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

PHILIPPINES MITIGATION COST-BENEFIT ANALYSIS

2018 Update Report – Transport Chapter

FINAL – January 2018

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ACRONYMS

ALU	Agriculture and Land Use Greenhouse Gas Inventory software
B-LEADERS	Building Low Emission Alternatives to Develop Economic Resilience and Sustainability
BRT	Bus Rapid Transit
BSP	Bangko Sentral ng Pilipinas
CBA	Cost-benefit analysis
CCC	Climate Change Commission
CNG	Compressed Natural Gas
CO2e	Carbon dioxide equivalent
DENR	Department of Environment and Natural Resources
DOE	Department of Energy
DOTr	Department of Transportation
g	Gram
GDP	Gross domestic product
GHG	Greenhouse gas
IEA	International Energy Agency
INDC	Intended nationally determined contribution
LDV	Light duty vehicle
LEAP	Long-range Energy Alternatives Planning system
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
MACC	Marginal abatement cost curve
MC	Motorcycle
MVIS	Motor vehicle inspection system
NDC	Nationally determined contribution
PHP	Philippine peso
PSA	Philippine Statistics Authority
t	Metric tonne
TC	Tricycle
TPES	Total primary energy supply
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USD	United States dollar
UV	Utility vehicle (jeepney)

IV. TRANSPORT

IV.1 INTRODUCTION TO COST-BENEFIT ANALYSIS (CBA) UPDATE

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 this growth. As part of this effort, the national Climate Change Commission (CCC) partnered with USAID to develop the quantitative evidence base for climate change mitigation by conducting a CBA of climate change mitigation options. The CBA was a systematic, transparent, and economy-wide study that assessed the advantages and disadvantages of mitigation strategies in all major sectors. Its intent was to help CCC identify socially beneficial mitigation opportunities in the Philippines.

The CBA Study was conducted under the USAID-funded B-LEADERS Project managed by RTI International. A CBA Study report was submitted to CCC in November 2015 to support the formulation of Nationally Appropriate Mitigation Actions and the Philippines' intended nationally determined contribution (INDC) under the United Nations Framework Convention on Climate Change's (UNFCCC's) Paris Agreement (B-LEADERS 2015). In 2017, to support the development of the Philippines' nationally determined contribution (NDC) under the Paris Agreement, CCC requested an update to the CBA. The update accounted for revised cross-cutting and sector-specific assumptions and was performed in late 2017 and early 2018.

The CBA covered all GHG-emitting sectors in the Philippines, including agriculture, energy, forestry, industry, transport, and waste. The 2015 analysis was carried out relative to a 2010-2050 baseline projection of GHG emissions. Mitigation options were assessed over the 2015-2050 period, except for the forestry sector where costs were assessed starting in 2010. The 2017 CBA update covered the same years for the baseline projection; however, mitigation options were evaluated over 2015-2030 to provide more actionable information for NDC development.[1]

For each sector, the CBA evaluated a collection of nationally appropriate mitigation options, comparing each to the baseline to determine its:

- **GHG abatement** – The expected reduction in GHG emissions attributable to the option. Abatement benefits were quantified but not monetized.
- **Costs** – Changes in direct, quantifiable social costs associated with the option.
- **Co-benefits** – Other quantifiable benefits related to the option. Depending on the option, the co-benefits may include beneficial economic/market impacts and non-market impacts.

The CBA employed two tools that have been adopted by various stakeholders in the Philippines:

[1] The NDC will focus on the period from now to 2030.

- **The Long-range Energy Alternatives Planning system (LEAP)** – LEAP is a flexible, widely used software tool for energy system and climate mitigation modeling, including cost-benefit analysis.
- **The Agriculture and Land Use Greenhouse Gas Inventory software (ALU)**, which was developed to guide a GHG inventory compiler through the process of estimating GHG emissions and removals related to agriculture and land use, land-use change, and forestry activities.

In addition to these tools, custom Excel models were developed to analyze industrial process, waste, and wastewater GHG emissions.

The CBA team used LEAP to model the energy and transport sectors and to integrate results from all sectors – energy, transport, and the non-energy sectors. A national-scale LEAP model was built for this purpose, covering 2010-2050 and representing all sectors and mitigation options. Results from the ALU and Excel modeling were supplied to the LEAP model and incorporated in overall national projections of GHG emissions, costs, and benefits.

This report presents the 2017 CBA update for the transport sector. It provides the following:

- A description of updated modeling methods, assumptions, and results for baseline GHG emissions.
- A description of changes in the mitigation options evaluated for the sector.
- Estimates of direct costs and benefits of the mitigation options for the 2015-2030 period, including GHG abatement and changes in direct social costs.
- An updated marginal abatement cost curve (MACC) for the sector, illustrating the cumulative abatement potential and the unit cost of abatement of the mitigation options.
- Where relevant, updated estimates of co-benefits associated with the mitigation options, such as health, energy security, employment, and traffic congestion benefits.

The 2017 CBA update incorporated inputs from multiple stakeholders in the Philippines, including CCC, the Department of Transportation (DOTr), and other government agencies. Feedback and advice were gathered in particular at consultative workshops conducted in September 2017.

IV.2 BASE YEAR GHG EMISSIONS

IV.2.1 Updated Methods and Assumptions

The transport modeling conducted for the 2017 CBA update was broadly similar to that performed for the 2015 CBA. Most methods, assumptions, and input data were unchanged, and the work was again carried out with the CBA national LEAP model. The scope of the transport modeling – including transport modes, vehicle types, pollutants, and years represented – was the same as in 2015, as were the overall approaches to calculating on-road and non-road emissions. Emissions of various pollutants were based on estimated fuel consumption and pollutant and technology-specific emission factors. Projected on-road fuel consumption was derived from a stock turnover model of vehicles, while non-road consumption was calculated in a top-down fashion based on gross domestic product (GDP). The parallels between the 2017 and 2015 analyses should make the update readily accessible to stakeholders familiar with the earlier CBA.

The 2015 CBA report details the methods, assumptions, and inputs for the transport model at that time (B-LEADERS 2015). Changes in methods, assumptions, and inputs since 2015 are described in this report. For the CBA's base year, several such changes led to modest differences in modeled GHG emissions from transport. As the 2015 report states, although 2010 was the official base year for the CBA, in the transport sector both 2010 and 2011 were considered base years to highlight a variation in modeling methodology between the two years. For 2010, energy demand for on-road transport was taken from the Philippines' national energy balances, prepared by the Department of Energy (DOE); for 2011 and later years, on-road energy demand was determined by a bottom-up model of vehicle stock (B-LEADERS 2015). As this distinction also applied in the modeling for the 2017 CBA update, this report adopts the same convention.

Changes since the 2015 CBA in methods, assumptions, and inputs for modeling base year GHG emissions are summarized below.

- **Updated energy balance data** – As noted earlier, the transport model reproduces historical energy demand data from the national energy balances for on-road transport in 2010. It does likewise for non-road transport in 2010 and 2011. For the 2017 CBA update, all energy balance data used in the model were updated using the most recent version of the balances (Department of Energy 2017b). This version included some corrections to data published in earlier releases of the balances.
- **Penetration of biofuels not allowed to exceed 2010 levels** – Following a request from CCC, the baseline scenario for the 2017 update excluded mitigation actions implemented since 2010. In the transport sector, this required ensuring that the proportion of ethanol in the gasoline supply and biodiesel in the diesel supply did not exceed 2010 levels. Demand for ethanol and biodiesel that would have occurred without this restriction were assumed to be met by conventional gasoline and diesel, respectively. In 2010, ethanol generally constituted 3.6% of the transport gasoline supply in energy terms, while biodiesel made up at most 1.8% of the transport diesel supply in energy terms (there were variations in penetration across transport subsectors). These levels were adopted as limits for ethanol and biodiesel in 2011 and later years.
- **Corrected historical stock of light duty vehicles (LDVs) using liquefied petroleum gas (LPG)** – The transport model for the 2017 update also included an adjustment to historical stock of LPG-fueled LDVs in order to reproduce LPG demand shown in the national energy balances. Stock for years through 2015 was adjusted.

