ASEAN Fuel Economy Roadmap for the Transport Sector 2018-2025: with Focus on Light-Duty Vehicles

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one identity
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ASEAN Fuel Economy Roadmap for the Transport Sector 2018-2025: with Focus on Light-Duty Vehicles

The ASEAN Secretariat
Jakarta

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Catalogue-in-Publication Data

ASEAN Fuel Economy Roadmap for Transport Sector 2018-2025: With Focus on Light-Duty Vehicles
Jakarta, ASEAN Secretariat, February 2019

388.0959
1. ASEAN – Transportation – Policy
2. LDV – Fuel Economy Platform

ISBN 978-602-5798-32-0

ISBN 978-602-5798-32-0

9 786025 798320

ASEAN: A Community of Opportunities for All

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german cooperation
DEUTSCHE ZUSAMMENARBEIT

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

The ASEAN Fuel Economy Roadmap for the Transport Sector 2018-2025: With Focus on Light-Duty Vehicles has been produced with the support of the German international development agency Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) under the ASEAN-German Technical Cooperation Project on Energy Efficiency and Climate Change Mitigation in the Land Transport Sector of the ASEAN Region Phase II, funded by the German Federal Ministry for Economic Cooperation and Development.

General information on ASEAN appears online at the ASEAN Website: www.asean.org

Table of Contents

Table of Figures, Tables and Boxes

Abbreviations

2DS	2-degree scenario
8DCT	8-gear dual-clutch transmission
ACE	ASEAN Centre for Energy
ADB	Asian Development Bank
ADEME	French Environment and Energy Management Agency (*Agence de l'Environnement et de la Maîtrise de l'Énergie*)
AMS	ASEAN Member States
APAEC	ASEAN Plan of Action for Energy Cooperation
ASEAN	Association of Southeast Asian Nations
ASI	avoid-shift-improve
AtkCPS	Atkinson cycle engine with cam phase shifting
BAU	business as usual
BEV	battery electric vehicle
BMS	benchmark scenario
BOI	board of investment
CAFE	corporate average fuel economy
CBA	cost benefit analysis
CEGR	cooled exhaust gas recirculation
CEVS	carbon emissions-based vehicle scheme
CNG	compressed natural gas
CO_2	carbon dioxide
DEDE	Department of Alternative Energy Development and Efficiency
DLT	Department of Land Transport
ED	Excise Department
EE&C-SSN	Energy Efficiency and Conservation Sub-Sector Network
EEA	European Environmental Agency
EGSLT	Expert Group on Sustainable Land Transport
EPPO	Energy Policy and Planning Office
EU	European Union
EV	electric vehicle
EVI	Electric Vehicle Initiative
FEPIT	Fuel Economy Policy Impact Tool
FEPS	Fuel Economy Policy Scenario

gCO_2	gramme carbon dioxide
GDP	gross domestic product
GFEI	Global Fuel Economy Initiative
GHG	greenhouse gas
GIZ	German international development agency (*Gesellschaft für Internationale Zusammenarbeit*)
GVW	gross vehicle weight
HC	hydro carbon
HDV	heavy-duty vehicle
HEPS	High Energy Performance Standard
HFT	heavy freight truck
ICCT	International Council on Clean Transportation
ICE	internal combustion engine
IEA	International Energy Agency
IMMA	International Motorcycle Manufacturers Association
ITF	International Transport Forum
JC08	Japan Chassis 08
kg	kilogramme
KLTSP	Kuala Lumpur Transport Strategic Plan
km/L	kilometre per litre
kW	kilowatt
L	litre
L/100km	litre per 100 kilometres
LCV	light commercial vehicle
LDV	light-duty vehicle
LGE	litres of gasoline equivalent
LGe/100km	litres of gasoline equivalent per 100 kilometres
LPG	liquified petroleum gas
M5	manual 5-gear transmission
MEPS	Minimal Energy Performance Standard
MFT	medium freight truck
MPV	multi-purpose vehicle
Mt	megatonne
Mtoe	megatonne of oil equivalent
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contribution
NEDC	New European Driving Cycle

NMT	non-motorised transport
NO	nitrous oxide
NO_2	nitrous dioxide
OBD	on board diagnostic
OECD	Organisation for Economic Co-operation and Development
OICA	International Organization of Motor Vehicle Manufacturers (*Organisation Internationale des Constructeurs d'Automobiles*)
OIE	Office of Industrial Economics
ONEP	Office of Natural Resources and Environmental Policy and Planning
OTP	Office of Transport and Traffic Policy Planning
PC	passenger car
PCD	Pollution Control Department
PHEV	plug-in hybrid electric vehicle
PLDV	passenger light-duty vehicle
PM	particulate matter
PPM	parts per million
PTIT	Petroleum Institute of Thailand
RL	road load
SGTDI	stoichiometric gasoline turbocharged direct injection
SOx	sulphur oxides
SS	start stop
SUV	sports utility vehicle
TAI	Thailand Automotive Institute
TISI	Thai Industrial Standards Institute
UNEP	United Nations Environment Programme
VAT	value added tax
VTPI	Victoria Transport Policy Institute
WHVC	World Heavy Duty Vehicle Cycle
WLTC	Worldwide Harmonized Light-Duty Vehicles Test Cycle

Preface

Within the next ten years, passenger car travel is projected to double across the ten Member States of the Association for Southeast Asian Nations (ASEAN) (IEA 2012a). By 2025, sales of passenger cars are estimated to be well above 3 million cars per year, from about 1.5 million in 2015 (OICA 2016). With increasing car ownership but overall still low motorisation levels in ASEAN, it is realistic to expect substantial further growth in motorisation, along with growth in fuel consumption and emissions of CO_2 and other pollutants. As a result, stepping up fuel economy policy efforts is vital for making these growth trends compatible with climate change efforts, including towards urban air quality and the need for resource efficiency.

Sustainable transport has been identified as a fundamental pillar of ASEAN's regional transport agenda under the Kuala Lumpur Transport Strategic Plan 2016-2025 (KLTSP). Energy efficiency of transportation is a key aspect of the plan's Sustainable Transport Strategic Goal, making fuel economy policy a priority for cooperation and implementation across the region.

This document provides a roadmap for the development and implementation of fuel economy policies for ASEAN Member States (AMS), aimed primarily at regulators in government agencies who are or who should be involved in fuel economy policy development. The roadmap is intended to serve as catalyser to engage all relevant stakeholders from government, industry and academia. It not only addresses experts but can also be used to inform the interested public about the issue of vehicle fuel economy.

This roadmap is meant to be used to advance fuel economy policies within the AMS, and also for AMS to venture together towards more coherent and eventually common policy approaches. It neither aims at a one-size-fits-all approach, nor does it provide country-specific policy proposals. Rather, it offers a policy toolbox that presents fuel economy policy measures, different data and regulatory requirements, and the steps for introducing them.

A vision, set of goals and list of recommended actions is presented as a comprehensive set of recommendations for AMS to establish and implement successful fuel economy policies, aiming for a common approach across ASEAN where possible. Furthermore, a comprehensive annex is included, with detailed information on each topic of the roadmap, such as global trends, country case studies, fuel economy policies of AMS, and related issues like clean fuels, electric mobility, two-wheelers, freight vehicles, and more.

The vision, goals and policy recommendations in this roadmap are non-binding and recognise the right of ASEAN and each AMS to develop their own goals and policies. Nevertheless, the roadmap is meant to be a guideline for future regional and national initiatives in the region.

Executive summary

Current status in the ASEAN region

Automotive fuel economy is part of the regional transport agenda of the Association of Southeast Asian Nations (ASEAN) through the Kuala Lumpur Transport Strategic Plan 2016-2025 (KLTSP). This roadmap implements the KLTSP's Sustainable Transport Milestone 1.3.2, which is to 'formulate a fuel economy roadmap for the transport sector in ASEAN including policy guidelines.' Fuel economy is represented in this document as a reduction in fuel consumption per 100 km.

Motorisation in ASEAN is on a growth path, along with increasing incomes and car ownership. However, overall motorisation levels remain relatively low in many ASEAN Member States (AMSs). Passenger car travel is projected to double within the ASEAN region within the next ten years (IEA 2012a), and sales of passenger cars could rise above 3 million cars per year by 2025, from about 1.5 million in 2015 (OICA 2016).

However, the light-duty vehicles (LDVs) that are on the market in ASEAN are typically less efficient than elsewhere in the world. While the relative small size and weight of the vehicles sold in the region would suggest low fuel consumption per 100 km, the average of vehicles sold in ASEAN is higher than, for example, in India, the European Union and Japan (although lower than Canada and the US).

The average LDV fuel consumption per 100 km, averaged across the sales of all vehicles in the market (i.e. sales-weighted average) was about 7.2 litres of gasoline equivalent (LGe) per 100km in 2015 across Thailand, Indonesia, Malaysia, the Philippines and Singapore (representing 95% of sales in the bloc), slightly higher than the world average of 7.0 LGe/100km. The average across the Organisation for Economic Co-operation and Development (OECD) is about 6.8 LGe/100km (GFEI 2017), indicating that in the long run, there is adequate technology to significantly improve the efficiency of vehicles in the region.

There is a need for AMS and ASEAN to put commitments in place to reduce the emissions of greenhouse gas (GHG) and to enhance the technological and innovation capabilities of their automotive industries, by making policy initiatives to drive improvements. In a world in which most major economies have introduced fuel economy targets for their markets, a policy push for higher efficiency will also strengthen export opportunities for cars made in ASEAN. Putting in place goals and policies is important not only to avoid AMS falling behind further in terms of fuel-efficient cars, but also to avoid them losing a competitive advantage for cars made in ASEAN in the global marketplace. Harmonising these policies gradually among AMS is also important for market integration, as it will reduce the burden of regulatory compliance for automakers operating across ASEAN.

The potential for increasing fuel efficiency is great across all AMS. This potential can be tapped by curbing the trend towards bigger size, weight and performance of cars, and by ensuring that state-of-the-art fuel efficiency technologies become mainstream. Ambitious policy frameworks, including fuel economy standards, labels and differentiated taxation by fuel economy, have proven to be successful around the world in catalysing such changes.

Some AMS are already taking action on fuel economy. Singapore, Thailand and Viet Nam have introduced mandatory fuel economy labelling schemes for new passenger light-duty vehicles (PLDVs). In Indonesia, such labels are voluntary and not yet standardised, while Brunei Darussalam, Malaysia and the Philippines plan to introduce fuel economy labels.

All AMS have vehicle registration taxes in place, either a one-off tax for new cars, an annual vehicle circulation tax, or both. In most cases, these taxes are related to vehicle attributes such as price or engine displacement. Singapore and Thailand are the only countries with fuel economy-specific tax schemes for consumers. Singapore's Carbon Emissions-Based Vehicle Scheme from 2013 assessed rebates or surcharges based on carbon emissions of vehicles. The scheme was replaced in 2018 by the Vehicular Emissions Scheme, which assesses a rebate or surcharge based on CO_2 emissions and emissions of other air pollutants. In Thailand, the registration tax for new vehicles has been based on CO_2 emissions since 2016. Indonesia and Malaysia both deploy incentives for their domestic car manufacturing industry to produce more efficient vehicles, but only for certain segments.

In terms of fuel economy standards, Thailand introduced voluntary Minimum Efficiency Performance Standards (MEPS) and High Efficiency Performance Standards (HEPS) in 2013. Also in Viet Nam, voluntary fuel consumption limits have been introduced for passenger cars in 2013. It is important to upgrade these standards over time in order to ensure their effectiveness.

Against this background, the roadmap establishes a vision as well as goals and accompanying recommended actions for ASEAN and its Member States up to 2025. While AMS retain the right to make individual choices in developing specific policies and measures and the timing of their implementation, the roadmap charts the course and offers broad guiding principles on how to do so.

Vision and goals for the ASEAN fuel economy roadmap

The vision of this roadmap is to transform the ASEAN light-duty vehicle market into one of the world's most fuel efficient by 2025, helping to meet regional and national goals for sustainable transport, energy efficiency and climate change mitigation, while supporting the vision of the ASEAN Economic Community 2025, and ensuring the health and quality of life of people across the region.

This roadmap sets six aspirational goals for ASEAN to help in moving towards this vision. The headline goal is an aspirational target to reduce the average fuel consumption of new light-duty vehicles sold in ASEAN by 26% between 2015 and 2025, which leads to an improvement in average fuel economy to around 5.3 LGe/100km by 2025, from an estimated 7.2 LGe/100km in 2015.

Table 1: Summary of the goals and actions of the roadmap

Goal	Actions to achieve goal
Goal 1: Average fuel consumption per 100 km of new light-duty vehicles sold in ASEAN is reduced by 26% between 2015 and 2025.	Action 1.1: Adopt an aspirational target to reduce average fuel consumption per 100 km of new light-duty vehicles sold in ASEAN by 26% between 2015 and 2025.
Goal 2: Common indicators and methodologies as well as baseline data for fuel economy are defined.	Action 2.1: Agree on common indicators and methodologies for measuring and analysing average new light-duty vehicle fuel economy.
	Action 2.2 Develop fuel economy baseline data to ensure that AMSs have sufficient information and data to develop, enact, and monitor fuel economy policies.
Goal 3: Regional cooperation, national action, and fuel economy policy leadership are established.	Action 3.1: Continue regional cooperation among relevant stakeholders through events related to fuel economy.
	Action 3.2 Enhance collaboration of government agencies, research institutions, and automotive industry within and between AMSs.
	Action 3.3 Identify appropriate lead government agencies within Member States.
Goal 4: Fuel economy label information is regionally aligned.	Action 4.1: Convene the agencies of AMS responsible for maintaining, implementing, or developing various fuel economy labels to take stock and explore alignment opportunities.
	Action 4.2: Develop a common set of baseline information to be included in member states' fuel economy labels.
Goal 5: Introduction or enhancement of fuel consumption- or CO_2 emission-based fiscal policies .	Action 5.1: Introduce and strengthen fiscal policy measures based on fuel economy or on CO_2 emissions at the national level, where applicable, to incentivise consumers to purchase efficient vehicles.
	Action 5.2 Exchange lessons learned on fiscal policy implementation.
Goal 6: Adoption of national fuel consumption standards for LDVs in all markets, striving towards a regional standard in the long term.	Action 6.1: Introduce and strengthen policy measures at national level that require manufacturers to meet stringent targets for new vehicle fleets based on fuel consumption or CO_2.
	Action 6.2 Develop an ASEAN wide light-duty vehicle fuel economy standard that unifies efforts across the region.

While AMS retain the right to make individual choices in developing specific policies and measures and the timing of their implementation, the roadmap charts the course and offers broad guiding principles on how to do so. The roadmap therefore provides a comprehensive suite of strategies and policies including labelling and public awareness, mandatory standards, and fiscal policies for achieving better fuel economy, as well as an annex describing related policies such as automotive emission standards, which may be taken into consideration while implementing the fuel economy roadmap.

1 Introduction

With increasing car ownership but overall still low motorisation levels in ASEAN, it is realistic to expect substantial further growth in motorisation. Within the next ten years, passenger car travel is projected to double within the ASEAN region (IEA 2012a). Sales of passenger cars are estimated to be well above 3 million cars per year by 2025, from about 1.5 million in 2015 (OICA 2016).

Stepping up fuel economy policy efforts is vital for making these growth trends compatible with climate change efforts, as well as with the drive for urban air quality and the need for resource efficiency. From the perspective of competitiveness, fuel economy policies can help cars made in ASEAN exportable to markets that have strict standards in place already, and strengthen local innovation capability. To date, almost 90% of the global light-duty vehicle market is already subject to fuel economy regulation (IEA 2016).

From a technology perspective, the fuel efficiency of LDVs can be increased two ways. The first approach is to promote smaller, lighter and less powerful vehicles. Since the energy use for maintaining a constant velocity of a vehicle is directly proportional to vehicle mass (through rolling resistance) and vehicle size (through frontal area and aerodynamic drag), reduction of both would directly lead to less energy use. However, in many AMS, consumers want larger and higher-performing vehicles. This highlights the importance of the second strategy, making technical improvements to use less energy while providing the desired size and performance. This can be achieved through more sophisticated engines and power trains as well as the development of more aerodynamic body work or tyres with less rolling resistance. See Annex Section 5.2.1 for more detail on LDV fuel-economy technology.

Globally, government regulation, incentives and standards have been the primary drivers of improved technology in passenger vehicles and of shifting consumer demand towards fuel-efficient models. ASEAN and its Member States can benefit greatly by introducing similar policies, enhance them where they exist already, and maximise the benefits through regional collaboration. This section will set the regional policy context for this roadmap and delineate its scope.[1]

1.1 Regional policy context: KLTSP, fuel economy platform and this roadmap

Sustainable transport is a fundamental pillar of ASEAN's regional transport agenda under the Kuala Lumpur Transport Strategic Plan 2016-2025 (KLTSP). The KLTSP goes beyond its predecessors by including a standalone chapter on sustainable transport. This chapter includes goals, actions and milestones as building blocks towards a policy framework for sustainable transport development in the region. As this roadmap focusses on fuel efficiency and on regional cooperation, it serves the vision and goals of ASEAN transport ministers, as shown in Table 1.

1 A detailed assessment of the approaches to fuel efficiency regulation can be found in Section 5.2.1 of the Annex.

Table 2: Vision and goals of the KLTSP with regard to sustainable transport

Post-2015 vision for transport cooperation	Towards greater connectivity, efficiency, integration, safety and **sustainability of ASEAN transport** to strengthen ASEAN's competitiveness and foster regional inclusive growth and development.
Sustainable Transport Strategic Goal	Formulate a regional policy framework to support sustainable transport, which includes low-carbon modes of transport, **energy efficiency** and user-friendly transport initiatives, integration of transport and land-use planning.
Sustainable Transport Specific Goal 1	Intensify **regional cooperation** in the development of sustainable transport-related policies and strategies
Sustainable Transport Specific Goal 2	Identify and implement the **key measures** on sustainable transport
Sustainable Transport Specific Goal 3	Enhance human resource activities and institutions for sustainable transport system

The KLTSP covers the full range of sustainable transport approaches, with measures to '*avoid* transport activity', to '*shift* to environment-friendly transport modes', and to '*improve* the environmental performance of vehicles'. While decisive action is needed in all three areas to meet goals under the Paris Climate Agreement and the 2030 development agenda, this roadmap zooms in on the category of *improve* measures.

Given rapidly rising transport fuel consumption across most AMS, KLTSP sets the right direction by not only mandating this roadmap (see KLTSP goal 1.3.2) but also by intensifying knowledge exchange through a regional platform (see KLSTP goal 1.2.1).

Table 3: Actions and milestones of the KLTSP with regard to fuel economy

Sustainable Transport Action 1.3	Initiate and support the development and implementation of **fuel economy policies and standards** as well as policies towards cleaner fuels, and vehicles and vessels.
Sustainable Transport Milestone 1.3.1	Establish a **platform** to discuss matters related to fuel economy for the transport sector.
Sustainable Transport Milestone 1.3.2	Formulate a fuel economy **roadmap** for the transport sector in ASEAN, including policy guidelines.
Sustainable Transport Milestones 1.3.3	Support the development and adoption of **nationally appropriate policies** for cleaner fuels and vehicles.

The regional platform has met three times since November 2016 in conjunction with the Expert Group on Sustainable Land Transport (EGSLT) and brought together experts from government, academia, non-governmental and international organisations. There is increasing momentum at national level to advance fuel economy policies in the region, yet also diversity in the status, stringency and progress of these policies among AMS. Therefore, further regional exchange is important for learning from each other and for coordinating policy approaches. In the context of national action, there has also been progress towards KLTSP milestone 1.3.3 as some AMS cooperate with GIZ and/or other organisations to advance their domestic fuel economy policies.

1.2 Scope and definitions

Definition of light-duty vehicles
Generally, the roadmap focusses on the category of LDVs. Heavy-duty vehicles (HDVs) are not in the scope due to their different characteristics in terms of technology and data, which necessitate different regulatory strategies. Annex Section 5.7.1 explains the challenges and opportunities for HDV fuel economy policy.

For this roadmap, LDVs are defined as the sum of all passenger cars (PCs) and light commercial vehicles (LCVs). Annex 5.6.2 and 5.6.3 provides an overview of definitions and examples of PCs and LCVs in major vehicle markets. Based on these specifications, the vehicle class of LDVs is defined as follows:

- PCs with a gross vehicle weight (GVW) of no more than 3,500 kg and no more than 10 seats (thus covering all kinds of cars, vans, multi-purpose vehicles (MPVs), sports utility vehicles (SUVs), jeeps, pick-up trucks and van-based minibuses).
- LCVs for cargo transport with a GVW of no more than 3,500 kg.
- Minibuses with no more than 16 seats and a GVW of no more than 3,500 kg.
- Indigenous vehicles such as three-wheelers and jeepneys are not included in the scope of this paper. LDVs are specifically described as having four or more wheels, while jeepneys typically weigh more than 3,500 kg (GVW) and take more than 16 passengers.

Timeframe
This roadmap covers the timeframe until 2025. This year was chosen in order to align with the 10-year planning horizon of higher-level strategies such as the ASEAN 2025 Roadmap and the Kuala Lumpur Transport Strategic Plan (KLTSP).

Newly registered vehicles versus vehicle stock
The vehicle-related policies proposed in this document focus on newly sold or newly registered automobiles (i.e. new vehicles, or used vehicles that are registered for the first time in an AMS). This is due to the rapid growth of the new LDV market as well as the multiple challenges related to the availability of data on the energy efficiency of the in-use vehicle stock. The in-use stock contains many vehicles which 15 years are or older, and it is difficult to find the necessary fuel consumption or CO_2 emission information. Only policies targeting the *use* of these vehicles would affect the fuel efficiency of the vehicle stock (e.g. fuel taxation or eco-driving campaigns).

Vehicle technology
This roadmap focuses on the use of conventional, readily available and cost-effective vehicle technologies such as advanced internal combustion engines (ICE), including those using gasoline or diesel but also alternative fuels such as compressed natural gas [CNG]

or liquefied petroleum gas [LPG]) or hybridised cars. These powertrains are expected to dominate vehicle sales within the roadmap 2025 timeframe and offer great opportunities to effectively reduce energy use and emissions.

Vehicles with advanced power trains such as battery electric vehicles (BEVs) or plug-in hybrid electric vehicles (PHEVs) also play an increasingly important role for reducing transport energy consumption and emissions. Therefore, Section 5.7.2 of the roadmap looks into fuel economy policy design aspects for these types of vehicles.

Measures and units

The measurement unit used to quantify vehicle fuel efficiency throughout this publication is in terms of litres of gasoline equivalent consumed per 100 kilometres (LGe/100km).[2,3] This is the unit used in most countries in Africa, Asia, Canada and Australia. Similarly, the EU determines fuel efficiency in terms of the CO_2 emitted per kilometre travelled (gCO_2/km), assuming specific emission factors for each fuel type. The CO_2 emission conversion factors for different fuels are listed in Table 17 of Section 0 in the Annex. Many Latin American countries as well as India and Japan use kilometres travelled per litre of fuel used (km/l) as their measurement unit, which is basically the inverse unit of LGe/100km. Similarly, the United States measures fuel economy in miles per gallon. See Annex Section 5.6.5 for a discussion of the benefits of the LGe/100km unit of fuel consumption from a regulatory and consumer perspective.

Fuel consumption, CO_2 emissions and air pollutants

This roadmap specifically refers to policies for more efficient fuel consumption of individual vehicles (LGe/100km). Fuel consumption can be reflected in terms of CO_2 emissions through a conversion factor. While the emission of other air pollutants such as particulate matter (PM), oxides of nitrogen (NO and NO_2, commonly together referred to as NOx), oxides of sulphur (SOx), un-burnt hydrocarbons (HC) and carbon monoxide (CO) are important, these other air pollutants are regulated using different types of regulation and with generally different technology solutions. Therefore this roadmap focuses on fuel consumption, expressed as CO_2 emissions where relevant. For further background on the relationship between air pollution and fuel economy, see Section 5.5.7 in the Annex.

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2 In order to account for the different energy densities of liquid fuels such as gasoline and diesel, all volumetric fuel consumption values are normalised to the energy content of gasoline, i.e. litres of gasoline equivalent (LGe, conversion factors see Table 17 in Section 5.7).

3 This unit of measure, in common parlance, is known simply as “fuel consumption”, and shall be referred to as such throughout the rest of this document.

2 Current status in the ASEAN region

Fuel economy policy is quickly evolving around the world. Today, over 80% of the global LDV market is in countries with fuel economy regulations in place. As these countries accelerate their efforts, ASEAN may risk falling behind technologically, remaining a market for lower-technology vehicles while losing opportunities to export vehicles in the competitive global market. Annex 5.1 provides an overview of policy developments around the world. This global overview demonstrates what is possible in terms of policy ambition and technical potential for fuel economy improvement, offering context for ASEAN.

2.1 Economic development and motorisation

The 10 countries of the ASEAN region are home to a total population of about 615 million people as of 2014 (IRENA & ACE 2016). The gross domestic product (GDP) of the region was about USD 2.4 billion in the same year. The region has enjoyed average economic growth of 5.2% per year over the last 23 years and is projected to continue at a comparable rate of 4.8% p.a. until the year 2025. With per capita incomes projected to rise from about USD 3,900 in 2014 to more than USD 5,600 by 2025, the road vehicle stock will face significant future growth.

The AMS are very diverse in both their economic development and their motorisation status. In 2014, per capita income ranged from USD 1,000 in Cambodia to USD 59,400 in Singapore (Table 4). Incomes are expected to grow by another 12% to 70% from 2014 to 2025, with the regional spread in per capita incomes expected to remain wide.

Table 4: Vehicle ownership, saturation level and GDP per capita today and future projections

	GDP per Capita (USD)		Vehicles per 1000 capita					Saturation level			
	2014	2025	2013	2020	2030	2040	Saturation	2013	2020	2030	2040
Brunei Darussalam	35000[2]	52000[2]	419[1]	418[1]	418[1]	419[1]	420[1]	100%	100%	100%	100%
Cambodia	1000[2]	1190[2]	NA	NA	NA	NA	NA	NA	NA	NA	NA
Indonesia	3472[2]	6018[2]	84[1]	146[1]	266[1]	385[1]	470[1]	18%	31%	57%	82%
Lao PDR	1333[2]	2000[2]	NA	NA	NA	NA	NA	NA	NA	NA	NA
Malaysia	10097[2]	12588[2]	427[1]	516[1]	584[1]	608[1]	617[1]	69%	84%	95%	99%
Myanmar	1132[2]	1563[2]	NA	NA	NA	NA	NA	NA	NA	NA	NA
Philippines	2720[2]	4622[2]	38[1]	45[1]	65[1]	100[1]	410[1]	9%	11%	16%	24%
Singapore	59400[2]	66333[2]	163[1]	165[1]	167[1]	168[1]	170[1]	96%	97%	98%	99%
Thailand	5954[2]	7304[2]	198[1]	275[1]	403[1]	492[1]	540[1]	37%	51%	75%	91%
Viet Nam[3]	1900[2]	2339[2]	18[1]	27[1]	59[1]	124[1]	320[1]	6%	8%	18%	39%

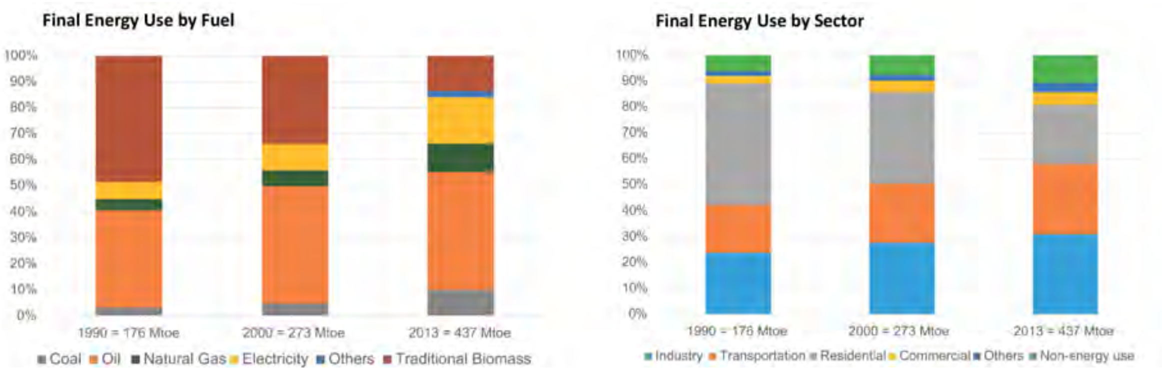
Source: 1) APERC; 2) IRENA & ACE 2016
Note: 3) Vehicle ownership and saturation data in Viet Nam refers to cars only

When estimating saturation levels for vehicle ownership (Table 5), many country-specific characteristics need to be considered. These include projections of GDP per capita, estimates regarding the future levels of urbanisation, the type of urban areas, and the country's capacity to accommodate increased levels of individual motorisation, as well as the provision of mobility alternatives in the form of well-developed public transport systems. Clearly, Singapore has by far the lowest saturation level, while Malaysia is projected to take a European-like transport path.

Different AMS will see different potential future benefits accruing from stringent fuel economy policies according to their current and future motorisation rates. Most AMS are projected to see increased motorisation levels and thus increased fuel use as well as emissions of CO_2 and pollutants, along with a surge in expenditures on fuel. Brunei Darussalam already has a high vehicle ownership, and could therefore also significantly benefit from fuel economy policies as the vehicle fleet is refreshed over time, while Singapore could benefit from less air pollution in its densely populated urban area.

