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Vehicle Emission Control Strategy Bhutan

TA-8572 Action on Climate Change in South Asia

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Acronyms

ADB	Asian Development Bank
BAU	Business as Usual
BC	Black Carbon
BRT	Bus Rapid Transit
BS	Bharat Standard
CAGR	Compound Annual Growth Rate
CCAC	Climate and Clean Air Coalition
CNG	Compressed Natural Gas
COC	Certificate of Conformity
COPERT	Computer Programme to calculate Emissions from Road Transport
Corinair	CORe Inventory AIR emissions of EEA
DPF	Diesel Particle Filter
EEA	European Environmental Agency
EF	Emission Factor
EPA	Environmental Protection Agency
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GVW	Gross Vehicle Weight
GWP	Global Warming Potential
HDV	Heavy Duty Vehicle
HSU	Hartridge Smoke Unit
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
IM	Inspection/Maintenance
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contribution
IPCC	Inter-Governmental Panel on Climate Change
IVE	International Vehicle Emissions
MAMSL	Meters Above Mean Sea Level
MOVES	Motor Vehicle Emission Simulator
NCV	Net Calorific Value
NEC	National Environment Commission
NEDC	New European Driving Cycle
OBD	On-Board Diagnostics
OECD	Organisation for Economic Co-Operation and Development
OEM	Original Equipment Manufacturer
PM	Particulate matter
$PM_{2.5}$	Particulate matter < 2.5 microns in diameter
ppm	parts per million
RSTA	Road Safety and Transport Authority
SAE	Society of Automotive Engineers
TCO	Total Cost of Ownership
TNA	Technology Needs Assessment
TTW	Tank-To-Wheel
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework on Climate Change Convention
vkm	vehicle-km
VOC	Volatile Organic Compounds
WHO	World Health Organization

Summary

1. Historically vehicle emission regulations are related to air pollutants. Poor air quality is detrimental to health with vehicle emissions being an important source of pollutants. Global warming has however resulted in CO_{2e}-emissions also being considered within vehicle emission regulations.

2. The air in Bhutan is considered largely as still unpolluted with measurements not surpassing national standards. Thimphu's annual average PM_{10} measurements however show increasing pollution with monitored levels below the national standard but above the WHO guideline. A bottom-up model to determine transport related emissions of pollutants for Bhutan was applied (see following table).

Vehicle Pollutant Emissions Bhutan 2015 (in tons and as share)

Vehicle category	$PM_{2.5}$		NO_2		SO_2	
	Tons	Share	tons	Share	tons	share
Passenger cars	9.5	24%	174	10%	12	28%
Taxis	0.9	2%	29	2%	2	5%
Motorcycles	0.1	0%	13	1%	0	1%
Heavy Duty Vehicles (HDVs)	28.3	73%	1,509	88%	30	67%
Total	**38.9**		**1,724**		**45**	

At the national level, HDVs are the major source of pollutants whilst considering only urban zones passenger cars play a more important role contributing to around 50% of emissions. More than 90% of emissions are caused by diesel vehicles. Projections show that pollution will triple by 2030 if no counter-measures are taken.

3. Greenhouse Gas (GHG) transport emissions of Bhutan are as of 2015 288,000 tCO_2 (including Indian vehicles circulating in the country) and 238,000 tCO_2 of Bhutanese vehicles. It is projected that GHG emissions will triple by the year 2030 reaching 660,000 tCO_2 if no counter-measures are taken.

4. The economic cost in terms of health costs, economic and environmental damages of vehicle emissions is as of 2015 around 12 MUSD. Primarily economic damages are due to CO_2 followed by particle emissions.

5. Vehicle regulations which potentially affect emissions and have already been implemented in Bhutan include the ban of two-stroke motorcycles and 3-wheelers, the ban of importing used vehicles, the usage of unleaded gasoline, a maximum commercial age of taxis and buses, tax policies which favour hybrid and electric vehicles as well as cars with a lower cc, Euro 2 vehicle emission standard and an implemented inspection/ maintenance system. The table below shows a summarized assessment of the status of vehicle regulations in Bhutan.

Summary Status Vehicle Emission Regulation

Area	Policy, Regulation or Procedure in Place	Critical Elements
Fuels	350ppm sulphur diesel from India; unleaded gasoline; fuel laboratory in operation	Standardized quality control of fuels lacks thus resulting potentially in fuel adulteration
Vehicle emission standards and regulations	vehicle emission standard requires Euro 2	Standard should be updated and lacks clarity concerning compatibility with standards of other countries; no documentary compliance control of imported vehicles
	Vehicle in-use exhaust emission standard and inspection for gasoline as well as diesel cars based on ralenti CO test for gasoline and snap-on test for diesel vehicles	Maximum permitted emission levels require revision; actual implementation of diesel measurement procedure is faulty; enforcement and control is poor
	No standard concerning CO_2 emissions; fiscal incentives for electric / hybrid vehicles	Incentives are not sufficient to have a major impact
General policies	Maximum age for commercial vehicle usage	Usage of commercial vehicles on a private base
	Diesel fuel is sold cheaper than gasoline	Widespread usage of light diesel vehicles causing major air pollution problems
	Ban of 2-stroke motorcycles and 3-wheelers	

6. Emission policies assessed include low sulphur fuels, new vehicle emission standards, changes in the Inspection/Maintenance (IM) program, CO_2 emission standards for vehicles respectively the promotion of low-carbon vehicles, retrofit of Diesel Particle Filters, limiting the lifetime of vehicles and providing for scrapping incentives, and restricting importation of new diesel cars (excluding heavy-duty vehicles).

7. The following table compares the different policies assessed in terms of environmental impact, economic impact, and complexity. Per policy an overall rating is given from ++ (highly positive) to -- (highly negative)[1].

Comparison of Proposed Policies

ID	Policy	Environmental Impact		Economic Impact	Complexity, Risk	Overall Rating
		Pollutants	GHG			
1	Low sulphur fuels	++	0	--	Low	+
2	Euro 4 and 6 emission standards	+++	++	++	Low	++
3a	IM improved current version	0	0	0	High	0
3b	IM240 (loaded tests)	0	0	--	Very high	--
4	Promotion of low-carbon vehicle technologies	+	+++	--	Low	++
5	Diesel Particle Filter retrofit	+	+	---	Very high	--
6	Limit vehicle lifetime	+++	0	---	Very high	--
7	Restrict usage of diesel fuel for passenger cars and taxis	+	+	++	Low	++

8. Recommended Policies

1. Follow the Indian fuel standards and import 50ppm sulphur diesel and gasoline as of 01.2018 and 10ppm sulphur diesel and gasoline as of 01.2021.

2. Implement in line with India new vehicle emission standards for gasoline and diesel vehicles requiring as of 01.2018 BS-IV (equivalent to Euro 4) and as of 01.2021 BS-VI (Euro 6).

3. Restrict the import and sale of diesel powered cars and light commercial vehicles with less than 3.5t Gross Vehicle Weight as of 01.2018.

4. Upgrade the current Inspection/Maintenance system concerning emission limits, data transmission, technical norms for measurement procedures of diesel vehicles, and improve controls.

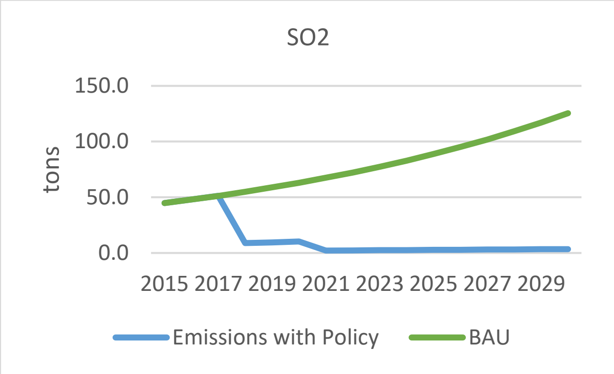
5. Keep the current maximum age of commercial vehicle lifespan for fossil fuel units. For hybrids, expand the commercial life-span to 12 years for taxis and 15 years for buses, for plug-in hybrids to 15 years for taxis and 20 years of buses and for electric vehicles to 20 years.

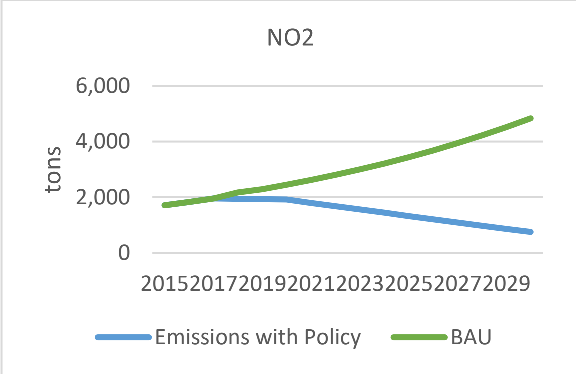
6. Establish a low-carbon vehicle strategy with a focus on urban vehicles including taxis, buses and urban delivery trucks.

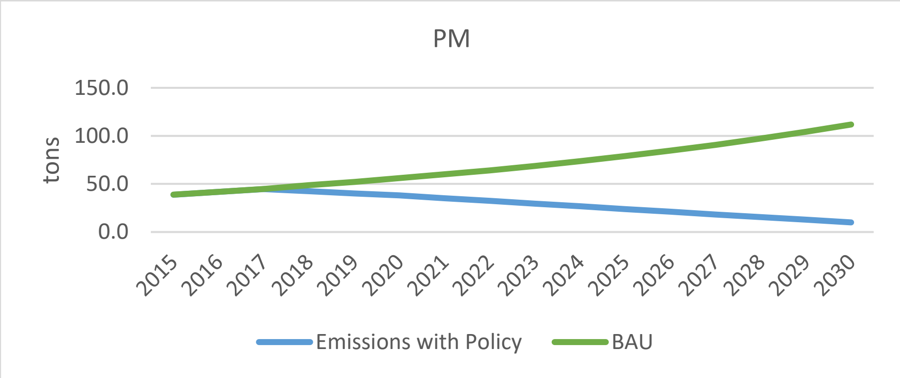
Priority policies are clean fuels (1), updated vehicle emission standards (2), limit import of diesel vehicles to vehicles >3.5t (3) and a low-carbon vehicle roadmap (4). The implementation of these policies is simple with very limited investment and manpower required whilst the impact is highly positive in environmental and economic terms.

9. The projected pollution impact of the proposed combined policies is shown in the following graphs. Urban emissions can be reduced by 90% or more compared to the BAU scenario by 2030 and relative to 2015 urban air pollution caused by transportation can be reduced by 60-90% i.e. the combination of policies proposed is an effective instrument towards achieving and sustaining clean air in Bhutan.

[1] For each policy environmental and economic benefits have been quantified







BAU= Business as Usual or emissions in absence of policy interventions

10. The combined impact of the proposed policies is a reduction of CO_2 emissions including Black Carbon of 24% by 2030 relative to BAU. Emissions by 2030 would still be 2.8x higher than currently i.e. the combined policies on vehicle emissions have an important impact but are not enough to stabilize in absolute terms GHG emissions.

11. The combined economic impact of the proposed policy combination is shown in the following table.

Economic Impact of Combined Policy Measures (in MUSD)

Parameter	Cumulative Benefit (+) or Cost (-) in MUSD (2018-2030)
Value PM, NO_2 and SO_2 reduction	39
Value GHG reduction	37
Additional cost fuel	-18
Additional cost vehicles	-69
Additional cost IM	-3
Total	**-14**
Total excl. additional fuel costs	**4**

Fuels are imported from India and Bhutan cannot influence the Indian fuel qualities or prices i.e. the additional cost of fuels must be borne independent of policies decided upon. The real economic impact of the combined policy which can be influenced by Bhutan is therefore +4 MUSD. In fiscal terms the government would have slightly higher supervision and control costs estimated at less than 0.1 MUSD per annum.

12. Rejected/Not Recommended Policies

1. Extension or upgrading to loaded vehicle testing of Inspection/Maintenance. This policy is rejected due to a limited environmental impact, a high additional cost and the high implementation complexity.

2. Realizing a retrofit program for Diesel Particle Filters is rejected due to its very high economic cost, the high complexity and the risk of low performance with retrofit installations.

3. Limiting the age of private vehicles or trucks and/or realizing a scrapping program for elder vehicles is rejected due to the limited environmental impact and the very high economic costs.

1. Introduction

1.1. Report Objective and Layout

The overall framework of the assignment is to support Bhutan in pursuing low-carbon and climate resilient development. Specifically, vehicle emissions shall be reduced through upgrading of vehicle emission regulation and testing. The focus of this report is on measures to reduce vehicle emissions per unit of distance driven through standards and regulations. The report does not discuss measures to curb vehicle emissions through traffic avoidance, mode shift or measures which improve transport efficiency or vehicle efficiency outside vehicle emission regulations.

The report reviews the current and projected vehicle emission levels of Bhutan, the vision and targets of the Royal Government of Bhutan and measures and strategies to curb in a cost-effective manner vehicle emissions. Technical aspects of vehicle emission regulations, operational details of the current inspection system and potentials to realize an automatic data transmission from inspection equipment to the vehicle registration department as well as capacity building are covered by other team members contracted by ADB[2].

The structure of this report is:

- Chapter 1.2. shows the relationship between air quality, air pollutants, vehicle emissions and climate change.
- Section 2 focuses on stock taking: the status of air quality, vehicle emissions, vehicle emission regulations and fuel quality standards. Also, stakeholders involved are outlined and the strengths and weaknesses of the current system are identified.
- Section 3 models the current and future vehicle emissions of Bhutan concerning pollutants (PM, NO_2, SO_2) and Greenhouse Gases (CO_2 and Black Carbon). Projections are based on a Business as Usual (BAU) scenario. The economic cost of current and projected future emissions is calculated.
- Section 4 outlines the vision and targets of stakeholders concerning air quality, greenhouse gases and vehicle emissions and identifies assessment criteria for selecting viable measures.
- Section 5 describes and assesses major strategies and instruments used in other countries for regulating vehicle emissions. The most promising strategies and measures are identified. A recommendation concerning vehicle emission regulations in Bhutan is given.

[2] Report on vehicle emission regulations for pollutants in Korea and their potential application in Bhutan (prepared by Kim Jong-Choon); Outline of a training program for automobile mechanics on emission controls (prepared by Lea Seang Wook); Statistical assessment of data from the current inspection system (prepared by Cheku Dorji); Report on automated data exchange from vehicle emission inspection equipment to the vehicle registration office (prepared by Sonam Tshering). The roadmap for vehicle emissions for Bhutan is realized separately with this report being the Technical Background Report of the Roadmap.

1.2. Linkage Climate Change and Vehicle Emissions

Historically vehicle emission regulations are related to air pollutants. Poor air quality is detrimental to health with vehicle emissions being an important source of pollutants. Global warming has however resulted in CO_2-emissions also being considered within vehicle emission regulations.

The most common air pollutants, known in the US as criteria pollutants, are Carbon Monoxide (CO), Lead (Pb), Ground-level Ozone, Particulate Matter (PM), Sulphur Dioxide (SO_2) and Nitrogen Dioxide (NO_2)[3]. Ground-level Ozone is not emitted directly into the air, but is created by chemical reactions between Oxides of Nitrogen (NO_x) and Volatile Organic Compounds (VOC) in the presence of sunlight.

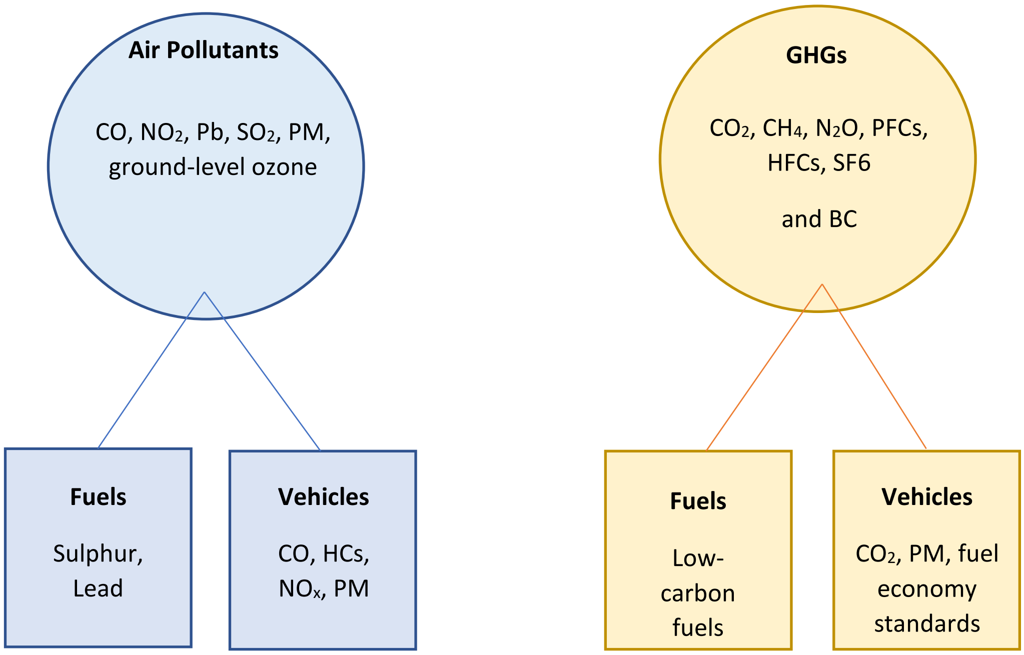
Lead and SO_2 emissions are related to fossil fuel usage by vehicles and are controlled through the usage of unleaded gasoline and through maximum sulfur levels in fuels, primarily diesel. The other air pollutants[4] are regulated through exhaust emission standards.

Due to the importance of vehicle emissions in climate change, GHG emission regulations and/or fuel economy standards have been put in place by various countries including the EU, USA, Canada, Japan, South Korea, Mexico, China, Brazil and Switzerland[5]. Fuel efficient vehicles have lower fuel usage related emissions (lead and SO_2), not however necessarily lower other pollutants. A linkage between pollution control and climate change exists with particle emissions. Increased particle emissions result not only in a worsening air quality but also in higher Black Carbon (BC) emissions. A scientific assessment of BC emissions and impacts found that these are second to CO_2 in terms of climate forcing. BC is on average 2,700 times more effective on a mass-equivalent basis than CO_2 in causing climate impacts within 20 years, and 900 times more effective within 100 years[6]. Air quality can be improved by reducing diesel exhaust ultrafine particles and BC thereby reducing also short-lived climate pollutants[7].

The following figure shows the role of vehicle emission regulations in curbing air pollution as well as global warming.

[3] https://www.epa.gov/criteria-air-pollutants
[4] In the case of ground-level ozone VOCs and NO_x are regulated.
[5] http://www.theicct.org/info-tools/global-passenger-vehicle-standards
[6] see Bond, 2013 or World Bank, 2014
[7] This is commensurate with a strategy followed e.g. by the Climate and Clean Air Coalition (CCAC) formed by the United Nations Environment Programme (UNEP)

Figure 1: Main Interactions Vehicle and Fuel Regulations with Air Pollution and Climate Change



Source: Grütter Consulting

2. Status of Vehicle Emission Controls in Bhutan

2.1. Impact of Air Pollution

Air pollution has multiple negative social and economic impacts:

- Scientific research shows that air pollution has a great impact on our health. Children, the elderly and poorer people are particularly vulnerable. Harmful effects caused by air pollution include premature mortality, respiratory and cardiovascular diseases and breathing difficulties.
- Poor air quality reduces the quality of life and the attractiveness of a country not only for its inhabitants but also for tourists which visit the Kingdom of Bhutan attracted by its precious environment. Increased pollution levels reduce happiness and thereby also productivity of the people. Also, pollution causes significant health and environmental costs which need to be borne by society.
- Poorer people are disproportionally affected by air pollution as they tend to be located closer to its sources[8]. At the same time, they contribute less to the air pollution problem as they do not own private cars. Recent studies also revealed that women are affected more by poor air quality than men[9].
- Air pollution and climate change adversely affect vegetation and animals reducing biodiversity and endangering species. It also poses serious risks to the built environment for example due to more frequent weather extremes whilst also increasing the maintenance and cleaning costs of buildings affected by particulates and NO_x emissions which cause discolouration and higher vulnerability to weathering.

The health impact of the 6 major pollutants identified previously is shortly described[10].

Particulate Matter (PM)

Particles may be emitted directly, or may be formed in the atmosphere by transformation of gaseous emissions such as SO_x, NO_x, and VOCs. PM_{10} represents inhalable particles small enough to penetrate deeply into the lungs. The fine fraction of PM_{10} called $PM_{2.5}$ is formed chiefly by combustion processes. Harmful health effects are caused primarily by fine particles and include premature mortality, aggravation of respiratory and cardiovascular diseases, decreased lung function and exacerbation of allergic symptoms. Children, older adults, individuals with pre-existing heart and lung diseases and persons with lower socioeconomic status are the highest risk groups. $PM_{2.5}$ can also have detrimental development effects such as low birth weight and increased infant mortality due to respiratory causes. The major source of vehicle $PM_{2.5}$ emissions are diesel units.

Ozone

Ground-level ozone poses a risk to human health, in contrast to the stratospheric ozone layer that protects the earth from harmful wavelengths of solar ultraviolet radiation. Short-term exposure to ground-level ozone can cause a variety of respiratory health effects, can decrease the capacity to perform exercise and can increase the susceptibility to respiratory infection resulting potentially in premature mortality. Exposure to ambient concentrations of ozone can aggravate respiratory illnesses

[8] Mitchell and Dorling, 2003
[9] Clougherty, 2010
[10] See EPA, 2015

such as asthma or bronchitis and can result in permanent lung tissue damage. The major source of vehicle emissions resulting in ground-level ozone are NO_x emissions and Non-Methane Hydrocarbon emissions.

Sulphur Dioxide (SO_2)

The health impact of SO_2 is basically related to increased breathing difficulties, increased respiratory symptoms in children and older adults and increased risks for people with asthma. The major source of vehicle SO_2 emissions is from diesel fuel.

Nitrogen Dioxide (NO_2)

Exposure to NO_2 is associated with respiratory-related health effects especially among asthmatic children and older adults. The major source of vehicle NO_x emissions is today from diesel vehicles.

Lead

Lead accumulates in bones, blood and soft tissues. Lead exposure can affect development of the central nervous system in young children resulting in neurodevelopmental effects including lowered IQ and behavioural problems. Lead caused by vehicle emissions is caused by the combustion of leaded gasoline. Due to elimination of lead in gasoline in Bhutan, vehicle emissions are no longer a cause of lead pollution.

Carbon Monoxide (CO)

Exposure to CO reduces the capacity of the blood to carry oxygen which can affect the body's ability to respond to increased oxygen demands of exercise or exertion. Risk populations are basically those with respiratory diseases, and those in prenatal or elderly life-stages. The major source of vehicle CO emissions is from gasoline vehicles.

2.2. Status Air Quality in Bhutan

Air quality data is to the moment limited to PM_{10}, while SO_x and NO_x are monitored periodically. The air is considered largely as still unpolluted with measurements not surpassing national standards[11]. The following table compares national and WHO guideline standards for air quality.

Table 1: National and WHO Guideline Air Quality Standards in µg/m³

Parameter	National Standard[12]		WHO Guideline	
	24-hour	Annual mean	24-hour	Annual mean
PM_{10}	100	60	50	20
NO_2	80	60	200 (1 hour)	40
SO_2	80	60	20	n.a.
CO	4,000 (1 hour) 2,000 (8 hour)	n.a.	3,000 (1 hour) 1,000 (8 hour)	n.a.

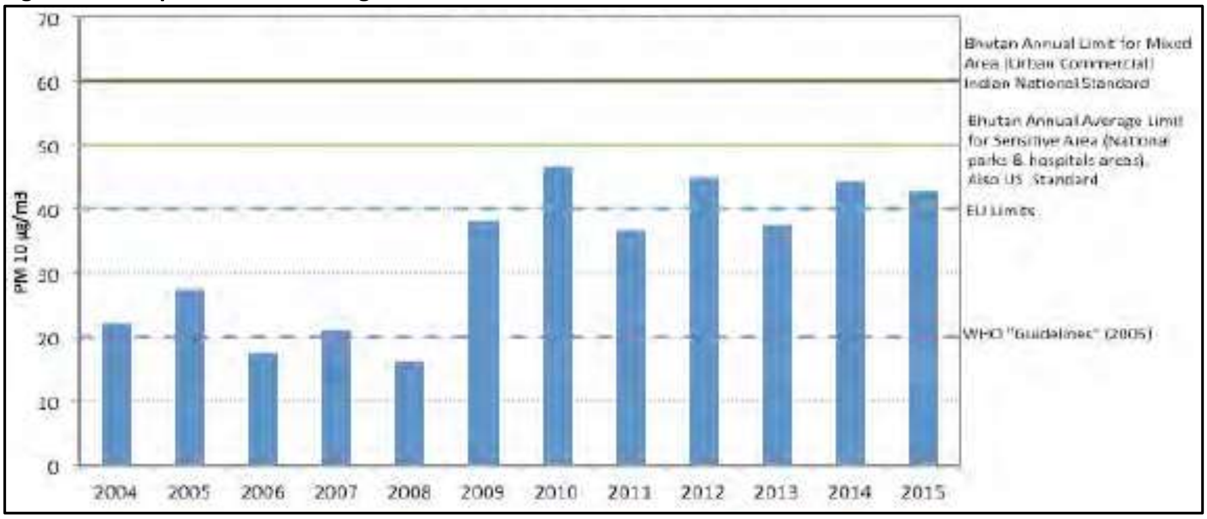
Source: WHO, 2006 and 2000; NEC 2013a

Thimphu's annual average PM_{10} measurements show increasing levels. Monitored levels are below the national standard but above the WHO guideline (see figure below).

[11] Gross National Happiness Commission, 2013, p. 236

[1212] For mixed areas, i.e. residential, commercial or both activities: standards for sensitive areas (schools, hospitals sensitive ecosystems are more stringent)

Figure 2: Thimphu Annual Average PM10 Levels



Source: NECS station, NEC, 2016, figure 34

Data from other stations (Rinchending, Bajothang, Kanglung) also show that PM_{10} levels are increasingly critical.

2.3. Global Warming and Vehicle Emissions

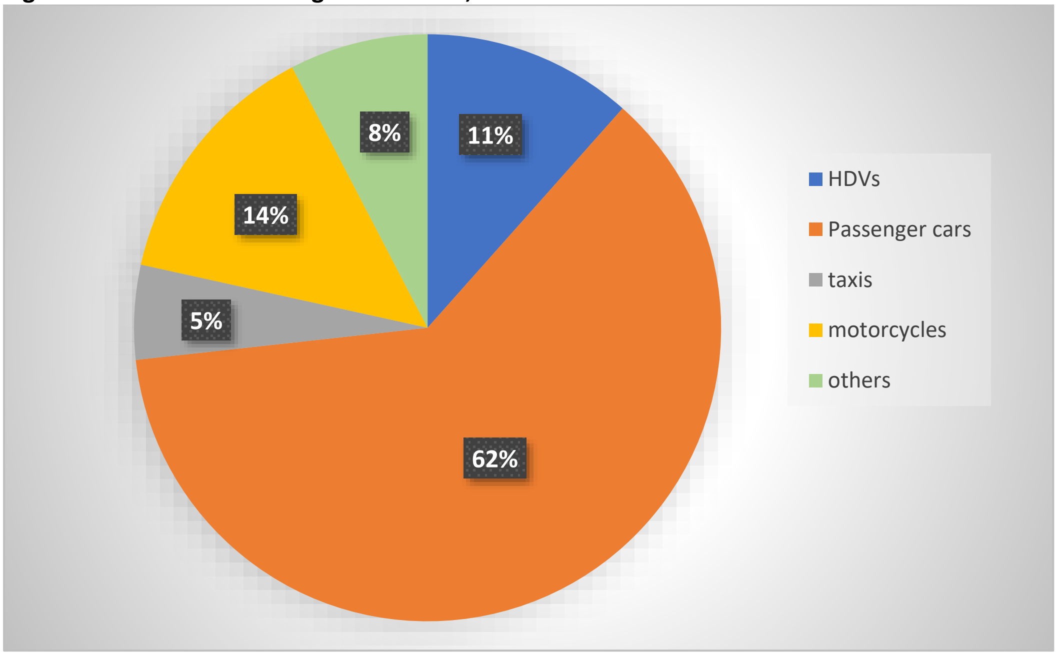
Transport consumes as of 2014 around 19% of world energy produced or 2,627 Mtoe (1973 this share was 18%). It is expected that this share will increase to 28% by 2040. Transport had 2014 a share of 65% of world oil consumed (1973 this share was 45%), 7% of natural gas (1973 3%), 2% of electricity (idem to 1973) and 0% of coal (1973 5%)[13]. Transport accounted 2010 for around 14% of global Greenhouse Gas (GHG) emissions with the overwhelming majority due to burning of petroleum based fuels[14]. Transport related CO_2 emissions have increased by 28% since the year 2000 and are expected to double under a BAU scenario from 2015 to 2050[15].

2.4. Vehicle Stock Bhutan

The number of vehicles operating in Bhutan is estimated at around 84,000 units as of end 2016 of which more than 50% are registered in Thimphu[16]. The Compound Annual Growth Rate (CAGR) in the last 10 years has been 10%. The following figure indicates the distribution of vehicle types. It shows that passenger cars are predominant followed by motorcycles. Latter are 4-stroke units due to a ban of 2-stroke motorcycles established in 1996 [17]. Around 50 urban public transport buses operated as of 2015 in Bhutan[18].

[13] IEA, 2016
[14] https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data#Sector
[15] ITF, 2016
[16] http://www.rsta.gov.bt/rstaweb/load.html?id=82&field_cons=MENU; data from RSTA of vehicles with annual registration indicate that these figures might overstate actually operating vehicles due to not considering sufficiently vehicles which have been scrapped.
[17] NEC, 2010
[18] MOIC

Figure 3: Share Vehicle Categories Bhutan, June 2015[19]



Source: RSTA Annual Report 2014/15

Heavy Duty Vehicles (HDVs) include diesel powered large and medium sized trucks and buses[20]. Trucks used in Bhutan are due to road conditions basically smaller units with a maximum of 26t GVW (Gross Vehicle Weight). Buses are basically smaller units of 6-8m with few 12m buses. More than 80% of taxis are gasoline and around 60% of passenger cars are gasoline. Diesel cars are in general higher motorized and used for larger passenger cars including SUVs and pick-ups. Vehicles are basically imported from India with major brands being Hyundai, Maruti and Toyota.

2.5. Status of Vehicle Regulations

Vehicle regulations which potentially influence emission levels and have already been implemented in Bhutan include:

- No two-stroke motorcycles can be sold since 1996. Whilst comparable power 2-stroke motorcycles can be more efficient in fuel usage than 4-stroke ones they can represent serious problems in air pollution due also to variations in the oil-gasoline mixture used. 2-stroke motorcycle PM emissions are for example nearly factor 10 higher than those of 4-stroke engines within the same Euro category[21].
- No 3-wheelers or motorized rickshaws can be imported into the country.
- The import of used vehicles has been banned since 1996.
- Bhutan only sells unleaded gasoline. No Bhutanese fuel standards exist and all fuel is sourced from India in compliance with the valid Indian national fuel standards.
- The age of vehicles to be used in commercial operations (taxis and buses) is limited to 9 years taxis and 14 years buses. Vehicles can however thereafter be used on a non-commercial i.e. private base.

[19] Based on a total of 73,815 vehicles
[20] Medium sized HDVs have been classified as trucks and buses between 3.5 and 7.5t whilst the remaining HDVs are classified as being primarily trucks and buses between 7.5 and 16t
[21] EEA, 2016, table 3-26

- Tax policies have been established with slightly reduced rates for hybrids and larger tax reductions for electric vehicles. Vehicles with a higher cylinder capacity are also taxed more than such with smaller engines. No tax differentiation is made relative to the emission standards, GHG emissions or type of fuel used. Indian made vehicles are exempted from customs tax which effectively reduces the tax advantage of electric vehicles by up to 50%.
- Vehicle type approval standards have been established (see below for details).
- In-use vehicle exhaust emission standards and an inspection program have been established (see below for details).

Type-Approval Emission Standards

Since 03/2008 all vehicles imported to Bhutan must meet the Euro 2 standard. Bhutan does not realize an own type approval testing. Vehicles are basically imported from India and effectively the Bharat Standard (BS) II is accepted although the Euro and the BS are not identical for passenger cars and motorcycles, whilst they are the same for HDVs (see below). Differences between the EU and Indian standards are marginal but for reason of clarity it is useful that a regulation includes explicitly other accepted standards.

Table 2: Comparison Euro 2/3 and BS II/III Standard Passenger Cars and Motorcycles (g/km)

Vehicle Category	CO	HC	HC+NO_x	NO_x	PM	Test Method
Gasoline passenger cars						
Euro 2	2.2	---	0.5	---	---	ECE_{15}
BS II[22]	2.2-5.0	---	0.5-0.7	---	---	Modified NEDC
Euro 3	2.3	0.2	---	0.15	---	ECE_{15}
BS III	2.3-5.22	0.20-0.29	---	0.15-0.21	---	Modified NEDC
Diesel passenger cars						
Euro 2	1.0	---	0.7	---	0.08	ECE_{15}
BS II[23]	1.0-1.5	---	0.7-1.2	---	0.08-0.17	Modified NEDC
Euro 3	0.64	---	0.56	0.5	0.05	ECE_{15}
BS III	0.64-0.95	---	0.56-0.86	0.50-0.78	0.05-0.10	Modified NEDC
Motorcycles						
Euro 2 (all cc)	5.5	1.0-1.2[24]	---	0.3	---	ECE Reg 47
BS II	1.5	---	1.5	---	---	Modified NEDC
Euro 3 (all cc)	2.0	0.3-0.8	---	0.15	---	ECE Reg 47
BS III	1.0	---	1.0	---	---	Modified NEDC

Source: ICCT, 2013, Appendix B

Table 3: Comparison Euro II/III and BS II/III Standard HDVs Diesel Engines (g/kWh)

Vehicle Category	CO	HC	NO_x	PM	Test Method
Euro II	4.0	1.1	7.0	0.15[25]	ECE R-49
BS II[26]	4.0	1.1	7.0	0.15	Modified NEDC test cycle
Euro III	2.1	0.66	5.0	0.1	ESC and ELR
BS III	2.1	0.66	5.0	0.1	ESC

Source: ICCT, 2013, Appendix B

[22] Exact value dependent on seat number and weight of vehicle
[23] Exact value dependent on seat number and weight of vehicle
[24] Value 1.0 for motorcycles with >150cc and value 1.2 for motorcycles with <150cc
[25] As of 10.1998
[26] Exact value dependent on seat number and weight of vehicle

In-Use Vehicle Exhaust Emission Standards

Bhutan has in-use exhaust emission standards and tailpipe inspections are performed at dedicated inspection centres[27]. The following table shows the standard effective as of March 2008. Vehicle emission testing is mandatory since 2003[28] and must be performed annually for private and bi-annually for commercial vehicles.

Table 4: In-Use Vehicle Exhaust Emission Standards Bhutan (effective as of 03/2008)

Fuel type	Vehicles registered prior 01/2005	Vehicles registered after 01/2005
Gasoline	4.5 % Vol. CO	4.0 % Vol. CO
Diesel	75% HSU	70% HSU

Source: NEC, 2010

Gasoline vehicles are tested for CO emissions during idling. Smoke tests are performed on diesel vehicles using a free acceleration “snap” test. Three measurements are performed which should not vary more than 10%, taking the average of the 3 measurements[29]. A print-out of the result is obtained from the equipment with results being punched in manually into a database connected to RSTA which thereby obtains results of all vehicles tested. The photos below show the new inspection centre in Thimphu, run by a private company contracted by government.

Photo 1: Emission Inspection Centre Thimphu

Source: Grütter

2.6. Fuel Availability and Quality

Bhutan purchases all its fuel from India. India produced until April 2017 diesel with 350ppm sulphur which can be used for vehicles adhering to the emission standard Euro 3 or BS-III and since April 2017 diesel fuel from India has 50ppm sulphur.

Bhutan will follow the fuel specifications for India without being able to purchase high quality fuel provided for urban hotspots in India. Therefore, vehicle emission standards for diesel vehicles will be dependent on the diesel fuel policy of India. The timetable of India is that since April 2017 diesel fuel of 50ppm sulphur is sold nationwide thus allowing for the vehicle emission standard BS-IV. As of April 2020, 10ppm sulphur diesel shall be distributed nationwide as India intends to introduce the BS-VI

[27] Recently a new contract for a 3-year period for privately run inspection centres has been closed.
[28] With effective inspection starting 2006
[29] The procedure is based on SAE J1167 method

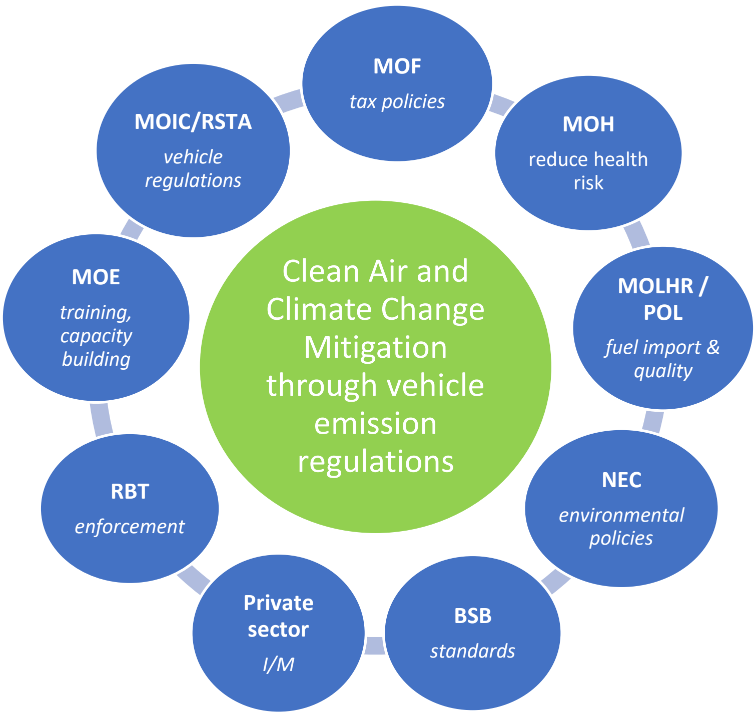
standard leapfrogging from BS-IV to BS-VI[30]. The fuel standards for BS are thereby comparable to the Euro standards.

