improvement of the country's railway infrastructure and services have led to high passenger numbers and a self-sufficient rail service industry with private and public investment (Marc, 2016; Rail Delivery Group, 2018).

Impact: Japan's policy framework brings competitiveness and thus efficiency in the rail services market but also allows the government to direct the market through the state-owned JR railways company. Japan's passenger rail modal share has steadily increased, reaching almost 35 per cent in 2014, and is the highest share worldwide. In contrast freight transport by rail has significantly decreased (from 31 per cent in 1965 to 5 per cent in 2014) due to lack of investment as the government focused on passenger transport and a shift to marine transport. Cheap overnight buses and low-cost airlines compete with railway services, so that once-popular night train routes have disappeared (Marc, 2016; Rail Delivery Group, 2018). The contrary trends reflect medium to high impact of the policy.

Replicability in India: The core of Japan's model is replicable to other country contexts: use public funds to build the infrastructure, then partially privatise railways, line-by-line, to find a balance in the market between public and private service providers, coupled with regulation for benchmark competition (Financial Times, 2019). As such, the policy framework enables the mobilisation of private funds to operate and innovate railway services, reducing the burden on the public budget. Public investment can be prioritised for infrastructure development, potentially bridging the investment gap in India's rail network. High passenger and freight rail activity are essential to recur infrastructure costs in a timely manner (IEA, 2019).

POLICY AREA 8 - ESTABLISH A LEVEL PLAYING FIELD AND TAX AIR TRAVEL TO LIMIT ITS EXPONENTIAL GROWTH

EXAMPLE OF GOOD PRACTICE: THE UK'S AVIATION TAX

The UK has the highest aviation tax for domestic and international flights, at an average of EUR 40/passenger and flight[5] (CE Delft, 2019). The main element of the tax is the Air Passenger Duty, which is a fixed departure tax depending on the distance, ticket class, number of passengers and aircraft weight; it ranges from EUR 14 to EUR 500 per passenger.

Maturity: UK's Air Passenger Duty has been in place since 2007.

Impact: In the UK, emissions from air travel are forecast to grow further despite the tax. Some attribute this to the fact that the UK does not have a VAT nor fuel taxes for the aviation industry (Aviation Environment Federation, no date), but most importantly the level of taxes is too low. The UK remains the largest air travel market for intra-European air travel demand and London Heathrow is Europe's the busiest airport (Eurostats, 2018). Ideally, taxes for air travel reflect externalities from air travel and compensate for the fact that there is no viable technical solution for emissions-free air travel. We find the UK policies do not achieve the level of emissions reduction needed, despite implementing the most ambitious air travel taxes. Strengthening the taxes and additional complementary policies - including those that facilitate modal shift - would be needed to increase the impact.

Replicability in India: The UK is an island state, and thus reliant on air travel, yet it was able to enforce an air ticket tax. Airline taxes are common and can have different forms. For instance, Hong Kong has implemented an excise duty on jet fuel and Hungary increased its VAT on flights. It is important to ensure a level playing field of different transport modes and account for externalities that come along with air travel. India could remove existing tax exemptions and introduce air travel taxes, as done in the UK or in other countries. The fact that India has only recently started to exempt air travel from taxes indicates that such a tax schemes is feasible there.

We find that the UK policies do not achieve the level of emissions reductions needed (impact). Although the UK has implemented the most ambitious air travel taxes, the rate of taxation is not sufficient to radically reduce air travel demand. However, there are few alternative approaches to decrease air travel demand other than increasing the cost of air travel and improving alternative transport modes in terms of time, cost, comfort. We therefore propose that strengthening the passenger duty tax and additional complementary policies, including those that facilitate modal shift, would be needed to increase the impact in the UK. If India were to also introduce a passenger duty tax, it would make sense to consider the cost thresholds required for

[5] The CE Delft study does not take into account charges as set by airports (for services) or of a revolving nature (funding aviation activities). When taking into account such charges, the cost of flying is considerably higher, depending on the country of departure.

effectiveness. Revenue generated from the tax could be used to support alternative transport modes, such as rail.

5.3 Policy recommendations for a modal shift to railway transport

Mid-term policy **goal**	Intermediate **Steps**
High quality passenger and freight transport	Decrease the currently high taxes for freight rail transport relative to other transport modes
	Use tax revenue from GHG-emitting transport modes to subsidise rail transport
Railway infrastructure could be prioritised over road or air travel infrastructure, where possible	The completion of the Golden Quadrilateral and other major routes, relying on passenger high-speed lines and dedicated freight corridors where demand is highest, could relieve congestion, ensure high-quality railway services and ensure an alternative to road and air transport
	The development of conventional train routes to connect other cities / areas to the main rail routes could further increase the current and future demand for rail transport
	It is important that also after current and future investments in the rail sector, train tickets and freight routes remain affordable, for example through the support of government funds
	Railway investments could continue to be directed towards congestion relief so to ensure reliable and punctual rail travel
A level playing field across transport modes, for example by adjusting road and aviation policies, would reflect the true cost of travel	Removing tax exemptions (such as jet fuel or plane ticket VAT) would create a level playing field with other transport modes
	Reflecting the real cost of travel, for example through a carbon tax, could support more environmentally-friendly transport modes
To avoid lock-in of long-term transport infrastructure, it is helpful to consider the compatibility of infrastructure investments with national climate targets and the long-term goal of the Paris Agreement	Considering climate change in permitting processes, for example in Environmental and Social Impact Assessments, could be a first step in avoiding carbon lock-in
	A national or state level environment authority could review infrastructure investment plans

6 Electrifying all road transport vehicle fleets

India's small vehicle fleet relative to its large population is expected to grow rapidly. In 2018, India was already the world's fifth largest market for passenger vehicles, which in India are typically lighter and less powerful compared to other countries, excluding two and three-wheel vehicles (2W and 3W). Although diesel vehicles have been predominant, their share has decreased in recent years (Yang, 2018a).

In this chapter, we focus primarily on policies that encourage the uptake of electric mobility, especially for LDVs, 2W and 3W (private personal transport). While this can include emission standards, if set correctly, this is a secondary effect of such policies. Modifications of emission standards, such as the EV credit in Europe, have incentivised car makers to offer EVs more prominently in their portfolio. However, such incentivisation only makes sense with an existing functioning and ambitious emissions standard in place and their outcomes are highly uncertain as carmakers still have the option to comply with emission standards without the use of EVs.

Given their rather indirect and uncertain approach to supporting EVs, we instead focus on measures that can more directly support EVs. Eventually all vehicles should be emissions free and thus policies stipulating more stringent emissions standards are an intermediary solution only, but they are an important tool in achieving significant emissions reductions over the short and medium term.

Governments can support the uptake of electric mobility primarily through 1) purchase subsidies and/or tax exemptions (lowered value added tax (VAT) or income tax waivers) reducing financial barriers, 2) behavioural incentives (such as priority access to certain services) and 3) implementing sufficient charging infrastructure to overcome refuelling and convenience barriers, and to reduce range anxiety (Sierzchula, Bakker, Maat and van Wee, 2014; NewClimate Institute, 2018).

India introduced Bharat Stage VI passenger and freight vehicles emission standards in April 2020 (Ministry of Road Transport & Highways, 2016; ICCT, 2020b). While passenger vehicle fuel consumption in India fell 11 per cent between 2006 and (ICCT, 2014), emission standards have since had a limited impact, with an annual CO_2 emissions reduction rate of 0.8 per cent between 2015 and 2018, lower than the rates in other countries (Yang, 2018b). On the other hand, manufacturers introduced Bharat Stage VI-compliant passenger cars and two/three-wheelers ahead of the more stringent standard (ICCT, 2020a).

The Faster Adoption and Manufacturing of Electric Vehicles in India scheme (FAME) Phase II came into effect in April 2019, and provides incentives to purchase electric vehicles such as financial upfront cost subsidies or tax concessions, or by supporting the roll-out of charging infrastructure (Ministry of Heavy Industries & Public Enterprises, 2020).

This is the succeeding legislation to the 2015 FAME India legislation and provides US$1.4 billion in funding in the form of subsidies for EVs (US$1.2 billion) and for the construction of charging infrastructure (US$140 million) (Department of Heavy Industry, 2019). This funding is heavily skewed towards subsidies for two and three-wheelers (52 per cent), reflecting the prominent representation of these vehicles in the composition of India's vehicle fleet.

