STUDY REPORT

ENHANCING ENERGY EFFICIENCY OF THE FREIGHT TRANSPORT SECTOR IN ASIA AND THE PACIFIC

ESCAP
Economic and Social Commission for Asia and the Pacific

The Economic and Social Commission for Asia and the Pacific (ESCAP) serves as the United Nations regional hub, promoting cooperation among countries to achieve inclusive and sustainable development. As the largest regional intergovernmental platform with 53 member States and 9 associate members, ESCAP has emerged as a strong regional think tank, offering countries sound analytical products that shed insight into the evolving economic, social and environmental dynamics of the region. The Commission's strategic focus is to deliver on the 2030 Agenda for Sustainable Development by reinforcing and deepening regional cooperation and integration to advance connectivity, financial cooperation and market integration. The research and analysis of ESCAP coupled with its policy advisory services, capacity-building and technical assistance to governments aims to support countries' sustainable and inclusive development ambitions.

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Contents

Figures

Tables

Acronyms and abbreviation

ADB	-	Asian Development Bank
BS	-	Bharat Stage (Indian emission standards)
CAFE	-	Corporate Average Fuel Economy
CAREC	-	Central Asia Regional Economic Cooperation
CH4	-	Methane
CNG	-	Compressed Natural Gas
COx	-	Carbon Oxides
COP	-	Conference of Parties
EAEU	-	Eurasian Economic Union
ECE	-	Economic Commission for Europe
ESCAP	-	Economic and Social Commission for Asia and the Pacific
EPA	-	Environmental Protection Agency (of the United States)
FAME	-	Faster Adoption and Manufacturing of (Hybrid &) electric vehicles
GDP	-	Gross Domestic Product
GST	-	Gross Sales Tax
GVW	-	Gross Vehicle Weight
GW	-	Gigawatt
HC	-	Hydrocarbons
ICCT	-	International Council on Clean Transportation
IEA	-	International Energy Agency
INDC	-	Intended Nationally Determined Contributions
IPCC	-	Intergovernmental Panel on Climate Change
ITS	-	Intelligent Transport Systems
ITF	-	International Transport Forum
LNG	-	Liquified Natural Gas
LPG	-	Liquid Petroleum Gas

Y	-	modal year
NAR	-	Net calorific value (heating value) in kilocalories per kilogram
NEEAP	-	National Energy Efficiency Action Plan
NMHC	-	Non-methane hydrocarbons
NOx	-	Nitrogen Oxides
OECD	-	Organisation for Economic Co-operation and Development
PM	-	Particulate Matter
PPP	-	Public-Private Partnership
PV	-	Photovoltaic
SO_2	-	Sulfur Dioxide
THC	-	Total Hydrocarbons
UNEP	-	United Nations Environment Program
UNFCCC	-	United Nations Framework Convention on Climate Change
VAT	-	Value-Added Tax

Executive summary

This study paper provides an in-depth analysis and overview of the strategies, technologies and policies crucial for implementing a modal shift and promoting the decarbonization of freight transport. It is a comprehensive guide, providing insights into the challenges and opportunities present in the freight transport sector of the Economic and Social Commission for Asia and the Pacific (ESCAP) region.

In chapter 1, the significance of a modal shift and its relationship with decarbonizing freight transport is explored. The chapter presents the challenges and influencing factors for implementing a modal shift, the role of synchromodal transport systems and the economic benefits tied to the reduction of logistics costs.

Chapter 2 contains an in-depth discussion of the technologies that are pivotal to greener mobility. Electric and alternative fuel vehicles, autonomous vehicles, intelligent transport systems (ITS) and information and communications technology (ICT) infrastructure, and alternative fuel applications form the core of the discussions. The chapter also includes discussions on the need for infrastructure modernization, with an emphasis on railway electrification, and the potential applications of renewable and nuclear energy in transport. Several country examples, such as ones involving Thailand and the United States of America, are used to illustrate current trends in promoting energy efficiency and green mobility.

Chapter 3 contains an outline of the vital role of policy and regulatory measures in driving sustainable and energy-efficient transport. The key policy tools examined are vehicle emission and fuel economy standards, greenhouse gas emissions pricing, policies promoting a shift to low-carbon transport modes, the role of national development policies as a tool to support and promote the growth of sustainable transport, including though financial incentives and subsidies. In addition, relevant international climate initiatives that are important policy references are presented.

The focus of chapter 4 is on designing a regional road map to achieve sustainable and energy-efficient freight transport. In the chapter, the concept of a regional road map for the Asia-Pacific region is explored, insight into regional approaches for enhancing sustainable freight transport is provided and a regional road map for promoting energy-efficient freight transport is presented.

The annexes provide case studies and figures illustrating the concepts and trends discussed in the main chapters. They present examples of decarbonization efforts in North and Central Asia, vehicle electrification in Pakistan, a modal shift in China, transport policies in Poland and the

European Union, vehicle efficiency and electrification policies in Indonesia and pathways to the deployment of zero-emission trucks in India.

In summary, this study paper is a comprehensive guide to understanding and implementing strategies for the transition towards sustainable and energy-efficient freight transport in the ESCAP region. It not only gives a detailed analysis of the current situation, but it also offers insights into future pathways and strategies for the transformation of the freight transport sector.

Introduction

The transport sector plays a significant role in global greenhouse gas emissions, accounting for about a quarter of these emissions. Yet, fossil fuels continue to be the dominate source of energy for the industry, making up 95 per cent of the world's transport energy. In nearly half of the countries worldwide, transport is the largest source of energy-related emissions, and in the rest, it is the second largest.[1]

Over the span of 19 years, from 2000 to 2019, there was a surge in transport-related carbon dioxide (CO_2) emissions across all regions, except for Europe, where it decreased by 2 per cent. Developing countries recorded the most rapid growth rates and Asia emerged as the largest absolute emitter of CO_2 by 2019.

In terms of energy consumption, the transport sector accounted for more than half of the global oil demand and nearly a third of the total energy usage. In response to these startling figures, initiatives, such as the Global Fuel Economy Initiative (GFEI), were launched This initiative is working with approximately 70 countries in capitalizing on the economic and CO_2 reduction benefits of an enhanced vehicle fuel economy.

In Asia, the demand for surface freight transport is the highest in the world, leading to high-energy consumption. The Asia-Pacific region plays a significant role in surface freight transport, accounting for nearly 60 per cent of global surface freight.[2] The freight transport sector plays a crucial role in the region's economic development and trade. It heavily relies on fossil fuels and contributes significantly to energy consumption and greenhouse gas emissions.

The fossil transport share in total consumption emissions varies across countries in the ESCAP region, ranging from 1 per cent (Lao People's Democratic Republic) to 39 per cent (New Zealand) (2017). The limited uptake of alternative fuels in the transport sector means that oil products will still dominate consumption in 2030. Given the dependence on imported fuels and recent fuel price fluctuations, improving energy efficiency is critical for ESCAP countries.

Being a component of the wider project, "Enhancing Energy Efficiency of the Freight Transport Sector in Asia and the Pacific", the objective of this study is to contribute towards improving energy efficiency in the region's freight transport sector in alignment with the Sustainable Development Goals and regional mandates, focusing on Goal 7 (affordable and clean energy),

[1] United Nations, "Fact sheet climate change" (n.d.). Available at https://www.un.org/sites/un2.un.org/files/media_gstc/FACT_SHEET_Climate_Change.pdf.
[2] International Transport Forum "Key transport statistics 2023 (2022 data)" (2023).

Goal 9 (industry, innovation, and infrastructure) and Goal 11 (sustainable cities and communities).

It is hoped that this study will enhance policymakers' capacity to develop and implement effective energy efficiency policies and plans. By leveraging the expertise and functions of ESCAP, it ultimately is intended to address the region's energy efficiency challenges and contribute towards realizing the Sustainable Development Goals in alignment with the regional road map for implementing the 2030 Agenda for Sustainable Development in Asia and the Pacific and the key outputs of the Regional Action Programme for Sustainable Transport Connectivity.

This comprehensive study paper embarks on a thorough exploration of the multifaceted freight transport sector. With a keen focus on understanding the sector's current state, this investigation delves into the nuances of spatial and temporal distribution of emissions, and the resultant environmental impact of long-range transport. Furthermore, the influential role of modern information and communications technologies (ICTs) in curbing CO_2 emissions is scrutinized, thereby contributing to the overarching goal of sustainable development. The study does not stop at identifying the issues, instead, it goes further by providing analyses of a spectrum of potent policy options that can galvanize sustainable practices in the road freight transport industry. By addressing these dimensions in a comprehensive manner, the study is driven by a quest to furnish meaningful insights and actionable recommendations for policymakers and stakeholders. The ultimate aspiration is to champion the transformation of the freight transport sector in the region, making it not only more sustainable, but also significantly more energy efficient.

Three key pillars underpin the framework of this study:

(a) The first pillar is the modal shift, which investigates how policy and regulatory changes and shifts in government structures can influence transport mode choices among road, rail and inland waterways. These shifts are significant as they have the potential to reduce energy intensity in freight transport systems, thereby making a substantial contribution towards the overall energy efficiency of the sector.

(b) The second pillar, technology, delves into the exploration of contemporary and prospective trends. This includes the exploration of vehicular efficiency standards, fuel economy and emission standards and emerging technological paradigms, such as hydro and battery electric vehicles, autonomous vehicles and alternative fuels. The integration of these advanced technologies into freight transport operations is expected to yield notable enhancements in terms of energy efficiency.

(c) The third pillar, policy, explores the various policy options, incentives, and other supportive measures that can expedite technology development and integration into the sector. A robust policy framework is paramount to encourage adoption of advanced technologies and foster a conducive environment for sustainable practices.

One of core objectives of this study is to develop a regional road map for sustainable and energy-efficient freight transport, drawing on the three previously mentioned pillars, while acknowledging their distinctive challenges and opportunities. The road map is based on the principle of adaptability, accommodating customized strategies that align with each country's unique situations and capabilities with the objective to unify countries' individualized strategies into a comprehensive regional plan that paves the way for a more sustainable and energy-efficient freight transport sector.

The findings, insights and recommendations in this study are the result of rigorous research, extensive consultation with industry experts, stakeholders and policymakers, and the application of robust analytical methodologies. The study makes a significant contribution towards the discourse on sustainable transport, offering valuable insights and strategic direction for the Asia and Pacific region's freight transport sector.

Chapter 1: Modal Shift, multimodality and decarbonization of freight transport

1.1 Modal shift and the initiatives for decarbonizing freight transport

The concept of modal shift refers to the process of transferring the transportation of goods from one mode (typically road) to more environmentally friendly alternatives, such as rail or inland waterways. The overall intent of a modal shift is to minimize the environmental footprint of the freight transport sector and optimize its energy efficiency.

Road transport dominates freight movement in the Asia and Pacific region; it is responsible for nearly 60 per cent of all freight tonnage in several countries. Road freight is preferred due to its flexibility, cost-effectiveness and ability to deliver door-to-door services. However, it also exhibits a higher energy intensity compared to rail and inland waterway transport, hence contributing more significantly to greenhouse gas emissions.

The International Energy Agency (IEA) estimates that the contribution of the transport sector to greenhouse gas emissions grew from 15 per cent in 1990 to 24 per cent in 2019,with CO_2 constituting the largest share of the emissions. The International Transport Forum (IFT) has predicted that the total freight-related CO_2 emissions would increase to 5.7 Gt in 2050 from 3.2 Gt in 2015, and that the share of freight in total transport would increase from 40 per cent to 43 per cent over this period.[3] Consequently, the freight transport sector must reverse this increase in greenhouse gas emissions, and in particular, CO_2 emissions. A broad range of measures is required to bring these fundamental changes. Among them are reducing demand for transport, improving energy efficiency, switching to lower-carbon energy sources and modal shifting from road to lower-carbon modes.

The rationale for decarbonization of freight transport attained momentum at the twenty-first United Nations Conference of Parties (COP21), held in Paris from 30 November to 15 December 2015, during which participating countries discussed climate change and the global warming of the planet, and concluded the Climate Change Accord. The Accord includes a serious intention of keeping the temperature increase of the planet well below 2°C by 2100, with 1.5°C now widely being advocated as the new limit. The Intergovernmental Panel on Climate Change (IPCC) calculated that if greenhouse gas emissions can be reduced by 40-70 per cent, there is a 50 per cent chance that global warming would be less than 2°C in 2100.

[3] International Transport Forum, *ITF Transport Outlook 2017* (Paris, OECD Publishing, 2017).

The agreements made at COP21 have catalysed a global commitment to mitigate the impacts of climate change and global warming; they have set clear and ambitious targets. To achieve these targets, substantial reductions in greenhouse gas emissions are needed, a task that calls for a strategic and holistic approach from countries around the world. Many countries are embracing the challenge by actively implementing strategies aimed at these established targets.

A notable example of this is China, which has committed to achieving a carbon peak by 2030 and transitioning to a state of carbon neutrality by 2060. The country has developed a strategic plan to reach these objectives, with a strong emphasis on shifting from road-based transportation to more sustainable and carbon-friendly rail systems. In boxes 1 and 2, a case study is presented that explores the country's policy adjustments regarding this modal shift, and its ongoing efforts to decarbonize freight transport.

Box 1: Experiences of the recent policy of China to support a modal shift from road to rail and decarbonize freight transport

China embarked on a modal shift policy from road to rail later than the European Union, the United States of America and Japan, but this policy gained momentum after 2016. The main objective of this policy is to contribute towards efforts to realize the new formulated goal by the Government of China to address the transport environmental protection. One of the measures was to prohibit transport of coal by road. Figure 1 presents the background for this new policy: an enormous rise of the carbon emissions from fuel combustion in China from 2000 to 2014, in relation with the small decrease in the United States and the European Union. Table 1 shows the carbon emissions from fuel combustion in 2015.

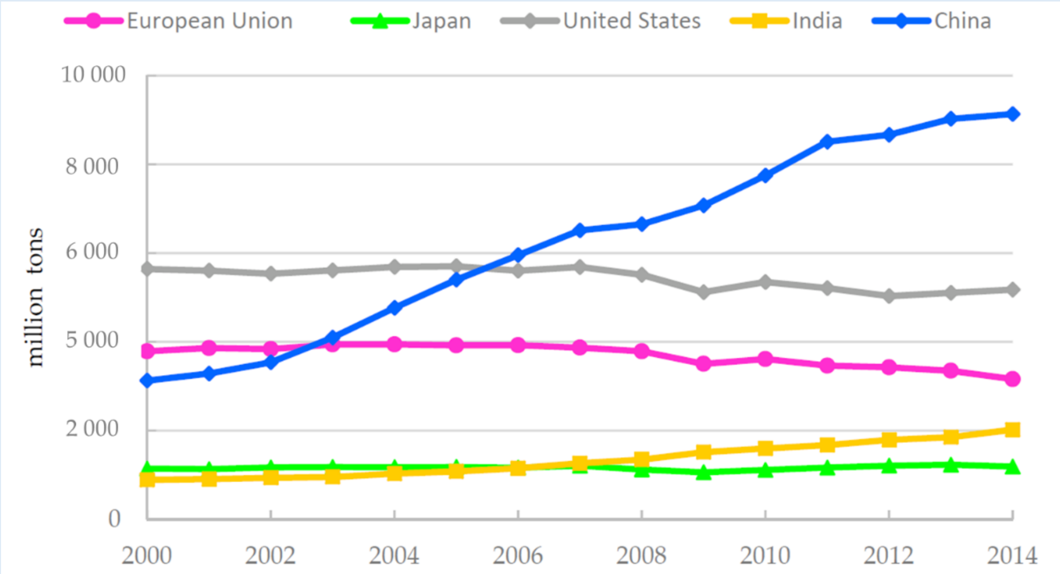

Figure 1 Carbon emissions from fuel combustion from 2000 to 2014[4]

Table 1 Carbon emissions from fuel combustion in 2015[5]

Countries	Total Carbon Emissions	Transport		of which Road	
	Million Tons	Million Tons	Share (%)	Million Tons	Share (%)
China	9084	843.9	9.3	698.2	82.73
United States	4997.5	1752	35.06	1492.8	85.21
European union	3201.2	886.9	27.71	845.7	95.35
Japan	1141.6	218.2	19.11	187	85.7
India	2066	271.8	13.16	236.5	87.01

[4] Shuling Chen, Jianhong Wu, and Yueqi Zong, "The impact of the freight transport modal shift policy on China's carbon emissions reduction", *Sustainability*, vol.12, No. 2 (2020), p. 583.

[5] Ibid. based on data sources from the International Energy Agency, *CO2 Emissions from Fuel Combustion* (Paris, IEA, 2017).

It is remarkable to observe the relatively small proportion of the share of transport in the total carbon emissions, namely 9.3 per cent in China and 13.16 per cent in India, while the share in the United States is 35.06 per cent and in the European Union, it is 27.71per cent. Recent policies on modal shift in China are listed in Table 2.

Table 2 Policies and regulations on modal shift in China.

The Title of Document	Enactment Department	Enactment Date
Highway management regulations for over-clearance transport vehicles	Ministry of Transport of China (MOT)	30 August 2016
Work plan for air pollution prevention and control in Beijing, Tianjin, and Hebei and surrounding areas in 2017	Ministry of Ecology and Environment of (MOEE); National Development and Reform Commission (NDRC); Ministry of Finance of China (MOF); Related Provincial Governments	17 February 2017
Three-Year Action Plan for Advancing Modal Shift (2018-2020) Work plan for comprehensive governance of air pollution in Beijing-Tianjin-Hebei and surrounding areas in the autumn and winter of 2018-2019	State Council;	17 September 2018
	MOEE, MOT, NDRC	21 September 2018

A “three-year action plan for advancing modal shift (2018−2020)” was issued by the State Council on 17 September 2018. It includes measures to optimize the structure of the freight transport sector and to substantially increase the proportion of railway freight transport to achieve the goals for environmental protection. This new policy has led to a massive investment in the railway sector. In their article “The impact of the freight transport modal shift policy on China’s carbon emissions reduction”, Shuling Chen, Jianhong Wu and Yueqi Zong carry out a cost-benefit analysis of this “Road to Rail” policy by conducting a number of case studies and found that the country’s “Road to Rail” policy was successful in reducing carbon emissions, but that it also increased the logistics costs and also resulted in other economic and social losses.

The main challenge facing China is to implement the “Road to Rail” policy in a way that it balances environmental protection and economic development. This requires further institutional reform and policy adjustment, which should be focused on making the Chinese railway system more competitive by opening up the railway freight market, reducing entering barriers and enticing the business sector to join in.

Another challenge is to create a level playing field between roads and railways, fair competition between different modes and internalizing external costs of all transport modes. The “Road to Rail” policy is part of the larger, much more comprehensive Carbon Peaking and Carbon Neutrality Roadmap in China, which is further elaborated in box 2.

Box 2: China Carbon Peaking and Carbon Neutrality Roadmap[6]

The energy sector is the source of almost 90 per cent of greenhouse gas emissions in China. Accordingly, energy policies must drive the transition to carbon neutrality. China has elaborated the Carbon Peaking and Carbon Neutrality Roadmap, which responds to the Government's invitation to IEA to cooperate on long-term strategies by setting out a road map for reaching carbon neutrality in the energy sector. The first pathway in this road map – the Announced Pledges Scenario[7] – reflects the country's enhanced targets that it declared in 2020 under which emissions of CO_2 peak before 2030 and reach net zero by 2060. The transport sector emissions in China were 950 Mt CO_2 in 2020, which was 9 per cent of the total energy sector emissions. According to the Announced Pledges Scenario, the peak would be 1Gt in 2030 and then would decline to 00 Mt in 2060, a reduction of 90 per cent in comparison with 2020.

By 2025, significant achievements are expected, including the formation of an initial framework for a green, low-carbon and circular economy. Key industries will have greatly improved energy efficiency, resulting in a 13.5 per cent reduction in energy consumption per unit of gross domestic product (GDP) and an 18 per cent decrease in CO_2 emissions per unit of GDP compared to 2020 levels. The share of non-fossil fuel consumption is projected to reach approximately 20 per cent, with a forest coverage rate of 24.1 per cent and a forest stock volume of 18 billion cubic meters.

By 2030, comprehensive green transformation in economic and social development will have yielded significant accomplishments. Key-energy-consuming industries will have achieved advanced international levels of energy efficiency, leading to a substantial decline in energy consumption per unit of GDP. CO_2 emissions per unit of GDP will have dropped by more than 65 per cent compared to 2005 levels. The share of non-fossil fuel consumption is expected to increase to approximately per cent, with a total installed capacity of wind and solar power exceeding 1,200 GW. The forest coverage rate is projected to be approximately 25 per cent, with a forest stock volume of 19 billion cubic meters. CO_2 emissions will have peaked, stabilized and begun to decline.

By 2060, a fully established green, low-carbon, and circular economy, along with a clean, low-carbon, safe, and efficient energy system, will be realized. Energy efficiency will have reached advanced international levels, and the share of non-fossil fuel consumption will exceed 80 per

[6] Source: China Daily (https://www.chinadaily.com.cn/)

[7] The Announced Pledges Scenario was introduced in 2021 with the objective to show to what extent the announced ambitions and targets, including the most recent ones, are on the path towards delivering emissions reductions required to achieve net zero emissions by 2060.

cent. China will have achieved carbon neutrality, making significant strides in ecological civilization[8] and attaining a new level of harmony between humanity and nature. Figure 2 shows that the country's transport emissions, which have risen more than threefold since 2000, will peak by 2030 and then drop by nearly 90 per cent by 2060, thanks to improved efficiency and low-carbon technologies.

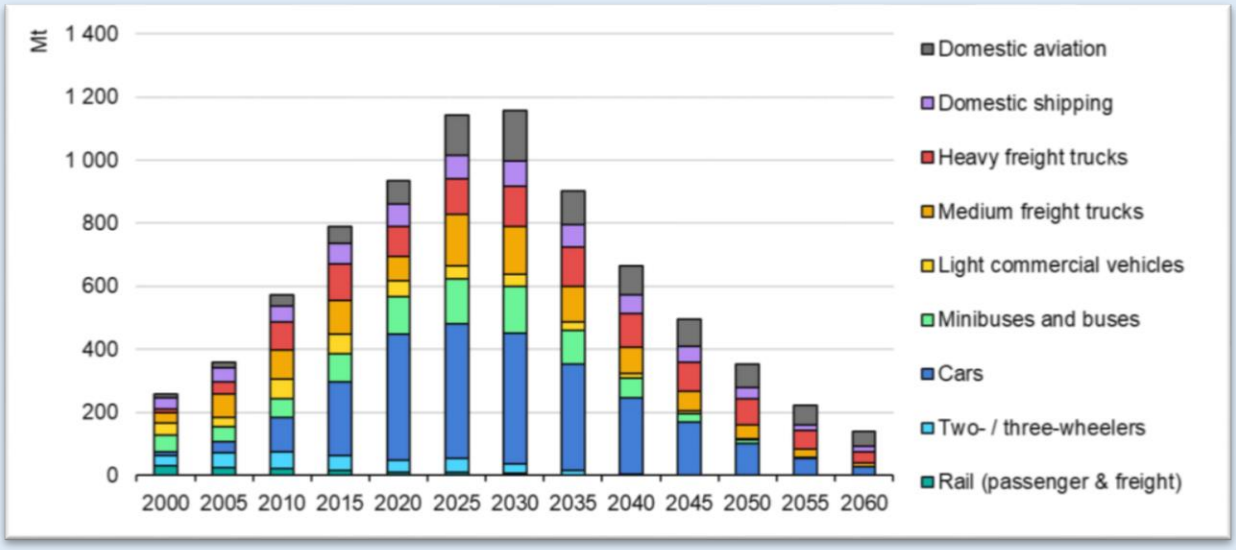

Figure 2 Carbon dioxide emissions from transport in China in the Announced Pledges Scenario[9]

Transport modes significantly vary in terms of CO_2 emissions per unit of freight movement. For instance, express air freight services can emit CO_2 at a rate 500 times higher than electric train bulk delivery.[10]. As such, an effective decarbonization strategy naturally includes a preference for transport modes with lower carbon intensity.

The concept of altering the "freight modal split," or modal shift, is a significant component in numerous decarbonization frameworks and government policy statements. As part of their commitment to the COP21 Paris Accord, countries have outlined intended nationally determined contributions aimed at reducing freight-related emissions. As indicated in figure 3, almost half (48 per cent) of these intended nationally determined contributions policy initiatives explicitly reference the strategy of a freight modal shift.

[8] The concept of "ecological civilization" can be understood as a new system of development and governance based on the perspective of political decision-making. Environmental management, ecological restoration, and green development are its primary principles.
[9] International Energy Agency, *An Energy Sector Roadmap to Carbon Neutrality in China* (IEA, September 2021).
[10] Alan Mckinnon, *Decarbonizing Logistics, Distributing goods in a Low Carbon World*. (London, Kogan Page Publishers, 2018).

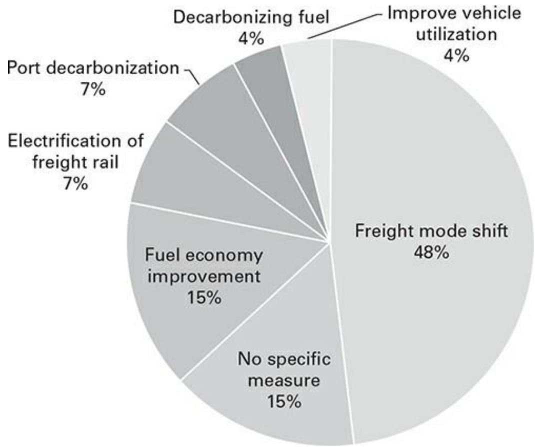

Figure 3 Proportion of intended nationally determined contributions documents mentioning freight decarbonization measures[11]

A challenge is to be able to quantify the carbon savings from a modal shift. Accordingly, it is necessary to calculate the carbon intensity of all freight transport modes. Figure 4 shows the average carbon intensity of freight transport modes in gCO_2/tonne-km based on freight transport operations of the United Kingdom of Great Britain and Norther Ireland from a study conducted by the Department for Environment, Food and Rural Affairs.

Building on the notion of a modal shift in freight transport, a significant challenge arises that is to quantify the carbon savings associated with such a shift. This necessitates calculating the carbon intensity of every freight transport mode. Figure 4 presents the average carbon intensity of various freight transport modes measured in gCO_2/tonne-km. These data, sourced from United Kingdom freight transport operations, are derived from a comprehensive study conducted by Department for Environment Food and Rural Affairs.[12]

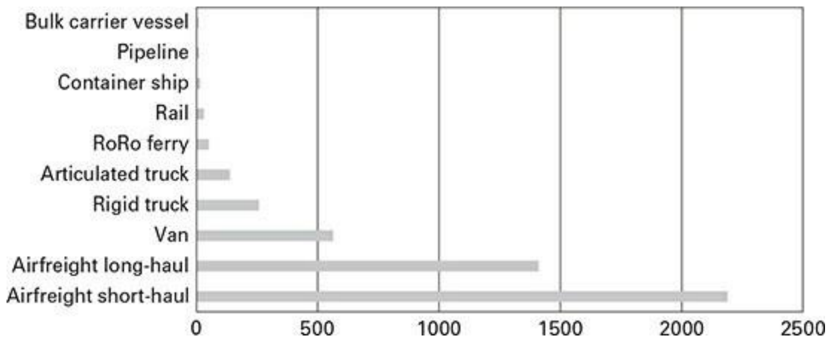

Figure 4 Average carbon intensity of freight transport modes: gCO_2/tonne-km

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[11] Alan Mckinnon, *A. Decarbonizing Logistics, Distributing goods in a Low Carbon World* (London, Kogan Page Publishers, 2018) based on data from Gota and others, “Nationally determined contributions (NDCs) offer opportunities for ambitious action on transport and climate change”(Partnership on Sustainable Low Carbon Transport, October, 2016).

[12] United Kingdom, Department for Environment, Food and Rural Affairs, Greenhouse gas reporting conversion factors 2017 (online) Available at https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2017.

Building on the previous discussion of the varying carbon intensity across different modes of transport, Table 3 offers a visual representation of CO_2 emissions from diverse transport methods spanning from 2009 to 2021. The data, drawn from multiple reliable sources, provide a tangible comparison and helps further illuminate the environmental impact associated with each form of transportation over the course of more than a decade.

Table 3 Carbon dioxide emissions for different transport modes in grams per tonne-kilometre[13]

Truck	Rail	IWT	SSS	Pipeline	Period	Place	Calculation	Source
88-256	12	24-38	22		2020	Netherlands	WTW	CE Delft (2021)
60-190	18-21	17-34		180 (gas), 16 (oil)	2002	United States	WTW	Nealer et al. (2014)
65	2		29		2017	Sweden	TTW	Johansson, vierth, and Holmgren (2021)
	14				2018	World		IEA-UIC (2017)
55-124			80					Hjelle 2014
			101					Leonardi and Browne (2010)
			11					IMO (2009)

Notes: WTW, well-to-wheel, TTW, tank-to-wheel; IWT, inland water transport; SSS, short-sea shipping.

Standard values for specific modes of transport should be employed judiciously, as they can fluctuate greatly due to various factors, such as the data sources, sampling frame, assumptions about load factors, country-specific conditions and energy sources. As stressed by McKinnon, when calculating carbon intensity, it's essential to incorporate the emission intensity of the primary energy source.[14] This becomes particularly important for electrified freight services when the energy used for electricity production needs to be considered.

To attain a more comprehensive understanding, transport modes should be compared on a well-to-wheel basis rather than merely a tank-to-wheel approach. Such a comprehensive perspective broadens the system boundary of the carbon calculation and could even be extended to encompass emissions from vehicle manufacture and maintenance, the construction and maintenance of infrastructure, and related information technology and administration aspects.

Box 3 covers the well-to-wheel energy concept, emphasizing the necessity to maximize the utilization of green and sustainable energy sources for electricity generation, as electricity can also originate from fossil fuels. The use of electricity as a power source does not inherently guarantee environmental friendliness. The source, if it leads to high emission intensity, can contradict the supposed “green' nature of electricity”.[15]

[13] International Transport Forum, *Mode Choice in Freight Transport* (Paris OECD Publishing, 2022) p. 27. For the references, please refer to https://www.itf-oecd.org/sites/default/files/docs/mode-choice-freight-transport.pdf.
[14] Alan Mckinnon, *Decarbonizing Logistics, Distributing Goods in a Low Carbon World*. (London, Kogan Page Publishers, 2018).
[15] Ibid., p.192 and p. 69.

Box 3: Well-to wheel energy concept and the need to maximize the use of green and sustainable energy sources to generate electricity

The concept of well-to-wheel energy refers to the complete life cycle of energy consumption of a fuel − from extraction to end-use. It is a valuable analysis tool to assess the overall impact of different energy sources on the environment, economy and society, despite its inherent complexity. The analysis consists of two parts, the energy expended in creating the fuel ("well") and the energy required to utilize it in a vehicle or similar application ("wheel").

Various factors influence the "well" portion, including, among them, the energy source, extraction and processing efficiency, and transportation needs. For instance, offshore oil drilling requires more energy than onshore drilling. In addition, energy-intensive processes, such as coal mining and transportation, significantly contribute to the total energy requirement.

The "wheel" segment, on the other hand, focuses on the application's efficiency in using the fuel. For example, vehicles powered by internal combustion engines are generally less efficient than their electric counterparts. This inefficiency results in wasted energy as heat rather than being utilized for propulsion. Factors, such as vehicle weight, aerodynamics and driving habits, further influence the "wheel" part of the analysis.

Despite its complexity, the well-to-wheel analysis remains a crucial tool for evaluating energy sources and technologies. It provides a comprehensive understanding of the energy system and helps assess the overall sustainability of a fuel. Accordingly, as transition to more sustainable energy systems gains traction, this method will remain essential.

In terms of electricity, it's crucial to maximize the use of green and sustainable energy sources, as the "environmental friendliness" of the electricity generated cannot be assured solely by its end use. The source of electricity can significantly influence emission intensity, underscoring the importance of using green energy sources.

To accurately assess the potential greenhouse gas savings that can be achieved by implementing a modal shift, all aforementioned factors must be considered when calculating carbon intensity.

Most modal shift policies pertain to transport at the national level. The European Union, for instance, has its own modal shift policy, which must be integrated into the national legislation of all of its member States. Implementing a modal shift policy at a national level can be particularly beneficial for large countries, such as China, India, the Russian Federation and the United States. Furthermore, the exploration of a transcontinental modal shift policy holds considerable merit.

Table 4 provides a comparative snapshot of trans-Asian services, highlighting the differences in CO_2 emissions, transit times and costs. These differences are represented as index values, serving as a straightforward tool for assessing the potential environmental and operational impacts of modal shifts in transportation. This comparison underscores the potential benefits and implications of such strategic changes in transport systems.

Table 4 Relative carbon dioxide emissions, transit times and costs for trans-Asian freight services[16]

Indicators	Rail	Air	Sea	Sea-air
CO_2 emissions	100	2100	150	**1450**
Transit time	100	20	200	**110**
Cost	100	475	50	**230**

Sea-air services between the Far East and Europe, for instance, involving sea transport and air transport, may be an attractive decarbonization option for companies shipping commodities in the mid-range of time sensitivity.

The latest ITF Statistics Brief publication, from 1 December 2022, however, bears the rather disappointing title "Modal shift to cleaner transport fails to materialise".[17] In the brief, it states that there still is a trend of freight shifting to roads. As indicated in Figure 5, only a few countries have increased their use of rail to transport freight, most notably Australia (+8%), Slovenia (+7%) and Italy (+5%), shifting from road transport.

Other countries that have recorded an increase in the share of rail freight are Finland, France, Germany and Hungary. Most countries that reported a modal shift show an increase in the use of road transport; Serbia (+40%), Lithuania (+21%) and Moldova (+13%) are the top three countries with the highest shift towards road transport resulting from a reduction in their shares of rail and inland waterways use. The remaining countries have also increased the use of trucks, on average, by 4 per cent.

[16] Alan Mckinnon, *Decarbonizing Logistics, Distributing Goods in a Low Carbon World* (London, Kogan Page Publishers, 2018), p. 75.
[17] International Transport Forum "Modal Shift Transport Trends" (2023). Available at Modal shift to cleaner transport fails to materialise | ITF (itf-oecd.org)

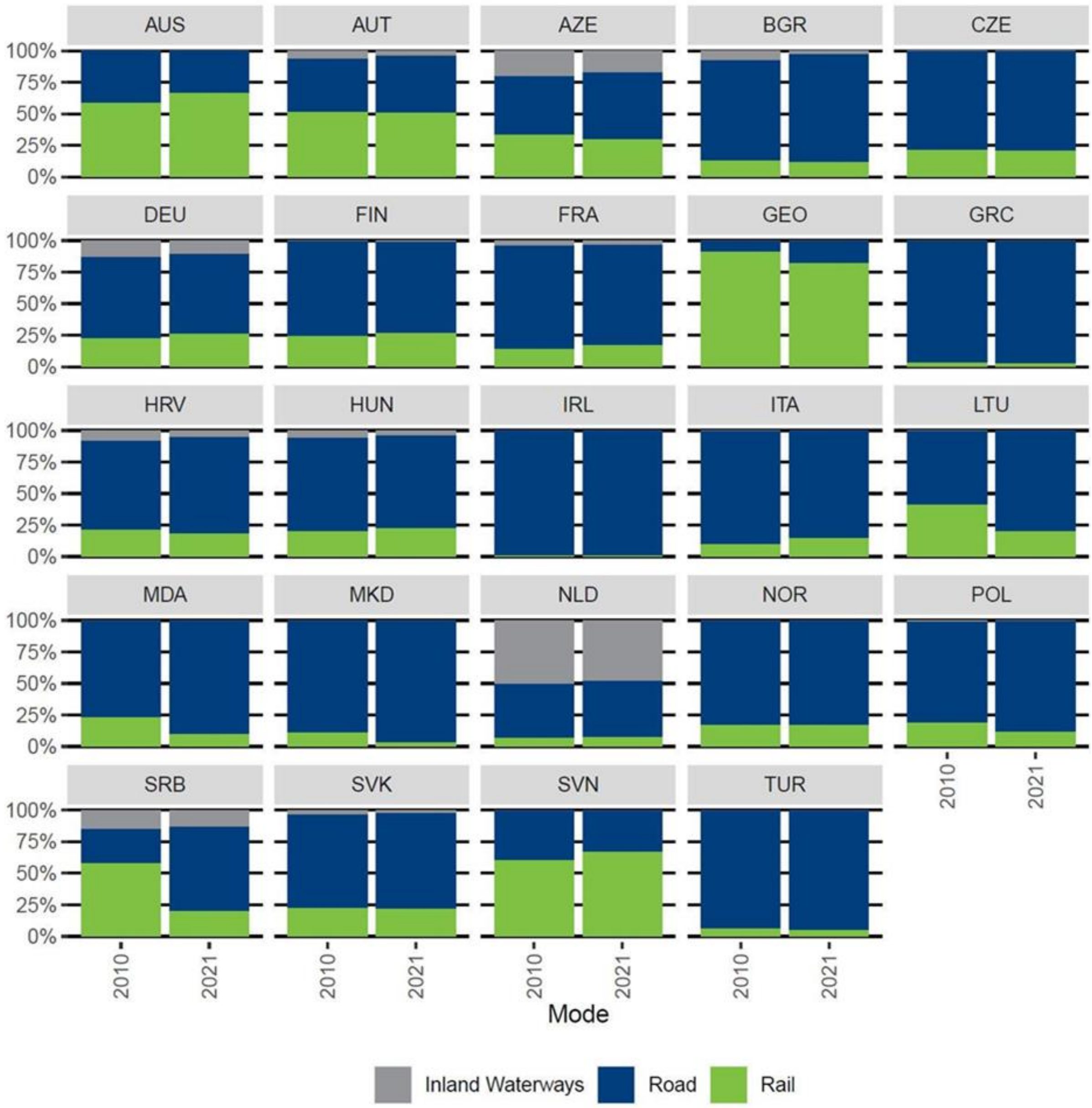

Figure 5 Mode shares of inland freight transport (excluding oil pipelines) in tonne-km[18]

Notes: AUS, Australia; AUT, Austria; AZE, Azerbaijan; BGR, Bulgaria; CZE, Czechia; DEU, Germany; FIN, Finland; FRA, France; GEO; Georgia; GRC, Greece; HRV; Croatia; Hun, Hungary; IRL, Ireland, ITA, Italy; LTU, Lithuania; MDA, Moldova; NLD, Netherlands; NOR, Norway; Pol, Poland; SRB, Serbia; SVK, Slovakia; SVN, Slovenia; Turkey, TUR

In conclusion, while the concept of modal shift presents a promising strategy for enhancing the energy efficiency of the freight transport sector, to realize it, significant challenges need to be addressed. Future chapters provide more detailed insights into potential solutions for these issues, drawing on the experiences of various countries within the Asia and Pacific region.