Bhutan has a fully equipped laboratory to realize fuel quality control. This is performed randomly at import site and at petrol stations. No regulations, norms or written procedures on how controls need to be realized and how to ensure a randomized quality control exist. Reports of fuel adulteration especially with kerosene are widespread among consumers but difficult to assess[31]. Also within India fuel adulteration especially with kerosene seems to be a serious problem[32] therefore highlighting the importance of an appropriate quality assurance system.

2.7. Stakeholders Involved

The core institutions involved in vehicle emission regulation are the RSTA (Road Safety and Transport Authority), the Royal Bhutan Police (RBP) and the NEC (National Environment Commission). However, multiple institutions and stakeholders play a role in ensuring clean air and low GHG vehicle emissions. An overview of involved institutions and their main roles is given in the following figure.

Figure 4: Institutional Map



MOF: Ministry of Finance
MOH: Ministry of Health
MOEA: Ministry of Economic Affairs
NEC: National Environment Commission
POL: Petroleum, Oil and Lubricant section (part of Department of Trade within MOEA)
BSB: Bhutan Standards Bureau
RBT: Royal Bhutan Police
MOLHR: Ministry of Labour and Human Resources
MOIC: Ministry of Information and Communications
RSTA: Road Safety and Transport Authority
I/M: Inspection/ Maintenance

30 See the final notification of the Ministry of Road Transport and Highway issued 16.09.2016; http://www.theicct.org/blogs/staff/india-leapfrogging-an-outdated-standard-to-bharat-stage-VI
31 Kerosene has a significantly lower price
32 see report ICCT, 2013, p. 18

2.8. Assessment of Status

Bhutan is upgrading the air quality management system including the establishment of an air quality monitoring network which can provide the required data to monitor appropriately ambient air quality. No emission inventory currently exists so the contribution of various sectors including natural background emissions, forest fires, households, industry, transport and waste is not well documented and tracked.

Fuels are purchased from India and follow Indian fuel standards and fuel availability. Due to logistical and financial reasons this cannot be changed. However, the Indian fuel sector is changing rapidly with 50ppm sulphur fuel being the norm nationwide since April 2017, and 10ppm sulphur fuel as of April 2020 (nationwide). Bhutan will thus also upgrade automatically its fuel quality. Quality control has been established and means are available for an adequate assurance of fuel qualities. However, procedures established are ad hoc thus not guaranteeing that fuel adulteration especially with cheaper kerosene does not occur.

General policies which favour lower vehicle emissions such as banning 2-stroke motorcycles, ban of 3-wheelers, tax preferences for hybrid and electric vehicles and a maximum age for commercial usage of vehicles have been put in place. However, tax preferences are not sufficient to allow for a significant change of the vehicle fleet due also to the fact that Indian vehicles have lower taxes thus reducing tax advantages of low carbon vehicles. The age limit for commercial vehicles is of limited impact as vehicles are not scrapped thereafter but further used on a private base. The lower tax and relative subsidy of diesel versus petrol fuels results in diesel being sold at a price around 15% lower than petrol whilst a taxation based on energy contents would result in diesel being more expensive than gasoline. Again, this is due at least partially to the Indian fuel policies of subsidizing diesel which is reflected in the selling price of fuels to Bhutan. This fuel price policy has resulted, just like in India, in a significant increase of the number of diesel passenger cars and light duty vehicles thereby causing a large part of the urban pollution problem.

The vehicle emission standard for new vehicles in force is Euro 2. The current fuel quality would allow for Euro 4 since mid-2017 and Euro 6 as of mid-2020. A non-systematic control of imported vehicles concerning compliance with emission standards is realized with some importers providing for Certificate of Conformity (COC) documentation and others providing simple letters.

In-use exhaust emission standards for diesel as well as gasoline vehicles are in place and inspection is realized at private centres. The measurement procedure for gasoline as well as diesel vehicles follows standard practices used in many countries. Critical parts identified include lack of calibration and maintenance of equipment, non-automatic data transmission (results are punched in manually to the RSTA database), the maximum permissible levels need revision and the measurement procedure for diesel vehicles is not in accordance with standard norms: Neither is the acceleration performed correctly nor do the 3 measurements fall within an acceptable variation range. The incorrect procedure is applied although the inspection centre is aware of the correct procedure i.e. it is neither a problem of information, know-how nor capacity. However, no norms are in place which protect the inspection centre of claims related to engine rupture whilst performing the snap-test. Also, the regulation does not specify that staff of the inspection centre must perform this test. The test procedures applied at the inspection centre results in non-compliant diesel vehicles passing the test. Data transmission from measurement equipment to the database is manually performed which is potentially a critical point. Enforcement lacks in three areas:

- Limited control of the inspection centres to assess if tests are performed adequately and data transmitted is correct;
- Limited control of vehicle owners on-road re-performing the emission test thereby ensuring that vehicles not only comply with regulations during the test at the inspection centre;
- The linkage between the annually issued permit to circulate and the emission inspection is not yet fully established thus allowing vehicles to circulate even if the testing was not performed;

GHG emissions of the transport sector are increasing rapidly as result of a high vehicle growth rate. Whilst overall policies favour electric vehicles no roadmap has been put in place with clear steps to implement this policy. Also, no regulations concerning vehicle CO_2 emissions have been put in place.

The following table summarizes core achievements and current critical points.

Table 5: Summary Status Vehicle Emission Regulation

Area	Policy, Regulation or Procedure in Place	Critical Elements
Fuels	50ppm sulphur diesel from India since 04/2017; unleaded gasoline; fuel laboratory in operation	Standardized quality control of fuels lacks thus resulting potentially in fuel adulteration
Vehicle emission standards and regulations	vehicle emission standard requires Euro 2	Standard should be updated based on available fuel quality; Standard lacks clarity concerning compatibility with standards of other countries e.g. BS from India; lack of documentary compliance control of imported vehicles (COC)
	Vehicle in-use exhaust emission standard and inspection for gasoline as well as diesel cars based on ralenti CO test for gasoline and snap-on test based on HSU standard for diesel vehicles	Maximum permitted emission levels require revision; actual implementation of measurement procedure is faulty[33]; enforcement and control should be improved e.g. with automated data transmission; equipment need regular calibration and maintenance
	No standards concerning CO_2 emissions	Lack of standards can result in increased GHG emissions
General policies	Maximum age for commercial vehicle usage (9 years taxis and 14 years buses)	Usage of commercial vehicles on a private base
	Tax incentives for low carbon emitting vehicles	Limited impact of strategy due to lack of a comprehensive and coordinated approach
	Diesel fuel is sold cheaper than gasoline	Widespread usage of diesel passenger cars and light vehicles causing major air pollution problems
	Ban of 2-stroke motorcycles and 3-wheelers	

[33] Not the measurement procedure itself but its application

3. Vehicle Emissions Bhutan

3.1. Introduction

A stocktaking is made of vehicle emissions in Bhutan as of 2015 followed by a Business as Usual (BAU) projection to 2030. No transport pollutant inventory or emission model like MOVES, COPERT or IVE has been applied at the national level or in Thimphu to estimate the amount of pollutants from vehicle sources. Grütter Consulting has therefore applied a proprietary bottom-up model[34] to determine pollutant and GHG emissions from vehicles. Following emission parameters are determined:

- Pollutants: $PM_{2.5}$, NO_2, SO_2;
- GHGs: CO_2 and Black Carbon (BC) expressed in CO_2 equivalent

Emissions are determined at a national level. An estimate is also made for urban areas as health impacts are predominant in these areas due to high concentrations of pollutants.

The methodological approach used is based on following core elements:

- A bottom-up model based on vehicle-km (vkm) per vehicle technology and fuel type is used.
- A Tier-2 approach is applied i.e. vehicle emissions are not related to speed and operating conditions (“hot” and “cold” emissions).
- Core data required to run the model are the number of vehicles per vehicle category, the emission standard and the vehicle classes per category, fuel types used, annual distance driven and the total quantity of fuel used (see the following table for data sources).
- Vehicle categories are based on registration data. For each vehicle category gasoline and diesel vehicles are separated. For each category, the main vehicle class is determined based on engine size for light vehicles and motorcycles and based on weight for HDVs.
- $PM_{2.5}$ and NO_2 are calculated based on Corinair emission factors per vehicle category, technology and emission standard[35].
- SO_2 is based on fuel consumption, type of fuel, the sulphur content of the fuel and the molar mass of SO_2. SO_2 emissions are not vehicle technology specific but related to the fuel quality (sulphur content).
- CO_2 emissions are based on the specific fuel consumption per vehicle category and fuel type based on Tier 2 Corinair values, the number of vehicles and the annual distance driven. Top-down (Tier 1) CO_2 emissions based on total diesel and gasoline transport fuel consumed is used to calibrate the annual distance driven per vehicle category. Latter is again used for calculation of pollutant emissions. CO_2 emissions are calculated based on the Net Calorific Value (NCV) and the EF_{CO2} per fuel (IPCC approach) applying IPCC default parameters[36].
- BC emissions are based on $PM_{2.5}$ emission, the BC fraction within $PM_{2.5}$ and the Global Warming Potential (GWP) at 10 years for BC. BC emissions are expressed as CO_2 equivalent. $PM_{2.5}$ emissions and the BC fraction are vehicle technology and category dependent and taken from Corinair (Tier 2 approach)[37].

[34] Top-down models rely on fuel consumption figures and do not allow for reliable pollutant inventories as latter are dependent on vehicle emission standards.
[35] EEA, 2016
[36] IPCC, 2006
[37] EEA, 2016

- Urban area emissions (all urban areas of Bhutan i.e. not only Thimphu) are based on an estimate of the share of urban distance driven per vehicle category. It is assumed that passenger cars have 70% of their total distance driven in urban areas, taxis 100%, motorcycles 90% and HDVs 20%. Latter have a much lower urban usage due to transporting basically goods from production to distribution sites.
- Results have been checked for plausibility based on inventories of other cities.

Table 6: Main Data Parameters and Sources

Parameter	Source
Vehicle numbers per category and fuel type	RSTA, as of mid-2015
Specific fuel consumption and emission values per km driven; BC fraction	EEA, 2016 (Corinair/COPERT model used in Europe)
Emission standard for 2015 (Euro 2)	NEC, 2010
Vehicle categories and classes	RSTA and expert observation
Annual average distance driven	Expert judgement based on average values of other countries and calibration with total gasoline and diesel fuel consumed excl. Indian vehicles
Total diesel and gasoline transport fuel consumed excl. Indian vehicles, agriculture and industrial usage	NSB, 2016
Sulphur contents of diesel and gasoline	Based on Indian fuel import and Indian standard for BS-III valid as of 2015 (350 ppm sulphur diesel)

For further details see Annex 1

Table 7: Vehicle Categories, Classes and Emission Standard

Category	Class	Emission Standard
Passenger cars	Gasoline 0.8 – 1.4 litre engine	Euro 2
	Diesel > 2.0 litre engine	
Taxis	Gasoline 0.8 – 1.4 litre engine	
	Diesel > 2.0 litre engine	
Motorcycles	Gasoline 4-stroke, <250cm^3	
HDVs	Diesel < 7.5t (midi)	Euro II
	Diesel 7.5-16t (large)	

The economic cost of emissions has been calculated using average unit costs per pollutant and the quantity of pollutants. The average unit cost per pollutant is based on median values of countries from Asia and Oceania excluding industrialized economies as no values are reported for Bhutan and also data on health costs, air pollution levels and air pollution related health problems is not available. The pollutant values for other countries calculated by the IMF are based on ground level local pollution levels and the health impact and costs caused by this pollution[38]. This is based on determining the pollution exposure of the population and how the additional pollution exposure increases mortality risks using concentration response functions relying primarily on work realized by the World Health Organization's Global Burden of Disease project. Mortality risks or more precisely the value per premature death avoided are thereafter valuated economically based on stated preference studies realized by the OECD[39].

[38] IMF, 2014 table A4.2.1 for pollutants

[39] Stated preference studies in general reveal lower values than revealed preference studies; therefore, pollution damage estimates might be understated by the IMF (see IMF, 2012, p.79)

Table 8: Economic Cost per Pollutant

Pollutant	Cost per ton emitted in USD 2015
Particle Matter $PM_{2.5}$	45,700
NO_2	330
SO_2	1,560
CO_2	40

Source: Calculations by Grütter Consulting based on the median of non-industrialized Asia/Oceania countries as listed in IMF, 2014, Table A.4.2.1. updated to USD 2015 using GDP deflator; methodology developed by IMF, 2014

3.2. Vehicle Pollutants 2015

The following table shows vehicle pollutant emissions per vehicle category for 2015.

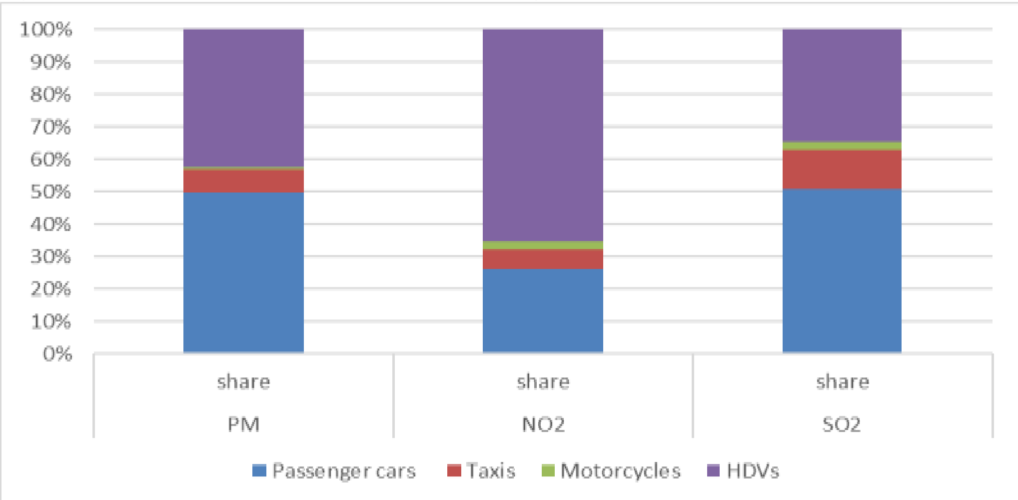
Table 9: Vehicle Pollutant Emissions Bhutan 2015 (in tons and as share)

Vehicle category	PM		NO_2		SO_2	
	tons	Share	tons	Share	tons	share
Passenger cars	9.5	24%	174	10%	12	28%
Taxis	0.9	2%	29	2%	2	5%
Motorcycles	0.1	0%	13	1%	0	1%
HDVs	28.3	73%	1,509	88%	30	67%
Total	**38.9**		**1,724**		**45**	

Source: Grütter Consulting, see for details Annex 1

HDVs are responsible for 70-90% of all pollutants. The figures of the table above reflect national emissions. Air quality and the resultant health impact is however basically a local or urban concern i.e. the concentration of pollutants is relevant. The impact on air quality and on health is not the same if a truck emits high loads of PM in a remote zone or if a vehicle pollutes in downtown Thimphu. The problem of pollutants (not however of GHGs) is therefore an urban issue. This is also the reason why many cities have stricter emission regulations than rural areas. Considering that HDVs basically circulate in rural areas whilst the other vehicle categories in their majority circulate in urban areas the following figure shows an approximative contribution towards pollution of vehicle categories for urban areas. This is important when devising a vehicle pollutant control strategy as the goal is to improve air quality in first instance and only in second instance the total pollution level.

Figure 5: Estimated Contribution of Vehicle Categories to Urban Pollution (2015)

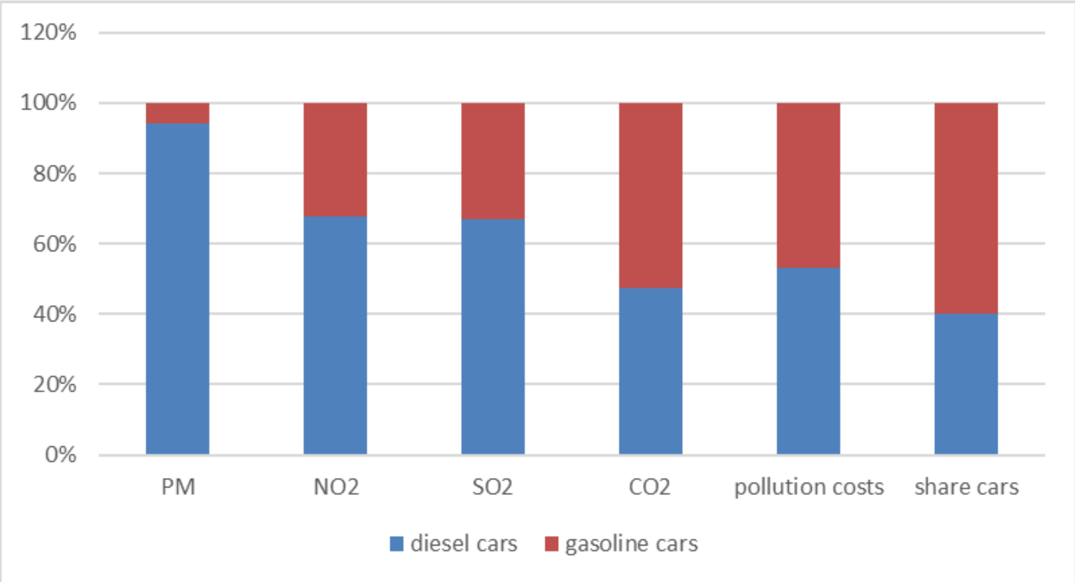


Source: Grütter Consulting; see Annex 1 for details including assumptions

Concerning urban emissions passenger cars play a very important role with 50% of PM and SO_2 emissions. HDVs have a much lower urban share of pollutants than for total emissions as HDVs are used outside urban areas.

The overall contribution of gasoline vehicles to $PM_{2.5}$ is only 2%, to NO_2 it is 5% and to SO_2 13% thereby showing clearly that diesel vehicles are the major source of these pollutants. Diesel passenger cars are around 40% of the fleet but they contribute to more than 90% of PM and 2/3rd of SO_2 and NO_2 emissions (see following figure).

Figure 6: Share Pollutants Gasoline and Diesel Passenger Cars



Source: Grütter Consulting, see for details Annex 1

3.3. GHG Vehicle Emissions 2015

According to the 2nd national GHG inventory, Bhutan had in the year 2000 emissions of 1.6 $MtCO_{2e}$ with an estimated sequestration capacity of 6.3 $MtCO_2$[40]. GHG transport emissions of 2005 are estimated at a total of 171,000 tCO_2 with 137,000 tCO_2 from diesel, 31,000 tCO_2 from petrol and 3,000 tCO_2 from kerosene domestic usage[41].

Based on the fuel import data of 2015 GHG emissions of Bhutan for the transport sector excluding kerosene for domestic air transport are 288,000 tCO_2 of which 74% are caused by diesel usage[42]. This represents a 70% increase from 2005 i.e. a CAGR of 5.5%.

The following table shows GHG emissions from the domestic transport sector excluding Indian vehicles (called re-export). This represents the GHG emissions of the registered Bhutanese vehicle fleet. Figures are calculated based on a bottom-up approach using vehicle registration data (including vehicle category and fuel type), Corinair Tier 2 fuel consumption values per vehicle type (fuel consumption relative to the Euro category and engine size) and the CO_2 emission factor based on the NCV and the EF_{CO2} of fuels. Distance driven per vehicle category was calibrated based on top-down

[40] Transport emissions of the year 2000 are 118,000 tCO_2.

[41] NEC (2011), Second National Communication to the UNFCCC, Figure 3.4

[42] This includes Indian vehicles

data. Black carbon emissions were estimated based on $PM_{2.5}$ emissions, the BC fraction within $PM_{2.5}$ and the Global Warming Potential (GWP) of BC for a 100-year period[43].

Total vehicle GHG emissions estimated bottom-up are 238,125 tCO_2 excl. BC. Using fuel import data for the same year the vehicle emissions based on a top-down approach result in 238,084 tCO_2 i.e. a marginal difference of 0.02% thus giving an indication of the high precision level of the bottom-up model.

Table 10: Vehicle GHG Emissions Bhutan 2015 (in tCO_{2e} and as share)

Vehicle category	CO_2		CO_2 plus Black Carbon	
	tons	share	Tons	share
Passenger cars	80,399	34%	86,988	33%
Taxis	17,315	7%	17,886	7%
Motorcycles	4,542	2%	4,575	2%
HDVs	135,868	57%	152,438	58%
Total	**238,125**		**261,887**	

Source: Grütter Consulting, see for details Annex 1

Around 60% of GHG emissions incl. BC are caused by HDVs followed by passenger cars with 1/3rd of GHG emissions. BC increases GHG transport emissions by around 10%.

3.4. Economic Cost of Vehicle Emissions 2015

The following table shows an estimate of the cost of vehicle emission in Bhutan for 2015. The methodology used for determining the economic cost is based on the emissions per vehicle category and the economic cost per ton of pollutant ($PM_{2.5}$, NO_2, SO_2 and CO_2) using data from the IMF (see table 8).

Table 11: Economic Cost of Vehicle Emissions Bhutan 2015

Vehicle category	Value in MUSD	share
Passenger cars	3.7	31%
Taxis	0.7	6%
Motorcycles	0.2	2%
HDVs	7.3	61%
Total	**11.9**	

Source: Grütter Consulting, see for details Annex; includes in CO_2 cost of BC

Total emission costs are for 2015 around 12 MUSD. 80% of this cost are due to GHG emissions, followed with 15% of costs due to $PM_{2.5}$ emissions and 5% due to NO_2. SO_2 emissions play a minor role in term of economic costs.

3.5. BAU Projection 2030

The Business as Usual (BAU) methodological approach is based on a continuation of current vehicle and fuel standards. It therefore represents a baseline against which the impact of policy interventions can be measured. The BAU scenario is based on following core assumptions:

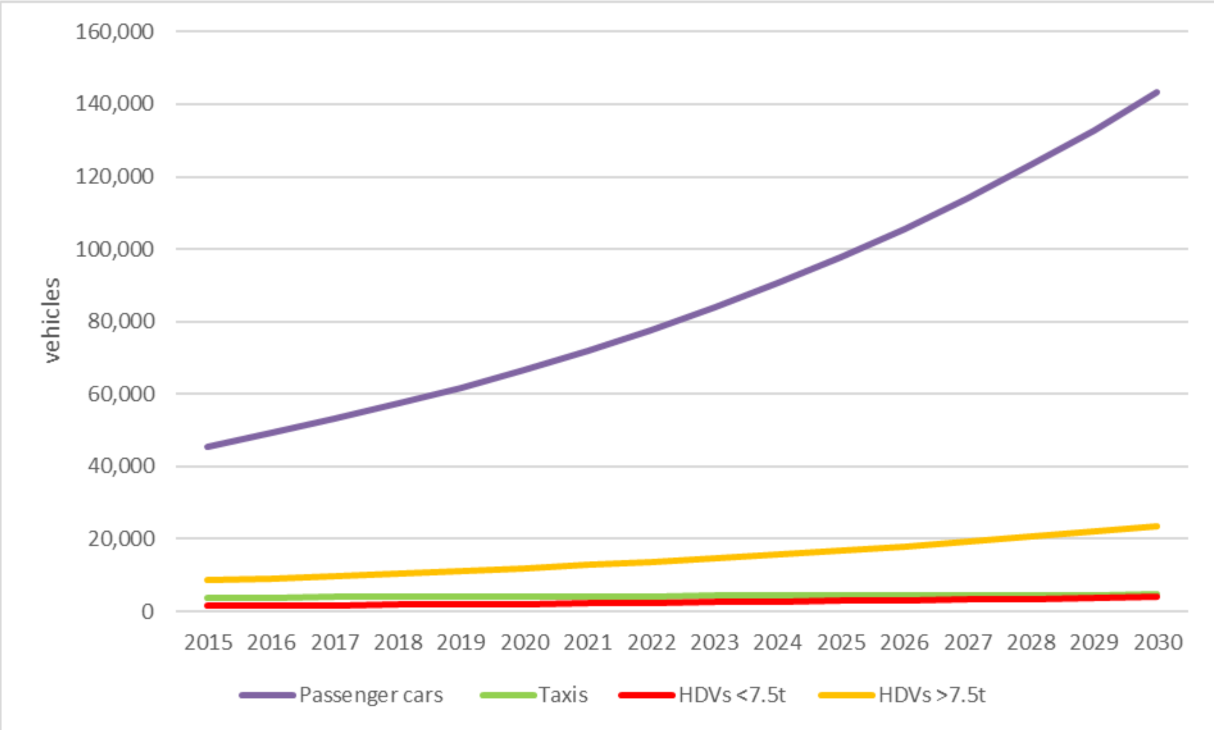
- The fuel is imported from India and corresponds to the national fuel quality standards of India. This implies that from 2018 onwards gasoline as well as diesel imported to Bhutan has a

[43] See details in Annex 1

sulphur content of 50ppm and as of 2021 of 10ppm[44] However, to measure the impact of changing fuel qualities, the BAU projection is based on constant sulphur levels in fuels.
- The same vehicle emission standard is kept as currently i.e. Euro 2.
- The average annual growth rate of passenger car and motorcycle numbers is estimated at 8% based on the historic CAGR between 2010 and 2016[45].
- The average annual growth rate of taxi numbers is estimated at 1% based on the historic CAGR of taxis between 2010 and 2015.
- The average annual growth rate of HDVs is estimated at 7% based on the GDP growth projections[46] and a freight-GDP elasticity of 1[47].
- The vehicle fuel distribution, vehicle classes, and annual average distance driven is assumed to remain constant.
- The specific fuel consumption and emission factors are calculated on an annual base based on vehicle stock projections. No tear and wear is assumed (this is modelled under one of the policy projections). The model accounts for vehicle replacement – however, this has no impact on emission calculations in the BAU scenario as a constant Euro standard is assumed with no tear and wear.

The following figure shows projected vehicle numbers per vehicle category.

Figure 7: Vehicle Projections (Vehicle Stocks) Bhutan 2015-2030



Source: Grütter Consulting

[44] The corresponding fuel quality is established nationwide in India as of April predecessor year i.e. 04/2017 and 04/2020 but it is assumed that until taking full effect in Bhutan it will be the calendar year 2018 and 2021; http://transportpolicy.net/index.php?title=India:_Fuels:_Diesel_and_Gasoline
[45] RSTA, 2016
[46] http://www.tradingeconomics.com/bhutan/forecast
[47] see OECD, 2013, p.93

It is expected that Bhutan will triple the number of vehicles from around 60,000 units 2015 to 180,000 units by 2030.

BAU vehicle emissions will also increase by factor 3 in this time. GHG emissions excluding BC will reach 660,000 tCO_2 by 2030 for the transport sector excluding Indian vehicles (including BC GHG emissions are projected to reach 730,000 tCO_{2e} by 2030). BAU emission costs would also increase by the factor 3 reaching around 33 MUSD by the year 2030.

4. Vision for Vehicle Emission Controls

4.1. Air Quality and GHG Vision and Targets

Bhutan has as vision to preserve its pristine environment and clean air and to be a carbon neutral or even carbon negative country. This was clearly reiterated by representatives of government at a stakeholder meeting realized January 2017 in Bhutan. Air pollution caused by vehicles is increasing rapidly and measures need to be taken as early as possible to prevent serious health and environmental problems. Acting prior to having an extreme situation also proves to be a more cost-effective strategy than trying to clean up a cities air once unsustainable levels are reached. Finally, measures in the vehicle sector take considerable time to result in a measurable impact due to the low vehicle replacement rate and therefore early action is required. If vehicles are used e.g. for 15 years or more the vehicle replacement figure is only around 6% annually and regulations concerning vehicle emission standards for new vehicles will only have a decisive impact on the vehicle stock and the corresponding air quality after around a decade.

Official documents which show vision, goal and strategy of government concerning vehicle emissions include:

- The 11th 5-year plan[48] for the period 2013-2018 has as target to revise the ambient air quality standard including as new parameters $PM_{2.5}$, Ozone and CO. It includes specifically as program the control of vehicle/transport emissions including as indicator the number of established emission testing centres.
- The Transport Vision 2040[49] has as vision “environment-friendly” transport and as one of the goals environmental sustainability.
- The Bhutan Sate of the Environment Report 2016[50] states that air pollution is becoming one of the emerging issues posing a serious risk to human health and environment. Air quality is deteriorating and GHG emissions are rising. It states the need to harmonize policies and incentives on the import of vehicles.
- The Technology Needs Assessment (TNA[51]) of Bhutan includes fuel-efficient cars as one of the prioritized technologies.
- The INDC[52] reiterates the commitment of Bhutan realized originally in the year 2009 to remain carbon neutral. The INDC includes the improvement of efficiency and emissions from existing vehicles through standards and capacity building as a mitigation strategy.

4.2. Core Assessment Criteria for Strategies and Instruments

The main identified assessment criteria for evaluating different intervention strategies and instruments are their environmental, economic and fiscal impact, and their complexity and risk. The health impact is assessed indirectly through the economic valuation as latter is based primarily on health costs. The following table summarizes core valuation areas and indicators used.

[48] Gross National Happiness Commission, 2013
[49] ADB, 2013
[50] NEC, 2016
[51] NEC, 2013c
[52] NEC, 2015

Table 12: Assessment Criteria

Area	Indicator	Comment
Environmental impact	a). climate change: tons of CO_2 and tons of CO_2+BC b). air quality pollutants: tons of $PM_{2.5}$, NO_2, SO_2	Measured in absolute numbers and relative to the BAU scenario to compare strategies
Economic impact	a). Economic cost in MUSD of CO_2, $PM_{2.5}$, NO_2 and SO_2 b). Fiscal impact	Measured in absolute terms and against cost of measures. Overriding target is that measures should be fiscally neutral or fiscally positive. The financial assessment of measures is also realized i.e. who pays and who profits from actions.
Complexity and risk	Criteria used include: - legal requirements; - control complexity; - fraud potential; - resources required for implementation; - novelty of approach; - probability and magnitude of failure	Descriptive qualitative assessment to assess the potential risks and barriers as well as possible strategies to overcome these

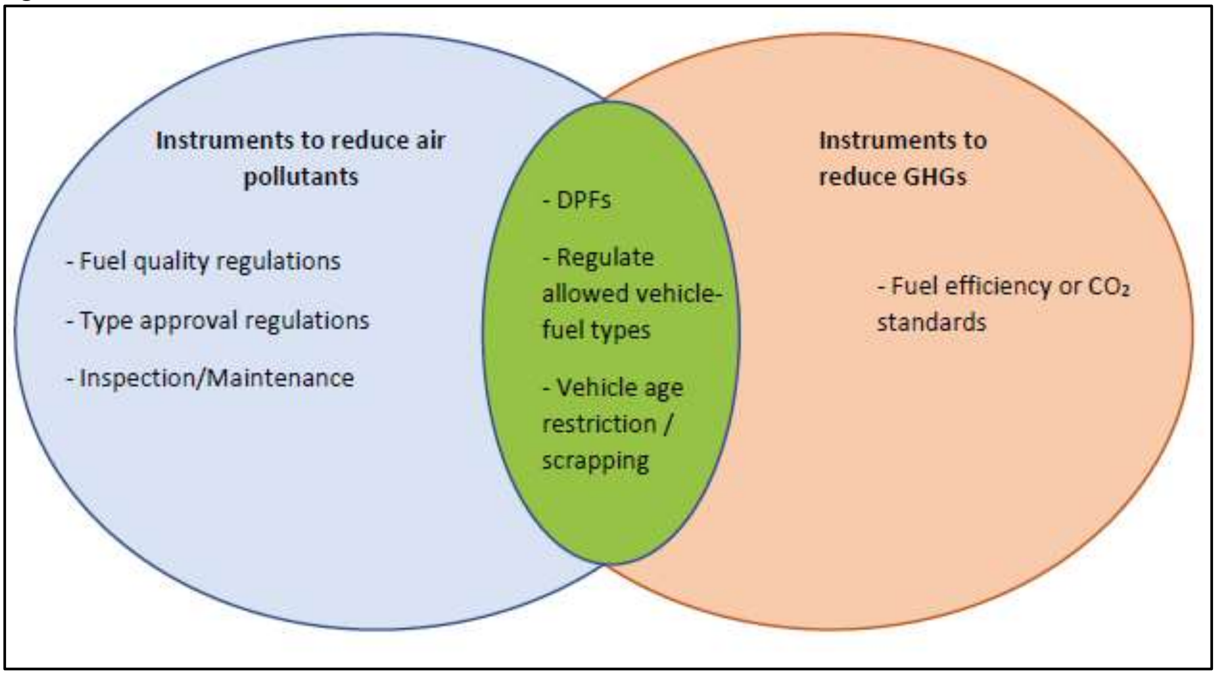
The environmental and economic impact is quantified. The area of complexity and risk is valued based on a qualitative assessment. This allows also to identify main barriers and potential strategies to overcome latter.

5. Review of Potential Instruments and Strategies

5.1. Overview

The following figure gives an overview of potential measures to reduce vehicle emissions and their effect either on GHGs and/or on pollutants.

Figure 8: Overview Instruments and Main Effects of Vehicle Emission Control Measures



Source: Grütter Consulting

Some instruments such as fuel quality regulations basically affect pollutants, some policies such as fuel performance standards affect basically GHG emissions whilst other measures can have an impact upon pollutants as well as GHG emissions.

5.2. Fuel Policies

5.2.1. Policy Description

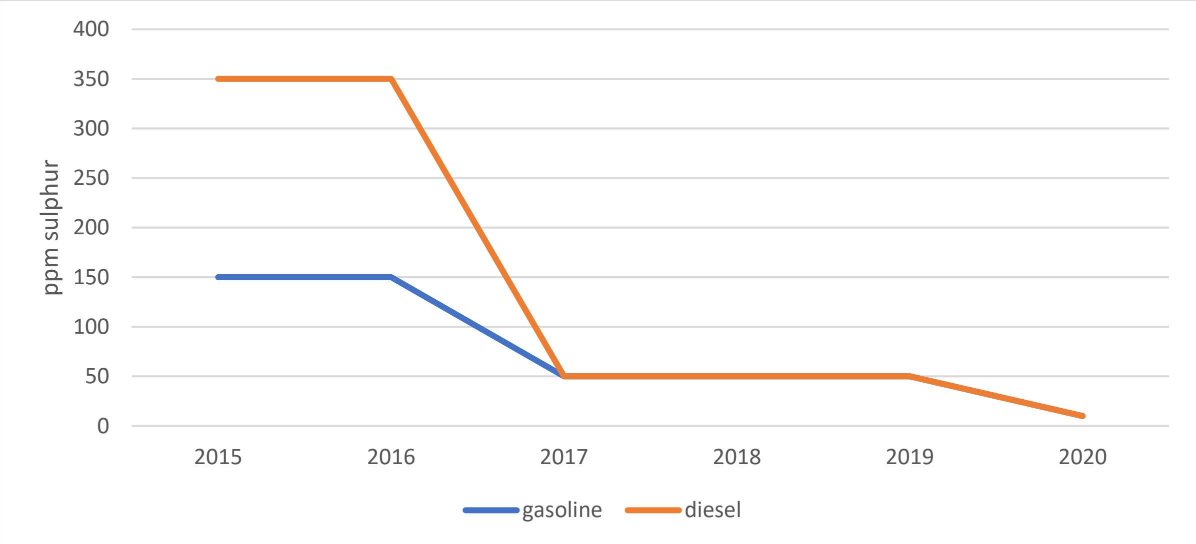
To achieve clean air, it is imperative to get sulphur out of fuels. Sulphur is a pollutant directly, but more importantly, sulphur prevents the adoption of major pollution control technologies. Advanced emission control technologies again are required to reduce basically PM, NO_x and hydrocarbons. Low sulphur fuels (<50 ppm) allow for the usage of diesel particle filters with approximatively 50% of control efficiency. Selective catalytic reduction can be used to control around 80% of NO_x emissions. Near-zero sulphur fuels (<10 ppm) allows for the use of NO_x absorbers controlling around 90% of NO_x emissions in gasoline and diesel vehicles and allowing for more fuel-efficient engine designs. Particulate filters can achieve their maximum efficiency with near-zero sulphur fuels[53]. Introducing advanced particulate control technologies such as diesel particulate filters are also very effective at reducing black carbon emission, an important added co-benefit.

[53] Walsh et.al.

The dominant adverse environmental result of desulfurization is that removing sulphur from fuel results in slightly increased upstream CO_2 emissions at the refineries because hydrodesulphurization involves the release of relatively small amounts of CO_2 and consumes additional energy. However, this will not affect the GHG balance of Bhutan as fuels are refined in India. Also, the impact is lower than the positive GHG impact caused through usage of new vehicle technologies and reduced BC.

Bhutan imports all its fuels from India. It has no refinery and can also not import fuels tailor-made for urban areas in India due to logistical issues. Therefore, Bhutan will need to adhere to the national fuel quality standards of India. The following timeline shows that India is on the pathway to eliminate within few years' sulphur from fuels, thereby resolving this problem for Bhutan.

Figure 9: Projected Fuel Sulphur Contents India (National Level)



Source: Ministry of Road Transport and Highway, 16.09.2016

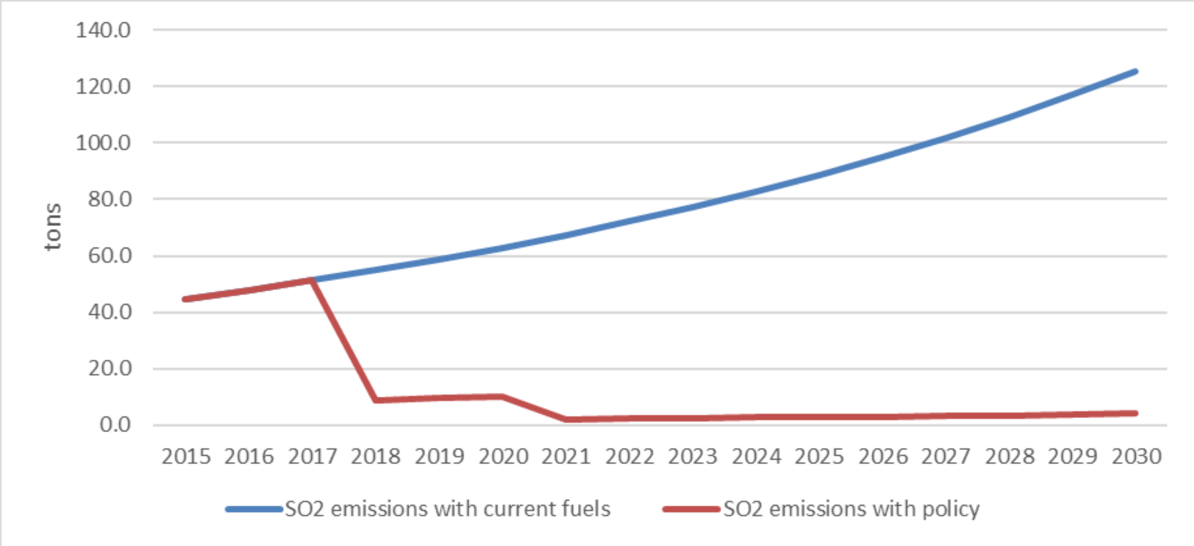
Since April 2017, all fuel (diesel as well as gasoline) sold in India has a maximum sulphur content of 50ppm and as of April 2020, 10ppm. If the timetable is implemented per plans Bhutan can expect to have only 50ppm sulphur fuel until 2018 and only 10ppm sulphur fuel until 2021 (considering usage of stocks).

