BUILDING LOW EMISSION ALTERNATIVES TO DEVELOP ECONOMIC RESILIENCE AND SUSTAINABILITY PROJECT (B-LEADERS)

PHILIPPINES MITIGATION COST-BENEFIT ANALYSIS

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November 2015

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Transport Sector Results

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS

ADB	Asian Development Bank
AFOLU	Agriculture, Forestry and Land Use
ALU	Agriculture and Land Use
ASEAN	Association of Southeast Asian Nations
BC	Black Carbon
BRT	Bus Rapid Transit
B-LEADERS	Building Low Emission Alternatives to Development, Economic Resilience, and Sustainability
CAA	Clean Air Asia
CBA	Cost-Benefit Analysis
CCC	Climate Change Commission
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CH_4	Methane
DENR	Department of Environment and Natural Resources
DOE	Department of Energy
DOTC	Department of Transport and Communications
DPF	diesel particulate filter
DPWH	Department of Public Works and Highways
EPPB	Energy Policy and Planning Bureau
EV	electric vehicle
GCR	Greater Capital Region
GFEI	Global Fuel Economy Initiative
GDP	Gross Domestic Product
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GPH	Government of the Philippines
GWP	Global Warming Potential
HDV	Heavy-Duty Vehicle
HFC 23	Hydrofluorocarbon 23
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
ITPS	Institute for Transport Policy Studies
LEAP	Long-range Energy Alternatives Planning tool
LECB	Low Emissions Capacity Building (UNDP Program)
LTO	Land Transportation Office
LDV	Light-Duty Vehicle
LGU	Local Government Unit
LNG	Liquefied Natural Gas

LPG	Liquefied Petroleum Gas
LTO	Land Transportation Office
LULUCF	land use, land-use change, and forestry
MAC	Marginal Abatement Cost
MACC	Marginal Abatement Cost Curve
MC	Motorcycle
MCTC	Motorcycle/Tricycle
MER	Market Exchange Rate
MMDA	Metro Manila Development Authority
MVIS	Motor Vehicle Inspection System
N	Nitrogen
NAMA	Nationally Appropriate Mitigation Action
NEDA	National Economic and Development Authority
NGO	Non-governmental Organizations
NMVOC	Non-Methane Volatile Organic Compounds
N_2O	Nitrous Oxide
NO_x	Nitrogen Oxides
O&M	Operation and Maintenance
PM	Particulate Matter
PSA	Philippines Statistics Authority
PSY	Philippine Statistical Yearbook
REMB	Renewable Energy Management Bureau
SEI	Stockholm Environment Institute
SO_2	Sulfur Dioxide
TC	Tricycle
UNDP	United Nations Development Programme
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
UP NCTS	University of the Philippines National Center for Transportation Studies
USA	United States of America
USD	United States Dollars
UV	Utility Vehicle
VMMR	value of mortality risk reduction
VKT	Vehicle Kilometers Traveled

IV. TRANSPORT

IV.1 EXECUTIVE SUMMARY

As the Philippine economy continues to expand, the Government of the Philippines is working to address the sustainability and greenhouse gas (GHG) emission challenges related to sustaining this growth. As a part of this effort, the Climate Change Commission (CCC) partnered with the United States Agency for International Development (USAID) to develop the quantitative evidence base for prioritizing climate change mitigation by conducting a cost-benefit analysis (CBA) of climate change mitigation options. An economy-wide CBA is a systematic and transparent process that can be used to evaluate the impact of potential government interventions on the welfare of a country's citizens. Thus, the CBA is well-suited for the identification of socially-beneficial climate change mitigation opportunities in the Philippines.

The CBA Study is conducted under the USAID-funded Building Low Emission Alternatives to Develop Economic Resilience and Sustainability (B-LEADERS) Project managed by Engility Corporation. The scope of the CBA covers all GHG emitting sectors in the Philippines, including agriculture, energy, forestry, industry, transport, and waste. The assessment is carried out relative to a 2010-2050 baseline projection of the sector-specific GHG emissions levels. The evaluation of the mitigation options covers the period spanning 2015-2050, except for the forestry where costs are assessed starting in 2010.

For each sector, the CBA evaluates a collection of nationally-appropriate mitigation options. To this end, each option is characterized in terms of:

- **The direct benefits** that are measured by the expected amount of GHG emissions reduced via the option. These GHG emission benefits are quantified, but not monetized;
- **The costs** associated with the mitigation option that can be quantified and monetized; and
- **The co-benefits** associated with the mitigation option that can be quantified and monetized. Depending on the option, the co-benefits may include beneficial economic/market impacts and non-market impacts.

The CBA employs two tools that are already being used by stakeholders in the country:

- **The Long-range Energy Alternatives Planning (LEAP) Tool** – LEAP is a flexible, widely used software tool for optimizing energy demand and supply and for modeling mitigation technologies and policies across the energy and transport sectors, as well as other sectors.
- **The Agriculture and Land Use Greenhouse Gas Inventory (ALU)** Software which was developed to guide a GHG inventory compiler through the process of estimating GHG emissions and removals related to agriculture, land use, land-use change, and forestry (LULUCF) activities.

The CBA is performed predominantly in the LEAP tool. The estimates of the agriculture and forestry sector GHG emissions are computed in the ALU tool and subsequently fed to LEAP. For some of the mitigation options, the estimates of costs and benefits are developed externally, with the LEAP model linking to the relevant datasets.

This Report represents the second update on the CBA model development work. It contains:

- A description of methods and sector-specific GHG emissions for the base year of 2010 and for the baseline projection spanning 2010-2050;
- A description of mitigation options evaluated for each sector;
- Estimates of the option/activity-specific direct benefits (i.e., the amount of GHG emissions reduced) as well as costs and economic co-benefits of the mitigation options for 2015-2050 time period, for which the Study Team already obtained data;
- Where relevant, estimates of indirect economic impacts (i.e., power sector impacts from mitigation activities in other sectors) and non-market co-benefits (congestion and public health) for those mitigation options where data are available;
- Where relevant, estimates of quantifiable energy security, employment, and public health-related gender impacts for the analyzed mitigation options;
- The development of a marginal abatement cost curve (MACC) which illustrates the cumulative abatement potential and costs per tonne of the mitigation options analyzed in this report; and
- A summary of next steps and specific areas for stakeholder involvement, including additional support for data sharing and review of proposed methodologies (Section IV.4.2.4 Conclusions).

This study builds on the output of the series of consultations conducted from February until July of 2015. The results of these consultations were vetted by CCC and stakeholders in each of the relevant sectors. As such, this does not include results of discussions, new assumptions and data collected after July 2015. An updated version of these report shall be done in consultation with the relevant national government agencies led by the CCC and hopefully will reflect outcome of the Conference of Parties (COP) in Paris where CCC played a key role in the Philippine Delegation.

Table IV. 1 summarizes the direct costs and benefits of mitigation options, including changes in capital, operating and maintenance (O&M), implementation, and fueling costs as well as GHG emissions. Co-benefits related to traffic congestion and health impacts are considered in the following section. Nine of the fifteen mitigation options assessed would have a negative cost per ton GHG mitigation even without considering congestion and health co-benefits. These nine options would provide direct cost savings compared to the Baseline scenario as well as GHG savings.

Table IV. 1 Direct Costs and Cost per Ton of Transport Sector Mitigation Options Excluding Co-benefits

Sequence Number of Mitigation Option	Mitigation Option	Incremental Cost (Cumulative 2015-2050) [Billion 2010 USD] Discounted at 5%			Incremental GHG Mitigation Potential (2015-2050) [$MtCO_2e$]	Incremental Cost per Ton Mitigation (2015-2050) [2010 USD] *without co-benefits*
		Capital, O&M, Implementation Costs	Cost of Fuel and Other Inputs	**Total Net Cost**		
Symbol		*A*	*B*	*C*	*D*	*E*
Formula				*(A+B)=C*		*C/D=E*
32	Biofuels	0.0	19.9	19.9	[1]	63
34	Buses and BRT	6.4	-2.4	4.0	10.5	377

N/A*	CNG Buses	0.1	-0.3	-0.2	0.5	-483
5	Congestion Charging	0.1	-6.0	-5.9	46	-129
7	Driver Training	1.5	-5.7	-4.2	40	-105
4	Jeepney Modernization	-0.3	-23.3	-23.6	172	-137
N/A	Electric LDV	1.2	-4.0	-2.7	14	-192
N/A	Electric MCTC	0.8	-1.4	-0.6	1.2	-483
N/A	Euro 4/IV and MVIS	2.3	83.6	85.9	55	1575
N/A	Euro 6/VI and MVIS	4.1	180.5	184.6	55	3363
N/A	LDV Efficiency	6.7	-10.8	-4.1	71	-57
3	MVIS	0.4	-7.3	-6.9	46	-150
36	Rail	9.1	-1.9	7.2	8.5	849
N/A	Road Maintenance	13.2	-13.9	-0.6	85	-7
N/A	Two-Stroke Replacement	0.2	-0.1	0.1	0.1	939

Notes:

Relatively Cost Effective. Negative Cost or Cost per Ton indicates lower costs than the baseline or preceding scenario.

* N/A indicates that a given mitigation option was not selected by DOTC for inclusion in the retrospective systems analysis. These mitigation options were evaluated individually against the baseline.

[1] The estimated GHG mitigation potential of transport biofuels would be 317 $MtCO_2e$, assuming no biogenic emissions from fuel combustion and not accounting for increased upstream emissions beyond domestic borders. This figure represents the potential to reduce emissions listed in the domestic emissions inventory, but excludes the considerable increase in upstream emissions that is likely in countries that export biofuels to the Philippines. These emissions outside the Philippine inventory are likely to reduce the net mitigation offered globally by increased Philippine biofuel imports by the order of 50%, dependent on the feedstock pathways used. These international emissions would proportionately increase the effective mitigation cost when considered from a global perspective by a factor of around 2. In the worst case, depending on feedstocks, the implementation of any sustainability assurance, and on forest governance in exporter countries, a policy of expanded biofuel use may deliver no global net GHG benefit. A comprehensive discussion of the land use implications of biofuel policies is available in Malins et al. (2014).

There are several non-market and market co-benefits which can add to the cost-effectiveness of a mitigation option. For this report the team have estimated the following co-benefits:

- Non-market co-benefits: the value of air quality-related improvements in public health as well as the value of congestion relief; and
- Market co-benefits: the value of timber and agroforestry commodities obtainable from reforested areas (designated for production) as well as the income generated from recyclables and composting.

Table IV. 2 summarizes the value of co-benefits that could be monetized for the transport mitigation options. Monetized co-benefits for health and congestion would apply to thirteen and five out of fifteen mitigation options, respectively. Column J shows the value of these benefits, normalized per ton of GHG mitigation potential. These "co-benefits only" results exclude direct costs; they are combined with direct costs and benefits in Table IV. 3.

Table IV. 2. Monetized Co-Benefits of Mitigation Options in the Transport Sector

Sequence Number of Mitigation Option	Mitigation Option	Incremental Co-benefits (Cumulative 2015-2050) [Billion 2010 USD] Discounted at 5%				Incremental Cost per Ton Mitigation (2015-2050) [2010 USD] *co-benefits only* [2]
		Health	Congestion	Income Generation	**Total Co-benefit**	
Symbol		*F*	*G*	*H*	*I*	*J*
Formula					*sum(F,G,H)=I*	*-I/D=J*
32	Biofuels					
34	Buses and BRT	13.7	9		22.7	-2162

N/A*	CNG Buses					
5	Congestion Charging	24	8.5		32.5	-707
7	Driver Training					
4	Jeepney Modernization	96.4			96.4	-560
N/A	Electric LDV	0.8			0.8	-59
N/A	Electric MCTC	0.1			0.1	-100
N/A	Euro 4/IV and MVIS	101.4			101.4	-1860
N/A	Euro 6/VI and MVIS [1]	140 to 308			140 to 308	-5603 to -2554
N/A	LDV Efficiency					
3	MVIS	125.1			125.1	-2720
36	Rail	5.2	3.3		8.5	-1000
N/A	Road Maintenance					
N/A	Two-Stroke Replacement	0.019			0.019	-194

Notes:

Relatively Cost Effective. Positive co-benefits reduce the net cost of mitigation options.

* N/A indicates that a given mitigation option was not selected by DOTC for inclusion in the retrospective systems analysis. These mitigation options were evaluated individually against the baseline.

[1] *Range of health co-benefits reflects uncertainty regarding the level of reduction in PM2.5 emissions from diesel jeepneys running on cleaner (10 ppm sulfur) fuel. Studies in the U.S. (MECA, 1999) and Japan (WWFC, 2000) have found 10-50% reductions in PM2.5 from uncontrolled diesel trucks switching from 300 ppm to 500 ppm to ultra-low sulfur fuel.*

[2] *Equal to the value of co-benefits divided by GHG mitigation potential. This could also be termed "Value of Co-Benefits per Ton Mitigation."*

Table IV. 3 combines the cost per ton without co-benefits (Column E) with the cost per ton of co-benefits (Column J from Table IV. 2). Three mitigation options – Buses and BRT, Euro 4/IV and MVIS, and Rail – have a negative cost per ton GHG mitigation only once co-benefits for health and traffic congestion have been taken into account. As the mitigation option is currently defined, the cost effectiveness of "Euro 6/VI and MVIS" depends on the emissions benefits of requiring cleaner (10 ppm sulfur) fuels for existing vehicles, since these cleaner fuels are presently assumed to be made available for the whole fleet rather than only those vehicles meeting more stringent emissions standards[1]. For this option, a range of health benefits is provided to reflect uncertainty regarding the level of $PM_{2.5}$ reduction from using cleaner fuels with existing vehicles, especially uncontrolled diesel jeepneys.

Table IV. 3. Net Present Value of Mitigation Options in the Transport Sector

Sequence Number of Mitigation Option	Mitigation Option	Incremental GHG Mitigation Potential	Incremental Cost per Ton Mitigation (2015-2050) [2010 USD]	Net Present Value Excluding Value of GHG Reduction (2015-2050)

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[1] As a follow-up to this analysis, three alternative mitigation options could be evaluated:

1) New HDVs (especially buses) are required to meet Euro 3/III and be equipped with a DPF installed by the original equipment manufacturer. Such vehicles would require diesel with fewer than 50 ppm sulfur. This measure could result in much greater $PM_{2.5}$ reductions than Euro 4/IV at a lower cost than Euro 6/VI.

2) Euro 6/VI standards could be applied only to diesel vehicles while Euro 4/IV Standards would remain in effect for gasoline vehicles.

3) Euro 6/VI fuels could be introduced nationwide but not sold exclusively (meaning only new Euro 6/VI vehicles would be required to use cleaner 10 ppm sulfur fuels).

		(2015-2050) [MtCO2e]	without co-benefits	with co-benefits	[Billion 2010 USD] *with co-benefits*
Symbol		*D*	*E*	*K*	*L*
Formula			*C/D=E*	*E+J*	*D * -K*
32	Biofuels	[1]	63	63	-23
34	Buses and BRT	10.5	377	-1136	12
N/A*	CNG Buses	0.5	-483	-483	0.2
5	Congestion Charging	46	-129	-766	35
7	Driver Training	40	-105	-105	4.2
4	Jeepney Modernization	172	-137	-679	117
N/A	Electric LDV	14	-192	-251	3.5
N/A	Electric MCTC	1.2	-483	-583	0.7
N/A	Euro 4/IV and MVIS	55	1575	-285	16
N/A	Euro 6/VI and MVIS	55	3363	-2240 to 810	-44 to 123
N/A	LDV Efficiency	71	-57	-57	4.0
3	MVIS	46	-150	-2870	132
36	Rail	8.5	849	90	-0.8
N/A	Road Maintenance	85	-7	-7	0.6
N/A	Two-Stroke Replacement	0.1	939	745	-0.1

Notes:

Relatively Cost Effective. Negative Cost per Ton and Positive Net Present Value.

[1] The estimated GHG mitigation potential of transport biofuels would be 317 $MtCO_2e$*, assuming no biogenic emissions from fuel combustion and not accounting for increased upstream emissions beyond domestic borders. This figure represents the potential to reduce emissions listed in the domestic emissions inventory, but excludes the considerable increase in upstream emissions that is likely in countries that export biofuels to the Philippines. These emissions outside the Philippine inventory are likely to reduce the net mitigation offered globally by increased Philippine biofuel imports by the order of 50%, dependent on the feedstock pathways used. These international emissions would proportionately increase the effective mitigation cost when considered from a global perspective by a factor of around 2. In the worst case, depending on feedstocks, the implementation of any sustainability assurance, and on forest governance in exporter countries, a policy of expanded biofuel use may deliver no global net GHG benefit. A comprehensive discussion of the land use implications of biofuel policies is available in Malins et al. (2014).*

Finally, Column L indicates the net present value of costs (including fuel savings) and co-benefits for health and traffic congestion. A positive value indicates a mitigation option has net benefits to society in addition to its potential to mitigate GHG emissions. Two mitigation options (Biofuels and Two-Stroke Replacement) would have costs that outweigh their (non-climate) benefits, indicating that society's willingness-to-pay for GHG mitigation would have to exceed the Cost per Ton Mitigation with Co-benefits (Column K) for these measures to be considered cost effective[2].

Figure IV. 1. Abatement Cost Curve for Selected Transport Sector Mitigation Options illustrates the marginal abatement cost curve (MACC) for seven transport mitigation options that were selected by the Department of Transport and Communications (DOTC) for further investigation, out of the fifteen options analysed in the CBA.

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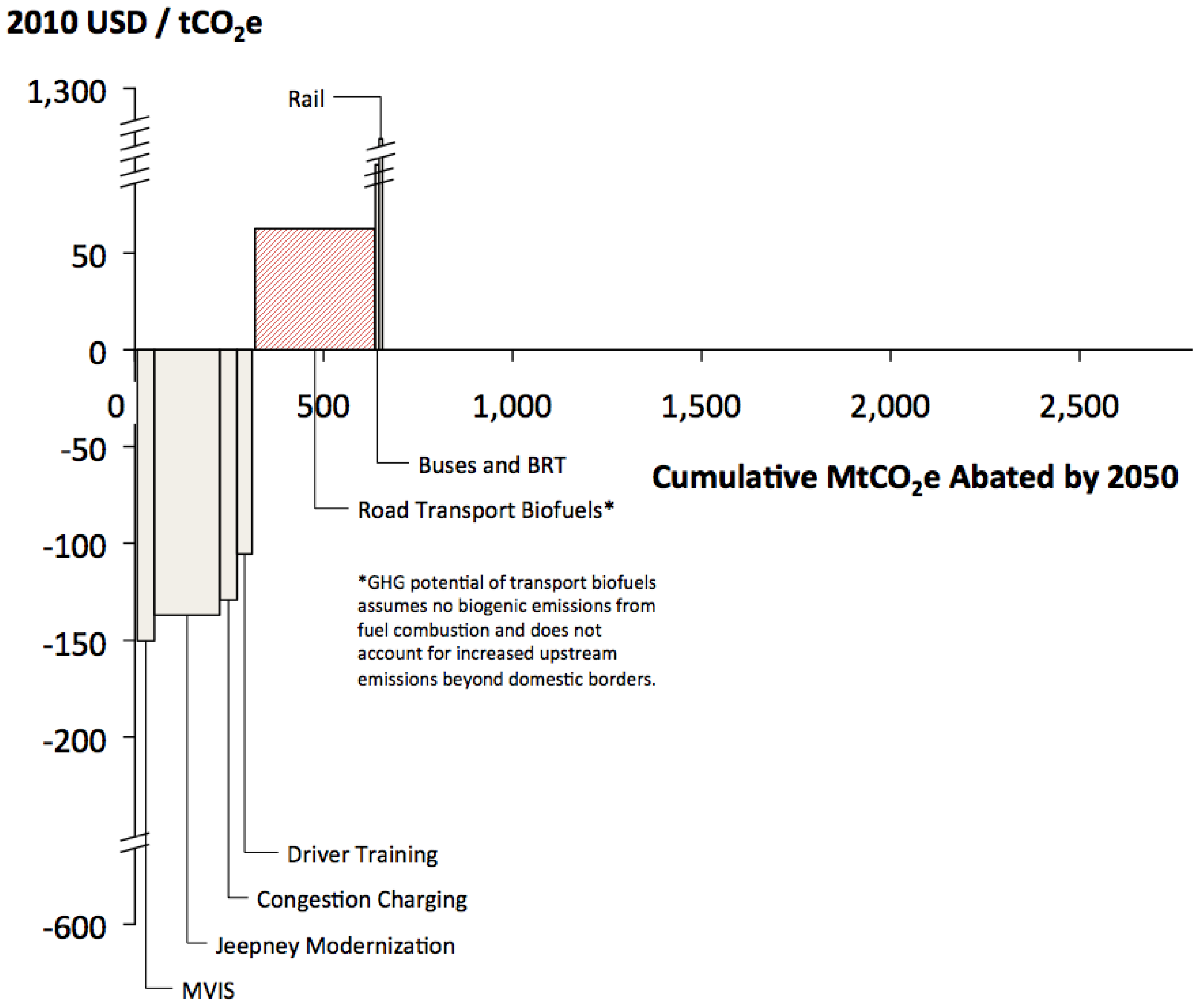
[2] Other mitigation options would still be considered cost effective even if the social cost of carbon-equivalent (expressed in USD per tonne) were zero.

Figure IV. 1. Abatement Cost Curve for Selected Transport Sector Mitigation Options



*GHG potential of transport biofuels assumes no biogenic emissions from fuel combustion and does not account for increased upstream emissions beyond domestic borders.

IV.1.1 Transport Sector Model Scope

The transport sector in the Philippines produces a number of GHGs including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), as well as pollutants that are directly harmful to human health including particulate matter (PM), nitrogen oxides (NO_x), carbon monoxide (CO), non-methane volatile organic compounds (NMVOC), and sulfur dioxide (SO_2). The transport sector model was developed within the LEAP tool and integrated with the energy sector model to provide estimates of fuel lifecycle emissions (including direct combustion emissions as well as upstream emissions associated with the domestic production and distribution of electricity and liquid fuels).

The transport sector model estimates fuel consumption and associated emissions of road transport using a bottom-up[3] structure with six vehicle categories (Table IV. 4). The model also considers fuel consumption and emissions of rail, domestic aviation, and domestic shipping using a top-down structure

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[3] Bottom-up transport sector models employ stock turnover methods to estimate fuel consumption as the product of vehicle activity (i.e. VKT) and vehicle efficiency (e.g. liters per 100 km) by age, vehicle type, and fuel type.

based on DOE's Energy Balance Tables (DOE, 2015). CO_2 emissions are calculated as the product of fuel consumption and the carbon intensity of fuels as defined in the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC, 2006) and applied in the Philippines' Second National Communication to the UNFCCC (Climate Change Commission, 2014). Emissions of non-CO_2 GHGs are calculated from fuel consumption for rail, domestic aviation, and domestic shipping, and as the product of vehicle activity[4] and emission factors[5] for road transport.