2.2 LDV energy use and CO_2 emissions

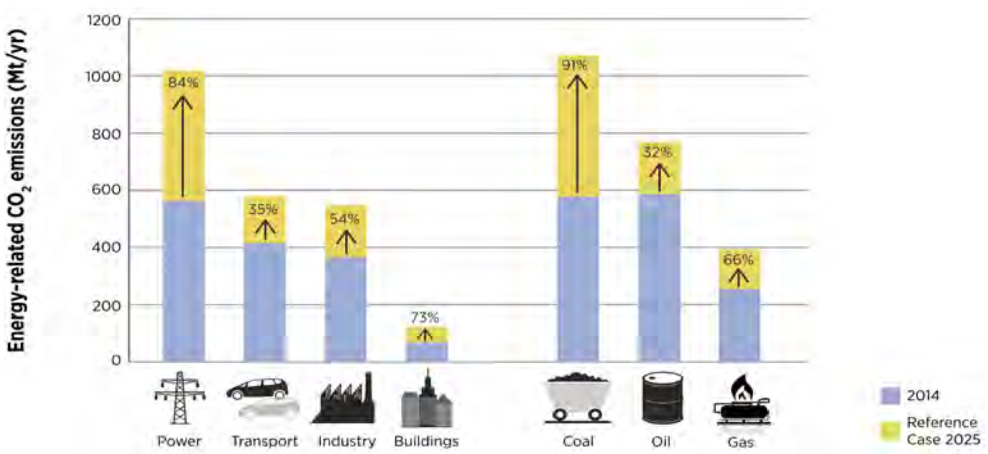
Final energy use in the ASEAN region almost doubled between the year 2000 and 2013 (Figure 1, left). Oil represented about 45% of final energy use in 2013 and maintained an almost constant share of total energy use over time. The transport sector is one of the main drivers of energy use and its weight has increased in recent years. While in 1990 transport accounted for about 21% of ASEAN's energy consumption, it grew to about 28% in 2013 (Figure 1, right).



SOURCE: ACE 2015

Figure 1: Historical total final energy use by fuel and by sector in 1990, 2000 and 2013 in the ASEAN region

The 2016 Renewable Energy Outlook for ASEAN (IRENA & ACE 2016) estimates that about 400 Mt of CO_2 were emitted by the transport sector in ASEAN in the year 2014 (equivalent to about 30% of total energy related CO_2 emissions), and that transport CO_2 emissions could grow by 35% until 2025 under business-as-usual conditions (Figure 2).



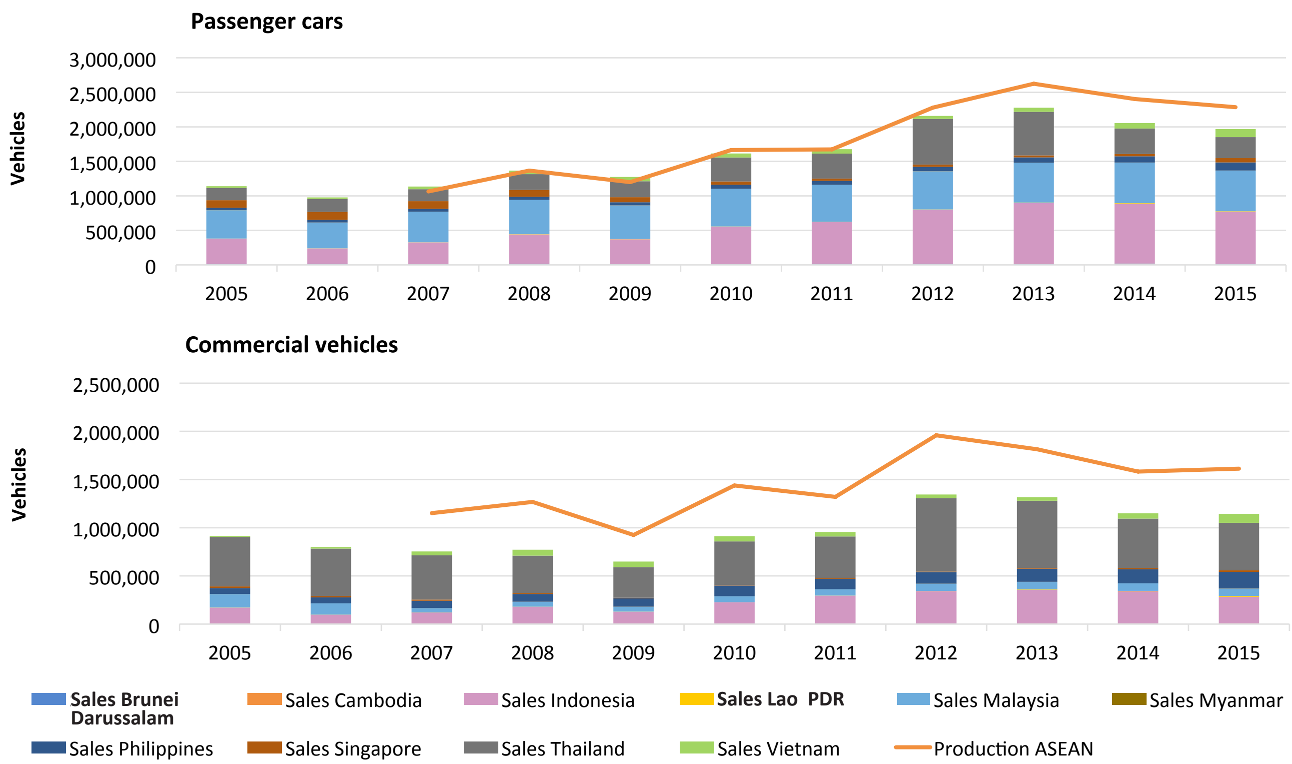
SOURCE: *IRENA & ACE 2016*

Figure 2: Energy-related CO_2 emission external costs in the ASEAN region by sector in 2018 and 2025

2.3 The LDV market in the ASEAN region

The ASEAN region is both a sizeable vehicle consumer as well as vehicle producer. In 2015, about 2 million passenger cars were sold in the AMS, with Indonesia, Malaysia and Thailand as the largest markets (Figure 3). In addition, about 1.15 million commercial vehicles were sold in the region. At more than 3.1 million newly registered cars and commercial vehicles in 2015, the ASEAN market is the sixth-largest vehicle market in the world. These numbers underline the importance of cooperation within the ASEAN region: Counted in isolation, even Indonesia, the region's largest vehicle market, would only rank 18th globally.

Comparing vehicle sales with production reveals that AMS are net vehicle exporters (Figure 3). This is particularly true for commercial vehicles, where production numbers have been about 40% to 50% higher than sales numbers, while in terms of motorcycles and scooters, almost all these vehicles produced in the region are also sold there.



Source: OICA 2016, AAF 2017
Figure 3: Overview of vehicle sales and production in the ASEAN region (Excluding two- and three-wheelers)

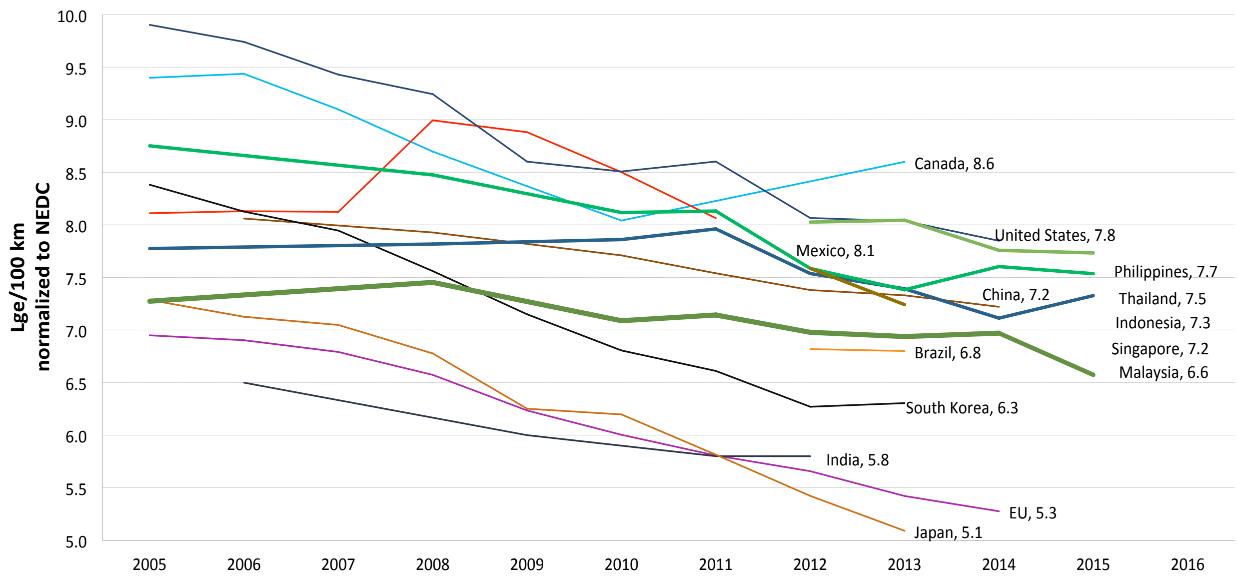
Since 2005, the ASEAN vehicle sales have grown by more than 50%. The production of passenger cars has even doubled since 2007. The increasing motorisation levels indicate a huge growth potential of the ASEAN vehicle market. This underlines the urgency of putting in place stringent fuel economy policies.

2.4 LDV fuel economy in the ASEAN region and the Member States

In order to understand the new LDV fuel economy trend, baseline data has been compiled and analysed for the region. Baseline data means information on sales-weighted average fuel consumption of newly registered LDVs for at least one historical year.[4] This information is required to evaluate the status quo, to establish any fuel economy policy, and to evaluate its effectiveness.

Fuel consumption baselines for several AMS as well as for other countries are shown in Figure 4. It is clearly visible that LDV fuel consumption varies significantly across countries and regions. While new LDV fuel consumption was 7.8 LGe/100km in the United States in 2014, it was as low as 5.1 LGe/100km in Japan in 2013. Furthermore, there is a clear trend towards lower fuel consumption over time.

New LDV fuel consumption within AMS is relatively high when compared to the rest of the world. Average fuel consumption in 2015 was between 7.7 LGe/100km for the Philippines and 6.6 LGe/100km for Malaysia. The sales-weighted average new LDV fuel consumption for ASEAN as a whole is about 7.2 LGe/100km.[5] It is thus higher than the world average of about 7.0LGe/100km. By means of comparison, the OECD average for new LDV fuel consumption of about 6.8LGe/100km for the year 2015 (GFEI 2017) indicates that there is considerable space for technological improvement in the rest of the world including ASEAN. The variation of average new LDV fuel consumption among the AMS is moderate, which indicates that the LDV markets in these countries are somewhat comparable to each other.



Source: ICCT 2015, GFEI 2016 and GFEI 2017[6]
Figure 4: Fuel Economy Baselines Study conducted by GFEI in ASEAN and the World

4 See Box 1 for the baseline calculation methodology on page 23

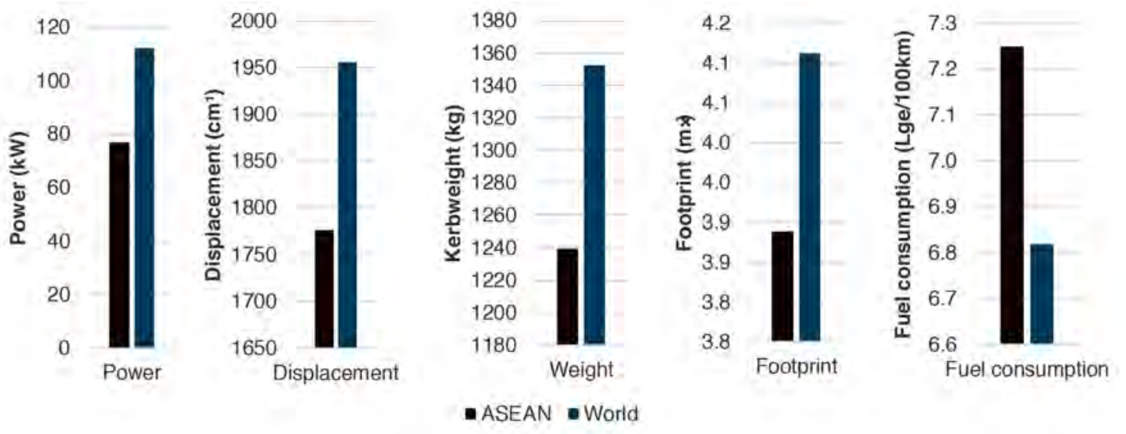
5 This aggregate figure calculated for ASEAN is based on data for Indonesia, Malaysia, the Philippines, Singapore and Thailand. These five countries account for 95% of LDV sales in ASEAN. Therefore, the fuel economy baseline data from these markets is sufficient for making a robust estimate of the *sales-weighted average fuel consumption of newly registered LDVs* for ASEAN as a whole.

6 Europe, Brazil, China and Saudi Arabia averages do not include light trucks (LT) in their average in this figure. For Europe and China, light trucks did not make up a significant part of sales. However, for Brazil and Saudi Arabia, the figure in this chart may be lower if LTs are included.

Based on data of the Global Fuel Economy Initiative (GFEI) for Indonesia, Malaysia, the Philippines and Thailand for the year 2015, the average ASEAN new car differs significantly from the world average: It is about 30% less powerful (77 kW in ASEAN vs. 112 kW for the world average), engine displacement is about 10% lower (1.8 L in ASEAN vs. almost 2.0 L for the world average), the vehicles are on average 8% lighter (1,240 kg in ASEAN vs. almost 1,350 kg for the world average) and about 5% smaller (3.9 m² in ASEAN vs. almost 4.1 m² for the world average). See Figure 5 below.

Based on the relatively high fuel consumption of new LDVs in ASEAN compared to other regions of the world mentioned above, it is clear that there is a technology gap: Although ASEAN cars are on average less powerful, with smaller engines, lighter and smaller in size, they still consume more fuel. This technology gap results from the absence of stringent fuel economy policies.

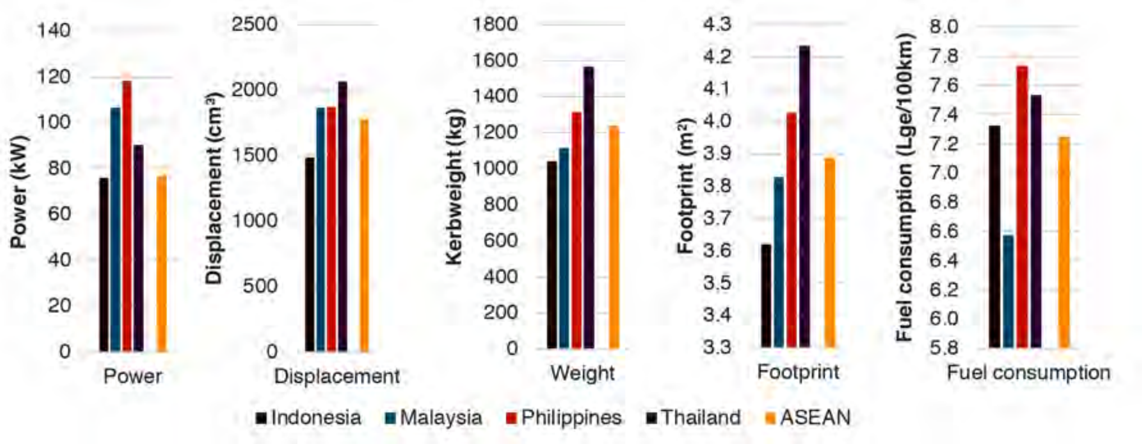
New LDVs in Indonesia cost about USD 18,000 in 2015, compared with USD 26,000 on average, globally, and about USD 23,000 in non-OECD countries (GFEI 2016a). They were also somewhat less powerful, smaller and lighter than the ASEAN average (Figure 6). The significantly lower price confirms a tendency: Vehicles offered in the Indonesian market are significantly cheaper compared to the global average, and even cheaper than those cars sold in non-OECD countries. Across ASEAN, where the average price of vehicles was USD 18,500 in 2015, trends are similar.



Note: Based on New LDV Data For Indonesia, Malaysia, the Philippines and Thailand for the year 2015
Data source: GFEI 2017

Figure 5: New LDV characteristics in the ASEAN region compared to the world in 2015

In Thailand, new LDVs are relatively heavy and large (Figure 6). They show high displacement but rather low average power rating. In addition, new LDVs in Thailand are characterised by a rather high average fuel consumption of about 7.5 LGe/100km. These patterns reflect the fact that more than 30% of newly registered LDVs in Thailand are pick-up trucks (GIZ 2017). Although these are rather large and heavy, they are mainly propelled by diesel engines which have high engine displacement at lower power rating. It is important to acknowledge specific situations such as the high share of pick-up trucks in Thailand. Here, strong fuel economy improvement is most likely not possible without a reduction in average vehicle size.



Source: GFEI 2017

Figure 6: New LDV characteristics in Indonesia, Malaysia, the Philippines, Thailand and the ASEAN region in 2015

A comparison between the characteristics of new LDVs in Malaysia and the Philippines shows that they are relatively similar with respect to power, engine size and vehicle dimensions (Figure 6). However, average fuel consumption of new LDVs is very different in the two countries: While Malaysian cars consume on average on 6.6 LGe/100km, new cars in the Philippines consume around 17% more, with an average fuel consumption of more than 7.7 LGe/100km. This might be linked due to the fact that Malaysian per capita GDP is about three times higher than in the Philippines, allowing consumers to buy more expensive and hence more modern and more efficient cars.

In summary, it can be noted that fuel economy improvement potential is great in *all* AMSs, but for varying reasons. While countries with higher per capita income and already high motorisation rates need to curb the trends towards increasing car size and car performance, those countries with lower per capita income need to make sure that state-of-the-art technology becomes mainstream. In some cases, for example in Thailand, legislation needs to ensure that the purchase of *appropriate* vehicles is incentivised, i.e. the share of pick-up trucks should represent the need to transport goods rather than being primarily used for passenger transport. The fact that the share of crew-cab pick-ups with four doors and five passenger seats increased over time seems to indicate the opposite (GIZ 2017).

2.5 Overview of LDV fuel economy policies in the ASEAN region

The current status of fuel economy policy development varies across the region. While some AMS lack specific measures, others such as Singapore have introduced a bundle of measures over the last years.

Singapore, Thailand and Viet Nam have mandatory labelling schemes for new PLDVs in place. Fuel economy labels are voluntary in Indonesia (Policy Overview Table 10 in the Section 5.3 of the Annex). Brunei Darussalam, Malaysia and the Philippines are planning to introduce fuel economy labels, while no such plans currently seem to exist in Cambodia, Lao PDR or Myanmar.

All AMS have vehicle registration taxes in place, either a one-off tax for new cars, an annual vehicle circulation tax, or both (Table 10 in the Annex Section 5.3). In most cases, these taxes are related to vehicle attributes such as price or engine displacement. Singapore and Thailand are the only countries with fuel economy-specific tax schemes. Singapore introduced the Carbon Emission Based Vehicle Scheme (CEVS) in 2013 to tax vehicles based on their carbon emission, but in 2018 transitioned to a new mechanism, the Vehicular Emissions Scheme (VES), which in addition to assessing vehicles based on CO_2 emissions, also assesses them based on hydrocarbon, carbon monoxide, nitrogen oxides and particulate matter emissions to calculate rebates and surcharges.[7] In Thailand, the registration tax for new vehicles has been based on CO_2 emissions since 2016. More detail on the Singapore VES as well as the Thai vehicle registration tax is provided in Table 10 of the Annex Section 5.3. Indonesia and Malaysia provide tax incentives for the domestic production of fuel efficient cars but not for consumers. These schemes are geared primarily towards industry development, rather than]the objective of reducing fuel consumption.

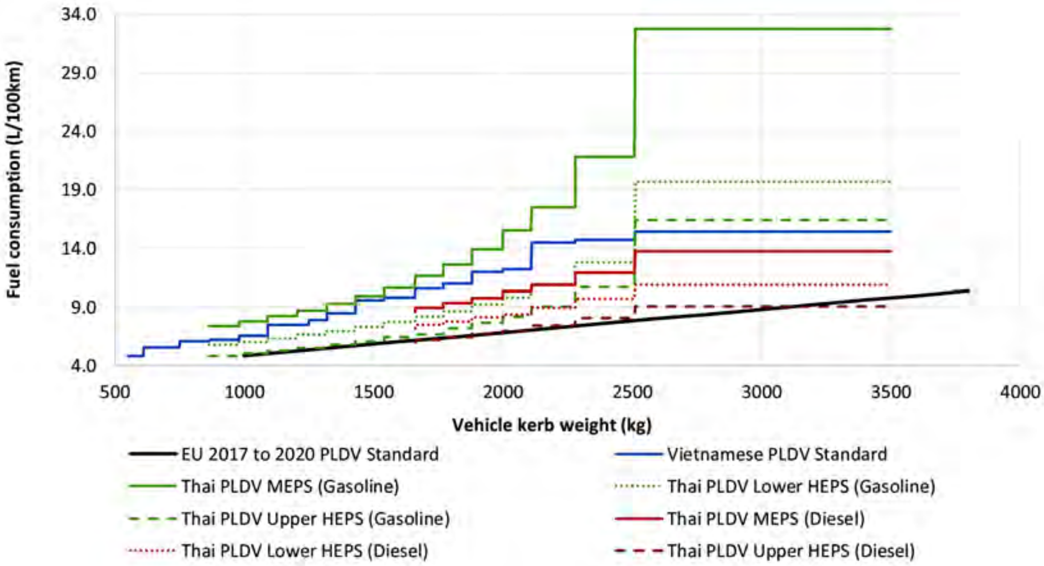
No AMS has mandatory fuel economy, fuel consumption or CO_2 emission standards in place yet. Thailand has introduced voluntary Minimum Efficiency Performance Standards (MEPS) and High Efficiency Performance Standards (HEPS). Also in Viet Nam, voluntary fuel consumption limits were introduced for two-wheelers and passenger cars in 2013. The standards for passenger cars in Thailand and Viet Nam differentiate classes of vehicles based on weight, as seen in the stepwise chart in Figure 7. Brunei Darussalam has indicated in its Nationally Determined Contribution to the Paris Climate Agreement that it wants to adopt the EU's CO_2 standards for LDVs.

A comparison of the voluntary standards in Thailand and Viet Nam to the mandatory standard in the European Union is shown in Figure 7. It is evident that both the Vietnamese fuel consumption standard as well as the Thai MEPS and HEPS are much less stringent than the EU CO_2 emissions standard. In fact, the Vietnamese standards as well as the Thai MEPS allow fuel consumption to be about twice as high as the European limits for a certain weight interval. Such weak and voluntary standards apply limited pressure on car manufacturers to improve vehicle fuel efficiency.

Table 5 shows gasoline prices in AMSs and selected reference countries. The prices are divided into several categories. The category 'high subsidies' denotes countries with gasoline price below the world market price for crude oil and includes Brunei Darussalam. The category 'subsidies' is used for countries with gasoline price being below the price in the US, which is assumed to be at a cost covering retail price.

Clearly, fuel taxes show a broad variance among the AMS, with Brunei Darussalam and Malaysia on the very low end, and Singapore reaching EU price levels. Fuel taxes are a very efficient means of motivating fuel efficiency improvement. Cutting fuel subsidies can thus be a key starting point towards effective fuel economy policies.

7 More information about the Singapore VES can be found at https://www.lta.gov.sg/apps/news/page.aspx?c=2&id=37654ca8-ef14-4c1a-851d-06fc527f839f



Source: GIZ 2015a, Asawutmangkul 2013, EEA 2015

Figure 7: Non-mandatory fuel consumption standards for passenger cars in Thailand and Viet Nam compared to the mandatory standard in the EU

Table 5: Gasoline Prices in AMSs and Reference Countries

ASEAN Member States	Fuel price USD ct	Category	Benchmark	Fuel price USD ct	Category
Brunei Darussalam	41	High subsidies	Venezuela	1.5	High subsidies
Malaysia	68	Subsidies	Crude oil	49	High subsidies
Indonesia	93	Taxation	Russia	81	Subsidies
Viet Nam	104	Taxation	United States	86	Taxation
Philippines	105	Taxation	China	117	Taxation
Myanmar	114	Taxation	Japan	138	Taxation
Thailand	129	Taxation	Poland	142	High taxation
Cambodia	134	Taxation	Germany	180	High taxation
Lao PDR	140	Taxation	Italy	214	High taxation
Singapore	158	High taxation	Eritrea	333	High taxation

Source: GIZ 2015

2.6 Gaps and Barriers

Gaps and barriers to development and implementation of fuel economy policy in ASEAN and AMS can be distinguished into several categories, including: a lack of knowledge and data on the current new and second-hand vehicle fleets currently in the region, and those that are entering the region; challenges in identifying administrative responsibility for fuel economy; and, the inertia of consumers to change their behaviour.

These key gaps and barriers are being addressed, but efforts will still need to be made in order to facilitate the eventual implementation of fuel economy policy across ASEAN. For example, baseline data for Brunei Darussalam, Cambodia, Lao PDR, Myanmar and Viet Nam are currently lacking. However, Myanmar and Viet Nam are working on their baselines with support by GFEI and by GIZ respectively. Similarly, administrative responsibilities and arrangements need to be identified and assigned in many AMS; and, AMS need to define policies that recognise the trends towards consumers purchasing larger and heavier vehicles, meaning that government action is required in order to implement efficiency technology and manage fuel consumption in the passenger vehicle sector. These themes are explored in detail in the Annex to this document, Section 5.4.

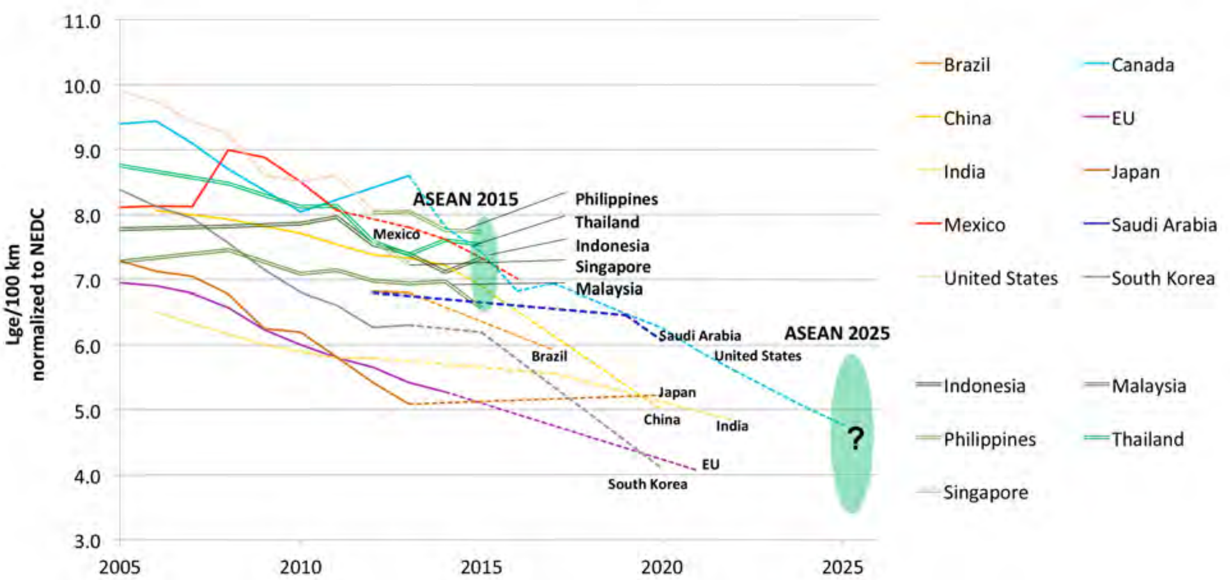
Some solutions to these gaps and barriers, such as cost-benefit analysis can help ASEAN and AMS to develop more well-informed policies that match their circumstances and help them achieve better outcomes are also available. Tools and methodologies from globally-leading institutions have been identified and described for relevant policy-makers of the AMS to consider as they develop policy for their jurisdictions in Section 5.2.3 of the Annex.

3 Vision, goals and recommended actions towards 2025

3.1 2025 Vision

ASEAN lags behind the rest of the world in terms of LDV fuel efficiency. In addition, all major LDV markets of the world except for ASEAN have set fuel consumption targets for their vehicle fleets in 2020 or 2025 (see dashed lines in Figure 8). In times of rapid motorisation and a growing regional automotive industry, AMS have the opportunity to close the gap towards international best practices. With the right policies in place and reasonable levels of ambition, AMS can reap the multiple benefits of better fuel economy. Against this background:

The vision of this roadmap is to transform the ASEAN light-duty vehicle market into one of the world's most fuel efficient by 2025, helping to meet regional and national goals for sustainable transport, energy efficiency and climate change mitigation, while supporting the vision of the ASEAN Economic Community 2025, and ensuring the health and quality of life of people across the region.



Source: ICCT 2015, GFEI 2016 and GFEI 2017

Figure 8: Enacted and Proposed LDV Fuel Economy Targets Around the World – With Unified Canada and US 2025 targets representing passenger vehicles and light trucks

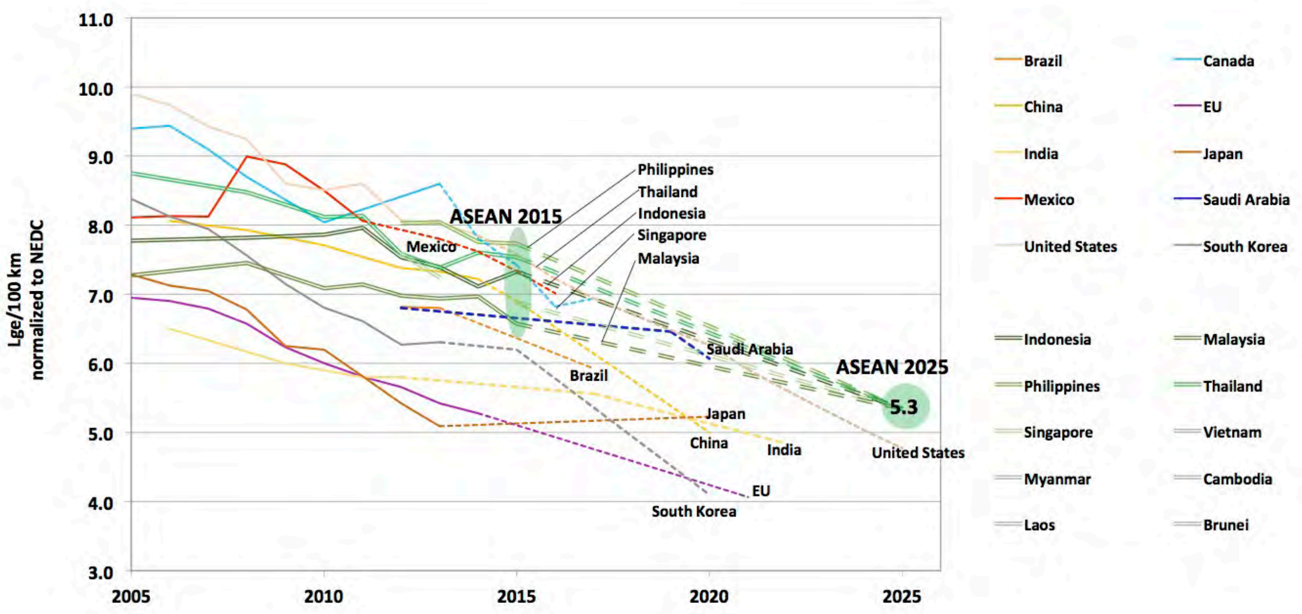
3.2 Aspirational goals towards 2025

The aspirational goals and actions are based on ASEAN's circumstances, specifically with reference to the data collected and analysed within Section 2. At the same time, they are founded on international experience and success stories to effectively develop and implement fuel economy policies.