Subsidies for EVs and hybrids are provided on the condition that they are manufactured in India, providing support to the recently-articulated government goal to make India a global EV manufacturing hub (The Economic Times India, 2019). Significant funding is also provided to subsidise the purchase of electric buses (41 per cent), a positive step in catalysing the transition to zero-emission public transport.

India has announced an aspirational goal of electrifying all public vehicles sales by 2030 and several cities have already implemented pilot programmes for including electric buses in their municipal bus fleets (Karali *et al.*, 2019). For example, the Bangalore Metropolitan Transport Corporation (BMTC), the largest public operator of transit buses in India, aims to transition to 100 per cent zero-emission vehicles by 2030 (Lingzhi Jin, Oscar Delgado, Ravi Gadepalli, 2014).

The Ministry of Power revised electric charging infrastructure guidelines to provide at least one public charging station in a grid of 3 km^2, and charging stations on both sides of major highways at an interval of about 25 km for LDVs and every 100 km (fast charging stations) for HDVs (Ministry of Power, 2019).

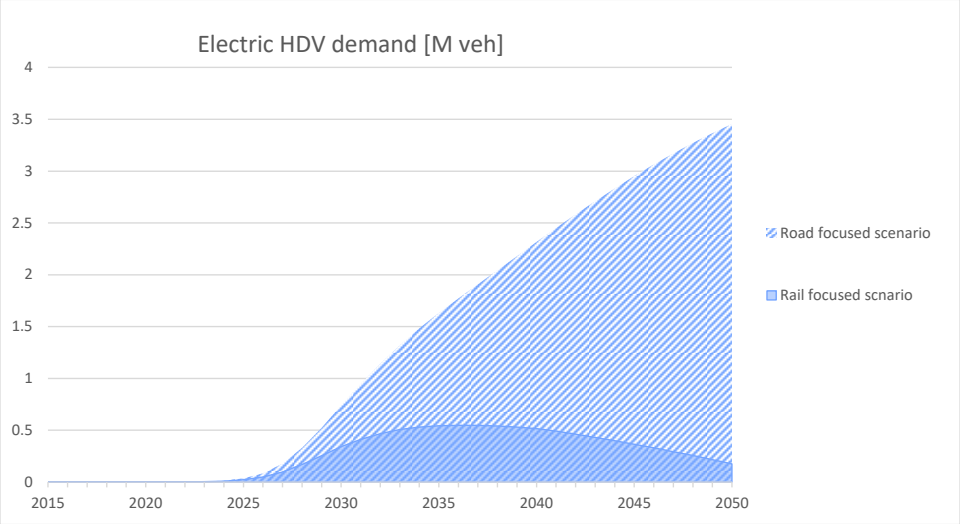

Figure 19. Demand for electric HDVs in the Rail- and Road Focused scenarios.

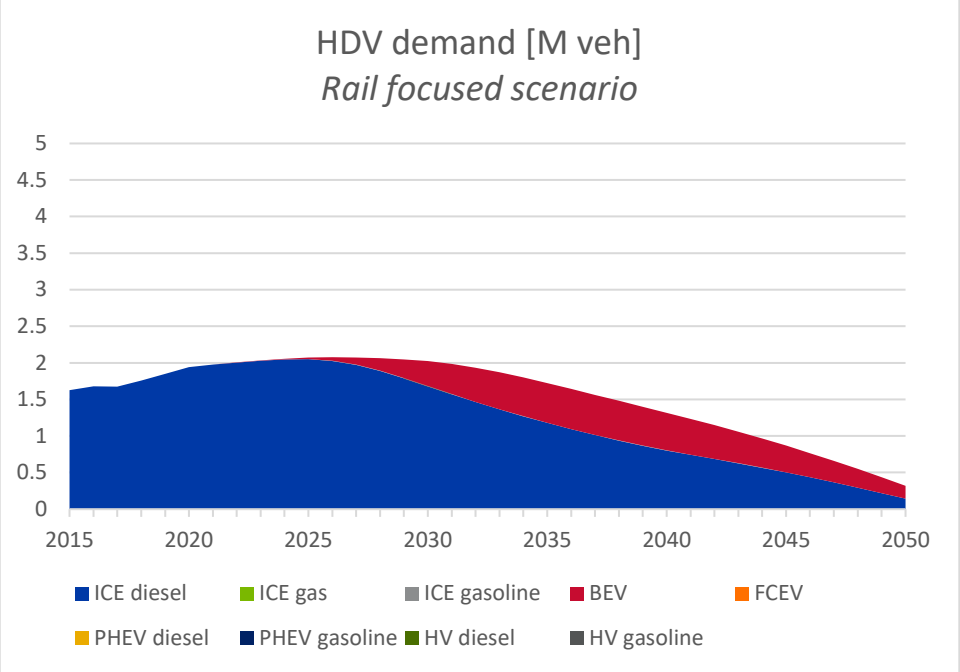

Figure 20. Total HDV demand in the Rail focused scenario.

Box 3 | Decarbonisation of HDVs

Heavy duty vehicles (HDVs) are responsible for an increasing proportion of total carbon emissions from the transport sector (ICCT, 2020b). In the EU, they emit roughly a quarter of all CO_2 emissions from road transport(European Commission, 2020).

Studies in the Indian context have demonstrated significant potential financial gains with short payback times and emissions reductions from upgrading to more efficient HDV engines and tires (Karali *et al.*, 2017, 2019). However, these are short-term measures and are only part of the solution as to how to rapidly decarbonise this transport sub-sector. A combination of fiscal, regulatory, and incentive-based policy is needed to ensure a rapid transition towards zero-emission HDVs.

Both hydrogen fuel cell and battery powered heavy duty trucks are expected to enter the market in 2021 (Ohnsman, 2019; Lambert, 2020), but for these to be viable options to replace current diesel variants requires a sufficiently comprehensive refuelling/charging network. Construction of such infrastructure on the most heavily-used freight corridors could be an area for early government intervention.

Utilities in the US states of California, Oregon and Washington have begun investigating the creation of the West Coast Clean Transit Corridor Initiative, whereby the Interstate-5 corridor would be fitted out with the suitable type and number of charging stations to facilitate widespread adoption of electric HDVs (S&P Global, 2019). Numerous companies in the US have placed pre-orders for the various class 8 electric trucks coming to market next year, indicating the expectation that in the US, charging infrastructure will be suitably developed to facilitate them.

Research has shown that in addition to the importance of government grants for charging infrastructure, marketing efforts and word of mouth between truck operators can influence the diffusion potential of electric trucks dramatically (Güldas, 2019). This provides significant impetus to the establishment of government marketing and resource provision efforts on this front.

A similar range and refuelling/recharging network is not necessary for heavy duty city transit buses or smaller HDV used for urban deliveries that are able to refuel/recharge upon returning to their depot. Accordingly, city buses are now being replaced with electric equivalents across India. However, their higher purchase price relative to ICE variants warrants ongoing financial support beyond the FAME II subsidies expiring in 2022. Such additional support could be strengthened by legislating a 2030 target year for all city bus sales to be electric or hydrogen powered, moving beyond the current broad aspirational 2030 EV sales target. As electric class 8 HDVs come to market over the next 12-24 months, India could also consider the inclusion of subsidies for such non-bus HDVs in the next iteration of its FAME legislation for the post-2022 period.

Given the significant challenges that remain for getting electrified HDVs off the ground, the magnitude of HDV uptake plays a significant role. Policymakers are encouraged to carefully consider how heavily they want to rely on these technologies, given their lack of commercial application and reliance on congested road networks. As the comparison in Figure 19 between the two scenarios shows, HDV demand is 12 times larger in the Road focused scenario than under the Rail focused scenario. Figure 20 and Figure 21 depict the relative reliance on BEVs compared to diesel ICEs in either scenario.

