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

PHILIPPINES MITIGATION COST-BENEFIT ANALYSIS

2018 Update Report – Waste Chapter

FINAL – January 2018

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ACRONYMS

ADB	Asian Development Bank
ALU Software	Agriculture and Land Use Greenhouse Gas Inventory Software
ASEAN	Association of Southeast Asian Nations
AWD	Alternate Wetting and Drying
B-LEADERS	Building Low Emission Alternatives to Development, Economic Resilience, and Sustainability
BOD	Biochemical Oxygen Demand
BOI	Board of Investments
BRT	Bus Rapid Transit
BSWM	Bureau of Soil and Water Management
CBA	Cost-Benefit Analysis
CCC	Climate Change Commission
CDF	Controlled Disposal Facility
CNG	Compressed Natural Gas
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
COD	Chemical Oxygen Demand
CH_4	Methane
CVD	Chemical Vapor Deposition
DOC	Degradable Organic Component
DOCf	Fraction of Degradable Organic Component
EMB	Environment Management Bureau
EO	Executive Order
FOD	First Order Decay
GBD	Global Burden of Disease
GDP	Gross Domestic Product
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GPH	Philippine Government
GWP	Global Warming Potential
HFCs	Hydrofluorocarbons
IEA	International Energy Agency
iF	Intake fraction
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IRG	International Resources Group
JICA	Japan International Cooperative Agency
LEAP	Long-range Energy Alternatives Planning tool
LECB	Low Emissions Capacity Building (UNDP Program)
LED	light emitting diode
LFG	landfill gas
LGU	Local Government Unit
LNG	Liquefied Natural Gas

LULUCF	Land Use, Land Use Change and Forestry
MAC	Marginal Abatement Cost
MACC	Marginal Abatement Cost Curve
MCF	Methane Correction Factor
MER	Market Exchange Rate
MRF	Material Recycling Facility
MSW	Municipal Solid Waste
MVIS	Motor Vehicle Inspection System
mW	megawatt
N	Nitrogen
NAMA	Nationally Appropriate Mitigation Action
NCSB	National Statistical Coordination Board
NEDA	National Economic and Development Authority
NF_3	Nitrogen Trifluoride
NGO	Non-governmental Organizations
NMVOC	Non-Methane Volatile Organic Compounds
N_2O	Nitrous Oxide
NO_x	Nitrogen Oxides
NPV	Net Present Value
NREP	National Renewable Energy Program
NSWMC	National Solid Waste Management Commission
OD	Open Dumpsite
OECD	Organization for Economic Cooperation and Development
O&M	Operation and Maintenance
OX	Oxidation factor
PDP	Philippine Development Plan
PFCs	Perfluorocarbons
PISI	Philippine Iron and Steel Institute
PM	Particulate Matter
PSA	Philippines Statistics Authority
RA	Republic Act
SLF	Sanitary Landfill Facility
SWDS	Solid Waste Disposal Site
SWM	Solid Waste Management
SO_2	Sulfur Dioxide
SF_6	Sulphur Hexaflouride
Ton	Metric ton, 1,000 kilograms
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USD	United States Dollars
VSL	Value per Statistical Life
WEEE	waste electrical and electronic equipment
WtE	waste-to-energy
WW	waste water

V. 2018 UPDATE REPORT – WASTE CHAPTER

V.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 RTI International. 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. For the 2018 Update Report, the evaluation of the mitigation options covers the period spanning 2015-2030.

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 2018 Update Report represents the third update on the CBA model development work. It is structured to integrate stand-alone sectoral reports that contain:

- A description of new methods and data used for this 2018 Update Report, including new cross-cutting assumptions such as projections for gross domestic product (GDP) and population growth to 2050 and a new discount rate and fuel prices. For the 2018 Update Report, these new cross-cutting assumptions were applied to the 2010-2050 baseline for all sectors except agriculture;
- 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. The 2018 Update Report includes updates to the mitigation analyses for all sectors, except agriculture;
- 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 2015-2030 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; and
- The development of a marginal abatement cost curve (MACC) which illustrates the cumulative abatement potential and costs per ton of the mitigation options analyzed in this report.

The 2018 Update Report includes methodological updates to all sectors, except agriculture. Therefore, this 2018 Update Report includes stand-alone sectoral reports for the energy, industry, forestry, transport, and waste sectors only.

This study builds on the output of the series of consultations with stakeholders from February until July of 2015 and then later during the fall of 2017 in order to update assumptions and methods used in prior versions of this report. These consultations included representatives from the CCC and stakeholders in each of the relevant sectors who acted as the final decision makers on which data, methods, and mitigation options to include.

Table V. 1. Direct Costs and Cost per Ton of Waste Sector Mitigation Options Excluding Co-benefits summarizes the direct costs and benefits of mitigation options, including changes in GHG emissions. An option’s sequence number indicates its relative mitigation cost-effectiveness, accounting for direct costs and benefits only and assuming no interactions with other options. The lower the sequence number, the more cost-effective the option—i.e., the lower the direct cost per ton of GHGs reduced. In the CBA, the ranking provided by sequence numbers is used in a separate assessment of interactions between options, called a retrospective systems analysis. This analysis assumes that options are implemented in the order given by the sequence numbers, and it defines the impacts of an option (costs and GHG abatement) as the marginal changes after the option is implemented. The results are expressed in million metric tons of carbon dioxide equivalent (MtCO2e).

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

Sector	Mitigation Option Sequence [1]	Mitigation Option	Incremental Net Costs (Cumulative 2015-2030) [Billion 2010 USD] Discounted at 10%[	Incremental GHG Mitigation potential (2015-2030) [$MtCO_2e$]	Incremental Cost per Ton Mitigation (2015-2030) [2010 USD] *without co-benefits*
Symbol			*A*	*B*	*C*
Formula					*(A*1000)/B=C*
Waste	16	MSW Digestion of Organic Waste	-0.02	6.95	-3.40
	17	Methane Recovery from Sanitary Landfills for Electricity	-0.01	11.69	-0.50
	23	Methane Recovery from Large Dumpsites for Electricity	0.03	7.66	3.77
	24	Methane Recovery from Medium Dumpsites for Flaring	0.02	2.79	5.78
	25	Sewage and Septage	0.06	9.12	6.63
	35	Eco-Efficient Cover at Small Dumpsites	0.32	9.45	34.28
	40	Composting	0.51	7.37	68.76
	43	Mandamus Compliance	1.68	16.81	99.87

Abbreviations:
$MtCO_2e$ = Million metric tons of carbon dioxide equivalent; GHG = greenhouse gas; USD = U.S. dollar; MSW = municipal solid waste
Notes:
[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.
Column Definitions:
[A] Incremental Costs - Total Net Cost: Equal to the sum of incremental capital, operating and maintenance (O&M), implementation, fuel, and input costs compared to the prior mitigation option using retrospective systems analysis. Represents the incremental net change in costs with implementation of the mitigation option. Negative costs indicate cost savings compared to the business as usual (e.g., fuel savings).
[B] Incremental GHG Mitigation Potential: Potential change in incremental cumulative GHG emissions from 2015-2030 with implementation of the mitigation option. Positive values indicate GHG emissions benefits.
[C] Incremental Cost per Ton Mitigation without Co-benefits: Equal to the total net cost divided by the mitigation potential. Represents the incremental cost per ton of a mitigation option using retrospective systems analysis where costs are calculated using the marginal emission reductions and costs incurred after the option was added to a prior mitigation option. Negative values indicate cost savings as well as GHG emissions benefits.