Goal 1: Average fuel consumption per 100 km of new light-duty vehicles sold in ASEAN is reduced by 26% between 2015 and 2025.

Setting an aspirational new LDV fuel efficiency target for the entire region is an important step forward in the near term. It provides long-term planning direction for manufacturers and enables governments to monitor progress against the aspirational target. It serves to benchmark potential reductions in energy demand, GHG emissions, and fuel costs, and is thus an important component of regional economic and climate policy making.

The aspirational goal represents an average annual improvement of 3% and leads to a regional average fuel consumption of around 5.3 LGe/100km by 2025, from an estimated 7.2 LGe/100km in 2015. When compared to the goals of other jurisdictions, most have either more ambitious improvement rates (>4% per year), more stringent target values (<5 LGe/100km), or have target years earlier than 2025 (see Table 8 on page 38). In addition, the goals of most of the other countries or regions have been formalised in the form of mandatory fuel economy standards.[8]



Source: ICCT 2015, GFEI 2016 and GFEI 2017

Figure 9: The ASEAN LDV fuel consumption goal in comparison to enacted and proposed LDV fuel economy – Note: Canada and US targets are unified for 2025 and represent passenger cars and light trucks together.

Goal 2: Common indicators and methodologies as well as baseline data for fuel economy are defined

Using common indicators and methodologies can make fuel economy efforts of AMSs comparable, reduce policy development costs, and allow for faster and less expensive testing of automotive fuel consumption. Furthermore, it may simplify customs procedures

8 The 2025 fuel consumption goal has been determined based on a process in which representatives of the ASEAN Expert Group on Sustainable Land Transport (EGSLT) selected one out of five different goal options with varying levels of stringency. The five options are presented in Annex Section 5.6.1. The EGSLT decided in favour of the fifth option which is to double the fuel economy improvement from the 1.5% BAU improvement rate to 3% per year.

among countries and facilitate the development of Mutual Recognition Agreements. Last but not least, harmonised test procedures and efficiency metrics may reduce costs and the compliance burden for manufacturers and build the foundation for regional policy approaches.

Goal 3: Regional cooperation, national action, and fuel economy policy leadership are established

The determination of responsible lead agencies in each AMS can create an institutional “home” for fuel economy and strengthen inter-institutional coordination. Continued and enhanced regional cooperation through knowledge exchange, research, and partnership among government, researchers, and industry is vital to build a strong basis of know-how, capacities and data in each AMS.

Goal 4: Fuel economy label information is regionally aligned

Making fuel economy information transparent to consumers plays an important part in nudging consumers towards buying more efficient vehicles. Harmonising a baseline set of information displayed on fuel economy labels, and agreeing on similar rating systems and benchmarks within the ASEAN region, facilitates manufacturers and importers to provide best available technology vehicles, and helps consumers to make more informed choices. Regional harmonisation can also help address barriers such as small markets and limited institutional capacity to develop labels. Furthermore, having regionally aligned fuel economy labels may enhance trade of LDVs between AMSs and support exports of LDVs by AMS beyond the bloc.

Goal 5: Introduction or enhancement of fuel economy- or CO_2 emission-based fiscal policies

Although all AMS have fiscal policies in place to generate government revenues by taxing vehicle purchase and use, only a few AMS effectively use vehicle and fuel taxes to control and manage the efficiency or the environmental impact of domestic LDV fleets. With a clear focus on the emissions output or fuel consumption of the vehicle as an alternative taxation basis, the cleanest vehicle technology becomes more affordable to consumers and their market adoption accelerates. The introduction or enhancement of fiscal measures, which are ideally technology-neutral and based on fuel economy or CO_2 emissions, is thus a crucial medium-term goal to achieve the vision of this roadmap.

Goal 6: Adoption of national fuel economy standards for LDVs, striving towards a regional standard in the long term

The combination of consumer information, fiscal fuel economy policies and fuel economy standards has proven to be the most effective policy package in other countries. Therefore, AMS should either introduce standards or strengthen them where they exist already. This roadmap further suggests working towards establishing an ASEAN-wide fuel consumption or CO_2 emissions standard that mandates fuel efficiency performance levels for new LDVs sold in the region.

3.3 Recommended actions to meet the goals

Goal 1: Average fuel consumption per 100 km of new light-duty vehicles sold in ASEAN is reduced by 26% between 2015 and 2025.

Action 1.1: Adopt an aspirational target to reduce average fuel consumption per 100 km of new light-duty vehicles sold in ASEAN by 26% between 2015 and 2025. The target should be adopted as part of this roadmap.

Goal 2: Common indicators and methodologies as well as baseline data for fuel economy are defined

Action 2.1: Agree on common indicators and methodologies for measuring and analysing average new light-duty vehicle fuel economy. Section 4.1 includes specific suggestions for indicators and methodologies that should either be commonly used or that require alignment. It is recommended to take stock of the current procedures and definitions in AMS, to agree on a baseline of common metrics to be used throughout the region and to works towards an agreement on fuel economy testing methodologies.

Action 2.2 Develop fuel economy baseline data to ensure that AMS have sufficient information and data to develop, enact, and monitor fuel economy policies. AMS which have no baseline data yet need to start compiling and analysing the data needed to establish a baseline (see Box 1: Baseline setting methodology). AMS whose baseline data have been computed by an external party should consider validating and updating the data independently in order to strengthen domestic capacity and procedures. For tracking progress, the sales-weighted average new LDV fuel consumption data needs to be assessed on a regular basis.

Goal 3: Regional cooperation, national action, and fuel economy policy leadership are established

Action 3.1: Continue regional cooperation among relevant stakeholders through events related to fuel economy. Such events as Fuel Economy Platform Forums have proven to be an effective avenue for the development of this roadmap.

Action 3.2 Enhance collaboration of government agencies, research institutions, and automotive industry within and between AMS. Academic experts can help generate the knowledge, analysis, and expertise needed for fuel economy policy development. However, tackling knowledge gaps together requires good connections between researchers and policymakers. Researchers therefore need to be involved in the regional policy dialogues on fuel economy. Car manufacturers, associations, and importers must be involved in the process of developing stringent fuel economy policies, including engagement in both regional and national policy dialogues. This collaboration could help enhance the capacity of AMS including in the areas of type-approval procedures, testing capacity, in-use fuel economy verification of durability, and mutual recognition of test results.

Action 3.3 Identify appropriate lead government agencies within Member States. Since many ministries and authorities such as the Ministry of Finance, the Ministry of Energy, the Ministry of Economy and the Ministry of Transport are concerned with fuel economy-related legislation and regulation, a leading agency in each AMS needs to be assigned in order to coordinate and guide the work across all stakeholders with other AMS. At the regional level, coordination is needed among the ASEAN sectoral bodies which are relevant for fuel economy issues, e.g. Transport (ASEAN Land Transport Working Group, ASEAN Senior Transport Officials Meeting), Energy (ASEAN Senior Officials Meeting on Energy), Standards (ASEAN Consultative Committee on Standards and Quality), Environment (ASEAN Senior Officials on Environment), among others.

Goal 4: Fuel economy label information is regionally aligned

Action 4.1: Convene the agencies of AMS responsible for maintaining, implementing, or developing various fuel economy labels to take stock and explore alignment opportunities.

Action 4.2: Develop a common set of baseline information to be included in AMSs' fuel economy labels. As a guide for AMS, Chapter 7 introduces international best practices for labelling scheme designs.

Goal 5: Introduction or enhancement of fuel economy- or CO_2 emission-based fiscal policies

Action 5.1: Introduce and strengthen fiscal policy measures based on fuel economy or CO_2 emissions at the national level, where applicable, in order to incentivise consumers to purchase efficient vehicles. Where such policies are not in place yet, the responsible government agencies should assess their costs and benefits and take concrete steps to develop and introduce them. Where they are in place, government should regularly review their effectiveness, increase their stringency over time, and close loopholes that may exist for certain vehicle types. Section 4.3 provides guidance on the different kinds of fiscal measures.

Action 5.2 Exchange lessons learned on fiscal policy implementation. As AMS develop and implement their respective policies, it is vital that they engage in regional dialogue on successes and issues encountered, allowing AMS to learn from each other.

Goal 6: Adoption of national fuel economy standards for LDVs, striving towards a regional standard in the long term

Action 6.1: Introduce and strengthen policy measures at national level that require manufacturers and importers to meet stringent targets for new vehicle fleets, based on fuel consumption or CO_2. Section 4.4 provides design considerations for the package of policy measure to introduce and implement fuel economy standards. The domestic standards, if applicable, should refer to the fuel consumption level specified in Goal 1.

Action 6.2 Develop an ASEAN wide light-duty vehicle fuel economy standard that unifies efforts across the region. Lessons can be drawn from ongoing regional efforts to achieve energy efficiency of other products.[9]

9 For example, the ASEAN Standards Harmonization Initiative for Energy Efficiency www.aseanenergy.org/engagements/asean-eu/asean-shine/

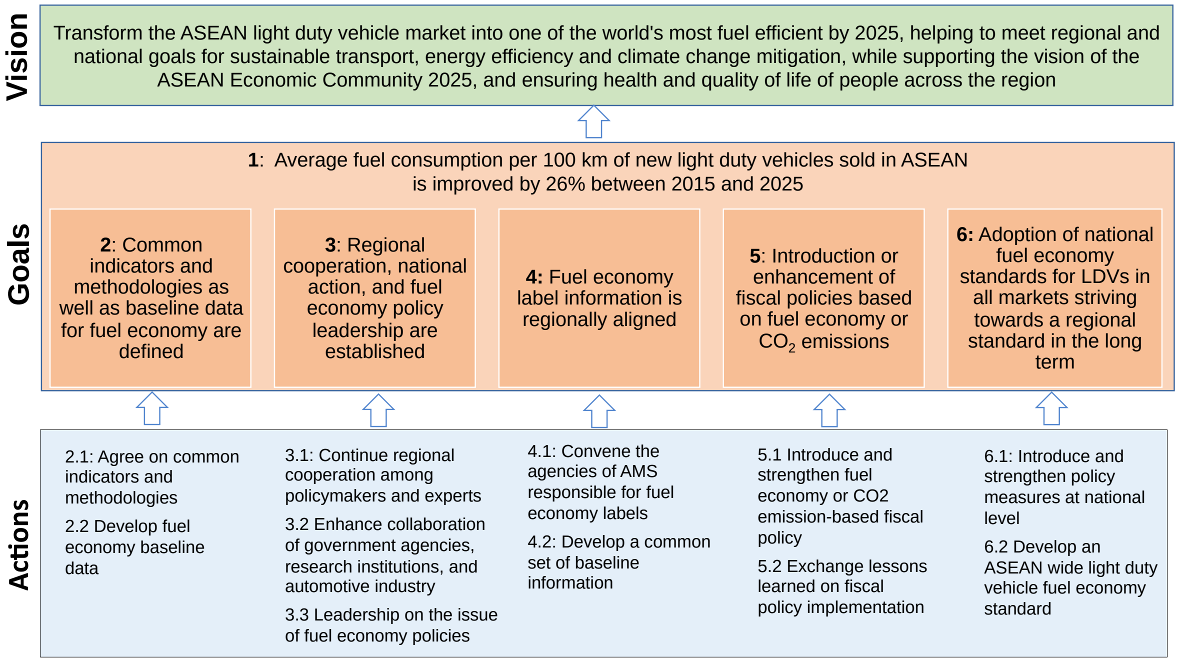


Figure 10: Schematic overview of the roadmap vision, goals and actions

4 Options for fuel economy policy development

The following section provides a range of options regarding fiscal, regulatory and other fuel economy policy measures. Each section focuses on one policy measure presented as a table. Each section also corresponds to a section of the Annex where the measures are discussed in detail. There are further options that are not directly linked to fuel efficiency but that help the adoption of advanced efficient vehicle technology, such as improved fuel quality and emission reduction equipment. These options are not presented here but are discussed in the annex for interested readers.

Fuel economy policies can be categorised by their target group (Figure 10). Fiscal instruments such as vehicle and fuel taxation or direct subsidies (for example for very efficient vehicles) mainly target the consumer to pull technology innovation into the market. However, fiscal incentives could also be given to manufacturers to incentivise production of efficient vehicles. An example is Malaysia’s Energy Efficient Vehicle Program.

On the other side, regulatory measures such as fuel-economy standards as well as pollutant-emission and fuel-quality standards oblige manufacturers and importers to supply the required technology to the market. Last but not least, adequate consumer information (for example through fuel economy labelling schemes) is essential to ensuring that the consumer can adequately quantify the value of vehicle fuel efficiency when making a purchase decision.

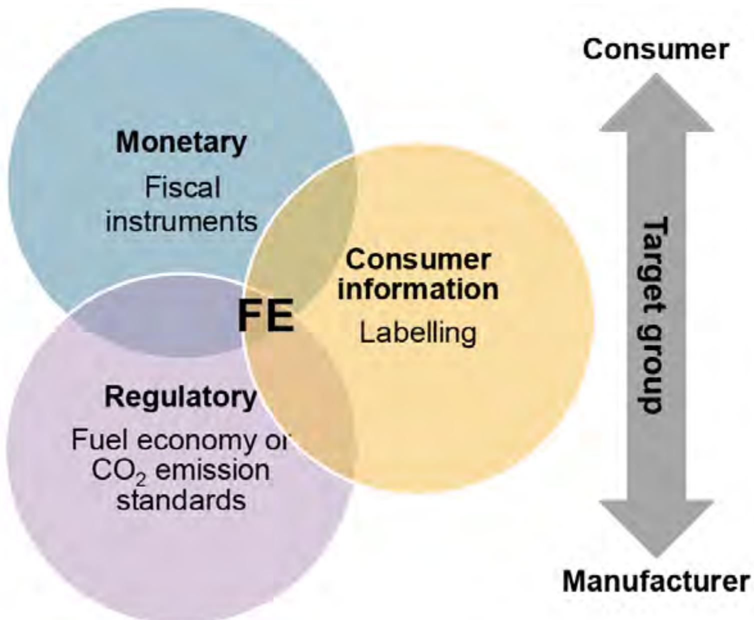


Figure 11: Overview of fuel economy policy measure categories

Fuel economy policy development should follow a set of best-practice guidelines to effectively lead to the intended results while minimising unintended side effects. Fuel economy policy measures should meet the following criteria:

1. **Comprehensive –** Fuel economy policies should be developed in a way that they apply to all LDVs and not only passenger cars. This ensures that manufacturers and consumers cannot circumvent the objective of improving fuel economy by offering and purchasing vehicle types that are not be affected by fuel economy policies. Such cases can emerge if, for example, pick-up trucks are classified as light commercial vehicles and excluded from fuel economy measures applied to passenger cars.
2. **Long-term –** Both manufacturers and consumers can much better anticipate the value of vehicle fuel efficiency if policies have a longer-term target covering at least the following 10 to 15 years.
3. **Periodically revised –** All fuel economy policy schemes need to be subject to periodical revisions. They should be adjusted to technology and market developments to address rebound effects or unintended costs.
4. **Technology-neutral –** Instead of developing various incentives targeting specific vehicle technologies (for example hybrid cars), fuel economy policies should be based on common indicators, such as fuel consumption (LGe/100km) or CO_2 emission (gCO_2/km) that apply to all powertrain options in a similar way.
5. **Continuous –** When developing fuel economy-based tax schemes, continuous functional relationships between fuel economy and taxation should be preferred to the use of bins and step functions. This limits unintended market distortions and the incentive for manufacturers to play off the definitions to maximise their benefits for minimal real-world changes.[10]

The strongest impact on improving LDV fuel economy improvement is by combining both consumer- and manufacturer-targeted fuel economy policies. This can be observed in most European countries, which are characterised by the presence of strong regulatory measurements, multiple fuel economy- or CO_2 emissions-based vehicle taxation schemes, and comprehensive consumer information. A discussion on the importance of combined regulatory, taxation and consumer information strategies can be found in a policy and technical toolbox in Section 5.5 of the Annex.

4.1 Definition of Indicators and methodologies

This roadmap proposes the use of measurement units, indicators, conversion factors and methodologies outlined in Table 6. It therefore proposes to use fuel consumption and CO_2 emissions as measurement units to quantify the energy efficiency and carbon intensity of LDVs. Energy use should be expressed as litres of gasoline equivalent, instead of using the volumetric fuel demand in litres, in order to account for the different energy densities of various liquid and gaseous fuels.

10 Taxing vehicles according to fuel economy bins where vehicles are grouped to specific fuel consumption intervals (e.g. below 4LGe/ 100km, 4 to 8LGe/100km, 8 to 12 LGe/100km, above 12LGe/100km) creates incentive to manufacturers whose vehicles are close to a lower bound to perform very minor changes (e.g. changing for a somewhat lower resistance tire) in order to benefit from great changes in taxation once the vehicle is reclassified from a higher into a lower tax class.

Furthermore, fuel efficiency and carbon intensity, measured as sales-weighted average of the tested new LDV fuel consumption as well as sales-weighted average of tested new LDV CO_2 emissions, should be the agreed indicators for monitoring the efficiency of the new LDV fleet in a country or region.

Table 6: Suggested measures, indicators, conversion factors and methodologies for fuel economy policy development, enacting and monitoring

Measures	Description	Unit
Fuel consumption	Litres of gasoline equivalent per 100 kilometers	Lge/100km
CO_2 emissions	Grams CO_2 per kilometer	gCO_2/km
Energy	Litres of gasoline equivalent	Lge
Indicators	**Description**	**Unit**
Energy efficiency of the new LDV fleet	Sales weighted average of tested new LDV fuel consumption	Lge/100km
Carbon intensity of the new LDV fleet	Sales weighted average of tested new LDV CO_2 emissions	gCO_2/km
Conversion factors	**Description**	**Unit**
Fuel specific energy content	Litres of gasoline equivalent	Lge
Fuel specific carbon dioxide emissions	Grams CO_2 per litre of gasoline equivalent	gCO_2/Lge
Methodologies	**Description**	
Fuel consumption measurements	New European Driving Cycle, World Light duty vehicle Test Cycle	
Pollutant emission measurements	Euro I to VI	
Fuel quality measurements	Euro I to VI	

In addition, a set of standardised conversion factors to normalise the energy content of fuels such as diesel, compressed natural gas (CNG), liquefied petroleum gas (LPG) but also various biofuel blends (depending on different crops such as palm oil [for biodiesel] or sugar cane [for bioethanol]) need to be developed and used collectively within the ASEAN region. A similar set of conversion factors needs to be agreed for fuel-specific carbon dioxide emissions.

Last but not least, there needs to be agreement on methodologies such as the test procedures used to determine vehicle fuel consumption as well as CO_2 and air pollutant emissions. While most AMSs are currently using the New European Driving Cycle (NEDC), a timely shift to the recently developed World Light-Vehicle Test Cycle (WLTC, UNECE 2013) should be considered.

The outdated NEDC is suspected to be largely responsible for the increasing gap between tested and real-world on-road fuel consumption of new vehicles (ICCT 2015b). The much more diverse WLTC is aiming at substantially reducing this gap.

AMS should refrain from the development of their own test drive cycles. The introduction of country-specific test protocols profoundly undermines the idea of a collaborative ASEAN vehicle market, and unnecessarily increases costs for manufacturers and, by extension, for consumers.

Common indicators and methodologies are also a precondition for the implementation of mutual recognition agreements. This could allow one AMS to recognise the fuel consumption testing results performed in another AMS, rather than having to invest in (re-)testing.

Box 1: Fuel consumption baseline setting methodology

Any fuel economy policy requires the information on tested fuel consumption or CO_2 emissions to be available for each newly registered vehicle in the country. While many other car specifications such as vehicle make, model, year of first registration, fuel type, engine power and displacement, as well as vehicle weight, are collected by all national vehicle registration offices, the fuel consumption or CO_2 emission data is most often not available.

In order to establish the national baselines, the vehicle-specific fuel consumption or CO_2 data needs to be added to the registration data. Due to the diversity of the vehicle market, it is most often not possible to find fuel consumption data for all newly registered vehicles. Within GFEI, the standard for a sufficiently accurate baseline is to have data available for at least 85% of all newly registered vehicles in one year.

Once fuel consumption data has been added to the national new vehicle registration data, the sales-weighted average fuel consumption can be calculated using the following equation:

Equation 1

$$\boldsymbol{FC = \frac{\sum_i^n Reg_i \times FC_i}{\sum_i^n Reg_i}}$$

With:

FC = weighted average fuel consumption
Reg_i = number of newly registered vehicles of type i
FC_i = fuel consumption of vehicle of type i

4.2 Consumer information

Type of measure	–	Use of on-vehicle labels and other technologies to clearly describe fuel economy and other fuel consumption and environmental information to the consumer.
Principle	–	Assists the consumer in purchasing a fuel-efficient vehicle or in improving the fuel efficiency of an in-use vehicle.
	–	Uses laboratory test procedures or in-use monitoring to clearly indicate fuel consumption to the consumer in an easy-to-understand format.
	–	Relates consumer behaviour to savings in fuel, CO_2 emissions and fuel cost.
Rationale	–	Consumers are given the ability to compare vehicles not just on look, feel, or technology but also according to fuel consumption and operating cost. Given this information, consumers may change their purchasing or operational behaviours.
Key Aspects	–	A common methodology is used to measure fuel economy and is displayed in a standardised fashion, such as a label or a fuel economy tracker.
	–	Labels are able to offer a qualitative comparison to other similar vehicles so that consumers can understand the relative performance of the vehicle they are looking at.
	–	Fuel-economy trackers allow consumers to observe the changing fuel economy of their vehicle and adjust behaviour as necessary.
Building Blocks	–	A standardised methodology for testing fuel economy of vehicles included in a labelling scheme, and a database of vehicles to compare the labelled vehicle to.
	–	A standardised method of indicating relative performance compared to other models of vehicles, or previous points in time.
	–	A display format that can easily communicate information to consumers and convince them to change behaviour, including local language, easy-to-understand units and appropriate graphic design.
Case Studies[1]	–	Fuel economy labels in US, China, Singapore, Thailand, Viet Nam and other countries.
	–	Fuel economy websites and trackers such as Little Bear (China), One Motoring (Singapore), Spritmonitor (Germany).
Impact Rating	–	Medium
Complexity Rating	–	Low
Detailed Annex	–	Section 5.5.2

4.3 Fiscal policy measures

Fiscal instruments play an important role in fostering vehicle fuel efficiency. Compared to vehicle regulation mainly targeting manufacturers and thus pushing efficient vehicle technologies into the market, fiscal policies can encourage a demand-side market pull (ICCT 2011). While the primary purpose of vehicle and fuel taxes is to raise government funds (which ideally should be used to cover transport-related expenditures), they should also be used to influence vehicle market development towards higher efficiency as well.

4.3.1 Fuel economy-based vehicle registration tax feebate schemes

Type of measure	– One-off vehicle excise tax paid at first time registration or sale of a new or used imported car or new domestically manufactured car.
Principle	– Based on vehicle fuel consumption (LGe/100 km) or vehicle CO_2 emissions (gCO_2/km). – The value of the tax gradually increases with fuel consumption or CO_2 emission according to a continuous function. – Very fuel-efficient vehicles below a defined fuel consumption or CO_2 emission threshold (i.e. pivot point) can be exempted from taxation or even be eligible to a rebate. – Can also include a component based on pollutant emissions (e.g. NOx).
Rationale	– Decreasing taxes with higher vehicle efficiency incentivises the consumer to switch towards the purchase of fuel-efficient cars and can offset possible technology costs.
Key aspects	– By adjusting slope and pivot point of the tax function, the scheme can be developed in order: o to generate government revenues – the tax scheme does not include rebates for very efficient vehicles; o to be revenue-neutral – tax revenues from inefficient (and often more expensive vehicles) are used to pay the rebates for very efficient vehicles; and o to generate costs – subsidies to efficient vehicles outweigh the revenues from inefficient vehicles. – As vehicles get more efficient the scheme needs to be adjusted periodically.
Prerequisites	– Fuel economy or CO_2 emission information is required for *all newly registered vehicles.* – A fuel-economy labelling scheme to inform the consumer needs to be in place.

Case studies	–	Carbon Emission-Based Vehicle Scheme (CEVS) and the new Vehicular Emissions Scheme (VES) in Singapore.
	–	Bonus-malus system in France.
	–	Vehicle registration tax in the Netherlands.
Impact rating	–	High
Complexity rating	–	Medium
Detailed annex	–	Section 5.5.3

4.3.2 Fuel economy-based vehicle circulation tax

Type of measure	–	Vehicle registration tax paid on an annual basis for all vehicles in the fleet
Principle	–	Based on vehicle fuel consumption (LGe/100 km) or vehicle CO_2 emissions (gCO_2/km).
	–	The value of the tax gradually increases with fuel consumption or CO_2 emission according to a continuous function.
	–	Can also include a component based on pollutant emissions (e.g. NOx).
Rationale	–	Decreasing taxes with higher vehicle efficiency incentivises the consumer to switch towards the purchase of fuel-efficient cars and can offset possible technology costs.
Key aspects	–	The starting point of the tax function, can be set in a way that vehicles below a fuel consumption (or CO_2 emission) threshold are exempted from the annual circulation tax.
	–	As vehicles become more efficient the scheme needs to be adjusted periodically.
Prerequisites	–	Fuel economy or CO_2 emission information is required for *all vehicles in the fleet.*
	–	A fuel-economy labelling scheme to inform the consumer needs to be in place.
Case studies	–	Annual vehicle registration tax in various European countries as well as China and Japan
Impact rating	–	High
Complexity rating	–	Medium
Detailed annex	–	Section 5.5.4

4.3.3 Fuel taxation

Type of measure	–	Excise tax paid on fuels at the station
Principle		Based on a fixed percentage share of the per-litre fuel price at the station.
	–	Can be differentiated by fuel type.
	–	Alternative fuels such as CNG, LPG or low-carbon biofuels can be taxed at a reduced rate.
Rationale	–	Higher fuel prices incentivise the customers to buy more efficient cars.
Key aspects	–	As vehicles get more efficient over time and the crude oil price is volatile, the fuel tax needs to be adjusted periodically to prevent a rebound effect.
Prerequisites	–	A fuel-economy labelling scheme to inform the consumer needs to be in place.
Case studies	–	Fuel taxation and new vehicle fuel economy in Turkey.
Impact rating	–	High
Complexity rating	–	Low
Detailed annex	–	Section 5.5.5

4.4 Regulatory policy measures

4.4.1 Fuel economy standards

Type of measure	–	Regulation which sets limits to vehicle fuel consumption or CO_2 emissions for brand-new vehicles
Principle	–	All new vehicles in the market need to comply with a fuel economy target, or alternatively a CO_2 emission target.
	–	The standard can either be set for each model or segment (Option 1), or as a corporate average fuel economy target (Option 2).
	–	For Option 1 standards, all vehicles which do not meet the standard are not allowed to be sold in the market
	–	For Option 2, manufacturer- or importer-specific targets are set based on the sales-weighted average fuel economy of all vehicles sold by the manufacturer/importer within a certain time frame. In cases of non-compliance, fines are issued to the manufacturer/importer.
Rationale	–	The standard pulls efficient vehicle technologies into the market by setting targets for all actors involved.

Key aspects	–	Corporate average fuel economy standards are largely preferable to model- or segment-specific fuel economy targets since they provide more flexibility to the manufacturers and prevent gaming of the vehicle definitions.
	–	Fuel economy standards can incorporate further vehicle attributes such as vehicle weight or footprint to better account for varying market portfolios of different manufacturers.
	–	Fuel economy standards need to be revised periodically to account for technology development.
Prerequisites	–	Fuel economy or CO_2 emission information is required for *all brand-new vehicles entering the market*, i.e. it needs to be part of the information provided by manufacturers for homologation[2] of a new vehicle.
	–	Corporate average fuel economy standards require close collaboration with manufacturers and/or importers during target setting as well as compliance.
	–	The administrative framework to set the target, to check compliance and to enforce the targets needs to be in place.
Case studies	–	Corporate average fuel economy standard of the United States (CAFE); EU LDV CO_2 emission standards; vehicle fuel efficiency standards in China and India.
Impact Rating	–	High
Complexity Rating	–	High
Detailed Annex	–	Section 5.5.6

4.4.2 Fuel quality regulation

Requiring fuel quality to be in-line with the requirements of modern engine and exhaust treatment systems is necessary to achieve fuel economy improvement and air pollution reduction targets. For example, fuels with higher octane levels can reduce knock in engines and facilitate higher compression ratios for more a complete fuel combustion and thus a more efficient use of fuel. Turbocharged engines also require higher octane fuel to properly reduce fuel consumption. Low-sulphur fuels ensure that emission control filters do not become clogged with ash, which would otherwise result in higher fuel consumption. ASEAN currently has a workstream under the Energy sector working on harmonising efforts around fuel quality across the region. Details about this policy strategy are noted in Annex 5.5.8.

4.5 Vehicle maintenance

Proper vehicle maintenance is key to ensuring the continued efficiency of cars during use. Vehicle maintenance can be improved through intensified technical vehicle controls. For example, in the EU a vehicle inspection is obligatory for all cars older than four years, and then needs to be repeated every two years for all passenger cars that are not used for commercial purpose, while commercially-used passenger cars need to be inspected one year after first registration and then on an annual basis (Directive 2014/45/EU).

During the vehicle inspection, if a vehicle has an on-board diagnostic device (OBD), it can be quickly evaluated by computer for any problems with the engine or emission control system that might decrease fuel efficiency. Gasoline vehicles complying with Euro 5 and diesel vehicles complying with Euro V standards are equipped with adequate OBD systems, thus reducing testing costs for the consumer. This may be one rationale for hastening the advance of emission control standards in vehicles.

In addition, vehicle inspections also inspect other parts of the car such as tyres, transmission and axles that impact rolling resistance and thus fuel economy.

4.6 In-use fuel economy measures

In-use fuel economy measures mainly concern the way vehicles are driven, unlike the way they are tested. They include training drivers to drive more efficiently through eco-driving, as well as the use of intelligent transport systems to improve traffic flow.

