Vietnam Transport Knowledge Series
Supported by AUSTRALIA–WORLD BANK GROUP STRATEGIC PARTNERSHIP IN VIETNAM, GOVERNMENT OF GERMANY and NDC PARTNERSHIP SUPPORT FACILITY

Addressing Climate Change in Transport

Volume 1: Pathway to Low-Carbon Transport

Jung Eun Oh, Maria Cordeiro, John Allen Rogers, Khanh Nguyen, Daniel Bongardt, Ly Tuyet Dang, and Vu Anh Tuan

FINAL REPORT
September 2019

WORLD BANK GROUP

Implemented by giz Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

On behalf of:
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
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Cover photo: Woman waiting on her motorbike in Hanoi, Vietnam. Credit: Beboy – stock.adobe.com.

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Climate change is set to have profound effects on Vietnam's development. With nearly 60 percent of its land area and 70 percent of population at risk of multiple natural hazards, Vietnam globally is among the most vulnerable countries to both chronic and extreme events. Over the past 25 years, extreme weather events have resulted in 0.4 to 1.7 percent of GDP loss, which climate change is predicted to steeply rise by 2050. At the same time, as Vietnam's economy grows, the country is becoming a significant emitter of greenhouse gases. While Vietnam's absolute volume of emissions is still small compared to that of larger and richer countries, emissions are growing rapidly and disproportionate to its economy size. Vietnam is the 13th most carbon intensive economy in the world, measured in terms of emissions per GDP, and 4th among the low- and middle-income countries in East Asia.

The transport sector plays a critical role in these recent trends. A steep rise in income and economic growth has led to rapid motorization: The country of around 96 million people is also home to nearly 40 million vehicles, including 35 million motorbikes. While car ownership is still relatively low in Vietnam, as income rises cars are quickly replacing motorbikes, especially in the largest cities. Public transport modal share remains persistently low, partly due to the low level of network development and partly to the convenience and affordability of two-wheeler-based mobility. Thanks to its economic success and rapid integration with the international trade, cargo transportation in Vietnam has seen remarkable growth in the recent years. Vietnam's long coastal lines and extensive inland waterway network have been extensively used for the movement of goods; however, their modal share vis-à-vis road transport is declining.

Vietnam's transport network, which has seen an impressive expansion over the past two decades, is increasingly vulnerable to the intensifying climate hazards. Today, Vietnam's road network extends to over 400,000 km, much of which was not built to withstand extreme hazard scenarios, which are expected to become more frequent due to climate change. Without efforts to improve the resilience of the built network, Vietnam's achievements in providing universal access to its rural communities may be undermined. Moreover, resilience of connectivity is critical to the continued success of Vietnam's economy, which heavily relies on external trade and would increasingly depend on seamless rural-urban linkages.

In this analytical work, *Addressing Climate Change in Transport* for Vietnam, carried out by the World Bank and several other partners with support from the Ministry of Transport of Vietnam, the study aims to set out a vision and strategy for climate-smart transport, in order to minimize the carbon footprint of the sector while ensuring its resilience against future risks. The analytical findings and recommendations are presented in two volumes of the report: *Volume 1—Pathway to*

Low Carbon Transport and *Volume 2—Pathway to Resilient Transport*. The first volume provides how Vietnam can reduce its carbon emissions by employing a mix of diverse policies and investments, under varying levels of ambition and resources. The second volume provides a methodological framework to analyze network criticality and vulnerability, and to prioritize investments to enhance resilience.

These two report volumes have been prepared at a critical time, where the Government of Vietnam is working to update its Nationally Determined Contribution and set out its next medium-term public investment plan for the period of 2021 to 2025. We hope that these findings can provide useful insights and specific recommendations towards these critical documents, contributing to Vietnam's achievement in developing a low-carbon and resilient transport sector.

Guangzhe Chen
Global Director
Transport Global Practice

Ousmane Dione
Country Director
Vietnam

Embassy of the Federal Republic of Germany to the Socialist Republic of Vietnam

This report is the product of a collaborative effort by the Vietnamese Ministry of Transport's Department for the Environment, the World Bank and the Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH (GIZ) on behalf of the German Federal Ministry of Environment, Nature Conservation and Nuclear Safety (BMU). It also marks three years of cooperation between the Ministry of Transport and the German Government-funded "Advancing Transport Climate Strategies" project, which has focused on providing support for the systematic assessment and reduction of greenhouse gas (GHG) emissions in the transport sector.

Vietnam's social and economic achievements are well known and mobility is key for further development. But progress has come at a cost: a growing demand for energy has led to a sharp increase in GHG emissions, a major contributing factor to rising global temperatures. The transport sector is a major consumer of energy in Vietnam.

Rising numbers of road vehicles are causing serious congestion and air pollution in cities, affecting the wellbeing of millions of people. If policy measures are not taken, GHG emissions from the transport sector are expected to triple by 2030 to nearly 90 million tons carbon dioxide equivalent (CO_2e).

The findings in the report are alarming. Even in the most ambitious scenario, the emission from transport will still rise to nearly 70 million tons CO_2e. Clearly, a new way of living, including a rethinking of mobility, is needed. This is a challenge, not only in Vietnam, but worldwide.

Therefore, I believe, this report contributes to Vietnam's ongoing Nationally Determined Contribution (NDC) Review and Update process lead by the Ministry of Natural Resources and Environment, and shows the importance of evidence-based mitigation policies for the Ministry of Transport's 2021–2030 Transport Climate Action Plan.

I would like to take this opportunity to thank the Ministry of Transport, especially the Department for the Environment, for its continuous commitment towards achieving sustainable transport in Vietnam. Such commitment is vital for successfully combating climate change.

Dr. Guido Hildner

Ambassador Extraordinary and Plenipotentiary
of the Federal Republic of Germany
to the Socialist Republic of Vietnam

Acknowledgments

This report was prepared by the Transport Global Practice and the East Asia and Pacific Region of the World Bank, and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) under its project "Advancing Transport Climate Strategies (TraCS) in Viet Nam" as part of the International Climate Initiative (IKI). The Bundesministerium für Umwelt, Naturschutz und nukleare Sicherheit (BMU), or the Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety of Germany, supports this initiative on the basis of a decision adopted by the German Bundestag. Further information on the project context under TraCS can be found at https://www.changing-transport.org/project/tracs.

The preparation of the report was led by Dr. Jung Eun Oh, senior transport specialist at The World Bank, and Daniel Bongardt, senior advisor at GIZ. The team includes, at the World Bank: Maria Cordeiro, John Rogers and Nguyen Quoc Khanh; at GIZ: Anna Schreyoegg, Ly Tuyet Dang, and Elena Scherer. Consultants Vu Anh Tuan, An Minh Ngoc, Diep Anh Tuan, and Pham Duy Hoang at University of Communications and Transport; and Le Anh Tuan and Tran Quang Vinh at Hanoi University of Science and Technology also contributed inputs to this report.

The team extends its appreciation for the guidance of the World Bank management, Guangzhe Chen (Global Director, Transport Global Practice), Franz R. Drees-Gross, (Director, Transport Global Practice), Ousmane Dione (Vietnam Country Director), and Almud Weitz (Transport Practice Manager, Southeast Asia and the Pacific). The team also extends its appreciation for the guidance of GIZ´s management.

The team conducted the study in collaboration with the Government of Vietnam and appreciates the strong support and advice generously provided by Mr. Le Dinh Tho, vice minister of transport. Tran Anh Duong (Director General), Mrs. Nguyen Thi Thu Hang (Deputy Director), Mr. Vu Hai Luu (Official), and Mrs. Doan Thi Hong Tham (Official), and Mr. Mai Van Hien (Official) at the Department of Environment, with knowledge sharing provided by Ministry of Transport. Several government entities and organizations provided vital inputs, including the Directorate for Roads of Vietnam, Vietnam Inland Waterways Administration, Vietnam Maritime Administration, Civil Aviation Authority of Vietnam, Vietnam Railway Authority, and Vietnam Register.

The work benefitted from the advice provided by the following peer reviewers: Stephen Ling (Lead Environmental Specialist), Cecilia M. Briceno-Garmendia (Lead Economist), Neha Mukhi (Senior Climate Change Specialist), and Ian Halvdan Ross Hawkesworth (Senior Governance Specialist) at the World Bank, and Robin Bednall (First Secretary) and Duc-Cong Vu (Senior Infrastructure Manager) at the Government of Australia. Kara Watkins (WBG Communications Consultant) thoroughly copyedited the report for consistency and readability, and Chi Kien Nguyen (Transport Specialist) reviewed the Vietnamese translation for accuracy, for which the team is grateful.

The team would like to thank the Government of Germany, the Government of Australia, and the NDC Partnership Support Facility for their generous support and funding toward this analytical work and publication.

About the Authors

Jung Eun "Jen" Oh is a senior transport economist at the World Bank. With a background in transport engineering and economics, Jen has led a number of investment projects and technical assistance for various client countries in Southeast Asia, Central Asia, Sub-Saharan Africa, and Europe, covering a broad range of transport sector issues. Jen served as a transport cluster leader for Vietnam from 2016 to 2019, overseeing and coordinating a large portfolio of World Bank-financed projects in Vietnam's transport sector, and led several knowledge pieces on climate change in transport, transport connectivity, urban mobility, and infrastructure financing. Jen holds an MSc in economics and a PhD in transportation systems, and has authored several articles, including a chapter in the book, *The Urban Transport Crisis in Emerging Economies* (2017), published by Springer International.

Maria Cordeiro is a former senior transport specialist at the World Bank and currently a consultant for the World Bank. Maria works with project teams globally to integrate climate change considerations in the preparation and design of lending operations, using tools like GHG accounting, shadow price of carbon, and climate and disaster risk screening. Maria also contributes to the provision of technical assistance to client countries to support planning and the deployment of low-carbon resilient transport systems. Before joining the World Bank, Maria worked with governments in Latin America, Middle East, Europe in the analysis, design and deployment of policies, planning and projects in the fields of climate change, air quality, water and waste management, and biodiversity conservation. Maria also worked with other multilateral development banks, bilateral agencies, and research centers in policy and planning as well as in the management of programs and projects in the environment, transport, and international development fields.

John Allen Rogers is an engineer specialized in emissions and low carbon development, particularly in transport and energy. Through multilateral development banks and bilateral organizations, he has provided technical support to many low- and middle-income countries to enhance green growth—low emissions, and low-carbon development planning—for the transport and energy sectors. With the World Bank, he has designed and applied emissions and energy models for many low-carbon development studies covering the power sector and transport in Latin America, Europe, Africa, and Asia, analyzing user activity and resultant emissions with associated costs and benefits, in transport as well as in the power, industry, and building sectors (nonresidential and household energy demand).

Khanh Nguyen, an energy expert, has worked on a number of projects with various international donor organizations in the last few years. He has more than 15 years' experience in sustainable development and related issues, such as energy system modeling, renewable energy project development, rural electrification, energy efficiency, and GHG emissions inventory and monitoring. Currently, Khanh is leading a study on future power sources to advocate sustainable policies for Vietnam. Prior to that, he provided support to the

UNDP-led effort on the formulation of an action plan to implement the renewable energy development strategy in Vietnam. Khanh earned a bachelor's degree in energy economics and energy planning from the University of Science and Technology in Hanoi in 1997. In 2001, he earned a master's degree in renewable energies from the University of Oldenburg in Germany, and a doctorate in energy system modeling, also from the University of Oldenburg, in 2005.

Daniel Bongardt, based at GIZ headquarters in Bonn, Germany, is senior advisor on transport and climate change and head of the *TraCS* project. From 2011 to 2015, he was program director of the Sustainable Transport Programme, a GIZ initiative, in Beijing. His responsibilities included projects on urban transport demand management, transport, and climate change as well as electric mobility. He worked on policy development, scenario building, and monitoring of greenhouse gas emissions in urban mobility and freight transport in China. Before coming to Beijing, he served as senior policy advisor at GIZ headquarters, where he developed GIZ's transport and climate change agenda and headed a project on Nationally Appropriate Mitigation Actions (NAMAs) in the transport sector. Daniel started his career in 2001 as a senior researcher at the transport division of the Wuppertal Institute for Climate, Environment and Energy, a major German think tank on sustainable development. Daniel holds a master's degree in political sciences.

Ly Tuyet Dang, based in Hanoi, Vietnam, is project officer on transport and climate change of the GIZ *TraCS* project. Previously, she worked as a consultant for a green freight project under TA 7779, which ADB implemented in Vietnam and Lao PDR. She worked on the initiative piloting green freight for trucking companies and associations in both Vietnam and Lao PDR, monitoring the greenhouse gases of green freight measures, training eco-drive skills for drivers, and providing policy recommendation for the governments. She also worked in CDM projects relating to transport and clean energy, and prepared documents for companies following the requirement of the World Commission on Dams. She earned a master's degree in science of climate change in 2011.

Vu Anh Tuan has worked for 12 years as a lecturer and independent consultant in the field of transportation. He is familiar with transport modeling software such as PTV VISUM, JICA-Strada, Omni-Trans, VISSIM, VisWalk, EFFECT and engineering software like AutoCAD and MapInfo. He has managed infrastructure performances, designed travel surveys, performed transport demand modeling, prepared business plans and engineering designs, and took on the position of team leader in several transport master plan studies. He oversaw many major public-funded capital investment programs of up to $70 million from diverse funding sources. He managed the transport master plan for the city of Hanoi in 2007 and 2012 as well as for Ha Nam in 2006. Furthermore, he prepared the traffic demand forecast for the technical prefeasibility of Ho Chi Minh City's Bus-Rapid-Transit system and developed Da Nang's transport model. He conducted accessibility surveys and facilities assessment surrounding the UMRT stations. In 2018 and 2019 he worked as a consultant for *TraCS*. Mr. Vu Anh Tuan earned a master's in transport planning and traffic engineering, with an emphasis in traffic modeling, from the National University of Road & Bridge and the University of Paris.

Abbreviations and Acronyms

ASI	Avoid-Shift-Improve
ADB	Asian Development Bank
BAU	Business as usual
BRT	Bus rapid transit
BY	Base year
CIEM	Central Institute of Economic Management
CNG	Compressed natural gas
CO_2	Carbon dioxide
DoE	Department of Environment, Ministry of Transport
EEA	European Economic Area
EFFECT	Energy Forecasting Framework and Emissions Consensus Tool
EMEP	European Monitoring and Evaluation Program
FTKT	Freight ton-km transported
GDP	Gross domestic product
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GSO	General Statistic Office
HBEFA	Handbook Emission Factors for Road Transport
HCV	Heavy commercial vehicles
ICAO	International Civil Aviation Organization
ICD	Inland container depot
IPCC	Intergovernmental Panel on Climate Change
IWT	Inland waterway transport
IWW	Inland waterway
JICA	Japan International Cooperation Agency
LCV	Light commercial vehicles
LEAP	The Long-Range Energy Alternatives Planning model
MAC	Marginal abatement cost
MACC	Marginal abatement cost curve
MMHE	Mean monthly household expenditure
MoNRE	Ministry of Natural Resources and Environment

MoIT	Ministry of Industry and Trade
MoT	Ministry of Transport
MRT	Metro rail transit
$MtCO_2e$	Million [metric] tons carbon dioxide equivalent
NAMA	Nationally Appropriate Mitigation Actions
NDC	Nationally Determined Contribution
NEH	National Express Highway
NPV	Net present value
OECD	Organization for Economic Co-operation and Development
O&M	Operations and maintenance
PC	Passenger car
PKT	Passenger-km transported
tCO_2	Tons carbon dioxide
TRaCS	Advancing Transport Climate Strategies
UNFPA	United Nations Population Fund
VAMA	Vietnam Automobile Manufacturers Association
VHLSS	Vietnam household living standard survey
VISUM	VISUM software
VNRA	Vietnam Railway Authority
VR	Vietnam Register
WBG	World Bank Group

CURRENCY MEASURE

Currency Units — US$ and VND

WEIGHT AND MEASURES

Metric system

BASELINE DATA YEAR

Commodity freights — 2014

Macroeconomic data — 2014 and 2016

Census data — 2014

EXCHANGE RATES

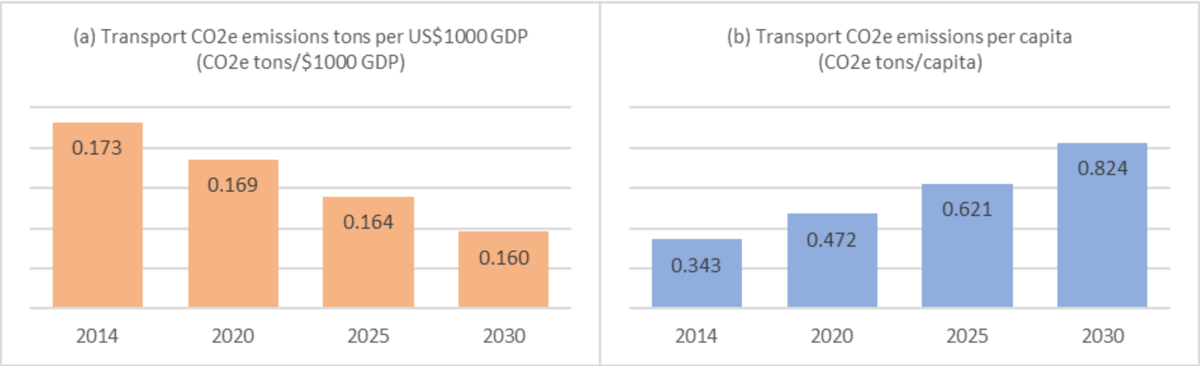
US$1, 2014 = 21,890 VND

Executive Summary

Vietnam's remarkable success in mitigating poverty and promoting economic development over the past decades has been enabled by the rapid development of supporting economic infrastructure, including transport. This accelerated increase in the mobility of people, goods, and services has benefited both the urban and rural populations. Since 1992, the length of Vietnam's road network has increased significantly and reached over 400,000 km as of 2016; as a result of this endeavor, the number of communes without access to all-weather roads dropped from 606 in 1997 to only 65 in 2016.

Partly thanks to this success, the transport sector is becoming a large and growing contributor to total greenhouse gas (GHG) emissions in Vietnam, accounting for 18 percent of total CO_2 emissions in 2014.[1] Even though the carbon intensity of the economy is coming down (figure E.1, panel a), increasing per capita income—coupled with population growth and rural/urban migration—are driving the demand for mobility, which would lead to continued growth in carbon intensity in the transport sector over the coming decades (figure E.1, panel b). Under the business-as-usual (BAU) scenario, it is estimated that carbon emissions from transport per capita would rise sharply, by 2.5 fold, between 2014 and 2030.

Figure E.1. GHG Emissions from Transport per Capita and per GDP (2014–2030)



Source: World Bank and GIZ data. Data produced using the EFFECT model (see appendix C for more information on EFFECT).

As one of the developing countries most affected by climate change, Vietnam is committed to addressing both mitigation and adaptation. In 1994 the country ratified the United Nations Framework Convention on Climate Change (UNFCCC), in 2002 the Kyoto Protocol (KP), in 2015 the Doha Amendment, and in 2016 approved the Paris Agreement. Vietnam established the National Climate Change Committee (NCCC) in 2012 to coordinate national action on climate change and fulfill reporting commitments to the UNFCCC.

In its Intended Nationally Determined Contribution (INDC or NDC) submitted in 2015, the country committed to an 8 percent reduction in GHG emissions against baseline by 2030, and to raise ambition to 25 percent reduction, contingent on receiving international support. Vietnam submitted its third national communication in February 2019 and is currently preparing a revision of its NDC for submission in September 2019. The transport sector would be responsible for a pro-rata unconditional reduction in GHG emissions of 8 percent in 2030 against the sector's BAU trajectory.

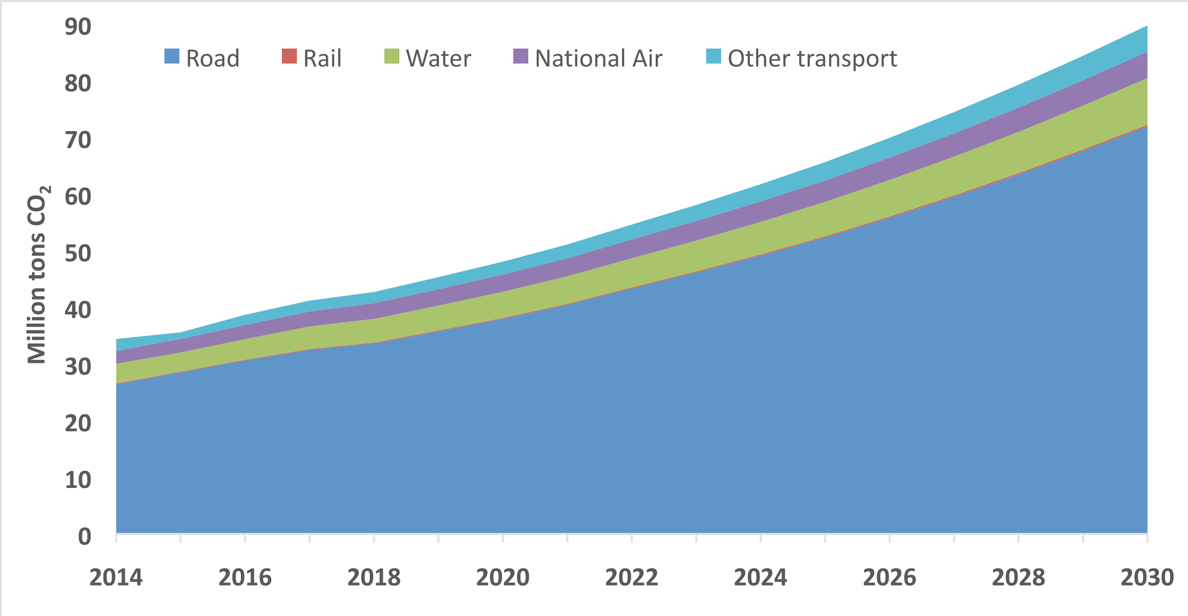
In the present technical assistance, the World Bank and GIZ collaborated with the Ministry of Transport (MoT) of Vietnam to help inform their future NDC modification through the selection and prioritization of policies and measures that mitigate GHG emissions. The activities and outputs included the development of a detailed GHG emissions inventory for the transport sector; scenario-based, bottom-up analysis of transport activities and resultant emissions from a base year of 2014 to 2030 and beyond to 2050; and an analysis of marginal abatement cost (MAC) for mitigation measures to help prioritize based on their cost-effectiveness.

Both the emission inventory and the scenario-based emissions bottom-up modeling were developed with tools specifically modified for Vietnam, with consideration of the data availability and institutional arrangement. The scenarios were developed through extensive stakeholder consultation, through which a consensus was built around what is achievable within certain levels of resources and existing regulatory framework. In addition to the scenario development and analysis, local experts and officials were supported so that the country could continue to make use of these calibrated tools for future evaluations and measurement, reporting, and verification (MRV) purposes.

Within the overarching framework of the country's NDC, four scenarios were developed and analyzed—BAU and Mitigation Scenarios 1, 2 and 3—each corresponding to varying levels of ambition in terms of emissions reduction targets and resources required to achieve them. The BAU forecast shows how transport activity and emissions can be expected to change under an agreed set of macro assumptions, which are uniformly used across the three mitigation scenarios. The three mitigation scenarios include increasingly ambitious sets of mitigation "levers"—policies or investments that would provide sustainable transport solutions and lead to a reduction in GHG emissions: Scenario 1 includes some policies and measures in the existing master plan and would be implemented only with domestic resources; Scenario 2 is also confined within the scope of the existing master plan but would require additional resources from international sources and private sector participation for implementation; and Scenario 3 includes ambitious measures outside the existing master plan.

BAU includes all policies and interventions that were enacted up to and including the base year of 2014, with no additional deployment of policies and measures after that date targeted at mitigating GHG emissions. Results show that in 2014 under BAU conditions, transport sector CO_2 emissions increase from 33.2 million tons CO_2 in 2014 to 89.1 million tons in 2030.[2] Throughout this period, road is the largest emitter with 26.4 million tons CO_2 in 2014 and increasing to 71.7 million tons in 2030. This is partly due to the relatively high share of road traffic, which carries 94 percent of passengers and 76 percent of freight tons,[3] but also its high energy intensity per passenger-km or freight ton-km compared to waterborne or rail transport.

Figure E.2. CO_2 Emissions Projection by Transport Subsectors under BAU Scenario

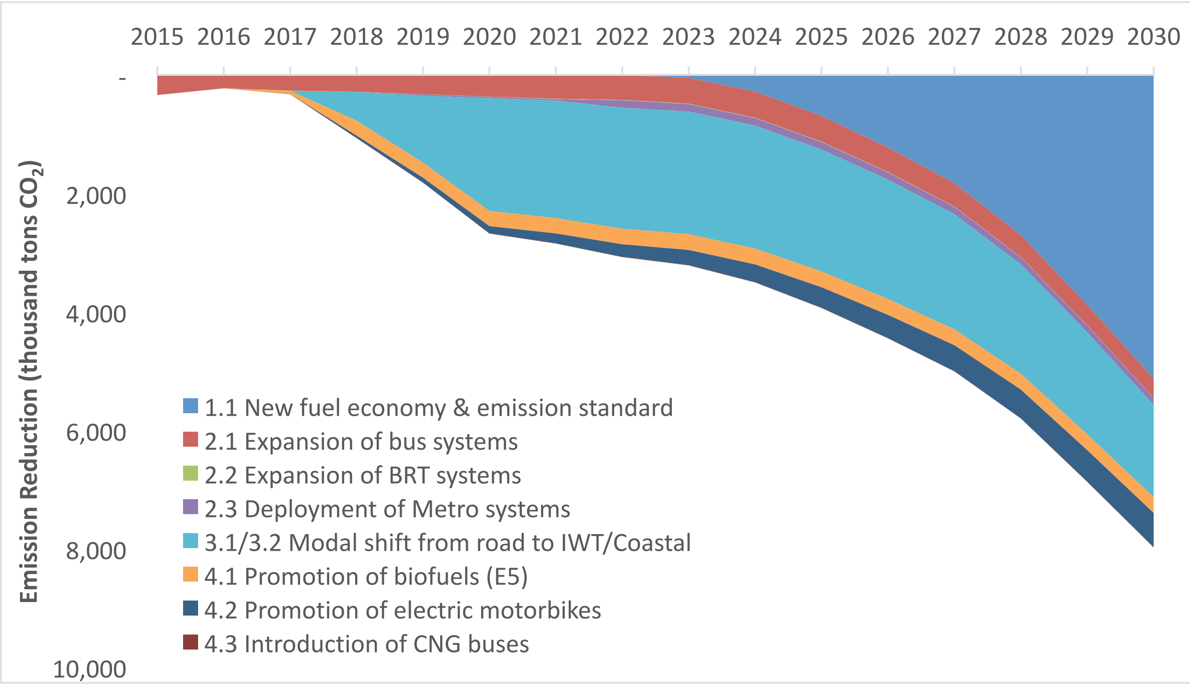


Mitigation Scenario 1 considers mitigation policies and measures that are foreseen in Vietnam's National Transport Master Plan and can be implemented using domestic resources. They include modal shifts towards public transport only in the large cities to achieve the targets set out in the master plan; improvements in vehicle fuel efficiency and emissions technology; shifts towards lower carbon fuels (compressed natural gas, or CNG, used in 623 urban buses, ethanol E5 in 40 percent of gasoline sales up to the supply cap for ethanol of 145,000 m^3); and promotion of electric two-wheelers. Freight modal shift is considered from road to inland waterways and near coastal shipping.

The combination of these measures reduces the sector's CO_2 emissions in 2030 from 89.1 to 81.1 million tons CO_2; a reduction by 9 percent compared to BAU. Policies and measures that improve vehicle fuel economy have the highest potential for GHG emissions reductions, at 5.1 million tons of CO_2. Other actions such as modal shift from road to waterways and from private to public transport, and the shift to the electric vehicles also greatly contribute, as shown in figure E.3.

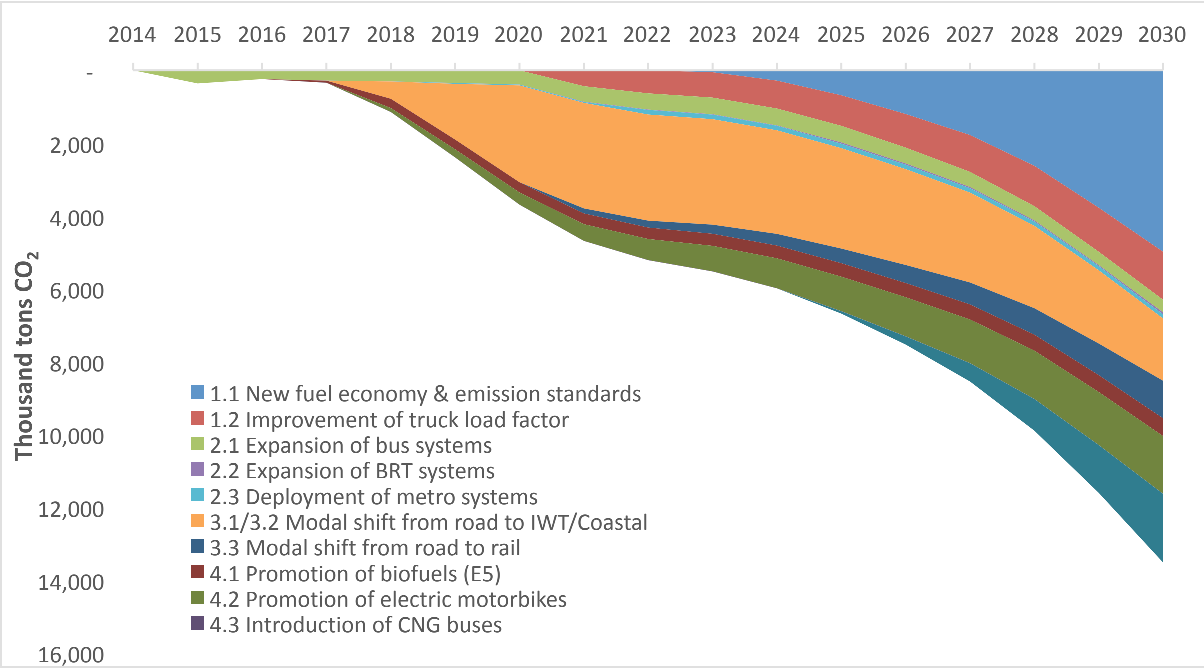
Most of the measures would bring about economic benefits greater than economic costs due to the improvement in energy efficiency of transport resulting in negative marginal abatement costs. Modal shift from road to waterborne transport would entail most economic benefits, followed by introduction of lower emissions vehicle technologies such as through electric vehicles, CNG buses and stricter fuel economy standards. Over the period from 2014 to 2050, all the measures except metro and bus rapid transit (BRT) development have negative marginal costs, providing strong economic justification for implementation.

Figure E.3. Reduction of CO_2 Emissions by Each Mitigation Option under Scenario 1



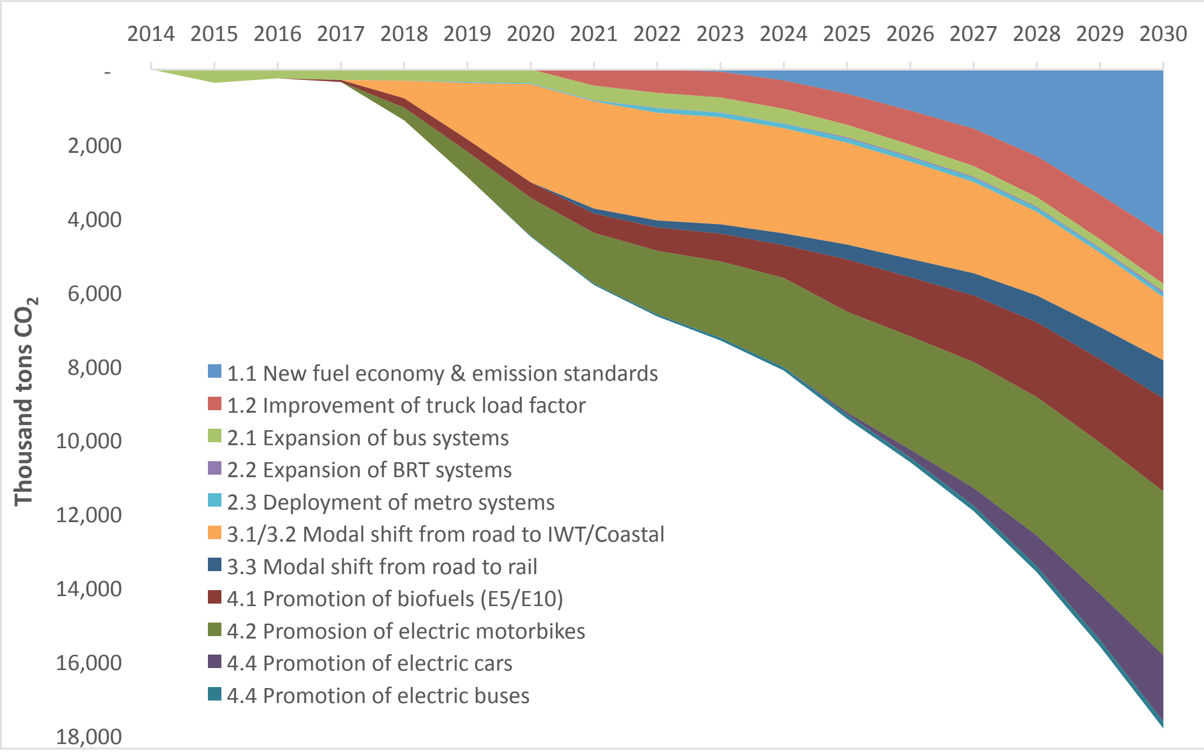
Mitigation Scenario 2 builds on the policies and measures in Scenario 1 and includes additional measures, such as improvements of freight truck load factors, the shift from road to rail transport, and a higher level of sales of electric motorcycles and cars. Such a set of measures would be implemented with support from international resources and active participation of the private sector. In this scenario, the total GHG emissions in the transport sector is 75.6 million tons CO_2 in 2030, corresponding to a decrease of 15.2 percent compared to BAU. The road sector is still the highest contributor of CO_2 emissions with 79.3 percent of total transport emissions. Improvements in vehicle fuel economy are assessed to bring the highest impacts, followed by the development of the electric vehicle market, which contributes to a 3.5 million-ton reduction in CO_2 emissions (see figure E.4). Similar to Scenario 1, most of the measures would present negative MAC and strong economic justification as they would reduce transport costs and bring efficiency in addition to the emissions reduction. Over the period from 2014 to 2050, all the measures except metro and BRT development have negative marginal costs.

Figure E.4. Reduction of CO_2 Emissions by Each Mitigation Option under Scenario 2



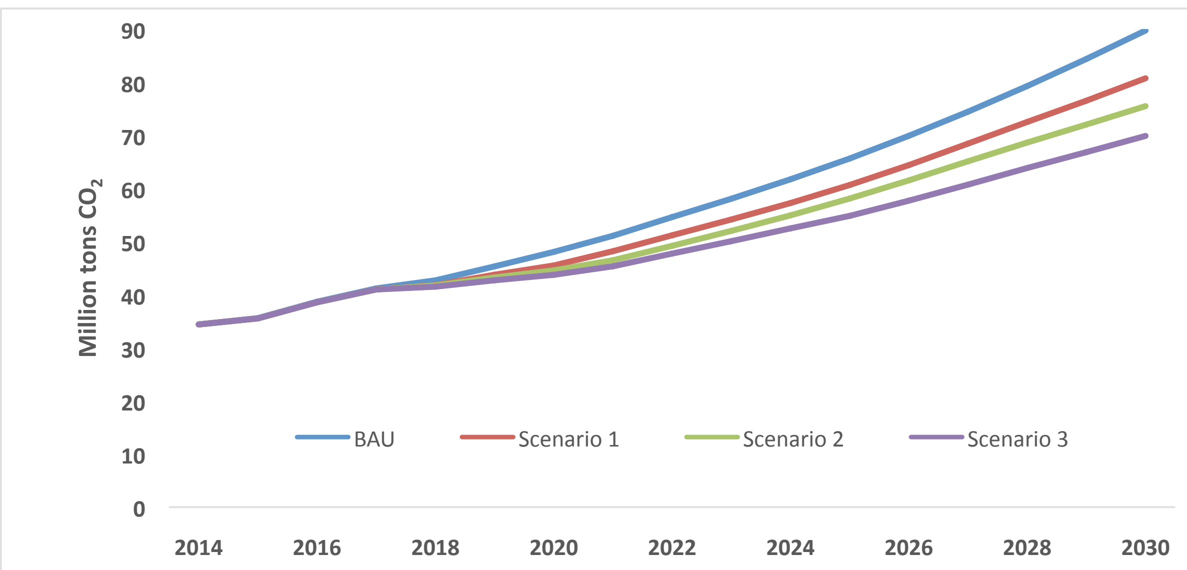
Mitigation Scenario 3 pushes the level of ambition and includes measures not currently considered in Vietnam's Transport Sector Master Plan, assuming significant support from international resources and active participation of the private sector. Such measures include a gradual increase in E10 content up to 100 percent of gasoline sales by 2030; achieving 30 percent of electric two-wheelers in motorbike fleet by 2030; achieving 10 percent of electric vehicles in bus sales in the period from 2020 to 2030; and improving the load factor of freight transport from 56 percent to 65 percent in 2024. These measures would result in a reduction of CO_2 emissions by the transport sector in 2030 to 71.2 million tons CO_2—or 20 percent compared to BAU. Road transport is still the largest contributor to CO_2 emissions, with 77.8 percent of total transport emissions in 2030. Waterways follow this with 10 percent, and aviation with 6 percent. Rail transport emits the lowest share, with 0.7 percent of CO_2 emissions in 2030 (see figure E.5). As in Scenarios 1 and 2, most measures have negative MAC, especially in the longer term, providing strong economic justification for implementation. MACs for several measures under Scenario 3 are lower than their comparators under the previous scenarios, suggesting greater ambition might result in greater cost-effectiveness of measures; in other words, additional measures to achieve more ambitious targets are likely to be economically justified.

Figure E.5. Reduction of CO_2 Emissions by Each Mitigation Option under Scenario 3



In sum, under the mitigation scenarios developed and analyzed in the present study, the transport sector of Vietnam would be able to achieve meaningful reductions in CO_2 emissions. As shown in figure E.6, against the CO_2 emissions trajectories of BAU, Scenario 1 would enable a 9 percent reduction in CO_2 emissions by 2030; Scenario 2, 15 percent; and Scenario 3, 20 percent. Cumulatively until 2050, Vietnam could achieve CO_2 emissions reduction of 512 million tons under Scenario 1, 853 million tons under Scenario 2, and over 1 billion tons under Scenario 3, compared to the BAU.