Table IV. 4. Transport Sector Model Scope

Transport sub-sector	Modes	Technologies and fuels
Road	Light-duty vehicle (LDV), Utility vehicle (UV), Truck, Bus, Motorcycle (MC), Tricycle (TC)	• Gasoline equivalent (gasoline, bioethanol) • Diesel equivalent (diesel, biodiesel) • CNG, LPG, EV
Rail	No additional detail	Diesel, electricity
Domestic Aviation	No additional detail	Aviation gasoline, kerosene type jet fuel
Domestic Shipping	No additional detail	Biodiesel, diesel, fuel oil, gasoline, kerosene

Six vehicle categories were modeled based on available registration data and the level of detail needed to appropriately model the impacts of mitigation options (Table IV. 5). In particular, motorcycles and tricycles were broken into two categories[6]. This was necessary since some of the mitigation options apply only to motorcycles or tricycles, and these vehicle types differ substantially with respect to the average level of annual vehicle-km traveled.

Table IV. 5. Vehicle Denominations

Short name	Description	Vehicle categories included (LTO, 2015a)
LDV	Light-duty vehicle	Passenger cars and sport utility vehicles
UV	Utility vehicle	Gross vehicle weight does not exceed 4,500 kg; includes public utility jeepneys and school jeepneys
Truck	Medium and heavy-duty trucks	Gross vehicle weight exceeds 4,500 kg
Bus	Urban and intercity buses	Includes public utility, shuttle, school, tourist buses
MC	Motorcycle	Motorcycles and mopeds (two-wheelers)
TC	Tricycle	Motorcycles and mopeds (three-wheelers)

IV.2 BASE YEAR GHG EMISSIONS

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[4] Expressed in vehicle-kilometers traveled (VKT).

[5] Expressed in grams of pollutant emitted per VKT.

[6] Tricycles were assumed to account for 20% of all MC/TC based on the share of for-hire vs. private vehicles. Tricycles are the primary target of mitigation measures for public utility MC/TC, whereas motorcycles are included for measures that would affect private MC/TC.

IV.2.1 Methods and Assumptions

For all transport modes, GHG emissions were calculated based on fuel consumption and carbon intensity of fuels (USAID LEAD, ICF International, 2015) consistent with the methods recommended by the IPCC (IPCC, 2006) and used in the national GHG inventory for the Philippines (Climate Change Communication, 2014). For rail, domestic aviation, and domestic shipping, estimates of fuel consumption are based on top-down estimates from the Department of Energy (DOE, 2015). For road transport, fuel consumption was estimated using available data on vehicle registrations, annual vehicle-kilometers traveled, and vehicle efficiency. All road transport emissions were calculated using a bottom-up approach, comparable to the Tier 3 method recommended by the IPCC (IPCC, 2006). These estimates were cross-checked with the results of multiple studies to ensure reasonability (Clean Air Asia, 2012; DOE, 2015; Esguerra et al., 2010; Gota, 2014; Manila Observatory, 2010; Regidor et al., 2014). Several of these studies also served as data sources for estimates vehicle-kilometers traveled and vehicle efficiency. Table IV. 6 provides a summary of key transportation data sources.

Table IV. 6. Key Transport Sector Data Sources

Transport Mode	Parameter	Data Sources
Road	Vehicle-km traveled	Inputs: Gota (2014); Esguerra et al. (2010) Validation: CAI-Asia (2011); Clean Air Asia (2012); Clean Air Asia and ITPS (2010); Regidor et al. (2014)
	Vehicle registrations	Inputs: LTO (2015b) Validation: PSY (2013)
	Vehicle efficiency	Vergel and Tiglao (2013); Esguerra et al. (2010); Clean Air Asia (2012); CAI-Asia (2011); ADB (2015); USEPA (2015); EVEE-I (2014); DOE & USAID (2015)
Rail, Domestic Aviation, Domestic Shipping	Gross domestic product (GDP)	IMF (2012)
	Fuel consumption	Energy Balance Tables (DOE, 2015)

IV.2.1.1 Road Vehicle Registrations

Vehicle sales and existing stock were approximated using data on new and renewal registrations from the Land Transportation Office (LTO) (Table IV. 7 and Table IV. 8). For all vehicle types except MC/TC, vehicle sales were approximated using new registrations, and stock was approximated using renewal registrations (with total vehicle population equal to the sum of new and renewal registrations). For MC/TC, there are one-third as many new registrations as renewal registrations, which means that if new registrations were equal to the number of MC/TC sold, then one-third of the MC/TC fleet would have to be scrapped each year to match the level of renewal registrations. Since such an assumption is not plausible, 40% of new MC/TC registrations were assumed to be vehicle sales, which results in a more reasonable rate of fleet turnover[7].

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[7] For example, if 1.046 million MC/TC were sold in 2012 (based on new registrations), the total number of renewal registrations in 2013 (3.110 million) would be equal to the sum of new and renewal registrations from 2012 (4.116 million), minus the number of vehicles that were either retired or did not need to be registered (1.006

Table IV. 7. New and Renewal Registrations 2005-2013 (PSY, 2013; LTO, 2015b)

Type	Registration Category	2005	2006	2007	2008	2009	2010	2011	2012	2013
Car	New	41,000	41,000	46,000	49,000	46,000	59,000	62,000	70,000	73,000
Car	Renewal	750,000	750,000	700,000	710,000	730,000	750,000	770,000	780,000	790,000
SUV	New	22,000	26,000	28,000	26,000	32,000	41,000	40,000	43,000	47,000
SUV	Renewal	140,000	150,000	170,000	170,000	190,000	220,000	240,000	250,000	300,000
UV	New	94,000	89,000	92,000	81,000	84,000	99,000	96,000	100,000	110,000
UV	Renewal	1,500,000	1,500,000	1,500,000	1,500,000	1,600,000	1,600,000	1,700,000	1,700,000	1,700,000
Bus	New	1,700	2,000	2,500	2,000	2,700	2,400	3,500	1,900	2,900
Bus	Renewal	29,000	27,000	28,000	28,000	30,000	33,000	31,000	32,000	29,000
Truck	New	15,000	17,000	18,000	20,000	19,000	20,000	21,000	20,000	24,000
Truck	Renewal	250,000	270,000	260,000	280,000	290,000	300,000	310,000	320,000	330,000
MC/TC	New	590,000	610,000	670,000	730,000	760,000	900,000	1,100,000	1,000,000	1,100,000
MC/TC	Renewal	1,600,000	1,800,000	2,000,000	2,200,000	2,400,000	2,600,000	2,800,000	3,100,000	3,100,000

Data are rounded to no more than two significant digits.

Table IV. 8. New and Renewal Registrations by Fuel Type in 2013 (LTO, 2015b)

Registration Category	Fuel Used	Car	SUV	UV	Bus	Truck	MC/TC
New	D	870	33,000	85,000	2,900	23,000	-
New	G	72,000	13,000	29,000	50	290	1,100,000
New	Total	73,000	47,000	110,000	2,900	24,000	1,100,000
Renewal	D	9,600	170,000	1,100,000	28,000	330,000	-
Renewal	G	780,000	130,000	550,000	450	5,100	3,100,000
Renewal	Total	790,000	300,000	1,700,000	29,000	330,000	3,100,000
Total	D	10,000	200,000	1,200,000	31,000	350,000	-
Total	G	850,000	140,000	580,000	500	5,400	4,300,000
Total	Total	860,000	350,000	1,800,000	32,000	360,000	4,300,000

Data are rounded to no more than two significant digits.

IV.2.1.2 Annual Vehicle-km Traveled

Fuel consumption and pollutant emissions are affected by the total distance that vehicles of a given type are driven each year (annual vehicle-kilometers traveled). Estimates of annual vehicle-km traveled were compared across studies in the Philippines and validated against estimates from other Southeast Asian countries (CAI-Asia, 2011; Clean Air Asia and ITPS, 2010; Esguerra et al., 2010; Gota, 2014; Regidor et al.,

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million). At this time, the CBA study applied the assumption that 40% of new MC/TC registrations are actually new vehicle sales (456,000), and the remaining 684,000 "new registrations" are part of the existing vehicle stock. The other possibility is that the actual vehicle stock is larger than the sum of new and renewal registrations, in which case the assumption that sales are equal to 40% of new MC/TC registrations should be replaced with an assumption that the actual MC/TC stock is equal to the number of renewal registrations times a multiplier greater than one that reflects the required frequency of registration renewal (for example, if registrations must be renewed only every 2-3 years, there would be roughly 2 or 3 times as many existing vehicles as renewal registrations).

2014) (Table IV. 9). While estimates of LDV and truck activity are similar or identical across studies, there is greater variation in estimates for UV (which includes Jeepneys) and Bus, and even greater variation for tricycles (TC). Estimates in Gota (2014) were selected and applied in the CBA Study as estimates of annual vehicle-km traveled by new vehicles. These annual estimates align well with the typical daily range of activity observed for each vehicle type (Table IV. 10). Notably, there is likely considerable variation in annual vehicle travel among vehicles in the same vehicle classification. Where necessary, estimates of annual vehicle travel were selected to match a reasonable range for vehicles that would be targeted by a specific mitigation measure (e.g., electrification of jeepneys, private MC, and for-hire TC).

Table IV. 9. Validation of Annual Vehicle-Km Traveled Estimates

Vehicle type	Average (unweighted)	Southeast Asia Average (CAA & ITPS, 2010)	Clean Air Asia (Gota, 2014)		World Bank/TTPI (Esguerra et al., 2010)	
			Gasoline	Diesel	Gasoline	Diesel
LDV	11,994	13,571	8,000	15,200	8,000	15,200
UV	25,533	32,459	36,003	36,003	8,000	15,200
Truck	26,657	42,426	-	26,000	12,200	26,000
Bus	28,485	41,238	-	34,500	12,200	26,000
MC	4,505	7,468	4,950	-	2,800	2,800
TC	11,254	16,315	23,100	-	2,800	2,800

Green fill indicates input to CBA Study

Table IV. 10. Annual Vehicle-Km Traveled (Gota, 2014)

Vehicle type	Annual VKT per vehicle		Daily VKT per vehicle		
	Gasoline	Diesel	Gasoline	Diesel	Range
LDV	8,000	15,200	22	42	*20 - 60*
UV	36,003	36,003	99	99	*100 - 150*
Truck	-	26,000	-	71	*30 - 140*
Bus	-	34,500	-	95	*30 - 140*
MC	4,950	-	14	-	*10 - 40*
TC	23,100	-	63	-	*70 - 80*

Range of daily VKT estimates from CAA & ITPS (2010), Esguerra et al. (2010), Gota (2014), ADB (2012)

IV.2.1.3 Fuel Economy of New Vehicles

In the absence of official estimates for the average fuel efficiency of new vehicles by vehicle type and fuel type in the Philippines, estimates were derived from a review of multiple studies. For each vehicle type and fuel type, estimates of local studies were validated against one another and compared with the range of efficiencies for comparable vehicles operating in other Southeast Asian countries. The best estimates[8] were selected as inputs to the CBA Study (Table IV. 11).

Table IV. 11. New Vehicle Fuel Economy by Vehicle and Fuel Type

Vehicle type	Fuel type	Fuel consumption		Source
		Value	Unit	
LDV	Diesel	10.2	L/100km diesel-equivalent	Vergel & Tiglao (2013)
	Gasoline	10	L/100km gasoline-equivalent	Assumption based on CAA (2012)
	Electricity	18.64	kWh/100km	USEPA (2015)
UV	Diesel	17.6	L/100km diesel-equivalent	Vergel & Tiglao (2013)
	Gasoline	13.3	L/100km gasoline-equivalent	Vergel & Tiglao (2013)
	Electricity	15.5	kWh/100km	EVEE-I (2014)
Bus	Diesel	40	L/100km diesel-equivalent	DOE & USAID (2015)
	CNG	40	L/100km diesel-equivalent	DOE & USAID (2015)
Truck	Diesel	38.3	L/100km diesel-equivalent	Esguerra et al. (2010)
MC	Gasoline (2-stroke)	3.0	L/100km gasoline-equivalent	Assumption based on CAA (2012)
	Gasoline (4-stroke)	2.5	L/100km gasoline-equivalent	Assumption based on CAA (2012)
	Electricity	3.50	kWh/100km	Based on ADB (2015) and MC/TC differential
TC	Gasoline (2-stroke)	4.1	L/100km gasoline-equivalent	Vergel & Tiglao (2013)
	Gasoline (4-stroke)	3.4	L/100km gasoline-equivalent	Vergel & Tiglao (2013)
	Electricity	8.75	kWh/100km	ADB (2015)

IV.2.1.4 Road Vehicle Non-CO_2 Emission Factors

Tailpipe emissions of non-CO_2 pollutants[9] from road vehicles were estimated using emission factors, expressed in units of grams per vehicle-km traveled. These emission factors are sensitive to vehicle type, fuel type, level of emission control technology, and fuel sulfur content (measured in parts per million). The only data source with emission factor estimates for the Philippines is an ADB study published in 1992; however, there are several limitations of this study with respect to estimating fleet wide emissions of on-road vehicles from 2010 to 2050:

- ADB (1992) emission factors are already over 20 years old, and current vehicle emissions are likely substantially lower than emissions of vehicles that were on the road in 1992.

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[8] There are several ongoing efforts that could improve upon the fuel economy assumptions applied in this study. These may include fuel economy runs conducted by the Department of Energy, studies of in-use vehicle efficiency by the National Center for Transportation Studies (NCTS), and a possible baseline study of light-duty vehicle fuel economy by Clean Air Asia. The inputs of this CBA study should be compared with the results of these efforts as they are completed, and be updated as needed.

[9] Including fine particles ($PM_{2.5}$), methane (CH_4), black carbon (BC), nitrous oxide (N_2O), oxides of nitrogen (NO_X), and carbon monoxide (CO). Black carbon estimates are not presently included in the calculation of global warming effects. Sulfur dioxide emissions are estimated based on fuel sulfur content.

- ADB (1992) emission factors likely reflect the results of emissions testing of a limited set of vehicles and may not be representative of all vehicles on the road.
- The study did not estimate emission factors for methane, nitrous oxide, or black carbon.

Considering these limitations, the CBA Study used emission factors from the ICCT Roadmap Model as a starting point, and checked these against ADB (1992) as a reference for uncontrolled vehicles. Where there were large discrepancies between emission factors reported in ADB (1992) for a specific pollutant or mode and those used in the Roadmap, the emission factors were adjusted using a third source, the zero-mile emission rates used in the ICCT India Model (ICCT, 2013). In some cases, additional adjustments were made to fill gaps for relevant pollutants and vehicle fuel types. Adjustments by mode, fuel type and pollutant are summarized in Table IV. 12.

Table IV. 12. Selection of Road Vehicle Emission Factors

Vehicle - Fuel type	$PM_{2.5}$	CH_4	BC	N_2O	NO_X	CO
MC - diesel	-	* (4-6)	-	-	-	-
MC - gasoline	†	-	* (6)	-	-	-
TC - diesel	-	* (6)	-	-	-	-
TC - gasoline	†	-	* (6)	-	-	-
Bus - CNG	‡ (VI, diesel)	‡ (VI, diesel)	* (all)	* (all)	-	-
Bus - diesel	-	-	-	-	-	-
Bus - gasoline	-	-	-	-	-	-
Truck - diesel	* (6)	-	-	-	-	-
Truck - gasoline	-	-	-	-	-	-
LDV - diesel	-	* (4-6)	* (6)	* (uncontrolled)	-	-
LDV - gasoline	†	-	†	-	-	-
LDV - LPG	†	-	†	* (uncontrolled, 6)	-	-
UV - diesel	•	-	•	-	•	•
UV - gasoline	•	-	•	-	•	•

Key:

Parentheses indicate Euro-equivalent emission standards/fuels. For example, (VI) indicates Euro VI.

- No change to ICCT Roadmap Model Emission Factors

* Missing emission factors for some control levels were filled in from ICCT India Model (emission control levels)

† India Model emission factors substituted for all control levels due to better match with ADB (1992)

‡ Emission factor for some control levels estimated to be reduced proportionally from EFs from earlier standards (emission control level, fuel type proportion was based on)

- Emission factor for uncontrolled vehicles taken from ADB (1992), emission factors for subsequent control levels calculated as a proportional reduction from uncontrolled level using reductions from Roadmap Model Emission Factors.

A study by Vergel and Tiglao (2013) assumes that an effective MVIS program could reduce emission factors of PM, NO_x and SO_x by 30%, and CO and HC by 40%. Based on these reductions, emissions of non-CO_2 pollutants in the Baseline scenario are multiplied by a factor greater than one to reflect the absence of an effective MVIS program:

- PM, NO_x and SO_x: 1.43, estimated as 1/(1-0.3) = 1.43
- CO and HC: 1.67, estimated as 1/(1-0.4) = 1.67

Vergel and Tiglao (2013) assume that an effective MVIS program would reduce emissions from a certain share of on-road vehicles for each vehicle type. Similar assumptions were used in the CBA Study for the share of vehicles that would be brought into better compliance with emission requirements as a result of enhanced vehicle inspection and emissions testing:

- LDV (cars): 25%
- UV (jeepneys): 100%
- Bus: 30%
- Truck: 30%

Fleet emission factor adjustments for the mitigation scenarios with enhanced MVIS are calculated as a weighted average based on the adjustment for affected vehicles (per-vehicle emission factor multipliers times the share of vehicles affected) and a factor of one for unaffected vehicles. For example, the PM emission factor adjustment for LDV is (1.43*0.25 + 1*0.75) = 1.11.

IV.2.1.5 Rail, Domestic Aviation, and Domestic Shipping

GHG emissions for rail, domestic aviation, and domestic shipping are based on fuel use reported in the DOE Energy Balance Tables (DOE, 2015)[10]. Activity is estimated from Gross Domestic Product (GDP), and energy intensity is defined as the level of energy consumed (tons of oil-equivalent) for each mode and fuel type per unit of GDP. As shown in Figure IV. 2, these modes accounted for 1-2 million tons of oil-equivalent each year from 1994 to 2010, with rail transitioning from a mix of diesel and electricity fuel to 100% electricity. In contrast, domestic aviation uses jet kerosene almost exclusively, while domestic shipping uses a mix of residual fuel oil, diesel, and motor gasoline.

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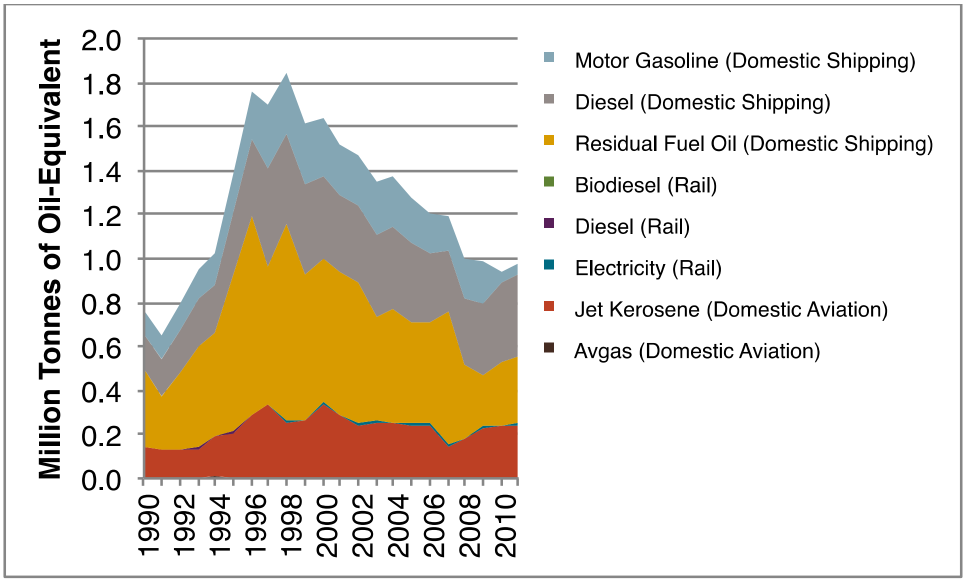
[10] It should be noted that a particular challenge in accounting for energy use and GHG emissions from aviation and shipping has to do with the share of activity allocated to domestic vs. international uses. For the purposes of this analysis, energy balance estimates from the Philippine Department of Energy were used directly in order to ensure consistency with national GHG inventory estimates.

Figure IV. 2. Historical Energy Demand for Rail, Domestic Aviation, and Domestic Shipping



IV.2.2 Results

Base year estimates of direct combustion GHG emissions from transport are shown in Figure IV. 3[11]. While 2010 is the official base year for the CBA Study, the first calculation year in the LEAP model is 2011. For this reason, the 2010 values shown in Figure IV. 3 indicate GHG emissions based on the fuel consumption levels reported in the DOE Energy Balance Tables (DOE, 2015), while the 2011 values reflect GHG emissions based on fuel consumption as estimated in the CBA Study. DOE Energy Balance Tables indicate that electricity was the only fuel consumed by rail in 2010; therefore, rail had zero direct combustion emissions. Emissions resulting fom upstream processes (including electricity generation) are accounted for under the Energy sector.

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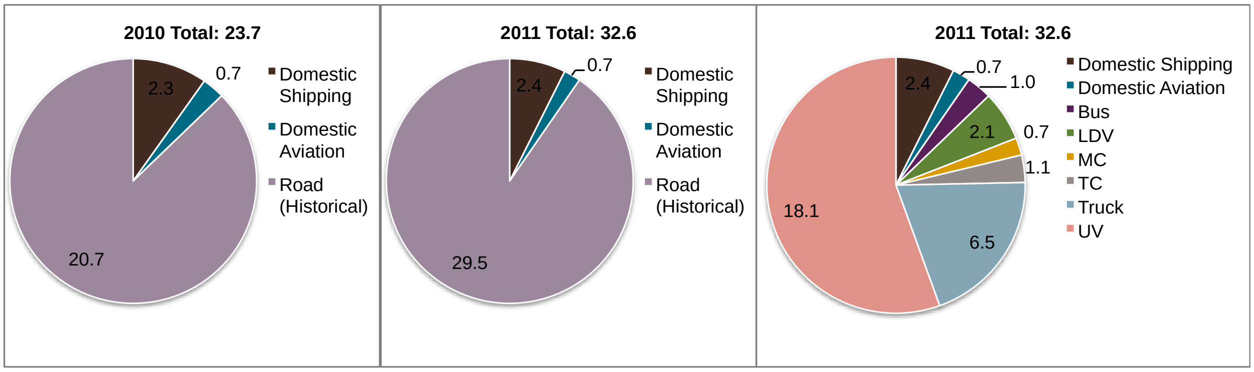
[11] Energy consumption in the transport sector has both direct and indirect GHG emissions. Direct emissions result from the combustion of fossil fuels and are also called tailpipe or "tank-to-wheel" emissions. Indirect emissions result from extraction, refining, and delivery (pipelines) of fossil fuels, as well as from the generation of electricity used for transport. Biofuels may have important upstream emissions resulting from indirect land use changes to grow biofuel feedstocks. The LEAP model accounts for direct and indirect GHG emissions resulting from transport activity; these are reflected in the resulting cost-benefit analysis of mitigation measures. However, since total indirect emissions cannot easily be disaggregated to the transport sector, transport-specific results for the base year and baseline cover emissions resulting from direct combustion of transport fuels. The only exception is biogenic CO_2 emissions (e.g. from the combustion of biofuels), which are counted as zero in the direct combustion results but counted in full in the all-sector results.