An EU study (Ecodriven 2008) concluded from field experiments in seven countries that eco-driving trainings lead on average to a 15% to 20% reduction of fuel consumption, with 10% as long-term reduction. It is therefore a cheap and useful measure to complement fuel economy policies which mainly target the vehicle itself.

According to a later study (UC Riverside 2015), intelligent transport systems can be categorised into vehicle systems, traffic management systems and travel information systems. Vehicle systems comprise all kind of driver assistance, including to keep front and rear distance or to change lanes. Adaptive cruise control systems will evolve into cooperative adaptive cruise control systems, where vehicles communicate with each other in order to improve traffic flow. Eventually, these systems will lead to autonomously driving cars, where input from the driver is reduced to a minimum.

Travel management systems include traffic monitoring, traffic incident management, corridor management and travel demand management, all of which rely on the increased communication of data and its more rapid processing in order to improve traffic flow and reduce congestion. Travel information systems mainly comprise technologies to better route the driver such as geographical positions systems (GPS).

All of these technologies will lead to an increased level of automation of driving, which again will lead to improved traffic flow, optimised routes and better anticipation of road conditions. Altogether, information technology systems have a large potential to significantly improve vehicle efficiency both in urban and rural environments.

Last but not least, measures targeting at improving air quality or reducing traffic in city centres such as low-emission zones, road pricing, congestion charging, and reduction of parking space can be designed in a way to stimulate improved vehicle efficiency. For example, some of these measures could include exemptions or additional rights in cases where fuel consumption or CO_2 emissions of specific vehicles are below ambitious thresholds.

Measuring in-use fuel consumption, e.g. through digital applications that crowd-source data from drivers, can also be a means to verify type-approved fuel consumption, allowing to compare lab test results with real-world performance.

5 Annex

5.1 Global context for fuel economy policy

5.1.1 Transport energy use, emissions and climate change

In 2014, more than 9,000 megatonnes of oil equivalent (Mtoe) of final energy was consumed globally. Almost 40% of the final energy use was based on petroleum oil, and about 65% of this oil was consumed by the transport sector (IEA 2016 KWES). In terms of greenhouse gas (GHG) emissions, transport accounts for about 26% of energy-related CO_2 emissions worldwide (IEA 2015), and added up to more than 10 megatonnes of CO_2 equivalent (Mt CO2e) in 2016 (Figure 12).

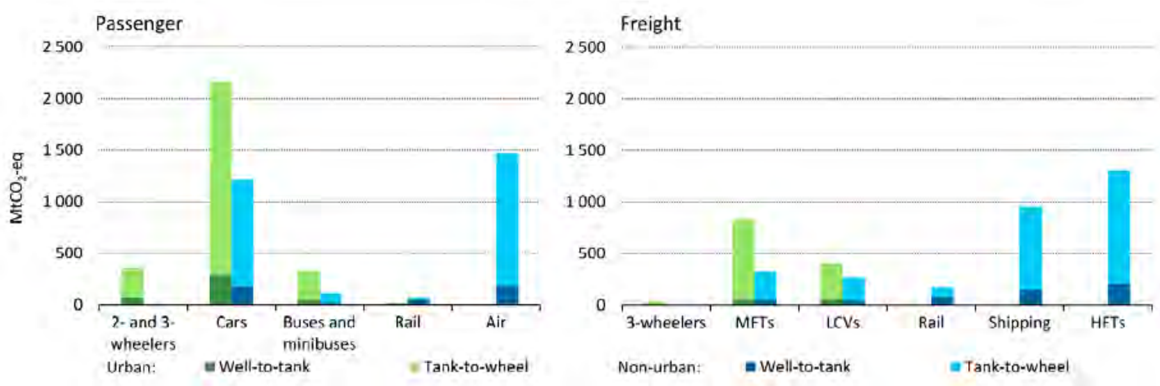


Figure 12: Global urban and non-urban transport CO2 emissions
Source: IEA 2016

Cars were the single largest category of emitter with a share of more than 34% of all transport emissions (including international shipping and aviation). Together with LCVs and minibuses, LDVs were responsible for more than 41% of all transport emissions globally in 2015.

In 2017, the Global Fuel Economy Initiative (GFEI) assessed the GHG emission reduction potential of passenger light-duty vehicles (PLDVs) if the fuel efficiency of newly sold passenger cars were to be improved to a global average of 4.4 LGe/100km by 2030 (from about 8.8 LGe/100km in 2005), and if the entire PLDV stock achieved a fuel consumption of 4 LGe/100km by 2050 (GFEI 2017). It turned out that this target, which was based on readily available, cost-effective technologies, would almost stabilise CO_2 emissions from PLDVs at the 2015 level by 2050 (Figure 13).

At the same time, reduced fuel use greatly helps to curtail air pollution as well as leading to significant savings of fuel cost expenditures. The GFEI quantified cumulative savings in its scenario between 2015 and 2050 to be in the order of USD 8 trillion worldwide (GFEI 2016a).

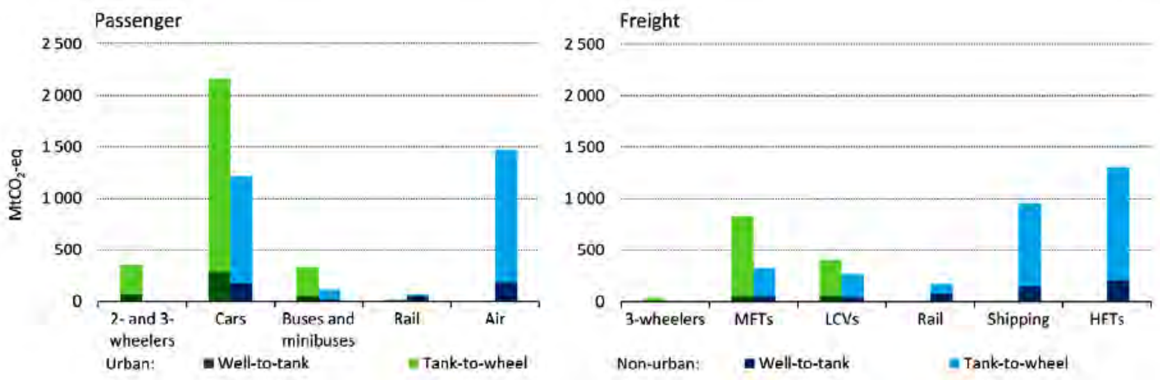


Figure 13: Global passenger light-duty vehicle emission reduction potential
Source: GFEI 2016a

Box 2: The Global Fuel Economy Initiative

Figure 15 GFEI target to double vehicle fuel economy by reducing new vehicle fuel consumption by 50% by 2030

The Global Fuel Economy Initiative (GFEI) was launched at the 2009 Geneva Motor Show to form a body to assist governments and transport stakeholders to promote better fuel economy. Using the skills and expertise of the GFEI partners (the International Energy Agency (IEA), United Nations Environment Programme (UN Environment), the International Transport Forum of the OECD (ITF), the International Council on Clean Transportation (ICCT), the Institute for Transportation Studies at UC Davis, and the FIA Foundation), the initiative invested a lot of effort to bring the issue of vehicle fuel efficiency high up on the international political agenda, and to support developing and emerging economies on the way to take stock of the current national sales-weighted new vehicle fuel consumption (i.e. the baseline fuel consumption) and develop fuel economy policies such as a CO_2 tax, feebate schemes, labelling, and standards.

The GFEI has set the target to reduce LDV fuel consumption of *all vehicles in the stock* by 50% from 8.8 LGe/100km in 2005 to 4.4 LGe/100km in 2050 (GFEI 2017). To reach this target, fuel consumption of all *new* LDVs needs to reach 4.4 LGe/100km by 2030.

5.1.2 Light-duty vehicle fuel economy standards around the world

Many countries have adopted ambitious fuel economy policies. While in 2005 only 60% of the global PLDV and only 4% of the heavy-duty vehicle (HDV) market were covered by fuel-economy or CO_2-emission standards, by 2015 almost 90% of the PLDV and more than 40% of the HDV market was subject to such regulations (Figure 14). In markets where new vehicles are not covered by fuel economy policies, manufacturers are still able to sell less efficient technologies, which earn higher margins. Consequently, it is important to fill gaps in markets to phase out old, inefficient technology globally.

The dominance of regulated LDV markets means countries that rely mostly on imported cars can introduce ambitious fuel economy policies and will obtain better new vehicles at competitive prices. Additionally, countries with domestic vehicle manufacturing industry can make their vehicles more competitive on the international market through the introduction of effective fuel economy policy measures.

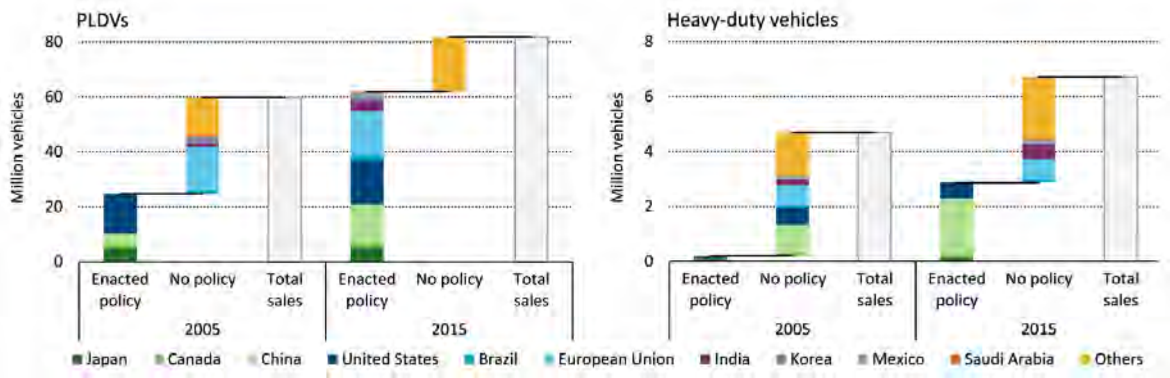


Figure 14: Overview of the global status of light-duty and heavy-duty vehicle fuel economy policies
Source: IEA 2016

Table 7 shows fuel-economy and CO_2-emission standards as well as baseline figures from around the world, exhibiting a variation in vehicle fuel consumption across markets. While US LDVs consumed almost 8 LGe/100km on average in 2014, LDVs in Europe only consumed about 5.5 LGe/100km in the same year. Nonetheless, the United States together with Canada are the only countries with fuel consumption targets set out to the year 2025. By that time, thanks to stringent standards in place, the US LDV fuel consumption will be almost 40% lower than in 2018.

Table 7: Enacted fuel consumption standards around the world

	Base year	Target year	Number of years	Base year fuel consumption Lge/100km	Target year fuel consumption Lge/100km	Total reduction base year to target year	Annual reduction base year to target year	Source for base year & target year
Existing LDV Standards								
EU LDV	2014	2021	7	5.5	4.3	-22%	-3.4%	Est. ICCT 2015
EU PC	2014	2021	7	5.3	4.1	-23%	-3.7%	ICCT 2015
EU LCV	2014	2020	6	7.2	6.3	-13%	-2.3%	ICCT 2015
USA LDV	2014	2025	11	7.8	4.8	-39%	-4.4%	ICCT 2015
USA PC	2014	2025	11	6.7	4.2	-38%	-4.3%	ICCT 2015
USA LT	2014	2025	11	9.5	6.0	-37%	-4.1%	ICCT 2015
Canada LDV	2015	2025	10	7.4	4.8	-36%	-4.3%	ICCT 2015
Canada PC	2015	2025	10	6.4	4.2	-35%	-4.2%	ICCT 2015
Canada LT	2015	2025	10	8.7	6.0	-31%	-3.6%	ICCT 2015
Mexico LDV	2014	2016	2	7.6	7.0	-8%	-4.1%	ICCT 2015
Mexico PC	2014	2016	2	6.8	6.2	-9%	-4.4%	ICCT 2015
Mexico LT	2014	2016	2	9.2	8.4	-8%	-4.3%	ICCT 2015
Existing PLDV Standards								
Brazil PC	2013	2017	4	6.8	5.9	-13%	-3.4%	ICCT 2015
China PC	2015	2020	5	6.9	5.0	-28%	-6.2%	ICCT 2015
India PC	2017	2022	5	5.6	4.8	-13%	-2.7%	ICCT 2015
Saudi Arabia PC	2012	2020	8	6.8	6.1	-11%	-1.4%	ICCT 2015
Korea PC	2015	2020	5	6.2	4.1	-34%	-7.9%	ICCT 2015

Table 7 also highlights the annual fuel consumption improvement rates inherent with the presented standards. All countries except Saudi Arabia have improvement rates close to or above 3% per year, with Korea opting for almost 8% annual reduction of fuel consumption of new PCs, and China envisaging a 6% improvement rate between 2015 and 2020. Linear extrapolations of the already enacted fuel economy and CO_2 emission standards out to

2030 indicate that many of those countries are on track to meet the GFEI target of 4.4 LGe/100km by 2030.

Although the trend is undoubtedly positive, it should be noted that all targets are based on tested new vehicle fuel economy. Unfortunately, recent publications by the International Council on Clean Transportation (ICCT) have demonstrated the increasing gap between tested and real-world, on-road fuel consumption (ICCT 2015a). While 10 years ago, this difference accounted for about 10% to 15%, it is as high as 30% on average as of 2018, with some cars having a real-world fuel consumption 50% higher than the laboratory test. This increasing gap is in part a result of auto manufacturers optimising their vehicles to perform well on tests. In the worst cases, it was due to manufacturers illegally programming vehicles to perform well on tests. This underlines the constant need for fuel economy policy to be carefully designed and implemented in a strong and pragmatic fashion. For example, introducing in-use testing to fuel economy policy could be an innovative way to ensure manufacturers are developing vehicles that will reduce fuel consumption and CO_2 emissions in the real world.

5.2 Costs, benefits and impact assessment of LDV fuel economy policy

Generating recommendations for the ASEAN Fuel Economy Roadmap involves both economic and environmental considerations. This section analyses the various perspectives on developing the aspirational goals, focusing on why fuel economy policy is important to achieving broader positive environmental and economic outcomes, as well as how the specific aspirational goal of this roadmap could be achieved.

5.2.1 Introduction to LDV fuel economy technology

This section provides a short overview of the most common LDV fuel efficiency technologies. It combines information on fuel economy improvement potential with technology costs and resulting pay-back times.

As outlined earlier in the document, several options exist to reduce the sales-weighted average fuel consumption of new LDVs. The principle ones are: 1) the reduction of average vehicle size and weight through a market shift towards smaller vehicle segments; 2) the reduction of average vehicle performance; and 3) the introduction of fuel efficient vehicle technology.

The most efficient way to improve fuel economy would be the combination of all three options. Nonetheless, since consumers demand larger and better performing cars, the focus of this section will be on technology improvement.

A selection of the most common technological measures to improve the fuel economy of LDVs is provided in Table 8. These measures are divided into four categories of improvement: the engine itself; the vehicle drive-train; the weight and aerodynamic performance of the vehicle; and the efficiency of auxiliary aggregates.

Combinations of various measures can lead to significant fuel economy improvements, but not all measures can be combined, and some of the measures come with significant costs. Comprehensive literature on the analysis of costs and fuel efficiency benefits of technology packages for different vehicle classes exist. A detailed summary of technical reports by Ricardo or FEV Inc. are provided in the easy-to-digest overview titled Summary of the EU Cost Curve Development Methodology (ICCT 2012a).

An example of a simulation-based cost curve is provided in Figure 16, representing the CO_2 emission reduction potential and respective costs for a segment-C gasoline car against a 2010 baseline car of the same size class for the European car market.[11] Future additional costs are estimated for the years 2015, 2020 and 2025. This is due to technologies becoming cheaper as a function of deployment and time, in a process dubbed 'technological learning'.

Table 8: Vehicle technologies for fuel efficiency improvement by category

Engine	Drive-train
Cam phase switching (CPS)	Automatic transmission with more than 6 gears
Charge air cooling	Continiously variable transmission (CVT)
Direct injection	Dual clutch gear shift
Downsizing through reduced number of cylinders	Full hybridization
Engine idle-off	Manual 6 gear shift
Exhaust gas recirculation (EGR)	Mild hybridization
Improved cycle, i.e Atkinson cycle	Plug-in hybrid
Increased compression ratio	Regenrative braking
Increased injection pressure	Shift optimization
Launch assist	
Stoichiometric combustion	
Turbo charching, also with multiple stages	
Variable valve timing and lift (VVT, VVTL)	
Light-weighting & Aerodynamics	**Auxiliaries**
Active aerodynamics	48V board system
Aerodynamic optimization	Advanced air conditioning
Low rolling resistance tyres	Advanced alterantor
Use of aluminium	Advanced electric coolant pump
Use of composite materials	Electronic power steering (EPS)
Use of high tension steel	Low friction lubricants
	Optimized particulate filter
	Optimized Selective Catalytic Reduction (SCR)
	Semi-autonomous driving
	Tyre pressure control

Source: based on ICCT 2012a; Ricardo 2012

The analysis shows that as of 2015 a 32% CO_2 emission reduction down to 95gCO_2/km (i.e. the EU 2021 PLDV emission standard) could be achieved at a cost of around EUR 1,750 per car and by applying measures such as start-stop technology in combination with strong engine downsizing to a displacement of 800ccm, based on a stoichiometric gasoline turbocharged direct injection engine. These costs could drop to about EUR 1,000 by the year 2025.

11 In this case, a 2010 Ford Focus 1.6L with no turbocharging and a manual six speed gear shift was used as the baseline vehicle. It has a tested fuel consumption of 6.4 LGe/100km (based on NEDC).

A 50% reduction to only 70gCO_2/km (equivalent to 2.9 LGe/100km) is feasible at 2015 costs of about EUR 3,500, possibly dropping to EUR 2,250 by 2025. This very low fuel consumption can only be achieved through full hybridisation of the vehicle in combination with significant weight reduction and reduced road load due to improved aerodynamics and the use of low rolling resistance tyres.

Similar results are obtained for other vehicle segments. The report shows that on average a 30% CO_2 emission reduction to 95 gCO_2/km (~3.9 LGe/100km, from 5.3 LGe/100km for all PLDVs in 2012 in the EU) could be achieved for all new passenger cars at additional costs of around EUR 1,100 per vehicle by the year 2020 (dropping to EUR 1,000 in 2025). Similarly, the average CO_2 emission of all new LCVs could drop by 30% to about 120 gCO_2/km (~4.5 LGe/100km) by 2020 at additional per vehicle costs of approximately EUR 2,000 (dropping to EUR 1,800 by the year 2025).

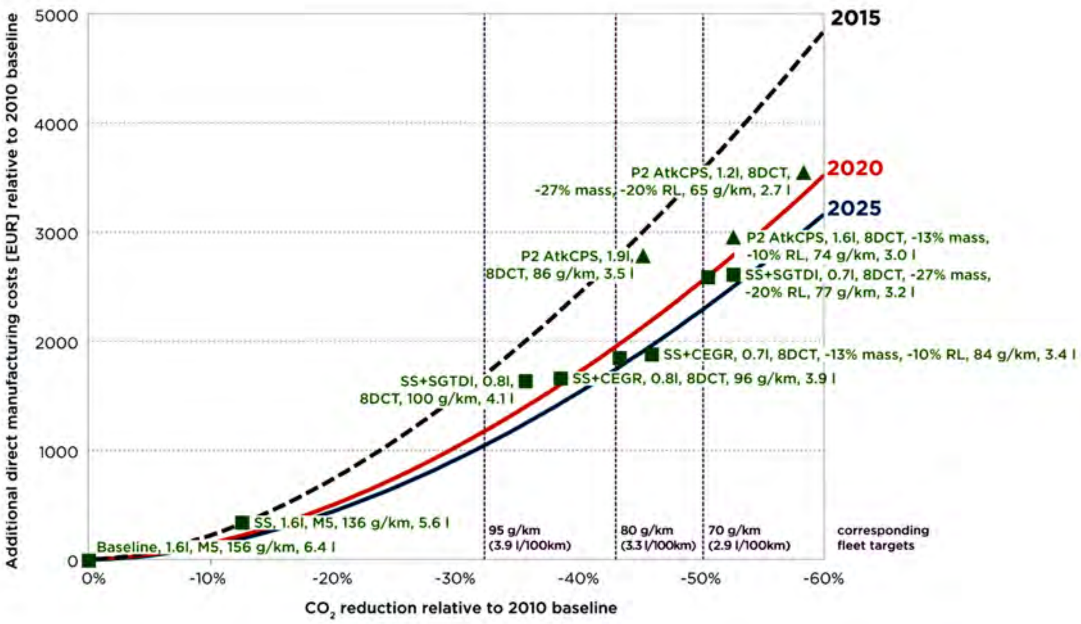


Figure 15: CO2 reduction potential and additional direct manufacturing costs for a segment c petrol car for the years 2015, 2020 and 2025.
Note: M5: manual 5 gear shift; SS: start-stop (idle-off) technology; SGTDI: Stoichiometric gasoline turbocharged direct injection; 8DCT: 8-speed dual clutch (automated) transmission; CEGR: cooled exhaust gas recirculation; RL: road load; AtkCPS: Atkinson cycle engine with cam phase shifting
Source: ICCT 2012a

The publication concluded that 'the introduction of neither electric or hybrid vehicle technology is required to meet the [European fleet] average CO_2 target' of 95 gCO_2/km, i.e. 3.9 LGe/100km for the year 2021 (ICCT 2012a).

The much higher baseline fuel consumption of 7.2 LGe/100km (2015) in the ASEAN region compared to about 5.5 LGe/100km (2014) in the European Union might indicate that the additional per-vehicle cost to achieve a 30% fuel consumption reduction could actually be lower than in Europe. On the other hand, since, on average, LDVs are assumed to be much cheaper in ASEAN region compared to the EU, it is likely that per-vehicle costs to achieve the same fuel economy improvement are higher than in the EU. Nonetheless, assuming even twice the per-vehicle cost compared to Europe, a 30% fuel consumption reduction for PLDVs could be achieved at an additional cost of EUR 2,200 per car (EUR 4,000 for LCVs).

In any case, fuel economy improvement in the order of almost 50% can be achieved without the introduction of costly vehicle power-train configurations such as hybridised or electric vehicles in the ASEAN region.[12] Ambitious fuel economy targets in the ASEAN region can be achieved based on cost-effective vehicle technology already sold in large numbers elsewhere in the world. The fact that many AMSs do not have own vehicle manufacturing capacities and, taken in isolation, are of relatively small market size should not be a limiting factor to bringing cost-effective and efficient vehicles to the market.

5.2.2 Economic costs and benefits of LDV fuel economy

Better fuel efficiency at similar car size is most often linked to increased vehicle costs, for example through the use of better materials, longer development times, and the demand for additional and more complex vehicle subsystems (e.g. turbo chargers). However, numerous studies on various world regions have shown that many vehicle efficiency technologies yield overall cost savings after taking into consideration the costs of fuel saved over the vehicle lifetime (Figure 16).

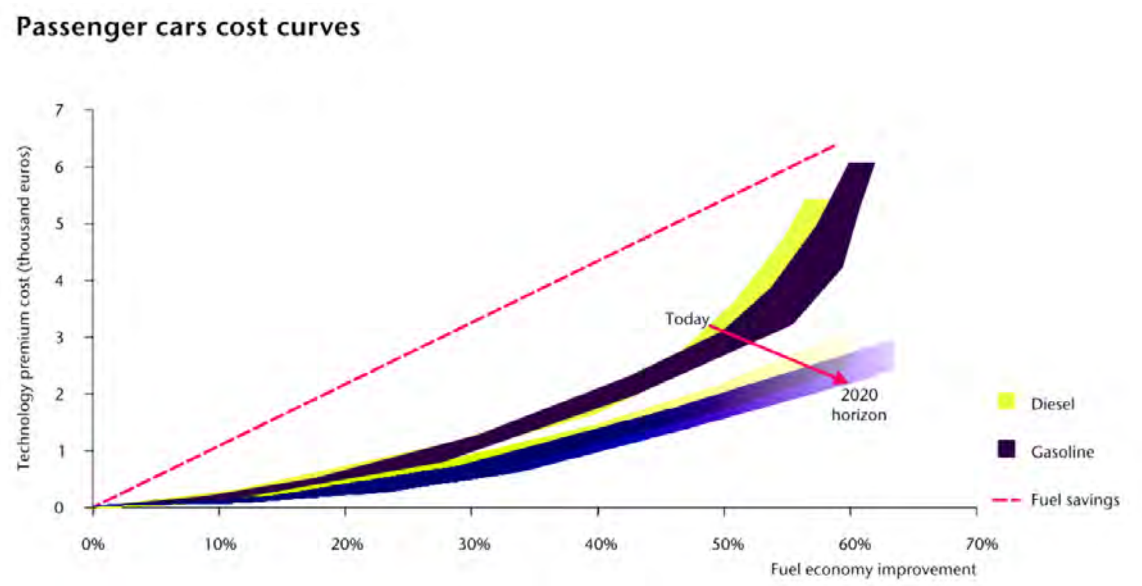


Figure 16: Comparison of technology costs and fuel savings of passenger cars
Source: IEA 2012

Table 9: Cost effectiveness of light-duty vehicle efficiency standards around the world

Rule	Per-vehicle cost (USD)	Payback period (years)
U.S. LDV CAFE Standard 2017-2025	1,800	3.5
U.S. LDV CAFE Standard 2012-2016	950	3
California Advanced Clean Car Program 2017-2025	1,340 to 1,840	3
Canada LDV 2017-2025 FE Standard	2,095	2-5
Canada LDV 2011-2016 FE Standard	1,195	1.5
European Union 95gCO_2/km Standard 2021	1,300	4-5
India LDV Fuel Consumption Standard 2020	400 to 600	2-3

Source: GFEI 2016a

12 Based on achieving 3.9 LGe/100km (i.e. the EU 2021 standard of 95 gCO_2/km) down from 7.2 LGe/100km in the ASEAN today.

Payback periods based on fuel savings and average compliance vary between two and five years, mainly depending on the level of ambition of the fuel-economy or CO_2-emission regulation.

In addition, fuel-economy policies can help improve the balance of trade for AMS, which are largely oil importing countries. In 2013, the region's net import of oil was more than USD 100 billion (ACE 2015). Each dollar that ASEAN consumers spend on imported energy cannot be spent on other products or services, and could be redirected to create more added value for the region. Annex Section 5.2.4 quantifies the savings potential based on different scenarios. It finds that if ASEAN meets the aspirational goal of this roadmap, about USD 9 billion can be saved in the ASEAN region by 2025.

To summarise, policies targeting the increased efficiency of LDVs can save substantial amounts of money, at both household and national levels. Increasing vehicle fuel economy is thus a fundamental approach to combining energy efficiency and climate policy targets with national economic development, as well as efforts to reduce energy dependency and air pollution.

5.2.3 Methodology and tools for cost-benefit analysis of fuel economy policy within AMSs

Cost-benefit analysis (CBA) is an important tool to assess various fuel-economy policy options. A simple CBA compares only a few monetary values over time: 1.) the value of fuel savings and emission reductions on the benefits side versus 2.) the additional cost for more efficient vehicles on the costs side.

But even in its simplest variant, the CBA requires substantial modelling work. On the benefits side, two effects need to be quantified, each requiring a specific tool. These effects are:

1. the impact of fuel economy policies on future sales-weighted new LDV fuel consumption; and
2. the impact of improved new LDV fuel economy on the average fuel economy of the entire rolling LDV stock, energy use, emissions and fuel costs.

The impact of vehicle and fuel taxation schemes on future average fuel economy of newly registered LDVs can be estimated using the freely available Fuel Economy Policy Impact Tool (FEPIT) developed by the International Energy Agency (see Box 3, below).

In order to assess the energy savings, emission reductions and fuel cost savings stemming from the introduction of fuel economy policies, a simple transport model is needed, able to estimate future energy use, emissions and fuel costs based on projections of travel demand.

The previously estimated average annual new LDV fuel economy improvement rate can then be used as an input for the transport model. By comparing a business-as-usual scenario (BAU), which has no changes in vehicle and fuel taxation, with a scenario incorporating the tax reforms and the resulting changes in new vehicle fuel economy, the fuel, emission and cost reduction potential of the proposed changes in taxation can be estimated up until the targeted year.

On the costs side of the CBA, the additional average per-vehicle costs to achieve a certain fuel economy improvement need to be estimated. As outlined in Section 5.2.1, comprehensive and expensive studies have been undertaken by Ricardo and FEV Inc. (Ricardo 2012, FEV 2012) for Europe. Similar studies can be found for the US. Although LDVs in the ASEAN are on average much cheaper than in Europe and North America, the results might be transferable to a certain extent. Given the available literature, even if large levels of uncertainty are applied to cost figures (such as those noted in Figure 11), technology costs as a function of fuel economy improvement can be obtained. As a result, the effort and expense of developing vehicle technology cost curves specifically for the ASEAN market might not be necessary for the purposes of developing fuel economy targets.

Box 3: Spotlight on modelling tools

Fuel Economy Policies Implementation Tool (FEPIT)

FEPIT[13] has been developed by the International Energy Agency and can be downloaded for free. This tool enables the estimation of future sales-weighted average fuel economy of new LDV sales. A key result of FEPIT consists of an annual fuel economy improvement rate of the entire new LDV market of a country between a historical base year and a set target year.

FEPIT estimates the effect of implementing one or more fuel economy policies based on their design as well as information regarding the historical sales-weighted average fuel economy of new LDVs as well as the current policy and market environment (such as the level of vehicle registration tax or the level of fuel duties). The estimates of the expected impacts are based on a set of elasticities linking the policy characteristics with changes in the output variables. In FEPIT, the current vehicle market needs to be characterised by dividing it into five fuel economy bins with equal step width, and by subsequently providing both the market share as well as the sales-weighted average. Once the status quo with respect to LDV market and vehicle taxation is described in FEPIT, the effect of various fuel economy policies on future average new LDV fuel economy can be tested. Such policies include the following:

1) a fuel economy standard
2) a feebate scheme for a one-off registration tax for newly registered light-duty vehicles (LDVs)
3) a feebate scheme for an annual registration tax of LDVs
4) an adjusted fuel tax

For the purposed of this analysis, the effect of the proposed feebate scheme on future average sales-weighted new LDV fuel economy will be estimated.