Fuel Policy Proposal:
From 01.2018 onwards gasoline and diesel imported has a maximum sulphur content of 50ppm.
From 01.2021 onwards gasoline and diesel imported has a maximum sulphur content of 10ppm.

5.2.2. Policy Impact

Bhutan does not need to take specific steps to achieve this sulphur reduction as the country imports the fuel from India which will no longer produce high sulphur fuels. The following graph shows the direct benefit from reduced SO_2 emissions. However, even more important is that low sulphur fuels allow to introduce new vehicle technologies (see next chapter).

Figure 10: SO_2 Emissions from vehicles with/without Low Sulphur Fuels



Source: Grütter Consulting

The direct economic benefit from reduced SO_2 emissions is with 0.1-0.2 MUSD per annum limited. The indirect benefit through the introduction of new vehicle technologies is however highly significant (see the following chapter). The indirect benefit includes PM and NO_2 reductions as well as potential fuel savings.

The economic cost of reducing the sulphur contents in fuels to 50ppm is estimated at 0.3 USD cents per litre of diesel and 0.5 USD cent per litre of gasoline. The further reduction to 10ppm is estimated to cost around 0.5 USD cent per litre of gasoline and 0.4 USD cent per litre of diesel[54] i.e. it can be expected that fuel costs will increase by 1-2 USD cent per litre with ultra-low sulphur fuels (equivalent to around 1 NU per litre of fuel at the pump station). The cost-benefit of the measure is assessed together with the introduction of new vehicle technologies.

5.2.3. Complexity and Risk

The measure is simple and has no risk. In fact, Bhutan cannot influence the fuel properties as fuels are produced in India and exported to Bhutan.

5.2.4. Conclusions

Bhutan will benefit from higher quality fuel receiving 50ppm sulphur fuel as of 2nd semester 2017 and 10ppm sulphur fuel as of 2nd semester 2020. Therefore, fuel qualities will be at a good standard and allow for the introduction of vehicles with new emission control technologies. However, it is recommended that Bhutan issues a regulation which states that fuel imported from India must comply with the national Indian fuel standards. The timetable would thereby be that all fuel imported as of 01.2018 onwards must comply with BS-IV fuel standards with a maximum sulphur contents of 50ppm for gasoline and diesel and all fuels imported as of 01.2021 onwards must comply with BS-VI fuel standards with a maximum sulphur contents of 10ppm for diesel as well as gasoline. A draft regulation is provided in Annex 2.

[54] ICCT, 2013 p.104 based on costs in India

Fuel quality control is considered an important issue to ensure that the fuel procured complies with the Indian standard and has not been altered either at the refinery, during transport or at pump stations. Random controls should be performed of import lots as well as at pump stations. This is also to ensure that fuels are not blended e.g. with kerosene which is reported to be widespread in India. Bhutan has a fully equipped laboratory with trained staff and experience in performing such controls. However, to the moment no formal procedure has been established on how such controls shall be performed (frequency, procedure, fraud prevention, fines). It is therefore recommended to establish directives on quality control checks for fuels. Steps to be realized include:

- Clear procedure on how it is ensured that fuel stations are selected on a random base with more frequent controls of high volume stations and of stations which have a negative track-record;
- Online publication of tests performed and their results to increase confidence of consumers in fuel quality sold at stations;
- Establish norms with clear sanctions in case fuel was adulterated;
- Include in the consumer protection as well as the Ministry website a complaint site which allows consumers to report adulterated fuel. If multiple reports are received of the same station, latter will receive a control visit.
- Strive to get the laboratory of the Ministry ISO certified.

Implementing these steps ensures that controls are carried out appropriately and could also increase the confidence of the public in the fuel quality sold at petrol stations.

5.3. Emission Standards New Vehicles (Type Approval)

5.3.1. Policy Description

Vehicle emission standards are made as type approval test for new vehicles. The testing is thereby realized only on one or a sample of identical vehicles for which the manufacturer receives the type approval certificate. Currently Bhutan has as emission standard Euro 2. Tighter emission standards reduce pollutants whilst only having a marginal effect on fuel efficiency and GHG emissions. The following table shows the maximum permitted emission levels of Euro and Bharat emission standards.

Table 13: Euro 2 to 6 and BS II to VI Standards Passenger Cars (g/km)

Vehicle Category	CO	HC	HC+NO_x	NO_x	PM
Gasoline cars					
Euro 2	2.2	---	0.5	---	---
BS II[55]	2.2-5.0	---	0.5-0.7	---	---
Euro 3	2.3	0.2	---	0.15	---
BS III	2.3-5.22	0.20-0.29	---	0.15-0.21	---
Euro 4	1	0.1	---	0.08	---
BS IV	1.0-2.27	0.10-0.16	---	0.08-0.11	---
Euro 6	1	0.1	---	0.06	0.005[56]
BS VI	1-2.27	0.1-0.16	---	0.06-0.082	0.0045[57]
Diesel cars					
Euro 2	1.0	---	0.7	---	0.08
BS II[58]	1.0-1.5	---	0.7-1.2	---	0.08-0.17

[55] Exact value dependent on seat number and weight of vehicle
[56] PN 6.0x10^11
[57] PN 6.0x10^11
[58] Exact value dependent on seat number and weight of vehicle

Euro 3	0.64	---	0.56	0.5	0.05
BS III	0.64-0.95	---	0.56-0.86	0.50-0.78	0.05-0.10
Euro 4	0.5	---	0.3	0.25	0.025
BS IV	0.50-0.74	---	0.30-0.46	0.25-0.39	0.025-0.06
Euro 6	0.5	---	0.17	0.08	0.005[59]
BS VI	0.50-0.74	---	0.17-0.215	0.08-0.125	0.0045[60]

Source: ICCT, 2013, Appendix B and for BS VI Notification in The Gazette of India 22.02.2016

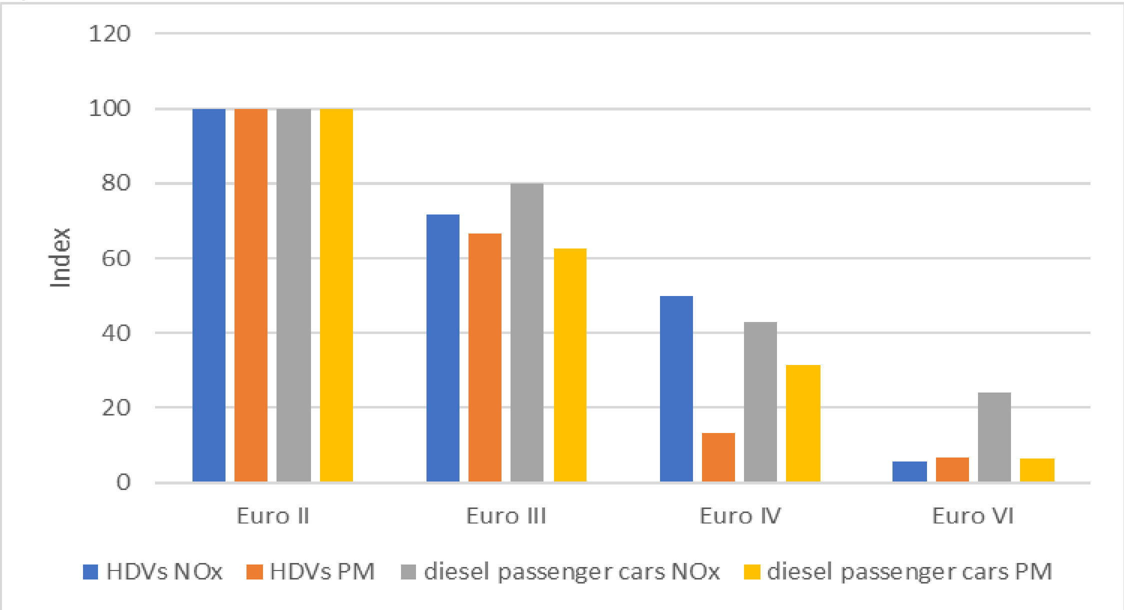
Table 14: Euro II to VI and BS II to VI Standards HDVs Diesel Engines (g/kWh)

Vehicle Category	CO	HC	NO_x	PM
Euro II	4.0	1.1	7.0	0.15[61]
BS II[62]	4.0	1.1	7.0	0.15
Euro III	2.1	0.66	5.0	0.1
BS III	2.1	0.66	5.0	0.1
Euro IV	1.5	0.46	3.5	0.02
BS IV	1.5	0.46	3.5	0.02
Euro VI	1.5	0.13	0.4	0.01
BS VI	1.5	0.13	0.4	0.01

Source: ICCT, 2013, Appendix B and for BS VI Notification The Gazette of India 22.02.2016

The following graph compares for diesel passenger cars and for HDVs the reduction of PM and NO_x from Euro 2 to Euro 6. Emissions can be reduced by more than factor 10.

Figure 11: NO_x and PM Emissions Euro II to VI



Source: see table above

Emission standards require a certain fuel quality. With the current fuel quality, Bhutan could already establish Euro 3 or 4 as emission standard for vehicles. India, which is the fuel and main vehicle provider of Bhutan is introducing together with the new fuel standards also the new Bharat standards i.e. on a national level BS-IV as of 04/2017 and BS-VI as of 04/2020 (BS-V is overjumped). The logical

[59] PN 6.0x10^11
[60] PN 6.0x10^11
[61] As of 10.1998
[62] Exact value dependent on seat number and weight of vehicle

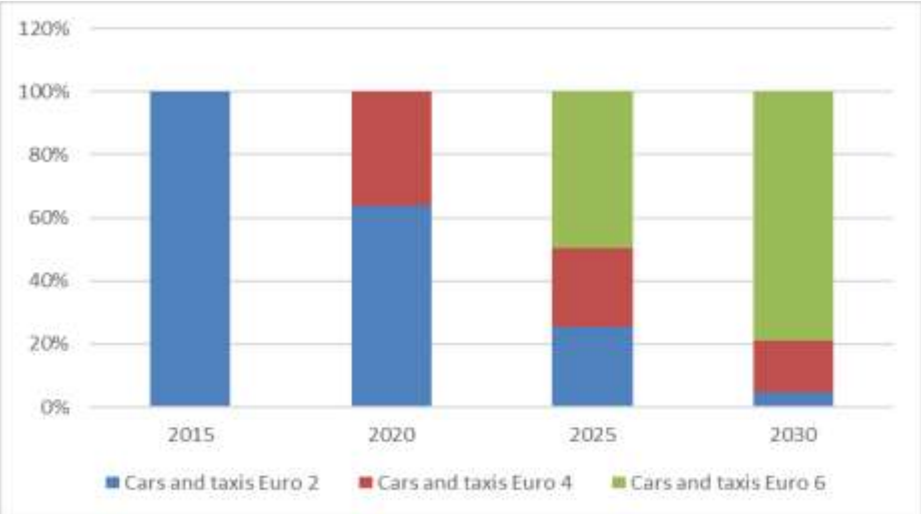
policy for Bhutan would be to also introduce the corresponding BS standards in line with the new fuels i.e. make compulsory as of 01.2018 BS-IV or Euro 4 and as of 01.2021 BS-VI or Euro 6[63].

Emission Standard Policy Proposal:
From 01.2018 onwards Bhutan requires all new vehicles sold in the country to comply with the vehicle emission standard BS-IV (Euro 4).
From 01.2021 onwards Bhutan requires all new vehicles sold in the country to comply with the vehicle emission standard BS-VI (Euro 6).

5.3.2. Policy Impact

All new registered vehicles from 2018 onwards would correspond to Euro 4 and from 2021 onwards to Euro 6. This results in a continuous replacement of the vehicle stock with lower polluting vehicles. The average replacement age has been calculated as 15 years i.e. around 7% of the vehicle fleet is replaced per annum. Due to high vehicle growth numbers the overall stock of vehicles however changes quicker. The following graph shows the share of Euro 2, Euro 4 and Euro 6 vehicles over time (vehicle stock) for passenger cars and taxis.

Figure 12: Share Cars and Taxis per Emission Standard in Bhutan 2015-2030 with Policy Implementation



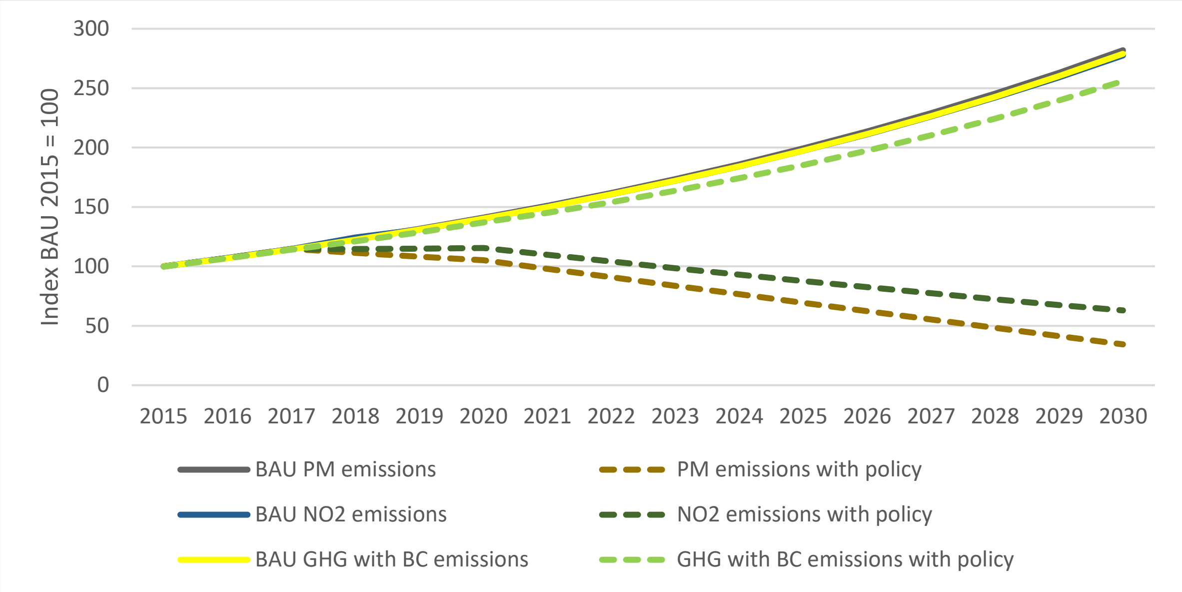
Source: Grütter Consulting

For HDVs the development is similar with a slightly slower change of the vehicle stock due to lower vehicle growth figures.

The environmental impact of new standards is highly significant on PM and NO_2 emissions, whilst the impact on GHG emissions is smaller and only due to the reduction of BC (see following indexed figure).

[63] In the following BS ad Euro standards are considered as equal

Figure 13: Emissions with and without Emission Standard Policy (Index 2015 = 100)



Source: Grütter Consulting

PM and NO_2 emissions fall, after an initial increase, below 2015 levels whilst under BAU they would increase. PM emissions reach by 2030 only 1/3rd of 2015 levels and NO_2 emissions 60% of the 2015 level. There is also an impact on GHG emissions through reduced BC. This results as of 2030 in a reduction of around 60,000 tCO_{2e} compared to a BAU scenario. This is equivalent to an 8% reduction compared to the BAU scenario.

In economic terms, incremental vehicle costs are compared with the economic benefits of reduced emissions. The following table shows the incremental estimated vehicle costs for Indian vehicles to adjust to BS-IV and thereafter to BS-VI.

Table 15: Incremental Vehicle Cost with New Emission Standards (USD per vehicle)

Vehicle category	BS-II to BS-IV	BS-IV to BS-VI	BS-II to BS-VI total
Passenger cars gasoline	60	60	120
Passenger cars diesel	500	800	1,300
HDVs	1,500	2,000	3,500

Source: Based on ICCT, 2013, Figure 9.2.1; for HDV average of commercial and utility vehicle as HDVs are relatively small units in Bhutan[64]

The cost increase affects more diesel than gasoline vehicles. This together with the probable reduction of the price differential between diesel and gasoline fuel will make diesel vehicles less attractive. The following table shows the economic cost-benefit of the measure including the cost of low-sulphur fuels.

Table 16: Cost-Benefit of New Emission Standards

Parameter	Cumulative Benefit (+) or Cost (-) in MUSD (2018-2030)
Value PM and NO_2 reduction	34.2
Value GHG reduction	14.4
Value SO_2 reduction	1.6

[64] Incremental cost is the additional cost of a vehicle with a higher emission standard compared to the vehicle with a lower standard. These costs are annualized based on a commercial life-span of 15 years to determine annual additional costs of vehicles with a higher emission standard. The annualization was made in a static manner i.e. incremental cost / commercial life-span without considering a discount factor.

Additional cost vehicles	-38.4
Additional cost low-sulphur fuels	-18.4
Balance incl. fuel sur-cost	*-6.6*
Balance excl. fuel sur-cost	**11.9**

Excluding fuel sur-costs, which will occur anyway as India will not produce a special fuel for Bhutan, the measure has a positive cost-benefit impact of cumulative 12 MUSD or around 1 MUSD annually.

In fiscal terms the measure is in first instance positive (higher vehicle prices result in higher tax revenues). Also, in the long term its impact is probably fiscal positive (however slightly less than in the short term due to price elasticities i.e. the higher vehicle price reduces the number of vehicles bought or customers acquire slightly cheaper vehicles reducing thereby fiscal revenues). However, the impact is marginal as the price increase of vehicles due to the new emission standards is very small in relation to the total price of the car including taxes. The additional cost is entirely born by the car owner following the polluter-pays-principle and therefore apart from above mentioned marginal tax income shifts, no fiscal impact is expected.

5.3.3. Complexity and Risk

Emission standards are enforced or controlled through type-approval testing. Type approval tests are complex, demand high investments and are costly. Therefore, most countries without a domestic car manufacturing industry do not make type approval testing but only control if vehicles imported have the appropriate documentation which states its conformity with standards such as established e.g. by a Certificate of Conformity (COC). Switzerland as example makes no type approval testing of vehicles with COC documentation. It makes no economic as well as environmental sense that Bhutan realizes its own type approval of vehicles. Bhutan can establish simply that all vehicles imported to the country must comply with the respective BS-standard or equivalent. The regulation could thereby state that equivalent regulations could be from Europe[65]. Importers of vehicles would need to provide the appropriate documentation showing that the vehicle complies with the EU or equivalent standard. Standards between countries are not exactly equivalent but very similar e.g. in terms of emissions levels, OBD requirements or deterioration factors for components and can therefore be treated “as in principle equivalent”. In Annex 3 a proposal for Bhutan concerning emission standards is made including the COC.

The complexity and risk of the measure is marginal. Bhutan does not need to invest in any control facility. The control procedure applied is a documentary review. The measure entails marginal risks due to document forging which do not go beyond the risks for any other commercial transaction.

5.3.4. Conclusions

Bhutan will receive 50ppm sulphur fuel as of 2nd semester 2017 and 10ppm sulphur fuel as of 2nd semester 2020. Therefore, fuel qualities will allow for the introduction of vehicles with new emission control technologies. Indian vehicle manufacturers supply BS-IV standard vehicles to the national market since 04/2017 and BS-VI vehicles as of 2020. Therefore, it is simple and straightforward to follow the timeline in India and to apply the Indian emission standards also in Bhutan.

[65] The EU standards serve also as base, amongst others, for the Chinese and the Indian standard.

The measure has a positive cost-benefit impact and the costs are born by the polluters without a negative fiscal impact. The measure is simple and with marginal risks. Bhutan does not need to invest in a laboratory or control institution but can realize a documentary control of vehicle imports, as is done in many other countries worldwide with success.

It is suggested to realize the new vehicle emission standards as soon as possible to be in line with the Indian standards and fuel quality. A draft proposal is included in Annex 3. The new regulation should be put into force during 2017 to ensure that vehicles are compliant with the standard as of 01/2018.

5.4. Inspection / Maintenance of Vehicles

5.4.1. Policy Description

Emission controls of in-use vehicles is a policy made to ensure that vehicles remain compliant (within normal degradation levels) with original emission standards for which they were certified. They shall ensure that maintenance is made appropriately and shall identify high emitters to oblige latter to realize the corresponding repairs. Bhutan has in place an inspection system which has recently been upgraded. It controls thereby separately gasoline and diesel vehicles (see chapter 2.5. for details).

Inspection/Maintenance (IM) policies have been enforced in many countries in the past with mixed results. The core elements of more successful programs have been identified as:

- A comprehensive public awareness program is required to make people aware of benefits of implementing such a program;
- Roadside apprehension or remote sensing programs for vehicles which have slipped through the system are important;
- Effective enforcement with controls to prevent corruption are required;
- Quality assurance, covert auditing and quality control are important;
- The car service industry must have the know-how and equipment to make adequate repairs;
- Frequency of controls must be related to vehicle age and usage;
- It must be ensured that all vehicles participate.

Emission controls are linked together with roadworthiness tests in many countries thus increasing convenience for users, reducing inspection costs and improving acceptability. Emission inspections are carried out either by authorized private garages which also repair vehicles (e.g. originally in Switzerland or the UK) or by test-only centres (private or public). The following table lists the core inspection system types used.

Table 17: Vehicle Emission Inspection Approaches

Vehicle category	Approach	Countries applied (examples)	Advantages	Disadvantages
Gasoline vehicles	Idle test for CO and potentially HC[66]	UK, Costa Rica, China in > 80% of Provinces, India, Korea (rural areas), Thailand, Japan, Indonesia, Vietnam	Simple, low cost, fast; can identify partially outlayers & malfunction of catalyst; for CO, reasonable correlation with type-approval test (not for HC); typical cost per vehicle <5 USD; error	Cannot measure NO_x emissions and potential fault of oxygen sensor; No good correlation of HC idle values with loaded type-approval values; relatively gross approximation of actual

[66] In some countries incl. Bhutan only CO; some countries also include for control purposes CO_2; some countries realize the test idle and under increased revolutions with no load (e.g. at 2,500rpm)

			of commission low i.e. few vehicles fail test which are in fact performing well[67]	emission levels; errors of omissions can be significant i.e. vehicles pass test which should not pass it
	Loaded test (acceleration simulation mode e.g. IM240)	Korea (urban areas), Mexico, 20% of Chinese Provinces, Singapore	Good correlation with type-approval test i.e. low error of omission & commission; reflects emission status well	Costly; takes more time; requires trained staff; typical cost per vehicle > 15 USD
Diesel vehicles	Snap acceleration	UK, Korea, India, China, Thailand, Japan, Indonesia, Vietnam	Low cost with typically < 5-10 USD/vehicle; simple and fast test;	Can result in engine damage; unreliable if not performed well i.e. test results are sensitive to test conduction; correlation with type-approval not very good; can be circumvented easily
	Loaded test with dynamometer or free-rollers using engine brake	Singapore, Chile[68]	Results are more reliable than with snap acceleration	expensive and difficult to perform; can result in accidents (free roller with engine brakes); typical cost > 50 USD for HDVs and > 25 USD for light vehicles

Sources: authors compilation; see also ICCT, 2015b and ICCT 2013b, CAA, 2016

The idle test as well as the snap acceleration tests are the most widely used and are useful as crude indicators for serious engine malfunctions. High smoke emissions are caused often by poor maintenance or by deliberate engine tampering to coax more power out of an engine beyond its rated capacity resulting in over-fuelling and excess smoke emissions.

The reason why inspection systems have been established is the underlying hypothesis that:

- Appropriate maintenance is required to maintain the emission system which will otherwise degrade rapidly;
- A significant share of vehicles has a malfunction of their system thereby resulting in very high emissions;
- Inspection systems can identify vehicles which have problems and owners will repair their vehicles or scrap them.

The validity of these hypothesis is, today more than ever, questioned.

Deterioration of Vehicles and Resultant Emission Increase

In the time of carburetted vehicles this was a common and well know problem. The fuel/air mixture would not be optimal, either caused intentionally or by degradation and a simple maintenance and adjustment could reduce emissions significantly. However, vehicles today are to an overwhelming majority, also in Bhutan, of electronic injection and control. The air/fuel mixture is thereby electronically controlled. Degradation would thus occur if systems malfunction. Therefore, it is

[67] This was basically an issue in the late 80ies but has been resolved in the meanwhile through vehicle adaptations
[68] Commercial vehicles; only Santiago; partial load with dynamometer

important to know what the average degradation factor is. The COPERT model used by the EU standard uses deterioration factors which are based on a very small sample of Euro 3 and 4 vehicles with limited high mileage ranges and on laboratory tests. Deterioration rates derived from more than 110,000 records collected over the past thirteen years from on-road emission remote sensing in Zürich/Switzerland however show that deterioration rates for gasoline vehicles are much lower than assumed so far with no evidence of high emitters[69]. Degradation will probably be even less of a problem in the future as Euro 6 standards ask for longer periods of guaranteed emission performance and durability of emission control parts of vehicles thus reducing degradation and reducing the share of high emitters. The deterioration of the emission control systems takes place gradually over the observed lifetime of up to twenty years. No significantly higher frequency or elevated levels of high emission events was found over time, thus ruling out an increased share of vehicles with dysfunctional emission control equipment. This means that the potential impact of inspection programs is limited and continuously decreasing with new vehicle technologies. The durability of emission controls has much improved since Euro 1 technologies. Deterioration is still an issue; however, simple idle tests do not prove to be effective for a better tuning of the emission control system. Given that vehicles with broken emission controls seem to be very rare, idle tests might also not be necessary in finding those cars. Well-managed on-board diagnostics (OBD) perform equally well.

Inspection Systems and Identification of High Emitters

The error of omissions should be as low as possible to avoid high emitting vehicles to pass the test. The error of omissions however not only depends on the test procedure but also on the test execution and the potential of cheating. Following points need to be observed:

- Idle gasoline tests have a relatively high error level of omission due to the test itself;
- Snap-on diesel tests have a regular level of error of omission due to the test itself but a high level of error of omissions due to incorrect test application. This is a very common problem and can be due to lack of training and know-how or be intentional;
- Inspection systems are prone to cheating. Persons which have a motivation to cheat are the ones whose vehicles would fail, especially those which would need a major repair and therefore investment. Cheating practices observed in many countries include intentional wrong measurement procedures (especially in diesel vehicles), adjustment of vehicles only for control purposes (especially diesel vehicles), registering of wrong data (from emission equipment or usage of vehicles in good conditions whilst registering for the control a different vehicle), fake pass certificates, usage of fuel additives (especially for diesel vehicles), etc. Some of the fraud possibilities can be reduced through more intense controls of inspection centres e.g. through direct data transmission, digital recording, web-based real-time transmission of inspections, usage of covert auditing etc. However, all these controls are expensive, and can be circumvented again as the experience has shown e.g. in Mexico City[70]. Other aspects cannot be controlled easily e.g. preparing the vehicle only for inspection purposes e.g. adjusting diesel engines with a lower fuel intake-ratio to reduce smoke and “re-adjusting” the same engine again after inspection to allow for more power. Appropriate controls require on-road measurements or remote sensing. Former are very costly, require trained staff and equipment and a certain frequency. Virtually no country has implemented this on a wide scale. Costa Rica realized this quite intensively during some years in the nineties with support from

[69] Borken-Kleefeld, 2015

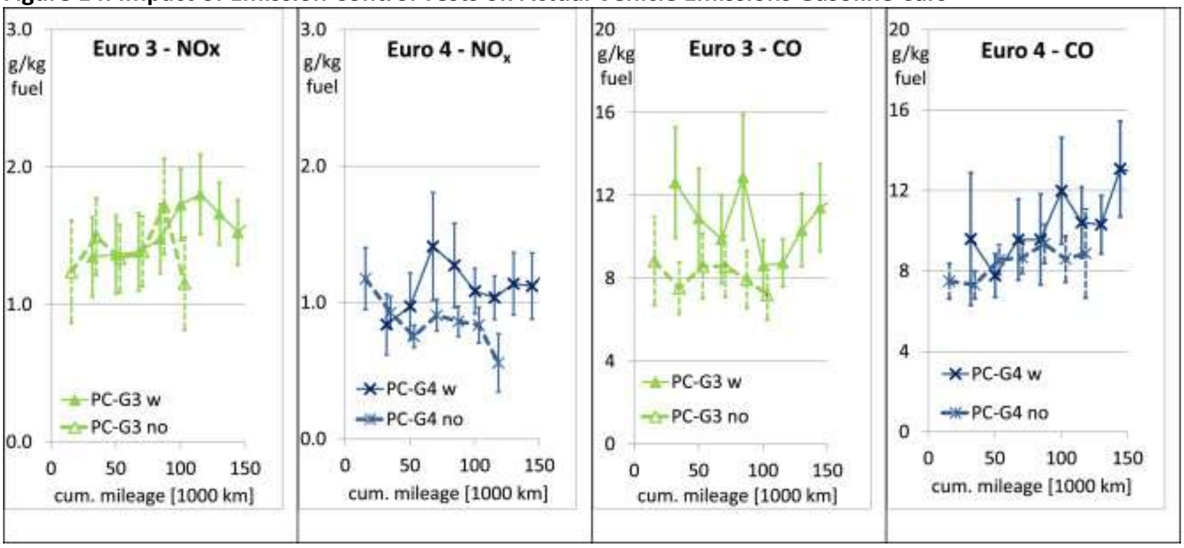
[70] In Mexico City software of digital-cameras was e.g. hacked to transmit images of different cars than those inspected.

a Swiss clean air project but results were mixed and the program was downscaled. Remote sensing is used in more countries but basically in a monitoring context and not to identify and track high emitters.

Usefulness of Emission Inspections

Summarized inspection systems in theory are useful. In practice their impact seems to be very limited whilst absorbing significant resources and being unpopular. Routine idle emission tests in Switzerland have for example not resulted in measurable emission reductions of the inspected vehicles[71]. To check on the potential influence of emission controls the on-road emission rates from cars which have not been inspected were compared with inspected cars. If the inspection has a positive influence on emissions, then you would expect that cars “with inspection” have lower emissions than cars of the same age “without inspection”. The figure below compares the on-road unit emissions from Euro 3 and Euro 4 gasoline cars with and without technical inspection with the result that there is no statistically discernible positive influence of the technical inspection on CO or NO_x emissions. The emission test therefore did not improve the emission tuning. As there is neither a significant share of vehicles with broken emission control system, which would stand out as high emitters, the simple idle test during routine inspections does not result in a measurable emission reduction.

Figure 14: Impact of Emission Control Tests on Actual Vehicle Emissions Gasoline Cars



Source: Borken-Kleefeld, 2015, figure 5; w = with emission inspection; no = without emission inspection

The international trend concerning IM is clearly to reduce emission inspection based on testing and to rely on OBD systems which register during driving the emission situation of the vehicle and report emission system malfunction. The date of the malfunction is also registered and a sign appears on the vehicle dashboard. Car owners can be fined for not repairing their vehicles based on the date the warning appeared. This approach can be combined with a roadworthiness test. Switzerland since 2013 as well as California also since 2013 have e.g. eliminated regular emission inspection of vehicles and have fully gone to OBD checks.

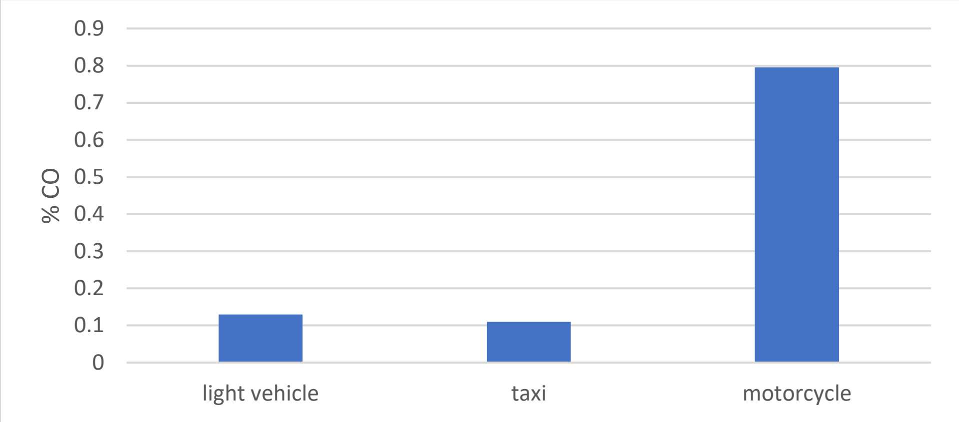
Inspection Data IM System Bhutan

The reported CO levels for gasoline vehicles and HSU for diesel vehicles have been assessed for all vehicles tested in the year 2016 (total > 30,000 vehicles). Data has been depurated and analysed for

[71] Borken-Kleefeld, 2015

average emission levels and for correlations between vehicle category as well as age and emission levels. Actual median emission levels might be slightly underestimated as non-passing vehicles were, in contrast to regulations, not always recorded. The following figures show core results.

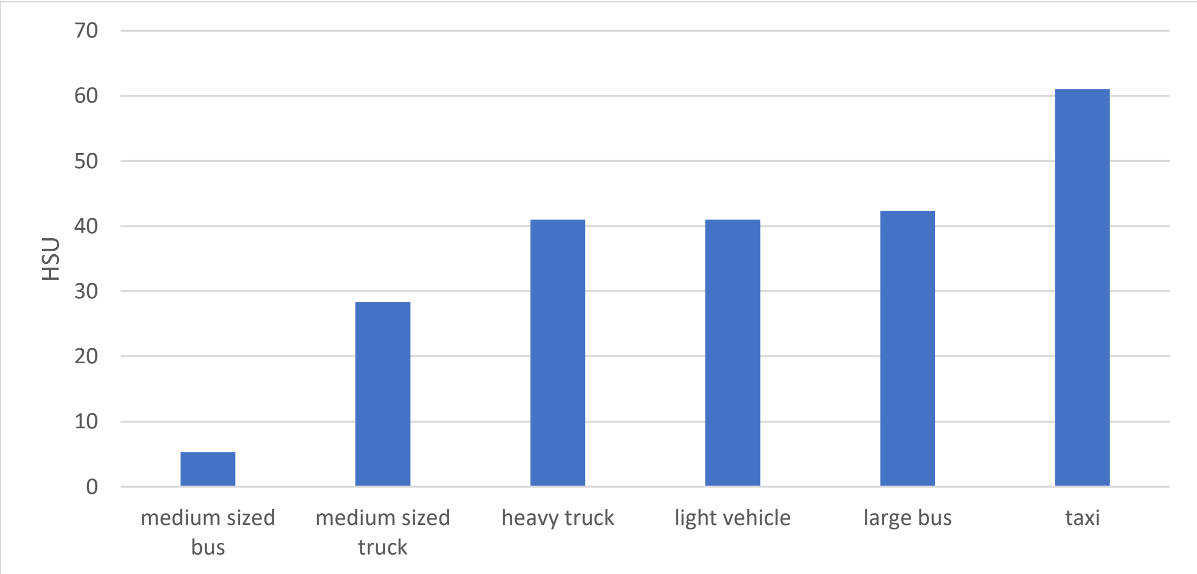
Figure 15: Median CO Levels Gasoline Vehicles per Vehicle Category in Bhutan 2016



Source: C. Dorji, 2017

Taxis and passenger cars have low median levels (far below the current official pass level of 4.5% respectively 4.0%). Motorcycles have the highest level but are still below 1% Vol. CO.

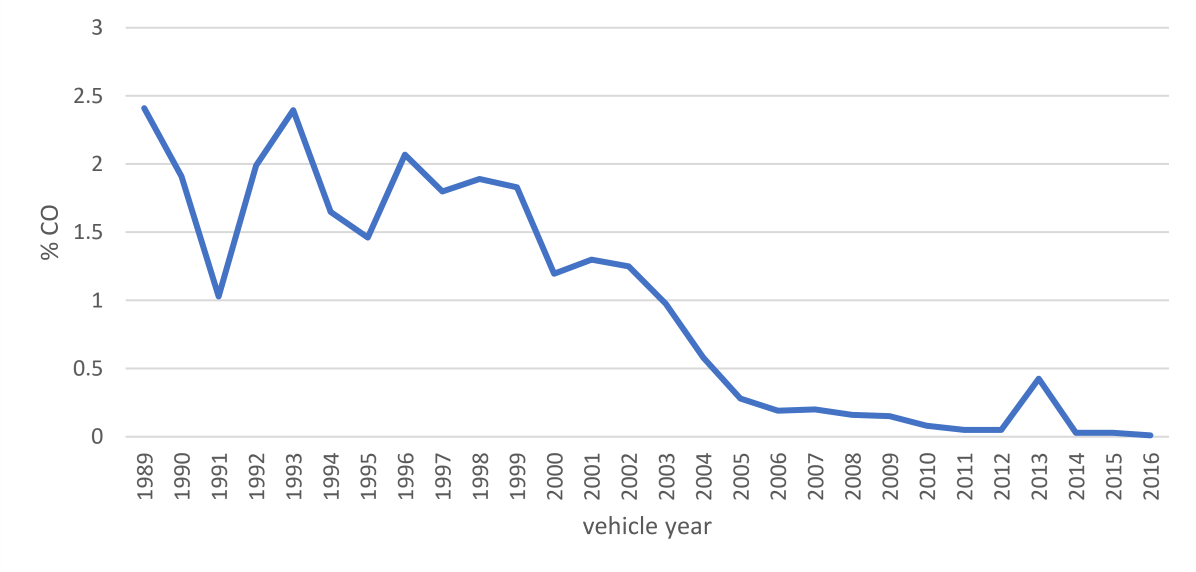
Figure 16: Median HSU Levels Diesel Vehicles per Vehicle Category Bhutan 2016



Source: C. Dorji, 2017

Median levels measured are also below the pass level of 70 respectively 75 HSU. Taxis has relatively high emission levels, especially taking into consideration that they are small vehicles. This clearly shows the problem of usage of diesel engines for small and light vehicles, constituting thereafter significant pollution problems.

