CALAC+ Programme

Analysis of the economic and environmental impact of migration to EURO 6/VI emission standards in Peru

OUTCOME 4. Final Report

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1 List of acronyms and abbreviations

Institutions

CALAC+	Climate and Clean Air project in Latin American Cities Plus
CBA	Cost Benefit Analysis
EEA	European Environment Agency
EPA	United States Environmental Protection Agency
ICCT	International Council on Clean Transportation
IHME	Institute for Health Metrics and Evaluation
IMF	International Monetary Fund (IMF)
INEI	National Institute of Statistics and Information Technology
MEF	Ministry of Economy and Finance of Peru
MINAM	Ministry of the Environment of Peru
OECD	Organization for Economic Co-operation and Development
OSINERGMIN	Energy and Mining Investment Supervisory Agency
SDC	Swiss Agency for Development and Cooperation
WHO	World Health Organization

Pollutants

BC	Black carbon
CO	Carbon monoxide
CO_2	Carbon dioxide
GGH	Greenhouse gases
H_2S	Hydrogen sulphide
HC	Hydrocarbons
NMVOCs	Non-methane volatile organic compounds
NOx	Nitrogen oxides
PM	Particulate matter

$PM_{10-2.5}$	Particulate matter smaller than 10 and larger than 2.5 µg/m3 in aerodynamic diameter
$PM_{2.5}$	Particulate matter smaller than 2.5 µg/m3 in aerodynamic diameter
SO_2	Sulphur dioxide

Units

Bar	Unit of pressure, approximately equal to one atmosphere
Bpd	Barrels per day
Ppm	Parts per million
µg/m3	Micrograms per cubic meter

Other abbreviations

ALRI	Acute lower respiratory infections
BAU	Business as usual
CBA	Cost-benefit analysis
COPD	Chronic Obstructive Pulmonary Disease
DALYs	Disability-Adjusted Life Years
DPF	Diesel Particulate Filter
EF	Emission factor
GBD	Global Burden of Disease
GDP	Gross Domestic Product
LPG	Liquified Petroleum Gas
NGV	Natural Gas Vehicles
OBD	Onboard diagnostic systems
PAF	Population Attributable Fraction
SCR	Selective Catalytic Reduction
VSL	Value of a statistical life
YLD	Years Lived with Disability
YLL	Years of Life Lost

2 Executive Summary

According to the 2016 emissions inventory, the mobile source sector is the largest emitter of particulate matter and its precursors. In addition, the transport sector has increased by a factor of 2.58 between 2000 and 2018. Given the sustained growth of this sector, mechanisms to reduce vehicle emissions must be examined to ensure that air quality levels in Lima and Callao improve over time.

This report assesses the introduction of the Euro 6 emission standard for light-duty vehicles and Euro VI for heavy-duty vehicles, hereafter referred to generically as the Euro 6/VI standard. Among the costs for implementing the new standard, the cost-benefit analysis considers the investment and maintenance costs associated with the technological improvements required to comply with the Euro 6/VI standard, as well as sulphur removal costs, and those associated with the use of AUS 32 (automotive aqueous urea solution), commonly known as AdBlue. Quantified benefits include premature mortality avoided, fuel consumption savings due to improved Euro 6/VI vehicle efficiency and CO_2 emission costs avoided. Additionally, other health metrics are reported: Disability Adjusted Life Years (DALYs), Years of Life Lost (YLL) and Years Lived with Disability (YLD).

As a digital annex to the report, an Excel spreadsheet is included containing the analysis estimates and user-modifiable parameters for evaluating scenarios in addition to those presented in this report. This spreadsheet will be hereinafter referred to as "attached spreadsheet".

The assessment assumptions are summarised in the table below.

Table 2-1: Assessment assumptions

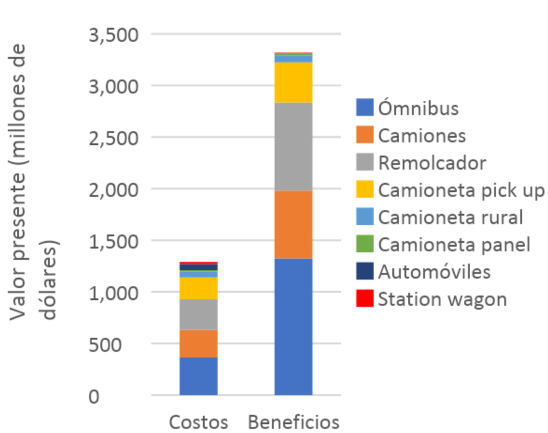
Parameters	Value/assumption	Section of the report
Regulatory standard (Maximum permissible limit - MPL)	EURO 6/VI	
New standard in force	2021	
Final year of the assessment	2030	
Emission factors	Tier 2	4.1.1
Entry rate of light-duty vehicles	7.7%	
Entry rate of heavy-duty vehicles	6.8%	
Exit rate of light-duty vehicles	0%	
Exit rate of heavy-duty vehicles	0%	
Fuel saving vs. Euro 4/IV, heavy-duty diesel vehicles	7%	4.3.4
GDP per capita growth	2.7%	4.2.2
Discount rate	8%	4.4
Exchange rate (soles per dollar)	3.37	
VSL (millions of dollars)	O.684	4.2.2
AUS 32 consumption	4%	4.3.3
AUS 32 cost	Medium	
Sulphur cost	ICCT Scenario	4.3.2
Social Price CO_2	7.17	4.3.5

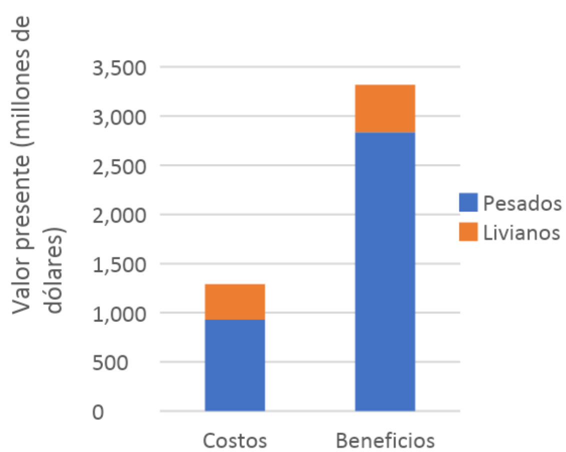
Mortality	Natural causes	4.2.1
Concentration emission ratio	Fantke et al. 2017	4.1.3
Lifetime of investment for light-duty vehicles (kilometres)	262,754	4.3.1
Lifetime of investment for heavy-duty vehicles (kilometres)	1,424,254	

Source: Own elaboration. For details of the selected references, refer to the sections of the report indicated in the final column of the table.

The results of the assessment indicate that:

- The environmental concentration of $PM_{2.5}$ would be reduced in 3.67 µg/m^3 by 2030.
- A total of 5,406 premature deaths (natural causes) would be avoided in the period 2021-2030
- The total benefits of the new standard would reach $3,317 million dollars in present value, equivalent to S/.11,179 million soles. The main benefits correspond to avoided mortality, equivalent to 78%, followed by benefits due to lower fuel consumption (21%) and CO_2 emissions avoided (1%).
- Total costs would reach US$1,291 million, equivalent to S/.4,349 million soles in present value. 41% of the costs would come from the consumption of AUS 32, followed by technology investment costs (30%), sulphur removal costs (30%) and particulate filter maintenance costs (1%).
- The standard would have a net profit of $2,027 million dollars, equivalent to S/.6,830 million soles and a benefit-cost ratio of 2.6.
- Both the costs and benefits of the standard fall largely on diesel vehicles (93% for costs and 100% for benefits, see Figure 5-9).
- Emitters would bear 91% of the costs, earning 22% of the benefits due to lower fuel. On the other hand, the population living in Lima and Callao would receive 78% of the benefits, as they would be exposed to a lower level of pollution and therefore reduce their probability of premature mortality (see section 5.3.1).





Translation of text in Figure

Valor presente (millones de dólares): Present value (millions of dollars)

Ómnibus: Bus

Camiones: Trucks

Remolcador: Trailer truck
Camioneta pick up: Pickup truck
Camioneta panel: Panel van
Automóviles: Cars
Station wagon: Station wagon

3 Background

The Swiss Agency for Development and Cooperation (SDC), through its Global Programme Climate Change and Environment (GPCCE), is promoting the implementation of the Climate and Clean Air project in Latin American Cities Plus (CALAC+), aimed at reducing harmful air pollutants and mitigating climate change. The program also seeks to facilitate capacity building and knowledge transfer.

In Peru, the process of controlling air emissions from road transport began in 1998, with the removal of lead from gasoline, followed by the gradual implementation of emission standards. The Euro 4/IV emission standard, established in November 2017 and effective from April 2018, is currently in force[1].

Migration towards the Euro 6/VI standards would reduce both greenhouse gases (such as CO_2 and BC), and local pollutants (PM, SO_2. NOx, among others) which are responsible for air pollution (see sections 4.1.1 and 5.1). According to the World Health Organisation (WHO), air pollution contributed to 7.6% of total mortality in 2016.[2] In Peru, it is estimated that by the same year, mortality associated with particulate matter and ozone will have risen to around 7,000 deaths[3], equivalent to 5.5% of the total estimated mortality in the country for that year[4]. It is worth mentioning that this analysis only considers mortality associated to particulate matter.

This study is part of CALAC+'s activities in Peru and provides an analysis of the economic and environmental impact of migration to Euro 6/VI emission standards in the Metropolitan area of Lima and Callao.

The objectives of the study are:

- Assess the economic and environmental impact of migrating to Euro 6/VI emission standards for vehicles with four or more wheels (light and heavy-duty vehicles) in Peru.
- Transfer capacities to staff of the Ministry of the Environment and Swisscontact, as well as to key government stakeholders (Ministry of Economy and Finance, Ministry of Energy and Mines and Ministry of Health, Ministry of Transport and Communications and the

[1] Supreme Decree Nº 10 of 2017, MINAM, available at https://busquedas.elperuano.pe/normaslegales/establecen-limites-maximos-permisibles-de-emisiones-atmosfer-decreto-supremo-n-010-2017-minam-1592399-2/
[2] Data available at https://www.who.int/gho/phe/outdoor_air_pollution/burden/en/
[3] Figure according to https://ourworldindata.org/air-pollution

[4] Using a 2016 total mortality value for Peru of 138,194 according to IHME (2018)

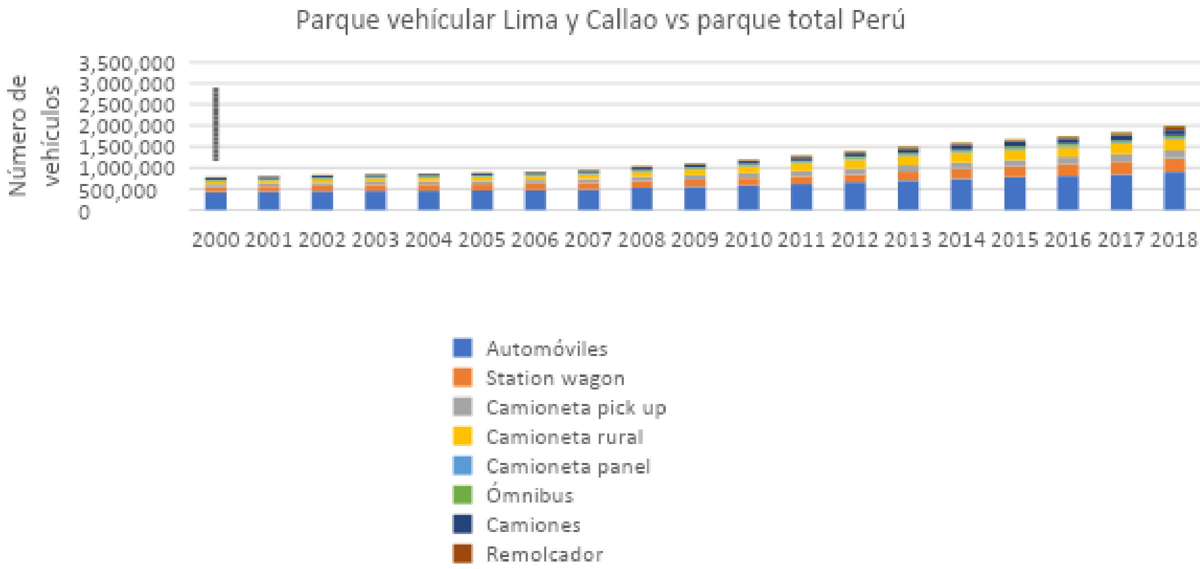
Metropolitan Municipality of Lima), to carry out the Cost-Benefit Analysis (CBA) of the regulatory change.

3.1 Vehicle fleet in Lima and Callao

According to data obtained from the Air Quality Management Diagnosis of Lima and Callao (2019) (provided by the Ministry of the Environment), the fleet of Lima and Callao represents 69% of Peru's total vehicle fleet (2018), amounting to a total of nearly 2 million vehicles, excluding motorcycles, which total 594 thousand units.

Figure 3-1 also shows that the vehicle fleet has grown considerably from 2000 onwards, having multiplied by a factor of 2.46 between 2000 to 2018.

Figure 3-1: Vehicle fleet in Lima and Callao (stacked bars) according to vehicle type vs. total fleet in Peru (line)

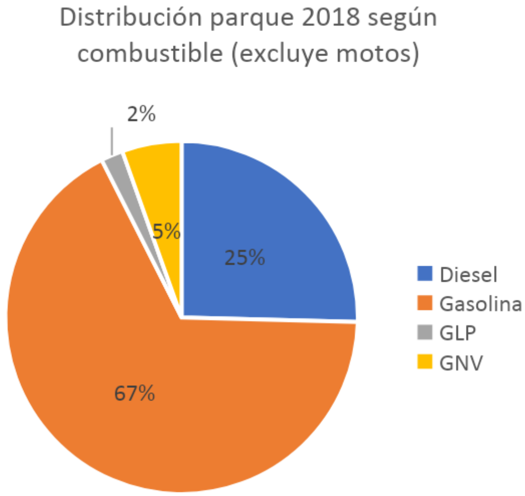


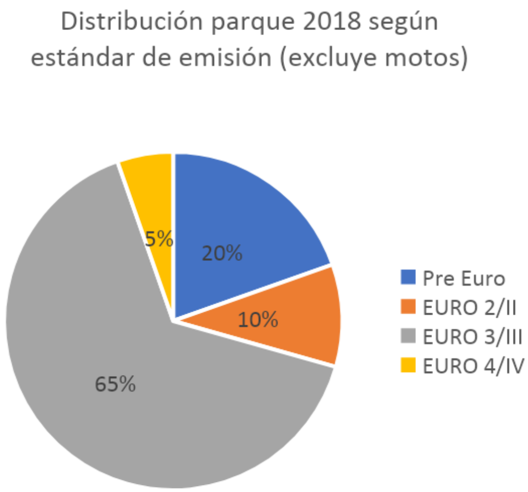
Source: Own elaboration based on data from the Ministry of Transport and Communications.

Translation of text in Figure 3-1

Parque vehicular Lima y Callao vs parque total Perú: Vehicle fleet in Lima and Callao versus total vehicle fleet in Peru
Número de vehículos: Number of vehicles
Automóviles: Cars
Station wagon: Station wagon
Camioneta pick up: Pickup truck
Camioneta rural: Minivan
Camioneta panel: Panel van
Ómnibus: Bus
Camiones: Trucks
Remolcador: Trailer truck

Figure 3-2: Distribution of the fleet according to fuel (left) and emission standard (right)





Source: Own elaboration based on data provided by MINAM (Diagnosis of Air Quality Management of Lima and Callao)

Translation of text from Figure 3-2
Diesel: Diesel
Gasolina: Gasoline
GLP: LPG
GNV: NGV
Distribución parque 2018…: Distribution of 2018 fleet according to emission standard (excluding motorcycles)

Figure 3-2 presents the distribution of the fleet in terms of fuel used (left) and emission standard (right) for 2018. It can be noted that 67% of the fleet uses gasoline as fuel, followed by diesel, NGV and LPG with a share of 25%, 6% and 2%, respectively.

Figure 3-2 also shows that the Euro 4/IV emission standard represents only 5% of the fleet, while the prevailing standard is Euro 3/III, with 65% of the fleet.

Table 3-1 presents the fleet composition according to vehicle type and fuel. The main vehicle category corresponds to cars, followed by station wagons and minivans. Further details of the fleet composition are presented in Table 7-4 in the Annexes.

Table 3-1: Distribution of vehicles in 2018, according to type of vehicle and fuel used.

Type of vehicle	Diesel	LPG	NGV	Gasoline	Total	(excluding motorcycles)
Cars	544	22,593	53,805	830,397	**907,340**	46.1%
Station wagon	1,246	12,999	47,013	258,126	**319,384**	16.2%
Pickup truck	165,965	865	92	17,116	**184,038**	9.3%
Minivan	68,108	2,206	505	194,916	**265,734**	13.5%
Panel van	12,838	1,003	495	20,502	**34,838**	1.8%
Bus	50,951	62	5,520	142	**56,676**	2.9%
Trucks	130,227	0	183	603	**131,013**	6.7%
Trailer truck	70,558	0	0	0	**70,558**	3.6%
Motorcycles	0	0	0	594,235	**594,235**	
Total (with motorcycles)	500,437	39,728	107,613	1,916,036	2,563,815	
Total (excluding motorcycles)	**500,437**	**39,728**	**107,613**	**1.321.802**	**1.969.581**	100.0%

Source: Own elaboration based on data provided by MINAM

3.2 Emissions in Lima and Callao

According to the 2016 emissions inventory, mobile sources contribute the largest amount of emissions of black carbon, particulate matter, nitrogen oxides and sulphur dioxide, among other pollutants, as shown in Table 3-2 and Figure 3-3. These pollutants contribute to the formation of $PM_{2.5}$ in the atmosphere and should therefore be controlled to prevent harmful health effects.

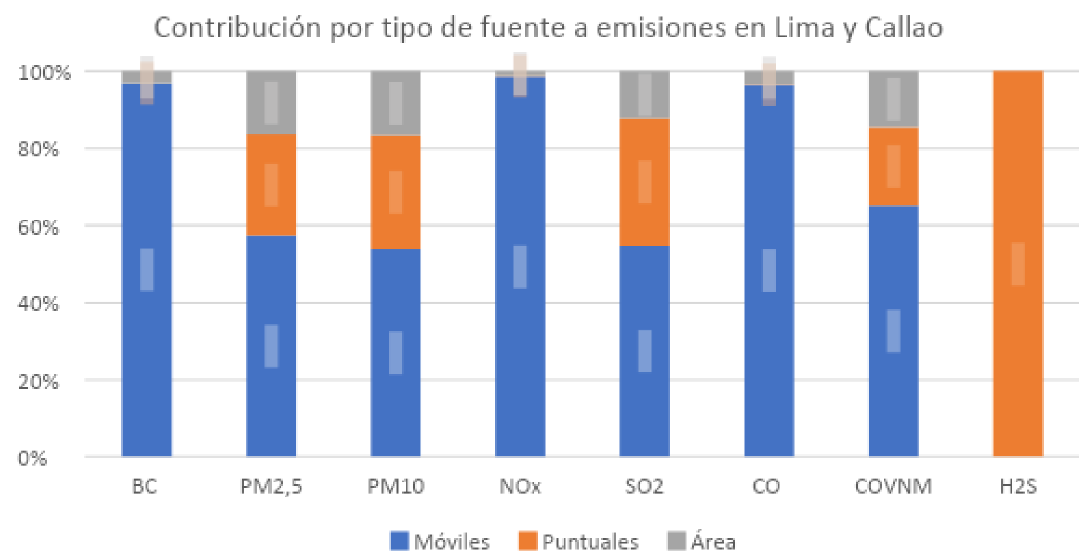
Table 3-2: Emission inventory in Lima and Callao, 2016

	BC	$PM_{2.5}$	PM_{10}	NOx	SO_2	CO	COVNM	H_2S
Mobile	2,228	3,898	3,898	152,106	38,765	272,905	24,582	0
Punctual	0	1,784	2,156	307	23,363	461	7,636	6
Area	71	1,108	1,200	1,774	8,615	9,549	5,476	0
TOTALS	2,299	6,789	7,254	154,188	70,743	282,915	37,695	6

Source: Information provided by MINAM.

The transport sector accounts for over 50% of PM and SO_2 emissions and more than 98% of NOx emissions (See Figure 3-3). Emissions from these pollutants would be reduced with the introduction of new emission standards for mobile sources, with a particularly relevant effect on diesel-powered heavy-duty vehicles.

Figure 3-3: Contribution to emissions by type of source in Lima and Callao, 2016.



Source: Based on information provided by MINAM (Diagnóstico de la Gestión de la Calidad del Aire de Lima y Callao).

Translation of text in Figure 3-3

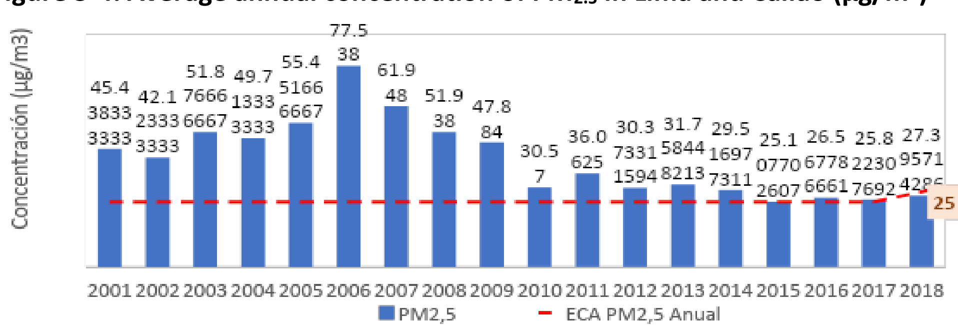
Contribución por tipo de fuente a emisiones en Lima y Callao: Contribution to emissions by type of source in Lima and Callao
Móviles: Mobile
Puntuales: Punctual
Área: Area

3.3 Air quality data

Figure 3-4 presents the evolution of air quality data for fine particulate matter between 2001 and 2018 in Lima and Callao. It can be noted that the annual values are above the environmental quality standard of 25 µg/m^3 although the values show a decreasing trend from 2006 onwards. However, $PM_{2.5}$ levels significantly exceed the WHO's recommended level of 10 µg/m^3 for annual $PM_{2.5}$ concentration (World Health Organization 2005).