Fuel Economy Standards Evaluation Tool (FESET)[14]

The New Vehicle Fuel Economy and CO_2 Emission Standards Emissions Evaluation Guide has been developed by GIZ with support from the ICCT, together with a Microsoft Excel-based spreadsheet tool (FESET) to help in calculating the CO_2 mitigation impacts of existing or planned fuel economy standards in a country or region. It provides guidance on the structure of mitigation effects, on determining the baseline and calculating emission reduction, and on monitoring, compliance and enforcement.

The ADB Transport Databank Model

This model has been designed to simulate national transport scenarios, taking into account all modes (i.e. road, rail, water and air), and to project transport activity, energy use, emissions and costs for urban as well as non-urban transport. Transport activity is a function of socio-economic input data such as GDP and population projections, in order to

13 The model as well as a user guide and a methodology report are available at: https://www.iea.org/topics/transport/subtopics/globalfueleconomyinitiativegfei/fepit/
14 Tool guide https://www.changing-transport.org/wp-content/uploads/2017_FES_GHG_Evaluation_Guide.pdf Tool download: https://www.changing-transport.org/wp-content/uploads/Tool_FESET.xlsm

take into account increases in welfare and thus vehicle ownership. The model considers a great variety of vehicle types, powertrain technologies and fuels, and provides a default set of transport policy measures, which can be applied in order to build various sustainable transport scenarios.

Country-specific historical transport data such as vehicle stocks and sales, annual mileages and load factors, as well as socio-economic data such as population and GDP, define the baseline data. Parameters such as vehicle fuel economy, vehicle lifetime or historical average fuel economy improvement rates are fed into the Transport Baseline Model, which then calculates travel activity, modal structure, fuel use and emissions (alongside further outputs with regard to safety and workforce) for the business-as-usual scenario (BAU). With the help of pre-set transport policy options defined in the Policy Inputs module, two alternative scenarios can be developed, calculated and compared to the BAU scenario.[15]

5.2.4 Impact assessment of the aspirational fuel economy goal

models can be utilised to predict the reduction of fuel consumption and CO_2 emissions as the outcome from a policy over time. This analysis first describes a benchmark scenario (BMS) and the fuel consumption as a result of the BMS into the future. Then, based on the actions identified in the roadmap, the impacts of the roadmap compared to the BMS can be determined. In his way, decision-makers can better understand the benefits of improving fuel economy compared to the likely predicted costs.

The scenarios are based on estimated population and GDP growth, where the BMS assumes vehicle ownership to increase from about 70 LDVs per thousand capita in 2015 (equivalent to about 44 million LDVs) to about 110 LDVs per thousand capita in 2025 (~75 million LDVs) and more than 315 LDVs per thousand capita in 2050 (~246 million LDVs).

In the benchmark scenario (BMS), average reduction in fuel consumption of new LDVs is estimated to maintain its historical rate of about 1% per year over the coming decades. Starting at 7.2 LGe/100km for new LDVs in 2015, average new LDV fuel consumption comes down to 6.6 LGe/100km by 2025, and 5.3 LGe/100km by 2050. Applying the targeted annual fuel economy improvement rate between now and 2025 of 3% as per the fuel economy policy scenario (FEPS)new LDV fuel consumption reaches 5.3 LGe/100km in 2025. After 2025, annual fuel economy improvement rate for ICE-powered LDVs is assumed to drop to 1%, since conventional technology is reaching its improvement limits, and sales-weighted average fuel consumption of new LDVs would fall to 3.3 LGe/100km by 2050[16].

15 http://transportdata.net/en/page/11

16 Shares of new vehicle powertrain technologies are identical in both the BAU and ASEAN FEPS. By 2025, conventional ICE cars still account for 95% of sales, the remaining 5% are hybridised vehicles. The share of diesel cars drops from about 37% in 2015 to about 25% in 2025. Even in the benchmark scenario it is assumed that by 2050, about 30% of newly sold cars are hybridised, and 5% each are battery electric and plug-in hybrid vehicles.

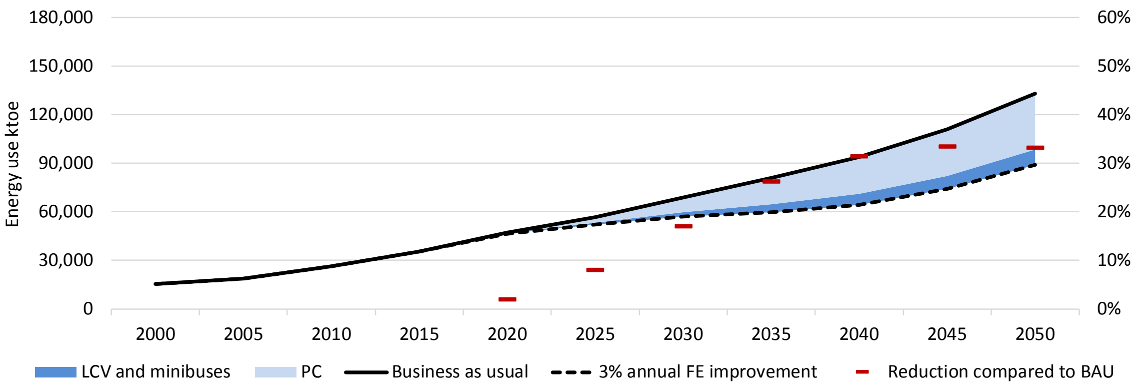


Figure 17: LDV energy use in the ASEAN 2000 to 2050 under the benchmark scenario (BMS) as well as the ASEAN Fuel Economy Policies Scenario (FEPS)
Source: Own analysis

Compared to the BMS, reducing new LDV fuel consumption to 5.3 LGe/100km by 2025 already leads to a 9% reduction of overall annual energy use of all LDVs in the stock in the FEPS (Figure 17).

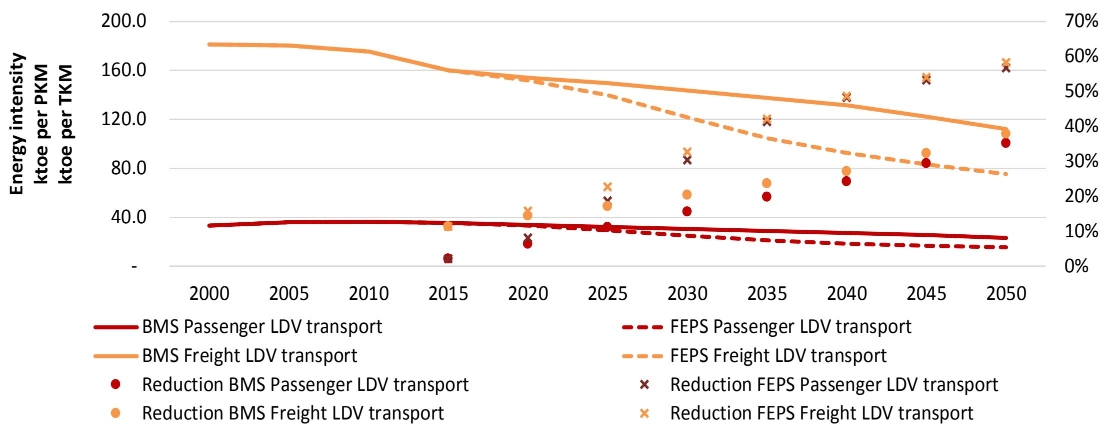


Figure 18: LDV transport energy intensity in the ASEAN 2000 to 2050 under the benchmark scenario (BMS) and the ASEAN Fuel Economy Policies Scenario (FEPS)
Source: Own analysis

The implementation of LDV fuel economy policies alone has a strong potential to greatly contribute to the aspirational target to reduce energy intensity of the ASEAN economy by 30% by 2030. While in the benchmark scenario, the energy intensity of LDV passenger and freight transport decreases by 16% and 20% compared to 2005, the energy intensity reduction exceeds the aspirational target in the FEPS and reaches 30% and 33% for passenger and freight transport, respectively (Figure 19).

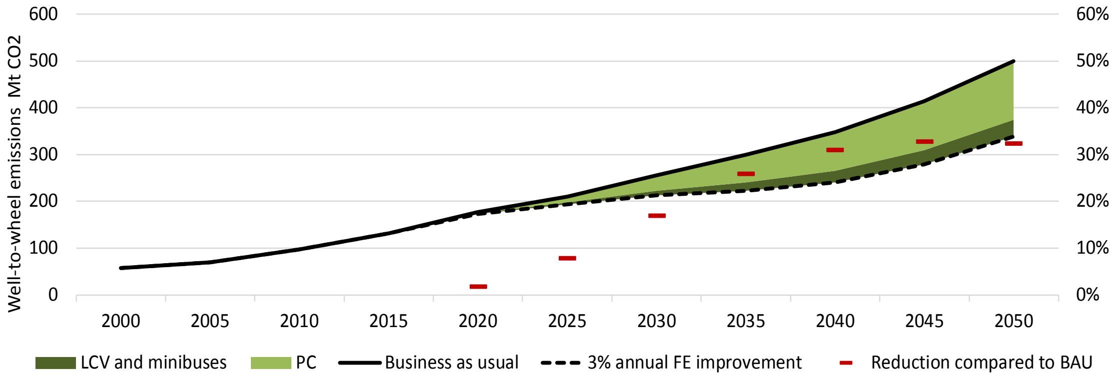


Figure 19: LDV wheel-to-wheel CO2 emissions in the ASEAN 2000 to 2050 under the benchmark scenario (BMS) and the ASEAN Fuel Economy Policies Scenario (FEPS)
Source: Own analysis

The decreased energy use leads to significantly reduced well-to-wheel CO_2 emissions in the LDV transport sector. As for energy use, annual CO_2 emission reductions account for 9% by 2025, about 17% by 2030 and almost 35% by 2050 (Figure 20).

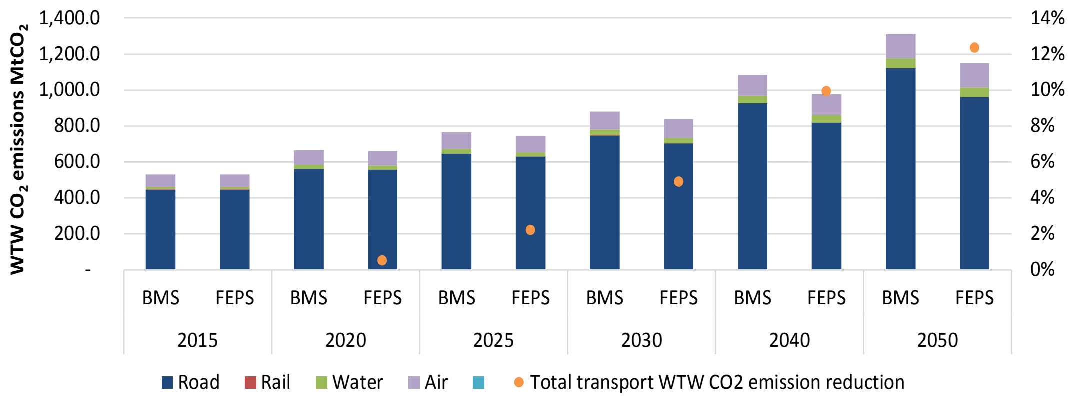


Figure 20: Total transport well-to-wheel CO2 Emissions and LDV emission reductions in the ASEAN for selected years under the benchmark scenario (BMS) as well as the ASEAN Fuel Economy Policies Scenario (FEPS)
Source: Own analysis

The LDV fuel efficiency improvements envisaged in this roadmap would result in a total transport CO_2 emissions reduction of 2% in 2025 compared to the BMS, and 6% by 2030, finally resulting in a 12% emission reduction by the year 2050 (Figure 16). Given this contribution to emission reductions, LDV fuel economy improvement is an important component when developing Nationally Determined Contributions (NDCs) and Nationally Appropriate Mitigation Actions (NAMAs) to mitigate climate change.

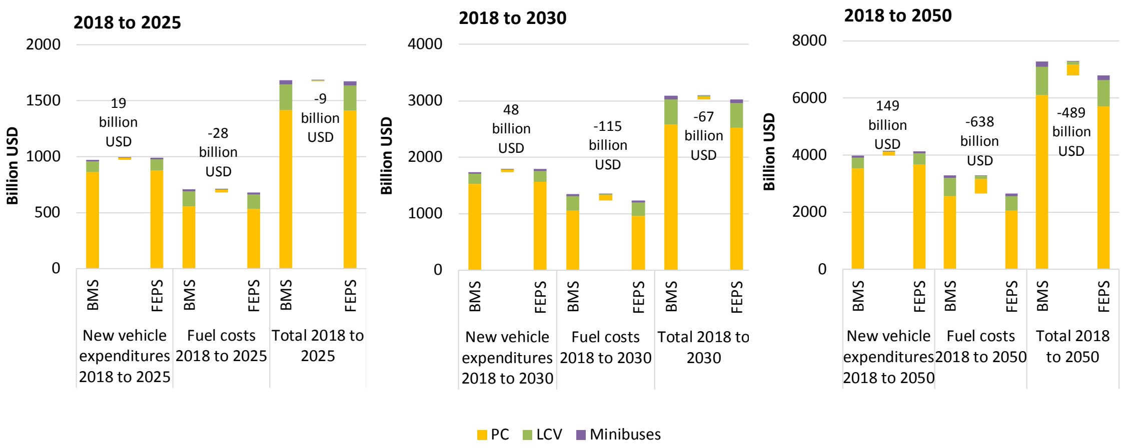


Figure 21: Cumulative costs of new LDV purchases and fuel use 2018 to 2025 and 2018 to 2040 in the ASEAN region under a business- as- usual (BAU) as well as the ASEAN FE RM Scenario
Source: Own analysis

Most importantly, the scenarios show that the implementation of stringent fuel economy policies to achieve the proposed fuel consumption target of 5.3 LGe/100km for new LDVs is economically feasible. When comparing cumulative additional costs resulting from the purchase of better vehicle technology with estimated cumulative fuel savings, it turns out that significant amounts of money can be saved in the scenario where the goals of the roadmap are achieved. Already by the year 2025, about USD 9 billion can be saved in the ASEAN region. If stringent fuel economy policies are continued, cumulative savings could add up to USD 67 billion by 2030 and almost USD 500 billion by the year 2050 (Figure 21).

5.3 Existing fuel economy policies in ASEAN Member States

Table 10: Overview of the status of fuel economy policies in the ASEAN region

	Brunei Darussalam	Cambodia
Fuel economy baseline	Working on developing the baseline.	No baseline calculations.
Fuel economy labelling and public information programmes	-	No labelling scheme in place.
Fuel economy related tax instruments	-	No fiscal incentives in place.
Fuel economy standards	Plans to introduce EU equivalent standards.	No fuel economy standards in place.
Fuel taxation	-	-
Pollutant emissions standards	-	-
Fuel quality standard	-	Euro II-compatible.
Import of used vehicles	-	-

	Indonesia	Lao PDR
Fuel economy baseline	Fuel economy baselines established for LDVs and 2-wheelers in 2012. Baseline calculations also available in GFEI WP15 (GFEI 2017).	No baseline calculations.
Fuel economy labelling and public information programmes	Voluntary labelling by manufacturers based on test data from type approval process. Eco-driving programmes and intensive public policy dialogues.	No labelling scheme in place.
Fuel economy related tax instruments	Low Cost Green Car Programme including zero luxury sales tax (LST) for 120ccm vehicles (diesel: 150ccm) with FE> 20km/litre or 128 gCO_2/km. To be replaced by Low Carbon Emission Vehicles Program (2017), which foresees a 50% LST reduction for advanced technology vehicles (e.g. hybrid, alternative fuels) with fuel economy greater to 28 km/l and 5% LST reduction for 20-28 km/l.	Duty reduction for LDVs using clean energy e.g. electric vehicles.
Fuel economy standards	Establishment of standards currently not under discussion.	No fuel economy standards in place.
Fuel taxation	-	Gasoline: 15% Special gasoline: 20% Diesel: 5%
Pollutant emissions standards	Euro 2 (LDVs) and Euro 4 since 2016. Expected to adopt Euro 4 standards for gasoline vehicles in 2017, diesel vehicles will follow. EURO III for 2-wheelers already in place.	Fuel quality is monitored by Ministry of Science and Technology. Ministry of Natural Resources and Environment has recently approved the National Environmental Standards which mentions vehicle pollutant emission standards. Biofuel production has been initiated by the private sector, however, the government has set up policies to promote biofuel productions and use, such as tax exemption, no import duty on production machinery etc. The government aims to reach a 10% .share of total transport energy consumption with biofuels
Fuel quality standard	2000 ppm sulphur diesel.	-
Import of used vehicles	-	Stopped import of second-hand LDVs in 2012.

	Malaysia	Myanmar
Fuel economy baseline	Baseline calculations available in GFEI WP15 (GFEI 2017).	No baseline calculations available yet, but ongoing support through GFEI for establishing baseline.
Fuel economy labelling and public information programmes	Ongoing preparation to introduce fuel economy (FE) label, which requires validation of OEM information. UNECE-drive cycles are not considered suitable for Malaysian conditions. The idea is to first develop national drive cycles, and then develop an energy-efficiency rating/labelling scheme.	No labelling scheme in place. The transport sector has been included in the energy efficiency action plan, which was launched early 2016 and is pending parliamentary approval. Available at: http://www.burmalibrary.org/docs22/2015-12-Myanmar_Energy_Master_Plan-spdf-red.pdf
Fuel economy related tax instruments	Customised incentives for local OEMs to produce energy efficient vehicles as defined in the National Automotive Policy 2014, which aims to develop Malaysia as the regional hub for energy-efficient vehicles (EEVs). EEVs are defined by consumption limits differentiated by kerb weight. All manufacturers now produce EEVs, thus benefitting from lower duties. In 2015, 32.6% of the sold cars were EEVs. The target number of EEV sales is 1 million units by 2020.	A fee has to be paid for imported vehicles, which is waived for electric vehicles. The amount depends on the engine capacity. The fees for imported buses are lower than for private cars.
Fuel economy standards	The National Automotive Policy 2014 report suggests fuel consumption standards as the basis to incentivise OEMs to produce EEVs. The specification for fuel consumption (L/100km) is based on international benchmarking. The unit gCO_2/km is to be used once EURO IV is introduced nationwide. It should focus on LDVs, including passenger cars, light commercial vehicles and 2-wheelers.	-
Fuel taxation	-	-
Pollutant emissions standards	-	.Euro II standards are under discussion
Fuel quality standard	In 2015, Euro V-compatible diesel has been introduced across Malaysia. Euro II-compatible diesel production remains permitted. RON97/Euro 4-compatible gasoline is available nationwide. RON94 gasoline is still Euro 2-compatible, but refinery upgrades .are ongoing	.Euro II-compatible fuel standards are under discussion
Import of used vehicles	-	Myanmar allows second-hand vehicles of no more than four years older than the current calendar year to be imported to the country, and only left-hand drive.

	The Philippines	Singapore
Fuel economy baseline	Baseline calculations completed in 2013 for LDVs. Baseline calculations also available in GFEI WP15 (GFEI 2017).	176g/km before Carbon Emission-based Vehicle Scheme (CEVS) in 2012, 168g/km after CEVS (2013). The scheme covers passenger cars and taxis.
Fuel economy labelling and public information programmes	Roll-out of labelling scheme for passenger cars in 2018 as part of the Energy Efficiency Roadmap. Re-launch of fuel economy run initiative in 2016. Driver training programmes exist in the private sector.	Mandatory fuel economy labelling for passenger cars and light commercial vehicles was first implemented in 2009. There is a fuel cost calculator available at https://vrl.lta.gov.sg/lta/vrl/action/pubfunc?ID=FuelCostCalculator
Fuel economy related tax instruments	The development of tax incentives is foreseen in the Energy Efficiency Roadmap.	The CEVS was a feebate scheme to incentivise consumers to purchase cars with lower carbon emissions. The CEVS was first introduced in January 2013 and revised once in July 2015. The revision tightened the carbon emission bands to account for technology improvement. The CEVS was replaced in January 2018 with a new Vehicular Emissions Scheme (VES), which accounts for five major pollutants, including hydrocarbon, carbon monoxide, nitrogen oxides and particulate matter emissions, along with carbon dioxide (representing fuel consumption) being just one of the five. In addition to being a feebate scheme, it also includes an on-vehicle label describing these emissions and rebates or surcharges, and also provides this data to the public in an online database.
Fuel economy standards	The development of a fuel-economy standard was proposed in the DOE Energy Efficiency roadmap in 2015. Development of national technical regulation (MEPS) for automobile fuel consumption is tentatively planned for 2018. Covers LDVs only.	No fuel economy standards in place.
Fuel taxation	-	Gasoline: 15% Special gasoline: 20% Diesel: 5%
Pollutant emissions standards	So far, Euro 2 is required for new LDVs. Euro IV was supposed to be introduced by 2016 depending on the fuel availability. Euro III is the .current standard in place for 2-wheelers	The CEVS was replaced in January 2018 with a new Vehicular Emissions Scheme (VES), which accounts for five major pollutants, with carbon dioxide being just one .of them
Fuel quality standard	The current sulphur limit for diesel is 500ppm. Euro II- and Euro IV-compatible fuels are supplied to the market. Since January 2017, Euro 4-compatible fuel standards will be in place for RON97 gasoline, from 2018 onwards Euro 4-compatible fuel will be the standard for .RON95 gasoline	Euro V-compatible standards for fuel quality, from September 2017 onwards Euro 6-compatible standards for petrol and from January 2018 Euro VI-compatible fuel standards for diesel too. The fuel quality standards are regulated by the national environment agency, and revised regularly (e.g. the sulphur content in diesel is measured regularly).
Import of used vehicles	-	-

	Thailand	Viet Nam
Fuel economy baseline	Fuel economy baselines for the years 2012 to 2015 in 2017 GIZ. Baseline calculations also available in GFEI WP15 (GFEI 2017).	No baseline calculations.
Fuel economy labelling and public information programmes	Fuel-economy and CO_2 label mandatory for LDVs since January 2016 (Eco-Sticker). www.car.go.th website showing info on every car that has Eco-Sticker.	Voluntary from 1 January 2014 and mandatory from 1 January 2015. Only applied to private cars with 7 or fewer seats. From 1 January 2018 applicable to private cars with 9 or fewer seats. Online information for consumers available at: http://www.vr.org.vn/vaq/Tieuthu_Nlieu/List_Tieuthu_nlieu.asp
Fuel economy related tax instruments	Excise tax based on CO_2 emissions since 2016. The Eco-Car programme phase II provides tax incentives to the car manufacturers such as cooperate income tax (CIT) exemptions for 6 years, reduction of import duty on imported parts, exemption of import duty on machinery. To qualify for the programme, fuel economy must be 23km/litre or more.	Only applied for private cars and LDVs with engine displacement less than 2.0 litres. Only applied for private cars with 9 seats or fewer.
Fuel economy standards	Voluntary MEPS & HEPS (km/l) for diesel and gasoline vehicles have been drafted in 2013 by DEDE (Ministry of Energy) together with Thailand Automotive Institute, but remain under discussion (the measures were postponed to secure an additional review by domestic industry) Voluntary MEPS for motorcycles regulated by TISI. But no one adopted so far Covers light-duty vehicles and 2-wheelers.	A study on fuel consumption standards for LDVs and motorbikes was completed in 2013. The non-mandatory standard on limit of fuel consumption for passenger cars and 2-wheeled motorcycles and mopeds has been issued by the Ministry of Science and Technology in the form of fuel consumption limits (L/100km). TCVN 9854 2013: Limits on fuel consumption for new passenger cars. TCVN 7356: 2014: Limits on fuel consumption for new motorcycles.
Fuel taxation	-	-
Pollutant emissions standards	LDVs need to comply with Euro IV standard since 2012. The Eco Car phase II programme raised the benchmark for classification to Euro V emission standard. Application of Euro VI .standard is considered by 2020	Type approval procedures require new vehicles to meet certain emission standards. All manufacturers and importers of new vehicles need to provide the necessary documents with pollutant emissions (included CO_2) and fuel consumption of the vehicle type to Viet Nam Register before type approval certificate is issued. Euro IV for manufactured, assembled and imported passenger cars mandatory from 1 January 2017. Euro III for manufactured, assembled and imported motorcycles mandatory from 1 January 2017.
Fuel quality standard	.50ppm sulphur diesel is available	Gasoline: Sulphur Euro 2-compatible max 500mg/kg; Euro 4-compatible max 50 mg/kg; diesel: Sulphur Euro II-compatible max 500mg/kg; Euro IV-compatible max 50 mg/kg. Euro II and Euro IV fuel will be supplied in the market by 2017.
Import of used vehicles	Besides an exception for importing one second-hand vehicle per person on a personal basis (already owned by the person), Thailand does not allow the import of second-hand vehicles.	Used cars can only be imported if they are not older than 5 years.

5.4 Gaps and barriers to fuel-economy policy in ASEAN and AMS

5.4.1 The lack of knowledge and data for developing fuel economy baselines

The development of fuel economy baselines is essential. First, they create an understanding of the status quo of new vehicle fuel economy in a country. Second, they serve as a starting point for the development of fuel consumption targets. Last but not least, they are needed to monitor the progress of average new LDV fuel consumption over time.

Section 2.4 already discussed available fuel consumption baselines for Indonesia, Malaysia, the Philippines, Singapore and Thailand. However, fuel consumption baseline data are not yet available for Brunei Darussalam, Cambodia, Lao PDR, Myanmar and Viet Nam. However, Myanmar and Viet Nam are working on their baselines with support from GFEI and GIZ, respectively.

Although these countries account for less than 5% of the ASEAN LDV market (Figure 22) and do not impact the aggregated results of the region dramatically, it is important to determine the sales-weighted average new LDV fuel consumption within these markets as soon as possible. Establishing the fuel consumption baselines can also serve to build capacity among the relevant government agencies and is thus a substantial step towards the development and implementation of fuel economy policies.

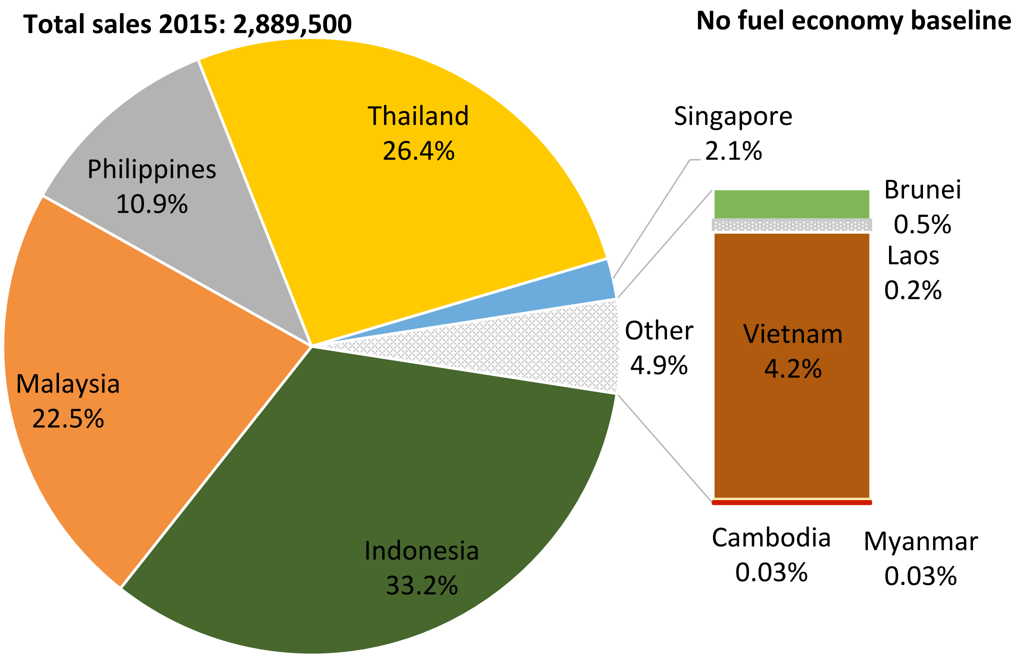


Figure 22: Fuel economy baseline coverage of the ASEAN LDV market 2015
Source: OICA 2016

5.4.2 The role of second-hand imported vehicles

The import of used vehicles can pose challenges to the introduction of fuel economy policies. For vehicles manufactured prior to 2000, it can be very challenging to find fuel consumption data, since vehicle labelling programmes became mandatory only about that time in Japan. In other countries exporting significant numbers of used vehicles to ASEAN, such as the United Kingdom, fuel economy labelling did not become mandatory until 2005.

An overview on import regulations for used vehicles in the AMS is provided in Table 9.

Table 11: Import regulation for used vehicles in the ASEAN region

	Import of used vehicles	Age restriction	Emission standard
Cambodia	Yes	-	-
Brunei Darussalam	Yes	Private: 3 years from first registration Commercial: 5 years form first registration	-
Indonesia	No	-	-
Lao PDR	Yes	-	-
Malaysia	Yes	5 years	-
Myanmar	Yes	4 years	-
The Philippines	No	-	-
Singapore	Yes	3 years	needs to comply with domestic standards
Thailand	No	-	-
Viet Nam	Yes	5 years	-

Source: UN Environment TBP

Used imported vehicles should comply with the air pollution regulation for newly registered cars. That way, the importation of very old cars can be prevented while flexibility is retained to import vehicles that may be slightly older than those with current limits but have the same technical standards as new vehicles in the region.

In any case, it should be the duty of importers of used cars to provide certified vehicle fuel-consumption or CO_2-emission data based on the test cycle of the country of origin of the vehicle. Fuel consumption values based on other cycles (e.g. Japanese JC08 or US CAFE) can then be transformed into NEDC equivalents using conversion formulas published by ICCT (ICCT 2014).

To better understand the importance of used imported vehicles it is therefore necessary to investigate the share of used imported cars as a proportion of all newly registered vehicles.

5.4.3 Administrative barriers for fuel economy policy development

During various fuel economy workshops carried out by GIZ, it turned out that fuel economy policy making is often a subject without a permanent institutional home base. In many cases, the issue of fuel economy policy falls under the responsibility of numerous government agencies, which are often organised under different ministries. A stakeholder diagram to illustrate the roles and responsibilities of government agencies related to vehicle fuel efficiency in Thailand is shown in Figure 23.

Eleven different agencies are involved with the development of various fuel economy policies, which in this case are categorised as consumer information-related, regulatory or fiscal. In addition, none of the government agencies with a mandate to propose legislation is situated at a cross-section of all policy areas.