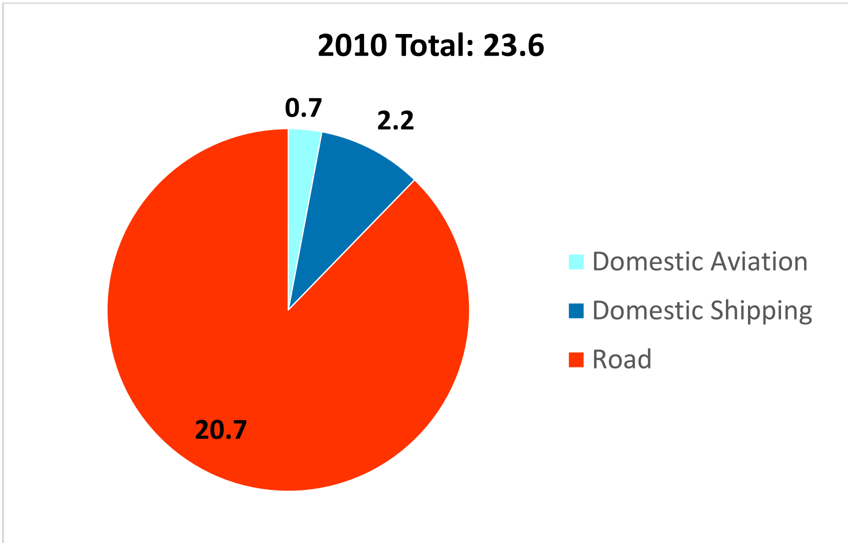
IV.2.2 Results

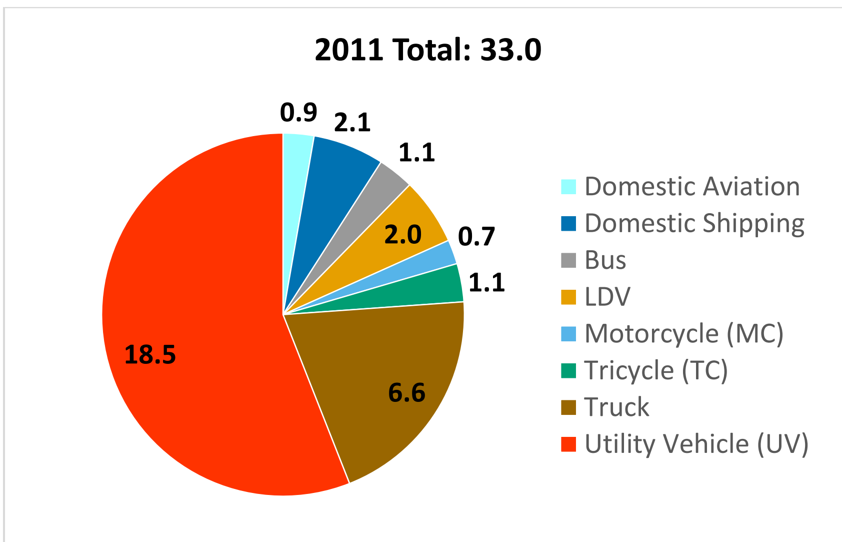
Figure IV.1 shows base year estimates of direct GHG emissions from transport.[2] Overall, the totals for 2010 and 2011 are within a few percent of those reported in the 2015 CBA. As in the 2015 analysis, there

[2] Energy consumption in the transport sector causes both direct and indirect GHG emissions. Direct emissions come from vehicles themselves and are also called tailpipe or "tank-to-wheel" emissions. Indirect emissions

is an important difference between on-road emissions in 2010 and 2011, due to the switch to a bottom-up model of vehicle stock in 2011.

Figure IV.1: Base Year Transport GHG Emissions (million metric tonnes carbon dioxide equivalent [$MtCO_2e$])





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result from the production of transport fuels, including fossil fuels, biofuels, and electricity. In the CBA, indirect emissions related to fuels produced in the Philippines were reported under the energy sector. Other indirect emissions – from fuel production outside the Philippines – were not assessed.

IV.3 BASELINE PROJECTION TO 2030

IV.3.1 Updated Methods and Assumptions

In addition to the changes noted in Section IV.2.1, the 2017 CBA update included a few other adjustments to modeling methods, assumptions, and inputs that affected transport baseline results for years after 2011. These are listed below. All other methods, assumptions, and inputs for the transport baseline were as in the 2015 CBA (B-LEADERS 2015). The general concept for the baseline scenario – an exploration of current trends in the transport sector, excluding new mitigation actions – did not change.

- **Revised projection of non-road energy consumption** – In the 2015 CBA, baseline non-road energy demand was assumed to grow at the same rate as GDP starting in 2014 (demand in 2012-2013 was reproduced from the national energy balances) (B-LEADERS 2015). This approach was revised somewhat for the 2017 update. For 2012-2016, non-road demand was taken from the updated national energy balances (Department of Energy 2017b). In later years, projected demand by subsector (aviation, rail, shipping) was calculated as the product of GDP and a subsectoral energy intensity of GDP. The resulting total demand by subsector was then distributed over fuels using estimated fuel shares. Equation IV-1 provides an illustration for subsector s, fuel f, and year y.

  Equation IV-1: Projection of Non-Road Energy Demand

  $$\boldsymbol{demand_{s,f,y} = GDP \times energy\ intensity_{s,y} \times fuel\ share_{s,f,y}}$$

  Subsectoral energy intensities and fuel shares were assumed to grow at their average rates established during 1990-2016, based on the national energy balances and historical GDP. The growth was constrained to within ±3%, and fuel shares were subject to the restriction that the sum of shares within each subsector must be 100%. As indicated in Section IV.2.1, fuel shares for biofuels were also adjusted as needed to avoid exceeding 2010 biofuel penetration levels.

- **Updated cross-cutting economic assumptions** – An important motivation for the 2017 CBA was updating cross-cutting economic assumptions in the modeling, including GDP, value added, population, fuel prices, currency exchange rates, and the discount rate. A subset of these were relevant to the transport modeling: GDP, fuel prices, exchange rates, and the study discount rate. GDP data and projections drove the non-road modeling as discussed above, while fuel prices were a key determinant of transport sector direct social costs. Exchange rates were necessary to convert cost and price inputs to the LEAP model's currency, year 2010 United States dollars (USD). The discount rate was applied to calculate discounted costs when needed.

  The annex in Section IV.5 provides sources and values for the GDP, fuel price, and exchange rate data and projections used in the 2017 update. At CCC's request, a real annual discount rate of 10% was adopted in the update to align with the rate utilized by the National Economic and Development Authority to evaluate potential investments (National Economic and Development Authority 2016).

IV.3.2 Results

Figure IV.2 shows the baseline projection of direct GHG emissions from transport through 2030. The corresponding projection of transport final energy demand is given in Figure IV.3. Both of these figures extend back to 1990, with results for 1990-2010 based on data from the national energy balances.