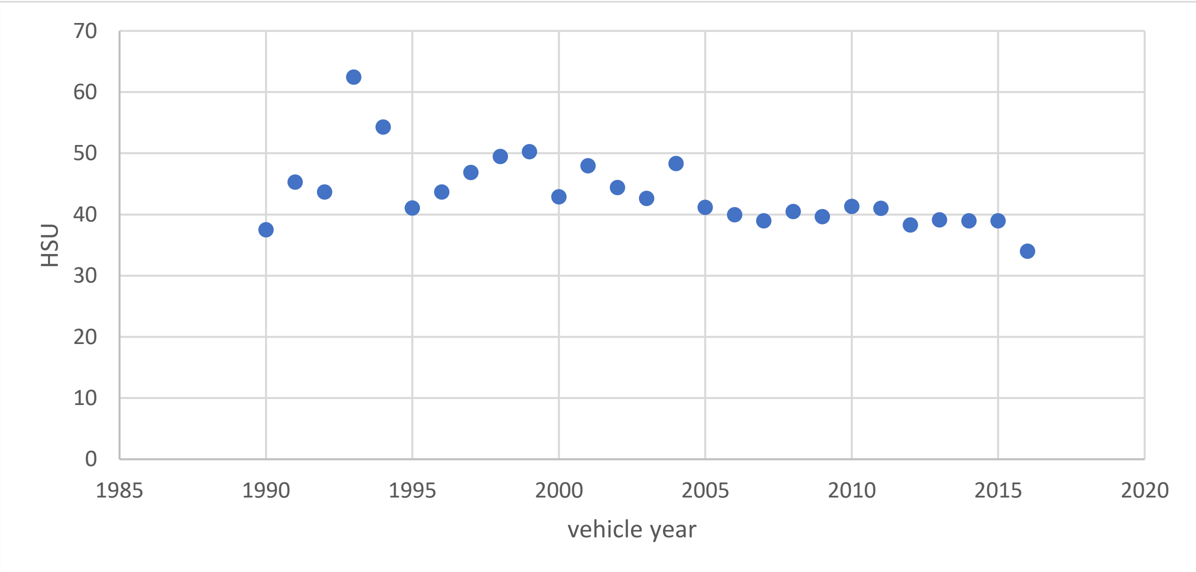
Figure 17: Correlation Age and CO Emissions of Gasoline Vehicles in Bhutan, 2016



Source: C. Dorji, 2017

A clear trend towards lower CO emissions with vehicle year is given. This trend is also logic due to prevalence of more modern 3-way catalysts in newer vehicles.

Figure 18: Correlation Age and HSU Emissions Diesel Vehicles in Bhutan, 2016



Source: C. Dorji, 2017

In contrast to gasoline vehicles no correlation between HSU emission levels and vehicle age can be found in diesel vehicles. This clearly shows the importance of adequate maintenance. New vehicle technologies, especially Euro IV upwards, have the potential of reducing significantly PM emissions – however, this will only materialize in real world operations if engines are properly maintained.

Policy Proposal Bhutan

The medium/long-term solution is to establish a vehicle roadworthiness test system with OBD controls. OBD is compulsory under most vehicle emission standards and is compulsory with the BS-VI standard i.e. vehicles will all be equipped with OBD in Bhutan from 2021 onwards. A roadworthiness test is potentially important to ensure safety of the vehicle. However, this will not influence vehicle

emissions and is therefore not element of this report. Separate vehicle emission testing is, considering above evidence, considered to be of limited usefulness. As temporary program until 2025 when OBD systems will be common in most vehicles in-use in Bhutan the current system could be improved, without incurring in major investments, thereby trying to capitalize on existing investments and optimizing system performance. Following changes to the existing regulations are thereby recommended:

a) Gasoline: continue with the idle test. A 2-gas analyser (lower cost) would be sufficient for this test i.e. no 4- or 5-gas analyse equipment is required. Only CO is monitored as HC has a poor correlation with type approval testing. The maximum CO level for vehicles could be fixed relative to their Euro or Bharat category. The maximum proposed CO level for gasoline cars is:
    - 4.5% Vol. CO for vehicles registered prior 03/2008
    - 1.5% Vol. CO for vehicles registered after 03/2008 and prior 03/2018
    - 0.5% Vol. CO for vehicles registered after 03/2018[72] .

    The criteria for setting the CO value is based on pass-values set in other countries for the equivalent Euro category of vehicle plus the status of gasoline vehicles in Bhutan based on data from the IM system. The pass value of 1.5% for vehicles after 01/2008 is currently being fulfilled by more than 90% of all vehicles (see also Figure 17). The 90-percentile range for gasoline vehicles 2008 as example is 1.3 Vol. % CO. The 90-percentile value for all vehicles since 2008 is 1.14 i.e. significantly lower than the threshold proposed. A maximum of 6% of vehicles which currently pass would have to be adjusted. These vehicles, which are Euro 2 or higher should have CO values which are significantly lower. UK uses e.g. the pass value of 0.5% since 1995 with Euro 2 being compulsory since 01.1996[73].

b) Diesel: continue with the snap-on test but change pass-levels set currently at 70 respectively 75 HSU to the following levels:
    - 70 HSU for all vehicles registered prior 03/2008
    - 65 HSU for all vehicles registered after 03/2008 and prior 03/2018
    - 50 HSU for all vehicles registered after 03/2018[74]

    The 80-percentil level for vehicles registered after 2008 was 63 HSU which shows that the level is achievable for the large majority of vehicles without changes.

   Additionally, correct measurements shall be ensured through the following changes:
    - Require that testing is performed by certified inspectors. The vehicle owner should not be allowed to perform the acceleration. This ensures correct test application.
    - Issue a decree that the inspection centre is freed from any claims from the vehicle owner due to engine malfunction after the test. The vehicle owner must sign a document stating that he has been informed of the test procedure and the potential risk this can cause to the engine in case latter is not in perfect conditions and that the car owner is responsible for the appropriate engine maintenance. In case the car

[72] Euro 2 in force in Bhutan
[73] DOT, 2014, Table 1; The EU and Switzerland have a value of 0.3% Vol CO since 01/1997 see http://ec.europa.eu/environment/archives/autooil/pdf/im.pdf
[74] Since 2009 Euro 2; from 2018 Euro 4; As example California has 40 HSU for post 1991 and 55 HSU for pre 1991 engines: Singapore uses 40 HSU since 2014 (http://www.nea.gov.sg/corporate-functions/newsroom/news-releases/tighter-emission-standards-for-in-use-diesel-vehicles); India uses for pre-BS-IV vehicles a level of 65 HSU and for BS-IV vehicles and later a level of 50 HSU (Sita, 2014)

owner does not free the inspection centre from responsibilities towards potential engine damage, the inspection centre is not obliged to perform the test and the vehicle owner does not receive the certificate. This allows the inspection centre to take the risk of realizing the test without potential financial damage thereafter due to lack of appropriate engine maintenance on behalf of the car owner. Such documentation is e.g. signed in the UK prior vehicle testing.

- Require that SAE test procedures are followed.
- The equipment software shall automatically emit a failure result if measured values are not within a 15% margin.
- Calibrate and maintain the equipment based on the industrial standard or manual of the equipment.

3. Enforcement: realize improvements in enforcement to ensure adequate controls through:

   a. Measured values should be sent automatically to RSTA from the monitoring equipment via web/datalink.
   b. Install web-based digital cameras in the inspection centre linked with the RSTA to control on-line if measurements are performed appropriately. Basically, the inspection lane is continuously filmed with at least two cameras: one shows the vehicle including testing equipment and allows to zoom in on the equipment to view the measured results or to zoom in on the licence plate; the other camera shows the tailpipe of the vehicle and allows to verify that the equipment has been placed appropriately. Both cameras transmit their images to RSTA real-time. At RSTA data of the cameras is recorded and randomly checked.
   c. Perform random covert auditing inspections of the centre.

Measures and regulatory changes above require only marginal investments and should improve significantly the quality of current emission inspections.

Policy Proposal IM:
Continue current IM system with adapted maximum CO levels for gasoline and HSU limits for diesel engines and with improved regulations and test procedures in diesel engines. Improve enforcement of regulations.

5.4.2. Policy Impact

To determine a potential impact of an IM policy assumptions concerning the actual range of high emitting vehicles, the probability that latter will be repaired and the level of reduction that can be achieved need to be made. Two scenarios have been calculated with an estimated probability of change (see following table).

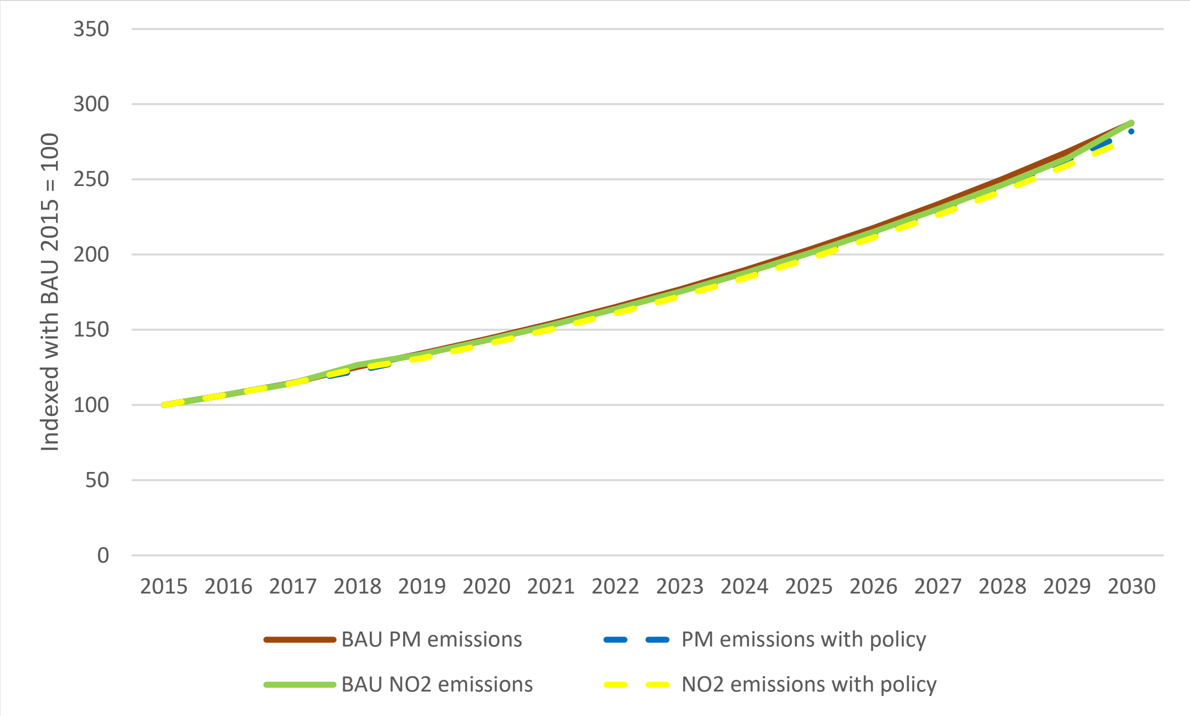
Table 18: Scenario Assumptions

Assumption	Value	Explanation
Share of high emitters gasoline cars identified which repair their vehicle	Average scenario: 1% High scenario: 2%	based on 2% (4%) high emitters of which 50% repair and rest circumvent
Share of high emitters diesel cars identified which repair their vehicle	Average scenario: 2% High scenario: 4%	based on 4% (8%) high emitters of which 50% repair and rest circumvent
Share of high emitters taxis identified which repair their vehicle	Average scenario: 1% High scenario: 2%	based on 2% (4%) high emitters of which 50% repair and rest circumvent
Share of high emitters HDVs identified which repair their vehicle	Average scenario: 2% High scenario: 4%	based on 2% (4%) high emitters of which 50% repair and rest circumvent

Improvement rate pollutants (PM, NO_2) due to repair	2	Factor 2 higher emissions of high emitting cars which can be controlled with repairs

The scenario results have been calculated against a BAU scenario. The impact of an improved IM system is limited as can be seen from the following figure.

Figure 19: Emissions with and without IM Policy (Index 2015 = 100; High Impact Scenario)



Source: Grütter Consulting

Total PM reductions by 2030 are around 2-4 tons (equivalent to 2-4% of total BAU PM emissions for the same year) and around 90-180 tons NO_2 (2-4% of BAU emissions of 2030) i.e. small.

For an economic assessment, incremental costs of improved inspection (this cost accrues to all tested vehicles) as well as the repair costs for vehicles, need to be considered (see following table). The time invested in vehicle inspection and repair and the eventual earnings loss (in case of taxis or HDVs) of vehicle owners has not been taken into consideration.

Table 19: Incremental Costs IM Improvement

Incremental cost of measures	USD/vehicle
Additional inspection cost per unit	1
Average repair cost gasoline cars/taxis	30
Average repair costs diesel cars	50
Average repair costs HDVs	200

The cost-benefit of measures is slightly negative (see table below). However, the annual negative cost is small (less than 0.2 MUSD per annum). The fiscal cost is marginal. The car owners pay for the controls and repairs. The additional inspection surveillance and control checks cost annually less than 20,000 USD and therefore represent marginal additional fiscal costs.

Table 20: Economic Profitability of Policy Measure IM (average scenario)

Parameter	Cumulative Benefit (+) or Cost (-) in MUSD (2018-2030)
Value PM and NO_2 reduction	1.1
Additional cost inspection, maintenance and repairs	-3.2
Balance	**-2.0**

Source: Grütter Consulting

The potential impact of following an advanced IM system using a loaded test such as IM240 has also been modelled. This test would only be applied to gasoline vehicles. It Is assumed that the test could identify 20% of high emitters (i.e. virtually all theoretically assumed high emitters are identified) of which 10% would get repaired i.e. a 5x higher impact rate than conventional idle test which is very optimistic. The additional costs refer to additional testing costs per vehicle and are assumed at 15 USD per test (in line with test costs in other countries of IM240 taking into consideration the limited volume of vehicles in Bhutan which would result in a higher per vehicle cost due to lower usage of infrastructure) plus the repair costs for the identified vehicles. The incremental benefit of applying IM240 or a comparable loaded test versus the current IM system is cumulative less than 1 MUSD whilst the incremental cost is around 13 MUSD i.e. introducing IM240 has clearly a negative economic impact. This is not surprising as IM240 is only applied to gasoline vehicles which are not the major source of pollutants. Therefore, the environmental impact and the resultant economic benefits are limited, whilst the incremental costs are significant.

5.4.3. Complexity and Risk

The complexity of upgrading the current system is regular. Whilst technically the measures are relatively simple, the clients of the inspection centre will try to circumvent the system and will put pressure on the inspectors to not perform measurements correctly. Covert audits and regular online checks are important to ensure that diesel vehicles are adequately tested. Without adequate testing, no impact will occur. The higher dropout rate of vehicles will not be very popular and must be well explained to the public. Also, the system requires that mechanical workshops can repair the vehicles adequately to reduce their emissions. This might require some efforts on the training of mechanical workshops. Also, it is clearly pointed out that even a good inspection system will not prevent that vehicles which visibly pollute continue to circulate as many vehicles, especially diesel units, will only be adjusted for testing and thereafter will be re-adjusted to gain power. This problem cannot effectively be resolved with an IM system and results in a certain lack of credibility of the system.

5.4.4. Conclusions

Investing in a more sophisticated system for IM is not recommended due to the limited environmental impact and the clearly negative cost-benefit. Overall the practical impact of inspection systems is of limited nature due to a relatively small degradation of vehicles over time and the many ways to circumvent the systems and not realize necessary repairs. In the medium term, no emission inspection centres are required as data can be drawn from OBD. This follows the industry trend and is the strategy in most countries. For the next 5-10 years, it is recommended to upgrade the quality of existing inspection centres through measures on the test procedure, operational responsibilities, enforcement and quality control. These measures have a limited cost and can ensure that the centres work, especially for diesel vehicles, with a far better result. These improvements are cost-effective and can

result in reducing partially emissions. Therefore, the emphasis should be on improving the current systems (the improvement scope is considerable) and not in embarking on costly new investments.

Following implementation stages are recommended:

a) Improve existing IM system in 2017 to be fully functional until January 2018. This includes new standards, clear measurement procedures, established responsibilities, electronic data transmission, real-time web based control systems, random covert audits including responsibilities, and fine structures.
b) Eliminate emission inspection centres by 2025 and rely on OBD controls. OBD equipment in the vehicles record engine malfunctions and failures of the emission control system. They report such failure to the car owner through the dash-board. At the same time the OBD registers the exact time when the malfunction occurred. In countries where emission checks are based on OBD the vehicle owner is legally required to repair his vehicle within a given time after the dashboard reports "emission malfunction". Enforcement is done either during the technical inspection (road and safety checks) of vehicles where the control centre reads the OBD data from the equipment, through reception of OBD malfunction signals with reception equipment (requires that OBD equipment sends out radio signals) or through identification of high-emitters with remote sensing equipment combined with license-plate identification and thereafter requesting the vehicle owner to bring-in his vehicle for a check. The vehicle owner is fined if the car has not been sent within the maximum allowed time after recording the malfunction (e.g., per day late). Until 2025 roadworthiness centres could be up and running in Bhutan which can realize the OBD checks. Vehicles without OBD could still be controlled at the road-worthiness centres following the current procedure.

5.5. Fuel Efficiency Standards

5.5.1. Policy Description

Most OECD countries and a few non-OECD ones (notably China) have introduced standards to promote fuel efficiency and/or CO_2 reductions of passenger cars and light duty vehicles[75]. Some countries e.g. USA, Japan or China have also introduced them for trucks.

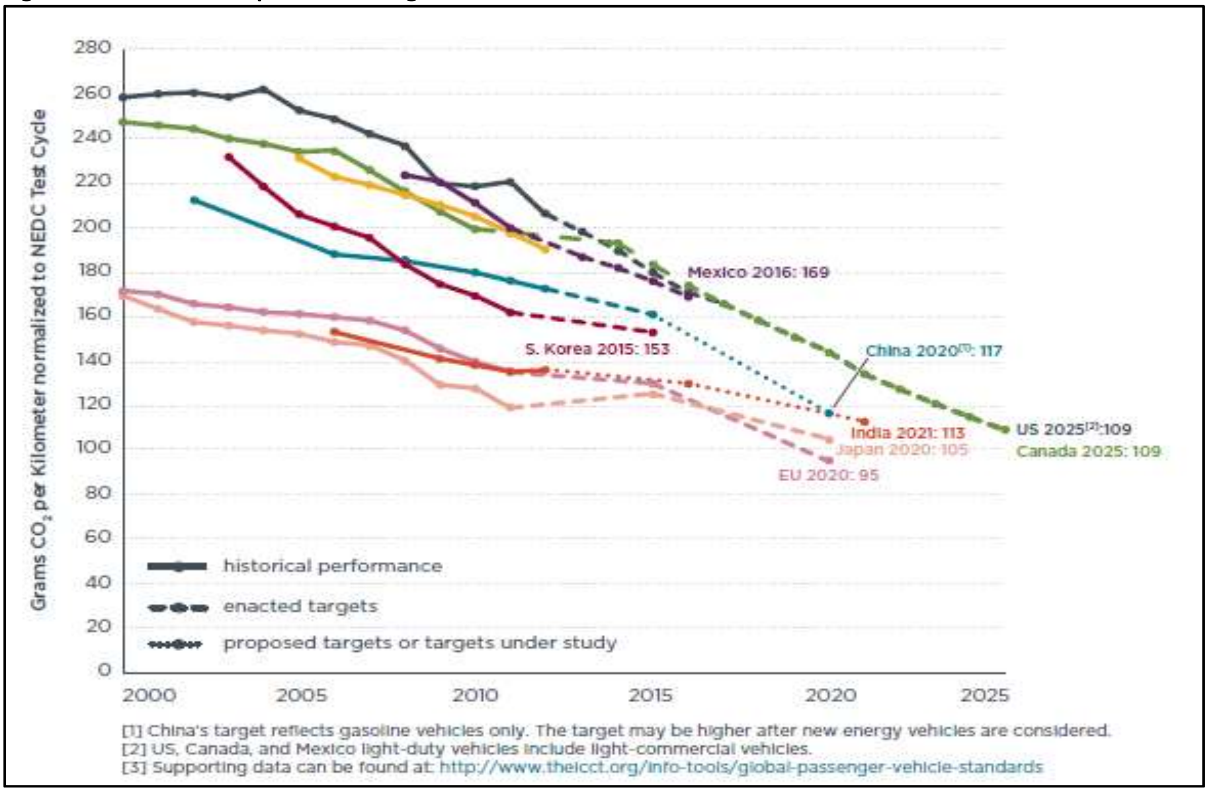
Some countries regulate fuel efficiency whilst the majority implement CO_2 standards related to tank-to-wheel (TTW, or in-use emissions) of vehicles. CO_2 standards allow to compare the GHG effect of various fuels e.g. gas, diesel, or gasoline powered vehicles. Many European countries, with exception of Switzerland, have followed a strategy to promote diesel vehicles as they expected this policy to reduce CO_2 emissions. However, they have disregarded that this has come at the cost of increasing NO_x and PM emissions and thereby also BC which is a strong climate agent.

Standards typically ask for a minimum level of fuel efficiency as an average across a class of vehicles (e.g. corporate standards such as in the EU or fleet averages such as in Australia). Most standards are based on vehicle attributes, with the fuel economy adjusted by either vehicle weight (e.g. Europe, Japan, China, South Korea) or vehicle size (e.g. in the US). A major flaw of weight based systems is that there is no incentive for manufacturers to reduce vehicle mass since a higher mass or larger size is rewarded with a more lenient standard. However, also the US system of using size has its flaws as vehicle manufacturers tend to increase the vehicle size beyond what is required to get more lenient

[75] See e.g. IEA, 2012

standards. The figure below shows past and proposed car GHG emission standards of different countries.

Figure 20: Past and Proposed Passenger Car GHG Emissions Standards in Various Countries



Source: ICCT, 2013b, figure 8.3.1.

As example, the EU law requires that new cars registered in the EU do not emit more than an average of 130 gCO_2/km by 2015 and 95 gCO_2/km by 2021. Emission limits are set according to the mass of vehicle, using a limit value curve. The curve is set in such a way that the targets set for new cars fleet average emissions are achieved. The limit value curve means that heavier cars are allowed higher emissions than lighter cars. Only the fleet average is regulated, so manufacturers are still able to make vehicles with emissions above the curve provided these are balanced by vehicles below the curve. If the average CO_2 emissions of a manufacturer's fleet exceed its limit value in any year, the manufacturer must pay an excess emissions premium for each car registered. Manufacturers can group together and act jointly to meet the emissions target. Switzerland has a comparable regulation – however as the country has, equal to Bhutan, no domestic car manufacturer, the responsible compliance party is the vehicle importer i.e. the fleet average of imported vehicles per importer must comply with the standard or he needs to team up with other importers or he needs to pay a penalty.

India has also established for passenger cars a CO_2 standard with a target of 130 gCO_2/km for 2016 and 113 gCO_2/km for 2021[76]. No standard has been established yet for light commercial vehicles or for trucks. The Indian standard is a weight-based corporate average[77]. According to the ICCT around 80% of the world producer market now has performance standards for CO_2 of cars.

The overall impact of the policy is surely positive. However, it also has its backlashes. GHG emissions per unit of distance are controlled and not total GHG emissions of vehicles. If small cars are used less

[76] http://www.egazette.nic.in/WriteReadData/2014/158019.pdf
[77] See also http://www.theicct.org/info-tools/global-passenger-vehicle-standards

than large cars, then the impact of a policy is less as no weighting of performance standards based on car usage is made. Importers of high powered and high CO_2 cars get an incentive to subsidize concurrently the import of small, cheap low emission cars to avoid penalties. Depending on income elasticities of different segments of car buyers (wealthy car buyers e.g. with low price elasticity for large cars and poorer car buyers with high price sensitivity for cheaper cars) this can result in additional cars imported to the country due to the policy[78].

The intention of the policy is to move manufacturers towards producing more efficient cars. On the other hand car buyers shall prefer fuel efficient vehicles. As small vehicle importer Bhutan will not be able to influence manufacturers. Putting an own domestic CO_2 standard has serious challenges including:

- Establishing the metric: The choice is between fuel/energy usage and CO_2 emissions. If CO_2 emissions are picked shall the trade-off with potentially higher PM and BC be considered or not? If yes, how and if not, then lower GHG emissions might be traded off against higher pollution levels.
- Establishing the methodology: Options are absolute emissions or emissions relative to size or weight. Different countries use different adjustment formulae. These are not based on physical laws and prone to lengthy discussions.
- Target level: The target level of CO_2 emissions per average vehicle needs to be established. This needs an understanding of the current CO_2 emissions of vehicles circulating in Bhutan and expected BAU emissions of these vehicles.
- Institutional structure: Bhutan has no vehicle manufacturers. Importers would need to be the responsible compliance party which means that latter need to be few and well organized. A specific problem is thereby the individual import of vehicles.
- Penalty: The level of penalties to be applied needs to be fixed and to whom and when penalties are levied. The penalty is for non-compliance i.e. for each gCO_2/km surpassing the target for the average of imported vehicles. The penalty must be high enough to create the incentive to import lower emitting cars.

Given the small domestic market of vehicles in Bhutan, its high heterogeneity (e.g. a considerable faction of small and low powered urban vehicles whilst for inter-urban routes larger SUVs and pick-ups are preferred; large share of HDVs), the high complexity of establishing and implementing a CO_2 based performance standard as well as the insecure impact of latter, it is recommended to promote low GHG efficiency vehicles based on technology standards or proxies. Useful technology proxies are thereby hybrid, plug-in hybrid and electric vehicles. In all CO_2 performance schemes adopted worldwide these vehicle-technologies are clearly dominant in the low-CO_2 part i.e. using these technologies as simple proxies will ensure lower average CO_2 emissions per car whilst avoiding complex regulatory systems. Through this also all vehicle categories could be targeted and not only passenger cars. Incentives could thereby be related to vehicle usage e.g. targeting high mileage vehicles such as taxis and buses and only in a 2^{nd} instance private passenger cars. A meaningful and comprehensive strategy would however need to be developed in the form of a low-carbon vehicle roadmap where hybrids form a stepping stone towards electrified transport. The economic means

[78] The same amount of large "gas-guzzlers" are imported by wealthy customers as in the baseline as these customers are not price elastic; to avoid penalties importers also bring in subsidized small cars which are picked up by less wealthy customers. The total CO_2 emitted might thus be more than in the baseline as more cars are on the street. This whilst at the same time the average CO_2/km drops. This phenomenon can be observed in Switzerland with an ever-increasing car population and increasing GHG transport emissions albeit having strict CO_2 performance standards.

required to implement such a policy should be quantified and finance sources need to be identified. Bhutan could tap internationally available climate funds to assist the country in implementing a low-carbon vehicle policy.

Policy Proposal CO_2-Emissions of Vehicles:
Develop 2017/18 a low-carbon vehicle roadmap with clear incentive instruments and targets and tap by 2018/2019 international climate finance to implement the policy. The promotion of low carbon vehicles would be based on technology standards including hybrids, plug-in hybrids and electric vehicles.

5.5.2. Policy Impact

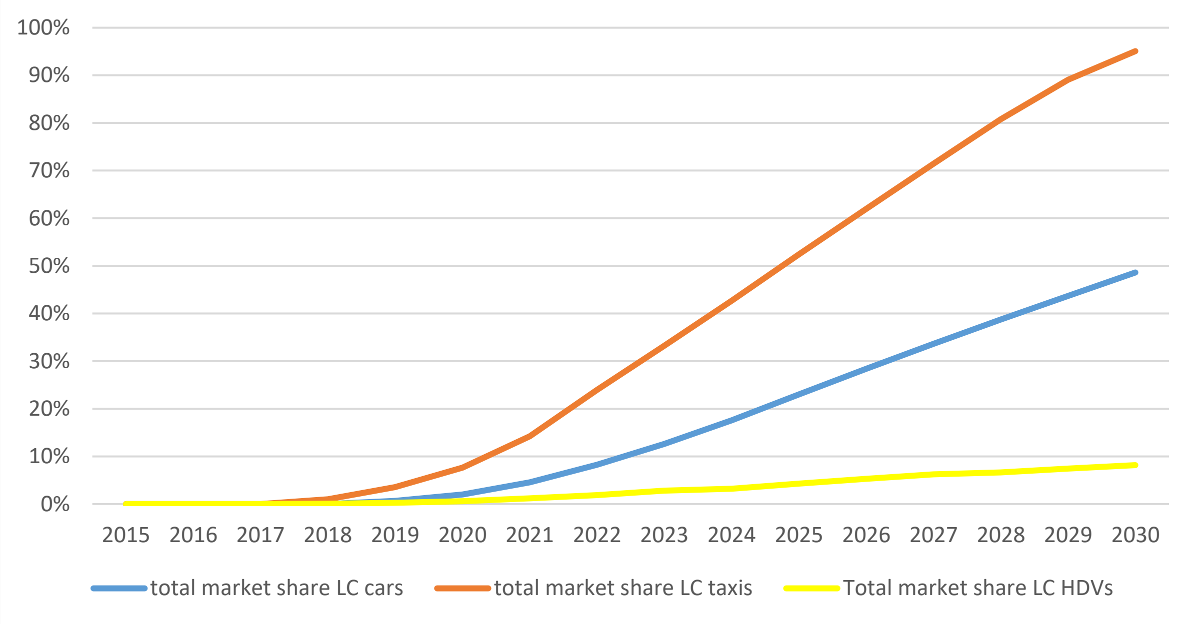
The policy impact is modelled through targets set for hybrid, plug-in hybrid and electric vehicles as set forth in the following table. These targets could be achieved through various instruments including tax and import incentives, regulations (e.g. licensing time for taxis, buses or access to urban areas) or procurement policies. Targets have been differentiated in taxis, buses, small urban trucks, and passenger cars based on the availability of low carbon vehicles and their commercial attractiveness. Motorcycles have not been included initially as Bhutan has a larger fleet of higher powered motorcycles used often in rural setting whilst electric motorcycles commercially available are basically low powered city scooters. Large trucks have not been included initially as hybrid or electric vehicles in this area are only in the pilot testing stage.

Table 21: Proposed Policy Targets Low-Carbon Vehicles

Vehicle category	Target year share of new registered vehicles			
	2018	2020	2022	2025
Taxis and buses				
Hybrids	25%	50%	25%	0%
Plug-in hybrids	0%	25%	50%	50%
Electric	0%	0%	25%	50%
Urban small trucks				
Hybrids	0%	25%	50%	25%
Plug-in hybrids	0%	0%	25%	25%
Electric	0%	0%	25%	50%
Passenger cars				
Hybrids	0%	10%	20%	20%
Plug-in hybrids	0%	0%	10%	20%
Electric	0%	0%	0%	10%

The policy target is for new registered vehicles. The stock of vehicles changes much slower as vehicles are kept for an average of 15 years. The figure below therefore shows the projected share of low-carbon vehicles including hybrids, plug-in hybrids and electric vehicles of the vehicle stock.

Figure 21: Share Low-Carbon Vehicles 2015-2030 with Policy (Vehicle Stock)



Source: Grütter Consulting; LC = Low Carbon Vehicles (hybrid, electric)

The share of low-carbon taxis increases much faster than of cars due to higher targets set for these vehicles. The share of low-carbon HDVs only grows slowly as only buses and small urban delivery HDVs are included with targets as these low-carbon vehicle categories are near-to-commercial.

The basic intended environmental impact is upon GHG emissions. However, also pollutants are reduced as hybrid vehicles have also proportional pollutant reductions and electric vehicles have not only 0 GHG but also 0 pollutant emissions. Bhutan produces all electricity based on renewables and therefore GHG emissions from electricity usage are 0. By 2030 some 90-100,000 tCO_{2e} can be reduced annually with an increasing trend as the vehicle stock renovates. This corresponds to around 14% of BAU GHG emissions. Pollutants can be reduced by 8-12%. However, the urban impact is much higher as pollutants are reduced basically from taxis, buses, urban delivery trucks and passenger cars which have the highest share of urban emissions.

The economic impact depends significantly on the incremental total cost of ownership (TCO) per vehicle category relative to a fossil powered car. For hybrid and plug-in hybrid units they are estimated at 0 based on various studies realized[79]. This however, does not mean that without incentives such vehicles would be procured due to perceived technology risk of buyers and due to higher upfront investment (buyers in general do not make a TCO assessment but compare upfront investment costs). For electric vehicles for taxis with a high annual mileage the TCO is also comparable to fossil fuel powered units i.e. no economic additional cost will occur[80]. For electric cars and small HDVs an annual average incremental cost of USD 1,000 for the year 2020 and ¼ for the year 2030 with a linear

[79] See e.g. World Bank, 2016; ICCT, 2015; Grütter Consulting, 2014
[80] See also World Bank, 2016 for a TCO for electric taxis Bhutan

reduction was assumed[81]. For buses the incremental annual cost is estimated at 25,000 USD for 2020 and 5,000 USD in the year 2030[82]. The following table shows the economic profitability of this policy.

Table 22: Economic Profitability of Policy Measure Low Carbon Vehicles

Parameter	Cumulative Benefit (+) or Cost (-) in MUSD (2018-2030)
Value PM and NO_2 reduction	2.7
Value GHG reduction	16.7
Value SO_2 reduction	0.1
Additional cost vehicles	-36.0
Balance	**-16.5**

Source: Grütter Consulting

The measure is clearly not profitable economically seen. This points to the necessity of tapping external finance e.g. from climate funds.

Fiscally seen incentives will be required to achieve the stated policy targets. However, these can be fiscally neutral e.g. tax reductions for low carbon vehicles can be compensated by corresponding tax increases for conventional fossil powered units (weighted based on projected sales figures per category) thereby resulting in a fiscal neutral outcome. Such an approach is strongly recommended to not burden state finance and to not create fiscal incentives for private motorization.

5.5.3. Complexity and Risk

The complexity of the proposed measure is simple. Many countries have realized tax incentives for hybrid and electric vehicles. One of the more successful countries in Asia was Mongolia were lower import taxes for hybrid vehicles have led to a fast upsurge of this technology and a hybrid vehicle penetration rate of passenger cars of 18% in the year 2015 after only few years of reduced taxes. The critical element is not so much the policy itself but what mixture of instruments to choose and what levels of incentives to provide to achieve the target. The risk of the measure is low. If not well designed it may result in a fiscal burden but this risk can easily be mitigated by allowing for annual adjustment of import tax rates of vehicles based on the actual share per technology to achieve a fiscal neutral impact.

5.5.4. Conclusions

A policy based on fuel efficiency or CO_2 performance standards is not recommended for Bhutan due to its complexity in establishment and the limited potential impact. It is however, recommended to foster low carbon vehicles with a focus on hybrid and electric vehicles. These technologies have a proven GHG and pollutant reduction rate. Electric vehicles in the situation of Bhutan with a completely renewable grid, are very attractive. Therefore, it is suggested to develop a comprehensive roadmap for Bhutan for low-carbon vehicles with clear targets, instruments, financial structuring and key parameters to measure implementation success. A possible target is suggested for a phased-in introduction of hybrid, then plug-in hybrid and finally electric vehicles focusing on taxis, buses and urban delivery trucks as for these vehicle categories well established technologies and experience

[81] See e.g. World Bank, 2016 for an incremental TCO of around 10,000 USD for an electric vehicle. Based on a life-span of 15 years and a lower average mileage for Bhutan an incremental average annual TCO of around 1,000 USD results

[82] Based primarily on experience of Chinese cities and actual operating costs of buses incl. bus availability rates; valid for 8-12m buses.

exist and TCOs are comparable to conventional vehicles. At a later stage passenger cars and HDVs could be included. Implementing this strategy would reduce local pollutants as well as GHGs but also entails an economic cost i.e. the projected costs are higher than the projected benefits. This cost-benefit relation is largely dependent of the number of electric vehicles promoted as only these have negative economic benefits whilst hybrids have positive ones.

5.6. Diesel Particle Filtres (DPFs)

5.6.1. Policy Description

Diesel engines cause significant fine particle emissions resulting also in Black Carbon (BC) which again is a major source of global warming. Diesel Particle Filters (DPFs) is the technology of choice to reduce fine particle as well as BC emissions. DPFs are equipped on Euro VI and partially Euro V vehicles. Various countries have however embarked also on programs to retrofit existing vehicles with DPFs, mainly HDVs and non-road mobile machinery (e.g. building machinery). As example, Santiago de Chile[83] has realized a retrofit of around 3,000 urban buses with DPFs, a measure also popular in other highly polluted cities. DPFs work with 50ppm sulphur diesel albeit only at around 50% of the control efficiency and require 10ppm sulphur diesel to work at full potential. Other important aspects which need to be considered for a retrofit program are:

- Installations of DPFs can be tricky. They are not realized by the vehicle manufacturer but by the filter manufacturer and require adjustments in the engine management. In some cases, the DPF can result in engine damage and engine fires.
- DPFs can only be installed without major problems in Euro III engines onwards.
- DPFs might not work well at high altitude. Many buses in Bogota (altitude 2,600 MAMSL) where DPFs were installed in a pilot program had difficulties, especially if the engine power is not sufficient or if the engine maintenance is not perfect.
- DPFs need regular professional maintenance to not get clogged. In case of lack or improper maintenance the engine can be harmed and the DPF will not work anymore accordingly. In 20% of the buses controlled randomly in Santiago the DPF had a malfunction and did not work properly.
- DPFs will result in an additional fuel consumption of around 3%. This offsets part of the GHG reductions due to reduced BC emissions.

As of 2018 Bhutan will have 50ppm sulphur diesel fuel adequate for DPFs, whilst from 2021 onwards DPFs introduced would work fully. DPF retrofit is not made on passenger cars and light commercial vehicles but only on large HDVs due to equipment and installation cost. Therefore, the policy assessed is the retrofit of large HDVs > 7.5t with DPFs.

Policy Proposal DPFs:
Install DPFs in all newly registered large HDVs (>7.5t) as of 2019 and retrofit large HDVs Euro III or later with a remaining life-span of at least 10 years.