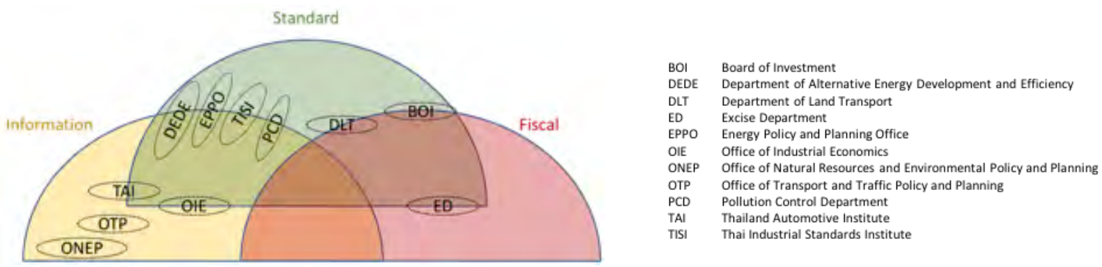


Figure 23: Stakeholder diagram to identify roles and responsibilities of vehicle fuel efficiency related government agencies in Thailand
Source GIZ 2017

It is thus important to appoint a lead agency to coordinate the development and implementation of fuel economy policies. Each of the other relevant institutions should also appoint a key contact person to deal with the topic.

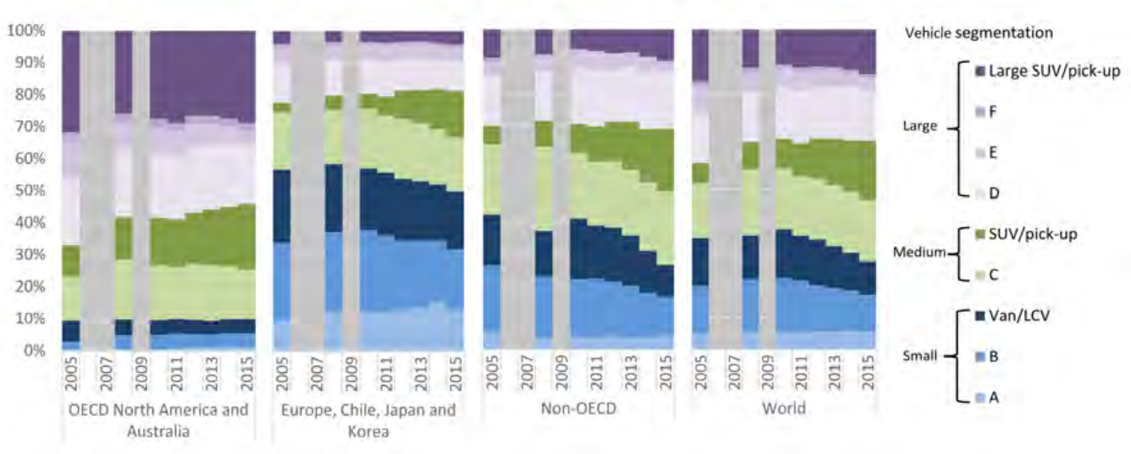
In addition, some of the proposed fuel-economy policy measures require more administrative infrastructure than others. The introduction of fuel-economy standards based on corporate average sales-weighted fuel consumption needs significant administrative capacity. First of all, it requires a close collaboration between the government agency and the vehicle manufacturers and/or importers. Since fuel consumption targets are set for each manufacturer individually and are based on historical market portfolios (see Section 4.4), the target setting as well as monitoring and compliance checking process require the protocoled exchange and verification process of detailed vehicle sales data. Since enforcement action needs to be taken against cases of non-compliance, it also requires the set-up of the legislative framework as well as an agency to administrate such issues, i.e. to issue fines. The development of manufacturer-specific fuel consumption targets will most likely be a lengthy negotiation process to find consensus among all stakeholders.

As a first step, the development of stakeholder maps similar to the one shown for Thailand (Figure 24) are helpful for orientation.

5.4.4 Behavioural challenges

When a consumer buys a new car, fuel efficiency is just one characteristic among many that are considered in making a decision, and is often not the most important purchase criteria. In addition, many new car buyers have issues with anticipating longer-term savings. As summarised in a publication on feebate schemes by ICCT, “customers are loss averse and the more uncertain the benefits of a purchase decision, the more customers will reject the purchase” (ICCT 2010). Future petroleum prices are highly uncertain, and so are future savings due to the purchase of more fuel-efficient vehicles. Providing an up-front financial incentive to buy an efficient vehicle seems to address that specific consumer behaviour. Financial incentives in combination with a fuel economy label that clearly presents future fuel cost savings or savings on additional expenditures compared to the average car can effectively convince consumers to buy a more fuel-efficient vehicle.

Apart from the above, behavioural changes are needed with respect to car size and utility. Over the past 10 years, large and medium-sized SUVs and pick-ups, especially the latter, have gained market share around the world. This trend is particularly pronounced in non-OECD countries (Figure 24) and needs to be reversed for ambitious fuel consumption targets to be achieved.



Source: GFEI 2017
Figure 24: Vehicle size evolution across the world 2005-15

5.5 Policy and technical toolbox for comprehensive fuel economy policy

5.5.1 International experience: strategies for fuel economy improvement

Between 2012 and 2015, the Netherlands, Cyprus and Bulgaria achieved the highest annual improvement rates of between 4% and 5% (Figure 25). Three of the four biggest European economies (France, Germany and Italy) achieved improvement rates of around 3%, and the entire EU27 reached 2.9% annual fuel economy improvement.

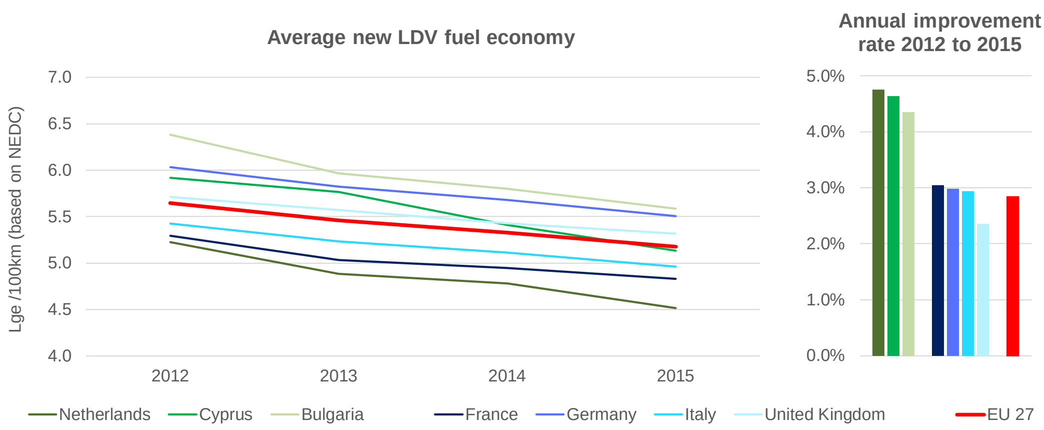


Figure 25: Historical fuel economy improvement and annual fuel economy improvement rate for selected EU countries and the EU27
Source: own calculations based on European Environment Agency (EEA) Data

It needs to be noted that these high improvement rates have been achieved despite the already good baseline fuel economy for passenger cars of 5.6 LGe/100km back in 2012 (compared to 7.2 LGe/100km in the ASEAN in 2015 for passenger cars and light trucks).

The countries with highest annual improvement rates are characterised either by a relatively high baseline fuel consumption (e.g. Bulgaria, Cyprus) or by very progressive fuel economy policies (e.g. the Netherlands).

Nonetheless, impressive fuel economy improvement can be achieved with the implementation of fiscal fuel economy policy measures (see case study on Turkey, Section 4.3.3). Between 2005 and 2015, average fuel consumption of new LDVs improved by 3.9% per year, while at the same time, the size of cars of all segments slightly increased (GFEI 2017).

A clear relationship can be observed between the strong fuel economy policies and the level of sophistication of vehicle engine technology. The ratio of fuel consumption per unit power (LGe/100km per kW) can be used as an indicator of modernity of engine technology. New LDVs in almost all OECD countries achieve low per-kW fuel consumption at relatively high power ratings, while the opposite is true for many non-OECD markets. Among the presented countries, average new LDVs in Indonesia have the highest per-kW fuel consumption while average power rating is the second-lowest after India. This is a clear indication of the use of outdated technology – naturally aspirated engines with lower compression ratios.

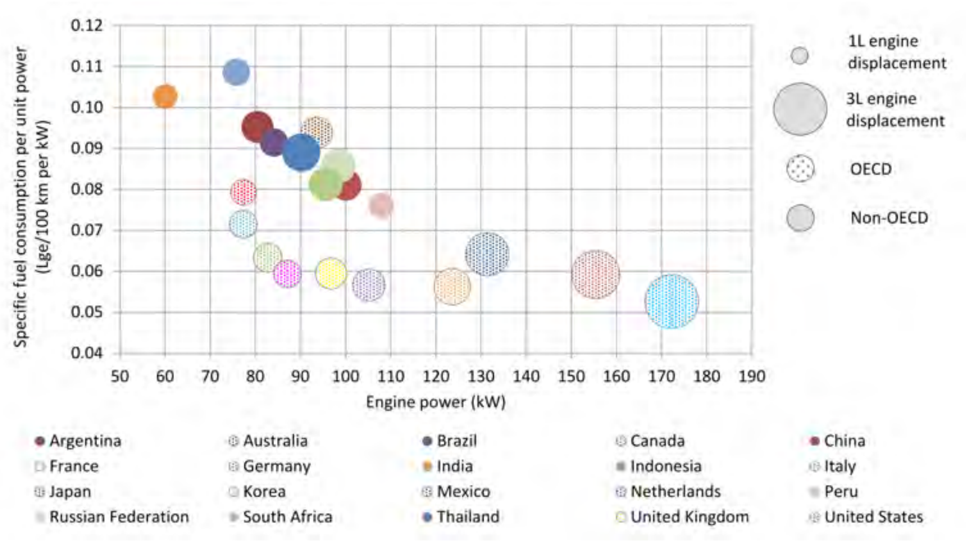


Figure 26: Specific fuel consumption per engine power as a function of engine power for various LDV markets
Source: GFEI 2017

5.5.2 Strategies for consumer awareness of fuel consumption

On-vehicle labels and other technologies that clearly describe fuel economy and other fuel and environmental information to consumers are highly effective for allowing consumers to make decisions about which vehicle to purchase. In addition, labels are a key means for governments to centralise data with regards to fuel consumption of vehicles.

Although some ASEAN countries have already developed fuel economy labels (see Section 2.5), often important information is missing. Figure 27 shows the labels of Singapore, Thailand and Viet Nam. They all show fuel consumption in L/100km, but only Singapore's label enables the consumer to understand whether the stated fuel economy is good or bad.

Figure 27: Fuel economy labels of Singapore, Thailand and Viet Nam

In contrast, US fuel economy labels contain a complete set of information, as shown in Figure 28.

The data provided not only informs about fuel consumption and emissions but offers additional specifications such as annual fuel costs or a five-year fuel cost differential compared to the average car. This information is very helpful to consumers as it allows them to directly compare short-term and long-term costs and savings of different cars under consideration.

1. Power train and fuel
2.+5. Fuel economy and fuel consumption
3. Vehicle class and fuel consumption range
4. Saved/additional fuel costs compared to the average car
6. Annual fuel costs
7. Fuel consumption and greenhouse gas rating
8. CO_2 emissions
9. Air pollutants rating
10. Assumptions for fuel cost calculation
11. Code to read with smart phone
12. Link to government website and fuel cost calculator

Figure 28: The fuel economy label of the United States
Source: Fueleconomy.gov 2017

In addition to fuel economy labels, other consumer awareness tools are available, such as websites, fuel consumption trackers and fuel economy runs. Fuel economy websites are often provided by governments and provide information on fuel economy of all vehicles approved for sale in their jurisdictions. The US EPA website, www.fueleconomy.gov, provides comprehensive information on tested fuel economy of vehicles available in the US, as well as information on strategies for saving fuel, self-monitoring of fuel consumption, and information about advanced vehicles and technologies. The website of China's Ministry of Industry and Information Technology (MIIT) on fuel consumption (www.chinaafc.miit.gov.cn) also provides a comprehensive list of the fuel economy ratings of vehicles approved for use in China. Yet these websites need not be operated by governments. Websites such as www.spritmonitor.de and Little Bear Fuel Consumption (www.xiaoxiongyouhao.com in Chinese) offer publicly collected data on thousands of vehicle models provided by users in real-world conditions.

Meanwhile, a number of products exist that can connect to a vehicle's on-board diagnostics (OBD) computer to report fuel consumption in real time, and record it either for real-time display, or to display over time depending on different driving conditions and speeds, or to help diagnose problems with cars.

Finally, governments and car clubs can undertake fuel economy runs, bringing cars out to track or highway conditions to demonstrate real-world fuel economy and to raise awareness about vehicle efficiency, eco-driving and efficient technologies of vehicles. Fuel economy runs have been undertaken in a number of AMS to bring awareness to this issue.

5.5.3 *Feebate design and implementation*

Feebates can take the form of vehicle registration tax schemes, where the purchase of inefficient vehicles is discouraged through high registration taxes, while the purchase of more efficient vehicles is incentivised through the payment of rebates to the consumer. Feebates need to be based on either vehicle fuel consumption or CO_2 emission as the main indicator and can be set up to generate government revenues to be cost-neutral or to result in net costs.

The latter is illustrated in with decreasing fuel consumption. Whether a feebate scheme is revenue-generating, cost-neutral or cost-incurring depends on the pivot point. The strength of the fiscal incentive to purchase efficient vehicles depends on the slope of the function.

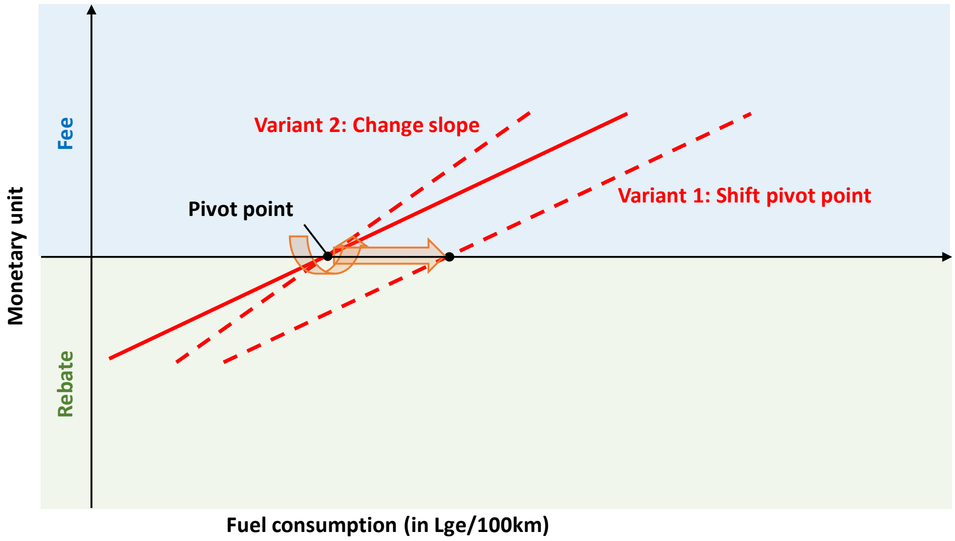


Figure 29: Schematic illustration of a fuel consumption -based feebate scheme

If the pivot point is set lower than the current fuel consumption baseline (to the left of the historical sales-weighted average new LDV fuel consumption), the system will be revenue-generating, as the larger part of the new vehicle purchases will be located within the blue area along the feebate function. The inverse is true in the case where the pivot point is shifted to the right (Variant 1), above the current sales-weighted average fuel consumption. In this case more vehicles will be eligible for a rebate.

The slope of the feebate function is equally important. A steeper slope increases the incentive to buy more efficient cars (Variant 2) and can result in a more rapid response of consumers shifting to buy increasingly efficient cars, thus reducing the revenues and increasing the costs to the government.

A third option to ensure that the system is revenue-generating is to combine a flatter slope of the rebate function to the left of the pivot point with a steeper fee function to the right. That way, even a significant shift of the purchase behaviour will lead to lower losses than in a system without changing slopes.

In any case, feebate schemes need to be adjusted to the market development on a periodic basis to account for the fact that vehicles are becoming more efficient and to prevent making the system a victim of its own success. Most systems today are based on bi-annual adjustments. In a well-designed system, it would be sufficient to gradually shift the pivot point to the left over time.

A freely available feebate design tool can be downloaded from the ICCT website[17]. This Excel-based simulation model helps to design a country-specific feebate scheme based on historical LDV sales. Key parameters such as the pivot point as well as the slope and the form of the feebate function can be estimated based on input data such as recommended future government revenues. It also provides estimates regarding the effect of the feebate scheme on future sales-weighted average new LDV fuel consumption and CO_2 emissions.

17 The tool can be downloaded from: http://www.theicct.org/feebate-simulation-tool

Since feebates are based on a continuous function that directly adds a price tag to fuel efficiency improvement, they promote fuel consumption improvement beyond any determined fuel consumption target, and thus do not have the problem of defining reasonable lead times.

Compared to fuel economy standards, feebate schemes require significantly less administrative infrastructure. Most ASEAN countries already have a vehicle registration tax in place. These structures can be used to turn a registration tax based on price or engine displacement into a feebate scheme based on fuel consumption or CO_2 emissions.

In addition, the need for data to characterise the LDV market is much less comprehensive than in the case of a corporate average fuel consumption standard. While a feebate scheme requires the existence of the fuel consumption baseline data as well as additional data such LDV market share by segment and price, (and potentially by power, weight and vehicle footprint), a standard requires the close interaction between the responsible government agency and the respective manufacturers and vehicle importers to set manufacturer-specific targets, check for compliance, and potentially issue fines.

Some argue that the principal aim of feebate schemes is to incentivise manufacturers to bring efficient vehicles to market, rather than encouraging the consumer to buy them (ICCT 2010). While this is true for larger vehicle markets with own manufacturing capacities, this is less the case in the AMSs. In the ASEAN region, a regional fuel-economy standard could be the means to convince manufacturers and importers to improve their offer. Complementarily, feebates would directly address the consumers. Collecting fees and offering rebates directly to the consumer seems to be the only way to quickly implement feebate schemes in the region, mainly building on the existing vehicle registration tax structures and using the administrative infrastructure.

The collection of the feebate needs to be under the responsibility of a ministry that has already been involved in vehicle taxation (e.g. in Thailand that would be the Department of Land Transport). The executive arm to enforce the collection of the feebates should be the same office that is already in charge of vehicle registration. Consumers should be responsible for the provision of certified fuel consumption information, in addition to the information that is already required to register a new car (such as bill of lading, certificate of payment, certificate of conformity, clearance papers from the national police, approved motor vehicle inspection report, and insurance certificates, as required depending on national legislation).

The introduction of a mandatory fuel economy label for cars is highly conducive to the success of these policies, as it allows consumers to completely understand the rationale and decision-making basis for fees or rebates related to the feebate programme. Countries which allow for the import of used vehicles need to put the importers in charge of providing official fuel-consumption or CO_2-emission data in the country of origin's certificate of conformity.

Case studies

The most prominent feebate scheme, the consumer-oriented French bonus-malus system, was introduced in 2008. Since then, it has been revised almost every year. It is essentially a one-off vehicle registration tax, which can be positive, zero or negative, depending on the car's CO_2 emissions. Its feebate function for the years 2016 and 2017 are shown in Figure 31. In the early days of the scheme, consumers were more enthusiastic than expected, resulting in significant unbudgeted costs to the government. While prior to the feebate, average new vehicle CO_2 emissions were reduced by 1 gCO_2/km on average per year, annual reductions amounted to 9 gCO_2/km and 7 gCO_2/km for the years 2008 and 2009 (ADEME 2011).

In the ASEAN region, Singapore is the only country with a feebate scheme in place. In the former CEVS feebate programme, fees and rebates were significantly higher compared to the French system, especially at its extreme ends. Vehicles with emissions below 95 gCO_2/km (~4.1 LGe/100km) were eligible for rebates of more than USD 20,000 (Figure 30). On the other side, vehicles emitting more than 230 gCO_2/km (~9.9 LGe/100km) were charged more than USD 20,000. The programme was replaced in 2018 with a multi-pollutant feebate scheme called the Vehicular Emission Scheme. In the new VES, vehicles that ambitiously reduce all emissions will receive greater rebates, and those that produce more of all emissions will see higher fees, up to USD 20,000.[18]

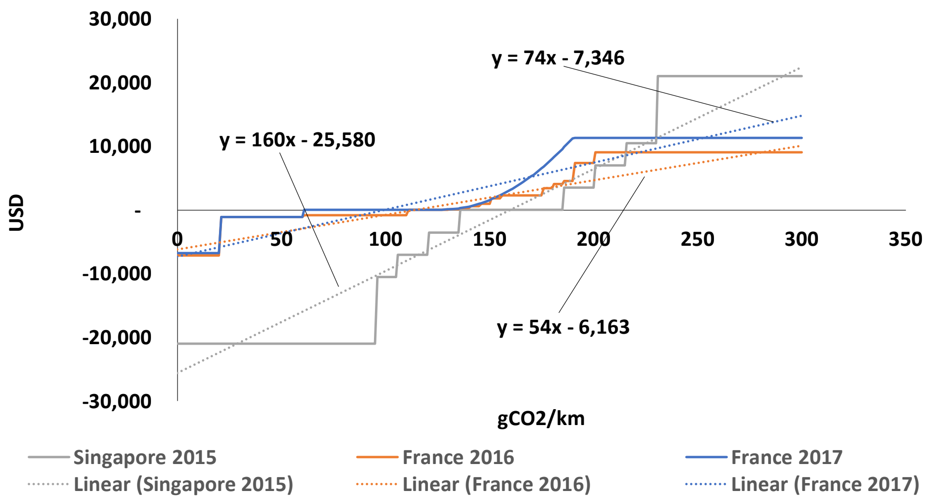


Figure 30: Feebate schemes of France 2016 and 2017 and Singapore 2015. The Singaporean CEVS was replaced by a multi-pollutant Vehicular Emissions Scheme in 2018.
Source: Caradisiac 2017, LTA 2017

Both the French and the Singapore schemes contain step functions. While these functions make the schemes easier to understand for consumers, the steps can create undesired side effects. They create some incentive to the manufacturers to game the rules, in cases where some of their models are only little above a threshold between tax classes. In such cases, fuel consumption can be reduced through measures such as slightly better tyres or changed engine management, resulting in much lower registration taxes in return for only small real-world changes. Thus, the environmental benefit is marginal, and the system fails its purpose. This is particularly true for a system with large steps, e.g. in Singapore.

18 Land Transport Authority. December 2017. JOINT MEDIA RELEASE BY THE LAND TRANSPORT AUTHORITY (LTA) & NEA - NEW VEHICULAR EMISSIONS LABEL FROM 1 JANUARY 2018. https://www.lta.gov.sg/apps/news/page.aspx?c=2&id=37654ca8-ef14-4c1a-851d-06fc527f839f

Similarly, the steps can create market distortions in cases where comparable vehicles of different manufacturers with close fuel consumption are classified in different tax clusters. In this case the somewhat arbitrary definition of the fuel consumption threshold can have severe consequences for the manufacturer whose car is classified in the more expensive tax bracket. Therefore, feebate schemes based on linear and continuous functions are highly preferable to schemes based on functions with discrete steps. This issue was partly addressed in the 2016/2017 revision of the French feebate scheme.

A more detailed discussion about the features of various feebate schemes can be found in Best Practices for Feebate Program Design and Implementation (ICCT 2010).

5.5.4 *Circulation tax design and implementation*

Type of measure	– Vehicle registration tax paid on an annual basis for all vehicles in the fleet
Principle	– Based on vehicle fuel consumption (LGe/100 km) or vehicle CO_2 emissions (gCO_2/km) – The value of the tax gradually increases with fuel consumption or CO_2 emission according to a continuous function – Can also include a component based on pollutant emissions (e.g. NOx)
Rationale	– Decreasing taxes with higher vehicle efficiency incentivise the consumer to switch towards the purchase of fuel-efficient cars and offset eventual technology costs
Key aspects	– The starting point of the tax function can be set in a way that vehicles below a fuel-consumption (or CO_2-emission) threshold are exempted from the annual circulation tax – As vehicles become more efficient the scheme needs to be adjusted periodically
Prerequisites	– Fuel-economy or CO_2-emission information is required for *all vehicles in the fleet* – A fuel economy labelling scheme to inform the consumer needs to be in place
Case studies	– Annual vehicle registration tax in various European countries as well as China and Japan (see Table 12).
Impact rating	– High
Complexity rating	– Medium

Similar to a registration tax, the primary purpose of circulation tax is to create revenues for the government. When based on fuel consumption (or CO_2 emissions), it can be used to control the development of the new LDV fuel efficiency. Some of the ASEAN countries already have schemes in place, where all LDVs in the stock needs to be registered on an annual basis. Based on fuel consumption or (CO_2 emissions) these annual registration taxes (referred to as circulation tax in the following to better distinguish them from the one-time new LDV registration tax discussed in Section 4.3.1) provides an incentive to both choose a fuel-efficient new car and also to replace an old inefficient vehicle by a more efficient new or used car. Thus, in contrast to a feebate scheme, a fuel consumption-based circulation tax acts both on newly registered and already existing vehicle stock and is a complementary measure to a feebate scheme.

A circulation tax can be designed in a way that is equal to a one-off registration tax over a selected time horizon (e.g. five years). Since circulation taxes affect newly registered vehicles and vehicles in the stock, they can be combined with attributes to control pollutant emissions. For example, a circulation tax scheme can contain a component that depends on the Euro emission standard of the vehicle, progressively adding costs with decreasing standards. It can also contain a component for taxing NOx emissions, thus discouraging old diesel cars with no effective exhaust treatment. Such a NOx component has recently been introduced within a vehicle registration tax in Chile (Lopez 2014), where the registration tax is designed to mimic circulation over a particular time horizon.

Table 12: Overview of annual circulation tax schemes around the world

Country	Annual circulation tax
Austria	Circulation tax based on engine power. EVs are exempted.
Denmark	Annual circulation tax based on fuel consumption. BEVs weighing < 2000 kg are exempted.
Germany	Circulation tax based on engine displacement and CO_2 emission. EVs are exempted for 10 years.
Netherlands	Circulation tax based on the vehicle weight, fuel type, and CO_2 emission. BEVs and most PHEVs are exempted.
Sweden	Road tax based on CO_2 emission. EVs are exempted.
United Kingdom	Excise duty from second year of purchase based on the CO_2 emission and vehicle price. BEVs and some PHEVs are exempted.
Norway	Circulation tax about EUR 350.
China	Vehicle and vessels fee based on engine displacement and price. EVs are exempted.
Japan	Tonnage tax based on vehicle weight. EVs are exempted. Automobile tax based on engine displacement. EVs are exempted 50%.

Source: ICCT 2014a

Similar to the feebate scheme, an annual circulation tax based on fuel economy or CO_2 emission should build on existing administrative structures, and requires the respective vehicle-specific data. Since the circulation tax affects the vehicle stock, the data is required for cars with ages of 15 years and more. As manufacturers were not required to provide fuel consumption/CO_2 emission data at that time, these data might be hard to find for vehicles above the age of 10 years. In this case, functions based on attributes such as engine displacement, power and fuel type will need to be developed to quantify circulation tax values.

Case studies

An overview of various annual circulation tax schemes is provided in Table 12. The tax schemes in Denmark, Germany, the Netherlands, Sweden and United Kingdom are based on either fuel consumption or CO_2 emission, among other attributes such as engine displacement, fuel type, vehicle price and weight. It can be seen that in many of the schemes electric vehicles (EVs) and PHEVs are exempted from the circulation tax. This is an important observation: Although fuel economy policies mainly target conventional cars, the proper inclusion of advanced vehicle technologies is a crucial component for the longer-term transition towards these powertrains.

Figure 31 on the left shows average annual circulation tax values for new vehicles for either gasoline and diesel or all cars ("generic"). The amount of the circulation tax varies significantly, from only EUR 50 per year in Germany to more than EUR 550 for diesel cars in Denmark. The right side of Figure 31 shows the average one-off registration for selected EU countries. Again, the spread is large, reaching from about EUR 200 in Belgium to more than EUR 5,000 for diesel cars in the Netherlands.

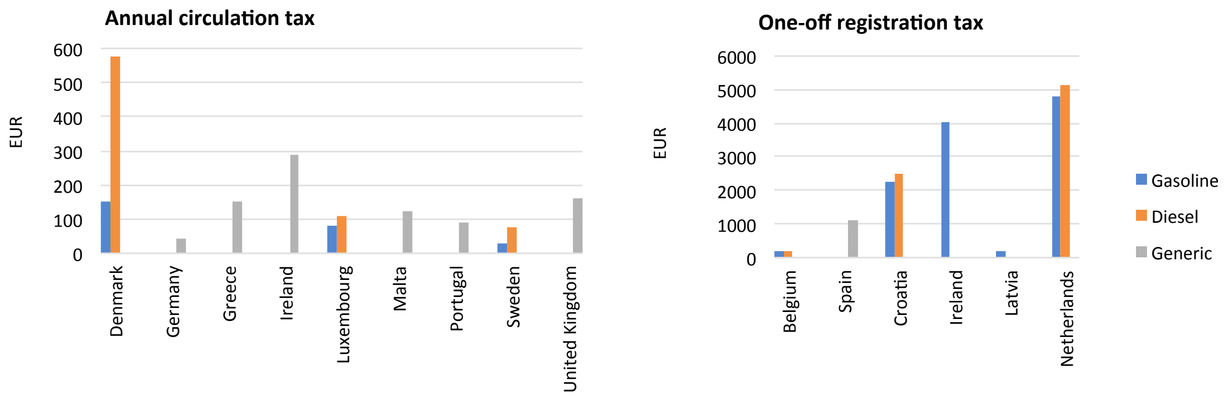


Figure 31: Annual average circulation and one-off registration tax for selected EU countries
Source: Adapted from Malina 2016

In fact, circulation taxes are about an order of magnitude smaller than registration taxes. This illustrates the complementary nature of circulation taxes: Even over a longer period of five to seven years, these on average do not reach the level of the one-off registration tax. Furthermore, since annual circulation taxes are future expenditures, which are not to be paid at the moment of purchasing/registering a new vehicle for the first time, most consumers do not fully internalise them at the time of purchase.

5.5.5 *Fuel tax design and implementation*

Fuel taxes are the most effective way of pricing externalities related to motorised transport. They affect both technical attributes of vehicles (e.g. fuel efficiency) and also their use, and are therefore a powerful means to control rebound effects.