Figure E.6. Comparison of CO_2 Emissions between BAU and Mitigation Scenarios 1, 2 and 3



Comparing the three scenarios against the BAU, we conclude that Vietnam can adopt and implement several highly cost-effective mitigation measures that are economically feasible to achieve significant emissions reduction in this rapidly growing sector. The emissions reduction under the above scenarios would help Vietnam achieving its NDC targets, when complemented by the policies and investments in other sectors, especially in power generation. As shown in table E.1, the net present values (NPVs) to 2018 of the additional investment (not counting changes in operation, maintenance, or fuel costs) are negative under all three mitigation scenarios and largest under Scenario 2, suggesting the strongest economic justification. Most of low-carbon transport measures presented and analyzed in this report are considered good transport solutions, not only because of the carbon price, but also because they are sustainable solutions. The economic benefits of these measures would, in fact, be greater if their co-benefits, such as local emissions, quality of life, and health, are also considered.

Table E.1. NPV of Additional Investment Needs by Mitigation Scenario and Analysis Period

Scenario	NPV of additional investment cost by period (in 2018 constant value)	
	2014–2030	2031–2050
Scenario 1: 9% reduction	(VND 18.7 trillion) (US$ 0.85 billion)	(VND 18.5 trillion) (US$ 0.84 billion)
Scenario 2: 15% reduction	(VND 132.4 trillion) (US$ 6.06 billion)	(VND 130.7 trillion) (US$ 5.98 billion)
Scenario 3: 20% reduction	(VND 94.0 trillion) (US$ 4.30 billion)	(VND 66.5 trillion) (US$ 3.04 billion)

Next Steps. While these measures are economically feasible, bringing in great long-term benefits through a reduction in transport costs, they would require significant investment for which financing needs to be mobilized even though the NPV of these investments is lower than in the BAU scenario. As a follow-up activity, a thorough financial analysis would therefore be required to estimate the financing needs of various measures. It would also be necessary to devise financing plans for the additional resources required from international support as well as private sector participation.

Additionally, even the most ambitious scenarios presented in this report still yield increasing CO_2 trajectory, and thus, even more ambitious mitigation measures are needed to reverse the trends and decrease emissions in absolute terms, posing significant challenge to the transport sector in Vietnam. The solutions to this problem may lie with “Avoid” measures, such as better integration between land-use and transport, which can help avoid unnecessary trips and complement the “Shift” and “Improve” measures identified and analyzed in this report. Long-term land use and infrastructure planning is crucial given their long-term lock-in effects.

Notes

1. Third National Communication to the UNFCCC: road transport emits 27,404.64 ktCO_2e which corresponds to 18.42 percent of total CO_2 emissions with land use, land-use change, and forestry (LULUCF); and 9.65 percent of total GHG emissions with LULUCF, in 2014.

2. Vietnam's Third National Communication to the UNFCCC reports that in 2014 emissions from the transport sector accounted for 30.4 million tons CO_2. The difference in values reported is justified by the National Communication using a top-down approach while this report using a bottom-up approach to the calculation of emissions.

3. Data taken from the *Statistical Yearbook of Vietnam 2016*, published by the Vietnam General Statistics Office, in 2016. When travel distance is included, the greatest share of freight traffic is on coastal (55%) while road and waterways accounted for 22.3 percent and 20.6 percent respectively.

Reference

GSO (General Statistics Office of Vietnam). 2016. *Statistical Yearbook of Vietnam 2016*. Hanoi: Government of Vietnam. https://www.gso.gov.vn/default_en.aspx?tabid=515&idmid=5&ItemID=18533.

Chapter 1: Introduction

Background and Objectives

Vietnam is committed to addressing climate change, including through signing of the Paris Agreement in 2015 under the United Nations Framework Convention on Climate Change (UNFCCC) and submission of its Intended Nationally Determined Contribution (INDC, or simply NDC). In its NDC, Vietnam set the goal of reducing its GHG emissions by 8 percent in 2030, compared to business as usual (BAU) using domestic resources, and raised its ambition to 25 percent emissions reduction against BAU, contingent on receiving international support. The UNFCCC requires member states to regularly update and adjust their NDC, and Vietnam is currently preparing a revision of its NDC for submission in September 2019. In recent years, Vietnam adopted legislation, policies, programs, plans to respond to climate change and sustainable development, including the following:

- The Central Committee of the Party, Session XI, adopted the Resolution No. 24-NQ/TW dated June 3, 2013, on active response to climate change, strengthening natural resources management, and environmental protection.
- The National Assembly of the Socialist Republic of Vietnam adopted the Law on Environmental Protection No. 55/2014/QH1, in Session XIII on June 23, 2014, in which the particular content responding to climate change is at Chapter IV of the Law.
- The National Assembly of Socialist Republic of Vietnam on November 23, 2015, adopted the Law on Meteorology and Hydrology No. 90/2015/QH13, including contents related to monitoring, impact assessment, and response to climate change.
- The Government of Vietnam approved Resolution No. 120/NQ-CP dated November 17, 2017, on Sustainable Development of the Mekong River delta adapting to climate change and issued a comprehensive action plan to implement this resolution with specific tasks, actions, and timeline to be carried out by ministries, sectors, and localities.
- The Prime Minister issued Decision No. 2053/QD-TTg, dated October 28, 2016, approving the implementation plan for Paris Agreement on climate change

The fast-growing transport sector contributes significantly to the total national GHG emissions, and thus plays an increasingly important role in delivering Vietnam's commitments under the NDC. Transport accounted for 30.55 $MtCO_2e$ or 10.8 percent of total CO_2e emissions in 2014.[1] Vietnam's increasing demand for greater mobility and the high motorization rate pose significant challenges for Vietnam's potential for reducing greenhouse gas emissions in this sector.

Vietnam's National Committee on Climate Change, led by the Ministry of Natural Resources and Environment (MoNRE), engages ministries from relevant sectors in the definition and implementation of policies and measures that reduce GHG emissions. In past years, several studies have been conducted, such as *Intended Nationally Determined Contribution of Viet Nam* (MoNRE 2016), and *Viet Nam's Second National Communication of Viet Nam to the UNFCCC* (MoNRE 2010). Based on these reports and on interagency dialogue, the National Committee on Climate Change stated the transport sector, using domestic resources, would be responsible for contributing to the commitment of reducing 8 percent its GHG emissions against BAU, in 2030.

Recognizing the importance of the transport sector to deliver on Vietnam's NDC commitment, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) and the World Bank Group cooperated with Vietnam's Ministry of Transport (MoT) and its Department of Environment (DoE) to (i) compile and analyze information on transport sector activities pertinent to GHG emissions, (ii) create knowledge and build capacity to facilitate the identification and prioritization of policies and measures for GHG emissions reductions from the transport sector in Vietnam, and (iii) inform and participate in Vietnam's NDC revision process. The specific objectives of this joint technical assistance include the following:

- To improve understanding of the sources of GHG emissions within the transport sector and their relative significance to facilitate the identification of policies and measures for emissions mitigation.
- To develop GHG emissions scenarios based on increasing levels of ambition, international resources, and private sector participation:

  BAU: Business as usual includes all policies and interventions up to and including the base year of 2014, but no additional deployment of targeted policies and measures after that date aimed at mitigation of GHG emissions in the transport sector.

  Scenario 1: Implementation of some of the policies and measures included in Vietnam's Transport Sector Master Plan that can be implemented without support from international resources.

  Scenario 2: Implementation of more ambitious policies and measures included in Vietnam's Transport Sector Master Plan, using domestic and international resources.

  Scenario 3: Implementation of more ambitious policies and measures including some not currently included in Vietnam's Transport Sector Master Plan—that use domestic and international resources and have active participation of the private sector.

- To assess the potential for emissions reduction and cost efficiency for each measure, through the development of a marginal abatement cost (MAC) curve.

The project team, in close coordination with the Department of Environment of MoT, developed scenarios in extensive consultation with various stakeholders, including national government agencies, sector and thematic experts from local and international academia, the private sector, and civil society. To ensure active participation and eventual consenus on the scenarios and individual measures, multiple workshops and bilateral meetings were held at each stage of the analysis and report preparation. Agencies that provided input to the data compilation and analysis include the MoT, the Ministry of Finance (MoF), the Ministry of Natural Resources and the Environment (MoNRE), Vietnam National Directorate of Roads (DRVN), Vietnam Railway Authority, Vietnam Inland Waterways Administration (VIWA), Vietnam Maritime Administration (VINAMARINE), Civil Aviation Authority of Vietnam (CAAV), the Vietnam Registry (VR), Transport Development Strategy Institute (TDSI), various research and academic institutes, and other entities.

Transport Sector Development in Vietnam

Vietnam's remarkable success in mitigating poverty and promoting economic development over the past decades was greatly enabled by the rapid development of supporting economic infrastructure, including those of transport. The transport infrastructure enabled the rapid increase in the mobility of people and goods, and improved the access of the rural population to essential services (such as health and education facilities) and economic opportunities. According to the MoT, since 1992 the length of Vietnam's road network increased significantly and reached over 400,000 km in 2016; as a result of this endeavor, the number of communes without access to all-weather roads dropped from 606 in 1997 to 235 in 2005 and then to 65 in 2016.

This rapid development in infrastructure was met with a rapid increase in mobility, which rose faster than the GDP growth since the late 1990s. Over the past 25 years, annual growth rates in freight and passenger demand measured in ton per passenger-km were 11 percent and 10 percent respectively, compared to GDP growth of 6.4 percent. The total national passenger-km increased from 32 billion in 2000 to 169 billion in 2016, or by about 520 percent; during the same period, the total national freight ton-km increased from 32 billion to 111 billion or by about 340 percent.[2] Such exponential growth in mobility, which on one hand was the contributor to and outcome of the impressive economic growth and poverty reduction in Vietnam, resulted in negative environmental consequences. The transport sector has become and will continue to be a significant emitter of greenhouse gases (GHG), contributing 30.6 million tons CO_2e, which corresponds to 10.76 percent of total CO_2e emissions[3] in 2014. Road transport accounted for 89.7 percent of transport emissions. Road transport, which carried 94 percent of passengers and 76 percent of freight tons,[4] represents one of the reasons for this large share of emissions. However, when travel distance is included (see table 1.1), the greatest share of freight flows occurs along coastal areas (55 percent), while road and waterways accounted for 22.3 percent and 20.6 percent respectively.

Table 1.1. Distances Traveled by Passengers and Freight in Vietnam in 2014

Passenger/Freight	Total	Railway	Road	Inland waterway	Coastal shipping	Aviation
Passenger-km (billion)	139.1	4.5	96.9	3.0		34.7
Freight ton-km (billion)	223.2	4.3	48.2	40.1	130.0	0.5

Source: General Statistics Office of Vietnam

The transport sector consumes five types of fuel: Gasoline[5] is consumed by almost all road transport modes, such as two-wheelers, passenger cars, light commercial vehicles; diesel is consumed by road, railway, and inland waterway transport; fuel oil (FO) is only used for maritime vehicles; kerosene is only used in aviation; and electricity is mainly consumed by electric two-wheelers, and in the future, by metro. Diesel and gasoline are projected to continue increasing significantly, more than doubling its consumption from 2014 to 2030. The consumption of fuel oil and jet kerosene is almost constant over the years, aligned with a modest increase in demand for inland waterways, coastal, and air transport (table 1.2 and figure 1.1).

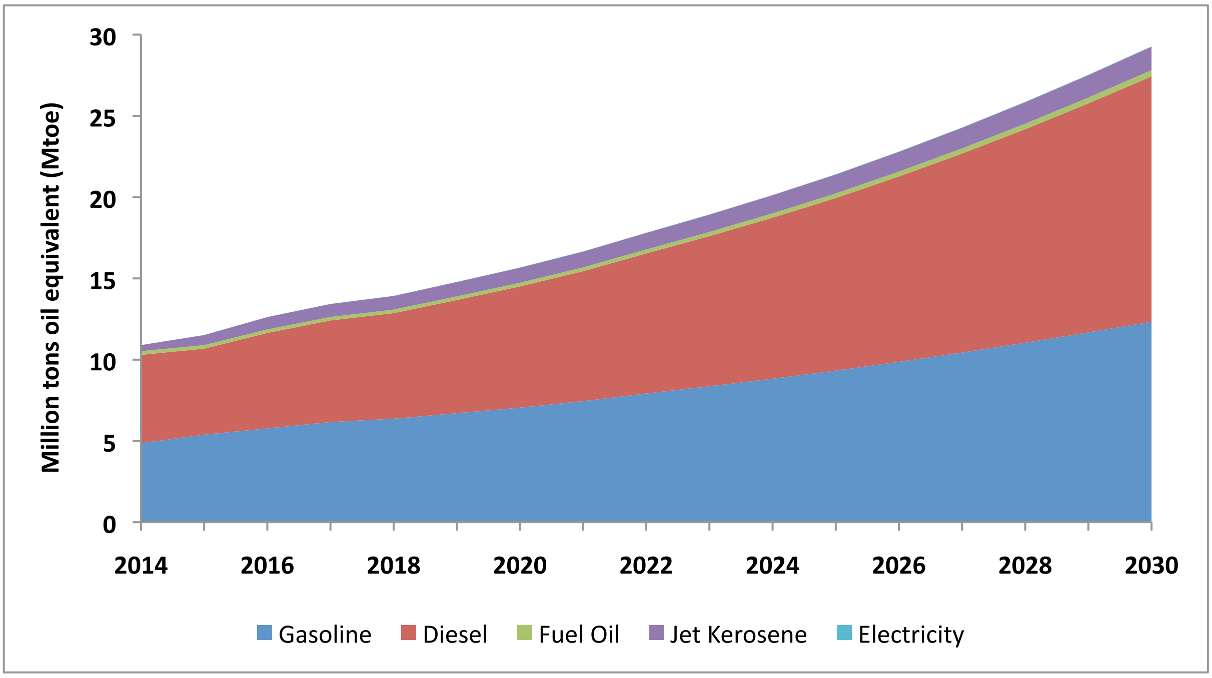
Table 1.2. Fuel Consumption by Fuel Type in Transport Sector in Vietnam

In million tons oil equivalent

Fuel type	2014	2020	2025	2030
Gasoline	4.86	7.05	9.33	12.33
Diesel	5.44	7.46	10.62	15.10
Fuel oil	0.23	0.23	0.29	0.38
Jet kerosene	0.37	0.93	1.16	1.44
Electricity	0.00	0.01	0.02	0.02

Source: World Bank and GIZ data.

Figure 1.1. Fuel Consumption in the Transport Sector by Fuel Type



The Avoid-Shift-Improve (ASI) Framework provides a systematic approach to assess emissions sources in the transport sector and to identify opportunities for emissions reduction:

- **Avoid** stands for actions that reduce the need for motorized transport or the distance traveled by motorized transport. This can include, for example, measures such as fostering the development of dense, polycentric, mixed-use cities, which enables people to live closer to locations of work, services, and goods. Another example is the application of intelligent services and applications that enable passengers and freight to go from origin to destination through shorter routes. A further example is the deployment of incentives for passengers to share transport services such as high occupancy lanes on toll roads where tolls are exempted for high occupancy vehicles.
- **Shift** stands for actions that enable and incentivize the shift from higher-emitting transport modes to cleaner transport modes. One example is the deployment of infrastructure and

systems to facilitate the integration of transport modes such as public transport with bicycle lanes, or road with railway and inland waterways. Another example would be the establishment of low-emissions or low-congestion zones and the provision of public and non-motorized transport options to address the continuing demand for transport mobility.

- **Improve** stands for actions that reduce emissions of transport per unit of distance traveled and can include measures such as improvement in vehicle fuel economy and the introduction and switching towards lower carbon fuels.

While the study used the ASI Framework as an approach to identify mitigation actions, the analysis focused on the Shift and Improve components, which fall under the mandate of the Ministry of Transport. Table 1.3 lists examples of GHG mitigation strategies within the MoT mandates.

Table 1.3. GHG Mitigation Strategies in the Transport Sector

Energy in transport	**Fuel shift**	Use of biofuels, including ethanol blend (E5/E10)
		Use of natural gas
		Use of electricity
	Modal shift	Shift from private vehicles to public transport modes (buses, bus rapid transit or BRT, and metro)
		Shift freight transport from road to other modes
		Encourage non-motorized transport (NMT)
	Energy efficiency	Vehicle maintenance
		Shift to energy efficiency vehicles
		Apply the energy saving technology
		Fuel economy standards

The scenario analysis assessed the mitigation impact of the listed policy measures, with each scenario considering different levels of ambition. All scenarios assume the demand for transport will continue to increase—driven by economic growth, population growth, rural to urban migration, and improved living standards. The business-as-usual scenario assumes there will not be deployment of new policies and measures targeted at reducing emissions in the transport sector after 2014. Scenario 1 considers modest levels of ambition, corresponding to the implementation of measures defined in Vietnam's Transport Development Plan that can be implemented without support from international resources. Scenario 2 considers a higher level of ambition than Scenario 1 for measures defined in Vietnam's Transport Development Plan and is contingent on having international financial support. Finally, Scenario 3 is again a higher level of ambition in terms of GHG emissions reduction and goes beyond measures and levels defined in Vietnam's Transport Development Plan (see table 1.4).

Table 1.4. List of GHG Mitigation Options Considered in Scenario Analysis

No.	Measure name	Scenario 1	Scenario 2	Scenario 3
1. Energy efficiency				
1.1	**New vehicle fuel economy and emissions standards**	*Fuel economy improvements deployed in two stages:* **Stage 1 (2022–2026)** • Small car (<1400cc): 6.1 L/100km • Medium car (1400-2000cc): 7.52 L/100km • Large car (>2000cc): 10.4 L/100km *In which* • 2022: 50% of car sales apply fuel economy • 2023: 75% of car sales apply fuel economy • 2024-2026: 100% of car sales apply fuel economy • 2025: Motorcycles: 2.3 L/100 km **Stage 2 (2027–)** • Small car (<1400cc): 4.7 L/100 km; • Medium car (1400-2000cc): 5.3 l/100 km; • Large car (>2000cc): 6.4 L/100km. *In which* • 2027: 50% of car sales apply fuel economy • 2028: 75% of car sales apply fuel economy • 2029: 100% of car sales apply fuel economy		
1.2	**Improvement of truck loading factors**	No	Freight load factor improves from 56% to 60%.	Freight load factor improves from 56% to 65%.
2. Passenger modal shift from private vehicles				
2.1	**Expansion of bus systems**	Bus development in 5 cities of central management (Hanoi, Ho Chi Minh City, Hai Phong, Da Nang, Can Tho)	Bus development in 13 cities including 5 cities of central management and 9 Class 1 cities: Hanoi, Ho Chi Minh City, Can Tho, Da Nang, Hai Phong, Viet Tri, Nam Dinh, Vinh, Hue, Quy Nhon, Da Lat, Nha Trang, and Buon Me Thuot	
2.2	**Expansion of BRT systems**	*Hanoi:* Line 1 in operation in 2017 *Da Nang:* Line 1 in operation in 2021 *HCMC:* Line 1 in operation in 2021 Line 2 in operation in 2025	*Hanoi:* Line 1 in operation in 2017; 1 new line in operation in 2025; 2 new lines in operation in 2030 *Da Nang:* Line 1 in operation in 2021; 1 new line in operation in 2030 *HCMC:* Line 1 in operation in 2021; 2 new lines in operation in 2025 *Can Tho:* Line 1 in operation in 2025; Line 2 in operation in 2030 *Hai Phong:* Line 1 in operation in 2025; Line 2 in operation in 2030 *New BRT lines using electric buses in Hanoi and HCM city from 2025*	
2.3	**Deployment of metro systems**	*Hanoi:* Line 2A in operation in 2019; Line 3 in operation in 2022 *HCMC:* Line 1 in operation in 2022		

Table 1.4 *continued*

No.	Measure name	Scenario 1	Scenario 2	Scenario 3
3. Freight modal shift from road				
3.1	**Modal shift from road to inland waterway transport**	*Modal shift for freight transport:* *By 2020*: • FTKT by IWT to increase from 65.0 (BAU) to 71.2 billion ton-km (20.7% to 22.6% of total FTKT); share of road to decrease from 23.0% to 19.1%. *By 2030*: • FTKT by IWT to increase from 127.8 to 128.8 billion ton-km (20.6% to 20.8% of total); modal share of road to decrease from 23.4% to 23.0% in 2030.	*Modal shift both for freight and passenger transport:* *By 2020*: • FTKT by IWT to increase from 65.0 (BAU) to 71.2 billion ton-km (20.7% to 22.6% of total FTKT); share of road to decrease from 23.0% to 19.1%. *By 2030*: • FTKT by IWT to increase from 127.8 to 128.8 billion ton-km (20.6% to 20.8% of total); modal share of road to decrease from 23.4% to 23.0% in 2030.	
3.2	**Modal shift from road to coastal shipping**	*Modal shift for freight transport:* • The FTKT from road to the coastal transport is assumed to be equivalent to the FTKT shifted from road to IWT in the same time.	*Modal shift for freight transport:* • The FTKT from road to the coastal transport is assumed to be double the FTKT shifted from road to IWT in the same time.	
3.3	**Modal shift from road to railway**	No	In accordance to the Decision 318/QĐ-TTg on transport service development, the growth rate of freight transport is expected to be 12.5%. The calculation assumes that the FTKT on the railway will increase at this same annual rate.	

Table 1.4 *continued*

No.	Measure name	Scenario 1	Scenario 2	Scenario 3
4. Fuel change				
4.1	**Promotion of biofuels (E5/E10)**	In 2018: E5 40% of total gasoline sales (first half of 2018) 2019–30: There is a supply constraint for ethanol of 145,000 cubic meters per year and transport demand does not exceed this figure.	In 2018: E5 40% of total gasoline sales (first half of 2018) 2019–30: E5 accounts for 40% of total gasoline sales; assume no supply constraint.	2018–24: E5 increases gradually from 40% of total gasoline sales in 2018 up to 100% in 2024. 2025–30: E5 is gradually replaced with E10, at 50% in 2025 increasing to 100% by 2030.
4.2	**Promotion of electric motorbikes**	Electric motorbikes account for 7% of annual motorbike sales.	Electric motorbikes account for 14% of annual motorbike sales.	Electric motorbikes account for 30% of total two-wheeler fleet.
4.3	**Introduction of CNG buses**	623 CNG buses: 423 in HCMC; 200 in Hanoi	HCMC: 423 CNG buses in 2017 Hanoi: 50 CNG buses in 2018 and 200 units by 2020	
4.4	**Promotion of electric cars and buses**	No	• Electric cars represent 5% of annual new car sales in 2025 • Electric cars represent 30% of annual new car sales in 2030 • All BRT lines after 2020 use electric buses	• 5% of annual new car sales in 2025 • 30% of annual new car sales in 2030 • All BRT lines after 2020 use electric buses • 10% of bus sales are electric vehicles in 2020–2030

Notes

1. According to Vietnam's *Third National Communication to the UNFCCC*: Transport emits 30,552.31 ktCO_2e, which corresponds to 10.76 percent of total CO_2e emissions without land use, land-use change, and forestry (LULUCF); and 9.51 percent of total CO_2e emissions with LULUCF, in 2014.
2. Taken from 2018 General Statistics Office (GSO) transport statistics, available at: https://www.gso.gov.vn/default_en.aspx?tabid=781.
3. Without LULUCF in 2014. The transport emissions of CO_2 (without CH_4 and N_2O) in that year were 30.35 million tons CO_2.
4. Taken from the *Statistical Yearbook of Vietnam 2016*, published by the General Statistics Office. Available at: https://www.gso.gov.vn/default_en.aspx?tabid=515&idmid=5&ItemID=18533.
5. Gasoline may contain a fraction of ethanol.

References

MoNRE (Ministry of Natural Resources and Environment). 2010. *Viet Nam's Second National Communication to the United Nations Framework Convention of Climate Change*. Hanoi: Ministry of Natural Resources and Environment, Vietnam. https://unfccc.int/sites/default/files/resource/Vietnam%20second%20national%20communication.pdf.

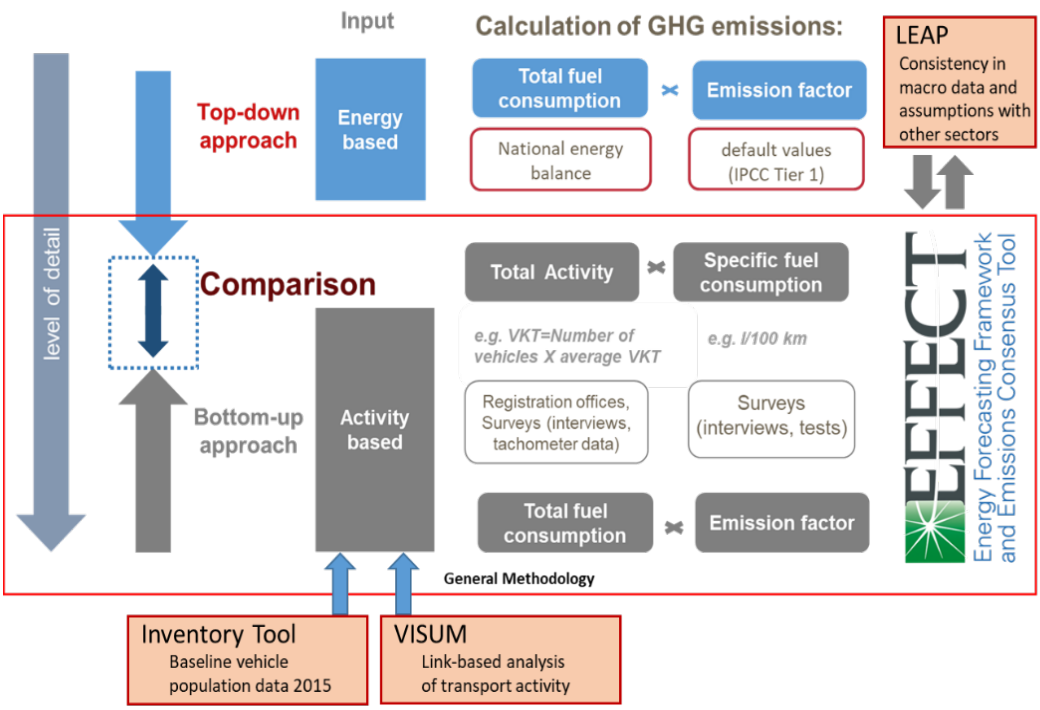
———. 2016. *Intended Nationally Determined Contribution of Viet Nam*. Technical Report. Hanoi: Ministry of Natural Resources and Environment, Vietnam. https://www4.unfccc.int/sites/ndcstaging/PublishedDocuments/Viet%20Nam%20First/VIETNAM%27S%20INDC.pdf.

———. 2019. *Third National Communication of Viet Nam to the United Nations Framework Convention of Climate Change.* Revised April 20, 2019. Hanoi: Ministry of Natural Resources and Environment, Vietnam. https://unfccc.int/sites/default/files/resource/Viet%20Nam%20-%20NC3%20resubmission%2020%2004%202019_0.pdf.

Chapter 2: Business-As-Usual Reference Scenario

This chapter presents the transport activities and emissions projection under the business-as-usual (BAU) scenario estimate, based on the comprehensive inventory of transport activities and macroeconomic assumptions. The study objectives required a suite of models that would allow a detailed bottom-up analysis of transport activity in all sectors, which determined the impact of policies and investments on the national greenhouse gas (GHG) emissions. In turn, the study used the emissions analysis to calculate the transportation sector's emissions scenarios for the Nationally Determined Contribution (NDC) update. Figure 2.1 illustrates the modeling framework, which employs various tools with unique capabilities.

Figure 2.1. Modeling Framework



Growth Projection in the Transport Sector under BAU

Transport sector emissions under the business-as-usual scenario are projected to increase with growing mobility demand and motorization. Based on population and economic growth assumptions, detailed in Appendix D, passenger-km traveled (PKT) are projected to increase at an annual average growth rate of 5.9 percent from 2014 to 2030 (figure 2.2). The modal share remains relatively stable throughout the forecast period: Road transport accounts for 94 percent of PKT consistently during the period, although the share of commercial PKT increases somewhat compared to private PKT; air transport PKT is maintained at around 4 percent of the total. Freight ton-km traveled (FTKT) is forecast to grow at an average annual rate of 6.9 percent (figure 2.3). Coastal shipping accounts for 55 percent of FTKT, while road and waterways account for 23 percent and 21 percent respectively.

Figure 2.2. Projection of Passenger-Kilometers Traveled under BAU

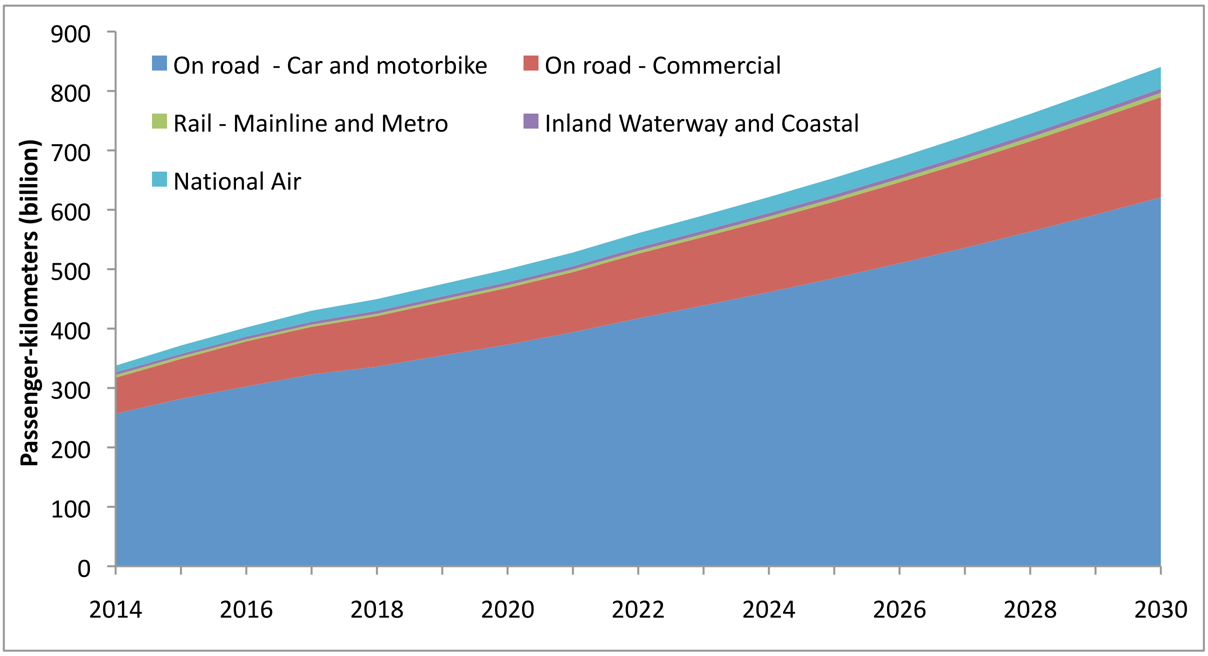
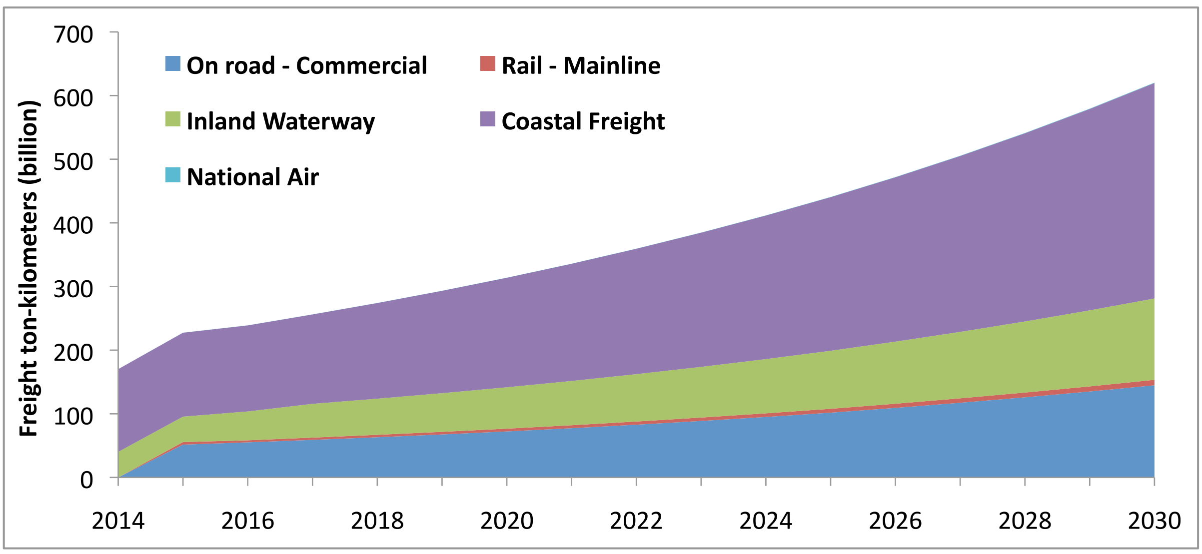


Figure 2.3. Projection of Freight Ton-Kilometers Transported under BAU



Road Transport. Road transport is not only one of the most dominant modes in Vietnam, but also the fastest growing mode. Road infrastructure received the vast majority of public funding allocation, and its length quadrupled over the past two decades; the motorization rate in Vietnam, while at a modest level compared to higher-income countries, is increasing rapidly. Based on the population and economic growth assumptions, the total kilometer traveled by road vehicles is forecast to increase from 212.7 billion km per year in 2014 to 476.4 billion km per year in 2030 (figure 2.4), at an average annual growth rate of 5.2 percent. Of the total kilometer traveled, motorcycles accounted for 60 percent, passenger cars for 23 percent, and trucks and coaches for 10 percent.

The total road vehicle fleet is projected to increase at an annual average rate of 6.5 percent during the same period, with great variation across vehicle types, ranging from 3.0 percent per annum for motorcycles (gasoline-fueled) and 6.5 percent for heavy commercial vehicles, to 13.3 percent for passenger cars (figure 2.5).

Figure 2.4. Projections of Road Distances Traveled by Vehicle Type

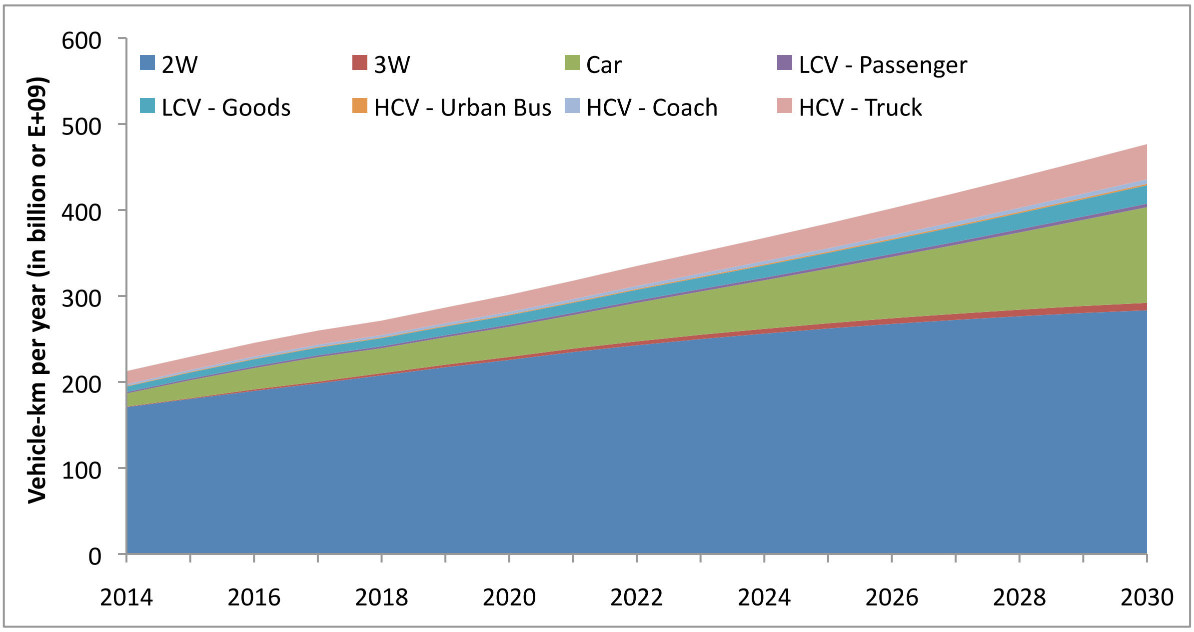
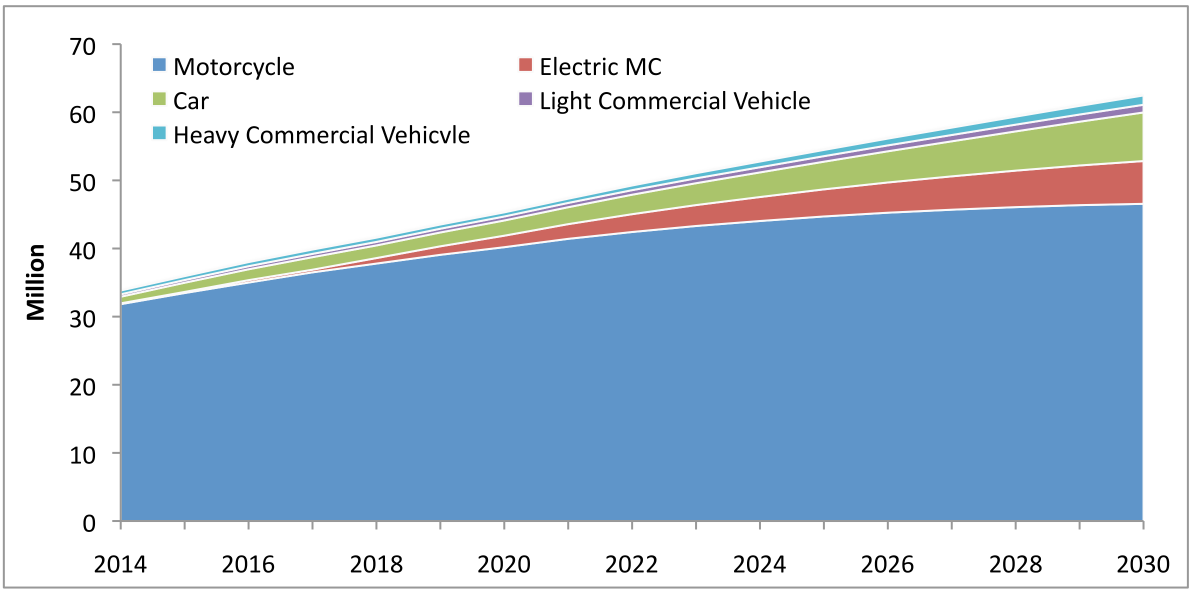


Figure 2.5. Projections of Road Vehicle Fleet Numbers by Vehicle Type



In 2014, motorcycles accounted for 94 percent of the total road vehicle fleet in Vietnam; however, this share is projected to reduce to 81 percent by 2030. Passenger cars have the second largest share, with 1 million in 2014, with a projected increase to 7.1 million vehicles by 2030. The share of electric vehicles in the vehicle fleet will remain low, reaching only a 2.5 percent share of private cars, by 2030. Light commercial vehicles (LCV)—typically small trucks—are projected to increase by 47 percent by 2030. Heavy commercial vehicles (HCV) for freight and passenger transport will increase 2.5 times in number by 2030. In 2014, medium-sized trucks (7 to 16 tons) accounted for 28 percent of HCV fleet and are projected to increase to 40 percent by 2030.