[83] See e.g. SDC, 2011

5.6.2. Policy Impact

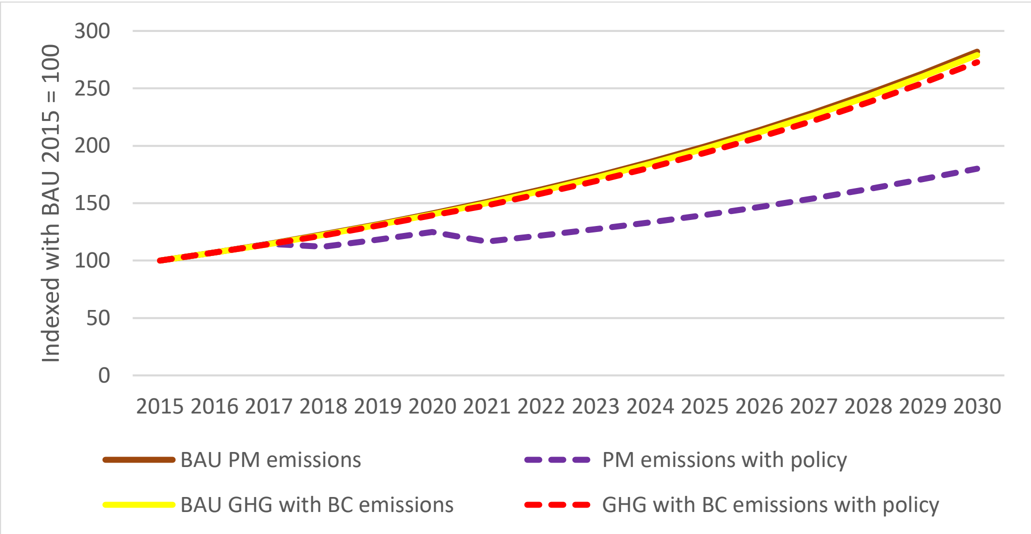
The policy impact is monitored against a baseline which only includes fuel improvements. If Bhutan introduces, as is the case in India, BS-VI standards as of 2021 these vehicles would already come equipped from the manufacturer with DPFs and therefore no further impact could be achieved from a retrofit program.

Calculations are made based on following assumptions[84]:

- Only vehicles with a remaining lifespan of 10 years and minimum Euro III are equipped. As of 2018, when 50ppm sulphur fuel is available, it is assumed that this condition would be met by 30% of existing HDVs. From 2019 onwards all new HDVs would be equipped with DPFs.
- Only HDVs > 7.5t are equipped.
- The maximum reduction efficiency of the DPF is estimated at 50% with 50ppm sulphur fuel and at 90% with 10ppm sulphur fuel.
- A malfunction rate of 20% is assumed resulting in a 50% lower PM reduction level.
- A surplus fuel consumption of 3% is assumed.

Based on above assumptions as of 2030 around 70% of large HDVs would be equipped with DPFs and latest as of 2034 all large HDVs would have a DPF. The following graph shows the environmental benefits of retrofitting large HDVs with DPFs in Bhutan.

Figure 22: $PM_{2.5}$ and GHG Benefit of Introducing DPFs in Bhutan (Index 2015 BAU = 100)



Source: Grütter Consulting

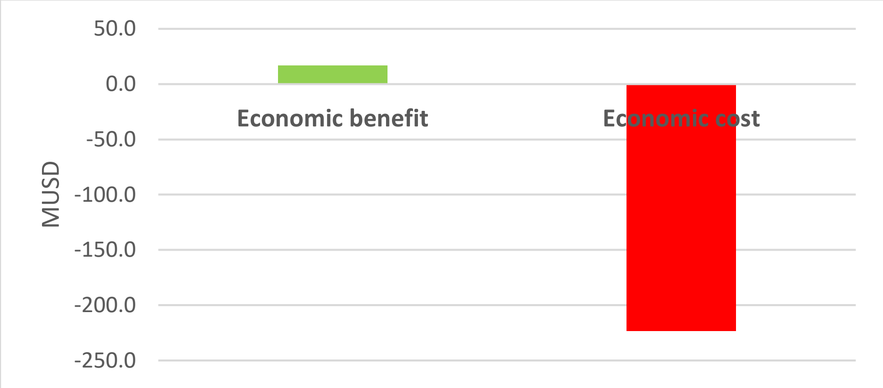
The impact on GHG emissions is marginal (16,000 tCO_{2e} reduced as per 2030 which represents 2% of projected 2030 BAU emissions). The $PM_{2.5}$ reduction is more important. However, the policy cannot revert the trend of increasing PM emissions in Bhutan.

The economic impact needs to take into consideration equipment incl. installation investment, incremental maintenance and additional fuel costs. The total lifetime cost of the DPF is around USD 18,000 per vehicle including annual maintenance costs. Additionally, a small amount of incremental

[84] Assumptions and data cited based on DPF program in Chile evaluated by Grütter in 2015; see Grütter, 2015

fuel costs arises. In total the cost of the measure is cumulative 2018 to 2030 over 200 MUSD higher than the benefits as shown in the following graph.

Figure 23: Economic Cost-Benefit of DPF Policy (cumulative 2015-2030 in MUSD)



Source: Grütter Consulting

5.6.3. Complexity and Risk

The policy is considered as complex. Multiple DPF manufacturers exist and not all produce high quality filters. Therefore, quality assurance and certification needs to be provided by an independent entity. Installation and maintenance of equipment is challenging and requires skills currently not available in Bhutan. The government needs to control that vehicles equipped with DPFs maintain these adequately as otherwise the DPF will not retain its original level of effectiveness. Also, trials in Bogota have shown that DPF manufacturers as well as engine manufacturers struggle with adapting systems to high altitude countries.

Overall the risk of such a policy is considered as high. Emission standards which require DPFs result in OEM (Original Equipment Manufacturer) instalment including warranty and durability tests of the manufacturer. This results in much less problems of such equipment. Retrofits are far riskier and prone to malfunction.

5.6.4. Conclusions

In numerous European cities as well as in e.g. in Santiago de Chile urban buses have been equipped with DPFs. However, the experience of other cities including Bogota as well as Mexico City with retrofitting DPFs has been negative or mixed. Whilst DPFs do have an impact on $PM_{2.5}$ and can reduce comparatively to a BAU scenario the PM emissions, the impact is not so significant as it would only warrant to equip large HDVs. Latter also circulate basically outside the cities making the impact less significant concerning health effect. The highly negative cost-benefit relation, the high policy complexity and the high risks of malfunction, result in a clear recommendation to not implement this policy.

5.7. Vehicle Age Restriction and Scrapping Programs

5.7.1. Policy Description

Vehicle age restrictions are often made for buses and taxis operating in urban areas. Replacing these vehicles has a much higher impact on reducing emissions than targeting private cars as they have a

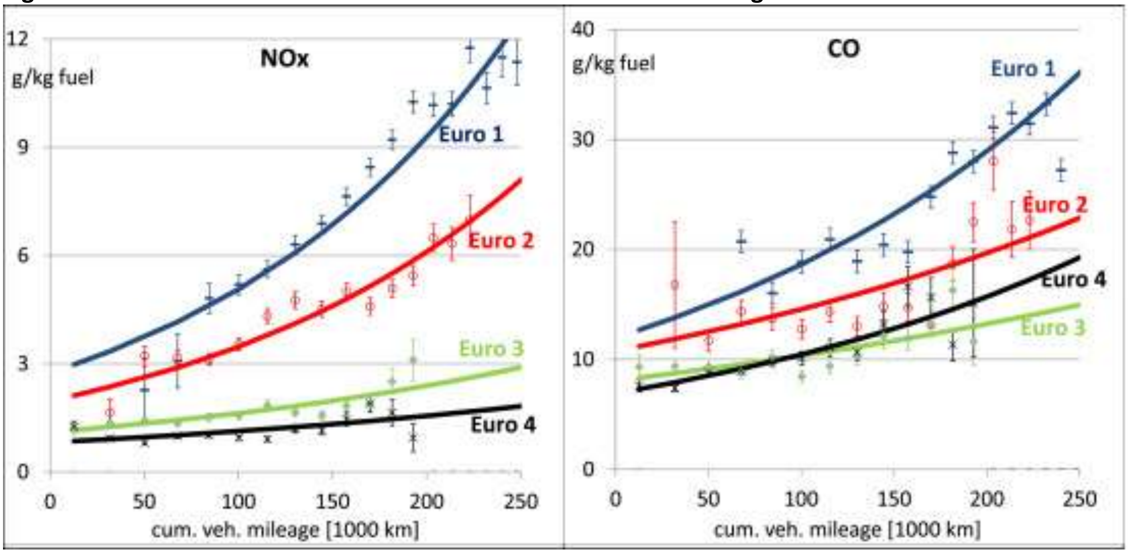
higher mileage and operate in urban conditions. Voluntary programs to reduce old vehicles are related to scrappage programs giving an incentive to turn-in old vehicles. Scrapping programs have been favoured by car manufactures as this allows them to sell more cars. It is therefore not surprising that many scrappage programs have been put forward by governments during a recession period whilst using the environmental tag to justify them.

Currently Bhutan manages for taxis and buses a vehicle age restriction for commercial usage i.e. the vehicle can be used thereafter for private purposes. This limits the financial cost for involved parties whilst still having a positive environmental impact as commercial vehicles have a higher mileage and are used more in urban spaces than private ones.

Limiting the vehicle age has following potential impacts:

- Faster vehicle renovation thus allowing for usage of vehicles with new technologies and lower emissions.
- Less problems of vehicle deterioration and problems caused due to tear and wear and lack of maintenance. Elder vehicles require more intense maintenance whilst the owners want to invest less in the vehicle. This results in an increasingly bad state of the vehicle resulting in higher emissions than at the design level. However, mass monitoring of vehicles has shown that deterioration rates of gasoline vehicles seem to be of minor nature, especially concerning CO and NO_x[85]. NO_x unit emissions from gasoline cars deteriorate exponentially with vehicle mileage doubling about every 115, 125, 180 and 220 thousand km for Euro 1 to Euro 4 technologies respectively (see figure below). Euro 4 gasoline cars seem to have nowadays consistently low NO_x unit emissions over their lifetime.

Figure 24: CO and NO_x Emissions Gasoline Vehicles relative to Mileage



Source: Borken-Kleefeld, 2015, Figure 2

This means that the benefit from scrappage schemes targeting Euro 2 and even more Euro 4 cars is limited. No deterioration of PM and NO_x emissions of HDVs was found in Europe based on Dutch and German data[86].

- Limiting vehicle lifetime will result in slightly lower vehicle numbers due to higher lifetime vehicle cost (the investment can be spread over less useful time). However, the impact will

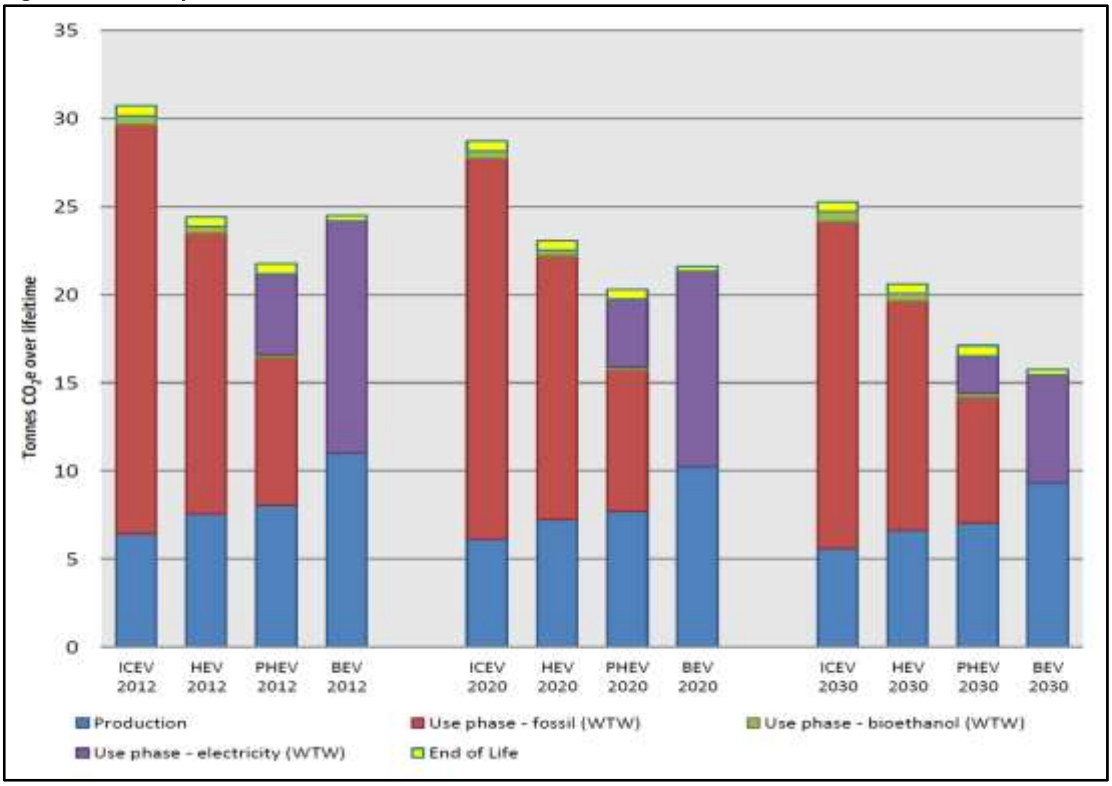
[85] Borken-Kleefeld, 2015

[86] Rexeis et.al., 2005

be marginal if the vehicle age is not very restrictive (restrictive would be if the maximum age would be 10 years or less).

- The policy will result in higher upstream emissions as the useful vehicle lifetime is reduced (see figure below). If only the commercial life-span is restricted this impact is non-existent or marginal.

Figure 25: Life-Cycle GHG Emissions Cars



ICEV: Internal Combustion Engine Vehicle; HEV: Hybrid Electric Vehicle; PHEV: Plug-In Hybrid Electric Vehicle; BEV: Battery Electric Vehicle
Source: PE, 2013, Figure 0-1

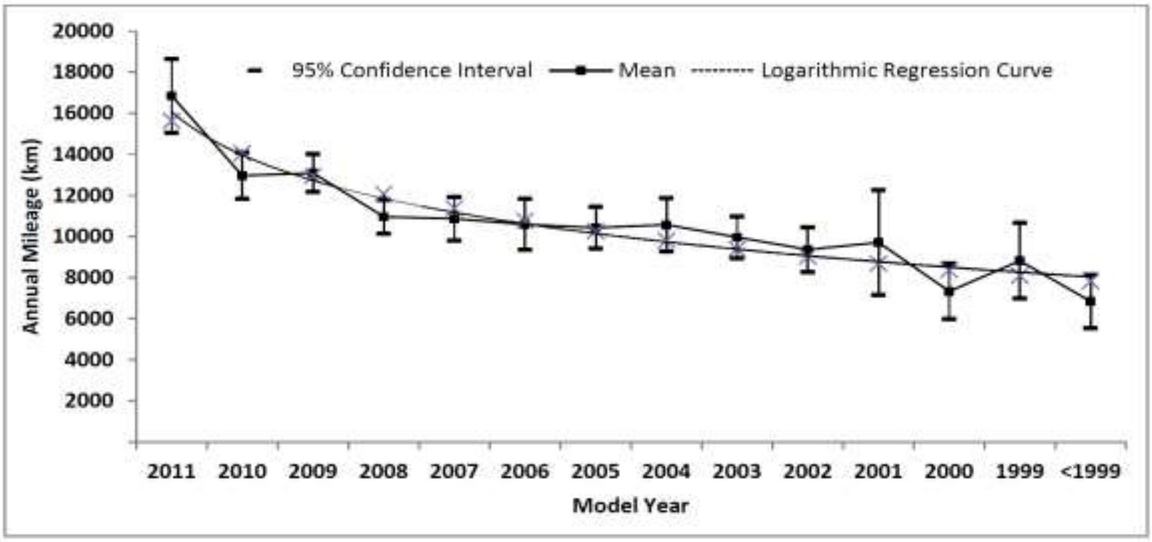
It is estimated that an average passenger cars embodies around 5 tCO_2 (including components, vehicle assembly and scrapping). Each year of shortened life-time therefore results in losing part of this GHG “investment”. While these emissions do not accrue geographically in Bhutan and are therefore not part of the national GHG emissions, they are an important factor to consider.

The overall impact on emissions of restricting the vehicle age is often over-estimated, especially if these are private vehicles. The elder the vehicle the lower the average annual distance driven. New vehicles are driven more due to higher convenience and reliability as well as lower operating costs. A clear negative correlation between vehicle age an annual mileage driven can be observed in all countries (see exemplary below for India; the relation is similar in other countries e.g. USA, Germany, UK, Costa Rica[87]). Replacing an old vehicle with low mileage with a new vehicle will result in increased vehicle usage and mileage and therefore in additional emissions. The vehicle might have lower emissions per unit of distance but this is, at least partially, compensated with a higher mileage. The

[87] See US-DOT, 2011; Bundesministerium für Verkehr, Bau und Stadtentwicklung, 2010; Department for Transport, NTS 0903; Grütter, 2016

result can be higher total emissions than without the policy. This is true of private vehicles, but less of concern with commercial vehicles which operate basically in response to client demand.

Figure 26: Relation Vehicle Age and Annual Distance Driven



Source: Goel R., 2015, Figure 4

To assess the potential impact of the policy it is assumed that vehicle age of taxis would be limited to 10 years usage as taxi without usage as private vehicle thereafter[88], and HDVs (includes basically trucks but also buses) and private vehicles to 12 years whilst BAU for all would be an average of 15 years[89]. This could theoretically be realized with or without giving incentives for scrapping vehicles.

Policy Proposal Vehicle Age Regulation:
Limit the maximum age of taxis to 10 years and of all other vehicles to 12 years.

5.7.2. Policy Impact

The policy impact is based on following assumptions and considers the following changes:

- In absence of the policy Euro 4 and 6 regulations come into force in 2018 and 2021 as under the policy scenario of new emission standards.
- The vehicle maximum age is governed by law. The following table summarizes the assumptions concerning maximum legal age and estimated average BAU age.

Table 23: Proposed Maximum Vehicle Age under Policy versus Average BAU Lifespan Age

Vehicle category	Max. permitted age	BAU lifespan
Passenger cars	12 years	15 years
Taxis	10 years	15 years (incl. private usage)
HDVs	12 years	15 years

Source: Assumptions Grütter Consulting as calculation base; motorcycles are not included

[88] Currently the maximum age of taxis is 9 years but vehicles can be used as private cars thereafter.
[89] The current maximum age of public transport buses is 14 years but units can be used thereafter on a private base.

- Emission reductions are based on the impact of renovating the vehicle fleet earlier and thus having larger shares of vehicles with a higher Euro standard plus reduced vehicle degradation emissions.

Table 24: Estimated Annual Average Degradation Percentage for $PM_{2.5}$ and NO_2

Vehicle category	Degradation factor at year 10	Average annual degradation factor after year 10
Passenger cars / taxis gasoline	1.85	6%
Passenger cars / taxis diesel	1.6	15%
HDVs	0	0%

Source: gasoline car based on Borken-Kleefeld, 2015, table 2; diesel car based on EEA, 2016; HDV based on Rexeis, 2005

- The economic assessment includes the value of reduced emissions and as costs the additional vehicle TCO due to shorter commercial life-span and due to having to procure earlier vehicles with a higher emission standard and the incremental annualized cost of these vehicles.

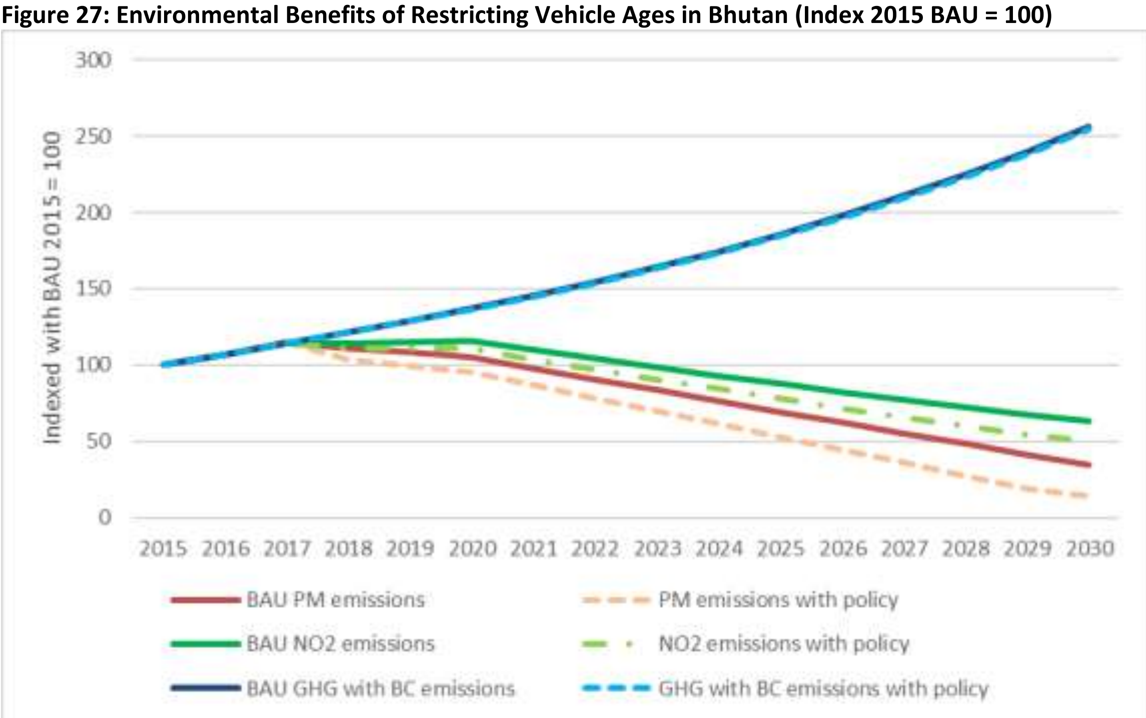
Table 25: Vehicle Investment Cost (USD/vehicle)

Vehicle category	Average investment cost (USD)
Passenger car gasoline 0.8-1.4l	10,000
Passenger car diesel > 2l	25,000
Taxi gasoline 0.8-1.4l	10,000
HDV < 7.5t	25,000
HDV 7.5-16t	40,000

Source: Grütter Consulting based on vehicle engine size and most popular models in Bhutan incl. tax

The following graph shows the environmental impact of the measure. As mentioned the comparison in this case is with BAU Euro 4 and 6 standards as of 2018 and 2021 respectively as it basically only makes sense to retire elder vehicles if they are replaced by such with a better environmental standard.

Figure 27: Environmental Benefits of Restricting Vehicle Ages in Bhutan (Index 2015 BAU = 100)



Note: BAU includes introduction of Euro 4 in 2018 and Euro 6 in 2021
Source: Grütter Consulting

Relative to BAU PM emissions can be reduced by 60% and NO_2 emissions by 20%. No significant impact on GHGs is observed.

The additional economic cost of the measures is highly negative as can be seen from the following table.

Table 26: Economic Profitability of Policy Measure Vehicle Age Restriction

Parameter	Cumulative Benefit (+) or Cost (-) in MUSD (2018-2030)
Value PM and NO_2 reduction	4.1
Value GHG reduction	1.7
Additional cost vehicles	511.8
Balance	**-506**

Source: Grütter Consulting

The additional cost can be fiscal neutral or fiscal negative. If the country regulates the maximum vehicle age and offers no scrapping incentive, then the full cost is born by the owner of the vehicle and not by the country. The fiscal impact would be minimal (slightly lower revenues from vehicle tax and fuel tax due to a smaller number of vehicles). However, a policy without offering fiscal incentives might not be politically feasible. The government would probably have to offer a scrapping incentive paying for cars to be retired. This would potentially create a significant burden on Bhutan's finance and would mean that general taxpayers are subsidizing vehicle owners which is socially and economically not reasonable.

5.7.3. Complexity and Risk

The measure is relatively easy and straightforward to control. It does involve an authority which checks that vehicles are retired and not used anymore and are eventually scrapped. However, this can be managed through an annual registration of vehicles.

The risk of the measure is basically of political nature. Without providing a financial incentive this will mean that car ownership becomes more expensive and the cost for freight and passenger transport might increase due to higher average annual vehicle cost. Therefore, most countries which have introduced such measures have given a financial incentive for car owners to scrap their vehicles. However, this creates a significant fiscal burden and does not correspond to the polluter pays principle. Also, it would mean a transfer of resources from poorer to wealthier segments of society as latter are basically car owners.

5.7.4. Conclusions

Scrapping incentives are a very costly policy and result in a limited impact due to following factors:

- Old vehicles brought in for scrapping might have not been used anymore or only very little thus also only causing limited emissions. The new vehicle acquired with money received from scrapping will however ply the streets continuously.
- The vehicle owner is incentivized to procure a new vehicle with money received from scrapping. This will result in additional mileage driven as new vehicles have a higher mileage.
- Paying for scrapping can create a fiscal burden and favour richer segments of society with access to vehicles whilst the incentive is paid by everybody through tax revenues i.e. the measure tends to have a negative distributional impact.

Overall paying incentives for scrapping vehicles is not considered an appropriate policy due to its limited impact on pollution, due to its negative distributional impact and due to potentially creating more traffic. Also, such policies do not follow the polluter-pays-principle. For commercial vehicles, especially buses, it has been a policy used in many BRT programs especially in Colombia as a mean to avoid conflicts with existing bus operators and to force them into new well-organized transport companies. In such a context, the policy might be justified.

The policy has a relatively limited impact on emissions and has a very negative cost-benefit i.e. it is not a recommended measure as the expected benefits are far less than the cost.

A policy of restricting vehicle age coupled with incentives to go for new vehicles and invest in new technologies without fiscal impact could be based however on the following pillars:

- Limit the commercial age of fossil fuel taxis to 9 and buses to 14 years as currently, whilst allowing them to be sold thereafter to the private market. This follows the current policy which is deemed as reasonable. The impact of selling the car into the private market is marginal as the mileage in the private market is much lower and the vehicles are not used exclusively in urban areas.
- Allow for longer operating age of taxis and buses if these are low-emitting vehicles. For hybrid units, e.g. a commercial age of 10/15 years (taxis/buses), for plug-in hybrids of 15/20 years and for electric units of 20 years could be proposed. This would give an incentive to procure such units. This procedure has been applied e.g. successfully by the BRT TransMilenio Bogota, Colombia where operators which invested in hybrid buses can use these for an additional 2 years compared to conventional units. This policy allowed to maintain the same passenger fare whilst operators invested voluntarily in hybrid units without requiring additional subsidies.
- Restrict circulation of HDVs which do not comply with Euro IV and later Euro VI in urban areas of Thimphu and Paro. This would create an incentive to renovate the fleet and would ensure that the newest vehicles are used in the environmental hotspots of the country where most people are affected by pollution. As Euro IV vehicles will only be introduced by 2018 and Euro VI vehicles by 2021 such a policy can only be introduced after 2020. This policy could easily be controlled with a "pollution sticker" e.g. as used by the Municipality of Paris, France[90]. Comparable policies either based on restricting entrance or on charging elder vehicles a "pollution fee" have been successfully introduced by many cities worldwide e.g. London, Paris, Mexico City or Santiago de Chile.

It is suggested to maintain the current policy of limiting the commercial age of taxis as well as buses without restriction on further usage as private vehicles after terminating the commercial lifespan. In the future, it is recommended to establish urban HDV access restriction policies based on the Euro standards thereby creating an incentive to modernize the fleet. Creating incentives such as an increased commercial lifespan for new technology vehicles including hybrids, plug-in hybrids and electric vehicles is considered a promising approach. However, it is suggested to include this measure in coordination with other incentives towards an electrification of transport in Bhutan. This can be addressed best by a comprehensive roadmap towards electric vehicles which requires separate strategies for taxis, buses, HDVs and private passenger cars. The Bhutan electric vehicle initiative[91] focuses on private passenger cars whilst a concentration on urban used vehicles especially taxis and buses could be a much more promising and low-cost strategy. It is therefore recommended to develop

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[90] http://www.drive-france.com/faqs/paris-pollution-stickers-critair/

[91] See World Bank, 2016

such a strategy specially for taxis and buses, in second instance for urban HDVs and motorcycles and as third priority for passenger cars.

5.8. Restricting Diesel Vehicles

5.8.1. Policy Description

The proposed policy is to restrict the usage of diesel vehicles to heavy trucks, buses and mobile machinery. No more passenger cars, taxis and light vehicles up to 3.5t using diesel fuel shall be registered in Bhutan. For these vehicle categories gasoline vehicles with comparable characteristics are easily available. This policy is justified based on the following grounds:

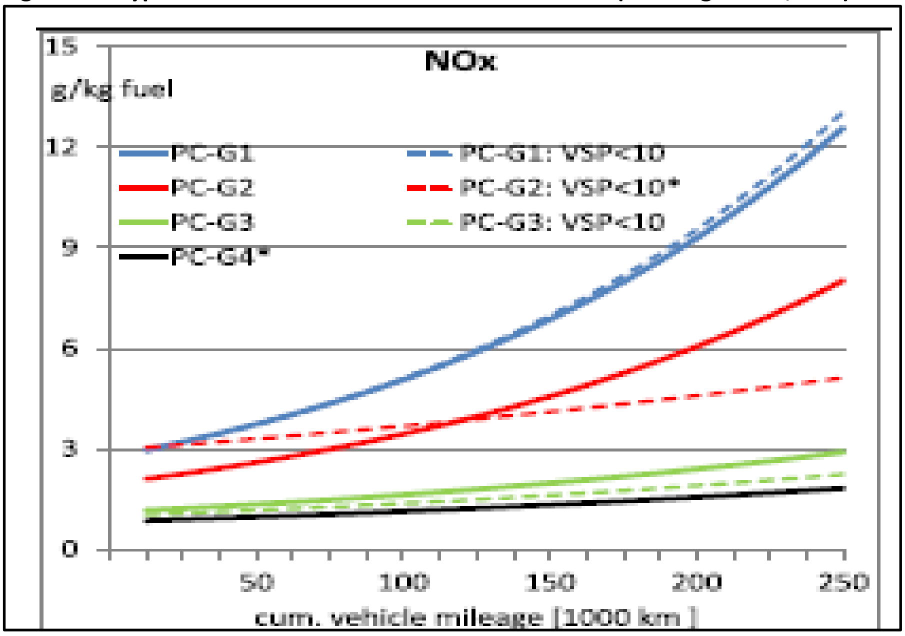
- 98% of PM, 95% of NO_2 and 87% of SO_2 emissions of Bhutan are caused by diesel vehicles although they only represent 40% of vehicles. The air pollution caused in urban areas is nearly entirely caused by diesel vehicles. Diesel passenger cars and taxis account for around 60% of urban PM and SO_2 and 1/3rd of NO_2 emissions. They are therefore the main target group to tackle if clean air shall be achieved.
- Introducing low-sulphur diesel and adopting strict vehicle emission standards (Euro 4 from 2018 and Euro 6 from 2021) reduces diesel related air pollution emissions. However, this reduction projection is based on the values as recorded when performing the standardized type approval test. For diesel cars, actual emission values especially of the critical pollutants PM and NO_2 are however significantly higher than reported values due to following factors:
    - Car manufacturers, not only since VW, do not necessarily comply with standards, circumvent the system and cheat. The trustworthiness of tests is therefore very limited, even if results are reported by 3rd parties as car manufacturers apply political pressure on weak environmental authorities.
    - Reports from ICCT as well as others show that under actual driving conditions vehicle emissions are still significantly higher, also of Euro 6 vehicles, than the type-approval values. Average on-road NO_x emissions of Euro 6 diesel passenger cars have been reported to be factor 7 higher than type-approval figures with some vehicles emitting factor 25 higher values than reported ones[92]. Latter is not surprising as for the type approval test normalized conditions are used with vehicles being conditioned and adjusted in a manner which is very much different from actual road usage (e.g. components are eliminated from the car, no AC is used, special wheels, tyres and fuels are used etc.). The type approval certification also does not capture real-world operating conditions of engines concerning torque and speed. Even with the expected introduction of the RDE (Real Driving Emissions) standard differences of factor 4 are still expected.
    - With low ambient temperatures emission control devices work with a far lower effectiveness. German investigators found that many car manufacturers have legally installed software which shuts off exhaust treatment systems in cold weather to reduce the risk of condensation building up in catalytic converters. Cold weather has been defined by some producers as temperatures below 19^{0}C i.e. most of the time the emission control equipment is shut off[93]. This reduces the need for expensive urea used as additive for eliminating NO_x from exhaust fumes but results in skyrocketing

[92] ICCT, 2016a, Figure 1
[93] http://www.srf.ch/sendungen/kassensturz-espresso/auto-schweiz-nimmt-im-kassensturz-stellung-zur-diesel-luege

NO_2 emissions[94]. Average ambient temperatures in Bhutan are relatively low, especially in winter months which is also the time with the highest potential for smog. Pollution control equipment which only works partially at lower temperatures is thus very problematic for Bhutan.

- In cold start conditions pollution control devices work far less effectively. Again, this is a prevalent condition in urban areas of Bhutan where driving distances are short and engines operate primarily at cold driving conditions. Cold engine emissions for PM are e.g. more than factor 3 higher compared to engines operating at high temperatures[95].
- At high altitude, prevalent in Bhutan, diesel engines lose a lot of power. To retain power vehicle owners adjust the air-fuel ratio thereby over-fuelling the car or driving in higher revolutions increasing fuel consumption as well as increasing significantly PM emissions.
- Controlling and enforcing adequate vehicle maintenance and vehicle inspection programs is far more complex and costly for diesel than for gasoline engines. The snap-on test used for diesel engines has limited reliability and depends basically on how the test is performed. Controls are very easily circumvented and on-road controls are costly and complex. Therefore, IM programs often fail with diesel vehicles.
- Vehicle degradation results in significantly higher PM and NO_2 emissions of passenger cars and light duty vehicles (not however of HDVs). The chart below shows as example typical vehicle degradation curves of pollutants. Real world emissions can therefore be factor 4 times or higher with an increasing vehicle age.

Figure 28: Typical Vehicle Emission Deterioration Rates (Passenger cars, NO_x)



Source: Borken-Kleefeld, 2016, Figure 3

- Maintenance of diesel engines is far more critical and complex than of gasoline ones. This results often in far higher actual emissions than if the vehicle would be maintained well. The required emission control devices including DPFs for Euro 6

[94] Walsh, 2017

[95] EEA, 2016, Table 3-47

require regular specialized maintenance. For NO_2 reduction most vehicles use an additive. If the DPF is not maintained properly or if the additive is not added to the engine, latter will continue to work and deliver power but the emissions will skyrocket reaching Euro 2 levels. Therefore, actual emissions of Euro 6 vehicles, if badly maintained, can be comparable to Euro 2 engines. Even with a strict enforcement and control system, random roadside checks performed in Santiago have shown that emission control equipment of diesel engines is often not working properly[96].

Based on above the slogan of “clean diesel” is nothing more than a marketing gag. Diesel vehicles are dirty and will also in the future be a major headache. Even with best available diesel technologies, the real-world performance of diesel engines results in high PM and NO_2 emissions creating air pollution and health problems. This fact is increasingly being recognized worldwide:

- A senior EU civil servant has called the EUs diesel-vehicle emissions policy an almost complete failure. He also stated that absolute NO_x emissions of diesel vehicles under real driving conditions have hardly changed despite all regulations[97].
- The government’s Chief Medical Officer of the UK Dame Sally Davies has called for a phase out of diesel vehicles as these cause tens of thousands of deaths each year[98].
- Oslo banned due to serious air pollution all diesel vehicles on municipal roads during a time of January 2017. This was due to very high levels of smog caused by NO_2 emissions. The ban was only levied on diesel vehicles and on all Euro categories.
- 4 major world-class cities (Mexico City, Madrid, Athens and Paris) will ban by 2025 diesel cars and vans from circulating in the city[99]. London will require from 04.2017 that diesel vehicles pay double the parking fee of gasoline vehicles[100]. The Institute for Public Policy Research indicated in a report released in 2016 that it is likely that diesel cars must be completely phased out on London’s roads over the next decade to reach compliance with safe and legal levels of air pollution[101].
- The National Green Tribunal in India has issued an order in July 2016 to ban more than 10-year-old diesel vehicles in Delhi[102].
- The Swiss Investment Bank UBS has made the claim that diesel cars will disappear from the global market by 2025 due to pollution problems[103].

Bhutan would not be the first or only country to restrict usage of diesel. Brazil, one of the largest vehicle markets in the world, completely banned small diesel cars in the 1970s[104].

Whilst more than a decade ago diesel vehicles were promoted as a “solution” to reduce GHG emissions, this policy has now been widely acclaimed as a mistake. The positive GHG impact is also

96 Grütter, 2015
97 Walsh, 2017
98 http://www.telegraph.co.uk/news/2016/12/30/diesel-cars-should-phased-stop-pollution-deaths-says-chief-medical/
99 http://www.bbc.co.uk/news/science-environment-38170794
100 http://www.dailymail.co.uk/news/article-4165882/Diesel-drivers-London-pay-50-percent-park.html
101 Pinner et.al, 2016
102 http://indianexpress.com/article/india/india-news-india/ngt-directs-delhi-govt-to-ban-10-yr-old-diesel-vehicles/
103 http://www.ibtimes.co.uk/electric-cars-vw-scandal-will-cause-diesel-sales-almost-disappear-1596077
104 http://www.theicct.org/blogs/staff/brazil-not-ready-for-diesel-cars; the policy is currently under revision due to pressure of the car industry and associated companies operating in Brazil including Bosch “famous” for its active and critical participation in “Dieselgate” see ICCT, 2016b

much smaller than originally estimated as the dieselization in Europe has shown that consumers buy higher powered and larger diesel vehicles thereby resulting in higher fuel consumption[105]. Many European countries subsidized relative to petrol diesel fuel which has resulted in a very high share of diesel cars and the corresponding air pollution problems. Other countries such as Switzerland or the US, aware of the environmental hazards of diesel cars, never followed such a policy and taxed diesel at the same rate as gasoline resulting in much lower diesel shares in the vehicle population[106].

Diesel cars are not required. Any diesel car could be replaced with an equivalent gasoline car. The US, the largest car market in the world, has less than 3% diesel passenger cars and SUVs[107]. Bolivia, a country landlocked and with a small vehicle number and in a comparable economic situation as Bhutan has virtually no diesel vehicles with less than 3.5t[108]. Brazil, banned diesel cars in the 70[ies]. It is therefore obvious that there is no technical requirement for using diesel except for HDVs.

The policy proposed is for Bhutan to restrict as of 01/2018 the import and sale of any diesel cars with a weight of less than 3.5t Diesel engines would only be permitted for vehicles with a weight > 3.5t (primarily trucks and buses). All other vehicles must be gasoline, gas or electric powered. Small diesel vehicles imported prior 01/2018 could continue to circulate without restrictions.