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 V. 2 summarizes the co-benefits that could be monetized for the mitigation options. Column H 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 V. 3.

Table V. 2. Monetized Co-Benefits of Mitigation Options in the Waste Sector

Mitigation Option Sequence [1]	Mitigation Option	Incremental Co-benefits (Cumulative 2015-2030) [Billion 2010,USD] Discounted at 10%				Incremental Cost per Ton Mitigation (2015-2030) [2010,USD] *co-benefits only* [2]
		Health	Congestion	Income Generation	**Total Co-benefit**	
Symbol		*D*	*E*	*F*	*G*	*H*
Formula					*sum(D,E,F)=G*	*-(G*1000)/B=H*
16	MSW Digestion of Organic Waste	-0.01	N/A	N/A	-0.01	1.68
17	Methane Recovery from Sanitary Landfills for Electricity	0.04	N/A	N/A	0.04	-3.44
23	Methane Recovery from Large Dumpsites for Electricity	0.04	N/A	N/A	0.04	-4.71
24	Methane Recovery from Medium Dumpsites for Flaring	0.00	N/A	N/A	0.00	0.00
25	Sewage and Septage	0.00	N/A	N/A	0.00	0.00
35	Eco-Efficient Cover at Small Dumpsites	0.00	N/A	N/A	0.00	0.00
40	Composting	0.00	N/A	0.47	0.47	-63.77
43	Mandamus Compliance	0.00	N/A	N/A	0.00	0.00

Abbreviations:
N/A = indicates inapplicability of a given co-benefits category; USD = U.S. dollar; MSW = municipal solid waste
Notes:
[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%.
Column Definitions:
[D] Co-benefits: Health: Monetized public health benefits reflect the reduced risk of premature death from exposure to air pollution exposure. 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 SO_2, fine particulates, and NO_X.
[E] Co-benefits: Congestion: Monetized congestion benefits reflect less time wasted on congested roadways. These are specific to the transport sector.
[F] 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.
[G] Total Co-benefits: Sum of valuation of monetized co-benefits.
[H] Incremental Cost per Ton Mitigation: Co-benefits Only: Value of monetized co-benefits (represented as a negative cost) divided by mitigation potential.

Table V. 3 combines the cost per ton without co-benefits (Column C) with the cost per ton of co-benefits (Column H from Table V. 2).

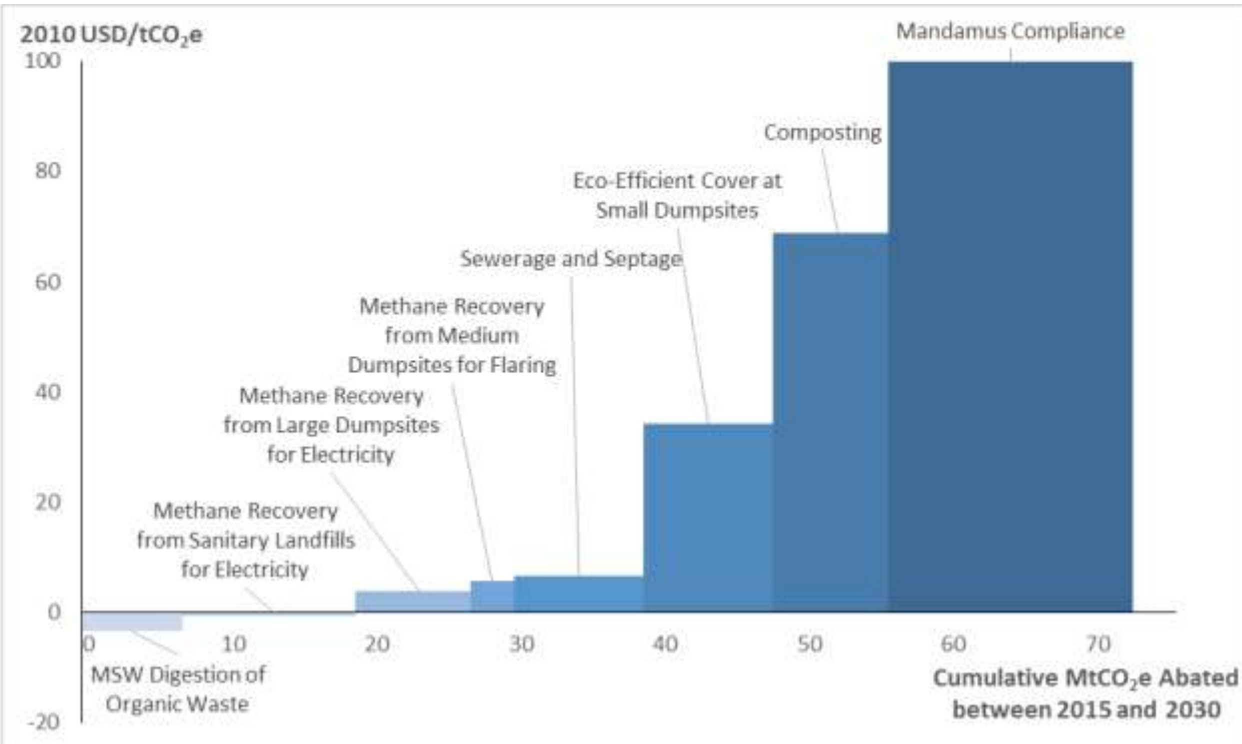
Table V. 3. Net Present Value of Mitigation Options In the Waste Sector during 2015-2030

Sequence Number of Mitigation Option[1]	Mitigation Option	GHG Mitigation Potential ($MtCO_2e$)[3]	Cost per Ton CO_2e Mitigation (2010 USD)[2]			Net Present Value Excluding Value of GHG Reduction (Billion 2010 USD)[2,6]
			without co-benefits	co-benefits only[4]	with co-benefits[5]	
		B	*C*	*H*	*I = C+H*	*J = –I * B/1000*
16	MSW Digestion of Organic Waste	6.95	-3.40	1.68	-1.72	0.01
17	Methane Recovery from Sanitary Landfills for Electricity	11.69	-0.50	-3.44	-3.94	0.05
23	Methane Recovery from Large Dumpsites for Electricity	7.66	3.77	-4.71	-0.94	0.01
24	Methane Recovery from Medium Dumpsites for Flaring	2.79	5.78	0.00	5.78	-0.02
25	Sewage and Septage	9.12	6.63	0.00	6.63	-0.06
35	Eco-Efficient Cover at Small Dumpsites	9.45	34.28	0.00	34.28	-0.32
40	Composting	7.37	68.76	-63.77	4.99	-0.04
43	Mandamus Compliance	16.81	99.87	0.00	99.87	-1.68

Abbreviations:
$MtCO_2e$ - Million metric tons of carbon dioxide equivalent
GHG – Greenhouse gas
USD – U.S. dollar
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 ton 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 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%.
[3] The 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 waste sector include income from composting activities and human health benefits due to reduced air pollution from the energy sector.
[5] Negative value indicates net benefits per ton mitigation. This excludes the non-monetized benefits of GHG reductions.
[6] 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 carbon dioxide-equivalent 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.