In this analysis, the baseline concentration will be 27.4 µg/m^3 for 2018.

Figure 3-4: Average annual concentration of $PM_{2.5}$ in Lima and Callao (µg/m^3)



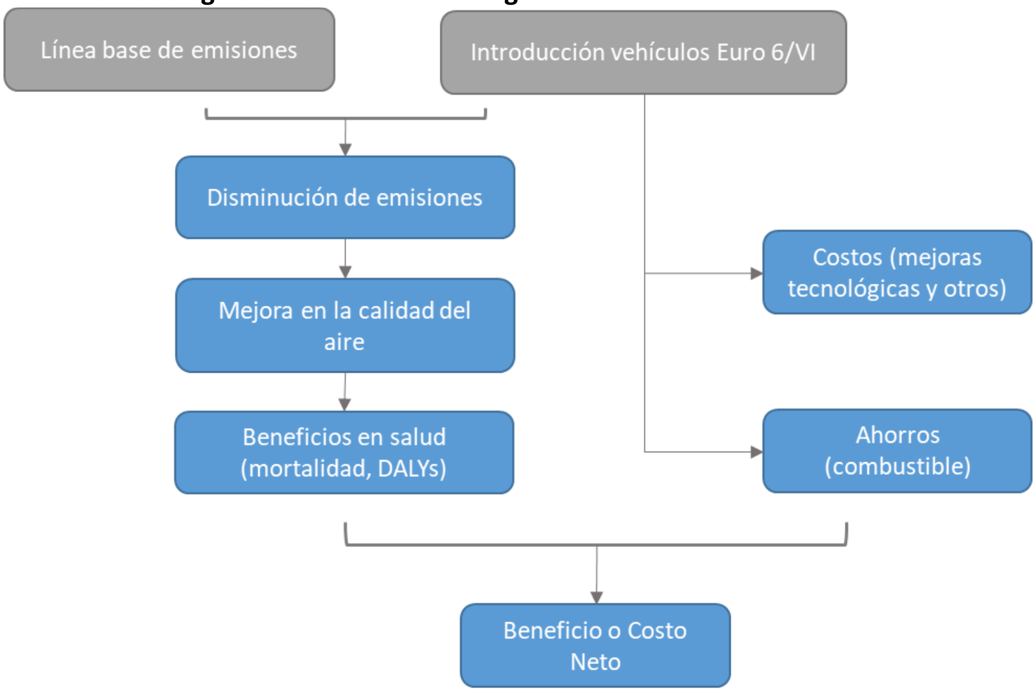
Source: Data provided by MINAM

Translation of text in Figure 3-4
Concentración: Concentration
ECA PM2.5 Anual: Annual $PM_{2.5}$ Environmental Quality Standards

4 Methodology and scope

The methodology for assessing the economic and environmental impact of migration towards Euro 6/VI emission standards is presented in Figure 4-1.

Figure 4-1: Methodological scheme for assessing standards



Source: Own elaboration

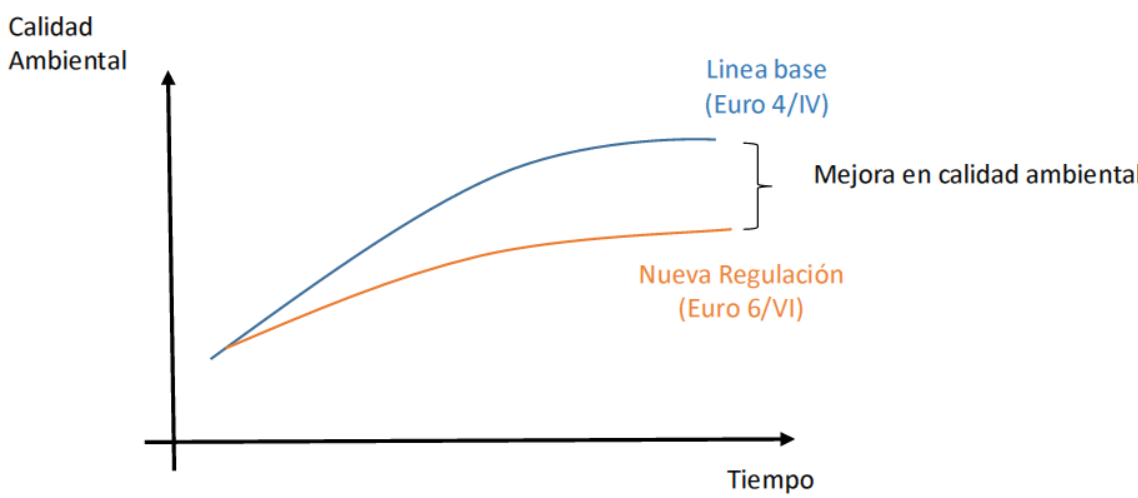
Translation of text in Figure 4-1
Línea base de emisiones: Emissions baseline
Introducción vehículos Euro 6/VI: Introduction of Euro 6/VI vehicles
Disminución de emisiones: Emissions reduction
Mejora en la calidad del aire: Air quality improvement
Costos (mejoras tecnológicas y otros): Costs (technological improvements and others)
Beneficios en salud (mortalidad, DALYs): Health benefits (mortality, DALYs)
Ahorros (combustible): Savings (fuel)
Beneficio o costo neto: Net Benefit or cost

The analysis includes the estimation of the emissions baseline, under the current standard (Euro 4/IV) and the emissions reductions that would be achieved by introducing an emissions standard (Euro 6/VI). Reduced emissions would result in improved air quality (see Figure 4-2) and this lower $PM_{2.5}$ concentration would translate into health benefits due to avoided mortality and morbidity.

On the other hand, there are also regulatory compliance costs associated with technological improvements and enforcement of standards. At the same time, new vehicle standards may bring about greater fuel efficiency, resulting in savings for vehicle users.

The regulatory analysis will consider both the benefits and costs of regulatory implementation to estimate the net benefit of regulation and indicators such as the cost/benefit ratio.

Figure 4-2: Environmental quality under the baseline scenario and the new standard scenario



Source: Own elaboration.

Translation of text in Figure 4-1

Calidad ambiental: Environmental quality
Línea base (Euro 4/IV): Baseline (Euro 4/IV)
Mejora en calidad ambiental: Environmental quality improvement
Nueva regulación (Euro 6/VI): New standard (Euro 6/VI)
Tiempo: Time

In accordance with the Terms of Reference, the scope of this consultancy is presented in Table 4-1

Table 4-1: Scope of the study

Type	Scope
Regulatory	Euro 6/VI standard
Geographic	Metropolitan Area of Lima and Callao
Temporary	Until 2030
Pollutants	NOx, $PM_{2.5}$, black carbon, SO_2, CO_2
Emission sources	Mobile sources, four or more wheels, light and heavy-duty vehicles

Receivers	Population of the Metropolitan Area of Lima and Callao
Effects	Air quality in the Metropolitan Area of Lima and Callao and contributions to climate change
Scenarios	- Baseline (BAU) Euro 4/IV (BAU) - Euro 6/VI from 2021

4.1 Methodology for emissions and concentrations

4.1.1 Emissions from the transport sector

The methodology proposed for calculating emissions is based on the European Environment Agency Air Pollutant Emission Inventory Guidebook 2016, chapter "*1.A.3.b.i-iv Road transport hot EFs Annex 2018*". The guidebook presents three levels of emission factors, depending on the available information: Tier 1. Tier 2 and Tier 3. The Tier 1 methodology requires the least information for its implementation, including default emission factors for European countries. The Tier 2 methodology requires more information than the Tier 1 methodology, but less information than the Tier 3 methodology. The Tier 2 emission factors are calculated on the basis of Tier 3 factors, assuming typical traffic speed values, among other operating parameters corresponding to average vehicle operating conditions in Europe.

Overall, vehicle emissions will be calculated using emission factors and local activity levels (kilometres travelled by vehicle category, presented in Table 7-2 in the Annexes), as presented in the following equation (4-1).

$$E_i = \sum_s \sum_f EF_{ifs}(v) * LA_i \tag{4-1}$$

Where:

E_i: Emissions from vehicle type *i*

EF_{if}: Emission factor (depending on speed) of vehicle type *i*, fuel type *f*, emission standard type *s* (gr/Km)

LA_i: Level of activity, vehicle type *i* (km/year)

The emissions to be included in the analysis from emission factors will be particulate matter, black carbon and nitrogen oxides (NOx). Subsequently, from the fuel consumption it is possible to calculate the emissions of sulphur oxides (SOx) and carbon dioxide (CO_2). SO_2 emissions depend on fuel consumption and the sulphur content of the fuel, according to expression (4-2).

$$E_{SO2.m} = 2 * K_{S,m} * FC_m \tag{4-2}$$

Where:

$E_{SO2.m}$: SO_2 emissions in fuel *m* [g]

$K_{S,m}$: Fuel sulphur content *m* [g/g fuel]

FC_m: Fuel consumption m [g]

Carbon dioxide emissions are not only dependent on fuel consumption, but also on the type of fuel and the emissions of carbon monoxide, hydrocarbons and particulate matter. For this analysis, the kilograms of CO_2 released per kg of fuel presented in Table 4-2, corresponding to the Tier 1 methodology, will be considered. The CO_2 emissions are obtained by multiplying the fuel consumption by the values indicated in the table.

Table 4-2: Kilograms of CO_2 per kg of fuel, TIER 1

Original fuel	Local Fuel	kg CO_2 per kg of fuel
Petrol	Gasoline	3,169
Diesel	Diesel	3,169
CNG	NVG	3,024
LPG	LPG	2,743

Source: Table 3-12. EEA (2016).

The attached spreadsheet applies both Tier 2 and Tier 3 methodologies. In Peru, emission inventories have used Tier 2 methodology, i.e. EF does not depend on traffic speed. The average traffic speed in Lima and Callao is not known with certainty, but it does have an impact on emissions. Figure 7-1 in the Annexes presents an example of the impact of traffic speed on emissions. Due to the importance of this parameter, the typical speed profile in the Lima and Callao area should be analysed for its subsequent inclusion in future emissions estimates.

With regard to black carbon emissions, these can be estimated as a fraction of particulate matter emissions, depending on the type of vehicle, fuel used and emission standard. Table 4-3 presents the values used to calculate black carbon emissions.

Table 4-3: Fraction of black carbon in relation to particulate matter.

Fuel	EF Category	Standard 2	$BC/PM_{10}-PM_{2.5}$
Gasoline	Cars and station wagons	Pre Euro	0.3
		EURO 2/II	0.25
		EURO 3/III	0.15
		EURO 4/IV	0.15
		EURO 5/V	0.15
		EURO 6/VI	0.15
	Pick-up, Panel van, Minivan	Pre Euro	0.3
		EURO 2/II	0.25
		EURO 3/III	0.15
	Cars and station wagons	EURO 4/IV	0.15
		EURO 5/V	0.15
		EURO 6/VI	0.15
Diesel	Cars and station wagons	Pre Euro	0.55
		EURO 2/II	0.8
		EURO 3/III	0.85
		EURO 4/IV	0.87
		EURO 5/V	0.1

		EURO 6/VI	0.2
	Pick-up, Panel, Minivan	Pre Euro	0.55
		EURO 2/II	0.8
		EURO 3/III	0.85
		EURO 4/IV	0.87
		EURO 5/V	0.1
		EURO 6/VI	0.2
	Buses**	Pre Euro	0.5
		EURO 2/II	0.65
		EURO 3/III	0.7
		EURO 4/IV	0.75
		EURO 5/V	0.75
		EURO 6/VI	0.15
	Truck and trailer truck**	Pre Euro	0.5
		EURO 2/II	0.65
		EURO 3/III	0.7
		EURO 4/IV	0.75
		EURO 5/V	0.75
		EURO 6/VI	0.15
Gasoline	Motorcycles	EURO 2/II	0.11
		Average	0.11

Source: Based on Table 3-91. EEA (2016). The same fraction of Euro 5/V vehicles is considered for Euro 6/VI vehicles. *light commercial vehicles < 3.5 tonnes, **heavy-duty vehicles > 3.5 tonnes.

Emissions of NOx (gasoline and diesel vehicles) and PM (in the case of diesel vehicles) can also be set according to the sulphur content of the fuels, as indicated in Table 7-3 of the Annexes, based on (Liu et al. 2008). The attached spreadsheet allows the user to select whether or not to apply this setting. The setting is applied by default in the spreadsheet, just as it was set in the MINAM emissions inventory

Finally, fuel consumption is converted from mass units to volume units using the densities presented in Table 4-4.

Table 4-4: Fuel densities

Fuel	**Density (kg/m^3)**
Gasoline	750
Diesel	840
LPG	520
NGV	175

Source: Table 3-28, FSS (2016).

Emissions from the transport sector must be projected over time, considering the growth of the fleet, technological evolution of the vehicles (i.e. emission standards), the fuels used and the vehicle level of activity (kilometres travelled). Section 4.1.2 presents the methodology for projecting the vehicle fleet over time.

It is worth mentioning that the emissions considered in the analysis will include only those emitted by the vehicles' exhaust, since the emissions of re-suspended road dust, brake and tire wear, will be considered equal under the baseline scenario and the Euro 6/VI standard scenario.

4.1.2 Projecting and characterising the vehicle fleet

As mentioned above, the vehicle fleet must be calculated from the baseline year (2018) to the final year of the assessment (2030), considering the technological evolution of the fleet, both for the baseline and for the new standard scenario..

The number of vehicles in the period *t* is calculated according to the existing vehicles in the fleet in the previous year, *t-1,* the vehicles entering the fleet in the year *t* and the vehicles removed from the fleet, according to expression (4-3).

$$Vehicles_t = Vehicles_{t-1} + VehiclesEntering_t - VehiclesRemoved_t \quad \textbf{(4-3)}$$

The assessment assumption is that vehicles entering the fleet will meet the current emission standard in the year of entry. The standard of the incoming vehicles will be Euro 4/IV for the baseline and Euro 6/VI as of 2021 for the new standard scenario. The number of vehicles entering each year is calculated as a percentage of the total number of vehicles in the existing fleet in the previous year, as shown in expression (4-5).

$$VehiculosEntering_t(vehicle\ year = t) = EntryRate * Vehicles_{t-1} \quad \textbf{(4-4)}$$

Similarly, the vehicles removed from the fleet each year are calculated as a percentage of the existing fleet in the previous period, according to expression (4-5).

$$VehiclesRemoved_t = RemovalRate * Vehicles_{t-1} \quad \textbf{(4-5)}$$

In this assessment, entry and exit rates are differentiated for light-duty vehicles (including cars, station wagons, pickup trucks, minivans and panel vans) and heavy-duty vehicles (buses, trucks and trailer trucks), which can be modified by the user in the attached spreadsheet.

For the fleet projection, a 7.7% light-duty vehicle entry rate was adopted, corresponding to the average percentage of imported light-duty vehicles with respect to the total fleet in Peru between 2009 and 2018. In the case of heavy-duty vehicles, an entry rate of 6.8% was considered, which also corresponds to the average number of heavy-duty vehicles imported between 2009 and 2018.

With regard to the removal rate, this is uncertain in the case of Lima and Callao. An alternative considered was a flat removal rate of 2% for all vehicle categories (PLANCC and Libelula 2013), but due to the lack of information and empirical evidence on minimal removal of vehicles from the fleet, a removal rate of 0% was assumed.

Figure 4-3 shows the parameters used in the fleet projection, which can be modified in the attached spreadsheet.

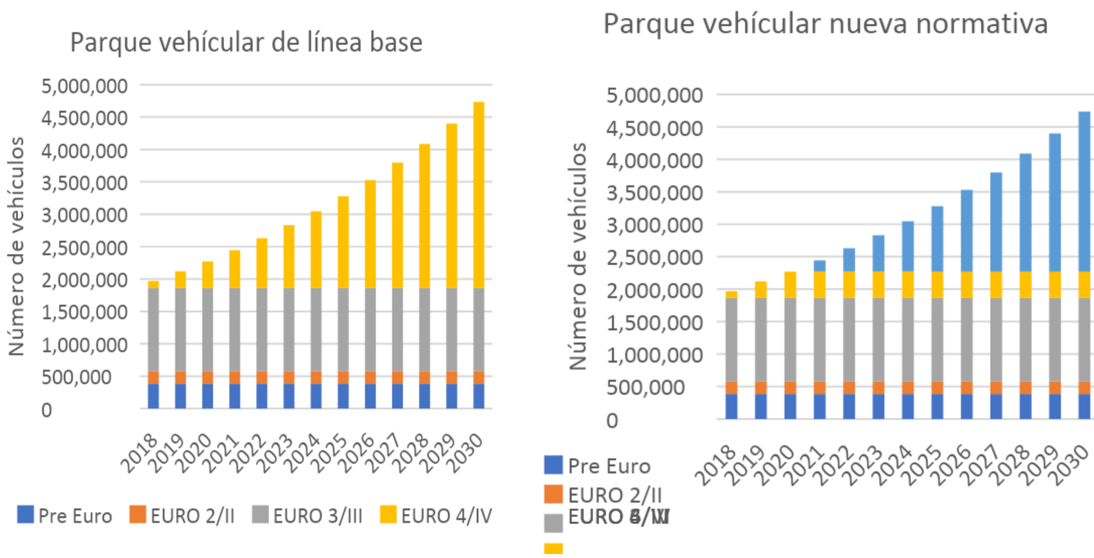
Figure 4-3: Parameters selected for fleet projection

Parámetros Parque		
Estándar normativo	EURO 6/VI	
Vigencia nueva normativa	2021	
Factores de emisión	Tier 2	
Ajuste Azufre	Sí	
	Livianos	Pesados
Tasa de entrada vehículos	7,7%	6,8%
Tasa de salida vehículos	0%	0%

Translation of text in Figure 4-3
Parámetros parque: Fleet parameters
Estándar normativo: Standard
Vigencia nueva normativa: Validity of new standard
Factores de emission: Emission factors
Ajuste azufre: Sulphur adjustment

Tasa de entrada vehículos: Vehicle entry rate
Tasa de salida vehículos: Vehicle exit rate
Livianos: Light-duty
Pesados: Heavy-duty

Figure 4-4: Fleet projection under baseline (left) and new standard (right) scenarios



Source: Own elaboration

Translation of text in Figure 4-3
Parque vehicular de línea base: Vehicle fleet under baseline scenario
Número de vehículos: Number of vehicles
Parque vehicular nueva normativa: Vehicle fleet under new standard scenario
Número de vehículos: Number of vehicles

Further details of the fleet projected for the baseline and new standard scenario are presented in Table 7-4 and Table 7-5 of the annexes, respectively.

4.1.3 Relationship between emissions and concentrations

Estimating the health impacts of the new standard requires linking the reduction of emissions to their impact on air quality. To establish this relationship, intake fractions from international literature are used.

Intake fractions relate the mass of pollutant inhaled by the exposed population, changes in environmental concentration of $PM_{2.5}$, the average breathing rate and the emission rate, as shown in expression (4-6).

$$iF = \frac{\sum_{i=1}^{N} \quad P_i * \Delta C_i * BR}{E} \qquad \textbf{(4-6)}$$

Where:

iF: Intake fraction expressed in terms of mass of inhaled $PM_{2.5}$ per tonne of emissions.

P_i: Population residing in the area, where i is the distance to the emitting source

ΔC_i: Change in ambient concentration of $PM_{2.5}$

E: Pollutant emission rate

BR: Average breathing rate

The literature review of intake fractions identified two studies that included intake fractions for urban sources at ground level for Lima: Apte et al. (2012) and Fantke et al. (2017). Both studies analysed intake fractions for $PM_{2.5}$ for more than 3.000 cities, representing all regions of the world.

The attached spreadsheet implements two options for relating emissions and concentrations: i) Based on Apte *et al.* (2012) and based on Fantke et al.

<u>Option 1.</u>

Apte et al. (2012) allow us to estimate changes in $PM_{2.5}$ concentration for each tonne emitted, reordering the terms of the expression (4-6), based on the intake fraction iF reported for Lima, as presented in expression (4-7).

$$\Delta C_{por\ ton} = \frac{iF}{Pop * BR} \qquad \textbf{(4-7)}$$

Apte et al. (2012) allow to quantify changes in $PM_{2.5}$ concentration resulting from direct $PM2_{.5}$ emissions. To include the impact of the main $PM_{2.5}$ precursors in the analysis, the recommendation of the World Bank document "*Local Environmental Externalities due to Energy Price Subsidies: A Focus on Air Pollution and Health*" (World Bank Group and ESMAP 2017) is followed. This paper proposes to use the Humbert et al. study (2011) together with Apte et al. (2012).

Humbert et al. (2011) analyse the literature on intake fractions published to date and recommend values for direct emissions of particulate matter ($PM_{10-2.5}$, $PM_{2.5)}$ and for the $SO_{2.}$ NOx and NH_3

precursors. The study recommends intake fractions for urban, rural and remote sources, emitted at ground level, low chimneys and high chimneys. In the case of transport emissions in Lima, the values for urban sources at ground level are considered. The recommended intake fractions in Humbert *et al.* (2011) are presented in Table 4-5.