[18] Ibid.

1.2 Main challenges and influencers for implementing a modal shift

Statistics show that implementation of a modal shift policy is very challenging and seldom very successful. The main objective of this chapter is to identify the main challenges for the implementation of a modal shift from the perspective of the government, but also, and maybe even more important, from the perspective of the shipper.

Much research has been conducted over the past 50 years about the factors that influence the companies' choice of a specific mode of transport. One of the latest studies on this topic was conducted in 2022 by the International Transport Forum (ITF), *Mode Choice in Freight Transport*. This study starts by introducing the main influencers in the mode choice, as explained in box 4:

Box 4: International Transit Forum: main influencers in the choice of the transport mode[19]

- *Shippers* generate demand for freight transportation as they are the senders or recipients of the goods. They plan shipments to satisfy their customers and define how their freight should be moved. Thus, they formulate their logistics strategy, which may include intermodal transport. They can organize their freight transport themselves or outsource this process to logistics service providers.
- *Logistics service providers* (including freight transport forwarders) carry out various logistics tasks within an intermodal transportation system. They provide a range of value-added logistics services, such as warehousing, distribution, shipping, inventory management, co-packing, labelling, repacking, weighing and quality control. They can also act as intermediaries for shippers for domestic and international intermodal transportation activities, also referred to as integrators. Shippers often outsource logistics activities to focus on their core businesses and benefit from the expertise of logistics providers.
- *Carriers* are the transport operators or transport companies that perform the transport for the shippers or logistics service providers. Some carriers operate dedicated services, in which a vehicle or container serves a single customer. Others operate based on consolidation in which each vehicle or container may contain different customers' freight with different origins or eventual destinations."

In addition, specific actors influence the conditions for private firms:

- *Infrastructure managers* may be public, private or hybrid entities. They deal with the management of the physical network and infrastructure, such as roads and highways, rail

[19] International Transport Forum, *Mode Choice in Freight Transport* (Paris, OECD Publishing, 2022).

infrastructure and intermodal port terminals. Thus, they play a central role by providing efficient physical networks and the necessary technology to control and optimize the use of infrastructure and facilities.

- *Policymakers* are governments and public administrations that tax, offer incentives, set policies and regulate transport activities. They also address externalities related to transport, namely the effects on non-direct transport users that are not considered in the price of transport such as environmental costs, accidents, congestion. Policymakers frequently aim to guide the transport and logistics system towards being more beneficial to society and having resilient operations. For example, the usage of specific corridors or vehicle and motorization types, mode changes from road-based to water- and rail-based transportation, the reduction of externalities and the consideration of environmental impacts. National governments and transnational institutions, such as the European Commission, are included in this class of actors.

Most studies consider that shippers and logistics service providers play a decisive role in this choice. Figure 6 shows the main determinants for freight transport mode choice.

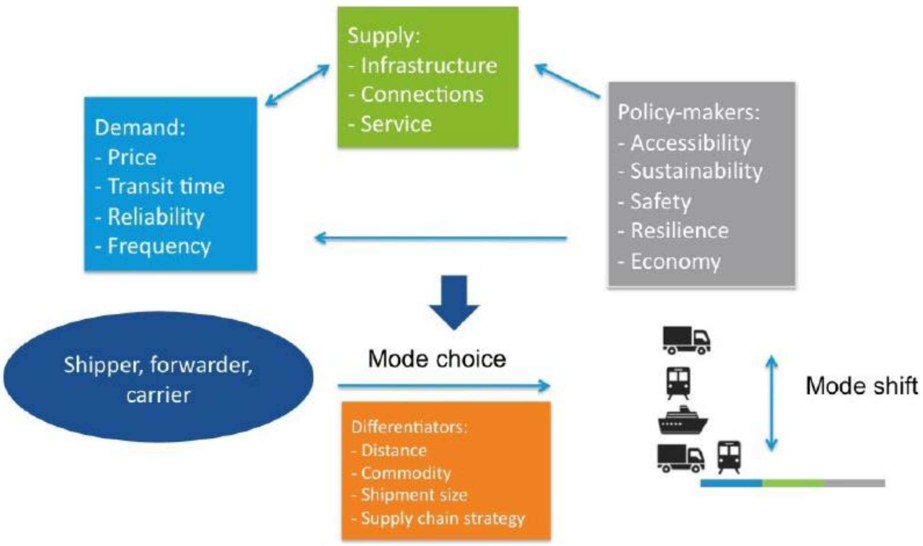

Figure 6 The main determinants for freight transport mode choice[20]

Decades of research have delved into the factors that influence a company's choice of transport modes and the decision-making process surrounding the use of intermodal transport services over road transport. Some common considerations are cost, travel time, reliability, flexibility, freight tracking and tracing, use of infrastructure, volume and freight characteristics, terminal services, legislation, including legal bottlenecks and advantages, and safety and security. However, transitioning shippers from road freight to rail or other forms of intermodal transport

[20] Ibid.

has proven to be a complex task. One researcher distinguishes three sets of interrelated disadvantages of using these lower-carbon modes: geographical; temporal; and operational.[21]

Geographical: In the first place, lower-carbon modes rail and waterways have much lower density and connectivity than road networks, which, in practice, means that goods have to be transhipped at least two more times, loading and unloading between road and rail or waterways, as not many few industrial premises have direct access to rail or waterways. In addition, the road network with the development of motorways has boosted the development of the road freight industry due to the reduced travel time of road transport. Of course, in larger countries, such as China, the Russian Federation and the United States, long-haul rail and waterborne transport services have economic advantages over road transport.

Temporal: Rail and waterborne transport services are, in general, slower than road transport. This may be a disadvantage for transport of more time-sensitive, higher-value cargo. The average speed of trains and vessels are much slower than the average speed of trucks. Another disadvantage of railways is that it is bound to fixed and tight schedules as other (passenger) trains use the same rail tracks. In modern transport operations flexibility is important, but so is reliability and sometimes also the just-in-time principle. In those cases, shippers often opt for road transport, which can be planned and controlled more easily, and is more flexible.

Operation: The consignment size across road, rail and waterborne transport vary significantly: road transport typically handles 20-40 tons, rail deals with 1,000-2,000 tons, while maritime vessels, depending on their size, can carry significantly larger volumes. As such, vessels and rail systems must operate at maximum capacity to maintain cost-efficiency.

The rail sector faces a unique set of challenges. Historically, it had transported large quantities of coal and oil, but the global shift away from fossil fuels threatens to decrease its cargo volume significantly in the near future. Additionally, the rail sector grapples with interoperability issues between different railway systems, including disparities in gauges and signalling systems.

In countries with extensive railway networks, the sector faces pressure to meet the business sector's demands for efficient, customer-centric and reliable operations. It must respond to these challenges swiftly and strategically to continue to be relevant and competitive.

[21] Alan Mckinnon, *Decarbonizing Logistics, Distributing Goods in a Low Carbon World*. (London, Kogan Page Publishers 2018), pp 76−78.

1.3 Modal shift and synchromodal transport systems

Government-led modal shift policies often encounter implementation challenges, largely because shippers and cargo owners are reluctant to transition from road transport to intermodal transport for various operational reasons, including, among them, the lack of flexibility inherent to rail and waterway transport. The comparatively recent concept of synchromodality addresses this hurdle, offering a framework that enables shippers and cargo owners to manage their supply chains more flexibly, thereby enhancing the potential for modal shift.[22]

The inherent inflexibility in delivery time, frequency and scheduling of lower-carbon modes, such as rail and inland water transport, hinders shippers, cargo owners and logistics managers from integrating these modes into their supply chains. This rigidity results in increased inventory costs due to the inability of these modes to adapt swiftly to fluctuating demand. Their efficiency also relies on large, consistent freight volumes. Furthermore, a conflict can arise between the interest of the shipper or cargo owner, who seeks prompt or just-in-time delivery, and the logistics service provider, who aims for optimal utilization of transport capacity, namely maximum loads for rail or water transport.

Synchromodality, the latest concept tied to multimodal transportation, offers the capacity to interchange transport modes at specific times and locations while a shipment is in transit. This method necessitates a degree of flexibility, along with efficient, responsive synchronization of the schedules of available transportation modes. Synchromodality should enable modal switching at various nodes along the route, in compliance with cost constraints and service-level requirements.[23] A distinctive feature of synchromodality is horizontal integration of freight transportation planning, which allows for parallel usage of different transport modes during the entire supply chain from the origin to the destination. Figure 7 shows the vertical and horizontal integration of freight transport planning.

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[22] Chuanwen Dong and others, “Investigating synchromodality from a supply chain perspective”, *Transportation Research Part D Transport and Environment*, June 2017.
[23] Ibid. p 5.

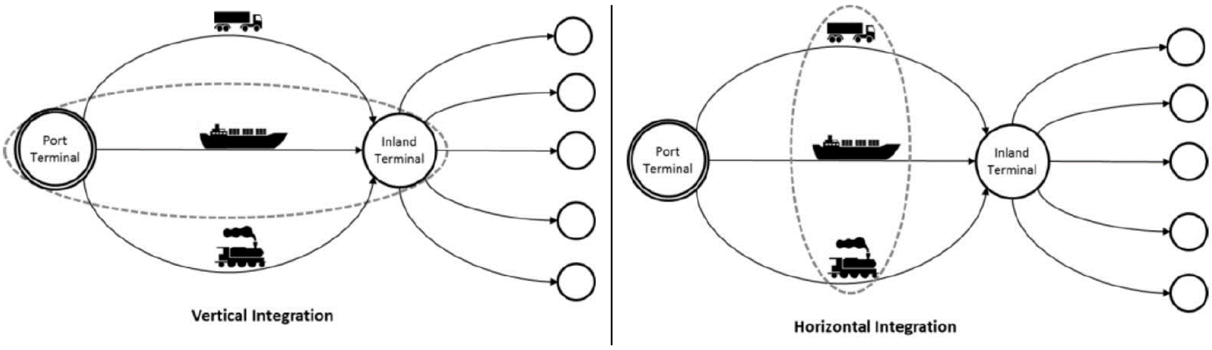

Figure 7 Vertical and horizontal integration of freight transportation planning[24]

It is generally acknowledged by most researchers that synchromodality contributes to improved sustainability in economic and environmental terms because it facilitates a modal shift towards low-carbon modes, provides more flexibility in the real-time planning of the cargo in the supply chain and may also adapt to variable demand. The main differences between intermodal transport, synchromodal transport and synchromodality from a supply chain perspective are presented in Figure 8.

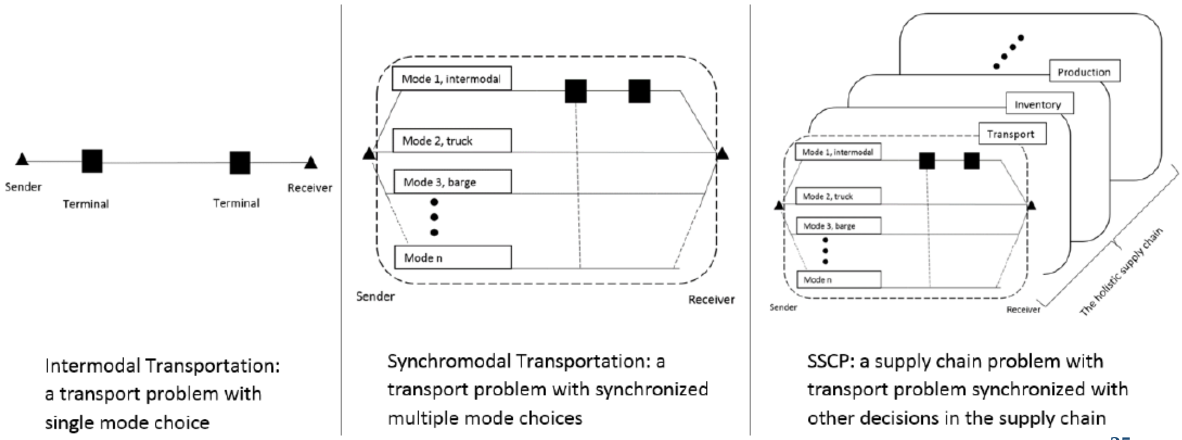

Figure 8 Intermodality and synchromodality from a supply chain perspective[25]

Intermodality uses a one-dimensional freight pathway, while synchromodality extends this to a two-dimensional freight flow network involving use of different modal pathways in the same corridor simultaneously. In the third option of synchromodality from a supply chain perspective, not only transportation is considered but also inventory levels, production and service levels among others, are taken into account. Synchronization and scheduling take place based on the performance of and needs from the entire supply chain. Shippers and cargo owners are working together with logistics service providers and transporters to optimize transport and logistics operations in the supply chain as much as possible, even though they have different interests and, therefore, different business models and operational strategies.

[24] Chuanwen Dong and others, "Investigating synchromodality from a supply chain perspective", *Transportation Research Part D Transport and Environment*, vol 61 (June 2017).
[25] Ibid.

Table 5 shows the different perspectives of synchromodality from a transport point of view and from a supply chain perspective.

Table 5 Different perspectives of synchromodality[26]

	Transportation perspective	Supply chain perspective
Organization	Mainly LSPs	Shippers
Scope	A transportation network	End-to-end supply chain
Complexity	Network extent and intermodal connections	Supply chain trade-offs and synergies
Objective	A flexible transportation network, where all transportation modes are efficiently utilized and modal shift facilitated	A synchronized supply chain, where inventory-transportation trade-offs are recalibrated to exploit multimodal flexibility
Quantitative research method	Transportation planning algorithms, e.g., the multi-objective k-shortest path problem used by Mes and Iacob (2016)	Supply chain optimization, e.g., models integrating transportation and inventory decisions

Note: LSP, logistics service providers.

Synchromodality from a supply chain perspective requires active involvement of the shipper in the decision-making process of the use of transport modalities, the modal split decisions and modal shift that also takes into account production and inventories in order to optimize the total supply chain performance.

Dong and others have described a real-world research project, which examined the potential for increasing a large shipper's relative use of intermodal rail transportation by using synchromodality from a supply chain perspective. They have shown that by applying this perspective with industry level parameters, the company can change its modal split from 30 per cent of the freight volume shipped via intermodal rail in one specific corridor, to as much as 70 per cent consigned on intermodal rail transportation in the same corridor. This has resulted in logistics cost saving of 6 per cent. The environmental impact of this modal shift would lead to a 30 per cent reduction in CO_2.[27]

Innovations are urgently needed to promote a substantial modal shift to lower-carbon modes. Application of synchromodality from a supply chain perspective may be one of those innovations.

[26] Ibid.
[27] Ibid.

1.4 How a modal shift contributes towards reducing logistics costs

Many countries are developing policies to reduce national logistics costs. Accordingly, they are drafting national logistics strategies and elaborating national logistics masterplans. To draft sound national logistics strategies and elaborate national transport and logistics masterplans, it is necessary to measure and monitor national logistics performance.

Below is a list of various methodologies and approaches to measure and monitor national logistics performance:

- Global logistics performance indexes
- Macrologistics, freight modelling and logistics costs
- Micrologistics and logistics surveys
- Measuring and monitoring logistics performance along transport corridors

The *first approach* involves global macrologistics performance indexes, such as the World Bank Doing Business Index, the World Bank Logistics Performance Index (LPI), the OECD Trade Facilitation Indicators and the World Economic Forum Global Competitiveness Index.

All these indices are national indices per country and mostly based on perception. Information is mostly based on surveys, less so for statistical data collection. They generally provide good indications for certain trends and can be used for global comparisons between countries.

As these indices are compiled on a regular basis and freely published and disseminated widely, most governments pay attention to the results. They want to see how they score and rank in the international context and compared with neighbouring countries and trading partners. A good score means a good image for a country, which may attract foreign investment.

The *second approach* provides an introduction of measuring and monitoring macrologistics performance. This approach is data driven, not based on perception, and includes freight flow modelling and associated logistics costs. In addition, the calculation of national logistics costs as percentage of the GDP is part of this approach. Based on this, a macrologistics strategy can be developed.

The *third approach* presents a micrologistics approach under which logistics surveys among manufacturing industries and logistics service providers play an import role. Real detailed concrete data are collected, along with more general data. This type of survey is conducted on a regular basis, for instance every two years, to see changes in time.

The *fourth approach* presents tools to measure and monitor logistics performance along transport corridors, in particular for road transport and rail transport. Concrete data regarding costs and time of transport are collected in the field along transport corridors and at border crossings. In addition, this type of data collection can be organized on a regular basis, annually or every two years to collect historical data in time revealing changes. An observatory can be set up to measure and monitor logistics performance.

These four approaches are *complementary* to each other. They all apply different methodologies to address the same topic: how to measure and monitor logistics performance. The best option is, therefore, to use and apply all four approaches simultaneously.

The second approach level includes an analysis of the existing structure of national and international freight flows by commodity, volume, origin-destination, cost, duration and reliability. Based on this analysis, a freight model can be developed using different growth scenarios and assigned to the transport and logistics infrastructure network. The outcome of this exercise provides important indications for the need for restructuring and to further develop the present transport and logistics infrastructure network. It may also guide investments needed to develop transport and logistics infrastructure and optimize the infrastructure network in such a way that logistics costs and greenhouse gas emissions are reduced.

Further development of a national transport and logistics infrastructure system should consider the concept of synchromodality, such as a flexible multimodal transport system, that offers a variety of transport options and alternative transport modes with multiple nodes in the network from which freight can be easily shifted from one mode of transport to another.

Modal shift of road to railway or to other low-carbon transport modes can be a useful policy instrument to reduce logistics costs and greenhouse gas emissions, such as CO_2, at the same time, as shown in box 7. It includes a good explanation from India where a modal shift policy from road to rail on the Eastern Corridor has produced good results.

Box 7: Modal shift from road to rail on the Eastern Transport Corridor in India

On 10 June 2022, the World Bank approved a $245 million rail logistics project to assist India in transferring a greater proportion of traffic from road to rail. This shift is projected to enhance freight and passenger transport efficiency while reducing millions of tons of greenhouse gas emissions (greenhouse gas) annually.[28] It also has the potential to attract further private sector investment into the railway sector.

Indian Railways, the world's fourth-largest rail network, transported 1.2 billion tons of freight in the fiscal year ending in March 2020. Despite this, road transport volume remains four times higher than rail transport, with 71 per cent of the country's freight moved by road, compared to only 17 per cent by rail. Capacity limitations within Indian Railways have restricted volumes, compromising the speed and reliability of shipments, thereby gradually eroding its market share in favour of road transport. In India, road freight contributes substantially to emissions, accounting for approximately 95 per cent of the freight sector's output. Notably, trucks were involved in approximately 12.3 per cent of road accidents and 15.8 per cent of total road transport-related fatalities in 2018. Rail transport emits approximately one fifth of the greenhouse gas emissions produced by trucks. With the ambition of Indian Railways to become a net-zero carbon emitter by 2030, it has the potential to eliminate 7.5 million tons of CO_2 and other greenhouse gas emissions annually.

Integrating the railways with the broader national logistics system is crucial to reducing the country's relatively high logistics costs, which exceed those of many developed countries. This could enhance the competitiveness of Indian firms. The Rail Logistics project aims to enhance multimodal transport hubs and terminals in India by improving rail links to ports and inland gateways and establishing efficient first- and last-mile connectivity with railways. The development of the Eastern Corridor, a part of the Dedicated Freight Corridor programme, includes constructing a 1,839 km-long freight line, stretching from Ludhiana in Punjab to Dankuni near Kolkata in West Bengal.

This initiative is spearheaded by the Dedicated Freight Corridor Corporation of India Limited, a specialized entity established by the Ministry of Indian Railways for the construction, operation and maintenance of the dedicated freight corridors. The entity is also responsible for planning, development financing and operation of the Dedicated Freight Corridor programme. The project will further bolster the institutional capacity of the Dedicated Freight Corridor Corporation of India Limited as a commercial organization, equipping it to provide multimodal logistics services.

[28] World Bank, "World Bank provides $245 million to help Indian Railways carry more freight, reduce GHG emissions", press release, 10 June 2022. Available at https://www.worldbank.org/en/news/press-release/2022/06/10/world-bank-provides-245-million-to-help-indian-railways-carry-more-freight-reduce-ghg-emissions.

Table 6 shows that the total transport cost for road and rail freight along the Eastern Corridor is $11.6 billion. Road transport accounts for 79 per cent of this cost, carrying 70 per cent of freight volume in tonne-kilometres, while rail represents 21 per cent of the cost, covering 30 per cent of the freight volume in tonne-kilometres.

Table 6 Road and Rail Freight on the Eastern Corridor of India[29]

Mode	Tonnes		Tonne-kms		Average distance	Transport cost	
	Millions	Share	Billions	Share	Km	USD billion	Share
Road	206.6	71%	224.3	70%	1086	9.1	79%
Rail	83.6	29%	97.6	30%	1167	2.5	21%
Total	**290.2**	**100%**	**321.8**	**100%**	**1108**	**11.6**	**100%**

Table 7 shows the Eastern Corridor of India savings potential in USD million, mainly related to improved utilization of rail and improved port system.

Table 7 Eastern Corridor of India savings potential in USD million[30]

Strategic objective	Intervention	Description	Dedicated freight corridor (USD millions)	Logistics hub and dedicated link	
				(USD millions)	%
Rail corridor solution	Modal shift within corridor	Rail-friendly freight on road shifts to rail (origin and destination are within the corridor)	1 647		44%
Kolkata as gateway for Uttar Pradesh, Jharkhand and Bihar	Hinterland port shift of rail-friendly freight	Freight that can use rail will shift to the closer port of Kolkata		496	13%
	Hinterland port shift of freight on road	Freight that cannot use rail (due to location of load points), but will shift exports away from Western ports due to the improved link and shorter distance		868	23%
Improve access and reduce congestion	Corridor-city link	Freight shifts from road to rail because it can more easily reach the port on rail		549	15%
	Kolkata city logistics improvement	The hub and link will also have a concomitant positive alleviation effect on inner-city congestion		146	4%
	Terminal-port link	Reduce current ExIm costs due to reduced congestion		39	4%
Total			**1 647**	**2 097**	

In conclusion, the modal shift from road to rail on the Eastern Transport Corridor in India offers considerable economic as well as environmental benefits.

[29] Aritua and others, "Unlocking India's logistics potential: the value of disaggregated macroscopic freight flow analysis", World Bank Policy Research Paper 8337 (2018).
[30] Ibid.

In conclusion, modal shift is explicitly mentioned as one of the priorities areas in the regional approach to enhancing the sustainability of freight transport in Asia and the Pacific by increasing the share of rail freight and other sustainable transport modes.

This chapter provides a review of many modal shift policies worldwide over the past 30 years and the rationale for these policies. It has also indicated if these policies were successful after being implemented. Statistics indicate that the share of road of road transport has hardly been reduced because of implementation of a modal shift policy, however, few studies calculate the impact on the modal split if the modal shift policies would not have been implemented. For such a study, it is likely to be assumed that the share of road transport in the modal split would have increased without these policies. The review has also indicated that the rationale for modal shift is important to take into consideration. The main rationale has always been environmental: both from the European Union and from China. It is, however, also important to consider the costs involved in implementing the modal shift policy. The case study from China has shown that it is important to also take into consideration the economic aspects and that it is possible to use both rationales simultaneously.

This chapter also includes the introduction of various concepts, such as multimodal transport and synchromodality. These concepts have emerged from concerns by the business sector, which felt almost forced by governmental regulations to shift transport from road to rail or waterway, prejudicing the efficiency of business operations, which, in turn, is resulting in hight logistics costs. The business sector needs an efficient and agile multimodal and synchromodal transport and logistics infrastructure system that can address all the needs for flexible transport and logistics operations. In addition, the internalization of external costs in all transport modes for all transport users would be a fair principle to be applied in a multimodal and synchromodal transport and logistics infrastructure system.

Summarizing the above, a modal shift may certainly contribute towards the decarbonization of the transport sector, reducing logistics costs and making the logistics infrastructure system more efficient, but tailor-made policies are needed to support this.

Chapter 2: Technologies for sustainable mobility

The sustainable transformation of the freight transport sector hinges on the strategic integration and adoption of advanced technologies. The objective of this chapter is to delve into these technologies, capturing their status, inherent potential, associated challenges, and the strides made in implementing them around the world.

The discussion covers key areas, namely electric vehicles and alternative fuel vehicles, highly and fully autonomous vehicles, and the role of ITS and ICT infrastructure. Alternative fuel applications and the necessity for infrastructure modernization are scrutinized, bringing a spotlight on renewable and nuclear energy applications, and the entry points for various types of renewable energy into the transport sector are reviewed. The chapter also includes an overview of country-led initiatives in harnessing these technologies to promote sustainable mobility. This exploration aims to foster a robust understanding of the technology landscape underpinning greener mobility.

2.1 Electric vehicles and alternative fuel vehicles

A battery electric vehicle is basically an electric vehicle that only consumes compound energy stored in rechargeable battery packs with no other source, such as an hydrogen energy component or an internal combustion engine. They are, otherwise, called unadulterated electric vehicles or just electric vehicles or all-electric vehicles.

The use of battery electric vehicles along with the other types of hybrid vehicles may reduce substantially greenhouse gas emissions over the life cycle. For example, a life-cycle comparison of the greenhouse gas emissions from combustion, electric, and hydrogen trucks and buses in Europe[31] has revealed that battery electric trucks and buses outperform their diesel, hydrogen, and natural gas counterparts in reducing greenhouse gas emissions over their lifetime. The 2021 vehicle models produce at least 63 per cent lower lifetime emissions compared to diesel models. The high energy efficiency of electric powertrains shrinks their carbon footprint, making them a cleaner option even if the source of electricity is not fully clean. As the European Union continues to decarbonize, the emissions of the battery electric vehicles will continue to fall −projections show up to a 92 per cent reduction of emissions when 100 per cent renewable electricity is used.

[31] Adrian O’Connell, and others, "A comparison of the greenhouse gas emissions from combustion life cycle assessment of greenhouse gas emissions of European heavy-duty vehicles and fuels", ICCT White paper (February 2023). Available at https://theicct.org/publication/lca- greenhouse gas-emissions-hdv-fuels-europe-feb23.

Fuel cell battery trucks and buses run on hydrogen produced from fossil fuels reduce greenhouse gas emissions by 15 to 33 per cent compared to their diesel counterparts in the life-cycle analysis. The emissions reduction depends heavily on the source of hydrogen. With hydrogen solely produced with renewable electricity, emissions fall by up to 89 per cent. In contrast to battery electric trucks and buses, the emissions of hydrogen trucks and buses are not reduced significantly when using a non-renewable energy source −in this case, fossil hydrogen (fFigure 9).

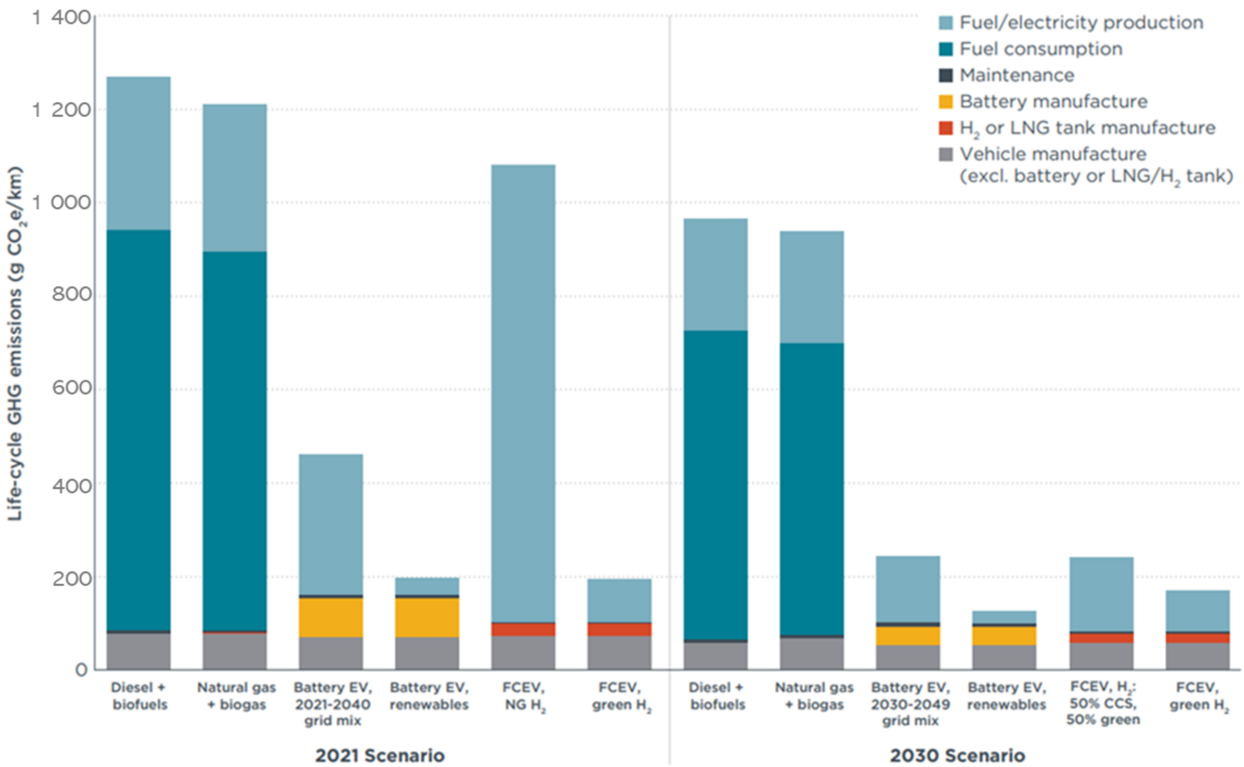

Figure 9 Life-cycle greenhouse gas emissions for 40-tonne tractor trailer in 2021 and 2030 scenarios[32]

Notes: H_2, hydrogen; LNG, liquified natural gas; EV, electric vehicle, FCEV, fuel cell electric vehicle.

Notably, natural gas trucks and buses provide marginal greenhouse gas reductions, ranging from 4 per cent to 18 per cent, compared to their diesel counterparts. The contribution of methane, a potent, which can leak from a vehicle and throughout the production and supply of the natural gas, is a significant driver of this powertrain's emissions. The benefits from natural gas disappear, however, when using a near-term global warming potential for methane, which results in them having a 0 to 21 per cent greater lifetime climate impact than diesel vehicles.

[32] Ibid.

The greatest portion of life-cycle greenhouse gas emissions produced by trucks and buses over their lifetime corresponds to the use (or fuel consumption) phase, not to the vehicle manufacturing. For diesel and natural gas trucks, the consumed fuel accounts for more than 90 per cent of their lifetime emissions. Accordingly, the higher vehicle and battery production emissions of battery electric trucks are offset by their high efficiency and low lifetime fuel cycle emissions.

Based on an IEA assessment,[33] the overall efficiency of mid-size battery electric vehicles in terms of greenhouse gas exhaust over the lifetime is twice as high vs, their internal combustion engine counterparts (Figure 10).

The "High-greenhouse Gas Minerals" case assumes double the greenhouse gas emission intensity for battery minerals (70 kgCO2-eq/kWh compared to 35 kgCO2-eq/kWh in the base case; other assumptions are the same).

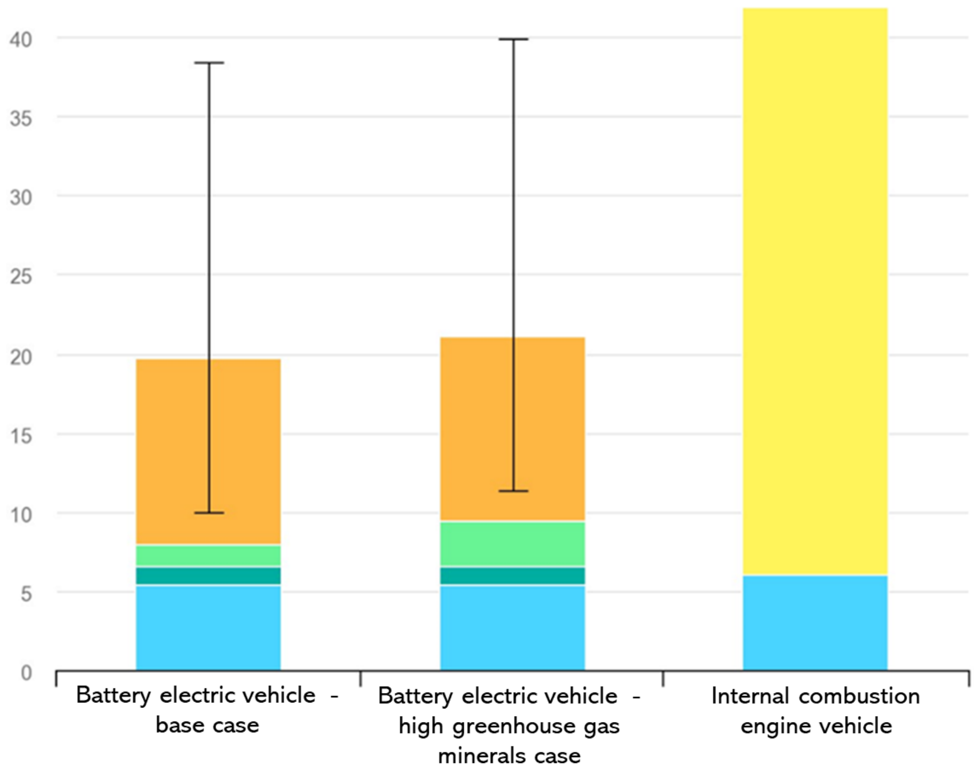

Figure 10 Comparative life-cycle greenhouse gas emissions of a mid-size battery electric vehicle and an internal combustion engine vehicle[34]

[33] International Energy Agency, "Comparative life-cycle greenhouse gas emissions of a mid-size BEV and ICE vehicle", 5 May 2021. Available at https://www.iea.org/data-and-statistics/charts/comparative-life-cycle-greenhouse-gas-emissions-of-a-mid-size-bev-and-ice-vehicle.

[34] Ibid.

The ranges shown for battery electric vehicles represent cases for charging with a static low-carbon (50 gCO2-eq/kWh) and high-carbon electricity mix (800 gCO2-eq/kWh). Vehicle assumptions: 200,000 km lifetime mileage; internal combustion engine fuel economy 6.8 l/100 km; battery electric vehicle fuel economy 0.19 kWh/km; battery electric vehicle battery 40 kWh NMC622. NMC622 = nickel manganese cobalt in a 6:2:2 ratio.

As the analyses show, greenhouse gas emissions can be reduced through different powertrain options (electric batteries, fuel cell batteries and combustion engines), and different fuel or energy choices (hydrogen, biofuels and natural gas). The climate impacts of these technologies and fuels vary over the lifetime of the vehicle model. From extracting and processing raw materials to operation and maintenance, some powertrain options are more energy intensive to build than their counterparts, while some fuel sources can produce higher emissions during their production or use.

The production and utilization of heavy-duty electric vehicles among ESCAP member States are gaining momentum as countries in the region prioritize sustainable transport solutions to address climate change and air pollution concerns. An overview of selected examples of production and utilization of for electric vehicle production and utilization in ESCAP countries is presented below.

China is a global leader in heavy-duty electric vehicle production and deployment. Major Chinese manufacturers, such as BYD, Dongfeng and Foton, have developed a wide range of electric truck models, from light-duty to heavy-duty trucks. The country's New Energy Vehicle (NEV) policy and various subsidies have accelerated the growth of the electric truck market. Its focus is on expanding charging infrastructure and the target to reach carbon neutrality by 2060 are expected to further boost the adoption of electric trucks.

In **Japan**, automakers, such as Mitsubishi Fuso, Hino and Isuzu, are developing electric trucks for domestic use and export markets. Mitsubishi Fuso has already launched the eCanter, a light-duty electric truck, and plans to expand its electric line-up. The country's commitment to achieve carbon neutrality by 2050 is likely to drive further investment in electric truck development and deployment.

The Republic of Korea has set ambitious goals for electrifying its transport sector. Hyundai, a leading automaker, has introduced the e-Mighty, an electric light-duty truck, and is developing a fuel cell electric truck to be called the XCIENT. The Government's target of increasing the number of electric commercial vehicles to 30,000 by 2025 and its plan to establish a nationwide electric vehicle charging network will support the growth of the electric truck market.

India has made significant progress in the electric vehicle sector; major players, such as Tata Motors and Mahindra, are developing electric trucks. Tata Motors introduced the Ultra T.7 electric light commercial vehicle, while Mahindra is working on electric versions of its commercial vehicles. The Government's Faster Adoption and Manufacturing of (Hybrid &) and Electric Vehicles (FAME) scheme and the National Electric Mobility Mission Plan (NEMMP) provide incentives for electric vehicle adoption, which are expected to encourage electric truck deployment.

In July 2022, **Viet Nam** announced Decision No. 876 under which it approved the Action Program on Green Energy Transition and Reducing Carbon and Methane Emissions in the Transport Sector, which aims to achieve net-zero emissions in the transport sector by 2050. The Decision sets specific national objectives related to promoting electric vehicle development:

- In the first period, from 2022 to 2030, promoting production, assembly, import, and use of electric vehicles and developing charging infrastructure.
- In the second period, from 2031 to 2040, the production, assembly, and import of fossil-fuelled cars, motorcycles and mopeds for domestic use;
- By 2050, requiring that 100 per cent of road motorized vehicles be powered by electric and green energy, and developing a charging infrastructure system across the country to meet the demand of people and businesses.