Figure IV.2: Baseline Transport GHG Emissions

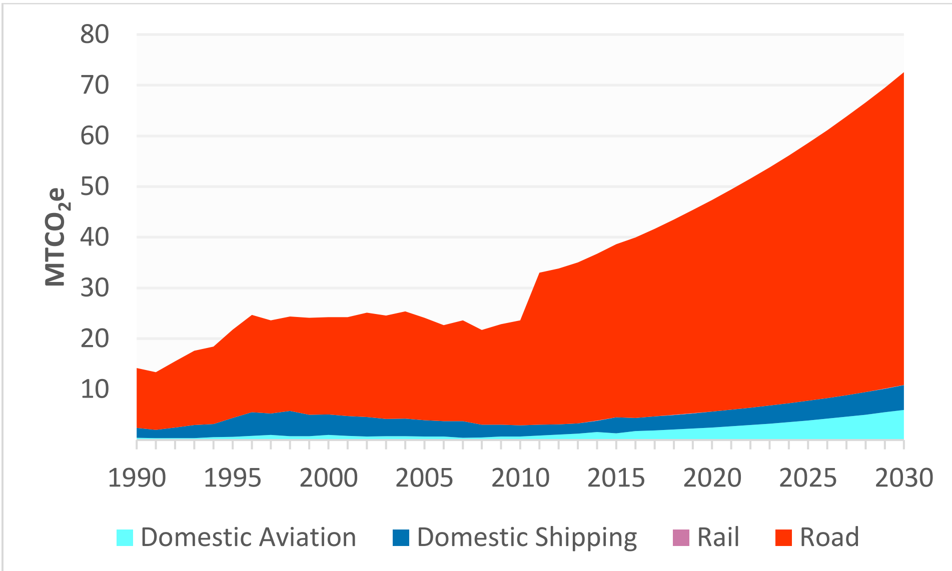
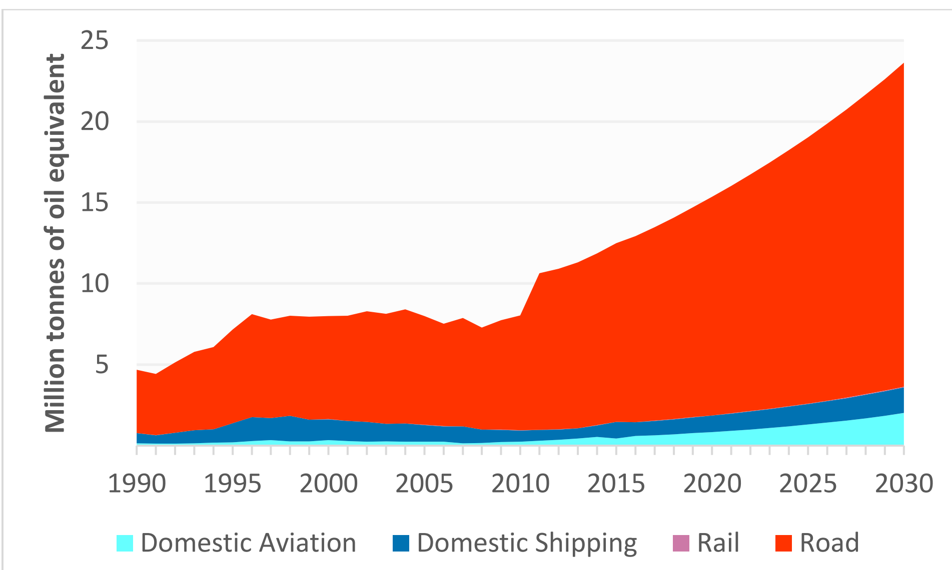


Figure IV.3: Baseline Transport Final Energy Demand



In their overall totals and the split among transport subsectors, the projections closely resemble the findings in the 2015 CBA. The most significant contributor to energy demand and GHG emissions is road transport, which accounts for 85% or more of demand and emissions between 2015 and 2030. Figure IV.4 through Figure IV.8 provide further insight into road transport, showing baseline on-road vehicle stock, sales, kilometers traveled, energy demand, and GHG emissions. Although UVs and trucks constitute a minority of the projected vehicle fleet, their average usage is high, resulting in an outsized share of vehicle activity. The intensive usage coupled with high energy requirements per kilometer traveled lead to even greater shares of final energy demand and GHG emissions – about 80% for the two categories together from 2015 to 2030.