Table 4-5: Urban intake fractions at ground level, Humbert et al. (2011)

Type of emission	Pollutant	iF (ppm)
$PM_{2.5}$ direct	$PM_{2.5}$	44
$PM_{2.5}$ precursors	SO_2	0.99
	NOx	0.2

Source: Table 3. Humbert et al. (2011)

According to World Bank Group and ESMAP (2017), intake fractions for secondary pollutants NOx and SO_2 can be obtained, using expression (4-8).

$$iF_{precursor\ Lima} = iF_{precursor\ Humbert\ et\ al.2011} * \frac{iF_{PM2.5\ Lima\ Apte\ et\ al.2012}}{iF_{PM2.5\ Humbert\ et\ al.2011}} \quad \textbf{(4-8)}$$

The results obtained for Lima are presented in Table 4-6

Table 4-6: Intake fractions (iF) and changes in $PM_{2.5}$ concentration per tonne for Lima

	$\boldsymbol{iF}$ (ppm)	$\Delta \boldsymbol{C_{per\ ton}}$ **[µg/m³ per tonne/year]**
$PM_{2.5}$	56.30	1.29E-03
SO_2	1.27	2.91E-05
NOx	0.26	5.88E-06

Source: Own elaboration based on (Apte et al. 2012) and (Humbert et al. 2011).

<u>Option 2.</u>

Fantke et al. (2017) present intake fractions for urban and rural areas, considering outdoor exposure to $PM_{2.5}$, indoor exposure and a combination of outdoor and indoor exposure. This study also presents a digital annex, which contains an intermediate result for calculating intake fractions, called "concentration matrices". CM, which directly relate $PM_{2.5}$ emissions to concentrations of the same pollutant. This intermediate result is equivalent to the $\Delta C_{per\ ton}$ calculated using Apte et al.

Fantke et al. (2017) only include the impact of $PM_{2.5}$ emissions, without considering the precursors of particulate matter. Following the same logic recommended by the World Bank Group and ESMAP (2017), it is again possible to use the intake fractions of Humbert et al. (2011) presented in Table 4-5 to obtain the coefficients CM for NOx and SO_2 precursors, as indicated in expression (4-9). The coefficient used for the matrix CM corresponds to urban areas and environmental concentration of $PM_{2.5}$.

$$CM_{precursor\ Lima} = CM_{precursor\ Humbert\ et\ al.2011} * \frac{CM_{PM2.5\ Lima\ Fantke\ et\ al.2017}}{iF_{PM2.5\ Humbert\ et\ al.2011}} \quad \textbf{(4-9)}$$

The results obtained are presented in Table 4-7.

Table 4-7: Coefficients relating emission and concentration for Lima

	CM [µg/m³ per ton/year]
$PM_{2.5}$	1.43E-03
SO_2	3.22E-05
NOx	6.51E-06

Source: Based on Fantke et al. (2017) and Humbert et al. (2011)

The results obtained with both methods are presented in Table 4-8, noting that although the results are similar, the changes in concentration obtained are greater under the second option.

The relationship between emissions and concentrations selected by default in the attached sheet corresponds to the option based on Fantke et al. (2017), since this is a more recent study that also directly reports the relationship between emissions and $PM_{2.5}$ concentrations.

Table 4-8: Concentration reduction as a result of the Euro 6/VI standard introduction

	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Apte	0.24	0.50	0.77	1.06	1.38	1.71	2.07	2.46	2.87	3.31
Fantke	0.27	0.55	0.85	1.18	1.53	1.90	2.30	2.72	3.18	3.67

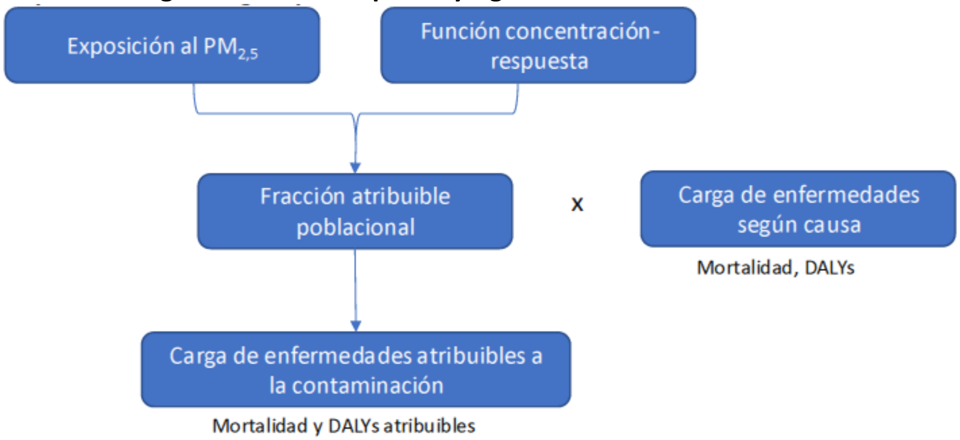
Source: Own elaboration. Assessment assumptions indicated in Table 2-1.

4.2 Methodology for quantifying health impacts

The reduction in environmental concentration of $PM_{2.5}$ involves a reduction in the burden of disease, which can be quantified and assessed using concentration-response functions (see Section 4.2.1) and a unit value associated with avoided mortality (see Section 4.2.2). In this analysis the focus will be on avoided mortality, while the DALYs metric is reported but not assessed.

Figure 4-5 presents an outline of the methodology to be used for the quantification of health impacts.

Figure 4-5: Methodological scheme for quantifying health effects



Source: Own elaboration based on World Health Organization 2018a.

Translation of text in Figure 4-5

Exposición al PM2.5: Exposure to $PM_{2.5}$
Función concentration-respuesta: Concentration-response function
Fracción atribuible poblacional: Population attributable fraction
Carga de enfermedades según causa: Burden of disease by cause
Mortalidad, DALYs: Mortality, DALYs
Carga de enfermedades atribuibles a la contaminación: Burden of disease attributable to pollution
Mortalidad y DALYs atribuibles: Attributable deaths and DALYs

The concentration level of $PM_{2.5}$ and the concentration-response function determine the relative risk (RR) for the various diseases associated with pollution. The RR is a measure of the change in risk of an adverse health effect associated with a change in a risk factor (in this case $PM_{2.5}$ exposure). The RR indicates the probability of developing an adverse effect, with respect to a group not exposed to the risk factor, in this case air pollution.

Once the RR has been determined, it is possible to calculate the population attributable fraction (PAF), using the expression (4-10), where c indicates the cause and a the age group to which the RR applies.

$$PAF_{c,a} = 1 - 1/RR_{c,a} \quad \textbf{(4-10)}$$

The burden of disease attributable to pollution, AB, corresponds to the multiplication of the PAF and the total burden of disease (mortality and DALYs) at baseline, for each cause c and age group a, as indicated in expression (4-11).

$$AB_{c,a} = PAF_{c,a} * Total\ Burden\ of\ Disease_{c,a} \quad \textbf{(4-11)}$$

It is worth mentioning that the mortality burden by cause and age group was provided by the National Centre for Epidemiology, Disease Prevention and Control (*Centro Nacional de Epidemiología, Prevención y Control de Enfermedades*) of the Ministry of Health and corresponds to the cases registered in Lima and Callao in 2016. Table 7-8 in the annexes presents the details of the mortality cases used in the analysis. Table 7-9 provides more details on mortality disaggregated by age group over 35 and the names of the diseases used in the international literature.

The distribution of mortality for these groups and causes of death for Peru obtained from the GBD 2017 Global Burden of Disease Study (Institute for Health Metrics and Evaluation 2018) is used to disaggregate cases into the group over 35.

In addition to mortality, this analysis also reports on Disability-Adjusted Life Years (DALYs). The values of DALYs, YLL and baseline YLD for 2016 were not calculated in this study but correspond to the results of the GBD 2017 Global Burden of Disease Study (Institute for Health Metrics and Evaluation 2018) for Peru, adjusted by the fraction of the population of Lima and Callao with respect to the total national population.

DALYs combine the years of life lost due to premature mortality (YLL) and the years lived in a non-optimal state of health (YLD). DALYs for each cause c and age group a, correspond to the sum of YLL and YLD, as indicated in expression (4-12).

$$DALY_{c,a} = YLL_{c,a} + YLD_{c,a} \tag{4-12}$$

Years of life lost, YLL, is calculated by multiplying the number of premature deaths by a loss function $L_{s,a}$, which accounts for the remaining years of life lost, according to expression (4-13).

$$YLL_{c,a} = Number\ of\ deaths_{c,a} * L_a \tag{4-13}$$

The years lived with disability (YLD) correspond to the multiplication of the prevalence $P_{c,a}$ of each condition associated with each cause and a disability weight $DW_{c,a}$ for each condition, on a scale from 0 (perfect health) to 1 (death), as presented in expression (4-14).

$$YLD_{c,a} = P_{c,a} * DW_{c,a} \tag{4-14}$$

Since the evaluation of the new standard considers the period 2018 to 2030. the burden of diseases (mortality and DALYs) must be estimated over time. For this, the mortality projections of the WHO (World Health Organization 2018b) were used since they project mortality according to the cause of death and age group. This projection makes a distinction according to the income level of the countries, since the lower the income, the greater the potential for reducing mortality, especially for preventable causes with better access to health. Projections were considered for upper-middle income countries, which is where Peru is classified by the World Bank.

The annual rate of change in mortality between 2016 and 2030 was estimated according to the expression (4-15). Mortality was then estimated for each year using the expression (4-18).

$$r_{mortality} = \left(\frac{Total\ mortality_{2030}}{Total\ mortality_{2016}}\right)^{1/(2030-2016)} - 1 \tag{4-15}$$

$$Mortality_t = \left(r_{mortality} + 1\right)^{(t-2016)} * Mortality_{2016} \tag{4-16}$$

Finally, the economic benefit of avoided mortality will be obtained by multiplying the number of avoided cases by the value of a statistical life (see section 4.2.2), as indicated in expression (4-17).

$$Benefit = \sum_{c} \Delta Mortality_c \cdot VSL \tag{4-17}$$

Where:

$Benefit$: Benefit associated with premature mortality avoided [$].

VSL: Value of a Statistical Life (VSL) [$/case]

4.2.1 Concentration-response functions

As mentioned above, the concentration-response function used and the concentration level of $PM_{2.5}$ will determine the relative risk associated with exposure to air pollution in Lima and Callao, for each cause of disease and age group.

The health effects considered in this analysis correspond to those incorporated in the AirQ+ software developed by the WHO[5]. The attached spreadsheet applies the concentration-response functions of AirQ+ described below, partially replicating the functionality of the software, but without requiring its use for estimating mortality attributable to pollution. The advantage of using the spreadsheet, instead of using AirQ+ directly, is that the user can directly calculate the health impacts associated with different regulatory scenarios or assessment assumptions, using only one tool.

Table 4-9 presents the causes of death, the age group to which they apply and the source of the values used in the attached spreadsheet.

Table 4-9: Mortality rates considered in AirQ+

Causes of death	Age range to which it applies	Source
All natural causes	Over 30 years of age	Log-linear, RR=1.062. RR_{low}=1.04. RR_{high}=1,083 (Hoek et al. 2013) $RR(x) = e^{\beta(x-x0)}$
Acute lower respiratory infections (ALRI)	Children under 5 years of age	GBD 2015-2016 (integrated function 2016)[6]
Chronic obstructive pulmonary disease (COPD)	Over 30 years of age	
Lung cancer (LC)	Over 30 years of age	

[5] Documentation and downloads for AirQ+ are available at http://www.euro.who.int/en/health-topics/environment-and-health/air-quality/activities/airq-software-tool-for-health-risk-assessment-of-air-pollution, accessed in October 2019.

[6] In addition to the GBD 2015-2016 functions, AirQ+ also includes the "integrated 2016 vs WHO AQG function" and other older methodological options.

Ischemic heart disease (IHD)	Over 25 years of age, differentiated by age group	
Stroke	Over 25 years of age, differentiated by age group	

Source: Own elaboration.

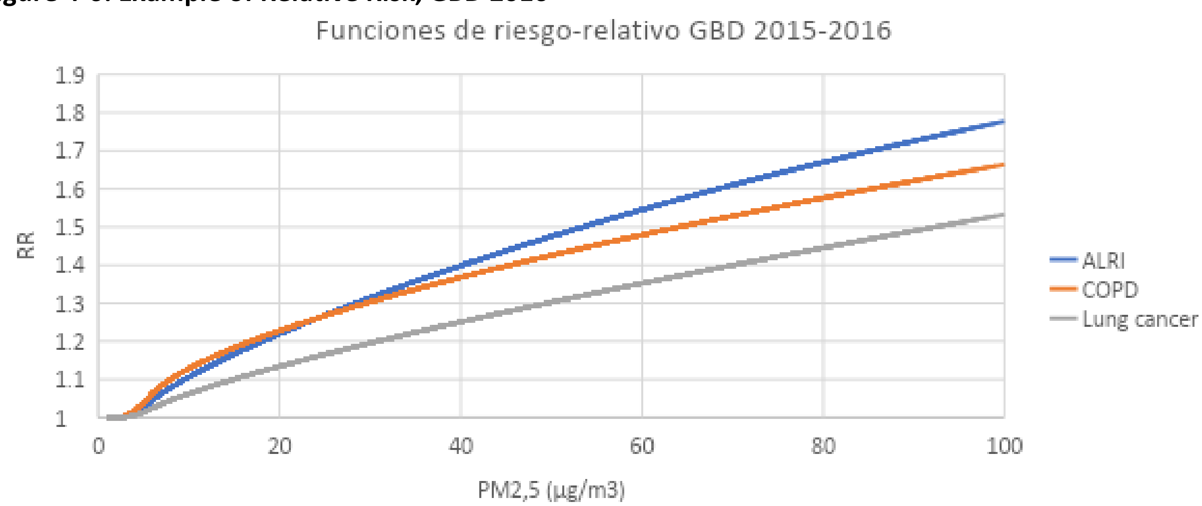
The response-concentration functions used by AirQ+ correspond (Hoek et al. 2013) to natural mortality and to the 2016 *Global Burden of Disease* study (GBD 2016 Risk Factors Collaborators 2017) for the other specific causes of death. The functions used in the GBD study correspond to integrated functions that, as their name indicates, integrate RR obtained from exposure to environmental pollution by $PM_{2.5}$, exposure of passive smokers, exposure to pollution due to the use of solid fuels for cooking and exposure of active smokers. These types of functions have been widely used, since it is possible to characterize exposure to high levels of $PM_{2.5}$, including ranges for which there are no cohort studies applied to environmental pollution.

In 2018 a new study was published relating mortality to air pollution using only $PM_{2.5}$ air pollution studies (Burnett et al. 2018) and developing a non-integrated concentration-response function. The study constructs a hazard-ratio function including a new cohort study developed in China, which captures the impact of pollution at relatively high exposure levels. The study results suggest that pollution-associated mortality may be higher than previously considered.

The attached spreadsheet implements the 5-cause mortality considering the GBD 2016 and Burnett et al. The option selected by default corresponds to the second study, since it considers only cohort studies for outdoor $PM_{2.5}$.

As an example, Figure 4-6 presents an example of the functional form of relative risk for ALRI, COPD and lung cancer. It can be seen that the RR increases as the $PM_{2.5}$ concentration level rises.

Figure 4-6: Example of Relative Risk, GBD 2016



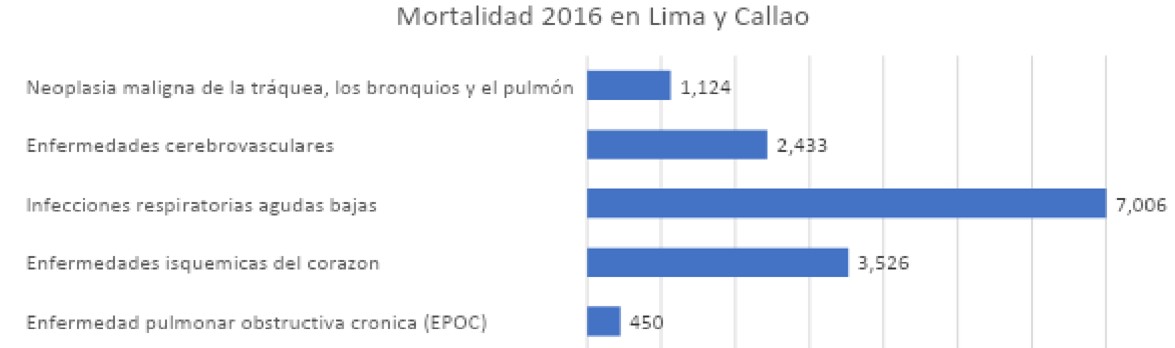
Source: Own elaboration based on (WHO Regional Office for Europe 2016), file IER2016_GBD2015-2016.csv

Translation of text in Figure 4-6

Funciones de riesgo relativo: Relative risk functions GBD 2015-2016

The total mortality in Lima and Callao reached 51,171 cases, while the natural (non-accidental) mortality recorded was 48,710 cases. The other causes associated with pollution are shown in Figure 4-7 and in more detail in Table 7-8 of the annexes.

Figure 4-7: Specific causes of death in Lima and Callao 2016



Source: Based on data provided by the National Centre of Epidemiology, Disease Prevention and Control

Translation of text in Figure 4-7
Mortalidad 2016 en Lima y Callao: 2016 Mortality in Lima and Callao
Neoplasia maligna de la tráquea, los bronquios y el pulmón: Malignant neoplasm of trachea, bronchus and lung
Enfermedades cerebrovasculares: Stroke
Infecciones respiratorias agudas bajas: Acute lower respiratory infections
Enfermedades isquémicas del corazón: Ischemic heart diseases
Enfermedad pulmonar obstructiva crónica (EPOC): Chronic obstructive pulmonary disease (COPD)

4.2.2 Valuation of avoided premature mortality

Assigning a value to avoided mortality is necessary for estimating the benefits of public policies that would result in changes in mortality (Robinson et al. 2019). There are different methods of valuing avoided mortality, including the value of a statistical life, associated with willingness to pay for risk reduction, and the human capital approach.

It is important to clarify that the value of a statistical life (VSL) does not represent the value of individual lives, but rather the economic benefit of avoiding premature mortality from the perspective of individual preferences and well-being. Using the willingness to pay approach, the VSL represents the value that large groups of people would be willing to pay for reductions in individual risk of dying in a given year, such that on average one death within that group of people is reduced during the year in expected terms.

On the other hand, the human capital approach assumes as the cost of premature death the productive potential of the individual, measured through the present value of his or her future income. The hypothesis is that with premature death there is a loss of productivity for the country. This approach ignores the well-being of individuals, their preferences, the value of a healthy life and the willingness of individuals to pay for risk reduction.

Table 4-10 presents different sources and values used for the valuation of avoided mortality in Peru, Chile, the United States and OECD countries. The valuation approaches in the table correspond to the human capital and the willingness to pay approaches, without considering possible transfers of international values, as will be explained later.

Table 4-10: Comparison of (non-transferred) value estimates for avoided mortality

Country	Type of risk	Approach	Original value	Value in millions of dollars, 2017	Source
Peru	All	Human capital	465,784 soles (average)	0.138	(Seminario de Marzi 2017)
Chile	Cardiovascular disease	Willingness to pay	426 million pesos	0.69*	(GreenLabUC 2014)
	Road risk		2,810 million pesos	4.5*	
	Cardiovascular disease		10,111 UF	0.34	(Ministry of Social Development 2017)
	Road risk		81,739 UF	3.2	
	Road risk	Human capital	67.2 million pesos	0.123*	(Ministry of Planning 2011)
United States (EPA)	Air pollution	Occupational risks and willingness to pay	7.4 million 2006[7]	8.7	(US EPA, n.d.)
OECD countries	Mortality valuation for environment, health and transport	Willingness to pay	3 million 2005	4.1**	(OECD 2012)

Source: Own elaboration based on (Seminario de Marzi 2017), (GreenLabUC 2014), (Ministry of Social Development 2017), (Ministry of Planning 2011), (US EPA, n.d.), (OECD 2012). *Values were adjusted for inflation between the value of the year indicated in the study and December 2018. ** Value adjusted for GDP per capita growth and inflation. Note: Road risk corresponds to the risk of death in a traffic accident.

From the table above, it can be noted that the value used to appraise avoided mortality correlates with the income level of the country in which it will be applied and that its value varies considerably according to the approach used for its quantification. Valuations using the human capital method are lower than those obtained through willingness to pay, since the former only considers future income that will not be received, without regard to other factors that are valued by individuals, thus representing a lower threshold for monetizing avoided mortality.

4.2.3 VSL transfer to Peru

Given that the VSL for Peru represents only the lost productivity resulting from a premature death, a transferred VSL is also proposed based on the studies by Narain and Sall (2016), OECD (2012) and Robinson et al. The transfer of VSL is a common practice in the cost-benefit analysis of public policies (Robinson et al. 2019) and in particular in with an impact on air quality (Narain and Sall 2016; OECD 2012). As an example, Table 4-11 presents the VSL used (transferred) by the ICCT in a global diagnostic study of the health impacts of the transport sector. It can be seen that for Argentina, Brazil and Mexico, the VSLs used exceed one million dollars, with values of over 2 million dollars.

[7] Value obtained from https://www.epa.gov/environmental-economics/mortality-risk-valuation, accessed October 2019.

Table 4-11: VSL values used for appraising avoided mortality in countries of the Region

Country	VSL (million USD 2015), unit elasticity, market exchange rate	VSL (million dollars 2011 PPP), difference in elasticity according to income level
Argentina	2.1	2.2
Brazil	1.7	1.3
Mexico	1.7	1.5

Source: Based on Table 2. ICCT (2019)

The methodological guide for cost-benefit analysis prepared by Robinson et al. (2019) also presents techniques for transferring VSL according to the country's GDP per capita (multiplied by 160 and 100), in addition to transferring the extrapolated VSL from the United States with an elasticity of 1.5. The values obtained for Peru are presented in the table below.