Figure V. 1 provides the MACC for the solid waste and wastewater mitigation options analyzed in the CBA. The MACC visually illustrates the cumulative abatement potential and costs per ton if all the waste mitigation options are implemented. It is designed to take into account interactions between mitigation options. Implementing certain options together can lower (or increase) their total effectiveness. Figure V. 1 shows that implementation of all the waste mitigation options included in the retrospective analysis could result in total cumulative emission reductions of about 72 $MtCO_2e$ compared with the baseline projection from 2015 - 2030.

Figure V. 1. Marginal Abatement Cost Curve for the Waste Sector



V.2 BASE YEAR GHG EMISSIONS

V.2.1 Methods and Assumptions

The 2010 base year emissions profile for the waste sector is divided into two primary sub-sectors: solid waste and wastewater. The Study Team developed MS Excel spreadsheet-based models for estimating GHG emissions from solid waste and wastewater, respectively. These were calibrated based on the best and most recent available data on solid waste and wastewater generation, disposal, and treatment in the Philippines along with the IPCC guidelines for national GHG inventories (IPCC, 2006a, 2006b).

V.2.1.1 Solid Waste

Consistent with the IPCC guidance, the CBA for solid waste is based on the first order decay (FOD) method recommended by the IPCC for estimating CH_4 emissions from this sector (IPCC, 2006a).

For the 2018 Update Report, the approach for developing the Base Year GHG emissions profile for solid waste remained the same as the method described in the 2015 CBA report. However, the study team updated some of the assumptions and data used to describe waste generation and disposal and estimate the resulting GHG emissions. These updates are described in the following subsections.

V.2.1.1.2 Solid Waste Generation

The following methods, data, and sources for characterizing solid waste generation were updated in 2018:

- The historical data for total national solid waste generation (tons) from 2001 – 2009 were revised slightly based on consultation with NSWMC during April 2016. These changes resulted in an overall increase of 2.5% in total waste generation over that period, relative to the values in the 2015 report.
- There was no change to the quantity of waste generated in 2010, the base year.

V.2.1.1.2 Solid Waste Segregation

There were no updates to the data sources or methods used in the 2018 Upate Report to describe the proportion of waste material in each sector that is: 1) recycled, 2) composted, 3) disposed of at a solid waste disposal site (SWDS), or 4) uncollected (i.e., unaccounted-for waste).

V.2.1.1.3 Solid Waste Disposal at SWDS

To determine the quantity of waste disposed at *different types* of SWDS, the study team updated the following data inputs for the 2018 Update Report:

- The historical proportion of disposed waste treated by Sanitary Landfills (SLF) from 2006 – 2010 was revised based on April 2016 consultations with the NSWMC. Since the historical proportion of disposed waste treated by Open and Controlled Dumpsites is estimated, in part, based on SLF utilization, these changes also resulted in changes to the proportion of waste treated by OD/CDFs.
- The table below presents the revised historical values; note that the proportions for 2010, the baseline year, did not change.

Table V. 4. Estimated Utilization of SWDS by Type of Facility (Percent Share)

SWDS Type	National SWDS Utilization by SWDS Type (% Share)								
Year	2002	2003	2004	2005	2006	2007	2008	2009	**2010**
Non-Industrial									
OD	100%	95.8%	90.5%	86.3%	77.0%	72.8%	55.5%	51.3%	46%
CDF	0%	4.3%	8.5%	12.8%	17.0%	21.3%	25.5%	29.8%	34%
SLF	0.0%	0.0%	1.0%	1.0%	6.0%	6.0%	19.0%	19.0%	20%
Source: NSWMC, 2014									

- The 2018 Update Report also adopts Methane Correction Factor (MCF) values for the baseline year that are consistent with the characterization of SWDS in the EMB/NSWMC inventory. OD and CDF facilities are assigned an MCF of 0.62, versus a previous value of 0.64. SLFs continue to be assigned an MCF of 1. Similar revisions were made to the historical MCFs, again to align with the EMB/NSWMC inventory. The overall effect of these changes lowers historical emissions, all else equal, due to the overall lower MCF values.

V.2.1.1.4 Solid Waste Emissions

The study team updated the following parameters for estimating emissions from solid waste for the 2018 Update Report:

- The 2018 Update Report includes two adjustments to the first-order decay inputs for organic waste in order to match EMB/NSWMC values for degradable organic carbon (DOC) and the decay rate. The decay rate increases from 0.17 to 0.34, which has the effect of increasing emissions, all else equal. On the other hand, the DOC value for organic waste decreases from 0.25 to 0.18, which has the effect of lowering emissions, all else equal.

Table V. 5. Other Variables Required for Estimating Solid Waste Methane Emissions

Methane Generation Rate Constant (k)	**Value**
Organic (food waste, garden, wood/straw, nappies, textiles)	0.34
Degradable Organic Carbon (DOC)	
Organic (food waste, garden, wood/straw, nappies, textiles)	0.18

- In addition, based on the April 2016 consultations with NSWMC, the baseline year no longer includes methane recovery from the San Pedro, Montalban, Quezon City facilties. The methane recovery from these facilities is captured in the mitigation analysis.