Figure IV. 3. Base Year GHG Emissions for Transport by Source Category ($MtCO_2e$)



IV.3 BASELINE PROJECTION TO 2050

IV.3.1 Methods and Assumptions

The Baseline scenario is designed to reflect current trends in the transport sector excluding the impacts of the mitigation measures evaluated in this study. For example, in order to evaluate the impact of DOE targets to increase future biofuel blends as a mitigation option (Philippine Energy Plan 2012-2030), the Baseline scenario must assume no further increase in biofuel blends, while the corresponding Biofuels mitigation scenario assumes increasing blends according to DOE targets.

IV.3.1.1 Road Vehicle Sales and Stock Forecasts

Sales of road vehicles are a key driver of future transport activity and associated emissions. Predicting future vehicle sales based on historical sales growth can lead to considerable variation in estimates across studies, since vehicle sales fluctuate from year to year. Given the long time horizon of the CBA Study, even small differences in assumed annual growth rates of vehicle sales can result in large differences in the estimated number of vehicles in use by 2050. These differences in assumed vehicle population can have a similarly large effect on estimates of mitigation options across studies. For this reason, annual vehicle sales of LDVs, Buses, and Trucks for future years were calibrated to align with estimates of future vehicle stock from a recent study conducted by the Institute for Transport Policy Studies and Clean Air Asia (Regidor et al., 2014)[12]. Table IV. 13 summarizes historical and projected growth rates of new vehicle registrations. Figure IV. 4 and Figure IV. 5 show projected road vehicle stock

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[12] Adjustments had to be made for MC/TC (assumed sales growth of 3.7%) and UV (assumed sales growth of 2.4%) to take into account the effects of compounded growth rates over a long period of time (2011-2050), a lower historical growth rate for UV registrations than forecast by Regidor et al. (2014), and discrepancies related to the classification of new and renewal registrations for MC/TC (sales assumed to account for 40% of new registrations to reflect a realistic turnover rate).

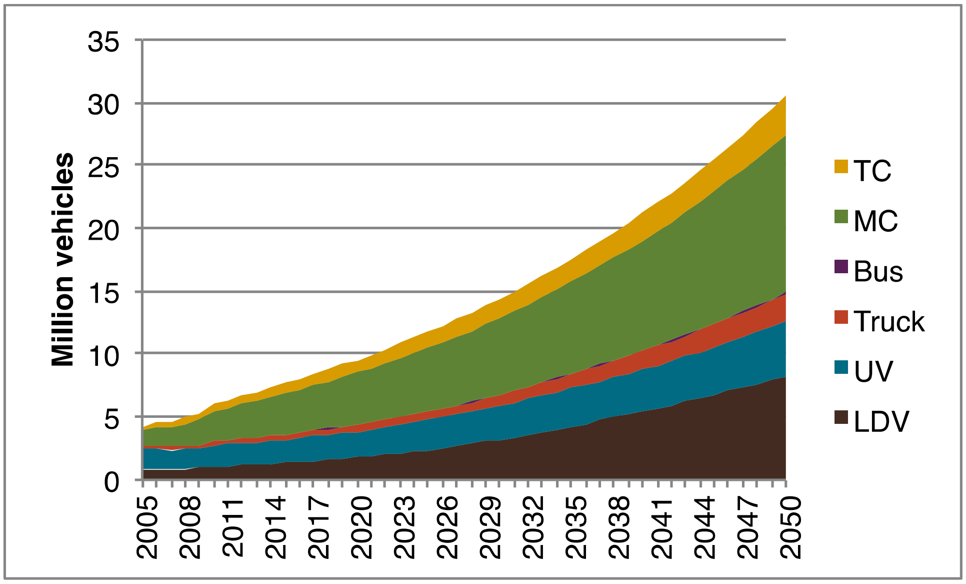
and sales by vehicle type for the Baseline scenario[13]. In summary, the road vehicle stock is projected to increase roughly fivefold from 2010 to 2050.

Table IV. 13. Historical New Registrations and Projected Growth Rates (LTO, 2015b)

Vehicle type	New registrations 2005 [thousands]	New registrations 2013 [thousands]	Annual growth 2005-2013 [%]	Projected growth 2015-2030 [%]	Projected growth 2030-2050 [%]
LDV	63	120	8.4%	6.4%	4.1%
UV	94	110	2.4%	8.0%	4.0%
Truck	15	24	5.7%	5.5%	4.2%
Bus	1.7	2.9	6.8%	1.6%	3.3%
MC/TC	590	1,100	8.7%	3.7%	3.7%
Total	**760**	**1,400**	**8.0%**	▨	▨

Values are rounded to no greater than two significant figures.

Figure IV. 4. Baseline Road Vehicle Stock 2005-2050



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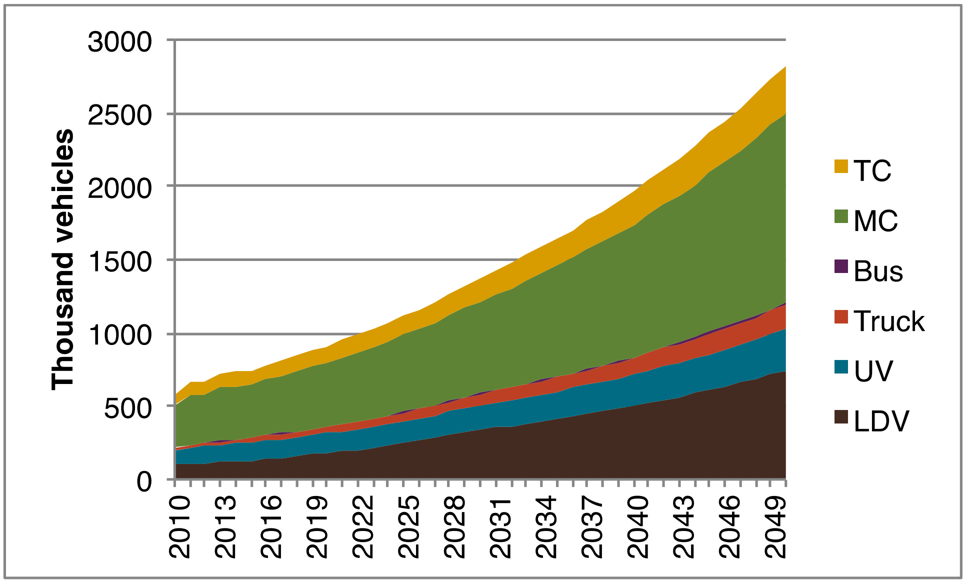
[13] Several refinements are needed should additional data become available: for example, more detailed registration data could help refine the characterization of motorcycles and tricycles, including the number of 2-stroke versus 4-stroke vehicles. Additionally, data on availability and sales of pre-owned (imported used), rebuilt, and brand new vehicles by vehicle type could enable refinement of vehicle sales and stock projections.

Figure IV. 5. Baseline Road Vehicle Sales 2010-2050



IV.3.1.2 Fuel Economy of New Vehicles

With proper maintenance, the fuel economy of vehicles need not degrade substantially over the lifetime of the vehicle; however, there can be a difference between "test cycle" efficiency (measured by laboratory tests in countries with vehicle efficiency standards) and in-use or "real-world" vehicle efficiency. Since the Philippine national government has not yet implemented any vehicle efficiency standards for new vehicles, the Baseline scenario assumes no changes in new vehicle efficiency over time. Holding efficiency constant in the Baseline allows evaluation of the impacts of mitigation options that improve the efficiency of new and in-use vehicles.

IV.3.1.3 Use of Alternative Fuels

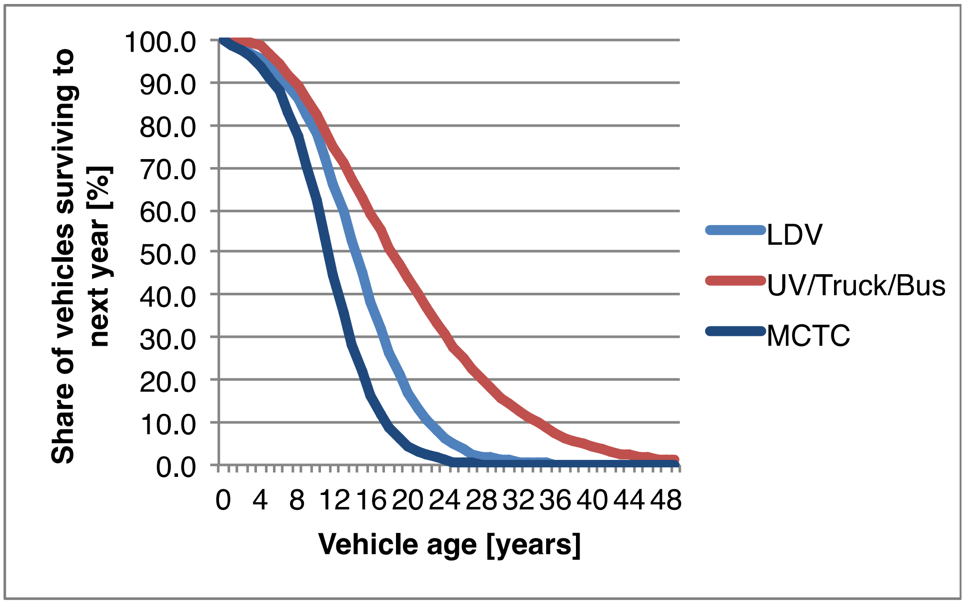
The cost of transport fuel is determined by the volume of fuel consumption multiplied by the fuel price. Fuel price assumptions are described in section IV.1 Cross-cutting Economic Assumptions. Several mitigation options involve a shift from traditional gasoline and diesel fuels to alternatives such as biofuels, compressed natural gas (CNG) and electricity. The price of electricity for road vehicles is determined by the energy sector module based on the level of demand for electricity across all sectors. The market price of all fuels (delivered cost) is assumed to include the cost of primary energy sources, production, and distribution of fuels (including electricity), as well as the cost of imported refined fuels and any costs of constructing additional fueling infrastructure.

It should be noted that promotion of electric vehicles will shift CO_2 emissions from the transport sector to the electric power sector (energy sector excluding transport); similarly, expanded use of biofuels may shift CO_2 emissions from the transport sector to the agriculture and land use sectors. When sectoral emissions are totaled, the analysis of mitigation options takes into account these cross-sectoral impacts, reflecting the net change in emissions as a result of transport electrification or expanded use of biofuels. Accounting for these upstream climate impacts is a critical factor in the assessment of these potential mitigation options.

IV.3.1.4 Vehicle Turnover and Vehicle-Km Traveled

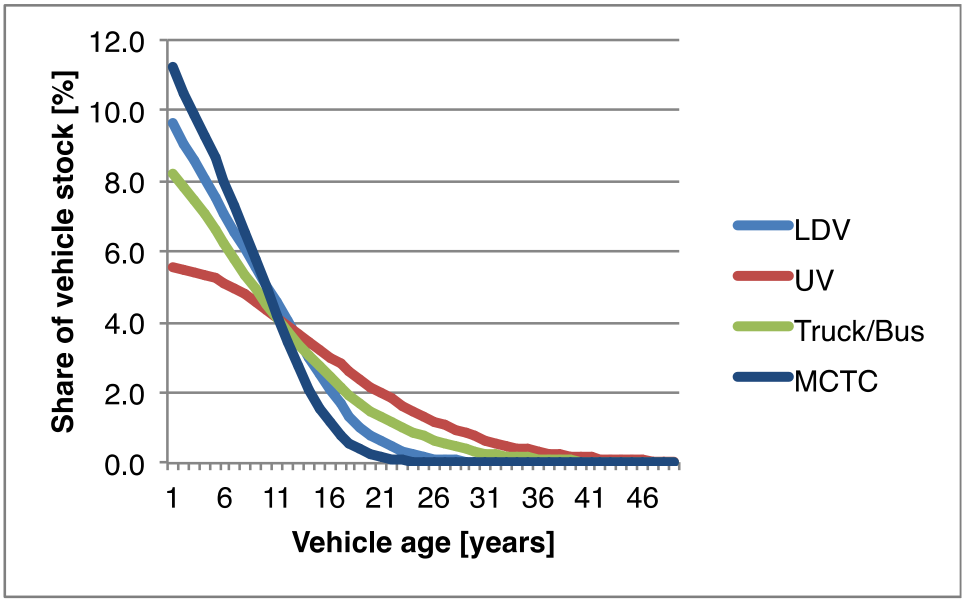
Lifecycle profiles are used to model changes in the vehicle stock and activity as vehicles age. *Survival curves* indicate how many vehicles remain in the fleet at a given age. Steeper curves indicate a shorter average vehicle lifetime, while shallower curves indicate longer vehicle lifetimes. Since survival curves were not available from Philippines-specific sources, these were approximated with estimates from the ICCT's India Emissions Model (ICCT, 2013). UVs, trucks, and buses were assumed to remain in the fleet longer than LDVs, with MC and TC having the shortest average vehicle lifetime (Figure IV. 6).

Figure IV. 6. Share of Vehicles Surviving by Age (ICCT, 2013)



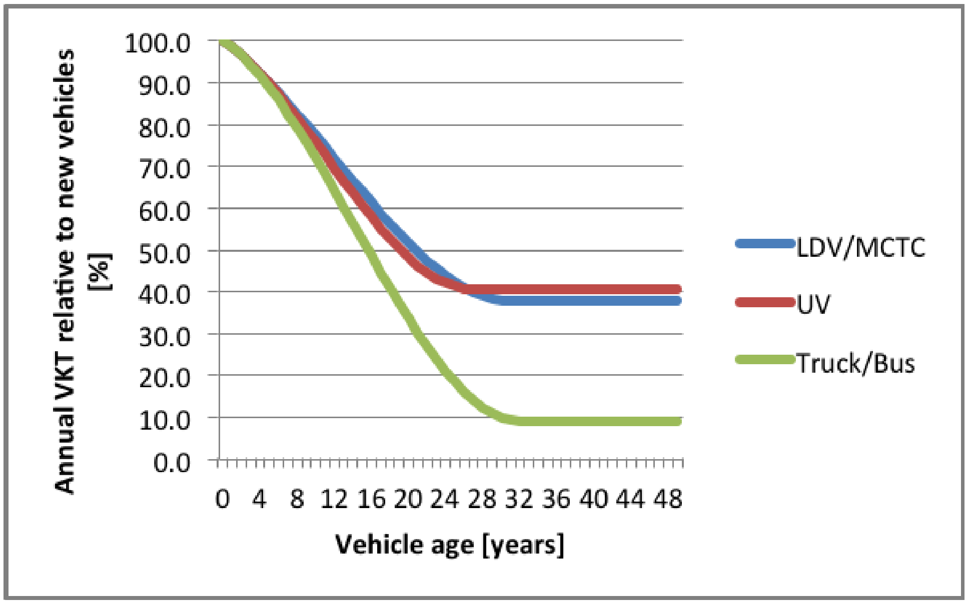
Stock vintage curves indicate the initial age distribution of the in-use vehicle fleet. These curves take into account historical changes in the total number of vehicles over time as well as survival rates. As for survival curves, estimates for the Philippines were derived from the ICCT's India Emissions Model (ICCT, 2013). Trucks and buses are assumed to have a similar age distribution, while UVs (which include jeepneys) are assumed to be older on average than other vehicle types (Figure IV. 7).

Figure IV. 7. Historical Distribution of Vehicles by Age (ICCT, 2013)



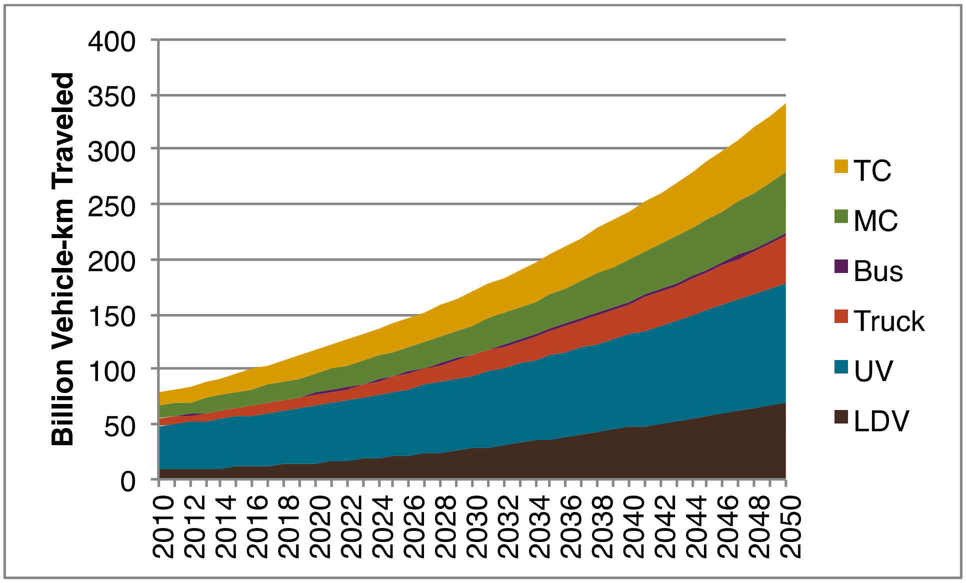
While older vehicles tend to account for a smaller share of the vehicle fleet due to retirement and sales growth, older vehicles also tend to be driven less than newer vehicles. *VKT degradation curves* indicate how far vehicles are driven per year relative to brand new vehicles (Figure IV. 8).

Figure IV. 8. Vehicle-km Traveled Degradation by Vehicle Age (ICCT, 2013)



In combination, survival curves, stock vintage curves, and VKT degradation curves determine the absolute level of vehicle activity and the share of vehicle-km traveled by vehicles of different ages[14]. Figure IV. 9 shows projected road vehicle activity in the Baseline scenario.

Figure IV. 9. Baseline Road Vehicle Activity 2010-2050



IV.3.1.5 Rail, Domestic Aviation, and Domestic Shipping

Rail, domestic aviation, and domestic shipping were modeled using top-down methods based on national energy balances by fuel type. Since the analysis of mitigation options focused on road transport, energy consumption and GHG emissions for rail, domestic aviation, and domestic shipping were projected using the forecast growth rate of economic activity, measured in terms of gross domestic product (GDP-MER). To the extent that economic activity grows at a slower pace, this could slow projected increases in energy use of rail, domestic aviation, and domestic shipping (Figure IV. 10).

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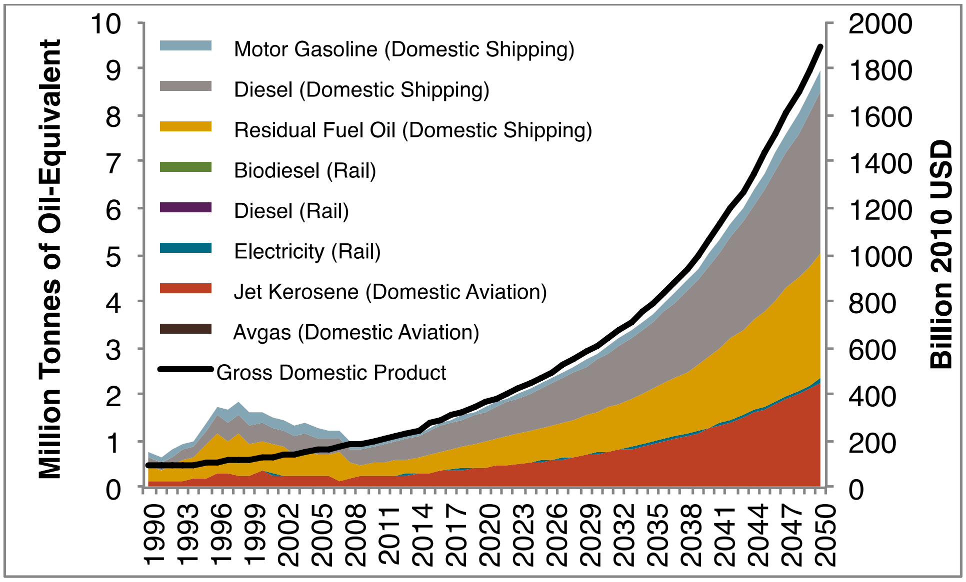
[14] Follow-up studies that measure the composition of vehicle activity by vehicle type and age in the Philippines could improve projections for vehicle fuel use and GHG emissions, as well as analysis of mitigation options.