Table 4-12: Average VSL estimated for Peru, *Reference Case Guidelines for Benefit-Cost Analysis in Global Health and Development*

	VSL Peru (international dollars 2015)
GDP per capita	12,100
GDP per capita *160	1,936,000
GDP per capita*100	1,210,000
Transferred from USA, elasticity of 1.5	898,024

Source: Appendix B, Robinson et al.

On the other hand, the World Bank document prepared by Narain and Sall (2016) proposes a methodology for the transfer of the VLS that is based on the results of the OECD study (2012). The OECD study (2012) proposes values for the economic valuation of mortality to be used in public environmental, health and transport policies. Narain and Sall (2016) provide specific recommendations in the case of health effects derived from air pollution.

Narain and Sall (2016) propose to implement the transfer of VSL, as this recommendation is specific to air pollution. The transfer is implemented in two steps. First the OECD VSL is updated according to per capita GDP growth and inflation, based on the expression (4-18) and then the OECD value for Peru is transferred and adjusted according to the ratio of per capita GDP between Peru and OECD countries, using expression (4-6).

$$VSL_{\ OECD\ 2017} = VSL_{OECD\ 2005} * \left(\frac{PIB_{OECD\ 2017}}{PIB_{OECD\ 2005}}\right)^{\eta} * (1 + inflation_{2017-2005}) \quad \textbf{(4-18)}$$

$$VSL_{Peru\ 2017} = \ VSL_{\ OECD\ 2017} * \left(\frac{GDP_{Peru\ 2017}}{GDP_{OECD\ 2017}}\right)^{\eta} \quad \textbf{(4-19)}$$

The value $VSL_{OECD\ 2005}$ corresponds to 3 MMUSD for 2005 (OECD 2012) and η corresponds to income elasticity. The best income elasticity estimator is 0.8; however, an elasticity of 1.2 is also used to obtain a more conservative and credible VSL value (Narain and Sall 2016). The tables in section 7.5 of the Annexes present the other parameters used for the transfer of VSL.

The result of the profit transfer for Peru is a VSL of **1.61 million dollars for an elasticity of 0.8 and a value of 1.05 million dollars for an elasticity of 1.2**.

The VSL transferred for Peru contrasts sharply with the value calculated in the study "Estimación del costo por fallecimiento prematuro" (Estimation of the Cost of Premature Death) (Seminario de Marzi 2017) presented in Table 4-10. which uses the human capital method to estimate a value for avoided mortality of US$138,000 on average for Peru. However, because the human capital approach fails to identify preferences and well-being of individuals, we propose the use of an intermediate value, corresponding to the average between the value estimated by Seminario de Marzi (2017) and the transferred value using an elasticity of 1.2. Table 4-13 presents the comparison of the estimated VSL for Peru, in which the value proposed for this assessment corresponds to 684 thousand dollars.

Table 4-13: Comparison of avoided mortality values for Peru

Value	Source
0.168	Seminario de Marzi(2017)
1.61	VSL Transferred (η=0.8)
1.2	VSL Transferred (η=1.2)
0.684	***Intermediate (Average Seminario de Marzi 2017 and transferred η=1.2)***

Source: Own elaboration

Finally, the VSL will be projected over time according to the expected growth of Peru's GDP per capita, using the projections of the International Monetary Fund's *World Economic Outlook (*2019) presented in Table 4-14 and the formula indicated in expression (4-20).

$$VSL_t = VSL_{2017} * ((1 + GDP\ per\ capita\ growth)^{t-2017})^{\eta} \quad \textbf{(4-20)}$$

Table 4-14: GDP per capita growth projections for Peru, IMF

	2017	2018	2019	2020	2021	2022	2023	2024	Average
Actual GDP, change	2.48%	3.99%	3.93%	3.98%	3.96%	3.90%	3.81%	3.76%	3.7%
Population (millions)	31.83	32.16	32.50	32.82	33.15	33.47	33.79	34.10	
Population growth		1.06%	1.04%	1.01%	0.99%	0.97%	0.95%	0.93%	1.0%
Estimated average GDP per capita growth									**2.7%**

Source: Own elaboration based on (International Monetary Fund 2019).

4.3 Costs and savings methodology

The technology improvement costs will be based on the incremental costs of shifting from a Euro 4/IV to a Euro 6/VI standard. These incremental costs will be compiled from reports from agencies such as the International Council for Clean Transport (ICCT), the United States Environmental Protection Agency, or the European Environment Agency.

In addition, as part of the costs associated with the standard, potential additional administrative costs derived from the new emission standard will be analysed, such as additional customs and/or local vehicle certification costs, but these will not be included in the valuation.

Implementation of the standard may also lead to greater fuel efficiency. This will be quantified in terms of the volume of fuel saved and will be valued according to fuel prices in Peru.

4.3.1 Investment and maintenance costs of technological improvements

The investment costs were collected from international literature, as detailed below, and then converted from the year of original value $t0$ to 2017 dollars, as shown in the expression (4-21), according to the United States Environmental Protection Agency (US EPA 2010).

$$Cost\ (\$\ 2017) = \frac{Cost_{t0} * Chained\ US\ GDP_{2017}}{Chained\ US\ GDP\ _{t0}} \qquad \textbf{(4-21)}$$

The GDP for the United States was obtained from the US *Bureau of Economic Analysis and* is presented in Table 4-15.

Table 4-15: Chained US GDP, in trillions of dollars, chained to 2009 dollars

Year	2010	2011	2012	2013	2014	2015	2016	2017
GDP (2009 US$ billion)	14,783.8	15,020.6	15,354.6	15,612.2	16,013.3	16,471.5	16,716,2	17,096,2

Source: Bureau of Economic Analysis, United States[8]

The incremental investment costs for *light-duty vehicles* were obtained from the document *Estimated Cost of Emission Reduction Technologies for Light-Duty Vehicles,* ICCT (2012a). These costs are broken down by engine capacity, but since this information was not available for Lima and Callao, the average cost for the reported engine capacity was considered. For light-duty vehicles using LPG or NGV, the same cost was assumed as for gasoline vehicles.

Table 4-16: Incremental costs of compliance with European standards for light-duty vehicles

Fuel	Displaceme nt	USD 2010			USD 2017	
		Euro 4 to Euro 5	Euro 5 to Euro 6	Euro 4 to Euro 6	Euro 4 to Euro 5	Euro 4 to Euro 6
Gasoline	Vd=1.5L	10		10	12	12
	Vd=2.5 L	30		30	35	35
Diesel	Vd=1.5L	306	471	777	354	899
	Vd=2.5 L	508	626	1.134	587	1.311

Source: Table ES-1. ICCT (2012a). For further breakdown of investment costs, see tables 4-8 and 4-9 for gasoline vehicles and tables 4-16 and 4-17 for diesel vehicles.

For heavy-duty vehicles, the incremental investment costs were obtained from the document *Costs of emission reduction technologies for heavy-duty diesel vehicles,* ICCT (2016). The costs reported are for diesel vehicles only. For heavy-duty vehicles that use other fuels, a zero incremental cost is

[8] Data available at https://www.bea.gov/national/xls/gdplev.xls

assumed, since there are no emission factors for them and thus it is not possible to quantify benefits or costs associated with implementing a Euro VI standard. Note that non-diesel heavy-duty vehicles account for a smaller fraction of the fleet. In 2018, 10.1% of buses and 0.6% of trucks in the fleet used a fuel other than diesel[9].

Table 4-17: Incremental cost of emission control technologies for a 12L diesel engine (USD 2015)

Fuel	USD 2015			USD 2017	
	Euro IV to Euro V	Euro V to Euro VI	Euro IV to Euro VI	Euro IV to Euro V	Euro IV to Euro VI
Diesel	460	2,280	2,740	477	2,844

Source: Table ES-1. ICCT (2016). Further details on cost disaggregation are available in Table 13 of ICCT (2016)

The lifetime of the investment used for the assessment corresponds to 262,754 kilometres for light-duty vehicles and 1,424,254 kilometres for heavy-duty vehicles, according to information provided by MINAM based on the average age of the vehicle fleet in Lima and Callao as per the Report on Urban Transport Compliance in Lima and Callao 2018 (Fundación Transitemos 2018).

Another relevant cost to be considered is maintenance of DPF filters in heavy-duty Euro VI diesel vehicles. For this analysis, a cost of 62 dollars per 75,000 kilometres travelled was estimated, based on Miller and Façanha (2016).

4.3.2 Sulphur removal costs

The implementation of the Euro 6/VI standard will require fuels with a lower sulphur content. The reduction of sulphur will mean lower emissions of SO_2, a particulate matter precursor. This analysis will consider the use of ultra-low sulphur fuels for Euro 6/VI vehicles, with an estimated content of 10 ppm.

With regard to the costs of sulphur removal, three possible sources of information are considered. The first source corresponds to a study carried out for Chile, by a US consultant, on behalf of the US EPA (Industrial Economics 2018), presented in Table 4-18. Sulphur removal costs in this case would represent 0.4% of the average price of gasoline and 1.2% of the price of diesel, using 2018 sales prices.

Table 4-18: Sulphur removal costs used for Santiago de Chile

	Dollars per gallon, 2016		Dollars per m^3, 2017	
	Gasoline	Diesel	Gasoline	Diesel
Reduce up to 15 ppm	0.0167	0.043	4.5	11.5
% Price			0.4%	1.2%

Source: (Industrial Economics 2018)

[9] According to data provided by MINAM, Fuente móviles.xlsx sheet

The second cost option considered corresponds to a sulphur removal cost study carried out by ICCT in 2012. which estimates costs for Mexico and Brazil. The average cost for both countries would be 1.3% of the average price of gasoline and 1.8% of the price of diesel, compared to the sales prices in 2018. The costs are presented in Table 4-19.

Table 4-19: **Sulphur removal costs up to 10 ppm for Mexico and Brazil, from ICCT (2012b)**

	Mexico (cent/L)		**Brazil (cent/L)**		**Average cent/L**		**Dollars 2017/m^3**	
	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel	Gasoline	Diesel
Refinery type 1	1.1	2.5	2	2	1.2	1.6	13.4	17,8
Refinery type 2			0.5	0.3				
% Price							1.3%	1.8%

Source: ICCT (2012b), Table 6.1b. and Table 2.

The third option for sulphur removal costs was calculated using investment data for Petro Peru's refinery plant. The cost estimate considers a 40-year investment life and a gasoline and diesel refining capacity of about 60,000 barrels per day. A value of $2.4 per cubic meter of refined fuel is obtained, which assumes that only the investments required for sulphur removal are considered. This value represents 0.236% of the price of gasoline and 0.249% of the price of diesel. It is worth mentioning that PetroPeru's investment costs are part of the baseline, as they are planned and executed prior to establishing the new emission standard. However, a higher fuel cost associated with a lower sulphur content is considered as part of the analysis costs. The parameters used in this calculation are presented in Table 4-20.

Table 4-20: Costs based on PetroPeru's information, using the lifetime of investment and the refining capacity

Investment associated with Euro 6/VI standard	**$ 335,157**	thousands of soles
	$ 99	million dollars
Lifetime of the investment	40	years
Annualised investment	$8	million dollars/year
Diesel and gasoline capacity	59,171	barrels/day
	9,407	m^3/day
	3,433,611	m^3/year
Cost per m^3	2.4	dollars/m^3
% price	0.236% of the price of gasoline and 0.249% of the price of diesel	

Source: Data provided by MINAM based on PetroPeru data[10]

The attached spreadsheet applies these three cost options for sulphur removal, which can be selected by the user. For the results presented, the second option was selected, as an intermediate cost value was considered.

[10] Details available at https://www.petroperu.com.pe/proyectos-y-unidades-operativas/proyectos/nueva-refineria-talara/, accessed October 2019

The total cost is calculated by multiplying the fuel consumption of Euro 6/VI vehicles using diesel or gasoline by the sulphur removal value.

4.3.3 AUS 32 costs

AUS 32 is an indispensable additive for gas control in diesel vehicles and should therefore be considered in the analysis. The sales prices of the additive in its different presentations vary between 2.3 and 3.5 soles per litre (Table 4-21). Its consumption rate varies between 2% and 6% of fuel consumption[11], depending on the specific gas treatment system.

On the attached spreadsheet it is possible to select three potential price levels for the AUS 32 or Adblue and enter the consumption rate considered relevant. The values selected by default correspond to the average values: a price of 2.9 soles per litre and a consumption rate of 4%.

Table 4-21: Price range of AUS 32

	Low	High	Average
Price in soles/litre	2.3	3.5	2.9

Source: Data provided by MINAM, based on data from Cofel (Comercio Federal del Pacífico)

4.3.4 Savings in fuel consumption

Migration towards the Euro 6/VI emission standard for heavy-duty vehicles would translate into fuel consumption savings of around 7%, according to expert Andreas Mayer (email of November 8th) who indicates that reductions in fuel consumption are between 6-10%, which is in line with Blumberg (2010). These savings were quantified using EEA Tier 2 fuel consumption factors (2016) (Table 7-10 in Annexes), on which a 7% reduction was applied for Euro VI heavy-duty diesel vehicles.

The savings were quantified using fuel prices for 2018, provided by MINAM based on information from SCOP-OSINERGMIN. These prices were adjusted using the Social Price Correction Factor for Fuel, according to MEF (2018).

Table 4-22: Fuel prices and social price correction factor

	FCF	Price	Unit
Diesel	0.735	12.4	Soles/gallon
Gasoline 97	0.622	14.8	Soles/gallon
Gasoline 95	0.626	13.9	Soles/gallon
Gasoline 90	0.672	12.1	Soles/gallon
Gasoline 84	0.672	11.7	Soles/gallon
LPG	0.485	6.0	Soles/gallon
NGV	0.649	256.6*	Soles/m^3

Source: Own elaboration based on MEF (2018) and data provided by MINAM. *Price adjusted from gas volume under normal conditions to volume compressed at 200 Bar.

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[11] Based on https://en.wikipedia.org/wiki/Diesel_exhaust_fluid, accessed October 2019

4.3.5 Costs avoided through CO_2 reduction

The Ministry of Economy and Finance reports a social price for carbon dioxide of US$7.17 per ton (Ministry of Economy and Finance Peru 2018). This value accounts for the damage that CO_2 represents by remaining in the atmosphere, evaluated over a 100-year horizon.

This value could be applied to other greenhouse gases, not only CO_2. However, in this analysis only the CO_2 reductions are valued, based on decreased fuel consumption generated by introducing the new standard. Its valuation corresponds simply to the multiplication of the social price and the reduction of CO_2 emissions that occurred in each year *t*, as shown in expression (4-22).

$$Avoided\ cost_{CO2.t} = Social\ price_{CO2} * Reduction\ _{CO2.t} \qquad \textbf{(4-22)}$$

As it is a social cost avoided, the flows will be considered as a benefit of the new standard.

4.3.6 Other possible costs

The new standard could involve additional administrative costs associated with compliance. In the case of vehicle certification and homologation (type approval), this is not an additional cost for the new emission standard, as such homologation must also be carried out for the standard currently in force. However, as a reference, tables 7-11 (Annexes) and 4-23 present the certification costs for Chile.

If foreign type approvals are considered valid – and local testing is not required – the costs charged are those presented in Table 4-23. In Peru, 653 models –corresponding to 84 brands of cars– were registered in 2016, while 647 models, corresponding to 80 brands, were registered in 2017[12]. With a total type approval cost of $525 dollars per model and 650 models registered annually, type approval costs would reach $341,250 dollars per year, well below the $207 million dollars per year for other costs associated with regulatory compliance.

Table 4-23: Costs of vehicle type approval (Table II) based on foreign certification

ITEM	SERVICE	Chilean Pesos	Soles	Dollars
a)	Type approval testing of construction and safety aspects of light and medium-duty vehicles and motorcycles	$202,703	$953	$284
b)	Technical background check of the vehicle configuration to be approved for light and medium-duty vehicles or motorcycles	$171,817	$808	$241

Source: 3CV 2019 laboratory services values, Chile[13]

[12] Data from the Peruvian Automotive Association. ModeloMarcaLivianos_2016_2017 sheet provided by the technical counterpart.

[13] Values available at https://www.mtt.gob.cl/wp-content/uploads/2014/01/TABLA-VALORES-SERVICIOS-2019.pdf, accessed September 2019

4.4 Cost-benefit analysis

After estimating the costs and benefits, as indicated in the previous sections, the following economic indicators will be analysed: benefits, costs, net present value and the benefit-cost ratio.

All the assessment flows will be annualised to compare costs with different lifetimes. The investment costs will be annualised according to formula (4-23).

$$I_a = \frac{I_0 * r * (1+r)^{VU}}{(1+r)^{VU} - 1} \quad \textbf{(4-23)}$$

Where:

I_a: Annualised investment $/year

I_0: Investment made in year 0

r; Discount rate

$$LT: Lifetime\ (years)$$

Once the annual flows have been calculated, the net present value of disaggregated costs and benefits will be calculated. The present value of a series of flows over time, *t*, is given by the sum of the discounted flows, as indicated in expression (4-24).

$$Present\ value_{2019} = \sum_{t=2019}^{2030} \frac{F_t}{(1+r)^{t-2019}} \quad \textbf{(4-24)}$$

Once the present value of the different assessment flows has been calculated (investment costs, operating costs, benefits, among others), the net present value, NPV, of the new standard will be calculated. The net present value will correspond to the benefits minus the costs associated with the standard, as indicated in the expression (4-25). A positive NPV indicates a positive social return on the project, while a zero NPV suggests indifference to investment and a negative NPV would indicate a social cost.

$$Net\ Present\ Value = Present\ value\ Benefits - Present\ value\ Costs \quad \textbf{(4-25)}$$

The discount rate used is 8%, as recommended in MEF (2018).

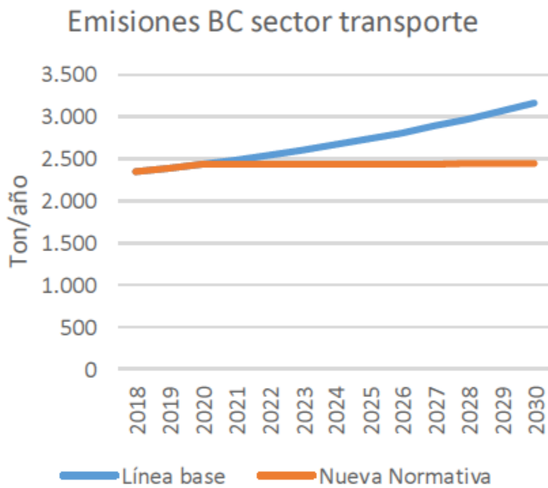
5 Results

5.1 Emissions and comparison of Euro VI and baseline scenarios

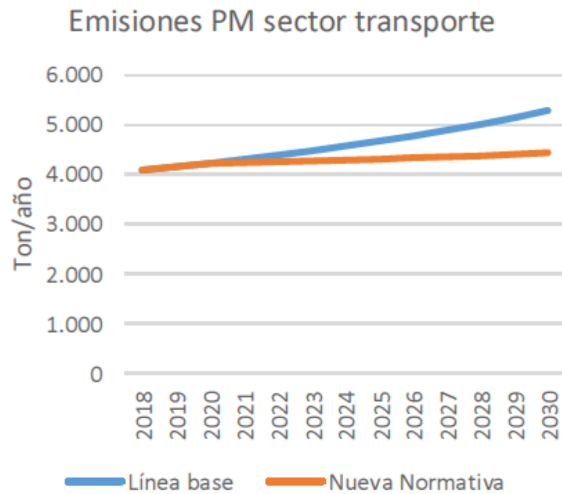
Figure 5-1 graphically presents the comparison of emissions in the baseline scenario and in the scenario with the implementation of Euro 6/VI standards as of 2021.