Inland Waterway and Coastal Transport. Vietnam's inland waterway transport (IWT) has grown and improved significantly in recent years, becoming a vibrant sector of activity strategically important to Vietnam's transport system. It carries nearly one in six tons of the domestic goods transported[1] and nearly 80 percent of the freight traffic (ton-km) carried by road transport.[2]

Passenger flows by inland waterways is expected to grow from 2.9 billion passenger-km in 2014 to 6.2 billion passenger-km in 2030, at an average annual growth rate of 1.7 percent. The great majority of vessels and barges (92 percent) are small, with a power capacity of below 100 HP. Inland waterways moved 40.1 billion ton-km in 2014. Freight flows are projected to grow at an average annual rate of 9.0 percent, reaching 127.8 billion ton-km in 2030. Bulk vessels with a capacity below 1,500 tons accounted for 94 percent of vessels operating in inland waterways. Freight flows moved by coastal transport is projected to increase from 130 billion ton-km in 2014 to 338.4 billion ton-km in 2030; vessels used in coastal transport are projected to be mostly bulk (64 percent) with capacity over 1,000 tons.

Domestic Aviation. Aviation is a rapidly growing sector of activity. Passenger kilometers traveled by domestic civil aviation rapidly increased from 4.4 billion PKT in 2000 to reach 11.0 billion PKT in 2014 and is projected to increase to 36.5 billion PKT in 2030. While no dedicated freight services are operating domestically, freight flows on passenger airplanes, so-called "belly cargos" is projected to increase from 0.1 billion ton-km in 2014 to 0.7 billion ton-km in 2030.

Railways. Rail transport in Vietnam accounts for a small and decreasing share of PKT and FTKT, largely due to the deteriorating condition of the legacy infrastructure that provides low-speed and low-capacity services. Passenger kilometers traveled by railway was 4.4 billion passenger-km in 2014 and are projected to increase to 7.1 billion passenger-km in 2030. Freight tons kilometers traveled by railway, which was 4.3 billion ton-km in 2014, gradually reduced in 2015 and 2016 to 3.1 billion ton-km. However, forecasts indicate railway FTKT could reach 8.5 billion ton-km in 2030.

GHG Emissions Results under BAU

Without any targeted policies and measures to reduce GHG emissions in the transport sector, the current composition of the energy sources is estimated to remain largely unchanged, with heavy reliance on gasoline and diesel fuels and low growth of electricity, as depicted in table 2.1.

Table 2.1. Projected Energy Consumption by Source in Transport Sector under Business-As-Usual Scenario

Fuel type	2014	2020	2025	2030	2014	2020	2025	2030
	(In million tons oil equivalent)				*(Fuels in million tons, electricity in GWh)*			
Gasoline	4.86	7.05	9.33	12.33	4.60 Mton	6.66	8.81	11.66
Diesel	5.44	7.46	10.62	15.10	5.29 Mton	7.26	10.34	14.70
Fuel oil	0.23	0.23	0.29	0.38	0.23 Mton	0.24	0.30	0.40
Jet kerosene	0.37	0.93	1.16	1.44	0.36 Mton	0.88	1.10	1.36
Electricity	0.00	0.01	0.02	0.02	19.4 GWh	110.3	192.7	275.0

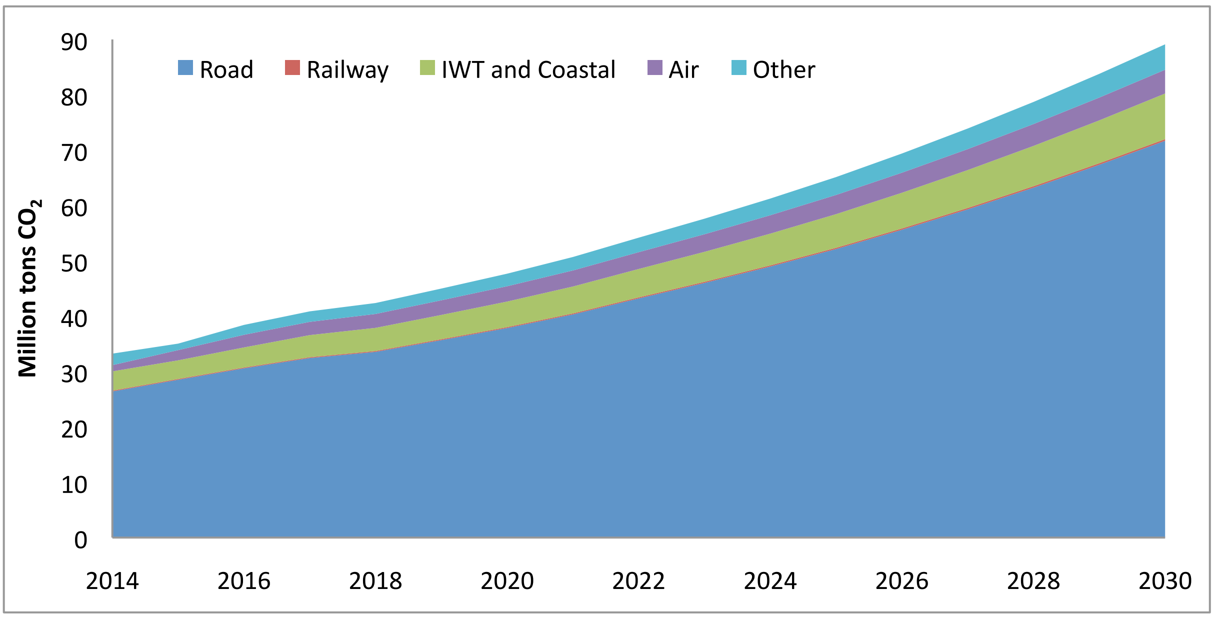
Consequently, emissions are projected to increase at an average of 6 to 7 percent per year, reaching nearly 90 million tons of CO_2 emissions in 2030 (table 2.2 and figure 2.6).

Table 2.2. Transport CO_2 Emissions in Vietnam under Business-As-Usual Scenario

In million tons

Subsector	2014	2020	2025	2030
Road	26.4	37.9	52.1	71.7
Railway	0.1	0.2	0.2	0.3
IWT and coastal transport	3.5	4.6	6.1	8.2
Aviation	1.1	2.8	3.5	4.3
Other	2.1	2.3	3.2	4.6
Total	**33.2**	**47.7**	**65.1**	**89.1**

Figure 2.6. Projected CO_2 Emissions by Transport Subsectors under BAU



Under the BAU scenario, changes in the activity levels of each mode affect the composition of total sectoral CO_2 emissions. The total emissions shares from rail (25 percent) and waterborne transport (11 percent) decrease, while the shares of road and aviation increase (table 2.3). Road transport is the highest source of CO_2 emissions, accounting for 80 percent of total transport emissions; followed by inland waterways and coastal transport, which account for about 10 percent of total transport CO_2 emissions. Emissions from railways are negligible.

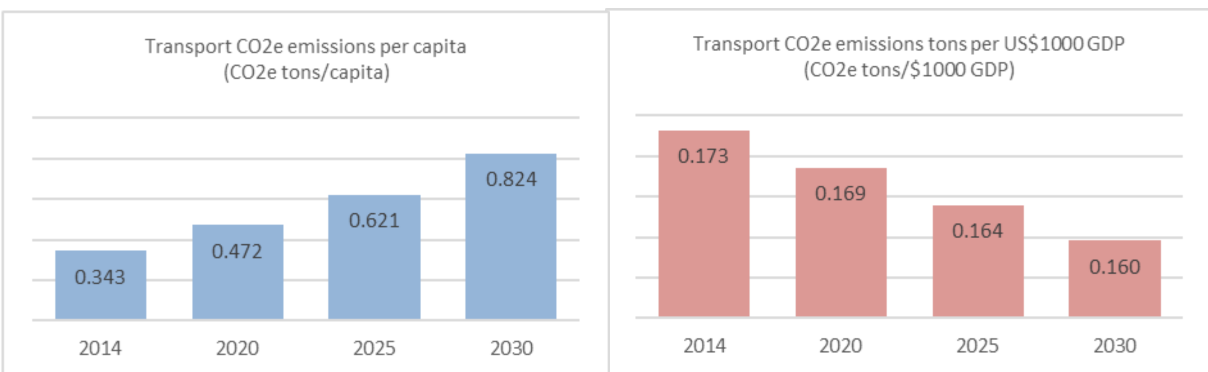
Table 2.3. Projected Share of CO_2 Emissions by Transport Subsectors

Subsector	2014	2020	2025	2030
Road	79.4%	79.4%	80.0%	80.4%
Railway	0.4%	0.4%	0.3%	0.3%
IWT and coastal transport	10.5%	9.7%	9.3%	9.3%
Aviation	3.4%	5.8%	5.3%	4.8%
Other	6.3%	4.8%	5.0%	5.2%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Income growth is the main driver of such rapid growth in mobility, and resultant increases in fuel consumption and emissions. As international experience suggests, income rise is closely related to increasing vehicle ownership and use, and Vietnam is currently going through rapid motorization. As shown in figure 2.5, Vietnam's motorization would see lower-emissions vehicles (motorbikes and light goods vehicles) replaced with higher-emissions vehicles (passenger cars and heavy goods vehicles), driving an increase in emissions per capita.

At the same time, Vietnam's economy is open and trade-dependent with its trade-to-GDP ratio nearing 200 percent in 2018. Economic growth in Vietnam is thus interdependent with increases in goods movement and trade volumes. It is, however, projected that emissions per GDP would decrease under the BAU scenario, suggesting future efficiency improvement in the transport sector. These trends are depicted in figure 2.7.

Figure 2.7. Projected GHG Emissions per GDP and per Capita under BAU



Notes

1. According to 2018 GSO statistics, in 2016 inland waterways = 216 million tons out of a total of 1,255 million tons. See *Statistical Yearbook of Vietnam 2018*. Transport and Postal Service Telecommunications. Table 295: Volume of Freight Carried by Types of Transport. Available at: https://www.gso.gov.vn/default_en.aspx?tabid=515&idmid=5&ItemID=19299.

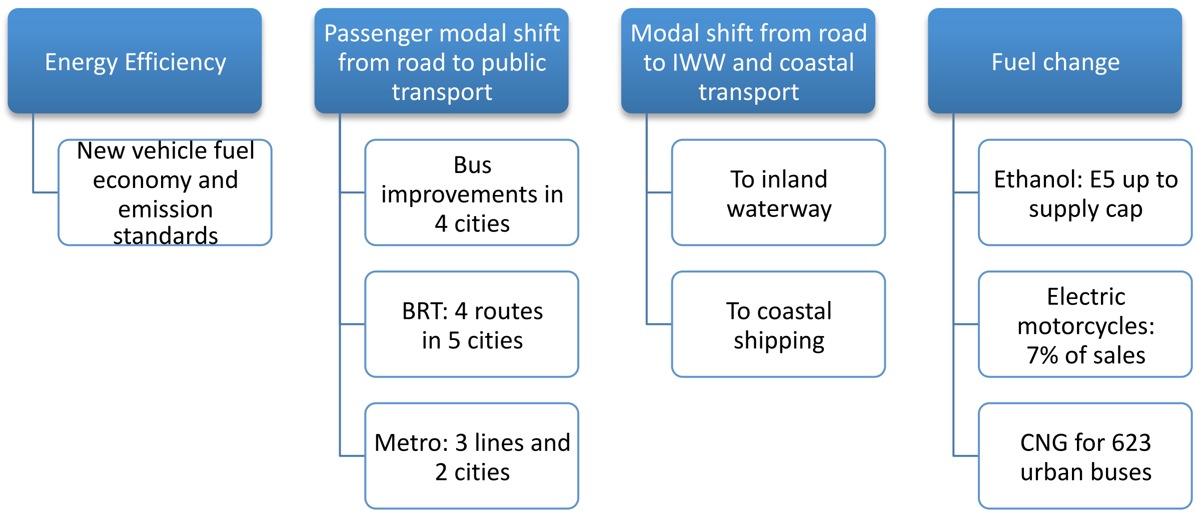
2. According to 2018 GSO statistics, in 2016 road = 57.4; inland waterways = 44.9 billion ton-km. See *Statistical Yearbook of Vietnam 2018*. Transport and Postal Service Telecommunications. Table 295: Volume of Freight Carried by Types of Transport. Available at: https://www.gso.gov.vn/default_en.aspx?tabid=515&idmid=5&ItemID=19299.

Chapter 3: Scenario 1—With Domestic Resources Only

Emissions Mitigation Measures under Scenario 1

Mitigation Scenario 1 includes policies and measures under the Shift and Improve components of the Avoid-Shift-Improve (ASI) framework firmly under the mandate of the Ministry of Transport (MoT), according to the transport sector strategy. In addition, the included mitigation measures have been assessed to be implementable with domestic resources. Figure 3.1 illustrates the mitigation options chosen for Scenario 1.

Figure 3.1. The Mitigation Actions Analyzed under Scenario 1



Note: IWW = Inland waterway; BRT = bus rapid transit; CNG = compressed natural gas.

Table 3.1 (a subset of table 1.4) lays out the detailed level of ambition for each defined mitigation measure, based on the review of existing transport plans and in extensive consultation with relevant stakeholders.

Table 3.1. Level of Ambition for Mitigation Measures Analyzed under Scenario 1

Measures	Mitigation options	Assumptions
1. Energy efficiency	1.1 New vehicle fuel economy and emissions standards	*Vehicle fuel economy standard for new vehicles deployed in two stages:* **Stage 1: (2022–2026)** Small car (<1400cc): 6.1 L/100km Medium car (1400-2000cc): 7.52 L/100km Large car (>2000cc): 10.4 L/100km *In which:* 2022: 50% of car sales comply with standard 2023: 75% of car sales comply with standard 2024–2026: 100% of car sales comply with standard 2025: Motorcycles: 2.3 L/100 km **Stage 2: from 2027 onwards** Small car (<1400cc): 4.7 L/100 km; Medium car (1400-2000cc): 5.3 L/100 km; Large car (>2000cc): 6.4 L/100km. *In which:* 2027: 50% of car sales comply with the standard 2028: 75% of car sales comply with the standard 2029: 100% of car sales comply with the standard
2. Passenger modal shift from private vehicles	2.1 Expansion of bus systems	Bus development in 5 cities of central management (Hanoi, Ho Chi Minh City, Hai Phong, Da Nang, Can Tho)
	2.2 Expansion of BRT systems	*Hanoi:* Line 1 in operation in 2017 *Da Nang:* Line 1 in operation in 2021 *HCMC:* Line 1 in operation in 2021 Line 2 in operation in 2025
	2.3 Deployment of metro systems	*Hanoi:* Line 2A in operation in 2019 Line 3 in operation in 2022 *HCMC:* Line 1 in operation in 2022
3. Modal shift from road	3.1 Modal shift from road to IWW transport	*Modal shift for freight transport* *By 2020*: • FTKT by IWT to increase from 65.0 (BAU) to 71.2 billion ton-km (20.7% to 22.6% of total FTKT); share of road to decrease from 23.0% to 19.1% *By 2030*: • FTKT by IWT to increase from 127.8 to 128.8 billion ton-km (20.6% to 20.8% of total); modal share of road to decrease from 23.4% to 23.0% in 2030
	3.2 Modal shift from road to coastal shipping	*Modal shift for freight transport* • The FTKT from road to the coastal transport is assumed to be equivalent to the FTKT shifted from road to IWT in the same time
4. Fuel change	4.1 Promotion of biofuels (E5/E10)	*In 2018*: • E5 40% of total gasoline sales (first half of 2018) *2019–30*: • There is a supply constraint for ethanol of 145,000 cubic meters per year and transport demand does not exceed this figure.
	4.2 Promotion of electric motorbikes	Electric motorbikes account for 7% of annual motorbike sales
	4.3 Introduction of CNG buses	623 CNG buses: 423 in HCMC; 200 in Hanoi

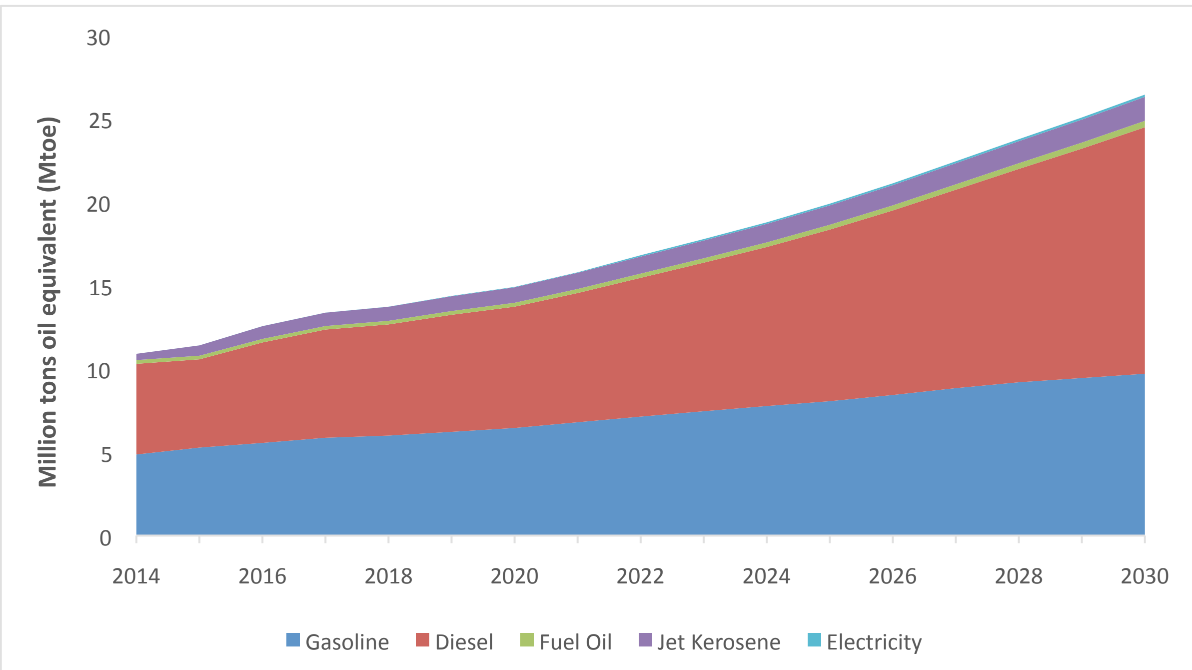
Note: BRT = bus rapid transit; IWW = inland waterway; FTKT = freight ton-km transported; BAU = business as usual; CNG = compressed natural gas; HCMC = Ho Chi Minh City.

The above measures would result in a reduction in projected fuel consumption under Scenario 1, compared to under business as usual (BAU), as summarized in table 3.2 and figure 3.2. Compared to BAU, the gasoline consumption under Scenario 1 would drop by 13 percent in 2025 and by 22 percent in 2030. The projected shift from private passenger transport to public transport such as bus, bus rapid transit (BRT), and metro accounts for this reduction. The shift from fossil-fuel vehicles to electric vehicles (electric motorbikes, electric bus) also contributes to the reduction in gasoline consumption, leading to a reduction in CO_2 emissions compared to BAU. However, emissions from electricity generation is not included in the transport sector analysis, but in that of the energy sector—both of which will be incorporated in the Government of Vietnam's overall Nationally Determined Contribution (NDC) commitment. While gasoline consumption would decrease, diesel consumption would increase by about 1 percent compared to BAU.

Table 3.2. Projected Energy Consumption by Source in Transport Sector under Scenario 1

Fuel type	2014	2020	2025	2030	2014	2020	2025	2030
	(In million tons oil equivalent)				*(Fuels in million tons, electricity in GWh)*			
Gasoline	4.86	6.46	8.08	9.67	4.60 Mton	6.10	7.64	9.14
Diesel	5.44	7.30	10.68	15.23	5.29 Mton	7.11	10.39	14.83
Fuel oil	0.23	0.23	0.29	0.39	0.23 Mton	0.24	0.30	0.40
Jet kerosene	0.37	0.93	1.16	1.44	0.36 Mton	0.88	1.10	1.36
Electricity	0.00	0.01	0.03	0.05	19.4 GWh	171.4	363.4	556.2

Figure 3.2. Projected Energy Consumption by Source in Transport Sector under Scenario 1



GHG Emissions Results under Scenario 1

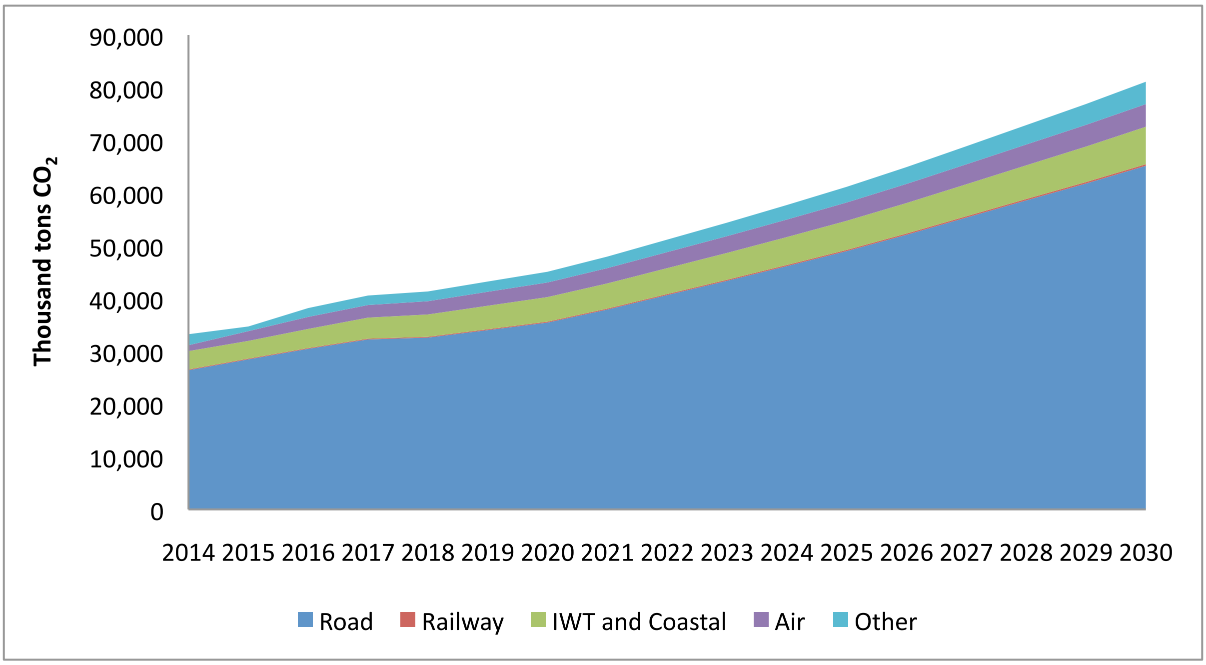
Table 3.3 and figure 3.3 present the total CO_2 emissions from the transport sector and breakdown by subsector under Scenario 1. Compared to BAU, most of the emissions reduction would occur in the road sector with some in the inland waterway transport (IWT) and coastal transport. The modal share of total greenhouse gas (GHG) emissions would remain relatively unchanged over the period.

Table 3.3. Transport CO_2 Emissions by Subsector under BAU and Scenario 1

In million tons CO_2

Transport mode	2014		2020		2025		2030	
	BAU	Scenario 1	BAU	Scenario 1	BAU	Scenario 1	BAU	Scenario 1
Road	26.4	26.4	37.9	35.3	52.1	49.0	71.7	65.2
Railway	0.1	0.1	0.2	0.2	0.2	0.2	0.3	0.3
IWT and coastal transport	3.5	3.5	4.6	4.7	6.1	5.5	8.2	7.1
Air	1.1	1.1	2.8	2.8	3.5	3.5	4.3	4.3
Other	2.1	2.1	2.3	2.0	3.2	3.0	4.6	4.2
Total	**33.2**	**33.2**	**47.7**	**45.1**	**65.1**	**61.2**	**89.1**	**81.1**

Figure 3.3. CO_2 Emissions by Subsectors under Scenario 1



Scenario 1 includes eight mitigation measures to reduce CO_2 emissions in the transport sector. As shown in table 3.4, investments or policies towards modal shifts from road to inland waterway and coastal transport would result in the largest emissions reduction during the 2014 to 2030 period. Strengthening of fuel economy and vehicle emissions standards would result in much greater emissions reduction over a longer period, as stronger standards would affect the large and growing fleet of future vehicles.

Table 3.4. Reduction of CO_2 Emissions by Each Mitigation Option under Scenario 1

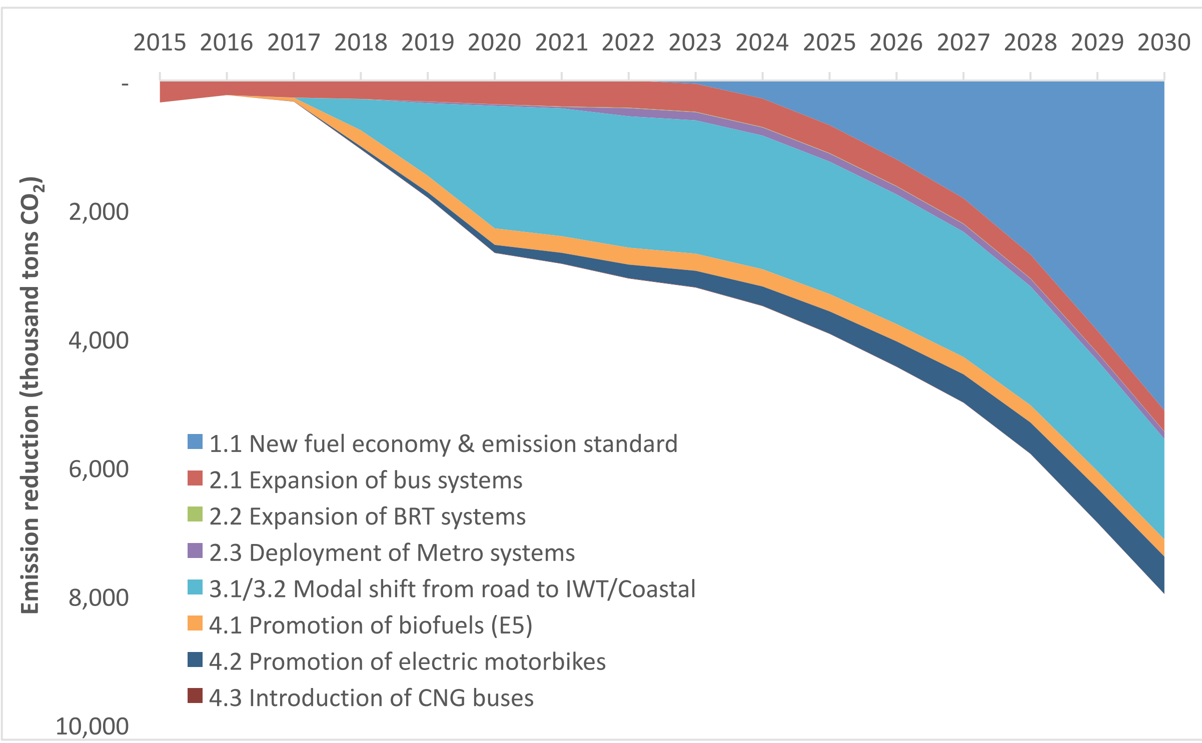
In thousand tons CO_2

Mitigation measures	2014	2020	2025	2030	2040	2050	Cumulative reduction	
							2014–30	2014–50
1.1 New fuel economy and emissions standard	0	0	695	5,130	17,749	24,904	15,810	360,462
2.1 Expansion of bus systems	53	370	436	326	594	1,619	5,815	20,836
2.2 Expansion of BRT systems	0	2	7	3	1	2	65	119
2.3 Deployment of metro systems	0	23	125	115	100	94	1,167	3,190
3.1/3.2 Modal shift from road to IWT/coastal transport	0	1,905	2,059	1,560	3,134	6,396	22,844	93,544
4.1 Promotion of biofuels (E5)	0	256	269	267	243	209	3,487	8,278
4.2 Promotion of electric motorbikes	0	122	345	580	1,046	1,517	3,945	25,343
4.3 Introduction of CNG buses	0	5	5	3	6	3	64	146

Note: BRT = bus rapid transit; IWT = inland waterway transport; CNG = compressed natural gas.

Figure 3.4 depicts these measures and their contributions to the overall emissions reduction against the business-as-usual (BAU) scenario.

Figure 3.4. Reduction of CO_2 Emissions by Each Mitigation Option under Scenario 1



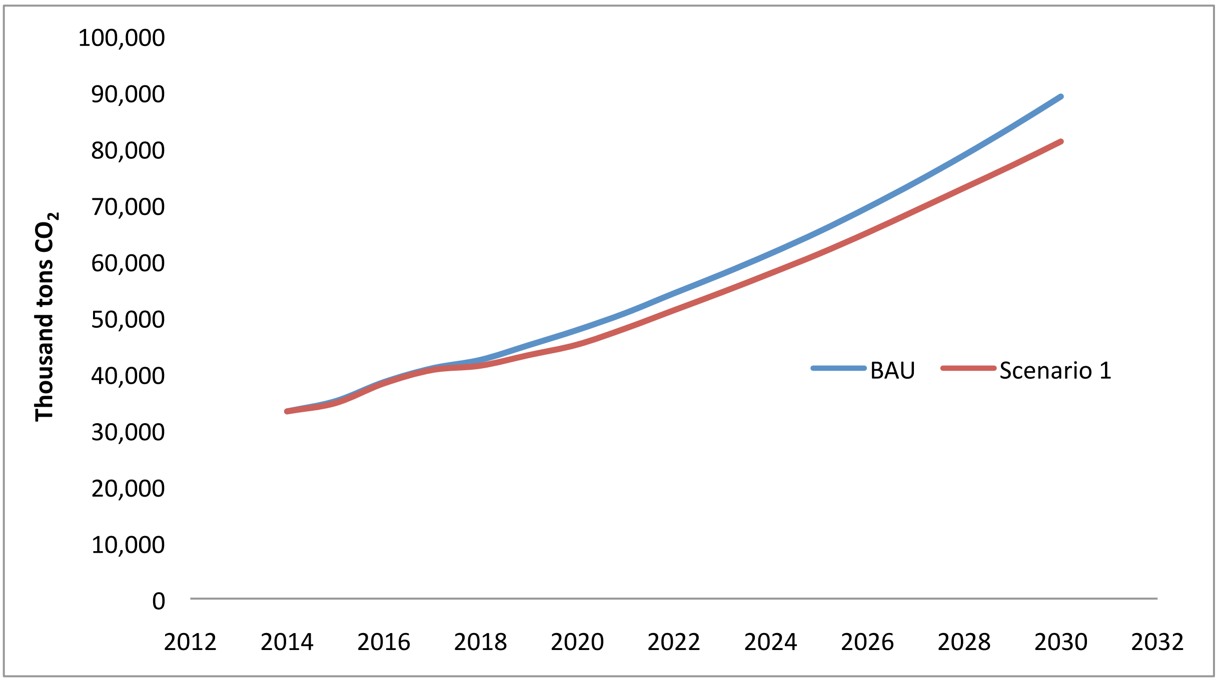
Aggregating the impacts of all measures, CO_2 emissions started to decline from 2015 to 2017 as a result of efforts to improve public transport and increase the use of biofuel. Looking ahead, CO_2 emissions are projected to reduce by 5.4 percent (2020), 6.1 percent (2025), and 9.0 percent (2030) in the comparison of BAU (see table 3.5 and figure 3.5).

Table 3.5. Comparison of CO_2 Emissions between BAU and Scenario 1

In million tons CO_2

Scenario	2014	2020	2025	2030
CO_2 emissions under BAU	33.2	47.7	65.1	89.1
CO_2 emissions under Scenario 1	33.2	45.1	61.2	81.1
CO_2 emissions reduction (1) – (2)	0.0	2.6	3.9	8.0
CO_2 emissions reduction percent	0.0%	5.4%	6.1%	9.0%

Figure 3.5. Comparison of CO_2 Emissions between BAU and Scenario 1



Marginal Abatement Cost under Scenario 1

To understand the costs of implementing the above mitigation measures, the study conducted a marginal abatement cost (MAC) analysis. The MAC analysis calculates for each measure the GHG mitigation potential (tCO_2e), economic costs of implementation—including for capital investments and operating expenses—and economic benefits from reduced transport costs, along with other benefits. Then, the net costs—economic costs less economic benefits—are calculated per GHG emissions mitigation ($/$tCO_2e$). Such information on cost-effectiveness is useful to inform dialogue among stakeholders and should be complemented with information on feasibility and analysis of other cost and benefits not included in the analysis.

Mitigation measures are then placed from lowest to highest cost-effectiveness to form a MAC curve plot. The y-axis shows the marginal abatement cost of GHG emissions ($/$tCO_2e$), where the height of each measure represents its net present cost per ton of CO_2e reduction over the analysis period. The x-axis shows the abatement potential of GHG emissions (tCO_2e), where the width of each measure represents the GHG abatement potential during the analysis period. The details of the methodology and data used for the analysis are provided in appendices D and E.

The study developed MAC curves (MACC) for two analysis periods: 2014 to 2030 and 2014 to 2050. As depicted in table 3.6 and figure 3.6, several measures would incur negative MACs, generating benefits greater than the required investments. In the longer term, covering the period from 2014 to 2050, most measures would generate net benefits except for measures with heavy upfront capital investments, such as metro and BRT systems. In the medium term (until 2030), mitigation measures 3.1 (modal shift from road to IWT and coastal transport), 4.2 (promotion of electric motorbikes), and 1.1 (new and stricter vehicle fuel economy and emissions standards) would bring in the largest emissions reduction. In the longer term (until 2050), measure 1.1 (vehicle fuel economy and emissions standards) would account for the predominant share of emissions reduction, as this measure would affect the entire, and continuously growing, future vehicle fleet.

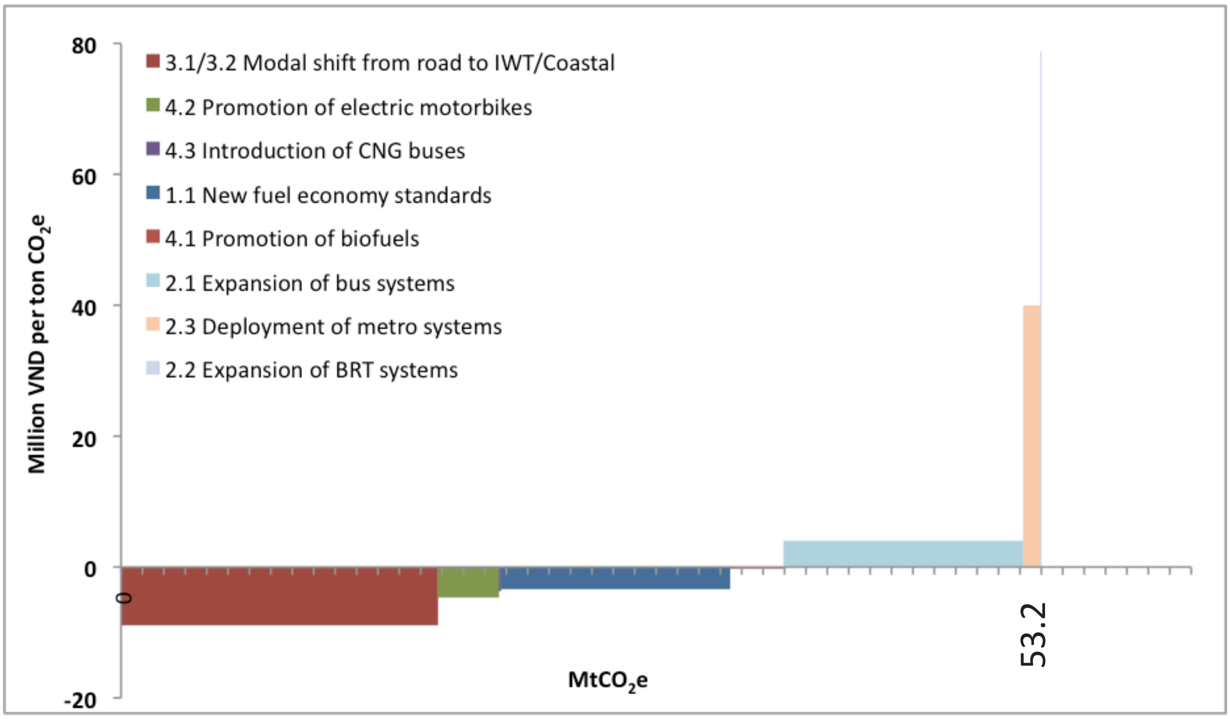
Table 3.6. MACC Results under Scenario 1, for Analysis Period 2014–2030 and 2014–2050

Measure	2014–2030		2014–2050	
	Mitigation potential	Mitigation cost	Mitigation potential	Mitigation cost
3.1/3.2 Modal shift from road to IWT/coastal	22.8	(8.9)	93.5	(3.1)
4.3 Introduction of CNG buses	0.1	(3.7)	0.2	(2.3)
4.2 Promotion of electric motorbikes	3.9	(4.7)	25.3	(1.7)
1.1 New fuel economy standards	15.8	(3.4)	360.5	(1.2)
4.1 Promotion of biofuels	3.5	(0.3)	8.3	(0.2)
2.1 Expansion of bus systems	5.8	4.0	20.8	(0.1)
2.3 Deployment of metro systems	1.2	40.0	3.2	18.6
2.2 Expansion of BRT systems	0.1	78.8	0.2	61.7

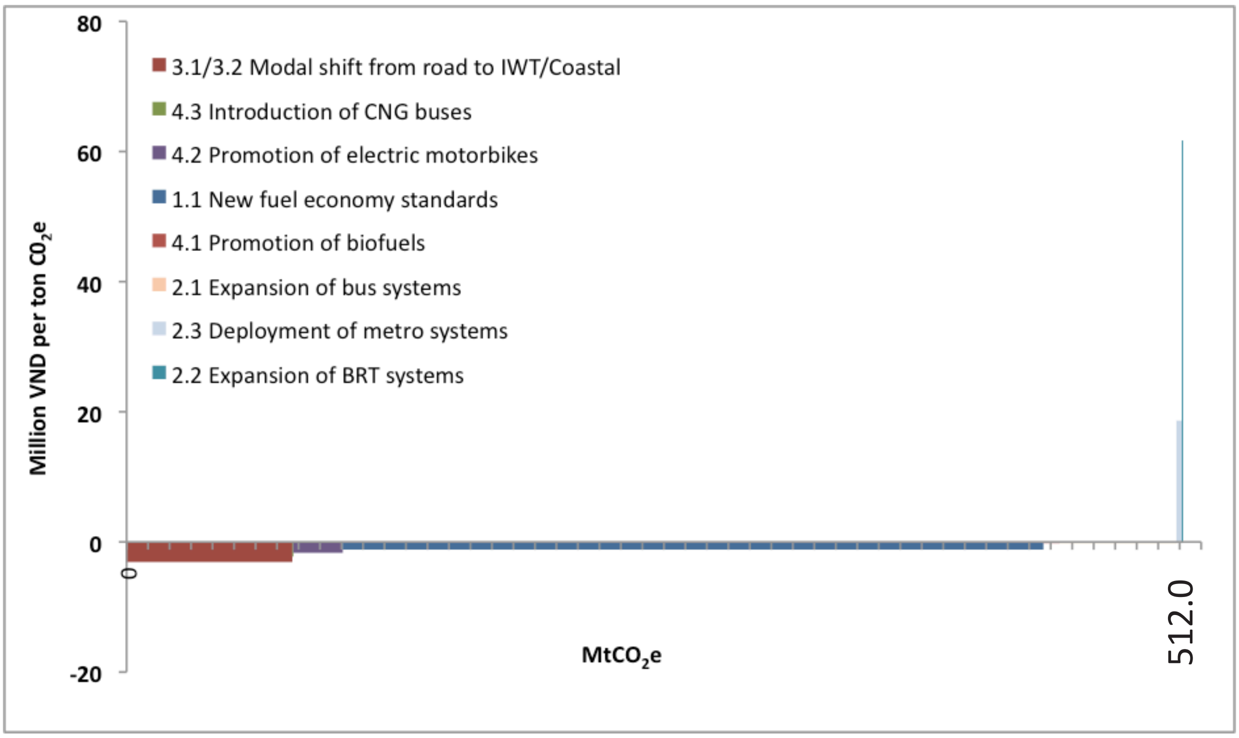
Note: Mitigation expressed in $MtCo_2e$. Mitigation costs expressed in million VND per ton CO_2e.