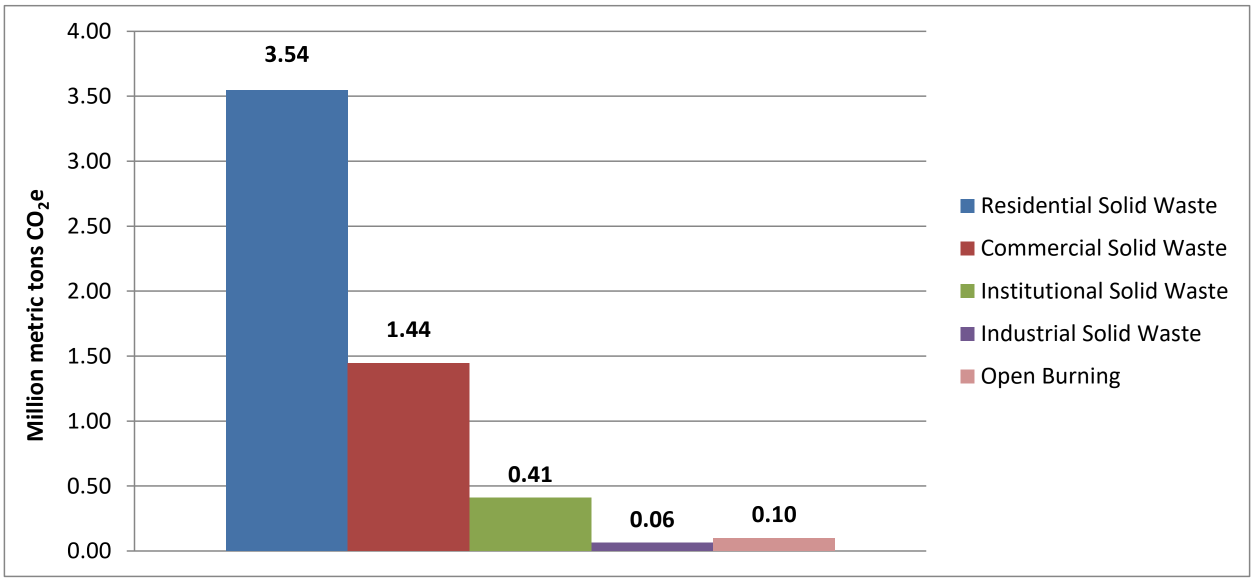
- The 2018 Update Report also includes emissions from open burning in the baseline, following IPCC guidelines and based on consultation with the NSWMC. Key assumptions required for this estimate include:
    - The proportion of the population burning waste, which is assumed to be 15%; and
    - The proportion of waste burned by that population, which is set to a value of 16%. Baseline, 2010, open burning emissions are estimated to be less than 2% of total solid waste emissions, at about 0.1 $MtCO_2e$.

The resulting estimate of total 2010 CH_4 emissions from solid waste is presented in Table V. 6. 2010 Base Year Emissions for Solid Waste by Source Category ($MtCO_2e$) and Figure V. 2, which shows a total of 5.56 million metric tons of CO_2e.

Table V. 6. 2010 Base Year Emissions for Solid Waste by Source Category ($MtCO_2e$)

Solid Waste Emission Source Category	2010
Residential Solid Waste	3.54
Commercial Solid Waste	1.44
Institutional Solid Waste	0.41
Industrial Solid Waste	0.06
Open Burning	0.10
Solid Waste Total Emissions	**5.56**

Figure V. 2. 2010 Base Year Emissions for Solid Waste by Source Category ($MtCO_2e$)



V.2.1.2 Wastewater

Wastewater can be a source of CH_4 when treated or disposed anaerobically. It can also be a source of N_2O emissions. Wastewater originates from a variety of residential, commercial and industrial sources and may be treated on site or disposed untreated nearby or via an outfall (uncollected) or sewered to a centralized plant or discharged through a system of storm drains (collected).

Wastewater as well as its sludge components can produce CH_4 if it degrades anaerobically. Key drivers of wastewater emissions include the quantity of degradable organic material in the wastewater and the type of treatment systems used. These characteristics in turn determine the emission factor that quantifies the extent to which the wastewater generates CH_4.

Treatment systems or discharge pathways that provide anaerobic environments will generally produce CH_4 whereas systems that provide aerobic environments will normally produce little or no CH_4 (IPCC, 2006b). Biochemical oxygen deman (BOD) is used to measure the organic component of domestic wastewater. Chemical oxygen demand (COD) is used to measure the corresponding degradable organic component in industrial wastewater. The total quantity of domestic BOD in the base year and subsequent years is driven by changes in population and per-capita BOD generation. The total quantity of COD in the base year and subsequent years reflects data and assumptions about the level of activity in different economic sectors and the associated use of different material inputs in the associated production processes.

The 2010 Base Year analysis includes emissions from domestic and industrial wastewater. Domestic wastewater refers to all residential, commercial, institutional, and industrial wastewater discharged to the wastewater system. Industrial wastewater refers to wastewater treated on-site at industrial facilities. Emissions from industrial wastewater are quantified by distinct industrial sectors to account for similarities in the materials, processes, and treatment techniques used within sectors of the economy. In the IPCC framework examples of these industrial sectors include: alcohol refining, dairy products, meat and poultry, petroleum refineries, sugar refining (IPCC, 2006b).

V.2.1.2.1 Domestic Wastewater

Key steps in estimating 2010 base year CH_4 emissions from domestic wastewater include:

- Estimate the total quantity of BOD generated and allocate the load to each domestic wastewater colletion/treatment approach;
- Assign CH_4 emission factors and methane correction factors (MCF) to each collection/treatment approach to estimate total methane production; and
- Adjust the total CH_4 production estimate to account for sludge removal and methane recovery.

The Study Team used the cross cutting national population projections for 2010, see *Annex V.5 Cross Cutting Economic Assumptions*, along with information from the United Nations (United Nations, 2014) to initially allocate the Philippine population to urban and rural groups.

The Study Team incorporated assumptions for the percent of urban and rural residents using different types of wastewater collection and treatment pathways used by DENR to support updates to recent analyses of national GHG emissions (e.g., DENR-Ateneo, 2016) to create a domestic wastewater collection/treatment profile for 2010. Table V. 7 presents the information on the 2010 domestic wastewater treatment and discharge profile from DENR (R. Abad, DENR, September 5, 2017, personal communication).

Table V. 7. Domestic Wastewater Treatment and Discharge Profile, 2010

Domestic Wastewater Treatment & Discharge Pathway	2010 Value (Percent)[1]
Urban Populations	
Collected Wastewater	**5.5**
Centralized aerobic treatment	1.7
Sea, river, lake discharge via storm drainage	3.7
Uncollected Wastewater	**94.5**
Septic system	84.1
Latrine: Wet climate/flush water use	4.0
Latrine: Dry climate, small family	0.2
Latrine: Dry climate, communal	0.3

Domestic Wastewater Treatment & Discharge Pathway	2010 Value (Percent)[1]
Latrine: Regular sediment removal	0.1
Sea, river, lake discharge	1.5
Others[2]	4.3
Rural Populations	
Collected Wastewater	**2.5**
Centralized aerobic treatment	0.0
Sea, river, lake discharge via storm drainage	2.5
Uncollected Wastewater	**97.5**
Septic system	61.7
Latrine: Wet climate/flush water use	17.4
Latrine: Dry climate, small family	1.0
Latrine: Dry climate, communal	1.3
Latrine: Regular sediment removal	0.6
Sea, river, lake discharge	1.9
Others[2]	13.7

[1] Totals may not correspond with the sums of the underlying components as a result of rounding for presentation
[2] The other category is linked to responses in the National Health Data Survey for wastewater collection/treatment associated with responses including: *No facility/bush/field, Public toilet,* and *Other*

The Study Team estimated the total quantity of BOD associated with each collection and treatment pathway for the urban and rural populations incorporating an assumption of 14,600 kg-BOD/1000 people/year based on an equivalent central value estimate of 40g BOD/person for the Asian region (IPCC, 2006b). The IPCC BOD value falls in-between the equivalent 1994 GHG inventory value of 12,775 and the 2000 GHG inventory value of 19,345 kg-BOD/1000 people/year. For wastewater handled with "Collected" pathway options, a further 1.25 multiplicative adjustment factor is applied to account for the portion of industrial wastewater discharged into sewers following IPCC protocol (IPCC, 2006b).