Figure 5-1: Baseline and Euro 6/VI emissions

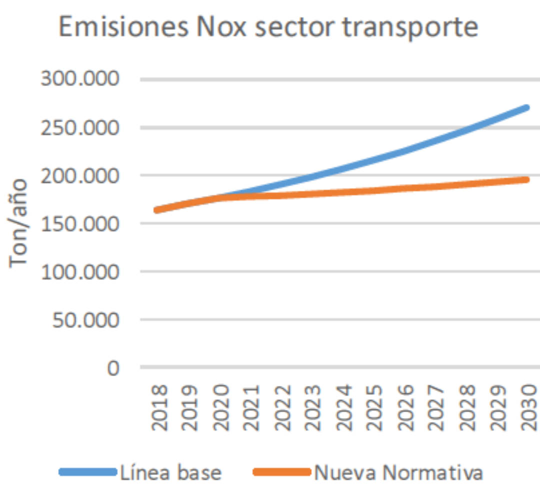
a) Black carbon



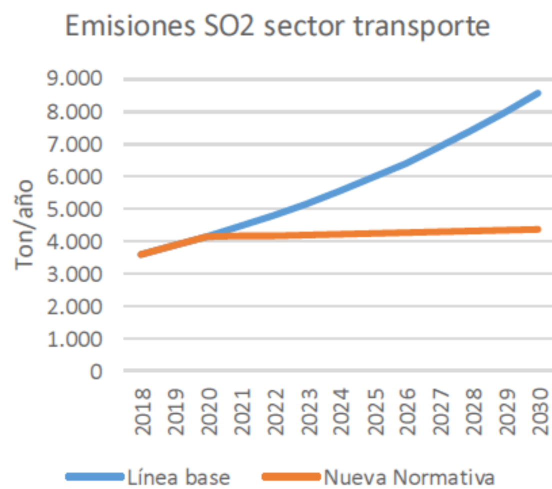
b) Particulate material



c) Nitrogen oxides



d) Sulphur dioxide



Source: Own elaboration

Translation of text in Figure 5-1

Emisiones BC sector transporte: BC emissions transport sector
Emisiones PM sector transporte: PM emissions transport sector
Ton/año: Ton/year
Línea base: Baseline
Nueva normativa: New standard
Emisiones Nox sector transporte: Nox emissions transport sector
Emisiones SO_2 sector transporte: SO_2 emissions transport sector

Table 5-1: Emission reductions by pollutant and fuel between 2021 and 2030

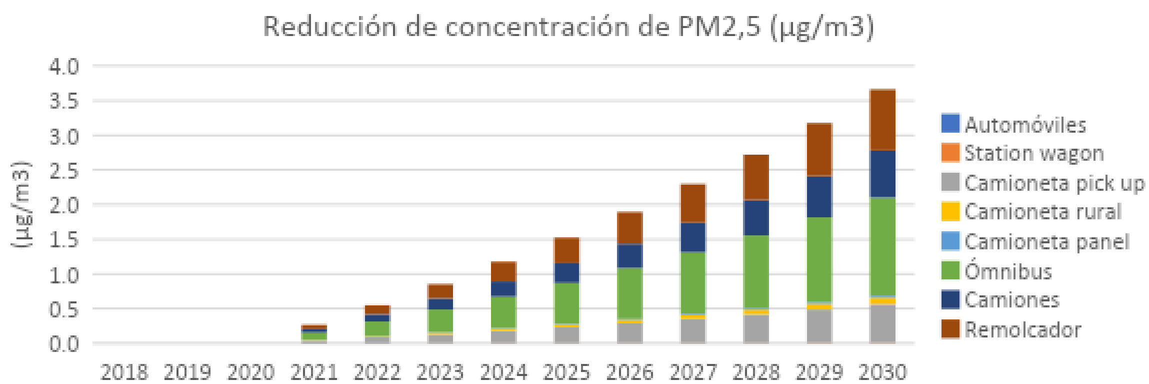
Pollutant	Fuel	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
PM	Gasoline	-1	-2	-3	-4	-5	-6	-8	-9	-11	-13

	Diesel	62	129	200	276	358	446	540	641	749	865
	LPG	0	0	0	0	0	0	0	0	0	0
	NGV	0	0	0	0	0	0	0	0	0	0
Total PM reduction		**61.16**	61	127	197	272	353	440	532	632	738
SO_2	Gasoline	224	464	724	1,003	1,304	1,629	1,978	2,355	2,761	3,198
	Diesel	30	63	98	135	175	218	263	312	364	420
	LPG	0	0	0	0	0	0	0	0	0	1
	NGV	0	0	0	0	0	0	0	0	0	0
Total SO_2 reduction		**254**	254	527	822	1,139	1,480	1,847	2,242	2,668	3,126
Nox	Gasoline	0	0	0	0	0	0	0	0	0	0
	Diesel	5,456	11,289	17,523	24,188	31,312	38,928	47,068	55,771	65,074	75,018
	LPG	0	0	0	0	0	0	1	1	1	1
	NGV	0	0	0	0	0	0	0	0	0	0
Total Nox reduction		**5,456**	5,456	11,289	17,524	24,188	31,313	38,928	47,069	55,772	65,074

Source: Own elaboration. *PM emissions for gasoline vehicles could increase, according to EEA emission factors (2016)

The emission reduction associated with the standard (see Table 5-1) would entail a reduction of fine particulate matter of 3.67 µg/m^3 by 2030, as shown in Figure 5-2.

Figure 5-2: Reduction of $PM_{2.5}$ concentration over time, according to vehicle type



Source: Own elaboration. Assessment assumptions in Table 2-1.

Translation of text in Figure 5-2

Reducción de concentración de PM2,5 (µg/m^3): Reduction of $PM_{2.5}$ concentration (µg/m^3)
Automóviles: Cars
Station wagon
Camioneta pick up: Pickup truck
Camioneta rural: Minibus
Camioneta panel: Panel van
Ómnibus: Bus
Camiones: Trucks
Remolcador: Trailer truck

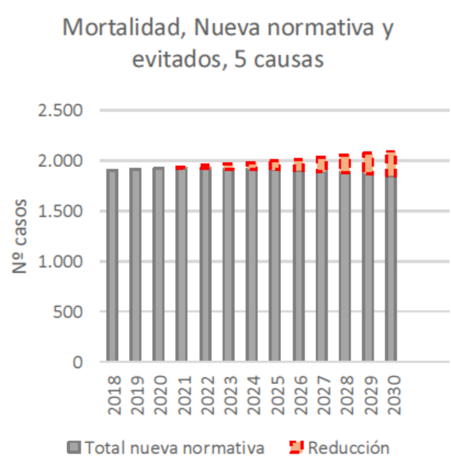
5.2 Health impacts

Figure 5-3 presents the mortality associated with baseline pollution and the reduction associated with the new standard. Mortality due to specific causes (left) and natural mortality in general (right) are presented (in both cases only the fraction associated with pollution).

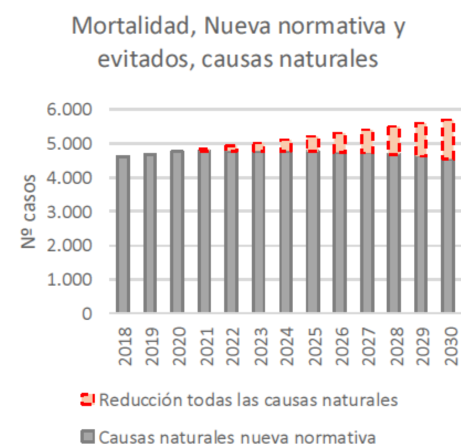
The total avoided cases of premature mortality, in the 2021-2030 period, would be 1,115 cases when considering only lower respiratory infections, chronic obstructive pulmonary disease, lung cancer, strokes and ischemic heart disease. Considering all natural (non-accidental) mortality cases, the number of cases avoided in the assessment period would be 5,406 cases.

Figure 5-3: Baseline and avoided mortality under new standard scenario

a) 5 reasons



b) All natural cause



Source: Own elaboration

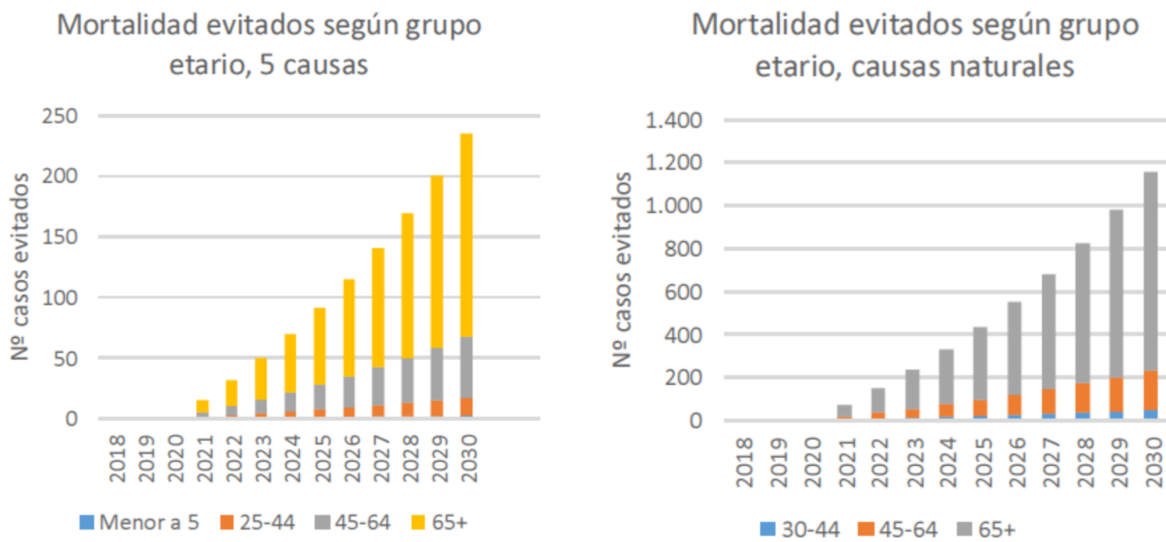
Translation of text in Figure 5-3

Mortalidad, nueva normativa y evitados, 5 causas: Mortality, new standard and avoided, 5 causes
No casos: Number of cases
Total nueva normativa: Total under new standard
Reducción: Reduction
Reducción todas las causas naturales: Reduction all natural causes
Causas naturales nueva normativa: Natural causes new standard

Figure 5-4 presents the distribution of avoided mortality by age range. It can be noted that in both cases the highest proportion of premature mortality avoided is generated in the group over 65 years of age.

Figure 5-4: Distribution of avoided mortality by age group

a) 5 reasons b) All natural causes



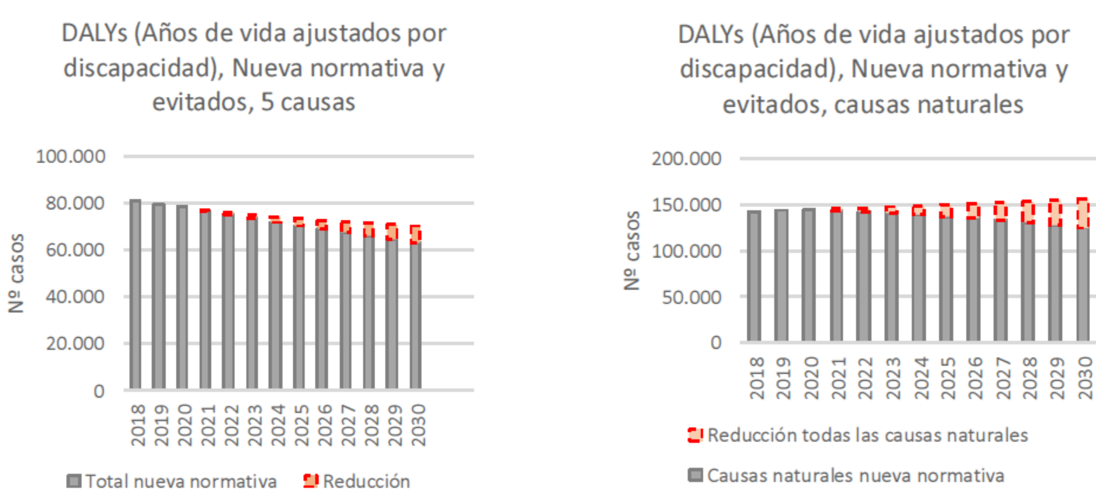
Translation of text in Figure 5-4

Mortalidad evitada según grupo etario, 5 causas: Avoided mortality by age group, 5 causes
Mortalidad evitada según grupo etario, causas naturales: Avoided mortality by age group, natural causes
No casos evitados: Number of cases avoided
Menor a 5: Under 5

Figure 5-5 presents avoided years lived with disability, considering only the 5 specific causes (Figure a) and accounting for all non-accidental causes of disability (Figure b).

Figure 5-5: Baseline and avoided DALYs under new standard scenario

a) 5 reasons b) All natural causes



Source: Own elaboration

Translation of text in Figure 5-5

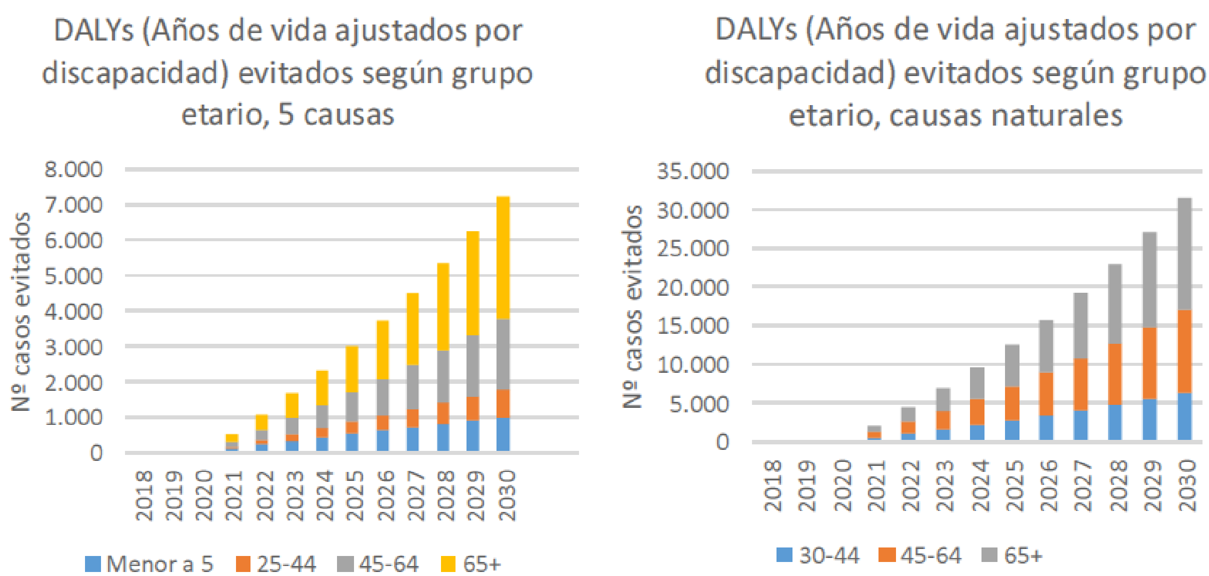
DALYs (Años de vida ajustados por discapacidad), Nueva normativa y evitados, 5 causas: DALYs (Disability-Adjusted Life Years), New standard and avoided, 5 causes

DALYs (Años de vida ajustados por discapacidad), Nueva normativa y evitados, causas naturales: DALYs (Disability-Adjusted Life Years), New standard and avoided, natural causes
No casos: Number of cases
Total nueva normativa: Total under new standard
Reducción: Reduction
Reducción todas las causas: Reduction, all causes
Causas naturales nueva normativa: Natural causes, new standard

Figure 5-6 presents the distribution of disability-adjusted life years avoided by age range. Unlike mortality, the distribution among age groups is more uniform, so that all age groups would benefit from improved health and quality of life associated with the new Euro 6/VI standards.

Figure 5-6: Distribution of avoided DALYs by age group

a) 5 reasons b) All natural causes



Translation of text in Figure 5-6

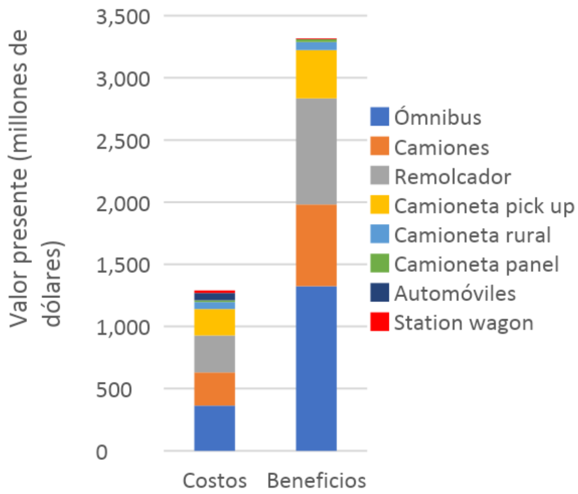
DALYs (Años de vida ajustados por discapacidad) evitados según grupo etario, 5 causas: DALYs (Disability-Adjusted Life Years) avoided, by age group, 5 causes
DALYs (Años de vida ajustados por discapacidad) evitados según grupo etario, causas naturales: DALYs (Disability-Adjusted Life Years) avoided, by age group, natural causes
No casos evitados: Number of avoided cases
Menor a 5: Under 5

5.3 Cost-benefit analysis

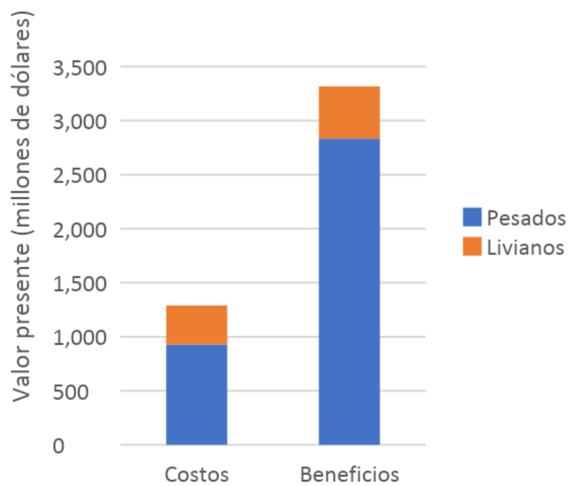
The benefits of introducing the Euro 6/VI standard would reach $3,317 billion in present value, while the costs would be $1,291 billion. The NPV of the standard would be $2,027 million dollars, with a benefit-cost ratio of 2.6. Figure 5-7 a) presents the distribution of costs and benefits according to vehicle type, while Figure 5-7 b) presents the breakdown for light and medium-duty vehicles. It can be noted that buses will contribute most of the benefits, since they mainly use diesel as fuel and have a large number of kilometres travelled per year (120,000 km/year). Heavy-duty vehicles are generally those on which the standards would have the greatest impact, in terms of cost and emissions reduction, since they use mostly diesel fuel.

Figure 5-7: Costs and benefits by vehicle type

a) Costs and benefits by vehicle type



b) Costs and benefits, light and heavy-duty vehicles



Source: Own elaboration

Translation of text in Figure 5-7

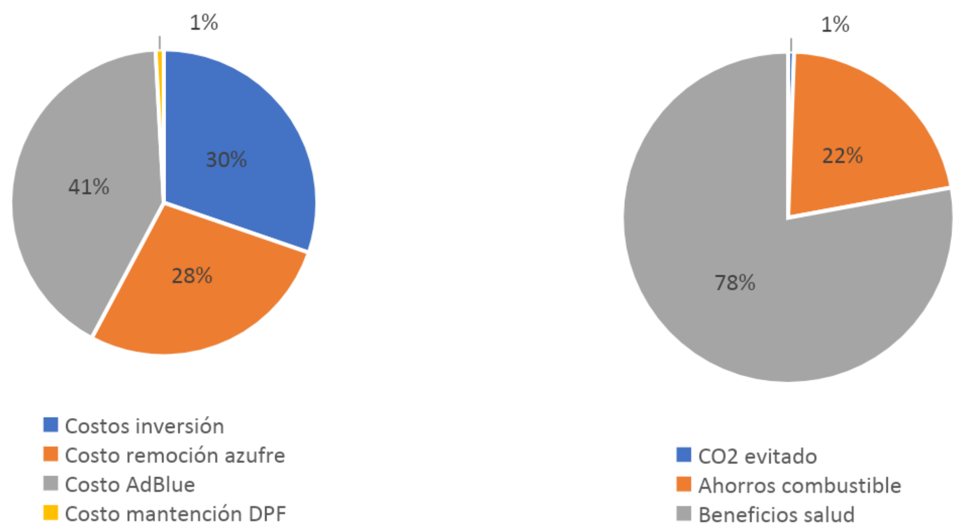
Valor presente (millones de dólares): Present value (millions of dollars)
Costos: Costs
Beneficios: Benefits
Ómnibus: Bus
Camiones: Trucks
Remolcador: Trailer truck
Camioneta pick up: Pickup truck
Camioneta rural: Minivan
Camioneta panel: Panel van
Automóviles: Cars
Station wagon

Figure 5-8 a) presents the distribution of costs by type of cost. Of the $1,291 billion in present value costs, 41% would be for AUS 32 consumption, followed by technology investment costs (30%), sulphur removal costs (30%) and particulate filter maintenance costs (1%).

Figure 5-8 b) shows the distribution of the $3,317 billion in benefits. The main benefits correspond to mortality avoided, equivalent to 78%, followed by benefits due to lower fuel consumption (21%) and CO_2 emissions avoided (1%).

Figure 5-8: Costs and benefits by type of cost and benefit

a) Costs by type b) Benefits by type



Source: Own elaboration

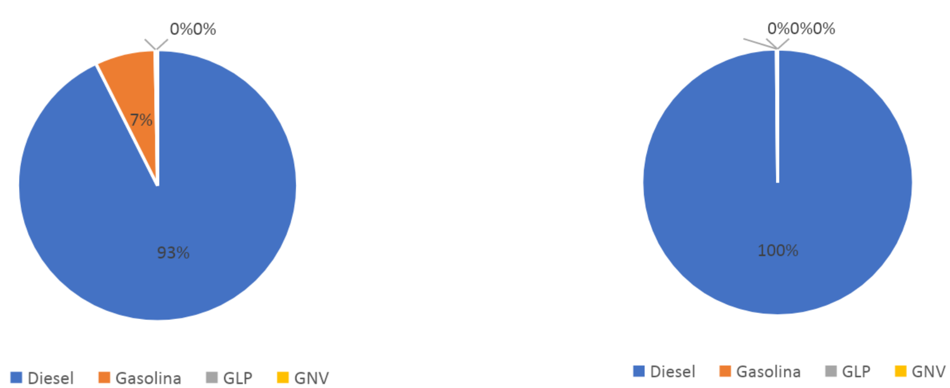
Translation of text in Figure 5-8

Costos inversión: Investment costs
Costo remoción azufre: Sulphur removal cost
Costo AdBlue: AdBlue cost
Costo mantención DPF: DPF maintenance cost
CO_2 evitado: Avoided CO_2
Ahorros combustible: Fuel savings
Beneficios salud: Health benefits

Figure 5-9 presents the distribution of costs and benefits according to the type of fuel used by the vehicles. It can be seen that the greatest impact of the standard is on diesel vehicles, which account for 93% of the costs and 100% of the benefits.