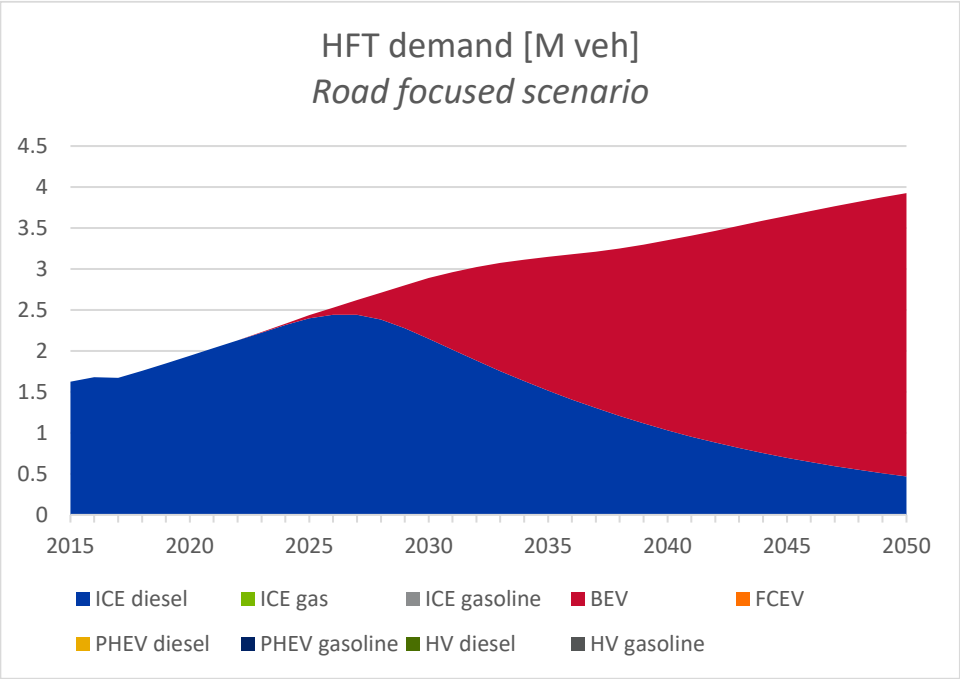

Figure 21. Total HDV demand in the Road focused scenario.

6.1 Paris Agreement-compatible road transport vehicle fleets

Globally, including in India, direct emissions from the transport sector mainly arise from fuel combustion of internal combustion engine (ICE) vehicles fuelled by gasoline or diesel, yet, since 2010, electric vehicles (EVs) have risen as an energy efficient alternative for two and three- wheelers, public transport vehicles, light-duty vehicles (LDVs) and heavy-duty vehicles (HDVs) (SLoCaT, 2018; IEA, 2020).

Although electric vehicles offer a critical step change for the road transport, how a future low carbon fuel mix for the road transport will look is yet to be determined and policies would ideally enable room for various types of zero-emission vehicles, rather than solely electric mobility. Yet, currently, based on energy efficiency considerations, and the level of maturity and steep recent cost reductions of battery technology and EVs, decarbonising road transport can best be achieved through the full electrification of vehicle fleets.

Other transport modes that cannot technically be electrified, such as long-distance maritime and air transport, a fuel switch to renewable-based synthetic fuels will most likely be needed. It is also important to note that electric mobility as well as renewable energy based synthetic fuels require the decarbonisation of the power sector to lead to effective emissions reductions. Further issues that need to be addressed include sustainable production and recycling of vehicles and batteries but are not investigated in this work.

EV sales in India, under a highest plausible ambition scenario, reach a share of 100 per cent in LDV, 2W and 3W by 20406 (Climate Action Tracker, 2020b) (see Figure 22) Under a current policy scenario, the share of EVs would only reach around 20 per cent in 2035, whereas under a highest plausible ambition scenario, they reach

[6] The EV sales benchmarks as developed under the CAT cannot be directly implemented into the CTI tool. This results in a small discrepancy in the year when 100 per cent EVs in new sales can be reached.

85-100 per cent by 2050 (Climate Action Tracker, 2020b). Under the Road focused scenario, the number of LDVs, 2W and 3W will grow significantly more than under the Rail focused scenario, resulting in a larger share of EVs in the total fleet as new vehicles dominate the picture.

Consequently, the mitigation potential from electrifying vehicles fleets, in particular road transport, is much higher in the Road focused scenario than in the Rail focused scenario (see and Figure 24). Despite the difference in absolute new sales between the Rail- and Road focused scenarios, the EV sales benchmark results in a very different pickup rate in both as compared to the current policies scenario. In India, the share of EVs in passenger transport is not dominated by LDVs, as is the case in many developed countries, but instead also includes the electrification of 2W and 3W.

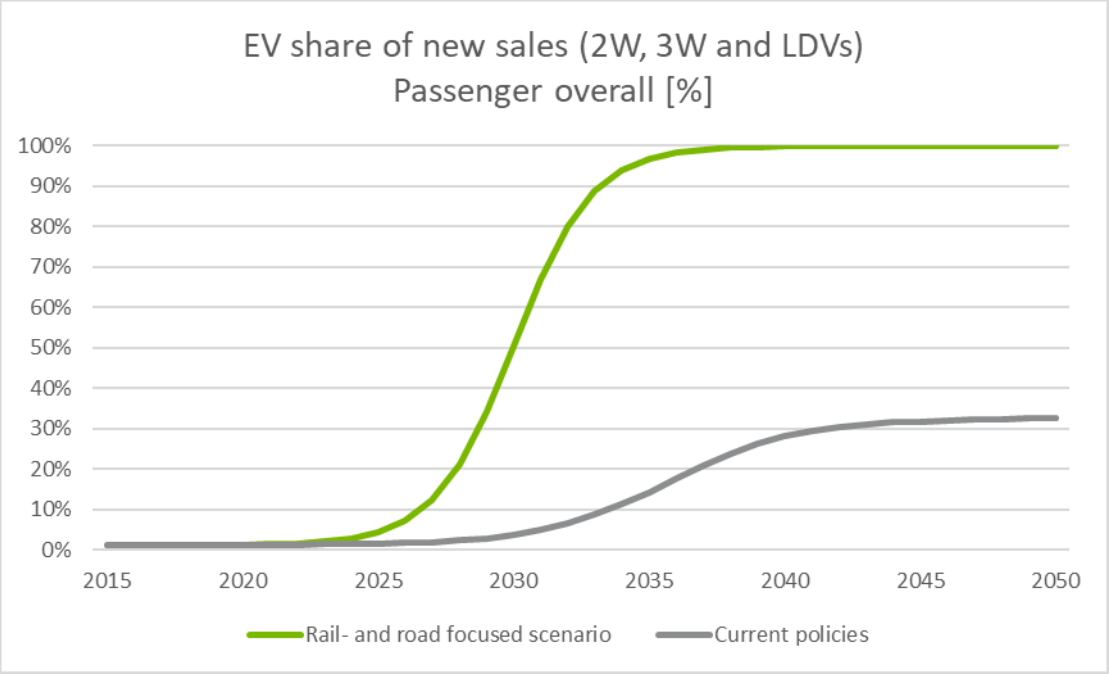

Figure 22. Paris Agreement-compatible trajectory for EV sales share in India vs current policies

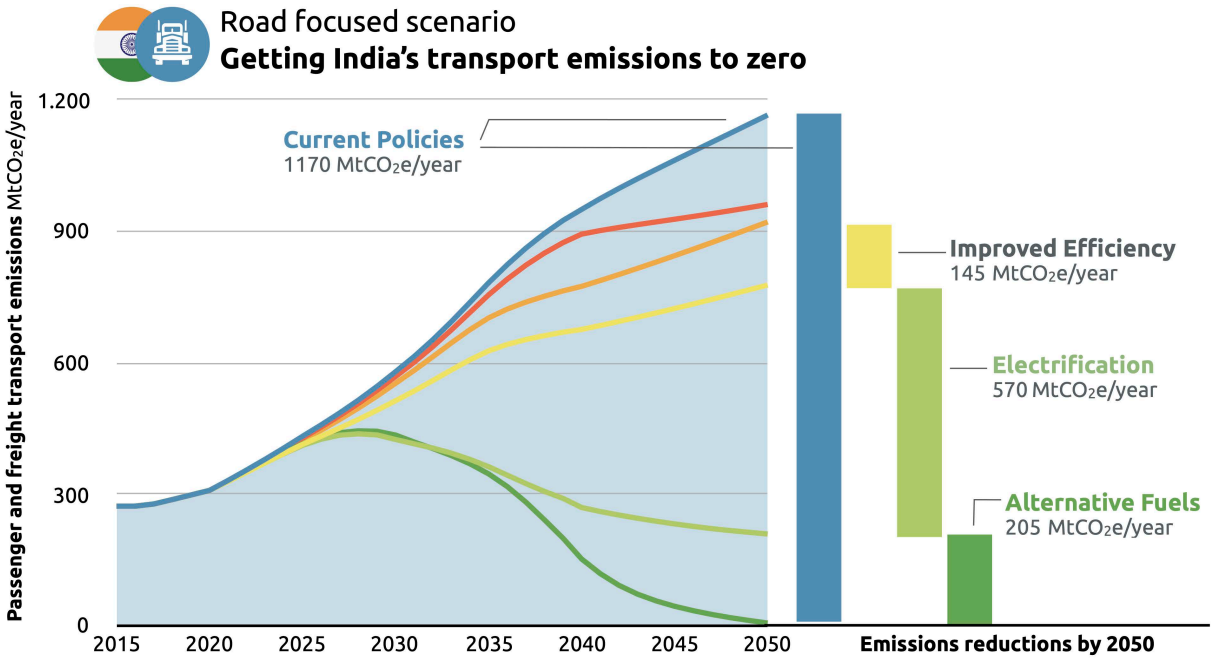

Figure 23. Emissions from passenger and freight transport in the Road focused scenario, showing emission reductions obtained from improved efficiency, electrification of vehicle fleets, and alternative fuels.