The emission factor determining CH_4 production for a given domestic wastewater collection and treatment pathway is the product of the maximum CH_4 producing potential (kg CH_4 / kg BOD) and the MCF for the specific wastewater collection and treatment pathway. In the absence of country-specific information on maximum CH_4 production potential, the Study Team adopted the IPCC default value of 0.6 kg CH_4 / kg BOD (IPCC, 2006b). The Study Team also adopted default IPCC MCF values for each collection and treatment pathway, as well as IPCC default assumptions of 0% sludge removal and 0%CH_4 recovery.

Table V. 8 provides a crosswalk between the collection and treatment pathways used in DENR-Ateneo estimates (DENR-Ateneo, 2016) and the default MCF values for the different collection and treatment pathways defined by by the IPCC protocol (2016b).

Table V. 8. Domestic Wastewater Methane Correction Factors, 2010

DENR-Ateneo Wastewater Collection and Treatment Pathway[1]	IPCC-defined Wastewater Collection and Treatment pathways[2]	IPCC MCF default Values[2]
Collected Wastewater		
Centralized aerobic treatment	Centralized, aerobic, treatment plant (well managed)	0.0
Sea, river, lake discharge via storm drainage	Sea, river, and lake discharge	0.1
Uncollected Wastewater		
Septic system	Septic system	0.5
Latrine: Wet climate/flush water use	Latrine:Wet climate/flush water use, ground water table higher than latrine	0.7
Latrine: Dry climate, small family	Latrine: Dry climate, ground water table lower than latrine, small family (3-5 persons)	0.1
Latrine: Dry climate, communal	Latrine: Dry climate, ground water table lower than latrine, communal (many users)	0.5
Latrine: Regular sediment removal	Latrine: Regular sediment removal for fertilizer	0.1
Sea, river, lake discharge	Sea, river, and lake discharge	0.1
Others[3]	N/A	0.0

[1] Source: DENR-Ateneo, 2016
[2] Source: IPCC, 2006b, Table 6.3
[3] The *Others* category is linked to responses in the National Health Data Survey for wastewater collection/treatment associated with responses including: *No facility/bush/field, Public toilet,* and *Other* based on supporting information this option is assigned a MCF value of 0.0 assuming aerobic conditions.

V.2.1.2.2 Nitrous Oxide Emissions from Domestic Wastewater

Nitrous oxide emissions can occur as direct emissions from treatment plants or from indirect emissions from wastewater after disposal of effluent into waterways, lakes or the sea. Direct emissions from nitrification and denitrification at wastewater treatment plants may be considered as a minor source. IPCC guidance suggests these emissions are much smaller than those from effluent and may only be of interest to countries that predominantly have advanced centralized wastewater treatment plants with nitrification and denitrification steps. Accordingly, the N_2O emissions inventory framework addresses indirect N_2O emissions from wastewater treatment effluent that is discharged into aquatic environments.

The emissions estimate is driven by the quantity of nitrogen in the effluent discharged to aquatic environments (kg N/year), and an emission factor for N_2O emissions from discharges (kg N_2O-N/kg N). The Study Team adopted the IPCC default emission factor of 0.005 kg N_2O-N/kg N (IPCC 2006). The quantity of nitrogen in discharged effluent is estimated based on the product of: population, annual per-capita protein consumption, the fraction of nitrogen in protein, and factors to account for non-consumed and industrial co-discharged protein added to wastewater (IPCC, 2006). A final adjustment is made to account for nitrogen removed with sludge, for which the default IPCC value of zero is used. Table V. 9 summarizes the key inputs to the N_2O emissions analysis.

Table V. 9. Key Inputs for N_2O Emissions Estimates from Domestic Effluent

Wastewater Treatment/Discharge Pathway	2010 Value	Source
Protein consumption (kg/person/year)	20.84	Household Food Consumption Dietary Survey (FNRI, 2008)
Fraction N in protein (kg N/kg protein)	16%	IPCC, 2006, Ch. 6.3.3
Adjustment factor for fraction of non-consumption protein	1.10	IPCC, 2006, Ch. 6.3.1.3
Adjustment factor for fraction of industrial and commercial co-discharged protein	1.25	IPCC, 2006, Ch. 6.3.1.3
N removed with sludge	0.0%	IPCC, 2006, Ch. 6
Emission factor (kg N_2O/kg N)	0.005	IPCC, 2006, Ch. 6.3.1.2
Convert N_2O-N to N_2O	1.571	IPCC, 2006, Ch. 6

V.2.1.2.3 Industrial Wastewater

Key steps in estimating 2010 base year CH_4 emissions from industrial wastewater include:

- Estimate the total quantity of COD generated for distinct industrial sectors and allocate the load, in each sector, to a distinct colletion/treatment approach;
- Assign CH_4 emission factors and methane correction factors (MCF) to each collection/treatment approach to estimate total methane production; and
- Adjust the total CH_4 production estimate to account for sludge removal and methane recovery.

There is a dearth of directly reported and verified data related to the production and collection/treatment pathways for industrial wastewater in the Philippines. As a result, the Study Team used available data on the total quantity of COD produced in different industrial sectors (DENR-Ateneo, 2016). Table V. 10 presents the industrial sectors addressed in the available data (DENR-Ateneo, 2016).

Table V. 10. Industrial Wastewater Sectors Addressed in 2010 Base year

Industrial Sector[1]
Beverages
Chemicals
Commercial Laundry
Dyes & Textiles
Food Processing
Hospitals
Leather Tanning
Paints and Solvents
Pharmaceuticals

Pulp and Paper
[1] The sectors used to define industrial wastewater emissions in DENR-Ateneo (2016) do not directly correspond with the list of sectors defined in the IPCC methodology for calculating industrial wastewater emissions (IPCC, 2016b).

As with domestic wastewater, the emission factor determining CH_4 production for a given wastewater collection and treatment pathway in a specific industrial sector is the product of the maximum CH_4 producing potential (kg CH_4 / kg COD) and the MCF for the specific wastewater collection and treatment pathway. In the absence of country-specific information on maximum CH_4 production potential, the Study Team adopted the IPCC default value of 0.25 kg CH_4 / kg COD (IPCC, 2006b). The Study Team also adopted default IPCC MCF values for each collection and treatment pathway , as well as IPCC default assumptions of 0% sludge removal and 0%CH_4 recovery in the industrial sectors.