Figure IV.4: Baseline Road Vehicle Stock

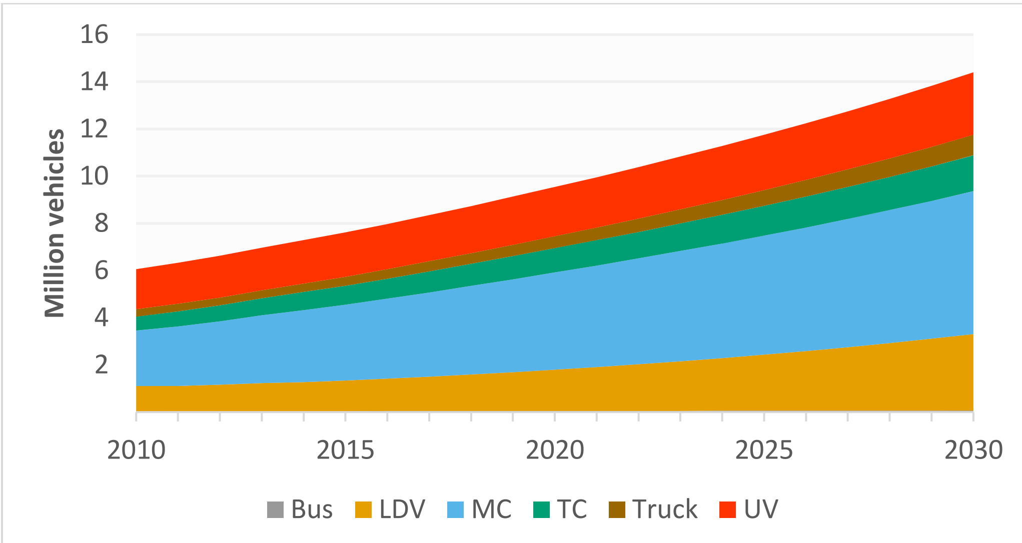


Figure IV.5: Baseline Road Vehicle Sales

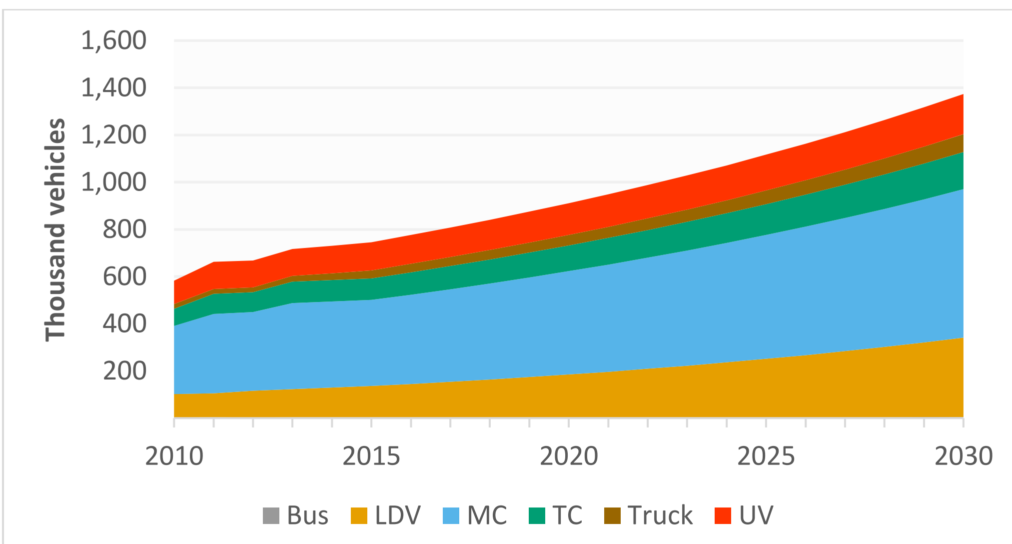


Figure IV.6: Baseline Road Vehicle Activity

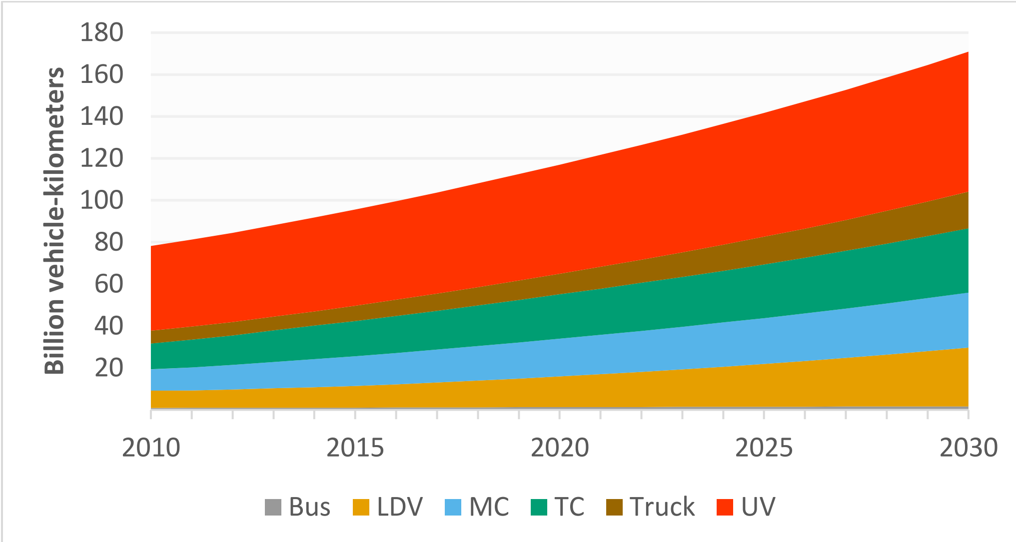


Figure IV.7: Baseline Road Transport Final Energy Demand

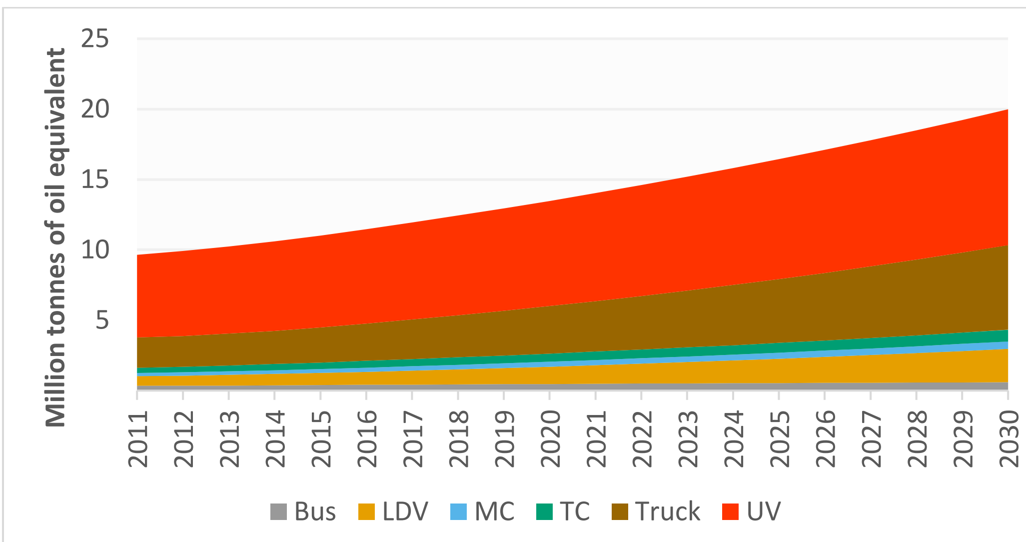
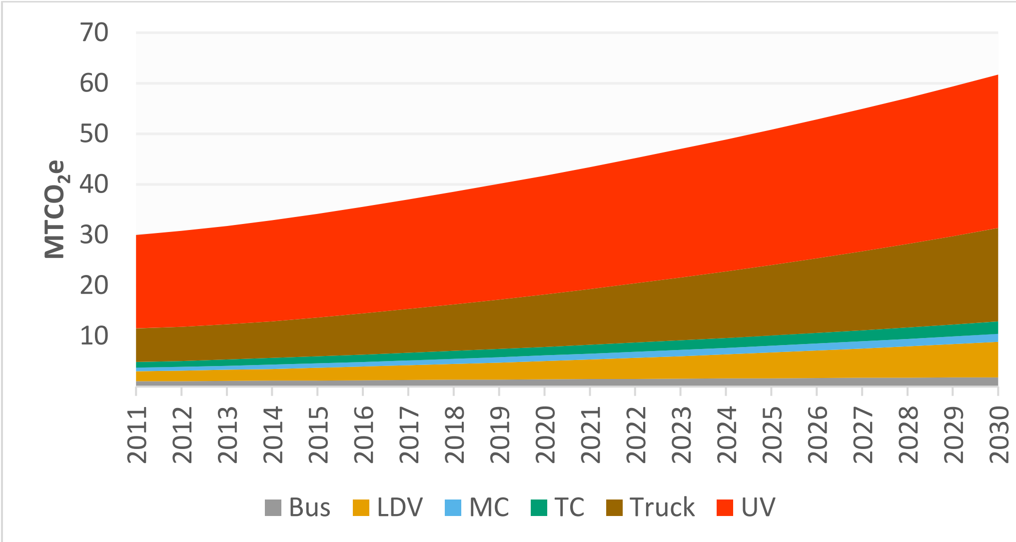


Figure IV.8: Baseline Road Transport GHG Emissions



IV.4 MITIGATION COST-BENEFIT ANALYSIS

IV.4.1 Updated Methods and Assumptions

The same set of transport mitigation options was evaluated in the 2017 CBA update as in the 2015 CBA. Methods, assumptions, and inputs for modeling the options were unchanged with one exception.

- **Revised Biofuels mitigation option** – The Biofuels option considers enhanced biofuel blending standards for on-road transport fuels. For ethanol in gasoline, the standard rises from baseline levels to 20% in energy terms; for biodiesel in diesel, the standard grows from baseline levels to 20% in volumetric terms. In the 2015 CBA, the 20% ethanol standard was assumed to be reached in 2020, while the 20% biodiesel standard was assumed to be met in 2025 (B-LEADERS 2015). For the 2017 update, the attainment year for the 20% ethanol standard was changed to 2023 (Department of Energy 2017a). The implementation year for the 20% biodiesel standard was not altered, but path to the target was. The 2015 analysis assumed that the biodiesel blend in on-road diesel would be 5% by volume in 2015, and 10% by volume in 2020. In the 2017 update, the assumed year for reaching 5% by volume was changed to 2018 (Department of Energy 2017a). All other assumptions and inputs for the Biofuels option were retained from 2015.

Within the transport LEAP model, the mitigation options were assessed against the updated baseline scenario, described in Sections IV.2 and IV.3. As in the 2015 analysis, outputs from the LEAP modeling were then used in separate calculations of transport mitigation co-benefits. The co-benefits calculations were performed in the same way as in 2015 (B-LEADERS 2015).