Several emerging markets and developing economies prioritize support for domestic production industries and fleet purchases through collaboration with international companies and international financing.[35]

Kazakhstan is transitioning to electric buses by establishing local manufacturing and assembly capacity, producing electric buses and minibuses, and purchasing hundreds of electric buses in partnership with international manufacturers. The country is developing a road map for manufacturing clean fuel vehicles, including zero-emission vehicles.[36]

Thailand has set production targets for electric vehicles, including setting goals to produce 3,000 electric buses by 2025 and achieve a 30 per cent share of electric vehicles for all produced vehicles, including urban buses, by 2030. The country is promoting the domestic production

[35] Tanzila Khan and others, “A critical review of ZEV deployment in emerging markets”, ICCT White Paper (February 2022). Available at ZEV-EMDE-white-paper-A4-v3.pdf (theicct.org)

[36] Tanzila Khan and Zifei Yang, “Electrification of heavy-duty vehicles in emerging markets”, ICCT Briefing (September 2022). Available at https://theicct.org/wp-content/uploads/2022/09/global-hvs-evs-zev-electrif-hdv-emerg-mkts-sep22.pdf.

industry and investments in electric vehicles, including electric buses and trucks, by offering incentives, such as corporate income tax exemptions and significantly reduced import duties for raw materials used to produce batteries. In Bangkok, the city transit's electric buses project was launched through a public-private partnership (PPP) initiative to produce new electric buses and retrofit old buses to become electric. Thailand is partnering with an international company to establish battery production plants for electric vehicles.[37]

Ukraine is manufacturing electric buses and trucks, and purchasing a fleet of electric buses through PPPs. The Government has signed an agreement with an international manufacturing company to build 5,000 electric buses and install 7,800 charging stations.[38]

Nepal is at an early phase of transition, but the country has actively supported bus electrification for many years. It has set electrification targets for various vehicle segments, including a goal that 60 per cent of purchases for public transportation be electric vehicles by 2030. The country is spearheading policy initiatives for deployment of electric buses, including fleet purchases, using government funding and international loans from the Asian Development Bank (ADB); incentivizing the assembly industry through government grants of free land; establishing assembly plants in partnership with international manufacturers to produce electric vehicles, including buses; and importing and distributing electric vehicles in the mini-bus and large bus segments.[39]

Cape Verde established a national electromobility strategy, the Electric Mobility Policy Charter, in 2019. Under the charter, it set a target for all new sales of medium and heavy-duty trucks and buses to be electric by 2035, to be achieved through incentives, international support and fleet purchase requirements. To alleviate the financial burden of electrification, the Government is mobilizing resources to subsidize public transportation electrification and charging infrastructure. A five-year (2020–2025) internationally supported project offers significant rebates to reduce the upfront costs of electric cars and buses. Moreover, from 2025, at least 50 per cent of new urban public transport purchases must be electric and rise incrementally to 100 per cent by 2035.[40]

In summary, the production and utilization of electric vehicles in ESCAP countries are on the rise, aided by strong government support and increasing investment in research and development. As more countries in the region set ambitious climate goals and adopt policies to

[37] Ibid.
[38] Ibid.
[39] Ibid.
[40] Ibid.

promote electric vehicles, the market for electric trucks is expected to expand significantly in the coming years.

2.2 Deployment of highly and fully autonomous vehicles

Autonomous vehicles, which are frequently referred to as self-driving or driverless cars, can travel without human intervention, equivalent to the highest level of fully automated systems. Technically, they use satellite positioning systems and various sensors, such as radar, ultrasonic, infrared and laser, to detect the surrounding environment.[41] These sensors interpret information to find appropriate paths considering obstacles and traffic signage by using wireless networks, digital maps, automated controls in vehicles and ICT.[42] Autonomous vehicles have existed primarily as prototypes, but they have recently become commercially available, and many cities are amending the legislation to permit automated driving on roadways. While the leading countries in ITS are developing such vehicles, some cities have already made noteworthy progress in this regard.

Connected vehicle applications have the potential to improve highway safety and mobility and reduce the environmental impact of highway travel. Connected vehicle technologies function within a vehicle-to-vehicle and vehicle-to-infrastructure data communications environment, supporting numerous applications to improve roadway safety and mobility. Connected vehicle technologies are expected to help reduce substantially thousands of fatalities recorded each year on roads and highways of the Asia-Pacific region.

The infrastructure-based and vehicle-based components of these applications are to be developed by different stakeholders. Infrastructure-based components are expected to be developed by State and local agencies responsible for building and maintaining the roadway infrastructure and their contractors, whereas vehicle-based components are expected to be developed by vehicle manufacturers, their tier one suppliers and aftermarket system suppliers.

Performance requirements encourage a synchronized and consistent exchange of data between infrastructure and vehicle application components to best capture the attention of the driver without confusion. Connected vehicles use many different communication technologies to communicate with the driver, other cars on the road, roadside infrastructure and the “Cloud”.

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[41] *Review of Developments in Transport in Asia and the Pacific: Towards Sustainable, Inclusive and Resilient Urban Transport* (United Nations publication, 2017).

[42] United Nations, Economic and Social Commission for Asia and the Pacific, “Policy framework for the use and deployment of intelligent transport systems in Asia and the Pacific”, Policy Brief, 8 February 2018. Available at https://www.unescap.org/resources/policy-framework-use-and-deployment-intelligent-transport-systems-asia-and-pacific-study.

This technology can be used to not only improve vehicle safety, but also to improve vehicle efficiency and commute times.

Highly and fully autonomous vehicles have the potential to improve energy efficiency in various ways, leading to lower energy consumption and reduced greenhouse gas emissions. Some of the energy efficiency advantages associated with highly and fully autonomous vehicles are the following:

- **Optimized driving behaviour:** Autonomous vehicles can employ advanced algorithms to optimize driving patterns, leading to smoother acceleration, braking and cruising. Research suggests that eco-driving algorithms can reduce energy consumption by 5-20 per cent compared to human-driven vehicles, depending on traffic conditions and vehicle types.
- **Improved traffic flow:** Autonomous vehicles can communicate with each other and with traffic management systems, enabling better coordination and synchronization. This vehicle-to-vehicle and vehicle-to-infrastructure communication can reduce traffic congestion and minimize stop-and-go traffic patterns. Studies have shown that improved traffic flow can lead to a 15-20 per cent reduction in energy consumption.
- **Eco-routing and navigation:** Autonomous vehicles can use real-time traffic data and advanced algorithms to determine the most energy-efficient routes, considering factors, such as road grade, congestion and weather. By optimizing routes to minimize energy consumption, it is estimated that eco-routing can reduce energy use by up to 10 per cent.
- **Platoon driving:** Autonomous vehicles can drive in tightly coordinated groups or platoons, which allows them to maintain a consistent speed and follow each other at closer distances. This reduces air resistance and improves aerodynamics, resulting in energy savings of 4-10 per cent for a lead vehicle and 10-20 per cent for following vehicles.
- **Lightweighting:** As autonomous vehicles eliminate the need for certain components, such as steering wheels, pedals, and mirrors, they can be designed to be lighter, further improving energy efficiency. A 10 per cent reduction in vehicle weight can result in a 6-8 per cent improvement in fuel economy.
- **Electrification and renewable energy integration:** Autonomous vehicles can facilitate the adoption of electric vehicles, as they can autonomously recharge during periods of low electricity demand or when renewable energy sources are abundant. This can lead to a more significant penetration of renewable energy in the transport sector and further reduce greenhouse gas emissions.

In summary, fully and highly autonomous vehicles have significant potential to enhance the energy efficiency of road freight transport. Innovative coupling with electric propulsion systems can substantially amplify this potential. Accordingly, autonomous vehicles, buttressed by supportive policy and infrastructure, constitute a pivotal element in the transition towards a sustainable and energy-efficient freight transport paradigm.

2.3 Deployment of intelligent transport systems and information communications infrastructure

Intelligent transport systems harness many technologies that aim to streamline traffic management and improve the safety, efficiency and convenience of transport systems. Simultaneously, ICT infrastructure provides the backbone that enables the data-driven decisions required in the increasingly interconnected world. The interplay of ITS and ICT can lead to remarkable advancements in freight transport, enabling real-time tracking, smart routing, fleet management and more. As a result, ITS can notably elevate energy efficiency and curtail emissions within freight transport, hinging upon the prowess of advanced communication technologies, data analytics and automation. Some of the fundamental avenues through which ITS can realize these goals encompass the following:

- **Optimized route planning:** ITS can help freight vehicles save up to 10-15 per cent in fuel consumption by using real-time traffic data and advanced algorithms to identify the most energy-efficient routes, according to the European Commission. This can also lead to a reduction in CO_2 emissions by a similar percentage.
- **Eco-driving assistance:** Studies have shown that eco-driving techniques can result in fuel savings of 5-20 per cent, depending on the vehicle type and driving conditions. Real-time feedback provided by ITS can help drivers maintain optimal speeds, gear shifting and acceleration patterns, which can significantly reduce fuel consumption and CO_2 emissions.
- **Vehicle-to-vehicle and vehicle-to-infrastructure communication:** By improving traffic flow and reducing congestion, vehicle-to-vehicle and vehicle-to-infrastructure communication can decrease fuel consumption by up to 10 per cent and reduce CO_2 emissions by up to 8 per cent, according to the United States Department of Transportation.
- **Load optimization:** Proper load optimization can result in a 5-10 per cent reduction in fuel consumption and CO_2 emissions, as reported by ITF. Efficiently distributing cargo within freight vehicles ensures they operate at their most energy-efficient capacity, leading to fewer trips and lower fuel consumption.
- **Fleet management:** A study by the National Renewable Energy Laboratory indicates that fleet management systems can lead to a reduction of up to 15 per cent in fuel consumption and emissions by providing real-time monitoring of vehicle performance and driver behaviour.
- **Autonomous vehicles:** Autonomous freight vehicles can improve energy efficiency by 10-15 per cent through optimized driving behaviours and platooning, according to a study by the National Renewable Energy Laboratory. Additionally, better integration with

electric vehicle charging infrastructure could further enhance the energy efficiency of these vehicles.

- **Intermodal transport:** The European Environment Agency reported that shifting 20 per cent of freight from road to rail and inland waterways could result in a 7 per cent reduction in CO_2 emissions from the transport sector. By optimizing the use of different transport modes, ITS can facilitate more energy-efficient and environmentally friendly freight transport systems.

Within the landscape of the ESCAP countries, ITS already commands a vital role in the quest for enhanced energy efficiency and the reduction of emissions. Not merely an abstract concept, ITS applications have taken tangible forms in the region, manifesting in numerous implementations that have begun to influence the way freight transport operates. The following are some illustrative instances of these ITS applications deployed across the region.

China has launched the National Intelligent Transportation System Development Plan (2020−2025), to upgrade and optimize traffic management systems, enhance connectivity and improve energy efficiency. In the city of Shenzhen alone, the implementation of ITS has contributed to a reduction in fuel consumption and emissions by approximately 10 per cent. Major Chinese ports, such as Shanghai, Shenzhen and Ningbo-Zhoushan, have implemented advanced ITS technologies to optimize port operations and reduce fuel consumption and emissions. These technologies include automated container handling systems, smart traffic management and real-time monitoring of port emissions. In addition, China has deployed ITS technologies along its vast highway network to monitor traffic flow, identify congestion and provide real-time traffic information to drivers. The Government of China has implemented policies and incentives to encourage the adoption of ITS technologies in the freight transport sector. Among them are subsidies for the development and deployment of smart logistics solutions and support for research and development in ITS technologies.

Some significant initiatives implemented by **Georgia** are the Anaklia Deep Sea Port on the Black Sea coast, as part of the country's effort to enhance its role as a regional transport and logistics hub. The project, with an estimated cost of $2.5 billion, will feature advanced ITS technologies, including automated container handling and port management systems. The country is investing in the improvement of its primary transport corridor, the East-West Highway, which connects the Black Sea coast with Azerbaijan. The project includes the deployment of ITS technologies, such as electronic toll collection systems, traffic management system and real-time traffic information, which will help reduce congestion, improve fuel efficiency and lower emissions from freight transport along this vital corridor.

India is working on the National Intelligent Transportation Systems Architecture and Standards, which aims to streamline ITS implementation across the country. In 2017, India launched the Green Highways Policy, which includes ITS provisions, to optimize freight movement and reduce fuel consumption. In addition, the country is working on the Delhi-Mumbai Industrial Corridor project, which incorporates ITS technologies for efficient freight transportation, potentially reducing logistics costs by 10-15 per cent.

Japan has a long history of implementing ITS technologies for better transportation management. The country's Eco-Drive Management System, which was adopted by several trucking companies, helps optimize routes, monitor driving behaviour and provides real-time feedback to drivers, resulting in a reported 5-10 per cent reduction in fuel consumption.

Kazakhstan has deployed the “single window” system, which streamlines customs processes and reduces waiting times at border crossings by up to 30 per cent. Electronic toll collection has been in operation since 2013 to cover more than 6,500 kilometres of primary highways, mostly using an open gate solution to avoid deceleration at toll plazas. The electronic toll collection system charges vehicles based on the distance travelled, which encourages more efficient use of transportation resources and incentivizes the use of newer, more fuel-efficient trucks. In turn, this reduces the overall environmental impact of freight transport. The country has also been working with ADB to implement the CAREC Program, which focuses on improving transport connectivity and facilitating trade in the region. Through this Programme, the country has invested billions in the modernization of its transport infrastructure and adopting best practices in ITS implementation.

The Russian Federation has been working on creating digital transport corridors to improve the efficiency of freight transport across the region. By implementing ITS solutions, such as real-time tracking, electronic documentation and optimized route planning, these digital corridors are intended to reduce fuel consumption and emissions. Another example of intense ITS usage is the Moscow Traffic Management Centre, which uses the solutions to manage traffic flow in the city. By implementing adaptive traffic signal controls, real-time traffic monitoring and route optimization, the Centre helps significantly reduce congestion and improve overall efficiency in urban transport. In addition, the country has been actively investing in research and development of autonomous vehicles. Companies, such as Yandex and Kamaz, have already tested autonomous vehicles on public roads. As the technology matures, autonomous vehicles are expected to contribute towards improving energy efficiency and reducing greenhouse gas emissions in the transport sector.

The Republic of Korea has leveraged ITS technologies within its freight sector to boost energy efficiency and mitigate emissions. A prominent example is the Smart Highway System, operational on several major highways, which employs real-time traffic data to streamline freight transport. Reportedly, this system has decreased travel times by 6.4 per cent and cut truck fuel consumption by 3.5 per cent. Key among the country's policy framework is the ITS Promotion Act. This Act lays the groundwork for the electric vehicle evolution and deployment of ITS by setting out to enhance traffic safety, optimize transportation efficiency and diminish environmental impact through advanced technologies and ICT. Another significant initiative is the Smart Transportation System Development Project, which is centred on the creation and application of intelligent transportation technologies and systems. The objective of the project is to enhance traffic management, improve public transportation services and alleviate congestion.

In the **United States**, the Environmental Protection Agency-led SmartWay Transport Partnership, which encompasses ITS elements, has helped partners save more than 44.5 billion litres of oil and $37.5 billion in fuel costs since its inception in 2004. As a result, SmartWay partners have reduced CO_2 emissions by 134 million metric tons, nitrous oxide (NOx) emissions by 2.6 million tons and PM emissions by 124,000 tons. Another example is the Connected Vehicle Pilot Deployment Program, which aims to test and deploy connected vehicle systems in various regions across the country. According to the National Highway Traffic Safety Administration, connected vehicle technologies can reduce unimpaired vehicle crashes by up to 80 per cent. In addition, the United States has been actively investing in the development and testing of truck platooning technologies. By maintaining an optimal following distance between trucks using vehicle-to-vehicle communication, platooning can save up to 10 per cent of fuel for the following truck and 4.5 per cent for the lead truck, according to the North American Council for Freight Efficiency.

As indicated through the above examples, the deployment of ITS can significantly bolster the energy efficiency of freight transport. By facilitating real-time information-sharing, enhancing traffic management and enabling more streamlined logistics processes, ITS can contribute towards reducing fuel consumption, decreasing idling times and promoting overall operational efficiency. Moreover, the potential for ITS to be integrated into other innovative technologies, such as autonomous vehicles, offers a promising avenue for further advancements. Given the transformative benefits, the exploitation and expansion of ITS in freight transport operations are not just foresighted, but are strongly advocated. Amplifying ITS deployment can robustly thrust the freight transport industry towards enhanced sustainability, improved energy efficiency and alignment with wider global commitments to curtail greenhouse gas emissions.

2.4 Application of alternative fuels

The growing need for environmental sustainability has significantly increased the demand for alternative fuels in transportation. These alternative fuels, such as electricity, biofuels, hydrogen, and natural gas, offer a wide range of benefits, including a reduction in carbon and other pollutant emissions, improved fuel economy and the potential for domestic production, which can enhance energy security. Recent trends suggest a growing global commitment to incorporate alternative fuels into the mainstream transport sector, supported by the considerable advancements in research, policy formulation and infrastructure development.

Alternative fuels for road transportation, notably biofuels, can be derived from a range of sources; the classification of them depends on various factors, such as feedstock, greenhouse gas emissions savings, technology maturity and the product type and quality.

The feedstock used for biofuel production plays a critical role in how it is classified. Conventional biofuels are predominantly sourced from feedstocks that also serve as food or animal feed. On the other hand, advanced biofuels leverage agricultural or forestry residues, organic waste and non-food or non-feed energy crops as feedstock. This distinction is necessary to identify biofuels, as the production of them may interfere with food or animal feed supply.

A significant factor that differentiates conventional and advanced biofuels is their capacity for greenhouse gas emissions savings. Biofuels that substantially reduce greenhouse gas emissions are considered advanced. In contrast, biofuels, whose potential for greenhouse gas savings, falls below a certain threshold, are categorized as conventional.

Furthermore, the maturity of the technology involved in biofuel production is a determining factor. Conventional biofuels are products of widely deployed conversion technologies. Advanced biofuels emanate from technologies that are in their nascent stages of development, even if they have already been entered into the first commercial plants.

The final product's type and quality also play a role in this classification. Advanced biofuels, also known as "drop-in" biofuels, mimic conventional fuels, such as gasoline, diesel, bunker and jet fuels. They can be blended in large proportions with these fuels or used purely. This characteristic distinguishes them from biofuels, whose properties restrict them to low blends in unmodified engines and pose compatibility issues with existing fuel distribution networks. Understanding these distinguishing factors is crucial for policymaking, and the development and deployment of biofuels in the pursuit of more sustainable and energy-efficient road transportation.

To ensure safety, efficiency and performance, fuels deployed in transport sectors must adhere to established national or international standards. Consequently, the blending of advanced biofuels with conventional fossil fuels is predicated on their specific properties. This means that most liquid biofuels are expected to be integrated with fossil fuels at varying stages in the distribution chain, based on the type of biofuel in question. Consumers then have access to these biofuel blends through the existing refuelling infrastructure. Table 8 elucidates the most prevalently used biofuels and alternative fuels, providing insights into their characteristics, applications and potential contribution to a sustainable and energy-efficient transport landscape.

Table 8 Examples of biofuel classification based on different definitions[43]

	Feedstock definition	Technology definition	Product definition
Conventional biofuels	• sugar crops • starch crops • vegetable oils	• transesterification • fermentation • hydrogenation	• FAME • ethanol • methanol
Area of ambiguity	• energy crops • used cooking oil • animal fats • tall oil		• butanol
Advanced biofuels	• algae • forest residues • agricultural residues • municipal solid waste	• cellulose fermentation • gasification • pyrolysis	• hydroprocessed esters and fatty acids • Fischer-Tropsch diesel and jet fuels

[43] International Renewable Energy Agency, *Innovation Outlook: Advanced Liquid Biofuels* (Abu Dhabi, 2016).

Table 9 gives a description of the different liquid biofuel products.

Table 9 Liquid biofuel product description and applications in transport[44]

Product	Description	Application/replacement	Blending limits
Methanol	Single carbon alcohol Energy density approximately 50 per cent lower than gasoline	May be blended with gasoline for use in road transport or converted to methyl tert-butyl ether for blending with gasoline (where vapour pressure limits restrict methanol blending). Use in rail and shipping is limited to dual-fuel converted engines. Methanol may be converted to dimethyl ether (DME) for use as a diesel replacement or to gasoline and diesel range HC. Barriers to its use include concerns about human toxicity and corrosive effects on conventional engines.	In the United States, regulations allow a 0.3per cent blend of methanol in gasoline or 2.75 per cent methanol in gasoline with equal volumes of butanol (ASTM D 4814-16b). European Union gasoline standards allow up to 3 per cent methanol in gasoline (EN 228). ASTM D5797-16 standards for 70-85 per cent methanol in gasoline are being updated. In China, a national standard for 85 per cent methanol in gasoline exists (GB/T 23799-200), but standard fuel grades vary across provinces.
Ethanol	Two carbon alcohol Energy density approximately 30 per cent lower than gasoline.	May be blended with gasoline for use in road transport or converted to ethyl tert-butyl ether for blending with gasoline (where vapour pressure limits restrict ethanol blending). Ethanol may be converted to jet fuel range HC via chemical catalysis. Barriers to expanding its use include corrosion in conventional engines at higher blends and incompatibility with existing fossil fuel pipelines.	In Europe and the United States, fuel standards allow for up to 10-15per cent ethanol in gasoline (EN 228, ASTM D 4814). In Brazil, regulation allows up to 27.5 per cent ethanol in gasoline. Flex-fuel vehicles may use blends of up to 85 per cent ethanol in gasoline or 100 per cent ethanol.

[44] Ibid.

Product	Description	Application/replacement	Blending limits
Butanol	Four carbon alcohol Energy density similar to gasoline.	May be blended with gasoline or diesel for use in road transport.	United States fuel standard allows up to 16 per cent butanol in gasoline (ASDM D 4814). European Union fuel standard allows up to 15 per cent in gasoline (EN 228).
FAME-biodiesel	Fatty acid methyl ester. Energy density similar to diesel.	May be blended with diesel for use in road, rail and shipping. Barriers to expanding its use include poorer cold flow properties, which limit use in some areas.	European Union fuel standards allow up to 7 per cent in diesel (EN 590). United States fuel standards allow up to 5 per cent in diesel (ASTM D 975).
Fischer Tropsch fuels	Range of paraffinic HC. Energy density similar to diesel.	Depending on the hydrocarbon chain lengths, Fischer-Tropsch products may be blended with gasoline, diesel or jet fuels for use in road, rail, shipping or aviation.	There are no regulatory limits to blending Fischer-Tropsch diesel. Fischer-Tropsch kerosene is certified for maximum 50per cent blends with jet fuel (ASTM D7566).
Hydrotreated esters and fatty acids	Range of straight chain paraffinic HC energy density similar to diesel.	Depending on the hydrocarbon chain lengths, it may be blended with diesel or jet fuels for use in road, rail, shipping or aviation.	There are no regulatory limits to blending hydro-treated esters and fatty acids in diesel. However, it is blended with conventional diesel fuel to meet fuel specifications. International standard ASTM D 7566 allows up to 50 per cent hydro treated esters and fatty acids in jet fuel.

Product	Description	Application/replacement	Blending limits
Synthetic paraffinic fuel	This category includes straight-chain and branched chain HC of various chain lengths (includes Fischer-Tropsch diesel). Energy density similar to diesel or kerosene.	Depending on the hydrocarbon chain lengths, it may be blended with diesel or jet fuels for use in road, rail, shipping or aviation.	Iso-synthetic paraffinic fuels are certified for maximum 10 per cent blends with jet fuel (ASTM D7566).
Synthetic aromatic fuel	Hydrocarbon fuel containing aromatic compounds.	May be blended with jet fuel for use in aviation. Aromatic compounds are an important component of jet fuel and not found in other biofuels. This route may enable fully renewable jet fuels.	ASTM certification currently under way.

Alternative gas fuels encompass a broad spectrum of energy sources that, when used for transportation, can contribute towards improved energy efficiency and reduced greenhouse gas emissions. These fuels, which vary widely in their chemical composition and physical properties, provide alternatives to traditional petroleum-based fuels, such as gasoline and diesel.

One of the most well-known and extensively used alternative gas fuels is natural gas. Composed primarily of methane, natural gas can be used in vehicles as compressed natural gas (CNG) or liquefied natural gas (LNG). CNG is commonly used in passenger vehicles and light-duty trucks, while LNG, due to its higher energy density, is typically used for heavy-duty and long-haul trucking applications. Natural gas vehicles produce significantly less tailpipe emissions than their gasoline or diesel counterparts, making them a popular choice in urban areas with stringent air quality standards.

Another increasingly important alternative gas fuel is hydrogen. When used in a fuel cell, hydrogen can generate electricity with water being the only by-product, making it a zero-emission fuel source. Fuel cell electric vehicles powered by hydrogen are becoming more common, particularly in the passenger vehicle sector, but they are also being explored for use in heavy-duty freight applications.

Biogas, another alternative gas fuel, is produced through the anaerobic digestion or fermentation of organic matter, including manure, sewage, municipal waste or plant material. Biogas, which primarily consists of methane, can be upgraded to a quality similar to natural gas and used as a vehicle fuel.

The application of these alternative gas fuels in transportation has can substantially decrease greenhouse gas emissions, improve energy security by diversifying fuel sources and reduce reliance on fossil fuels. Despite the challenges related to infrastructure, fuel storage and vehicle availability, the growing interest in and implementation of these alternative fuels offer a promising future for their use in the transport sector.

Biofuel applications display considerable variation across different countries, reflecting the diversity in national policies, resource availability, technological capabilities and environmental objectives. This heterogeneity underscores the necessity for a nuanced understanding of the real-world implementation of biofuels. To illustrate this breadth and depth of biofuel applications, below is a selection of country-specific cases to provide insights into the diverse approaches and experiences related to biofuel deployment around the world:

The European Union blends biodiesel at the pump at approximately 7 per cent blend rates, or B7. This blend level is expected to continue to be the standard diesel blend. Biodiesel blends of 20 per cent, or B20, were also approved for sale in 2015 under EN 16709 fuel standards and are available in separate fuelling pumps at some locations. In the European Union, biodiesel is sourced from three primary feedstocks: roughly 40 per cent of biodiesel is sourced from rapeseed; 20 per cent from used cooking oil; 20 per cent from palm oil; and the remainder from soybean oil, animal fats, and other feedstocks, such as sunflower oil.[45]

Japan is a pioneer in hydrogen fuel cell vehicles. Under the country's "Basic Hydrogen Strategy" 200,000 hydrogen-powered vehicles are targeted to be on the road by 2025. The Hydrogen Economy Roadmap of the **Republic of Korea** envisions 6.2 million fuel cell vehicles by 2040. The Technology Roadmap for Energy-Saving and New Energy Vehicles of **China** also includes the development of hydrogen fuel cell technology. Renewable energy can be used in in hydrogen production through water electrolysis, making it a sustainable option for transportation.

Central Asian countries have made some progress in the development of biofuels, but the industry is still in its early stages, and progress has been slow. The countries in this subregion, Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, Tajikistan and Uzbekistan, have abundant natural resources and significant potential for biofuel production, but many obstacles are impeding the development of this industry. One of the main challenges is the lack of government incentives and regulations to encourage private investment in biofuel production. Additionally, the low price of conventional fuels in the subregion makes it difficult for biofuels to compete economically. Despite these challenges, many initiatives have been launched in the subregion to promote the development and application of biofuels.

Kazakhstan has set a target to produce 30 per cent of its energy from renewable sources by 2030, including biofuels. The country is investing in the construction of biofuel plants and is exploring the use of feedstocks, such as rapeseed, sunflower and soybean, for biodiesel production. It has constructed biofuel plants, including a biodiesel plant in the city of Aktau and a biogas plant in the city of Almaty. The biodiesel plant has a production capacity of 50,000 tons per year and uses sunflower and soybean oil as feedstocks. The biogas plant uses organic waste to produce biogas, which is used for heating and to generate electricity. A bioethanol plant was established in the Akmola region, which has the capacity to produce 30,000 tons of bioethanol per year. The plant uses corn as a feedstock for bioethanol production, and the bioethanol

[45] Jane O'Malley, "Air quality impacts of biodiesel in the European Union", ICCT fact sheet (November 2021). Available at https://theicct.org/publication/air-quality-impacts-of-biodiesel-in-the-european-union/.

produced is used to meet domestic demand for fuel. In 2020, the Government signed a memorandum of understanding with a Chinese company for the construction of another biodiesel plant with a production capacity of 600,000 tons per year.

The Government of Kazakhstan has provided subsidies to produce biodiesel, helping to prompt several private companies to invest in biofuel production in the country. It has also established a bioenergy cluster in the city of Astana, which aims to create a sustainable bioenergy industry in the country, including the production of biofuels, biogas and other bioenergy products.

Kyrgyzstan has a lot of livestock, and their waste can be a valuable source of biogas. Several pilot projects are being implemented in the country to test the feasibility of using biogas for cooking and heating, particularly in rural areas where access to energy is limited. One such project is entitled "Promoting Sustainable Energy Solutions in the Kyrgyz Republic", which aims to increase the use of renewable energy, including biogas, in the country. The project has helped to establish small-scale biogas plants in rural areas, and has also provided training and support for local communities.

Tajikistan has been exploring the use of waste-to-energy technologies, including the conversion of agricultural waste and other organic waste into biogas and other forms of renewable energy. These technologies are being used to provide electricity and heat to local communities and businesses. One project that is using waste-to-energy technologies is the Waste-to-Energy for Rural Development project, which is focused on converting agricultural waste into biogas and other forms of renewable energy in the Gorno-Badakhshan Autonomous Region of Tajikistan. The project has helped to establish small-scale biogas plants in the region, which have the capacity to produce enough biogas to meet the energy needs of a typical household.

Turkmenistan has also shown interest in the development of biofuels and has signed agreements with international companies for the construction of biofuel plants in the country. The Government has also expressed its commitment to develop renewable energy sources, including biofuels.

In **Uzbekistan**, a bioethanol plant was constructed in 2019 with a production capacity of 100,000 tons of bioethanol per year. The plant uses corn as the primary feedstock and is expected to help reduce the country's dependence on imported fuel. The Government has set a target to produce 3 per cent of the country's energy from renewable sources, including biofuels, by 2020 and to generate 25 per cent of the country's energy from renewable sources by 2030.

The Russian Federation adopted a law requiring a 5 per cent blend of biofuels in gasoline and diesel fuel, which came into effect in 2015, and the Government has announced plans to increase the share of biofuels in transportation fuels to 11 per cent by 2025. The country's main biofuel feedstocks are rapeseed, soybean, sunflower and corn. The country also has great potential to produce biofuels from forestry residues, agricultural waste and other biomass sources. In August, 2021, the Government introduced a document entitled "The concept for the development of hydrogen energy". The main goals stated in the document are to unlock the national potential in the production and export of hydrogen and to become one of the leading countries in this industry. Among the initiatives proposed in the document are the production of low-carbon hydrogen, the establishment of equipment and component manufacturers, and developing the infrastructure for hydrogen storage and transportation. It also provides for the creation of at least three production clusters in the region.

Countries in South-East Asia are making significant strides in promoting renewable energy sources for the freight transport sector, with a specific focus on biofuels. Notable policies and programmes related to this in Indonesia, Malaysia, the Philippines, Singapore, Thailand and Viet Nam, underscore the region's dedication to a sustainable future in freight transport.

Indonesia and **Malaysia** are the world's largest producers of palm oil, which is used to produce biodiesel. Both countries have policies in place to support the use of biodiesel; Indonesia mandated the use of a 30 per cent blend of biodiesel (B30) in the country's transportation sector in 2020 and Malaysia mandated the use of a 10 per cent blend of biodiesel (B10) in the country's transportation sector since 2019. Palm oil biodiesel is seen as a more sustainable alternative to fossil fuels, as it produces less greenhouse gas emissions and can be produced from a renewable resource. However, concerns have been raised about the environmental impact of palm oil production, including deforestation and habitat destruction.

Similarly, **Thailand** is actively embracing biofuel under its Alternative Energy Development Plan (AEDP) for 2015−2036. The country's ambitious plan aims to utilize 11.3 million litres of biodiesel and 9 million litres of ethanol per day by 2036. Currently, Thailand promotes the use of B7 biodiesel in the transportation sector, but it plans to transition to B10 biodiesel and B20 biodiesel.

The Philippines has legislated the use of biofuels in the Biofuels Act of 2006. The Act stipulates a minimum 1 per cent biodiesel blend (B1) and a 5 per cent bioethanol blend (E5) for all diesel and gasoline fuels sold in the country. Over time, the country aims is to raise the bioethanol blend to 10 per cent (E10) and the biodiesel blend to 2 per cent (B2).

The Biofuel Development and Utilization Project of Viet Nam focuses on replacing 1 per cent of total diesel consumption with biodiesel by 2025 and 5 per cent by 2050. As of 2020, Viet Nam has mandated the use of B5 biodiesel nationwide.

Finally, **Singapore**, a highly urbanized country, which has limited potential for biofuel production, encourages the use of biodiesel through its Sustainable Singapore Blueprint. The city-State has set a target to achieve a 35 per cent improvement in energy efficiency from 2005 levels by 2030.

In conclusion, the concerted endeavours undertaken by the highlighted countries underscore the tangible possibilities and efficiency of incorporating biofuels into the transport landscape, with a particular emphasis on the freight sector. These initiatives, bolstered by dedicated governmental funding and clear temporal benchmarks, manifest a robust commitment towards the progression of a more sustainable and environmentally friendly freight transport framework. These examples are encouraging precedents for other countries embarking on similar sustainable journeys, thus promoting the global adoption of cleaner fuel alternatives in the freight industry.

2.5 Renewable and nuclear energy applications

Definition and main types of renewable energy sources

Renewable energy, also known as clean energy, is derived from natural sources or processes that are continuously replenished. It offers a more sustainable alternative to conventional fossil fuels, resulting in reduced greenhouse gas emissions and less environmental degradation.[46] The use of renewable energy is crucial for achieving long-term sustainable development by providing power for various sectors, including transportation.[47]

There are several types of renewable energy sources, each with its own technicalities and applications. Among them are solar energy, wind energy, water energy, geothermal energy, biomass and biofuels; the specifics of biofuels was already dissected in previous section.

Solar energy is one of the most rapidly growing renewable energy sources worldwide. Solar power is harnessed using photovoltaic (PV) cells that convert sunlight directly into electricity. Large-scale solar power plants, such as the Tengger Desert Solar Park in China − the world's largest solar power plant with a capacity of 1,547 MW − demonstrate the potential of this

[46] Tanner Güney, "Renewable energy, non-renewable energy and sustainable development", *International Journal of Sustainable Development and World Ecology*, vol. 5, No, 26 (2019), pp. 389−397.
[47] Ibid.

technology. Moreover, India has embarked on an ambitious plan with the Jawaharlal Nehru National Solar Mission from which it aims to produce 100 GW of solar power by 2022.

Wind power is harnessed by wind turbines that convert the kinetic energy from wind into mechanical power. This mechanical power can be used for specific tasks, such as grinding grain or pumping water, or be converted into electricity by a generator. China is the global leader in wind energy, with an installed capacity of over 237 GW in 2020. The Gansu Wind Farm Project aims to increase this capacity to 20,000 MW by the end of 2025.

Hydroelectric power, the most mature and widely used renewable energy source, involves harnessing the kinetic energy of moving water. The Three Gorges Dam in China is the world's largest hydroelectric power station in terms of installed capacity (22,500 MW). Other countries with significant hydroelectric power are Brazil, Canada and the United States.

Geothermal energy exploits the Earth's natural heat in the form of steam and hot water to drive turbines and produce electricity. Countries located along the Pacific Rim's "Ring of Fire," such as Indonesia and the Philippines, have significant geothermal potential. Iceland is another country that uses geothermal energy extensively, which accounts for approximately 30 per cent of its electricity production.

Nuclear energy is generated using heat produced during nuclear fission when atoms split apart. France gets approximately 70 per cent of its electricity from nuclear energy, while in the United States, it's approximately 20 per cent. China, with 50 nuclear power reactors in operation and more under construction, is notable for its commitment to nuclear power. The challenge for nuclear energy remains in managing the radioactive waste it produces and addressing safety concerns.

In the realm of freight transport, hydropower, sola, and wind power are the most promising renewable energy sources. However, it's crucial to distinguish between renewable energy and sustainable energy, as the two are not identical. Existing research underscores the necessity for multidimensional approaches to address the unintended outcomes of renewable energy measures, encompassing economic, environmental and social ramifications.[48] Furthermore, shifting to sustainable energy sources demands deliberate reflection on economic growth strategies and the promotion of inclusive development.[49]

[48] Alan Brent, “Renewable energy for sustainable development”, *Sustainability*, vol. 12, No.13 (2021), 6920.
[49] Festus Bekun, “Mitigating emissions in India: accounting for the role of real income, renewable energy consumption and investment in energy”, *International Journal of Energy Economic and Policy*, vol.1, No 12 (2022), pp. 188−192.

Potential entry points for renewables to the transport sector

Transport remains the sector the lowest share of using renewables; more than 95 per cent of energy needs came from oil and petroleum products and less than 4 per cent were from biofuels and renewable electricity in 2018.[50] The share of energy from renewable sources used for transport in the European Union increased from less than 2 per cent in 2005 to 10.2 per cent in 2020.[51] The data indicate that in 2021, the share of energy from renewable sources used for transport in the European stabilized at around the same level (10.2 per cent). Progress in integrating renewable energy sources among the European Union member States varies significantly, from 5.6 per cent in Greece to 34 per cent in Sweden.

The ESCAP region, despite having a very large share of global coal generation (76 percent) and expansion plans,[52] has made significant progress towards developing renewable energy sources, as many countries are implementing policies and initiatives to promote sustainable energy generation, including for transport.

Policies to promote renewable energy in the transport sector continue to focus mainly on road transport, giving less emphasis on rail, aviation and shipping, even though these industries are large energy consumers. As of the end of 2019, only 46 countries had some form of renewable energy target for transport, and just 11 per cent of the countries included measures for renewables-based transport in their nationally determined contributions towards reducing emissions under the Paris Agreement. Heavy-duty vehicles account for three quarters of the energy demand and CO_2 emissions from freight, yet they remain the most challenging type of road vehicle for which to find cost-effective energy alternatives.