Table V. 811 provides a crosswalk between the collection and treatment pathways used in the DENR-Ateneo estimates (DENR-Ateneo, 2016) and the default MCF values for the different collection and treatment pathways for industrial wastewater defined by by the IPCC protocol (2016b).

Table V. 11. Industrial Wastewater Methane Correction Factors, 2010

DENR-Ateneo Wastewater Collection and Treatment Pathway[1]	IPCC-defined Wastewater Collection and Treatment pathways[2]	IPCC MCF default Values[2]
Untreated System		
Raw discharge	Sea, river, and lake discharge	0.1
Treated System		
Aerobically treated – well managed	Aerobic treatment plant (well managed)	0.0
Aerobically treated – overloaded	Aerobic treatment plant (poorly managed)	0.3
Anaerobic deep lagoon	Anaerobic deep lagoon	0.8
Anaerobic digester	Anaerobic digester for sludge	0.8
N/A	Anaerobic shallow lagoon	0.2
N/A	Anaerobic reactor (e.g., UASB, fixed film reactor)	0.8
[1] Source: DENR-Ateneo, 2016 [2] Source: IPCC, 2006b, Table 6.8.		

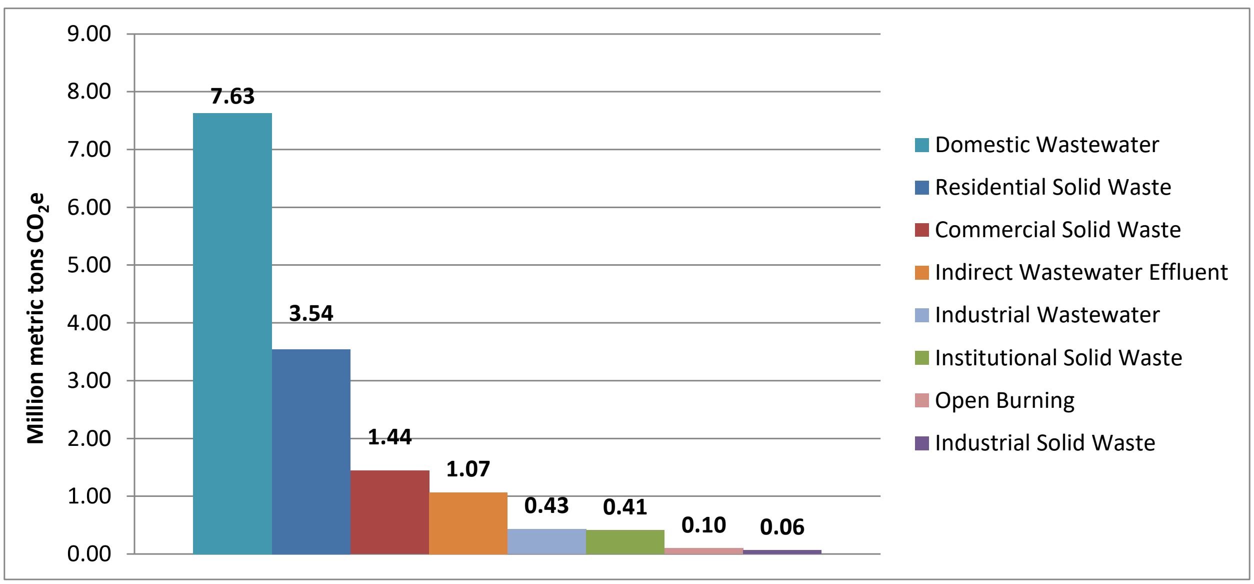
V.2.2 Results

Table V.12 and Figure V.4 below summarize total 2010 base year emissions from the waste sector, which inludes 5.56 $MtCO_2e$ from solid waste and 9.13 $MtCO_2e$ from wastewater, for a total contribution of 14.69 $MtCO_2e$ in 2010.

Table V. 12. 2010 Base Year Emissions for Waste by Source Category ($MtCO_2e$)

Source Category	2010
Residential Solid Waste	3.54
Commercial Solid Waste	1.44
Institutional Solid Waste	0.41
Industrial Solid Waste	0.06
Open Burning	0.10
Solid Waste Subtotal	**5.56**
Domestic Wastewater (excluding indirect N and N_2O related emissions)	7.63
Domestic Wastewater: Indirect Wastewater Effluent from N and N_2O related emissions	1.07
Industrial Wastewater	0.43
Wastewater Subtotal	***9.13***
TOTAL	**14.69**

Figure V. 3. 2010 Base Year Emissions for Waste by Source Category ($MtCO_2e$)



V.3 BASELINE PROJECTION 2010 TO 2050

The 2010-2050 baseline projection describes expected GHG emissions under "business as usual" economic activity. It also serves as a reference against which the impacts of current and planned mitigation actions can be measured. The goal of this CBA is to quantify the GHG emissions impact, costs and benefits of *existing* and *proposed* mitigation actions, regulations, and policies in the Philippines. Therefore, the baseline excludes some of the existing policies that contribute to GHG mitigation, even though these policies have already been passed into law and are being implemented in the Philippines. Instead, these policies and measures are analyzed as sector-specific mitigation options. This approach enables stakeholders to assess the future GHG impact, costs and co-benefits of the many recent initiatives that are being implemented to reduce GHG emissions. Using this approach, several components of the Ecological Solid Waste Management Act of 2000 (RA 9003) are analyzed as mitigation even though the Act is already being implemented by the government and therefore could have been part of the baseline. Similarly, current and future progress toward achieving the goals in the Mandamus agreement for domestic wastewater collection and treatment in an area including the national capital region is analyzed as a mitigation option even though its implementation is mandated by court rulings.

This subsection describes the estimated annual GHG emissions for 2010 to 2050 for the waste sector, including the data and key assumptions used for developing this baseline for the 2018 Addendum to the CBA report.