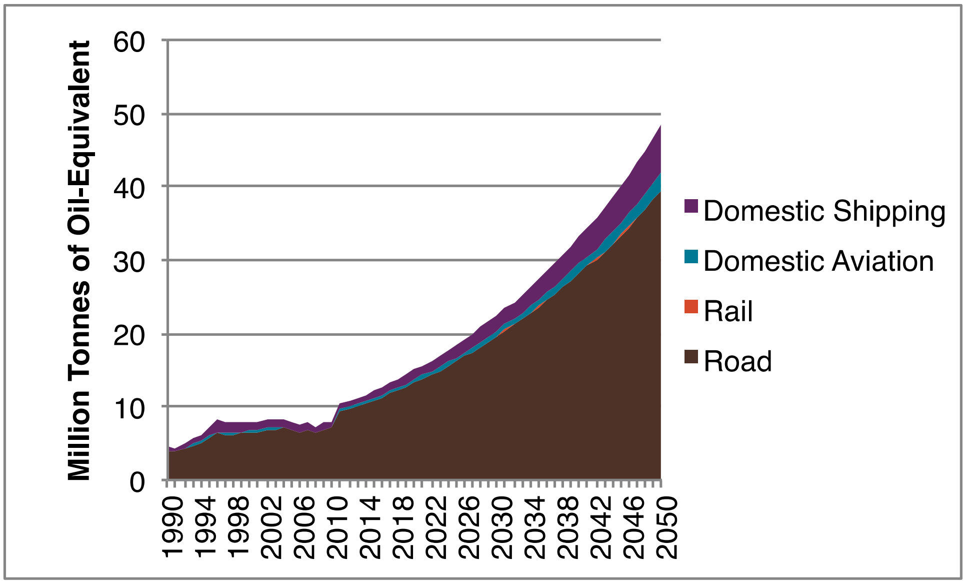
Figure IV. 10. Baseline Energy Demand for Rail, Domestic Aviation and Shipping 1990-2050



IV.3.2 Results

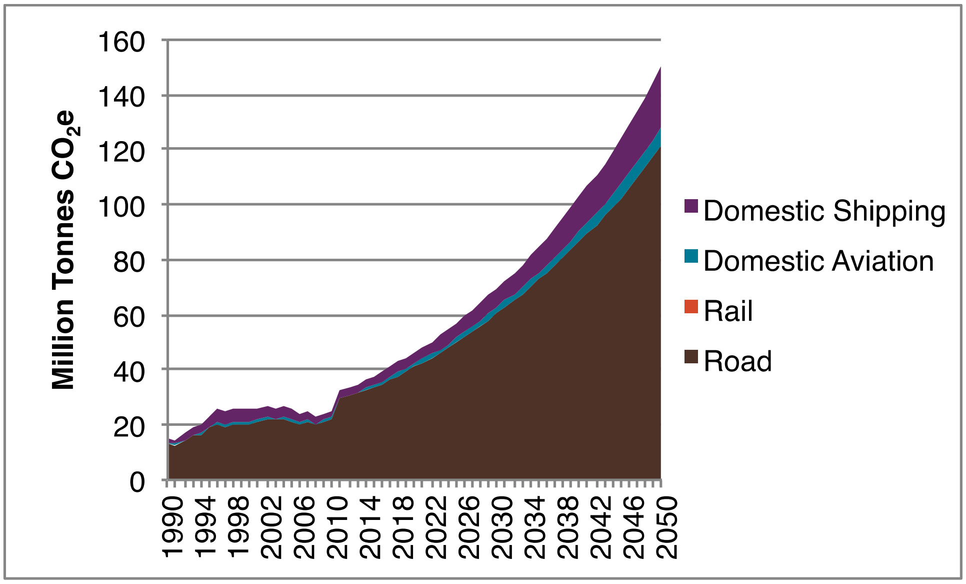
Considering the projections of economic activity described in the appendix on cross-cutting assumptions (Section IV.1 Cross-cutting Economic Assumptions) and expected growth in vehicle sales and stock, transport energy demand is projected to increase fivefold from 2011-2050 (Figure IV. 11), from an estimated 10 million tonnes of oil-equivalent (Mtoe) in 2011 to nearly 50 Mtoe by 2050.

Figure IV. 11. Baseline Transport Energy Demand by Source Category 1990-2050



Correspondingly, transport GHG emissions from direct combustion of fuels are projected to increase roughly fivefold by 2050, to approximately 150 $MtCO_2e$ (Figure IV. 12). Upstream emissions associated with the domestic production and distribution of electricity and liquid fuels are accounted for under the Energy sector.

Figure IV. 12. Baseline Transport GHG Emissions by Source Category 1990-2050 ($MtCO_2e$)



IV.4 MITIGATION COST-BENEFIT ANALYSIS

IV.4.1 Methods

IV.4.1.1 Selection of Mitigation Options

In 2014, the UNDP supported by the CCC developed a list of mitigation options for the waste, industry, transport, and agriculture sectors that could be included in future Nationally Appropriate Mitigation Actions (NAMAs) (Mejia, 2014). At the request of the CCC, B-LEADERS built upon the mitigation options listed in the UNDP study to develop a list of mitigation options for this study. Some of the mitigation options on the UNDP list consist of general policies that could include more than one mitigation option. Those general policies are not included in this CBA study, since the CBA is targeted towards distinct mitigation options, technologies, or processes that can be individually quantified, monetized, and compared for cost effectiveness.

The ICCT supplemented the initial list[15] with additional mitigation options identified through the stakeholder consultations, existing national policies and regulatory documents, and the Philippines'

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[15] The UNDP study acknowledges the preliminary nature of the list of mitigation options therein: "The list of NAMA options stated in this document is therefore suggested to be the list of actions/programs/policies that can initially be explored by the relevant government units as the initial set of options for NAMAs for the transportation sector. These embody a mix of avoid-shift-improve strategies at the local and national levels. There is also a good mix of policies and programs in these NAMA options. However, it must be remembered that the list is by no means an exhaustive one and that the process of NAMA identification is specific to this project and is not recommended to be adopted for future identification exercises" (Mejia, 2014).

Second National Communication to the UNFCCC (CCC, 2010; CCC, 2011; DOE, 2013; Esguerra et al., 2010; DOTC and DENR, 2011; DOE, 2009; DOE, 2012). **Error! Reference source not found.** lists the mitigation options selected for analysis, taking into account availability of relevant data on costs and GHG impacts. **Error! Reference source not found.** lists key assumptions for each transport sector mitigation option. **Error! Reference source not found.** shows how the mitigation options in the CBA study relate to the mitigation options from the UNDP study.

Table IV. 14. Summary of Transport Sector Mitigation Options Assessed in the CBA Study

CBA Mitigation Option	Description
Improving the efficiency of the road transport sector	
LDV Efficiency	New light-duty vehicles (LDVs) are required to meet more stringent fuel efficiency requirements based on standardized testing to gain type approval. This option assumes the Philippines follow US LDV standards with a lag of 10 years, improving the efficiency of brand new LDVs (assumed 70% of new registrations) by 26% in 2025 and 47% in 2030 compared to a baseline assumption of 10 L/100km. Such standards are consistent with the level of improvement targeted by the Global Fuel Economy Initiative (GFEI). Vehicle efficiency labeling and baseline studies of new light-duty vehicle efficiency in the Philippines could support the development of standards.
MVIS	The Motor Vehicle Inspection System (MVIS) tests and regulates emissions of in-use vehicles to ensure compliance with the emissions standards to which they are certified. An enhanced inspection and maintenance program could improve in-use vehicle efficiency and emissions performance by establishing new testing facilities nationwide and improving system wide reliability.
Driver Training	Driving behavior has a substantial effect on in-use fuel economy. Training vehicle drivers to use fuel-saving best practices such as maintaining a steady speed and avoiding unnecessary acceleration and braking can reduce fuel use of affected vehicles by 5-10 percent or more. Eco-driving programs have been recognized for their benefits to health, safety, and the environment by the IPCC, IEA, and WHO, and such programs have been established in the U.S., EU, Japan, Australia, and elsewhere (Killian, 2012).
Shifting to cleaner fuels and vehicles	
Euro 4/IV and MVIS	Includes MVIS along with implementation of Euro 4/IV standards for new LDV, Buses, Trucks, and MC/TC starting in 2016, ensuring availability of 50 ppm sulfur gasoline and diesel. Enhanced MVIS is considered necessary to ensure real-world compliance with Euro 4/IV standards.
Euro 6/VI and MVIS	Includes MVIS and Euro 4/IV standards along with successive implementation of Euro 6/VI standards for new LDV, Buses, Trucks, and MC/TC starting in 2022, ensuring availability of 10 ppm sulfur gasoline and diesel. Enhanced MVIS is considered necessary to ensure real-world compliance with Euro 6/VI standards.
Electric LDV	Involves fiscal incentives that increase the share of LDVs that are battery electric vehicles (BEVs). Evaluated by comparing the total costs of new BEVs with conventional gasoline-powered models. BEVs are assumed to reach 15 percent of LDV sales by 2030.
Electric MCTC	Fiscal incentives promote the sale of battery electric motorcycles and tricycles (MCTC). Sales of electric MCTC increase to meet a target of one million BEVs on the road by 2020; tricycles are assumed to account for 20% of this target.

CBA Mitigation Option	Description
Jeepney Modernization	Because jeepneys are rebuilt rather than newly manufactured, they are not subject to emissions or fuel economy standards. This measure involves fiscal incentives that promote the sale of battery electric jeepneys equipped with lithium-ion batteries. Since electric jeepneys may not be suitable for all routes, they are assumed to only apply to up to 25% of new UV registrations by 2030. Jeepneys with lithium-ion batteries were assessed due to their greater operating range and longer lifetime compared to lead acid batteries. Includes costs to scrap older jeepneys.
Biofuels	Biodiesel and bioethanol pathways are evaluated based on the 2012-2030 Philippine Energy Plan (DOE). These pathways are compared to a baseline in which biofuel blends remain at historical levels (8.3% ethanol and 2% biodiesel for gasoline and diesel blends, respectively).
Sustainable urban transport program	
Buses and BRT	A nationwide program is implemented at 3.5 times the scale of a proposal to MMDA, DOTC, and DPWH for Metro Manila (MMDA-DOTC-DPWH Partnership, 2015). Involves the transformation and expansion of road-based public transport in Metro Manila and other major urban areas nationwide, including the C-5 and Manila bus rapid transit (BRT) systems; express buses with dedicated lanes and facilities for non-motorized transport; and intelligent transportation systems that support bus monitoring, priority signaling, and remote traffic enforcement.
Rail	Considers the impacts of six rail projects in DOTC's project pipeline: MRT 3 Capacity Expansion, Mass Transit System Loop, LRT 1 South Extension, MRT 7, LRT 2 East and West Extensions, and expansion of the North-South Railway (Limcaoco, 2014).
CNG Buses	The Philippine Energy Plan for 2012-2030 sets a target for 15,000 compressed natural gas (CNG) buses to be on the road in 2030 (DOE). New CNG buses are assumed to be purchased in place of conventional diesel buses in order to reach this target. At this time, CNG buses were assumed to meet the same emissions standards as the diesel buses they replace; however, the benefits of CNG buses could be greater if these were required to meet Euro VI-equivalent standards. Such a requirement could take effect before ultra-low sulfur diesel is available for conventional buses.
Two-Stroke Replacement	Sales of new two-stroke motorcycles and tricycles have been banned since 2006. While it is unknown exactly how many two-stroke vehicles remain in operation, the long lifetime of vehicles in the Philippines indicates that there may be a significant benefit of targeting replacement of these high-emitting vehicles. Evaluates the impact of scrapping 30,000 two-stroke tricycles in 2016 and replacing these with electric models. In addition to reducing emissions, electric TC could cut fuel costs compared to gasoline TC.
Congestion Charging	Involves implementation of a program in Metro Manila modeled after London's Congestion Charging Scheme. Such a scheme would levy a charge on four-wheeled traffic during specified hours, thereby reducing the volume of vehicle travel, improving travel speeds, and reducing fuel use and associated vehicle emissions. The program is assumed to reduce nationwide four-wheeled vehicle activity by 5.1% in 2030. Cost inputs are based on an analysis by Esguerra et al. (2010).
Improving efficiency in the freight and logistics sector	
Road Maintenance	Poor road quality increases vehicle operating costs and associated fuel use. Evaluates the impact of a one percent improvement in the international roughness index of roads at a cost of 23 billion PHP (Esguerra et al., 2010).

Table IV. 15. Key Assumptions for Transport Sector Mitigation Options

Mitigation Option	Key Assumptions
LDV Efficiency	**General:** Standards for brand new LDVs (assumed 70% of new registrations) phase in for model years 2020 to 2035, resulting in efficiency improvements of 26% in 2025 and 47% in 2030 compared to a baseline assumption of 10 L/100km. **Capital Cost:** New vehicle purchase prices increase to reflect the cost of efficient technology: First 26% based on US 2012-2016: 36 USD per % reduction (ICCT, 2010) Next 21% based on US 2017-2025: 94 USD per % reduction (NHTSA, 2010) **O&M Cost:** No changes in maintenance costs. **Fuel Cost:** No changes from baseline fuel prices. **Implementation Cost:** Not modeled. Since brand new light-duty vehicles are imported, certification could be based on fuel economy testing conducted in other countries with standards (including US, Japan, China, EU, India). **Notes:** Fuel economy standards could be applied to other vehicle types, including jeepneys, MC, TC, buses, and trucks. This potential should be explored in subsequent analyses.
MVIS	**General:** Enhanced MVIS facilities reduce fleet-wide fuel consumption by 3% starting in 2019 (TTPI, 2010). This assumption is the low end of the range cited in Esguerra et al. (2010) based on ADB (2004). Assumes 30% reduction in PM emission rates applying to 25% of LDVs, 100% of UVs, and 30% of buses and trucks (Vergel & Tiglao, 2013). **Capital Cost:** The cost of designing and constructing new MVIS facilities has been estimated at 430 million (2004 USD) over 12 years, or 488 million (2010 USD) (Public-Private Partnership Center of the Philippines, 2011). **O&M Cost:** Average vehicle maintenance costs are assumed to increase by the equivalent of 1% of annual fueling costs (accounted for in net fuel consumption reduction of 2% instead of 3%). **Fuel Cost:** No changes from baseline fuel prices. **Implementation Cost:** Assumed to be included in capital cost.
Driver Training	**General:** Assumes the introduction in 2019 of a nationwide effort to train drivers of for-hire utility vehicles, for-hire buses, and commercial trucks. These vehicles accounted for 11.7% of UVs, 75% of buses, and 90.8% of trucks on the road in 2013. Such a program is conservatively assumed to reduce fuel use of affected vehicles by 5%. **Capital Cost:** No assumed changes in capital costs. **O&M Cost:** The cost of driver training is assumed to be $80 per participant, assuming trainings are conducted annually starting in 2019. This cost would vary based on the specific design of the program. **Fuel Cost:** No assumed changes from baseline fuel prices. **Implementation Cost:** A national program that compiles eco-driving tips, trains driving instructors, and develops training curriculum could cost $4 million based on the level of funding provided to a similar EU program (Jellinek, 2011). **Notes:** This measure assesses the impact of a mandatory program (for example, tied to vehicle registration). A voluntary program might have lower participation, in which case impacts would scale with number of vehicles affected.
Euro 4/IV and MVIS	**General:** Includes all costs and impacts of enhanced MVIS program, plus the introduction of Euro 4/IV in 2016 for brand new LDVs, MC, TC, buses, and trucks. Brand new vehicles are assumed to account for 70% of new LDV registrations, 20% for buses and trucks, and 100% for MC and TC. **Capital Cost:** The incremental costs of emission control technologies to meet Euro 4/IV compared to Euro 2/II vary by vehicle and fuel type. These costs can range from about $15 for motorcycles to $3,800 for diesel buses (ICCT, 2013). **O&M Cost:** Minimal maintenance required. No assumed changes in maintenance costs. **Fuel Cost:** Lower sulfur fuels are required for optimal function of emission controls. Estimated incremental costs are 1.3 and 0.4 cents per liter for 50 ppm sulfur diesel and gasoline, respectively (Hart Energy & MathPro Inc., 2012).

Mitigation Option	Key Assumptions
	Implementation Cost: No implementation costs are assumed for Euro 4/IV standards other than those included for the enhanced MVIS program. **Note:** The import of used secondhand vehicles is technically banned; however, this ban is not uniformly enforced. Stepping up enforcement of requirements for imported vehicles to be brand new could significantly increase the impact of emissions standards.
Euro 6/VI and MVIS	**General:** Includes all costs and impacts of Euro 4/IV standards and MVIS, plus the introduction of Euro 6/VI in 2022 for brand new vehicles. **Capital Cost:** The incremental costs of emission control technologies to meet Euro 6/VI standards compared to Euro 2/II vary by vehicle and fuel type. These costs can range from about $50 for motorcycles to $7,100 for diesel buses (ICCT, 2013). **O&M Cost:** Minimal maintenance required. No assumed changes in maintenance costs. **Fuel Cost:** Lower sulfur fuels are required for optimal function of emission controls. Estimated incremental costs are 3.4 and 1.2 cents per liter for 10 ppm sulfur diesel and gasoline, respectively, compared to 500 ppm fuels (Hart Energy & MathPro Inc., 2012). **Implementation Cost:** No implementation costs are assumed for Euro 6/VI standards other than those included for the enhanced MVIS program. **Note:** Research and development efforts have resulted in improvements in the efficiency of engines progressing largely in parallel with European emissions standards. Due to the lack of studies relevant to conditions in the Philippines, reductions in fuel use were not included as a benefit of adoption of new vehicle standards. It is, however, likely that adoption of Euro IV and VI emissions standards will result in additional fuel savings that are not modeled here.
Electric LDV	**General:** BEVs reach 15 percent of LDV sales by 2030 (DOE, 2012). Based on recent fuel prices and vehicle efficiency estimates, electric vehicles have lower fuel costs than gasoline models, which can result in net savings over the lifetime of the vehicle. **Capital Cost:** Incremental costs to manufacturers are forecast to decline from 11,000 USD in 2015 to 3,000 USD in 2030 for BEVs (National Research Council, 2013). **O&M Cost:** Not modeled due to constraints on data availability. **Fuel Cost:** Fuel costs reflect the switch from gasoline or diesel to electric charging. The cost of basic Level 1 (overnight) charging equipment is assumed to be covered in the price of electricity, which is captured in this analysis; other charging infrastructure would require capital investment and operating costs beyond those considered here. **Implementation Cost:** Total technology costs are evaluated rather than the fiscal impacts of a particular program.
Electric MCTC	**General:** Sales of electric motorcycles and tricycles increase to meet a target of one million EVs on the road by 2020 (Ranada, 2014); tricycles are assumed to account for 20% of this target. **Capital Cost:** MC: 841 USD for gasoline (Philmotors, 2015); 766 USD for electric (TAiLG, 2015). TC: 2,090 USD for gasoline (Ranada, 2014); 5,740 USD for electric (Ranada, 2014). **O&M Cost:** Annual maintenance costs are assumed to be 61 USD for electric motorcycles (assuming replacement of lead acid batteries every two years), compared to 11 USD for gasoline motorcycles. **Fuel Cost:** Fuel costs reflect the switch from gasoline or diesel to electric charging. The cost of basic Level 1 (overnight) charging equipment is assumed to be covered in the price of electricity, which is captured in this analysis; other charging infrastructure would require capital investment and operating costs beyond those considered here. **Implementation Cost:** Total technology costs are evaluated rather than the fiscal impacts of a particular program.
Jeepney Modernization	**General:** Older diesel jeepneys are scrapped and replaced with battery electric models. Sales of electric jeepneys reach 10% of new UV registrations by 2020, and 25% by 2030. **Capital Cost:** Electric jeepneys are assumed to cost 800,000 pesos (Ranada, 2013), equivalent to $16,000 in 2010 USD, or about $3,500 more than gasoline and diesel models (USAID, 2014). Incremental costs of electric jeepneys are assumed to decline at the same rate as electric LDVs

Mitigation Option	Key Assumptions
	(National Research Council, 2013). **O&M Cost:** Assuming lithium-ion batteries are replaced every 7-8 years, electric jeepneys would cost 400 USD per year to maintain. Gasoline and diesel jeepneys cost an average of 50,000 PHP (960 USD) per year to maintain. Fueling costs are considered separately. **Fuel Cost:** Fuel costs reflect the switch from gasoline or diesel to electric charging. The cost of basic Level 1 (overnight) charging equipment is assumed to be covered in the price of electricity, which is captured in this analysis; other charging infrastructure would require capital investment and operating costs beyond those considered here. **Implementation Cost:** Includes 150,000 PHP (2,900 USD) per vehicle to scrap older jeepneys. **Notes:** Aside from electric models, there are numerous technology options available that could improve the efficiency of gasoline and diesel jeepneys; however, given current fuel quality limitations and the difficulty of applying emissions standards to rebuilt jeepneys, electrification appears to be the most viable near-term option to eliminate harmful tailpipe emissions.
Biofuels	**General:** Ethanol meets 20% of road gasoline demand by 2020, and biodiesel meets 20% of road diesel demand by 2025. Since lifecycle GHG emissions of biofuels are accounted for in the agricultural and refining sectors, results reflect the net change in GHG emissions including production, refining, and distribution, as well as land use changes from domestically produced fuels. However, the mitigation potential should be interpreted very carefully, since emissions associated with imported biofuels are not counted toward the GHG total in the Philippines. For example, if the Philippines were to import 80% of biodiesel after 2025, this may reduce the level GHG emissions attributed to the Philippines, even if net GHG emissions increased in biofuel-producing countries. **Capital Cost:** Capital costs assumed to be reflected in market fuel prices. **O&M Cost:** O&M costs assumed to be reflected in market fuel prices. **Fuel Cost:** No changes from baseline fuel prices. **Implementation Cost:** Technology costs of biofuels are evaluated apart from the impacts of any particular biofuel policy. The costs borne by government and taxpayers will vary depending on the regulation or fiscal incentive applied.
Buses and BRT	**General:** From 2016-2025, a total of 46,400 buses are added under service contracts to run on designated routes and displace passenger activity, 10% of which would otherwise be carried by LDVs, and 90% of which is from jeepneys based on mode share estimates (Clean Air Asia, 2012). Additional buses are assumed to displace sales of LDVs and UVs, weighted by average passengers per vehicle: assumed 40 for buses, 2 for LDVs, and 10 for UVs. **Capital Cost:** Investment costs for institutional development, capacity building, physical infrastructure, measures to facilitate the transition, and other planning and preparatory activities average 340 million USD annually from 2016-2025 (MMDA-DOTC-DPWH Partnership, 2015). **O&M Cost:** Annual costs to provide bus service, collect fares, and provide other customer services increase from 1.8 million USD in 2016 to 480 million USD in 2025 (MMDA-DOTC-DPWH Partnership, 2015) **Fuel Cost:** Fuel costs and savings scale with bus service. Fuel prices are identical to the baseline. **Implementation Cost:** Equal to the sum of Capital, O&M, and fuel costs. **Note:** New buses should be as clean as possible in order to maximize air quality benefits of transforming road-based public transport. Buses are assumed to meet Euro IV standards at a minimum or Euro VI standards three years ahead of an implementation date, if applicable.
Rail	**General:** Completion of 6 planned rail projects reduces annual sales of LDVs, buses, and jeepneys by 4900, 270, and 950, respectively, by 2025. Operating system capacity increases from 50% in 2019 to 90% in 2021 and 100% in 2025. By 2025, new systems carry 1.74 million passengers per day. Investments in electrified rail add 145 million kWh in annual electricity demand by 2025. North-South Railway expansion consumes 3.7 million liters of diesel fuel by 2025. **Capital Cost:** Combined cost to build 6 rail projects is 12.4 billion USD in 2019 (Limcaoco, 2014). **O&M Cost:** Starting in 2020, annual costs scale with system capacity, up to 134 million USD in