Renewable energy sources hold significant potential for transforming the transport sector, especially freight transport, into a more sustainable and energy-efficient system. To fully leverage this potential, it is important to pinpoint the strategic entry points for the integration of these energy sources. These avenues, when effectively exploited, can facilitate the seamless adoption of renewable energies, bolstering the strategic planning and execution of sustainable energy initiatives.

[50] SLOCAl, "Renewable energy in transport", Transport and change global status report 2nd edition (2021). Available at https://tcc-gsr.com/responses-to-policies/renewable-energy-in-transport/.
[51] European Environment Agency, "Use of renewable energy for transport in Europe", 24 October 2023. Available at https://www.eea.europa.eu/ims/use-of-renewable-energy-for.
[52] United Nations, Economic and Social Commission for Asia and the Pacific. *Coal Phase Out and Energy Transition Pathways for Asia and the Pacific* (ST/ESCAP/2936, 2021).

The primary point of integration is the application of “green” electricity generated from renewable energy technologies to power electric vehicles. This application extends across various types of vehicles, from light-duty electric cars to heavy-duty electric trucks and buses. As electric vehicle technology continues to mature and electric vehicle adoption rates increase, this entry point will increasingly contribute towards a reduction in emissions from the transport sector.

A secondary entry point is the deployment of renewable energy in the production of “green” hydrogen, which can be used in fuel cell electric vehicles. While this technology is still in its developmental stages, hydrogen fuel cells offer great promise in terms of their potential for energy storage and high-energy density, making them particularly suitable for heavy-duty and long-haul transport applications.

A third integration pathway is through the production of advanced biofuels using sustainable biomass feedstocks. These biofuels can serve as direct replacements for conventional fossil-based fuels, enabling the decarbonization of existing vehicles and infrastructure without requiring significant modifications.

Finally, renewable energy technologies can be integrated into the transport infrastructure itself. For example, solar panels can be installed at transport hubs or along transport routes, providing a source of locally generated “green” electricity to power infrastructure facilities or to supply charging points for electric vehicles. Similarly, wind turbines can be used in areas with favourable wind conditions.

Each of these entry points represents an opportunity to harness the power of renewable energies to propel the transport sector towards a more sustainable future. However, the successful implementation of these strategies requires comprehensive policy support, significant investment and strong stakeholder collaboration, along with continued research and development to overcome existing technical and economic barriers. By considering these factors, a transition towards sustainable energy use in freight transport will be smoother.

Transitioning into the discussion of specific country examples, it's pertinent to note that while the direct linkage of renewable sources to transport has been relatively infrequent, the uptake of electricity in the transport sector has persisted through 2021 and 2022. This trend signifies promising avenues for coupling transport with renewable energy. Although fiscal measures, such as public subsidies, can help mitigate the costs associated with the adoption of sustainable transport strategies, the reality is that government support has remained somewhat restrained.

Paradoxically, in many jurisdictions, substantial subsidies are still being allocated towards fossil fuels, or these energy sources are inadequately taxed. This practice results in artificially suppressed retail prices of petrol, making them lower than the global market prices for crude oil, and, in turn, hampers proactive climate actions. Moving forward, tackling these systemic issues is critical in realizing the full potential of renewable energy in transport.

As an example, the Government of **Kyrgyzstan** has set a goal to generate 60 per cent of the country's electricity from renewable sources by 2030. This could support the transition towards more sustainable and green mobility options, such as electric vehicles and public transportation powered by renewable energy. To achieve this goal, the Government is implementing various renewable energy projects, including the construction of wind and solar power plants. The city of Bishkek had planned to acquire 120 electric buses in 2023 and establish workshops for their maintenance, charging stations and the construction of transformer stations. The Ministry of Transport and Communications is developing a project proposal to be submitted to the Green Climate Fund for the purchase of electric buses for intercity passenger transport and the creation of electric charging infrastructure. As part of the ADB project, the Almaty-Bishkek Economic Corridor, transporting passengers between Bishkek and Almaty using electric buses and creating electric charging infrastructure is being considered.

China, as the world's largest emitter of greenhouse gases, has made substantial efforts to promote renewable energy. The country implemented the renewable portfolio standard policy in 2019, which aimed to increase the share of renewable energy in the power generation mix.[53] The effectiveness of this policy in promoting renewable energy consumption and reducing the need for government subsidies is still uncertain. However, the implementation of the renewable portfolios standard policy, along with feed-in-tariff mechanisms, has contributed towards the growth of renewable energy capacity in China.[54]

In other Asian countries, the adoption of renewable energy sources has also gained momentum. **Pakistan** has allocated a portion of its annual development budget for the development of renewable energy, signalling its commitment to promoting sustainable energy generation.[55] **Bangladesh** has set a target to increase the share of renewable energy to 10 per cent by 2020.[56]

[53] Chuanwen Dong and others, "Investigating synchromodality from a supply chain perspective", *Transportation Research Part D Transport and Environment*, vol 61 (June 2017).
[54] Ibid.
[55] Nilhary Neupane and others, "The role of renewable energy in achieving water, energy, and food security under climate change constraints in South Asia", *Frontiers and Sustainable Food Systems*, vol. 6 (2022).
[56] Ibid.

The Republic of Korea is undergoing an energy transition, which entails reducing its reliance on nuclear and coal-fired power generation and expanding into renewable energy sources.[57] The public has shown support for this transition, indicating a willingness to accept an increase in their monthly electric bills to promote renewable energy.[58]

Saudi Arabia, a major oil-producing country, has also recognized the importance of renewable energy. The country has conducted research to assess the status and willingness to adopt renewable energy technologies, revealing that education plays a crucial role in increasing awareness and knowledge about renewable energy sources.[59] Economic factors have been identified as the main driver influencing the willingness to adopt renewable energy technologies in Saudi Arabia.[60]

Costa Rica has set ambitious goals to decarbonize its economy and has implemented policies to promote the use of renewable energy in various sectors, including transportation. The country has invested in electric buses and plans to electrify its entire bus fleet by 2035.[61]The country's efforts in promoting renewable energy for freight transport is recognized globally, and it serves as a model for neighbouring countries.

In **Malaysia**, **Thailand**, **Indonesia, the Philippines, Viet Nam** and **Singapore** steps have also been taken to develop renewable energy sources for the freight transport sector. These countries have implemented policies and initiatives to promote the use of biofuels, such as biodiesel and bioethanol, in the transportation sector. Additionally, they have invested in the development of infrastructure for electric vehicles and have encouraged the adoption of electric-powered freight vehicles.[62]

Supported by public advocacy and awareness-building efforts, the strategies discussed have incited an expansion of renewable energy capacity, thereby steering a shift towards sustainable power generation. Yet, certain obstacles persist. The sporadic nature of renewable energy supply poses formidable operational challenges, and the pursuit of cost-effective support models

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[57] Hyo-Jin Kim, Seung-Hoon Yoo and Seu-Ye Lim, "The South Korean public's electric evaluation of the mix of power generation sources: a choice experiment study", *Energy & Environment*, vol. 7, No. 31 (2019), pp. 1181−1190.
[58] Ibid.
[59] Ibraham Mosly and Anas Makki, "Current status and willingness to adopt renewable energy technologies in Saudi Arabia", *Sustainability*, vol. 11, No. 10 (2018), 4269.
[60] Ibid.
[61] David Groves and others, The benefits and costs of decarbonizing Costa Rica's economy: informing the implementation of Costa Rica's national decarbonization plan under uncertainty (Santa Monica, CA., The Rand Corporation, 2020).
[62] Maw Tun and others, "Biomass energy: an overview of biomass sources, energy potential, and management in Southeast Asian countries", *Resources*, vol.2, No. 8 (2019), 81.

continues unabated.[63, 64] Consequently, it has become apparent that ongoing efforts and collaboration among governments, policymakers and diverse stakeholders are paramount to advance the development of renewable energy in the Asia-Pacific region.

Nuclear energy in enhancing freight transport sustainability

Nuclear energy is seen as a reliable, low-carbon energy source by many countries worldwide, including countries in the ESCAP region. Many countries strive to increase the share of nuclear power in their energy mix as a part of efforts to meet Sustainable Development Goal 7 and ensure access to affordable, reliable and sustainable energy for all.

Although nuclear energy has limited direct application in transportation, its role in decarbonizing the power sector can indirectly contribute towards cleaner transportation. The application of nuclear energy for the transport sector may contribute significantly to the overall increase of the freight transport energy efficiency while reducing substantially the lifetime emissions of heavy duty vehicles.

Nearly 450 reactors around the world supply countries with nuclear power, providing approximately 10 per cent of the world’s electricity, or approximately 4 per cent of the global energy mix. This share is expected to increase in the coming decades as the world moves towards net-zero emissions by 2050. In the Asia and the Pacific region, many nuclear power units are already in operation, while others will be commissioned within the next couple of years.

One fourth of the operational nuclear power units in the world are in Asia. As of June 2021, six Asian markets and regions (Japan, Republic of Korea, China, India and Pakistan) are running 113 reactors, totalling 97.4 GW, over half of which were built before 2011 (see Figure 11). The 2011 Fukushima disaster raised serious concerns about nuclear project safety. Most countries have slowed new nuclear power project approval, and many of the projects that are still under construction have been reviewed and delayed, owing to a stricter safety check. Ten years since the Fukushima tragedy, all the Asian Governments have reconsidered the future of nuclear in their regions.

[63] Lincheng Kong and others, “RES-E capacity investment under uncertain renewable energy supply and volatile electricity spot price”, *International Management and Data System*, vol. 6, No. 117 (2017), pp. 1145−1165.
[64] Chien-Fe Chen, C., Xiaojing and Scott Frey, “Who Wants solar water heaters and alternative fuel vehicles? Assessing social–psychological predictors of adoption intention and policy support in China”, *Energy Research & Social Science*, vol. 15 (2016), pp. 1−11.

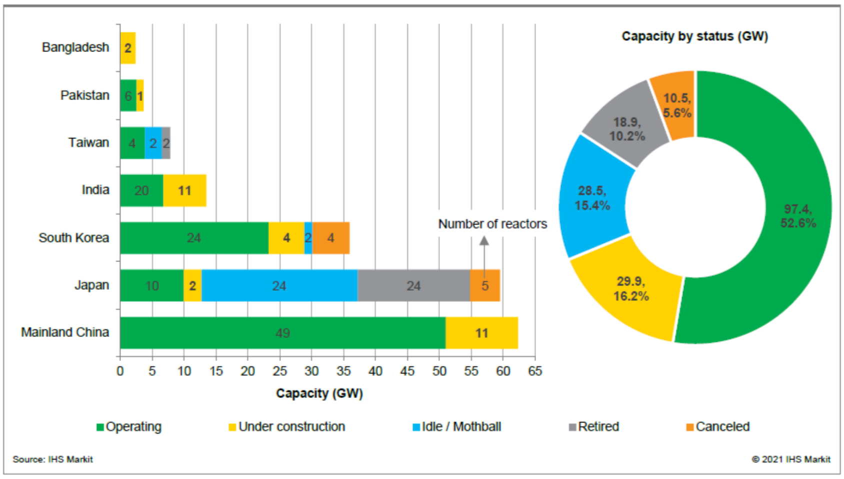

Figure 11 Nuclear power capacity and number of reactors in selected ESCAP states[65]

Countries that are actively involved in nuclear power development in Asia are scaling up the game. **China** and **India** share many common drivers in developing nuclear power and are expected to be the primary promotors of this industry in the Asia-Pacific region. IHS Markit estimates that these two populous and rapidly growing markets will likely underpin 32 per cent of the world's total power demand additions during the period 2021−2050. A diversified power supply structure is necessary to meet such great demand and will avoid substantial environmental stress and fuel supply risks. Increasingly stable, efficient, and low-carbon power supply, such as nuclear power, will help mitigate these pressures.

China had 49 operating nuclear power units at the end of 2020, with total capacity of 51,027.16 MW, which was up 5 per cent from 48,751.16 MW a year earlier, following the commissioning of two units with a combined capacity of 2,268 MW, according to the China Nuclear Energy Association. Power produced by these units was 5 per cent higher year-on-year at 366.24 TWh, similar to power produced by burning 104.74 mt of 7,000 kc (net caloric value) coal. This accounted for 4.94 per cent of the country’s total power output, up from 4.88 per cent in 2019. In addition, the civilian nuclear sector and mastering nuclear technologies are essential to major markets, such as China and India. China has called for a 40 per cent increment (70 GW) in nuclear power in its recent 14th Five-Year Plan (2021−2025). Meanwhile, the nuclear programme of India has entered into its third phase, which aims to use indigenously developed technology and fuel to scale the nuclear capacity in the country. India plans to achieve 27.5 GW of nuclear capacity by 2030.

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[65] Dirk Mallants and others. “The state of the science and technology in deep borehole disposal of nuclear waste”, *Energies*, vol. 4, No. 13 (2020).

Pakistan and **Bangladesh** view nuclear power as a solution to address the increasing intense energy security problems after phasing out coal, and, as a result, is projecting more gas imports. Both markets are highly reliant on gas supply, which were 43 per cent and 58 per cent of the energy mix, respectively, as of 2019. Nuclear power may reduce the market risk of reliance on a single fuel source by diversifying the energy mix. Pakistan runs five reactors (2,562 MW) and is developing KANUPP II & III (1,100 MW) with help from China. For the long-term development, the Government enacted Nuclear Energy Vision 2050 in 2015 and seeks to have 44 GW of nuclear capacity by 2050. As progress in developing nuclear projects has been very slow, the country will likely miss its target set under the 2015 vision. Pakistan has only 2,200 MW of capacity in the pipeline, which is expected to get commissioned by 2030. Meanwhile, Bangladesh began construction on its first of two reactors with assistance from the Russian Federation in November 2017 and aims for it to be operational by 2026.

Nuclear power is a cleaner and more environmentally friendly energy source compared to thermal power for powering electric vehicles.[66] According to data from IEA, nuclear power emits on average approximately 16 grams of CO_2 per kWh of electricity generated, while thermal power emits approximately 820 grams of CO_2 per kWh.[67] This significant difference in carbon emissions highlights the potential of nuclear power to reduce greenhouse gas emissions from the transport sector.

However, it is important to consider the potential side effects and drawbacks associated with nuclear power. One of the main concerns is the risk of accidents, as demonstrated by past incidents, such as the Chernobyl and Fukushima disasters.[68] The safe disposal of nuclear waste is another significant challenge, as it requires long-term storage and management to prevent potential harm to the environment and human health.[69] Additionally, there is a concern about the potential for the proliferation of nuclear weapons technology.[70]

To support the usage of electric vehicles, it is crucial to carefully electric evaluate the benefits and drawbacks of increasing the share of nuclear power in the energy mix. This evaluation

[66] Dirk Mallants and others. “The state of the science and technology in deep borehole disposal of nuclear waste”, *Energies*, vol. 4, No. 13 (2020).

[67] Ibid.

[68] Annuka Vainio, Riika Paloniemi and Vilja Varho, “Weighing the risks of nuclear energy and climate change: trust in different information sources, perceived risks, and willingness to pay for alternatives to nuclear power”, *Risk Analysis*, vol. 3 No. 37 (216), pp. 557−569.

[69] Dirk Mallants and others. “The state of the science and technology in deep borehole disposal of nuclear waste”, *Energies*, vol.4, No. 13 (2020).

[70] Annuka Vainio, Riika Paloniemi and Vilja Varho, “Weighing the risks of nuclear energy and climate change: trust in different information sources, perceived risks, and willingness to pay for alternatives to nuclear power”, *Risk Analysis*, vol. 3 No. 37 (216) pp. 557-569.

should consider the potential risks associated with nuclear power and compare it to other sources of clean energy.[71] While nuclear power emits significantly less CO_2 than thermal power, the potential risks and drawbacks associated with nuclear power should be thoroughly assessed before making any decisions.

2.6 Modernization of infrastructure

Infrastructure modernization plays a crucial role in the sustainable transition of the freight transport sector. It involves upgrading or replacing existing transportation infrastructure with advanced, environmentally friendly infrastructure that support new technologies and practices. Some of the most common practices are considered below.

Intermodal transportation facilities enable the smooth transition of goods from one mode of transportation to another, such as from rail to road or from sea to rail. They help in achieving a modal shift by allowing more efficient utilization of different modes of transportation based on their comparative advantages, thus reducing fuel consumption and emissions.

Widespread adoption of electric or alternative fuel vehicles depends on the availability of charging stations or refuelling infrastructure. Modern infrastructure should, therefore, include a network of these stations that are strategically located across cities and highways.

Modernization of infrastructure also involves integrating information technology with transportation infrastructure to manage and control traffic, optimize routing, improve safety and reduce environmental impacts. This could include technologies, such as real-time traffic management systems, connected and autonomous vehicles, and truck platooning technologies.

Being eco-friendly versions of traditional logistics centres and ports, green logistics hubs and ports are equipped with renewable energy sources, advanced energy management systems and low-emission handling equipment. They help in reducing the energy consumption and emissions associated with goods handling and storage.

Railway electrification is another key aspect of infrastructure modernization in the context of sustainable freight transport. It enhances the efficiency of train traction, bolstering the appeal of rail over road transportation. This not only stimulates a modal shift, but it also plays a pivotal role in slashing greenhouse gas emissions. This reduction is particularly pronounced in countries harnessing renewable or nuclear energy sources.

[71] Ibid.

In 2021, the level of railway electrification worldwide was close to 30 per cent, or approximately 375,000 km of electrified rails out of 1.3 million in total.[72] The degree of electrification among ESCAP countries ranged from 2 per cent in Pakistan to 100 per cent in the Philippines (2021); the lengthiest electrified network in China.[73]

Overall, railways are up to nine times more energy efficient as compared to roads for long distance freight, four times more economical in terms of land use and six times more cost effective versus roads in terms of construction costs for comparable levels of traffic. Among the modes of rail transport, electric traction is the most energy efficient. The greenhouse gas emissions from trains are 60-75 per cent lower.[74]

The subsequent examples from selected countries illustrate the current practices that effectively bridge the gap between strategy and execution, and offer elements of a road map that could potentially guide future endeavours aimed at further enhancing the sustainability of the sector.

China has been a global leader in promoting electric mobility and has built a comprehensive network of charging stations across the country. By 2020, China had approximately 800,000 public charging stations. In addition, the country has been extensively electrifying its railways. More than 71 per cent of its railway network was electrified by 2020.

Japan has also made notable strides in developing charging infrastructure; as of 2020, there are 40,000 charging stations. It has been promoting hydrogen as an alternative fuel, and as such, has been developing a network of hydrogen refuelling stations. Japan has one of the densest railway networks in the world, with a large proportion of it being electrified. The country is also a pioneer in green logistics hubs, with many companies focusing on eco-friendly practices in their logistics operations.

Republic of Korea is investing heavily in electric vehicle charging infrastructure and, as a result, as of 2020, has more than 30,000 public charging stations. The country has also been promoting hydrogen fuel-cell vehicles and building hydrogen refuelling stations. The Republic of Korea has an extensive electrified railway network, with the KTX high-speed rail being a notable example.

India is promoting electric mobility under its National Electric Mobility Mission Plan. The plan aims to establish charging infrastructure across the country. India also has one of the largest

[72] RailwayPro, “Worldwide rail electrification remains a high volume”, 19 February 2019. Available at https://www.railwaypro.com.
[73] Prepared by authors based on data from various open sources.
[74] OCS ANA Group. "Trucks vs Trains: the pros and cons of road and rail transport” (n.d.) Available at https://www.ocsmiddleeast.com/trucks-vs-trains.

railway networks globally and is planning to electrify the entire network by 2024. The country's Dedicated Freight Corridor project is a significant initiative to improve freight transport efficiency.

Australia is gradually increasing its charging station infrastructure to accommodate the growing number of electric vehicles. The Australian Renewable Energy Agency has funded a project to build a network of ultra-fast electric vehicle charging stations along major highways.

Thailand is promoting electric and hybrid vehicles under its Thailand 4.0 initiative. The Government planned to have 690 charging stations in operation nationwide by 2020. The Eastern Economic Corridor is a notable green logistics hub in the country.

Singapore plans to deploy 28,000 electric vehicle charging points at public carparks island-wide by 2030. Singapore is also well-known for its efficient and green logistics practices, with many companies operating eco-friendly logistics hubs.

Malaysia is gradually building its charging station infrastructure under its National Electric Mobility Blueprint. Malaysia also has an electrified railway network, with the Electric Train Service (being a significant initiative.

Uzbekistan has gradually electrified its railway lines though several projects completed recently. However, the overall proportion of electrified tracks is still low compared to some countries.

The Russian Federation, as one of the world's leading producers of natural gas, has an extensive network of natural gas refuelling stations. It also has a broad electric vehicle charging infrastructure, particularly in larger cities. The Russian Railways has a high degree of electrification, as more than half of its network is electrified. This percentage is even higher on the main routes used for freight transport.

In summary, the modernization of transport infrastructure is a strategic endeavour that spans the long term, necessitating substantial financial resources, comprehensive planning, and coordination among a multitude of stakeholders. PPPs often emerge as a viable model for funding such extensive infrastructure initiatives. Simultaneously, it is imperative to design and execute infrastructure modernization initiatives with an eye towards future resilience. This includes considerations for rapid technological advancements, the effects of climate change, and adaptability to potential challenges, such as shifts in logistics flows, electric even those induced by geopolitical variations.

However, infrastructure modernization alone is not enough. It needs to be complemented with other policy measures, such as emission standards, fiscal incentives and regulations, to achieve significant reductions in the freight sector's environmental footprint.

Chapter 3: Policy and regulatory measures

Policies affecting the freight transport sector within the ESCAP region are notably diverse, reflecting the distinct social, economic and environmental factors that characterize different countries. These policies encompass a broad spectrum, including international conventions, intergovernmental initiatives, vehicle emission standards and incentives encouraging the adoption of energy-efficient technologies and transport modes, such as the modal shift.

Recognizing policy as a pivotal instrument for enhancing energy efficiency in the freight transport sector has become increasingly common. This growing awareness is leading countries across the region to integrate transport energy efficiency into national energy and climate strategies more intentionally. Ambitious goals are being set for the deployment of zero-emission vehicles, alternative fuel promotion is on the rise and significant investments are being made into infrastructure that support more efficient modes of transport, such as rail and inland waterways.

3.1 Vehicle emission and fuel economy standards

Greenhouse gas emission and fuel economy standards represent one of the principal regulatory strategies adopted by governments globally to encourage the shift towards sustainable road freight transport.[75] These standards set specific limits on the emissions and fuel consumption of vehicles, pushing manufacturers to design and produce cleaner, more efficient vehicles.

In terms of emissions, standards are often aimed at controlling the output of CO_2, NOx. PM and other harmful pollutants. By setting limits on these emissions, governments can mitigate the environmental and public health impacts of road transport.

Fuel economy standards, on the other hand, directly influence the energy efficiency of vehicles. By requiring vehicles to travel a certain distance on a given volume of fuel, these standards can significantly reduce fuel consumption, leading to lower greenhouse gas emissions and energy use.

The implementation of these standards has proven to have a significant impact on reducing emissions. For example, the United States Corporate Average Fuel Economy (CAFE) standards and greenhouse gas emission standards require automakers to meet criteria for fleet fuel efficiency and CO_2 emission rates. These standards have led to the introduction of incentives for manufacturers to sell alternative fuel vehicles, which has helped encourage a transition to cleaner

[75] Walid Chatti, “Information and communication technologies, road freight transport, and environmental sustainability”, *Environmental Economics*, vol. 1, No. 11 (2020), p. 124.

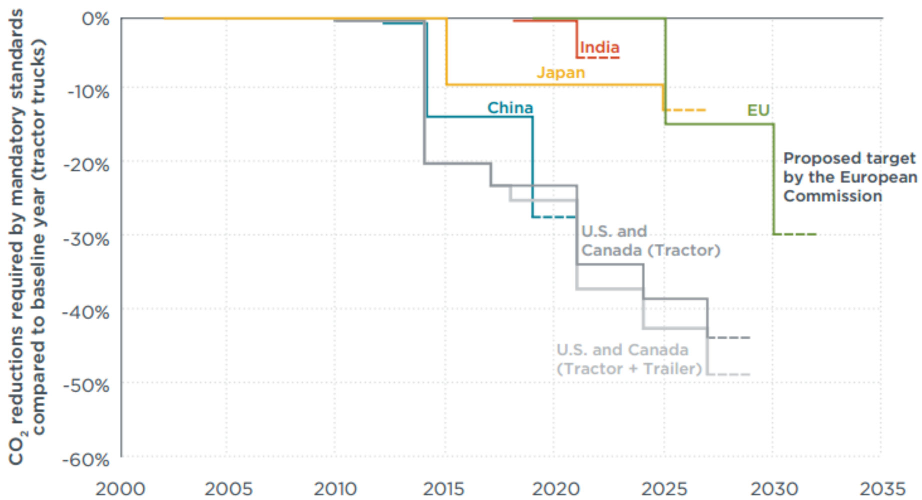
technologies in the collective range of vehicles manufactured and sold by automakers in the United States.[76]

At the same time, the current pace of conventional fuel economy improvements is insufficient, as supported by the IEA publication *Global Outlook 2020*. Several factors contribute to fuel consumption, including fuel prices, technology adoption influenced by regulations and standards, and vehicle size and power. The recent trend towards larger vehicles in many markets has exacerbated the issue, leading to increased average fuel consumption and higher emissions.

Governments worldwide recognize the importance of addressing this issue and are taking steps to implement fuel economy and greenhouse gas standards. Ten countries have established or proposed fuel economy or greenhouse gas standards for passenger vehicles, while six countries have done the same for heavy-duty vehicles. These standards are intended to regulate and improve the fuel efficiency of vehicles, thereby reducing emissions.

A promising sign of progress is that 17 countries have announced a target to achieve 100 per cent zero-emission vehicle sales or phase out internal combustion engine vehicles by 2050. However, it is important to note that few of the standards being implemented in the largest markets are stringent enough to reach the 2030 targets of the Global Fuel Economy Initiative, let alone the necessary longer-term CO_2 reduction and electric vehicle adoption targets.

Figure 12 shows the relative stringency of the different tractor-trailer efficiency standards with respect to the baseline defined when the standards were introduced.



[76] Alan Jenn, Inês Azeveo, and Jeremy Michalek, "Alternative fuel vehicle adoption increases fleet gasoline consumption and greenhouse gas emissions under united states corporate average fuel economy policy and greenhouse gas emissions standards", *Environmental Science and Technology*, vol. 5, No. 50 (2016), pp. 2165−2174.

Figure 12 Tractor truck emission standards around the world relative to the baseline[77]

In the ESCAP region, countries, such as China, Japan and the Republic of Korea, have taken the lead in implementing stringent greenhouse gas emission standards for heavy-duty vehicles. For instance, China has introduced China VI standards and Japan has enforced the Post New Long-Term Emission Standards, both of which are equivalent to the Euro VI standards. The Republic of Korea has also implemented the Korea Stage 7 (KNR 07) standards, targeting reduced emissions of pollutants such as CO_2, hydrocarbons (HC), NOx and PM.

Other countries, namely India, Indonesia and Thailand, have been following suit in recent years. India adopted the Bharat Stage (BS) VI emission standards, which are on par with Euro VI standards, and implemented them in April 2020. Thailand has implemented the Euro IV emission standards and has plans to move towards the Euro V standards. Indonesia has enforced Euro IV-equivalent standards and is in the process of developing a road map for implementing Euro V and Euro VI standards. However, some countries in the region, such as Myanmar, the Philippines and Viet Nam have yet to set comprehensive and stringent greenhouse gas emission standards for heavy-duty vehicles. This lag in policy adoption poses a significant challenge to achieving regional climate goals and mitigating the environmental impact of the transportation sector.

Australia has taken consecutive steps to improve fuel efficiency and reduce vehicular emissions. The country has implemented the Australian Design Rules, which sets vehicle standards, including those related to fuel consumption and emissions. Australian emission standards are based on European regulations for light-duty and heavy-duty (heavy goods) vehicles, while noting United States and Japanese standards. The long-term policy is to fully harmonize Australian regulations with Economic Commission for Europe (ECE) standards. The emission standards apply to new vehicles, including petrol (gasoline) and diesel cars, light omnibuses, heavy omnibuses, light goods vehicles, medium goods vehicles and heavy goods vehicles, as well as to passenger vehicles and larger motor tricycles. They also cover off-road passenger vehicles (but not off-road engines, such as those used in construction or agricultural machinery). A summary of the Australian emission standards that apply from 2002/2003 and later is presented in Table 10.

[77] Zev Technology Center webpage. Available at https://zevtc.org.

Table 10 Vehicle Emission Standards in Australia: 2002/03 and later[78]

ADR Categories			ECE Cat	ADR	02/03 Diesel	03/04 Petrol	05/06 Petrol	06/07 Diesel	07/08 Diesel	08/10[a] Petrol	10/11 Petrol	10/11 Diesel	13/16[b] All	17/18[c] All
Descr	GVM†	Cat‡												
Passenger Vehicles														
	≤ 3.5t	MA, MB, MC	M1	ADR 79/..	Euro 2	Euro 2	Euro 3	Euro 4		Euro 4			Euro 5[d]	Euro 6
	> 3.5t			ADR 80/..	Euro 3	US96	US98		Euro 4		Euro 4			
Buses														
Light	≤ 3.5t	MD	M2	ADR 79/..	Euro 2	Euro 2	Euro 3	Euro 4		Euro 4			Euro 5[d]	Euro 6
	3.5 ≤ 5t			ADR 80/..	Euro 3	US96	US98		Euro 4 or US04, JE05		Euro 4 or US08	Euro 5 or US07, JE05		
Heavy	> 5t	ME	M3	ADR 80/..	Euro 3 or US98[e]	US96	US98		Euro 4 or US04, JE05		Euro 4 or US08	Euro 5 or US07, JE05		
Goods Vehicles (Trucks)														
Light	≤ 3.5t	NA	N1	ADR 79/..	Euro 2	Euro 2	Euro 3	Euro 4		Euro 4			Euro 5[d]	Euro 6
Medium	3.5 ≤ 12t	NB	N2	ADR 80/..	Euro 3 or US98[e]	US96	US98		Euro 4 or US04, JE05		Euro 4 or US08	Euro 5 or US07, JE05		
Heavy	> 12t	NC	N3	ADR 80/..	Euro 3 or US98[e]	US96	US98		Euro 4 or US04, JE05		Euro 4 or US08	Euro 5 or US07, JE05		

† Gross vehicle mass
‡ Vehicle categories: MA - passenger cars; MB - forward control vehicles, MC - passenger off-road vehicles
a - 1 July 2008/1 July 2010 for new/existing models
b - 1 November 2013/1 November 2016 for new/existing models
c - 1 July 2017/1 July 2018 for new/existing models
d - 'Core' Euro 5 applicable to new models from 1 November 2013, full Euro 5 applicable from 1 November 2016 (see notes below)
e - US EPA model year 2000 or later certificate or equivalent testing required (to ensure that no emission "defeat devices" are used)

In **China**, the national emission standards are applicable to all on-road vehicles and their engines, including heavy-duty vehicles and medium-duty vehicles. These standards were developed progressively in several stages. The last one, China VI, is divided into two phases, VI-a and VI-b, with VI-a implemented in 2019 for new vehicle models and 2020 for all vehicles, and VI-b implemented in 2021 for new vehicle models and 2023 for all vehicles. The China VI standard is equivalent to the Euro VI standard and represents a significant leap in terms of emissions reduction, with stricter limits on CO_2, NOx, PM and HC emissions. A summary of emission norms established by the above-mentioned standards is provided in Table 11.

Table 11 Summary of pollutant emission norms in China

Standard	Year of implementation	CO	HC	NOx	PM
China I	1999	4.5	1.1	8	0.36
China II	2003	4	1.1	7	0.25
China III	2007	2.1	0.66	5	0.1
China IV	2013	1.5	0.46	3.5	0.02
China V	2017	1.5	0.13	2	0.02
China VI	2021*	1.5	0.13	0.4	0.01

[78] Dieselnet, "Emission standards Australia". Available at https://dieselnet.com/standards/au/.

* The implementation date may vary by region.

In China, the first phase of fuel economy standards was introduced in 2015, and the second phase was introduced in 2019, with full implementation by 2021. These fuel efficiency standards are designed to reduce fuel consumption of heavy-duty vehicles by setting specific fuel consumption limits based on the vehicle's weight and engine power (Table 12).

Table 12 Summary of fuel consumption norms in China[79]

Phase	GVW (tons)	Engine power (kW)	Fuel consumption (L/100 km)
Phase 1	16-18	140-220	42.8
	18-25	180-260	39.8
	>25	250-400	38.1
	16-18	140-220	37.8
Phase 2	18-25	180-260	34.8
	>25	250-400	33.1

The Government of China is actively promoting the adoption of alternative fuels and advanced transportation technologies, such as electric vehicles, hydrogen fuel cell vehicles and natural gas vehicles, to further reduce emissions from the transportation sector. Various incentive programmes and subsidies were introduced to encourage the development and deployment of these cleaner technologies.

The Eurasian Economic Union is harmonizing policies and regulations in various sectors, including the transportation industry. Although the Union has not yet established a unified set of greenhouse gas emissions and fuel efficiency standards for heavy- and medium-duty vehicles, efforts have been made to align the member countries' regulations with international norms, including the standards set by the European Union. EAEU has been gradually adopting the Euro emission standards, which are designed to limit the release of air pollutants from vehicles, including heavy-duty vehicles. While the Euro standards primarily target air pollutants, such as NOx, PM, HC, and carbon monoxide (CO), they also contribute towards reducing greenhouse gas emissions and improving fuel efficiency indirectly. The adoption of Euro standards in the EAEU member countries has been progressing at different rates. For example, the Russian Federation has implemented Euro 5 standards for new vehicles since 2014, while Kazakhstan adopted the Euro 4 standards in 2016 and has been working on transitioning to Euro 5. Belarus, on the other hand, introduced Euro 5 standards for new vehicles in 2014 and Euro 6 standards for certain categories of vehicles in 2019 (Table 13).

[79] DieselNet, "China: heavy-duty engines". Available at https://dieselnet.com/standards/cn/hd.php.

Table 13 Summary of emission standards applied in the Eurasian Economic Union[80]

Country	Standards in force	Types of vehicles	Year of implementation
Russian Federation	Euro 5	Heavy-duty and light-duty	2014
	Euro 4	Heavy-duty and light-duty	2016
Kazakhstan	Euro 5 (transition)	Heavy-duty and light-duty	TBD
	Euro 5	Heavy-duty and light-duty	2014
Belarus	Euro 6 (selective)	Certain categories	2019
Armenia	Euro 4	Heavy-duty and light-duty	2014
Kyrgyzstan	Euro 4	Heavy-duty and light-duty	2016

In 2022, the Government of the Russian Federation decided to drop its current Euro-5 vehicle standards to “Euro-0” due to sanctions. The temporary change, which allows vehicles to build to pre-1992 Euro-1 EU emission standards, will have a negative impact on air quality according to the country’s Ministry of Natural Resources. In addition, the country has allowed the manufacturing of so-called “simplified" cars without airbags, anti-lock braking system or electronic stability systems.

In addition to adopting the Euro emission standards, EAEU member countries have been focusing on the development and promotion of alternative fuels and advanced transportation technologies. For instance, the Russian Federation is investing in electric vehicles and charging infrastructure, while Kazakhstan has launched programmes to promote the use of natural gas as an alternative fuel for vehicles.

Although EAEU has not yet implemented a unified set of greenhouse gas emissions and fuel efficiency standards for heavy- and medium-duty vehicles, the adoption of Euro emission standards and the promotion of alternative fuels and advanced transportation technologies contribute to the region's efforts in reducing emissions and enhancing the sustainability of the transportation sector. As EAEU continues to integrate and harmonize its policies, it is expected that further progress will be made in establishing and enforcing more stringent environmental and fuel efficiency standards for heavy-duty vehicles.

The European Union has established greenhouse gas emissions and fuel efficiency standards for heavy- and medium-duty vehicles through the combined efforts of the European Commission, the European Parliament and the Council of the European Union. The regulations

[80] Prepared by authors based on open information.

apply to all on-road vehicles with a gross vehicle weight (GVW) greater than 3.5 tonnes, and the engines that power them.

In 2019, the European Union adopted its first-ever CO_2 emission standards for heavy-duty vehicles under Regulation 2019/1242.

The Regulation establishes two main targets:

- A 15 per cent reduction in CO_2 emissions by 2025, compared to the 2019 baseline.
- A 30 per cent reduction in CO_2 emissions by 2030, compared to the 2019 baseline.

The standards apply to specific categories of heavy-duty vehicles, including large trucks, buses, and coaches. In addition, under the regulation the declaration, monitoring, and reporting of CO_2 emissions and fuel consumption data for new heavy-duty vehicles registered in the European Union.

In 2023, the European Commission proposed a revision of the regulation on CO_2 emission standards for heavy-duty vehicles. If adopted, CO_2 emission standards for heavy-duty vehicles would be more stringent from 2030 onwards. Additionally, the scope of the regulation would be extended to cover smaller trucks, city buses, long-distance buses, and trailers. The targets are as follows:

- A 45 per cent reduction in CO_2 emissions by 2030, compared to the 2019 levels.
- A 65 per cent reduction in CO_2 emissions by 2035, compared to the 2019 levels.
- A 90 per cent reduction in CO_2 emissions by 2040, compared to the 2019 levels.

These targets represent significant increases in the level of emission reductions compared to the current standards. The proposed revision aims to accelerate the transition to cleaner and more sustainable heavy-duty vehicles, contributing to the overall climate goals and commitment of the European Union to reduce greenhouse gas emissions.

The European Union has also introduced the Clean Vehicles Directive (Directive 2009/33/EC, amended by Directive (EU) 2019/1161), to promote the adoption of energy-efficient and environmentally friendly vehicles in public fleets. Under the directive, public authorities and public transport operators must consider energy and environmental impacts, including energy consumption and CO_2 emissions, when procuring road transport vehicles.