V.3.1 Methods and Assumptions

V.3.1.1 Solid Waste

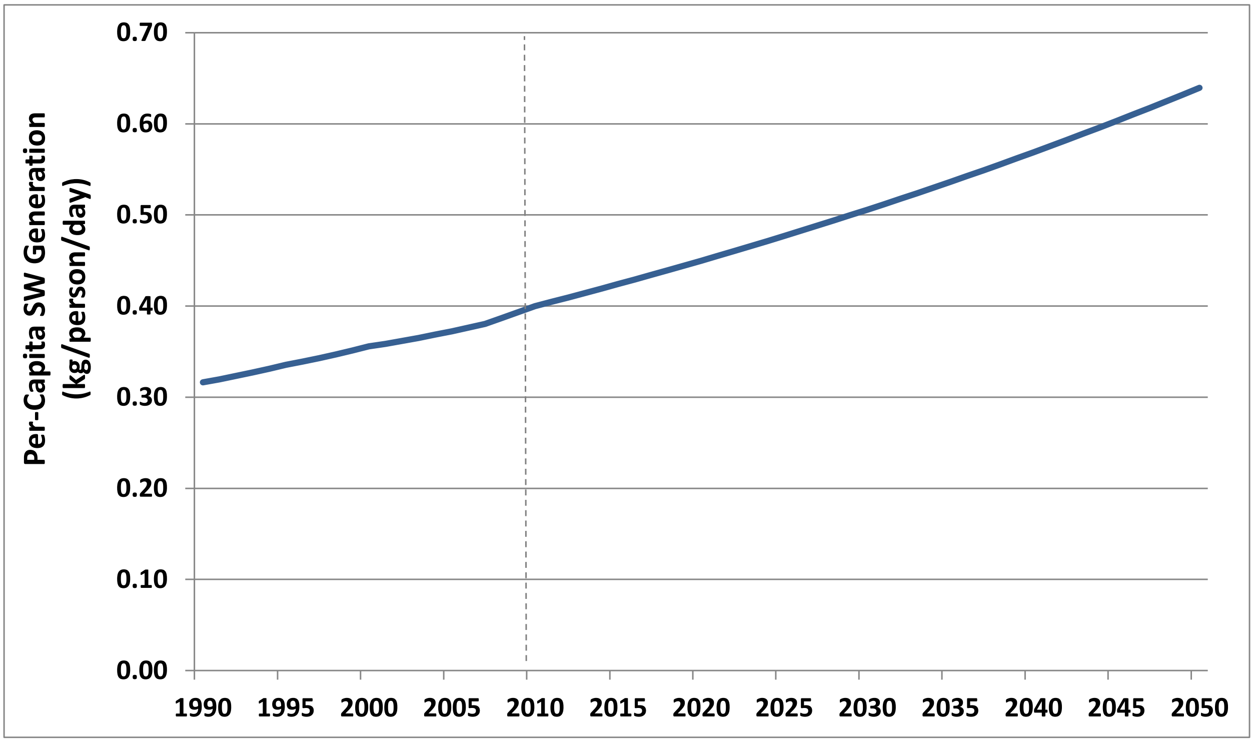
The overall methodology for estimating the quantity and type of waste disposed at SWDS, as well as for estimating CH_4 emissions from disposal, is similar for each year from 2011 – 2050 as it is for the base year, 2010. That is, allocation parameters specified annually are used to characterize the generation, segregation, and disposal of the solid waste generated each year. Then, the FOD method is used to estimate annual CH_4 emissions.

V.3.1.1.1 Solid Waste Generation

For the 2018 Update Report, the study Team used the general approach described in the 2015 CBA report and the updated population projection described in *Appendix V.5 Cross Cutting Economic Assumptions* to project changes in waste generation during 2011-2050.

In addition to total population, solid waste generation is a function of the per-capita waste generation input value. For the 2018 Update Report, based on consultation with the NSWMC, future per-capita waste generation is assumed to increase 1.2% per year, whereas it was previously based on forecast GDP growth. Using this approach, per-capita waste generation is forecast to increase from 0.4 kg/person/day in 2010 to 0.64 kg/person/day in 2050 (Figure V. 4). This change results in a significant reduction in forecasted solid waste generation (e.g., about 40% less by 2030, compared to the prior 2015 report).

Figure V. 4. Forecast of Per-Capita Solid Waste Generation per Day, 2011-2050



V.3.1.1.2 Solid Waste Characterization

The allocation factors used to specify the type of waste generated by source category in the baseline to 2050 for the 2018 Update Report are summarized in Table V. 13 below.

Table V. 13. Baseline Solid Waste Characterization Parameter Values (% by Weight)

Solid Waste Baseline Parameter	2011 – 2050 Value		Source
Sector sources of Solid Waste	Residential = 56.7% Commercial = 27.1% Institutional = 12.1% Industrial = 4.1%		NSWMC, 2014
Composition of Solid Waste by Type			
Residential, Commercial, Institutional, and Industrial	Biodegradable = 52.3% Recyclable = 27.8% Residual = 17.9% Special = 1.9%		NSWMC, 2014
Composition of Solid Waste by Material			
Residential	Paper = 11.5% Glass = 3.8% Metal = 5.6% Plastic = 22.9%	Other Organic = 52.6% Other Inorganic = 3.1% Hazardous = 0.3% Special = 0.1%	ADB, 2003

Solid Waste Baseline Parameter	2011 – 2050 Value		Source
Commercial	Paper = 18.6% Glass = 2.3% Metal = 2.7% Plastic = 21.4%	Other Organic = 52.7% Other Inorganic = 2.0% Hazardous = 0.3% Special = 0.0%	ADB, 2003
Institutional	Paper = 30.8% Glass = 2.1% Metal = 2.3% Plastic = 25.0%	Other Organic = 34.3% Other Inorganic = 4.6% Hazardous = 0.2% Special = 0.6%	ADB, 2003
Industrial	Paper = 14.3% Glass = 2.9% Metal = 3.5% Plastic = 29.5%	Other Organic = 35.8% Other Inorganic = 11.7% Hazardous = 1.9 Special = 0.3%	ADB, 2003

V.3.1.1.3 Solid Waste Segregation and Disposal

To more accurately capture continued improvements in overall solid waste management and compliance with RA 9003 between 2010 and 2015, the baseline to 2050:

- Assumes no change in 2010 baseline segregation rates for both recyclable waste and biodegradable waste from 2010 – 2015. In the 2015 report, these rates increased during 2011 – 2015 based on adopted targets set forth under the Philippine Development Plan (PDP) for 2011 – 2016 (NSWMC, 2014);
- The baseline to 2050 assumes a 1% decrease in the uncollected/unmanaged portion of waste annually from 2010 – 2015; and
- The baseline to 2050 assumes that the percentage of waste that is disposed at SLFs continues to increase from 2010 – 2015, and the use of OD and CDF facilities continues to decline. Estimates of the increase in SLF utilization are based on the percentage change in total SLF capacity from 2010 – 2015 and an assumed 60% capacity utilization of SLF facilities. Total SLF capacity for 2010 and 2013 are obtained from the NSWMC (2014, Table 12), and values for 2011, 2012, 2014, and 2015 and interpolated based on these estimates.

The input values reflecting the above trends are summarized in Table V. 14, Table V. 15, and Table V. 16.

Table V. 14. Rate of Recyclable Material Segregation by Sector and Material, 2010 - 2015 (% of Total Quantity of Material Waste Generated by weight)

Sector and Material	National Segregation Rates for Recyclable Materials
Households	
Paper	34%
Aluminum	32%
Other Metals	21%
Plastics	24%

Sector and Material	National Segregation Rates for Recyclable Materials
Glass	29%
Businesses	
Paper	38%
Aluminum	46%
Other Metals	49%
Plastics	33%
Glass	29%
Source: JICA, 2008; ADB, 2003; and CBA model estimates.	