Figure 3.6. MACC Results under Scenario 1 for Analysis Period 2014–2030 and 2014–2050

During 2014–2030 period



During 2014–2050 period



Conclusions

Up to 2030, the implementation of vehicle fuel economy standards for new cars and motorcycles are considered the most effective GHG emissions mitigation action, cumulatively accounting for 15.8 million tons CO_2 emissions reduction against business as usual during 2014 to 2030. Other actions analyzed, such as freight modal shift from road to waterway, passenger modal shift from private to public transport, and an increased share of electric vehicles, also contribute greatly to the reduction of GHG emissions in the transport sector. With the above measures, the transport sector overall can reduce CO_2 emissions by 9.0 percent compared to BAU in 2030.

The objectives set out in Vietnam's transport development plans, such as in the inland waterway infrastructure development plan and the public transport development plan, need a large investment to generate significant GHG emissions reduction. However, creating the market conditions to promote the change of habits involved in modal shift implies the need for many measures—not only to make the cleaner mode more attractive, but also to disincentivize the use of on-road transport.

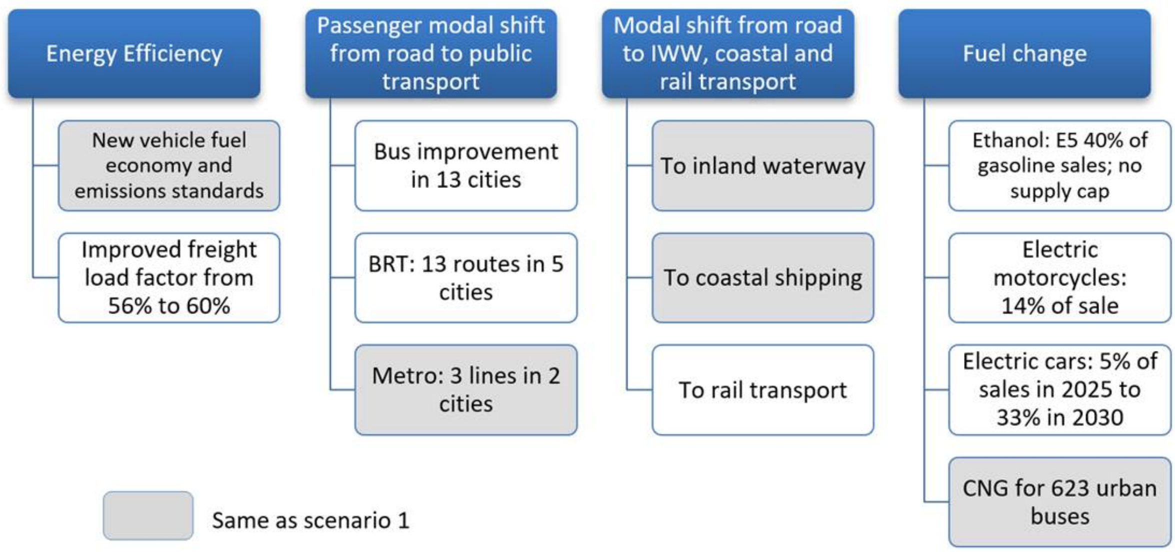
Measures that promote the uptake of electric motorcycles beyond the 7 percent of sales contemplated in this report could result in an attractive additional emissions reduction. Electrification of mobility solutions represents an area with an expectation of notable technology innovation and market maturation, which are further explored in Scenarios 2 and 3 in subsequent chapters.

Chapter 4: Scenario 2—Increasing Ambition with International Support and Active Engagement of the Private Sector

Emissions Mitigation Measures under Scenario 2

Mitigation Scenario 2 includes policies and measures that can be strengthened with international assistance under the Shift and Improve components of the ASI framework, components under the Ministry of Transport (MoT) mandate (figure 4.1).

Figure 4.1. The Mitigation Actions Analyzed under Scenario 2



Note: BRT = bus rapid transit; CNG = compressed natural gas.

This extra effort includes greater modal shift from private road transport (cars and motorcycles) to buses, bus rapid transit (BRT) and metro, promoting more efficient passenger mass transit with higher load factors and increasing the sale of new electric cars and motorcycles. Table 4.1 describes the mitigation measures and the level of ambition considered under Scenario 2.

Table 4.1. Level of Ambition for Mitigation Measures Analyzed under Scenario 2

Measures	Mitigation options	Assumptions
1. Energy efficiency	1.1 New vehicle fuel economy and emissions standards	Same as Scenario 1
	1.2 Improvement of truck load factor	Freight load factor improves from 56% to 60%
2. Passenger modal shift from private vehicles	2.1 Expansion of bus systems	Bus development in 13 cities including 5 cities of central management and 9 cities of class 1 (Hanoi, Ho Chi Minh City, Can Tho, Da Nang, Hai Phong, Viet Tri, Nam Dinh, Vinh, Hue, Quy Nhon, Da Lat, Nha Trang, and Buon Me Thuot)
	2.2 Expansion of BRT systems	*Hanoi:* Line 1 in operation in 2017; 1 new line in operation in 2025; 2 new lines in operation in 2030 *Da Nang:* Line 1 in operation in 2021; 1 new line in operation in 2030 *HCMC:* Line 1 in operation in 2021; 2 new lines in operation in 2025 *Can Tho:* Line 1 in operation in 2025; 2 line in operation in 2030 *Hai Phong:* Line 1 in operation in 2025; Line 2 in operation in 2030 *New BRT lines using electric buses in Hanoi and HCM city from 2025*
	2.3 Deployment of metro systems	Same as Scenario 1
3. Modal shift from road	3.1 Modal shift from road to IWT	*Modal shift both for freight and passenger transport* *By 2020*: • FTKT by IWT to increase from 65.0 (BAU) to 71.2 billion ton-km (20.7% to 22.6% of total FTKT); share of road to decrease from 23.0% to 19.1%. *By 2030*: • FTKT by IWT to increase from 127.8 to 128.8 billion ton-km (20.6% to 20.8% of total); modal share of road to decrease from 23.4% to 23.0% in 2030.
	3.2 Modal shift from road to coastal shipping	*Modal shift for freight transport* The FTKT from road to the coastal transport is assumed to be double the FTKT shifted from road to IWT in the same time
	3.3 Modal shift from road to rail	In accordance to the Decision 318/QĐ-TTg on transport service development, the growth rate of freight transport is expected to be 12.5%. The calculation assumes that the FTKT on the railway will increase at this same annual rate.
4. Fuel change	4.1 Promotion of biofuels (E5/E10)	*In 2018*: E5 40% of total gasoline sales (first half of 2018) ***2019–30:*** E5 accounts for 40% of total gasoline sales; assume no supply constraint
	4.2 Promotion of electric motorbikes	Electric motorbikes account for 14% of annual motorbike sales
	4.3 Introduction of CNG buses	HCMC: 423 CNG buses in 2017 Hanoi: 50 CNG buses in 2018 and 200 units by 2020
	4.4 Promotion of electric cars and buses	5% of annual new car sales in 2025; 30% of annual new car sales in 2030; all BRT lines after 2020 use electric buses

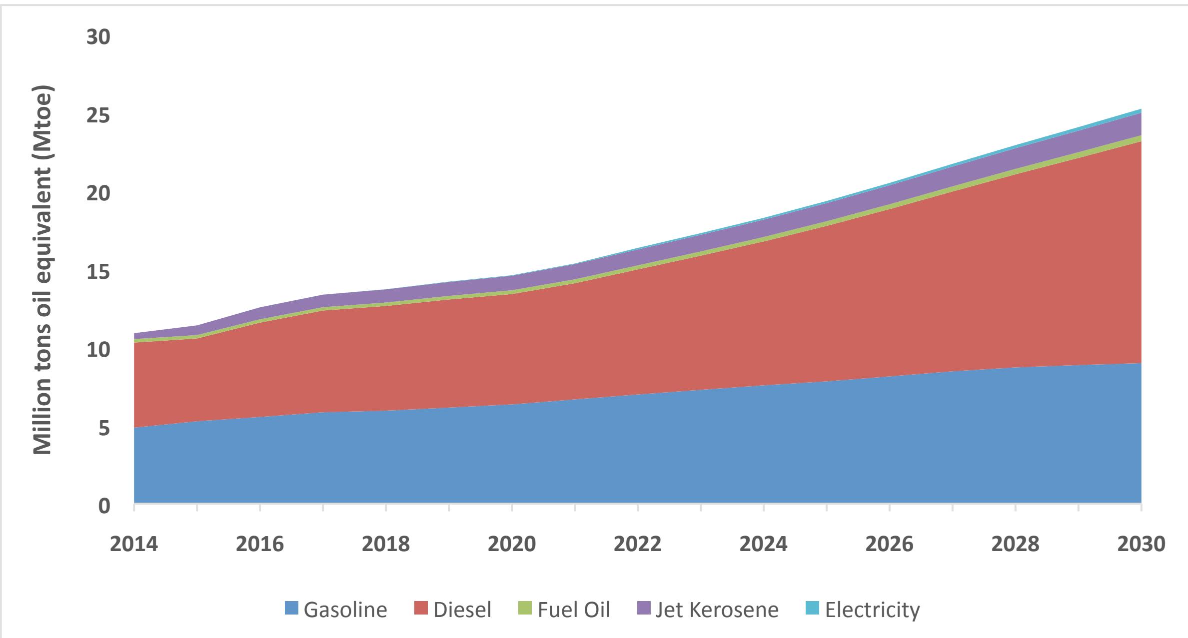
Note: BRT = bus rapid transit; IWT = inland waterway transport; FTKT = freight ton-km transported; BAU = business as usual; CNG = compressed natural gas; HCMC = Ho Chi Minh City.

These measures would result in a reduction of projected fuel consumption under Scenario 2, as summarized in table 4.2 and figure 4.2. With Scenario 2, gasoline consumption would be lower than business as usual (BAU) by 16 percent in 2025 and by 27 percent in 2030. Diesel consumption during this period decreases by an average of 7 percent compared to BAU. Such a reduction in fuel consumption is possible based on a marked modal shift from passenger road transport to buses, BRT and metro systems, and significant adoption of electric motorbikes and private cars.

Table 4.2. Project Energy Consumption by Source in Transport Sector under Scenario 2

Fuel type	2014	2020	2025	2030	2014	2020	2025	2030
	(In million tons oil equivalent)				*(Fuels in million tons, electricity in GWh)*			
Gasoline	4.86	6.36	7.86	8.98	4.60 Mton	6.01	7.43	8.49
Diesel	5.44	7.08	10.03	14.17	5.29 Mton	6.89	9.76	13.80
Fuel oil	0.23	0.24	0.30	0.39	0.23 Mton	0.25	0.31	0.40
Jet kerosene	0.37	0.93	1.16	1.44	0.36 Mton	0.88	1.10	1.36
Electricity	0.00	0.02	0.06	0.15	19.4 GWh	278.0	691.0	1,777.9

Figure 4.2. Projected Energy Consumption by Source in Transport Sector under Scenario 2



GHG Emissions Results under Scenario 2

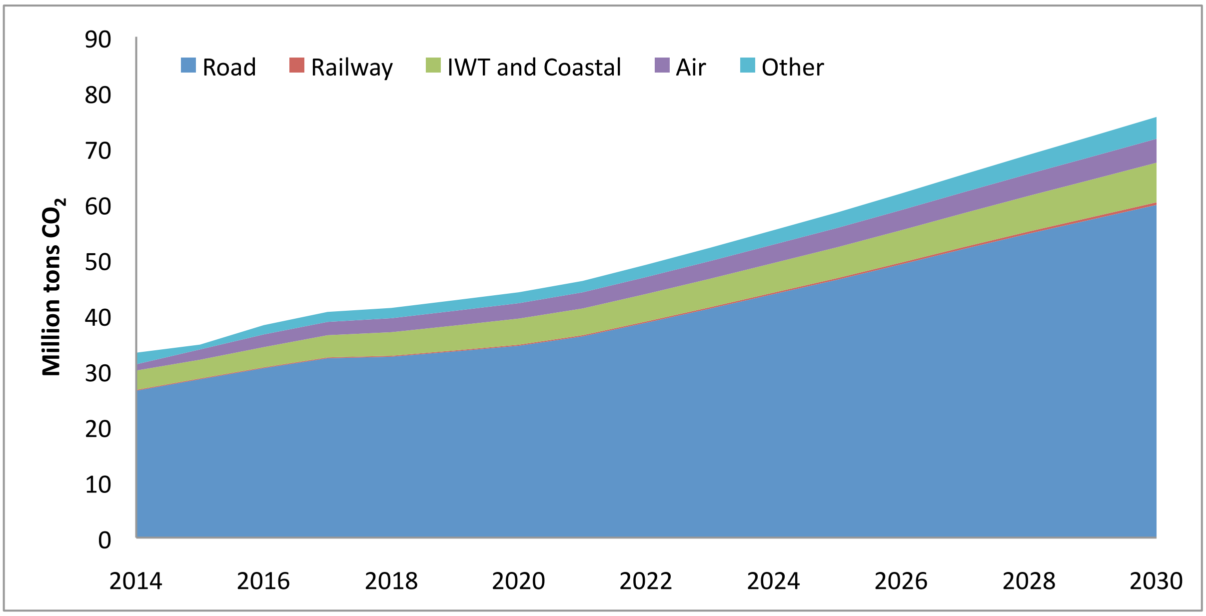
Table 4.3 and figure 4.3 present the total CO_2 emissions from the transport sector and breakdown by subsector under Scenario 2. Compared to BAU and Scenario 1, steeper emissions reduction would occur in the road sector and waterborne transport. The road sector's share of road sector of the total emissions would marginally decrease.

Table 4.3. Transport CO_2 Emissions by Subsector under Scenario 2

In million tons CO_2

Transport mode	2014		2020		2025		2030	
	BAU	Scenario 2	BAU	Scenario 2	BAU	Scenario 2	BAU	Scenario 2
Road	26.4	26.4	37.9	34.5	52.1	46.4	71.7	60.0
Railway	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.5
IWT and coastal transport	3.5	3.5	4.6	4.7	6.1	5.6	8.2	7.1
Air	1.1	1.1	2.8	2.8	3.5	3.5	4.3	4.3
Other	2.1	2.1	2.3	2.0	3.2	2.8	4.6	3.9
Total	**33.2**	**33.2**	**47.7**	**44.1**	**65.1**	**58.5**	**89.1**	**75.6**

Figure 4.3. Total CO_2 Emissions by Transport Subsectors under Scenario 2



Scenario 2 applies 11 mitigation options to reduce CO_2 emissions in the transport sector. For each option, the specific emissions reduction is summarized in table 4.4.

Much like in Scenario 1, Scenario 2 measures to promote modal shifts from road to waterborne transport would bring in the largest emissions reduction during the 2014 to 2030 period; strengthening of fuel economy and vehicle emissions standards would result in much greater emissions reduction over the 2014 to 2050 period. Figure 4.4 shows these measures and their contributions to the overall emissions reduction against the BAU scenario.

Contingent to international support, under Scenario 2, emissions from the transport sector are expected to reduce by 7.5 percent (2020), 10.3 percent (2025), and 15.2 percent (2030), against business as usual (table 4.5 and figure 4.5).

Table 4.4. Reduction of CO_2 Emissions by Each Mitigation Option Analyzed in Scenario 2

In thousand tons CO_2

Mitigation measures	2014	2020	2025	2030	2040	2050	Cumulative reduction	
							2014–30	2014–50
1.1 New fuel economy and emissions standards	0	0	686	4,986	17,250	24,065	15,388	349,787
1.2 Improvement of truck load factor	0	0	840	1,318	2,497	4,854	8,941	64,560
2.1 Expansion of bus systems	360	389	455	347	608	1,745	6,116	21,711
2.2 Expansion of BRT systems	0	3	35	53	15	52	264	857
2.3 Deployment of metro systems	0	23	124	115	99	78	1,167	3,119
3.1/3.2 Modal shift from road to IWT/coastal transport	1	2,661	2,759	1,712	3,404	6,927	30,084	106,853
3.3 Modal shift from road to rail	0	0	401	1,029	1,971	3,845	5,015	48,928
4.1 Promotion of biofuels (E5)	0	280	370	490	738	872	4,708	19,241
4.2 Promotion of electric motorbikes	0	334	946	1,586	2,851	4,129	10,803	69,120
4.3 Introduction of CNG buses	0	5	5	3	6	3	63	145
4.4 Promotion of electric cars	0	0	64	1,886	8,329	12,576	4,855	168,386

Note: BRT = bus rapid transit; IWT= inland waterway transport; CNG = compressed natural gas.

Contingent to international support, under Scenario 2, emissions from the transport sector are expected to reduce by 7.2 percent (2020), 11.5 percent (2025), and 15.9 percent (2030), against business as usual (table 4.5 and figure 4.5).

Figure 4.4. Reduction of CO_2 Emissions by Each Mitigation Option under Scenario 2

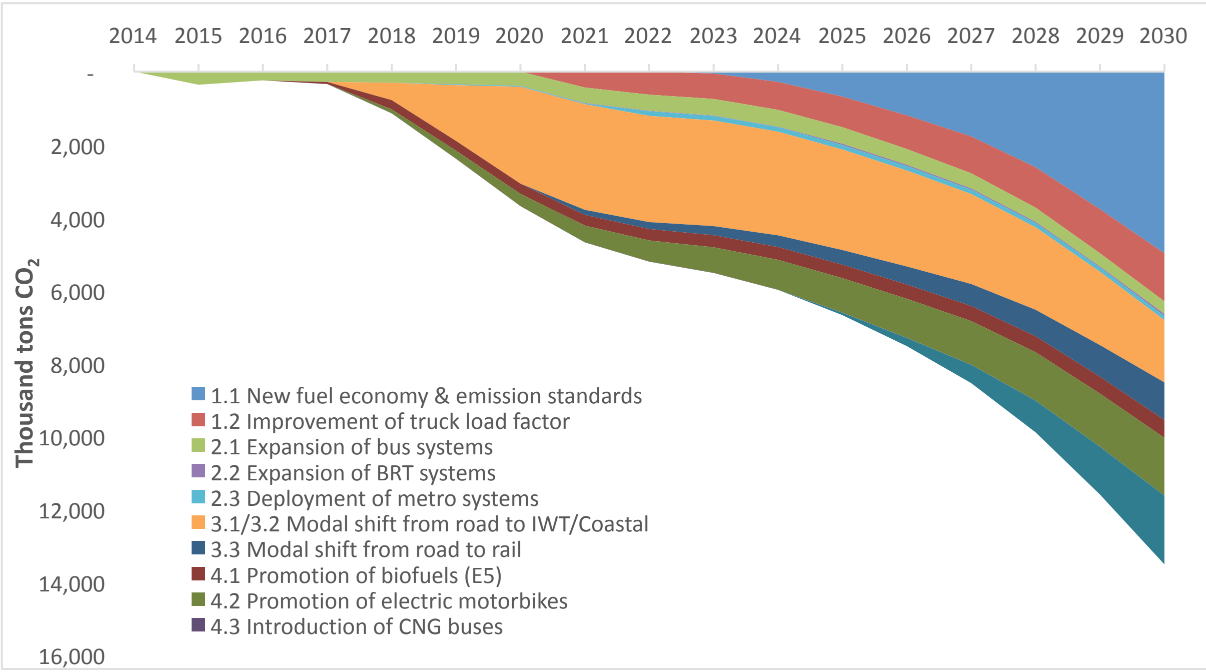
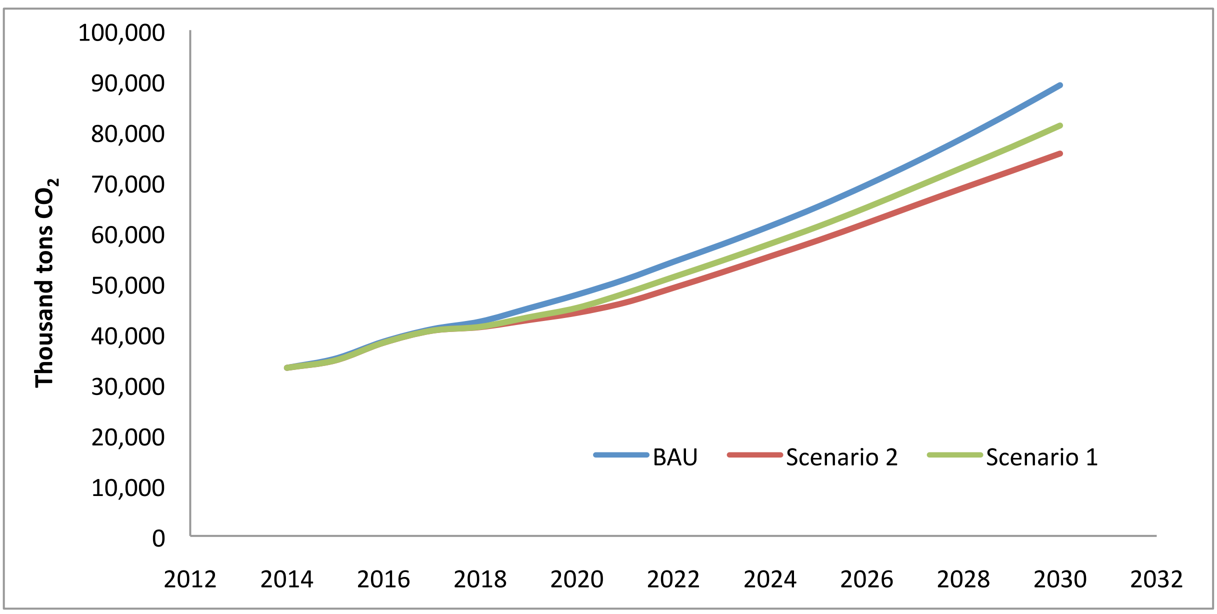


Table 4.5. Comparison of CO_2 Emissions from Transport between BAU and Scenario 2

In million tons CO_2

Scenario	2014	2020	2025	2030
CO_2 emissions under BAU	33.2	47.7	65.1	89.1
CO_2 emissions under Scenario 2	33.2	44.1	58.5	75.6
CO_2 emissions reduction (1) – (2)	0.0	3.6	6.7	13.5
CO_2 emissions reduction percent	0.0%	7.5%	10.3%	15.2%

Figure 4.5. Comparison of CO_2 Emissions between BAU and Scenarios 1 and 2



Marginal Abatement Cost under Scenario 2

The study developed two marginal abatement cost curves (MACCs) for Scenario 2 (shown in figure 4.6), covering the analysis periods from 2014 to 2030 and 2014 to 2050. As listed in table 4.6, from 2014 to 2030 the measures with negative marginal abatement cost (MAC) include 3.1/3.2 (modal shift from road to IWW (inland waterway) and coastal transport), 1.2 (improvements in truck load factor), 4.2 (promotion of electric motorbikes), and 1.1 (new fuel economy standards).

From 2014 to 2050, as also seen in Scenario 1, most measures would generate net benefits except the measures with heavy upfront capital investments such as metro and BRT systems. Particularly, MACs for measures 3.3 (modal shift to railway) and 2.1 (expansion of bus systems) would become negative in the longer term, as they generate net economic benefits in the period beyond 2030.

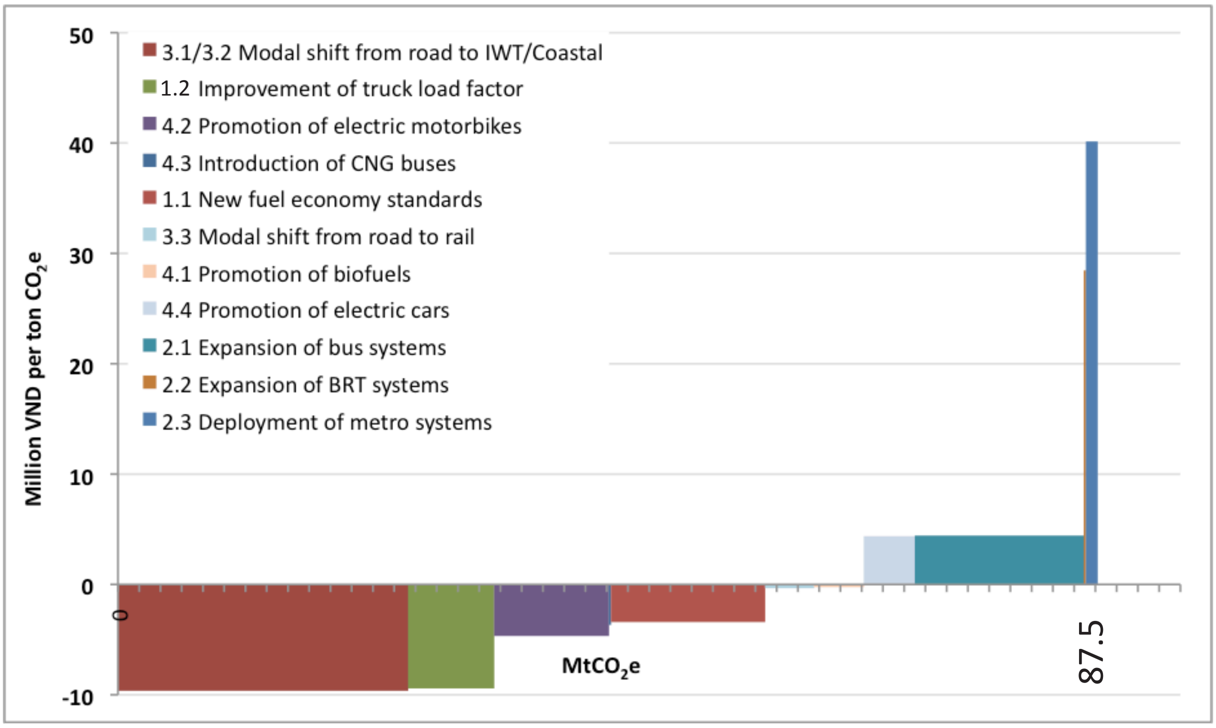
Table 4.6. MACC Results under Scenario 2, for Analysis Period 2014–2030 and 2014–2050

Measure	2014–2030		2014–2050	
	Mitigation potential	Mitigation cost	Mitigation potential	Mitigation cost
3.1/3.2 Modal shift from road to IWT/coastal	30.1	(9.6)	106.9	(3.6)
1.2 Improvement of truck load factor	8.9	(9.4)	64.6	(3.5)
4.3 Introduction of CNG buses	0.1	(3.7)	0.2	(2.3)
4.2 Promotion of electric motorbikes	10.8	(4.7)	69.1	(1.7)
1.1 New fuel economy standards	15.4	(3.4)	349.8	(1.2)
4.4 Promotion of electric cars	4.9	4.4	168.4	(0.6)
3.3 Modal shift from road to rail	5.0	(0.3)	48.9	(0.6)
4.1 Promotion of biofuels	4.7	(0.2)	19.2	(0.1)
2.1 Expansion of bus systems	6.1	4.4	21.7	0.1
2.2 Expansion of BRT systems	0.3	28.5	0.9	14.0
2.3 Deployment of metro systems	1.2	40.1	3.1	18.8

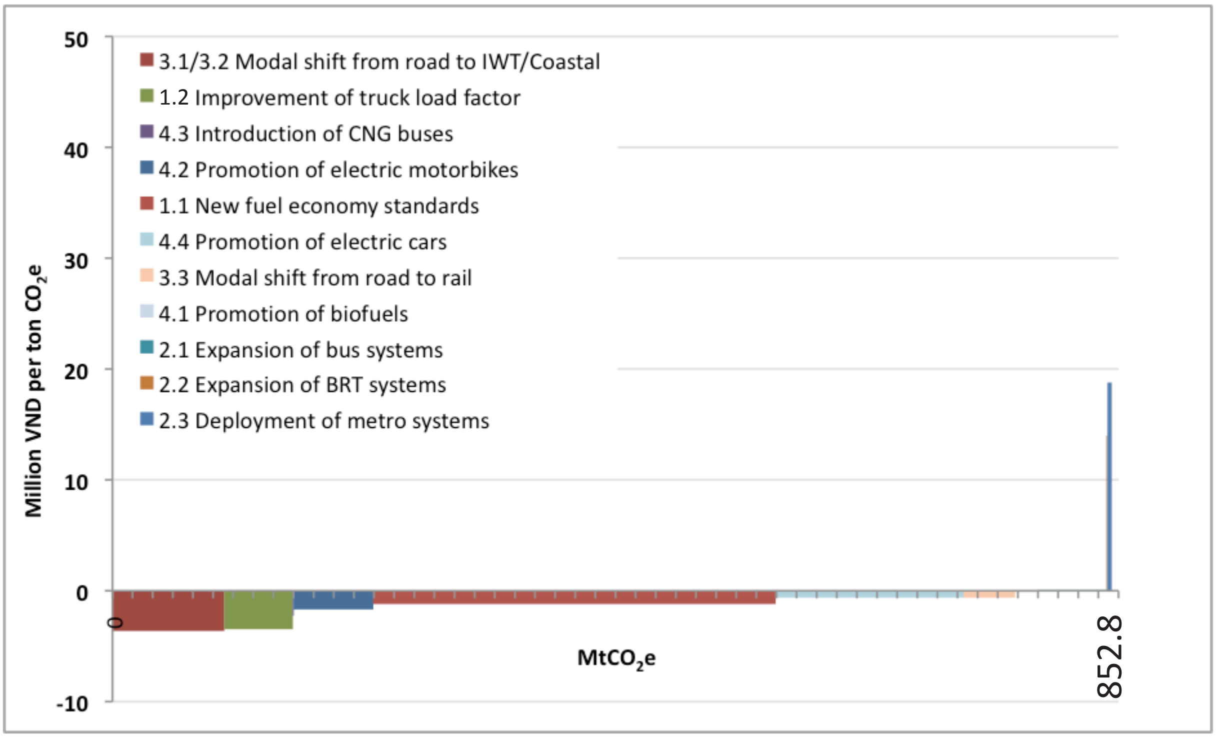
Note: Mitigation expressed in $MtCo_2e$; mitigation costs expressed in million VND per ton CO2e.

Figure 4.6. MACC Results under Scenario 2, for Analysis Period 2014–2030 and 2014–2050

During 2014–2030 period



During 2014–2050 period



Conclusions

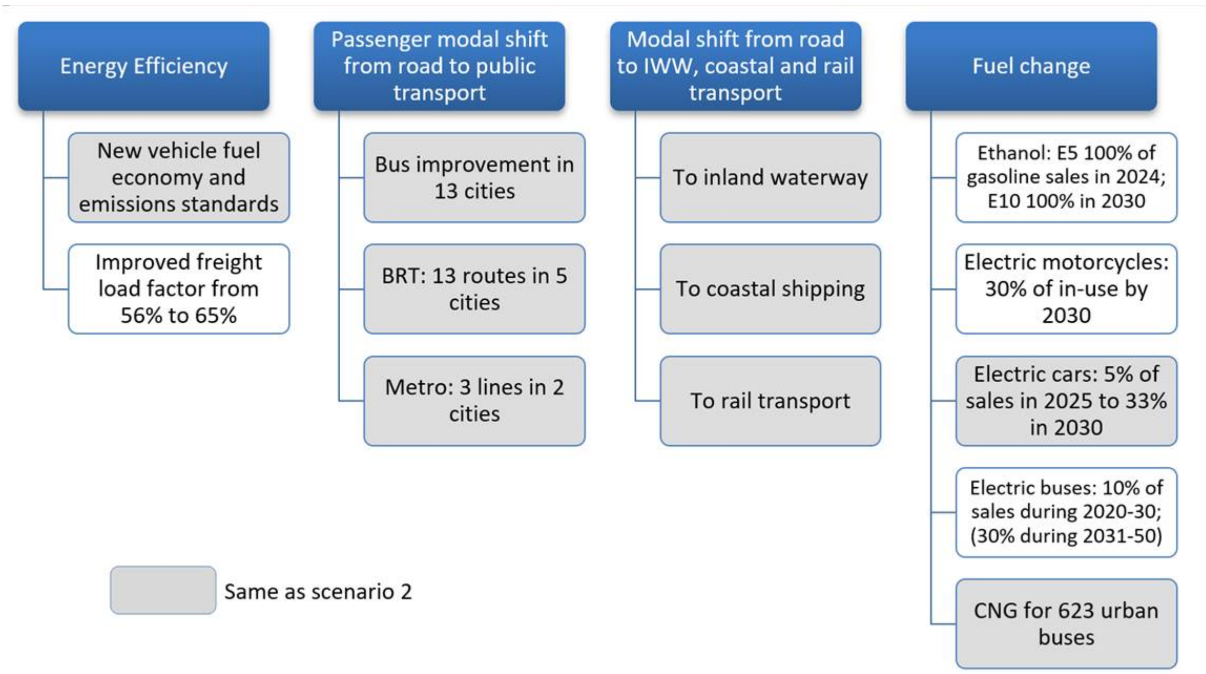
With international support and active participation of the private sector, under Scenario 2 the transport sector is expected to reduce 15 percent of its CO_2 emissions in 2030, against BAU. Improvements in vehicle fuel economy are assessed to be the most impactful mitigation measures, resulting in an emissions reduction of 5.0 million tons CO_2 in 2030 compared to BAU. Mainstreaming the electric vehicle market would be the second highest contributor to emissions reductions, with potential to reduce 3.5 million tons CO_2 in 2030 against BAU. Modal shifts from road to waterways and railways also have a significant potential for emissions reduction. However, this is dependent on infrastructure investments and their timelines. Improvements in freight load factors due to an improvement in logistics service capability and reduction in empty backhaul is also a remarkable option to reduce CO_2 emissions from the transport sector.

Chapter 5: Scenario 3—Pushing Transformation of the Sector with Larger Support from International Resources and Strong Private Sector Engagement

Emissions Mitigation Measures under Scenario 3

Mitigation Scenario 3 sets out a vision in which additional policies and measures currently not part of the mandate of the Ministry of Transport (MoT), to push the level of ambition and attain a greater level of mitigation impacts. These measures, presented in figure 5.1 and table 5.1, would potentially require a greater level of investments.

Figure 5.1. The Mitigation Actions Analyzed under Scenario 3



Note: BRT = bus rapid transit; CNG = compressed natural gas.

Scenario 3 includes all the mitigation options from Scenario 2, but with an additional high level of ambition in table 5.1.

Table 5.1. Level of Ambition for Mitigation Measures Analyzed under Scenario 3

Measures	Mitigation options	Assumptions
1. Energy efficiency	1.1 New vehicle fuel economy and emissions standards	Same as Scenarios 1 and 2
	1.2 Improvement of truck loading factors	Freight load factor improves from 56% to 65%.
2. Passenger modal shift from private vehicles	2.1 Bus systems	Same as Scenario 2
	2.2 BRT systems	Same as Scenario 2
	2.3 Metro systems	Same as Scenarios 1 and 2
3. Modal shift from road	3.1 Modal shift from road to IWT	Same as Scenario 2
	3.2 Modal shift from road to coastal shipping	Same as Scenario 2
	3.3 Modal shift from road to railway	Same as Scenario 2
4. Fuel change	4.1 Promotion of biofuels (E5/E10)	*2018–24*: E5 increases gradually from 40% of total gasoline sales in 2018 up to 100% in 2024 *2025–30*: E5 is gradually replaced with E10, at 50% in 2025 and 100% by 2030
	4.2 Promotion of electric motorbikes	Electric motorbikes account for 30% of total two-wheeler fleet
	4.3 Introduction of CNG buses	Same as Scenario 2
	4.4 Promotion of electric cars and buses	• 5% of annual new car sales in 2025 • 30% of annual new car sales in 2030 • All BRT lines after 2020 use electric buses • 10% of bus sales are electric vehicles in 2020–2030

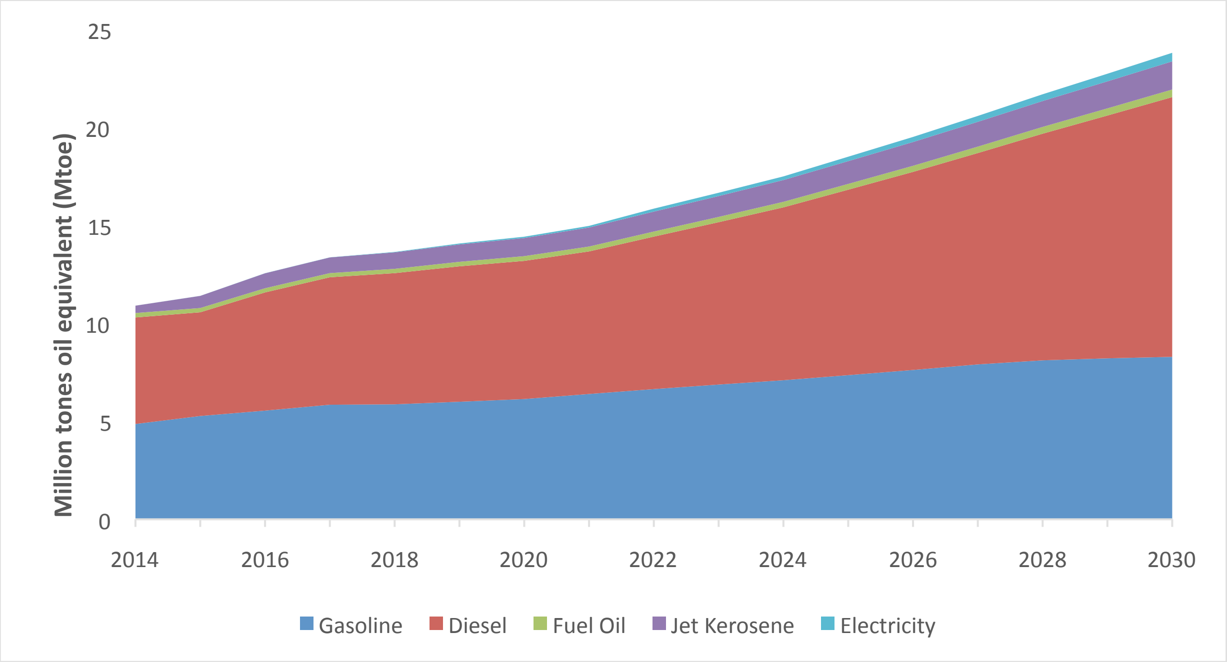
Note: BRT = bus rapid transport; IWT = inland waterway transport; CNG = compressed natural gas.