The long-term fuel consumption trends for heavy commercial vehicles in Europe indicate that the real-world fuel consumption of commercial fleets, and consequently their CO_2 emission performance, has been relatively stagnant over time. Reductions in pollutant emissions driven by the Euro VI standard were not accompanied by significant improvements in fuel consumption or reductions in CO_2 emissions. The available data, which are not necessarily representative of the fleet, suggest a fuel consumption improvement of Euro VI tractor-trailers of approximately 3 per cent, or 1 litre of diesel electric every 100 km.[81]

Figure 13 presents a summary of fuel consumption of tractor-trailers with engines in the 300 to 400 kW power range, as measured by Lastauto Omnibus. Solid lines are average fuel consumption of trucks certified to the different Euro standards.

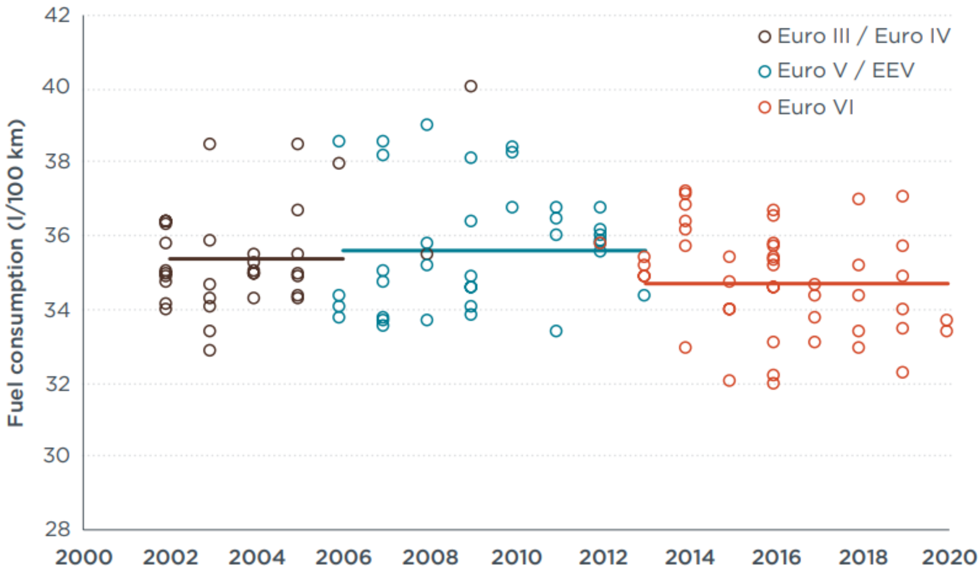


Figure 13 Tractor-trailers with engine power between 300 kW and 400 kW.

According to the European Automobile Manufacturers' Association data, the certified average fuel consumption of Euro VI long-haul tractor-trailers registered in the second half of 2019 was approximately 30 l/100 km. Approximately 10 per cent of long-haul trucks had a fuel consumption of at least 7 per cent better than the average, and 10 per cent had fuel consumption of at least 5 per cent worse than the average.

In summary, the European Union has made significant strides in regulating greenhouse gas emissions and fuel efficiency for heavy-duty vehicles and medium-duty vehicles through the adoption of CO_2 emission standards and the Clean Vehicles Directive.

India is actively striving to improve fuel efficiency and reduce vehicular emissions. The country has introduced the CAFÉ norms for vehicles, which set fuel consumption targets for manufacturers based on the average weight of their vehicle fleet. It launched the implementation of more stringent Phase 2 CAFE norms in 2022, aiming to achieve a 30 per cent reduction in fuel consumption compared to 2014 levels. The country has also introduced Bharat Stage emission standards, with the most recent BS-VI standards significantly reducing the allowed emission

[81] Felipe Rodrigues, "Commercial fleet renewal programs as a response to the COVID-19 crisis in the European Union", International Council on Clean Transportation briefing, August 2020. Available at https://theicct.org/publication/commercial-fleet-renewal-programs-as-a-response-to-the-covid-19-crisis-in-the-european-union/.

limits for both light and heavy-duty vehicles. Emission standards for new heavy-duty road engines − applicable to vehicles of GVW > 3,500 kg − are listed in Table 14.

Engines that meet Stage VI (also known as Euro VI) emissions standards are certified with specific types of fuel: gasoline engines are certified with E10, a blend of 10 per cent ethanol and 90 per cent gasoline, while diesel engines are certified with B7, a blend of 7 per cent biodiesel and 93 per cent petroleum diesel. An "in-use conformity factor" is used in the standards for pollutants such as CO, total hydrocarbons (THC), non-methane hydrocarbons (NMHC), methane (CH4) and NOx. This factor, set at a maximum of 1.50, allows for a slight increase in emissions during real-world driving conditions compared to the strict conditions under which the engines are tested for certification.

Table 14 Emission Standards for heavy-duty vehicles in India[82]

Stage	Year	Test	CO	HC	CH_4	NOx	PM	PN	NH_3
			g/kWh					kWh^{-1}	ppm
	1992	ECE R49	17.3	2.7		-	-		
	1996	ECE R49	11.2	2.4		14.4	-		
India 2000	2000	ECE R49	4.5	1.1		8.0	0.36[a]		
BS II	2005†	ECE R49	4.0	1.1		7.0	0.15		
BS III	2010†	ESC	2.1	0.66		5.0	0.10		
		ETC	5.45	0.78		5.0	0.16		
BS IV	2010‡	ESC	1.5	0.46		3.5	0.02		
		ETC	4.0	0.55		3.5	0.03		
BS V	n/a[b]	ESC	1.5	0.46		2.0	0.02		
		ETC	4.0	0.55	1.1[d]	2.0	0.03		
BS VI	2020[c]	WHSC (CI)	1.5	0.13		0.40	0.01	$8.0×10^{11}$	10
		WHTC (CI)	4.0	0.16		0.46	0.01	$6.0×10^{11}$[e]	10
		WHTC (PI)	4.0	0.16[f]	0.50	0.46	0.01	$6.0×10^{11}$[e]	10

† earlier introduction in selected regions, see India: Table 1
‡ only in selected regions, see India: Table 1
[a] 0.612 for engines below 85 kW
[b] Initially proposed in 2015.11 [3297][3298] but removed from a 2016.02 proposal [3349]
[c] Proposed schedule and limits
[d] For CNG engines only
[e] Applicable from April 1, 2025 for new models and April 1, 2026 for existing models
[f] NMHC

Singapore emission requirements are based on European Union, Japanese and United States emission standards and test methods, which are incorporated into regulations by reference. Singapore emission regulations are part of the Environmental Protection and Management Act of 1 July 1999 and a number of later amendments. Emissions are regulated for new light- and heavy-duty road vehicles and engines, new off-road diesel engines and new motorcycles and scooters. The effective dates for new vehicle emission stages given in the following sections refer to the date the vehicle is first registered in Singapore. Emission requirements for new heavy-duty diesel engines are provided in Table 15.

[82] DieselNet, "India: heavy-duty truck and bus engines". Available at https://dieselnet.com/standards/in/hd.php.

Table 15 Emission requirements for new heavy-duty diesel engines in Singapore[83]

Date	Requirement
1998.07	Euro I (Directive 91/542/EEC Stage I)
2001.01	Euro II (Directive 91/542/EEC Stage II)
2006.1	Euro IV (Directive 1999/96/EC-B1 (2005))
2014.01	Euro V (Directive 2005/55/EC-B2(2008)) or Japan 2009 standards
2018.01	Euro VI (Regulation (EC) 595/2009 and (EU) 582/2011) or Japan 2009 plus Euro VI PN limit

Japan has long been at the forefront of fuel efficiency and emission reduction initiatives in the automotive sector. The country has implemented Top Runner fuel efficiency standards for passenger vehicles, which set ambitious targets for each vehicle weight class based on the best-performing vehicles in the market. The Top Runner standards have been successful in driving innovation and increasing the overall fuel efficiency of vehicles in Japan. Furthermore, Japan has also introduced fuel efficiency standards for heavy-duty vehicles, which aim to reduce fuel consumption and greenhouse gas emissions from the trucking industry. Emission standards for new diesel engines used in heavy commercial vehicles are summarized in Table 16.

Table 16 Emission standards for diesel engines on vehicles, gross vehicle weight > 3,500 kg[84]

Date	Test	Unit	CO	HC	NOx	PM
			mean (max)	mean (max)	mean (max)	mean (max)
1988/89	6 mode	ppm	790 (980)	510 (670)	DI: 400 (520) IDI: 260 (350)	
1994	13 mode	g/kWh	7.40 (9.20)	2.90 (3.80)	DI: 6.00 (7.80) IDI: 5.00 (6.80)	0.70 (0.96)
1997[a]			7.40 (9.20)	2.90 (3.80)	4.50 (5.80)	0.25 (0.49)
2003[b]			2.22	0.87	3.38	0.18
2005[c]	JE05		2.22	0.17[d]	2.0	0.027
2009[e]			2.22	0.17[d]	0.7	0.01
2016[f]	WHTC		2.22	0.17[d]	0.4	0.01

a - 1997: GVW ≤ 3500 kg; 1998: 3500 < GVW ≤ 12000 kg; 1999: GVW > 12000 kg
b - 2003: GVW ≤ 12000 kg; 2004: GVW > 12000 kg
c - full implementation by the end of 2005
d - non-methane hydrocarbons
e - 2009: GVW > 12000 kg; 2010: GVW ≤ 12000 kg
f - 2016: GVW > 7500 kg; 2017: tractors; 2018: 3500 < GVW ≤ 7500 kg

In 2017, Japan took a significant step towards reducing its petroleum usage and greenhouse gas emissions. The Ministry of Land, Infrastructure and Transportation established new fuel economy standards, specifically targeting heavy-duty vehicles, which account for 35 per cent of CO_2 and 42 per cent of total carbon emissions from all on-road vehicles.

Under the newly introduced Phase 2 regulation, targets are set for diesel commercial vehicles with GVW of 3.5 tons or more, from the 2025 model year onwards. Notably, Japan is the first country worldwide to implement such a fuel efficiency performance regulation for commercial trucks. Table 17 presents the 2025 requirements, contrasted with the 2015 baseline fuel

[83] DieselNet “Emission standards: Singapore”. Available at https://dieselnet.com/standards/sg/.
[84] DieselNet. "Japan: heavy duty engines”. Available at https://dieselnet.com/standards/jp/hd.php.

consumption values, showing the targeted percentage reduction for major truck and bus categories over the decade.

Table 17 Summary of 2025 fuel efficiency targets and improvements[85]

Vehicle type	Class	Fuel economy (liters / 100 km)		Improvement
		2015 baseline	2025 target	
Trucks	Tractor trucks	35.2	34.0	3.4%
	Other trucks	14.1	12.3	12.7%
	Total average	14.9	13.1	11.9%
Buses	Urban buses	21.0	20.0	4.8%
	Highway buses	16.5	13.9	15.5%
	Total average	17.5	15.3	12.4%

Table 18 gives an outline of the specific targets for each vehicle subcategory defined in the regulation. Similar to its Phase 1 predecessor, the Phase 2 fuel economy targets will be evaluated based on individual standards. These standards are broken down by vehicle class, gross vehicle weight and for lighter trucks, their rated cargo load. Each manufacturer must achieve the fuel efficiency target for every category in which its vehicles are sold.

Table 18 Summary of 2025 fuel efficiency targets by vehicle type, gross value weight and cargo capacity[86]

Vehicle type	Gross vehicle weight (tonnes)	Rated cargo (tonnes)	Fuel economy target (liters / 100 km)
Other Truck	3.5 ≤ GVW < 7.5	cargo ≤ 1.5	7.4
		1.5 < cargo ≤ 2	8.4
		2 < cargo ≤ 3	9.4
		cargo < 3	10.1
	7.5 < GVW ≤ 8	-	11.9
	8 < GVW ≤ 10	-	13.4
	10 < GVW ≤ 12	-	13.4
	12 < GVW ≤ 14	-	15.6
	14 < GVW ≤ 16	-	17.0
	16 < GVW ≤ 20	-	20.5
	20 < GVW ≤ 25	-	22.6
Tractor truck	GVW ≤ 20	-	32.2
	20 < GVW	-	43.1

85 Ben Sharpe, "Second phase fuel economy standards for on-road heavy-duty vehicles in Japan", ICCT policy update, 28 January 2019. Available at Second-phase fuel economy standards for on-road heavy-duty vehicles in Japan - International Council on Clean Transportation (theicct.org).
86 DieselNet,. "Japan: fuel economy". Available at https://dieselnet.com/standards/jp/fe.php#hd.

Sri Lanka has implemented various measures to upgrade the fuel quality standards in the country. These measures include the phasing out of leaded petrol in June 2002, reducing the sulfur content of auto diesel to 3,000 ppm in January 2004, introducing RON 92 petrol instead of RON 90 petrol in January 2014 and reducing the sulfur content of super diesel from 500 ppm to 10 ppm by introducing 4-star diesel in August 2014. In June 2018, Sri Lanka introduced Euro IV standards fuel under RON 95 petrol and Lanka Super Diesel (10 ppm sulfur). These improvements in fuel quality have facilitated the use of modern engines with better efficiency and emission control technologies. Moreover, better quality fuel also reduces engine wear and tear, which results in an increase in fuel consumption and emissions. These efforts reflect the commitment of Sri Lanka to reduce emissions and promote sustainable transport.

The Republic of Korea has implemented fuel efficiency standards for passenger vehicles, which set targets based on the average weight of the vehicles produced by each manufacturer. The country has also introduced fuel efficiency standards for heavy-duty vehicles, with the goal of reducing fuel consumption and emissions in the logistics and transportation industries. Additionally, the Republic of Korea has been promoting the adoption of electric vehicles and alternative fuels to further reduce the environmental impact of the transportation sector.

Emission standards for heavy-duty diesel truck and bus engines are listed in Table 19.[87] Early standards were based on Japanese emission requirements. Since 2003, emission standards set by the Republic of Korea are based on European regulations.

Table 19 Emission standards for heavy-duty diesel engines in the Republic of Korea

Date	Test	CO	HC	NOx	PM	PN	Reference
		g/kWh				1/kWh	
1993.01	6-mode	980f	670**	350** IDI 750** DI	-		
1996.01	13-mode	4.9	1.2	11	0.9		
1998.01	13-mode	4.9	1.2	6.0 (9.0)*	0.25 (0.50)*		
2000.01	13-mode	4.9	1.2	6	0.25 (0.10)*		
2002.01	13-mode	4.9	1.2	6	0.15(0.10)*		
2003.01	ESC	2.1	0.66	5	0.1		Euro III
	ETC	5.45	0.78	5	0.16		
2006.01	ESC	1.5	0.46	3.5	0.02		Euro IV
	ETC	4	0.55	3.5	0.03		
2009.09	ESC	1.5	0.46	2	0.02		Euro V
	ETC	4	0.55	2	0.03		
2014.01	WHSC	1.5	0.13	0.4	0.01	$8.0x10^{11}$	Euro VI
	WHTC	4	0.16	0.46	0.01	$6.0x10^{11}$	

* Applies to buses, ** JP 6-mode test, limits expressed in ppm.

[87] DiesetNet, "Korea: heavy-duty engines". Available at https://dieselnet.com/standards/kr/hd.php.

Thailand has implemented vehicle emission standards based on the European regulations. For light-duty vehicles (passenger cars and light commercial vehicles), the country has been applying Euro 4 standards since 2012. As of September 2018, Thailand had implemented Euro 5 standards for diesel passenger cars and light commercial vehicles, with plans to fully adopt Euro 5 standards for all light-duty vehicles. For heavy-duty vehicles (trucks and buses), Thailand introduced Euro 3 standards in 2008 and Euro 4 standards in 2012, and plans to introduce Euro 5 standards to support the implementation of more stringent emission standards. Thailand has also been improving the quality of its fuels. The country has imposed sulfur limit of 50 ppm for diesel fuel since 2012, making it compatible with Euro 4 emission standards. As of 2019, ultra-low sulfur diesel (10 ppm) is available in the country, which is necessary to support the adoption of Euro 5 and 6 standards.

In 2015, Thailand introduced fuel economy standards for light-duty vehicles, which are based on the Corporate Average Fuel Consumption approach. The first phase of the standards, implemented in 2015, aims for a fleet average fuel consumption of 6.7 litres/100 km for gasoline vehicles and 5.6 litres/100 km for diesel vehicles by 2020. The second phase, set to begin in 2021, targets a fleet average fuel consumption of 5.3 litres/100 km for gasoline vehicles and 4.4 litres/100 km for diesel vehicles by 2025.

Thai emission regulations are based on European emission standards and test procedures. The regulations are published as Thai Industrial Standards. Emission standards for heavy-duty truck and bus engines are summarized in Table 20.

Table 20 Emission Standards for heavy-duty diesel engines in Thailand[88]

Date	EU Reference Standard	Thai Standard
1998.05	Euro I	
2000.05	Euro II	TIS 1295-1998
2008.01	Euro III	TIS 2315-2550
2012.01	Euro IV	TIS 2315-2551

In **the United States,** greenhouse gas emissions and fuel efficiency standards for heavy- and medium-duty vehicles were jointly established the by Environmental Protection Agency and the National Highway Traffic Safety Administration, under the Department of Transportation. The greenhouse gas programme consists of CO_2 emission standards, N2O and CH4 emission standards, and measures to control hydrofluorocarbon leaks from air conditioning systems. The standards apply to all on-road vehicles with a GVW ≥ 4.25 tonnes and the engines that power

[88] DieselNet. "Thailand: on road vehicles and engines”. Available at https://dieselnet.com/standards/th/ (accessed in March 2023).

them, excluding those covered by the greenhouse gas emissions and CAFE standards for model year (MY) 2012−2016 and MY 2017−2025 light-duty vehicles. The standards were implemented in two phases. Under Phases 1 and 2, distinct CO_2 and fuel consumption standards apply to various vehicle categories, such as combination tractors, trailers, vocational vehicles, and heavy-duty pickups and vans:

- Combination tractors (semi-trucks that typically pull trailers): Phase 1 engine and vehicle standards start in MY 2014, achieving a 7-20 per cent reduction in CO_2 emissions and fuel consumption by MY 2017 compared to 2010 baselines. Phase 2 standards start in MY 2021, achieving a 15-27 per cent reduction in CO_2 emissions by MY 2027 compared to 2017 baselines.
- Trailers: Standards begin in MY 2018, achieving a 6-10 per cent reduction in fuel consumption and CO_2 emissions by MY 2027 compared to 2017 baselines.
- Vocational vehicles: Phase 1 engine and vehicle standards start in MY 2014, achieving up to a 10 per cent reduction in fuel consumption and CO_2 emissions by MY 2017 compared to 2010 baselines. Phase 2 standards start in MY 2021 and require a 10-18 per cent reduction in CO_2 emissions for gasoline vehicles and a 12-24 per cent CO_2 emission reduction for diesel vehicles by MY 2027 compared to 2017 baselines.
- Heavy-duty pickup trucks and vans: Phase 1 standards phase in from MY 2014, achieving up to a 10 per cent reduction in CO_2 emissions and fuel consumption for gasoline vehicles and 15per cent reduction for diesel vehicles by MY 2018. Phase 2 standards require a 16 per cent CO_2 emissions reduction from MY 2021−2027.[89]

In December 2022, the United States Environmental Protection Agency finalized the strongest-ever national clean air standards to cut smog- and soot-forming emissions from heavy-duty trucks beginning with MY 2027.[90] Relative to current rules, the new standards are more than 80 per cent stronger, increase useful life of governed vehicles by 1.5–2.5 times and will yield emissions warranties that are 2.8–4.5 times longer. The standards will reduce smog and soot from new heavy-duty trucks starting with MY 2027.

The new standards require an industry-wide fleet average of 4.8 litre per 100 kilometres for passenger cars and light trucks in model year 2026, the greatest cost savings and highest fuel efficiency standards to date. They are expected to increase fuel efficiency by 8 per cent annually for MYs 2024−2025 and 10 per cent annually for MY 2026. They will also increase the

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[89] DieselNet, "United States: heavy-duty vehicles: GHG emissions & fuel economy". Available at https://dieselnet.com/standards/us/fe_hd.php .

[90] United States Environmental Protection Agency, "Final EPA standards for heavy-duty vehicles to slash dangerous pollution and take key step toward accelerating zero-emissions future", news release, 20 December 2022. Available at https://www.epa.gov/newsreleases/final-epa-standards-heavy-duty-vehicles-slash-dangerous-pollution-and-take-key-step.

estimated fleetwide average by nearly 23.5 litres/100 km for MY 2026, relative to MY 2021. The regulation introduces new NOx, PM, HC, and CO emission standards for heavy-duty engines for MY 2027 and later (Table 21).

Table 21 The United States emission standards for light, medium, and heavy-duty diesel engines[91]

Duty Cycle	NOx[a]	HC	PM	CO
	mg/bhp-hr	*mg/bhp-hr*	*mg/bhp-hr*	*g/bhp-hr*
SET & FTP	35	60	5	6
LLC	50	140	5	6
MAW Bin 2	58[b]	120	7.5	9

[a] A NO_X compliance allowance of 15 mg/bhp·hr applies for in-use testing of medium heavy- duty engine and heavy-heavy duty engine.
[b] For ambient temperatures ≥ 25°C, the standard adjusted (increased) at lower temperatures.

The Environmental Protection Agency estimates that by 2045, the rule will result in the following annual public health benefits:

- Up to 2,900 fewer premature deaths 6,700 fewer hospital admissions and emergency department visits;
- 18,000 fewer cases of childhood asthma;
- 3.1 million fewer cases of asthma symptoms and allergic rhinitis symptoms;
- 78,000 fewer lost days of work;
- 1.1 million fewer lost school days for children;
- $29 billion in annual net benefits.

In the **Islamic Republic of Iran**, fuel economy standards have been in place since 2005 for light-duty vehicles, and, in 2019, the Government announced plans to introduce similar standards for heavy-duty vehicles. However, enforcement of these standards remains a challenge, and many vehicles on the road do not meet the required fuel efficiency targets.

In **Uzbekistan**, the Government is developing fuel economy standards for light-duty vehicles, which are expected to be introduced in 2023. The standards will be mandatory, and non-compliance will result in fines.

In conclusion, the varied implementation of emission and fuel economy standards across the ESCAP region underscores the necessity for heightened collaboration, capacity enhancement and knowledge exchange. Bodies, such as ESCAP, could play pivotal roles in aiding these countries

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[91] DieselNet, "United States: heavy-duty vehicles: GHG emissions & fuel economy". Available at https://dieselnet.com/standards/us/fe_hd.php

in the development and execution of sustainable transport policies. By encouraging regional cooperation and disseminating successful strategies, ESCAP member countries can collectively address disparities in emission standards. This collaborative effort can create a more eco-friendly and sustainable freight transport sector throughout the region, thereby making substantial strides towards a greener future.

3.2 Greenhouse gas emissions pricing

Greenhouse gas emissions pricing is an effective regulatory measure to reduce emissions, including those from the transport sector. It is based on the "polluter pays" principle, which places a financial cost on the emission of greenhouse gas. This can be done through mechanisms, such as carbon taxes or emissions trading systems.

A carbon tax is a fee imposed on the carbon content of fuels. This means that the more a person or business pollutes, the more they have to pay. The objective of this is to incentivize individuals and businesses to reduce their carbon emissions by adopting cleaner technologies and practices.

An emissions trading system, also known as cap-and-trade, sets a cap on the total amount of greenhouse gas that can be emitted by certain sectors. Companies or other groups can buy or sell emission allowances, which gives them the right to emit a specified amount. The cap is reduced over time, so that total emissions fall.

The application of greenhouse gas emissions pricing in the freight transport sector would encourage operators to switch to more fuel-efficient vehicles or alternative fuels, reduce the number of vehicle miles travelled, or improve logistics and operational efficiency. It can also stimulate innovation and the development of new technologies and practices in the sector.

There are challenges associated with implementing greenhouse gas emissions pricing, such as setting the right price, dealing with potential competitiveness impacts and ensuring fairness and equity, particularly for low-income households or small businesses. Moreover, the effectiveness of greenhouse gas pricing also depends on the broader policy context, including existing energy and transport policies.

As of 2022, some countries have already implemented or are considering implementing greenhouse gas emissions pricing, including in the transport sector. These include countries in the European Union, which has a comprehensive emissions trading system, and Canada, which has a federal carbon pricing system.

3.3 Policies to promote a modal shift to low-carbon modes

The rationale for future policies in promoting a modal shift may continue to be that a modal shift from road transport to other modes of transport, such as railways and waterway transport, helps to mitigate carbon emissions in the transport sector even though the potential carbon benefits of a freight modal split are possibly overestimated and the practical problems of getting large numbers of companies to switch mode are underestimated.[92] The main challenge is how to implement such a modal shift policy.

Historically, numerous countries, particularly those with a regulated market and limited free competition, have imposed quantitative restrictions on access to the road transport market. Some have even tried to mandate a shift in transport modes without properly assessing their impact or considering the economic costs this could impose on society.

One way to implement a modal shift policy is to introduce fairer pricing mechanisms and internalize environmental costs of freight transport in all modes of transport on equal basis. The European Commission in its white paper on transport, for instance, has committed to proceed to the full and mandatory internalization of the external costs of all transport modes over the period 2016−2020.

The internalization includes noise, local pollution and congestion on top of the mandatory recovery of wear and tear costs for road and rail transport. In addition, the costs associated with local pollution and noise in ports and airports, as well as for air pollution at sea should be internalized and a mandatory application of internalization charges on all inland waterways on European Union territory should be examined. Market-based measures to further reduce greenhouse gas emissions should, therefore, need to be developed.[93] Although this policy has not resulted in much success, useful preparatory research has been conducted to calculate and estimate the monetary values of transport externalities to be considered for the environmental tax calculation. Box 5 contains a discussion on some experiences of the European Union in calculating external costs of transport and an introduction to the European Commission Handbook on External Costs of Transport.

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[92] Alan Mckinnon, *A. Decarbonizing Logistics, Distributing Goods in a Low Carbon World* (London, Kogan Page Publishers, 2018).pp. 192, 80.
[93] European Commission. *WHITE PAPER Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system* (Brussels, 2011), p. 29.

Box 5: Calculating external costs of transport in the European Union

The latest European Commission *Handbook on External Costs of Transport* from 2019 considers the calculation of transport externalities, the costs of accidents, air pollution, climate change, noise, congestion, well-to-tank emissions, habitat damage, soil and water pollution, up- and downstream emissions of vehicles and infrastructure and extra costs in sensitive areas. Table 22 shows the average external costs of freight transport in 2016 for the 28 countries of the European Union by cost category and transport mode.[94]

Table 22 Average external costs for EU28 freight transport (2016).

Cost category	Freight Transport					
	Road			Rail		IWT
	LCV-petrol	LCV-diesel	HGV - total	Electric freight	Diesel freight	Inland vessel
	€-cent/vkm	€-cent/vkm	€-cent/tkm	€-cent/tkm	€-cent/tkm	€-cent/tkm
Accidents	4.1	4.1	1.3	0.1	0.1	0.1
Air Pollution	1.2	3.4	0.8	0	0.7	1.3
Climate	2.6	2.8	0.5	0	0.2	0.3
Noise	1.1	1.1	0.5	0.6	0.4	n/a
Congestion**	11.6	11.6	0.8			
Well-to-Tank	0.8	0.8	0.2	0.2	0.1	0.1
Habitat damage	0.9	0.9	0.2	0.2	0.2	0.2
Total	**22.3**	**24.7**	**4.2**	**1.1**	**1.8**	**1.9**

**Congestion in terms of delay cost
Notes: LCV, low calorific value; HGV, heavy goods vehicles.

To effectively estimate the costs of CO_2 emissions, it is necessary to convert emissions into monetary values. The fluctuation of these values over time is captured in a report by the Organisation for Economic Co-operation and Development (OECD) titled "Effective carbon rates 2021". This report defines a historic low-end benchmark of EUR 30 per tonne of CO_2 for the early and mid-2010s; a low-end benchmark of EUR 60 per tonne of CO_2 for 2030, aligning with a mid-range 2020 benchmark according to the High-Level Commission on Carbon Pricing; and EUR 120 per tonne of CO_2 as a central estimate needed in 2030 to achieve decarbonization by mid-century, assuming that carbon pricing will play a significant role in these efforts.[95]
For a detailed breakdown, refer to annex 1, which includes tables from the European Commission *Handbook on External Costs of Transport*. In its May 2019 report titled "Sustainable transport infrastructure charging and internalisation of transport externalities: main findings", the European Commission concluded that the “user-pays” principle has not yet fully been achieved and significant progress remains to internalize the external costs of transport. The

[94] European Commission, *Handbook on the External Costs of Transport* (Version 2019-1.1) (Publications Office, 2020).
[95] Organisation for Economic Co-operation and Development, *Effective Carbon Rates 2021* (2021).

input values used in the study for the different cost categories are listed in **ผิดพลาด! ไม่ใช่ผลลัพธ์ที่ถูกต้องสำหรับตาราง.**

Table 23 Input values for different cost categories used in the European Commission study[96]

Cost category	Used/recommended methodology	Important input values (EU28 values)
Accidents	Damage cost approach Top-down approach, based on the following input values: – Accidents: number of casualties (fatalities, injuries) per vehicle category – Costs per casualty (human costs, production loss, medical costs, administrative costs, material costs) – Allocation to different transport modes (according to responsibility) and to vehicle types (according to damage potential/intrinsic risk)	Total external cost per casualty: – Fatalities: € 3,274,000 – Serious injuries: € 498,600 – Slight injuries: € 38,500 Value of statistical life: € 3.6 million
Air pollution	Damage cost approach, covering the following impacts: health effects, crop losses, material and building damage, biodiversity loss. Bottom-up approach, based on the following input values: – Emission factors (per vkm) – Transport performance – Cost factors (health costs and non-health costs)	Some important cost factors for average air pollution damage costs: – NOx transport city: 21.3 €/kg – NOx transport rural: 12.6 €/kg – PM2.5 trsp. Metrop.: 381 €/kg – PM2.5 transport city: 123 €/kg – PM2.5 transport rural: 70 €/kg – PM10 average: 22.3 €/kg – SO_2: 10.9 €/kg – NH3:17.5€/kg – NMVOC: 1.2 €/kg Value of life year lost (VOLY): € 70,000

[96] Arno Schroten and others, *Sustainable Transport Infrastructure Charging and Internalisation of Transport Externalities: Main Findings* (Luxembourg, Publications Office of the European Union, 2019).

Cost category	Used/recommended methodology	Important input values (EU28 values)
Climate change	Avoidance cost approach: global avoidance costs, based on the targets from the Paris Agreement, namely, preventing temperature rises above 1.5-2 degrees Celsius (CO_2 concentration in the atmosphere below 450 ppm). Bottom-up approach, based on the following input values: – Greenhouse gas emission factors per vehicle type – Transport performance data — climate change costs per tonne of CO_2 equivalent – Factor 2 increase for aviation due to non-CO_2 impacts, however, it should be noted that there is currently still high uncertainty regarding the non-CO_2 impacts and thus the factor to be used.	Cost factor for CO_2 emissions (based on a literature review: – Central value for the short -and-medium-run costs (up to 2030): ○ € 100/tCO2-eq. [a] ○ Main value used in handbook – Central value for the long run costs (up to 2060): ○ € 269/tCO2-eq. [b]
Noise	Damage cost approach, covering health effects and annoyance due to noise exposure. Bottom-up approach, based on the following input values: – Number of people exposed to noise for each transport mode – Noise costs per person exposed (health costs and annoyance costs)	Noise costs per person exposed, differentiated by noise class: decibel-class Lden (dB(A)). Costs for road transport: • 50-54 dB: 17 €/dB/person/year • 55-59 dB: 31 €/dB/person/year • 60-64 dB: 34 €/dB/person/year • 65-69 dB: 63 €/dB/person/year • 70-74 dB: 67 €/dB/person/year • >75 dB: 72 €/dB/person/year

Cost category	Used/recommended methodology	Important input values (EU28 values)
Congestion	Two approaches have been developed to estimate congestion costs at urban and inter-urban levels: Delay costs Deadweight loss For both methodologies common input values are the following: – Speed-flow functions – Transport demand curves (based on literature cost elasticity) – Value of time for car and coach passengers by purpose (namely, commuting, business and leisure) and for road freight transport – Average vehicle occupancy/load factors for cars, buses, coaches, large goods vehicles an heavy goods vehicles. Additional inputs to estimate urban congestion: – Data on the level congestion and road network length by road type (such as trunk urban road, other urban road), average delay per day and total accumulated delay per year (related to peak period journeys) – Car mode share in a set of European cities – Population of European cities Typology of NUTS3 according to the degree of urbanization urban/mixed/rural – Additional inputs to estimate inter-urban congestion: – localization of the congested spots on the European inter-urban road network Road network characteristics to determine speed flow functions of the roads where the spots are located in order to estimate the amount of vehicles experiencing congestion in in peak time Daily traffic profiles	- Elasticity values: such as for cars: • Urban demand, commuting-business -0.49 • urban demand, personal -0.58 • interurban demand, commuting-business -0.56 • inter-urban demand, personal -0.67 - value of time: e.g. the average for cars: • Short distance, commuting-business 13.3 • € per passenger per hour • long distance, commuting-business 16.3 € per passenger per hour • personal 6.1 € per passenger per hour - vehicle occupancy/load factors - level of congestion available from TomTom for a set of European cities - localization of congested spots on the European inter-urban road network provided by the European Commission, Joint Research Centre

Cost category	Used/recommended methodology	Important input values (EU28 values)
Well-to-tank emissions	– Damage cost approach for the air pollution costs and avoidance costs for the climate change costs caused by the well-to-tank emissions of energy production – Bottom-up approach, based on the following input values: – Production and transport/transmission of fossil fuels and electricity (differentiated by country) – Transport performance – Cost factors: air pollution and climate change costs	See cost factors for air pollution and climate change costs.
Habitat damage	Restauration cost approach for the following costs: habitat loss (ecosystem loss) and habitat fragmentation. Bottom-up approach, based on the following input values: – Infrastructure network length (or area) – Average cost factors for habitat loss and habitat fragmentation	Total habitat damage costs per year: • Road motorways: 93,500 €/km/y • Other roads: 4,100 €/km/y • Rail high speed: 84,500 €/km/y • Rail other rail: 14,100 €/km/y • Aviation: 437,500 €/km/y • Inland waterways: 6,600 €/km/y

[a] Short-and-medium-run costs: cost range from € 60/tCO2-eq. (low estimate) to € 189/tCO2-eq. (high estimate).
[b] Long run costs: cost range from € 156/tCO2-eq. (low estimate) to € 489/tCO2-eq. (high estimate).
Note: US$ 1equals €.92

Despite all the challenges in implementing modal shift from road to low-carbon transport modalities has faced in the past, this policy will remain on the agenda of most countries in the world. Many governments, in cooperation with international organizations and institutions, will continue to facilitate and promote the use of intermodal transport services. They are often doing this by using a corridor framework: the European Union with its nine intermodal transport corridors linking most of its member States and their neighbouring countries; the Indian subcontinent with its dedicated rail freight corridors; the Eurasian railway network linking China with Europe; and the ESCAP Asian Highway, Trans-Asian Railway and dry ports.

Box 6 shows the example of the development of the International North-South Transport Corridor, which basically links India with the Russian Federation through a combination of land and sea corridors as an alternative for using the Suez Canal and the Strait of Gibraltar.

In the land component of this corridor railways is the preferred mode of transport. This alternative provides a much shorter delivery time from Mumbai, India to St. Petersburg, the Russian Federation, than sailing via Suez Canal and the Strait of Gibraltar: 15-24 days instead of 20-45 days. The carbon footprint of using the International North-South Transport Corridor is comparable with deep-sea maritime transport.[97] With improvements along the corridor this carbon footprint can be reduced even more.

[97] Evgeny Vinokurov, Arman Ahunbaev and Alexander Zaboev, "International North-South Transport Corridor boosting Russia's 'pivot to the South' and Trans-Eurasian connectivity". *Russian Journal of Economics*, vol. 8 No. 2, (2022), pp. 159−173.

Box 6: The International North-South Transport Corridor

The International North-South Transport Corridor, a 7,200-km multimodal transport corridor that combines road, rail and maritime routes, connects the Russian Federation and India through Central Asia and the Islamic Republic of Iran and links the Indian Ocean to the Caspian Sea via the Persian Gulf onwards into the Russian Federation and Northern Europe.

Tracing the inception of the International North-South Transport Corridor starts in September 2000. At the second International Eurasian Conference on Transport, an Inter-Governmental Agreement was inked by India, the Islamic Republic of Iran and the Russian Federation. Following ratification by these three countries, the Agreement took effect on 16 May 2002.

In addition to the founding members, the Corridor also includes Armenia, Azerbaijan, Belarus, Kazakhstan, Kyrgyzstan, Oman, Syria, Tajikistan, Türkiye and Ukraine, with Bulgaria as an observer. It stretches from India and Oman, via the Islamic Republic of Iran, across the Caspian Sea to the Russian Federation and beyond. In 2005, a land route on the western side of the Caspian Sea's was added. Current projects include completing a 167 km missing rail link between Rasht and Astara in the Islamic Republic of Iran.

A study conducted by the Federation of Freight Forwarders Associations in India found that using the Noth-South Transport Corridor route is 30 per cent cheaper and 40 per cent shorter than the traditional route via the Suez Canal and the Strait of Gibraltar.[98] It is anticipated that the Noth-South Transport Corridor freight traffic will reach 15-25 million tons per year. Being a meridional transcontinental corridor, the Corridor offers potential synergies by interlinking with the Eurasian East-West corridors. This transformative alignment could convert the landlocked countries of Central Asia into “landlinked” countries, transforming the transport corridor into an economic artery with dry ports, industrial parks and special economic zones.