IV.4.2 Results

All results presented in this section were calculated with the retrospective systems method used in the 2015 CBA. As detailed in the 2015 CBA report, this method accounts for interactions between mitigation options by assuming that options are implemented in order of abatement cost-effectiveness, and by computing the impacts of each option in comparison to a scenario in which all lower-cost options are deployed (Sathaye and Meyers 1995).[3]

IV.4.2.1 Direct Costs and Benefits of Mitigation Options

Table IV.1 and Figure IV.9 summarize the core findings from the modeling of the transport mitigation options: direct GHG abatement costs, GHG mitigation potential, and direct costs per tonne of GHG mitigation in the 2015-2030 period.

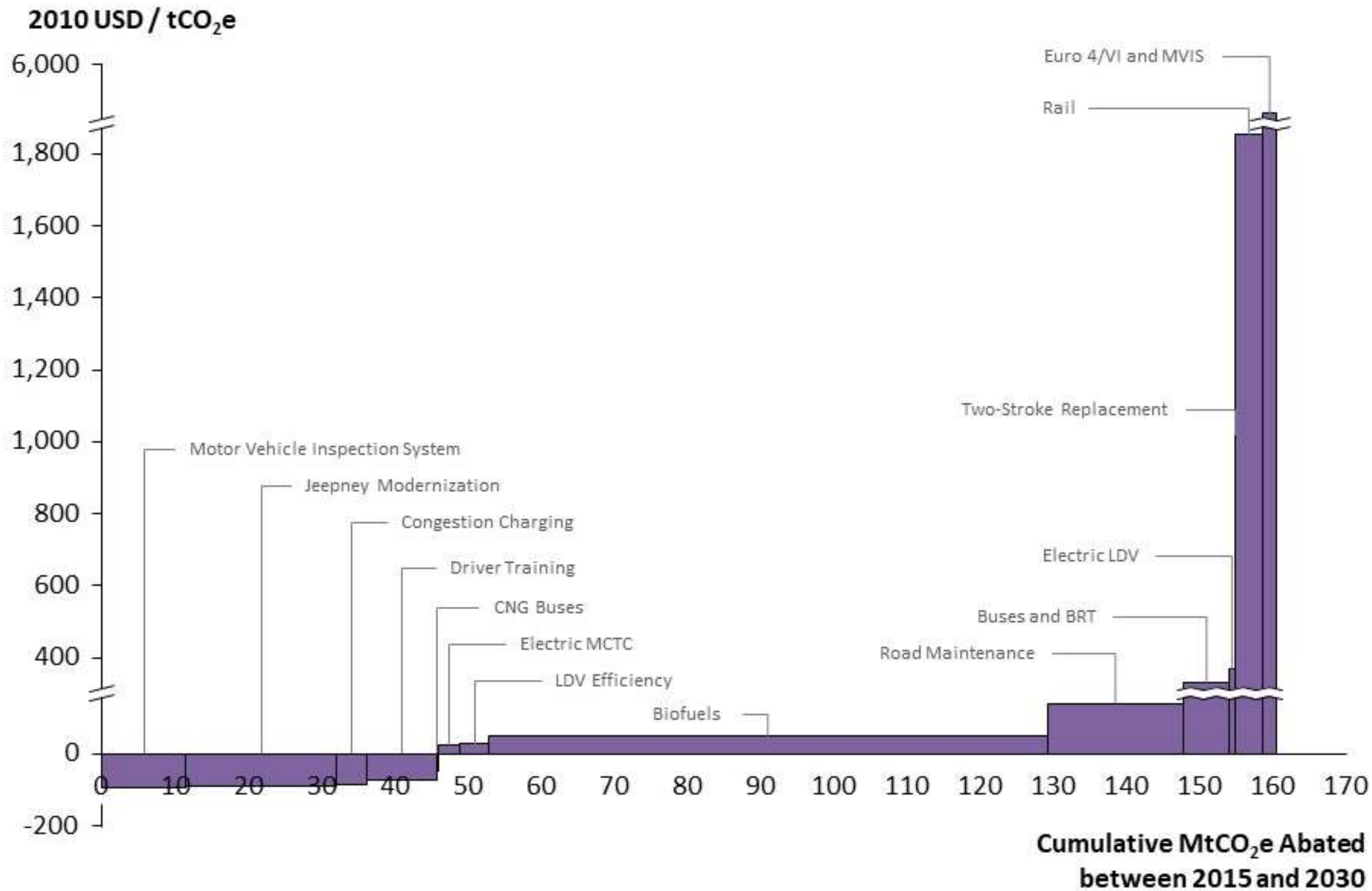
Table IV.1: Direct Cost-Benefit Results for Transport Sector Mitigation Options

Mitigation Option	Abatement Costs (Cumulative 2015 - 2030), Discounted to 2015 at 10% [Billion 2010 USD]	GHG Mitigation Potential (Cumulative 2015 - 2030) [$MtCO_2e$]	Cost per Tonne Mitigation, Without Co-benefits [2010 USD/tCO_2e]
Biofuels	3.64	76.31	47.68
Buses and Bus Rapid Transit (BRT)	2.05	6.17	331.47
Compressed Natural Gas (CNG) Buses	-0.01	0.27	-48.94
Congestion Charging	-0.37	4.27	-86.29
Driver Training	-0.68	9.44	-72.47
Electric LDV	0.28	0.77	369.81
Electric MCTC	0.07	2.94	25.08
Euro 4/IV and Motor Vehicle Inspection System (MVIS)	10.74	1.83	5,864.24
Euro 6/VI and MVIS	5.79	*No abatement*	*No abatement*
Jeepney Modernization	-1.87	20.51	-91.12
LDV Efficiency	0.11	3.98	26.68
MVIS	-1.09	11.54	-94.49
Rail	6.94	3.74	1,853.67
Road Maintenance	2.61	18.72	139.32

[3] The abatement costs used to order options for the retrospective systems analysis are determined by comparing each option individually to the baseline.

Mitigation Option	Abatement Costs (Cumulative 2015 - 2030), Discounted to 2015 at 10% [Billion 2010 USD]	GHG Mitigation Potential (Cumulative 2015 - 2030) [$MtCO_2e$]	Cost per Tonne Mitigation, Without Co-benefits [2010 USD/tCO_2e]
Two-Stroke Replacement	0.11	0.11	1,018.29

Figure IV.9: Transport Sector MACC



These results are not dissimilar from those obtained in the 2015 CBA. For the seven mitigation options that were included in the 2015 retrospective systems analysis[4], mitigation potentials through 2030 differ by 20-30% in two cases (Buses and BRT, Rail) and by 10% or less in others (MVIS, Jeepney Modernization, Congestion Charging, Driver Training, Biofuels). Mitigation costs per tonne CO_2e vary to a greater extent, but the general cost-effectiveness of each of the seven options is the same. The options are split between those with a substantial negative cost per tonne (highly cost-effective) and those with a substantial positive cost per tonne (not cost-effective in direct cost terms). The mitigation options not included in the 2015 retrospective systems analysis offer a range of mitigation potentials but are predominantly positive-direct-cost measures. One option, Euro 6/VI and MVIS, does not provide any incremental GHG abatement when considered with other options in the retrospective systems framework, so it is omitted from the MACC.

IV.4.2.2 Co-Benefits of Mitigation Options

Table IV.2 presents the incremental human health impacts calculated for the transport sector mitigation options, and Table IV.3 shows the average annual incremental impact of each option on four energy security indicators. Table IV.4 provides estimates of changes in direct power sector employment due to the options.

Table IV.2: Incremental Human Health Impacts for Transport Sector Mitigation Options, Cumulative 2015-2030

Mitigation Option	Incremental Present Value, Discounted to 2015 at 10% [Million 2010 USD]	Incremental Cases of Premature Death Avoided	Incremental Cases of Premature Death Avoided (Females)
Biofuels	0.0	0	0
Buses and BRT	3,169.3	6,650	2,600
CNG Buses	158.5	300	120
Congestion Charging	581.0	1,400	550
Driver Training	0.0	0	0
Electric LDV	365.4	630	270
Electric MCTC	12.4	-10	30
Euro 4/IV and MVIS	1,921.6	4,150	1,590
Euro 6/VI and MVIS	767.8	1,740	640
Jeepney Modernization	5,379.0	11,850	4,620

[4] The other options were excluded at the request of various stakeholders.