Table 5.2 and figure 5.2 present transport sector fuel consumption under Scenario 3. With Scenario 3, gasoline consumption reduces by 22 percent in 2025 and by 36 percent in 2030 against business as usual (BAU). Diesel consumption during this period decreases by an average of 6 percent compared to the BAU, similar to Scenario 2. Such a reduction in fuel consumption is attributed to modal shifts from road freight to waterborne transport and from private vehicles to public transport, and rapidly increasing market shares of electric motorbikes and private cars.

Table 5.2. Projected Energy Consumption by Source in Transport Sector under Scenario 3

Energy Source	2014	2020	2025	2030	2014	2020	2025	2030
	(In million tons oil equivalent)				*(Fuels in million tons, electricity in GWh)*			
Gasoline	4.86	6.14	7.35	8.29	4.60 Mton	5.80	6.95	7.83
Diesel	5.44	7.05	9.46	13.25	5.29 Mton	6.86	9.21	12.90
Fuel oil	0.23	0.24	0.30	0.39	0.23 Mton	0.25	0.31	0.40
Jet kerosene	0.37	0.93	1.16	1.44	0.36 Mton	0.88	1.10	1.36
Electricity	0.00	0.07	0.23	0.44	19.4 GWh	767.2	2,634.7	5,081.5

Figure 5.2. Projected Energy Consumption by Source in Transport Sector under Scenario 3



GHG Emissions Results under Scenario 3

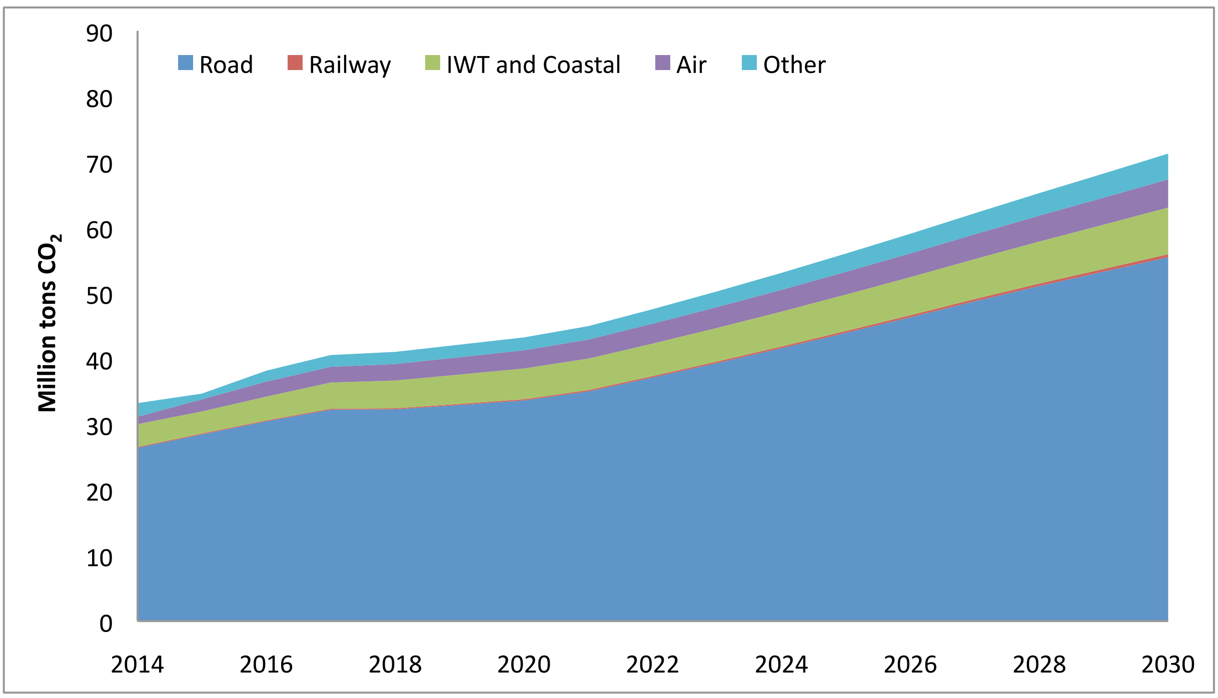
Table 5.3 and figure 5.3 present the total CO_2 emissions from the transport sector and breakdown by subsector under Scenario 3. A significant emissions reduction would occur in the road sector (23 percent) and waterborne transport (13 percent). The road sector share of the total emissions would further decrease.

Table 5.3. Transport CO_2 Emissions by Subsector under Scenario 3

In million tons

Transport mode	2014		2020		2025		2030	
	BAU	Scenario 3	BAU	Scenario 3	BAU	Scenario 3	BAU	Scenario 3
Road	26.4	26.4	37.9	33.6	52.1	44.0	71.7	55.5
Railway	0.1	0.1	0.2	0.2	0.2	0.3	0.3	0.5
IWT and coastal transport	3.5	3.5	4.6	4.7	6.1	5.6	8.2	7.1
Air	1.1	1.1	2.8	2.8	3.5	3.5	4.3	4.3
Other	2.1	2.1	2.3	2.0	3.2	2.8	4.6	3.9
Total	**33.2**	**33.2**	**47.7**	**43.3**	**65.1**	**56.1**	**89.1**	**71.3**

Figure 5.3. Transport CO_2 Emissions by Subsectors under Scenario 3



Each of the 11 measures under Scenario 3 contributes to the overall emissions reduction as summarized in table 5.4. Under this scenario, the measure to promote electric motorbikes would bring in the greatest emissions reduction during the 2014 to 2030 period, at about 4.4 million tons CO_2 in 2030. This is closely followed by the measures to promote modal shifts from road to waterborne transport, to strengthen fuel economy and vehicle emissions standards, and to promote the use of biofuels. Electric mobility, much more prominently featured under this scenario compared to previous ones, is projected to bring in great longer-term reduction totaling 24.2 million tons CO_2 in 2050. These measures and their contributions to the overall emissions reduction against the BAU scenario are depicted in figure 5.4.

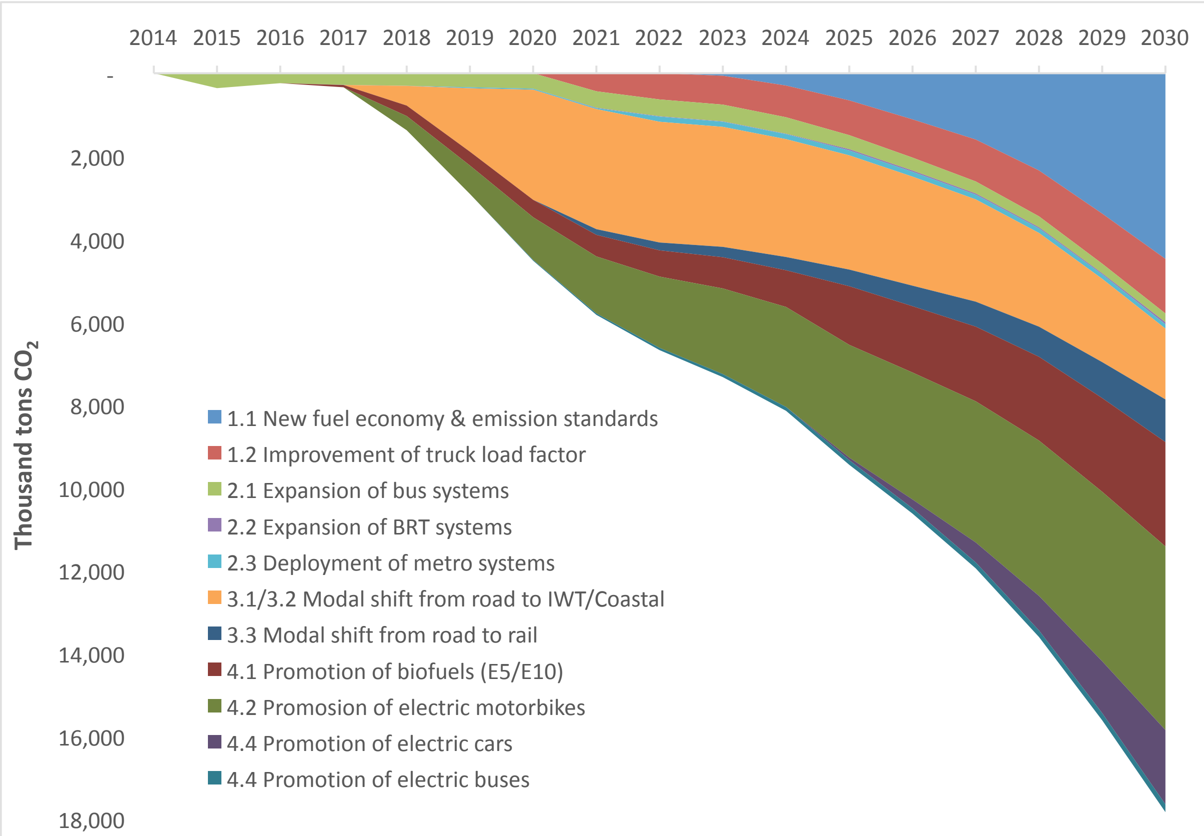
Table 5.4. Reduction of CO_2 Emissions by Each Mitigation Option under Scenario 3

In thousand tons

Mitigation measures	2015	2020	2025	2030	2040	2050	Cumulative reduction	
							2014–30	2014–50
1.1 New fuel economy and emissions standards	0	0	656	4,484	15,402	20,902	13,952	310,186
1.2 Improvement of truck load factor	0	0	840	1,318	2,497	4,854	8,941	64,560
2.1 Expansion of bus systems	360	372	338	211	540	1,713	5,145	19,493
2.2 Expansion of BRT systems	0	2	31	49	17	45	235	804
2.3 Deployment of metro systems	0	24	119	104	84	75	1,119	2,828
3.1/3.2 Modal shift from road to IWT/coastal transport	0	2,660	2,758	1,711	3,403	6,927	30,074	106,838
3.3 Modal shift from road to rail	0	0	402	1,030	1,971	3,845	5,022	48,941
4.1 Promotion of biofuels (E5/E10)	0	421	1,416	2,520	3,797	4,484	15,483	90,248
4.2 Promotion of electric motorbikes	0	1,031	2,723	4,435	8,599	12,810	31,120	207,446
4.4 Promotion of electric cars	0	0	62	1,794	7,897	11,918	4,640	159,691
4.4 Promotion of electric buses	0	19	112	188	847	1,388	1,179	18,233

Note: BRT = bus rapid transit; IWT = inland waterway transport.

Figure 5.4. Reduction of CO_2 Emissions by Each Mitigation Option under Scenario 3



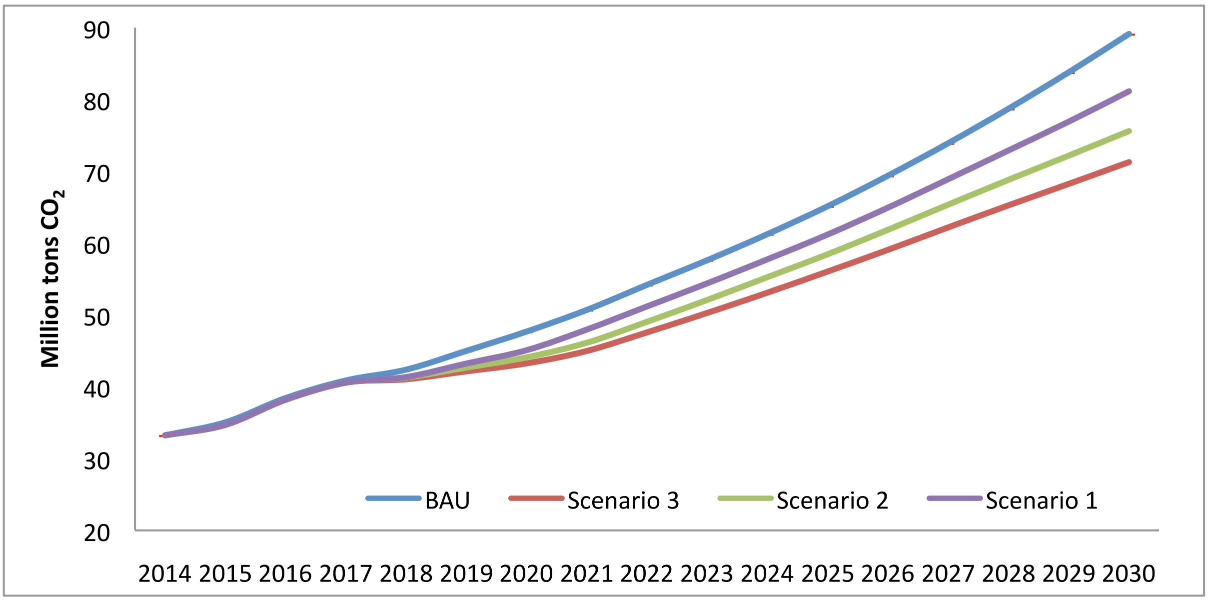
In sum, Scenario 3 enables 20 percent reduction in CO_2 emissions by 2030, compared to BAU, while Scenario 2 results in 15 percent and Scenario 1 results in a 9 percent emissions reduction. These results are presented in table 5.5 and figure 5.5.

Table 5.5. Comparison of Transport CO_2 Emissions in BAU and Scenario 3

In million tons CO_2

Scenario	2015	2020	2025	2030
CO_2 emissions under BAU	33.2	47.7	65.1	89.1
CO_2 emissions under Scenario 3	33.2	43.3	56.1	71.3
CO_2 emissions reduction (1) – (2)	0.0	4.4	9.1	17.8
CO_2 emissions reduction percent	0.0%	9.3%	14.0%	20.0%

Figure 5.5. Comparison of CO_2 Emissions between BAU and Scenarios 1, 2, and 3



Marginal Abatement Cost under Scenario 3

Figures 5.6 and 5.7 present the two marginal abatement cost curves (MACCs) developed for Scenario 3, covering the analysis periods from 2014 to 2030 and 2014 to 2050. During the period from 2014 to 2030, several measures have negative marginal abatement costs (MACs), indicating their cost-effectiveness. These include 3.1/3.2 (modal shift from road to IWW and coastal transport), 1.2 (improvements in truck load factors); 4.2 (promotion of electric motorbikes); and 1.1 (introduction of new fuel economy standards). As in previous scenarios, during the period from 2014 to 2050, most measures generate net benefits, except measures with high upfront capital costs, such as metro and BRT systems. MACs for measures 4.4 (promotion of electric cars and buses) and 2.1 (expansion of bus systems) would become negative in the longer term, as they generate net economic benefits during the period beyond 2030.

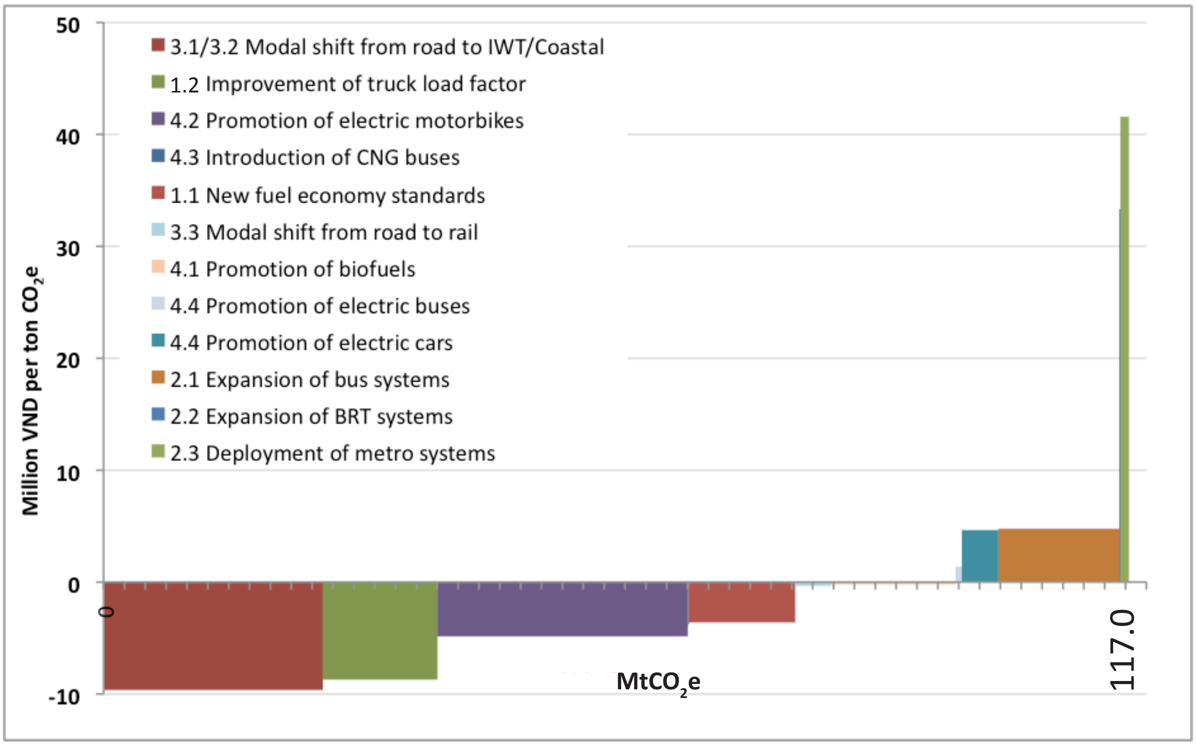
Table 5.6. MACC results under Scenario 3, for Analysis Period 2014-2030 and 2014-2050

Measure	2014–2030		2014–2050	
	Mitigation potential	Mitigation cost	Mitigation potential	Mitigation cost
4.3 Introduction of CNG buses	0.1	(3.8)	1.1	(3.7)
3.1/3.2 Modal shift from road to IWT/coastal	30.1	(9.6)	106.8	(3.6)
1.2 Improvement of truck load factor	8.9	(8.7)	64.6	(3.3)
4.2 Promotion of electric motorbikes	31.1	(4.9)	207.5	(1.7)
1.1 New fuel economy standards	14.0	(3.6)	310.2	(1.3)
4.4 Promotion of electric cars	4.6	4.7	159.7	(0.6)
3.3 Modal shift from road to rail	5.0	(0.3)	48.9	(0.6)
4.4 Promotion of electric buses	1.2	1.4	18.2	(0.1)
4.1 Promotion of biofuels	15.5	(0.2)	90.3	(0.1)
2.1 Expansion of bus systems	5.2	4.8	20.5	0.1
2.2 Expansion of BRT systems	0.2	33.3	1.0	19.2
2.3 Deployment of metro systems	1.1	41.6	2.8	19.7

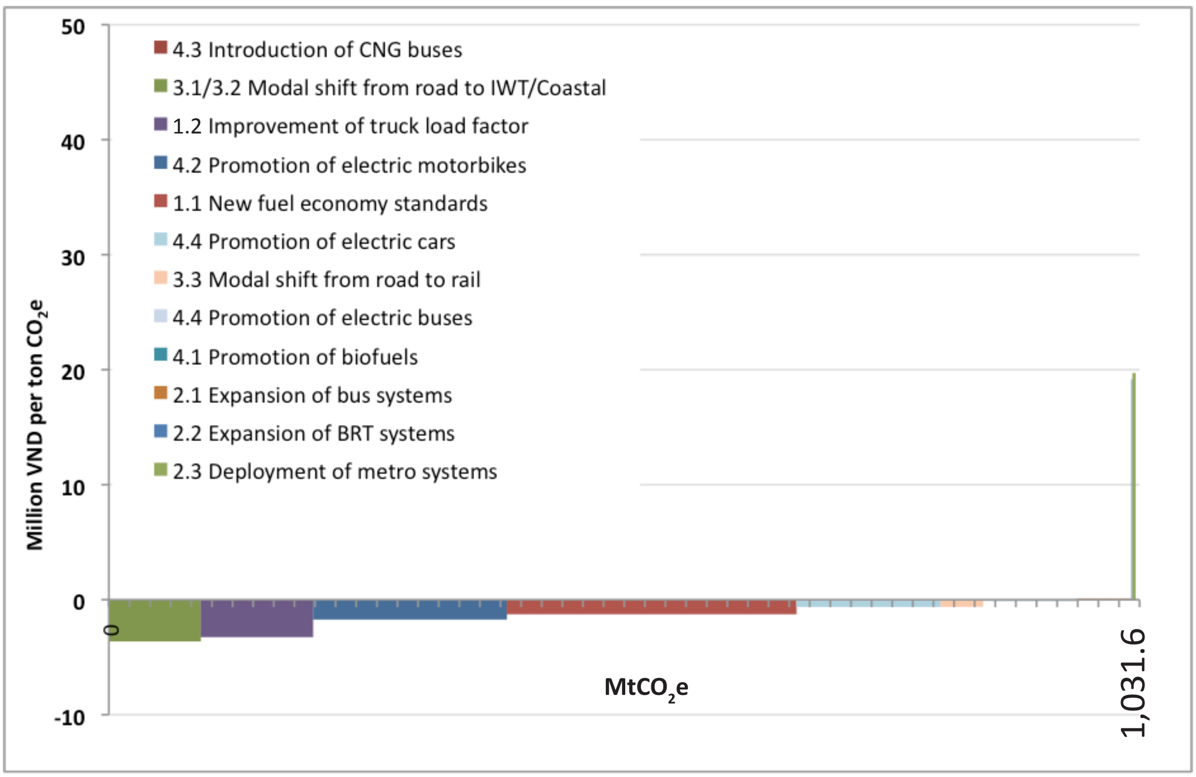
Note: Mitigation expressed in $MtCo_2e$. Mitigation costs expressed in million VND per ton CO_2e.

Figure 5.6. MACC results under Scenario 3, for Analysis Period 2014–2030 and 2014–2050

During 2014–2030 period



During 2014–2050 period



Conclusions

Scenario 3 focuses on market development trends such as increasing the use of electric motorcycles (accounting for 30 percent of the total number of electric motorcycles in use) and electric cars and electric buses (accounting for 10 percent of the nationwide in-use fleet). Also, the freight load factor is expected to improve up to 65 percent due to improved freight consolidation and efficient logistics system. Scenario 3 clearly shows that promotion of an expanded market for electric vehicles would result in significant emissions reductions, with expected implications for the national electric grid. Therefore, these promotional measures—and their expected benefits—would need to be further analyzed and addressed accordingly.

Chapter 6: Cost of Implementation

This chapter presents the marginal abatement cost of each GHG emissions mitigation measure considered under the three scenarios. The marginal abatement cost provides a quantitative basis for discussion about the relative cost-effectiveness of each measure in delivering emissions reductions and the overall abatement potential of the measures considered. This analysis can serve as input to discussions on which measures would be implemented using national resources, along with which measures could be implemented conditional to receiving international support.

Marginal Abatement Cost Methodology

The marginal abatement cost (MAC) is calculated using data on the incremental cost of emissions savings by each measure, and the potential amount of emissions savings by each measure during the period of analysis. See Equation 1, below:

$$MAC_M = NPV_{INC,MM}/E_{MM} \qquad (1)$$

Where:

MAC_M = Marginal abatement cost of the mitigation measure over the analysis period, comparing the cash flow of implementing the measure to a counterfactual alternative scenario in which this measure is not implemented in thousand VND per ton of CO_2e reduction (thousand VND/tCO_2e);

NPV_{INCMM} = Net present value of the difference in cash flow (costs and benefits) of implementing the mitigation measure over the analysis period when compared to an alternative counterfactual scenario in which this measure is not implemented (thousand VND); and

E_{MM} = Reduction in GHG emissions over the analysis period when compared to the counterfactual scenario in which this measure is not implemented (tCO_2)

The costs and benefits of mitigation measures are analyzed relative to a business-as-usual (BAU) scenario, which reflects what could be expected to have happened had that particular mitigation policy or intervention not been implemented. The difference in costs (between the business-as-usual and mitigation scenarios) includes differences in capital costs, operating costs, and fuel costs relevant to energy use (and should not include transaction costs and taxes). Benefits are limited to cost savings associated with reductions in energy consumption and GHG emissions and do not include co-benefits such as avoided environmental damages, health costs, avoided congestion, and other benefits to society.

The base year for this study is 2014, and the analysis period is from 2014 to 2030, to align with the NDC update assumptions defined by the Ministry of Natural Resources and Environment (MoNRE). However, many measures are expected to be implemented toward the end of this period, such as the deployment of metro rail transit (MRT), electric buses, and electric cars. In these cases, modeling to 2030 captures most of the associated, expenses, but few of the benefits since a vehicle's, or system's useful life extends considerably beyond this date. To address this situation, this study extended the analytical timeframe to 2050. It should be noted that the extension of the analysis period enables capturing fully the benefits associated with GHG emissions reductions and did not entail adding any additional measures after 2030.

All cash flow values presented in this report are at constant VND 2018 values. Fuel prices in 2014 are taken from retail price by Petrolimex, after removal of applicable taxes and fees. Fuel prices until 2025 are provided by the revised Vietnam Power Development Plan (PDP7) forecast. Fuel prices after 2025 adjust the 2025 values to accommodate changes in crude oil and gas wholesale prices, as projected by U.S. Energy Information Administration (EIA).

Marginal Abatement Cost Results for Each Measure

Promotion of biofuel

The promotion of biofuel considers the share of ethanol in gasoline sales in Vietnam. Ethanol is mixed with gasoline in two fractions, known as E5 and E10. E5 contains 5 percent ethanol and 95 percent gasoline, while E10 contains 10 percent ethanol and 90 percent gasoline.

According to the Ministry of Industry and Trade (MoIT), in 2018[1] seven ethanol plants operated in Vietnam, with a combined production capacity of 600,000 tons, including three plants owned by PetroVietnam (PVN), namely Phu Tho, Quang Ngai, and Binh Phuoc, each with an annual production capacity of 100,000 tons.[2] Ethanol can also be imported, and at present is subject to a 20 percent import tax. Ongoing discussion prioritizes reducing the import tax to 17 percent and lowering ethanol prices to provide more choice for petrol distributors.

Ethanol sales in 2018 to transport totaled 145 thousand tons, and during the first six months of that year, E5 accounted for 40.18 percent of gasoline sales.

The level of penetration of E5 and E10 in gasoline sales varies with the level of ambition of each analysis scenario, as follows:

- *Scenario 1*: In 2018, E5 represents 40.18 percent of gasoline sales. Over the period from 2019 to 2030, this percentage reduces to maintain a constant production (for transport) of 145 thousand tons of ethanol per year.
- *Scenario 2*: Ethanol production increases to maintain E5 at a constant 40 percent of gasoline sales over the period to 2030.
- *Scenario 3*: E5 reaches 100 percent of gasoline sales in 2024; 50 percent of the fuel is switched to E10 in 2025, reaching 100 percent E10 in 2030.

Ethanol has less energy content and a higher specific density than gasoline. It has an energy content of 0.027 gigajoule (GJ) per kg and a specific density gravity of 0.79 kg per liter, while gasoline has an energy content of 0.0443 GJ per kg and a specific density gravity of 0.74 kg per liter. Thus, the energy content of E5 per liter is 98.4 percent that of gasoline and E10 is 96.8 percent of gasoline.

This analysis assumes that, on an energy basis, the prices of E5, E10, and gasoline will stay equal (which is the case today). Thus, on a mass basis over the analysis period, the E5 price will remain consistently at 98 percent that of gasoline, with the E10 price staying at 96 percent of the gasoline price. However, vehicles will consume proportionally more fuel to receive the same amount of energy.

Table 6.1 provides the marginal abatement cost (MAC) results for the promotion of biofuels, showing that this measure is cost-effective for GHG emissions abatement.

Table 6.1. MAC Calculation Summary for Promotion of Biofuel

Item	Unit	Value by scenario and analysis period					
		Scenario 1		Scenario 2		Scenario 3	
		2014–30	2014–50	2014–30	2014–50	2014–30	2014–50
NPV of capital cost	VND trillion	—	—	—	—	—	—
NPV of fuel cost	VND trillion	(0.88)	(1.21)	(1.13)	(2.01)	(3.3)	(7.97)
NPV of O&M cost	VND trillion	—	—	—	—	—	—
Total cost	**VND trillion**	**(0.88)**	**(1.21)**	**(1.13)**	**(2.01)**	**(3.3)**	**(7.97)**
CO_2 avoided	Thousand tCO_2	3,497	8,293	4,718	19,256	15,483	90,248
MAC	VND million/tCO_2	(0.252)	(0.146)	(0.239)	(0.105)	(0.213)	(0.088)
	US$/$tCO_2$	(11.5)	(6.7)	(10.9)	(4.8)	(9.7)	(4.0)

Note: — = not available.

MAC values are negative in all scenarios and both analysis periods.

The MAC calculated over the more extended period (to 2050) is higher because of how the MAC formula is calculated: The net present value (NPV) of the future cost savings appears smaller because further out from the base year, future values have less impact in the NPV while the emissions savings are not discounted.

These estimations do not include emissions from the production of ethanol since these are accounted for in other sectors of the economy and the Intergovernmental Panel on Climate Change (IPCC) guidelines look to avoid duplication.

Promotion of electric motorbikes

The three scenarios analyzed the promotion of electric motorbikes at different levels of ambition, as follows:

- *Scenario 1*: Electric motorbikes account for 7 percent of annual new motorbike sales.
- *Scenario 2*: Electric motorbikes account for 14 percent of annual new motorbike sales.
- *Scenario 3*: Electric motorbikes account for 30 percent of the motorbike in-use population by 2030.

Currently, the electric motorbikes sold in the market have a low initial purchase price (which ranges between VND 7 million and VND 15 million depending on the model), but they have short lifetimes (usually less than ten years) and high maintenance costs because the lead-acid batteries must be replaced, on average, every two years. Thus, in terms of life-cycle costs, current electric motorbikes can be more expensive than conventional gasoline motorcycles.

Newer designs featuring lithium-ion batteries have a longer lifetime, but are also more expensive. For example, the sales price for an electric motorcycle with a lithium-ion battery manufactured by Vinfast, a VINGROUP company, is currently around VND 57 million, while comparable models with lead batteries cost around VND 34 million. However, the cost of lithium-ion batteries (the major cost component of electric vehicles), is expected to reduce significantly in the coming years. In 2010, lithium-ion automotive batteries cost US$1,000 per kilowatt hour (kWh). By 2016, the price had fallen to US$273 per kWh and is expected to reduce further to a price point of US$90 per kWh by 2030[3] or sooner. As production volume increases, other vehicle components are also expected to experience cost reductions.

Therefore, the analysis assumes that when leading motorcycle manufacturers come into the market with mainstream vehicles, the price of the electric motorcycle will be comparable with the gasoline-powered design it looks to replace, and the lifetime of these vehicles will also increase substantially to that currently enjoyed by gasoline-powered units.

Additionally, the analysis assumes that by 2025 the currently cheaper, short life lead-acid battery units will be phased out and substituted by lithium-ion powered motorcycles that can genuinely compete with conventional gasoline motorcycles.

Concerning the charging infrastructure, the analysis considered that most electric motorcycles will be charged at home. However, for these two-wheelers to mainstream, the analysis expects Level 2 fast charging stations will need to be deployed, with international experience suggesting a need for one fast charging station per 1,000 electric motorcycles.

Table 6.2 provides cost assumptions for electric motorcycles.

Table 6.2 Cost Assumptions for Electric Scooters (Light Motorcycles)

Cost items	Unit	2018	2025	2030
Vehicle cost				
• Purchase price[a, b]	VND million per vehicle	13.5	20.8	20.8
• O&M cost	VND per vehicle-km	193	130	120
Infrastructure[c]	VND million	328.35	328.35	328.35

Note:

a. Price for 2018 is based on PEGA electric scooter, which is amongst the most demanded light electric motorcycles in the market. From 2025 onwards, the purchase price is set to be equivalent to Honda Wave, which is the reference motorcycle.

b. Average lifetime of the current light electric motorcycles is assumed at ten years. From 2025 onwards, an average lifetime of 17.5 years, equivalent to that of a conventional motorcycle, is assumed.

c. One fast charging station costs US$15,000 and can serve 1,000 electric scooters.

As shown in table 6.3, the MAC for this measure is negative for both analysis periods, indicating measure 4.2, promoting electric motorbikes, is economically beneficial. The reduction in fuel cost represents the main contributor to the beneficial result.

Table 6.3. MAC Calculation Summary for Promotion of Electric Motorcycles

Item	Unit	Value by scenario and analysis period					
		Scenario 1		Scenario 2		Scenario 3	
		2014–30	2014–50	2014–30	2014–50	2014–30	2014–50
NPV of capital cost[a]	VND trillion	(5.23)	(6.01)	(14.40)	(16.45)	(43.28)	(49.57)
NPV of fuel cost	VND trillion	(15.26)	(37.82)	(41.94)	(103.96)	(125.62)	(320.75)
NPV of O&M cost	VND trillion	0.78	1.00	2.18	2.77	6.64	8.76
NPV of residual cost	VND trillion	1.36	0.23	3.75	0.64	11.32	2.13
Total cost	**VND trillion**	**(18.38)**	**(42.60)**	**(50.41)**	**(116.99)**	**(150.94)**	**(359.43)**
CO_2 avoided	Thousand tCO_2	3,945	25,343	10,803	69,120	31,120	207,446
MAC	VND million/tCO_2	(4.66)	(1.68)	(4.67)	(1.69)	(4.85)	(1.73)
	US$/$tCO_2$	(212.85)	(76.79)	(213.16)	(77.32)	(221.58)	(79.15)

Note: a. Includes investment cost for infrastructure.

The GHG emissions presented in table 6.3 exclude GHG emissions from electricity generation, as this is accounted for by the power sector, as per IPCC guidelines.

New vehicle fuel economy standards

New vehicle fuel economy standards are considered in all three analysis scenarios and are assumed to be deployed in two stages:

Stage 1 (2022–2026):
- Small car (<1400cc): 6.1 L/100km
- Medium car (1400-2000cc): 7.52 L/100km
- Large car (>2000cc): 10.4 L/100km

In which
- 2022: 50 percent of car sales meet the standard
- 2023: 75 percent of car sales meet the standard
- 2024–2026: 100 percent of car sales meet the standard
- 2025: Motorcycles: 2.3 L/100 km

Stage 2 (from 2027):
- Small car (<1400cc): 4.7 L/100 km
- Medium car (1400-2000cc): 5.3 L/100 km
- Large car (>2000cc): 6.4 L/100km

In which
- 2027: 50 percent of car sales meet the standard
- 2028: 75 percent of car sales meet the standard
- 2029: 100 percent of car sales meet the standard

The implementation of these standards is accompanied by a transition to Euro 5 emissions standards by 2022, with a resultant and significant improvement in the level of local pollutant emissions of particulate matter (PM less than 2.5 microns), Nitrogen oxides (NO_x), carbon monoxide (CO) and volatile organic carbon (VOC).

Vietnam is following the Chinese standard with a five-year lag, which will minimize development costs for vehicle manufacturers who already have supply chains identified and in place. However, any new vehicle emissions or fuel economy standard will require that the manufacturer first demonstrates prototype new vehicles meet the standard and then demonstrates production compliance. For prototype compliance, the manufacturer submits proof in country-of-origin, but for production compliance, MoIT should select vehicles at random for testing in an independent laboratory. The manufacturer normally bears the cost of the tests.

Experience in Germany, where vehicle specifications have developed from Euro 2 to Euro 6 emissions and at the same time meet strict economy standards, shows despite original estimates of a large corresponding increase in manufacturing costs, vehicles have not increased in price. This price stability has been due to competitive market pressure and creative product design and supply chain management.

Therefore, the only expected cost associated with the deployment of vehicle fuel economy standards is administrative cost, e.g., the cost for the formulation of regulations and cost for setting up an administrative unit to check and ensure regulations are being met.

For the purpose of the analysis and based on empirical examples, the following estimates were applied for various cost items, as shown in table 6.4. These input data can be confirmed when they are implemented in the future:

- Cost of two study tours (with 10 delegates each) to learn how fuel economy standards regulation has been formulated and enacted in other countries = estimated cost per trip: US$50,000
- Cost for technical research to apply this regulation = estimated US$50,000
- Cost (government fee) to formulate the regulations = estimated US$10,000
- Cost for setting up an office to ensure compliance of these regulations. Office would be staffed by five employees and located inside the Ministry of Transport (MoT) building to allow rooms, electricity, water consumption, and internet access to be provided by MoT. Set-up costs, for office furniture and office equipment = estimated US$4,000.
- Cost of operating expenses, including wages and social obligations and operations cost (estimated: US$27,000 per year).

Table 6.4. Implementation Costs for New Vehicle Fuel Economy Standards

Cost items (US$)	2019	2020	2021	2022	2030	2050
Study tours	50,000	50,000				
Cost for technical research	50,000					
Drafting the legal text			10,000			
Office set-up			4,000			
Office running cost			27,000	27,000	27,000	27,000
Total	**100,000**	**50,000**	**41,000**	**27,000**	**27,000**	**27,000**

Policy development costs, however, are not considered in the MACC calculation. Thus, there will be no investment cost for this measure.

Table 6.5 provides the MAC result for the measure on new fuel economy standards. This regulation leads to reduced gasoline consumption by motorcycles and cars, which in turn results in decreased fuel cost and lower GHG emissions. Thus, its MAC is negative for the three scenarios and both periods.

Table 6.5. MAC Calculation Summary for New Fuel Economy Standards

Item	Unit	Value by scenario and analysis period					
		Scenario 1		Scenario 2		Scenario 3	
		2014–30	2014–50	2014–30	2014–50	2014–30	2014–50
NPV of capital cost[a]	VND trillion	—	—	—	—	—	—
NPV of fuel cost	VND trillion	(50.69)	(424.60)	(49.57)	(415.80)	(48.11)	(394.07)
NPV of O&M cost	VND trillion	—	—	—	—	—	—
Total cost	**VND trillion**	**(50.69)**	**(424.60)**	**(49.57)**	**(415.80)**	**(48.11)**	**(394.07)**
CO_2 avoided	Thousand tCO_2	14.958	358.571	14.542	347.929	13.343	309.285
MAC	VND million/tCO_2	(3.39)	(1.18)	(3.41)	(1.20)	(3.60)	(1.27)
	US$/$tCO_2$	(154.79)	(54.09)	(155.71)	(54.59)	(164.69)	(58.20)

Note: — = not available.
a. Includes investment cost for infrastructure.

Though this measure applies in all the three scenarios, the impact of the measure will vary due to the cumulative effect of other measures. For example, Scenario 3 introduces more electric motorcycles and thus has fewer gasoline motorcycles. Hence, the impact of applying tighter fuel economy standards to these gasoline-powered units will consequently be lower.