Mitigation Option	Key Assumptions
	2025 (Limcaoco, 2014). These O&M costs were adjusted to exclude fuel costs. **Fuel Cost:** Fuel costs and savings scale with rail service. Fuel prices are the same as in the baseline. **Implementation Cost:** Equal to the sum of Capital, O&M, and fuel costs.
CNG Buses	**General:** New CNG buses are purchased in place of conventional diesel buses in order to reach the target of 15,000 buses on the road in 2030. This target could be subject to revision based on local fuel availability. CNG and diesel buses are each assumed to consume 40 L/100km (DOE, 2015). **Capital Cost:** CNG buses are assumed to cost about 10,130 USD more than conventional diesel buses (Grütter Consulting, 2014). This incremental cost could vary significantly depending on the contract negotiated with bus suppliers. **O&M Cost:** No assumed change from the baseline. **Fuel Cost:** Fuel prices are assumed to reflect the cost of delivering CNG and diesel. While there is some uncertainty regarding the future availability and cost of CNG relative to diesel, current prices indicate potential savings with CNG buses. **Implementation Cost:** No additional costs. **Note:** In this analysis, new CNG buses were evaluated at the same level of emission control as new diesel buses. It should be noted, however, that given appropriate regulatory or fiscal incentives, CNG buses could meet Euro VI requirements using a three-way catalyst, potentially at a lower cost than diesel buses and in advance of ultralow-sulfur diesel availability. Subsequent analyses could consider the impacts of a program to introduce Euro VI CNG buses compared to Euro II or Euro IV diesel buses.
Two-Stroke Replacement	**General:** Tricycles are assumed to account for 20% of the 3.1 million registered MC/TC nationwide, and 20% of these tricycles are assumed to have two-stroke engines. Roughly one in four, or 30,000 of the estimated 120,000 two-stroke tricycles are assumed to be scrapped and replaced with a new battery electric model in 2016. Electric and gasoline tricycles are assumed to consume 8.75 kWh/100km (ADB, 2015) and 4.1 L/100km, respectively (Vergel & Tiglao, 2013). The new electric vehicles are assumed to travel roughly the same distance as the two-stroke vehicles they replace. **Capital Cost:** 2,090 USD for gasoline; 5,740 USD for electric (Ranada, 2014). **O&M Cost:** Annual maintenance costs are assumed to be 83 USD for electric and 15 USD for gasoline tricycles, respectively. **Fuel Cost:** Reflects the switch from gasoline fuel to electric charging. Since tricycles have relatively low energy requirements, these vehicles are assumed to charge overnight through a standards electricity outlet. Other (faster) charging infrastructure would require capital investment and operating costs beyond those considered here. **Implementation Cost:** No additional costs.
Congestion Charging	**General:** A congestion charging program phases in from 2026 to 2030, applying to 39% of four-wheeled vehicles (LDVs, UVs, Buses, and Trucks), with 12 charging hours that cover 66% of daily vehicle activity (5.5% per hour for peak hours) (JICA, 2014). These assumptions translate to the equivalent of a 5.1% reduction in nationwide vehicle activity. **Capital Cost:** Included in implementation cost. **O&M Cost:** 5 million USD per year based on the costs of the London scheme (Esguerra et al., 2010). **Fuel Cost:** Scale with fuel savings. No changes in fuel prices from the baseline. **Implementation Cost:** Based on the London scheme, an initial investment of $50 million would be needed to design the program, install automated enforcement mechanisms, and conduct public outreach (Esguerra et al., 2010). **Note:** The allocation of revenues from congestion charging could significantly impact the viability of the program. For example, re-investing revenues in public transport expansion could mitigate negative effects on low-income travelers and reduce the incentive to shift to motorcycle and

Mitigation Option	Key Assumptions
	tricycle travel.
Road Maintenance	**General:** Improved maintenance of existing roads is modeled as a 1% improvement in the IRI (international roughness index), reducing road vehicle fuel consumption by 3.6%. **Capital Cost:** Included in implementation cost. **O&M Cost:** No changes modeled; however, improved road maintenance could potentially reduce vehicle maintenance costs due to less wear and tear from driving on better roads. **Implementation Cost:** 23 billion in 1999 PHP (880 million in 2010 USD) based on a 2009 World Bank study as assessed in Esguerra et al. (2010). **Fuel Cost:** No changes in fuel price from the baseline. **Note:** This measure would not involve the construction of new roads, but only improvements to the surface quality of existing roads.

Table IV. 16. Comparison of Transport Sector Mitigation Option Lists

Strategy	UNDP List of Mitigation Options	CBA Mitigation Option[16]	Included in CBA
Improving the efficiency of the road transport sector	Adoption of fuel economy standards	LDV Efficiency	▯
	Enhanced inspection and maintenance program (including MVIS facilities)	MVIS	▯
	Stricter standards for imported second hand vehicles	*Not currently assessed due to constraints on data on the number and characteristics of imported second hand and domestic rebuilt vehicles.*	
	Eco-driving program	Driver Training	▯
	Adoption of age limits for vehicles and Vehicle scrappage scheme for old/inefficient vehicles	*Not currently assessed. Additional inputs would be needed from government partners regarding the costs of vehicle scrappage programs.*	
Shifting to cleaner fuels and vehicles	Fiscal and non-fiscal incentives to promote low emissions vehicles	Euro 4/IV and MVIS; Euro 6/VI and MVIS	▯
		Electric LDV; Electric MCTC; Jeepney Modernization	▯
		DOE's LPG taxi program is no longer under active development, so it is not assessed.[17]	
	Fiscal and non-fiscal incentives to promote cleaner fuels	Biofuels	▯
	Vehicle scrappage schemes	*Not currently assessed as discussed in "Adoption of age limits for vehicles and Vehicle scrappage scheme for old/inefficient vehicles"*	

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[16] Multiple mitigation options are separated by a semicolon.

[17] The Philippine Energy Plan for 2012-2030 sets a target for 23,000 LPG taxis to be on the road in 2030. According to the DOE's Auto LPG program, an estimated 19,000 LPG taxis were on the road as of 2011; however, due to a declining differential between LPG and gasoline fuel prices and safety concerns related to LPG fueling infrastructure, the number of LPG taxis declined to 9,957 in 2014.

Sustainable urban transport program	Support for developing integrated plans for urban transport	*Not currently assessed due to limited data on costs of developing and implementing integrated land use and transport plans.*	
	Infrastructure development for public transport and non-motorized transport	Buses and BRT; Rail	☐
	Financing mechanisms for adopting low emitting alternatives for public transport	CNG Buses; Two-Stroke Replacement	☐
	Transport demand management schemes	Congestion Charging	☐
Improving efficiency in the freight and logistics sector	Support for the development of a national freight and logistics master plan	*Not currently assessed due to data limitations.*	
	Reduction of over-loading and empty hauls made by trucks through the use of ICT	*Not currently assessed due to data limitations.*	
	Vehicle replacement and/or scrapping scheme for trucks	*Not currently assessed. Discussed in "Adoption of age limits for vehicles and Vehicle scrappage scheme for old/inefficient vehicles"*	

IV.4.1.2 Congestion Co-Benefits

Three mitigation actions for the transport sector—Congestion Charging, Buses and BRT, and Rail—result in reductions in overall vehicle activity, expressed in units of vehicle-km traveled (VKT). By reducing vehicle activity in densely populated areas, these actions have the co-benefit of reducing traffic congestion and time spent in traffic by all road users. Time savings co-benefits of reduced vehicle activity were calculated based on a simple cost-per-VKT metric for the Greater Capital Region (GCR), an area including the three regions of Metro Manila, Central Luzon, and Calabarzon.

The transportation issues faced by Metro Manila today and in the future were examined in a recent report by JICA, sponsored by NEDA (JICA, 2014). The authors of this study found that traffic volume already exceeds road capacities in most urban road sections, and is projected to worsen significantly in the future. The total cost of congestion in the GCR in 2030 is projected to be 3.5 trillion PHP per year (9.5 billion PHP per day), with 50% of that cost attributable to time spent in traffic and the other 50% attributable to increased vehicle operating costs. Dividing this estimate of the total time cost of traffic (1.73 trillion PHP per year) congestion by the projected level of vehicle activity in the GCR in 2030 (estimated in the CBA Study to grow to 96 billion vehicle kilometers[18]) would yield a time loss worth $0.35 (in 2010 USD) per VKT, compared to $0.25 per VKT in 2012. Values between 2012 and 2030 were

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[18] Based on the number of vehicles registered in each region (LTO, 2015b), an estimated 56% of nationwide vehicle activity takes place within the GCR.

interpolated linearly, with no further increases in the average time cost of congestion per VKT assumed after 2030[19].

This congestion cost per VKT was validated against values estimated in other urban contexts from a meta-analysis conducted by Aftabuzzaman, Currie, and Sarvi (2010). This comparison is shown in Figure IV. 13. Variation in congestion cost per VKT is high across the cities surveyed, ranging from $0.05/VKT in the city of Christchurch in the United Kingdom, where traffic congestion is relatively low, to $1.79/VKT on "A" (or major) roads in the UK, with a median value of $0.39/VKT. The value estimated for the Philippine GCR falls within this range, slightly below the median. This aligns with expectations: an income-based value assigned to time savings would be higher in high-income countries than in the Philippines, but the high level of congestion in the GCR indicates that the amount of time lost due to each additional VKT may be greater than the amount of time lost per VKT in less-congested areas, for example in the United States or New Zealand.

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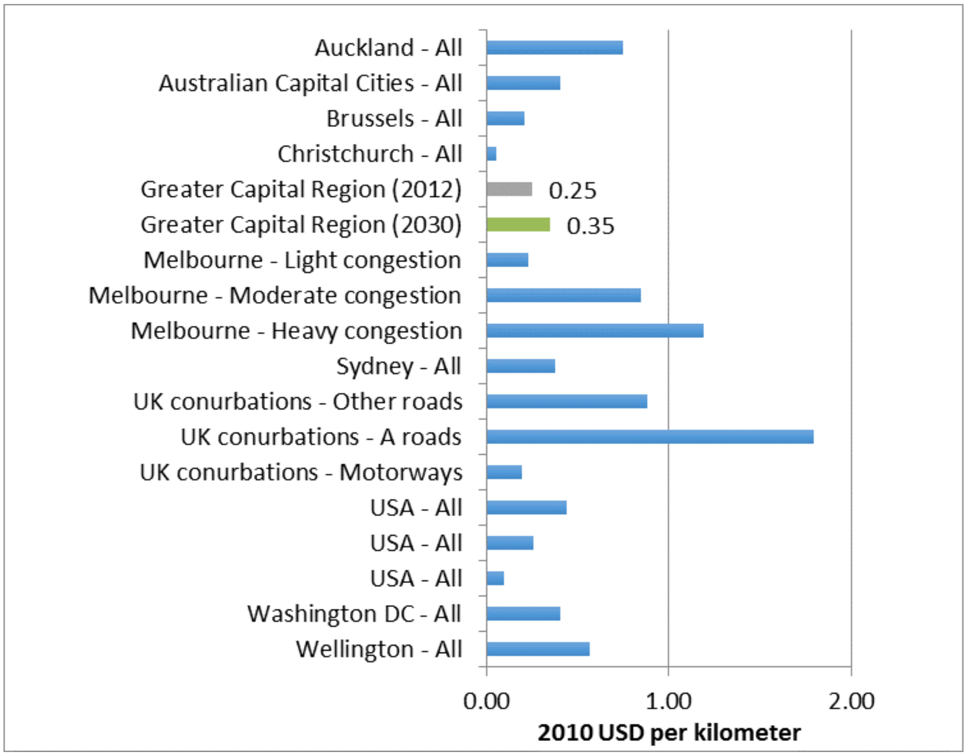
[19] A more refined approach could estimate the total cost of congestion based on roadway capacity and the projected level of VKT in the Baseline scenario as well as for each mitigation option. Such an approach could then take the difference between the two as the level of congestion co-benefit. The primary constraint to this approach has to do with a lack of nationwide data on roadway capacity and current vehicle volumes. Additional data that could improve the characterization of congestion co-benefits include estimates of the value of travel time saved for different vehicle types and trip purposes, as well as traffic volume by vehicle type. The value of travel time saved could be estimated using the average wage rate, then converted to the value of time saved per vehicle based on trip purpose and vehicle occupancy ratios for each vehicle type. These methods are discussed in more detail in a report by the Institute for Global Environmental Strategies (2011).

Figure IV. 13. Congestion Cost per Vehicle-km Traveled (2010 USD)



IV.4.1.3 Health Co-Benefits

Ten of the mitigation options for the transport sector produce health co-benefits by reducing vehicle emissions of $PM_{2.5}$. These options are Buses and BRT, Congestion Charging, Electric LDV, Jeepney Modernization, Electric MCTC, Euro 4/IV and MVIS, Euro 6/VI and MVIS, MVIS, Rail, and Two-Stroke Replacement. Co-benefits of mitigation options were calculated according to the basic framework presented in Figure IV. 14. Emissions of tailpipe $PM_{2.5}$ from the CBA model were converted to air pollution concentrations that inform the baseline concentration estimates and predict the air quality change in each mitigation scenario. The health benefits of reduced exposure to air pollution were calculated using exposure-response functions, and then the value of health benefits was calculated using the commonly-applied value of mortality risk reduction (VMMR)[20] approach. Each of these steps is described in depth in IV.2 Health Co-benefits Methods, as well as methodological differences between health impact calculations in the transport and energy sectors.

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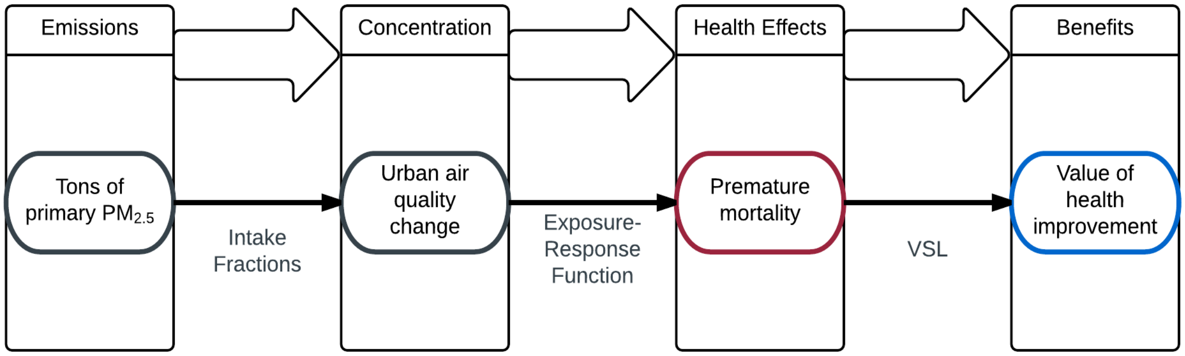
[20] Also known as value of a statistical life (VSL).

Figure IV. 14. General Framework for Health Co-benefits Calculation



IV.4.2 Results

The following two sections (IV.4.2.1 Direct Costs and Benefits & IV.4.2.2 Co-Benefits) present the results of each mitigation option compared individually against the Baseline scenario. The third section presents the combined effects of implementing selected mitigation options starting with the least cost option.

Error! Reference source not found. provides a description of each of the variables given in the subsequent results tables. Each mitigation option is assigned a symbol (e.g. "A") to allow efficient referencing in the row of formulas provided for each table. These formulas explain the process for calculating variables such as "Total Net Cost" or "Cost per Ton Mitigation with Co-benefits."

Table IV. 17. Description of Result Variables

Symbol	Variable	Description
-	Sequence Number of Mitigation Option	Refers to the sequential order in which individual mitigation options are initiated as described by the retrospective systems approach. In the retrospective systems approach, mitigation options are compared to the baseline as stand-alone options and then ranked or sequenced according to their cost per ton of mitigation (without co-benefits) from lowest cost per ton of mitigation to highest cost per ton of mitigation. Then the incremental cost and GHG mitigation potential of mitigation options is calculated as compared to the baseline and all prior sequenced mitigation options. The advantage of this approach is that the interdependence between a given mitigation option and every other previous option on the MACC curve is taken into account.
-	Mitigation Option	Mitigation options selected by DOTC for inclusion in the MACC are evaluated using the retrospective systems approach (IV.4.2.3 Marginal Abatement Cost Curve for Transport Sector Mitigation Options), while the remaining mitigation options are evaluated individually against the Baseline scenario.
A	Capital, O&M, Implementation Costs	Includes capital, O&M, and implementation costs compared to the Baseline scenario.
B	Cost of Fuel and Other Inputs	Includes the cost of delivered fuels, and plus the cost of fertilizer for the agriculture sector, all relative to the Baseline scenario. Fuel savings or reductions in fertilizer use are reflected as negative costs (co-benefits).
C	Total Net Cost	Equal to the sum of capital, O&M, implementation, fuel, and input costs compared to the Baseline. Represents the net change in costs with implementation of the mitigation option. Negative costs indicate cost savings compared to the Baseline (e.g., fuel savings).
D	GHG Mitigation Potential	Potential change in economy-wide, cumulative GHG emissions from 2015-2050 with implementation of the mitigation option. Positive values indicate GHG emissions benefits. Considers the impacts of Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), and Hydrofluorocarbon 23 (HFC 23).
E	Cost per Ton Mitigation without co-benefits	Equal to the total net cost divided by the mitigation potential. Represents the cumulative cost per ton of a mitigation option if implemented relative to the Baseline. Negative values indicate cost savings as well as GHG emissions benefits.
F	Co-benefits: Health	Monetized public health benefits reflect the reduced risk of premature death from exposure to air pollution exposure. For the transport sector, based on reduced emissions of fine particles from vehicle tailpipes. For the energy sector, these are based on the reduced power plant emissions of SO2, fine particulates, and NOx.
G	Co-benefits: Congestion	Monetized congestion benefits reflect less time wasted on congested roadways. Specific to the transport sector.
H	Co-benefits: Income Generation	Economic co-benefits from creation of new markets and/or expansion of productive capacity. For ALOFU, these include timber production from re-forested areas.
I	Total Co-benefit	Sum of valuation of monetized co-benefits. Co-benefits that were quantified but not

Symbol	Variable	Description
		monetized (i.e. energy security) are summarized in a separate table.
J	Cost per Ton Mitigation: co-benefits only	Value of monetized co-benefits (represented as a negative cost) divided by mitigation potential. This indicator can be added to the cost per ton without co-benefits to get the net cost per ton with co-benefits (column K).
K	Cost per Ton Mitigation with co-benefits	Equal to the total net cost minus valuation of co-benefits, divided by mitigation potential.
L	Net Present Value Excluding Value of GHG Reduction	Total co-benefits minus total net cost. Reflects the present value to society of a mitigation option relative to the baseline, including changes in costs (e.g. capital, fuel, and other inputs) and co-benefits such as public health, but excluding climate benefits. A true net present value would include a valuation of climate benefits based on the social cost of carbon dioxide-equivalent in the Philippines times the mitigation potential (column D).

IV.4.2.1 Direct Costs and Benefits

Table IV. 18 summarizes the direct costs and benefits of mitigation options, including changes in capital, operating and maintenance (O&M), implementation, and fueling costs as well as GHG emissions. Co-benefits related to traffic congestion and health impacts are considered in the following section. Nine of the fifteen mitigation options assessed would have a negative cost per ton GHG mitigation even without considering congestion and health co-benefits. These nine options would provide direct cost savings compared to the Baseline scenario as well as GHG savings.

Table IV. 18. Direct Costs and Cost per Ton of Transport Sector Mitigation Options Excluding Co-benefits

Sequence Number of Mitigation Option	Mitigation Option	Incremental Cost (Cumulative 2015-2050) [Billion 2010 USD] Discounted at 5%			Incremental GHG Mitigation Potential (2015-2050) [$MtCO_2e$]	Incremental Cost per Ton Mitigation (2015-2050) [2010 USD] *without co-benefits*
		Capital, O&M, Implementation Costs	Cost of Fuel and Other Inputs	**Total Net Cost**		
Symbol		*A*	*B*	*C*	*D*	*E*
Formula				*(A+B)=C*		*C/D=E*
32	Biofuels	0.0	19.9	19.9	[1]	63
34	Buses and BRT	6.4	-2.4	4.0	10.5	377
N/A*	CNG Buses	0.1	-0.3	-0.2	0.5	-483
5	Congestion Charging	0.1	-6.0	-5.9	46	-129
7	Driver Training	1.5	-5.7	-4.2	40	-105
4	Jeepney Modernization	-0.3	-23.3	-23.6	172	-137
N/A	Electric LDV	1.2	-4.0	-2.7	14	-192
N/A	Electric MCTC	0.8	-1.4	-0.6	1.2	-483
N/A	Euro 4/IV and MVIS	2.3	83.6	85.9	55	1575
N/A	Euro 6/VI and MVIS	4.1	180.5	184.6	55	3363
N/A	LDV Efficiency	6.7	-10.8	-4.1	71	-57
3	MVIS	0.4	-7.3	-6.9	46	-150
36	Rail	9.1	-1.9	7.2	8.5	849
N/A	Road Maintenance	13.2	-13.9	-0.6	85	-7
N/A	Two-Stroke Replacement	0.2	-0.1	0.1	0.1	939

Notes:

Relatively Cost Effective. Negative Cost or Cost per Ton indicates lower costs than the baseline or preceding scenario.

* N/A indicates that a given mitigation option was not selected by DOTC for inclusion in the retrospective systems analysis. These mitigation options were evaluated individually against the baseline.

[1] The estimated GHG mitigation potential of transport biofuels would be 317 $MtCO_2e$, assuming no biogenic emissions from fuel combustion and not accounting for increased upstream emissions beyond domestic borders. This figure represents the potential to reduce emissions listed in the domestic emissions inventory, but excludes the considerable increase in upstream emissions that is likely in countries that export biofuels to the Philippines. These emissions outside the Philippine inventory are likely to reduce the net mitigation offered globally by increased Philippine biofuel imports by the order of 50%, dependent on the feedstock pathways used. These international emissions would proportionately increase the effective mitigation cost when considered from a global perspective by a factor of around 2. In the worst case, depending on feedstocks, the implementation of any sustainability assurance, and on forest governance in exporter countries, a policy of expanded biofuel use may deliver no global net GHG benefit. A comprehensive discussion of the land use implications of biofuel policies is available in Malins et al. (2014).

IV.4.2.2 Co-Benefits

Table IV. 19 summarizes the value of co-benefits that could be monetized for the transport mitigation options. Monetized co-benefits for health and congestion would apply to ten and three out of fifteen mitigation options, respectively. Column J shows the value of these benefits, normalized per ton of GHG mitigation potential. These "co-benefits only" results exclude direct costs; they are combined with direct costs and benefits in Table IV. 20.