Mitigation Option	Incremental Present Value, Discounted to 2015 at 10% [Million 2010 USD]	Incremental Cases of Premature Death Avoided	Incremental Cases of Premature Death Avoided (Females)
LDV Efficiency	0.0	0	0
MVIS	10,652.3	23,120	9,000
Rail	574.5	1,160	500
Road Maintenance	0.0	0	0
Two-Stroke Replacement	-426.3	-800	-300

Table IV.3: Incremental Changes in Energy Security Indicators for Transport Sector Mitigation Options, Average Annual Impact During 2015-2030

Mitigation Option	Average Annual Incremental Impact 2015-2030[1]			
	Change in GHG Intensity of GDP [grams (g) CO_2e/2010 USD][2]	Change in Share of Renewables in Total Primary Energy Supply (TPES) [%][3]	Change in Share of Imports in TPES [%][4]	Change in Energy Intensity of GDP [megajoules/ 2010 USD] [5]
Biofuels	-9.6	1.7	-0.5	-
Buses and BRT	-0.8	0.1	-	-
CNG Buses	-	-	-	-
Congestion Charging	-0.4	-	-	-
Driver Training	-1.2	0.1	-0.1	-
Electric LDV	-0.1	-	-	-
Electric MCTC	-0.4	-	-	-
Euro 4/IV and MVIS	-0.2	-	-	-
Euro 6/VI and MVIS	-	-	-	-
Jeepney Modernization	-2.3	0.1	-0.3	-
LDV Efficiency	-0.4	-	-	-
MVIS	-1.4	0.1	-0.1	-
Rail	-0.5	-	-	-
Road Maintenance	-2.6	0.2	-0.2	-
Two-Stroke Replacement	-	-	-	-

Notes:

[1] All indicators are calculated in the LEAP model. Results reflect the average of annual results from 2015-2030 that compare the indicator value for a given mitigation option relative to the value for the previous mitigation option.
[2] GHG intensity is measured as gCO_2e emissions (economy-wide, including from energy and non-energy sources) per unit of GDP (2010 USD).
[3] Percentage share of renewable energy in total primary energy supply.
[4] Percentage share of imports in total primary energy supply.
[5] Energy intensity is measured as total megajoules of primary energy supply (indigenous production of primary energy + energy imports - energy exports) divided by GDP (2010 USD).

Table IV.4: Incremental Changes in Power Sector Job-Years for Transport Sector Mitigation Options, Cumulative 2015-2030

Mitigation Option	Incremental Job-Years Impact (Unrounded Cumulative Job-Years 2015-2030)
Biofuels	0
Buses and BRT	-9
CNG Buses	0
Congestion Charging	-10
Driver Training	-5
Electric LDV	19
Electric MCTC	41
Euro 4/IV and MVIS	0
Euro 6/VI and MVIS	0
Jeepney Modernization	805
LDV Efficiency	0
MVIS	0
Rail	-2
Road Maintenance	-8
Two-Stroke Replacement	12

IV.4.2.3 Summary of Monetized Costs and Benefits

Table IV.5 shows the monetized co-benefits of each mitigation option in the transport sector. Table IV.6 combines direct costs and benefits of the transport sector mitigation options with their monetized co-benefits to arrive at co-benefits-adjusted abatement costs per tonne and net present values.

Table IV.5: Monetized Co-Benefits of Mitigation Options in the Transport Sector

Sequence Number of Mitigation Option[1]	Mitigation Option	GHG Mitigation Potential (Cumulative 2015-2030) ($MtCO_2e$)	Incremental Co-benefits (Cumulative 2015-2030) [Billion 2010 USD] Discounted to 2015 at 10%				Cost per Tonne Mitigation (2015-2030), Co-benefits Only[2] [2010 USD/tCO_2e]
			Health	Conges-tion	Income Genera-tion	**Total Co-benefit**	
Symbol		*A*	*B*	*C*	*D*	*E*	*F*
Formula						*E=B+C+D*	*F =-E*1000/A*
38	Biofuels	76.31	0.00	-	N/A	0.00	0.00
45	Buses and BRT	6.17	3.17	7.00	N/A	10.17	-1,648.19
8	CNG Buses	0.27	0.16	-	N/A	0.16	-587.07
5	Congestion Charging	4.27	0.58	1.40	N/A	1.98	-463.94
6	Driver Training	9.44	0.00	-	N/A	0.00	0.00
46	Electric LDV	0.77	0.37	-	N/A	0.37	-474.57
34	Electric MCTC	2.94	0.01	-	N/A	0.01	-4.21
48	Euro 4/IV and MVIS	1.83	1.92	-	N/A	1.92	-1,050.03
50	Euro 6/VI and MVIS	N/A	0.77	-	N/A	0.77	[2]
4	Jeepney Modernization	20.51	5.38	-	N/A	5.38	-262.26
32	LDV Efficiency	3.98	0.00	-	N/A	0.00	0.00
3	MVIS	11.54	10.65	-	N/A	10.65	-923.07
49	Rail	3.74	0.57	1.80	N/A	2.37	-634.90
44	Road Maintenance	18.72	0.00	-	N/A	0.00	0.00
47	Two-Stroke Replacement	0.11	-0.43	-	N/A	-0.43	3,875.38

Notes: N/A indicates inapplicability of a given co-benefits category

[1] Sequence Number of Mitigation Options 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 is taken into account.

[2] The costs and co-benefits expected to occur in years other than 2015 were expressed in terms of their present value (i.e., 2015) using a discount rate of 10%. The values reported are calculated using the full precision of the values for GHG Mitigation Potential in tCO_2e (A) and Total Co-Benefits in 2010 USD (E).

Column Definitions:

[B] Co-benefits: Health: Monetized public health benefits reflect the reduced risk of premature death from exposure to air pollution. For the transport sector, these are based on reduced emissions of fine particles from vehicle tailpipes. For the energy sector, these are based on the reduced power plant emissions of sulfur dioxide, fine particulates, and nitrogen oxides.

[C] Co-benefits: Congestion: Monetized congestion benefits reflect less time wasted on congested roadways. These are specific to the transport sector.

[D] Co-benefits: Income Generation: Economic co-benefits from creation of new markets and/or expansion of productive capacity. For forestry, these include timber and fruit production from re-forested areas. For waste, these include recyclables and composting from waste diverted from landfills.

[E] Total Co-benefits: Sum of valuation of monetized co-benefits. Co-benefits that were quantified but not monetized (i.e. energy security) are summarized in the results shown in Section IV.4.2.2: Co-benefits of Mitigation Options.

[F] Cost per Tonne Mitigation, Co-benefits Only: Value of monetized co-benefits (represented as a negative cost) divided by mitigation potential.