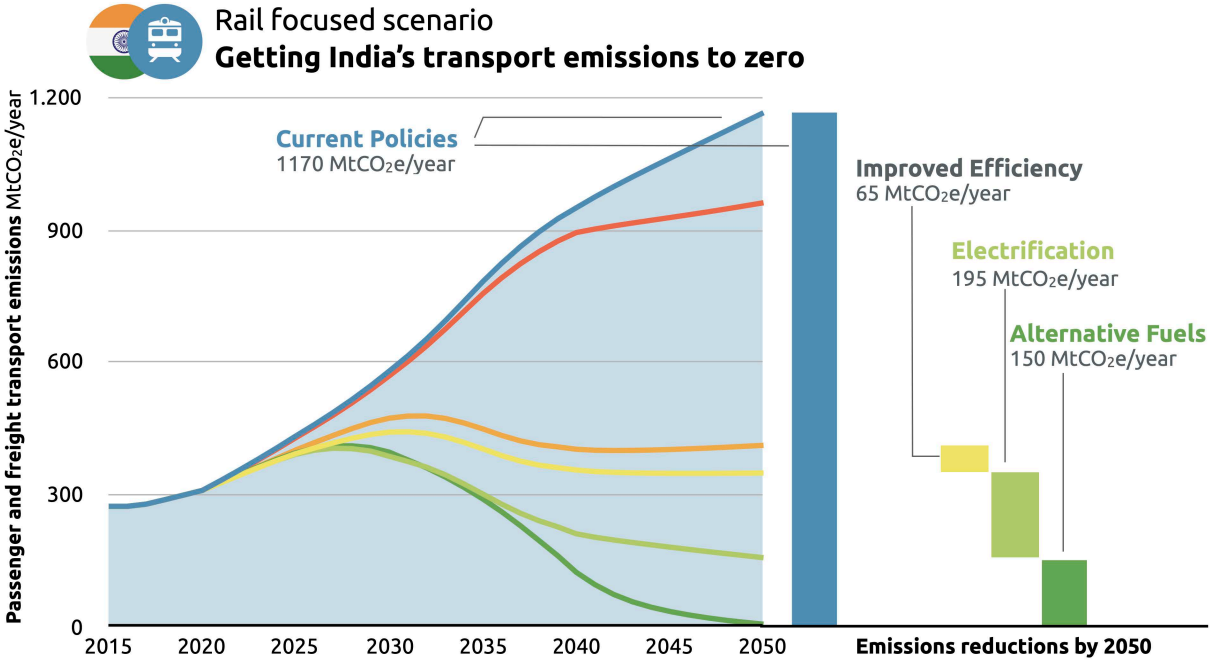

Figure 24. Emissions from passenger and freight in the Rail focused scenario, emission reductions obtained showing emission reductions obtained from improved efficiency, electrification of vehicle fleets, and alternative fuels.

6.2 Good practice policies implemented in other countries to move toward Paris Agreement compatibility

Despite a recent strengthening of India's EV policy landscape, significant additional policies are needed to catalyse a strong EV uptake to reach the highest plausible ambition.

The available literature around factors that impact on EV uptake show that financial incentives, availability of charging infrastructure, and local presence of production facilities are significant and positively correlated to a country's electric vehicle market share (Sierzchula, Bakker, Maat and Van Wee, 2014). With India's currently very low levels of charging infrastructure and only limited funding allocated for expansion, this is a critical policy area in need of further focus.

We investigate China's financial EV support package to lift both the demand and supply side of the EV market, Norway's behavioural incentives for EVs on top of financial incentives such as parking privileges, and California and China's EV infrastructure roll-outs which establish clear targets and allocate public investment.

Policy area	Good practice policy	Governance level
EV uptake financial support package	Chinese EV support package to overcome upfront capital costs	National
Supply-side measures to increase EV uptake	China and California's Credits-Based Quota Programs	National and regional
Behavioural incentives for zero emission vehicles.	Norway's behavioural incentives for EVs	National
Improve EV charging infrastructure	California & Chinese EV infrastructure	National and regional

POLICY AREA 9 - EV UPTAKE FINANCIAL SUPPORT PACKAGE

EXAMPLE OF GOOD PRACTICE POLICY: CHINESE EV SUPPORT PACKAGE

Since 2009, China has provided generous financial incentives to encourage the uptake of both publicly and privately purchased EVs. These have come in the form of subsidies for both consumers, as well as manufacturers, consequently encouraging the domestic EV manufacturing industry.

Central government consumer subsidies over the majority of the scheme have offered between US$3,000 and US$6,600 per vehicle. These were reduced by half in 2019, as EV sales continued to soar, and are scheduled to be reduced further in 2020, 2021 and 2022 as the scheme approaches its end date (Sun and Go, 2020). These subsidies have often been met with additional subsidies from local governments, further increasing the affordability of EVs (Hao *et al.*, 2014).

To further increase the affordability of EVs, the Chinese government has exempted them from the five per cent consumption tax (China Briefing, 2016), and the ten per cent vehicle sales taxes (Bloomberg Tax, 2020), while registration fees have been reduced by 50 per cent (Erdenebileg, 2016).

Maturity: China has subsidised EV and hybrid vehicles since 2009, with numerous iterations of its subsidy programme over the subsequent years altering the design and relative generosity of the scheme. The scheme is nearing the end of its intended duration, in 2022. Other countries have had financial incentives in place since the 1990's (Norway) or early 2000's (Japan), while numerous countries throughout Europe began to implement them around the same time as China, at the turn of the decade.

Impact: In the early years of the Chinese subsidy schemes, the then high cost of battery technology and the infancy of the EV manufacturing sector meant that total volumes of vehicles sold remained low. However, the investment certainty provided by these subsidies helped foster a dramatic increase in the number and variety of domestic manufacturers, with over 400 manufacturers of EVs registered in China as of 2020 (Vincent, 2020).

As battery technology became cheaper and the overall cost of EVs fell, the number of EVs sold in China began to skyrocket. Sales of BEVs increased more than twenty times between 2014 and 2018 to 1.8 million (International Energy Agency (IEA)., 2019).

Replicability in India: The scale of China's EV support scheme is unrivalled anywhere in the world, with expenditure on subsidies in 2017 from federal and local governments combined totalling US$7.7 billion, and total expenditure between 2009 and 2017 of US$36.6 billion (Kennedy and Qiu, 2018; Perkowski, 2018).

This level of public expenditure would prove to be unfeasible for most countries, however given its success in stimulating both demand for EVs in China and the domestic manufacturing industry, it is valuable as a benchmark for comparison purposes. If the batteries used in EVs are also produced locally, the manufacture of EVs produces a greater number of jobs than those involved in the manufacture of ICE vehicles (IEA/IMF, 2020).

Given India's nascent EV manufacturing industry and China's now booming EV manufacturing sector, this co-benefit of stimulating job creation could be considered when developing additional EV uptake incentives. The supplemental jobs associated with the construction of EV charging infrastructure further emphasises the job-creation potential of stimulating EV demand.