Figure 5-9: Costs and benefits by fuel type

a) Costs by fuel type b) Benefits by to fuel type

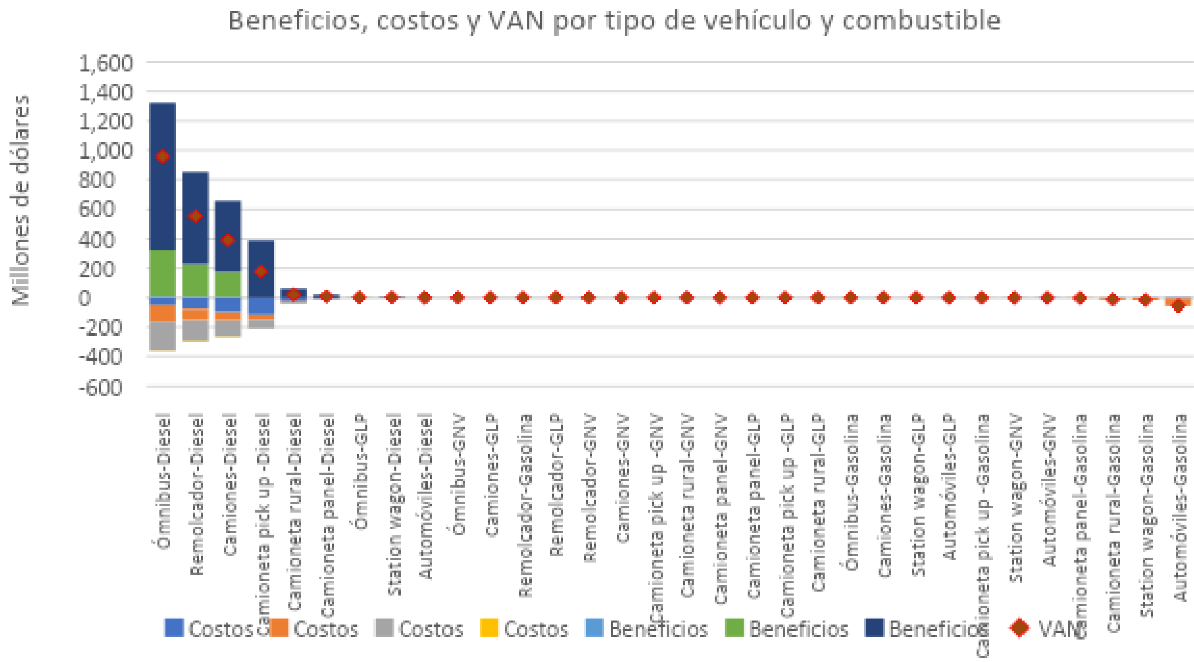


Source: Own elaboration

Translation of text in Figure 5-9
Diesel
Gasolina: Gasoline
GLP: LPG
GNV: NGV

Finally, Figure 5-10 presents the detail of costs and benefits for each combination of vehicle type and fuel. It can be seen that the largest NPVs correspond to the categories of diesel bus, diesel trailer truck, diesel truck, diesel pickup truck and diesel minivan. Table 7-12 in the Annexes presents the table with the values used in Figure 5-10.

Figure 5-10: Detail of costs, benefits and NPV according to vehicle type and fuel.



Source: Own elaboration

Translation of text in Figure 5-10
From left to right:
Bus-Diesel
Trailer truck-Diesel
Trucks-Diesel
Pickup truck-Diesel
Minivan-Diesel
Panel van-Diesel
Bus-LPG
Station wagon-Diesel
Cars-Diesel
Bus: NGV
Trucks-LPG
Trailer-truck-Gasoline

Trailer truck-NGV
Trucks-NGV
Pickup truck-NGV
Minivan-NGV
Panel van-NGV
Panel van-LPG
Pickup truck-LPG
Minivan-LPG
Bus-Gasoline
Trucks-Gasoline
Station wagon-Gasoline
Cars-LPG
Panel van-Gasoline
Minivan-Gasoline
Station wagon-Gasoline
Cars-Gasoline
Costos: Costs
Beneficios: Benefits
VAN: NPV

Figure 5-11: Costs and benefits by vehicle type

	Costos				**Beneficios**		
Tipo de vehiculo	**Costos inversión**	**Costo remoción azufre**	**Costo AdBlue**	**Costo mantención SCR**	**CO2 evitado**	**Ahorros combustible**	**Beneficios salud**
Ómnibus	55,39	103,90	200,69	3,21	8,48	316,48	999,13
Camiones	95,57	57,17	110,22	3,43	4,60	172,63	479,41
Remolcador	76,81	74,17	143,32	4,45	5,98	224,48	623,39
Camioneta pick up	113,08	34,31	64,33	0,00	0,00	0,00	389,41
Camioneta rural	28,29	17,01	10,58	0,00	0,00	0,00	64,51
Camioneta panel	7,17	4,01	3,56	0,00	0,00	0,00	21,64
Automóviles	9,27	49,71	0,06	0,00	0,00	0,00	1,94
Station wagon	5,32	14,80	0,74	0,00	0,00	0,00	5,19
Total	**390,91**	**355,08**	**533,50**	**11,09**	**19,06**	**713,59**	**2584,62**

Source: Own elaboration

Translation of text in Figure 5-11
Tipo de vehículo: Type of vehicle
Costos: Costs
Beneficios: Benefits
Costos inversión: Investment costs
Costo remoción azufre: Sulphur removal cost
Costo AdBlue: AdBlue cost
Costo mantención SCR: SCR maintenance cost
CO2 evitado: Avoided CO_2
Ahorros combustible: Fuel savings
Beneficios salud: Health benefits
Ómnibus: Bus
Camiones: Trucks
Remolcador: Trailer truck
Camioneta pick up: Pickup truck
Camioneta rural: Minivan
Camioneta panel: Panel van
Automóviles: Cars
Station wagon

5.3.1 Distribution of costs and benefits by stakeholder

The distribution of costs and benefits corresponds to the final step of the analysis. Often this step is not carried out as it may be difficult and does not affect the results of the assessment in terms of costs, benefits, or benefit-cost ratio. The stakeholders identified and the assumptions made for the distribution of costs and benefits are explained below.

Private: Vehicle importers could partially absorb the additional cost of new vehicles that must comply with the new standard, while fuel stations could offset some of the increase in fuel prices due to sulphur removal.

Emitters: Applies to users of light and heavy-duty vehicles under the standard. These users will bear investment costs associated with the higher cost of Euro 6/VI vehicles, variable costs of sulphur removal due to the higher price of lower sulphur fuels, variable costs of AUS 32 consumption, and maintenance costs of DPFs.

Government: The government could partially take on sulphur removal costs, should it support the financing of necessary investments in fuel refining facilities. The government will also benefit from reductions in CO_2 emissions, which could partially contribute to the country's commitment under the Paris Agreement.

Population: All inhabitants of Lima and Callao will benefit from the reduction of pollution. The mortality and morbidity avoided due to cleaner air will directly influence their well-being, quality of life and medical expenses resulting from illnesses made worse by pollution..

Table 5-2 presents the assumptions of cost and benefit distribution according to the stakeholders identified.

Table 5-2: Distribution of costs and benefits according to stakeholders identified

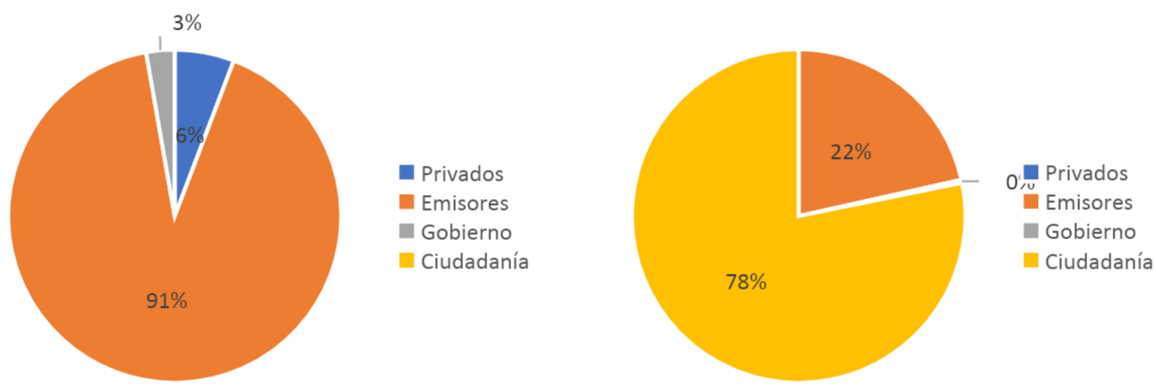
Stakeholder	Costs				Benefits		
	Investment	Sulphur removal	AUS 32	DPF maintenance	CO_2 avoided	Fuel savings	Health benefits
Private	0.1	0.1					
Emitters	0.9	0.8	1	1		1	
Government		0.1			0.5		
Population					0.5		1
Total	1	1	1	1	1	1	1

Source: Own elaboration

Figure 5-11 presents the percentage distribution of costs by stakeholder. It can be seen that the emitters absorb the vast majority of the costs (91%), while they receive only 22% of the benefits. In contrast, the general population does not bear the costs but receives 78% of the benefits, largely because of the premature mortality avoided.

Figure 5-12: Percentage distribution of costs and benefits by stakeholder

a) Distribution of costs by stakeholder b) Distribution of profits by stakeholder



Source: Own elaboration

Translation of text in Figure 5-12

Privado: Private
Emisores: Emitters
Gobierno: Government
Ciudadanía: Population

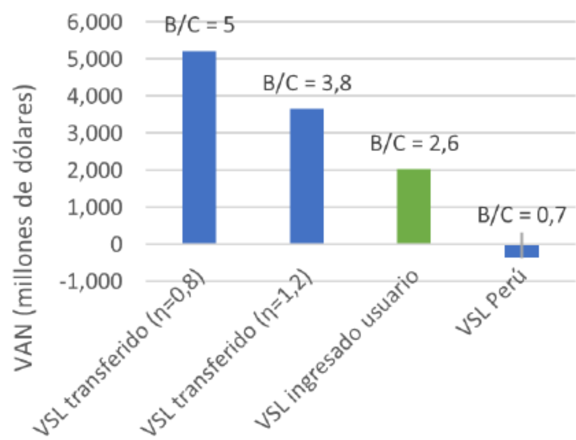
5.4 Sensitivity analysis

Figure 5-12 presents a sensitivity analysis for the value of a statistical life, AUS 32 consumption rate for fuel consumption, discount rate and fuel economy rate for Euro VI heavy-duty diesel vehicles. The bars highlighted in green represent the original value used in the assessment. All the assessment assumptions selected as the main scenario are detailed in Table 2-1 of the Executive Summary, and only the selected parameter is modified in the sensitivity analysis. All other parameters are kept constant and equal to the main scenario.

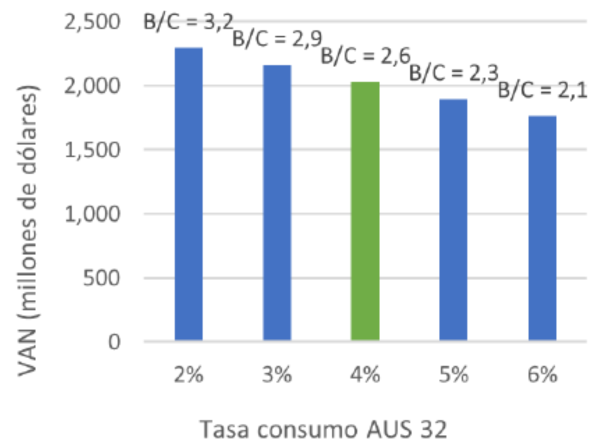
It is noted that the most sensitive parameter corresponds to the value of a statistical life, which could make the benefit-cost ratio vary up to a maximum value of 5 and a minimum value of 0.7 when using the VSL obtained using the human capital approach for Peru. It is worth mentioning again that this VSL calculation approach considers only the lost productivity associated to premature mortality, representing the lower level to assign a value to the avoided mortality.

Figure 5-13: Sensitivity analysis for selected assessment parameters

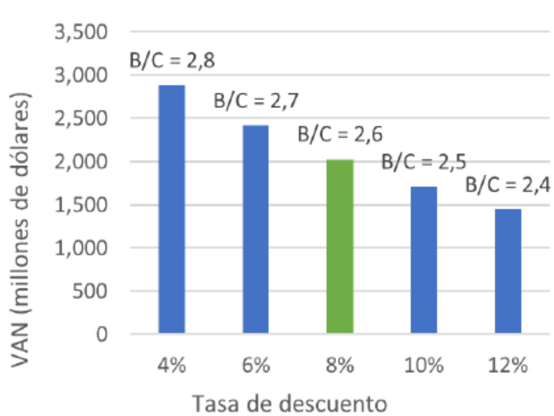
a) Value of a statistical life



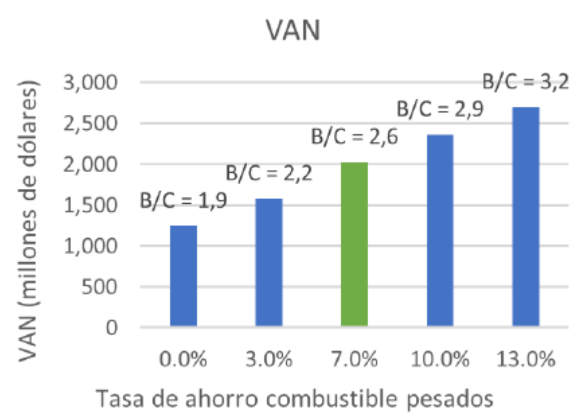
b) AUS 32 consumption rate



c) Discount rate



d) Fuel efficiency of heavy-duty vehicles



Source: Own elaboration

Translation of text in Figure 5-13

VAN (millones de dólares): NPV (millions of dollars)
VSL transferido: NPV transferred (η = 0.8)
VSL transferido: NPV transferred (η = 1.2)
VSL ingresado usuario: NPV entered by user
VSL Perú: NPV Peru
Tasa consumo AUS 32: AUS 32 consumption rate
Tasa de descuento: Discount rate
Tasa de ahorro combustibles pesados: Heavy fuel economy rate

6 Conclusions

The introduction of more stringent emission standards for light and heavy-duty vehicles in Peru, particularly in the area of Lima and Callao, is necessary because the transport sector is the largest emitter of particulate matter and its precursors (see Figure 3-3). Furthermore, the number of vehicles on the road has multiplied by a factor of 2.58 between 2000 and 2018, leading to an increase in emissions from this sector.

This report assesses the Euro 6/VI introduction through a cost-benefit analysis, considering the investment and maintenance costs associated with technological improvements needed to meet the standard, costs of sulphur removal from fuels, and costs associated with the use of automotive urea AUS 32. Quantified benefits include premature mortality avoided, fuel consumption savings, and avoided costs due to reduced CO_2 emissions.

The assessment considers that the standard will be in force in 2021 and the scope of the assessment will extend until 2030. The assumptions are summarized in Table 2-1 and were documented in section 4 of this report.

The results of the assessment indicate that both the costs and the benefits of the standard would fall largely on diesel vehicles (93% for costs and 100% for benefits). Likewise, the emitters would bear the vast majority of the costs (91%) while realizing 22% of the benefits due to savings in fuel consumption. On the other hand, the population living in Lima and Callao would receive 78% of the benefits, as they are exposed to a lower level of pollution and therefore reduce their probability of premature mortality. Table 6-1 presents a summary of the main results of the assessment.

Table 6-1: Summary of results

Indicator	Value
Reduction of $PM_{2.5}$	3.67 $\mu g/m^3$ (year 2030)
Premature deaths avoided between 2021 and 2030	5,406 (natural causes)
Benefits in present value	11,179 (millions of soles)
Costs in present value	4,349 (millions of soles)
Net profit	6,830 (millions of soles)
Cost-benefit ratio	2.6

Source: Own elaboration

The cost-benefit ratio of the implementation of the Euro 6/VI standards suggests that the standard is profitable from a social point of view, and that for every sol invested, a social benefit of 2.6 soles would be obtained.

Finally, it is worth mentioning that this report includes a spreadsheet, where the user can review the detail of the calculations made, modify assessment assumptions, evaluate different regulatory scenarios and develop sensitivity analyses for the main parameters.

7 Recommendations

As mentioned in the report, the inventory of transport emissions in Lima and Callao used the Tier 2 methodology, i.e. the EF does not depend on vehicle traffic speed. The average traffic speed in Lima and Callao is not known with certainty, but it does have an impact on emissions, as shown in Figure 7-1 in the Annexes. The consequence of considering a local traffic speed could significantly increase emissions.

Also, the use of the vehicles increases emissions. This wear and tear can be incorporated into the emissions calculation by means of "deterioration factors". A study to measure the actual operating conditions of the vehicles (including traffic speed) would improve the estimation of emissions, while also introducing vehicle deterioration factors. To illustrate the impact of operating conditions on emissions, the study "Análisis y desarrollo de factores de deterioro y caracterización de las emisiones de la flota mediante el sistema Remote Sensing Devices (RSD)" (Analysis and development of deterioration factors and characterization of fleet emissions using the Remote Sensing Devices (RSD) system) (SECTRA 2015) should be reviewed[14].

Due to the importance of traffic speed and deterioration of abatement systems, local information will be collected in the area of Lima and Callao to be incorporated into future emission estimates.

Another aspect that could improve the estimation of emissions is establishing patterns for removing vehicles from the fleet. Although vehicle removal is known to be very low in the area, it is recommended that vehicle removal statistics be collected according to the category and age of the vehicles.

Finally, the air quality in the area should be modelled and the contribution of the various emission sources to air pollution and secondary pollutants in particulate matter formation should be identified. Knowing in greater detail the impact of sources located in Lima and Callao, as well as external emissions (which are carried to Lima and Callao) could improve air quality management.

[14] Study available at http://www.sectra.gob.cl/biblioteca/detalle1.asp?mfn=3378

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9 Annexes

9.1 Information provided by the technical counterpart

The documents received to date from the technical counterpart are presented in Table 7-1.

Table 9-1: Documents provided by the technical counterpart

Topic	Document	Description
1_Population	Pob_LimaCallao.xlsx	Total population Lima and Callao 2007 and 2017. Projections between 2008 and 2016. Population is not disaggregated by age group.
	EsperanzaVida.xlsx	Life expectancy at birth
	PobEdad_LimaCallao.xlsx	Population in 5-year increments for 2007 and 2017
2_Epidemiology	1_Morb_LimaCallao.xlsx	Number of treatments for acute respiratory infection, acute lower respiratory infection, chronic obstructive pulmonary disease, Malignant neoplasm of bronchus and lung, Ischemic heart disease and stroke
	2_Mort_LimaCallao.xlsx	Total mortality and according to six causes, from 1997 to 2016
	2_Mort_LimaCallao_v2	Total mortality was updated considering only natural causes
	3_Mort_DistGen_LimaCallao.xlsx	Mortality distributed by gender and department, province and district, from 1986 to 2016
	3_Mort_DistGen_LimaCallao (1)	Excel spreadsheet that replaces mortality records by district, gender and sex
	4_Mort_DistEdad_LimaCallao.xlsx	Mortality distributed by age and department, province and district, from 1986 to 2016
5_ValueStatistLife	1_Parametros_EvSocial.pdf	Parameters such as discount rate, social carbon price, fuel price adjustment factors.
	2_Metodologia_ValorEstVida.pdf	Peru´s VSL methodology
	ValorEstadVida_Peru	VSL by age
3_Air quality	CalidadAire_v2.xlsx	Annual seasonal averages
	Reseña.doc	Includes the geographical location of the monitoring stations
	PM2.5_PromDiario.xlsx	Based on DIGESA and SENAMHI
	PM2.5_PromDiario2018	Hourly data for $PM_{2.5}$ for 2018
4_Emissions	Resultados_Totales_2016.xlsx	2016 emissions by sector
	Fuente móviles.xlsx	Contains detailed calculations. Very relevant information.
	(2018) BA-AO.Inventario de emisiones por fuente moviles - Lima y Callao.xlsx	Inventory for the transport sector for 2018
5_Vehiclefleet	InscripcionVehiculos_Nacional.xlsx	2017 and 2018. Broken down by vehicle type.

	Importacionvehiculos_Nacional_v2.xlsx	Units imported from 1991 to 2018.
	KmRecorridos_DptoLimaCallao2016.xlsx	Kilometres travelled according to vehicle type, emission standard for gasoline and NGV
	ModeloMarcaLivianos_2016-2017.xlsx	Characteristics of vehicle models and makes 2016 and 2017.
	ParqueAutomotor_DptoLimaCallao.xlsx	Information from 2000 to 2018.
	TecnVehicular_DptoLimaCallao2016.xlsx	Vehicle fleet distribution according to 2016 emission standard.
	ParqueAutomotor_DptoLimaCallao	Fleet from 2000 to 2018 according to vehicle type.
	NormativaEuro.doc	Implementation dates of emission standards in Peru.
	PaqueAutomotor_nacional	Total vehicle fleet in Peru, 2000 to 2018
	VidaUtil.xlsx	Vehicle lifetime in terms of kilometres travelled
6_Fuels	Demanda_LimaCallao	Sales from 2006 to 2011 by fuel type.
	Precios_LimaCallao.xlsx	Fuel prices
	Precios_LimaCallao_v2.xlsx	Fuel prices. Includes 2018 prices
7_Others	1_InformeMovilidad2015.pdf	Information on public transport, average speeds, trips, accidents, etc.
	2_EstimacionPoblacional_1950-2070.pdf	2019 Report. Mortality and Population Projection. Table 01: Total population projection by sex 1950-2070 Table 02: Total population projection by sex and age group 2020-2070 Table 04: Projected life expectancy at birth, 2020-2070
	3_EstimPoblacion1995-2025.pdf	
	4_CALAC+ Euro 5 Vs Euro 6 20190619 v3 sincontroldecambios.doc	Comparative analysis of the Euro 5/V and Euro 6/VI vehicle emissions standards, requirements and benefits of their implementation in Peru
	5_Tablas1950-2070	Tables of document 2_EstimacionPoblacional_1950-2070.pdf
	6_Liu2008_Emisiones.pdf	Document containing correction factors for NOx, CO and HC and PM_{10} emissions (for diesel vehicles only) according to the sulphur content of the fuels, in accordance with the vehicle's emission standard.
8_Costs	Datos_PMRT.docx	Data from the Talara Refinery modernisation project
	Datos.docx	Prices of AUS 32 in different presentations vary between 2.3 and 3.5 soles per litre
	CostosReferenciales.docx	Costs of maintaining DPF, corresponds to off-road vehicles

9.2 Parameters for calculating emissions

Table 9-2: Kilometres travelled according to vehicle type

Average number of trips per vehicle (km/year)							
Type of fuel	Cars		Vans	Buses**	Truck***		

		Station wagon	Pick up	Miniv an	Panel			Trailer truck	Motorcy cles
Diesel	15000	78000	35000	14000	25000	120000	50000	120000	0
LPG	78000	78000	35000	14000	25000	60000	0	0	0
NGV	78000	78000	35000	14000	25000	60000	50000	0	0
Gasoline	15000	14000	14000	14000	25000	60000	50000	0	14400

Source: Proyecto Planificación ante el Cambio Climático (PlanCC, 2014), Escenarios de Mitigación del Cambio Climático en el Perú al 2050: Construyendo un Desarrollo Bajo en Emisiones. Annex 4.3
*For Diesel and Gasoline, under the Car category, the following source has been used: SWISSCONTACT (May 2014). Elaboración de propuesta para el uso de etiquetado energético en vehículos livianos en el Perú. Informe Final.
**For LPG and gasoline, under the Bus category, the same average km travelled has been assumed for NGV (spark).
***For NGV and Gasoline, under the Truck category, the same average km travelled has been assumed for Diesel.