Table IV.6: Net Present Value of Mitigation Options in the Transport Sector during 2015-2030

Sequence Number of Mitigation Option[1]	Mitigation Option	GHG Mitigation Potential (Cumulative 2015-2030) (MtCO2e)[3]	Cost per Tonne Mitigation (2010 USD/tCO_2e)[2]			Net Present Value Excluding Value of GHG Reduction
			Co-benefits only[4]	Without co-benefits	With co-benefits[5]	(Billion 2010 USD)[6]
Symbol		*A*	*F*	*G*	*H*	*I*
Formula					*F+G = H*	*I = -H*A/1000*
38	Biofuels	76.31	0.00	47.68	47.68	-3.64
45	Buses and BRT	6.17	-1648.19	331.47	-1316.72	8.12
8	CNG Buses	0.27	-587.07	-48.94	-636.01	0.17
5	Congestion Charging	4.27	-463.94	-86.29	-550.23	2.35
6	Driver Training	9.44	0.00	-72.47	-72.47	0.68
46	Electric LDV	0.77	-474.57	369.81	-104.76	0.08
34	Electric MCTC	2.94	-4.21	25.08	20.87	-0.06
48	Euro 4/IV and MVIS	1.83	-1050.03	5,864.24	4814.21	-8.81
50	Euro 6/VI and MVIS	No abatement	N/A	N/A	N/A	N/A
4	Jeepney Modernization	20.51	-262.26	-91.12	-353.38	7.25
32	LDV Efficiency	3.98	0.00	26.68	26.68	-0.11
3	MVIS	11.54	-923.07	-94.49	-1017.56	11.74
49	Rail	3.74	-634.90	1,853.67	1218.77	-4.56
44	Road Maintenance	18.72	0.00	139.32	139.32	-2.61
47	Two-Stroke Replacement	0.11	3875.38	1,018.29	4893.67	-0.54

Notes:
[1] Refers to the sequential order in which the mitigation option is introduced in the retrospective analysis. In this analysis, mitigation options are compared to the baseline as stand-alone options, and then ranked according to their cost per tons mitigation (excluding co-benefits) from lowest cost per ton mitigation to highest cost per ton mitigation. The cost and GHG mitigation potential of a given mitigation option is calculated relative to a scenario that embeds all options with lower cost per ton mitigation.
[2] The incremental costs and co-benefits expected to occur in years other than 2015 were expressed in terms of their present (i.e., 2015) value using a discount rate of 10%. 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 prior mitigation option using retrospective systems analysis. Negative values indicate cost savings as well as GHG emissions benefits.
[3] The incremental GHG mitigation potential is a total reduction in GHG emissions that is expected to be achieved by the option during 2015-2030.
[4] The co-benefits for the transport sector include human health benefits due to reduced air pollution from electricity generation.
[5] Negative value indicates net benefits per tonne mitigation. This excludes the non-monetized benefits of GHG reductions.
[6] The values reported are calculated using the full precision of the values for GHG Mitigation Potential in tCO_2e (A). Total co-benefits minus total net cost reflects the present value to society of a mitigation option relative to the prior mitigation option, 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 CO_2e in the Philippines times the mitigation potential. A negative value indicates net loss in social welfare, cumulative over 2015-2030. This loss does not account for the non-monetized benefits of GHG reductions.

IV.5 ANNEX: CROSS-CUTTING ECONOMIC ASSUMPTIONS

The sector-specific modeling in the CBA was based on a common set of cross-cutting economic variables. These included population, GDP, value added, fuel prices, and currency exchange rates. Sources, projection methods, and values for these variables are listed in the following tables.

Table IV.7: Data Sources and Projection Methods for Population, GDP, Economic Sector-Specific Value Added, and Fuel Prices (changes highlighted in blue)

Variable	Sources of Historical Data	Projection Method
Population	1990-2015: Philippine Statistics Authority (PSA) (2017b)	2016-2020: Projection is taken from PSA and Inter-Agency Working Group on Population Projections (2015b). 2021-2045: Projection is taken from PSA and Inter-Agency Working Group on Population Projections (2015a). 2045-2050: Population is assumed to grow at average annual rate established 2035-2045.
GDP	1990-2010: PSA (2015a) 2011-2016: PSA (2017a)	GDP growth rate increased to 7.5% based on guidance from CCC on 26 September 2017.
Value Added by Industrial Subsectors	1990-1997: Based on percent share of GDP 1998-2016: PSA (2017a) (Manufacturing and Total)	Shares of total GDP for sectoral and sub-sectoral values added are projected based on historical trends. Projected shares in each year are multiplied by GDP to obtain projected values added.
Value Added by Commercial Sector	1990-1997: Based on percent share of GDP 1998-2016: PSA (2017a)	
Value Added by Agriculture, Forestry, Fishing Subsectors	1990-1997: Based on percent share of GDP 1998-2016: PSA (2017a) (Agricultural, Hunting, Forestry, & Fishing)	

Variable	Sources of Historical Data	Projection Method
Biomass Price	Department of Environment and Natural Resources (DENR) (2013)	Assumed same as the constant price historically.
Coal Price	World Bank (2017b). Taken from free-on-board Newcastle/Port Kembla price	Price growth rate taken from *Current Policies* scenario, International Energy Agency (IEA) (2016)
Natural Gas Price	DOE (2015b)	Price growth rate taken from *Current Policies* scenario, IEA (2016)
Nuclear Fuel Price	Schlömer et al. (2014). Comprises all fuel cycle costs, from uranium mining and enrichment to spent fuel reprocessing and disposal.	Assumed same as the constant price historically.
Crude Oil Price	DOE (2015b)	Price growth rate taken from *Current Policies* scenario, IEA (2016)
Bagasse Price	Assumed to be equal to wood on an energy basis.	Assumed same as the constant price historically.
Animal Wastes Price	Assumed to be equal to wood on an energy basis.	Assumed same as the constant price historically.
Coconut Residue Price	Assumed to be equal to wood on an energy basis.	Assumed same as the constant price historically.
Rice Hull Price	Assumed to be equal to wood on an energy basis.	Assumed same as the constant price historically.
Wood Price	DENR (2013)	Assumed same as the constant price historically.
Aviation Gasoline Price	DOE (2015b)	Grows at rate of crude oil price
Lubricants Price	Same as residual fuel oil	Same as residual fuel oil
Bitumen Price	DOE (2015b)	Grows at rate of crude oil price
Naphtha Price	DOE (2015b)	Grows at rate of crude oil price
Other Oil Price	Same as residual fuel oil	Same as residual fuel oil
LPG Price	DOE (2015b)	Grows at rate of crude oil price
Residual Fuel Oil Price	DOE (2015b)	Grows at rate of crude oil price

Variable	Sources of Historical Data	Projection Method
Diesel Price	DOE (2015b)	Grows at rate of crude oil price
Kerosene Price	DOE (2015b)	Grows at rate of crude oil price
Jet Kerosene Price	DOE (2015b)	Grows at rate of crude oil price
Motor Gasoline Price	DOE (2015b)	Grows at rate of crude oil price
Biodiesel Price	Renewable Energy Management Bureau (2015)	Grows at rate of crude oil price
Ethanol Price	DOE (2015b)	Grows at rate of crude oil price
CNG Price	DOE (2015a)	Price held constant until 2016 (Velasco 2014). After 2016, price based on price of natural gas plus cost additions for compression, distribution, refining, taxes, and retail mark-up shown in American Clean Skies Foundation (2013).
Charcoal Price	DENR (2013)	Assumed same as the constant price historically.
Liquefied Natural Gas (LNG) Price	DOE (2015b). The Delivered Cost of natural gas references either the Indigenous Cost (of domestically produced gas) or the Import Cost (of imported LNG) depending on the remaining reserves of domestic gas	Price growth rate taken from *Current Policies* scenario, IEA (2016)
Electricity Price	Not specified exogenously – cost of electricity calculated endogenously by LEAP model.	

[a] For fuel prices: Available historical data cover 1990-2016 or a subset of those years, depending on the fuel.

[b] For fuel prices: Projections begin where the historical data end and run through 2050.