To roughly downscale the size of financial support India could provide based on the Chinese example, a scaling by GDP per capita can be applied. In 2018, China's GDP per capita was roughly five times that of India's (World Bank, 2020). Adjusting for this differentiation, a similar scale of ambition would equate to annual expenditure of roughly US$900 million per year. That is almost double the planned annual expenditure under the three-year FAME II program adopted in 2019, which also includes expenditure on charging infrastructure. Given the larger population size but also smaller share of cars on the road per capita, it is unclear how this would affect the EV share.

Despite not reaching the scale of China's EV incentives, numerous other countries either currently have - or have previously had - considerable EV support schemes in place. For example, Norway with a similar scale of purchase subsidies, reaching up to EUR 10,000 per vehicle, and VAT tax exemption for EV purchases, managed to achieve a 46 per cent EV share of new LDVs in 2018, the

highest in the world and more than double the next highest (International Energy Agency (IEA)., 2019).

In 2019, Germany increased the subsidy for EVs under EUR40,000 to EUR6,000 (Deutsche Welle, 2019), while the US offers a consumer tax break of US$7,500 for the first 200,000 EVs produced by each automaker (Bellon, 2019), supplemented by various state-based EV subsidies like California's $2,500 one-off payment. Since 2018, Canada offers up to US$5,000 for new EVs, while Romania, an example of a less developed country with substantial EV subsidies, currently offers EUR9,500 for new EV purchases.

The scale of India's EV support scheme has increased substantially with the adoption of the FAME II program, but to sufficiently stimulate uptake, there is scope for additional resources to be allocated.

POLICY AREA 10 – SUPPLY-SIDE MEASURES TO INCREASE EV UPTAKE

EXAMPLE OF GOOD PRACTICE POLICY: CHINA AND CALIFORNIA'S CREDITS-BASED QUOTA PROGRAMMES

In order to build on the demand-stimulating fiscal incentives in place in both jurisdictions, China and California have both implemented a regulatory regime that requires automakers to produce a specified level of low and zero-emission vehicles. More specifically, both regimes require automakers to maintain a certain level of "credits" that are generated by the sale of such vehicles.

Maturity: The stage of implementation of the Californian and Chinese schemes offer two distinct paths for such a policy.

California's Zero Emission Vehicle (ZEV) program was introduced in 1990, well before EV technology was mature, and stipulated targets well in advance, with gradual increases in the required number of sales (two per cent in 1998, five per cent in 2001, ten per cent in 2003, including PHEVs). These targets were deemed in the end to be too ambitious and were subsequently rolled back, but through continued evolution of the program, California now has a target of 1.5 million ZEVs on the road and ten per cent of all new vehicle sales by 2025, climbing to five million by 2030 (Office of Governor Edmund G. Brown Jr., 2018). This is in conjunction with binding legislation requiring automakers to maintain credits equal to roughly 15 per cent of ZEV sales (classified as battery electric vehicles, fuel cell vehicle and plug-in hybrid electric vehicles) by 2025 (California Environmental Protection Agency Air Resources Board, 2012).

This early and stringent regulatory approach contrasts with China's New Energy Vehicle (NEV) mandate, which took effect in 2018 when EV technology was already widespread in China and considerable domestic demand had already been established. In the EU an EV credit has been applied under the vehicle emission standards for the sale of EVs since 2012 (European Commission, 2020).

Impact: The key design features of both of these programmes have two primary effects, the first being the provision of investment certainty to automakers and a clear stipulation of the required composition of supply in target years. The second is a financial incentive for automakers to overproduce the stipulated targets to benefit from the revenue stream created by selling excess credits to automakers that do not meet these targets and must purchase such excess credits to remain in compliance with the regulation.

In the Californian example, this has been a crucial additional revenue stream for Tesla, helping the company, founded in only 2003, to thrive and become the US's most valuable automaker of all time in 2020 (Langley, 2020). Between 2017 and 2019, revenue earned by Tesla from regulatory credits sold to other automakers amounted to roughly US$1.4 billion (Tesla Inc., 2019). Indeed, this provides an incentive for all automakers to introduce electric models to capture this additional revenue stream.

In the Chinese context, the saleability of the carbon credits required by the NEV scheme has provided a competitive advantage for domestic automakers. While a large number of Chinese automakers sell sufficient numbers of EVs to satisfy the required number of credits, most foreign automakers do not, and therefore must purchase surplus credits from Chinese companies, in effect, subsidising the Chinese automotive industry(Finamore, 2018).

With EV subsidies set to expire at the end of 2022, China is now increasingly relying on carbon credit quotas to ensure the transition away from ICE vehicles continues at pace. The quota of credits required of automakers was increased from 10 to 12 per cent in 2020, with an expectation of further increases over time as subsidies are phased out (Jian, 2019).

Replicability in India: Numerous Indian automakers are already producing EV models, and the cost of battery technology has fallen rapidly in recent years. These two factors alone create favourable conditions for the implementation of an EV credit scheme in the same vein as the Chinese and Californian models.

In order for such a scheme to achieve a dynamic similar to the Chinese programme, however, where foreign automakers effectively subsidise the domestic automotive industry, the scheme would need to take effect prior to the coming shift towards EV production from many large automakers. In any case, implementing a credit-based scheme that requires domestic automakers to pivot to EV production is a way to ensure their competitiveness against the rising number of foreign EV models entering the market (Coren, 2019). In effect, this is a way to "futureproof" the Indian automotive industry.

There is evidence of China achieving considerable synergies thanks to the current coexistence of subsidies and its carbon credit scheme, with both policies complementing each other and favouring models with ranges over 300km (Chen *et al.*, 2018). This may have implications for the Indian policy context, as current subsidies under FAME II are heavily skewed towards two and three- wheelers at the expense of LDVs.

If India intends to foster domestic manufacturing of LDVs, subsidies and quotas would ideally be designed accordingly. Given the large demand for two and three-wheel vehicles across Asia, a significant export opportunity exists for the Indian automaker industry and therefore any

increase in subsidies for LDVs would ideally not come at the expense of those for two and three-wheelers

POLICY AREA 11 - BEHAVIOURAL INCENTIVES FOR ZERO EMISSION VEHICLES

EXAMPLE OF GOOD PRACTICE POLICY: NORWAY'S BEHAVIOURAL INCENTIVES FOR EVS

Norway is the only country to have a comprehensive set of national policies addressing behavioural incentives for zero emission vehicles (De Villafranca Casas *et al.*, 2018).

Maturity: Norway established free parking and toll road fee exemptions as national BEV incentives from 1997 and 1999 by national laws and, in 2003, opened bus lanes for BEV owners in Oslo and surrounding municipalities showcasing high maturity of such policies (Steinbacher, Goes and Jörling, 2018). Something similar, but different in approach is the Californian example, where hybrid and electric vehicles have had access to carpool lanes since 2005 (Sheldon and DeShazo, 2017).

Impact: Access to free public EV parking, exemption on city driving restrictions or the privilege to drive on bus lanes, has rather low impact (De Villafranca Casas *et al.*, 2018). Yet, due to increasing toll roads and congestion zones around cities and main roads, exemptions and privileges have shown to have a high impact (Steinbacher, Goes and Jörling, 2018).

Replicability in India: Behavioural incentives are almost budget-neutral and can quite easily be replicated to other regions, but they need to be tailored to national circumstances. Municipalities, states and the government can develop such schemes. For example in India, the city of Guangzhou exempts EVs from restrictions related to heavy pollution days and incentivises the use of EV time-sharing vehicles while the city of Zhengzhou exempts EVs from restrictions on accessing specific roads (Feiteng, 2018). In India, Tamil Nadu has announced ten per cent of parking spaces in some buildings such as hotels, shopping malls, cinemas and apartments (Vaitheesvaran, 2019).

POLICY AREA 12 - IMPROVE EV CHARGING INFRASTRUCTURE

EXAMPLE OF GOOD PRACTICE POLICY: CALIFORNIA & CHINESE EV INFRASTRUCTURE

To reach its goal of five million zero emission vehicles (ZEVs) on the roads by 2030, California aims to establish 250,000 zero-emission vehicle charging stations (including 10,000 electric fast chargers and 200 hydrogen fuelling facilities) by 2025, which will lead to more than 6,000 stations per 1 million inhabitants.

California finances pilot programmes under the new Zero-Emission Vehicle Investment Initiative (2017-2025) to develop the state's charging infrastructure with public investments in the order of USD 2.5 billion (U.S. Department of Energy, no date; State of California, 2019).