Table 9-3: Adjustment factors to emissions according to the sulphur content of fuels

Fuel	Pollutant	Standard 2	2000 ppm	800 ppm	500 ppm	350 ppm	50 ppm	10 ppm
Diesel	NOx	Pre Euro	1		0.869	0.856	0.83	0.827
	NOx	EURO 2/II	1.15		1	0.985	0.955	0.951
	NOx	EURO 3/III	1.081		1.007	1	0.985	0.983
	NOx	EURO 4/IV	2.261		1.291	1.194	1	0.974
	NOx	EURO 5/V	2.261		1.291	1.194	1	0.974
	NOx	EURO 6/VI	2.261		1.291	1.194	1	0.974
	CO	Pre Euro	1		0.365	0.301	0.174	0.157
	CO	EURO 2/II	2.74		1	0.826	0.478	0.432
	CO	EURO 3/III	2.069		1.097	1	0.806	0.78
	CO	EURO 4/IV	2.569		1.362	1.241	1	0.968
	CO	EURO 5/V	2.569		1.362	1.241	1	0.968
	CO	EURO 6/VI	2.569		1.362	1.241	1	0.968
	HC	Pre Euro	1		0.443	0.388	0.276	0.261
	HC	EURO 2/II	2.256		1	0.874	0.623	0.59
	HC	EURO 3/III	2.147		1.104	1	0.791	0.764
	HC	EURO 4/IV	2.713		1.395	1.264	1	0.965
	HC	EURO 5/V	2.713		1.395	1.264	1	0.965
	HC	EURO 6/VI	2.713		1.395	1.264	1	0.965
	PM_{10}	Pre Euro	1		0.652	0.617	0.549	0.54
	PM_{10}	EURO 2/II	1.535		1	0.947	0.842	0.828
	PM_{10}	EURO 3/III	2.22		1.111	1	0.778	0.749
	PM_{10}	EURO 4/IV	5.855		2.12	1.747	1	0.75
	PM_{10}	EURO 5/V	5.855		2.12	1.747	1	0.75
	PM_{10}	EURO 6/VI	5.855		2.12	1.747	1	0.75
Gasoline	NOx	Pre Euro		1	0.986	0.95	0.917	0.868
	NOx	EURO 2/II		1.084	1	0.896	0.86	0.633
	NOx	EURO 3/III		1.291	1.225	1	0.937	0.886
	NOx	EURO 4/IV		2.572	2.079	1.364	1	0.883
	NOx	EURO 5/V		2.572	2.079	1.364	1	0.883
	NOx	EURO 6/VI		2.572	2.079	1.364	1	0.883

	CO	Pre Euro		1	0.967	0.883	0.806	0.694
	CO	EURO 2/II		1.11	1	0.844	0.769	0.69
	CO	EURO 3/III		1.396	1.285	1	0.813	0.811
	CO	EURO 4/IV		2.209	1.799	1.245	1	0.77
	CO	EURO 5/V		2.209	1.799	1.245	1	0.77
	CO	EURO 6/VI		2.209	1.799	1.245	1	0.77
	HC	Pre Euro		1	0.973	0.904	0.841	0.749
	HC	EURO 2/II		1.125	1	0.827	0.745	0.663
	HC	EURO 3/III		1.247	1.15	1	0.897	0.815
	HC	EURO 4/IV		1.601	1.407	1.133	1	0.864
	HC	EURO 5/V		1.601	1.407	1.133	1	0.864
	HC	EURO 6/VI		1.601	1.407	1.133	1	0.864

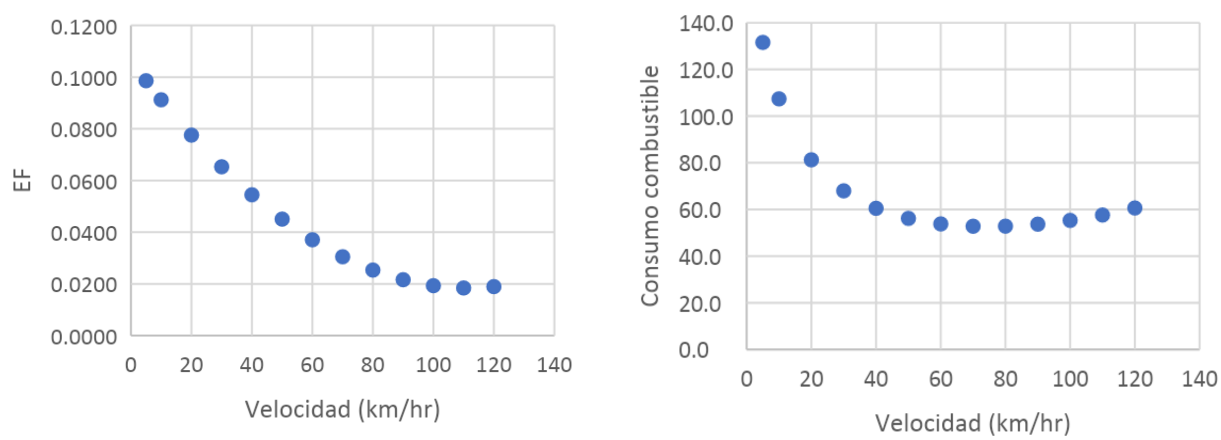
Source: (Liu et al. 2008)

9.3 Example of emission factor variation based on traffic speed

Figure 9-1: Example of EF variation according to traffic speed

a) Emission factor NOx [g/km], Euro 4 gasoline passenger vehicle

b) Fuel consumption [g/km] , Euro 4 gasoline passenger vehicle



Source: Own elaboration based on (European Environment Agency 2016)

Translation of text in Figure 9-1:

EF: EF

Consumo combustible: Fuel consumption

Velocidad (km/hr): Speed (km/hr)

9.4 Description of the projected vehicle fleet

Table 9-4: Projection of the baseline fleet, 2018, 2025 and 2030 (excluding motorcycles)

Baseline	Cars	Station wagon	Pickup truck	Minivan	Panel van	Bus	Trucks	Trailer truck	Total
2018	907,340	319,384	184,038	265,734	34,838	56,676	131,013	70,558	1,969,580
Diesel	544	1,246	165,965	68,108	12,838	50,951	130,227	70,558	500,436
Pre Euro	383	876	116,664	27,170	5,121	20,326	21,156	11,462	203,158
EURO 2/II	13	29	3,856	1,165	220	872	6,718	3,640	16,513
EURO 3/III	120	274	36,554	36,123	6,809	27,024	95,376	51,675	253,956
EURO 4/IV	29	67	8,891	3,649	688	2,730	6,976	3,780	26,809
LPG	22,593	12,999	865	2,206	1,003	62	0	0	39,728
Pre Euro	7,304	4,202	280	237	108	7	0	0	12,137
EURO 2/II	3,649	2,100	140	73	33	2	0	0	5,997
EURO 3/III	10,429	6,001	399	1,777	809	50	0	0	19,465
EURO 4/IV	1,210	696	46	118	54	3	0	0	2,128
NGV	53,805	47,013	92	505	495	5,520	183	0	107,614
Pre Euro	12,714	11,109	22	13	13	144	5	0	24,020
EURO 2/II	8,120	7,095	14	4	4	39	5	0	15,280
EURO 3/III	30,089	26,291	51	461	452	5,041	163	0	62,548
EURO 4/IV	2,882	2,519	5	27	27	296	10	0	5,765
Gasoline	830,397	258,126	17,116	194,916	20,502	142	603	0	1,321,802
Pre Euro	75,031	23,323	1,546	42,152	4,434	31	51	0	146,567
EURO 2/II	113,643	35,326	2,342	3,130	329	2	4	0	154,776
EURO 3/III	597,238	185,650	12,310	139,192	14,641	101	516	0	949,647
EURO 4/IV	44,486	13,828	917	10,442	1,098	8	32	0	70,811
2025	1,522,228	532,849	308,765	446,929	58,542	89,326	207,866	111,956	3,278,461
Diesel	913	2,089	278,343	114,457	21,575	80,731	206,634	111,956	816,698
Pre Euro	383	876	116,664	27,170	5,121	20,326	21,156	11,462	203,158
EURO 2/II	13	29	3,856	1,165	220	872	6,718	3,640	16,513
EURO 3/III	120	274	36,554	36,123	6,809	27,024	95,376	51,675	253,956

EURO 4/IV	398	910	121,269	49,998	9,424	32,509	83,384	45,178	343,070
LPG	37,987	21,856	1,454	3,714	1,689	99	0	0	66,800
Pre Euro	7,304	4,202	280	237	108	7	0	0	12,137
EURO 2/II	3,649	2,100	140	73	33	2	0	0	5,997
EURO 3/III	10,429	6,001	399	1,777	809	50	0	0	19,465
EURO 4/IV	16,605	9,554	636	1,626	740	40	0	0	29,200
NGV	84,942	74,220	145	797	781	8,271	275	0	169,430
Pre Euro	12,714	11,109	22	13	13	144	5	0	24,020
EURO 2/II	8,120	7,095	14	4	4	39	5	0	15,280
EURO 3/III	30,089	26,291	51	461	452	5,041	163	0	62,548
EURO 4/IV	34,019	29,725	58	319	313	3,046	101	0	67,582
Gasoline	1,398,386	434,684	28,822	327,962	34,497	225	957	0	2,225,533
Pre Euro	75,031	23,323	1,546	42,152	4,434	31	51	0	146,567
EURO 2/II	113,643	35,326	2,342	3,130	329	2	4	0	154,776
EURO 3/III	597,238	185,650	12,310	139,192	14,641	101	516	0	949,647
EURO 4/IV	612,475	190,386	12,624	143,488	15,093	91	386	0	974,542
2030	2,209,729	773,505	448,216	648,781	84,982	124,307	289,269	155,799	4,734,587
Diesel	1,325	3,032	404,054	166,150	31,318	112,346	287,555	155,799	1,161,580
Pre Euro	383	876	116,664	27,170	5,121	20,326	21,156	11,462	203,158
EURO 2/II	13	29	3,856	1,165	220	872	6,718	3,640	16,513
EURO 3/III	120	274	36,554	36,123	6,809	27,024	95,376	51,675	253,956
EURO 4/IV	810	1,854	246,980	101,691	19,168	64,125	164,304	89,021	687,953
LPG	55,144	31,727	2,111	5,391	2,452	138	0	0	96,963
Pre Euro	7,304	4,202	280	237	108	7	0	0	12,137
EURO 2/II	3,649	2,100	140	73	33	2	0	0	5,997
EURO 3/III	10,429	6,001	399	1,777	809	50	0	0	19,465
EURO 4/IV	33,761	19,425	1,293	3,304	1,503	79	0	0	59,364
NGV	123,305	107,740	211	1,157	1,134	11,510	382	0	245,439
Pre Euro	12,714	11,109	22	13	13	144	5	0	24,020
EURO 2/II	8,120	7,095	14	4	4	39	5	0	15,280
EURO 3/III	30,089	26,291	51	461	452	5,041	163	0	62,548

EURO 4/IV	72,382	63,245	124	679	666	6,285	209	0	143,590
Gasoline	2,029,955	631,005	41,840	476,083	50,077	313	1,331	0	3,230,604
Pre Euro	75,031	23,323	1,546	42,152	4,434	31	51	0	146,567
EURO 2/II	113,643	35,326	2,342	3,130	329	2	4	0	154,776
EURO 3/III	597,238	185,650	12,310	139,192	14,641	101	516	0	949,647
EURO 4/IV	1,244,043	386,707	25,641	291,609	30,673	179	761	0	1,979,613

Table 9-5: Projection of the fleet regulatory scenario, 2018, 2025 and 2030 (excluding motorcycles)

Regulatory scenario	Cars	Station wagon	Pickup truck	Minivan	Panel van	Bus	Trucks	Trailer truck	Total
2018	907,340	319,384	184,038	265,734	34,838	56,676	131,013	70,558	1,969,580
Diesel	544	1,246	165,965	68,108	12,838	50,951	130,227	70,558	500,436
Pre Euro	383	876	116,664	27,170	5,121	20,326	21,156	11,462	203,158
EURO 2/II	13	29	3,856	1,165	220	872	6,718	3,640	16,513
EURO 3/III	120	274	36,554	36,123	6,809	27,024	95,376	51,675	253,956
EURO 4/IV	29	67	8,891	3,649	688	2,730	6,976	3,780	26,809
LPG	22,593	12,999	865	2,206	1,003	62	0	0	39,728
Pre Euro	7,304	4,202	280	237	108	7	0	0	12,137
EURO 2/II	3,649	2,100	140	73	33	2	0	0	5,997
EURO 3/III	10,429	6,001	399	1,777	809	50	0	0	19,465
EURO 4/IV	1,210	696	46	118	54	3	0	0	2,128
NGV	53,805	47,013	92	505	495	5,520	183	0	107,614
Pre Euro	12,714	11,109	22	13	13	144	5	0	24,020
EURO 2/II	8,120	7,095	14	4	4	39	5	0	15,280
EURO 3/III	30,089	26,291	51	461	452	5,041	163	0	62,548
EURO 4/IV	2,882	2,519	5	27	27	296	10	0	5,765
Gasoline	830,397	258,126	17,116	194,916	20,502	142	603	0	1,321,802
Pre Euro	75,031	23,323	1,546	42,152	4,434	31	51	0	146,567
EURO 2/II	113,643	35,326	2,342	3,130	329	2	4	0	154,776
EURO 3/III	597,238	185,650	12,310	139,192	14,641	101	516	0	949,647
EURO 4/IV	44,486	13,828	917	10,442	1,098	8	32	0	70,811

2025	1,522,228	532,849	308,765	446,929	58,542	89,326	207,866	111,956	3,278,461
Diesel	913	2,089	278,343	114,457	21,575	80,731	206,634	111,956	816,698
Pre Euro	383	876	116,664	27,170	5,121	20,326	21,156	11,462	203,158
EURO 2/II	13	29	3,856	1,165	220	872	6,718	3,640	16,513
EURO 3/III	120	274	36,554	36,123	6,809	27,024	95,376	51,675	253,956
EURO 4/IV	114	260	34,669	14,388	2,712	9,791	25,235	13,673	100,842
EURO 6/VI	284	650	86,599	35,610	6,712	22,718	58,149	31,505	242,228
LPG	37,987	21,856	1,454	3,714	1,689	99	0	0	66,800
Pre Euro	7,304	4,202	280	237	108	7	0	0	12,137
EURO 2/II	3,649	2,100	140	73	33	2	0	0	5,997
EURO 3/III	10,429	6,001	399	1,777	809	50	0	0	19,465
EURO 4/IV	4,786	2,754	183	471	214	12	0	0	8,420
EURO 6/VI	11,819	6,800	452	1,155	526	28	0	0	20,780
NGV	84,942	74,220	145	797	781	8,271	275	0	169,430
Pre Euro	12,714	11,109	22	13	13	144	5	0	24,020
EURO 2/II	8,120	7,095	14	4	4	39	5	0	15,280
EURO 3/III	30,089	26,291	51	461	452	5,041	163	0	62,548
EURO 4/IV	7,592	6,633	13	71	70	719	24	0	15,122
EURO 6/VI	26,427	23,092	45	248	243	2,327	77	0	52,460
Gasoline	1,398,386	434,684	28,822	327,962	34,497	225	957	0	2,225,533
Pre Euro	75,031	23,323	1,546	42,152	4,434	31	51	0	146,567
EURO 2/II	113,643	35,326	2,342	3,130	329	2	4	0	154,776
EURO 3/III	597,238	185,650	12,310	139,192	14,641	101	516	0	949,647
EURO 4/IV	177,402	55,145	3,656	41,451	4,360	27	117	0	282,159
EURO 6/VI	435,072	135,241	8,967	102,037	10,733	63	269	0	692,383
2030	2,209,729	773,505	448,216	648,781	84,982	124,307	289,269	155,799	4,734,587
Diesel	1,325	3,032	404,054	166,150	31,318	112,346	287,555	155,799	1,161,580
Pre Euro	383	876	116,664	27,170	5,121	20,326	21,156	11,462	203,158
EURO 2/II	13	29	3,856	1,165	220	872	6,718	3,640	16,513
EURO 3/III	120	274	36,554	36,123	6,809	27,024	95,376	51,675	253,956
EURO 4/IV	114	260	34,669	14,388	2,712	9,791	25,235	13,673	100,842

EURO 6/VI	696	1,593	212,310	87,304	16,456	54,334	139,069	75,348	587,111
LPG	55,144	31,727	2,111	5,391	2,452	138	0	0	96,963
Pre Euro	7,304	4,202	280	237	108	7	0	0	12,137
EURO 2/II	3,649	2,100	140	73	33	2	0	0	5,997
EURO 3/III	10,429	6,001	399	1,777	809	50	0	0	19,465
EURO 4/IV	4,786	2,754	183	471	214	12	0	0	8,420
EURO 6/VI	28,975	16,671	1,109	2,833	1,289	67	0	0	50,944
NGV	123,305	107,740	211	1,157	1,134	11,510	382	0	245,439
Pre Euro	12,714	11,109	22	13	13	144	5	0	24,020
EURO 2/II	8,120	7,095	14	4	4	39	5	0	15,280
EURO 3/III	30,089	26,291	51	461	452	5,041	163	0	62,548
EURO 4/IV	7,592	6,633	13	71	70	719	24	0	15,122
EURO 6/VI	64,791	56,612	111	608	596	5,566	185	0	128,469
Gasoline	2,029,955	631,005	41,840	476,083	50,077	313	1,331	0	3,230,604
Pre Euro	75,031	23,323	1,546	42,152	4,434	31	51	0	146,567
EURO 2/II	113,643	35,326	2,342	3,130	329	2	4	0	154,776
EURO 3/III	597,238	185,650	12,310	139,192	14,641	101	516	0	949,647
EURO 4/IV	177,402	55,145	3,656	41,451	4,360	27	117	0	282,159
EURO 6/VI	1,066,641	331,562	21,985	250,158	26,313	151	644	0	1,697,454

9.5 Parameters used in the VSL transfer

Table 9-6: GDP per capita, adjusted by purchasing power parity, constant prices 2011

Year	OECD members	Peru
2017	39,589,21	12,236,8
2010	36,012	9,957
2005	35,408	7,595

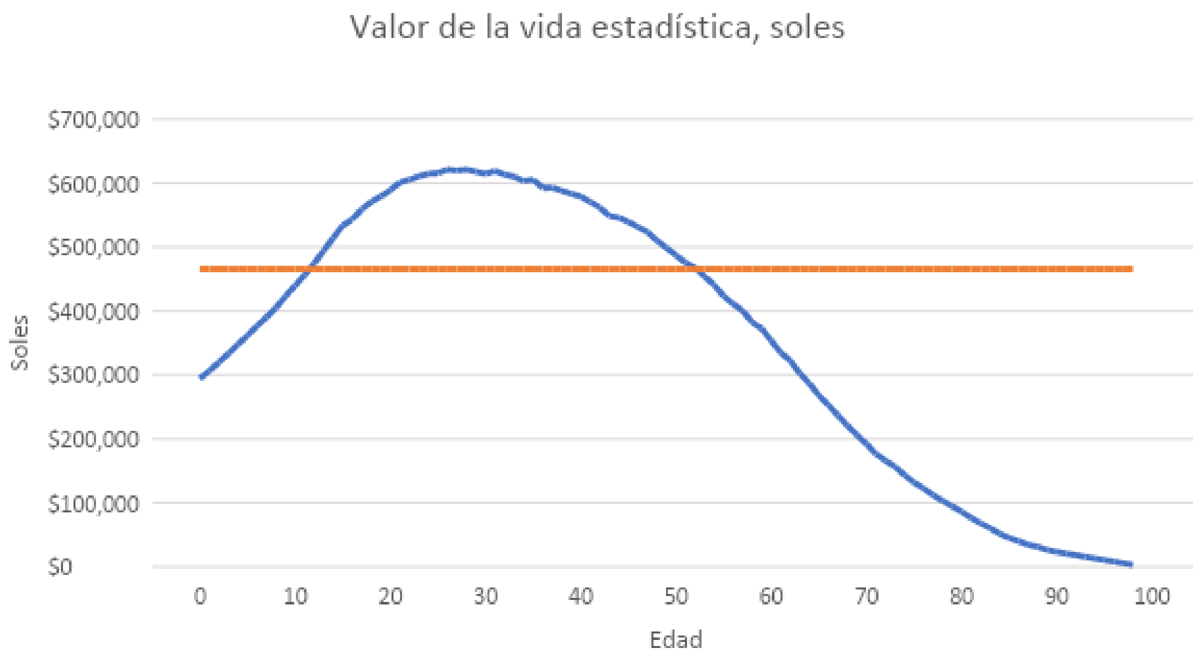
Source: World Bank, International Comparison Program database[15].