Expansion of bus systems

Bus system development would result in GHG emissions reductions as a result of a modal shift of passengers from motorcycles and private cars toward buses, which can have a lower energy consumption per passenger-km. The analysis assumes that the bus occupancy rate will improve from the current 25 percent in 2019 to 50 percent in 2024. Assumptions for the MAC analysis for the expansion of bus systems are as follows:

- *Scenario 1*: More bus routes will be built in five centrally managed cities—Hanoi, Ho Chi Minh City (HCMC), Hai Phong, Da Nang, and Can Tho.
- *Scenarios 2 and 3*: Bus systems are expanded in 13 cities, including the above five cities plus nine Class 1 cities—Hanoi, HCMC, Da Nang, Can Tho, Hai Phong, Viet Tri, Nam Dinh, Vinh, Hue, Quy Nhon, Da Lat, Nha Trang, and Buon Me Thuat.

Cost items of a new bus route generally include buses, a global positioning system (GPS), LED board, and communication system; infrastructure; fuel costs, and O&M costs. In terms of infrastructure, the costs might involve route infrastructure improvements.

The analysis assumed that users will move only some of their travel to the new buses (for example, commuting to work) and that this will not affect their decisions to purchase private motorization (motorcycles and cars).

Table 6.6 provides a cost estimate for a bus route in two cases: (i) with the requirement for on-route infrastructure improvement, and (ii) without investment in on-route infrastructure improvement. They are presented per bus unit to be useful for all scenarios.

Table 6.6. Cost Estimate for a Bus Route

Cost items	Unit	Bus route with the requirement for on-route improvement[a]	Bus route without requirement for on-route improvement[b]
Bus cost[c]	US$ per vehicle	130,000	130,000
Infrastructure and others	US$ per vehicle	156,500	6,600
O&M cost	US$ per vehicle-km	0.23	0.23

Note:
a. Based on a project funded by the World Bank in Hai Phong
b. Based on an FS for a bus route development in Da Nang
c. Medium-sized bus, including GPS and LED board and communication system

To derive the cost estimate for the expanded bus systems measure and subsequently calculate the MAC, the analysis assumes that 10 percent of new buses will require on-route infrastructure improvements investments, while the remaining 90 percent will operate on existing routes and therefore no infrastructure investment cost as assigned. This is based on the team's judgment that while the bus network expansion would be prioritized in areas where there is already suitable road infrastructure in place, some new routes may need improvements in infrastructure to accommodate a large fleet of buses.

Table 6.7 provides the MAC results for this measure. The MAC value is positive over the 2014 to 2030 period, indicating this measure is more expensive than the counterfactual BAU due to the low load factor; until 2018, buses operated at a 25 percent load factor. In the scenarios, more buses would be required, incurring more purchase costs and operation costs, which in this case outweighs fuel savings. However, for the 2014 to 2050 period, the MAC is smaller, reflecting more benefits gained (more saving in purchase cost, lower operating costs and fuel costs) that result from the increased average number of passengers per bus.

Table 6.7. MAC Calculation Summary for Expansion of Bus Systems

Item	Unit	Value by scenario and analysis period					
		Scenario 1		Scenario 2		Scenario 3	
		2014–30	2014–50	2014–30	2014–50	2014–30	2014–50
NPV of capital cost[a]	VND trillion	118.42	118.42	125.95	125.95	125.95	125.95
NPV of fuel cost	VND trillion	(88.00)	(139.75)	(90.56)	(142.63)	(90.43)	(142.52)
NPV of O&M cost	VND trillion	32.41	11.01	35.67	14.73	37.04	16.36
NPV of residual cost	VND trillion	0.09	5.18	(0.56)	5.24	(0.56)	5.24
Total cost	**VND trillion**	**62.93**	**(5.13)**	**70.51**	**3.30**	**72.01**	**5.04**
CO_2 avoided	Thousand tCO_2	15,721	59,722	15,917	59,924	15,092	58,165
MAC	VND million/tCO_2	4.00	(0.09)	4.43	0.06	4.77	0.09
	US$/$tCO_2$	182.9	(3.9)	202.4	2.5	218.0	4.0

Note: a. Includes investment cost for infrastructure.

These results indicate that along with bus development, initiating supporting measures to increase bus load is equally important, as this will make bus systems more cost-effective. If families were to forego buying a motorcycle or car because of the improved bus service, all MACs could be negative, though this is unlikely.

Promotion of electric buses

The analysis considered the promotion of electric buses in Scenario 3 and assumed 10 percent of annual bus sales in the period from 2020 to 2030 would be of electric buses.

Table 6.8 presents the costs associated with this measure.

Table 6.8. Cost Estimate for Electric Buses

Cost items	Unit	Value in		
		2020	2025	2030
Electric bus cost[a]	US$ per vehicle	189,000	170,400	153,700
Infrastructure and other items[b]	US$ per vehicle	86,700	55,011	46,257
O&M cost	US$ per vehicle-km	0.14	0.14	0.14

Note:

a. Lower battery costs account for the reduction in electric bus costs over time.

b. Includes civil works in bus depots, runways, and station; depot equipment; signage system ,and charging infrastructure, among others.

The analysis considered the 2014 purchase price of a medium-sized electric bus was US$192,000,[4] approximately 1.6 times higher than an equivalent diesel bus. The analysis also considered that the price of batteries, a costly component of electric buses, would decrease over time. Electric buses have large batteries of about 400 kWh, with average electricity energy consumption of 1.5 to 2 kWh per km, giving the bus a range of 150 km. Therefore, to increase the availability of electric buses, is the analysis assumed additional batteries would be purchased and then charged daily while buses are on duty—and thus would be ready for swapping. In addition, the analysis considered that bus charging systems would be deployed at bus depots, allowing for one charger per three buses in the fleet,[5] at a price of around $20,000[6] per charger. Electric buses have 30 percent fewer parts than diesel buses, which dramatically reduces maintenance and operation costs—by approximately 39 percent.[7]

The marginal abatement cost of the promotion of electric buses is positive during the 2014 to 2030 period, because the capital cost of electric vehicles is not offset by the savings in fuel consumption, O&M, and GHG emissions (see table 6.9). The full benefits of this measure are only captured when considering the extended period from 2014 to 2050, which then sees a negative MAC.

Table 6.9. MAC Calculation Summary for the Deployment of Electric Buses

Item	Unit	Value by scenario and analysis period					
		Scenario 1		Scenario 2		Scenario 3	
		2014–30	2014–50	2014–30	2014–50	2014–30	2014–50
NPV of capital cost[a]	VND trillion	No consideration		No consideration		4.01	10.71
NPV of fuel cost	VND trillion					(2.44)	(12.64)
NPV of O&M cost	VND trillion					0.36	1.47
NPV of residual cost	VND trillion					(0.99)	(0.78)
Total cost	**VND trillion**					**0.94**	**(1.24)**
CO_2 avoided	Thousand tCO_2					686	10,544
MAC	VND million/tCO_2					1.37	(0.12)
	US$/$tCO_2$					62.6	(5.4)

Note: a. Includes investment cost for infrastructure.

Expansion of the BRT system

The analysis considered the expansion of bus rapid transit (BRT) systems under the three scenarios. Assumptions for this measure are as follows:

- **Scenario 1:**
  - Hanoi: Line 1 in operation in 2017
  - Da Nang: Line 1 in operation in 2021
  - HCMC: Line 1 in operation in 2021; Line 2 in operation in 2025
- **Scenario 2:**
  - Hanoi: Line 1 in operation in 2017; 2 new lines in operation in 2025
  - Da Nang: Line 1 in operation in 2021; 2 new lines in operation in 2025
  - HCMC: Line 1 in operation in 2021; 2 new lines in operation in 2025
  - Can Tho: Line 1 in operation in 2025
  - Hai Phong: Line 1 in operation in 2025; Line 2 in operation in 2030
  - New BRT lines using electric buses in Hanoi and HCM city from 2025
- **Scenario 3:**
  - Same BRT lines as in Scenario 2 but new BRT lines in Hanoi and HCM city from 2025 will use electric buses

To estimate the costs associated with BRT development in Vietnam using diesel buses, the analysis used the reported operating costs for the BRT line in Hanoi along with cost estimates for the BRT lines in Da Nang and HCMC. These cost items are presented on a per-vehicle basis in table 6.10.

Table 6.10. Cost Assumptions for BRT System Using Diesel Buses

Cost items	Unit	Value
Vehicle cost[a]	US$	230,000
Infrastructure and others[b]	US$ per vehicle	706,571
O&M cost	US$ per vehicle-km	0.36

Note:
a. Medium sized, conventional buses
b. Civil works for depot, runways and station; equipment for depot, signage system and others

The investment required for BRT developing using electric buses is more expensive. The analysis assumed the cost ratio between diesel and electric buses used for BRT would be the same as that for normal bus services. Similarly, the cost for charging infrastructure is assumed to be the same as the cost for normal electric buses (table 6.11).

Table 6.11. Cost Assumptions for BRT System Using Electric Buses

Cost items	Unit	Value in	
		2025	2030
Electric bus cost[a]	US$	300,000	270,000
Infrastructure and others[b]	US$ per vehicle	740,000	731,000
O&M cost	US$ per vehicle-km	0.22	0.22

Note:
a: The lower cost in 2030 is due to reduced battery cost
b: Civil works for depot, runways and station; equipment for depot, signage system, charging infrastructure and others.

Table 6.12 shows the MAC calculation summary for the expansion of BRT systems. Similar to bus development, BRT development would lead to reduced use of motorcycles and private cars and subsequently less energy consumption due to BRT's higher energy efficiency on a per-passenger basis. However, the MACs for this measure for both analytical periods are positive, meaning that this measure is not cost-effective for GHG emissions reduction. The high cost of the required infrastructure—which cannot be compensated by savings in fuel costs—stems from a lower expected passenger flow (and number of buses) than the required BRT infrastructure would need to be cost-effective.

Since BRT lines have a lower passenger-handling capacity than a metro rail system, but also a much lower investment requirement, it would be worth re-studying the BRT option, perhaps on distinct routes, considering the transport-related benefits BRT can offer—such as improve travel time, reduced congestion, and reduced local air pollution.

The calculated GHG emissions do not include emissions from electricity generation, which, according to IPCC guidelines, are counted in the power sector category.

Table 6.12. MAC Calculation Summary for Expansion of BRT Systems

Item	Unit	Value by scenario and analysis period					
		Scenario 1		Scenario 2		Scenario 3	
		2014–30	2014–50	2014–30	2014–50	2014–30	2014–50
NPV of capital cost[a]	VND trillion	2.27	2.62	7.34	8.57	7.31	8.53
NPV of fuel cost	VND trillion	(0.21)	(0.24)	(0.76)	(1.28)	(0.71)	(1.14)
NPV of O&M cost	VND trillion	0.13	0.14	0.25	0.24	0.26	0.25
NPV of residual cost	VND trillion	(0.13)	(0.02)	(2.42)	(0.34)	(2.41)	(0.33)
Total cost	**VND trillion**	**2.06**	**2.51**	**4.42**	**7.20**	**4.46**	**7.31**
CO_2 avoided	Thousand tCO_2	26	41	155	515	134	381
MAC	VND million/tCO_2	78.76	61.70	28.46	13.99	33.32	19.17
	US$/$tCO_2$	3,597.78	2,818.81	1,300.05	638.95	1,522.15	875.86

Note: a. Includes investment cost for infrastructure.

Deployment of metro systems

The analysis assumed a metro rail transit (MRT) system would be deployed in all three scenarios, with the same level, as follows:

- Hanoi: Line 2A in operation in 2019; Line 3 in operation in 2022
- HCMC: Line 1 in operation in 2022

Currently, three MRT lines are under construction. In Hanoi, Line 2A, running from Cat Linh to Ha Dong, will be operational in 2019. Line 3, connecting Nhon and Hanoi railway station, is expected to start operations in 2022. Line 1 in HCMC, the 19.7 km Ben Thanh-Suoi Tien line, also plans to launch operations in 2022.

Table 6.13 provides an overview of the cost assumptions for metro systems in Vietnam.

Table 6.13. Cost Assumptions for Metro Systems in Vietnam

Cost items	Unit	Value	Data source
Investment cost[a]			
• Line 2A in Hanoi	VND billion	11,529	TEDI (Transport Engineering Design Inc. 2016. *Ha Noi Transport Development Plan to 2030 with Vision to 2050.*
Line 3 in Hanoi	VND billion	20,750	TEDI (Transport Engineering Design Inc. 2016. *Ha Noi Transport Development Plan to 2030 with Vision to 2050.*
Line 1 in HCMC	VND billion	47,325	*Revised investment cost*. (https://english.vietnamnet.vn/fms/business/176266/hcm-city-metro-projects-short-on-capital.html)
O&M cost	Percent of initial investment cost	1.4%	HCMPC (Ho Chi Minh City People's Committee). 2014. *Establishment Proposal: Ho Chi Minh City Urban Railway No.1*. (http://open_jicareport.jica.go.jp/pdf/12261772_02.pdf)

Note: a. Investment cost does not include land compensation cost.

As shown in table 6.14, the MAC for the deployment of an MRT in Vietnam is positive for all scenarios and analysis period. Infrastructure capital costs compose the main cost element for metros, with no savings in fuel or O&M costs due to (i) the operating expectations of these metro lines in Vietnam showing energy efficiencies and costs above international benchmarks; and (ii) most of the expected modal shift is from motorcycles, which are a highly efficient form of passenger transport, particularly with the accelerated incorporation of electric motorcycles.

Similar to BRT, the MRT measure is driven more by transport-related benefits such as reduced travel time and travel comfort rather than the cost-effectiveness for GHG emissions reduction. It should be noted that, as per IPCC guidelines,[8] GHG emissions from electricity generation are not included in the analysis as this is accounted by the power sector.

Table 6.14. MAC Calculation Summary for Deployment of MRT System

Item	Unit	Value by scenario and analysis period					
		Scenario 1		Scenario 2		Scenario 3	
		2014–30	2014–50	2014–30	2014–50	2014–30	2014–50
NPV of capital cost[a]	VND trillion	48.18	48.18	48.18	48.18	48.18	48.18
NPV of fuel cost	VND trillion	0.77	1.53	0.77	1.53	0.77	1.54
NPV of O&M cost	VND trillion	4.01	6.09	4.02	6.10	4.07	6.17
NPV of residual cost	VND trillion	(8.40)	0	(8.4)	0	(8.4)	0
Total cost	**VND trillion**	**44.56**	**55.80**	**44.58**	**55.82**	**44.63**	**55.90**
CO_2 avoided	Thousand tCO_2	1,114	2,993	1,110	2,972	1,073	2,833
MAC	VND million/tCO_2	39.96	18.64	40.14	18.78	41.58	19.72
	US$/$tCO_2$	1825.7	851.5	1833.7	858.0	1899.7	901.0

Note: a. Includes investment cost for infrastructure.

Promotion of electric cars

The promotion of electric cars in car sales is considered in Scenarios 2 and 3 with the same level of ambition, as follows:

- 2025: Electric cars account for 5 percent annual car sales
- 2030: Electric cars account for 33 percent annual car sales

Still a new technology, electric vehicles experience modest sales, even in developed markets. In the United States, battery-powered electric vehicles and plug-in hybrid electric vehicles[9] now account for just over 1 percent of all new vehicle sales. Between 2014 and 2016, approximate sales for the top four models reached 70,000 for the Tesla Model S, 60,000 for the Nissan LEAF, 60,000 for the Chevrolet Volt, and 40,000 for the Ford Fusion Energi.[10]

For electric cars in Vietnam, the analysis takes the popular Nissan LEAF as the reference. The Nissan LEAF has 48 lithium-ion modules that store up to 24 kWh. According to the manufacturer's data, the LEAF has a range of 200 km per charge; however, a range of between 120 and 150 km is more realistic. In 2016, the Nissan LEAF retailed in the United States for approximately US$31,500, with the battery accounting for 40 percent of the vehicle's cost, down 73 percent from US$1,000 per kWh in 2010 to US$273 per kWh in 2016. According to Consultancy.uk, the price of an automotive lithium-ion battery could drop to US$90 per kWh by 2030. If this savings is passed on to the consumer, only with battery cost improvement, the price of a Nissan LEAF could drop in real terms to US$25,000 in 2025 and to US$23,000 in 2030.

As major car manufacturers enter the electric vehicle market, costs should continue to decrease. Volkswagen plans to price its upcoming new generation of fully electric vehicles lower than it had previously hinted—as low as €18,000 in Europe, or approximately US$21,000 for an entry-level fully electric model set for a late-2019 launch in the United States.[11] In view of this, a Deloitte study predicts that by 2021, electric vehicles could cost the same as gasoline and diesel cars.[12] The analysis assumed that by around 2025, electric cars would compete directly with conventional cars in Vietnam.

As for the operations and maintenance costs—excluding battery replacement—with fewer parts versus gasoline and diesel cars, electric cars would see a dramatic reduction in O&M costs.

The promotion of electric cars does require an investment in charging infrastructure. A normal Level 2 charger (with a power capacity between 2 and 4 kilowatts and a charging time from 3 to 6 hours) costs between US$500 and US$1,500. However, not all car owners have garages where normal chargers can be installed, indicating the need to install semi-fast chargers for public use. Currently in the Netherlands, nearly 50,000 fully electric cars drive on Dutch roads. In Amsterdam alone, 838 public charging stations offer a total of 2,000 charging points. In Vietnam, approximately 50 percent of electric cars would rely on public chargers. International experience suggests developing one fast-charging station per 100 electric cars, with each charging station costing between US$10,000 and US$20,000. Figure 6.1 provides an example of fast-charging station, located at the MoIT. In addition, the analysis expects the development and deployment of at-home chargers and semi-fast chargers for public use. A semi-fast charger costs between US$1,500 and US$5,000.

Table 6.15 lists the summary cost assumptions for electric cars, including purchase price, O&M, and infrastructure.

Table 6.15. Summary Cost Assumptions for Electric Cars

Cost items	Unit	2025	2030
Vehicle cost			
• Purchase price[a]	VND million per vehicle	612	612
• O&M cost	VND per vehicle-km	329	329
Infrastructure	VND million per vehicle	59.10	59.10

Note: a. From 2025 onwards, purchase price is set to be equivalent to Toyota Vios, which is the reference car <2L.

Figure 6.1. A Fast Charger at the Ministry of Industry and Trade Building in Hanoi

Though this measure requires investment cost for electric vehicles and infrastructure, it leads to reduced fuel and O&M costs. The total cost for the electric cars measure during the period from 2014 to 2030 is positive because benefits are not fully captured (electric cars would be first deployed in 2025), rendering a positive MAC value. After the benefits are fully captured in the 2014 to 2050 period, the total cost and MAC results become negative.

Table 6.16. MAC Calculation Summary for Promotion of Electric Cars

Item	Unit	Value by scenario and analysis period					
		Scenario 1		Scenario 2		Scenario 3	
		2014–30	2014–50	2014–30	2014–50	2014–30	2014–50
NPV of capital cost[a]	VND trillion			32.68	105.18	32.68	105.18
NPV of fuel cost	VND trillion			(15.54)	(182.44)	(15.27)	(178.42)
NPV of O&M cost	VND trillion			(2.20)	(26.56)	(2.20)	(26.56)
NPV of residual cost	VND trillion			6.06	3.52	6.06	3.52
Total cost	**VND trillion**	No consideration		**21.00**	**(100.29)**	**21.27**	**(96.27)**
CO_2 avoided	Thousand tCO_2			4,804	162,767	4,570	153,982
MAC	VND million/tCO_2			4.37	(0.62)	4.65	(0.63)
	US$/$tCO_2$			199.7	(28.1)	212.6	(28.6)

Note: a. Includes investment cost for infrastructure (charge stations).

Freight modal shift from road to inland waterway and to coastal shipping

Another measure considered in the analysis is the promotion of freight modal shift from road to inland waterway transport (IWT) and coastal transport. The assumptions for this measure are as follows:

Scenario 1:

- IWT by 2020: Freight ton-km transported (FTKT) to increase from 65.0 (BAU) to 71.2 billion ton-km
- Coastal by 2020: FTKT to increase from 172.0 (BAU) to 178.2 billion ton-km
- IWT by 2030: FTKT to increase from 127.8 to 128.8 billion ton-km
- Coastal by 2030: FTKT to increase from 338.4 (BAU) to 339.4 billion ton-km

Scenario 2 and Scenario 3:

- IWT by 2020: FTKT same as Scenario 1
- Coastal by 2020: FTKT to increase from 172.0 (BAU) to 184.4 billion ton-km
- IWT by 2030: FTKT same as Scenario 1
- Coastal by 2030: FTKT to increase from 338.4 (BAU) to 340.4 billion ton-km

Enabling this level of modal shift requires investments in inland waterway and coastal transport infrastructure.

The following investments in inland waterway infrastructure are considered in Scenario 1:

- Upgrade the waterway corridor of the Red River Delta
- Upgrade the waterway corridor of the Mekong Delta
- Improve the Cho Gao Canal
- Upgrade the port facilities (e.g., crane) to handle cargo from trucks to ships
- Construct new river ports

The following investments in coastal transport infrastructure are considered in Scenario 1:

- Upgrade coastal corridor and development and upgrade of logistic infrastructure
- Construct new sea ports

For Scenario 2, the analysis assumed an increased capacity of inland container depots (ICDs) near Hai Phong and HCMC to enable shipment of containerized cargo for long hauls and upgrade of road infrastructure near ports.

Costs for these interventions are presented in table 6.17.

Table 6.17. Cost Assumptions for Inducing Modal Shift of Freight from Road to Inland Waterways and Coastal Transport

Scenario	Subsector	Action	Cost US$ million
Scenario 1	IWT	Red River Delta: Upgrade waterway Corridor 1[a]	200.0
Scenario 1	IWT	Mekong River Delta: Upgrade waterway corridor[a]	216.6
Scenario 1	IWT	Improve Cho Gao Canal[b]	39.5
Scenario 1	IWT	Upgrade port facilities upgrade (e.g., crane)[c]	35.4
Scenario 1	Coastal	Upgrade coastal corridor and logistic infrastructure[a]	340.0
Scenario 2 and 3	Coastal	Set up ICDs and capacity improvement[c]	300.0
Scenario 2 and 3	Coastal	Upgrade road infrastructure near ports[c]	398.0

Source: a. Blancas Mendivil et al 2013. b. World Bank 2017. c. World Bank 2018.

MAC calculations for this measure are presented in table 6.18, table 6.19 and table 6.20, which show negative MAC values in all three scenarios and for both analytical periods, indicating this modal shift from road to inland and coastal waterway transport would be cost-effective measure for GHG emissions reduction. Looking into the cost structure of this measure, it seems that this measure is also cost-effective for transport efficiency improvement, since all cost items see a reduction, with reduced costs associated with the purchase of new trucks as well as operational and maintenance costs. In inland waterways, the incremental investment for additional vessels to handle the freight previously transported by road would be offset somewhat by a shift from the current fleet of mainly small vessels to more medium and large vessels. The measure would also provide fuel savings, associated with improved mode efficiency and the shift to larger vessels.

In terms of mobility, this measure is also cost-effective. The reduced number of required trucks and improvements in transport and fuel efficiency—resulting from the shift to larger vessel sizes—produce lower totals on cost items.

Table 6.18. MAC Calculation Summary for Modal Shift from Road to IWT and Coastal Waterways for Scenario 1

Item	Unit	Value by related sector and analysis period					
		Road		IWT and coastal transport		Total	
		2014–2030	2014–2050	2014–2030	2014–2050	2014–2030	2014–2050
NPV of capital cost[a]	VND trillion	(109.35)	(127.64)	35.08	39.77	(74.27)	(87.87)
NPV of fuel cost	VND trillion	(63.03)	(75.24)	(19.94)	(73.53)	(82.97)	(148.77)
NPV of O&M cost	VND trillion	(24.21)	(27.40)	0.56	0.82	(23.66)	(26.57)
NPV of residual cost	VND trillion	(9.59)	1.93	5.47	(1.80)	(4.11)	0.13
Total cost	**VND trillion**	**(206.18)**	**(228.33)**	**21.20**	**(34.73)**	**(185.01)**	**(263.07)**
CO_2 avoided	Thousand tCO_2	14,867	26,353	5,909	58,820	20,777	85,173
MAC	VND million/tCO_2					(8.90)	(3.09)
	US$/$tCO_2$					(407)	(141)

Note: — = not available.
a. Includes investment cost for infrastructure.

Table 6.19. MAC Calculation Summary for Modal Shift from Road to IWT and Coastal Waterways for Scenario 2

Item	Unit	Value by related sector and analysis period					
		Road		IWT and coastal transport		Total	
		2014–2030	2014–2050	2014–2030	2014–2050	2014–2030	2014–2050
NPV of capital cost[a]	VND trillion	(157.20)	(184.54)	46.63	51.73	(110.57)	(132.81)
NPV of fuel cost	VND trillion	(91.41)	(109.71)	(19.17)	(72.60)	(110.57)	(182.31)
NPV of O&M cost	VND trillion	(34.81)	(39.59)	0.58	0.85	(34.23)	(38.74)
NPV of residual cost	VND trillion	(13.73)	2.89	5.52	(1.82)	(8.21)	1.08
Total cost	**VND trillion**	**(297.14)**	**(330.93)**	**33.57**	**(21.84)**	**(263.57)**	**(352.77)**
CO_2 avoided	Thousand tCO_2	21,670	38,895	5,671	58,387	27,341	97,282
MAC	VND million/tCO_2					(9.64)	(3,63)
	US$/$tCO_2$					(440)	(166)

Note: a. Includes investment cost for infrastructure.

Table 6.20. MAC Calculation Summary for Modal Shift from Road to IWT and Coastal Waterways for Scenario 3

Item	Unit	Value by related sector and analysis period					
		Road		IWT and coastal waterway		Total	
		2014–2030	2014–2050	2014–2030	2014–2050	2014–2030	2014–2050
NPV of capital cost[a]	VND trillion	(157.20)	(184.54)	46.63	51.73	(110.57)	(132.81)
NPV of fuel cost	VND trillion	(91.41)	(109.71)	(19.17)	(72.60)	(110.57)	(182.31)
NPV of O&M cost	VND trillion	(34.81)	(39.59)	0.58	0.85	(34.23)	(38.74)
NPV of residual cost	VND trillion	(13.73)	2.89	5.52	(1.82)	(8.21)	1.08
Total cost	**VND trillion**	(297.14)	(330.93)	33.57	(21.84)	(263.57)	(352.77)
CO_2 avoided	Thousand tCO_2	21,670	38,895	5,671	58,387	27,341	97,282
MAC	VND million/tCO_2					(9.64)	(3.63)
	US$/$tCO_2$					(440)	(166)

Note: a. Includes investment cost for infrastructure (including logistics parks).

Modal shift from road to railway

Scenario 2 and Scenario 3 consider the modal shift of freight transport from road to railways, with deployment levels as follows:

- Freight traffic (FTKT) to increase from 4.4 (BAU) to 5.1 billion ton-km by 2020
- Freight traffic (FTKT) to increase from 8.6 (BAU) to 16.5 billion ton-km by 2030

The shift to railway will require investment in train carriages and railway infrastructure, including development, improvement of railway freight terminals and ICDs, railway expansion, access ports, and cargo handling facilities. Table 6.21 presents the cost assumptions for this measure.

Tables 6.22 and 6.23 provide MAC calculation summary for this measure for Scenario 2 and Scenario 3. As covered above, this measure requires investment in rolling stock and infrastructure, but these costs are compensated by the reduced need to purchase trucks and in particular a reduction in on-road fuel cost. In total, the costs associated with this measure are negative. Therefore, this measure is cost-effective for GHG emissions reduction.

Table 6.21. Cost Assumptions for Deployment of Rail Passenger and Freight Systems

Cost items	Unit	Value	Data source
Investment cost			
Diesel locomotive	VND billion	15.76	*Vietnam Express* news article (2004): "Vietnam Bought 20 New Chinese Locomotives." https://vnexpress.net/tin-tuc/thoi-su/vn-mua-20-dau-may-xe-lua-moi-cua-trung-quoc-2000471.html (accessed October 2018)
Passenger car	VND billion	10.60	*Tuoi Tre* news article (2018): "Bringing 6 New Trains to Exploit Thong Nhat Railway." https://tuoitre.vn/dua-6-doan-tau-moi-vao-khai-thac-tuyen-duong-sat-thong-nhat-20180110224437811.htm (accessed October 2018)
Freight car	VND billion	6.91	Assumed at 65% of passenger car
Infrastructure	VND billion/locomotive	631.00	Based on the master plan for railway development, in particular based on planned number of new locomotives and the required infrastructure
O&M cost			
Operating cost	(E+03)VND/locomotive-km	44.60	World Bank. 2018 (unpublished). *Strengthening Sector Performance for Rail Transport Services in Vietnam – Phase 2*.
Operating cost	(E+03)VND/car-km	5.10	
Infrastructure cost	(E+03)VND/train-km	16.20	
Personnel cost, train control, management	(E+03)VND/train-km	43.0	

Table 6.22. MAC Calculation Summary for Modal Shift from Road to Rail for Scenario 2

Item	Unit	Value by related sector and analysis period					
		Road		Railway		Total	
		2014–2030	2014–2050	2014–2030	2014–2050	2014–2030	2014–2050
NPV of capital cost[a]	VND trillion	(46.56)	(92.76)	42.10	103.81	(4.45)	11.06
NPV of fuel cost	VND trillion	(18.57)	(68.63)	3.99	14.54	(14.59)	(54.10)
NPV of O&M cost	VND trillion	(5.80)	(18.42)	10.54	33.31	4.74	14.89
NPV of residual cost	VND trillion	19.58	8.64	(6.84)	(8.00)	12.74	0.64
Total cost	**VND trillion**	**(51.35)**	**(171.16)**	**49.79**	**143.65**	**(1.56)**	**(27.50)**
CO_2 avoided	Thousand tCO_2	5,384	52,747	(846)	(8,276)	4,538	44,471
MAC	VND million/tCO_2					(0.34)	(0.62)
	US$/$tCO_2$					(15.67)	(28.25)

Note: a. Includes investment cost for infrastructure (charge stations).

Table 6.23. MAC Calculation Summary for Modal Shift from Road to Rail for Scenario 3

Item	Unit	Value by related sector and analysis period					
		Road		Railway		Total	
		2014–2030	2014–2050	2014–2030	2014–2050	2014–2030	2014–2050
NPV of capital cost[a]	VND trillion	(46.56)	(92.76)	42.10	103.81	(4.45)	11.06
NPV of fuel cost	VND trillion	(18.57)	(68.63)	3.99	14.54	(14.59)	(54.10)
NPV of O&M cost	VND trillion	(5.80)	(18.42)	10.54	33.31	4.74	14.89
NPV of residual cost	VND trillion	19.58	8.64	(6.84)	(8.00)	12.74	0.64
Total cost	**VND trillion**	**(51.35)**	**(171.16)**	**49.79**	**143.65**	**(1.56)**	**(27.50)**
CO_2 avoided	Thousand tCO_2	5,384	52,747	(846)	(8,276)	4,538	44,471
MAC	VND million/tCO_2					(0.34)	(0.62)
	US$/$tCO_2$					(15.67)	(28.25)

Note: a. Includes investment cost for infrastructure.

Introduction of CNG buses

This measure pertains to the introduction of CNG buses—which run on compressed natural gas (CNG)—in city fleets, under the three analysis scenarios, as follows:

- *HCMC*: 423 units in 2017
- *Ha Noi*: 50 units in 2018 and 200 units in 2020

Generally, CNG buses are more expensive than diesel buses and the deployment of CNG buses require the installation of CNG filling stations. A CNG filling station for 100 buses can cost approximately US$1 million. Table 6.24 presents the cost assumptions for this measure.

Table 6.24. Cost Assumption for Deployment CNG Buses

Cost items	Unit	Value
Bus cost[a]	US$ per vehicle	140,000
Infrastructure and others[b]	US$ per vehicle	21,590
O&M cost	US$ per vehicle-km	0.23
CNG filling station[c]	US$ per station	1,000,000

Note:
a. Medium sized bus, including GPS system, LED board, and communication system.
b. Includes costs for bus stops and depots. This cost component is similar to that of diesel buses.
c. Filling station for 100 CNG buses.

Despite higher bus cost and additional infrastructure requirement (e.g., CNG filling stations) compared to diesel buses, the CNG bus measure saves money due to the lower CNG fuel costs, shown in table 6.25. MAC values for both analytical periods are negative.

Table 6.25. MAC Calculation Summary for Deployment of CNG Buses

Item	Unit	Value by scenario and analysis period					
		Scenario 1		Scenario 2		Scenario 3	
		2014–30	2014–50	2014–30	2014–50	2014–30	2014–50
NPV of capital cost[a]	VND trillion	0.30	0.35	0.3	0.35	0.25	0.25
NPV of fuel cost	VND trillion	(0.87)	(1.11)	(0.87)	(1.11)	(0.72)	(0.74)
NPV of O&M cost	VND trillion	—	—	—	—	—	—
NPV of residual cost	VND trillion	—	—	—	—	—	—
Total cost	**VND trillion**	**(0.56)**	**(0.75)**	**(0.56)**	**(0.75)**	**(0.46)**	**(0.48)**
CO_2 avoided	Thousand tCO_2	152.7	333.7	152.7	333.7	120.1	127.5
MAC	VND million/tCO_2	(3.67)	(2.25)	(3.67)	(2.25)	(3.80)	(3.73)
	US$/$tCO_2$	(168)	(103)	(168)	(103)	(174)	(170)

Note:
— = not available.
a. Includes investment cost for infrastructure (including CNG filling stations).

Improvement of truck load factor

Scenario 2 and Scenario 3 consider the improvement of truck load factors, as follows:

- *Scenario 2*: increases the average truck loading factor from 47 percent in 2014, to 56 percent in 2018, and 60 percent in 2027
- *Scenario 3*: increases from 47 percent in 2014, to 56 percent in 2018, and 65 percent in 2027

The deployment of logistics parks near industrial parks and seaports is anticipated to enable multimodality and freight aggregation, at a cost of around VND 9,500 billion (Lam et al 2019). The analysis assumes the Scenario 2 investment would double for Scenario 3.

The MAC for this measure is negative for both scenarios, indicating cost-effectiveness for reducing GHG emissions. As presented in table 6.26, this measure results in a reduction of fuel costs and number of trucks required, thereby reducing capital as well as O&M costs. These savings more than offset the expected investment costs required to improve the logistics infrastructure.

Table 6.26. MAC Calculation Summary for Improvement of Truck Load Factor

Item	Unit	Value by scenario and analysis period					
		Scenario 1		Scenario 2		Scenario 3	
		2014–30	2014–50	2014–30	2014–50	2014–30	2014–50
NPV of capital cost[a]	VND trillion	No consideration		(56.24)	(106.49)	(100.19)	(203.26)
NPV of fuel cost	VND trillion			(9.55)	(23.09)	(15.79)	(43.89)
NPV of O&M cost	VND trillion			18.60	9.14	41.15	19.04
NPV of residual cost	VND trillion			**(76.64)**	**(203.49)**	**(125.15)**	**(389.75)**
Total cost	**VND trillion**			8,132	58,719	14,374	119,456
CO_2 avoided	Thousand tCO_2			(9.42)	(3.47)	(8.71)	(3.26)
MAC	VND million/tCO_2			(431)	(158)	(398)	(149)
	US$/$tCO_2$			(56.24)	(106.49)	(100.19)	(203.26)

Note: a. Includes investment cost for infrastructure (including logistics parks).

Marginal Abatement Cost Curve

The marginal abatement cost curve (MACC) provides an effective visualization tool that enables the comparison of GHG emissions mitigation measures based on their cost-effectiveness and their potential for emissions reduction.

The marginal abatement cost, or MAC, results when each measure is presented in a graph, ordered from the lowest to the highest MAC value, which then shows the cumulative mitigation. The graph's x-axis of the graph represents the cumulative CO_2e abatement potential of the mitigation measures during the analysis time span, while the y-axis represents the cost associated with a reduction of one ton CO_2e emissions provided by each of the analyzed measures.

Measures that appear above zero in the y-axis reflect a positive cost, meaning the net present value (NPV)—across the analytical time span—of the cash flow (investment, operating costs, and fuel costs) associated with implementing the measure is higher than the counterfactual alternative in the BAU scenario.

Measures that fall below zero on the y-axis reflect a negative cost, meaning that those measures offer net cost savings compared to the BAU. For these economically attractive measures, it is important to analyze why they have not been implemented previously, to discover any barriers to implementation that could be removed via incentives or other policy measures.

Table 6.27 provides an overview of the mitigation potential and cost of mitigation measures considered under each of the three scenarios, in both analysis periods.

Table 6.27. Mitigation Potential and Costs of Mitigation by Scenarios

Scenario and measure	2014–2030		2014–2050	
	Mitigation potential	Mitigation cost	Mitigation potential	Mitigation cost
Scenario 1				
3.1/3.2 Modal shift from road to IWT/coastal	22.8	(8.9)	93.5	(3.1)
4.3 Introduction of CNG buses	0.1	(3.7)	0.2	(2.3)
4.2 Promotion of electric motorbikes	3.9	(4.7)	25.3	(1.7)
1.1 New fuel economy standards	15.8	(3.4)	360.5	(1.2)
4.1 Promotion of biofuels	3.5	(0.3)	8.3	(0.2)
2.1 Expansion of bus systems	5.8	4.0	20.8	(0.1)
2.3 Deployment of metro systems	1.2	40.0	3.2	18.6
2.2 Expansion of BRT systems	0.1	78.8	0.2	61.7
Scenario 2				
3.1/3.2 Modal shift from road to IWT/coastal	30.1	(9.6)	106.9	(3.6)
1.2 Improvement of truck load factor	8.9	(9.4)	64.6	(3.5)
4.3 Introduction of CNG buses	0.1	(3.7)	0.2	(2.3)
4.2 Promotion of electric motorbikes	10.8	(4.7)	69.1	(1.7)
1.1 New fuel economy standards	15.4	(3.4)	349.8	(1.2)
4.4 Promotion of electric cars	4.9	4.4	168.4	(0.6)
3.3 Modal shift from road to rail	5.0	(0.3)	48.9	(0.6)
4.1 Promotion of biofuels	4.7	(0.2)	19.2	(0.1)
2.1 Expansion of bus systems	6.1	4.4	21.7	0.1
2.2 Expansion of BRT systems	0.3	28.5	0.9	14.0
2.3 Deployment of metro systems	1.2	40.1	3.1	18.8
Scenario 3				
4.3 Introduction of CNG buses	0.1	(3.8)	1.1	(3.7)
3.1/3.2 Modal shift from road to IWT/coastal	30.1	(9.6)	106.8	(3.6)
1.2 Improvement of truck load factor	8.9	(8.7)	64.6	(3.3)
4.2 Promotion of electric motorbikes	31.1	(4.9)	207.5	(1.7)
1.1 New fuel economy standards	14.0	(3.6)	310.2	(1.3)
4.4 Promotion of electric cars	4.6	4.7	159.7	(0.6)
3.3 Modal shift from road to rail	5.0	(0.3)	48.9	(0.6)
4.4 Promotion of electric buses	1.2	1.4	18.2	(0.1)
4.1 Promotion of biofuels	15.5	(0.2)	90.3	(0.1)
2.1 Expansion of bus systems	5.2	4.8	20.5	0.1
2.2 Expansion of BRT systems	0.2	33.3	1.0	19.2
2.3 Deployment of metro systems	1.1	41.6	2.8	19.7

Note: Mitigation expressed in million (metric) tons carbon dioxide equivalent ($MtCO_2e$). Cost expressed in million VND per ton CO_2e.