Policy Proposal Diesel Vehicles:
From 01.2018 onwards Bhutan will not allow the registration of diesel powered vehicles with a Gross Vehicle Weight of less than 3.5 tons. Previously registered diesel vehicles can continue to circulate.

5.8.2. Policy Impact

The policy impact is calculated based on all passenger cars and taxis entering the country after 01/2018 being gasoline units. For gasoline units, it is assumed that these would have a slightly smaller engine (based on the European experience) with the same Euro standard as diesel engines.

The environmental impact of the policy is that total PM emissions can be reduced by 25% as of 2030 without a negative impact on GHG emissions[109]. Urban air pollution of PM and SO_2 can be reduced by more than 50% and NO_2 emissions by around 1/3[rd].

Currently diesel vehicles, especially for larger cars and if used with a high mileage, are more economic than gasoline vehicles. This is basically due to the lower price of diesel fuel compared to gasoline which again is due to diesel fuel being subsidized relatively to gasoline currently in India[110]. At world market conditions and with equal taxing of all fuels relative to its energy content, low-sulphur diesel is more

[105] Zachariadis, 2013; gasoline cars would have been bought with smaller engines
[106] E.g. in Switzerland end of the nineties a parliamentary motion launched by fuel importers wanted to promote diesel vehicles by reducing the tax on diesel fuel arguing that this would reduce GHG emissions; however, the motion was rejected due to the potential increase of pollutants caused by diesel vehicles based on a study performed by Infras/Grütter Consulting
[107] http://www.bbc.co.uk/news/world-us-canada-34329596
[108] Bolivia produces petrol and gas but must import diesel; this has resulted in diesel prices being equivalent or higher than petrol prices and sometimes limited availability of diesel; customers therefore prefer buying gasoline or CNG vehicles.
[109] Including BC GHG emissions would even reduce slightly.
[110] Taxes levied on fuels are not equal: as of January 2017, petrol pays in India an excise duty tax of INR 21.48 per litre and diesel INR 17.33; the VAT of petrol is 27% and of diesel 18%.

expensive than gasoline[111]. Excluding subsidies i.e. with diesel prices higher than gasoline prices, diesel vehicles would only be attractive for users with a very high mileage as only then will fuel savings compensate the higher maintenance cost and the higher vehicle investment cost of diesel units. If a diesel or gasoline vehicle will result more expensive or not depends on factors such as differential investment, differential maintenance costs, fuel efficiency, annual mileage, fuel price and capital cost. The following table shows the parameters and values used for the economic calculations.

Table 27: Parameters for Economic Calculations of Restricting Diesel Cars

Parameter	Value	Comment
Incremental investment for diesel car	USD 2,000	Based on differential cost of diesel versus gasoline cars[112]
Annual maintenance sur-cost diesel car	USD 50/a	Slightly less frequent maintenance of diesel cars but more expensive maintenance and repairs; as example diesel cars will require DPF replacement after around 100,000km as well as turbo repairs and injectors which petrol cars do not require
Fuel usage diesel car	8.6 l/100km	Corinair, 2016, Table 3-27, based on Euro 1 to 3, > 2.0 litre
Fuel usage gasoline car	10.3 l/100km	Corinair, 2016, Table 3-27, based on average Euro 1 to 3, 1.4-2.0 and >2.0 litre
Diesel cost	0.86 USD/l	Fuel price at pump station in Bhutan as of January, 2017
Gasoline cost	1.01 USD/l	
Annual savings fuel cost of diesel car	276 USD/a	Calculated based on the average annual mileage driven by cars and taxis, the specific fuel consumption and the fuel costs of Bhutan[113]
Commercial lifespan	10 years	Commercial life-span is shorter than technical life-span; this is used to consider discounting over time
Annual sur-cost of gasoline cars	26 USD/a	Incremental cost of a gasoline versus a diesel car at above specified values per annum.

Source: Grütter Consulting

At current relative fuel prices, customers in Bhutan choose to procure a diesel car except for very small models. The table above shows that this decision is rational at current prices as the diesel car in general will have lower TCO than a comparable gasoline unit. The higher the annual mileage the larger the difference will be. However, this choice will become less obvious in the future due to price hikes of diesel cars with the introduction of Euro 4 and Euro 6 (these affect the cost of diesel cars more than of gasoline ones) and a probable price hike of diesel fuel as India intends to phase out diesel subsidies.

The following table shows the economic cost of a policy based on restricting new diesel cars.

Table 28: Economic Profitability of Policy Measure Restriction of Diesel Vehicles

Parameter	Cumulative Benefit (+) or Cost (-) in MUSD (2018-2030)
Value PM, NO_2 and SO_2 reduction	8.3
Value GHG reduction	6.5
Additional cost vehicles (investment plus operations)	-9.0
Balance	**5.9**

Source: Grütter Consulting

[111] Switzerland is one of the only countries worldwide with uniform taxation of diesel and fuel based on its energy contents with the resultant that diesel is at the pump station more expensive than gasoline. The country not surprisingly has one of the lowest share of diesel cars in Europe.

[112] See e.g. http://www.which.co.uk/reviews/cars/article/how-to-choose-between-petrol-and-diesel; http://www.carbuyer.co.uk/tips-and-advice/112073/petrol-or-diesel

[113] annual mileage based on passenger cars and taxis relative to the share of vehicles

The policy has a positive cost-benefit relation. Whilst it will cost the individual car owner slightly more, the society in general will have benefits due to reduced air pollution and health costs which surpass the additional cost born by the car owner.

The fiscal impact of the policy is expected to be neutral. Slightly lower vehicle import tax revenues (due to lower price of gasoline vehicles) are offset through slightly increased fuel sales revenues (due to increased fuel usage and higher petrol price).

5.8.3. Complexity and Risk

The measure is simple and easy to control. It requires a regulation stating that as of January, 1st 2018 the importation and sale of diesel powered light vehicles is not permitted. Medium and heavy vehicles as defined by RSTA could still be diesel powered. Existing diesel vehicles would still be allowed to operate and could still be re-sold as used vehicles but no new light diesel vehicles could be imported anymore.

The risk of the measure is potentially a certain resistance of car dealers and importers who prefer diesel models. However, for all light vehicle applications gasoline versions are available with comparable specifications and at a lower investment price.

5.8.4. Conclusions

It is recommended to implement this measure. The environmental benefits are obvious and in practice probably much higher due to actual on-road emissions of diesel cars being far higher than stated emissions under controlled (and manipulated) test situations. Bhutan will not be able to attain the goal of clean air whilst having large diesel fleets. Diesel should be restricted to vehicles where currently alternatives lack or are very costly i.e. HDVs. For light vehicles petrol alternatives are available. Petrol vehicles are environmentally, also with the most stringent regulations, far better than diesel vehicles and come at a comparable total cost of ownership. Even considering climate aspects, it is not justified to foster diesel vehicles as latter emit less CO_2 due to better fuel efficiency but emit far more Black Carbon due to $PM_{2.5}$ emissions. Euro 2 diesel vehicles as used currently in Bhutan are therefore from a GHG perspective including BC comparable to gasoline ones. Euro 6 diesel vehicles are theoretically better than gasoline ones in terms of total GHG emissions – however, this is only true if all emission control devices work per the standards, which in practice and under real driving conditions, is not the case.

The policy to prohibit the import and sale of new diesel light vehicles as of January 2018, is a bold measure and will show to the world once again that Bhutan takes the required steps to preserve a clean environment. The measure results in no technical problems, creates no problems for inhabitants as alternative petrol vehicles are widely available, is cost-effective and has a significant positive environmental impact. Also, this measure is in line with proposals made by major city majors worldwide and in line with calls from independent scientists calling for a ban of diesel vehicles.

5.9. Comparative Assessment of Policies

The following table compares the different policies discussed in terms of environmental impact, economic impact, and complexity. Per policy an overall rating is given from ++ (highly positive) to -- (highly negative).

Table 29: Comparison of Proposed Policies

ID	Policy	Environmental Impact		Economic Impact	Complexity, Risk	Overall Rating
		Pollutants	GHG			
1	Low sulphur fuels	++	0	--	Low	+
2	Euro 4 and 6 emission standards	+++	++	++	Low	++
3a	IM upgrading	0	0	0	High	0
3b	IM240 (loaded tests)	0	0	--	Very high	--
4	Promotion of low-carbon vehicles	+	+++	--	Low	++
5	DPF retrofit	+	+	---	Very high	--
6	Limit vehicle lifetime to 10 years taxi and 12 years other vehicles	+++	0	---	Very high	--
7	Diesel powered vehicles are only allowed for vehicles > 3.5t	+	+	++	Low	++

Rating:
Pollutants based on reduction relative to BAU for 2030; average of $PM_{2.5}$, NO_2, and SO_2 weighting $PM_{2.5}$ double: +++ > 30% reduction; ++ 20-30% reduction; + >10% reduction; 0 0-10% reduction; - increase
GHG based on CO_2 incl. BC reduction relative to BAU for 2030: +++ > 10% reduction; ++ 5-10% reduction; + 1-5% reduction; <1% reduction; - increase
Economic impact based on annual savings for 2030: +++ > 2 MUSD; ++ 1-2 MUSD; + 0.5-1 MUSD; 0 0-0.5 MUSD; - additional costs up to 1 MUSD; -- additional costs 1-5 MUSD: --- additional costs > 5 MUSD

Highly positive policies are upgrading emission standards of vehicles together with low-sulphur fuels (without low-sulphur fuels higher emission standards cannot be implemented therefore these policies are inter-related), promotion of low-carbon vehicle technologies and restricting diesel vehicles. Also, these policies are complementary as emission standards and low sulphur fuels basically reduce air pollutants whilst low-carbon vehicles basically reduce GHG emissions. Restricting diesel vehicles has a major impact in urban areas. Additionally, improving the current IM procedures is considered a useful policy option. Implementing IM240 or loaded gasoline tests, DPF retrofit and limiting the vehicle lifetime except eventually for taxis and buses are not considered useful policies due either to a very limited environmental impact and/or due to very high economic costs and complexity.

5.10. Combined Policy Option

5.10.1. Policy Combination

The following combination of policies is assessed[114]:

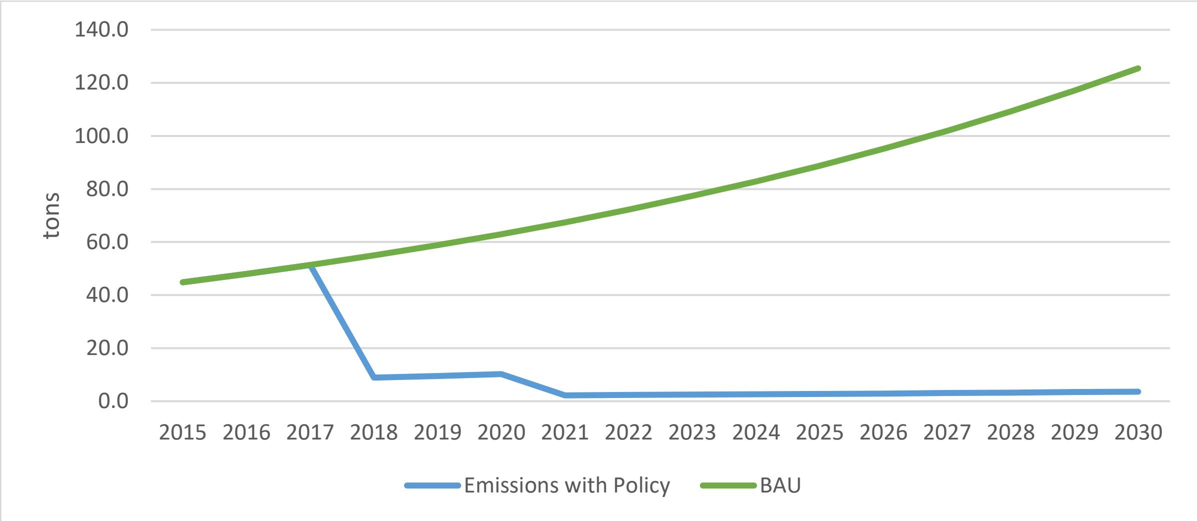
- Introduction of low-sulphur fuels in accordance with the Indian fuel standards;
- Introduction of Euro 4 and Euro 6 emission standards in accordance with the Indian emission standards;
- Improved IM system without switching to loaded tests;
- Promotion of low-carbon vehicle technologies with targets for hybrids, plug-in hybrids and electric vehicles;
- Limit the import of diesel vehicles to those with a GVW of > 3.5t;
- Age limit of taxis and buses as currently for fossil powered vehicles and longer age limits for low-carbon units (hybrids, plug-in hybrids and electric units).

[114] In accordance with the policies described in the respective sections

5.10.2. Environmental Impact of a Combined Policy Effort

The impact of combining different policies is not summative. Therefore, the environmental and the economic impact of combining measures is assessed. Also, an assessment on the pollution impact on urban areas is realized. The following graph shows the impact on the different emissions of a combined policy.

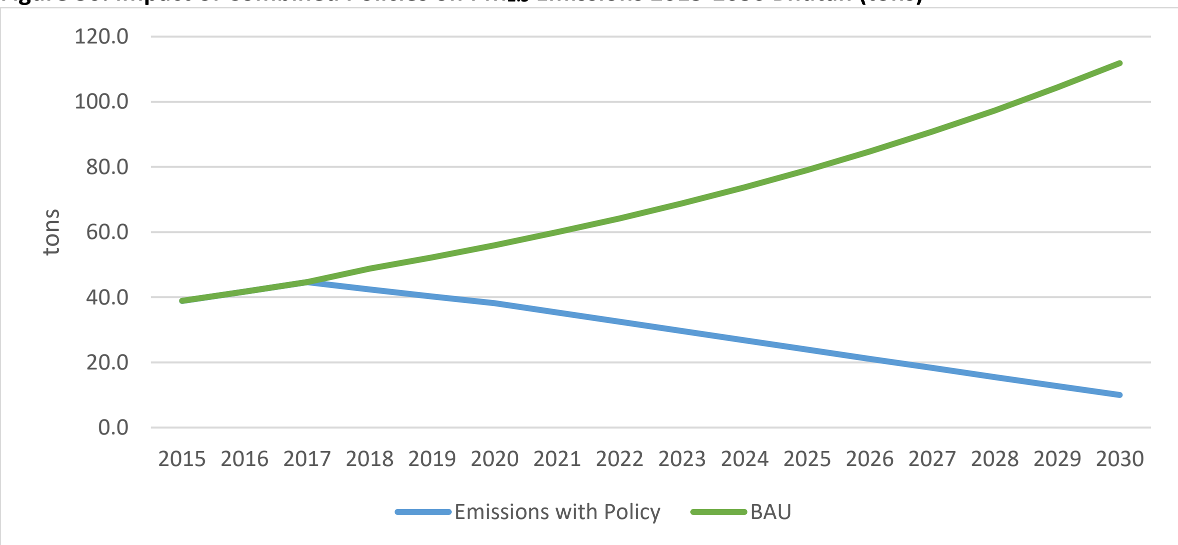
Figure 29: Impact of Combined Policies on SO_2 Emissions 2015-2030 Bhutan (tons)



Source: Grütter Consulting

SO_2 emissions can be reduced by 97% relative to BAU by 2030. Emissions by 2030 would be less than 10% of what emissions are currently i.e. no more air quality problems concerning SO_2 from transport could be observed.

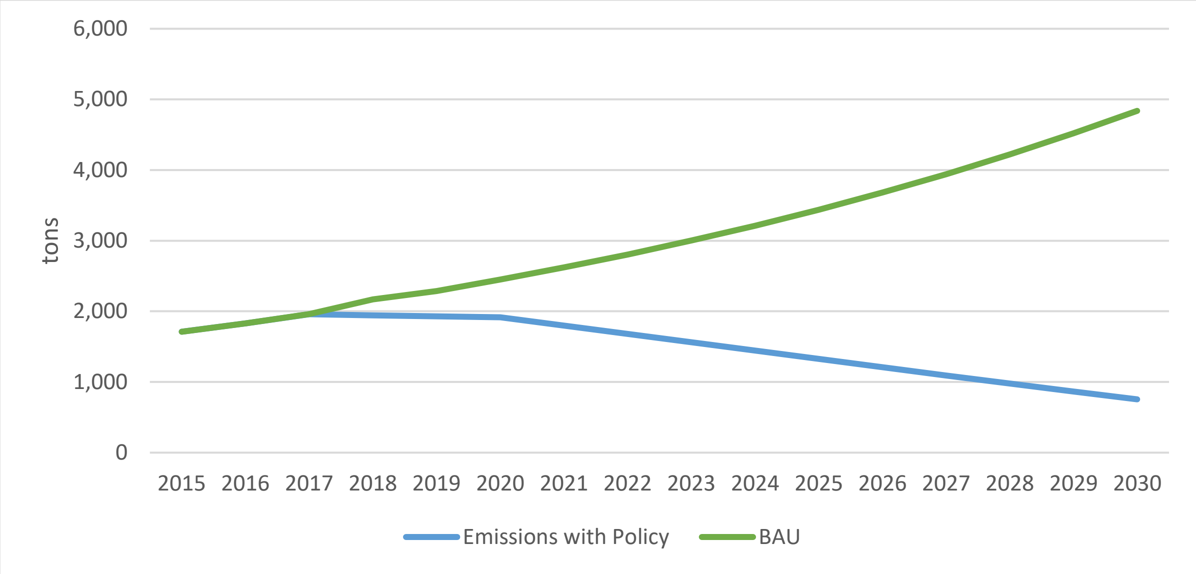
Figure 30: Impact of Combined Policies on $PM_{2.5}$ Emissions 2015-2030 Bhutan (tons)



Source: Grütter Consulting

$PM_{2.5}$ emissions can be reduced by 91% relative to BAU by 2030. Emissions by 2030 would be around 25% of what emissions are currently i.e. air quality problems concerning $PM_{2.5}$ from transport would be largely controlled.

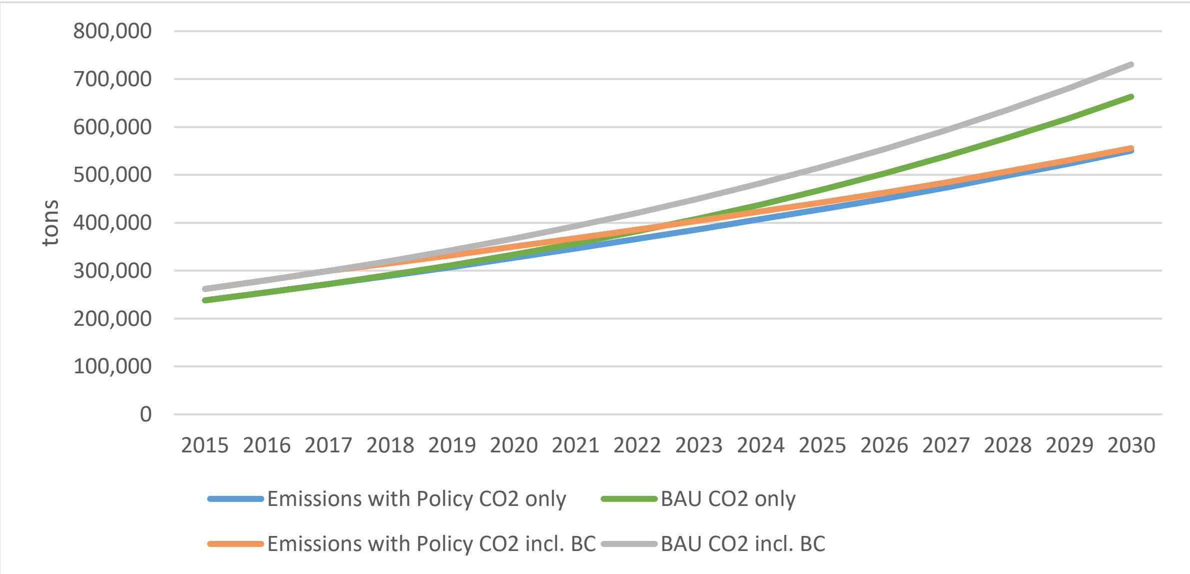
Figure 31: Impact of Combined Policies on NO_2 Emissions 2015-2030 Bhutan (tons)



Source: Grütter Consulting

NO_2 emissions can be reduced by 84% relative to BAU by 2030. Emissions by 2030 would be around 40% of what emissions are currently i.e. air quality problems concerning NO_2 from transport would be largely controlled.

Figure 32: Impact of Combined Policies on CO_2 Emissions (incl./excl. BC) 2015-2030 Bhutan (tons)



Source: Grütter Consulting

CO_2 emissions can be reduced by 17% excluding BC and 24% incl. BC relative to BAU by 2030. Emissions by 2030 would still be around factor 2.8 higher than currently i.e. the combined policies on vehicle emissions have an important impact on reducing relative to BAU GHG transport emissions but are by far not enough to stabilize or even reduce in absolute terms GHG emissions compared to current levels. The policy with the largest positive impact is on hybrid and electric vehicles. The impact of the policy is however only felt over time due to vehicle stock replacement. Also, HDVs, which represent more than 50% of fuel consumption, are largely not included in this policy due to current lack of commercially viable hybrid and electric trucks. Therefore, other policies e.g. in the realm of fostering urban public transport or a green freight strategy, are required to control GHG transport emissions.

The following table shows estimated urban pollution caused by transport based on the same assumptions as detailed in chapter 3.2. concerning usage in urban areas per vehicle category.

Table 30: Estimated Urban Emissions of Pollutants, Bhutan 2030 (tons)

Pollutant	Emissions 2015 (t)	Emissions BAU 2030 (t)	Emissions with policies 2030 (t)	Reduction relative to 2015	Reduction relative to BAU
$PM_{2.5}$	13.4	38.1	3.7	72%	90%
NO_2	464	1,287	204	56%	84%
SO_2	17	48	1	92%	97%

Source: Grütter Consulting

Urban emissions can be reduced by around 90% compared to the BAU scenario by 2030 and relative to 2015 urban air pollution caused by transport can be reduced by 60-90% i.e. the combination of policies proposed is an effective instrument towards achieving and sustaining clean air in Bhutan.

5.10.3. Economic and Fiscal Impact of a Combined Policy Effort

The following table shows the summarized combined economic impact of the proposed policy combination.

Table 31: Economic Impact of Combined Policy Measures (in MUSD)

Parameter	Cumulative Benefit (+) or Cost (-) in MUSD (2018-2030)
Value PM, NO_2 and SO_2 reduction	39
Value GHG reduction	37
Additional cost fuel	-18
Additional cost vehicles[115]	-69
Additional cost IM	-3
Balance	**-14**
Balance excl. additional fuel costs	**4**

Source: Grütter Consulting

The value of pollution and GHG reductions are comparable at around 40 MUSD cumulative or on average annually 3 MUSD from 2018-2030. The additional costs are basically on the vehicle side being the cost of higher emission standards, the cost of restricting diesel cars and the cost of low-carbon vehicles. The highest share by far is thereby the cost of electric vehicles. Overall the policy measures have an economic cost of 14 MUSD or 1 MUSD on average per year. However, excluding fuel sur-costs the impact is positive with 4 MUSD cumulative or around 0.3 MUSD per annum. This is relevant as the fuel quality decision is taken by India and the sur-costs are simply passed on to Bhutan i.e. Bhutan will have these sur-costs anyway, also under a BAU scenario. Therefore, the real economic impact of the combined policy is positive.

In fiscal terms the government would only have marginal additional costs being:

- Marginally higher supervision and control costs for fuel quality and for the improved IM system estimated at less than 0.1 MUSD per annum;
- Marginally higher costs for operating government vehicles in line with increasing costs of private vehicle owners.

[115] Due to higher emission standards and hybrids, plug-in hybrids as well as electric vehicles plus no diesel vehicles

The polluter pays principle can be fully followed without major problems including:

- Fuel prices are adjusted to actual fuel cost of imports;
- Vehicle prices and sur-costs of vehicles with higher emission standards are paid by vehicle owners;
- IM costs are paid through charges for inspections.

The low carbon vehicle strategy will however require incentives for vehicle buyers to purchase hybrid, plug-in hybrid and electric vehicles. Current incentives are not sufficient to achieve a trend towards such vehicles. These policies can however be formulated in a fiscal neutral manner by providing investment incentives to buyers of low-carbon vehicles and increasing proportionally registration or import taxes on fossil fuel powered vehicles i.e. buyers of conventional vehicles pay the incentives for low-carbon vehicles. A market-based incentive system is thereby considered as more promising than setting regulations which do not allow procurement of conventional vehicles.

36 MUSD or 40% of the total additional cost are due to electric vehicles. This represents by far the most expensive policy in economic terms but is also justified primarily by the GHG reduction. However, the economic costs of the measure could be financed partially by climate finance.

5.11. Recommendations

Based on the positive economic and environmental impacts it is proposed to implement the following policies and strategies.

Recommended Policies

1. Follow the Indian fuel standards and import 50ppm sulphur diesel and gasoline as of 01.2018 and 10ppm sulphur diesel and gasoline as of 01.2021. Bhutan only imports fuel from India and has no influence on the fuel standard. Still it is recommended to establish a regulation that the Indian standard for fuels will be followed to prevent lower quality fuels from being imported and to establish a quality assurance guideline to reduce fuel tampering and to ensure the public of appropriate fuel quality.

2. Implement in line with India new vehicle emission standards for gasoline and diesel vehicles requiring as of 01.2018 BS-IV (equivalent to Euro 4) and as of 01.2021 BS-VI (Euro 6). Imported vehicles must have the appropriate documentation to proof compliance with this standard to avoid that sub-standard vehicles (not allowed for circulation in India) are imported to Bhutan.

3. Restrict the import and sale of diesel powered cars and light commercial vehicles with less than 3.5t GVW as of 01.2018.

4. Continue the current IM system but require all new vehicles from 01.2018 to be equipped with OBD. This will allow to change from a system of measuring emissions to a system of controlling vehicle based data. The current system should be upgraded concerning emission limits, on-line data transmission, technical norms for measurement procedures of diesel vehicles, improved controls of inspection procedure through on-line camera supervision and improved enforcement linking IM tighter with vehicle registration and tax payment.

5. Keep the current age limit of commercial conventional fossil fuel powered taxis and buses at 9 and 14 years respectively. For hybrids, the age limit could be expanded to 12 years for taxis and 15

years for buses, for plug-in hybrids to 15 years for taxis and 20 years for buses and for electric vehicles to 20 years.

6. Establish a low-carbon vehicle strategy with a focus on urban vehicles including taxis, buses and urban delivery trucks. The strategy should include hybrid, plug-in hybrid and electric vehicles with clear vehicle uptake targets.

The following policies are not recommended for implementation due to a limited environmental impact and/or a highly negative economic impact and/or due to a high complexity and risk.

Rejected/Not Recommended Policies

1. Extension or upgrading to loaded vehicle testing of IM. This policy is rejected due to a limited environmental impact (only gasoline vehicles and limited emission reductions), a high additional cost of 1-2 MUSD compared to the current system and the complexity of implementing and enforcing IM programs.

2. Realizing a retrofit program for DPFs due to its very high economic cost (on average 17 MUSD per annum) and the high complexity and risk of low performance or equipment failure with retrofit installations, especially in elder engines and at high altitude.

3. Limiting the age of private vehicles or HDVs and/or realizing a scrapping program for elder vehicles due to the limited environmental impact (only on differential years and limited impact of tear and wear especially in HDVs) and the very high economic costs of on average 40 MUSD per annum which would probably have to be borne at least partially with fiscal moneys to be politically feasible.

Annex 1: Vehicle Emission Data

1. General Technical Input Parameters

Parameter	Value	Unit	Source
NCV of diesel	43	MJ/kg	IPCC, 2006, table 1.2
CO_2 emission factor of diesel	74.1	gCO_2/MJ	IPCC, 2006, table 1.4
Density of diesel	0.844	kg/l	IEA, 2005
NCV of gasoline	44.3	MJ/kg	IPCC, 2006, table 1.2
CO_2 emission factor of gasoline	69.3	gCO_2/MJ	IPCC, 2006, table 1.4
Density of gasoline	0.741	kg/l	IEA, 2005
GWP100 of BC (total effect incl. direct and Cryosphere effect)	900		World Bank, 2014a

2. Vehicle Parameters

PM is $PM_{2.5}$

Nitrogen oxides are given as NO_2 equivalent

Tier 2 method is used as mean vehicle speed is not known

Passenger Cars

Parameter	Value	Unit	Source
Specific fuel consumption gasoline cars	7.6	l/100km	Corinair, 2016, Table 3-27, based on Euro 1 to 3, 0.8-1.4l
Specific fuel consumption diesel cars	8.6	l/100km	Corinair, 2016, Table 3-27, based on Euro 1 to 3, >2.0l
PM emissions gasoline cars	0.002	g/km	Corinair, 2016, Table 3-18, based on Euro 2, 0.8-1.4l
PM emissions diesel cars	0.055	g/km	Corinair, 2016, Table 3-18, based on Euro 2, >2.0l
NO_2 equivalent emissions gasoline cars	0.229	g/km	Corinair, 2016, Table 3-17, based on Euro 2, 0.8-1.4l
NO_2 equivalent emissions diesel cars	0.716	g/km	Corinair, 2016, Table 3-17, based on Euro 2, >2.0l
BC fraction diesel cars	80%		Corinair, 2016, Table 3-117, based on Euro 2, passenger car BC fraction in PM2.5
BC fraction gasoline cars	25%		Corinair, 2016, Table 3-117, based on Euro 2, passenger car BC fraction in PM2.5
Average annual distance driven passenger cars	9,000	km	Same amount assumed for gasoline and diesel vehicle; Value calibrated with fuel usage
Number of gasoline cars	27,320	cars	RSTA, annual report 2014-15, table viii as of mid 2015 for total number of passenger cars: fuel share based on RSTA statistics
Number of diesel cars	18,213	cars	

Note: Diesel and gasoline vehicle engine size based on average registered fleet in Bhutan

Taxis

Parameter	Value	Unit	Source
Specific fuel consumption gasoline taxis	7.6	l/100km	Corinair, 2016, Table 3-27, based on Euro 1 to 3, 0.8-1.4l
Specific fuel consumption diesel taxis	8.6	l/100km	Corinair, 2016, Table 3-27, based on Euro 1 to 3, >2.0l
PM emissions gasoline taxis	0.002	g/km	Corinair, 2016, Table 3-18, based on Euro 2, 0.8-1.4l
PM emissions diesel taxis	0.055	g/km	Corinair, 2016, Table 3-18, based on Euro 2, >2.0l
NO_2 equivalent emissions gasoline taxis	0.229	g/km	Corinair, 2016, Table 3-17, based on Euro 2, 0.8-1.4l
NO_2 equivalent emissions diesel taxis	0.716	g/km	Corinair, 2016, Table 3-17, based on Euro 2, >2.0l
BC fraction gasoline taxis	25%		Corinair, 2016, Table 3-117, based on Euro 2, passenger car BC fraction in PM2.5
BC fraction diesel taxis	80%		Corinair, 2016, Table 3-117, based on Euro 2, passenger car BC fraction in PM2.5
Average annual distance driven taxis	25,000	km	Value calibrated with fuel usage
Number of gasoline taxis	3,302	taxis	RSTA, annual report 2014-15, table viii as of mid 2015; fuel share based on RSTA statistics
Number of diesel taxis	537	taxis	

Motorcycles

Parameter	Value	Unit	Source
Specific fuel consumption motorcycles	4.9	l/100km	Corinair, 2016, Table 3-27, based on Euro 1 to 3, <250cm^3, 4-stroke
PM emissions motorcycles	0.0035	g/km	Corinair, 2016, Table 3-26, based on Euro 2, <250cm^3, 4-stroke
NO_2 equivalent emissions motorcycles	0	g/km	Corinair, 2016, Table 3-25, based on Euro 2, <250cm^3, 4-stroke
BC fraction motorcycles	25%		Corinair, 2016, Table 3-117, based on Euro 2, fraction in PM2.5
Average annual distance driven motorcycles	4,000	km	Value calibrated with fuel usage
Number of motorcycles	10,275	motorcycles	RSTA, annual report 2014-15, table viii as of mid 2015

Note: all motorcycles 4-stroke based on legislation since 1996; all motorcycles gasoline

HDVs < 7.5t (in registration called midi vehicles)

Parameter	Value	Unit	Source
Specific fuel consumption HDV < 7.5t	12.0	l/100km	Corinair, 2016, Table 3-27, based on Euro I and later
NO_2 equivalent emissions HDV < 7.5t	3.49	g/km	Corinair, 2016, Table 3-21, based on Euro II
PM emissions HDV < 7.5t	0.061	g/km	Corinair, 2016, Table 3-22, based on Euro II
BC emissions HDV < 7.5t	0.040	g/km	Corinair, 2016, Table 3-117, based on Euro II, HDV 65% BC fraction in PM2.5
Average annual distance driven HDV < 7.5t	29,000	km	Value calibrated with fuel usage
Number of HDV < 7.5t	1,457	vehicles	RSTA, annual report 2014-15, table viii as of mid 2015

Note: 100% HDVs diesel based on RSTA

HDVs 7.5-16t (includes urban buses and coaches)

Parameter	Value	Unit	Source
Specific fuel consumption HDV7.5-16t	18.4	l/100km	Corinair, 2016, Table 3-27, based on Euro I and later
NO_2 equivalent emissions HDV 7.5-16t	5.5	g/km	Corinair, 2016, Table 3-21, based on Euro II
PM emissions HDV 7.5-16t	0.104	g/km	Corinair, 2016, Table 3-22, based on Euro II
BC emissions HDV 7.5-16t	0.068	g/km	Corinair, 2016, Table 3-117, based on Euro II, HDV 65% BC fraction in PM2.5
BC fraction HDVs	65%		Corinair, 2016, Table 3-117, based on Euro II
Average annual distance driven HDV	29,000	km	Value calibrated with fuel usage
Number of HDVs heavy	8,537	vehicles	RSTA, annual report 2014-15, table viii as of mid 2015

Note: 100% HDVs diesel based on RSTA

3. Fuel Consumed

Parameter	Value	Unit	Source
Gasoline	26.79	Million liter	NSB, National Account Statistics, 2016, table 30; value for 2015; excludes agriculture, industry and Indian vehicles (called re-export)
Diesel	65.87	Million liter	

4. Fuel Emissions

Parameter	Value	Unit	Source
Diesel fuel sulphur contents	350	ppm	Indian BS III standard
Gasoline fuel sulphur contents	150	ppm	
SO_2 emissions per liter of diesel	0.590	gSO_2/l	Based on molecular weight of S against SO_2
SO_2 emissions per liter of gasoline	0.222	gSO_2/l	

5. Economics

Parameter	Value	Unit	Source
Social cost of carbon SCC (CO_2)	40	USD/t	IMF, 2014, p.67 has a SCC of USD 35 with USD 2007 which corresponds to 40 USD USD of 2015
Cost of SO_2	1,560	USD/t	Median levels of ground level local pollution Asia and Oceania; includes countries reported with values excluding Australia, Brunei, Japan, Korea, Singapore and Taiwan; IMF, 2014, Table A.4.2.1. (USD 2010 converted to USD 2015 using http://stats.areppim.com/calc/calc_usdlrxdeflator.php)
Cost of NO_2	330	USD/t	
Cost of PM	45,698	USD/t	

Results Base Year 2015

1. GHG Emissions

Parameter	Value	Unit	share
Excluding Black Carbon			
Passenger cars	80,399	tCO_2	34%
Taxis	17,315	tCO_2	7%
Motorcycles	4,542	tCO_2	2%
HDVs	135,868	tCO_2	57%
Total	**238,125**	**tCO_2**	
Based on consumed fuel	238,084	tCO_2	
Including Black Carbon			
Passenger cars	86,988	tCO_2	33%
Taxis	17,886	tCO_2	7%
Motorcycles	4,575	tCO_2	2%
HDVs	152,438	tCO_2	58%
Total	**261,887**	**tCO_2**	

2. PM Emissions

Parameter	Value	Unit	share	share gasoline
Passenger cars	9.5	t	24%	6%
Taxis	0.9	t	2%	20%
Motorcycles	0.1	t	0%	100%
HDVs	28.3	t	73%	0%
Total	38.9	t		2%

3. NO_2 Emissions

Parameter	Value	Unit	share	share gasoline
Passenger cars	174	t	10%	32%
Taxis	29	t	2%	66%
Motorcycles	13	t	1%	100%
HDVs	1,509	t	88%	0%
Total	1,724	t		5%

4. SO_2 Emissions

Parameter	Value	Unit	share	share gasoline
Passenger cars	12	t	28%	33%
Taxis	2	t	5%	67%
Motorcycles	0	t	1%	100%
HDVs	30	t	67%	0%
Total	**45**	t		13%

Urban Impact of Pollution (aproximation; not only Thimphu but all urban areas)

Urban usage of passenger cars	70%	Assumption Grutter; share of mileage
Urban usage of taxis	100%	
Urban usage of motorcycles	90%	
Urban usage of HDVs	20%	

Urban Estimated Emissions

Parameter	PM		NO_2		SO_2	
	Value in tons	share	Value in tons	share	Value in tons	share
Passenger cars	6.7	50%	122	27%	9	51%
Taxis	0.9	7%	29	6%	2	12%
Motorcycles	0.1	1%	0	0%	0	2%
HDVs	5.7	42%	302	67%	6	35%
Total	**13.4**		**452**		**17**	

Pollution costs

	Value in MUSD	share	share gasoline vehicles
Passenger cars	3.7	31%	47%
Taxis	0.7	6%	100%
Motorcycles	0.2	2%	100%
HDVs	7.3	61%	0%
Total	**11.9**		**22%**

	Value in MUSD	share
PM	1.78	15%
NO_2	0.56	5%
SO_2	0.07	1%
CO_2	9.52	80%
Total	**11.94**	

BAU and Projection Parameters		
Core assumptions BAU:		
1. CAGR of passenger car and motorcycle growth based on historic growth level		
2. CAGR of HDV and taxi growth based on projected GDP growth		
3. Fuel standards based on India		
4. Same share of fuels as 2015		
5. Same vehicle categories and classes as 2015		
6. All vehicles assumed as Euro II i.e. not adaption to emission standard		