Governments recognize the need to establish an intermodal transport network for synchromodality, facilitating seamless mode-switching for consignments in transit. Accordingly, investments should be channelled into developing synchromodal transport networks with various modal options. McKinnon, in his research, identifies additional facilitators for shifting towards lower-carbon modes: freeing up freight capacity through high-speed passenger rail lines; enhancing rail and waterborne services via upgrades to infrastructure, signalling systems,

[98] Vaishali Sharma "The political economics of the International North-South Transport Corridor: India, Iran, Russia", *The Wire*, 30 June 2020. Available at https://thewire.in/world/political-economics-international-north-south-transport-corridor-india-iran-russia.

information technology and intermodal terminals; mitigating road network congestion; regulating truck driver times and rest periods; and reducing speed limits on highways.[99]

Empirical evidence has shown that the results of the implementation of modal shift policies have not fully responded to the expectations that the policymakers had when designing them. Some recent developments, such as the growing need for integrated synchromodal systems, collaboration among stakeholders in the supply chain and improved interoperability may contribute towards making the modal shift policy more successful. However, it must be taken into account that road transport has also undergone rapid development towards cleaner motor engines and less emissions increasing its carbon efficiency.

3.4 Sustainable transport in national development policies

Across the ESCAP region, numerous countries have implemented initiatives to enhance energy efficiency in freight transport. These initiatives form an integral part of their national development policies, strategies and programmes. The following discussion explores a few such noteworthy endeavours.

Pakistan recognizes the importance of promoting sustainable transport as a key pillar of its National Transport Policy. To achieve this goal, the Government has introduced the Electric Vehicle Policy under which it has set a target to transition 30 per cent of all new vehicles to electric by 2030.

In addition, the country has set vehicle standards in line with the World Forum for Harmonization of Vehicle Regulations (WP-29), which promotes fuel efficiency and reduce emissions. Furthermore, the main line of Pakistan Railways between Karachi to Lahore is being electrified, which will further reduce the carbon footprint of the transport sector in the country. The implementation of the Electric Vehicle Policy and other measures aimed at promoting sustainable transport are expected to result in more than a 20 per cent reduction in CO_2 emissions by 2030. It is also estimated that approximately 10 MT CO_2 emissions could be reduced from the transport sector alone.

The Transport Strategy of **the Russian Federation** to 2030 outlines a comprehensive plan for promoting sustainable transport in the country. This includes the electrification and gasification of public transport and the introduction of new transport and information technologies, such as

[99] Alan Mckinnon, *Decarbonizing Logistics, Distributing Goods in a Low Carbon World* (London, Kogan Page Publishers 2018), pp. 76−78.

automatic driving systems, automated control, monitoring and positioning systems. The Strategy also calls for the transition of road transport to hybrid analogues and the development of charging infrastructure for electric vehicles. In addition, the Concept for the Development of Production and Use of Electric Road Transport in the Russian Federation to 2030 aims to facilitate the development of transport infrastructure, remove existing regulatory barriers to the use of electric road transport and fostering the development of electric motor vehicles production in the country. In addition, Russian Railways has formulated the Energy and Environmental Development Strategy for the period up to 2030 and beyond with the main goals being to increase energy efficiency and minimize the environmental impact.

The Republic of Korea has set mandatory fuel efficiency standards for heavy-duty vehicles, requiring a 15 per cent reduction in CO_2 emissions by 2025 compared to 2012 levels. The Electric Vehicle Promotion Plan includes financial incentives, such as subsidies and tax breaks, for the purchase of electric vehicles, including freight vehicles.

In **Sri Lanka**, the National Transport Policy 2009, which was revised in 2019, aims to reduce the country's dependence on petroleum fuels by promoting the use of energy-efficient vehicles and setting tariffs to discourage the importation and use of energy-inefficient vehicles. The policy also aims to facilitate goods transport and logistics. Additionally, the National Energy Policy 2019 aims to reduce transport energy use by promoting "avoid, shift, and improve" strategies with a strong focus on high-quality public transport and intelligent traffic management solutions. The fuel efficiency of vehicles is a key consideration in deciding applicable taxes on vehicles to encourage a more efficient vehicle fleet. The National Environmental Policy sets environmental standards on used motor vehicles and engines imports, and promotes the use of non-motorized transport to reduce air pollution and encourage modal shift of transport of people and freight from road to rail. To reduce traffic congestion, pollution and accidents on the country's roads, the Ministry of Transport and the Ministry of Energy have jointly decided to increase the distribution of petroleum products by railways. In line with this, Sri Lanka has taken steps to increase the distribution of oil by rail by up to 40 per cent of the total volume in 2022.

In **Thailand**, the Sustainable Transport Development Strategy is guided by a vision and goal that focuses on green and safe transport, inclusivity and transport efficiency. To achieve a more sustainable transport system, the Strategy promotes the use of green and environmentally friendly transport, and clean and alternative fuels, and encourages the adoption of environmentally friendly transport technology. In addition, the Strategy aims to improve access to transport services with affordability and equity, while also promoting universal design and service design to ensure inclusivity. Furthermore, it aims to improve transport and logistics efficiency, reduce transport and logistics costs, and enhance domestic and international transport connectivity to increase efficiency in the transport sector.

In **Türkiye,** one of the key strategic initiatives is the Green Corridor Project, which aims to encourage the adoption of eco-friendly practices and technologies in freight transportation. This project includes a network of designated routes optimized for fuel-efficient vehicles, eco-driving practices, and advanced logistics management systems. In addition, the National Energy Efficiency Action Plan includes a comprehensive strategy to improve energy efficiency across various sectors, including transportation. Under the plan, targets and actions are set to boost the share of environmentally friendly vehicles, promote public transportation and improve energy efficiency in the freight sector. Under the Ministry of Transport and Infrastructure, the Green Ports Initiative aims to minimize the environmental impact of port operations, including the freight transport sector. The initiative encourages the adoption of environmentally friendly practices, such as using alternative fuels and renewable energy, implementing energy-efficient technologies and reducing emissions.

The Government of **Turkmenistan** has invested in sustainable transport infrastructure, including the construction of a new railway line that will connect the country to the Islamic Republic of Iran and Türkiye. The railway line is designed to transport freight more efficiently and reduce carbon emissions. The Government has also invested in the construction of new highways and bridges and in the public transportation systems in major cities, such as Ashgabat.

The Green Economy Strategy of Georgia includes measures to promote sustainable transport, including the development of energy-efficient public transportation, the expansion of electric vehicle charging infrastructure and the promotion of sustainable urban mobility plans.

The Green Freight Initiative of the Philippines aims to improve the efficiency and environmental performance of the country's freight sector by promoting green technologies, policies and practices. Ultimately, the objective of the Initiative is to reduce fuel consumption, cut emissions and enhance the competitiveness of the Philippine freight sector.

Several initiatives and projects promoting energy efficiency and sustainable freight transport are being carried out beyond the ESCAP region, particularly in Africa, Latin America and the Caribbean. These efforts are facilitated under the framework of South-South cooperation, a few of which are highlighted in the following discussion.

Africa Clean Mobility Week aims to accelerate the shift to cleaner, more efficient transport systems in African countries. The event brings together stakeholders from various sectors to share best practices, discuss policy interventions and explore innovative solutions for sustainable freight transport.

Latin American Green Freight Initiative, supported by the Climate and Clean Air Coalition, focuses on improving the energy efficiency and environmental performance of the freight sector in Latin American countries. The programme promotes the adoption of cleaner fuels, energy-efficient technologies and best practices to reduce fuel consumption and emissions.

The EcoLogistics Project, supported by the International Council for Local Environmental Initiatives, aims to promote low-carbon urban freight systems in cities across Africa, Asia and Latin America. The project helps cities develop and implement sustainable urban freight plans, drawing on best practices and lessons learned from other developing countries.

The African Sustainable Transport Forum provides a platform for African countries to share knowledge and experiences related to sustainable transport, including freight transport. The Forum encourages policy dialogue, capacity-building and the development of innovative solutions to address the challenges of sustainable transportation in Africa.

The National Policy on Urban Mobility, set by Brazil, aims to improve the sustainability and efficiency of the country's urban transportation systems, including freight transport. The policy encourages the development of integrated urban mobility plans, the promotion of non-motorized and public transportation, and the adoption of cleaner fuels and technologies.

These examples illustrate the power of South-South cooperation in advancing energy efficiency and sustainable freight transport across developing countries. By fostering an environment of knowledge exchange, technology transfer and shared resources, the countries can collaboratively forge more sustainable and efficient transport systems. This collective action is key to reducing greenhouse gas emissions and enhancing environmental health.

3.5 Financial incentives and subsidies

Governments across the globe are effectively implementing incentive schemes aimed at fostering environmentally friendly practices and bolstering energy efficiency within the road freight transport sector. They are leveraging a range of fiscal and taxation incentives to catalyse this much-needed transformation. Financial incentives play a crucial role in fostering sustainable freight road transport by stimulating businesses to adopt more environmentally friendly practices.

One common type of incentive is to set fuel taxes or levies. Higher fuel taxes can encourage freight carriers to adopt more fuel-efficient vehicles and practices. For example, in countries with large distances between cities or limited alternatives to road freight transportation, lower fuel taxes may be in place. Conversely, some countries are eliminating diesel fuel subsidies to discourage the use of polluting fuels.[100]

Another type of incentive is to offer tax credits or rebates for the adoption of cleaner technologies. Governments may provide tax incentives for the purchase of low-emission vehicles or for the installation of energy-efficient equipment in freight vehicles. For instance, the Government of the United States offers tax credits for the purchase of electric and hybrid vehicles.[101]

Fiscal policies targeting infrastructure investments and internalizing external costs of road freight can promote a modal shift and decarbonization of the freight transportation sector. These policies can include incentives for rail and water transport, as well as taxes or charges on road freight to internalize the environmental costs.[102]

Financial incentives have been effective in promoting sustainable transport services. One survey conducted a large-scale field experiment and found that both monetary and non-monetary incentives increased the demand for a sustainable demand responsive transport system. Financial incentives, such as vouchers, have been particularly effective in increasing the demand for the service.[103]

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[100] Lynn Kaack and others, "Decarbonizing intraregional freight systems with a focus on modal shift", *Environmental Research Letters*, vol. 8, No. 13 (2018), 083001.

[101] Ibid.

[102] Ibid.

[103] Aljoscha Minnich, Holger Rau and Jan Schlüter, "The effects of financial and non-financial incentives on the demand for a sustainable DRT system", CeGE discussion papers, No. 394. DRT System.

Another emerging trend leaning towards energy-efficient vehicles involves offering fleet renewal subsidy schemes, typically introduced as facets of comprehensive environmental and economic strategies. The primary objectives of these initiatives are to bolster the automobile industry, reduce both economic and environmental costs of transport, decrease CO_2 emissions and enhance air quality, lessen reliance on imported oil and boost road safety. By replacing older, less efficient vehicles with new, environmentally friendly alternatives, these programmes are intended to stimulate economic growth and promote sustainable practices in the automotive sector.

Several examples listed below highlight the challenges and opportunities associated with the introduction and management of various incentive programmes to promote energy-efficient vehicles.

China is a prominent example with its 2009 “cash for clunkers” programme. The programme incentivized vehicle owners to replace their old, high-emission vehicles with new, fuel-efficient ones, focusing particularly on heavy-duty diesel trucks. Owners could receive subsidies of up to CNY 18,000 ($2,830) for each vehicle replaced. As a result of this initiative, more than 2.3 million vehicles were taken off the roads by the end of 2010. China has established low emission zones in cities, such as Beijing and Shanghai, to restrict high-polluting vehicles, further promoting sustainable transportation. [104]. In addition, the Green Freight Initiative programme promotes the adoption of cleaner technologies, such as advanced vehicle engines, aerodynamics, and alternative fuels, targeting a 10 per cent reduction in energy consumption per ton-kilometre for road freight by 2020.

In 2021 the Government of **India** introduced the Voluntary Vehicle Fleet Modernization Program, which targets vehicles older than 15 years. Under this programme, vehicle owners scrapping their old vehicles receive financial incentives, including a 25 per cent discount on the road tax and a 5 per cent discount on the purchase of a new vehicle. Additionally, under the programme, registration fees for new replacement vehicles are waived. In addition, the FAME scheme provides financial incentives for the purchase of electric and hybrid vehicles, including freight vehicles. In 2021, the FAME-II scheme allocated approximately $1.2 billion for this purpose over three years.

[104] Fugui Dong and others, “Study on China’s renewable energy policy reform and improved design of renewable portfolio standard”, *Energies*, vol. 11, No. 12 (2019), 2147.

In 2014, **Japan** launched the Eco-Drive Management initiative, with the objective to promote fuel-efficient driving habits and the utilization of fuel-saving technologies in commercial vehicles, such as trucks. This programme incentivizes fleet operators with financial rewards when they integrate eco-driving methods, leading to a reduction in fuel consumption and emissions. Furthering its commitment to environmental sustainability, Japan declared an ambitious goal in 2020 to boost the proportion of electrified vehicles – encompassing electric vehicles, plug-in hybrids and fuel cell vehicles – to comprise 50-70 per cent of all new vehicle sales by 2030. The Government provides subsidies for the purchase of low-emission and fuel-efficient vehicles, including electric and hybrid freight trucks.

The Republic of Korea offers subsidies for the purchase of new trucks with lower emissions and higher fuel efficiency. These subsidies can cover up to 50 per cent of the price difference between new eco-friendly trucks and conventional diesel trucks. In addition, under the Green Freight Initiative, the Government provides support for eco-friendly truck technologies and encourages the adoption of fuel-saving devices and efficient driving practices. The Government has also set a target to have 2.1 million electric vehicles and 80,000 hydrogen fuel cell vehicles on the roads by 2025. To achieve this goal, the Government provides financial incentives for the purchase of electric and hydrogen trucks and invests in charging and refuelling infrastructure.

In 2014 the Government of **the Russian Federation** offered financial incentives to replace truck fleet with more fuel-efficient models.

In **Canada**, the Government's 2030 Emissions Reduction Plan aims for zero emission vehicles to make up 35 percent of total sales of medium- and heavy-duty vehicles by 2030 and 100 percent of medium- and heavy-duty vehicles sales by 2040 for certain vehicle types. Incentives for zero-emission medium- and heavy-duty vehicles received a further boost from the 2022 federal budget, which set aside the following:

- $545.7 million over four years to launch a new purchase incentive programme for medium- and heavy-duty vehicles.
- $119.6 million over five years to expand the Green Freight Program to support assessments and retrofits of internal combustion engine vehicles used for hauling freight.
- $33.8 million over five years to assist provinces and territories in developing regulations and conducting safety testing for long-haul zero-emission trucks

In addition, the Specialty Use Vehicle Incentive (SUVI) Program offers a maximum rebate of $100,000 or 33 percent of the purchase price of an on-road zero-emission heavy-duty vehicles, whichever is lower.[105] The Quebec Écocamionnage subsidy programme offers significant subsidies for the acquisition of medium- and heavy-duty electric vehicles, with a budget of up to $175,000 for larger class 8 electric vehicle trucks. The government of Quebec is also offering an additional subsidy of up to 15 per cent if the electric vehicle is assembled and deployed in Quebec.

In **Germany**, the Government's measures include supporting the automotive industry through fiscal incentives for plug-in hybrid electric vehicles and battery electric vehicles. The Government incentivizes the purchase of a plug-in hybrid electric vehicles by up to €4,500, in the case of battery electric vehicles, up to €6,000. In addition, plug-in hybrid electric vehicles and battery electric vehicles receive fiscal incentives in the form of lower vehicle ownership and company car tax rates.[106]

In **Spain,** the State Budget for 2022 provides for extended financial support to incentivize the purchase of electric vehicles and promotes sustainable mobility.[107] Proposed subsidies include an initial budgetary item of €445 million for the electric mobility sector. They encompass subsidies for the purchase of electric vehicles, innovation in electromobility projects, the roll-out of networks with charging points and the renewal of company vehicle fleets. With a budgetary item of €50 million annually extendable until 2023, a programme was set up to help companies with more than 500 vehicles renew their fleet of pollutant vehicles. For plug-in hybrids, with an electric range of between 30 and 90 km, the subsidies for scrapping a polluting vehicle can be up to €5,000.

The Government of **Australia** provides financial support for research and development of advanced technologies and alternative fuels for the freight transport sector through programmes, such as the Australian Renewable Energy Agency and the Clean Energy Finance Corporation. Some Australian states, such as Queensland, offer incentives such as stamp duty reductions and registration fee discounts for low-emission or fuel-efficient heavy-duty vehicles.

The Low Carbon Emission Vehicle programme in **Indonesia**, launched in 2013, provides fiscal incentives, such as reduced luxury tax and import duties, for the production and purchase of energy-efficient vehicles.

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[105] 7GEN, "How government incentives support your you transition of fleet electrification", 6 May 2022. Available at https://7gen.com/how-government-incentives-support-your-transition-to-fleet-electrification/.

[106] Georg Bieker and others, "Life-cycle greenhouse gas emission benefits and physical incentives of plug-in and battery electric vehicles in Germany", ICCT factsheet, 24 March 2022 Available at https://theicct.org/publication/fs-greenhouse gas-benefits-incentives-ev-mar22/.

[107] Dandolla Barcelona, "Subsidies to incentivise electromobility in 2022", 16 December 2021. Available at https://www.endolla.barcelona/en/news/endolla-service/subsidies-incentivise-electromobility-2022.

3.6 International climate initiatives

Over the past decades, a myriad of international climate initiatives were launched with the objective to mitigate climate change and drive sustainability across all sectors of the global economy, including freight transport. These initiatives, ranging from policy directives to comprehensive conventions, provide structure for collective action and establish tangible goals that guide countries on their path towards a more sustainable future. They represent the international community's commitment to a shared vision of reduced greenhouse gas emissions, energy efficiency, and a sustainable and resilient global economy. Understanding these conventions and their implications for the freight transport sector is critical for aligning the sector's practices with global climate goals. The following section presents an overview of these crucial international agreements and organizations and their relevance to the sustainable transformation of the freight transport industry.

The **United Nations Framework Convention on Climate Change** (UNFCCC) is an international treaty that aims to address climate change by stabilizing greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic (human-induced) interference with the climate system. The treaty was adopted in 1992 during the Earth Summit in Rio de Janeiro, Brazil, and entered into force in 1994. As of September 2021, it has been ratified by 197 parties, including 196 countries and the European Union.

The United Nations Framework Convention on Climate Change provides a framework for the negotiation of specific protocols and agreements to reduce greenhouse gas emissions and adapt to the impacts of climate change. The primary goal of the Convention is to achieve stabilization of greenhouse gas concentrations at a level that allows ecosystems to adapt naturally, ensures that food production is not threatened and promotes sustainable economic development.

The United Nations Framework Convention on Climate Change establishes a few key principles, including, among them, the principle of "common but differentiated responsibilities", which acknowledges that developed countries have a greater responsibility to reduce emissions due to their historical contributions to the problem. It also emphasizes the importance of international cooperation and the need for financial and technical support for developing countries to help them address climate change.

Under UNFCCC, countries are required to regularly report on their greenhouse gas emissions and their efforts to reduce emissions and adapt to climate change impacts. COP is the supreme decision-making body of UNFCCC. It meets annually to assess progress and negotiate additional measures to address climate change. UNFCCC plays a central role in shaping global climate policy and fostering international cooperation to address the challenges posed by climate change.

The Kyoto Protocol is an international treaty that commits its parties to reduce greenhouse gas emissions. Adopted in 1997 in Kyoto, Japan, and entered into force in 2005, the Protocol is linked to UNFCCC. The Kyoto Protocol establishes legally binding emissions reduction targets for developed countries, also known as Annex I Parties, based on their 1990 levels of emissions.

The main objectives of the Kyoto Protocol are to reduce the overall emissions of six main greenhouse gas, CO_2 CH4, NOx, HC, perfluorocarbons and sulfur hexafluoride, by at least 5 per cent below 1990 levels during the first commitment period (2008−2012) and encourage developed countries to take the lead in reducing emissions, acknowledging their historical contribution to the problem.

The Kyoto Protocol introduced three market-based mechanisms to help countries achieve their emissions reduction targets:

- International Emissions Trading: This allows countries that have emission units to spare (emissions permitted but not used) to sell their excess capacity to countries that are exceeding their targets.
- Joint Implementation: This enables a developed country to invest in emission reduction projects in another developed country, earning emission reduction units that can be counted towards meeting its own Kyoto target.
- Clean Development, Mechanism: This allows a developed country to implement emission reduction projects in developing countries and earn certified emission reduction credits, which can be counted towards meeting its own Kyoto target.

The Kyoto Protocol was followed by the **Paris Agreement,** an international treaty under UNFCCC, aimed at addressing climate change by limiting global warming. Adopted on 15 December 2015, and entered into force on 4 November 2016, the Paris Agreement sets the goal of limiting global warming to well below 2°C, preferably to 1.5°C, compared to pre-industrial levels.

The key objectives of the Paris Agreement are the following:

- Strengthen the global response to climate change by limiting the global temperature increase and promoting climate resilience and low greenhouse gas emissions development.
- Enhance financial, technological and capacity-building support to help countries, particularly developing countries, achieve their climate goals.
- Encourage transparency and accountability in reporting and assessing countries' progress towards meeting their climate goals.

Under the Paris Agreement, countries are required to submit nationally determined contributions under which they outline their plans to reduce greenhouse gas emissions and adapt to climate change impacts. The nationally determined contributions are to be updated every five years to reflect each country's evolving circumstances and ambitions. The Agreement also requires countries to report on their emissions and progress towards meeting their nationally determined contributions.

The Paris Agreement emphasizes the principle of "common but differentiated responsibilities and respective capabilities" established under UNFCCC. This means that while all countries are required to contribute to the global effort to combat climate change, developed countries are expected to take the lead in reducing emissions and providing financial and technological support to developing countries in that regard.

The Paris Agreement established a global stocktake process, which is a periodic assessment of collective progress towards achieving the Agreement's long-term goals. It is recognized as a landmark agreement in international climate policy, as it brings together all countries in the world in a common effort to combat climate change.

The Global Electric Mobility Programme is an ambitious initiative spearheaded by the **United Nations Environment Programme (UNEP)** designed to support the worldwide adoption of electric mobility and promote a transition to more sustainable transport systems. The programme focuses on assisting countries in developing and implementing policies, strategies and measures that encourage the uptake of electric vehicles, including those related to the freight transport sector, as part of their broader efforts to combat climate change and improve air quality.

The Global Electric Mobility Programme works closely with governments, industry stakeholders and international organizations to facilitate knowledge-sharing, technical assistance and capacity-building in the field of electric mobility. By providing guidance on policy development, infrastructure planning and financing mechanisms, the programme helps countries create enabling environments for the widespread adoption of electric vehicles. One of the key objectives of the Global Electric Mobility Programme is to support the development of national electric mobility targets and strategies.

The United Nations Climate Change Conference, also known as the **Conference of the Parties (COP),** is an annual international event, which brings together representatives from countries around the world to address the pressing issue of climate change. The Conference serves as the primary forum for countries to discus, negotiate and implement global climate policies under UNFCCC.

Since the first COP, which was held in 1995, these conferences have played a vital role in shaping international climate change policies and facilitating global cooperation on climate action. One of the most significant achievements of COP is the adoption of the Kyoto Protocol in 1997, which established legally binding targets for industrialized countries to reduce their greenhouse gas emissions. Another major milestone is the 2015 Paris Agreement, which was adopted at COP21 in Paris.

In addition to formal negotiations, the COP conferences serve as a platform for various stakeholders, such as governments, businesses, and civil society organizations, to showcase their climate actions, share best practices and form partnerships to accelerate the global transition to a low-carbon, climate-resilient future. In November 2022, COP27 was concluded with a historic decision to provide "loss and damage" funding for vulnerable countries hit hard by climate disasters.[108]

The Economic Commission for Europe (ECE), established in 1947, is one of the five regional commissions under the United Nations. Its primary mission is to promote economic integration and cooperation among its 56 member countries, which include countries from Europe, North America and Central Asia. The Commission aims to facilitate sustainable development, economic growth and environmental protection in the region.

[108] For more information see https://unfccc.int/event/cop-27.

One of the key areas of focus of ECE is sustainable transport in which it facilitates international agreements and regulations to improve the safety, efficiency and environmental performance of road, rail and inland waterway transportation. For instance, ECE was instrumental in creating vehicle regulations and standards that were adopted by many countries worldwide, contributing to cleaner and safer vehicles.

The Economic Commission for Europe has facilitated several multilateral environmental agreements, such as the Convention on Long-range Transboundary Air Pollution and, the Convention on the Protection and Use of Transboundary Watercourses and International Lakes (Water Convention), which have been vital in improving the region's environmental quality.

The International Energy Agency, an intergovernmental organization, focuses on energy policy and promotes energy efficiency and clean energy technologies. IEA develops and shares best practices, data and policy recommendations with its member countries. Its Transport Energy Efficiency Implementation Partnership, for instance, supports the adoption of energy-efficient technologies and practices in the transport sector.

The Clean Vehicles Directive of the European Union encourages the use of clean and energy-efficient vehicles in public transportation fleets within the European Union. This Directive can serve as an example for other countries and regions looking to promote energy efficiency and sustainable transport.

The G20 Energy Efficiency Leading Programme, endorsed by the G20 leaders, aims to enhance voluntary collaboration and knowledge-sharing among G20 countries on energy efficiency. It covers various sectors, including transportation, and can contribute to the promotion of energy-efficient and sustainable freight transport.

The Global Logistics Emissions Council (GLEC) Framework of the Smart Freight Centre is a voluntary, industry-led initiative, which provides guidelines for companies to measure, report and reduce logistics emissions across global supply chains. The Framework helps companies make more informed decisions and drives improvements in energy efficiency and sustainability in the freight transport sector.

The Transport Decarbonization Alliance is a global multi-stakeholder platform, which brings together countries, cities and companies to accelerate the decarbonization of the transport sector. The mission of the Alliance is to catalyse the transition to low-carbon, sustainable transport systems by promoting ambitious climate actions, fostering innovation and facilitating knowledge-sharing among its members and the broader international community.

The Central Asia Regional Economic Cooperation (CAREC) aims to promote economic growth and improve living standards in Central Asian countries, including Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan. One of the programme's key areas is regional transport connectivity, which is supported by it work on the developing efficient, safe and sustainable transport corridors.

Countries may also engage in bilateral or regional agreements to cooperate on energy efficiency and sustainable freight transport initiatives. For example, the United States and China, under the US-China Energy Cooperation Program, collaborate on clean energy and energy efficiency projects, including transportation sector initiatives.

These initiatives, agreements, and programmes play an essential role in promoting energy efficiency and sustainable freight transport by providing policy guidance, technical support, and sharing best practices among countries and stakeholders.

Chapter 4: Design of a regional road map

Over the years, the pressing need to transition to sustainable and energy-efficient freight transport has been recognized globally. As countries grapple with the intertwined challenges of rising freight demand, climate change and the urgency to reduce environmental footprints, the design of a cohesive and strategic regional road map for the transition becomes paramount. Such a road map not only serves as a guiding blueprint for individual countries, but it also fosters collaboration, shared learnings and mutual progress across the region. It ultimately aims to transform the freight transport sector of the Asia-Pacific region, ensuring it is sustainable and energy-efficient, aligning with global ambitions and regional nuances. The key components, strategic approaches and potential pathways that can shape a comprehensive road map are explored in this chapter.

4.1 The concept of a regional road map

The development of a regional road map towards a sustainable and energy efficient freight transport requires a comprehensive approach that considers a range of factors, including, among them, infrastructure, policy, technology and stakeholder engagement. This type of road map in Asia and Pacific may consist of five steps:

1. Conducting a baseline assessment, which includes a comprehensive assessment of the state of the region's freight transport system, including its energy use, emissions and efficiency to attain a sound base from which to identify areas that require improvement and the setting of the goals for the future.
2. Development of a stakeholder engagement plan, engaging the key stakeholders, such as policymakers, shippers, carriers, logistics service providers and community groups, to understand their needs and priorities. This makes the development of a regional road map a realistic endeavour and relevant to the region's context as well as builds support for it. Engagement of stakeholders in an early stage also enables implementation and enforcement of the regional road map
3. Setting targets and developing strategies: Set targets for reducing energy use and emissions and develop strategies to achieve them. This may include investment in alternative fuels and vehicle technologies, improvements to infrastructure and logistics and policies that incentivize sustainable practices
4. Identification of funding sources: Identify potential funding sources, such as PPPs, partnerships, grants and loans to support the implementation of the road map.
5. Monitoring and evaluating progress of implementation: Development of a monitoring and evaluation plan to track progress towards attaining the road map's goals and make adjustments as needed. This enables the road map to remain relevant and effective over time.

Box 9 give a summary of the five steps for developing a regional road map towards sustainable and energy efficient freight transport in Asia and Pacific.

Box 9: Five steps for developing a regional road map towards sustainable and energy efficient freight transport in Asia and Pacific

1. **Conducting of a baseline assessment**
   - Conduct a baseline assessment.
   - Measure and report on corporate transport and logistics emissions annually across modes and transhipment centres (including dry ports).
   - Measure and report on national transport and logistics emissions annually across modes and transhipment centres (including dry ports).
   - Apply internalization of external costs in transport and logistics operations.
   - Support a common methodology for development within the ESCAP domain.
   - Support data collection and data exchange within the ESCAP domain.
2. **Development of a stakeholder engagement plan**
   - Define and involve stakeholders in the transition towards sustainable and energy efficient freight transport.
   - Facilitate and promote horizontally and vertically multi-stakeholder collaboration mechanisms.
   - Promote the elaboration of sustainable and energy efficient freight programmes.
3. **Setting targets and developing strategies**
   - Develop national targets for transport and logistics emissions.
   - Develop sectoral targets for transport and logistics emissions.
   - Develop corporate targets for transport and logistics emissions.
   - Integrate transport and logistics into the nationally determined contributions.
   - Develop national strategies and action plans for the transport and logistics sector, including infrastructure, vehicles, trains, vessels and their operation.
   - Develop corporate strategies and action plans.
   - Develop and implement policies to enforce implementation of the measures.
   - Disseminate examples and best practices of implementation strategies and action plans at the system level (corridors, supply chains, regions, cross-border) based on successful results of measures taken at the local, company or pilot levels.
4. **Identification of funding sources**
   - Identify sources for funding: national, regional and local government agencies; international organisations; multilateral organisations; banks; business sector; and PPPs
5. **Monitoring and evaluation**

- Establish uniform national monitoring and evaluation mechanisms in the ESCAP domain.

In general, a successful regional road map towards a sustainable and energy efficient freight transport system requires a collaborative and iterative approach that involves multiple stakeholders and considers a range of factors. By taking these steps, regions can make meaningful progress towards a more sustainable and efficient future for the freight sector.

4.2 Regional approach for enhancing sustainable freight transport

The Economic and Social Commission for Asia and the Pacific is developing a regional strategy to deepen sustainability and energy efficiency in freight transport and give further momentum and coherence to initiatives being carried out at the region-wide level for Asia and the Pacific. The regional strategy encompasses the following:

- Definition of common challenges;
- Presentation of a guiding vision;
- Formulation of objectives;
- Linkages to Sustainable Development Goals directly supported;
- Promotion of decarbonization of transport in the Asia and Pacific region;
- Improvement of energy efficiency;
- Definition of enablers;
- Identification of priority areas;
- Settings for implementation of arrangements.

The policy document brings a range of stakeholders onto a common platform to plan and implement sustainable and energy-efficient freight transport policies that contribute towards achieving the Sustainable Development Goals, decarbonization of transport and resilient energy efficient transport systems.

Key elements of a regional approach to enhancing the sustainability and energy efficiency of freight transport in Asia and the Pacific is presented in box 10.

Box 10: Regional approach for enhancing sustainable and energy efficient freight transport in Asia and Pacific[109]

Guiding vision

A regional freight transport system that is efficient, connected, safe, clean, energy efficient and to support the achievement of the Sustainable Development Goals, decarbonization of transport in the Asia and Pacific region and resilient transport systems.

Objectives

1. Providing coherence to sustainable and energy efficient freight initiatives.
2. Creating synergies through partnerships.
3. Ensuring high-level political support.

Sustainable Development Goals supported directly

1. Target 9.1: develop quality, reliable, sustainable and resilient infrastructure, including regional and transborder infrastructure, to support economic development and human well-being, with a focus on affordable and equitable access for all.
2. Indicator 9.a: facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States.
3. Target 3.6: by 2020, halve the number of global deaths and injuries from road traffic accidents.
4. Target 12.3: by 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains, including post-harvest losses.
5. Target 9.4: by 2030, upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes, with all countries taking action in accordance with their respective capabilities.
6. Target 7.3: by 2030, double the global rate of improvement in energy efficiency.

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[109] United Nations, Economic and Social Commission for Asia and the Pacific, “Enhancing the sustainability of freight transport in the decade of action for the Sustainable Development Goals”, Working Group on the Trans-Asian Railway Network (2021) (ESCAP/TARN/WG/2021/4), p. 16; United Nations, Economic and Social Commission for Asia and the Pacific, “Modal shift, technologies for greener mobility and policy and regulatory measures to enhance energy efficiency of the freight transport sector in Asia and Pacific”, May 2023, merger of ESCAP/TARN/WG/2021/4 and René Meeuws,, Andrey Yershov and Edouard Chong, "Study report on Transport Sector in Asia and the Pacific”, July 2023. Available at chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://www.unescap.org/sites/default/d8files/event-documents/Aug9-10_Final-Consolidated-Report-V2.pdf (2023).

7. Target 13.1: strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries.

Cross-cutting enabling conditions

1. Strengthening governance for sustainable and energy efficient freight transport at the national level.

2. Enhancing coordination for sustainable and energy efficient freight transport at the regional level through appropriate modalities or instruments.

3. Building the capacity of transport officials to mainstream sustainability considerations into freight transport including in gathering and analysing related statistics.

4. Promoting the use of transformative transport technologies, in particularly digitalization.

5. Encouraging private sector engagement to plan and implement sustainable and energy efficient freight transport policies.

6. Diversifying sources of financing to meet funding requirements for sustainable and energy efficient freight transport.

Priority areas

1. Decarbonize freight transport.

2. Improve energy efficiency of freight transport.

3. Build the resilience of freight transport to effectively deal with climate challenges and pandemics.

4. Strengthen cross-border and transit transport connectivity.

5. Enhance rural freight transport linkages.

6. Improve urban freight logistics.

7. Reduce accidents related to freight transport.

8. Support sustainable and energy efficient freight transport in countries with special needs.

9. Increase the share of rail freight and other sustainable transport modes.

Implementing, monitoring and evaluating

1. Converting strategy into action plans.

2. Implementing mechanism/arrangements/partnerships.

3. Monitoring and evaluating through a results framework.

Charting a course towards sustainable and energy-efficient freight transport necessitates a comprehensive understanding of a broad spectrum of elements integral to fostering a more environmentally friendly and energy-conserving freight transport and logistics sector. Figure 14 offers an insightful structural design for the decarbonization of freight transport and logistics. This design is composed of five distinct yet interconnected clusters:

1. Freight demand growth is managed;
2. Transport modes are smartly used and combined;
3. Fleets and assets are shared and used to the maximum;
4. Fleets and assets are energy efficient;
5. Fleets and assets use lowest emissions energy source feasible.

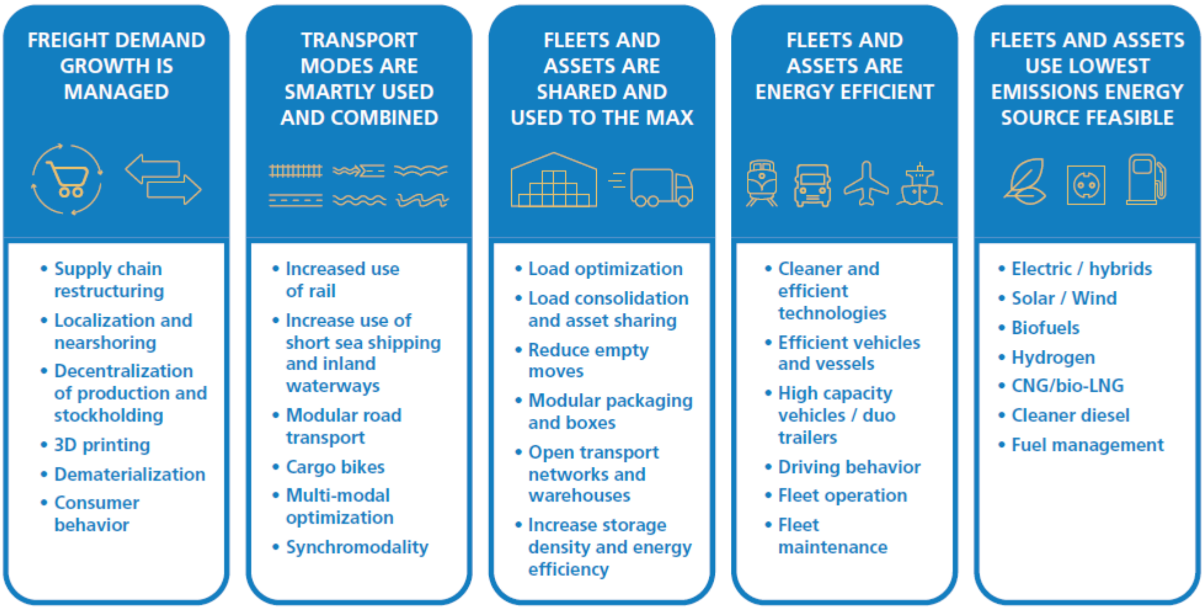


Figure 14 Framework for freight transport and logistics decarbonization[110]

Freight demand growth is managed. The first cluster is focused on the management of the growth of freight demand. A reduction in freight demand can be achieved by restructuring supply chains; applying the principles of nearshoring and replacing business processes; decentralization of production and stockholder closer to the market; 3D printing; and change in consumer behaviour.

[110] Smart Freight Center and Alice-ETP based on Alan Mckinnon, *Decarbonizing Logistics, Distributing Goods in a Low Carbon World* (London, Kogan Page Publishers, 2018).

Transport modes are smartly used and combined. The second cluster focuses on the smart and combined use of various transport modes with multimodal transport and logistics optimization, synchromodal transport systems and a modal shift towards more decarbonized and energy-efficient transport modes, such as railways, maritime transport and inland waterways transport.