Under Scenario 1, five out of eight mitigation measures have negative MAC values, meaning these measures would save money if implemented. For the period from 2014 to 2030, the total mitigation potential for these measures is 46 million tCO_2e, or 86 percent of total mitigation potential under Scenario 1. The measures in this period with the largest mitigation potential include 3.1/3.2 (modal shift from road to IWT and coastal transport), 2.1 (expansion of bus systems), and 1.1 (new fuel economy standards). These three measures account for 83 percent of total mitigation potential for the period from 2014 to 2030.

Under Scenario 1, measure 2.2 (expansion of BRT systems) and 2.3 (deployment of metro systems) have positive MAC, indicating these measures are not cost-effective for GHG emissions reduction.

Part of the reason, particularly for BRT, are the analysis assumptions of (i) very conservative low-volume corridors (but high-volume infrastructure) and (ii) low level of emissions reduction since many new bus or metro users would shift from riding fuel-efficient motorcycles that can carry at least one passenger. The expansion of bus systems is not a cost-effective measure for GHG emissions reductions, but the cost-efficiency of this measure can be improved by increasing the bus load factor.

For Scenario 1, the total investment cost (capital costs associated with vehicles and required infrastructure) is estimated at VND 252 trillion for 2014 to 2030; the cost for measures with a negative MAC totals VND 169.6 trillion (67.2 percent of total investment cost). Measures showing the highest investment cost include 2.2 (expansion of bus systems) and 2.3 (deployment of metro systems), which are, unfortunately, not cost-effective as GHG emissions reduction measures.

Under Scenario 2, seven out of eleven measures for the period from 2014 to 2030 and seven out of eleven measures for the period from 2014 to 2050 have negative MACs, meaning these mitigation measures are cost-effective. These measures include 3.1/3.2 (modal shift from road to inland waterway and coastal transport), 1.1 (establishment of new fuel economy standards), 4.1 (promotion of biofuels), and 4.2 (promotion of electric motorcycles).

For Scenario 2, from 2014 to 2030 the total investment required (capital costs associated with vehicles and required infrastructure) is estimated at VND 1,082 trillion; costs for measures with a negative MAC totals VND 232.67 trillion (21.5 percent of total investment cost). Despite having the highest investment cost, measure 4.4 (promotion of electric cars) has the potential to be a cost-effective measure.

Under Scenario 3, seven out of twelve measures for the period of 2014 to 2030 and nine out of eleven measures for the period of 2014 to 2050 have negative MACs, indicating their cost-effectiveness. The total mitigation potential for these measures, from 2014 to 2030, is 106.32 million tCO_2e, or 83 percent of the scenario's total mitigation potential.

Measure 4.4 (promotion of electric buses), which is an added measure, can be cost-effective for GHG emissions reduction. It should be noted that emissions due to electric consumption were excluded from the analysis. Emissions reductions can be scaled up with the deployment of other cost-effective measures, such as the promotion of biofuels and electric motorcycles, and the improvement of truck load factors.

The total investment required for Scenario 3 (capital costs associated with acquisition of vehicles and deployment of required infrastructure) is estimated at VND 1,273 trillion for the period from 2014 to 2030, with VND 416 trillion (32.6 percent total investment) of that amount having a negative MAC. Measure 4.4 (promotion of electric cars) represents the measure with the highest investment cost, accounting for 49.2 percent of the total investment cost required in Scenario 3.

Notes

1. CafeF 2018.

2. See page 15 in PetroVietnam 2019.

3. See the Environmental and Energy Study Institute (EESI) "Fact Sheet: Plug-in Electric Vehicles (2017)." Accessed online: https://www.eesi.org/papers/view/fact-sheet-plug-in-electric-vehicles-2017.

4. JICA 2016.

5. Lu et al 2018.

6. See page 49 in Karlsson 2016.

7. See PROTERRA's overview discussion on electric vehicles: http://proterra.com.

8. See Chapter 2 ("Stationary Combustion") in Volume 2 of the *2006 IPCC Guidelines for National Greenhouse Gas Inventories*: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf.

9. Plug-in hybrid electric vehicles (PHEVs) are powered by a combination of grid electricity and liquid fuel.

10. See the Environmental and Energy Study Institute (EESI) "Fact Sheet: Plug-in Electric Vehicles (2017)." Accessed online: https://www.eesi.org/papers/view/fact-sheet-plug-in-electric-vehicles-2017#5.

11. Halverson 2018.

12. Edelstein 2019.

References

Blancas Mendivil, Luis C.; El-Hifnawi, M. Baher. 2013. *Facilitating trade through competitive, low-carbon transport : the case for Vietnam's inland and coastal waterways (English)*. Directions in development; countries and regions. Washington, DC: World Bank Group. http://documents.worldbank.org/curated/en/800501468320727668/Facilitating-trade-through-competitive-low-carbon-transport-the-case-for-Vietnams-inland-and-coastal-waterways

CafeF. 2018. "Vì sao có 7 nhà máy sản xuất nhưng chỉ một công ty quyết định số lượng xăng E5 ở Việt Nam?"[in Vietnamese]. *CafeF,* May 8. http://cafef.vn/vi-sao-co-7-nha-may-san-xuat-nhung-chi-mot-cong-ty-quyet-dinh-so-luong-xang-e5-o-viet-nam-20180427100053261.chn.

Edelstein, Stephen. 2019. "Electric Vehicles Could Cost the Same as Gasoline and Diesel Cars by 2021: Report." The Drive, January 21. https://www.thedrive.com/news/26087/electric-vehicles-could-cost-the-same-as-gasoline-and-diesel-cars-by-2021-report.

Halverson, Bengt. 2018. "Base Price of VW's Electric Cars Could Be As Low As $21,000." *Green Car Reports*, November 9. https://www2.greencarreports.com/news/1119827_base-price-of-vws-electric-cars-could-be-as-low-as-21000

JICA (Japan International Cooperation Agency). 2016. "Socialist Republic of Vietnam Data Collection Survey on BRT in Hanoi: Final Report." Tokyo: JICA. http://open_jicareport.jica.go.jp/pdf/12266391_01.pdf

Karlsson, Elin. 2016. "Charging Infrastructure for Electric City Buses: An Analysis of Grid Impact and Costs." Student thesis. Stockholm: Department of Electric Power and Energy Systems, Royal Institute of Technology, KTH.

Lam, Yin Yin, Kaushik Sriram, and Navdha Khera. 2019. *Strengthening Vietnam's Trucking Sector: Towards Lower Logistics Costs and Greenhouse Gas Emissions*. Vietnam Transport Knowledge Series. Washington, DC: World Bank Group. http://documents.worldbank.org/curated/en/165301554201962827/Strengthening-Vietnam-s-Trucking-Sector-Towards-Lower-Logistics-Costs-and-Greenhouse-Gas-Emissions.

Lu, Lu, Lulu Xue, and Weimin Zhou. 2018. "How Did Shenzhen, China Build World's Largest Electric Bus Fleet?" World Resources Institute (blog), April 4. https://www.wri.org/blog/2018/04/how-did-shenzhen-china-build-world-s-largest-electric-bus-fleet.

PetroVietnam. 2019. *Annual Report 2018*. Hanoi: PetroVietnam. https://www.pvoil.com.vn/Data/Sites/1/media/tai-lieu/%C4%91hc%C4%912019/cbtt_baocaothuongnien-pvoil-2018-eng.pdf.

World Bank. 2017 (unpublished). *Feasibility Study for Vietnam Southern Region Waterways and Transport Logistics Corridor Project.*

World Bank. 2018 (unpublished). *Strengthening Sector Performance for Rail Transport Services in Vietnam – Phase 2*

Chapter 7: Conclusions and Policy Recommendations

Vietnam is committed to climate change mitigation, and the transport sector can provide a significant contribution to greenhouse gas (GHG) emissions reductions. In 2014, the transport sector emitted 33.2 million tons of CO_2. With growing transport demand and motorization, these emissions are projected to increase in a business-as-usual (BAU) scenario, at an annual average rate of 6 to 7 percent, reaching 89.1 million tons in 2030.

Road transport is the highest source of CO_2 emissions, with nearly 80 percent of total transport emissions in 2014. Inland waterways and coastal transport emissions account for an additional 11 percent of the total transport CO_2 emissions. Rail produces the smallest source of transport CO_2 emissions due to its low levels of activity and emissions intensity.

The study's analysis defined three GHG emissions mitigation scenarios based on a review of the Government of Vietnam's policies and regulatory framework and through consultation of government authorities and local stakeholders. These scenarios indicate it is possible to reduce GHG emissions significantly, with the analysis showing Vietnam could achieve a 9 percent reduction in CO_2 emissions by deploying the measures considered in transport development plans and by using domestic resources (Scenario 1). With international support, Vietnam could reduce CO_2 emissions even further, from 15 to 20 percent by 2030 (Scenarios 2 and 3).

The analysis expects most emissions mitigation measures to be highly cost-effective, generating significant economic benefits through reduced transport costs. Other co-benefits such as a reduction in local pollutants have not been quantified in the analysis; nevertheless, they would be significant.

The study's economic analysis of emissions scenarios indicates that ambition would pay off. The present value (NPV) of additional investment needs (both public and private) compared to BAU decreases significantly with the level of ambition in each scenario and are negative under all three scenarios (table 7.1).

Table 7.1. NPV of Additional Investment Needs by Mitigation Scenario and Analysis Period

Scenario	Analysis period	
	2014–2030	2014–2050
Scenario 1 (9% reduction)	(VND 18.7 trillion) (US$0.85 billion)	(VND 18.5 trillion) (US$0.84 billion)
Scenario 2 (15% reduction)	(VND 132.4 trillion) (US$6.06 billion)	(VND 130.7 trillion) (US$5.98 billion)
Scenario 3 (20% reduction)	(VND 94.0 trillion) (US$4.30 billion)	(VND 66.5 trillion) (US$3.04 billion)

In addition to requiring a lower NPV for additional investments, each scenario reduces GHG emissions. Table 7.2 shows the cumulative reduction in GHG emissions achieved under each scenario and timeframe.

Table 7.2. Cumulative CO_2 Emissions Reduction by Mitigation Scenario and Analysis Period

In million tons CO_2

Scenario	Cumulative CO_2 emissions reduction (million tons CO_2)	
	2014–2030	**2031–2050**
Scenario 1 9% reduction	53.2	512.0
Scenario 2 15% reduction	87.5	852.8
Scenario 3 20% reduction	117.0	1,031.6

The MAC analyses for the policies and measures show that, across all scenarios, the most cost-effective measures—those with negative costs—include the following: (1) investments and policies aimed at shifting traffic to other transport modes such as inland waterways and coastal transport; (2) deployment of stricter vehicle fuel economy standards; and (3) promotion of electric mobility. In addition, the improvements in freight truck load factors considered in Scenario 3 also offer significant potential for emissions reduction at negative costs.

Measures with positive costs, but with higher potential for emissions reduction include the expansion of bus systems. Investments in rail, metro, and bus rapid transit (BRT) have positive costs, and thus more limited potential for emissions reductions. The relatively low level of two-wheeler emissions per capita accounts for the limited potential for reductions in these measures; as higher emissions standards and electrification are introduced, a modal shift from motorbikes to public transport would further lower two-wheeler emissions levels. With additional measures to increase occupancy and distances traveled by these alternative transport modes, the analysis indicates the cost efficiency of investments would increase, together with the potential for emissions reductions from these measures.

In conclusion, Vietnam can adopt and implement several highly cost-effective and economically feasible mitigation measures to achieve significant emissions reduction in the rapidly growing transport sector. The emissions reduction under the three mitigation scenarios would help Vietnam meet its Nationally Determined Contribution (NDC) targets, along with the policies and investments in other sectors, especially in power generation. However, while these measures are economically feasible and would bring significant long-term benefits through a reduction in transport costs, they would require a considerable investment, even though the NPV of these investments is lower than in the BAU scenario. As a reference point, the Ministry of Transport invested US$25 billion from 2001 to 2015—an average of US$1.7 billion per year.

Based on these conclusions, for emissions mitigation, the study recommends the Ministry of Transport (MoT) prioritizes the implementation of investments and policies aimed at shifting freight and passenger transport from roads to inland waterways and coastal transport. Consideration should also be given to the promotion of electric mobility through two-wheeled vehicles and cars. Finally, the study recommends MoT deploy stricter vehicle fuel economy standards, as these measures have significant potential for emissions reductions based on their estimated negative NPVs (compared to BAU), indicating the benefits outweigh the costs of implementation.

Also worth noting: Some of the analyzed policies and measures—such as modal shift to inland waterways and rail—offer improvements in transport efficiency, which would reduce the cost of transport. Inland waterway transport requires one-quarter the costs of road transport, and railway requires one-half the costs of road transport, per ton-km, indicating the improved transport efficiency that results from a modal shift from trucking to cleaner transport modes offers added economic benefits. Furthermore, and importantly, the policies and measures considered for GHG mitigation also generate other associated benefits, such as a reduction of local pollutant emissions—which, in turn, provide health benefits for the local population.

In addition to the findings from the study results, the following are also critical to keep in mind:

- The need to consider "Avoid" measures not captured in this study, such as better integration between land-use and transport to help reduce unnecessary trips;
- The importance of considering long-term land-use and infrastructure planning, given their lock-in effects;
- The question of how to make economically cost-effective measures financially attractive to private investment;
- The need for even more ambitious mitigation measures to reverse the overall trends seen in the three scenarios of an increasing CO2 trajectory (despite a reduction in emissions against BAU) and decrease emissions in absolute terms
- The need for more cross-sectoral analysis to help avoid unrealistic proportional targets (e.g., 8 percent for all sectors), especially in developing countries where the transport sector is typically difficult for mitigation and energy (power generation) often offers easier and cheaper mitigation; and
- Transport solutions should never be enacted because of carbon prices alone, but because they are good sustainable transport solutions. A comprehensive framework should also assess mitigation measures according to their co-benefits, such as reduction in local emissions, quality of life, and health.

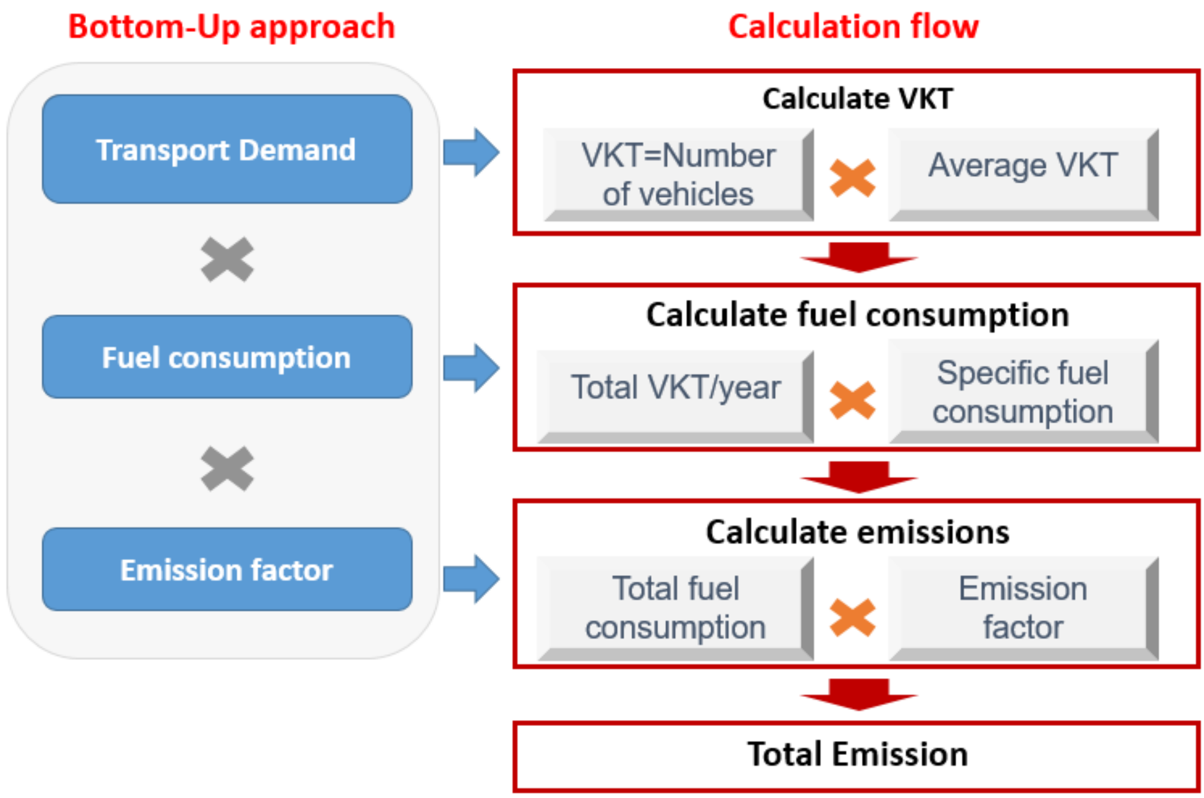
The relative emissions contribution of transport subsectors, the potential for emissions abatement, and the cost-effectiveness of measures that enact this abatement provide valuable information for dialogue among stakeholders and decision-makers on where to focus mitigation efforts. Through consideration of alternative scenarios discussed in this report, an actionable package of measures can be developed. In addition, an understanding of the each scenario's cumulative abatement and cost can also inform the dialogue on the desirable ambition level of actions and support target setting for the transport sector.

Appendices

A. GHG Emissions Inventory

Shown in figure A-A.1, the greenhouse gas (GHG) emissions inventory used a bottom-up approach to analyze, in a disaggregated manner, the relative sizes of emissions sources within the transport sector and facilitate the identification of levers for emissions reductions.

Figure A-A.1. Bottom-Up Approach Calculating the GHG Emissions in Transport Sector



B. Scenario Formulation

The study defined the GHG emissions scenarios based on different levels of ambition and international support:

- **The business-as-usual (BAU) scenario** that considers that after 2014 (base year), targeted policies and measures aimed at mitigating GHG emissions in the transport sector will not be deployed. This scenario also considered expected technological and socio-economic development forecasts for the country, such as evolution in demographics and gross domestic product (GDP), as defined in the country's Nationally Determined Contribution (NDC).
- **The non-conditional scenario** considers implementation of policies and measures—included in Vietnam's Transport Sector Master Plan—that enable the reduction of transport emissions of 10 percent, by 2030, without international support.
- **The conditional scenario** considers implementation of more ambitious policies and measures—included in Vietnam's Transport Sector Master Plan—to enable a reduction of transport emissions of 16 percent against BAU, by 2030, with international support.
- **The ambitious scenario** considers implementation of more ambitious policies and measures that go beyond those included in Vietnam's Transport Sector Master Plan, to enable a reduction of transport emissions of 22 percent against BAU, by 2030, with international support.

The base year for scenario analysis was selected as 2014 in reference and to be aligned with Vietnam's Second Biennial Updated Report (BUR2)[1] and the Third National Communication (2019)[2] submitted to the UNFCCC. The timeline of scenario analysis is 2020 to 2030/2040/2050, reflecting that 2020 to 2030 is of interest to the current NDC dialogue, while the 2030 to 2040 and 2050 timeframes enable consideration of policies and measures that may be implemented toward the end of the 2020 to 2030 period with long-term impacts.

The study selected policies and measures assigned to each scenario through the screening of existing laws and regulations, Vietnam's National Transport Plan, and other planning documents. After the identification of an initial list of policies and measures, government agencies and sector experts reviewed them to ensure clarity of assumptions and building consensus.

Notes

1. Available online at: http://unfccc.int/files/national_reports/non-annex_i_parties/biennial_update_reports/application/pdf/97620135_viet_nam-bur2-1-viet_nam_-_bur2.pdf.

2. Available online at: https://unfccc.int/sites/default/files/resource/Viet%20Nam%20-%20NC3%20resubmission%2020%2004%202019_0.pdf.

C. Modeling Methodology

Selection of Models

The study objectives required a suite of models that facilitated a detailed bottom-up analysis of transport activity in all sectors to determine the impact of policies and investments on the national greenhouse gas (GHG) emissions, and then to calculate the transportation sector's emissions scenarios for the Nationally Determined Contribution (NDC) update.

The desired features of this suite, as identified by national and international experts who are specialists in this field, included:

- Should analyze activity and emissions at the national level to 2030 and beyond (2050).
- Should calculate for all transport subsectors (road, rail, air, inland waterway/coastal, and maritime sector)
- Should analyze changes in travel demand and vehicle technologies in business as usual (BAU) and different mitigation scenarios
- Should calculate the economic costs of each policy change or other intervention
- Should provide results that can be integrated to analyze and compare marginal abatement costs (MACs) for emissions reduction from different policy interventions.
- Should easily integrate with the Ministry of Transport's GHG Excel-based inventory tool.
- Should be freely and fully accessible to Department of Environment (DoE) in the Ministry of Transport (MoT) to enable the department to maintain and update the model with new data, assumptions, and policy choices.

After detailed analysis of different options, the study chose the following suite of models:

EFFECT (Energy Forecasting Framework and Emissions Consensus Tool) is a free, Excel-based tool that can analyze various transport activity scenarios, including detailed technological and behavioral changes for the transportation and other sectors at the national level. As an Excel-based, engineering-style, bottom-up tool with some built-in optimization developed by the World Bank, EFFECT can be used by multiple stakeholders to build consensus around policy implementation to reduce GHG emissions, and is designed to facilitate a transparent sharing of data and assumptions.

Freely available from the World Bank, the tool is easily customizable to local requirements, such as analyzing specific activities and policies, and can be readily set up to run in any local language. It has an extensive self-paced training course provided through World Bank's Open Learning Portal (available at: https://olc.worldbank.org/content/low-carbon-development-planning-modelling-self-paced) and the World Bank has trained over 2,000 practitioners in facilitated courses. The model currently analyzes separately up to 250 vehicle types and technologies, including 28 low-carbon technologies, along with travel demand management (TDM) and other behavioral measures.

The EFFECT model met most of the abovementioned requirements. The model was first built by the World Bank for work on national energy planning analysis in India. Since then, EFFECT has been used in several other countries, including Brazil, Poland, Georgia, Macedonia, Malaysia, Indonesia, Thailand, Philippines, Nigeria, and Vietnam.

Use of EFFECT in Transport studies in Viet Nam

EFFECT has been used in Vietnam for transport studies over several cycles, providing continuity between studies and allowing each to build on data and analyses provided from previous studies, as listed in Table A-C.1.

Table A-C.1. Vietnam Transport Studies Using EFFECT

Year	Supported by	Study
2010	World Bank	*Winds of Change: East Asia's Sustainable Energy Future* Available online: http://documents.worldbank.org/curated/en/942471468244547200/Winds-of-change-East-Asias-sustainable-energy-future)
2011	Asian Development Bank	*Strengthening Planning Capacity for Low Carbon Growth in Developing Asia* Overview PPT: https://openei.org/w/images/2/25/Strengthening_Planning_Capacity_for_Low_Carbon_Growth_in_Developing_Asia.pdf
2013	World Bank	*Exploring a Low Carbon Development Path for Viet Nam* Available online: http://documents.worldbank.org/curated/en/773061467995893930/Exploring-a-low-carbon-development-path-for-Vietnam
2014	Asian Development Bank	*Viet Nam 2050: Evaluating longer-term options for low carbon development in Viet Nam*

Emissions calculation tool for the transport sector (Trigger) was developed for DoE and GIZ in early 2017 to calculate transport emissions for national GHG inventories. This tool includes some statistical data on traffic activity data, such as number of vehicles, traffic performance, and the total amount of fuel sold in 2015 according to all types of transport modes in Vietnam.

VISUM, a geographic information system (GIS)-based data management tool that simulates all transport modes, is used in traffic planning to analyze and forecast traffic volumes. Travel demand and performance of transport activities can be modeled based on socio-economic data, operating costs, transport infrastructure, etc. VISUM also provides input data of major cities (such as Hanoi and Da Nang), national roads, and express highways from previous analyses. Data for the entire national transport network in Vietnam can also be integrated from other sources.

LEAP is a free tool for all sectors. LEAP was used for Vietnam's Intended Nationally Determined Contribution (INDC, or NDC) in 2015 and was planned for use in the next NDC. While LEAP includes the transport sector, it is applied only at a more macro level than other tools, which severely limits its ability to analyze the emissions impact and cash flow implications of individual transport policy interventions. Previous data available in LEAP can be a source of input data (such as GDP and population projections) for other models.

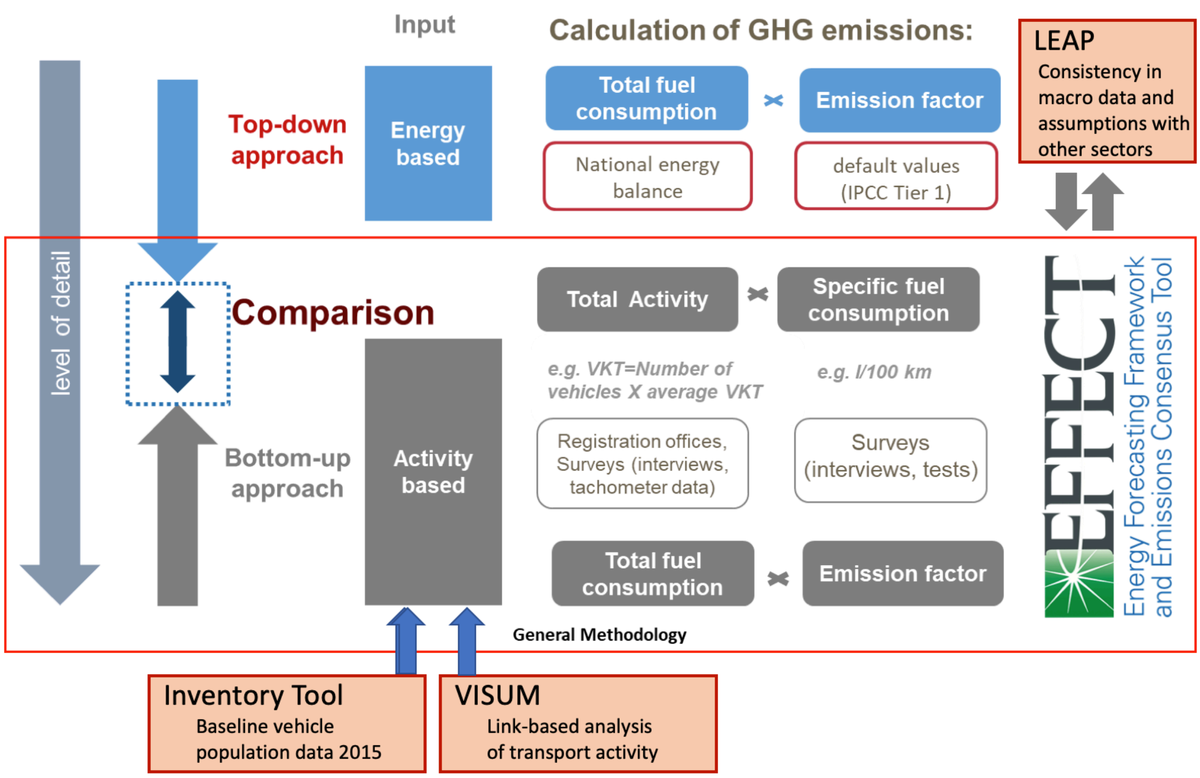
Based on discussions, the study agreed that EFFECT would be used as the main tool for calculating scenarios. Other models (either listed or not listed here) may be used to complement the calculation. In order to combine current data, the study suggested the following steps:

- Include basic data (2014) from the inventory tool into EFFECT (to be consistently used in other complementary models)
- Include socio-economic data for BAU associated with NDC
- Build consensus among stakeholders on the future inclusion of technology and behavioral mitigation scenarios, based on agreed plausible policy interventions and calculations from other scenarios.
- Forecast future travel demand for BAU scenario, using calculations in EFFECT and analyzing in VISUM if necessary.
- Provide results of calculated transport parameters, such as vehicle kilometers traveled (VKT), passenger-kilometers (PKM), and ton-kilometers (TKM), emissions, and fuel use produced in EFFECT to the NDC team, to ensure consistency with LEAP-based forecasts.

The use of EFFECT, together with VISUM, to estimate travel demand would be further elaborated based on group discussions, workshops, and analysis of probability of results (within certain limitations on time and budget).

Figure A-C.1 illustrates how the study integrated the suite of models for scenarios calculation.

Figure A-C.1. Integration of Models for Scenarios Calculation



EFFECT Methodology

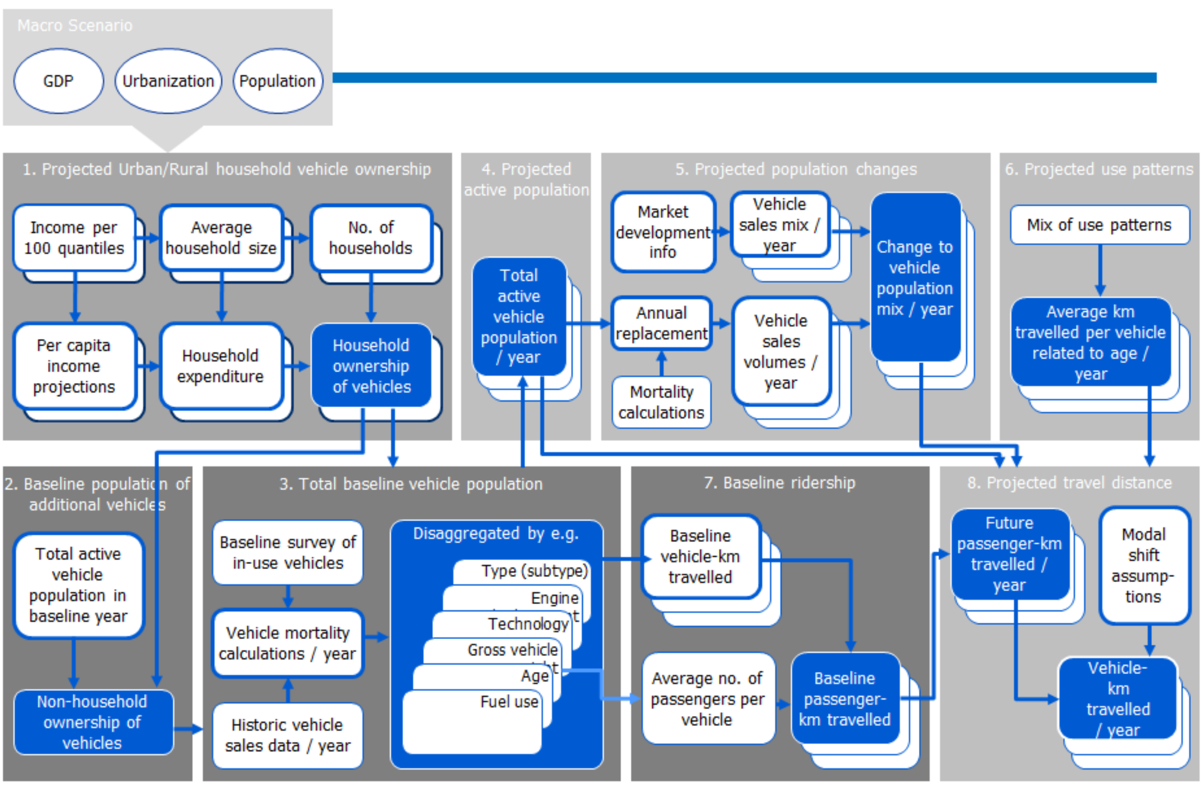
The EFFECT methodology and use is documented in a stand-alone user manual.

In the following figures, also listed in table A-C.2, the calculation flow schematic is shown for each subsector. With a base year of 2014, the model calculates over a modeling window of up to 2055.

Table A-C.2. Calculation Flow Schematics by Sector

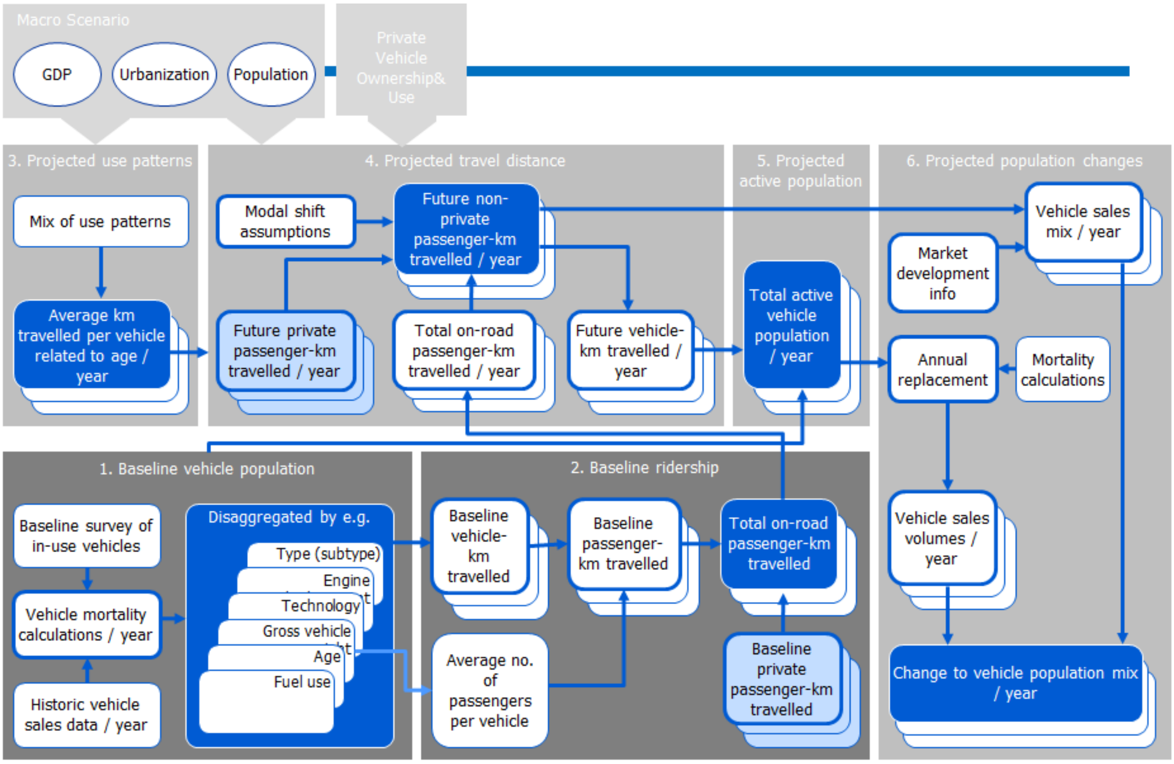
Figure	Contents
A-C.2	Calculation Flow Schematic for Passenger Cars and Motorcycles
A-C.3	Calculation Flow Schematic for Passenger Mass Transport (Light Commercial Vehicles, Buses, and Coaches)
A-C.4	Calculation Flow Schematic for On-Road Freight Transport (Light, Medium and Heavy-Duty Vehicles, Trucks, and Tractor-Trailers)
A-C.5	Calculation Flow Schematic for the Fuel Efficiency and Emissions Calculations for All On-Road Vehicles
A-C.6	Calculation Flow Schematic for Passenger and Freight Rail Transport (Metro, Light Rail, High-Speed Rail, Suburban and Mainline Passenger and Freight Service)
A-C.7	Calculation Flow Schematic for Waterborne Passenger and Freight Transport (Inland Waterways and Coastal Shipping)
A-C.8	Calculation Flow Schematic for Civil Aviation (National Passenger and Freight, Plus International Passenger and Freight for Bunker Calculations)

Figure A-C.2. Calculation Flow Schematic for Passenger Cars and Two-Wheelers



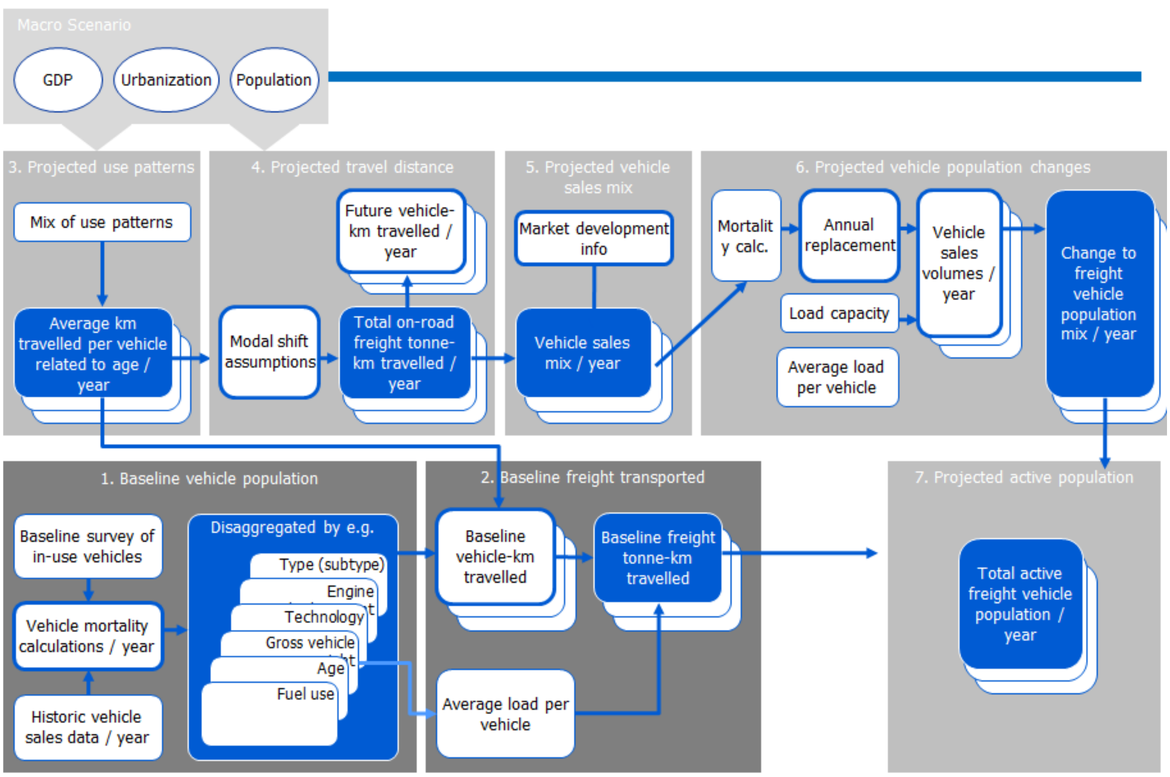
Note: Passenger cars and two-wheelers include private, commercial, and government vehicle ownership and use.

Figure A-C.3. Calculation Flow Schematic for Passenger Mass Transport



Note: Passenger mass transport includes light commercial vehicles, buses and coaches.

Figure A-C.4. Calculation Flow Schematic for On-Road Freight Transport



Note: On-road freight transport includes light, medium and heavy-duty vehicles, trucks, and tractor-trailers.