Table IV. 19. Monetized Co-Benefits of Mitigation Options in the Transport Sector

Sequence Number of Mitigation Option	Mitigation Option	Incremental Co-benefits (Cumulative 2015-2050) [Billion 2010 USD] Discounted at 5%				Incremental Cost per Ton Mitigation (2015-2050) [2010 USD] *co-benefits only* [2]
		Health	Congestion	Income Generation	**Total Co-benefit**	
Symbol		*F*	*G*	*H*	*I*	*J*
Formula					*sum(F,G,H)=I*	*-I/D=J*
32	Biofuels					
34	Buses and BRT	13.7	9		22.7	-2162
N/A*	CNG Buses					
5	Congestion Charging	24	8.5		32.5	-707
7	Driver Training					
4	Jeepney Modernization	96.4			96.4	-560
N/A	Electric LDV	0.8			0.8	-59
N/A	Electric MCTC	0.1			0.1	-100
N/A	Euro 4/IV and MVIS	101.4			101.4	-1860
N/A	Euro 6/VI and MVIS [1]	140 to 308			140 to 308	-5603 to -2554
N/A	LDV Efficiency					
3	MVIS	125.1			125.1	-2720
36	Rail	5.2	3.3		8.5	-1000
N/A	Road Maintenance					
N/A	Two-Stroke Replacement	0.019			0.019	-194

Notes:

Relatively Cost Effective. Positive co-benefits reduce the net cost of mitigation options.

* N/A indicates that a given mitigation option was not selected by DOTC for inclusion in the retrospective systems analysis. These mitigation options were evaluated individually against the baseline.

[1] *Range of health co-benefits reflects uncertainty regarding the level of reduction in PM2.5 emissions from diesel jeepneys running on cleaner (10 ppm sulfur) fuel. Studies in the U.S. (MECA, 1999) and Japan (WWFC, 2000) have found 10-50% reductions in PM2.5 from uncontrolled diesel trucks switching from 300 ppm to 500 ppm to ultra-low sulfur fuel.*

[2] *Equal to the value of co-benefits divided by GHG mitigation potential. This could also be termed "Value of Co-Benefits per Ton Mitigation."*

Table IV. 20 combines the cost per ton without co-benefits (Column E) with the cost per ton of co-benefits (Column J). Three mitigation options – Buses and BRT, Euro 4/IV and MVIS, and Rail – have a negative cost per ton GHG mitigation only once co-benefits for health and traffic congestion have been taken into account. As the mitigation option is currently defined, the cost effectiveness of "Euro 6/VI and MVIS" depends on the emissions benefits of requiring cleaner (10 ppm sulfur) fuels for existing vehicles, since these cleaner fuels are presently assumed to be made available for the whole fleet rather than only those vehicles meeting more stringent emissions standards[21]. For this option, a range of health benefits is provided to reflect uncertainty regarding the level of $PM_{2.5}$ reduction from using cleaner fuels with existing vehicles, especially uncontrolled diesel jeepneys.

Table IV. 20. Net Present Value of Mitigation Options in the Transport Sector

Sequence Number of Mitigation Option	Mitigation Option	Incremental GHG Mitigation Potential (2015-2050) [MtCO2e]	Incremental Cost per Ton Mitigation (2015-2050) [2010 USD]		Net Present Value Excluding Value of GHG Reduction (2015-2050) [Billion 2010 USD] *with co-benefits*
			without co-benefits	with co-benefits	
Symbol		*D*	*E*	*K*	*L*
Formula			*C/D=E*	*E+J*	*D * -K*
32	Biofuels	[1]	63	63	-23
34	Buses and BRT	10.5	377	-1136	12
N/A*	CNG Buses	0.5	-483	-483	0.2
5	Congestion Charging	46	-129	-766	35
7	Driver Training	40	-105	-105	4.2
4	Jeepney Modernization	172	-137	-679	117
N/A	Electric LDV	14	-192	-251	3.5
N/A	Electric MCTC	1.2	-483	-583	0.7
N/A	Euro 4/IV and MVIS	55	1575	-285	16
N/A	Euro 6/VI and MVIS	55	3363	-2240 to 810	-44 to 123
N/A	LDV Efficiency	71	-57	-57	4.0
3	MVIS	46	-150	-2870	132
36	Rail	8.5	849	90	-0.8
N/A	Road Maintenance	85	-7	-7	0.6
N/A	Two-Stroke Replacement	0.1	939	745	-0.1

Notes:

Relatively Cost Effective. Negative Cost per Ton and Positive Net Present Value.

[1] The estimated GHG mitigation potential of transport biofuels would be 317 $MtCO_2e$, assuming no biogenic emissions from fuel combustion and not accounting for increased upstream emissions beyond domestic borders. This figure represents the potential to reduce emissions listed in the domestic emissions inventory, but excludes the considerable increase in upstream emissions that is likely in countries that export biofuels to the Philippines. These emissions outside the Philippine inventory are likely to reduce the net mitigation offered globally by increased Philippine biofuel imports by the order of 50%, dependent on the feedstock pathways used. These international emissions would proportionately increase the effective mitigation cost when

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[21] As a follow-up to this analysis, three alternative mitigation options could be evaluated:

1) New HDVs (especially buses) are required to meet Euro 3/III and be equipped with a DPF installed by the original equipment manufacturer. Such vehicles would require diesel with fewer than 50 ppm sulfur. This measure could result in much greater $PM_{2.5}$ reductions than Euro 4/IV at a lower cost than Euro 6/VI.

2) Euro 6/VI standards could be applied only to diesel vehicles while Euro 4/IV Standards would remain in effect for gasoline vehicles.

3) Euro 6/VI fuels could be introduced nationwide but not sold exclusively (meaning only new Euro 6/VI vehicles would be required to use cleaner 10 ppm sulfur fuels).

considered from a global perspective by a factor of around 2. In the worst case, depending on feedstocks, the implementation of any sustainability assurance, and on forest governance in exporter countries, a policy of expanded biofuel use may deliver no global net GHG benefit. A comprehensive discussion of the land use implications of biofuel policies is available in Malins et al. (2014).

Finally, Column L indicates the net present value of costs (including fuel savings) and co-benefits for health and traffic congestion. A positive value indicates a mitigation option has net benefits to society in addition to its potential to mitigate GHG emissions. Two mitigation options (Biofuels and Two-Stroke Replacement) would have costs that outweigh their (non-climate) benefits, indicating that society's willingness-to-pay for GHG mitigation would have to exceed the Cost per Ton Mitigation with Co-benefits (Column K) for these measures to be considered cost effective[22].

Table IV. 21 summarizes the effect of each mitigation option on a range of indicators of co-benefits. Indicators for each mitigation option are compared against the Baseline scenario, and are averaged over the years 2015-2050. While these co-benefits (with the exception of public health) were not assigned a monetary value, the change in each indicator shows the positive effect of mitigation options across a variety of categories. Energy intensity, measured as the total primary energy supply per unit GDP, decreases in all mitigation options except for Two-Stroke Replacement. GHG intensity, measured as economy-wide CO_2-equivalent emissions per unit GDP, decreases in all mitigation options. The share of imports (expressed as the percentage share of the total primary energy supply) decreases across all mitigation options, indicating energy security benefits. A similar pattern of benefits is shown in the increase in the share of renewables (expressed as the percentage share of the total primary energy supply) across all mitigation options. Employment increases were estimated for five mitigation options that would increase electricity demand – these co-benefits do not consider changes in employment for other reasons. Ten mitigation options would provide public health benefits, expressed as the cumulative number of outdoor air pollution-related deaths avoided, with the greatest benefits for public health achieved through Jeepney Modernizations, MVIS, and more stringent emission standards. The final column indicates the percentage share of outdoor air pollution-related female deaths avoided. A complete description of each indicator follows in Table IV. 22.

Table IV. 21. Additional Indicators for Mitigation Options in Transport

Mitigation Option	Change in Indicator						
	Energy Intensity	GHG Intensity	Share of Imports	Share of Renewables	Employment Generated	Public Health	Gender Health
2	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Biofuels	-0.040	-10.924	-0.466	2.116			
Buses and BRT	-0.007	-0.529	-0.049	0.037		14,177	37
CNG Buses	-0.001	-0.065	-0.004	0.003			
Congestion Charging	-0.017	-1.254	-0.117	0.074		23,789	37
Driver Training	-0.018	-1.319	-0.131	0.081			

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[22] Other mitigation options would still be considered cost effective even if the social cost of carbon-equivalent (expressed in USD per tonne) were zero.

Mitigation Option	Change in Indicator						
	Energy Intensity	GHG Intensity	Share of Imports	Share of Renewables	Employment Generated	Public Health	Gender Health
Electric LDV	-0.007	-0.378	-0.041	0.031	3,200	1,799	37
Electric MCTC	-0.003	-0.132	-0.016	0.012	790	244	36
Euro 6/VI and MVIS	-0.025	-1.952	-0.148	0.109		287,200 to 619,896 [1]	37 to 48
Euro 4/IV and MVIS	-0.025	-1.939	-0.148	0.109		209,537	37
Jeepney Modernization	-0.063	-4.904	-0.488	0.313	10,000	95,341	37
LDV Efficiency	-0.028	-1.813	-0.158	0.121			
MVIS	-0.022	-1.543	-0.153	0.092		124,808	37
Rail	-0.005	-0.315	-0.046	0.022	690	5,264	38
Road Maintenance	-0.050	-3.261	-0.273	0.216			
Two-Stroke Replacement	0	-0.013	-0.001	0.001	40	28	36

[1] Range of health co-benefits reflects uncertainty regarding the level of reduction in $PM_{2.5}$ emissions from diesel jeepneys running on cleaner (10 ppm sulfur) fuel. Studies in the U.S. (MECA, 1999) and Japan (WWFC, 2000) have found 10-50% reductions in $PM_{2.5}$ from uncontrolled diesel trucks switching from 300 ppm to 500 ppm to ultra-low sulfur fuel.

Table IV. 22. Description of Co-benefits Indicators

Notes	Variable	Description
2	Mitigation Option	Mitigation options are evaluated individually against the Baseline scenario.
3	Energy Intensity	Energy intensity is measured as total primary energy supply (indigenous production of primary energy + energy imports - energy exports) divided by GDP. The reported quantity is energy intensity with mitigation option minus energy intensity in the baseline scenario, averaged over 2015-2050. The data output for this metric is derived from the LEAP model. For the methods and data used to determine primary energy supply and GDP, please refer to Section 4 Energy.
4	GHG Intensity	Greenhouse (GHG) intensity is measured as CO_2e emissions (economy-wide, including from energy and non-energy sources) per unit of GDP. The reported quantity is carbon intensity with mitigation option minus GHG intensity in baseline scenario, averaged over 2015-2050.
5	Share of Imports	Percentage share of imports in total primary energy supply. The reported quantity is percentage share of energy imports with mitigation option minus percentage share of energy imports in baseline scenario, averaged over 2015-2050. The data output for this metric is derived from the LEAP model. For the methods and data used to determine energy imports and GDP, please refer to Section 4 Energy.
6	Share of Renewables	Percentage share of renewable energy in total primary energy supply. Renewable energy sources include biomass, geothermal, hydro, solar, wind, and ocean. The reported quantity is percentage share of renewables with mitigation option minus percentage share of renewables in reference scenario, averaged over 2015-2050. For the data and methods used to determine renewable energy supply please refer to Section 4 Energy.
7	Employment Generated	Cumulative number of job-years created in the power sector under a mitigation option over 2015-2050. This indicator does not account for employment gains or losses due to the mitigation option elsewhere in the economy.
8	Public Health	Cumulative number of outdoor air pollution-related deaths avoided due to a mitigation option.
9	Gender Health	Percentage share of outdoor air pollution-related female deaths avoided

IV.4.2.3 Marginal Abatement Cost Curve for Transport Sector Mitigation Options

Figure IV. 15 illustrates the marginal abatement cost curve (MACC) for seven transport mitigation options that were selected by the Department of Transport and Communications (DOTC) for further investigation, out of the fifteen options analysed in the CBA. A key issue in the estimation of mitigation potential and cost effectiveness is how to account for interactions between mitigation options and avoid overlap. For example, some mitigation options would reduce vehicle-kilometers traveled while others would improve in-use vehicle efficiency, leading to a potential overestimation of total GHG emission reductions if all mitigation options were simply summed up. The CBA addresses this issue by following the retrospective systems approach in Sathaye and Meyers (1995).

The MACC visually illustrates the cumulative abatement potential and direct costs per ton (not including co-benefits) if the seven transport mitigation options selected by DOTC were implemented, which could result in total cumulative emission reductions of about 640 $MtCO_2e$ compared with the baseline. The monetized co-benefits of these options are reported in the preceding section. Four mitigation options – MVIS, Jeepney Modernization, Congestion Charging, and Driver Training – have a negative cumulative net cost, where their capital and operational costs are outweighed in the long-term by the fuel and other savings. Transport Biofuels, Buses and BRT, and Rail have a positive cumulative net cost without considering co-benefits[23].The GHG mitigation potential of transport biofuels assumes no biogenic emissions from fuel combustion and does not account for the increase in upstream emissions that is likely in countries that export biofuels to the Philippines. If all the negative cost (not counting co-benefits) mitigation options were implemented (i.e., all those below the horizontal axis), the Philippines could achieve reductions of about 300 $MtCO_2e$ by 2050 compared to the baseline.

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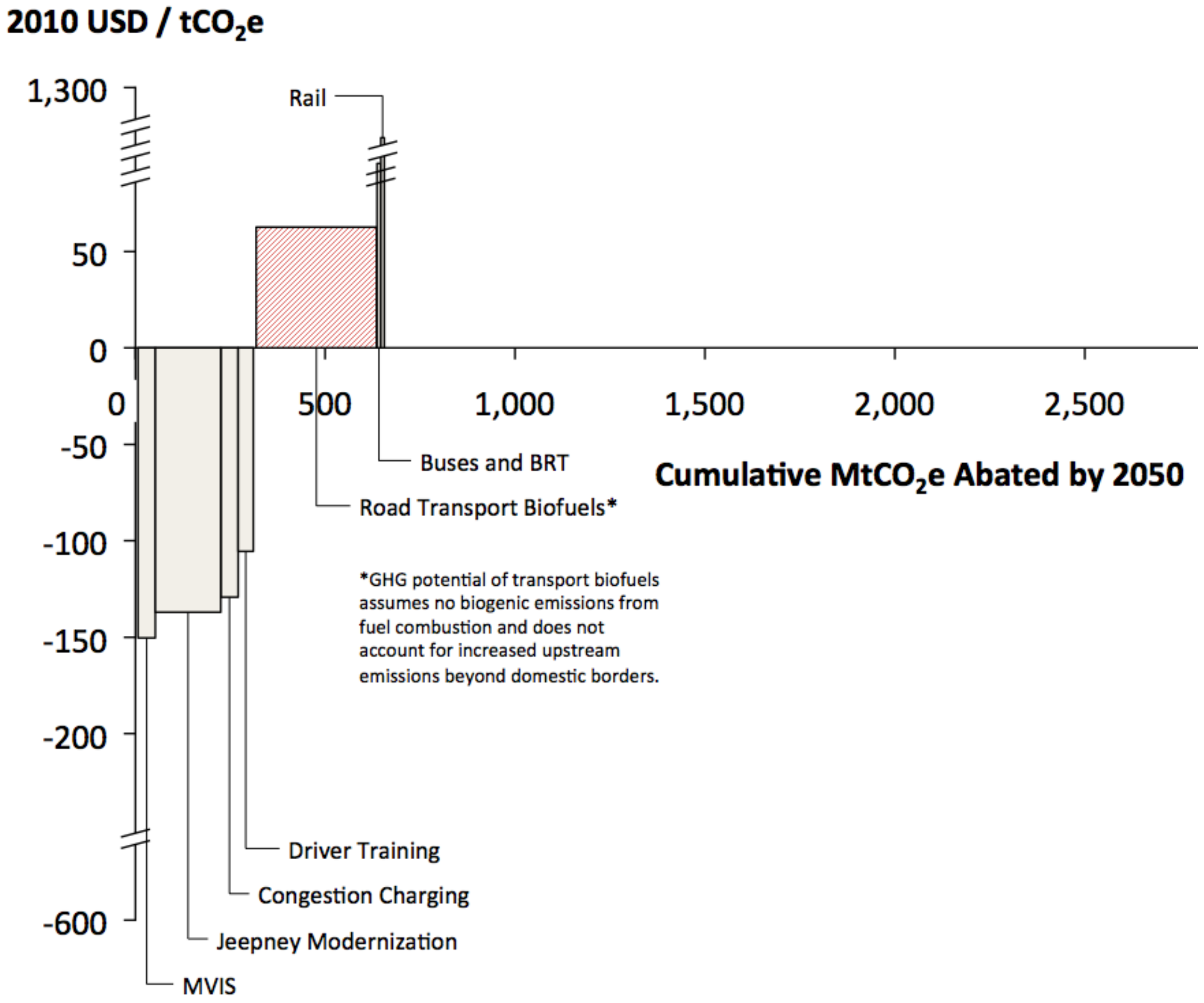
[23] Note that both Buses and BRT and Rail have a negative cumulative net cost when accounting for health and congestion co-benefits.

Figure IV. 15 . Marginal Abatement Cost Curve for the Transport Sector



*GHG potential of transport biofuels assumes no biogenic emissions from fuel combustion and does not account for increased upstream emissions beyond domestic borders.

IV.4.2.4 Conclusions

The findings of the CBA study have important implications for climate policy in the Philippines. Of the fifteen transport sector mitigation options assessed, thirteen options have the potential to reduce GHG emissions at a negative cost per ton when their co-benefits for congestion and public health are taken into consideration (Table IV. 23). Nine of these options have a negative cost per ton GHG mitigation based on their direct costs alone (comparing the sum of capital, O&M, implementation, and fueling costs with the Baseline). Considering the emphasis that has been placed on monetization of co-benefits during consultations with government officials and civil society, we recommend using the estimates of *Cost per Ton with Co-Benefits* and refining these estimates as needed to support decisions regarding the implementation of these mitigation options. Suggested next steps for each individual mitigation option are discussed in Table IV. 24.

Table IV. 23. Transport Sector Options with Negative Cost per Ton GHG Mitigation

Mitigation Option	Negative Incremental Cost per Ton *without co-benefits*	Negative Incremental Cost per Ton *with co-benefits*	Incremental GHG Mitigation Potential (2015-2050) [$MtCO_2e$]
Biofuels			[1]
Buses and BRT		▯	10.5
CNG Buses	▯	▯	0.5
Congestion Charging	▯	▯	46
Driver Training	▯	▯	40
Jeepney Modernization	▯	▯	172
Electric LDV	▯	▯	14
Electric MCTC	▯	▯	1.2
Euro 4/IV and MVIS		▯	55
Euro 6/VI and MVIS		▯	55
LDV Efficiency	▯	▯	71
MVIS	▯	▯	46
Rail		▯	8.5
Road Maintenance	▯	▯	85
Two-Stroke Replacement			0.1
Number of Options	9	13	

[1] The estimated GHG mitigation potential of transport biofuels would be 317 $MtCO_2e$, assuming no biogenic emissions from fuel combustion and not accounting for increased upstream emissions beyond domestic borders. This figure represents the potential to reduce emissions listed in the domestic emissions inventory, but excludes the considerable increase in upstream emissions that is likely in countries that export biofuels to the Philippines. These emissions outside the Philippine inventory are likely to reduce the net mitigation offered globally by increased Philippine biofuel imports by the order of 50%, dependent on the feedstock pathways used. These international emissions would proportionately increase the effective mitigation cost when considered from a global perspective by a factor of around 2. In the worst case, depending on feedstocks, the implementation of any sustainability assurance, and on forest governance in exporter countries, a policy of expanded biofuel use may deliver no global net GHG benefit. A comprehensive discussion of the land use implications of biofuel policies is available in Malins et al. (2014).

Table IV. 24. Suggested Next Steps for Transport Sector Mitigation Options

Mitigation Option	Suggested Next Steps
Biofuels	*By definition, the national GHG accounting method applied in the CBA Study could not take into account the full physical scope of net changes in GHG emissions as a result of increased use of biofuels in the transport sector. Follow-up analyses should consider biogenic emissions from fuel combustion as well as increased upstream emissions beyond domestic borders. Both of these factors are expected to reduce the estimated GHG mitigation potential of biofuels strategies.*

Mitigation Option	Suggested Next Steps
Buses and BRT	New buses should be as clean as possible to maximize the air quality benefits of shifting from jeepneys to buses and BRT. Low sulfur diesel is already available, which should allow for the introduction of buses that meet Euro IV standards. Euro VI buses could be introduced once ultra-low sulfur diesel is available in major cities.
CNG Buses	In the CBA Study, CNG buses were assumed to meet the same emissions standards as the diesel buses they replace; however, the benefits of CNG buses could be greater if these were required to meet more advanced (i.e. Euro VI) standards. Given appropriate regulatory or fiscal incentives, CNG buses could meet Euro VI requirements using a three-way catalyst, potentially at a lower cost than diesel buses and in advance of ultralow-sulfur diesel availability. Subsequent analyses could consider the impacts of a program to introduce Euro VI CNG buses compared to Euro II or Euro IV diesel buses. Such a program could be combined with the Buses and BRT mitigation option to accelerate benefits for air quality and public health.
Congestion Charging	As mentioned earlier, the allocation of revenues from congestion charging could significantly impact the viability of the program. For example, re-investing revenues in public transport expansion (e.g. Jeepney Modernizations, Buses and BRT, or Rail) could mitigate negative effects on low-income travelers and reduce the incentive to shift to motorcycles and tricycles. While the CBA Study focused on the climate benefits of a congestion charge, such a program could also be structured to promote cleaner vehicles and improve air quality. For example, Euro 4/IV vehicles could pay a lower charge than Euro 2/II vehicles, and electric vehicles could be exempted.
Driver Training	The CBA Study considered the impacts of a nationwide effort to train drivers of for-hire utility vehicles, for-hire buses, and commercial trucks to use fuel-saving best practices such as maintaining a steady speed and avoiding unnecessary acceleration and braking. In addition to saving fuel, such a program has the potential to improve road safety and reduce traffic congestion, though these potential co-benefits were not monetized for this option. One possible path forward would be to include the cost of driver training sessions in registration fees applied to for-hire and commercial vehicles, and require training certification to operate these vehicles.
Jeepney Modernization	Jeepney Modernization had one of the highest GHG mitigation potential of the options assessed, as well as substantial health co-benefits comparable with those of enhanced MVIS and emission standards. While replacing older diesel jeepneys with electric models was assessed to be cost effective from both a private and a societal perspective, substantial fiscal and non-fiscal incentives may be needed in order to reach the level of deployment assessed in this analysis (up to 25% of UV sales in 2030). Consultations with government officials revealed that previous efforts to promote electric vehicles utilized lower cost but older electric vehicle technology (e.g. lead acid batteries), which may have resulted in performance and reliability issues. As a result, it may be necessary to build trust in electric jeepney technologies, for example by working with manufacturers to offer purchase incentives, attractive leasing arrangements, driving range guarantees, or extended equipment and service warranties.
Electric LDV	The CBA Study evaluated total technology costs rather than the fiscal impacts of a particular program. A program to promote electric LDVs could involve a combination of fiscal and non-fiscal incentives. While purchase rebates or tax credits have been commonly offered in high-income countries, there may be a valid concern that these incentives disproportionately benefit high-income consumers who can afford to purchase brand new vehicles. Fiscal incentives could be more equitable if funded by equivalent fees on less efficient, brand new vehicles (i.e. as part of a feebate program to improve vehicle efficiency).
Electric MCTC	As with Electric LDV, the CBA Study evaluated total technology costs rather than the fiscal impacts of a particular program. A follow-up analysis could assess the costs and impacts of several possible programs to promote the sale of electric MC and TC over conventional models.