Table 9-7: OECD Consumer Price Index

	2005	2015	2017
Consumer Price Index	82.2	100.0	103.4

Source: OECD

9.6 Valuation of avoided mortality, human capital approach, Peru



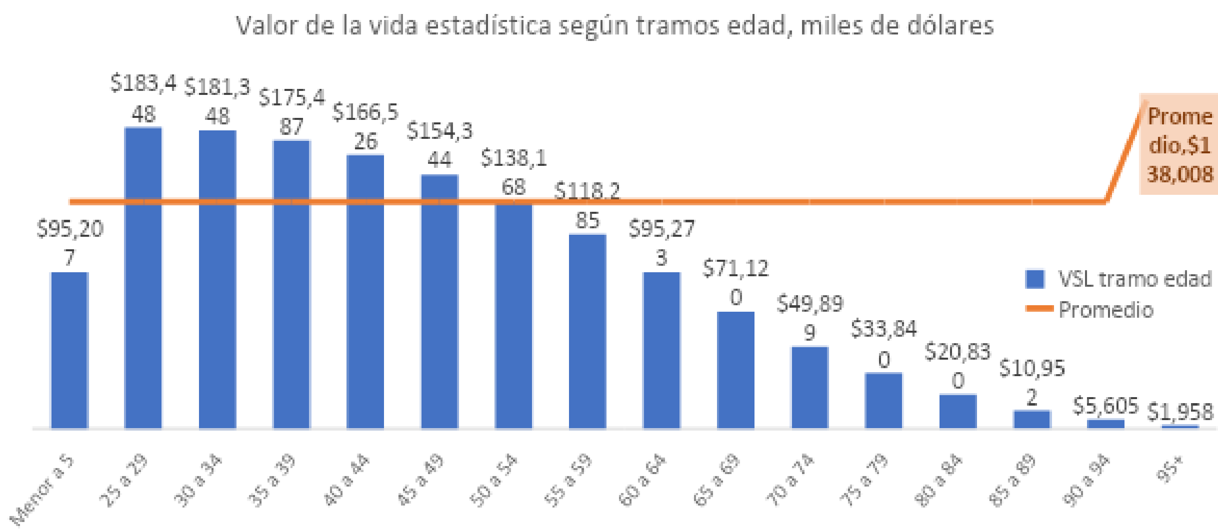
Source: Own elaboration based on (Seminario de Marzi 2017)

Translation of text in Figure

Valor de la vida estadística, soles: Value of a statistical life, soles

Figure 9-2: Value of a statistical life of health effects by age groups, thousands of dollars

[15] Data available at https://datos.bancomundial.org/indicator/NY.GDP.PCAP.PP.KD, accessed October 2019



Source: Own elaboration based on (Seminario de Marzi 2017)

Translation of text in Figure 9-2

Valor de la vida estadística según tramos de edad, miles de dólares: Value of a statistical life by age group, thousands of dollars
Promedio, $138,008 = Average, $138,008
VSL tramo edad: VSL by age group
Promedio: Average
Menor a 5: Under 5
25 a 29 = 25 to 29

9.7 2016 mortality data for Lima and Callao

Table 9-8: 2016 mortality data for Lima and Callao, by cause and age group

Age group	All deaths	Chronic obstructive pulmonary disease (COPD)	Ischemic heart disease	Acute lower respiratory infections	Stroke	Malignant neoplasm of trachea, bronchus and lung	Natural causes
0-4	2,048	6	11	149	14		1,950
5-9	222		5	10	1	1	211
10-14	159			11	4	1	151
15-19	343		3	20	16		327
20-24	589		11	22	17	5	561
25-29	654		27	23	20	5	623
30-34	759		28	39	15	6	722
35+	46,397	444	3,441	6,732	2,346	1,106	44,166
Total	**51,171**	**450**	**3,526**	**7,006**	**2,433**	**1,124**	**48,710**

Source: Data provided by the National Centre for Epidemiology, Disease Prevention and Control

Table 9-9: 2016 Mortality data for Lima and Callao, according to relevant cause for health effects, with a further disaggregation for age group 35+

	COPD	IHD	ALRI	Stroke	Lung cancer	Natural causes
Under 5	6	11	149	14	0	1.950
5-9	0	5	10	1	1	211
10-14	0	0	11	4	1	151
15-19	0	3	20	16	0	327
20-24	0	11	22	17	5	561
25-29	0	27	23	20	5	623
30-34	0	28	39	15	6	722
35-39	5	43	111	28	135	880
40-44	7	57	154	50	129	1,142
45-49	10	73	193	87	127	1,467
50-54	14	109	252	130	117	1,930
55-59	19	139	312	184	105	2,437
60-64	25	188	380	252	91	3,038
65-69	33	243	471	322	86	3,762
70-74	40	337	575	371	78	4,538
75-79	55	463	764	364	77	5,705
80-84	70	589	919	281	69	6,491
85-89	74	621	1,155	185	52	6,411
90-94	57	374	939	70	26	4,154
95+	35	205	509	22	12	2,210
TOTAL	***450***	***3,526***	***7,006***	***2,433***	***1,124***	***48,710***

Source: Own elaboration based on data provided by the National Centre of Epidemiology, Disease Prevention and Control and (Institute for Health Metrics and Evaluation 2018) for Peru.

9.8 Fuel consumption factors

Table 9-10: Fuel consumption factors (FC)

Type of vehicle	Fuel	Category	technology	CF (g/km)
Passenger vehicles	Gasoline	Gasoline Medium	PRE-ECE to open loop	77
	Gasoline	Gasoline Medium	Euro 1 and later	66
	Diesel	Diesel Medium	Conventional	63
	Diesel	Diesel Medium	Euro 1 and later	55
	LPG	LPG	Conventional	59
	LPG	LPG	Euro 1 and later	57
	CNG	CNG	Euro 4 and later	63
Light commercial vehicles	Gasoline	Gasoline	Conventional	85
	Gasoline	Gasoline	Euro 1 and later	70
	Diesel	Diesel	Conventional	89
	Diesel	Diesel	Euro 1 and later	80
Heavy trucks	Gasoline		Conventional	85

	Diesel	7.5-16 t	Conventional	182
	Diesel	7.5-16 t	Euro I and later	155
Buses	CNG	Urban CNG buses	HD Euro I	555
	CNG	Urban CNG buses	HD Euro II	515
	CNG	Urban CNG buses	HD Euro III	455
	CNG	Urban CNG buses	EEV	455
	Diesel	Urban buses, standard	Conventional	366
	Diesel	Urban buses, standard	Euro I and later	301
Motorcycles	Gasoline	Mopeds 4-stroke < 50 cm^3	Conventional	25
	Gasoline	Mopeds 4-stroke < 50 cm^3	Euro 1	20
	Gasoline	Mopeds 4-stroke < 50 cm^3	Euro 2	20
	Gasoline	Mopeds 4-stroke < 50 cm^3	Euro 3 and on	20

Source: Table 3-27 European Environment Agency (2016), chapter "1.A.3.b.i-iv Road transport hot EFs Annex 2018"

9.9 Certification costs

Table 9-11: Costs of the vehicle type approval process (Table I), 3CV Chile laboratory

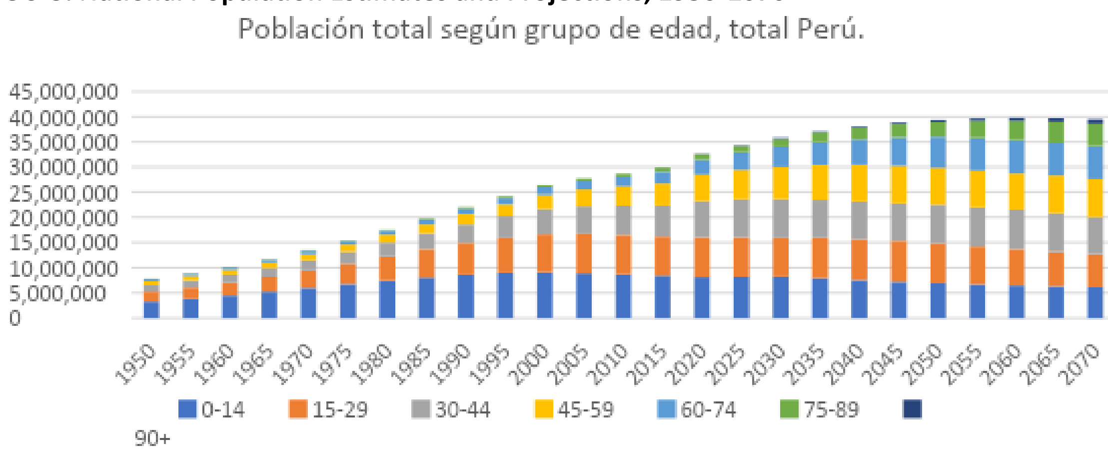
ITEM	SERVICE	Chilean Pesos	Soles	Dollars
1	Type approval of light and medium-duty vehicles and motorcycles with gasoline engine	$2.037,262	$9,575	$2.852
2	Type approval of light and medium-duty vehicles with gasoline engine and chromatography analysis	$2.627,551	$12.349	$3.679
3	Type approval of light and medium-duty vehicles with diesel engines	$3.140.045	$14.758	$4.396
4	Type approval of light and medium-duty vehicles with diesel engines and chromatography analysis	$4.136,350	$19,441	$5,791
5	Individual type approval of emissions and structural aspects of light and medium-duty vehicles and motorcycles	$807,626	$3.796	$1.131
6	Individual type-approval of emissions and structural aspects of light and medium-duty vehicles, and with chromatography analysis	$1.004.391	$4.721	$1.406
7	Individual certification of emissions from light and medium-duty vehicles.	$500.729	$2.353	$701
8	Certification of emissions from heavy-duty vehicles	$294.846	$1.386	$413
9	Certification of emissions from heavy-duty vehicle engines	$120.023	$564	$168
10	Certification applied to already certified engines of heavy-duty vehicles (S.D. Nº 55/94. S.D. Nº 130/2001 of the Ministry of Transport)	$120.023	$564	$168
11	Certification of noise emissions from urban and rural public transport buses	$151.407	$712	$212
12	Accreditation of dimensional and functional requirements of article 7 of the S.D. Nº 122/91 of the Ministry of Transport	$923.576	$4.341	$1.293
13	Certification of emissions post-treatment systems, S.D. Nº 65/2004 of the Ministry of Transport	$2.784.327	$13.086	$3.898

14	Certification of emissions for trucks or semi-trailer trucks, S.D. Nº 55/94 of the Ministry of Transport	$294.846	$1.386	$413
15	Certification applied to already certified engine on a truck or semi-trailer truck, S.D. Nº. 55/94 of the Ministry of Transport	$294.846	$1.386	$413
16	Certification of Replacement Catalytic Converters S.D. Nº 15/2000 of the Ministry of Transport	$162.033	$762	$227
17	Certification of safety conditions and construction criteria for bodies of intercity buses. S.D. Nº 175/2006 of the Ministry of Transport	$340.083	$1.598	$476
18	Certification of electronic registration devices for intercity passenger transport vehicles. Ruling Nº 100/2005 of the Ministry of Transport	$302.408	$1.421	$423

Source: 3CV 2019 laboratory services values, Chile[16]

9.10 Population evolution in Peru

Figure 9-3: National Population Estimates and Projections, 1950-2070



Source: Own elaboration based on (INEI, UNFPA, and ECLAC 2019)

Translation of text in Figure 9-3

Población total según grupo de edad, total Perú: Total population by age group, total for Peru

[16] Values available at https://www.mtt.gob.cl/wp-content/uploads/2014/01/TABLA-VALORES-SERVICIOS-2019.pdf, accessed September 2019

9.11 Breakdown of costs and benefits

Table 9-12: Breakdown of costs and benefits

			Costs				Benefits				
Vehicle type	**Fuel**	**Contribution to a reduction in concentration**	**Investment**	**Sulphur removal**	**AUS 32**	**DPF maintenance**	**CO_2 avoided**	**Fuel savings**	**Health**	**NPV**	**B/C**
Bus	Diesel	38.7%	55.4	103.9	200.7	3.2	8,4	314.3	999.09	958,.6	3.6
Trailer truck	Diesel	24.1%	76.8	74.2	143.3	4.5	6,0	224.5	623.39	555,1	2.9
Trucks	Diesel	18.5%	95.6	57.0	110.2	3.4	4.6	172.6	479.41	390.4	2.5
Pickup truck	Diesel	15.1%	112.9	33.3	64.3	0.0	0.0	0.0	389.37	178.8	1.8
Minivan	Diesel	2.5%	26.7	5.5	10.6	0.0	0.0	0.0	64.04	21.3	1.5
Panel van	Diesel	0.8%	6.9	1.8	3.6	0.0	0.0	0.0	21.56	9,2	1.7
Bus	LPG	0.0%	0.0	0.0	0.0	0.0	0.1	2.1	0.04	2.3	
Station wagon	Diesel	0.2%	1.6	0.4	0.7	0.0	0.0	0.0	4.74	2.0	1.7
Cars	Diesel	0.0%	0.2	0.0	0.1	0.0	0.0	0.0	0.40	0.1	1.3
Bus	NGV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Trucks	LPG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Trailer truck	Gasoline	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Trailer truck	LPG	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Trailer truck	NGV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Trucks	NGV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
Pickup truck	NGV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Minivan	NGV	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
Panel van	NGV	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.0
Panel van	LPG	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.0
Pickup truck	LPG	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	-0.01	0.0
Minivan	LPG	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	-0.02	0.0
Bus	Gasoline	0.00	0.00	0.04	0.00	0.00	0.00	0.00	0.00	-0.03	0.1
Trucks	Gasoline	0.00	0.00	0.13	0.00	0.00	0.00	0.00	0.01	-0.12	0.1
Station wagon	LPG	0.0%	0.4	0.0	0.0	0.0	0.0	0.0	0.00	-0.4	0.0
Cars	LPG	0.0%	0.6	0.0	0.0	0.0	0.0	0.0	0.00	-0.6	0.0

Pickup truck	Gasoline	0.0%	0.1	1.0	0.0	0.0	0.0	0.0	0.04	-1.1	0.0
Station wagon	NGV	0.0%	1.2	0.0	0.0	0.0	0.0	0.0	0.00	-1.2	0.0
Cars	NGV	0.0%	1.4	0.0	0.0	0.0	0.0	0.0	0.00	-1.4	0.0
Panel van	Gasoline	0.0%	0.2	2.2	0.0	0.0	0.0	0.0	0.09	-2.3	0.0
Minivan	Gasoline	0.0%	1.6	11.5	0.0	0.0	0.0	0.0	0.47	-12.7	0.0
Station wagon	Gasoline	0.0%	2.1	14.4	0.0	0.0	0.0	0.0	0.45	-16.1	0.0
Automobiles	Gasoline	0.1%	7.0	49,7	0.0	0.0	0.0	0.0	1.54	-55.2	0.0
TOTAL			**390.9**	**355.1**	**533.5**	**11.1**	**19.1**	**713.6**	**2.584.6**	**2.026.7**	**2.6**

Source: Own elaboration

9.12 AirQ+ Health Effects, comparison with attached spreadsheet

Natural causes

Input data for AirQ+:

- Life table as .CSV file

Figure 9-4: Example of input file for AirQ+, life table

```
Edad_0;Edad_f;poblacion;n_muertes_nat
0;4;758069;1874.21147901473
5;9;774611;206.434331327665
10;14;751994;147.851615680625
15;19;792442;319.569612651139
20;24;945956;548.76531152047
25;29;914333;609.32515065261
30;34;850668;714.635220308423
35;39;796215;870.667331595012
40;44;732127;1129.44798370433
45;49;625904;1450.87553037264
50;54;544872;1939.58988400174
55;59;461786;2448.76348330997
60;64;385183;3052.21218325623
65;69;297390;3780.20951003436
70;74;219025;4653.65928668761
75;79;153846;5850.91945691834
80;84;106607;6656.24696271358
85;89;63703;6575.08525973688
90;94;26259;4260.47762466293
95;119;8281;2266.1022007851
```

Source: Own elaboration

Figure 9-5: Example of input file for AirQ+, $PM_{2.5}$ daily average data

Fecha;Promedio diario
1/1/2018;86.9059523809524
2/1/2018;19.8446428571429
3/1/2018;21.6150602409638
4/1/2018;14.9451388888889
5/1/2018;14.9055555555555
6/1/2018;16.9458333333333
7/1/2018;13.5748201438849
1/2/2018;19.7408333333333
2/2/2018;15.6
3/2/2018;18.0822916666667
4/2/2018;14.0916666666667
5/2/2018;12.9944444444444
6/2/2018;17.1395833333333
7/2/2018;22.0444444444444
8/2/2018;23.8958333333333
9/2/2018;23.8364583333333
10/2/2018;20.5739583333333
11/2/2018;14.2947916666667
12/2/2018;18.6902173913043
13/2/2018;18.9158333333333

Air Q+ provides the total pollution impacts associated with the air quality data entered. In this case, one of the results is the "Attributable Fraction" or PAF, which corresponds to the proportion of mortality cases attributable to air pollution In the case of Lima and Callao, between 6.1% and 12% of the cases are estimated to be attributable to pollution, with a core value of 9.2%.

Figure 9-6: AirQ+ Results for Natural Causes

POLLUTION CONCENTRATION			
Mean Concetration;27.4			
EVALUATION RESULTS			
Result Table:			
Central;Lower;Upper			
Estimated Attributable Proportion;9.94%;6.6%;12.95%;			
Estimated	092;2	716;5	334;
Estimated number of Attributable Cases per 100 000 Population at Risk;78;52;101;			

DETAILED EVALUATION RESULTS							
Detailed Result Table:							
Concentra	000 population at risk;estimated number of cases attrib. to exposure						
27.4;365;1	091.81;						
Detailed Result Table Lower:							
Concentra	000 population at risk;estimated number of cases attrib. to exposure						
27.4;365;1	716.20;						
Detailed Result Table Upper:							
Concentra	000 population at risk;estimated number of cases attrib. to exposure						
27.4;365;1	333.98;						

The total number of deaths associated with pollution, using natural causes, is 4,092 deaths for the central scenario.

It is worth mentioning that in its "Health" sheet, the attached Excel spreadsheet implements the methodology obtaining the PAF core value of 9.2%. Both analysis sources provide the same result in terms of PAF.

Similarly, for cases of COPD, AirQ+ estimates a fraction attributable to pollution of 21.56% as the core value. The result coincides with that obtained in the spreadsheet.

Figure 9-7: AirQ+ results for COPD

EVALUATION RESULTS											
Result Table:											
Central	Lower	Upper									
Estimated /	21.56%	11.50%	33.01%								
Estimated r	3,337	1,779	5,109								
Estimated r	63	34	97								
DETAILED EVALUATION RESULTS											
Detailed Result Table:											
Concentrat	number of	%Person*D	RR	RR*p	(RR-1)*p	Number of	estimated number of cases attrib. to exposure				
26.03	365	100%	1.274912	1.274912	0.274912	63.3	3,336.91				

Table 9-13: Fraction of cases attributable to pollution estimated on attached spreadsheet, Health sheet (from row 213)

	Age	Code	PAF
ALRI	Under 5	ALRI-Under 5	22.6%
COPD	30+	COPD-30+	22.3%
Lung cancer	30+	Lung cancer-30+	15.3%

Natural causes	30+	Natural causes-30+	9.9%
Stroke	25 to 29	Stroke-25 to 29	25.8%
Stroke	30 to 34	Stroke-30 to 34	24.6%
Stroke	35 to 39	Stroke-35 to 39	23.5%
Stroke	40 to 44	Stroke-40 to 44	21.9%
Stroke	45 to 49	Stroke-45 to 49	20.7%
Stroke	50 to 54	Stroke-50 to 54	19.6%
Stroke	55 to 59	Stroke-55 to 59	17.5%
Stroke	60 to 64	Stroke-60 to 64	16.1%
Stroke	65 to 69	Stroke-65 to 69	14.7%
Stroke	70 to 74	Stroke-70 to 74	13.2%
Stroke	75 to 79	Stroke-75 to 79	11.4%
Stroke	80 to 84	Stroke-80 to 84	11.1%
Stroke	85 to 89	Stroke-85 to 89	8.5%
Stroke	90 to 94	Stroke-90 to 94	7.7%
Stroke	95+	Stroke-95+	5.2%
IHD	25 to 29	IHD-25 to 29	33.8%
IHD	30 to 34	IHD-30 to 34	32.0%
IHD	35 to 39	IHD-35 to 39	30.1%
IHD	40 to 44	IHD-40 to 44	28.4%
IHD	45 to 49	IHD-45 to 49	26.5%
IHD	50 to 54	IHD-50 to 54	24.3%
IHD	55 to 59	IHD-55 to 59	22.4%
IHD	60 to 64	IHD-60 to 64	20.5%
IHD	65 to 69	IHD-65 to 69	18.7%
IHD	70 to 74	IHD-70 to 74	16.9%
IHD	75 to 79	IHD-75 to 79	14.9%
IHD	80 to 84	IHD-80 to 84	12.8%
IHD	85 to 89	IHD-85 to 89	10.8%
IHD	90 to 94	IHD-90 to 94	8.8%
IHD	95+	IHD-95+	6.7%

Source: Own elaboration