A larger, more sweeping program has been drafted this year by the Los Angeles-based public-private Transportation Electrification Partnership, which includes $85 billion for zero-emission vehicle infrastructure, of which $10 billion would go towards light duty charging infrastructure, with $15 billion towards medium- and heavy-duty vehicle charging infrastructure (Shieber, 2020). The plan identifies Opportunity Zones (Government of California, 2020), the New Markets Tax Credit (US Internal Revenue Service, 2020), and Community Development Finance Institutions (Centre on Household Assets and Savings Management, 2011), as tools that could boost the government's commitment with private capital.

While the California example shows a strong medium-term target of 6,000 stations per million inhabitants, it is also worth considering that China has a 2020 target of 4.8 million public and private charging points (National Development and Reform Commission, 2015). As of 2019, however, only 1.2 million had been built, though this still represents the world's largest EV power network by far (Xinhua, 2020). An additional US$1.4 billion in funding was announced in 2020 to increase this by 50 per cent by the end of 2020, suggesting, however, that the 2020 target will be missed by a substantial margin.

Maturity: Currently, only 22,000 public charging outlets are available throughout the State, and many measures from the running pilot programmes are still in the proposal phase, showing low to medium maturity (U.S. Department of Energy, no date). In China, customers face relatively high prices and sometimes long queuing at charging stations, and many still queue at night when prices are low (Bloomberg, 2020)

Impact: Charging infrastructure is the supporting infrastructure needed to reach EV fleet targets, but the relationship between availability of charging stations and effect on EV uptake is not always straightforward. This is demonstrated in the case of Norway, where inhabitants prefer to charge at home and at the workplace rather than public charging stations. However, the EV stocks in Norway and California consist primarily of larger, luxury models with relatively high ranges. Where there is a higher concentration of smaller EVs with lower ranges, as in India and China, reliance on public charging infrastructure is likely to be higher.

Another crucial factor is the high urban density in India and China, whereby many residences do not have access to their own private charging point, further increasing the need for public charging infrastructure.

Indeed it has been found that high numbers of charging stations positively correlates with EV numbers within a country (Sierzchula, Bakker, Maat and Van Wee, 2014), indicating the potential for increasing levels of charging infrastructure to have a positive effect. In California, there is considerable support for residential, commercial and utility-scale infrastructure.

One study finds the main barrier to private sector electric charging station deployment is not the investment barrier but rather the penetration of EVs in the market (demand), and that charging prices are the main driving force behind electric charging station deployment (Fang *et al.*, 2020). This highlights the need for creative methods to stimulate private sector investment and public-private partnerships in addition to substantial public funding while EV demand remains relatively low.

This kind of availability dilemma, whereby low EV numbers dampens private charging infrastructure construction, which acts to suppress EV uptake, suggests that public investment in charging infrastructure could break this impasse and spur EV uptake and consequently private charging infrastructure investment. The example of China, where extensive government investment into charging infrastructure has coincided with a rapid uptake in EVs, suggests that prolific public charging infrastructure may play a critical role in accelerating EV uptake

Replicability in India: Although the rolling-out of extensive charging infrastructure network is capital intensive, co-benefits such as human health and job creation substantially outweigh the costs.

Given the capital intensity of such measures, investigating the potential for public-private partnerships (PPP) is crucial to ensuring the fiscal burden to the federal and regional governments is minimised. One study that investigated a regional PPP charging project in China that was deemed 'good practice', identified key lessons and recommendations including: planning a coordinated and dynamic development, constructing with unified standards, identifying project risks comprehensively and sharing them properly, building a smart service platform to provide diversified services, and ensuring the selection of the right private partners (Wang and Ke, 2018).

6.3 Policy recommendations to electrify the road transport sector

India has a set of policies to improve fuel efficiency and support EV uptake. We recommend complementing existing legislation with the following policies:

Mid-term policy **goal**	Intermediate Steps
Demand-side EV uptake measures to incentivise the electrification of vehicle fleets	Potential financial support measures for EVs • Increased subsidies for the purchase of EVs • The inclusion of subsidies for non-bus HDVs in the next iteration of FAME legislation • Exemption from or reduction in registration fees • Tax benefits when purchasing EVs • Tax benefits during ownership of an EV • Tax benefits for electric company cars
	Behavioural incentives could include • Free parking for EVs • Access to bus/taxi lanes for EVs • Exemption from restricted driving days rules where applicable • Exemption for EVs from waiting times for vehicle registration where applicable
	Legislating a 2030 target for all public vehicle purchases to be EVs, in line with the broad aspirational 2030 target of 100 per cent EV sales could enable a role model and further trigger EV demand
Widely available public charging infrastructure	Funding for charging infrastructure under the FAME II program could be significantly increased, while the programme's duration could also be extended beyond 2022
Supply-side EV uptake measures to incentivise domestic EV supply	The introduction of EV sales targets, EV quotas or a carbon credit scheme for battery electric vehicles for automakers could boost the supply of (domestic) EVs
Prohibition of ICE vehicle sales and registrations	Prohibiting ICE vehicle sales no later than 2040, and registration of ICE vehicles by no later than 2050 could be considered to send a strong message and ensure full electrification of the road transport by 2050
Strengthened fuel efficiency standards	Strengthening fuel efficiency standards could be done in different ways • Adjusting EV super-credit multiplier and phasing the multipliers out by 2022–23, before the next phase of standards come into effect • Incorporating Medium and Light HDVs with GVW between 3.5 tonnes and 12 tonnes in fuel efficiency standards • Adding longer-term targets to fuel efficiency standards to eventually reach zero emissions by 2050 • Ensuring quality testing and disclosure of test results

7 Support is key for India to scale up interventions

The scale of the task facing India to rapidly decarbonise its transport sector is immense. High current and projected levels of population and GDP growth means that simply maintaining current transport-related emissions levels will be difficult. However, as described in the chapters above, there are various policy interventions that could steer India's transition to a low carbon economy. To be fully realised, many of these will require substantial financial investments, institutional development, knowledge sharing, technology transfer and capacity building.

Many decarbonisation interventions in the transport sector are accompanied with co-benefits, particularly health co-benefits related to reductions in air pollution. These co-benefits provide additional incentives for India to invest in these measures and reduce the overall economy-wide costs. However, reshaping the transport sector, particularly through major infrastructure projects, is likely to require high up-front investment costs that make such interventions too costly for India acting alone.

In accordance with the Paris Agreement's Article 4.5, developed countries should provide assistance in order to allow developing countries like India to raise its ambition on overall mitigation action. The Paris Agreement follows the effort-sharing principles that those countries with higher responsibility for past emissions and higher current capacities should not only reduce their domestic emissions as far as possible but also support other countries in reducing their emissions.

Mechanisms that could be used to deliver on this include the Green Climate Fund, established under the UNFCCC, to support efforts of developing country climate action. Other sources of finance with a track record of funding transport projects include development banks like the Asian Development Bank, the Asian Infrastructure Investment Bank, and the World Bank. The Asian Development Bank has "*addressing climate change in the transport"* sector as one of its key priorities. This is promoted through its Sustainable Transport Initiative, which promotes environment-friendly modes of transport such as rail – both within private and public sectors. The good thing is that the bank uses the same avoid-shift-improve framework we have used in this analysis in guiding its work.

A key step in establishing and developing a flow of funds from wealthier nations is the identification of where investments are needed. National Long-Term Strategies provide a vehicle to establish visions for a low-carbon society and the identification of near-term interventions that are required to shift sectors onto pathways toward those visions. Immediate investment into these pathways will shift sectoral development toward low carbon development pathways, realign investment priorities, and facilitate knowledge building, thereby lowering long-term cumulative costs. This report has also come up with a summary of key interventions required to transform the transport sector, thereby contributing to a low carbon economy and society.

Not all support and resources needed are in the form of financial investments. Various initiatives are in place that support collective learning and institution building across different sectors. One approach that has proven successful at the country level is the establishment of an international leadership initiative for the purpose of generating and disseminating sector transition roadmaps. We propose that such an initiative that leverages existing knowledge for both public and private sectors could prove effective in the transport sector. Other existing platforms, such as C40, could be further leveraged as a knowledge sharing platform.

Green Climate Fund

The Green Climate Fund (GCF), set up by the UNFCCC in 2010, is the world's largest dedicated fund helping developing countries reduce their greenhouse gas emissions and enhance their ability to respond to climate change (Green Climate Fund, 2020a). Transport is one of the eight mitigation and adaptation 'Result Areas' that

the GCF invests in, with a stated aim to "reduce emissions through increased access to low-emission transport, through supporting low- and zero-emission public and private transport systems" (Green Climate Fund, 2020b).