Mitigation Option	Suggested Next Steps
Euro 4/IV and MVIS	While the CBA Study assessed the impacts of requiring Euro 4/IV technologies on brand new vehicles only, it did not consider the impacts of applying these standards to all new and imported vehicles. Expanding Euro 4/IV standards to cover imported secondhand vehicles could augment the benefits of the program, particularly for older imported trucks and buses. A follow-up analysis could address these impacts, starting with the collection of additional data on sales of imported vehicles by vehicle type.
Euro 6/VI and MVIS	This analysis considered the incremental costs of providing ultra-low sulfur fuels for all on-road vehicles and Euro 6/VI technologies for brand new vehicles; however, there remains some uncertainty regarding the level of $PM_{2.5}$ reduction achievable from diesel jeepneys running on cleaner (10 ppm sulfur) fuel. Studies in the U.S. (MECA, 1999) and Japan (WWFC, 2000) have found 10-50% reductions in $PM_{2.5}$ from uncontrolled diesel trucks switching from 300 ppm to 500 ppm to ultra-low sulfur fuel. As a follow-up to this analysis, three alternative mitigation options could be evaluated: 1) New HDVs (especially buses) are required to meet Euro 3/III and be equipped with a DPF installed by the original equipment manufacturer. Such vehicles would require diesel with fewer than 50 ppm sulfur. This measure could result in much greater $PM_{2.5}$ reductions than Euro 4/IV at a lower cost than Euro 6/VI. 2) Euro 6/VI standards could be applied only to diesel vehicles while Euro 4/IV Standards would remain in effect for gasoline vehicles. 3) Euro 6/VI fuels could be introduced nationwide but not sold exclusively (meaning only new Euro 6/VI vehicles would be required to use cleaner 10 ppm sulfur fuels).
LDV Efficiency	LDV efficiency standards had one of the highest GHG mitigation potential amongst all options evaluated, and it could offer payback to consumers and operators on top of societal benefits of GHG mitigation. In terms of implementation, both a vehicle efficiency labeling program and a baseline study of new light-duty vehicles sold in the Philippines could support the development of mandatory efficiency standards. In the future, such standards could be applied to other vehicle types, including UV, MC, TC, buses, and trucks. This mitigation potential should be explored in subsequent analyses.
MVIS	Enhancing the MVIS is an essential first step to controlling emissions of local air pollutants from conventional vehicles. Consultations with government officials revealed widespread acknowledgment that the current system is not sufficient to catch high-emitting vehicles and ensure appropriate maintenance of engines and emission control equipment. In addition to promoting compliance with new emission standards, MVIS could be designed to enable additional emission control strategies by collecting data on the number of vehicles in operation, annual distance driven, fuel economy, vehicle age, and level of emission control.
Rail	The analysis of rail projects in DOTC's pipeline did not consider the costs of road maintenance that could be avoided through the expansion of rail services. Even without considering these potential avoided costs, DOTC's planned rail projects were estimated to have benefits that would exceed system costs, even before taking climate benefits into account.
Road Maintenance	In addition to saving fuel, improved road maintenance could potentially reduce vehicle maintenance costs due to less wear and tear, as well as increase travel speeds in rural areas. Considering the fivefold increase in vehicle activity projected in the Baseline scenario, the CBA Study did not consider rebound effects resulting from improved road quality. It is especially important to note that this measure considered the maintenance of existing roads rather than the construction of new roadways.

Mitigation Option	Suggested Next Steps
Two-Stroke Replacement	Replacement of two-stroke tricycles was not found to be a high priority GHG mitigation option under the assumptions for fuel efficiency, annual distance traveled, and maintenance cost applied in this analysis. Follow-up analyses could consider alternate strategies focused on air quality and public health, such as age limits or financial incentives to scrap high-emitting vehicles.

IV.1 CROSS-CUTTING ECONOMIC ASSUMPTIONS

The sector-specific baseline projections are based on the common set of projections for the Philippine economy characteristics. Table IV. 25 shows the data sources and assumptions used to generate these projections, while Table IV. 26 presents historical and projected values in select years that were used in the analysis. Table IV. 27 lists historical exchange rates and inflation rates used for inter-temporal and cross-country currency conversions.

Table IV. 25. Data Sources and Assumptions Used for Projections of Population, GDP, Economic Sector-Specific Value Added, and Fuel Price

Characteristic	Data Sources for 2010-2014 Estimates	Projection Method for 2015-2050
Population	1990-2010: Philippine Statistics Authority, National Statistical Coordination Board (http://www.nscb.gov.ph/secstat/d_popn.asp). Accessed 13 March 2015. 2011-2020: Philippine Statistics Authority, National Statistics Office (http://web0.psa.gov.ph/sites/default/files/attachments/hsd/pressrelease/Table4_9.pdf). Accessed 13 March 2015.	2011-2020: Philippine Statistics Authority, National Statistics Office (http://web0.psa.gov.ph/sites/default/files/attachments/hsd/pressrelease/Table4_9.pdf). Accessed 13 March 2015. 2021-2045: Philippine Statistics Authority, National Statistics Office (http://web0.psa.gov.ph/sites/default/files/attachments/hsd/pressrelease/Table1_8.pdf). Accessed 13 March 2015 2045-2050: Population is assumed to grow at average annual rate during 2035-2045.
GDP	1990-2010: Philippine Statistics Authority, National Statistical Coordination Board (http://www.nscb.gov.ph/sna/Rev_Ann_Qtr/1946_2010_NAP_Linked_Series_NSIC.xls). Accessed 12 March 2015. 2011: Philippine Statistics Authority, National Statistical Coordination Board (http://www.nscb.gov.ph/sna/2013/4th2013_RevisedMay2014/Revised_Q1_to_Q4_2011_to%202013.rar). Accessed 12 March 2015. 2012-2014: Philippine Statistics Authority, National Statistical Coordination Board (http://www.nscb.gov.ph/sna/2014/4th2014/tables/1Q4-Rev_Summary_93SNA.pdf). Accessed 12 March 2015.	GDP assumed to grow at similar rate as that projected by ADB in *Low-Carbon Scenario and Development Pathways for the Philippines* (ADB, 2015)

Characteristic	Data Sources for 2010-2014 Estimates	Projection Method for 2015-2050
Value Added by Industrial Sectors	1998-2010: Philippine Statistics Authority, National Statistical Coordination Board (http://www.nscb.gov.ph/sna/revisedQuarterlyPSNA/Annual (revised,rebased%2098-2000.rar). Accessed 12 March 2015. 2011-2013: Philippine Statistics Authority, National Statistical Coordination Board (http://www.nscb.gov.ph/sna/2013/4th2013_RevisedMay2014/Revised_Q1_to_Q4_2011_to%202013.rar). Accessed 12 March 2015. 2014: Philippine Statistics Authority, National Statistical Coordination Board (http://www.nscb.gov.ph/sna/2014/4th2014/tables/10MFG_93SNA_Q4.pdf, http://www.nscb.gov.ph/sna/2014/4th2014/tables/9MAQ_93SNA_Q4.pdf, http://www.nscb.gov.ph/sna/2014/4th2014/tables/11CNS_93SNA_Q4.pdf, and http://www.nscb.gov.ph/sna/2014/4th2014/tables/12EGW_93SNA_Q4.pdf). Accessed 12 March 2015.	All value added variables projected based on trends in their historical share of GDP.
Value Added by Commercial Sector	1998-2010: Philippine Statistics Authority, National Statistical Coordination Board (http://www.nscb.gov.ph/sna/revisedQuarterlyPSNA/Annual(revised,rebased%2098-2000.rar). Accessed 12 March 2015. 2011-2013: Philippine Statistics Authority, National Statistical Coordination Board (http://www.nscb.gov.ph/sna/2013/4th2013_RevisedMay2014/Revised_Q1_to_Q4_2011_to%202013.rar). Accessed 12 March 2015. 2014: Philippine Statistics Authority, National Statistical Coordination Board (http://www.nscb.gov.ph/sna/2014/4th2014/tables/1Q4-Rev_Summary_93SNA.pdf). Accessed 12 March 2015.	All value added variables projected based on trends in their historical share of GDP.

Characteristic	Data Sources for 2010-2014 Estimates	Projection Method for 2015-2050
Value Added by Agriculture, Forestry, Fishing	1998-2010: Philippine Statistics Authority, National Statistical Coordination Board (http://www.nscb.gov.ph/sna/revisedQuarterlyPSNA/Annual(revised,rebased%2098-2000.rar). Accessed 12 March 2015. 2011-2013: Philippine Statistics Authority, National Statistical Coordination Board (http://www.nscb.gov.ph/sna/2013/4th2013_RevisedMay2014/Revised_Q1_to_Q4_2011_to%202013.rar). Accessed 12 March 2015. 2014: Philippine Statistics Authority, National Statistical Coordination Board (http://www.nscb.gov.ph/sna/2014/4th2014/tables/8AFF_93SNA_Q4.pdf). Accessed 12 March 2015.	All value added variables projected based on trends in their historical share of GDP
Biomass	Department of Environment and Natural Resources, 2013 Philippine Forestry Statistics, Table 4.10 MONTHLY RETAIL PRICES OF FUELWOOD AND CHARCOAL: 2013 (http://forestry.denr.gov.ph/PFS2013.pdf)	Assumed same as the constant price for 2010-2014
Coal Sub bituminous	Data gathered by B-LEADERS project, 2015 (Philippine Coal Importation.xlsx) and national energy balances. Note that prices are based on imported coal only.	IEA (2014), World Energy Outlook 2014, IEA, Paris. (Current Policies scenario)
Natural Gas	Fuel price data provided by DOE to B-LEADERS project, 2015 (USAID Request_historical prices-03.04.2015.xls)	IEA (2014), World Energy Outlook 2014, IEA, Paris. (Current Policies scenario)
Nuclear	IPCC AR5 WG3 Annex III	Assumed same as the constant price for 2010-2014
Crude Oil	Fuel price data provided by DOE to B-LEADERS project, 2015 (USAID Request_historical prices-03.04.2015.xls)	IEA (2014), World Energy Outlook 2014, IEA, Paris. (Current Policies scenario)
Avgas	Fuel price data provided by DOE to B-LEADERS project, 2015 (USAID Request_historical prices-03.04.2015.xls)	Grows at the rate of crude oil
Lubricants	Same as Residual Fuel Oil	Same as Residual Fuel Oil
Bitumen	Fuel price data provided by DOE to B-LEADERS project, 2015 (USAID Request_historical prices-03.04.2015.xls)	Grows at the rate of crude oil
Naphtha	Fuel price data provided by DOE to B-LEADERS project, 2015 (USAID Request_historical prices-03.04.2015.xls)	Grows at the rate of crude oil
Other Oil	Same as Residual Fuel Oil	Same as Residual Fuel Oil
LPG	Fuel price data provided by DOE to B-LEADERS project, 2015 (USAID Request_historical prices-03.04.2015.xls)	Grows at the rate of crude oil

Characteristic	Data Sources for 2010-2014 Estimates	Projection Method for 2015-2050
Residual Fuel Oil	Fuel price data provided by DOE to B-LEADERS project, 2015 (USAID Request_historical prices-03.04.2015.xls)	Grows at the rate of crude oil
Diesel	Fuel price data provided by DOE to B-LEADERS project, 2015 (USAID Request_historical prices-03.04.2015.xls)	Grows at the rate of crude oil
Kerosene	Fuel price data provided by DOE to B-LEADERS project, 2015 (USAID Request_historical prices-03.04.2015.xls)	Grows at the rate of crude oil
Jet Kerosene	Fuel price data provided by DOE to B-LEADERS project, 2015 (USAID Request_historical prices-03.04.2015.xls)	Grows at the rate of crude oil
Motor Gasoline	Fuel price data provided by DOE to B-LEADERS project, 2015 (USAID Request_historical prices-03.04.2015.xls)	Grows at the rate of crude oil
Biodiesel	Renewable Energy Management Bureau, DOE	Grows at the rate of crude oil
Ethanol	Fuel price data provided by DOE to B-LEADERS project, 2015 (USAID Request_historical prices-03.04.2015.xls)	Grows at the rate of crude oil
CNG	Department of Energy. “Compressed Natural Gas,” 2015. http://www.doe.gov.ph/programs-projects-alternative-fuels/297-compressed-natural-gas	CNG price held constant until 2016 per Velasco, Myrna. “DOE Admits Delayed Rollout of CNG Buses.” Manila Bulletin, 2014. http://www.mb.com.ph/doe-admits-delayed-rollout-of-cng-buses/. After 2016, CNG price based on price of natural gas plus cost adders for compression, distribution, refining, taxes, and retail mark-up shown in American Clean Skies Foundation. Driving on Natural Gas: Fuel Price and Demand Scenarios for Natural Gas Vehicles to 2025, 2013.

Table IV. 26 Data and Projections of Population, GDP, Economic Sector-Specific Value Added, and Fuel Price in Select Historical and Baseline Years

	Historical Data				Baseline								
Year	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Population (Millions)	61	69	77	85	92	102	110	118	125	132	138	142	147
GDP (Billions 2010 USD)	98	106	132	161	200	274	336	474	611	793	1,060	1,433	1,895
Value Added by Economic Sectors (Millions 2010 USD)													
Beverages	1094	1187	1413	1232	1573	2166	2392	2631	2884	3152	3437	3739	4059
Tobacco	515	558	725	364	169	129	119	110	100	92	83	76	69
Food Manufactures	7123	7725	10420	14346	18193	23711	30501	39089	49929	63590	80780	102383	129502
Textile and Leather	2785	3021	3314	3156	2508	2542	2343	2153	1971	1799	1638	1488	1349
Wood and Wood Products	819	888	954	1049	777	1006	965	923	879	835	792	748	706
Paper Pulp and Print	684	742	879	650	627	865	837	807	776	743	710	677	645
Chemical and Petrochemical	1694	1837	2126	2468	2595	5697	7351	9449	12106	15465	19705	25050	31782
Non Metallic Minerals	762	827	795	771	1146	1274	1338	1400	1460	1518	1575	1629	1683
Iron and Steel	661	717	650	819	1040	835	808	778	748	716	684	652	620
Machinery	1532	1662	2624	2668	2603	2469	2566	2657	2742	2821	2895	2965	3030
Rubber and Rubber Products	424	460	534	532	616	634	644	652	657	661	663	664	664
Petroleum and Other Fuel Products	1080	1171	1892	2616	2984	3126	3859	4746	5819	7112	8672	10548	12805
Other Manufacturing	3791	4112	5913	8029	7972	7010	7586	8177	8786	9413	10058	10724	11410
Mining	830	900	829	1972	2854	2493	3111	3868	4794	5923	7300	8976	11015

	Historical Data				Baseline								
Year	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Construction	6225	6752	7504	7625	12220	16201	19385	23107	27453	32522	38427	45302	53298
Electricity Gas Water Supply	3649	3958	4828	6139	7128	8200	9398	10729	12208	13851	15675	17699	19943
All Commercial	49783	53995	67958	86076	110009	145430	180027	222018	272898	334462	408861	498673	606984
Agri Crops Product	7201	7810	9214	10318	13304	16309	18733	21437	24449	27804	31537	35691	40310
Livestock and Poultry	3666	3976	4725	5177	5592	5882	6106	6313	6507	6687	6854	7009	7153
Agri Services	946	1026	1172	1314	1633	1907	2117	2341	2580	2836	3109	3400	3711
Forestry	94	102	192	129	54	91	84	77	70	64	58	53	48
Fishing	2544	2759	3100	3439	3995	3799	3860	3908	3943	3967	3981	3986	3982
Value Added by Economic Sectors (Millions 2010 USD)													
Biomass	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Coal Sub bituminous	1.77	1.77	1.77	2.75	4.27	4.39	5.14	5.37	5.62	5.78	5.95	6.13	6.31
Natural Gas	1.46	1.46	1.46	6.54	8.89	9.96	9.43	9.83	10.24	10.55	10.87	11.2	11.54
Nuclear	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
Crude Oil	5.13	5.13	5.13	8.67	12.49	15.68	16.73	18.31	20.05	21.18	22.37	23.63	24.96
Avgas	14.44	14.44	14.44	21.7	32.79	33.45	35.69	39.07	42.78	45.19	47.73	50.41	53.24
Lubricants	8.46	3.49	9.33	14.02	18.76	19.41	20.71	22.68	24.83	26.22	27.7	29.25	30.9
Bitumen	5.5	5.5	5.5	5.24	13.12	13.14	14.01	15.34	16.8	17.74	18.74	19.8	20.91
Naphtha	7.51	7.51	7.51	7.74	11.19	14.13	15.07	16.5	18.07	19.09	20.16	21.29	22.49
Other Oil	8.46	3.49	9.33	14.02	18.76	19.41	20.71	22.68	24.83	26.22	27.7	29.25	30.9
LPG	6.8	5.59	7.69	11.24	15.34	16.38	17.47	19.13	20.95	22.13	23.37	24.69	26.07
Residual Fuel Oil	8.46	3.49	9.33	14.02	18.76	19.41	20.71	22.68	24.83	26.22	27.7	29.25	30.9

Year	Historical Data				Baseline								
	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Diesel	11.99	9.34	11.9	21.6	19.93	21.47	22.91	25.08	27.46	29	30.63	32.36	34.18
Kerosene	12.47	9.71	11.89	23.04	25.35	26.23	27.97	30.63	33.54	35.42	37.41	39.52	41.74
Jet Kerosene	21.72	18.65	15.47	25.57	29.52	30.04	32.04	35.08	38.41	40.57	42.85	45.26	47.81
Motor Gasoline	20.42	13.65	17.85	27.27	29.09	30.58	32.62	35.71	39.1	41.3	43.62	46.08	48.67
Biodiesel	28.59	28.59	28.59	28.59	28.59	31.3	33.39	36.56	40.03	42.28	44.66	47.17	49.82
Ethanol	19.08	19.08	19.08	19.08	33.89	29.71	31.69	34.7	38	40.13	42.39	44.77	47.29
CNG	9.07	9.07	9.07	9.07	9.07	9.07	19.16	19.56	19.97	20.28	20.61	20.94	21.28

Table IV. 27 Historical Exchange Rates and Inflation Rates used to Build the Baseline

Year	Philippine Peso per US Dollar[1]	Philippine Peso Annual Inflation Rate (%)[2]	US Dollar Annual Inflation Rate (%) [3]
1990	24.31	12.30	3.71
1991	27.48	19.40	3.32
1992	25.51	8.60	2.28
1993	27.12	6.70	2.38
1994	26.42	10.50	2.12
1995	25.71	6.70	2.09
1996	26.22	7.50	1.82
1997	29.47	5.60	1.72
1998	40.89	9.30	1.08
1999	39.09	5.90	1.43
2000	44.19	4.00	2.28
2001	50.99	6.80	2.28
2002	51.60	3.00	1.53
2003	54.20	3.50	1.99
2004	56.04	6.00	2.75
2005	55.09	7.60	3.22
2006	51.31	6.20	3.07
2007	46.15	2.80	2.67
2008	44.47	9.30	1.93
2009	47.64	3.20	0.79
2010	45.11	3.80	1.23
2011	43.31	4.40	2.06
2012	42.23	3.20	1.80
2013	42.45	3.00	1.49
2014	44.40	4.10	1.25

Notes:

[1] Source: Bangko Sentral Ng Pilipinas (http://www.bsp.gov.ph/statistics/statistics_online.asp -> Online Statistical Interactive Database -> Exchange Rates -> Philippine Peso per US Dollar). Accessed 12 March 2015.
Bankers Association of the Philppines (BAP) reference rate from December 13,1984 to August 3,1992 weighted average rate. Philippine Dealing System (PDS) starting August 14,1992 From: Reference Exchange Rate Bulletin, TD-BSP

[2] Sources:
1990-2011: Bangko Sentral Ng Pilipinas (http://www.bsp.gov.ph/statistics/statistics_online.asp -> Online Statistical Interactive Database -> Prices -> Consumer Price Index, Inflation Rate, and Purchasing Power of the Peso). Accessed 12 March 2015.
2012-2014: http://web0.psa.gov.ph/statistics/survey/price/summary-inflation-report-consumer-price-index-2006100-february-2015. Accessed 12 March 2015.

[3] Sources:
1990-2013: World Bank World Development Indicators (http://data.worldbank.org/indicator/NY.GDP.DEFL.KD.ZG). Accessed 12 March 2015.
2014: US. Bureau of Economic Analysis, Gross Domestic Product: Implicit Price Deflator [GDPDEF], retrieved from FRED, Federal Reserve Bank of St. Louis https://research.stlouisfed.org/fred2/series/GDPDEF/, March 25, 2015.

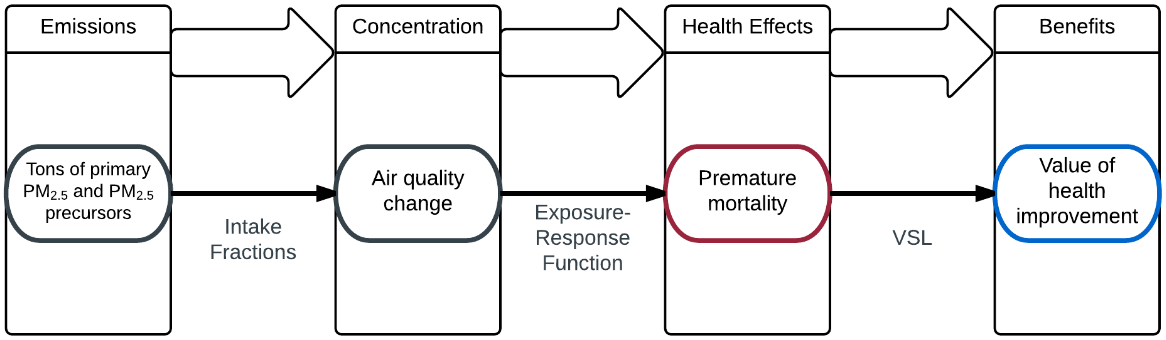
IV.2 HEALTH CO-BENEFITS METHODS

B-LEADERS team estimated the human health co-benefits of the mitigation options according to the basic framework presented in Figure IV. 16:

- Emissions from the LEAP model are converted to outdoor air pollution concentrations. The emissions from the LEAP Baseline case inform the baseline concentration estimates and the predicted change in emissions in each mitigation scenario is translated to air quality change. We focus on concentrations of fine particulate matter ($PM_{2.5}$), which has dominated cost-benefit analyses of reduced air pollution.[24]
- The health benefits of reduced exposure to outdoor air pollution come from reduced risk of morbidity and premature mortality. The risk reductions are calculated using research literature-based epidemiological relationships known as "exposure-response functions". In this analysis, we estimate the co-benefits associated with reduced risk of premature mortality.[25]
- To express the social benefit of fewer premature deaths in monetary terms, we rely on the concept of the aggregate willingness to pay (WTP) for small reductions in annual mortality risk by a population of a given size. We estimate the WTP is as a product of the number of premature deaths avoided due to a mitigation option and the value per statistical life (VSL), a risk reduction-normalized WTP estimate derived from the research literature.