Fleets and assets are shared and used to the maximum. The sharing of transport fleets and assets and the optimization of its use may also contribute to sustainable and more energy efficient transport: load optimization; load consolidation and asset sharing; modular packing; optimization of storage density; open transport networks and warehouses; and reduction of empty loads and moves.

Fleets and assets are energy efficient. The application of cleaner and efficient technologies may make fleets and assets more energy efficient. In addition, more efficient vehicles, trains and vessels, introduction of high-capacity vehicles, more efficient and safer driving behaviour, optimization of fleet operations and improved fleet maintenance may contribute to more energy efficiency.

A widely accepted strategy for decarbonizing the transport sector relies on three core policy pillars. This method, as detailed in the referenced report, incorporates a robust set of 17 targeted measures cohesively designed to mutually reinforce each other, contributing to a comprehensive approach to transport decarbonization. The outlined measures encompass a wide range of interventions, from technological advancements and infrastructural improvements to behavioural changes and regulatory mechanisms.

As follows in box 11, the integrative policy approach underscores the importance of a multifaceted strategy in combating climate change and steering the transport sector towards a more sustainable and carbon-neutral future.

Box 11: Key Policies and measures for achieving decarbonization in the freight transport[111]

"Avoid" policies

- Measures to minimize transport needs
    1) Develop sustainable metropolitan areas
    2) Avoid unsustainable infrastructure with a long lifespan
- Encourage shared mobility
    3) Establish an intermodality regulatory framework

"Shift" policies

- Shift to walking and cycling
    4) Improve walking infrastructure
    5) Improve cycling infrastructure
- Shift to public transport
    6) Shift away from passenger and delivery service vehicles in cities
    7) Financial incentives (for public transport)
    8) Develop light-rail and bus transit through plans and public investment
- Shift to passenger and freight railways
    9) Develop and support railway infrastructure and services (including high-speed railways)
    10) Taxing national and European flights at levels at least equal to that of high-speed trains and tax international flights even more

"Improve" policies

- Fuel economy improvement
    11) Fuel economy financial incentives and taxes
    12) Vehicle emission standards/fuel economy standards for new vehicles
- Zero-emission (electric/hydrogen) mobility
    13) Zero-emission vehicles purchase subsidy and other financial incentives
    14) Ban on sale of vehicles with internal combustion engines)
    15) Improve electric vehicle charging infrastructure
    16) Behavioural incentives for zero-emission vehicles
- Sustainable fuels in transport
    17) Support alternative fuels for aviation and maritime transport

[111] Benoit Martin and others, "A radical transformation of mobility in Europe: exploring the decarbonisation of the transport sector by 2040 −Explorative scenario and related policy packages", New Climate Institute and Climact, Project number 819028 (2020). Available at https://newclimate.org/resources/publications/a-radical-transformation-of-mobility-in-europe-exploring-the-decarbonisation.

In addition, when drafting a regional road map, it is important to consider two ambition policy scenarios (current ambition and hight ambition) for freight demand and choice and for the transition to cleaner vehicle fleets developed by the *ITF Transport Outlook 2023*.[112]

The current ambition policy scenario specification for freight demand and mode choice

2020s	2030s	2040s
Decarbonisation measures for urban freight are slowly introduced. The uptake of pick-up and drop-off locations for parcels, and asset sharing, increase linearly. Restricted access zones also start to become more widely implemented. Meanwhile, the use of electric cargo bikes for last-mile distribution of various commodities grows exponentially.	The uptake of cargo bikes keeps growing exponentially until 2035, when this growth slows but continues to progress linearly. Restricted access zones expand at a linear rate half of what was observed in the 2020s. The use of pick-up and drop-off locations for parcels, and asset sharing, continue to increase at the same rate.	All of the developments from the 2020s and 2030s have cemented their place in the urban logistics system. All measures continue to expand their share at the same rate.
Incentives for high-capacity vehicles (road tractors) encourage a transition in interurban freight. By 2025, there is a 10% increase in the average load utilisation (load factor) of road freight.	Road tractors begin to have a larger impact, increasing the truck loads and decreasing the cost per tonne-kilometre.	Load factors continue to increase, ending up 25% higher in 2050, compared to 2019.
Distance-based charges are encouraged for road transport and introduced in policy discussions.	Distance-based charges are introduced in 2030 and begin to grow continuously.	Distance-based charges rise further in the 2040s.
Slow and smart steaming are incentivised in the shipping sector to reduce emissions.	Vessel speed reductions lead to a 5% improvement in efficiency.	Vessel speed reductions lead to a 10% improvement in efficiency compared to the baseline (2019).
Digital transformation strategies leveraging near-real-time data are used to reduce intermodal dwell times in journeys with sections undertaken by rail or on waterways.	Improvements in travel times make intermodal solutions more attractive but do not improve to the same extent as under the High Ambition scenario.	Travel times for intermodal solutions continue to reduce at a slower rate than under the High Ambition scenario.
Transport network improvement plans for rail, waterways and port infrastructure begin to be phased in and funded.		
	Carbon pricing is introduced but with prices set at varying levels in different regions.	Carbon pricing continues to vary by region, and between sea-based transport modes and other modes. The price of carbon ranges between USD 150-250 per tonne of carbon dioxide (CO_2).
The **trade in and consumption of petroleum- and coal-based commodities begins to decrease**, directly impacting freight transport demand for fossil fuels and the freight activity associated with the trade of these commodities.	While the trade in other commodities continues to increase, the trade in oil and coal grows to a lesser extent.	While the trade in other commodities continues to increase, the trade in oil and coal grows to a lesser extent.

[112] International Trade Forum, ITF Transport Outlook 2023 (Paris, ITF/OECD, 2023).

The high ambition policy scenario specification for freight demand and mode choice

2020s	2030s	2040s
Sustainable urban logistics measures are implemented more widely than under the Current Ambition scenario. Cargo bikes and asset-sharing double the growth observed in the Current Ambition scenario. The use of pick-up and drop-off locations for parcels is 60% higher than in the Current Ambition scenario. Restricted access zones are stricter, increasing by a factor of three the likelihood that electric vehicles are used to transport goods in cities.		
Incentives for high-capacity vehicles (road tractors) encourage a transition in interurban freight. By 2025, there is a 10% increase in the average load utilisation (load factor) of road freight.	Road tractors begin to have a larger impact, increasing the truck loads and decreasing the cost per tonne-kilometre.	Load factors continue to increase, ending up 25% higher in 2050, compared to 2019.
Distance-based charges are encouraged for road transport and introduced in policy discussions.	Distance-based charges are introduced in 2030 and begin to grow continuously.	Distance-based charges rise further in the 2040s.
Slow and smart steaming are incentivised in the shipping sector to reduce emissions.	Vessel speed reductions lead to an average 10% improvement in efficiency which reduces dwell times and environmental impacts.	Vessel speed reductions lead to a 25% improvement in efficiency compared to the baseline (2019).
By 2025, **digital transformation strategies** leveraging near-real time data cause truck-to-port and truck-to-rail dwell times to decrease by 20%. Meanwhile, rail-to-port dwell times decrease by 15% by 2025. Inland waterways dwell times decrease by 5%.	Reductions in dwell times across road, rail and inland waterways result in a reduction in travel times associated with intermodal trips, making intermodal solutions more attractive. The improvements continue to increase.	Travel times for intermodal solutions continue to reduce. Truck-to-port and truck-to-rail dwell times decrease by 45% by 2050. Rail-to-port dwell times decrease by 45% by 2050. Inland waterways dwell times decrease by 25%.
The acceleration and expansion of investments in **transport network improvement plans** is greater than under the Current Ambition scenario.		
	Carbon pricing is introduced but with prices set at varying levels in different regions.	Carbon pricing continues to vary by region but at higher values than under the Current Ambition scenario. The price of carbon ranges between USD 300-500 per tonne of carbon dioxide (CO_2).
The **trade in and consumption of petroleum- and coal-based commodities begins to decrease**, directly impacting freight transport demand for fossil fuels and the freight activity associated with the trade of these commodities.	While the trade in other commodities continues to increase, there is a yearly decrease in demand for coal and petroleum.	There is a 50% yearly decrease in demand for coal and petroleum.

The current ambition policy scenario specification for the transition to cleaner vehicle fleets

2020s	2030s	2040s
The **turnover of vehicle fleets** continues in line with historical trends. New vehicle efficiency improvements continue, driven by existing fuel economy standards and in line with historical trends.	Mandatory and aspirational zero-emission vehicle (ZEV) sales targets are met. European Union member states and signatories to the COP26 Accelerating to Zero Coalition declaration reach 100% ZEV sales by 2035.	Mandatory and aspirational ZEV sales targets are met in countries and regions with stated targets.
	Signatories to the **Global Memorandum of Understanding (MOU) on Zero-Emission Medium- and Heavy-Duty Vehicles** reach the target of 30% ZEV sales for heavy-goods vehicles (HGVs) in 2030.	Signatories to the Global MOU on Zero-Emission Medium- and Heavy-Duty Vehicles reach the target of 100% ZEV sales for HGVs in 2040.
Biofuel blending targets for road fuels are met in countries with defined targets, including Finland, India, Indonesia and the United Kingdom.	Biofuel blending targets for road fuels are met in countries with defined targets, including Argentina, Finland, India, Indonesia and the United Kingdom.	
Sustainable aviation fuel (SAF) mandates are introduced in the EU and the United States according to the ambitions set out in the ReFuel EU and SAF Grand Challenge initiatives, respectively (see note).	Mandates for SAFs increase in Europe and the United States.	By 2050, SAFs make up 85% of aviation fuels in Europe and 100% in the United States.

Note: The carbon intensity of fuels is estimated according to Yoo, Lee and Wang (2022[7]) and Ueckert et al. (2021[8]).

The high ambition policy scenario specification for the transition to cleaner vehicle fleets

2020s	2030s	2040s
The **turnover of vehicle fleets** continues in line with historical trends and to meet travel demand. New vehicle efficiency improvements for road vehicles double from historical trends, driven by more stringent fuel economy standards. Meanwhile, aviation efficiency improvements increase to 3% per year.	By 2035, 100% of sales of new passenger vehicles and vans in East and Northeast Asia (ENEA), Europe, and in the United States, Canada, Australia and New Zealand (UCAN) are zero-emission vehicles (ZEVs). This is in line with the Global Fuel Economy Initiative (GFEI) ZERO Pathway. By 2030, 100% of new bus sales in high-income regions (ENEA, Europe and UCAN) are ZEVs. Meanwhile, by 2035, 100% of new two- and three-wheelers in all regions are ZEVs.	By mid-decade, 100% of sales of new passenger vehicles and vans in emerging markets are ZEVs, in line with the GFEI's ZERO Pathway. By 2040, 100% of new bus sales in the remaining markets are ZEVs. Also by 2040, 100% of sales of new heavy-duty vehicles in high-income regions are ZEVs. Meanwhile, emerging markets will reach this 100% target by the end of the decade.
	Signatories to the **Global Memorandum of Understanding (MOU) on Zero-Emission Medium- and Heavy-Duty Vehicles** reach the target of 30% ZEV sales for heavy-goods vehicles (HGVs) in 2030.	Signatories to the Global MOU on Zero-Emission Medium- and Heavy-Duty Vehicles reach the target of 100% ZEV sales for HGVs in 2040. Non-signatories reach the target of 30% of ZEV sales for HGVs in 2040 and 100% in 2050.
		By 2040, all **new trains** in high-income regions (UCAN, ENEA, and Europe) are zero-emission. The remaining markets reach this target by 2050.
Sustainable aviation fuel (SAF) mandates are introduced in the EU and the United States according to the ambitions set out in the ReFuel EU and SAF Grand Challenge initiatives, respectively (see note).	The roll-out of SAF mandates continues and alternatives to conventional fuels begin to come down in price. SAF mandates also expand to other regions. Aircraft with electric powertrains become available and begin to take share for short-haul flights with low passenger capacities.	Commercial applications of electric aircraft emerge in niche sectors. SAFs make up 85% of aviation fuels globally by 2050 (see note).
	Initial deployment of **zero-emission shipping fuels** occurs in green corridors.	By 2050, zero-emission fuels make up 100% of shipping fuels. Also by 2050, the electrification of short sea shipping routes occurs (see note).

Note: The carbon intensity and lifecycle emissions of biogenic and synthetic pathways are estimated according to Yoo, Lee and Wang (2022[7]) and Ueckert et al. (2021[8]). The electrification of short-sea shipping is in line with Kersey et al. (2022[9]).

Building on the discussions surrounding policy scenarios and tools, the ensuing section presents a proposal for a regional road map. In its design, this proposed road map serves as a flexible blueprint, adaptable to the specific needs, priorities and resources of individual countries. It provides a general strategic direction, while taking into account each country's position at a different juncture in the journey towards sustainable and energy-efficient freight transport. Accordingly, the road map is built on a principle of customization, advocating countries to align its recommendations with their unique contexts, paving the way for tailored solutions that address country-specific challenges and leverage available resources most effectively.

4.3 Framework regional road map for promoting energy-efficient freight transport

Directions and activities	Target indicators	Implementation timing	Responsible entities	Form of deliverables	Data sources for monitoring
1. Development and implement fuel economy standards for vehicles					
• Develop fuel economy standards for passenger cars, light-duty vehicles and heavy-duty vehicles in line with international best practices • Conduct a study to assess the potential impact of the standards on fuel consumption and greenhouse gas emissions • Implement the fuel economy standards through regulations and enforcement	• Reduction in fuel consumption and greenhouse gas emissions from vehicles • Increase in the adoption of fuel-efficient vehicles	• Year 1: develop fuel economy standards • Year 2-3: conduct study and finalize standards • Year 4-10: implement fuel economy standards through regulation and enforcement	• Ministry of Transportation and Communications • Environmental Protection Agency • Customs and Border Protection	• Fuel economy standards document • Study report on the potential impact of fuel economy standards • Regulation on fuel economy standards	• Vehicle registration data • Fuel consumption data • Greenhouse gas emissions data
2. Promote the use of alternative fuels and renewables					
• Develop comprehensive policies, incentives, and support mechanisms to encourage the integration of alternative fuels and renewable energy sources in the freight transport sector • Develop financial incentives • Develop infrastructure to support alternative fuels, such as charging stations for electric vehicles and CNG filling stations • Conduct public-awareness campaigns to promote the benefits of alternative fuels	• Increase in the adoption of alternative fuels, such as CNG, LNG and electric vehicles • Increase in the availability of infrastructure to support alternative fuels • Reduction in greenhouse gas emissions from the transport sector	• Year 1-2: develop policies, financial incentives and infrastructure to support alternative fuels • Year 3-4: conduct public-awareness campaigns • Year 5-10: monitor and adjust policies and initiatives, as needed	• Ministry of Transportation and Communications • Environmental Protection Agency • Local governments	• Financial incentive programmes • Infrastructure development plans • Public-awareness campaign materials	• Adoption rate of alternative fuels • Availability of infrastructure to support alternative fuels • Greenhouse gas emissions data

3. Encourage the use of intermodal transport					
• Develop and implement policies and regulations to promote intermodal transport, such as reducing road freight congestion and improving railway and waterway infrastructure • Establish logistics centres and freight villages to improve the efficiency of the logistics system and reduce unnecessary trips made by freight vehicles	• Increase in the use of intermodal transport modes, such as rail and waterway transport • Reduction in the number of unnecessary trips made by freight vehicles	• Year 1-2: develop policies and regulations to promote intermodal transport • Year 3-5: establish logistics centres and freight villages • Year 6-10: develop transportation systems to support logistics centres and freight villages	• Ministry of Transportation and Communications • Environmental Protection Agency • Local governments	• Policy and regulation documents • Logistics centre and freight village plans • Transportation data	• Use of intermodal transport modes • Number of unnecessary trips made by freight vehicles
4. Develop and implement policies and regulations to reduce environmental impact					
• Develop and implement policies and regulations to reduce air pollution and noise pollution from freight transport, such as emissions standards for vehicles and noise limits for freight operations • Implement energy-efficient technologies in the transport sector, such as the use of fuel-efficient engines and energy-efficient driving practices	• Reduction in air pollution and noise pollution from freight transport • Increase in the adoption of energy-efficient technologies in the transport sector	• Year 1-2: develop policies and regulations to reduce environmental impact • Year 3-4: implement policies and set regulations • Year 5-10: monitor and adjust policies and initiatives, as needed	• Ministry of Transportation and Communications • Environmental Protection Agency • Local governments	• Policy and regulation documents • Technology adoption reports • Environmental impact assessments	• Air pollution data • Noise pollution data • Adoption rate of energy-efficient technologies

Directions and activities	Target indicators	Implementation timing	Responsible entities	Form of deliverables	Data sources for monitoring
5. Establish logistics centres and freight villages					
• Identify key transport hubs for logistics centres and freight villages • Develop and implement plans for logistics centres and freight villages, including consolidation and distribution of goods, customs clearance, and warehousing services • Develop and implement transportation systems to support logistics centres and freight villages, such as rail and waterway transport	• Improvement in the efficiency of the logistics system • Reduction in the number of unnecessary trips made by freight vehicles	• Year 1-2: identify key transport hubs and develop plans • Year 3-5: establish logistics centres and freight villages • Year 6-10: develop transportation systems to support logistics centres and freight villages	• Ministry of Transportation and Communications • Environmental Protection Agency • Local governments	• Logistics centre and freight village plans • Transportation system development plans • Freight vehicle trip reduction reports	• Logistics efficiency data • Number of unnecessary trips made by freight vehicles
6. Encourage the use of low-carbon transport modes					
• Develop and implement policies and regulations to encourage the use of low-carbon transport modes • Develop infrastructure to support low-carbon transport modes • Conduct public-awareness campaigns to promote the benefits of low-carbon transport modes	• Increase in the use of low-carbon transport modes • Reduction in greenhouse gas emissions from the transport sector	• Year 1-2: develop policies and regulations to encourage the use of low-carbon transport modes • Year 3-4: develop infrastructure to support low-carbon transport modes • Year 5-10: conduct public awareness campaigns	• Ministry of Transportation and Communications • Environmental Protection Agency • Local governments	• Policy and regulation documents • Infrastructure development plans • Public-awareness campaign materials	• Use of low-carbon transport modes • Greenhouse gas emissions data

Directions and activities	Target indicators	Implementation timing	Responsible entities	Form of deliverables	Data sources for monitoring
7. Develop and implement freight route optimization strategies					
• Develop and implement technologies and policies to optimize freight routes, such as route planning software and road pricing schemes • Encourage the use of off-peak delivery times to reduce road congestion • Implement measures to reduce empty vehicle miles, such as promoting backhauling and load consolidation	• Improvement in the efficiency of freight transport • Reduction in road congestion and traffic-related emissions	• Year 1-2: develop and test freight route optimization technologies and policies • Year 3-4: implement freight route optimization measures • Year 5-10: monitor and adjust policies and initiatives as needed	• Ministry of Transportation and Communications • Environmental Protection Agency • Local governments	• Route optimization technologies and policies • Off-peak delivery policies and guidelines • Measures to reduce empty vehicle miles	• Freight transport efficiency data • Road congestion data
8. Provide heavy-duty vehicle scrappage subsidies					
• Develop and implement a programme to provide subsidies for scrapping old and high-emission heavy-duty vehicles and replacing them with new, low-emission heavy-duty vehicles • Establish eligibility criteria, such as age and emission standards, for heavy-duty vehicles to qualify for the subsidy • Conduct public-awareness campaigns to promote the benefits of heavy-duty vehicle scrappage and replacement	• Reduction in emissions from heavy-duty vehicles • Increase in the adoption of low-emission heavy-duty vehicles	• Year 1-2: develop and implement a heavy-duty vehicle scrappage subsidy programme • Year 3-5: monitor and adjust the programme as needed • Year 6-10: increase the subsidy amount and expand the programme if necessary	• Ministry of Transportation and Communications • Environmental Protection Agency • Local governments	• Heavy-duty scrappage subsidy programme guidelines • Eligibility criteria and application process • Public awareness campaign materials	• Heavy-duty vehicle scrappage and replacement data • Emissions reduction data

Directions and activities	Target indicators	Implementation timing	Responsible entities	Form of deliverables	Data sources for monitoring
9. Stimulate a modal shift to less-emitting modes from road freight					
• Develop and implement policies and initiatives to promote the shift from road freight to less-emitting modes, such as rail, waterway and pipeline transport • Establish incentive schemes to encourage shippers and logistics companies to use less-emitting modes • Develop infrastructure to support less-emitting modes, such as rail terminals and waterway ports	• Increase in the use of less-emitting modes for freight transport • Reduction in emissions from the transport sector	• Year 1-2: develop policies and initiatives to promote modal shift to less-emitting modes • Year 3-4: establish incentive schemes • Year 5-10: develop infrastructure to support less-emitting modes	• Ministry of Transportation and Communications • Environmental Protection Agency • Local governments	• Policy and initiative documents • Incentive scheme guidelines • Infrastructure development plans	• Modal shift data • Emissions reduction data
10. Join international conventions and treaties promoting energy-efficient freight transport					
• Join international conventions and treaties promoting energy-efficient freight transport, such as the Kyoto Protocol, the Paris Agreement and the Fuel Economy Campaign of IEA • Align national development policies with the goals and principles of these conventions and treaties • Establish monitoring and evaluation systems to track progress towards meeting the goals of these conventions and treaties	• Alignment of national development policies with international conventions and treaties promoting energy-efficient freight transport • Progress towards meeting the goals of international conventions and treaties	• Year 1-2: join relevant international conventions and treaties • Year 3-4: align national development policies with the goals and principles of these conventions and treaties • Year 5-10: establish monitoring and evaluating systems	• Ministry of Transportation and Communications • Environmental Protection Agency • Ministry of Foreign Affairs	• International convention and treaty membership documents • National development policy alignment documents • Monitoring and evaluation system guidelines	• Progress towards meeting the goals of international conventions and treaties • Alignment of national development policies

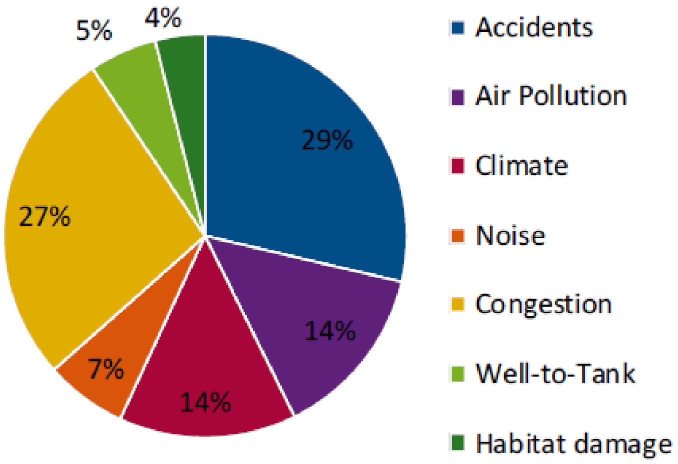
Directions and activities	Target indicators	Implementation timing	Responsible entities	Form of deliverables	Data sources for monitoring
11. Integrate target indicators for freight transport efficiency into national development policies					
• Develop and implement policies and initiatives to integrate target indicators for freight transport efficiency into national development policies • Establish a monitoring and evaluation system to track progress towards the target indicators • Provide regular reports and updates on progress towards the target indicators to stakeholders	• Improvement in freight transport efficiency • Reduction in emissions from the transport sector	• Year 1-2: develop policies and initiatives to integrate target indicators for freight transport efficiency • Year 3-4: establish a monitoring and evaluation system • Year 5-10: provide regular reports and updates on progress towards the target indicators	• Ministry of Transportation and Communications • Environmental Protection Agency • National Development Planning Agency	• Policy and initiative documents • Monitoring and evaluation system guidelines • Progress reports	• Freight transport efficiency data • Emissions reduction data

Annexes and case studies

Annex 1 Figures and tables from the Handbook on External Costs of Transport (EC 2019)

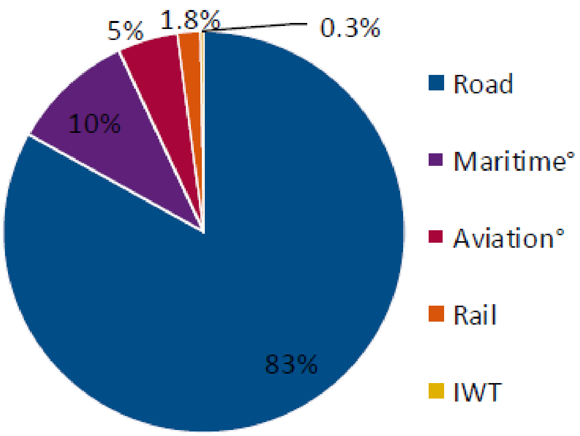
Selected figures and tables from the *Handbook on External Costs of Transport* (EC 2019)

Figure 13 - Share of the different cost categories on total external costs 2016 for EU28



Including data for aviation and maritime: rough estimations for EU28.

Figure 14 - Share of the different transport modes on total external costs 2016 for EU28



* Data for aviation and maritime: rough estimations for EU28.

Table 64 - Total external costs 2016 for road transport, rail transport and IWT per country

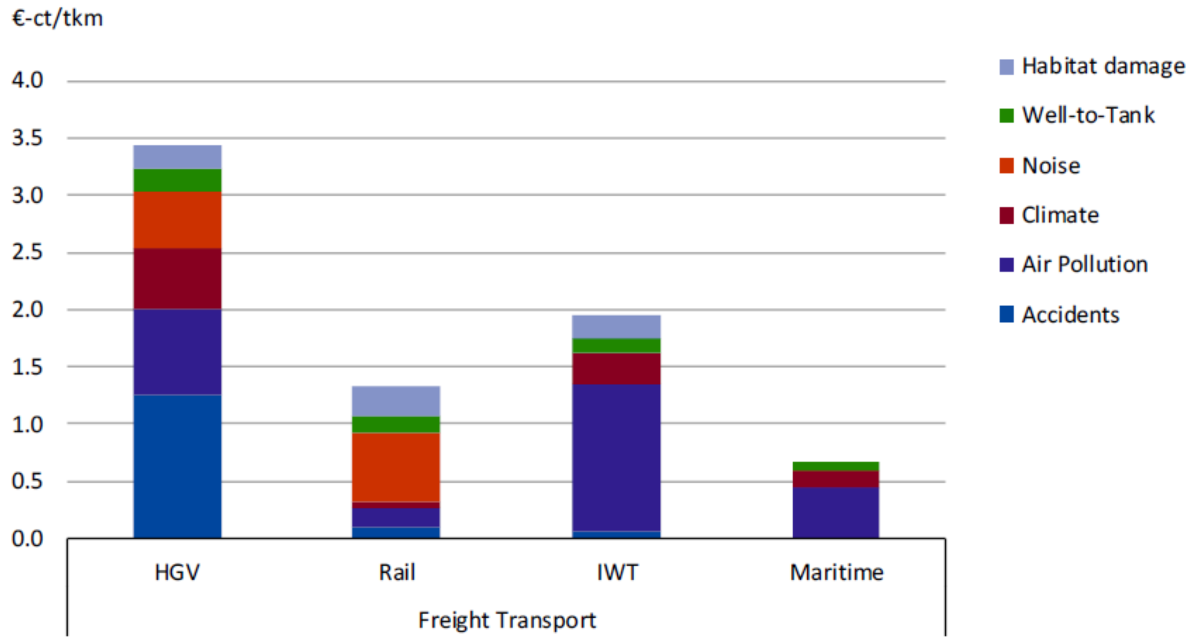
Country	Road (bn €)	Rail (bn €)	IWT (bn €)	Total (bn €)	% of GDP
EU 28	820.4	17.87	2.90	841.1	5.7%
Austria	18.3	0.85	0.044	19.2	5.9%
Belgium	26.4	0.42	0.183	27.0	7.0%
Bulgaria	6.5	0.12	0.047	6.6	6.5%
Croatia	5.0	0.07	0.015	5.1	6.9%
Cyprus	1.1	-	-	1.1	5.1%
Czech Republic	13.6	0.40	0.004	14.0	5.2%
Denmark	8.2	0.18	-	8.4	4.1%
Estonia	1.5	0.04	0.014	1.5	5.3%
Finland	7.4	0.23	0.073	7.7	4.4%
France	109.1	1.76	0.181	111.0	5.5%
Germany	165.7	5.37	1.228	172.3	5.8%
Greece	12.8	0.06	-	12.8	6.0%
Hungary	11.1	0.43	0.037	11.5	6.0%
Ireland	14.3	0.06	-	14.4	5.7%
Italy	115.0	2.20	0.009	117.2	6.8%
Latvia	2.3	0.18	-	2.5	6.7%
Lithuania	3.9	0.12	-	4.0	6.3%
Luxembourg	3.2	0.03	0.009	3.3	7.5%
Malta	0.4	-	-	0.4	3.6%
Netherlands	29.6	0.35	0.848	30.8	4.9%
Poland	40.2	1.28	0.018	41.5	5.5%
Portugal	16.8	0.18	-	16.9	7.2%
Romania	21.2	0.46	0.171	21.8	6.5%
Slovakia	5.4	0.33	0.012	5.7	4.7%
Slovenia	2.7	0.05	-	2.7	5.5%
Spain	64.3	0.83	-	65.1	5.2%
Sweden	15.3	0.46	-	15.8	4.5%
United Kingdom	99.4	1.42	0.009	100.8	4.9%
Norway	7.4	0.17	-	7.6	3.4%
Switzerland	15.3	0.76	0.001	16.1	4.1%

Table 66 – Total external costs 2016 for EU28 freight transport by cost category and transport mode

	Freight Transport						
	Road				Rail		IWT
	LCV-petrol	LCV-diesel	LCV-total	HGV - total	Electric freight	Diesel freight	Inland vessel
Cost category	bn €/a	bn €/a	bn €/a	bn €/a	bn €/a	bn €/a	bn €/a
Accidents		19.8		23.0	0.3		0.1
Air Pollution	0.3	15.2	15.5	13.9	0.01	0.7	1.9
Climate	0.7	12.5	13.2	9.6	0.00	0.2	0.4
Noise		5.4		9.1	2.1	0.4	
Congestion*		55.5		14.6			
Well-to-Tank	0.2	3.6	3.8	3.7	0.5	0.1	0.2
Habitat damage	0.2	4.2	4.4	3.6	0.8	0.2	0.3
Total			**117.6**	**77.5**	**5.4**		**2.9**
Total per mode			**195.1**		**5.4**		**2.9**
Total as % of EU28 GDP			**1.31%**		**0.04%**		**0.02%**
Total freight transport				**203.4**			

* Congestion in terms of delay cost generated by the various vehicle categories.

Figure 16 - Average external costs 2016 for EU28: freight transport (excluding congestion)



* Maritime: average for selected EU28 ports.

Notes: HGV, heavy goods vehicle; IWT, inland water transport.

Table 69 – Average external costs 2016 for EU-28

	Passenger transport						Freight Transport		
	Car	Bus/Coach°	MC	Rail	Aviation°*	LCV	HGV	Rail	IWT
Cost category	€-cent/pkm	€-cent/pkm	€-cent/pkm	€-cent/pkm	€-cent/pkm	€-cent/vkm	€-cent/tkm	€-cent/tkm	€-cent/tkm
Accidents	4.5	1.0	12.7	0.5	0.02	4.1	1.3	0.1	0.1
Air Pollution	0.7	0.7	1.1	0.12	0.2	3.4	0.8	0.2	1.3
Climate	1.2	0.5	0.9	0.05	2.2	2.8	0.5	0.06	0.3
Noise	0.6	0.3	9.0	0.9	0.2	1.1	0.5	0.6	n.a.
Congestion**	4.2	0.8	0.0	0.0	0.0	11.6	0.8	0.0	0.0
Well-to-Tank	0.4	0.2	0.5	0.7	0.9	0.8	0.2	0.2	0.1
Habitat damage	0.5	0.1	0.3	0.6	0.01	0.9	0.2	0.2	0.2
Total	**12.0**	**3.6**	**24.5**	**2.8**	**3.4**	**24.7**	**4.2**	**1.3**	**1.9**

° Bus/coach: average for bus and coach. Aviation: average for the different distance classes.

* For aviation, the EU average costs are averages for the selected EU airports that may not be representative for all EU airports.

** Congestion in terms of delay cost.

Source: European Commission. Handbook on the External Costs of Transport. Version 2019- 1.1.
Notes: LCV, light commercial vehicle; HGV, high goods vehicle; IWT, inland water transport.

Annex 2 Decarbonizing transport in North and Central Asia by 2050[113]

This case study involves ambitions, policies and measures to decarbonize transport in North and Central Asia by 2050 and is based on research recently carried out by ITF. The North and Central Asia subregion consists of the countries of Central Asia and the Caucasus. It is strategically important, as it connects Eastern Asia with Europe. The cost of trading and transporting goods in North and Central Asia are among the highest in the world. The subregion is landlocked and must rely on inland transport over long distances along various corridors. The Covid-19 pandemic resulted in border closures, causing enormous disruptions of trade and transport. The subregion is formulating a new policy to improve connectivity to address the most important bottlenecks of the subregional transport system. To do this, it is dealing with the difficult task to harmonize these ambitions of improving the transport system with the nationally determined contributions to address the necessary reduction in greenhouse gas emissions.

Technical and environmental upgrades of the regional transport infrastructure system is needed. The Asian Highway Network, a regional transport cooperation platform aimed at enhancing the efficiency and development of road infrastructure in Asia under the umbrella of ESCAP, is the backbone of the road networks in North and Central Asia. It is part of the overall goal of the Commission to foster the development of an international, integrated, intermodal transport and logistics system for the subregion, with the Asian Highway, the Trans-Asian Railway networks and dry ports of international significance as major components. The Asian Highway Network comprises more than 145,000 km of roads passing through 32 countries.

Many countries in the subregion have included the Asian Highway in their national plans. Even so, the planned network remains incomplete and the quality of the existing road infrastructure is of great concern. Primary and Class-I roads account for only 13 per cent of the existing road infrastructure. Roads of Class-III or below account for more than 30 per cent of the existing road infrastructure in the subregion.

Non-physical barriers in the subregion related to operational connectivity, including border crossings and transit facilitation, which are essential for efficient road transport along the Asian Highways, need to deal with urgently. There is a lack digitalization and facilitation of cross-border transport operations. Table 24 presents a summary of climate plans of the countries of North and Central Asia in the context of the nationally determined contributions.

[113] This case study is based on International Transport Forum, "ITF North and Central Asia transport outlook", International Transport Forum Policy Papers, No. 105 (Paris, OECD Publishing, 2022).

Table 24 Climate action plans in selected North and Central Asian countries[114]

North and Central Asia Country	Commitment to United Nations Nationally Determined Contribution (UNNDC)	Date pledged	Updated commitment to UNNDC contingent on international support	Date pledged
Armenia	-	23/03/2017	40% reduction in emissions by 2030 (base year 1990)	05/05/2021
Azerbaijan	35% reduction in emissions by 2030(base year 1990)	09/01/2017	-	-
Georgia	15% reduction in emissions by 2030(base year 1990)	08/05/2017	35% reduction in emissions by 2030 (base year 1990)	05/05/2021
Kazakhstan	15% reduction in emissions by 2030(base year 1990)	06/12/2016	-	-
Kyrgyzstan	11.5-13.70% reduction in emissions by 2030	18/02/2020	16% reduction in emissions by 2030	09/10/2021
Tajikistan	10-20% reduction in emissions by 2030 (base year 1990)	22/03/2017	30-40% reduction in emissions by 2030 (base year 1990)	12/10/2021
Turkmenistan	Commitment to reduction	21/10/2016	-	-
Uzbekistan	10% reduction in emissions per unit of GDP by 2030 (base year 2010)	09/11/2018	35% reduction in emissions per unit of GDP by 2030 (base year 2010)	30/10/2021

Notes: All reported commitments are unconditional reductions; some North and Central Asia countries have also made larger conditional commitments subject to further conditions; and values for Kyrgyzstan have been rounded up to be consistent with other country data.

The International Transit Forum has developed three scenarios to assess potential impacts of future transport activity on climate change through detailed CO_2 emissions projections. Figure 15 shows the three scenarios and their main characteristics.

[114] International Transport Forum, "ITF North and Central Asia transport outlook", International Transport Forum Policy Papers, No. 105 (Paris, OECD, 2022 Publishing); and . NDC Registry "All NDCs" (n.d.). Available at https://www4.unfccc.int/sites/NDCStaging/Pages/All.aspx..

Figure 15 ITF Transport Outlook 2021 scenario overview[115]

The *Recover* scenario is the baseline in terms of policy measures. Under *Recover*, it is assumed that transport trends return to levels seen prior to the COVID-19 pandemic by 2025 and that only planned or committed policies are implemented. From a policy perspective, it can be considered the business-as-usual scenario.