The Paris Agreement stipulates the need for $100 billion a year in climate finance from developed to developing countries, but so far, total confirmed commitments fall far short of this benchmark. As of 12 May 2020, the total pledged funds for the GCF's first replenishment period of 2020-2023 was less than US$10 billion; translating into less than US$2.5 billion per year, and pledged by only 27 developed countries (Green Climate Fund, 2020c). Wealthy countries must dramatically increase their contributions to the GCF to ensure sufficiently impactful climate action is achieved in developing countries, including India.

According to the GCF, low carbon transport programmes account for a growing share of mitigation finance provided, and a significant share of this is already in South Asia. In 2018, $49 million in funding was approved for the construction of a BRT in Karachi, Pakistan, expected to avoid 2.6 million tonnes of CO_2. Elsewhere in the region, in 2019 the GCF approved funding to assist Bhutan in submitting a proposal for a Green Transport Plan for the city of Thimphu.

India, as a developing country, qualifies for similar support. However, India will need to ensure that its proposed interventions will result in transformative changes in the sector, and at the same time achieve sustainable growth which would result in co-benefits such as the creation of jobs and reduction in air pollution.

Establishment of International Transport Leadership Initiative

Many cities around the world have successfully created comprehensive and world-class public transport networks, cycling and walking infrastructure, or have implemented forward-thinking urban planning to minimise GHG emissions from transport. Others have begun implementing 21st century solutions to transition existing polluting forms of transport to low or zero-carbon alternatives.

The countries where these successful initiatives have been implemented, together with any companies that were involved in their delivery, possess valuable experience and insights that could be leveraged to replicate their successes in India, as well as other countries. Such a leveraging of public and private sector expertise to catalyse the necessary transition of a particular sector is not a novel idea. Numerous examples of such collaborative initiatives already exist for catalysing power sector and industry transition, including the UN's Sustainable Energy for All, the IEA's Clean Energy Transitions Programme, the Energy Transitions Commission, and the Leadership Group for Industry Transition.

The aims and compositions of such groups can vary widely, with some consisting primarily of government officials, others comprised primarily of companies, while others attempt to include both government and corporate representatives. For example, the Getting to Zero Coalition is an alliance of primarily commercial entities tasking themselves with accelerating the decarbonisation of maritime shipping, while the Leadership Group for Industry Transition consists of both companies and countries.

The Leadership Group for Industry Transition is worth further consideration, as it offers potentially useful parallels for any future transport leadership initiative. India played a key role in the establishment of the group, being one of the group's co-founders along with Sweden, with a number of the inaugural corporate members also hailing from India. Accordingly, the group has a definitively Indian focus, with the first Industry Transition Roadmap that will be completed by the group to be tailored to a region in India.

These Industry Transition Roadmaps aim to provide region-specific information to assist heavy industry like iron, steel and cement production to reduce GHG emissions, and ultimately to decarbonise. An equivalent regional or city-based transport roadmap for an Indian city or region has the potential to be highly beneficial in assisting the decarbonisation of the overall Indian transport sector. The execution of such a roadmap would inevitably lead to

a scaling up of local expertise and domestic commercial capabilities that would enable a scaling up of similar initiatives in other Indian cities and/or regions.

If such roadmaps are created with the use of expertise and resources from developed countries, this is a further avenue through which developed countries can help fast-track climate mitigation efforts in the Indian transport sector. This could be through the establishment of a new international body in the same vein as the Leadership Group for Industry Transition, or through an existing body such as C40.

8 Summary and recommendations

Global transport emissions have continued to steadily increase, with transport emissions accounting for 24 percent of direct CO_2 emissions from fuel combustions (IEA, 2020). The Indian transport sector is no different, showing a growing trend, and accounting for 13.5 per cent of India's energy-related CO_2 emissions, with road transport accounting for 90 per cent of the sector's total final energy consumption. This remains a challenge for the Indian government in efforts to achieve its NDC and contributing to the achievement of the Paris Agreement long-term temperature goal.

This is the time for India to show leadership, by transforming its transport sector, and at the same time achieving sustainable development benefits such as reducing air pollution, climate change impacts, fossil fuel import dependency, contributing to economic development and the creation of jobs (Climate Analytics, 2019). These benefits would also be supportive of many social and economic challenges faced by India – acknowledging that it will not be possible to achieve these ambitious plans without international support.

In accordance with the Paris Agreement's Article 4.5, developed countries should provide assistance in order to allow developing countries like India to raise its ambition on overall mitigation action. Mechanisms that could be used to deliver on this include the Green Climate Fund and development banks, such as the Asian Development Bank, the Asian Infrastructure Investment Bank, and the World Bank.

A key step in establishing and developing a flow of funds from wealthier nations is the identification of where investments are needed. In this analysis we have outlined options that would support India's transport sector to become consistent with the Paris Agreement. Our analytical approach has combined modelling with policy analysis, focused around good practice policies that could either be replicated in India or at least provide important lessons that India could draw from.

Our 'Highest Plausible ambition scenarios' illustrate two possible routes for India to decarbonise its transport sector in line with the Paris Agreement. The scenarios highlight strong mitigation opportunities from four priority mitigation areas that are consistent with further developing a reliable, effective transport network in India, see Figure 25 and Figure 26.

We further identify a series of good practice policies that can be used as inspiration to develop the transport sector along these scenarios. Some of these policies can be copied to the Indian context fairly directly, whereas others serve more to highlight good principles that will need more adaption to the Indian context. Indeed, very few of the policies identified score equally well on all three aspects assessed (maturity, impact and replicability), indicating that further improvements and developments are possible or necessary.

We find that sustainable urban development has strong potential to avoid urban sprawl. Transport demand could increase more than threefold until 2050 compared to 2011-12 levels, 22 per cent lower compared to a current policy scenario, avoiding 1800 Mt CO_2e between 2020 and 2050. A national framework for transport-oriented development and sustainable urban mobility plans is needed, which would leave states and municipalities the freedom to enable their own vision anchored in the local context.

Table 3 Overview of policies to mitigate CO2 emissions in the Indian transport sector.

Priority action area and their respective mitigation potential (MtCO2 2020-2050)	Policy area	Global good practice example	Scalability		
			Maturity	Impact	Replicability in India
Sustainable and urban planning to counter-act urban sprawl 205 Mt CO_2e /year in 2050	Develop sustainable metropolitan areas	Copenhagen's Urban Development Plan			
Strengthening high-quality and safe non-motorised and public transport infrastructure and services  155 Mt CO_2e /year in 2050 20 Mt CO_2e /year in 2050	Shift away from passenger cars and freight trucks in cities	London's congestion and ultra-low emission zones			
	Offer integrated transport services and encourage the use of public and shared services	The Finnish act on transport services			
	Improving walking infrastructure	Singapore' walking and cycling plan			
	Improving cycling infrastructure	Bicycle infrastructure in the Netherlands			
	Funding and developing affordable public transport	Funding affordable public transport in the Paris metropolitan region			
High quality railway infrastructure and services  395 Mt CO_2e /year in 2050 20 Mt CO_2e /year in 2050	Build sustainable long-term infrastructure in line with climate targets and the Paris agreement	France's decision to reconsider Marseille's airport expansion			
	Develop and support railway infrastructure and services	Japan's railway system			
	Establish a level-playing field and tax air travel to limit an exponential growth of air travel	The UK's aviation tax			
Electrification of all road transport vehicle fleets  195 Mt CO_2e /year in 2050 570 Mt CO_2e /year in 2050	EV uptake financial support package	The Chinese EV support package			
	Supply-side measures to increase EV uptake	China and California's credits-based quota programs			
	Behavioural incentives for zero emission vehicles	Norway's behavioural incentives for EVs			
	Improve EV charging infrastructure	California & Chinese EV infrastructure			

Continued rapid increases in road passenger and freight transport would lead India onto a pathway to a congested road network and high energy demand, putting pressure on the deployment of renewable energy. It is crucial to shift transport demand to the most environmentally friendly transport modes. Such a shift has the highest emission mitigation potential, decreasing the annual emissions down to 550 CO_2eq /year in 2050.