Table IV.8: Historical and Projected Values for Population, GDP, Economic Sector-Specific Value Added, and Fuel Prices

	Historical Data						Baseline						
Year	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Population (Millions)	61	69	77	85	92	101	110	118	125	132	138	142	147
GDP (Billions 2010 USD)	98	106	132	161	200	252	360	516	741	1,064	1,527	2,192	3,147
Value Added by Economic Sectors (Million 2010 USD)													
Beverages	1,077	1,168	1,413	1,232	1,573	2,124	2,952	3,882	5,087	6,647	8,659	11,253	14,592
Tobacco	490	531	725	364	169	177	216	260	313	376	450	536	639
Food Manufactures	7,147	7,752	10,420	14,346	18,193	23,184	34,837	52,453	78,700	117,710	175,563	261,200	387,748
Textile and Leather	2,741	2,973	3,314	3,156	2,508	2,617	2,867	3,462	4,166	4,998	5,979	7,135	8,495
Wood and Wood Products	783	849	954	1,049	777	874	992	1,198	1,442	1,730	2,070	2,470	2,940
Paper Pulp and Print	685	743	879	650	627	977	1,170	1,412	1,700	2,039	2,439	2,911	3,466
Chemical and Petrochemical	1,664	1,805	2,126	2,468	2,595	6,251	9,430	14,622	22,595	34,804	53,461	81,914	125,233
Non Metallic Minerals	783	849	795	771	1,146	1,309	1,485	1,814	2,208	2,679	3,242	3,912	4,711
Iron and Steel	685	743	650	819	1,040	892	1,227	1,482	1,784	2,141	2,562	3,058	3,643
Machinery	1,566	1,699	2,624	2,668	2,603	2,433	3,250	4,047	5,022	6,212	7,663	9,429	11,577
Rubber and Rubber Products	392	425	534	532	616	617	798	966	1,167	1,404	1,685	2,017	2,410
Petroleum and Other Fuel Products	1,077	1,168	1,892	2,616	2,984	2,285	2,633	3,384	4,334	5,534	7,046	8,949	11,341
Other Manufacturing	3,818	4,141	5,913	8,029	7,972	6,774	7,711	9,512	11,691	14,325	17,503	21,332	25,942
Mining	783	849	829	1,972	2,854	2,046	2,755	3,799	5,218	7,147	9,760	13,296	18,073

Year	Historical Data						Baseline						
	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Construction	6,266	6,796	7,504	7,625	12,220	17,117	26,463	38,594	56,089	81,258	117,392	169,173	243,253
Electricity Gas Water Supply	3,622	3,929	4,828	6,139	7,128	8,217	10,742	14,412	19,266	25,676	34,122	45,233	59,830
All Commercial	49,832	54,049	67,958	86,076	110,009	148,352	218,565	321,104	470,097	686,067	998,455	1,449,464	2,099,538
Agri Crops Product	7,245	7,858	9,216	10,323	13,307	14,340	17,835	23,008	29,579	37,907	48,444	61,755	78,550
Livestock and Poultry	3,622	3,929	4,725	5,174	5,590	5,965	7,098	8,657	10,521	12,747	15,400	18,559	22,317
Agri Services	979	1,062	1,172	1,314	1,634	1,842	2,419	3,142	4,066	5,247	6,751	8,665	11,097
Forestry	98	106	192	129	54	54	52	63	76	91	109	130	155
Fishing	2,545	2,761	3,098	3,436	3,993	3,667	4,006	4,838	5,822	6,984	8,355	9,970	11,871
Fuel Prices (2010 USD/gigajoule)													
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	2.55	2.28	1.76	2.89	5.26	3.13	4.02	4.33	4.68	4.83	4.98	5.14	5.30
Natural Gas	1.46	1.46	1.46	6.54	8.89	15.40	13.99	13.62	13.26	13.26	13.01	12.76	12.52
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	14.86	12.12	15.09	18.77	20.13	21.57	23.13	24.79
Bagasse	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Animal Wastes	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Coconut Residue	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Rice Hull	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Wood	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84

Year	Historical Data						Baseline						
	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Avgas	14.44	14.44	14.44	21.70	32.79	31.71	25.87	32.19	40.05	42.94	46.03	49.34	52.89
Lubricants	8.46	3.49	9.33	14.02	18.76	18.40	15.01	18.68	23.25	24.92	26.71	28.64	30.70
Bitumen	5.50	5.50	5.50	5.24	13.12	12.45	10.16	12.64	15.73	16.86	18.08	19.38	20.77
Naphtha	7.51	7.51	7.51	7.74	11.19	13.39	10.93	13.60	16.92	18.14	19.44	20.84	22.34
Other Oil	8.46	3.49	9.33	14.02	18.76	18.40	15.01	18.68	23.25	24.92	26.71	28.64	30.70
LPG	6.80	5.59	7.69	11.24	15.34	15.53	12.67	15.76	19.61	21.03	22.54	24.16	25.90
Residual Fuel Oil	8.46	3.49	9.33	14.02	18.76	18.40	15.01	18.68	23.25	24.92	26.71	28.64	30.70
Diesel	11.99	9.34	11.90	21.60	19.93	20.35	16.60	20.66	25.71	27.56	29.54	31.67	33.95
Kerosene	12.47	9.71	11.89	23.04	25.35	24.86	20.28	25.23	31.40	33.66	36.08	38.68	41.46
Jet Kerosene	21.72	18.65	15.47	25.57	29.52	28.47	23.22	28.90	35.96	38.55	41.33	44.30	47.49
Motor Gasoline	20.42	13.65	17.85	27.27	29.09	28.98	23.64	29.42	36.61	39.25	42.07	45.10	48.35
Biodiesel	32.08	32.08	32.08	32.08	32.08	33.28	27.15	33.79	42.05	45.07	48.32	51.80	55.53
Ethanol	19.08	19.08	19.08	19.08	33.89	28.16	22.97	28.59	35.57	38.14	40.88	43.82	46.98
CNG	9.07	9.07	9.07	9.07	9.07	9.07	15.95	16.87	17.91	18.36	18.83	19.33	19.85
Charcoal	6.01	6.01	6.01	6.01	6.01	6.01	6.01	6.01	6.01	6.01	6.01	6.01	6.01
LNG	15.40	15.40	15.40	15.40	15.40	15.40	13.99	13.62	13.26	13.26	13.01	12.76	12.52

Table IV.9: Historical Exchange Rates and Inflation Rates

Year	Philippine Peso per US Dollar[1]	Philippine Peso Annual Inflation Rate (%)[2]	US Dollar Annual Inflation Rate (%)[3]
1990	24.31	12.3	3.70
1991	27.48	19.4	3.33
1992	25.51	8.6	2.28
1993	27.12	6.7	2.38
1994	26.42	10.5	2.13
1995	25.71	6.7	2.09
1996	26.22	7.5	1.83
1997	29.47	5.6	1.71
1998	40.89	9.3	1.09
1999	39.09	5.9	1.53
2000	44.19	4.0	2.28
2001	50.99	6.8	2.28
2002	51.60	3.0	1.54
2003	54.20	3.5	1.99
2004	56.04	6.0	2.75
2005	55.09	7.6	3.22
2006	51.31	6.2	3.07
2007	46.15	2.8	2.66
2008	44.47	9.3	1.96
2009	47.64	3.2	0.76
2010	45.11	3.8	1.22
2011	43.31	4.4	2.06
2012	42.23	3.2	1.84
2013	42.45	3.0	1.62
2014	44.40	4.1	1.79
2015	45.50	1.4	1.08
2016	47.49	1.8	1.32

[1] Source: Bangko Sentral ng Pilipinas (BSP) (2017)

[2] Sources:
1990-2011: : BSP (2011)

2012-2014: PSA (2015b)

2015: PSA (2016)

2016 : PSA (2017)

[3] Source: World Bank (2017)

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