The overall target of fuel economy policies is to reduce fuel use, emissions and related costs. Improved vehicle fuel economy on its own might not necessarily lead to that target, as consumers might decide to increase annual driving as a result of lower per-kilometre costs. Therefore, pricing *the use* of vehicles is essential to reduce energy use and emissions.

Extensive literature exists on fuel price and income effects on vehicle travel and fuel use. A comprehensive review of fuel price elasticities is contained in a 2017 publication by Victoria Transport Policy Institute (VTPI 2017). According to Goodwin, Dargay and Hanly (Goodwin et al 2004), a long-term fuel price increase causes vehicle travel and fuel consumption to decline, with the reduction in fuel consumption about twice the decline in kilometres travelled. According to their review, this can be explained by the fact that the effect of purchasing smaller or more efficient cars as well as changing driving behaviour is about twofold that of the reduction in vehicle ownership and annual driving. Fuel taxes are thus a proven means to directly affect fuel economy of new cars.

Long-run elasticities of vehicle travel with respect to fuel prices are between -0.3 and -0.8, making fuel tax adjustments an effective instrument to limit rebound effects from increased vehicle fuel economy, even if, for various reasons, fuel taxes might not be the instrument of choice for stimulating vehicle fuel economy improvement.

Case study

Turkey is among the countries with the highest fuel prices in the world. In 2014, the average price of one litre of gasoline was USD 2.06, while one litre of diesel cost about USD 1.90.

The high fuel price in combination with a high vehicle registration tax and the proximity to the EU as a market for vehicle exports makes Turkey one of the countries with the most efficient new LDV fleet. Although the tax scheme is not optimal because of the linkage of registration tax with vehicle price, the system effectively contributes to improved LDV fuel economy over time. In 2015, average new LDV fuel consumption was about 5.2 LGe/100km (NEDC). Starting at 7.2 LGe/100km in 2005, fuel consumption fell by almost 30% by 2015, at an annual improvement rate of 3.3%.

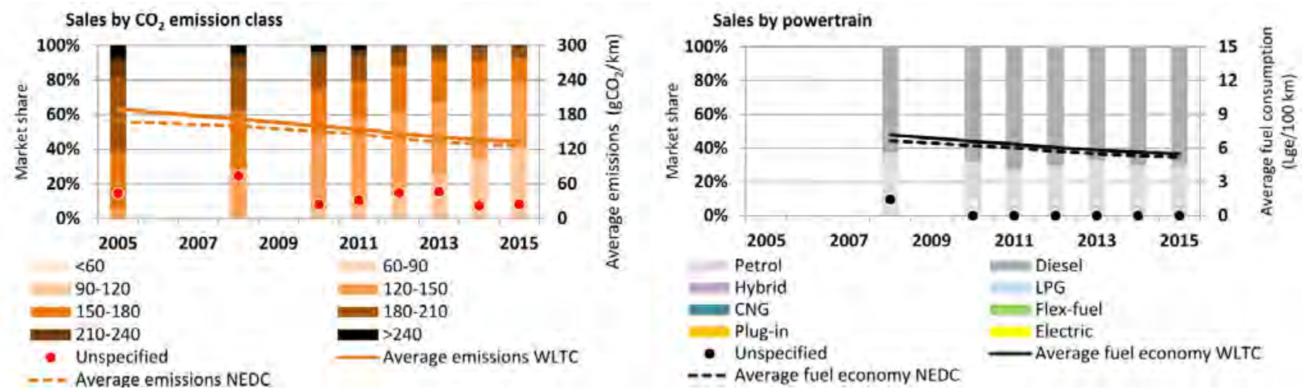


Figure 32: Sales by CO2 emission class (left), and sales by powertrain type (right), and powertrain and sales-weighted average CO2 emissions and fuel consumption for Turkey, 2005 to 2015
Source: GFEI 2017

The high vehicle taxation is illustrated in Figure 33 for a set of common car models among countries in Europe. Although similar models are cheaper in Turkey than in France, Germany or the Netherlands, the tax burden is higher. This is especially true for larger and more luxurious cars: A medium-size VW Passat has a tax burden of about 140% of its price, in the case of a Mercedes E class, taxes account for almost 200% of the vehicle price. Although vehicle taxation is not related to fuel efficiency, the combination with high fuel prices has turned out to be effective.

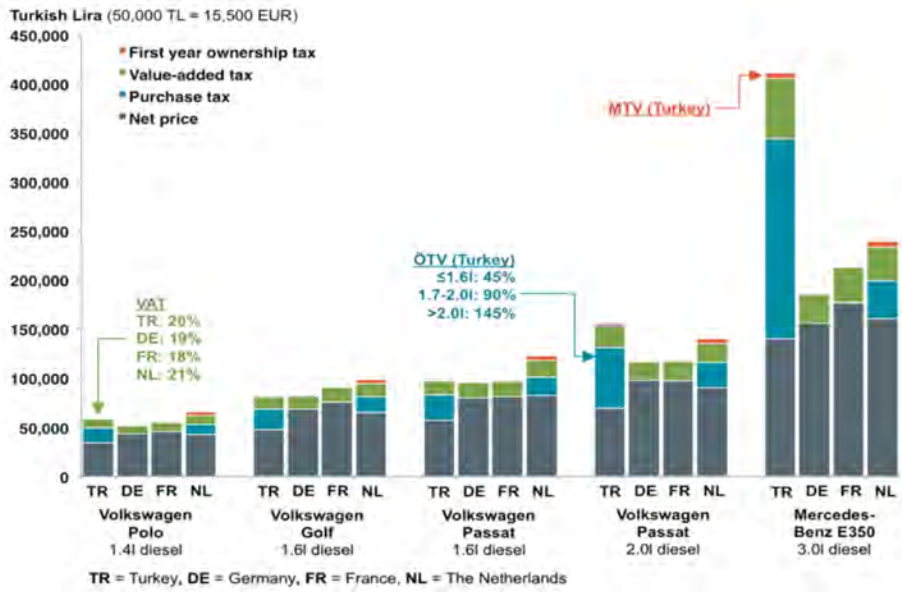


Figure 33: Vehicle prices and taxation selected models in Turkey, Germany, France and the Netherlands. Source: ICCT 2016

5.5.6 Design and implementation of fuel economy standards

Fuel economy standards are a very powerful means to stimulate vehicle efficiency. The first country to regulate vehicle fuel economy was the US, which in 1975 introduced the first Corporate Average Fuel Economy (CAFE) standard. Since then, many countries and regions have followed, and since 2015 almost 90% of the global vehicle market has been regulated in this respect.

China was the first non-OECD country to implement a fuel consumption standard. Phase I was introduced in 2005. At the time, each vehicle model had to comply individually with a minimum performance standard (MPS). Under Phase III, introduced in 2012, the regulation changed towards a corporate average fuel consumption standard. In this case, the production-weighted average fuel consumption of all vehicles produced by a manufacturer needs to comply with a manufacturer-specific target. While the corporate average fuel consumption standards are tightened from phase to phase, individual vehicles, particularly for domestically produced vehicles, need only fulfil Phase II weight-based limits. As of 2018, with the implementation of New Energy Vehicle (NEV) quotas, companies also need to manufacture a certain proportion of electric or plug-in hybrid electric vehicles annually, or else pay a fine or purchase credits from other companies.

For developing manufacturer-specific standards, additional attributes such as vehicle size or vehicle weight need to be taken into consideration to account for the different sales portfolios among manufacturers. Therefore, fuel consumption or CO_2 emission targets are set taking into account the sales-weighted average size or weight of all vehicles sold by a certain manufacturer in a certain year.

The procedure to develop a target value curve necessary to set-up manufacturer-specific fuel consumption or CO_2 emission standards has been summarised by ICCT (ICCT 2011a) and is illustrated in Figure 34.

Three main issues need to be investigated beforehand:

1. What is the current sales-weighted (or production-weighted) average new LDV fuel consumption or CO_2 emission as a function of the vehicle utility parameter (i.e. size or weight)?
2. What is the targeted sales-weighted average fuel consumption or CO_2 emission?
3. What is the average percentage reduction to shift from the current sales-weighted fuel consumption or CO_2 emission to the future target value?

The purple line in Figure 35 denotes the present sales-weighted average CO_2 emissions of all LDVs in the market as a function of a vehicle attribute such as size or weight (on the x-axis). In the first step, the purple line needs to be shifted by applying the same desired percentage CO_2 emission reduction y to each point on the purple curve. This results in the blue 100% slope curve. A standard based on such a 100% slope curve would provide incentive to manufacturers to increase average size or weight of their fleet in order to relax their specific CO_2 emission target. Therefore, the blue 100% slope curve needs to be tilted around the previously set overall CO_2 emission or fuel consumption target (step 3). On the other side, a flat target (red line) would require the same CO_2 emission (or fuel consumption) target to be met by all manufacturers, regardless of the average size or weight of the vehicles they sell. A viable compromise between the request to diversify the CO_2 emission targets among different manufacturers, and the risk that manufacturers are provided with an incentive to game the rules and to increase weight or size of the vehicle fleet needs to be found. According to the summary provided by ICCT, previous studies indicate a 40% slope to be a good compromise to set up a weight-based target value curve.

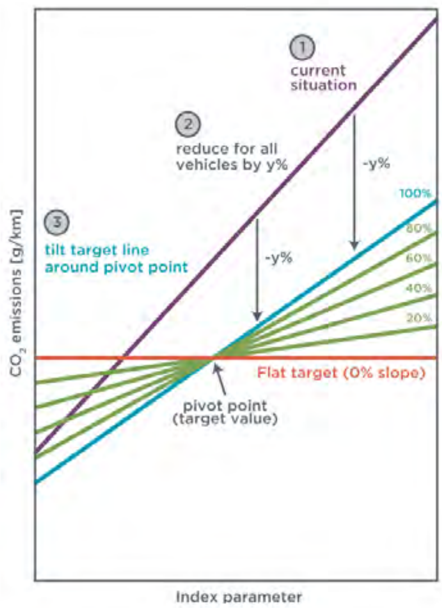


Figure 34: Schematic procedure of setting a manufacturer specific and attribute- based CO2 emission standard Source ICCT 2011a

Many discussions have been around the question whether vehicle size or vehicle weight is the better attribute to set up fuel economy regulation. Light-weighting of vehicles is a promising measure to improve vehicle fuel efficiency while keeping the same vehicle utility. Under a weight-based system, the reduction of average vehicle weight to reduce fuel consumption and CO_2 emissions would lead to a tightened fuel consumption or CO_2 emission target (see Figure 36, left). In the case of a size-based system, the fuel consumption or CO_2 emissions reduction due to light-weighting leads to fleet well below the target line, which on the individual vehicle basis provides a strong incentive for light-weighting to the manufacturer.

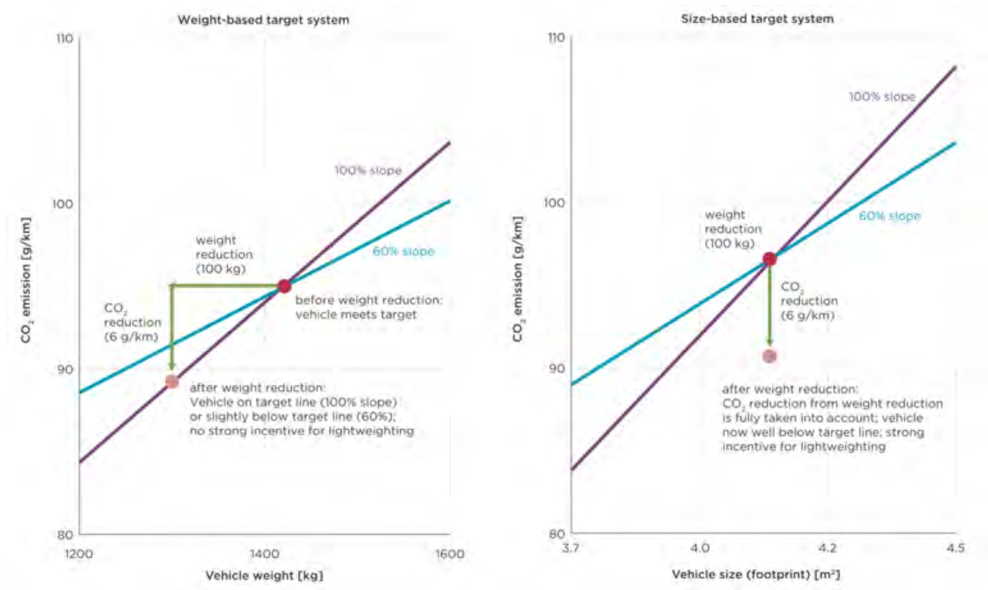


Figure 35: Weight- versus size- based fuel consumption and CO2 emission standard
Source ICCT 2011 EU emission

Case study

The European Union has implemented a standard specifying the sales-weighted average CO_2 emission to reach 95 gCO_2/km (~4.1 LGe/100km) for PLDVs by 2021 and 147 gCO_2/km (~6.3 LGe/100km) for LCVs by the year 2020. It is a corporate average standard with manufacturer-specific emission targets, which are developed taking into account the sales-weighted average vehicle weight of the year prior to the target year. The resulting target curves for PLDVs and LCVs as a function of vehicle weight are shown in Figure 37.

In addition, further rules have been developed for the calculation of manufacturer-specific CO_2 emission targets. Super credits can be allocated for low-emission vehicles emitting less than 50 gCO_2/km. These vehicles are given a higher weight of up to three times the actual sales numbers when calculating the sales-weighted average emissions. E85 extra credits have been introduced to account for the lower emissions of vehicles which can use E85 biofuel blends (containing up to 85% of bioethanol in the petroleum fuel blend). Last but not least, manufacturers can apply for approval of eco-innovations at the European Commission. If a manufacturer fits its fleet with such an eco-innovation, fleet-wide sales-weighted average emissions can be reduced by up to 7 gCO_2/km (EEA 2015).

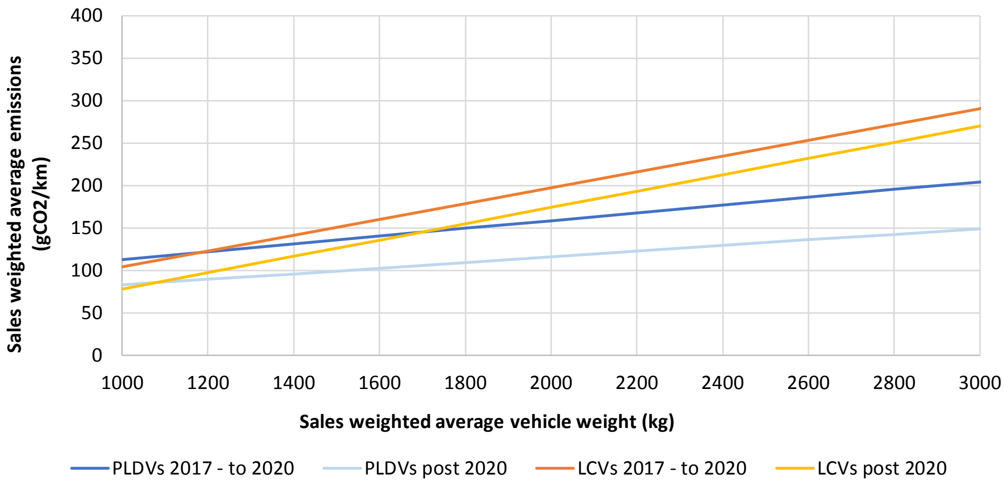


Figure 36: CO2 emission target curves for PLDVs and LCVs in the European Union for the years 2017 to 2020 and post 2020
Source: Own calculations based on EEA 2015

5.5.7 Air pollutant emission standards and fuel economy

It is important to distinguish between CO_2 emissions and pollutant emissions (see Table 13). Air pollutants include particulate matter (PM), nitrogen oxides (NO and NO_2, often referred to together as NOx), sulphur oxides (SOx), un-burnt hydrocarbons (HC) and carbon monoxide (CO). The two categories of emissions and their respective policies often cause confusion. Carbon dioxide, or CO_2, is a greenhouse gas, but is not considered a toxic pollutant as such. Although CO_2 emissions and pollutant emissions both result from burning fuels, their methods of control are very different, from technological and regulatory perspectives. CO_2 emissions are reduced by lowering fuel consumption and adjusting energy sources, while air pollutants are reduced through the use of technologies such as catalytic converters and particulate filters, through reducing sulphur in fuel, and using urea-based NOx reduction technologies. Hence, a large and powerful SUV can emit very small amounts of air pollutants and be considered clean in that specific respect. But it could remain an inefficient vehicle that consumes a lot of fuel and emits a lot of CO_2.

The implementation of stringent fuel economy policies, pollutant emission standards and fuel quality standards need to go hand-in-hand to ensure the following:

1. Increased vehicle efficiency does not lead to greater air pollution. This especially important to avoid an increased rate of dieselisation (induced by fuel economy policies), which might occur as a response to fuel-economy pressures without improved emission standards. Older Euro II, III and IV diesel cars emit significantly more particulate matter (PM) than most recent Euro V and IV vehicles. This shift can also be avoided by banning diesel LDVs and ensuring adequate supplies of gasoline.
2. The required fuels are available on the market. Vehicles complying with tightened fuel efficiency and pollutant emission standards needs to be fuelled with suitable fuels. These need to have high octane ratings and low sulphur contents in order to

ensure a controlled combustion process under high pressure and temperatures as well as to prevent the generation of soot.

Table 13: Overview of vehicle emissions

Pollutant	Classification	Can be filtered/captured on-board a vehicle	Reduction method	Regulation
Carbon dioxide (CO_2)	Greenhouse gas	No	Reduced fuel consumption, reduced carbon content in the fuel	CO_2 emission standard (or indirectly through fuel consumption standard)
Particulate matter (PM)	Air pollutant	Yes	Particulate filters, improved combustion	Euro I-VI, US Tier 1 and 2 among others
Nitrogen oxides (NO and NO_2, often referred to as NO_x)	Air pollutant	Yes	Catalytic converter, exhaust gas recirculation (EGR)	Euro I-VI, US Tier 1 and 2 among others
Sulphur oxides (SO_x)	Air pollutant	No	Reduced sulphur content in the fuel	Euro I-VI, US Tier 1 and 2 among others
Un-burnt hydrocarbons (HC)	Air pollutant	Yes	Catalytic converter, improved combustion	Euro I-VI, US Tier 1 and 2 among others
Carbon monoxide (CO)	Air pollutant	Yes	Catalytic converter	Euro I-VI, US Tier 1 and 2 among others

The regulation of air pollutants often refers to the European Euro I to VI standards for diesel vehicles and Euro 1 to 6 standards for gasoline vehicles. These *pollutant emissions standards* should not be confused with *carbon emission or fuel consumption standards*. While the former is concerned with the reduction of air pollution, the latter is concerned with the reduction of GHG emissions and fuel consumption by vehicles.

The air pollutant emission standards for passenger vehicles do have some relationship to fuel consumption, but the connection has been demonstrated to be of less importance over time in mature markets. Nonetheless, certain technologies for fuel efficiency, such as turbocharging in diesel engines, require higher-quality fuels in order to operate properly, and higher fuel quality standards are often driven by more stringent vehicle pollutant emission standards.

An overview of current pollutant emission standards for PLDVs in selected AMS is illustrated in Figure 38.

Fuels matching the Euro 4/IV standard are now available in Brunei Darussalam, Indonesia, Malaysia, the Philippines, Singapore and Viet Nam, and Euro 5/V in Singapore. Indonesia only provides Euro 4 gasoline, while diesel there has very high sulphur concentration. Cambodia, Lao PDR and Myanmar plan to adhere only to the standards of Euro 2/II or even Euro 1/I fuels until the beginning of the 2020s.

These low-quality fuels impose a barrier to LDV fuel efficiency improvement. However, raising the minimum standards would increase production costs. Refineries need to be retrofitted to produce fuel with increased octane rating, necessary for fuel-efficient vehicles, while lowering the concentration of harmful components such as benzene in order to comply with those higher Euro standards.

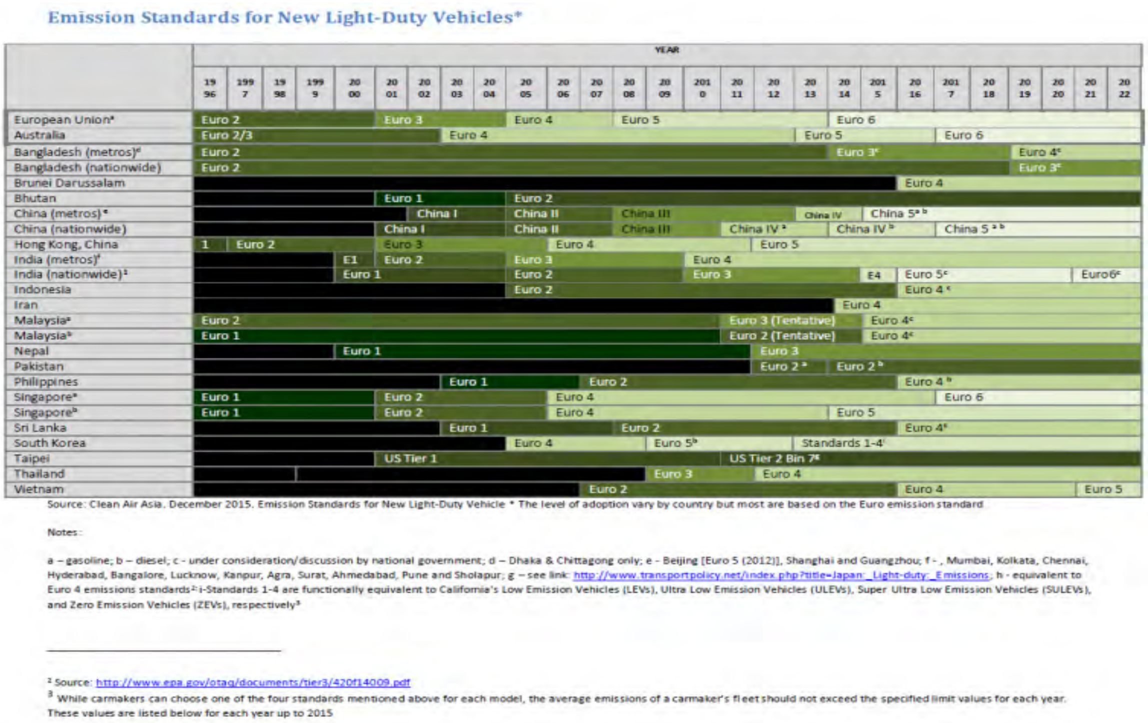


Figure 37: Overview of vehicle pollutant emission standards in selected AMSs and other global jurisdictions
Source: Clean Air Asia, 2015

Case study

Between the years 2000 and 2012 the share of diesel vehicles among new LDVs grew from 17% to more than 40% globally (ICCT 2012). At the same time, fuel consumption of new LDVs in India remained low, at around 6 LGe/100km, while vehicle size increased by about 13% between 2005 and 2015 (GFEI 2017). The increased share of efficient diesel vehicles certainly accounts for a large part of the stable and low average LDV fuel consumption.

Nonetheless, under the current pollutant emission regulation, diesel LDVs are allowed to emit about three times more NOx and about 10 times more particulate matter compared with gasoline cars. Both, NOx and particulate matter emissions are at the source of serious diseases, and "correlations between ambient fine particulate matter (PM2.5) and cardiopulmonary mortality" (ICCT 2012) can be clearly detected. According to calculations performed by ICCT, almost 10,000 premature deaths could be provoked through the emissions of particulate matter by the year 2030, if pollutant emission standards are not tightened.

In this case study, although CO_2 emissions may have decreased due to dieselisation, air pollutants increased dramatically resulting in a difficult cost-benefit balance.

5.5.8 Fuel quality regulation

Type of measure	–	Regulation which sets fuel quality requirements for a number of physical and chemical properties
Principle	–	All fuels for sale in the market must meet the requirements
Rationale	–	The standard pulls clean fuels into the market, which are a requirement for the implementation of pollutant and fuel-economy standards
	–	Standards for vehicle pollutant emission, fuel quality and fuel economy are tightly linked to ensure that the potential of efficient vehicle technologies is fully exploited
Key aspects	–	The EU fuel quality standards Euro I to VI are often used as a baseline for country-specific fuel quality standard development all over the world
	–	Fuel quality standards needs to be tightened periodically to enable more stringent emission and efficiency standards
	–	Fuel quality standards also regulate the blend shares and specifications of biofuels
Prerequisites	–	The administrative framework needs to be in place to set the target, to check compliance by regularly testing fuels and to enforce the standards
Case studies	–	Euro VI standard in the EU, EPA gasoline and diesel standards the US, Bahrat IV in India, China IV/V
Impact rating	–	High
Complexity rating	–	High

Fuel quality standards regulate the physical properties as well as the chemical composition of fuels. They also contain regulation on composition and shares of biofuels, which are blended with gasoline and diesel in order to reduce their carbon footprint.

Table 14: Pros and cons of harmonisation of ASEAN fuel quality standards

	Pros	Cons
Consumer	Flexible cross-border trade	Higher fuel costs
	Confidence in fuel quality	
	Reduced health risk	
Environment	Reduced exhaust emissions	
	Reduced emissions of GHGs	
	Better air quality	
Economy	Higher economic value	Investment needs to upgrade refineries
	Increased freight transport efficiency	Higher production costs
	Increased economy of scale in fuel trading	
	Increased sectproduct of supply with respect ot ASEAN strategic reserve	
Other		ASEAN has no enforcement mechanism in place to convert harmonization efforts into national law

Source: Adapted from Thitiratsakul 2016

Efficient vehicles with engines that have higher compression ratios, are turbocharged, downsized or down-speeded all require high-quality fuels with high octane ratings. Meeting Euro standards with respect to the concentration of harmful components such as benzenes and achieving higher octane ratings at the same time requires substantial upgrading of existing refineries.

The Petroleum Institute of Thailand (PTIT) has compiled the pros and cons of harmonised fuel quality standards in the ASEAN region (Table 14). While advantages are evident, the largest barrier is the investment needed to upgrade existing refineries.

The study Cleaning Up the On-Road Diesel Fleet (CCAC 2016) details the investment needs for average refineries in developing economies to produce low-sulphur diesel. According to the publication, adding, replacing or retrofitting existing distillate hydrotreating capacity and ensuring increased hydrogen supply in order to reduce sulphur levels to 50ppm would require investment of around USD 4,000 per barrel per day of additional low sulphur diesel capacity. Assuming typical refineries in the region to account for 30,000 barrels per day of diesel production, investment amounts to about USD 200 million. The study published by CCAC estimates the total investment needs to produce 50ppm sulphur diesel in South-East Asia amount to USD 13 billion.

Case study

In 2016, ICCT published the case study Refineries in Vietnam (ICCT 2016a), which analyses in detail Viet Nam's measures to significantly improve fuel quality through the introduction of ambitious fuel quality standards as well as to increase its independence from fuel imports.

According to the study, from 2009 gasoline and diesel fuels domestically produced at the country's only refinery Dung Quat both needed to meet Euro II standard with a sulphur limit of 500ppm. By 2016, fuels need to comply with Euro IV, with sulphur content limited to 50ppm. Since 2018, domestically produced gasoline and diesel need to comply with Euro V, which requires sulphur levels to be below 10ppm. This development goes hand-in-hand with the requirement for new vehicles in the country to meet Euro IV by 2017 and Euro V by 2022.

In order to bring the required fuel quality to market, the Dung Quat refinery was to have been upgraded to produce Euro V fuels by 2016, and construction has started on several new refineries, although progress has been slow, with completion at the Dung Quat refinery pushed to 2021. Altogether, according to the original plan, between 57 and 70 million tons of crude oil can be processed to Euro IV and V fuels when the initiative is complete, although the original timeline to complete construction by 2018 faces delays. In total, upgrading the existing and constricting the new refinery capacity is expected to cost between USD 42 billion to USD 44 billion.

If the projects come online as planned, Viet Nam will become a high-quality fuel producer. Its success in this will depend in part on its ability to increase both fuel quality and production capacity at the same time. The ability to attract foreign capital also partly relies on the fact that a market for these fuels is guaranteed through the introduction of the respective Euro standards for cars as well as the regulation of the fuel market. By managing to obtain interest of Middle East crude oil producers to invest in Viet Nam's refinery sector while closing contracts for longer term supply with own crude oil, the avenue towards the production of clean fuels ahead of time seems to be paved.

According to CCAC some key take-aways can be formulated:

- National government takes the lead in setting an ambitious fuel quality standard, starting with major cities. This builds demand for low-sulphur fuels, sends a clear signal to producers.
- The state-owned refineries are required by law to comply with the new standard, partnering with a private refinery operator to ensure the deadline for upgrade is met.
- Funding for upgrades is often a combination of both public and private funds, made profitable by coupling desulfurisation capacity with investments to increase capacity and yields.

(CCAC 2016)

5.6 Methodological considerations

5.6.1 Options for determining the level of ASEAN's aspirational LDV fuel consumption goal

During the drafting of this roadmap, the government officials representing AMS in the ASEAN EGSLT considered a menu of five proposed options for the ambition level of the goal. In brief, the options were:

1) Based on 2030 GFEI target
2) Based on arithmetic mean of existing LDV fuel economy improvement rates
3) Based on arithmetic mean of existing 2020 LDV fuel consumption targets
4) Based on a 40% fuel consumption reduction target by 2030
5) Based on a doubling of historical LDV fuel economy improvement rates

In addition, the EGSLT members had the possibility of proposing further alternative options but none did so. The Expert Group decided in favour of option 5. *Further elaboration of each proposed option can be found below:*

Option 1: Based on the 2030 new-vehicle fuel economy target by GFEI

Option 1 is based on the target set by the Global Fuel Economy Initiative (GFEI) to double LDV fuel economy of *all vehicles in the stock* by 2050 by reducing fuel consumption by 50% from 8.3 LGe/100km in 2005 to 4.2 LGe/100km by 2050 (GFEI 2017). To reach this target, fuel consumption of all *new* LDVs needs to reach 4.2 LGe/100km 20 years earlier, by 2030. This value is used to set the fuel economy target in Option 1.

Based on the estimated ASEAN-wide new LDV fuel consumption of 7.3 LGe/100km for the year 2015, an LDV fuel consumption target of 4.2 LGe/100km by 2030 implies an annual LDV fuel economy improvement rate of 3.7%. This would mean a 2025 fuel consumption target of 5.0 LGe/100km for the ASEAN region.