In an urban context, non-motorised and public transport infrastructure are key to achieving this mitigation potential, accounting for 27% of the modal shift reduction potential in 2050. Large cities with high population density play a central role, and have partly already taken the lead, ahead of national policies. They provide viable alternatives to private passenger vehicles, and some cities already have private passenger vehicle modal shares as low as ten per cent.

A focus on public transport, walking, and cycling brings multiple co-benefits, including energy savings, lower congestion on roads, and significantly reduced air pollution levels. For those alternatives to private passenger vehicles, India needs an intermodal and affordable transport offer, namely enabling seamless transport chains such as the switch from a metro line to a shared bike.

In a non-urban context, supporting a high modal share for passenger and freight railway has the potential to reduce the annual emissions intensity by 42% in 2050, relative to a current policies scenario with reduced demand. India is in a strong position to achieve such high modal shares due to past public sector investments and national policies supporting rail transport. Competing policies could be re-oriented to rail transport and counter-act the rapid increase of road and air transport demand and their related emissions. Immediate investment in long-term infrastructure, such as dedicated freight corridors and high-speed rail lines would enable safe, reliable, punctual and affordable railway services in the future.

Finally, where road transport is used, it needs to be fully electrified. To that end, all new vehicle sales need to be electric by 2035, so to reach a total mitigation potential of 570 Mt CO_2eq in 2050. To achieve this, a comprehensive policy package with purchase subsides, manufacturing quotas, the support of electric charging infrastructure and behavioural incentives would need to be carefully elaborated. The FAME II scheme provides a good basis for doing so.

A crucial aspect for India will be to effectively implement ambitious policies and schemes at all levels of government, drawing lessons from existing transport policies from around the world.

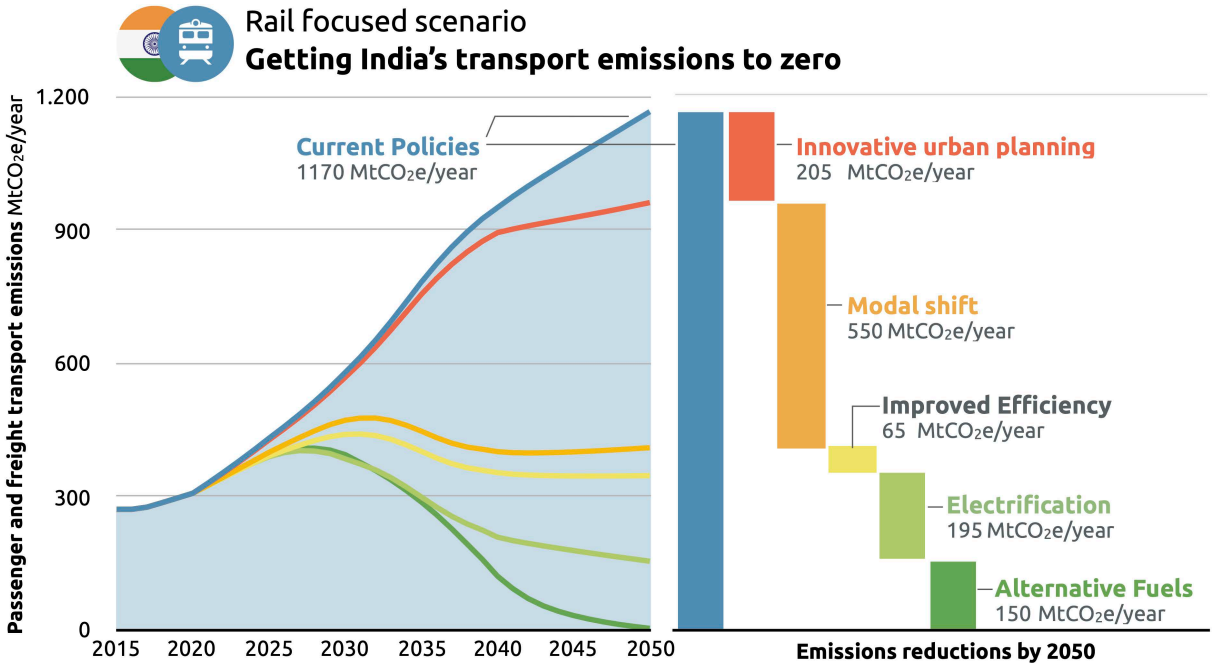

Figure 25. Annual emissions from the transport sector until 2050 – Rail focused scenario ($MtCO_2e$).

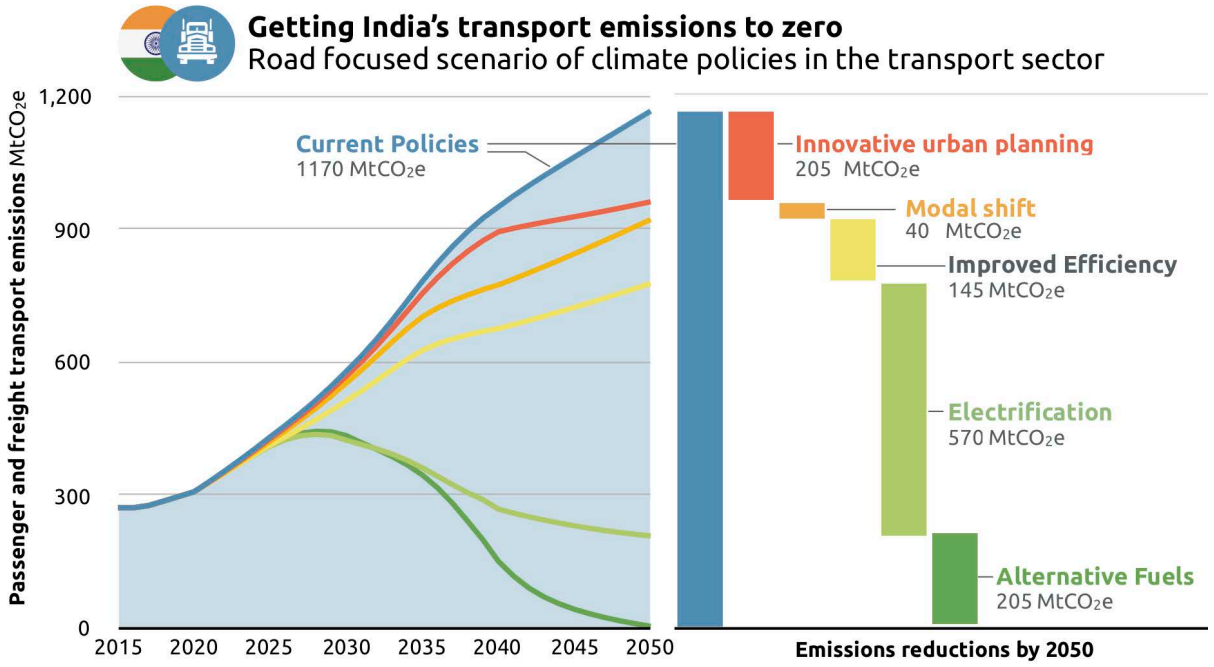

Figure 26. Annual emissions from the transport sector until 2050 – Road focused scenario ($MtCO_2e$).

The graphs above represent the emission reduction wedges compared to a Current Policies scenario, based on the avoid-shift-improve framework for the two scenarios used in this report. Each wedge represents the potential emission reduction in each priority action area as defined in the report. The wedges build on each other: emissions are avoided through innovative urban planning, reduced by shifting transport demand to more efficient transport modes such as public transport, with the resulting vehicle fleet being electrified as far as technology allows, and lastly, modes that cannot be/are difficult to electrify (such as aviation or shipping) are shifted to run on bio- and synthetic fuels. The order does not represent a prioritisation of action, but simply follows the model logic as described here.

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NewClimate Institute is a non-profit institute established in 2014. NewClimate Institute supports research and implementation of action against climate change around the globe, covering the topics international climate negotiations, tracking climate action, climate and development, climate finance and carbon market mechanisms. NewClimate Institute aims at connecting up-to-date research with the real world decision making processes.

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Climate Analytics is a non-profit climate science and policy institute based in Berlin, Germany with offices in New York, USA, Lomé, Togo and Perth, Australia, which brings together interdisciplinary expertise in the scientific and policy aspects of climate change. Climate Analytics aims to synthesise and advance scientific knowledge in the area of climate, and by linking scientific and policy analysis provide state-of-the-art solutions to global and national climate change policy challenges.

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