Each of these steps is described in depth below, and methodological differences between the transportation and energy sectors are explained.

Figure IV. 16. General Framework for Health Co-Benefits Calculation



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[24] Ozone is another important pollutant, but modeling ozone levels is outside of the scope of this analysis. Furthermore, the Global Burden of Disease Study found that deaths attributable to ambient ozone levels were less than 5% the number of deaths attributable to ambient $PM_{2.5}$ levels (Lim et al., 2013).

[25] We focus on all-cause mortality, since there may not be sufficient data to estimate cause-specific mortality. There are also associations between $PM_{2.5}$ and non-mortality (morbidity) health endpoints, but these tend to be smaller in cost benefit analysis.

IV.2.1 Emissions

The relevant emissions for the health co-benefits we consider are primary $PM_{2.5}$ and two gaseous precursors to secondary $PM_{2.5}$, NOx and SO_2. Primary $PM_{2.5}$ is the mass of particulates that is emitted directly from an emissions source, while secondary $PM_{2.5}$ forms from the oxidation of primary gases in the atmosphere. The LEAP model provides national-scale estimates of primary $PM_{2.5}$ and secondary $PM_{2.5}$ precursors for each sector and each mitigation scenario. For the transport sector, health co-benefits are estimated based on tank-to-wheel primary $PM_{2.5}$ emissions only. For the energy sector, health co-benefits are estimated based on emissions of NOx, SO_2, and primary $PM_{2.5}$.

IV.2.1.1 Transportation sector emissions

For the transportation sector, the mitigation options focus on on-road vehicles. For these mitigation options, we only model the co-benefits of downstream (tank-to-wheel) reductions in primary $PM_{2.5}$ emissions. With one exception, the team does not estimate the additional upstream (well-to-tank) impacts that these policies may have by reducing refinery emissions or emissions elsewhere in the energy sector, as the team does not have sufficient information to characterize the resulting change in exposure. The exception is for vehicle electrification policy. For the three options that involve replacing a share of the fleet with electric vehicles, we account for the increased upstream emissions by on-grid power generation.

The team followed the same general methods for calculating conventional pollutant emissions for on-road transportation as those described for GHG emissions. The team used emission factors from the ICCT Roadmap Model (ICCT 2014). A report by the Asian Development Bank (1992) was the only resource providing emission factor information specific to the Philippines, and presents emission factors that do not likely apply to most vehicles currently on the road, and did not include emission factors for methane, nitrous oxide, or black carbon. The team used emission factors from the ICCT Roadmap Model, and used the ADB report as a reference to check against the emission factors for uncontrolled vehicles. Where there were large discrepancies between emission factors reported by ADB (1992) for a specific pollutant or mode and those used in the Roadmap, the emission factors were adjusted using a third source, the zero-mile emission rates used in the ICCT India Model (Bansal and Bandivadekar, 2013). In some cases, additional adjustments were made to fill gaps for relevant pollutants and vehicle fuel types. Adjustments by mode, fuel type and pollutant are shown in Table IV. 28.

Table IV. 28. Selection of Road Vehicle Emission Factors

Vehicle - Fuel type	$PM_{2.5}$	CH_4	BC	N_2O	NO_X	CO
MC - diesel	-	* (4-6)	-	-	-	-
MC - gasoline	†	-	* (6)	-	-	-
TC - diesel	-	* (6)	-	-	-	-
TC - gasoline	†	-	* (6)	-	-	-
Bus - CNG	‡ (VI, diesel)	‡ (VI, diesel)	* (all)	* (all)	-	-
Bus - diesel	-	-	-	-	-	-

Bus - gasoline	-	-	-	-	-	-
Truck - diesel	* (6)	-	-	-	-	-
Truck - gasoline	-	-	-	-	-	-
LDV - diesel	-	* (4-6)	* (6)	* (uncontrolled)	-	-
LDV - gasoline	†	-	†	-	-	-
LDV - LPG	†	-	†	* (uncontrolled, 6)	-	-
UV - diesel	•	-	•	-	•	•
UV - gasoline	•	-	•	-	•	•

KEY:

Parentheses indicate Euro-equivalent emission standards/fuels. For example, (VI) indicates Euro VI.

- No change to ICCT Roadmap Model Emission Factors
* Missing emission factors for some control levels were filled in from ICCT India Model (emission control levels)

† India Model emission factors substituted for all control levels due to better match with ADB (1992)

‡ Emission factor for some control levels estimated to be reduced proportionally from EFs from earlier standards (emission control level, fuel type proportion was based on)

• Emission factor for uncontrolled vehicles taken from ADB (1992), emission factors for subsequent control levels calculated as a proportional reduction from uncontrolled level using reductions from Roadmap Model Emission Factors.

IV.2.1.2 Energy sector emissions

Within the energy sector, the team models the health impacts of emissions from on grid power generation only. While on grid power generation produces the largest share of $PM_{2.5}$, NOx, and SO_2 emissions, other activities within the energy sector (grid electricity generation, oil production and transport, biofuel production, and charcoal production) also contribute to local air pollution and health impacts. As the team does not have sufficient information to characterize exposure to emissions from these sources, the impacts of other activities are not included in our health co-benefit estimates.

In general, Philippine sources were used for all pollutants except PM. As the available Philippine sources do not cover PM, factors for this pollutant were taken from international literature. International sources were also consulted to fill gaps in the Philippine sources relating to other pollutants and particular fuels or fuels and technologies (e.g., emissions from ultrasupercritical coal power plants). The $PM_{2.5}$ emission factors for on grid power generation are taken from U.S. EPA (2014) and IEA (2012); NOx emission factors are taken from DENR (2011), Manila Observatory (2010), IPCC (2015), U.S. EPA (2014), and IEA (2012); and SO_2 emission factors are taken from Manila Observatory (2010), U.S. EPA (2014), and IEA (2012).

IV.2.2 Concentrations

The next step in estimating health co-benefits is to use the projected emissions from the LEAP model to estimate the baseline $PM_{2.5}$ concentration and the change in $PM_{2.5}$ concentration resulting from each of the mitigation options. Specifically, we estimate the annual average ambient $PM_{2.5}$ concentration in urban and rural areas. The team does not conduct dispersion modeling, but instead apply the results of previous dispersion modeling studies using intake fractions.

IV.2.2.1 Baseline concentrations

The exposure-response function used to estimate the change in health requires an estimate of the baseline $PM_{2.5}$ concentration in addition to the change in concentration from each mitigation option. The team estimates the baseline ambient $PM_{2.5}$ concentrations using both measured data and modeled data, the latter using the previously discussed modeled emissions from the transportation and energy sectors as a key input. Since the annual average concentration of $PM_{2.5}$ varies significantly between rural areas and urban areas, we model concentrations separately for rural and urban areas. For rural areas, baseline exposure integrates measured concentrations (see Table IV. 29)Table IV. 1Table IV. 29 and changes from the power sector only. The effects of transportation in rural areas are minor and dominated by secondary $PM_{2.5}$ formation, which we are not modeling for transport. For urban areas, baseline exposure is informed by measured concentrations and the contribution of the transportation and power sectors. A single baseline urban exposure is assumed for energy sector impacts, while transportation impacts assume two baselines: one average concentration for major cities in the Philippines and a separate baseline concentration for Metro Manila.

The team models the urban baseline concentration in all years by estimating a background concentration, defined as the concentration without contributions from the transportation or energy sectors, and then adding the additional modeled concentration from the Baseline case transportation and energy sector emissions in a given year. This calculation is shown in Equation 1 and Equation 2 below:

Equation 1. $$C_{Background} = C_{Measured,2010} - (C_{Transport,2010} + C_{Energy,2010})$$

Equation 2. $$C_y = C_{Background} + C_{Transport,y} + C_{Energy,y}$$

The background concentration ($C_{Background}$) is calculated as the measured concentration in the year 2010 ($C_{Measured,2010}$) minus the modeled contribution from transportation ($C_{Transport,2010}$) and energy ($C_{Energy,2010}$) in the year 2010. The background concentration is held constant through 2050, and the baseline concentration in a given year y (C_y) is calculated as the sum of the background concentration and the modeled contribution from transportation ($C_{Transport,y}$) and energy ($C_{Energy,y}$) in the Baseline Scenario in the year y. The rural baseline concentration is calculated using similar methods, but excluding $C_{Transport,2010}$ and $C_{Transport,y}$.

There are limited data reporting measurements of $PM_{2.5}$ in the Philippines for use as $C_{Measured,2010}$ in Equation 1 above. Three measurements were available monitoring sites for the year 2010 (Cities Act

2010), shown in Table IV. 29 and two additional studies provided supplementary measurements from previous years. A value of 35 µg/m^3 was assumed for Manila, an average of monitoring data and concentrations reported in supplementary studies (Cities Act 2010, Oanh et al. 2012). For urban areas where there was no measurement data, a default value of 15 µg/m^3 was assumed. For rural areas, a $PM_{2.5}$ concentration of 9.5 µg/m^3 was taken from Oanh et al. (2012).

Table IV. 29. Urban and rural measurements of $PM_{2.5}$ concentrations

City/station	Annual mean $PM_{2.5}$ (µg/m^3)	Year(s) of measurement	Source
Baguio	49	2010	Cities Act 2010
Cebu	22	2010	Cities Act 2010
Manila	22	2010	Cities Act 2010
Manila	46	2001-2007	Cohen et al. 2009
Manila	45	2006-2008	Oanh et al. 2012
Rural background	9.5	2006-2008	Oanh et al. 2012

IV.2.2.2 Converting emissions to concentrations using intake fractions

Estimates of $\mathbf{C}_{\mathbf{Transport}}$, $\mathbf{C}_{\mathbf{Energy}}$, and the change in concentrations from both sectors resulting from each of the mitigation options are produced using source-specific intake fractions. The relationship between emissions of $PM_{2.5}$ and $PM_{2.5}$ precursor species (including NOx and SO_2) to the change in ambient $PM_{2.5}$ concentrations is complex, and depends on numerous factors including local meteorological patterns (e.g. wind speed, temperature) and characteristics of the emissions source (location, plume height, exhaust temperature). Use of a chemical transport model would produce detailed, localized concentration estimates, but for our purposes would introduce undue complexity to the task of projecting the air quality impacts of many scenarios up to 35 years into the future, with little baseline information about local air quality. We use a set of factors called intake fractions (iFs) to estimate the contribution of emissions from transport and energy sectors to ambient $PM_{2.5}$ levels, separately for the Baseline Scenario and for the mitigation options under consideration. Because of the uncertainty associated with this simplified method, this analysis is useful to indicate the order of magnitude of the health benefits but does produce highly precise results. The iFs are derived from more complex air quality modeling using the equation shown in Equation 3. They are specific to a given emissions source, such as on-road vehicles, and to a given pollutant, such as primary $PM_{2.5}$ or NOx.

$$\text{intake fraction} = \frac{\text{population intake}}{\text{total emissions}} = \frac{\int_{T_1}^{\infty} \left(\sum_{i=1}^{P} (C_i(t)Q_i(t))\right)dt}{\int_{T_1}^{T_2} E(t)dt}$$

Equation 3. Equation for calculating intake fraction (from Apte et al. 2012)

Equation 3 shows that intake fraction is specific to a population of size P, with breathing rate Q. Once the value of the intake fraction has been calculated, and the population and breathing rate are known, the equation can be re-arranged and solved to directly give the relationship between total emissions E and concentration C. The team keeps this ratio of unit of concentration per unit emissions fixed over time, and use it to calculate air pollution change for each mitigation option.[26]

IV.2.2.3 Transport sector intake fractions

The set of intake fractions (iFs) used for on-road vehicles were developed for major urban areas worldwide, and include 30 specific to the Philippines (Apte et al. 2012). These intake fractions apply only to conserved pollutants like primary $PM_{2.5}$, not pollutants that undergo significant transformation in the atmosphere, like NOx and SO_2. The team used these emission factors for the 18 largest cities in the Philippines, as the team had reliable population projections for these cities. As described above, the intake fractions were divided by the relevant city populations (Angel et al. 2010, as cited in Apte et al. 2012) and a breathing rate of 5292.5 m^3/year to derive the ratio of unit concentration per unit emissions for each city, shown in Table IV. 30Table IV. 30. Variation in these values across cities occurs due to differences in city size, as well as meteorological factors such as average wind speed. In a city with a larger footprint, emissions are distributed over a larger area and so the ratio of concentration to emissions is lower. For example, the ratio is lowest in Metro Manila, which has a footprint of about 900 km^2 compared to an average of 100 km^2 across the other cities (Angel et al. 2010). However, a low ratio should not be understood to indicate a low impact; in fact, because of the large share of emissions and the large population in Manila, it is modeled to have the largest share of transportation-related health impacts.

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[26] Rather than solving for the concentration-to-emissions ratio in a single year and holding that value constant, year-to-year change in city-specific intake fractions may be modeled using population projections and assumptions about linear population density (see Chambliss et al. 2013, Marshall 2007). The concentration-to-emissions ratio is then calculated separately for each year. This approach was not applied in this analysis due to maintain consistency in calculations across sectors.

Table IV. 30. Concentration-to-emissions ratio used for 18 largest cities in the Philippines

City	Concentration-to-emissions ratio (ug/m^3 change per kiloton emitted)
Metro Manila	1.4
Lipa City	14.3
Butuan	19.8
Batangas City	9.5
Iligan	25.2
Cotabato	8.4
Baguio City	5.6
Angeles City	3.3
Mandaue City	11.2
Basilan City (including City of Isabela)	11.2
Lapu-Lapu City	11.2
Iloilo City	11.9
Bacolod	6.8
General Santos City	7.0
Cagayan de Oro City	10.5
Zamboanga City	17.4
Cebu City	2.5
Davao City	5.3

Although the intake fractions used for the transportation sector cover only contributions to ambient $PM_{2.5}$ from primary $PM_{2.5}$ emissions, on-road vehicles contribute to the formation of secondary $PM_{2.5}$ in the atmosphere from emissions of NOx and SO_2. The health impacts of secondary PM were not included in the assessment of health co-benefits from the transportation sector. An initial estimate was made that compared both the scale of reductions of NOx and SO_2 emissions expected from emission control policies and the intake fractions for secondary $PM_{2.5}$ from NOx and SO_2 (Humbert et al. 2011) to those for primary $PM_{2.5}$. This estimate found that the health impacts from secondary particulates would add roughly 25% to the health co-benefits of policies focused on conventional pollutant reduction (e.g. emission standards).

IV.2.2.3 Energy sector iFs

For the energy sector, three iFs are used, one for primary $PM_{2.5}$ (6 x 10^{-7}), one for secondary $PM_{2.5}$ from SO_2 (2 x 10-7), and one for secondary $PM_{2.5}$ from NO_2 (6 x 10^{-8}). These iFs are based on a study of exposure to energy sector emissions in the US from (Levy et al. 2003). The resulting concentration-to-emissions ratios are shown in Table IV. 31. The concentration change is assumed to occur throughout the country.

Table IV. 31. Concentration-to-emissions ratio used for the energy sector

Concentration-to-emissions ratio (ug/m^3 change per kiloton emitted)		
$PM_{2.5}$	NOx	SO_2
0.91	0.09	0.30

IV.2.2.4 Disaggregating national transportation emissions to urban areas

As the on-road intake fractions only apply to urban areas, the emissions outputs from the LEAP model must also be scaled to the urban level. The share of national emissions occurring in Metro Manila ($Share_{MM}$) was estimated for each mode based on the national share of vehicle registrations within the national capital region. Less information on registration share was available for the 17 remaining cities. The cumulative share of national emissions occurring in those cities and excluding Metro Manila (urban share without Manila, or $Share_{UR-M}$) was estimated from the share of population and highway infrastructure in urban areas following a methodology applied and described previously by Chambliss et al. (2013). The urban share for Metro Manila and the combined share across the other 17 cities are given in Table IV. 32. $Share_{UR-M}$ is further subdivided across each of the 17 cities based on population.

Table IV. 32. Share of national emissions in Metro Manila and aggregate of 17 largest cities in the Philippines (excluding Metro Manila)

Mode	Share of emissions in Metro Manila, $Share_{MM}$	Share of emissions aggregated across 17 largest cities excluding Metro Manila, $Share_{UR-M}$
Bus	44%	24%
LDV	52%	15%
MC	18%	32%
TC	18%	32%
Truck	22%	13%
UV	32%	16%

IV.2.3 Health Impacts

Outdoor air pollution is associated with adverse health effects ranging from worsened asthma symptoms to early death from heart and lung disease. This study focuses on the fatal impacts of $PM_{2.5}$, and estimates impacts using Integrated Exposure-Response (IER) functions developed for the Global Burden of Disease 2010 study (Lim et al. 2012, Burnett et al. 2014).

The integrated exposure-response (IER) functions are described in depth in Burnett et al. 2014. The GBD 2010 study applied the IER functions to estimate the mortality attributed to $PM_{2.5}$ from ambient sources, as well as indoor sources, such as cook stoves and smoking (Lim et al. 2013). The IER functions combine the results of several types of epidemiological studies, including those conducted in high $PM_{2.5}$ exposure settings (e.g., exposure to tobacco smoke). Therefore, a health impact assessment based the IER functions is a better extrapolation of air pollution mortality risk for populations exposed to high ambient $PM_{2.5}$ levels, compared to extrapolations based on a single epidemiological study conducted in a population with low baseline $PM_{2.5}$ exposure (e.g., Anenberg et al. (2012)).

The IER functions were developed for five types of mortality: lung cancer (for all ages), ischemic heart disease (IHD, for ages 25 or older), stroke (for ages 25 or older), chronic obstructive pulmonary disease (COPD, for all ages), and acute lower respiratory infection (for children). In this assessment, we focus on the first four causes of death, i.e., lung cancer, IHD, stroke, and COPD.

Application of the IER functions required two inputs in addition to the change in exposure attributable to mitigation options:

- Cause-specific mortality rates, which were obtained at a national level from the Global Health Data Exchange catalog created by the Institute for Health Metrics and Evaluation (IHME 2013); and
- Ambient $PM_{2.5}$ exposure levels for urban and rural populations in the Philippines, the computation of which was described earlier.

The analysis also accounts for the impact of a potential lag in reductions of mortality risk following the reductions in $PM_{2.5}$ exposure. Specifically, the team applies a 20-year mortality lag consistent with that used by the EPA, which assumes that 30 percent of the total estimated mortality effects occur in the first year, 50 percent are distributed evenly among years 2 through 5, and the remaining 20 percent are distributed evenly among years 6 through 20 (USEPA SAB, 2004). However, there is uncertainty about the length and the structure of this lag.

The health impacts were computed using a Monte Carlo simulation. We characterized the statistical uncertainty in the risk estimates by taking 50 draws from the 1000 available IER curve parameter sets. In addition, the team also characterized the statistical uncertainty in the cause-specific mortality rates by sampling from lognormal distributions with that were consistent with the mean and the uncertainty bounds reported by IHME. We also represented the age- and sex-related variability in health impacts. To this end, we computed the health impacts for each cause separately for 12 age groups and two sexes, by combining: 1) our estimates of the age group- and sex-specific exposed population sizes (based on the national-level demographic data); 2) the age group-specific IER functions; and 3) the age group- and sex-specific mortality rates for each cause. Note that the team was unable to model the likely important spatial variability in the health impacts, because the information on cause-specific mortality rates did not have the sufficient spatial resolution.

IV.2.4 Valuation

The value of a statistical life, or VSL, is a value that reflects the amount people are willing to pay for small reductions in risk of early death. The conceptual foundation and application of the VSL are described in detail elsewhere (OECD 2011, Hammit and Robinson 2011, Lindhjem and Navrud 2011). A range of values for VSL have been estimated worldwide based on stated preference (contingent valuation studies) and revealed preference (labor market studies) (OECD 2011). We use the benefit transfer approach to take a VSL value calculated for broad international application and adjust it for use in the Philippine context. This approach has been applied in numerous contexts, as discussed by Minjares et al. (2014) and Miller et al. (2014). The benefit transfer equation is shown in Equation 4.

$$VSL_b = VSL_a \; X \; \frac{PPP\ GNI\ per\ capita_b}{PPP\ GNI\ per\ capita_a}$$

Equation 4. Benefit transfer equation

VSL_a is taken from a recent meta-analysis of international studies that recommends a value of $2.9 million 2005 USD for OECD countries, adjusted to $3.2 million 2010 USD (OECD 2011). Values for gross national income at purchasing power parity (PPP GNI) in the year 2005 from the World Bank (2015) are used to transfer from the OECD to the Philippines. The value is transferred using the average per-capita PPP GNI across OECD countries and in the Philippines, resulting in a VSL of $0.76 million in 2015. Future increases in VSL are projected based on an average annual GDP growth rate consistent with LEAP model assumptions. The present value is calculated assuming a 5% discount rate.

Note that the team's calculations implicitly assume that the income elasticity of the WTP for mortality risk reductions is 1: That is, a 1% increase in income will result in a 1 % increase in the WTP (and, thus, the VSL). However, there is considerable uncertainty regarding the income elasticity appropriate for income-related VSL adjustments. A recent synthesis of the VSL studies conducted in high-income countries found the VSL income elasticity to be in the range of 0.25-0.63 (Doucouliagos et al. 2014). On the other hand, Hammitt and Robinson (2011) suggest that a VSL income elasticity value in the range of 1-2 would be more appropriate for transfers in low income countries, because mortality risk reductions in these settings are likely to be perceived as a luxury good. Given that the Philippines is a lower-middle-income country, we opted for a proportional scaling of the VSL using an elasticity value of 1. An elasticity of 1 has been used in other recent studies valuing health benefits in lower- and upper-middle-income economies, including India (Garg 2011), Colombia (Castillo 2010), China (Rabl 2011), Thailand (Sakulniyomporn et al. 2011), Mexico (Crawford-Brown et al. 2011), and Iran (Hoveidi 2013). The uncertainty in VSL elasticity warrants a sensitivity analysis exploring the results with different elasticity values (e.g. 0.5 – 1.5), but this was not within the scope of this analysis.

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