Under *Reshape*, transport trends are again assumed to have returned to their pre-pandemic levels by 2025, and it is assumed that significantly more ambitious policies to decarbonize transport will be implemented. This scenario is considered "transformational". It assumes policy measures that "encourage changes in the behaviour of transport users, uptake of cleaner energy and vehicle technologies, digitalisation to improve transport efficiency, and infrastructure investment to help meet environmental and social development goals."[116] "Measures, such as carbon pricing or port fees, would be assumed to be more stringent, while the attractiveness of more sustainable modes would be increased. The improved attractiveness would be due to assumed lower penalties for multimodal interchanges, greater investment in infrastructure and services, more efficient operations (through asset sharing in freight, for example) and broader uptake of innovative transport solutions and alternative fuels or power".[117]

Reshape+ is the most ambitious of the three scenarios. It assumes that "governments seize decarbonization opportunities created by the COVID-19 pandemic, which reinforce the policy efforts in *Reshape*".[118]

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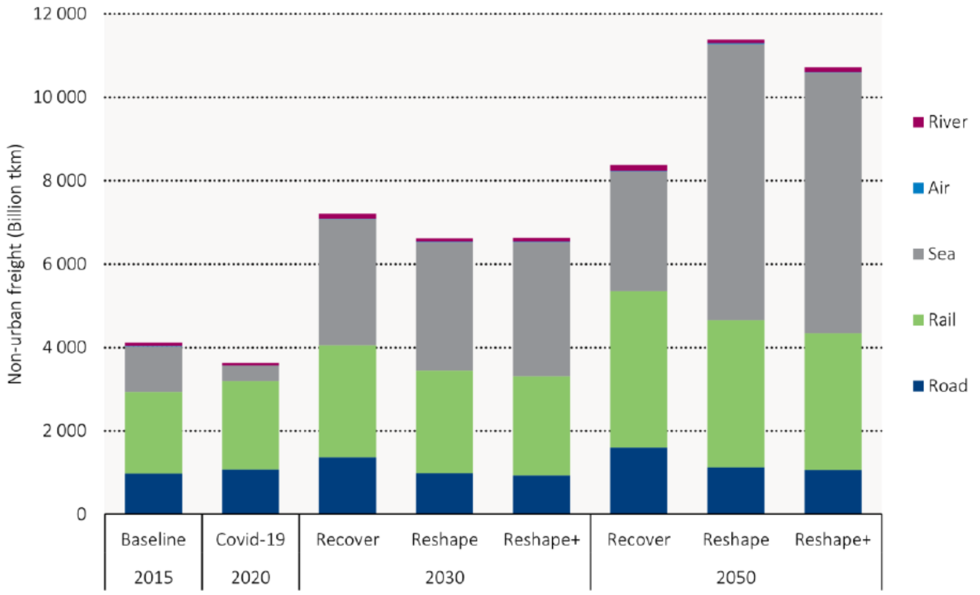
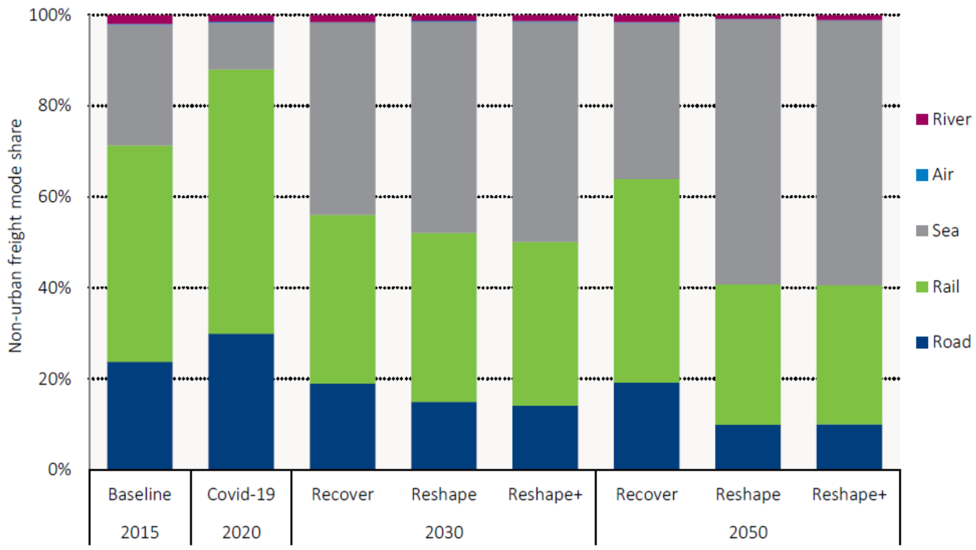
[115] International Transit Forum, "ITF Southeast Asia transport outlook", International Transport Forum Policy Papers, No. 103 (Paris, OECD Publishing, 2022).
[116] International Transit Forum, *ITF Transport Outlook 2021* (Paris, OECD Publishing, 2021).
[117] International Transit Forum, "ITF North and Central Asia transport outlook", International Transport Forum Policy Papers, No. 105 (Paris, OECD Publishing, 2022, p.14). .
[118] International Transit Forum, *ITF Transport Outlook 2021* (Paris, OECD Publishing, 2021).

Figure 16 and 1Figure 17 show the total non-urban freight activity by mode and scenario by volume and their modal share, respectively, in North and Central Asia to 2050.



Note: Figure depicts ITF modelled estimates. *Recover*, *Reshape* and *Reshape+*, which refer to the three scenarios modelled, which represent increasingly ambitious post-pandemic policies to decarbonise transport.

Figure 16 Scenarios of non-urban freight activity in North and Central Asia to 2050[119]



Note: Figure depicts ITF modelled estimates. *Recover*, *Reshape* and *Reshape+*, which refer to the three scenarios modelled, which represent increasingly ambitious post-pandemic policies to decarbonise transport.

Figure 17 Scenarios of modal share of non-urban freight in North and Central Asia to 2050[120]

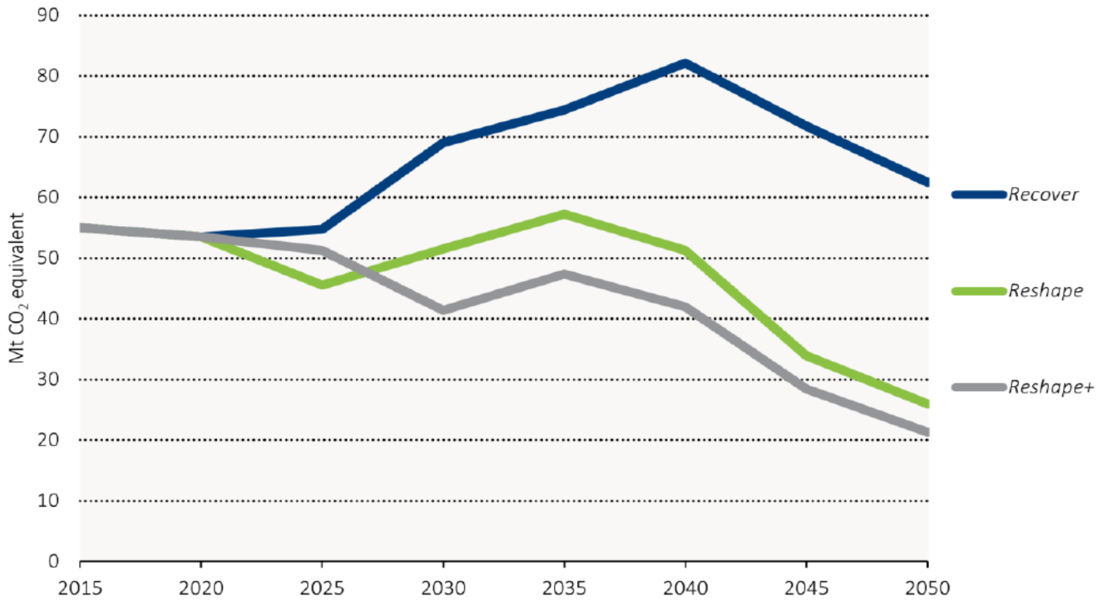
The share of maritime freight transport in the modal split decreased significantly from 26 per cent in 2015 to 10 per cent in 2020, mainly caused by the Covid-19 pandemic. The model shows that maritime freight transport will recover and have the largest relative modal growth in the subregion if ambitious decarbonization policies are put in place. It is expected that under the

[119] International Transit Forum, *ITF Transport Outlook 2021* (Paris, OECD Publishing, 2021).
[120] Ibid.

business-as-usual *Recover* scenario, maritime freight is projected to account for 42 per cent of freight activity by 2030 before settling at 34 per cent by 2050. Under *Reshape* and *Reshape+*, the importance of maritime is even more significant. Under both scenarios, the maritime share is projected to be above 45 per cent by 2030 and nearly 60 per cent by 2050. For this substantial increase to occur, soft policy measures, including transit policies, are required to ensure the operational feasibility of transit activities.

The total tonne-kilometres of rail freight is also expected to increase. Rail remains an important component of the subregional transport system under all scenarios analysed, accounting for 31 per cent of the trips. The road transport sector expands modestly under the *Recover* scenario, but its relative share in the modal split will be reduced.

Figure 18 shows the total tank-to-wheel emission trends for non-urban freight by scenario for North and Central Asia to 2050. Tank-to-wheel emissions are generated by transport activity directly. These emissions can be directly subject to transport policies, and potentially reduced by changes in the organization of transport activity, but also by technological innovation in vehicles, for instance. The peak of the emissions caused by non-urban freight in North and Central Asia under the *Recover* scenario is in 2040, with more than 80 Mt CO_2 equivalent and under the *Reshape* and *Reshape+* scenarios in 2035 with 58 Mt CO_2 equivalent and 48 Mt CO_2 equivalent, respectively.



Note: Figure depicts ITF modelled estimates. *Recover*, *Reshape* and *Reshape+*, which refer to the three scenarios modelled, which represent increasingly ambitious post-pandemic policies to decarbonise transport.

Figure 18 Scenarios of tank-to-wheel emission trends for North and Central Asia to 2050[121]

[121] Ibid.

Finally, Table 25 shows the proportion of well-to-tank emissions in total emissions in North and Central Asia by year and mode to 2050.

In the 2015 baseline analysis, it was found that 72 per cent of the total well-to-wheel emissions attributed to rail freight transport in North and Central Asia were generated during the well-to-tank phase. This phase includes emissions from fuel extraction, processing and delivery, highlighting its significant impact on the total emissions profile of rail freight in the region. In contrast, emissions shares for other modes of transport varied, with maritime transport accounting for 15 per cent and aviation for 28 per cent of their respective well-to-tank emissions.

Table 25 Proportion of well-to-tank emissions in total emissions in North and Central Asia 2050[122]

Year	Scenario	Air	Rail	Inland waterways	Road	Maritime	Urban
2015	Baseline	28%	72%	26%	19%	15%	16%
2020	Covid-19	28%	66%	24%	19%	15%	17%
2030	*Recover*	29%	67%	30%	24%	17%	20%
	Reshape	35%	88%	30%	23%	18%	21%
	Reshape+	35%	88%	32%	29%	19%	27%
2050	*Recover*	31%	59%	36%	27%	23%	28%
	Reshape	69%	100%	36%	31%	24%	36%
	Reshape +	70%	100%	40%	35%	26%	39%

On aggregate, the share of non-urban tan to wheel emissions will decrease from 73 per cent in 2015 to 66 per cent under the *Reshape+* scenario in 2050. In 2015, worldwide tank-to-wheel emissions are estimated to account for 77 per cent of non-urban emissions but by 2050, well-to-tank emissions will account for 42 per cent of non-urban freight emissions.

As stated earlier, it is important to consider the leg well-to-tank, which is often ignored by policymakers, as it shows the importance of coupling energy and transport policies to ensure better environmental outcomes. In particular, subregions that possess significant natural and energy resources, such as North and Central Asia, can leverage improvements in the energy sector to reduce the environmental costs of transport. They should be able to minimize wheel-to-wheel emissions to an extent that other regions cannot.[123]

[122] Ibid.
[123] International Transit Forum, "ITF North and Central Asia Transport Outlook", International Transport Forum Policy Papers, No. 105 (Paris, OECD, 2022).

Annex 3 A vision towards vehicle electrification in Pakistan

Pakistan approved an ambitious national electric vehicles policy in 2020,[124] which included targets and incentives to achieve a goal for electric vehicles to capture 30 per cent of all the passenger vehicle and heavy-duty truck sales by 2030, and 90 per cent by 2040. It includes even more ambitious goals for two- and three-wheelers and buses; 50 per cent of new sales by 2030 and 90 per cent by 2040.

Manufacturers, assemblers, and suppliers in the electric vehicle and related infrastructure industries benefit from lower taxes – 1 per cent gross sales tax (GST) for electric vehicles as compared to 17 per cent for regular vehicles. The import duty for charging equipment was also slashed, to 1 per cent. Additionally, the Government lowered the unit rate of electricity for charging station operators to encourage private investments in charging stations. It planned to install at least one direct current fast-charging station electric every 10 square kilometres in all major cities (targeting the more than 3,000 defunct CNG stations as locations) and every 15–30 kilometres on all motorways.

The Government believes that greater use of electric vehicles can dramatically lead to a reduction or the elimination of oil imports (a significant burden on the country's economy, amounting to $13 billion annually). It is also hoping that this policy will spur economic development and help the country keep pace with its neighbours and competitors, as Pakistan switches from importing fossil fuels and vehicles to domestically produced electric vehicles fuelled by domestically produced electricity.

Research conducted by the work of the International Council of Clean Transportation indicates that nearly all the world's 7 million electric vehicle sales through late 2019 were made possible by the following: regulations to make electric vehicle models widely available; incentives to increase electric vehicle affordability; addition of charging infrastructure to ensure electric vehicles are convenient; and electric vehicle awareness programmes to increase consumer understanding. The success of the electric vehicle depends on coordination between the applicable ministries on the incentive programme, and whether Pakistan can overcome the other barriers related to model availability, infrastructure and consumer understanding. In addition, a reliable power supply is crucial.

[124] Moaz Uddin, "Pakistan's national electric vehicle policy: charging towards the futures", ICCT blog, 10 January 2020. Available at https://theicct.org/pakistans-national-electric-vehicle-policy-charging-towards-the-future/.

The country's electric power sector is notoriously volatile; brownouts and blackouts are common occurrences. The Government has various power projects in the pipeline and forecasts surplus generation capacity in the next decade. A growing electric vehicle industry and market could capitalize from that surplus.

Accordingly, the electric vehicle industry can contribute significantly to the economy by saving precious foreign exchange, creating thousands of jobs and enabling related industries to grow as technology transfers occur. Switching to electric vehicles can also help improve urban air quality, reduce noise pollution and significantly reduce the health costs associated with pollution in urban areas. However, consistent policy support and a reliable grid are prerequisites for this transformation.

Annex 4 A case on modal shift in China

To reduce air pollution from heavy-duty vehicles, the key port of Tangshan, China, which is near the capital of China, Beijing, is shifting the transport of iron ore imports from truck to rail. As a result, 30,000 truck trips daily are projected to be eliminated and based on the current train fleet, approximately 70 per cent electric and 30 per cent diesel, diesel use is expected to decline by 85 per cent annually.[125]

Figure 19 shows a normalized tank-to-wheel emissions of PM and CO_2 from the current truck fleet as 1. As illustrated, switching transport to the current train fleet offers significant savings of local CO_2 and some reduction in local NOx, but PM increases because there is no emission control technology required for diesel trains. PM and CO_2 emissions are higher when upstream emissions are included, and all emissions are higher than if all trucks used were to meet the world-class China VI emission standard. Advanced emission control technologies, either to address upstream emissions from electricity production or on diesel train engines, would avoid most of the well-to-wheel emissions associated with rail transport.

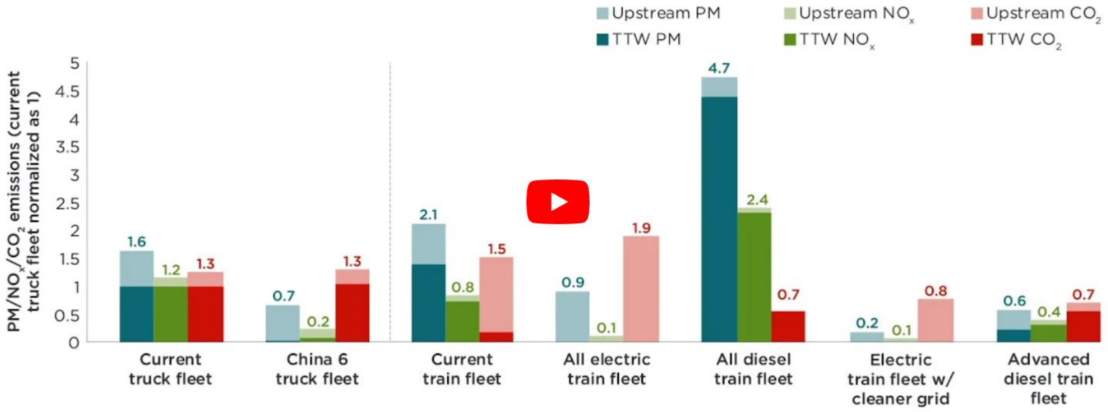


Figure 19 Environmental impacts of modal shift from truck to rail Tangshan in China.
Note: TTW, tank-to-wheel.

[125] The International Council of Clean Transport, "Environmental impacts of modal shift from truck to rail – Tanghshan, China", video, 3 June 2020. Available at https://theicct.org/environmental-impacts-truck-to-rail-china-video-jun20/.

Annex 5 Policies to foster modal shift in Poland and the European Union[126]

As indicated in a white paper on transport, at least 30 per cent of road freight transported more than 300 km should be shifted to other modes, and by 2050, that modal share should exceed 50 per cent.[127] To enable the shift, the share of road transport in total inland freight needs to be reduced from 75 per cent to 52 per cent, the share of rail needs to increase from 21 per cent to 39 per cent, and that of inland shipping—from 4 to 8 per cent. Research studies have shown that the European Union policy and measures taken by member States at the national level have halted or slowed the increase in road transport in absolute figures and in terms of shares held by individual modes of transportation in cargo haulage. As a result, the dramatic downward trend shown by the modal share of rail transport in freight carriage was reversed. In addition, the impact of funds earmarked for railway infrastructure development, especially cross-border connections, and interoperability, was underlined.[128] Table 26 presents the programmes implemented at the country (Poland) level and by the European Union.

Table 26 Selected measures to support modal shift in Poland and other European Union member States.

Name	Scope	Goals
II National Environmental Policy (2000)	Poland	The need to rationalize transport via changing the transport system and developing the rail transport while reducing freight transit by road
White Paper on transport (2001)	European Union	Aiming at the 1998 modal split, as the model for 2010
Marco Polo I Program (2003−2006)	European Union	Shifting 12 bn tonne-kilometres of cargo traffic per year from roads to other, more ecological means of transport
Sectoral Operational Program (2004−2006)	Poland	The need to shift the demand from road transport to rail haulage, in particular between: S-7 (Gdańsk-Warszawa) expressway and E-65 (Gdynia-Warszawa) railway line, S-8 (Warszawa-Piotrków) expressway and E-65 (Warszawa-Katowice) railway line, and S-7 (Warszawa-Radom) expressway and Warszawa-Radom railway line
National Transport Policy 2006−2025 (2005)	Poland	Taking measures towards division of the total number of ton-kilometres between the means of transport in such a way so that the ones with the least adverse environmental impact are used to the greatest extent
Marco Polo II (2006−2013)	European Union	Shifting the total annual increase in the number of ton-kilometres in the international road transport to short sea shipping, rail transport, waterborne transport, inland shipping or combined transport

[126] Adapted from Sywia Kowalska and Damian Bonk, "Evaluation of *Modal Shift in Freight Transport: Case Study of* Poland, *European Research Studies Journal*, vol. XXIV (2021), pp. 851−862.
[127] European Commission. *WHITE PAPER Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system* (Brussels, 2011).
[128] European Parliament, Resolution of 14 November 2018 on the 2018 UN Climate Change Conference in Katowice, Poland (COP24), Document No. A8-0409/2018.

Name	Scope	Goals
Country Development Strategy (2007–-2015)	Poland	The need to enhance the role of rail transport (in particular, in relation to heavy cargoes that are hazardous to humans and the environment), shifting freight "from road to rail"
White Paper on transport (2011)	European Union	(1) by 2030, 30 per cent of road freight transported over 300 km is to be shifted to alternative transport modes. By 2050, the share should exceed 50 per cent; (2) by 2050, part of the medium range passenger traffic should be shifted to rail transport
The strategy for sustainable production and consumption patterns (2011)	Poland	Implementation of measures aimed at introducing sustainable production and consumption patterns. The modal imbalance in passenger and freight transport was observed
Strategy for Sustainable Development of Transport by 2030 (2019)	Poland	The need to shift some tonne-kilometres from road to alternative transport. The key factor should be development of railway and inland shipping infrastructure; as a result, the shift may be noticeable after 2025
Sustainable and Smart Mobility Strategy-putting European transport on track for the future (2020)	European Union	Enhancing the role of sustainable transport by shifting a substantial part of the 75% of inland freight carried by road to rail transport and inland waterways.

Annex 6 Vehicle efficiency and electrification policies of Indonesia[129]

Greenhouse gas emissions in Indonesia nearly doubled between 1990 and 2016. Approximately 28 per cent of that total comes from transport, the same volume as from energy generation. The country has pledged to reduce greenhouse gas emissions through its nationally determined contributions, but progress in decarbonizing the transport sector is slow and the focus is instead on adoption of biofuels.

The electrification of the transport sector offers great potential to reduce its impact on air quality and climate, but this effort requires massive and requires widespread support. Traditional transport modes have relied on diesel and gasoline engine technologies. A transition to electrification in the transport sector would require significant policy and technical efforts.

The Government of Indonesia is preparing to become a major player in the electric vehicle economy. By the end of 2020, several strategic documents had been issued that included or could help generate policies to accelerate the uptake of more efficient vehicles and electric vehicles in Indonesia. Table 27 gives a list of the relevant strategic documents that lay out visions for various vehicle types in the transportation sector.

Table 27 Strategic documents related to electric vehicles and fuel efficiency in Indonesia

Policy Area	Year	Description
National Master Plan for Industry (RIPIN) (Government Regulation No. 14/2015)	2015	Envisions a transformation of Indonesia's industry to become more robust through innovation and technology between 2015 and 2035. It indicates the direction of vehicle efficiency and EV technology development.
National Medium-Term Plan (RPJMN) 2015 – 2019 (Presidential Regulation No. 2/2015)	2015	Served as the guiding document for strategic planning activity in national ministries from 2015 to 2019. It set targets to accelerate development of physical transportation infrastructure to promote economic growth.
National Energy Plan (RUEN) (Presidential Decree No. 22/2017)	2017	Mainly focused on energy security. It included a target of GHG emissions to 2050 for all sectors, including transport. It indicated policy measures that will improve vehicle fuel efficiency and increase adoption of EVs.
Presidential Regulation on Battery Electric Vehicles (Presidential Decree No. 55/2019)	2019	Enacted at the end of 2019 to provide direction and serve as a basis for the acceleration of the BEV program set by the national government.
National Medium-Term Plan (RPJMN) 2020 – 2024 (Presidential Regulation No. 18/2020)	2020	Serves as the guiding document for any strategic planning of national ministries for the 2020-2024 period. It encourages prioritization of renewable energy over fossil fuels.
Strategic Plan of National ministries 2020-2024	2020	Strategic plan of national ministries that follows the development targets outlined within the RPJMN 2020 - 2024.

[129] Adapted from Aditya Mahalana, Zifei Yang and Francisco Posada, "Indonesia transport electrification strategy", ICCT Working Paper 2021-36, October, 2021. Available at https://theicct.org/publication/indonesia-transport-electrification-strategy%E2%80%AF/; and Aditya Mahalana and Zifei Yang, "Overview of vehicle fuel efficiency and electrification policies in Indonesia", ICCT Briefing, 19 July 2021. Available at https://theicct.org/publication/overview-of-vehicle-fuel-efficiency-and-electrification-policies-in-indonesia/.

The National Energy Policy (KEN)is the guiding document for energy policy. Enacted through Government Regulation No 79/2014,18, KEN is used to oversee the creation of the National Energy Plan and provides direction for national energy management, with a goal of enhancing the country's energy security and supporting broader national Sustainable Development Goals. The implementation timeline for KEN runs through to 2050. Under KEN, there is a renewable energy target of 23 per cent of the primary energy mix by 2025. The National Energy Plan provides guidance for energy planning for national and subnational governments. It includes a projection of greenhouse gas emissions for the power, transport, commercial, industrial, household and other sectors; each projection features a business-as-usual scenario and a highly efficient scenario, the latter aiming for a 58 per cent reduction in greenhouse gas emissions by 2050. Regarding electric vehicles and fuel economy, the strategic guidance of the National Energy Plan includes the following:

- Mass uptake of electric (and hybrid-electric) powered vehicles;
- Preparation and implementation of fiscal policies to incentivize production and purchase of electric vehicles and conventional hybrid vehicles (2016–2019);
- Design and implementation of a carbon tax policy on fossil fuels (2017–2019);
- Establishment of fuel economy standards for motorized vehicles, especially private vehicles with model years before 2020 (2017–2019).

Presidential Regulation No.55/2019 on battery electric vehicles marks a new chapter in the development of battery elective vehicles in Indonesia. The regulation offers clear guidance to the automotive industry on battery electric vehicles and provides opportunities for local governments and universities to become involved. This regulation has four objectives: (a) identify responsible and leading ministries/agencies for implementation; (b) set a definition for battery electric vehicles and develop technical specifications; (c) create manufacturing capacity battery electric vehicles; and (d) facilitate the market transition from internal combustion engines to battery electric vehicles.

The regulation emphasizes building domestic manufacturing capacity and follows the road map set up by the Ministry of Industry for development of a national motor vehicle industry, which set an ambitious goal of producing an increasing share of electric vehicles (including hybrid, plug-in hybrid electric vehicles and fuel cell vehicles) locally. In particular, the manufacturers need to increase local manufacturing content from 40 per cent in 2019 to a minimum of 80 per cent in 2030. To achieve these targets, the regulation also calls for universities and research institutions in Indonesia to cooperate with industry on research and development, and innovation.

General guidelines are provided for deployment of charging infrastructure, opening infrastructure development to national State-owned enterprises (SoE or BUMN), locally owned State enterprises (or BUMD) and private companies. A State-owned electric company is tasked with pioneering the development of public charging stations, from designing the charging technology and grid integration to creating the business model and setting the charging rate. The regulation allows power companies with an official licence from the government and their business partners to supply electricity to these public charging stations. Fiscal and non-fiscal incentives suggested for battery electric vehicles, according to the regulation, include the following:

- Import duties for completely knocked down and incompletely knocked down products, or for the main components, for a certain period
- Luxury taxes
- Tax deductions or tax exemptions (applies to locally regulated taxes, such as a transfer tax and circulation tax, and to nationally regulated taxes)
- Import duties on engines, goods and other materials to support domestic capital investment
- Suspension of import duties for export
- Import duties on raw materials and/or other supporting materials required for battery electric vehicle production
- Incentives for production of equipment related to charging infrastructure
- Incentives for export financing
- Fiscal incentives for research and development, and for technology innovation
- Reduced parking fees (with formulations developed by local governments)
- Reduced electricity fees at charging stations
- Funding for development and construction of charging stations
- Labour certification for human resources involved in manufacturing battery electric vehicles
- Product certifications and/or technical standards for manufacturers of battery electric vehicles and components
- Exclusion from vehicle restriction policies
- Handover, to electric vehicle manufacturers production rights of battery electric vehicle technology whose patent licences were acquired by national and/or local governments
- Security assurances for industries involved in the production of battery electric vehicles and inclusion of these industries in the list of national vital strategic assets

Table 28 gives a summary the of recommendations provided under the case study.

Table 28 Example of summary recommendations for Indonesia

Area of intervention	Recommended actions/initiatives
Coordination in making a binding commitment to achieve electrification targets	• Support the Coordinating Ministry of Maritime and Investment (coordinating ministry for the implementation of PR 55/2019) in engaging other line ministries and stakeholders • Establish platform and set up policy dialogue • Contribute to political and policy dialogues • Facilitate the set-up of financing pool
Development of regulatory and fiscal policies and guidelines that spur demand for and supply of electric vehicles and technologies	• Develop /revise the implementing regulation for PR 55/2019 • Develop technical guidelines for fiscal policies • Develop vehicle fuel economy standards and incentives for electric vehicles • Formulate more favourable electricity tariffs for electric vehicle users
Research and development that builds domestic manufacturing and service capacity	• Conduct research for technology options and pathways • Establish a platform to facilitate communication among key stakeholders • Establish partnerships among research agencies • Provide expert opinions and international experiences to the Ministry of Research
Strengthen charging infrastructure	• Conduct technical assessments of charging options • Support the State-owned electric company to assess charging needs for electric two-wheelers/electric three-wheelers • Support development of implementation guidelines for electricity tariff • Establish an ad hoc multistakeholder forum • Support development of charging infrastructure plan at the local level
Increase consumer awareness to support electric vehicle uptake	• Organize outreach campaigns • Establish a platform for knowledge-sharing • Engage and mobilize local stakeholders • Navigate international experiences and resources to support grass-root groups
Accelerate deployment of electric vehicles in public and private fleets	• Document best practices from electric bus trials • Establish a mandate for procurement of electric vehicles in public fleets • Develop public vehicle procurement guidelines • Create preferential operational environment for electric fleets • Support the "buy-the-service" scheme of the Ministry of Transport for electric buses • Make the case to encourage electrification of private fleets with feasible financial solutions • Make the case to electrify two-wheelers fleets used by on-demand services • Design innovative business models
Establish pilot projects in cities and replicate success cases to other cities	• Collaborate with cities with strong electrification intention to develop electrification strategies • Create and enhance reward and recognition for leadership in promoting electric vehicles • Develop an electric vehicle guidebook for cities • Showcase how implementing low-emission zones and congestion charges can serve as effective strategies to encourage the adoption of electric vehicles • Engage the private sector to support pilot projects • Promote peer learning among cities

Annex 7 Pathways to zero emission truck deployment in India

India is also an important producer of road freight vehicles. The country plans to start producing zero-emission trucks and could become a crucial player in the inevitable transition to zero-emission freight vehicles. Box 8 presents the findings of the study entitled "Transforming trucking in India; pathways to zero emission truck deployment"[130] (September 2022) carried out by NITI Aayog[131] and the Rocky Mountain Institute Innovation Institute.

[130] NITI Asyog, "About us", The Statistics Portal. Available at https://www.niti.gov.in/sites/default/files/2022-09/ZETReport09092022.pdf.
[131] NITI Aayog is the National Institution for Transforming India, the premier policy think tank of the Government of India.

Box 12: Transforming trucking in India: pathways to zero-emission truck deployment

India is the world's sixth-largest economy, with a growing GDP, which is close to $3 trillion. The freight transportation sector is expanding rapidly to ensure more goods and products reach a rising number of end consumers. Demand for goods is increasing on the back of urbanization, the increasing population, a rise in e-commerce and higher income levels. As this demand continues to increase, associated road freight movement is expected to become greater from 2.9 trillion tonne-km in 2020[132] to 9.6 trillion tonne-km by 2050.

Road transport (namely, trucks) carries 70 per cent of the domestic freight demand. Heavy- and medium-duty trucks are responsible for most of that road transportation. As road freight travel continues to grow, the number of trucks is expected to more than quadruple, from 4 million in 2022 to roughly 17 million trucks by 2050.

In the light of these market trends, zero-emissions trucks, including battery electric trucks and fuel cell electric trucks, offer an alternative to the diesel trucks, the dominant carrier of the road freight of India. The production and use of zero-emission trucks present an opportunity for India to showcase how the adoption of such vehicles is economically efficient and better for air quality, public health and the environment.

Realizing the economic and environmental benefits of zero-emission trucks, many countries are transitioning away from diesel trucks. The European Union has committed to electrifying freight vehicles and has set a goal to have 80,000 zero-emission trucks on the road by 2030; the United Kingdom has pledged that all heavy-duty trucks in the country will be zero-emission trucks by 2040.

The most substantial growth in freight and trucking demand is expected to come from emerging markets, such as India, The country can exhibit global leadership by scaling adoption of zero-emission trucks. The growth of this market requires coordinated private and public actions to increase the manufacturing supply of zero-emission trucks and deploy the supporting charging infrastructure. Ambitious policies are required to drive growth, seed the market and accelerate the supply and demand of zero-emissions trucks.

[132] Statista, Freight movement by road transportation in India from financial year 2001 to 2020 (2023). Available at https://www.statista.com/statistics/667440/road-transport-freight-india/.

The following are eight key findings from the study:

1. **Zero-emission trucks can lead to sustained logistics cost savings.** Transportation costs are a major driver (62%) of overall logistics costs in India, accounting for 14% of the country's GDP. As diesel fuel costs account for the overwhelming majority of transportation costs, adoption of zero-emission trucks adoption can dramatically lower associated fuel costs by up to 46% over the vehicle's lifetime, with broad implications for the Indian economy.

2. **A robust domestic zero-emission truck market can transform India into a global green hub for battery manufacturing.** These trucks would be a significant source of demand for domestically produced batteries (up to 4,000 gigawatt-hours [GWh] cumulative through 2050), supporting and underpinning the National Energy Storage Mission and providing the impetus for the country to become a low-cost and low-carbon manufacturing hub.

3. **If produced at scale, the total cost of ownership for zero-emission trucks in the medium-duty truck segment can be less than diesel trucks, and total cost of ownership parity can be reached in the heavy-duty truck segment by 2027. Currently, zero-emission trucks** have a higher upfront cost compared to diesel trucks, but they also have significantly lower per-kilometre operating costs.

4. **With supportive polices zero-emission trucks can achieve an 85% sales penetration by 2050.** With cost **competitiveness**, and technology maturity, nearly 9 in 10 trucks sold in 2050 could be zero-emission trucks.

5. **Zero emission trucks can help shift India off oil import dependency, supporting the vision of a self-reliant India.** Road freight accounts for more than 25% of oil import expenditures—and is expected to grow by more than four times by 2050. The adoption of zero-emission trucks can eliminate a **cumulative** total of 838 billion litres of diesel consumption by 2050, which would reduce oil expenditures by 16 lakh crore through 2050.

6. **Widespread adoption of zero emission trucks could reduce cumulative trucking PM and NOx pollution -40% by 2050, substantially improving air quality in India.** Trucks represent just 3% of the total vehicle fleet (including both passenger and freight) yet are responsible for 53% of PM emissions. A purposeful transition to zero-emission trucks can lead to considerable improvements in air quality and benefit citizens' public health.

7. **Widespread adoption of zero-emission trucks could reduce annual trucking carbon emissions 46% by 2050, lowering the country's greenhouse gas emissions.** The trucking sector is responsible for one third of transport-related CO_2 emissions in India. A determined transition to zero-emission trucks can lead to 2.8-3.8 gigatonnes of cumulative CO_2 savings through 2050, which is equal to or greater than entire economy-wide annual greenhouse emissions of India.

8. **The early state of the overall zero-emission trucks market in India requires a coordinated ecosystem approach spanning the public and private sectors.** Such an approach can help overcome challenges, such as the upfront capital needed to make the zero-emission transition through a combination of finance, technology, infrastructure and policy strategies.

Based on the study, the following strategies, solutions and pathways for scaling the zero-emissions market in India were formulated:

POLICY

- **Demand-side policies to increase consumer demand,** such as purchase subsidies, feebates, interest subvention, scrappage incentives, zero-emissions zones and fleet purchase requirements.
- **Supply-side policies to encourage traditional original equipment managers to innovate and start-ups to enter zero-emission trucks manufacturing,** such as original equipment manufacturer, zero-emission truck credit schemes, zero-emission truck production targets, air quality regulations and fuel efficiency standards that promote zero-emission trucks and improve air quality.

TECHNOLOGY & MANUFACTURING

- **Improve battery chemistry, energy density, and fuel cell efficiency** to increase the range and improve the payload capacity of zero-emission trucks.
- **Foster a domestic manufacturing strategy** to help build a robust supply chain of wide varieties of zero-emission trucks, which, in turn, would help fulfil the long-term trucking demands of Indi.

CHARGING

FINANCING & BUSINESS MODELS

- **Provide a mix of charging strategies and types,** with a focus on depot charging and en route fast charging, which together can provide charging coverage for both short- and long-range freight trucking needs.
- **Leverage policy intervention to reduce charging costs,** including upfront subsidies, electricity tariffs that remove demand charges and/or implement electric vehicle-friendly rate structures, and concessional land for installing zero-emission truck charging infrastructure.
- **Strategically build adequate power infrastructure** to meet the electricity needs of the growing zero-emission truck market, including load assessments, dedicated funding for infrastructure buildout, demand-side management, investment in energy storage and smart charging capabilities.
- **Streamline the infrastructure installation process to minimize the permit and interconnection processing times;** also streamline the land procurement process for charging infrastructure development to minimize charging deployment soft costs.

- **Central and state governments can mitigate risks of investing in zero-emission truck production and expand opportunities to purchase zero-emission trucks through** strategies, such as public-backed loans, demand aggregation, and interest subvention schemes and risk-sharing mechanisms.
- **Original equipment managers and fleet operators can update their business models to lower the cost of owning zero-emission trucks and ultimately help nudge sector-wide adoption** via strategies, such as lease purchasing, battery leasing or financing, as-a-service business models, performance guarantees and more-robust and/or extended warranties.
- **Lenders and other financial institutions can work to structure more-favourable financing for zero-emissions trucks loans** through tailored loan products, better-informed depreciation criteria and alternative credit evaluations.

Pathways to the adoption of zero-emission trucks in India

Policy	Financing & Business Models	Charging	Technology & Manufacturing
• Introduce demand-side policies to increase consumer demand. • Craft supply-side policies to encourage traditional original equipment managers to innovate and start-ups to begin manufacturing zero-emissions trucks.	• Central and state governments can mitigate risks of investing in zero-emission truck production and expand opportunities to purchase zero-emission trucks. • Original equipment managers and fleet operators can update their business models to lower the cost of owning zero-emission trucks and ultimately help nudge sector-wide adoption.	• Provide a mix of charging strategies and types. • Leverage policy intervention to reduce charging costs. • Strategically build adequate power infrastructure. • Streamline the infrastructure installation process to minimize processing times.	• Improve battery chemistry, energy density, and fuel cell efficiency. • Enhance performance characteristics, such as payload capacity. • Foster a domestic manufacturing strategy.

	• Lenders and other financial institutions can work to structure more favourable financing for zero-emission truck loans.		

Zero-emissions truck corridors can be a catalyst that aligns ecosystem solutions

A total of 50 per cent of the vehicle freight traffic in India travels along seven major corridors, which connect the country's cities and ports. The concentration of road freight travel and economic activity along these corridors also presents an opportunity to strategically invest in charging infrastructure to scale the adoption of zero-emission trucks. Enabling these trucks on high-use routes could build market momentum and empower invaluable testing and refining of best-in-class solutions.

Effective multi-stakeholder collaboration is key to accelerating the deployment of zero-emission trucks.

India is in a prime position to become a global leader in the transition to zero-emissions trucking. To realize the significant long-term economic and environmental benefits of zero-emission trucks, however, government, technology, industry and finance leaders must align decisively with development plans and enact near-term, precise market and policy interventions.

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