Such a 2025 target is above the arithmetic mean of all existing LDV fuel consumption targets for that year (~4.5 LGe/100km) in countries with regulation covering both PCs and LCVs. The implied annual fuel economy improvement rate of 3.7% is a little below the arithmetic mean for other regions.

Please note that for this exercise, linear extrapolations based on the annual improvement rates have been used to estimate fuel consumption targets beyond the time frames set in the respective regulation of the country or region (values in red). This methodology is valid for smaller differences with regard to the time frame (e.g. the EU 2021 target vs. an estimated 2025 target based on the 2014 to 2021 improvement rate), but provides only a rough estimate for time frames that stretch further beyond that of the regulations (e.g. in the case of Mexico and Brazil where the actual target years are 2016 and 2017, respectively).

Option 2: Based on the average LDV fuel economy improvement rate indicated by existing LDV fuel economy regulation around the world

Option 2 is based on the average annual fuel economy improvement rate of 4.1%, which is derived from existing LDV fuel economy regulations in other regions of the world. This improvement rate is then applied to the estimated ASEAN-wide base year fuel economy of 7.3 LGe/100km (2015). The calculation results in an ASEAN-wide LDV fuel consumption target of 4.8 LGe/100km for the year 2025.

Option 2 implies a total reduction of LDV fuel consumption of 34% between 2015 and 2025. By 2025, the ASEAN target of 4.8 LGe/100km would still be somewhat above the arithmetic mean of the existing LDV fuel consumption targets (4.5 LGe/100km). By 2030, the extrapolation of the ASEAN fuel consumption target (3.9 LGe/100km) would be below the target proposed by the GFEI (4.2LGe/100km).

Option 3: Based on the average of all LDV fuel consumption targets for the year 2020 around the world

Option 3 is based on the arithmetic mean of all existing absolute fuel consumption targets for LDVs around the world for the year 2020. Thus, the average fuel consumption of 5.6 LGe/100km is set as the target value for that year. In addition, the resulting fuel economy improvement rate of 5.2% per year from 2015 to 2020 (again based on the ASEAN-wide 2015 baseline fuel consumption of 7.3 LGe/100km) is used to determine the 2025 target, which then accounts for 4.3 LGe/100km.

The 2025 LDV fuel consumption target of 4.3 LGe/100km represents a 42% reduction compared to the year 2015 in the ASEAN region. By 2025, fuel consumption of new LDVs in the ASEAN region would be somewhat below the arithmetic mean of existing fuel economy regulation (4.5 LGe/100km). The annual average fuel economy improvement rate of 5.2% would be above the global average of 4.1% for all LDVs and 4.2% for PCs only. If linearly extrapolated out to 2030, the ASEAN-wide fuel consumption target would be 3.3 LGe/100km, indicating that in this case, the annual fuel economy improvement rate would need to be lowered after the year 2025.

Option 4: 40% reduction of LDV fuel consumption by 2025 compared to 2015

Option 4 suggests setting a 40% LDV fuel consumption reduction target by 2025 compared to the 2015 baseline fuel consumption of 7.3 LGe/100km in the ASEAN region. In this case, average new LDV fuel consumption would drop to 4.4 LGe/100km by 2025, which is about equal to the arithmetic mean of existing new LDV fuel consumption targets by that time (4.5 LGe/100km). Annual fuel economy improvement rate would reach 4.9%. With no further adjustment to the post-2025 LDV fuel economy improvement rate, new LDV fuel consumption would reach 3.4 LGe/100km by 2030.

Option 5: Based on doubling the historical global fuel economy improvement rate between 2005 and 2015

Between 2005 and 2015, the global average fuel economy improvement rate accounted for 1.5% per year (GFEI 2017).

Option 5 is based on doubling the historical fuel economy improvement rate to 3.0% and applying it to the ASEAN new LDV baseline fuel consumption of 7.3LGe/100km in 2015. This results in a 2025 ASEAN new LDV fuel consumption target of 5.4 LGe/100km for the year 2025.

In this case, even by 2025, ASEAN new LDV fuel consumption is still significantly higher compared to regions with LDV fuel economy regulation already in place (5.4LGe/100km vs. 4.5 LGe/100km, respectively). The 2025 fuel consumption target of the ASEAN will then be just 0.1 LGe/100km lower than the EU baseline LDV fuel consumption for the year 2015.

5.6.2 Definition of passenger cars and light commercial vehicles in major markets

Table 15: Definition of passenger cars and light commercial vehicles in major markets

	Passenger cars		Light commercial vehicles	
	Max. GVW	Max seats	Cargo vehicles max. GVW	Other vehicles
US and Canada	3,856 kg	12	3,856 kg	Medium duty SUVs and passenger vans with GVW<= 4,536 kg
Mexico	3,857 kg	12	3,857 kg	-
EU	3,500 kg	9	3,500 kg	-
China	3,500 kg	9	3,500 kg	Passenger vehicles with more than 9 seats and GVW <= 3,500 kg
Japan	3,500 kg	-	3,500 kg	-
South Korea	3,500 kg	10	3,500 kg	Passenger vehicles with 11-15 seats and GVW <= 3,500 kg
India	3,500 kg	-	3,500 kg	-
Brazil	3,856 kg	12	3,856 kg	-
ASEAN FE RM	3,500 kg	10	3,500 kg	Minibuses with no more than 16 seats and GVW <= 3,500 kg

Source: ICCT 2015c, own definition

5.6.3 Examples of light-duty vehicles

Table 16: Examples of light-duty vehicles

Light duty vehicles	Passenger cars		
	Cars		Mazda 3
	Van		Honda Odyssee
	MPV		Kia Carens
	SUV		Lexus NX
	Jeep		Toyota Landcruiser
	Pick-up truck		Isuzu D-Max
	Minibus <= 10 seats		Hyundai Starex
	Light commercial vehicles		
	LCV		Hyundai H350
	Pick-up truck		Toyota Hilux
	Minibus > 10 seats and <=16 seats		Toyota Hiace

5.6.4 Conversion factors

Table 17: Fuel-specific conversion factors to normalise fuel consumption values to the energy content of gasoline

Fuel	Base unit	Multiplicator	Target unit
Gasoline	L/100km	1.00	Lge/100km
Diesel		1.08	
CNG (retrofit adjustment)		1.12	
LPG (retrofit adjustment)		1.15	

Table 18: Fuel-specific CO2 emission factors

Fuel	Base unit	Multiplicator	Target unit
Gasoline	Lge/100km	23.2	gCO_2/km
Diesel		24.8	
CNG		18.8	
LPG		21.1	

5.6.5 Fuel economy versus fuel consumption

Both measures are widely used around the world. Nonetheless, the use of fuel consumption (L/100km) instead of fuel economy (km/L) is preferable from a regulatory point of view.

In the end, we are interested in quantifying the fuel savings while performing the same transport demand, i.e. travelling the same distance. The good thing with fuel consumption is that the incremental fuel savings to perform a certain transport demand stay the same with increasing vehicle efficiency. In other words, the difference between a fuel consumption of 15 L/100km and 14 L/100km versus the difference between 6 L/100km and 5 L/100km stays the same: Fuel savings account for 1 L when travelling a distance of 100km no matter if one compares vehicles with high or low fuel consumption.

In the case of fuel economy (measured in km/L), the difference in fuel consumption between a car running 10 km/L and a car running 11 km/L (10.0 L/100km vs 9.1 L/100km, respectively) equals 0.9 L/100km. The same difference between a car running 20 km/L and a car running 21 km/L (5.0 L/100km versus 4.8 L/100km) shrinks to fuel savings of only 0.2 L/100km.

If a tax system to incentivise vehicle fuel efficiency were based on fuel economy (km/L) instead of fuel consumption (L/100km), rewarding increased fuel efficiency through, for example, reduced vehicle registration tax (i.e. -USD 500 per 1 km/L increased fuel economy), then the net value of saving 0.9 L/100km at low fuel economy levels would equal the same USD 500 as saving only 0.2 L/100km at higher fuel economy levels. Such a system would be likely to fail over time, since the same incentive would be paid for increasingly slim gains in real fuel savings, as vehicle efficiency improves.

Energy use by vehicles can also expressed in terms of CO_2 emitted. CO_2 emissions can be calculated through the use of fuel-specific emission factors that account for the total CO_2 emitted when a certain volume of fuel is burned. These figures are valuable for climate change policy, and therefore some jurisdictions choose to use gCO_2/km as the unit of regulation. However, there are advantages in targeting fuel consumption instead. The concept is closer to consumers and more closely related to costs of vehicle operation. Furthermore, using energy consumption as a comparative measure can help compare the efficiency of vehicle models with different power trains directly, irrespective of whether they are fuelled with gasoline, diesel, biofuels or electricity. Finally, measures to regulate fuel consumption specifically can include minimum performance standards, corporate average fuel consumption standards, fiscal or tax incentives or disincentives, and public information such as vehicle labelling.

5.7 Widening the scope beyond LDV fuel economy

Improving the fuel economy of conventional LDVs is an imperative step on the way to reduce energy use and emissions in line with mitigating climate change to a maximum temperature increase of 2 degrees Celsius above preindustrial levels by the end of this century. However, fuel economy measures alone are in no way sufficient to reach this target. To achieve it, the emissions from the transportation sector as a whole, including non-road modes such as air, rail and shipping, need to be cut substantially in the future, compared to a business-as-usual scenario. Therefore, the strategy of *avoid-shift-improve* (ASI) has been promoted by numerous stakeholders in the global transport and energy scene. Its main components are outlined in Figure 39.

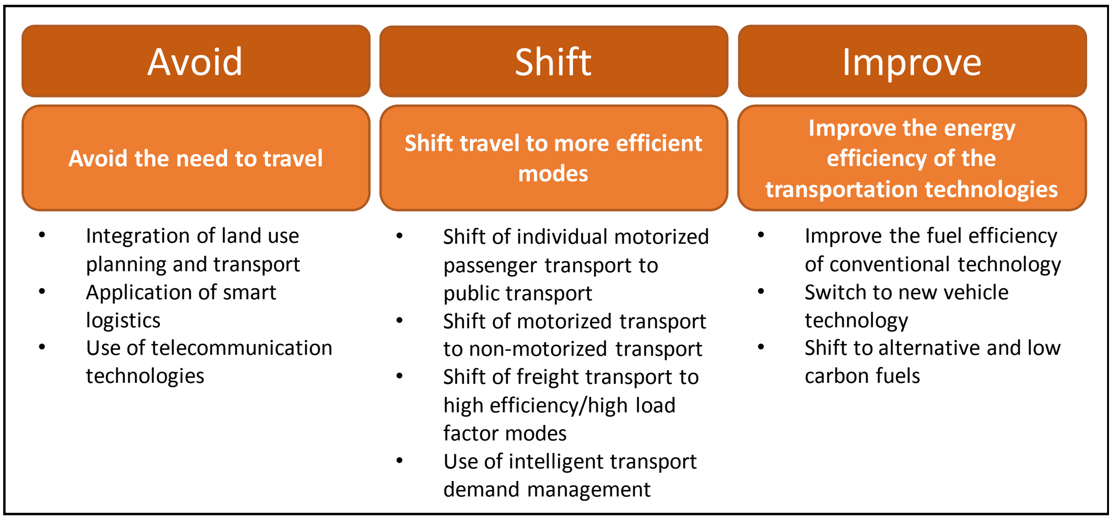


Figure 38: Overview of the avoid-shift-improve strategy to reduce energy use and emissions in the transport sector

Below, three fuel efficiency-related building blocks of a longer-term sustainable transport strategy will be briefly discussed: heavy-duty truck fuel economy, electric mobility, and two-wheelers.

5.7.1 Heavy-duty vehicle fuel economy

As of 2015, medium freight trucks (MFT, 3.5t < GVW < ~15t) and heavy freight trucks (HFT, GVW > ~15t) accounted for almost one quarter of total GHG emissions from transport, in spite of the relatively low number of these vehicles compared to passenger cars. Furthermore, less than half of the global MFT and HFT market has been regulated with respect to fuel economy (Figure 41). Tractor-trailer combinations and rigid trucks are responsible for the largest part of the medium and heavy-duty vehicle stock and energy use. It is thus evident that improving the fuel efficiency of trucks has a great potential to reduce energy use, emissions and fuel costs.

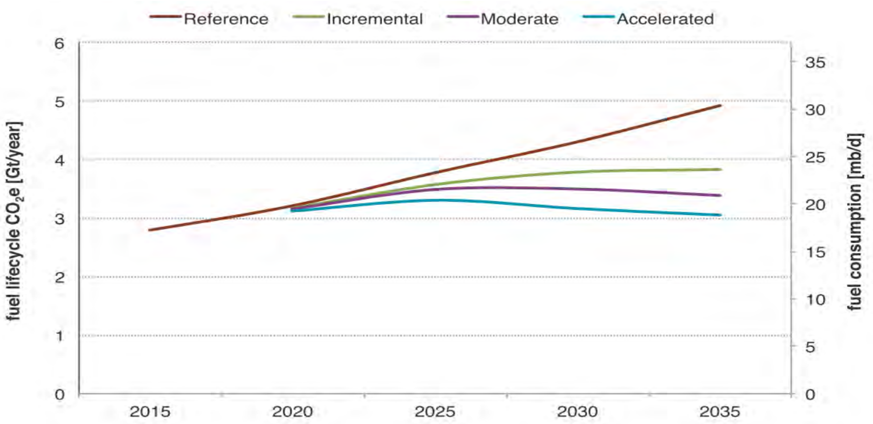


Figure 39: Annual GHG emissions and fuel consumption from tractor-trailers and rigid trucks worldwide by efficiency scenario, 2015-2035
Source: GFEI 2016b

In 2016, the ICCT developed a study for GFEI titled Investigating the Fuel Efficiency Technology Potential of Heavy-Duty Trucks in Major Markets Around the World (GFEI 2016b). The analysis revealed that accelerated improvement of the fuel efficiency of medium and heavy freight trucks has the potential to almost stabilise energy use and emissions at year-2015 levels on a global scale by the year 2035 (Figure 40).

Nonetheless, compared to LDV fuel economy policy making, it is more complicated to develop effective fuel economy measures for heavy road freight transport. The most important reason for this is the strong impact of vehicle load and trip profiles on truck fuel economy. Conditions vary from long haul at relatively constant speeds on highways, to urban delivery with large portions of stop-and-go, to use of trucks at construction sites and off-road, to name but a few. Already, the availability of numerous configurations of trucks built on the same chassis (e.g. refrigerator box with cooling unit, cargo box, flatbed etc.) makes is it difficult to establish reference fuel-consumption or CO_2-emission figures because it requires the laboratory testing of a large number of vehicles or the use of programmes combining laboratory test results and computer simulation software.

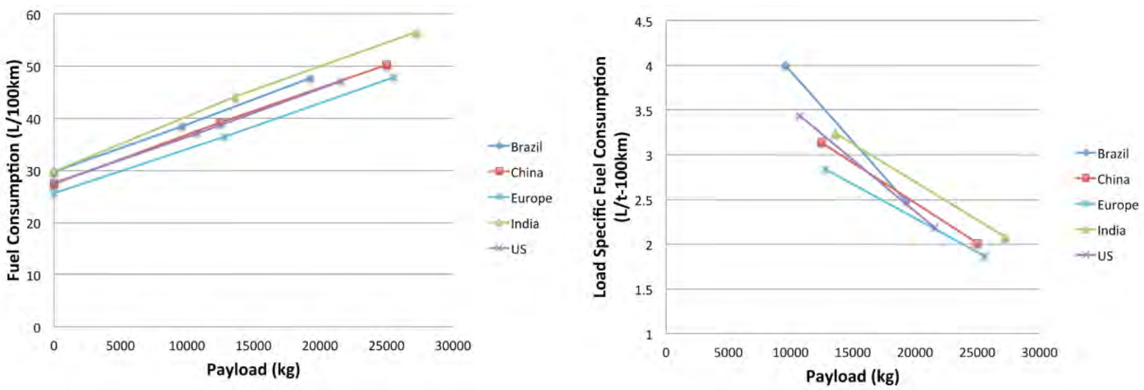


Figure 40: Vehicle fuel consumption (left) and load specific fuel consumption (right) of baseline tractor-trailers over the world heavy duty vehicle cycle (WHVC) at empty, half, and full load
Source: GFEI 2016b

The impact of loading on truck fuel consumption is shown in Figure 42. The consumption increase from an empty to a fully loaded tractor-trailer combination is about 80% to 90% in all the shown regions. Equally, Figure 42 shows that load-specific fuel consumption greatly drops with load: A fully loaded truck consumes about a third less the fuel per kg payload compared to a half-loaded truck. This comparison clearly shows not only the importance of increasing truck fuel efficiency but also of improving logistics. Empty running (e.g. when returning from a delivery) or half-loaded trucks significantly reduce the efficiency of the heavy-duty road freight sector.

Table 19: Tractor-trailer baseline fuel consumption for various world markets

	Driving Cycle	Payload (kg)	Baseline fuel consumption (L/100km)	Baseline fuel consumption (Lge/100km)
Brazil	WHCV	19,500	39.8	43.0
China	WHCV-China	25,000	41.6	44.9
Europe	VECTO Long-Haul	19,300	33.6	36.3
India	WHCV-India	27,230	54.8	59.2
United States	US Phase 2 Cycles	17,237	40.4	43.6

Source: GFEI 2016b

The ICCT has quantified the baseline fuel consumption of new tractor-trailer combinations based on the country-specific vehicle offer as well as operating conditions. Results of that simulation are shown for Brazil, China, Europe, India and the United States in Table 19. These results indicate large variations among regions: While new tractor-trailers in Europe consume on average about 36 LGe/100km, trucks of the same category consume more than 59 LGe/100km in India. Truck fuel consumption in Brazil, China and the US is about 30% higher than in Europe. In the cases of India and China, the much higher fuel consumption can be partly explained by the higher payload. Still, much of the fuel efficiency gap is based on technology differences.

Although no heavy-duty vehicle fuel economy regulation is yet implemented in Europe, high fuel prices have clearly incentivised manufacturers and hauling companies to opt for better technology. Since fuel costs constitute a major part of hauling costs, high fuel prices have a strong impact on the economics of hauling companies.

Policy support

A powerful instrument for incentivising truck manufacturers to offer more efficient trucks, and haulers to buy them, would be to completely cut fuel subsidies where still applied. Furthermore, fuel taxes on diesel would need to be increased to a level where fuel costs become a decisive factor in consumer decisions. This is generally when additional investment into more efficient vehicles pays for itself over one year on average, in the case of small hauling companies (IEA 2017a). Nonetheless, the lack of capital to renew truck fleets, especially in the case of very small haulers, needs to be taken into account. This could be addressed by offering cheap and targeted credits to small hauling companies.

The introduction of fuel-consumption or CO_2-emission standards for rigid trucks and tractor-trailer combinations is another strong measure to be considered in the ASEAN region. Prominent examples are the standards for tractor-trailer combinations in the US and the Chinese HDV standard covering tractor-trailers, straight trucks, dump trucks, coaches and city buses (ICCT 2015e). While the US standard is a corporate average standard based on engine testing and vehicle modelling, forming two separate parts during the approval procedure, the Chinese standard is a pass-fail system. All vehicles need to comply with a dedicated benchmark and cannot be approved for sale in the Chinese market in cases of non-compliance (ICCT 2015e).

Last but not least, consumer information and driver trainings are both important parts of effective HDV fuel economy improvement. So far, in the ASEAN region truck manufacturers are not obliged to disclose any fuel consumption or CO_2 emission data. Starting to introduce fuel economy labels for tractors and long-haul rigid trucks would be a good first step in providing better information to the consumers. Furthermore, training drivers to drive in a more fuel-efficient manner can be easily added to existing courses to obtain the truck-driving licence. This is especially true as a large share of trucks used and sold in AMS still have manual transmission.

5.7.2 Electric vehicles and shared mobility

According to IEA's 2017 Global Electric Vehicle Outlook (EVI 2017), new EV registrations hit a sales record in 2016, accounting for more than 750,000 vehicles sold worldwide. With the global passenger car sales accounting for almost 70 million vehicles in the same year, the share of electric cars increased to a little more than 1%. China, by far the largest EV market, accounted for almost 40% of global EV sales.

By 2016 the global EV vehicle stock had reached about 2 million cars (Figure 43), with China and the US home to more than half of the global EV stock. So far, battery electric vehicles make up more than two-thirds of the global EV stock. The remaining third are plug-in hybrids which can both be plugged-in to charge a battery as well as use an on-board, petrol-fuelled engine to power the vehicle, which are mainly sold in Europe, Japan and the US.

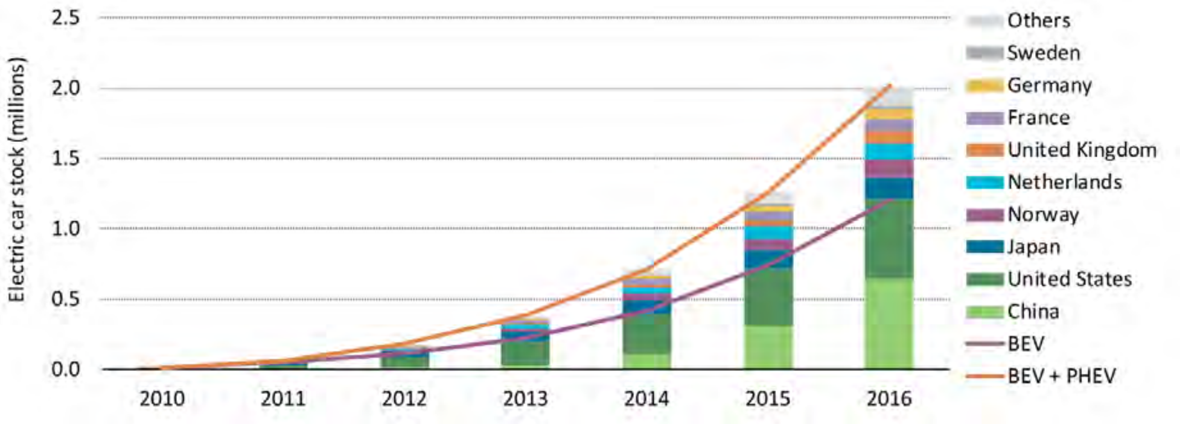


Figure 41: Global electric vehicle stock by country
Source: IEA 2017
Note: The electric car stock shown here is primarily estimated on the basis of cumulative sales since 2005. When available, stock numbers from official national statistics have been used, provided they have good consistency with expected trends in sales.

Although electric vehicle sales are strong, they still are mainly driven by policy support. According to IEA analysis (IEA 2017), ownership costs of BEVs and PHEVs were still significantly higher when compared to conventional cars in 2015. Figure 44 shows powertrain (including the engine, transmission and energy storage) and fuel costs for conventional cars (ICE), battery electric vehicles (BEV) and plug-in hybrids (PHEV) for the US, China, Japan and Europe for the years 2015 and 2030. Fuel costs comprise cumulative costs for gasoline and/or electricity (including taxes) over a period of 3.5 years, as well as potential individual infrastructure costs for home charging, which are not covered in the fuel costs.

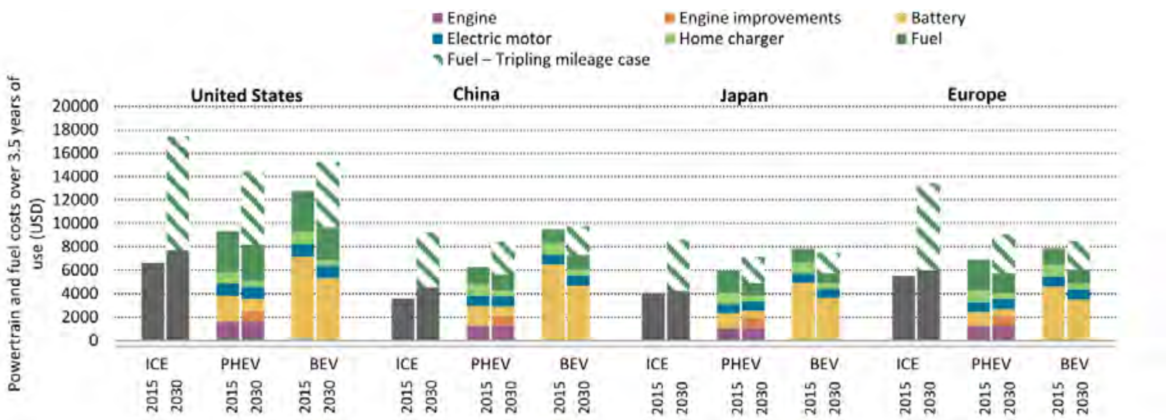


Figure 42: Powertrain and fuel costs for conventional cars, battery electric vehicles and plug-in hybrids for the years 2015 and 2030 for the US, China, Japan and Europe
Source: IEA 2017

The analysis shows that in 2015, BEVs are on average USD 3,000 to USD 6,000 more expensive than conventional vehicles based on total cost of ownership over a time of 3.5 years. By 2030, BEVs and PHEVs are fully competitive in Europe, mainly due to high fuel prices and smaller average vehicle size. In the rest of the world, the costs gap is also significantly reduced by that time.

The IEA investigated an additional case in which annual kilometres driven are tripled in order to represent the driving patterns of taxis and shared cars. In this case, BEVs and PHEVs become competitive with conventional cars in all regions by 2030. This analysis underlines the great synergies between shared mobility and vehicle electrification. The latter result can be of special interest in the context of densely populated urban areas in the ASEAN region: Vehicle electrification, together with a reduced future car ownership resulting from an increased use of car sharing, can reduce energy use, emissions and costs dramatically. This is especially true since shared mobility has the potential to significantly reduce urban congestion.

Policy support

Fuel economy policies need to be set up to incentivise the sales of electric vehicles right from the beginning: As lined out in earlier sections, fuel-economy or CO_2-emission taxation schemes are favourable for electric vehicles, but can be improved by exempting the registration of electric cars from taxation until the market volume has reached a certain level (EVs are exempted from registration taxes in China, Denmark, Germany, India (partly), Netherlands, Norway, Sweden and United Kingdom).

Feebate schemes can be set up in a way that very high efficiency or very low emission vehicles are eligible for substantial rebates in the order of several thousand USD (e.g. feebate schemes in Singapore, France).

Average corporate fuel consumption or CO_2 emission standards can be set up in a way that EVs are weighted several times their actual sales numbers through the use of multipliers (super credits) or through counting the electricity consumption as zero fuel consumption in order to incentivise manufacturers to bring EVs on the market (e.g. EU LDV CO_2 emission standards, US CAFE). Jurisdictions such as China and California have brought Zero-Emission Vehicle standards into place that require automotive companies to produce or sell a certain percentage of their new vehicle fleet as electrified vehicles. It should be noted that electric vehicles are not necessarily zero emission, but emissions occur at the source of electricity, rather than at the vehicle.

Apart from monetary incentives, soft measures such as preferential access to otherwise restricted zones (e.g. low-emission zones), priority parking, road toll exemptions, the right to use bus lanes etc. provide incentives to buy electric vehicles especially in urban areas.

As of 2018, direct subsidies (e.g. as part of a feebate scheme) or substantial tax exemptions (especially in countries with high vehicle registration taxes) at the time of purchasing an EV have the strongest impact on EV sales: Norway, the Netherlands and Sweden have EV sales share in the order of 3.4% (Sweden) to 6.4% (Norway) while providing monetary incentives in the range of USD 5,000 to USD 15,000 to EV buyers.

5.7.3 Two-wheelers

In ASEAN, two-wheelers are a major mode of transport. In fact, ASEAN has the highest number of two-wheelers per capita in the region. In 2015, almost 10 million motorised two-wheelers were newly registered in the ASEAN region, accounting for almost 20% of global motorcycle sales. Sales of motorcycles peaked in 2011 and have decreased by 15% since then to 2015., . Around 94% of new motorcycles registered in the bloc have a displacement of 50 ccm to 350 ccm (IMMA 2015).

Prospects to fully electrify motorcycles and scooters with moderate engine displacement are high, and already today electric scooters are available at competitive costs, mainly on the Chinese market. In 2016, about 26 million electric two-wheelers were sold in China, with an on-road vehicle population of over 100 million (IEA 2017 EV). This roadmap calculates that increasing shares of electric two-wheelers together with strategies to decarbonise power generation can save more than 1 million tonnes of CO_2 by year 2030 in ASEAN, and more than 300 million tonnes of CO_2 by 2050, if by then two-wheelers are more than 80% electric and the carbon footprint of power generation is reduced by 70% compared to 2012 levels.

This roadmap therefore suggests providing strong incentives, such as registration tax reductions or tax holidays for manufacturers of two-wheelers.

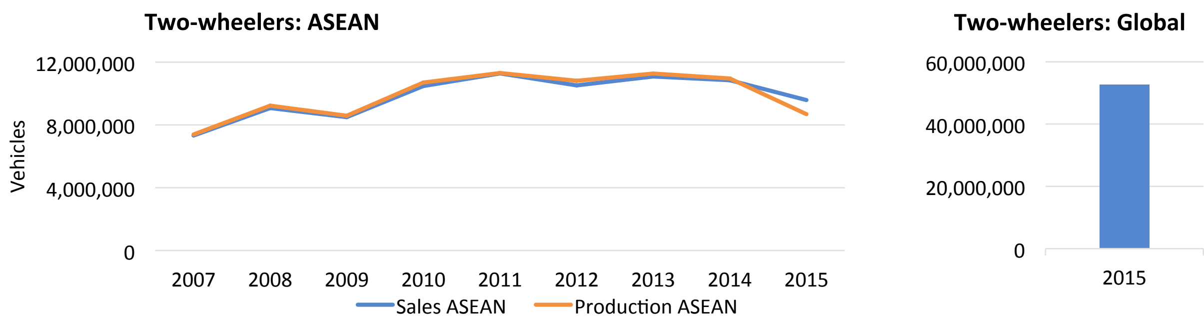


Figure 43: Motorcycle Sales and Production in ASEAN and the World
Source: AAF 2017, *Marklines 2017*

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Footnotes

1 A review and evaluation the vehicle fuel efficiency labelling and consumer information programmes of 18 countries is available at https://www.theicct.org/publications/review-and-evaluation-vehicle-fuel-efficiency-labeling-and-consumer-information. The report also identifies international best practice.

2 Homologation is the process of certifying vehicles or vehicle components to make sure they comply with national or regional environmental and security regulation. New car models need to be homologated to receive the permit for sale in a certain country or region.