Projection Parameters

Parameter	Value	Unit	Source
CAGR passenger car and motorcycle growth	8%		Average growth rate 2010 to 2016 all vehicles based on RSTA
CAGR taxi growth	1%		Average growth rate 2010 to 2015 of taxis based on RSTA
CAGR HDV growth	7%		Based on GDP growth projections with elasticity of 1; http://www.tradingeconomics.com/bhutan/forecast
Introduction year BS IV	2018		India is expected to introduce nationwide BS IV by 04/2017 (notification MRTH India)
Introduction year BS VI	2021		India is expected to introduce nationwide BS VI by 04/2020 (notification MRTH India)
sulfur level gasoline BS IV	50	ppm	http://transportpolicy.net/index.php?title=India:_Fuels:_Diesel_and_Gasoline
sulfur level gasoline BS VI	10	ppm	
sulfur level diesel BS IV	50	ppm	
sulfur level diesel BS VI	10	ppm	
Specific fuel consumption gasoline cars Euro IV and later	7.6	l/100km	Corinair, 2016, Table 3-27,0.8-1.4l
Specific fuel consumption diesel cars Euro IV and later	8.6	l/100km	Corinair, 2016, Table 3-27, >2.0l
PM emissions gasoline cars Euro IV	0.001	g/km	Corinair, 2016, Table 3-18, 0.8-1.4l
PM emissions gasoline cars Euro VI	0.001	g/km	Corinair, 2016, Table 3-18, 0.8-1.4l
PM emissions diesel cars Euro IV	0.031	g/km	Corinair, 2016, Table 3-18, >2.0l
PM emissions diesel cars Euro VI	0.002	g/km	Corinair, 2016, Table 3-18, , >2.0l
NO_2 equivalent emissions gasoline cars Euro IV	0.0061	g/km	Corinair, 2016, Table 3-17, 0.8-1.4l
NO_2 equivalent emissions gasoline cars Euro VI	0.0061	g/km	Corinair, 2016, Table 3-17, 0.8-1.4l
NO_2 equivalent emissions diesel cars Euro IV	0.58	g/km	Corinair, 2016, Table 3-17, >2.0l
NO_2 equivalent emissions diesel cars Euro VI	0.5	g/km	Corinair, 2016, Table 3-17, >2.0l
BC fraction diesel cars Euro 4	87%		Corinair, 2016, Table 3-117
BC fraction diesel cars Euro 6	10%		Corinair, 2016, Table 3-117
BC fraction gasoline cars	15%		Corinair, 2016, Table 3-117
Specific fuel consumption HDV < 7.5t Euro IV and later	12.0	l/100km	Corinair, 2016, Table 3-27
NO_2 equivalent emissions HDV < 7.5t Euro IV	1.64	g/km	Corinair, 2016, Table 3-21
NO_2 equivalent emissions HDV < 7.5t Euro VI	0.18	g/km	Corinair, 2016, Table 3-21
PM emissions HDV < 7.5t Euro IV	0.0106	g/km	Corinair, 2016, Table 3-22
PM emissions HDV < 7.5t Euro VI	0.0005	g/km	Corinair, 2016, Table 3-22
Specific fuel consumption HDV7.5-16t Euro IV and later	18.4	l/100km	Corinair, 2016, Table 3-27
NO_2 equivalent emissions HDV 7.5-16t Euro IV	2.65	g/km	Corinair, 2016, Table 3-21
NO_2 equivalent emissions HDV 7.5-16t Euro VI	0.291	g/km	Corinair, 2016, Table 3-21
PM emissions HDV 7.5-16t Euro IV	0.0161	g/km	Corinair, 2016, Table 3-22
PM emissions HDV 7.5-16t Euro VI	0.0008	g/km	Corinair, 2016, Table 3-22
BC fraction HDV Euro IV	75%		Corinair, 2016, Table 3-117
BC fraction HDV Euro VI	15%		Corinair, 2016, Table 3-117
Average vehicle replacement rate of stock cars and HDVs	7%		Assumption Grutter Consulting based on averag 15e years lifespan; all vehicle categories
Average vehicle replacement rate taxis	9%		Based on maximum commercial lifespan of 11 years
Motorcycles only up to MOT-Euro 3			

BAU Scenario

Assumptions

1. Fuel standards from India
2. Euro 2 all vehicles
3. No changes fuel etc.
4. All cars compliant with standard i.e. no high emitters

NO_2 emissions																	
Passenger cars gasoline	tons	56	61	66	71	76	83	89	96	104	112	121	131	141	152	164	177
Passenger cars diesel	tons	117	127	137	148	159	172	186	200	216	234	252	272	294	317	342	370
Total passenger cars	tons	174	187	202	218	236	255	275	297	320	346	373	403	435	469	507	547
Motorcycles	tons	13	14	15	16	18	19	21	22	24	26	28	30	33	35	38	41
Taxis gasoline	tons	19	19	19	20	20	20	20	21	21	21	22	22	22	22	23	23
Taxis diesel	tons	10	10	10	41	10	10	10	11	11	11	11	11	11	11	12	12
Taxis total	tons	29	29	29	61	30	30	31	31	32	32	32	33	33	34	34	35
HDVs	tons	1,509	1,615	1,728	1,849	1,978	2,117	2,265	2,423	2,593	2,774	2,969	3,176	3,399	3,637	3,891	4,164
Total	**tons**	**1,724**	**1,845**	**1,975**	**2,144**	**2,262**	**2,421**	**2,591**	**2,773**	**2,969**	**3,178**	**3,402**	**3,642**	**3,899**	**4,175**	**4,470**	**4,786**
SO_2 emissions																	
Passenger cars gasoline	tons	4.1	4.5	4.8	5.2	5.6	6.0	6.5	7.0	7.6	8.2	8.9	9.6	10.3	11.1	12.0	13.0
Passenger cars diesel	tons	8.4	9.0	9.7	10.5	11.4	12.3	13.2	14.3	15.4	16.6	18.0	19.4	20.9	22.6	24.4	26.3
Total passenger cars	tons	12.5	13.5	14.6	15.7	17.0	18.3	19.8	21.3	23.0	24.9	26.8	29.0	31.3	33.7	36.4	39.3
Motorcycles	tons	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.3	1.4
Taxis gasoline	tons	1.4	1.4	1.4	1.4	1.5	1.5	1.5	1.5	1.5	1.6	1.6	1.6	1.6	1.6	1.7	1.7
Taxis diesel	tons	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Taxis total	tons	2.1	2.1	2.1	2.2	2.2	2.2	2.2	2.3	2.3	2.3	2.4	2.4	2.4	2.4	2.5	2.5
HDVs	tons	29.8	31.9	34.1	36.5	39.1	41.8	44.7	47.9	51.2	54.8	58.6	62.7	67.1	71.8	76.9	82.2
Total	**tons**	**44.8**	**48.0**	**51.3**	**54.9**	**58.8**	**63.0**	**67.4**	**72.2**	**77.4**	**82.9**	**88.8**	**95.1**	**101.9**	**109.2**	**117.1**	**125.5**
CO_2 emissions excl. BC																	
Passenger cars gasoline	tons	42,271	45,630	49,256	53,169	57,394	61,954	66,877	72,191	77,927	84,119	90,802	98,017	105,805	114,212	123,287	133,083
Passenger cars diesel	tons	38,127	41,157	44,427	47,957	51,768	55,881	60,321	65,114	70,288	75,873	81,901	88,409	95,434	103,016	111,202	120,038
Total passenger cars	tons	80,399	86,787	93,683	101,127	109,162	117,835	127,198	137,305	148,215	159,991	172,704	186,426	201,239	217,229	234,489	253,121
Motorcycles	tons	4,542	4,903	5,293	5,713	6,167	6,657	7,186	7,757	8,374	9,039	9,757	10,533	11,370	12,273	13,248	14,301
Taxis gasoline	tons	14,190	14,374	14,561	14,750	14,942	15,136	15,333	15,532	15,734	15,938	16,146	16,355	16,568	16,783	17,001	17,222
Taxis diesel	tons	3,125	3,166	3,207	3,249	3,291	3,334	3,377	3,421	3,465	3,510	3,556	3,602	3,649	3,696	3,745	3,793
Taxis total	tons	17,315	17,540	17,768	17,999	18,233	18,470	18,710	18,953	19,199	19,449	19,702	19,958	20,217	20,480	20,746	21,015
HDVs	tons	135,868	145,379	155,555	166,444	178,095	190,562	203,902	218,175	233,447	249,788	267,273	285,982	306,001	327,421	350,341	374,865
Total	**tons**	**238,125**	**254,610**	**272,299**	**291,283**	**311,658**	**333,525**	**356,996**	**382,190**	**409,235**	**438,268**	**469,436**	**502,899**	**538,827**	**577,403**	**618,824**	**663,302**

CO_2 emissions incl. BC																	
Passenger cars gasoline	tons	42,393	45,761	49,397	53,322	57,559	62,133	67,070	72,399	78,151	84,361	91,064	98,300	106,110	114,541	123,642	133,467
Passenger cars diesel	tons	44,595	48,138	51,963	56,092	60,549	65,360	70,553	76,159	82,211	88,743	95,794	103,406	111,622	120,491	130,065	140,400
Total passenger cars	tons	86,988	93,900	101,361	109,415	118,108	127,493	137,623	148,558	160,362	173,104	186,858	201,705	217,732	235,033	253,707	273,866
Motorcycles	tons	4,575	4,938	5,331	5,754	6,211	6,705	7,238	7,813	8,433	9,104	9,827	10,608	11,451	12,360	13,343	14,403
Taxis gasoline	tons	14,231	14,416	14,603	14,793	14,985	15,180	15,377	15,577	15,779	15,984	16,192	16,402	16,616	16,832	17,050	17,272
Taxis diesel	tons	3,655	3,703	3,751	3,800	3,849	3,899	3,950	4,001	4,053	4,106	4,159	4,213	4,268	4,324	4,380	4,437
Taxis total	tons	17,886	18,119	18,354	18,593	18,834	19,079	19,327	19,578	19,833	20,090	20,351	20,616	20,884	21,155	21,430	21,708
HDVs	tons	152,438	163,109	174,527	186,744	199,816	213,803	228,769	244,783	261,917	280,252	299,869	320,860	343,320	367,353	393,067	420,582
Total	**tons**	**261,887**	**280,066**	**299,572**	**320,505**	**342,970**	**367,079**	**392,956**	**420,732**	**450,546**	**482,549**	**516,906**	**553,789**	**593,387**	**635,901**	**681,547**	**730,560**
Pollution costs																	
Passenger cars gasoline	MUSD	1.7	1.9	2.0	2.2	2.4	2.6	2.8	3.0	3.2	3.5	3.7	4.0	4.4	4.7	5.1	5.5
Passenger cars diesel	MUSD	2.0	2.1	2.3	2.5	2.7	2.9	3.1	3.4	3.7	4.0	4.3	4.6	5.0	5.4	5.8	6.3
Total passenger cars	MUSD	3.7	4.0	4.3	4.7	5.1	5.5	5.9	6.4	6.9	7.4	8.0	8.6	9.3	10.1	10.9	11.7
Motorcycles	MUSD	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6
Taxis gasoline	MUSD	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.7	0.7	0.7
Taxis diesel	MUSD	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Taxis total	MUSD	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.9	0.9	0.9	0.9	0.9
HDVs	MUSD	7.3	7.8	8.3	8.9	9.5	10.2	10.9	11.7	12.5	13.4	14.3	15.3	16.4	17.5	18.8	20.1
Total	**MUSD**	**11.9**	**12.8**	**13.7**	**14.6**	**15.6**	**16.7**	**17.9**	**19.2**	**20.6**	**22.0**	**23.6**	**25.3**	**27.1**	**29.0**	**31.1**	**33.3**

Indexed Emissions																
Emission	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
$PM_{2.5}$	100	107	115	123	132	141	151	162	173	186	199	214	229	245	263	282
NO_2	100	107	115	124	131	140	150	161	172	184	197	211	226	242	259	278
SO_2	100	107	115	123	131	141	150	161	173	185	198	212	227	244	261	280
CO_2 incl. BC	100	107	114	122	131	140	150	161	172	184	197	211	227	243	260	279

Policy: Low Sulfur Fuels

Assumptions

1. without policy the current sulfur level remains
2. with policy from 2018 onwards 50ppm sulfur fuels and from 2021 onwards 10ppm sulfur fuels
3. no other policy is put in place specifically the emission norms are not adjusted

Resultant

Only SO2 emissions will change. These are therefore modelled.

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
SO_2 emissions with constant sulfur levels in fuels																	
Passenger cars gasoline	tons	4.1	4.5	4.8	5.2	5.6	6.0	6.5	7.0	7.6	8.2	8.9	9.6	10.3	11.1	12.0	13.0
Passenger cars diesel	tons	8.4	9.0	9.7	10.5	11.4	12.3	13.2	14.3	15.4	16.6	18.0	19.4	20.9	22.6	24.4	26.3
Total passenger cars	tons	12.5	13.5	14.6	15.7	17.0	18.3	19.8	21.3	23.0	24.9	26.8	29.0	31.3	33.7	36.4	39.3
Motorcycles	tons	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.8	0.8	0.9	1.0	1.0	1.1	1.2	1.3	1.4
Taxis total	tons	2.1	2.1	2.1	2.2	2.2	2.2	2.2	2.3	2.3	2.3	2.4	2.4	2.4	2.4	2.5	2.5
HDVs	tons	29.8	31.9	34.1	36.5	39.1	41.8	44.7	47.9	51.2	54.8	58.6	62.7	67.1	71.8	76.9	82.2
SO_2 emissions with current fuels	**tons**	**44.8**	**48.0**	**51.3**	**54.9**	**58.8**	**63.0**	**67.4**	**72.2**	**77.4**	**82.9**	**88.8**	**95.1**	**101.9**	**109.2**	**117.1**	**125.5**
SO_2 emissions with policy	**tons**	**44.8**	**48.0**	**51.3**	**8.9**	**9.5**	**10.2**	**2.2**	**2.3**	**2.5**	**2.7**	**2.9**	**3.1**	**3.3**	**3.5**	**3.8**	**4.1**
SO_2 reduction due to policy	**tons**	**0.0**	**0.0**	**0.0**	**46.0**	**49.3**	**52.8**	**65.3**	**69.9**	**74.9**	**80.2**	**85.9**	**92.0**	**98.6**	**105.7**	**113.3**	**121.4**
Economic value of SO_2 reduction	**MUSD**	**0.0**	**0.0**	**0.0**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.1**	**0.2**	**0.2**	**0.2**	**0.2**

Additional fuel cost in USD per litre

Parameter	diesel	gasoline
Reduction to 50 ppm	0.005	0.003
Reduction form 50 to 10 ppm	0.004	0.005

Source: ICCT, 2013 for India p.104; see also Walsh (no date) based on various studies

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Diesel consumption	Mliter	64.7	69.4	74.4	79.7	85.5	91.6	98.3	105.3	112.9	121.1	129.8	139.2	149.3	160.1	171.6	184.0
Gasoline consumption	Mliter	28.2	29.9	31.8	33.8	36.0	38.3	40.8	43.5	46.4	49.5	52.9	56.5	60.4	64.6	69.1	74.0
Additional cost low sulfur fuels	MUSD	0	0	0	0.5	0.5	0.6	1.2	1.3	1.4	1.5	1.6	1.7	1.8	2.0	2.1	2.2

Policy: New Emission Standards

Assumptions
1. New fuel qualities
2. 2018 onwards all new vehicles Euro IV and 2021 all new vehicles Euro VI

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Passenger cars Euro 2 gasoline	vehicles	27,320	29,491	31,834	29,712	27,589	25,467	23,345	21,223	19,100	16,978	14,856	12,734	10,611	8,489	6,367	4,245
Passenger cars Euro 2 diesel	vehicles	18,213	19,660	21,223	19,808	18,393	16,978	15,563	14,148	12,734	11,319	9,904	8,489	7,074	5,659	4,245	2,830
Passenger cars Euro 4 gasoline	vehicles	0	0	0	4,652	9,504	14,574	14,574	14,574	14,574	14,574	14,574	14,574	14,574	14,574	14,574	14,574
Passenger cars Euro 4 diesel	vehicles	0	0	0	3,101	6,336	9,716	9,716	9,716	9,716	9,716	9,716	9,716	9,716	9,716	9,716	9,716
Passenger cars Euro 6 gasoline	vehicles	0	0	0	0	0	0	5,304	10,860	16,690	22,814	29,256	36,041	43,197	50,752	58,740	67,193
Passenger cars Euro 6 diesel	vehicles	0	0	0	0	0	0	3,536	7,240	11,127	15,209	19,504	24,027	28,798	33,835	39,160	44,795
Taxis Euro 2 diesel	vehicles	537	544	552	501	451	401	351	301	251	201	150	100	50	0	0	0
Taxis Euro 4 diesel	vehicles	0	0	0	57	115	172	172	172	172	172	172	172	172	172	115	0
Taxis Euro 6 diesel	vehicles	0	0	0	0	0	0	58	115	173	231	289	347	405	463	529	652
Taxis Euro 2 gasoline	vehicles	3,302	3,344	3,388	3,080	2,772	2,464	2,156	1,848	1,540	1,232	924	616	308	0	0	0
Taxis Euro 4 gasoline	vehicles	0	0	0	352	705	1,058	1,058	1,058	1,058	1,058	1,058	1,058	1,058	1,058	706	1
Taxis Euro 6 gasoline	vehicles	0	0	0	0	0	0	354	708	1,063	1,419	1,775	2,132	2,489	2,847	3,250	4,006
HDVs <7.5t Euro II	vehicles	1,457	1,559	1,668	1,557	1,446	1,334	1,223	1,112	1,001	890	778	667	556	445	334	222
HDVs <7.5t Euro IV	vehicles	0	0	0	228	464	709	709	709	709	709	709	709	709	709	709	709
HDVs <7.5t Euro VI	vehicles	0	0	0	0	0	0	254	519	794	1,080	1,379	1,690	2,016	2,357	2,714	3,088
HDVs >7.5t Euro II	vehicles	8,537	9,135	9,774	9,122	8,471	7,819	7,168	6,516	5,864	5,213	4,561	3,910	3,258	2,606	1,955	1,303
HDVs >7.5t Euro IV	vehicles	0	0	0	1,336	2,719	4,154	4,154	4,154	4,154	4,154	4,154	4,154	4,154	4,154	4,154	4,154
HDVs >7.5t Euro VI	vehicles	0	0	0	0	0	0	1,490	3,038	4,649	6,328	8,078	9,905	11,815	13,812	15,904	18,096
PM emissions																	
Passenger cars gasoline	tons	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.0	1.1
Passenger cars diesel	tons	9.0	9.7	10.5	10.6	10.9	11.1	10.5	9.8	9.2	8.5	7.9	7.3	6.6	6.0	5.4	4.7
Total passenger cars	tons	9.5	10.3	11.1	11.3	11.5	11.8	11.1	10.5	9.9	9.3	8.7	8.1	7.5	6.9	6.4	5.8
Motorcycles	tons	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5
Taxis	tons	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.7	0.6	0.6	0.5	0.4	0.4	0.3	0.2	0.2
HDVs	tons	28.3	30.3	32.4	31.0	29.5	28.1	26.0	23.9	21.7	19.6	17.5	15.4	13.3	11.2	9.1	6.9
Total	**tons**	**38.9**	**41.7**	**44.6**	**43.3**	**42.1**	**40.9**	**38.1**	**35.3**	**32.5**	**29.8**	**27.0**	**24.2**	**21.5**	**18.8**	**16.1**	**13.4**

NO_2 emissions																	
Passenger cars gasoline	tons	56	61	66	61	57	53	49	45	41	37	33	29	25	21	17	13
Passenger cars diesel	tons	117	127	137	144	152	160	167	174	183	192	202	214	226	239	254	271
Total passenger cars	tons	174	187	202	205	209	213	216	220	224	229	235	243	251	261	271	284
Motorcycles	tons	13	14	15	16	18	19	21	22	24	26	28	30	33	35	38	41
Taxis	tons	29	29	29	27	26	24	22	20	18	16	15	13	11	9	9	9
HDVs	tons	1,509	1,615	1,728	1,726	1,728	1,735	1,634	1,533	1,433	1,334	1,235	1,137	1,039	943	847	752
Total	**tons**	**1,724**	**1,845**	**1,975**	**1,975**	**1,981**	**1,992**	**1,893**	**1,795**	**1,699**	**1,605**	**1,512**	**1,422**	**1,333**	**1,247**	**1,165**	**1,086**
SO_2 emissions																	
Passenger cars gasoline	tons	4.1	4.5	4.8	1.7	1.9	2.0	0.4	0.5	0.5	0.5	0.6	0.6	0.7	0.7	0.8	0.9
Passenger cars diesel	tons	8.4	9.0	9.7	1.5	1.6	1.8	0.4	0.4	0.4	0.5	0.5	0.6	0.6	0.6	0.7	0.8
Total passenger cars	tons	12.5	13.5	14.6	3.2	3.5	3.8	0.8	0.9	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6
Motorcycles	tons	0.4	0.5	0.5	0.2	0.2	0.2	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Taxis	tons	2.1	2.1	2.1	0.6	0.6	0.6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
HDVs	tons	29.8	31.9	34.1	4.9	5.3	5.6	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.1	2.211
Total	**tons**	**44.8**	**48.0**	**51.3**	**8.9**	**9.5**	**10.2**	**2.2**	**2.3**	**2.5**	**2.7**	**2.9**	**3.1**	**3.3**	**3.5**	**3.8**	**4.1**
CO_2 emissions excl. BC																	
Passenger cars gasoline	tons	42,271	45,630	49,256	53,169	57,394	61,954	66,877	72,191	77,927	84,119	90,802	98,017	105,805	114,212	123,287	133,083
Passenger cars diesel	tons	38,127	41,157	44,427	47,957	51,768	55,881	60,321	65,114	70,288	75,873	81,901	88,409	95,434	103,016	111,202	120,038
Total passenger cars	tons	80,399	86,787	93,683	101,127	109,162	117,835	127,198	137,305	148,215	159,991	172,704	186,426	201,239	217,229	234,489	253,121
Motorcycles	tons	4,542	4,903	5,293	5,713	6,167	6,657	7,186	7,757	8,374	9,039	9,757	10,533	11,370	12,273	13,248	14,301
Taxis	tons	17,315	17,540	17,768	17,999	18,233	18,470	18,710	18,953	19,199	19,449	19,702	19,958	20,217	20,480	20,746	21,015
HDVs	tons	135,868	145,379	155,555	166,444	178,095	190,562	203,902	218,175	233,447	249,788	267,273	285,982	306,001	327,421	350,341	374,865
Total	**tons**	**238,125**	**254,610**	**272,299**	**291,283**	**311,658**	**333,525**	**356,996**	**382,190**	**409,235**	**438,268**	**469,436**	**502,899**	**538,827**	**577,403**	**618,824**	**663,302**
CO_2 emissions incl. BC																	
Passenger cars gasoline	tons	42,393	45,761	49,397	53,308	57,530	62,087	67,009	72,323	78,060	84,253	90,938	98,155	105,946	114,356	123,435	133,236
Passenger cars diesel	tons	44,595	48,138	51,963	55,677	59,701	64,060	68,002	72,297	76,973	82,060	87,592	93,603	100,131	107,217	114,907	123,247
Total passenger cars	tons	86,988	93,900	101,361	108,985	117,231	126,147	135,011	144,620	155,033	166,313	178,530	191,757	206,076	221,573	238,342	256,483
Motorcycles	tons	4,575	4,938	5,331	5,754	6,211	6,705	7,238	7,813	8,433	9,104	9,827	10,608	11,451	12,360	13,343	14,403
Taxis	tons	17,886	18,119	18,354	18,568	18,786	19,006	19,194	19,386	19,581	19,779	19,981	20,185	20,393	20,605	20,836	21,037
HDVs	tons	152,438	163,109	174,527	184,619	195,491	207,195	219,275	232,289	246,302	261,384	277,611	295,062	313,822	333,985	355,647	378,913
Total	**tons**	**261,887**	**280,066**	**299,572**	**317,927**	**337,718**	**359,053**	**380,719**	**404,108**	**429,349**	**456,580**	**485,948**	**517,612**	**551,742**	**588,523**	**628,167**	**670,836**
Pollution costs																	
Passenger cars gasoline	MUSD	1.7	1.9	2.0	2.2	2.3	2.5	2.7	2.9	3.2	3.4	3.7	4.0	4.3	4.6	5.0	5.4
Passenger cars diesel	MUSD	2.0	2.1	2.3	2.5	2.6	2.8	2.9	3.1	3.3	3.5	3.7	3.9	4.2	4.5	4.8	5.1
Total passenger cars	MUSD	3.7	4.0	4.3	4.6	5.0	5.3	5.7	6.0	6.5	6.9	7.4	7.9	8.5	9.1	9.8	10.5
Motorcycles	MUSD	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.4	0.5	0.5	0.6	0.6
Taxis	MUSD	0.7	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.9
HDVs	MUSD	7.3	7.8	8.3	8.6	9.1	9.5	9.9	10.3	10.8	11.3	11.9	12.5	13.2	13.9	14.7	15.6
Total	**MUSD**	**11.9**	**12.8**	**13.7**	**14.3**	**15.1**	**15.9**	**16.6**	**17.5**	**18.4**	**19.4**	**20.5**	**21.7**	**23.0**	**24.4**	**25.9**	**27.5**

Comparison

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
BAU PM emissions	tons	39	42	45	48	51	55	59	63	68	72	78	83	89	95	102	110
PM emissions with policy	tons	39	42	45	43	42	41	38	35	33	30	27	24	22	19	16	13
BAU NO_2 emissions	tons	1,724	1,845	1,975	2,144	2,262	2,421	2,591	2,773	2,969	3,178	3,402	3,642	3,899	4,175	4,470	4,786
NO_2 emissions with policy	tons	1,724	1,845	1,975	1,975	1,981	1,992	1,893	1,795	1,699	1,605	1,512	1,422	1,333	1,247	1,165	1,086
BAU GHG with BC emissions	tons	261,887	280,066	299,572	320,505	342,970	367,079	392,956	420,732	450,546	482,549	516,906	553,789	593,387	635,901	681,547	730,560
GHG with BC emisisons with policy	tons	261,887	280,066	299,572	317,927	337,718	359,053	380,719	404,108	429,349	456,580	485,948	517,612	551,742	588,523	628,167	670,836
Indexed																	
BAU PM emissions		100	107	115	123	132	141	151	162	173	186	199	214	229	245	263	282
PM emissions with policy		100	107	115	111	108	105	98	91	84	77	69	62	55	48	41	34
BAU NO_2 emissions		100	107	115	124	131	140	150	161	172	184	197	211	226	242	259	278
NO_2 emissions with policy		100	107	115	115	115	116	110	104	99	93	88	82	77	72	68	63
BAU GHG with BC emissions		100	107	114	122	131	140	150	161	172	184	197	211	227	243	260	279
GHG with BC emissions with policy		100	107	114	121	129	137	145	154	164	174	186	198	211	225	240	256

Economic assessment

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	cumulative
Value PM and NO_2 reduction	MUSD	0.0	0.0	0.0	0.3	0.5	0.8	1.2	1.6	2.0	2.5	2.9	3.4	3.9	4.5	5.0	5.6	34.2
Value GHG reduction	MUSD	0.0	0.0	0.0	0.1	0.2	0.3	0.5	0.7	0.8	1.0	1.2	1.4	1.7	1.9	2.1	2.4	14.4
Value SO_2 reduction	MUSD	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	1.6
Additional cost vehicles	MUSD	0.0	0.0	0.0	0.3	0.6	0.9	1.3	1.8	2.3	2.8	3.3	3.8	4.4	5.0	5.7	6.4	38.4
Additional cost fuels	MUSD	0.0	0.0	0.0	0.5	0.5	0.6	1.2	1.3	1.4	1.5	1.6	1.7	1.8	2.0	2.1	2.2	18.4
Balance	**MUSD**	**0.0**	**0.0**	**0.0**	**-0.3**	**-0.3**	**-0.3**	**-0.8**	**-0.7**	**-0.7**	**-0.6**	**-0.6**	**-0.5**	**-0.5**	**-0.5**	**-0.4**	**-0.4**	**-6.6**
Balance excl. fuels	**MUSD**	**0.0**	**0.0**	**0.0**	**0.2**	**0.2**	**0.3**	**0.5**	**0.6**	**0.7**	**0.9**	**1.0**	**1.2**	**1.3**	**1.5**	**1.7**	**1.8**	**11.9**
additional cost vehicles no cars diesel	MUSD	0.0	0.0	0.0	0.2	0.4	0.6	0.9	1.1	1.4	1.7	2.0	2.4	2.7	3.1	3.5	3.9	23.8

Incremental costs	USD/vehicle	annualized cost
Gasoline passenger car to Euro 4	60	4
Gasoline passenger car Euro 4 to 6	60	4
Diesel passenger car to Euro 4	500	33
Diesel passenger car Euro 4 to 6	800	53
HDV to Euro 4	1,500	100
HDV Euro 4 to 6	2,000	133

Policy: Vehicle Age Limit

	gasoline	diesel
taxi shares	86%	14%

Vehicle emission degradation factor

vehicle category	pollutant	Degradation at year 10	Annual additional degradation after year 10
gasoline car and taxi	NOx	1.85	6%
diesel car and taxi	PM	1.6	15%
HDV	all	0	0%

assumes 10,000km per year; degradation after 100,000km

annual additional degradation based on CARG with rate 200,000 to 100,000km

gasoline car based on Borken-Kleefeld, 2015, table 2

HDV based on Rexeis, 2005

Assumptions

vehicle category	max age	average age BAU	vehicle replacement rate new	Additional annual degradation due to longer lifespan
taxis	10	15	10%	16%
HDVs	12	15	8%	0
all others	12	15	8%	9%
				23%

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Passenger cars Euro 2 gasoline	vehicles	27,320	29,491	31,834	29,181	26,528	23,875	21,223	18,570	15,917	13,264	10,611	7,958	5,306	2,653	0	0
Passenger cars Euro 2 diesel	vehicles	18,213	19,660	21,223	19,454	17,685	15,917	14,148	12,380	10,611	8,843	7,074	5,306	3,537	1,769	0	0
Passenger cars Euro 4 gasoline	vehicles	0	0	0	5,182	10,565	16,166	16,166	16,166	16,166	16,166	16,166	16,166	16,166	16,166	16,166	10,983
Passenger cars Euro 4 diesel	vehicles	0	0	0	3,455	7,044	10,777	10,777	10,777	10,777	10,777	10,777	10,777	10,777	10,777	10,777	7,322
Passenger cars Euro 6 gasoline	vehicles	0	0	0	0	0	0	5,834	11,921	18,281	24,936	31,909	39,224	46,911	54,997	63,515	75,028
Passenger cars Euro 6 diesel	vehicles	0	0	0	0	0	0	3,890	7,948	12,188	16,624	21,272	26,150	31,274	36,665	42,343	50,019
Taxis Euro 2	vehicles	3,839	3,889	3,939	3,545	3,152	2,758	2,364	1,970	1,576	1,182	788	394	0	0	0	0
Taxis Euro 4	vehicles	0	0	0	445	891	1,337	1,337	1,337	1,337	1,337	1,337	1,337	1,337	892	1	0
Taxis Euro 6	vehicles	0	0	0	0	0	0	447	895	1,344	1,793	2,243	2,693	3,145	3,648	4,598	4,659
HDVs <7.5t Euro II	vehicles	1,457	1,559	1,668	1,529	1,390	1,251	1,112	973	834	695	556	417	278	139	0	0
HDVs <7.5t Euro IV	vehicles	0	0	0	256	520	792	792	792	792	792	792	792	792	792	792	537
HDVs <7.5t Euro VI	vehicles	0	0	0	0	0	0	282	574	877	1,191	1,518	1,857	2,211	2,580	2,964	3,483
HDVs >7.5t Euro II	vehicles	8,537	9,135	9,774	8,960	8,145	7,331	6,516	5,702	4,887	4,073	3,258	2,444	1,629	815	0	0
HDVs >7.5t Euro IV	vehicles	0	0	0	1,499	3,045	4,643	4,643	4,643	4,643	4,643	4,643	4,643	4,643	4,643	4,643	3,144
HDVs >7.5t Euro VI	vehicles	0	0	0	0	0	0	1,653	3,364	5,138	6,979	8,892	10,883	12,955	15,115	17,370	20,409
PM emissions																	
Passenger cars gasoline	tons	0.5	0.6	0.6	0.6	0.6	0.6	0.7	0.7	0.7	0.7	0.8	0.8	0.9	0.9	1.0	1.1
Passenger cars diesel	tons	9.0	9.7	10.5	10.6	10.7	10.9	10.1	9.3	8.4	7.6	6.8	6.0	5.2	4.4	3.6	2.7
Total passenger cars	tons	9.5	10.3	11.1	11.2	11.3	11.5	10.7	9.9	9.1	8.4	7.6	6.8	6.1	5.3	4.6	3.8
Taxis	tons	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.7	0.6	0.5	0.4	0.4	0.3	0.2	0.2	0.2
HDVs	tons	28.3	30.3	32.4	30.5	28.6	26.7	24.1	21.4	18.8	16.1	13.4	10.8	8.1	5.5	2.9	2.2
Total	**tons**	**38.8**	**41.5**	**44.5**	**42.6**	**40.8**	**39.1**	**35.6**	**32.0**	**28.5**	**25.0**	**21.5**	**18.0**	**14.5**	**11.1**	**7.6**	**6.1**
NO_2 emissions																	
Passenger cars gasoline	tons	56	61	66	60	55	50	45	40	35	30	25	19	14	9	4	5
Passenger cars diesel	tons	117	127	137	143	151	159	174	190	207	225	245	267	290	315	342	376
Total passenger cars	tons	174	187	202	204	206	209	219	229	242	255	270	286	305	325	346	381
Taxis	tons	29	29	29	27	25	23	21	19	17	15	13	11	9	9	9	9
HDVs	tons	1,509	1,615	1,728	1,711	1,699	1,690	1,562	1,434	1,306	1,180	1,053	928	803	680	557	458
Total	**tons**	**1,711**	**1,831**	**1,959**	**1,942**	**1,930**	**1,923**	**1,802**	**1,682**	**1,565**	**1,450**	**1,336**	**1,225**	**1,117**	**1,013**	**912**	**847**

Passenger cars gasoline	tons	56	61	66	60	55	50	45	40	35	30	25	19	14	9	4	5
Passenger cars diesel	tons	117	127	137	143	151	159	174	190	207	225	245	267	290	315	342	376
Total passenger cars	tons	174	187	202	204	206	209	219	229	242	255	270	286	305	325	346	381
Taxis	tons	29	29	29	27	25	23	21	19	17	15	13	11	9	9	9	9
HDVs	tons	1,509	1,615	1,728	1,711	1,699	1,690	1,562	1,434	1,306	1,180	1,053	928	803	680	557	458
Total	**tons**	**1,711**	**1,831**	**1,959**	**1,942**	**1,930**	**1,923**	**1,802**	**1,682**	**1,565**	**1,450**	**1,336**	**1,225**	**1,117**	**1,013**	**912**	**847**
CO_2 emissions excl. BC																	
Passenger cars gasoline	tons	42,271	45,630	49,256	53,169	57,394	61,954	66,877	72,191	77,927	84,119	90,802	98,017	105,805	114,212	123,287	133,083
Passenger cars diesel	tons	38,127	41,157	44,427	47,957	51,768	55,881	60,321	65,114	70,288	75,873	81,901	88,409	95,434	103,016	111,202	120,038
Total passenger cars	tons	80,399	86,787	93,683	101,127	109,162	117,835	127,198	137,305	148,215	159,991	172,704	186,426	201,239	217,229	234,489	253,121
Taxis	tons	16,834	17,052	17,274	17,499	17,726	17,956	18,190	18,426	18,665	18,908	19,154	19,403	19,655	19,910	20,169	20,431
HDVs	tons	135,868	145,379	155,555	166,444	178,095	190,562	203,902	218,175	233,447	249,788	267,273	285,982	306,001	327,421	350,341	374,865
Total	**tons**	**233,101**	**249,218**	**266,512**	**285,069**	**304,983**	**326,354**	**349,289**	**373,906**	**400,327**	**428,688**	**459,131**	**491,811**	**526,895**	**564,560**	**604,999**	**648,417**
CO_2 emissions incl. BC																	
Passenger cars gasoline	tons	42,393	45,761	49,397	53,306	57,526	62,082	67,003	72,315	78,050	84,242	90,926	98,141	105,931	114,339	123,417	133,226
Passenger cars diesel	tons	44,595	48,138	51,963	55,630	59,607	63,918	67,737	71,909	76,463	81,428	86,837	92,725	99,131	106,096	113,664	121,749
Total passenger cars	tons	86,988	93,900	101,361	108,936	117,133	126,000	134,740	144,225	154,513	165,670	177,762	190,866	205,062	220,435	237,081	254,975
Taxis	tons	17,405	17,631	17,860	18,066	18,274	18,486	18,663	18,842	19,025	19,211	19,400	19,593	19,788	20,006	20,190	20,452
HDVs	tons	152,438	163,109	174,527	184,360	194,972	206,418	218,182	230,881	244,578	259,345	275,256	292,391	310,836	330,682	352,029	376,038
Total	**tons**	**256,831**	**274,640**	**293,747**	**311,362**	**330,379**	**350,904**	**371,585**	**393,948**	**418,117**	**444,226**	**472,418**	**502,850**	**535,686**	**571,124**	**609,299**	**651,465**
Deterioration additional emissions																	
PM passenger cars	tons	0.0	0.0	0.0	2.3	2.1	2.0	1.8	1.6	1.5	1.3	1.2	1.0	0.8	0.7	0.5	1.0
NO_2 passenger cars	tons	0.0	0.0	0.0	35.2	32.7	30.2	27.7	25.2	22.6	20.1	17.6	15.1	12.6	10.1	7.5	16.8
PM taxis	tons	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
NO_2 taxis	tons	0.0	0.0	0.0	4.2	3.8	3.3	2.9	2.5	2.1	1.7	1.3	0.8	0.4	0.4	0.3	0.0
Reductions relative to P2																	
PM emissions	tons	0.0	0.0	0.0	3.0	3.3	3.7	4.2	4.8	5.3	5.9	6.4	6.9	7.5	8.0	8.6	7.8
NO_2 emissions	tons	0	0	0	56	70	83	101	118	135	151	167	182	197	210	223	215
GHG incl. BC	tons	482	488	494	811	1,127	1,444	1,896	2,348	2,799	3,251	3,703	4,154	4,606	5,038	5,525	4,968
Indexed		**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
BAU PM emissions		100	107	115	111	108	105	98	91	84	77	69	62	55	48	41	34
PM emissions with policy		100	107	115	104	100	96	87	79	70	61	53	44	36	28	19	14
BAU NO_2 emissions		100	107	115	115	115	116	110	104	99	93	88	82	77	72	68	63
NO_2 emissions with policy		100	107	115	111	111	111	104	97	91	84	78	72	66	60	55	51
BAU GHG with BC emissions		100	107	114	121	129	137	145	154	164	174	186	198	211	225	240	256
GHG with BC emissions with policy		99.8161155	107	114	121	129	137	145	153	163	173	184	196	209	223	238	254