Figure A-C.5. Calculation Flow Schematic for the Fuel Efficiency and Emissions Calculations for All On-Road Vehicles

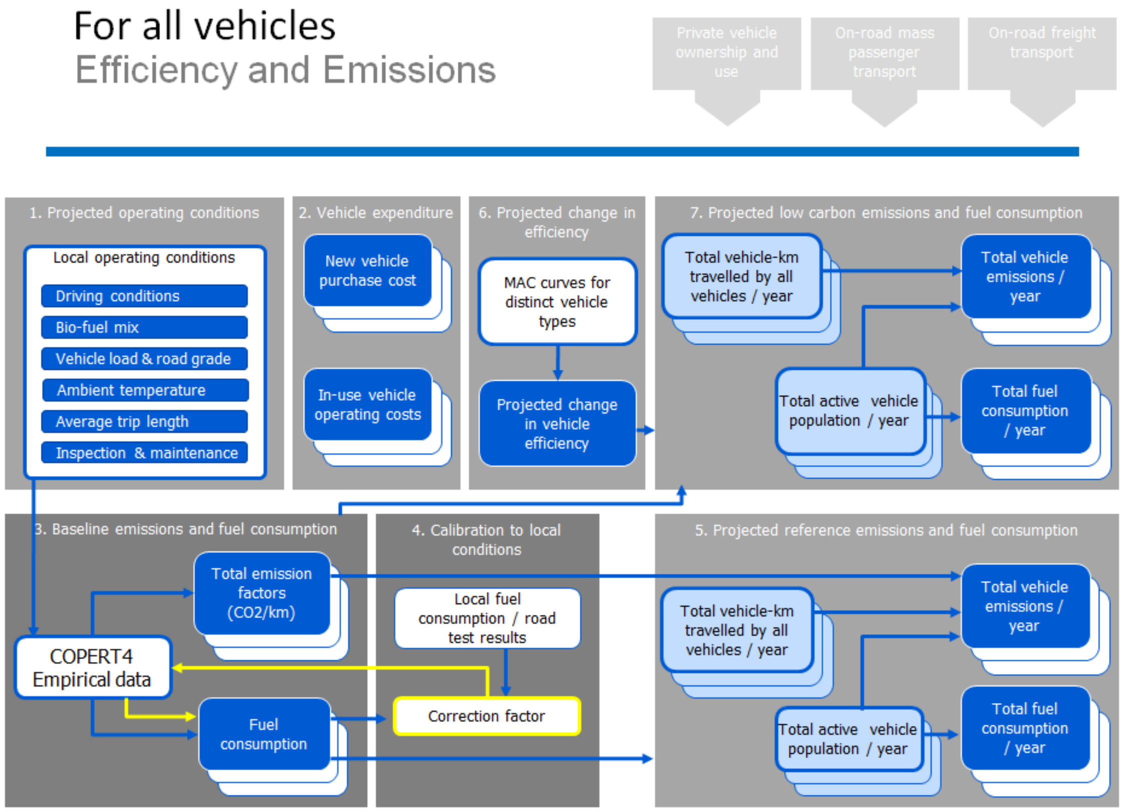
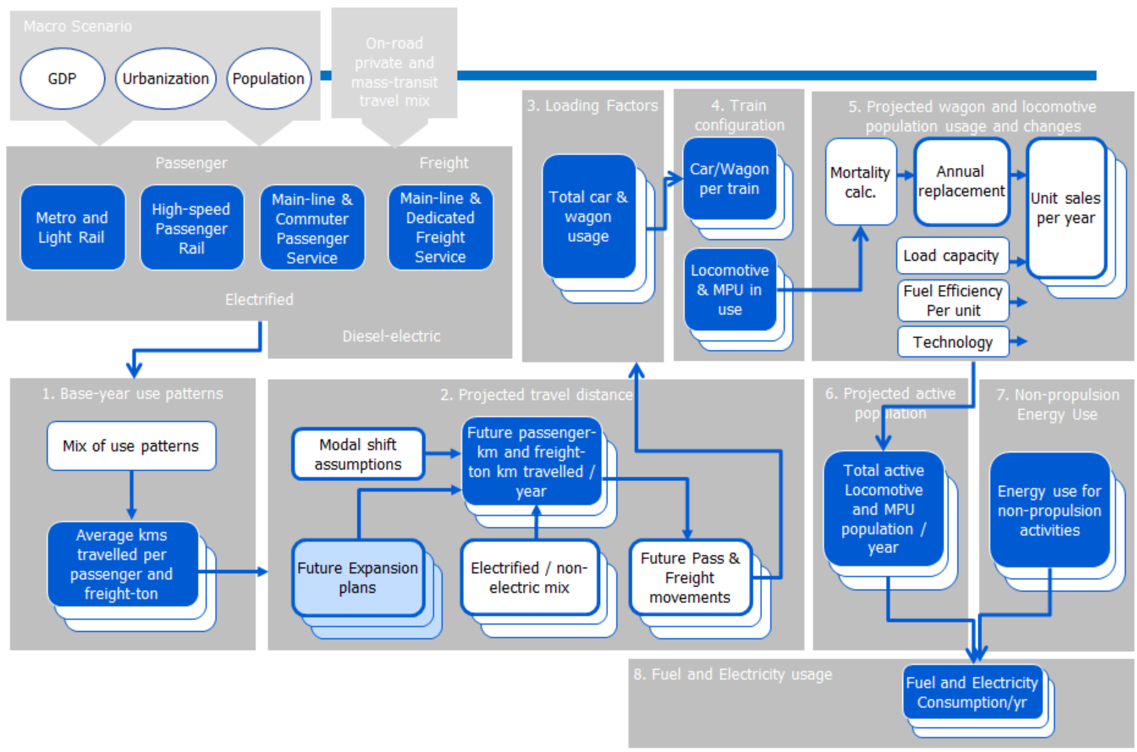
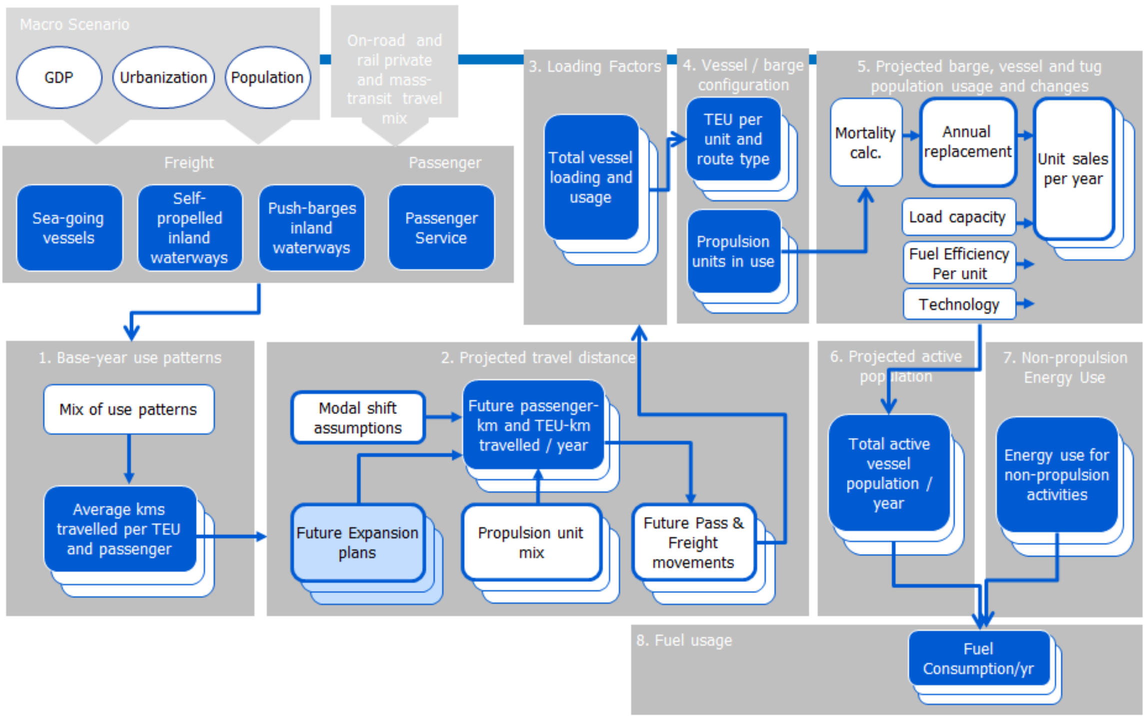


Figure A-C.6. Calculation Flow Schematic for Passenger and Freight Rail Transport



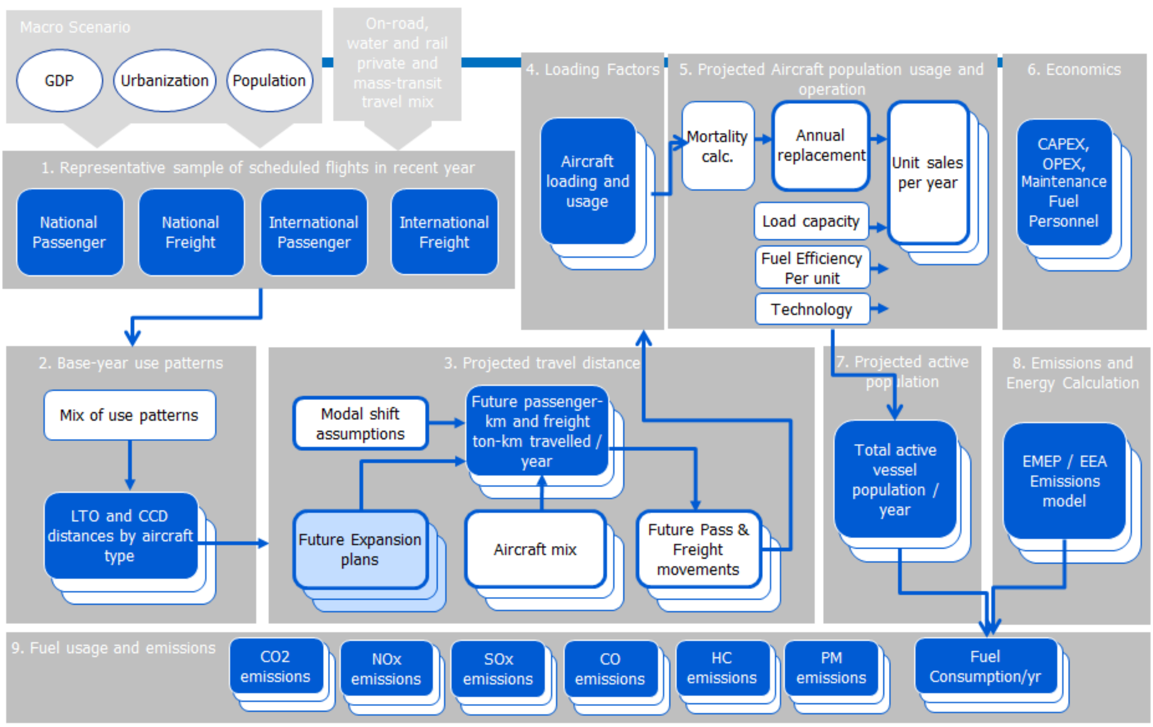
Note: Passenger and freight rail transport includes metro, light rail, high-speed rail, suburban, and mainline passenger and freight service.

Figure A-C.7. Calculation Flow Schematic for Waterborne Passenger and Freight Transport



Note: Waterborne passenger and freight transport includes inland waterways and coastal shipping.

Figure A-C.8. Calculation Flow Schematic for Civil Aviation



Note: Civil aviation includes national passenger and freight, plus international passenger and freight for bunker calculations.

D. Key Data and Assumptions

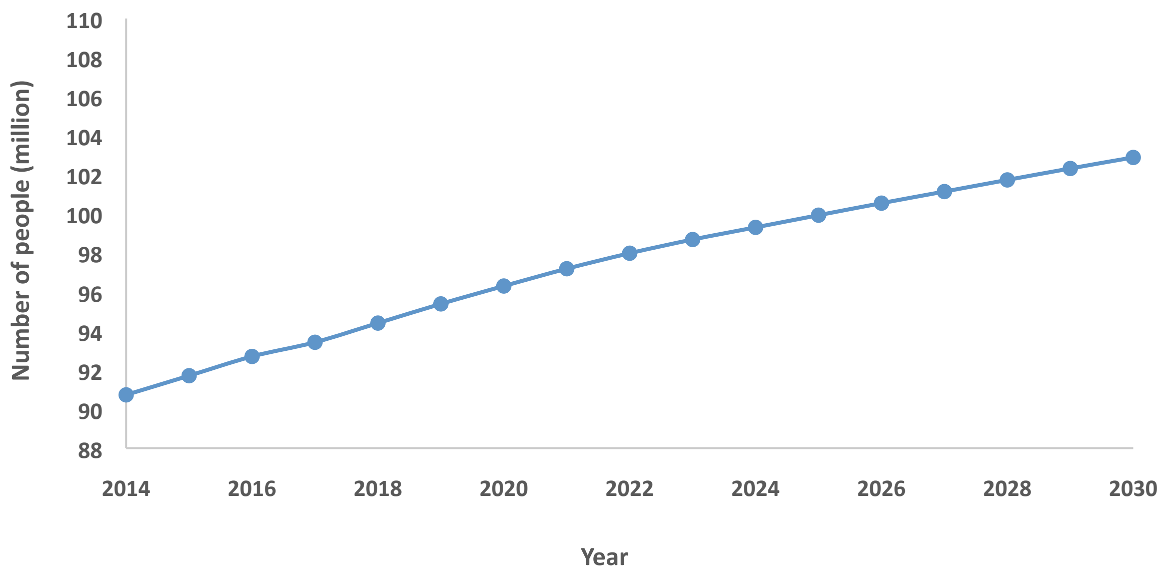
The key data and assumptions that support this analysis are arranged below according to information group, including:

General Information

Gross domestic product (GDP). According to statistics provided by the General Statistics Office (GSO),[1] Vietnam's GDP grew at 6.0 percent in 2014 and 6.7 percent in 2015. Expected GDP growth rate is 7 percent from 2015 to 2030, as defined by the Decision 428/QD-TTg on the *National Power Development Plan Adjustment for the period 2011 to 2020, with vision up to 2030*.[2]

Population. GSO statistics indicate the Vietnam population reached 90.7 million people in 2014.[3] As shown in figure A-D.1, Population projection for the period from 2015 to 2030 is based on Vietnam's Population Forecast 2016, conducted by GSO and the United Nation Population Fund (UNFPA).

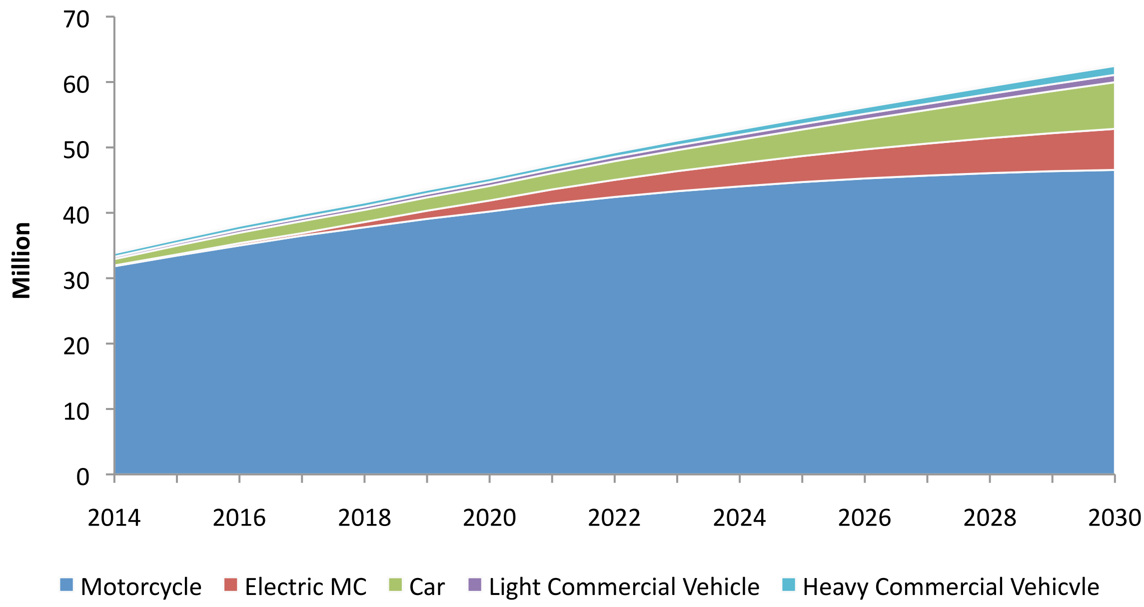
Figure A-D.1. Population Projection from 2015 to 2030



Data on Road Transport

Number of vehicle fleets. The study collected 2014 data for the number of vehicle fleets from official reports prepared by the Vietnam Register (http://vr.org.vn) as well as inland waterway transport, maritime, aviation, and railway authorities. The GSO's yearly statistics books provided another crucial source of data. Figure A-D.2 illustrates the increase of road vehicles.

Figure A-D.2. Total Road Vehicle Fleet in Vietnam from 2014 to 2030



In 2014, motorcycles occupied 94 percent of the total vehicle fleet; by 2030, this number is projected to reduce to 82 percent, with ownership rate projected to reach 513 motorcycles per 1,000 population.

Conversely, private passenger cars have experienced a fast growth rate, reaching 1 million in 2014, and should continue to increase to a projected 7.1 million by 2030. The economy increase takes an increase of mean monthly household expenditure (MMHE) as a surrogate for income, which leads to the ownership rate of cars increasing. The ownership rate for cars is projected to reach 56 cars per 1,000 population.

In the business as usual scenario (BAU), the growth of electric vehicles remains low, with electric vehicles accounting only for 2.5 percent of the vehicle fleet in 2030.

In 2030, light commercial vehicles (LCVs) are expected to see growth rates three times compared to 2014. LCVs include goods carriers (mostly small trucks less than 3.5 GVW and a growing share of light pick-up trucks), and passenger vans. Goods carriers are suitable for short-distance transport in both urban and rural areas. Forecasts call for the number of lighter pick-up trucks used to carry goods to account for 47 percent of the total LCVs in 2030.

In 2030, heavy commercial vehicles (HCVs) for goods and passenger coaches, operating mainly on long- and medium-distance routes, are expected to increase 2.5 times compared to 2014. In 2014, the medium-sized trucks (7 to 16 tons GVW) accounted for 28 percent of the total fleet, and are expected to claim a 40 percent share by 2030.

Transport volume. Table A-D.1 and figure A-D.3 show GSO statistics for passenger-km transported (PKT) and freight ton-km transported (FTKT) in base year 2014.

Table A-D.1. Passenger Km-Traveled and Freight Ton-Km Transported in 2014

Passenger/Freight	Total	Railway	Road	IWT	Coastal shipping	Aviation
Passenger km-traveled (E+09)	139.1	4.5	96.9	3.0		34.7
Freight ton-km transported (E+09)	223.2	4.3	48.2	40.1	130.0	0.5

PKT is projected based on the relation between passenger-km per capita and GDP per capita. FTKT is projected based on the elasticity between the growth rate of FTKT and GDP growth rate. As illustrated in figure A-D.3, on-road PKT (private and commercial) accounts for 94 percent in 2030, with the PKT for private vehicles comprising 74 percent of the total PKT.

Figure A-D.3. Passenger Kilometer Traveled (PKT) from 2014 to 2030

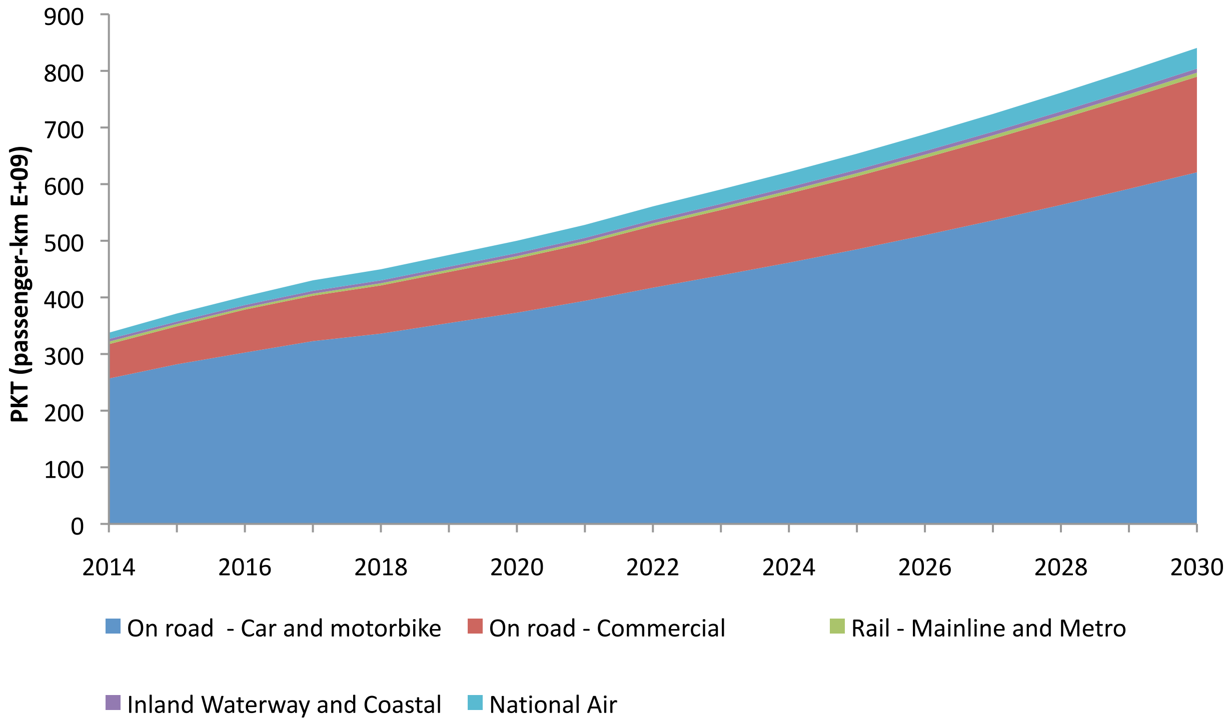
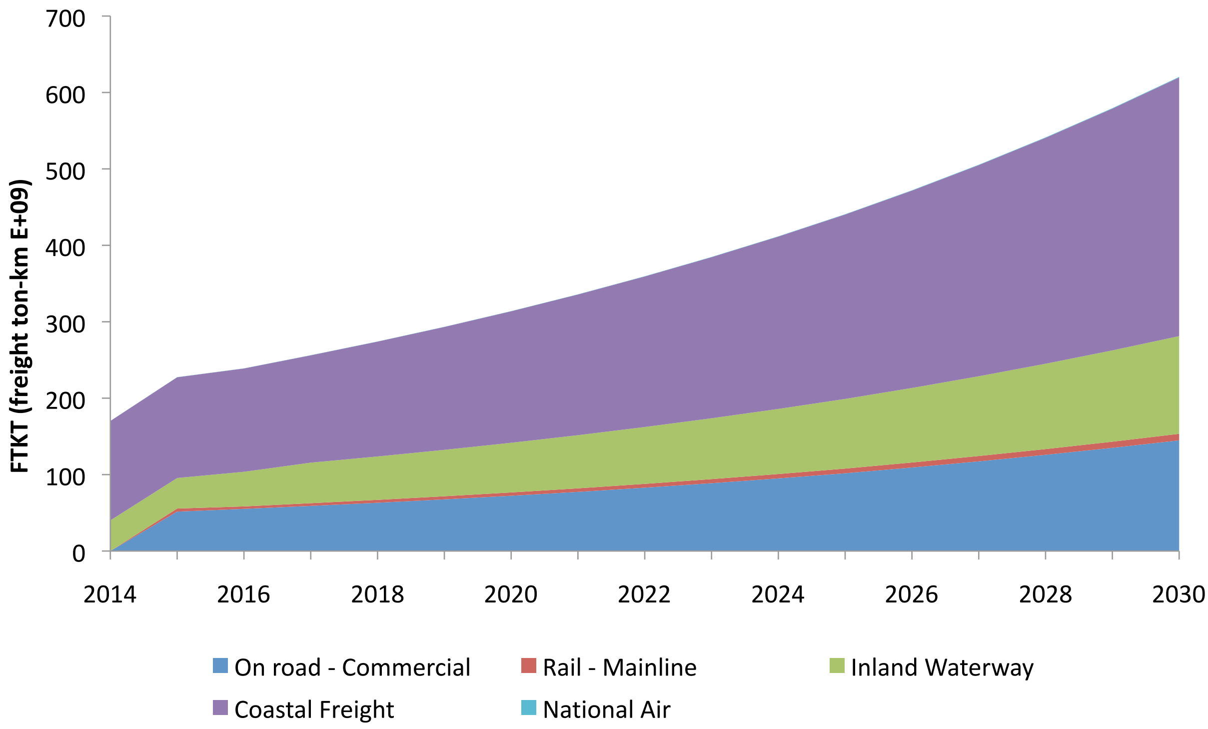


Figure A-D. 4 details the projected FTKT, showing the coastal transport contributing 55 percent of FTKT. Road and waterway accounts for 22.3 percent and 20.6 percent respectively, with other transport modes combined making up only 1.5 percent.

Figure A-D.4. Freight Ton-Kilometer Transported (FTKT) from 2014 to 2030



Notes

1. GSO statistic for 2014 GDP growth rate accessed online at: https://www.gso.gov.vn/default_en.aspx?tabid=784.

2. GSO population statistics for Vietnam accessed online at: https://www.gso.gov.vn/default_en.aspx?tabid=774.

3. More information on Decision 428/QD-TTg available via the MOIT/GIZ Energy Support Programme. See: http://www.gizenergy.org.vn/media/app/media/PDF-Docs/Legal-Documents/PDP%207%20revised%20Decision%20428-QD-TTg%20dated%2018%20March%202016-ENG.pdf.

E. MACC Methodology

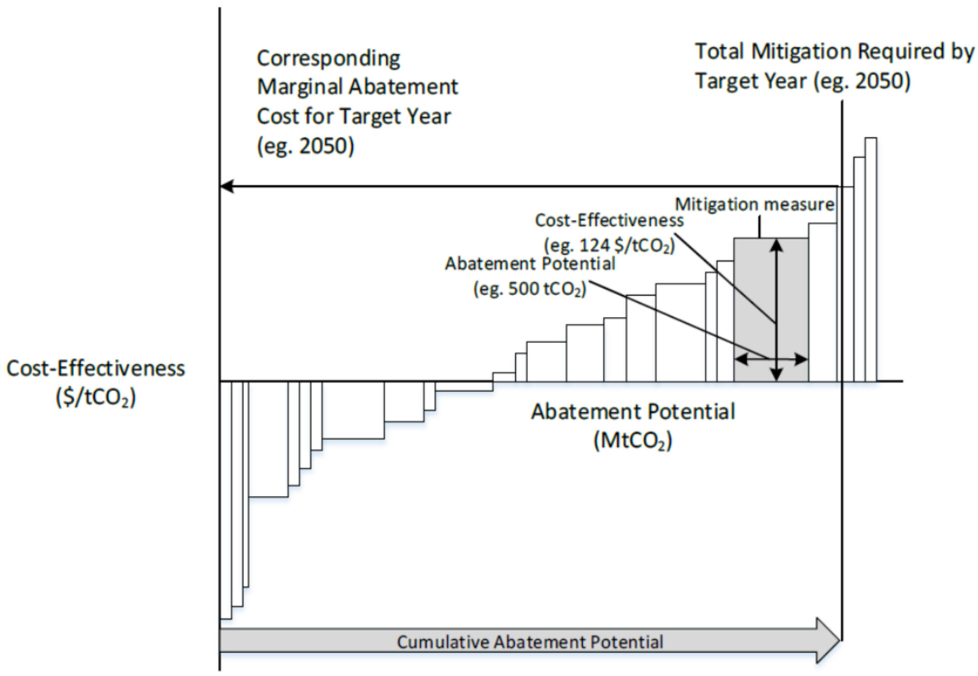
What is a MACC?

The marginal abatement cost (MAC) analysis provides information on the greenhouse gas (GHG) mitigation potential (tCO_2e) of a policy or measures and the cost for unit of GHG emissions mitigation ($\$/tCO_2e$). See figure A-E.1. This information on cost-effectiveness is useful to inform dialogue among stakeholders and should be complemented with information on feasibility and analysis of other costs and benefits not included in the analysis.

Mitigation measures are then placed from lowest to highest cost-effectiveness, where each measure is represented as a step along the MAC curve, or MACC, plot. The y-axis is the marginal abatement cost of GHG emissions ($\$/tCO_2e$), where the height of each step represents the net present cost (incremental costs less benefits) of the mitigation measure per ton of CO_2e reduction over the analysis period. The x-axis is the abatement potential of GHG emissions (tCO_2e), where the width of each step represents the GHG abatement potential of a mitigation measure during the analysis period. The y-axis is the marginal cost implicit in achieving this abatement. The height of the step is the total marginal cost for the CO_2e abatement potential achieved by the mitigation measure.

The cumulative emissions reduction achieved by the prioritized mitigation measures is obtained by adding the abatement potential of each of the mitigation measures plotted. Measures that fall below zero on the y-axis reflect a negative cost-effectiveness, which means the measures offer net savings (benefits exceed costs). Measures that appear above zero, reflect a positive cost-effectiveness, which means the measures have costs that exceed their benefits. Therefore, MACC provides a quantitative basis for discussions about which measures would be most effective in delivering emissions reductions, and what they might cost. Accordingly, the MACC informs decisions on which measures should be implemented voluntarily through domestic resources and which should be implemented with international support (conditional measures).

Figure A-E.1. Marginal Abatement Cost Curve Components



Once the measures have been selected and confirmed, MACC is also helpful in developing enabling policies for implementation. For measures with negative abatement costs—very cost-effective and usually implemented by domestic resources—enabling policies aim at reducing barriers, risks, and hidden costs. For measures with costs above zero—but lower than a certain level[1] and thus implemented with conditions—policies should aim at reducing costs, risks, and offering concessional finance. For measures whose costs are above capped level, the policies should aim at research and development to make those measures implementable as soon as possible.

How is a MACC developed? The Marginal Abatement Cost, $\mathrm{MAC_{MM}}$ (\$/tCO_2e), is calculated using data for incremental costs and incremental emissions savings achieved by the mitigation measure, along with and the emissions savings over the analysis period (Equation 1). In the case of large investment projects, it is preferable to calculate the marginal abatement cost over the lifetime of the investment.

$$MAC_M = NPV_{INC,MM}/E_{MM} \qquad (1)$$

Where:

MAC_M = marginal abatement cost of the mitigation measure over the analysis period in thousand VND per ton of CO_2e reduction (thousand VND/tCO_2e);

NPV_{INCMM} = Net present value (NPV) of the difference in cash flow (costs and benefits) of the mitigation measure over the analysis period (thousand VND); and

E_{MM} = reduction in GHG emissions over the analysis period (tCO_2)

An economic analysis evaluates the costs and benefits of each measure to the country. The analysis examines the costs and benefits of mitigation measures relative to a business-as-usual (BAU) scenario, which should reflect what could have happened if that particular mitigation policy or intervention not been implemented. The difference in costs (between the BAU and mitigation scenarios) should include differences in capital costs, operating costs, and fuel costs relevant to energy use—and should not include transaction costs and taxes. Benefits are limited to cost savings associated with reductions in energy consumption and GHG emissions, and do not include co-benefits such as avoided environmental damages, health costs, and other social problems.

Key data and assumptions

The base year for the marginal abatement cost (MAC) analysis is 2014, with the analysis period from 2014 to 2030 aligning with the Nationally Determined Contribution (NDC) update assumptions and prior communication by the Ministry of Natural Resources and Environment (MoNRE). However, to show a more comprehensive picture of impact, particularly for key measures, which are implemented after 2020—metro rail transport (MRT), for example—an extended analysis period, from 2014 to 2050, allows a more comprehensive account of the resultant impact on GHG emissions.

All cost components in the model are valued in constant 2014 prices, but are presented in 2018 prices in this report to provide a better sense of costs. Traditionally, the World Bank uses a discount rate between 10 percent and 12 percent for all World Bank-financed projects. In this analysis, a discount rate of 10 percent is applied to align with the NDC update assumption. The analysis uses the 2014 exchange rate of 1 US$ = VND 21,890.

Fuel prices. The study used the data presented in table E.1 for fuel prices.

Table A-E.1. Fuel Prices

In thousand VND per ton

Fuels	2014	2015	2020	2025	2030
Fuel oil (FO)	14,589	12,705	15,995	21,966	23,898
Diesel oil (DO)	20,693	17,516	22,391	31,007	33,734
Jet fuel	18,943	14,326	26,511	30,808	32,864
Petro	25,631	19,218	25,476	28,684	29,555
CNG	14,677	12,423	18,527	27,490	29,907

Note: Prices for 2014 and 2015 are based on Petrolimex and are actual prices after removing applicable taxes and fees. Prices after 2015 are based PDP7 revised for DO and FO and *Annual Energy Outlook 2018* by the EIA (https://www.eia.gov/outlooks/aeo/pdf/AEO2018.pdf) for others.

Vehicle prices. Vehicles purchase prices and operating costs are calculated based on a reference technology for each vehicle type. The reference technology is assumed to be that of the vehicle with highest market penetration. For example, the Kia Morning defined the reference technology for less than a 1.4-liter car, while the Honda Wave defined the reference technology for motorcycles.

The purchase price for buses include GPS system, LED boards, and communications. Future costs are forecast based on past trends and consideration of technology evolution, such as the introduction of electric cars in fleets. Costs are also defined based on a literature review. For example, the operation and maintainence (O&M) cost for trucks is based on a World Bank study, *Strengthening Vietnam's Trucking Sector for Lower Logistics Costs and GHG Emissions* (Lam et al 2019).

Traditionally, the World Bank has used a discount rate of 10 percent to 12 percent for all Bank-financed projects. In this analysis, a discount rate of 10 percent is applied to align with the assumptions used in the revision of Vietnam's NDC. The exchange rate used is for 2014 (1 US$ = VND 21,890).

Railway. The study used the data shown in table A-E.2 to define railway costs.

Table A-E.2. Railway Costs Assumptions

Cost type	Cost items	Unit	Value	Data source
Investment costs	Diesel locomotive	Thousand VND	15,760,800	*Vietnam Express* news article (2004): https://vnexpress.net/tin-tuc/thoi-su/vn-mua-20-dau-may-xe-lua-moi-cua-trung-quoc-2000471.html
	Passenger car	Thousand VND	10,600,000	*Tuoi Tre* news article (2018): https://tuoitre.vn/dua-6-doan-tau-moi-vao-khai-thac-tuyen-duong-sat-thong-nhat-20180110224437811.htm
	Freight car	Thousand VND	6,911,000	
O&M costs	Operating cost	Thousand VND per locomotive-km	44.6	Lam et al 2019
	Operating cost	Thousand VND per car-km	5.1	
	Infrastructure cost	Thousand VND per train-km	16.2	
	Personnel cost	Thousand VND per train-km	1.3	
	Passenger handling, Train control, management	Thousand VND per train-km	41.8	

Fuel economy standards. The study used the data in tables E.3 through E.6 for vehicle emissions and fuel economy standards.

Table A-E.3. Vehicle Emissions Standards

Vehicle type	2014	2017	2022
Motorcycle	Euro 2	Euro 3	—
Car	Euro 2	Euro 4	Euro 5

Note: — = not available.

Table A-E.4. Fuel Economy for Cars

Vehicle size	2022 (l/100km)	2027 (l/100km)	Gasoline density (kg/l)	2022 (g/km)	2027 (g/km)
Small car (<1.4L)	6.1	4.7	0.74	45.14	34.78
Medium car (<2.0L)	7.52	5.3	0.74	55.65	39.22
Large car (>2.0L)	10.4	6.4	0.74	76.96	47.36

Table A-E.5. Road Map for Fuel Economy for Cars

Vehicle size	2022	2023	2024	2027	2028	2029
Small car (<1.4L)	50%	75%	100%	50%	75%	100%
Medium car (<2.0L)	50%	75%	100%	50%	75%	100%
Large car (>2.0L)	50%	75%	100%	50%	75%	100%

Table A-E.6. Fuel Economy for Motorcycles

	2025	2026	2027
Road map	50%	75%	100%
Fuel economy (L/100km)	2.3	2.3	2.3

Notes

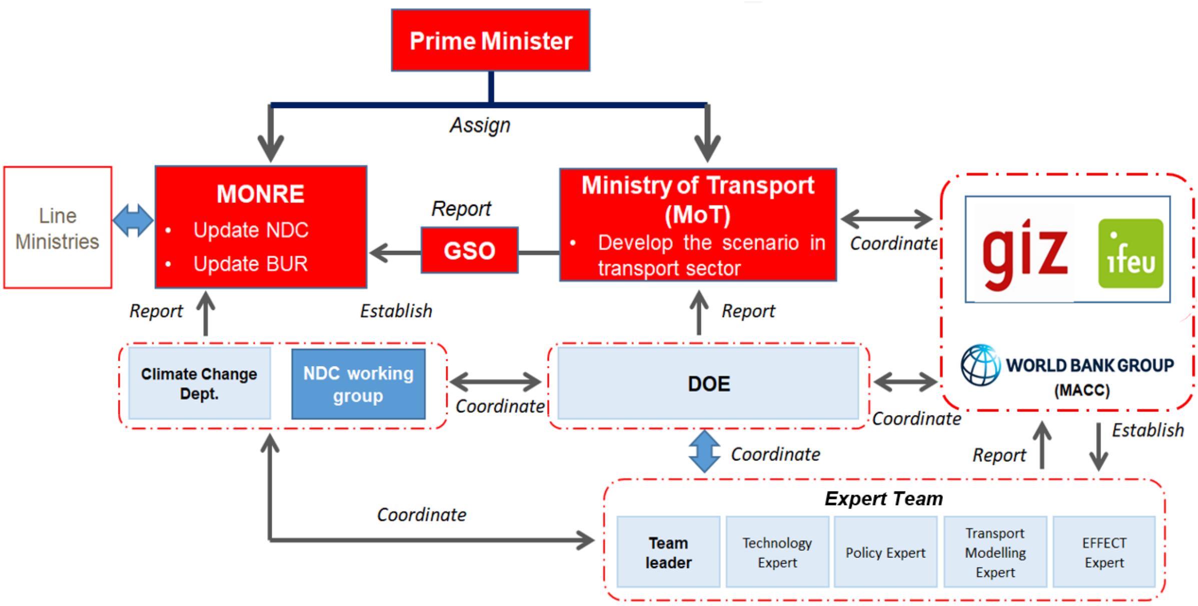
1. The shadow price for carbon is most often used. When setting CO_2 emissions reduction targets for the Green Growth Development Strategy, the level of US$10/t$CO_2$e) was adopted.

References

Lam, Yin Yin, Kaushik Sriram, and Navdha Khera. 2019. *Strengthening Vietnam's Trucking Sector: Towards Lower Logistics Costs and Greenhouse Gas Emissions*. Vietnam Transport Knowledge Series. Washington, DC: World Bank Group. http://documents.worldbank.org/curated/en/165301554201962827/Strengthening-Vietnam-s-Trucking-Sector-Towards-Lower-Logistics-Costs-and-Greenhouse-Gas-Emissions.

F. Coordination of Technical Assistance

Figure A-F.1. Institutional Arrangements and GIZ/WBG Technical Assistance: Flowchart for Project Implementation



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