Economic assessment relative to P2

Parameter	**Unit**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**cumulative**
Value PM and NO_2 reduction	MUSD	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.4	4.1
Value GHG reduction	MUSD	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	1.7
Additional cost vehicles	MUSD	0.0	0.0	0.0	24.4	26.2	28.2	30.4	32.7	35.3	37.9	40.8	43.9	47.3	50.9	54.7	58.9	511.8
Balance	**MUSD**	**0.0**	**0.0**	**0.0**	**-24.2**	**-26.0**	**-28.0**	**-30.1**	**-32.4**	**-34.9**	**-37.5**	**-40.3**	**-43.4**	**-46.7**	**-50.2**	**-54.1**	**-58.2**	**-506.0**

Incremental costs	USD/vehicle	annualized cost	incremental annualized cost
Gasoline passenger car to Euro 4	60	4	1
Gasoline passenger car Euro 4 to 6	60	4	1
Diesel passenger car to Euro 4	500	33	8
Diesel passenger car Euro 4 to 6	800	53	13
HDV to Euro 4	1,500	100	25
HDV Euro 4 to 6	2,000	133	33
Taxis Euro 4			2
taxi Euro 4 to 6			2

This reflects the incremental cost due to procuring a vehicle with a higher emission standard which is costlier and using is less years

Incremental lifespan cost	Value USD	Annualized USD	Annual additional cost USD
Gasoline car	10,000	667	167
Diesel car	25,000	1,667	417
Taxi	10,000	667	333
HDV <7.5t	25,000	1,667	417
HDV > 7.5t	40,000	2,667	667

This reflects the additional cost of reduced lifespan of the vehicle; it is the annual additional cost per vehicle circulating; non-dynamic cost as also finance costs are not included and investment is upfront

Relative impact (reduction) by 2030	
PM	58%
NO_2	21%
SO_2	0%
average with PM double weight	34%
GHG	1%

Policy: IM

Elements

1. Idle test gasoline with tightened standards and improved control
2. Snap test diesel with improved procedure and tightened control

Assumptions

Parameter	Value	Explanation
Share of high emitters gasoline cars identified which actually repair their vehicle	1%	based on around 2% high emitters of which 50% actually repair and rest circumvent
Share of high emitters diesel cars identified which actually repair their vehicle	2%	based on around 5% high emitters of which 60% actually repair and rest circumvent
Share of high emitters taxis identified which actually repair their vehicle	1%	based on around 2% high emitters of which 50% actually repair and rest circumvent
Share of high emitters HDVs identified which actually repair their vehicle	2%	based on around 10% high emitters of which 20% actually repair and rest circumvent
Improvement rate pollutants (PM, NO_2) due to repair	2	Factor 2 higher emissions of high emitting cars which can be controlled with repairs

Calculations based on BAU

Emission reductions

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
PM reduction gasoline cars and taxis	tons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NO_2 reduction gasoline cars and taxis	tons	0.0	0.0	0.0	0.9	1.0	1.0	1.1	1.2	1.2	1.3	1.4	1.5	1.6	1.7	1.9	2.0
PM reduction diesel cars and taxis	tons	0.0	0.0	0.0	0.2	0.3	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6
NO_2 reduction diesel cars and taxis	tons	0.0	0.0	0.0	3.8	3.4	3.6	3.9	4.2	4.5	4.9	5.3	5.7	6.1	6.6	7.1	7.6
PM reduction HDVs	tons	0.0	0.0	0.0	0.7	0.7	0.8	0.9	0.9	1.0	1.0	1.1	1.2	1.3	1.4	1.5	1.6
NO_2 reduction HDVs	tons	0.0	0.0	0.0	37.0	39.6	42.3	45.3	48.5	51.9	55.5	59.4	63.5	68.0	72.7	77.8	83.3
Indexed																	
BAU PM emissions		100	107	115	125	134	144	154	165	177	190	203	218	233	250	268	287
PM emissions with policy		100	107	115	123	132	141	151	162	173	186	199	214	229	245	263	282
BAU NO_2 emissions		100	107	115	127	134	143	153	164	176	188	201	215	231	247	264	283
NO_2 emissions with policy		100	107	115	124	131	140	150	161	172	184	197	211	226	242	259	278

BAU based on scenario with emission standards implemented

Economic assessment

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	cumulative
Value PM and NO_2 reduction	MUSD	0	0.00	0.00	0.06	0.06	0.06	0.07	0.07	0.08	0.09	0.09	0.10	0.10	0.11	0.12	0.13	1.1
Additional cost	MUSD	0	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.4	3.2
Balance	MUSD	0.0	0.0	0.0	-0.1	-0.1	-0.1	-0.1	-0.1	-0.1	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-0.2	-2.0

Incremental cost of measures		
Additional inspection cost per unit	1	USD
Repair cost gasoline cars/taxis	30	USD
Repair costs diesel cars	50	USD
Repair costs HDVs	200	USD
IM240 controls		
Incremental costs		
Additional inspection costs gasoline	15	USD
Impact only gasoline vehicles		
Assumption share high emitters which repair	10%	

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	cumulative
Additional reduction IM240 of PM	tons	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	
Additional reduction IM240 of NO_2	tons	0.0	0.0	0.0	8.5	9.1	9.6	10.3	10.9	11.7	12.5	13.3	14.2	15.2	16.3	17.4	35.5	
Incremental benefit	MUSD	0.0	0.0	0.0	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.1
Incremental cost	MUSD	0.0	0.0	0.0	0.63	0.68	0.73	0.79	0.85	0.92	0.99	1.07	1.15	1.24	1.34	1.45	1.56	13.4
Balance	MUSD	0.0	0.0	0.0	-0.6	-0.7	-0.7	-0.8	-0.8	-0.9	-1.0	-1.1	-1.1	-1.2	-1.3	-1.4	-1.5	-13.3

Policy: Low Carbon Vehicles

Vehicle category	**Target year share of new registered vehicles**				
	2018	**2020**	**2022**	**2025**	**2030**
Taxis and buses					
Hybrids	10%	30%	40%	10%	0%
Plug-in hybrids	0%	10%	30%	50%	0%
Electric	0%	0%	20%	40%	100%
Urban small trucks					
Hybrids	0%	10%	30%	50%	30%
Plug-in hybrids	0%	0%	10%	20%	20%
Electric	0%	0%	10%	30%	50%
Passenger cars					
Hybrids	0%	10%	20%	20%	20%
Plug-in hybrids	0%	0%	10%	20%	25%
Electric	0%	0%	0%	10%	15%

Efficiency low carbon vehicles GHG and pollutants

Vehicle category	**value**
Hybrids	25%
Plug-in hybrids	45%
Electric	100%

Source: Grutter Consulting based on fleets of vehicles with monitoring data, see also ICCT, 2015

Vehicle numbers																	
Parameter	**Unit**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Hybrid passenger cars	vehicles	0	0	0	0	418	1,322	2,785	4,890	7,162	9,615	12,264	15,122	18,208	21,538	25,134	29,015
Plug-in hybrid passenger cars	vehicles	0	0	0	0	0	0	488	1,540	3,055	5,100	7,748	10,749	14,143	17,973	22,288	27,139
Electric passenger car	vehicles	0	0	0	0	0	0	0	0	379	1,196	2,520	4,093	5,944	8,109	10,626	13,536
total market share LC cars	%	0%	0%	0%	0%	1%	2%	5%	8%	13%	18%	23%	28%	34%	39%	44%	49%
Hybrid taxis	vehicles	0	0	0	41	124	250	399	571	702	791	836	872	899	918	886	763
Plug-in hybrid taxis	vehicles	0	0	0	0	21	63	148	277	437	629	853	1,031	1,169	1,262	1,310	1,289
Electric taxis	vehicles	0	0	0	0	0	0	43	159	275	423	602	838	1,132	1,486	1,901	2,379
total market share LC taxis	vehicles	0%	0%	0%	1%	4%	8%	14%	24%	33%	43%	52%	62%	71%	81%	89%	95%
Hybrid HDVs , 7.5t	vehicles	0	0	0	2	11	26	53	92	137	140	198	256	311	364	414	460
Plug-in hybrid HDVs < 7.5t	vehicles	0	0	0	0	1	4	14	32	56	61	102	141	179	214	248	279
Electric HDVs < 7,5t	vehicles	0	0	0	0	0	0	7	22	46	55	103	163	237	328	437	565
Hybrid HDVs > 7.5t	vehicles	0	0	0	7	21	44	73	108	136	156	166	176	183	188	184	163
Plug-in hybrid HDVs> 7.5t	vehicles	0	0	0	0	4	11	28	28	62	105	159	205	242	229	244	240
Electric HDVs > 7.5t	vehicles	0	0	0	0	0	0	8	16	41	75	118	177	256	271	394	545
Total market share LC HDVs	vehicles	0%	0%	0%	0%	0%	1%	1%	2%	3%	3%	4%	5%	6%	7%	7%	8%

Environmental impact																	
Parameter	**Unit**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
PM emission reductions																	
Passenger cars	tons	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.4	0.7	1.2	1.9	2.7	3.5	4.5	5.6	6.9
Taxis	tons	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.2	0.3	0.4	0.5	0.5	0.6	0.8
HDVs	tons	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.6	0.8	1.2	1.7	2.3	2.7	3.4	4.2
Total	**tons**	**0.0**	**0.0**	**0.0**	**0.0**	**0.1**	**0.2**	**0.4**	**0.8**	**1.5**	**2.2**	**3.4**	**4.7**	**6.3**	**7.7**	**9.7**	**11.9**
NO_2 emission reductions																	
Passenger cars	tons	0	0	0	0	0	1	3	7	14	22	35	48	64	82	103	126
Taxis	tons	0	0	0	0	0	1	2	3	5	7	9	11	14	17	20	23
HDVs	tons	0	0	0	0	2	4	10	17	32	42	65	91	122	141	181	226
Total	**tons**	**0**	**0**	**0**	**0**	**2**	**6**	**15**	**28**	**50**	**71**	**108**	**151**	**200**	**241**	**304**	**376**
SO_2 emission reductions																	
Passenger cars	tons	0.0	0.0	0.0	0.0	0.0	0.1	0.3	0.5	1.0	1.6	2.5	3.5	4.6	5.9	7.4	9.1
Taxis	tons	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.5	0.6	0.8	1.0	1.2	1.5	1.7
HDVs	tons	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.3	0.6	0.8	1.3	1.8	2.4	2.8	3.6	4.5
Total	**tons**	**0.0**	**0.0**	**0.0**	**0.0**	**0.1**	**0.2**	**0.6**	**1.1**	**1.9**	**2.9**	**4.4**	**6.1**	**8.0**	**9.9**	**12.4**	**15.2**
CO_2 emission reductions excl. BC																	
Passenger cars	tons	0	0	0	0	185	583	1,617	3,382	6,258	10,409	16,020	22,443	29,770	38,107	47,566	58,274
Taxis	tons	0	0	0	46	182	409	942	1,923	2,920	4,074	5,388	6,855	8,493	10,300	12,233	14,206
HDVs	tons	0	0	0	30	137	331	885	1,560	2,841	3,788	5,828	8,206	10,957	12,731	16,336	20,378
Total	**tons**	**0**	**0**	**0**	**77**	**504**	**1,324**	**3,443**	**6,865**	**12,019**	**18,271**	**27,236**	**37,503**	**49,221**	**61,138**	**76,134**	**92,858**
CO_2 emission reductions incl. BC																	
Passenger cars	tons	0	0	0	0	200	631	1,749	3,660	6,771	11,262	17,333	24,282	32,210	41,230	51,465	63,050
Taxis	tons	0	0	0	48	188	423	973	1,986	3,017	4,209	5,565	7,081	8,773	10,640	12,636	14,675
HDVs	tons	0	0	0	34	154	372	993	1,750	3,187	4,250	6,539	9,206	12,294	14,284	18,328	22,863
Total	**tons**	**0**	**0**	**0**	**82**	**542**	**1,426**	**3,715**	**7,396**	**12,975**	**19,721**	**29,437**	**40,569**	**53,278**	**66,154**	**82,428**	**100,588**
Indexed		**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
BAU PM emissions		100	107	115	123	132	141	151	162	173	186	199	214	229	245	263	282
PM emissions with policy		100	107	115	123	131	141	150	160	170	180	191	201	213	226	238	251
BAU NO_2 emissions		100	107	115	124	131	140	150	161	172	184	197	211	226	242	259	278
NO_2 emissions with policy		100	107	115	124	131	140	149	159	169	180	191	202	215	228	242	256
BAU SO_2 emissions		100	107	115	123	131	141	150	161	173	185	198	212	227	244	261	280
SO_2 emissions with policy		100	107	115	123	131	140	149	159	168	178	188	199	209	222	233	246
BAU CO_2 emissions excl. BC		100	107	114	122	131	140	150	161	172	184	197	211	226	242	260	279
CO_2 emissions excl. BC with policy		100	107	114	122	131	140	148	158	167	176	186	195	206	217	228	240
BAU CO_2 emissions incl. BC		100	107	114	122	131	140	150	161	172	184	197	211	227	243	260	279
CO_2 emissions incl. BC with policy		100	107	114	122	131	140	149	158	167	177	186	196	206	218	229	241

Indexed		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
BAU PM emissions		100	107	115	123	132	141	151	162	173	186	199	214	229	245	263	282
PM emissions with policy		100	107	115	123	131	141	150	160	170	180	191	201	213	226	238	251
BAU NO_2 emissions		100	107	114	124	131	140	150	161	172	184	197	211	226	242	259	277
NO_2 emissions with policy		100	107	114	124	131	140	149	159	169	180	191	202	214	228	241	255
BAU SO_2 emissions		100	107	115	123	131	141	150	161	173	185	198	212	227	244	261	280
SO_2 emissions with policy		100	107	115	123	131	140	149	159	168	178	188	199	209	222	233	246
BAU CO_2 emissions excl. BC		100	107	114	122	131	140	150	161	172	184	197	211	226	242	260	279
CO_2 emissions excl. BC with policy		100	107	114	122	131	140	148	158	167	176	186	195	206	217	228	240
BAU CO_2 emissions incl. BC		100	107	114	122	131	140	150	161	172	184	197	211	227	243	260	279
CO_2 emissions incl. BC with policy		100	107	114	122	131	140	149	158	167	177	186	196	206	218	229	241

Economic assessment																		
Parameter	**Unit**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**cumulative**
Value PM and NO_2 reduction	MUSD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.4	0.5	0.7	2.7
Value GHG reduction	MUSD	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.3	0.5	0.8	1.2	1.6	2.1	2.6	3.3	4.0	16.7
Value SO_2 reduction	MUSD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Additional vehicle cost	MUSD	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.4	1.1	2.1	3.4	4.6	5.8	5.8	6.4	6.2	36.0
Balance	MUSD	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	-0.5	-1.2	-2.0	-2.7	-3.3	-2.7	-2.5	-1.5	-16.5

Additional vehicle cost is based on annuallized total cost of ownership

Vehicle category	incremental annual cost	
Hybrid vehicles	0	
Plug-in hybrids	0	
Electric taxi 2020	0	see WB, 2016 for Bhutan
Electric taxi 2030	0	
Electric car 2020	1,000	due to lower mileage less profitable
Electric car 2030	250	
Electric bus 2020	25,000	
Electric bus 2030	5,000	
Electric small HDV 2020	1,000	
Electric small HDV 2030	250	

Justification: based on entry stage of plug-ins. Based on high-mileage vehicles and data from China, UK, Colombia for buses and taxis; very aproximative costs

TCO electric cars see e.g. World Bank, 2016, p.48ff

Policy: DPF Retrofit

Assumptions

1. Only vehicles Euro III are equipped with a remaining lifespan of 10 years. As of 2017/18 it is assuemd that this corresponds to 30% of all vehicles
2. All vehicles entering 2019 onwards are equipped with DPFs

Parameter	value
reduction efficiency with 50 ppm diesel	50%
reduction efficiency with 10 ppm diesel	90%
malfunction rate	20%
malfunction impact on reduction rate	50%
incremental fuel consumption	3%
Source: CALAC program, Grutter, 2015	

Environmental impact

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
HDVs >7.5t Euro	vehicles	8,537	9,135	9,774	10,458	11,190	11,974	12,812	13,709	14,668	15,695	16,794	17,969	19,227	20,573	22,013	23,554
HDVs equipped with DPF	vehicles	0	0	0	3,137	3,870	4,653	5,491	6,388	7,347	8,374	9,473	10,648	11,906	13,252	14,692	16,233
Average efficiency level DPFs	%	0%	0%	0%	45%	45%	45%	81%	81%	81%	81%	81%	81%	81%	81%	81%	81%
$PM_{2.5}$ emission reduction due to DPFs	tons	0	0	0	4	5	6	13	16	18	20	23	26	29	32	36	40
GHG reduction due to DPFs incl. BC	tons	0	0	0	1,143	1,410	1,695	5,488	6,384	7,343	8,370	9,468	10,643	11,900	13,245	14,684	16,224
Indexed																	
BAU PM emissions		100	107	115	123	132	141	151	162	173	186	199	214	229	245	263	282
PM emissions with policy		100	107	115	112	118	125	117	122	127	133	140	147	154	162	171	180
BAU GHG with BC emissions		100	107	114	122	131	140	150	161	172	184	197	211	227	243	260	279
GHG with BC emissions with policy		100	107	114	122	130	140	148	158	169	181	194	207	222	238	255	273

Economic assessment

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	cumulative
Value PM reduction	MUSD	0	0.0	0.0	0.2	0.2	0.3	0.6	0.7	0.8	0.9	1.1	1.2	1.3	1.5	1.6	1.8	12.3
Value GHG reduction	MUSD	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.3	0.4	0.4	0.5	0.5	0.6	0.6	4.3
Additional cost	MUSD	0	0.0	0.0	6.1	7.5	9.0	10.6	12.4	14.2	16.2	18.3	20.6	23.0	25.7	28.4	31.4	223.5
Balance	MUSD	0.0	0.0	0.0	-5.8	-7.2	-8.7	-9.8	-11.4	-13.1	-14.9	-16.9	-19.0	-21.2	-23.6	-26.2	-29.0	-206.9

Incremental costs	USD/vehicle	annualized cost
Equipment cost lifetime incl. maintenance	18,000	1,800
Cost per litre of diesel		0.85
Annual incremental fuel cost		136
annualized based on 10 year lifespan for retrofit		
Cost based on retrofit costs Bogota and Santiago de Chile for HDVs incl. maintenance		
Cost per litre of diesel based on 58 NU per litre valid as of 01/2017		

Policy: No Diesel

1. Replaced vehicles: all diesel passenger cars
2. Replacement units: gasoline cars with average between cc 1.4 to 2.0l and > 2.0l

Vehicles which replace diesel units from 1.2018 onwards

Parameter	Value	Unit	Source
Specific fuel consumption gasoline cars	10.3	l/100km	Corinair, 2016, Table 3-27, based on average Euro 1 to 3, 1.4-2.0l and >2.0l
PM emissions gasoline cars	0.002	g/km	Corinair, 2016, Table 3-18, based on average Euro 2, 1.4-2.0l and > 2.0l
NO_2 equivalent emissions gasoline cars	0.2485	g/km	Corinair, 2016, Table 3-17, based on average Euro 2, 1.4-2.0l and > 2.0l
BC fraction gasoline cars	25%		Corinair, 2016, Table 3-118, based on Euro 2

Emissions reduced by gasoline cars replacing diesel units

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
PM emissions reduced	tons	0	0	0	1.5	3.2	4.8	6.6	8.4	10.3	12.3	14.4	16.7	19.0	21.5	24.0	26.7
NO_2 emissions reduced	tons	0	0	0	13.7	28.0	42.9	58.4	74.7	91.7	109.6	128.3	148.0	168.8	190.7	213.2	237.0
SO_2 emissions reduced	tons	0	0	0	0.8	1.7	2.6	3.5	4.5	5.5	6.6	7.8	8.9	10.2	11.5	12.9	14.3
CO_2 emissions reduced	tons	0	0	0	-21	-43	-66	-90	-115	-141	-169	-197	-228	-260	-293	-328	-365
CO_2 incl. BC emissions reduced	tons	0	0	0	1,122	2,290	3,509	5,401	7,380	9,454	11,631	13,917	16,323	18,856	21,529	24,303	27,239
Indexed		**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
BAU PM emissions		100	107	115	123	132	141	151	162	173	186	199	214	229	245	263	282
PM emissions with policy		100	107	115	119	124	129	134	140	147	154	162	171	180	190	201	213
BAU NO_2 emissions		100	107	115	124	131	140	150	161	172	184	197	211	226	242	259	278
NO_2 emissions with policy		100	107	115	124	130	138	147	157	167	178	190	203	216	231	247	264
BAU SO_2 emissions		100	107	115	123	131	141	150	161	173	185	198	212	227	244	261	280
SO_2 emissions with policy		100	107	115	121	127	135	143	151	160	170	181	192	205	218	232	248
BAU CO_2 emissions excl. BC		100	107	114	122	131	140	150	161	172	184	197	211	226	242	260	279
CO_2 emissions excl. BC with policy		100	107	114	122	131	140	150	161	172	184	197	211	226	243	260	279
BAU CO_2 emissions incl. BC		100	107	114	122	131	140	150	161	172	184	197	211	227	243	260	279
CO_2 emissions incl. BC with policy		100	107	114	122	130	139	148	158	168	180	192	205	219	235	251	269

Economic assessment

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	cumulative
Value PM and NO_2 reduction	MUSD	0.0	0.0	0.0	0.1	0.2	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.3	8.2
Value GHG reduction	MUSD	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	6.5
Value SO_2 reduction	MUSD	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1
Surcost gasoline vehicles	MUSD	0.0	0.0	0.0	0.1	0.2	0.3	0.3	0.4	0.5	0.7	0.8	0.9	1.0	1.1	1.3	1.4	9.0
Balance	MUSD	0.0	0.0	0.0	0.0	0.1	0.1	0.2	0.3	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	5.9

Differential investment			
Surcost investment diesel	2,000	USD	
Fuel usage diesel	8.6	l/100km	
Fuel usage gasoline	10.3	l/100km	
Maintenance surcost diesel	50	USD	
Cost diesel Bhutan	0.86	USD/l	as of Jan 2017
Cost gasoline Bhutan	1.01	USD/l	as of Jan 2017
Annual fuel cost savings diesel	276	USD	
Commercial lifespan	10	years	due to non-discounting a shorter commercial than technical life-span is taken
surcost gasoline per annum non-discounted	26		

Combined Policies
The following policies are combined:
P1: low sulphur fuels
P2: new emission standards
P4: IM improvement but not IM240
P5: Low carbon vehicles
P7: No diesel vehicles
P3: age limit taxis 10 years

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Passenger cars Euro 2 gasoline	vehicles	27,320	29,491	31,834	29,712	27,589	25,467	23,345	21,223	19,100	16,978	14,856	12,734	10,611	8,489	6,367	4,245
Passenger cars Euro 2 diesel	vehicles	18,213	19,660	21,223	19,808	18,393	16,978	15,563	14,148	12,734	11,319	9,904	8,489	7,074	5,659	4,245	2,830
Passenger cars Euro 4 gasoline	vehicles	0	0	0	7,753	15,840	24,290	24,290	24,290	24,290	24,290	24,290	24,290	24,290	24,290	24,290	24,290
Passenger cars Euro 6 gasoline	vehicles	0	0	0	0	0	0	8,840	18,101	27,816	38,023	48,760	60,068	71,994	84,587	97,900	111,989
Taxis Euro 2 diesel	vehicles	537	544	552	501	451	401	351	301	251	201	150	100	50	0	0	0
Taxis Euro 2 gasoline	vehicles	3,302	3,344	3,388	3,080	2,772	2,464	2,156	1,848	1,540	1,232	924	616	308	0	0	0
Taxis Euro 4 gasoline	vehicles	0	0	0	409	819	1,230	1,230	1,230	1,230	1,230	1,230	1,230	1,230	1,230	821	0
Taxis Euro 6 gasoline	vehicles	0	0	0	0	0	0	411	823	1,236	1,650	2,064	2,479	2,894	3,311	3,779	4,659
HDVs <7.5t Euro II	vehicles	1,457	1,559	1,668	1,557	1,446	1,334	1,223	1,112	1,001	890	778	667	556	445	334	222
HDVs <7.5t Euro IV	vehicles	0	0	0	228	464	709	709	709	709	709	709	709	709	709	709	709
HDVs <7.5t Euro VI	vehicles	0	0	0	0	0	0	254	519	794	1,080	1,379	1,690	2,016	2,357	2,714	3,088
HDVs >7.5t Euro II	vehicles	8,537	9,135	9,774	9,122	8,471	7,819	7,168	6,516	5,864	5,213	4,561	3,910	3,258	2,606	1,955	1,303
HDVs >7.5t Euro IV	vehicles	0	0	0	1,336	2,719	4,154	4,154	4,154	4,154	4,154	4,154	4,154	4,154	4,154	4,154	4,154
HDVs >7.5t Euro VI	vehicles	0	0	0	0	0	0	1,490	3,038	4,649	6,328	8,078	9,905	11,815	13,812	15,904	18,096
Hybrid passenger cars	vehicles	0	0	0	0	418	1,322	2,785	4,890	7,162	9,615	12,264	15,122	18,208	21,538	25,134	29,015
Share hybrid passenger cars	%	0%	0%	0%	0%	1%	2%	4%	6%	9%	11%	13%	14%	16%	18%	19%	20%
Plug-in hybrid passenger cars	vehicles	0	0	0	0	0	0	488	1,540	3,055	5,100	7,748	10,749	14,143	17,973	22,288	27,139
Share plug-in hybrid passenger cars	%	0%	0%	0%	0%	0%	0%	1%	2%	4%	6%	8%	10%	12%	15%	17%	19%
Electric passenger car	vehicles	0	0	0	0	0	0	0	0	379	1,196	2,520	4,093	5,944	8,109	10,626	13,536
share electric passenger cars	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	3%	4%	5%	7%	8%	9%
Hybrid taxis	vehicles	0	0	0	41	124	250	399	571	702	791	836	872	899	918	886	763
share hybrid taxis	%	0%	0%	0%	1%	3%	6%	10%	14%	16%	18%	19%	20%	20%	20%	19%	16%
Plug-in hybrid taxis	vehicles	0	0	0	0	21	63	148	277	437	629	853	1,031	1,169	1,262	1,310	1,289
share plug-in hybrid taxis	%	0%	0%	0%	0%	1%	2%	4%	7%	10%	15%	20%	23%	26%	28%	28%	28%
Electric taxis	vehicles	0	0	0	0	0	0	43	159	275	423	602	838	1,132	1,486	1,901	2,379
share electric taxis	%	0%	0%	0%	0%	0%	0%	1%	4%	6%	10%	14%	19%	25%	33%	41%	51%
Hybrid HDVs < 7.5t	vehicles	0	0	0	2	11	26	53	92	137	140	198	256	311	364	414	460
share hybrid HDVs < 7.5t	%	0%	0%	0%	0%	1%	1%	2%	4%	5%	5%	7%	8%	9%	10%	11%	11%
Plug-in hybrid HDVs < 7.5t	vehicles	0	0	0	0	1	4	14	32	56	61	102	141	179	214	248	279
Share plug-in hybrids < 7.5t	%	0%	0%	0%	0%	0%	0%	1%	1%	2%	2%	4%	5%	5%	6%	7%	7%
Electric HDVs < 7,5t	vehicles	0	0	0	0	0	0	7	22	46	55	103	163	237	328	437	565
share electric HDVs < 7.5t	%	0%	0%	0%	0%	0%	0%	0%	1%	2%	2%	4%	5%	7%	9%	12%	14%
Hybrid HDVs > 7.5t	vehicles	0	0	0	7	21	44	73	108	136	156	166	176	183	188	184	163
share hybrid HDVs > 7.5t	%	0%	0%	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%	1%	1%	1%
Plug-in hybrid HDVs> 7.5t	vehicles	0	0	0	0	4	11	28	28	62	105	159	205	242	229	244	240
Share plug-in hybrids > 7.5t	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%	1%	1%	1%	1%
Electric HDVs > 7.5t	vehicles	0	0	0	0	0	0	8	16	41	75	118	177	256	271	394	545
share electric HDVs > 7.5t	%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	1%	1%	1%	2%	2%

SO_2 emissions in tons	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Cumulative**
Passenger cars	12.5	13.5	14.6	3.2	3.5	3.8	0.8	0.9	0.9	1.0	1.0	1.1	1.1	1.2	1.2	1.3	61
Motorcycles	0.4	0.5	0.5	0.2	0.2	0.2	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	3
Taxis	2.1	2.1	2.1	0.6	0.6	0.6	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	9
HDVs	29.8	31.9	34.1	4.9	5.3	5.6	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.2	128
Emissions with Policy	44.8	48.0	51.3	8.9	9.5	10.2	2.2	2.3	2.5	2.6	2.7	2.9	3.1	3.2	3.4	3.6	201
BAU	44.8	48.0	51.3	54.9	58.8	63.0	67.4	72.2	77.4	82.9	88.8	95.1	101.9	109.2	117.1	125.5	1,258
Share of BAU	100%	100%	100%	16%	16%	16%	3%	3%	3%	3%	3%	3%	3%	3%	3%	3%	16%

PM emissions in tons	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Cumulative**
Passenger cars	9.5	10.3	11.1	10.4	9.8	9.1	8.5	7.8	7.2	6.6	5.9	5.3	4.6	4.0	3.4	2.7	116
Motorcycles	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.4	0.4	0.4	0.5	4
Taxis	0.9	0.9	0.9	0.9	0.8	0.7	0.6	0.6	0.5	0.4	0.3	0.2	0.2	0.1	0.1	0.1	8
HDVs	28.3	30.3	32.4	31.0	29.5	28.1	26.0	23.8	21.7	19.6	17.4	15.3	13.1	11.0	8.9	6.8	343
Emissions with Policy	38.9	41.7	44.6	42.4	40.3	38.1	35.3	32.5	29.6	26.8	24.0	21.1	18.3	15.5	12.7	10.0	472
BAU	38.9	41.7	44.6	48.7	52.2	56.0	59.9	64.2	68.8	73.8	79.1	84.7	90.8	97.3	104.3	111.9	1,117
Share of BAU	100%	100%	100%	87%	77%	68%	59%	51%	43%	36%	30%	25%	20%	16%	12%	9%	42%

NO_2 emissions in tons	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Cumulative**
Passenger cars	174	187	202	189	176	162	150	137	124	111	98	85	72	59	46	33	2,004
Motorcycles	13	14	15	16	18	19	21	22	24	26	28	30	33	35	38	41	393
Taxis	29	29	29	27	24	21	19	16	14	11	8	6	3	0	0	0	236
HDVs	1,509	1,615	1,728	1,726	1,728	1,734	1,631	1,528	1,425	1,323	1,220	1,118	1,016	918	819	722	21,758
Emissions with Policy	1,724	1,845	1,975	1,958	1,945	1,935	1,820	1,704	1,587	1,471	1,354	1,238	1,124	1,012	903	796	24,392
BAU	1,724	1,845	1,975	2,186	2,306	2,468	2,641	2,827	3,026	3,240	3,468	3,713	3,975	4,256	4,557	4,879	49,086
Share of BAU	100%	100%	100%	90%	84%	78%	69%	60%	52%	45%	39%	33%	28%	24%	20%	16%	50%

CO_2 emissions in tons	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Cumulative**
Passenger cars	80,399	86,787	93,683	99,433	105,539	112,018	118,544	125,081	131,348	137,258	142,708	148,332	154,119	160,052	166,116	172,287	2,033,704
Motorcycles	4,542	4,903	5,293	5,713	6,167	6,657	7,186	7,757	8,374	9,039	9,757	10,533	11,370	12,273	13,248	14,301	137,115
Taxis	17,315	17,540	17,768	17,868	17,886	17,819	17,464	16,685	15,893	14,955	13,868	12,638	11,248	9,700	8,112	6,488	233,248
HDVs	135,868	145,379	155,555	166,415	177,967	190,255	203,101	216,826	230,982	246,384	262,121	278,786	296,431	316,581	336,382	357,415	3,716,448
Emissions with Policy CO2 only	238,125	254,610	272,299	289,430	307,560	326,749	346,296	366,349	386,597	407,636	428,454	450,288	473,167	498,607	523,858	550,491	6,120,515
BAU CO2 only	238,125	254,610	272,299	291,283	311,658	333,525	356,996	382,190	409,235	438,268	469,436	502,899	538,827	577,403	618,824	663,302	6,658,879
Share of BAU	100%	100%	100%	99%	99%	98%	97%	96%	94%	93%	91%	90%	88%	86%	85%	83%	92%

CO_2 incl. BC emissions in tons	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Cumulative**
Passenger cars	86,988	93,900	101,361	106,609	112,215	118,192	124,221	130,260	136,030	141,442	146,394	151,521	156,810	162,247	167,814	173,489	2,109,496
Motorcycles	4,575	4,938	5,331	5,754	6,211	6,705	7,238	7,813	8,433	9,104	9,827	10,608	11,451	12,360	13,343	14,403	138,092
Taxis	17,886	18,119	18,354	18,402	18,368	18,249	17,843	17,011	16,167	15,177	14,038	12,755	11,312	9,712	8,123	6,499	238,016
HDVs	152,438	163,109	174,527	184,589	195,360	206,883	218,466	230,927	243,819	257,960	272,434	287,836	304,220	323,109	341,649	361,423	3,918,750
Emissions with Policy CO2 incl. BC	261,887	280,066	299,572	315,355	332,154	350,030	367,768	386,011	404,450	423,683	442,693	462,720	483,793	507,428	530,929	555,814	6,404,354
BAU CO2 incl. BC	261,887	280,066	299,572	320,505	342,970	367,079	392,956	420,732	450,546	482,549	516,906	553,789	593,387	635,901	681,547	730,560	7,330,952
Share of BAU	100%	100%	100%	98%	97%	95%	94%	92%	90%	88%	86%	84%	82%	80%	78%	76%	87%

Urban Estimated Emissions 2030

Parameter	PM		NO_2		SO_2	
	with policy	BAU	with policy	BAU	with policy	BAU
Passenger cars	1.9	21.0	23	383	1	28
Taxis	0.1	1.1	0	35	0	3
Motorcycles	0.4	0.4	0	0	0	1
HDVs	1.4	15.6	144	833	0	16
Total	**3.7**	**38.1**	**167**	**1,250**	**1**	**48**
reduction relative BAU	90%		87%		97%	
reduction relative 2015	72%		63%		92%	

Economic assessment

Parameter	Unit	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	cumulative
Value PM, SO_2 and NO_2 reduction	MUSD	0.0	0.0	0.0	0.4	0.7	1.1	1.5	1.9	2.4	2.9	3.3	3.9	4.4	5.0	5.6	6.2	39.3
Value GHG reduction	MUSD	0.0	0.0	0.0	0.2	0.4	0.7	1.0	1.4	1.8	2.4	3.0	3.6	4.4	5.1	6.0	7.0	37.1
Fuel surcost	MUSD	0.0	0.0	0.0	0.5	0.5	0.6	1.2	1.3	1.4	1.5	1.6	1.7	1.8	2.0	2.1	2.2	18.4
Vehicle surcost	MUSD	0.0	0.0	0.0	0.3	0.5	0.8	1.4	1.9	3.1	4.5	6.2	7.9	9.5	10.0	11.1	11.5	68.9
IM surcost	MUSD	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3	0.3	0.3	0.3	0.3	0.4	3.2
Balance (+ additional benefit; - add. cost)	MUSD	0.0	0.0	0.0	-0.3	-0.1	0.2	-0.3	-0.1	-0.5	-1.0	-1.7	-2.4	-2.8	-2.2	-1.9	-1.0	-14.1

Annex 2: Draft Fuel Regulations

1. Fuel imported must adhere to the nationally valid standards for fuel sold commercially at national level in India as of time of import to Bhutan. Fuel imports which do not adhere to these standards are not permitted.

2. The fuel importer must provide a fuel data sheet for each import lot which shows that Indian fuel specifications are met.

3. The valid Indian fuel specifications are:

Prior 04/2017: BS-III fuel with maximum 150ppm sulphur in gasoline and 350ppm in diesel

From 01/04/2017 onwards: BS-IV fuel with maximum 50ppm sulphur in gasoline and diesel

From 01/04/2020 onwards: BS-VI fuel with maximum 10ppm sulphur in gasoline and diesel

4. The MOC will establish a norm for fuel quality control to prevent adulteration and to ensure high quality fuels to the public. The norm is based on random spot checks at the time of import and distribution (pump stations) of fuels.

Annex 3: Draft Regulation Vehicle Emission Standard (New Vehicles)

1. All vehicles imported to Bhutan as of 01/01/2018 must comply as minimum with the Indian vehicle standard Bharat-IV.

2. All vehicles imported to Bhutan as of 01/01/2021 must comply as minimum with the Indian vehicle standard Bharat-VI.

3. Importers of vehicles must provide documentary proof showing adherence to the standard.

4. Emission standards from other countries are also accepted if they comply at minimum with the Bharat standard. Explicitly vehicles can also be imported with the respective documentation that adhere to the standards as detailed below.

Table 32: Required Emission Standard New Vehicles Bhutan

Standard	Requirement as of 01/01/2018	Requirement as of 01/01/2021
India: Bharat Stage	BS-IV	BS-VI
European Union: Euro	Euro 4 / Euro IV	Euro 6 / Euro VI
China Standard	China 4	China 6

5. A Certificate of Conformity (COC) is required from the importer of vehicles. This can be the Indian Certificate for Conformity of Production as already being supplied by some importers to RSTA (e.g. by Hyundai Motor India), the EU, US, Japanese or Korean COC.

For EU COC documents of multiple manufacturers see e.g. https://www.eurococ.eu/en/certificate-of-conformity.

For US vehicles these certificates can be obtained by the manufacturer or the EPA see https://www.epa.gov/importing-vehicles-and-engines/how-obtain-copy-certificate-conformity-light-duty-vehicle-car-truck.

In Japan, the Japan Inspection Organization issues the COC, also called certificate of compliance, or certificate of conformance for all used and new Japanese vehicles (see https://japaninspection.org/certificate-of-conformity-coc/).

COCs need not be issued newly for each vehicle imported as COCs are for specific vehicle models and manufacturing years e.g. one COC can be issued and be used by the importer repeatedly for a specific vehicle model e.g. Hyundai Creta 1.6 VTVT in the manufacturing period 2016-2017.

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