Table V. 15. Rate of Biodegradable Material Segregation and Rate of Uncollected Waste, 2010 - 2015 (by Weight)

Waste Type	National Segregation Rates for Biodegradable Materials and Fraction of Waste that is Uncollected					
year	2010	2011	2012	2013	2014	2015
Biodegradable Waste Segregation Rate	5%	5%	5%	5%	5%	5%
Percentage of Waste Uncollected/Unmanaged	10%	9%	8%	7%	6%	5%
Source: CBA model estimates.						

Table V. 16. Percentage of Disposed Waste that is Disposed at Different SWDS (by Weight)

SWDS Type	Percentage of Solid Waste Disposed by SWDS Type					
year	2010	2011	2012	2013	2014	2015
Open DumpsiteOD	46%	45.9%	45.6%	44.6%	43.8%	43.0%
Controlled Dumpsite FacilityCDF	34%	33.9%	33.7%	32.9%	32.4%	31.8%
Sanitary Landfill FacilitySLF	20%	20.2%	20.6%	22.5%	23.8%	25.2%
Total SLF Capacity per Day (tons)	13,600	13,875	14,300	16,471	18,095	19,835
Total SLF Disposal per Day (tons)	5,428	5,723	6,086	6,847	7,500	8,201
Source: NSWMC, 2014; CBA model estimates.						

V.3.1.1.4 Development of Additional Sanitary Landfill Facilities

The baseline from 2010 – 2050 accounts for the number and land area associated with the construction of new SLFs. The Study Team estimated the number of new SLFs required each year from 2016 – 2050 in the baseline by assuming that there are no additional changes in SLF utilization (on a percentage basis) for disposal beyond 2015. The analysis accounts for all SLFs that became operational annually from 2003 – 2016, the replacement of these existing SLFs as they eventually go offline – assuming a 15-year lifetime – and the SLF capacity requirements to absorb the continued increases in waste generation and disposal based on population growth and growth in the per-capita waste generation value. The analysis assumed an overall average of 116 tons per day capacity for new SLFs, which reflects weighted average SLF size requirement for LGUs across the four landfill size categories based on Gerstmayer and Krist (2012). The number of SLFs operational in each year from 2008 – 2016 was obtained from NSWMC. The number of SLFs operational from 2004 – 2007 was linearly interpolated based on the 2003 value of 1 and the 2008 value of 21 (NSWMC, 2014). In addition, it was estimated that the land area of 7 hectares was required for each new SLF based on the total number of hectares per SLF reported for 2013 by NSWMC (2014). The results of this analysis for the baseline are summarized in Table V. 17 below.

Table V. 17. Requirements for Additional SLFs in the Baseline

Sector and Material	Baseline SLF Requirements								
year	2010	2015	2020	2025	2030	2035	2040	2045	2050
Number of Operational SLFs	29	101	111	88	16	0	0	0	0
Annual SLF Capacity (million tons) (with no new construction after 2015)	4.9	7.2	6.8	3.0	0.68	0	0	0	0
Total Additional SLF Capacity Requirement (million tons)	0	0	0	1.4	4.4	5.9	6.8	7.8	8.9
Cumulative Number of New SLFs Required	**0**	**0**	**0**	**38**	**123**	**165**	**190**	**216**	**247**
Land Area Required (hectares)	**0**	**0**	**0**	**266**	**861**	**1,155**	**1,330**	**1,512**	**1,729**
Source: NSWMC, 2014; CBA model estimates.									

V.3.1.1.5 Results of the Solid Waste Baseline to 2050

The figures below summarize the results for the solid waste baseline forecast for the 2018 Update Report. The figures show solid waste emissions rising from about 5.5 $MtCO_2e$ in 2010 to 18 $MtCO_2e$ in 2050. As seen in Figure V. 5, since the baseline forecast does not include any future waste management actions, the relative proportion of waste that is disposed in a SWDS does not change over time, and continues to represent the largest share of overall waste disposition in 2050.

Figure V. 5. Solid Waste Generation by Disposition Method, 2000 - 2050

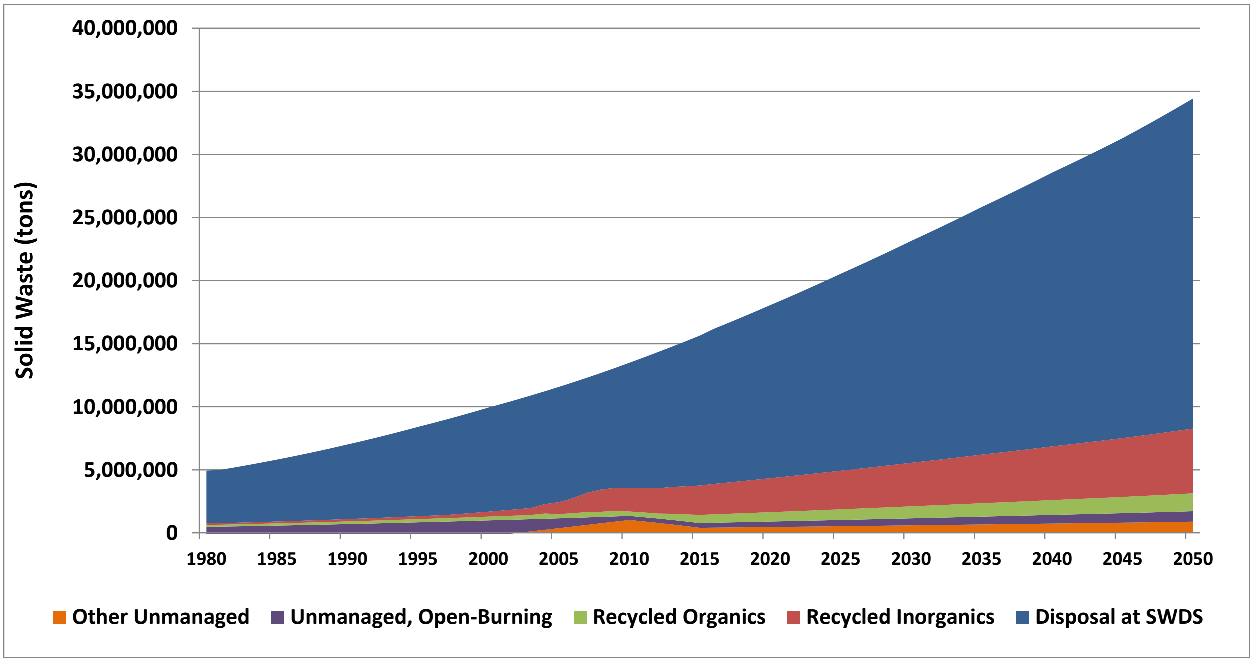
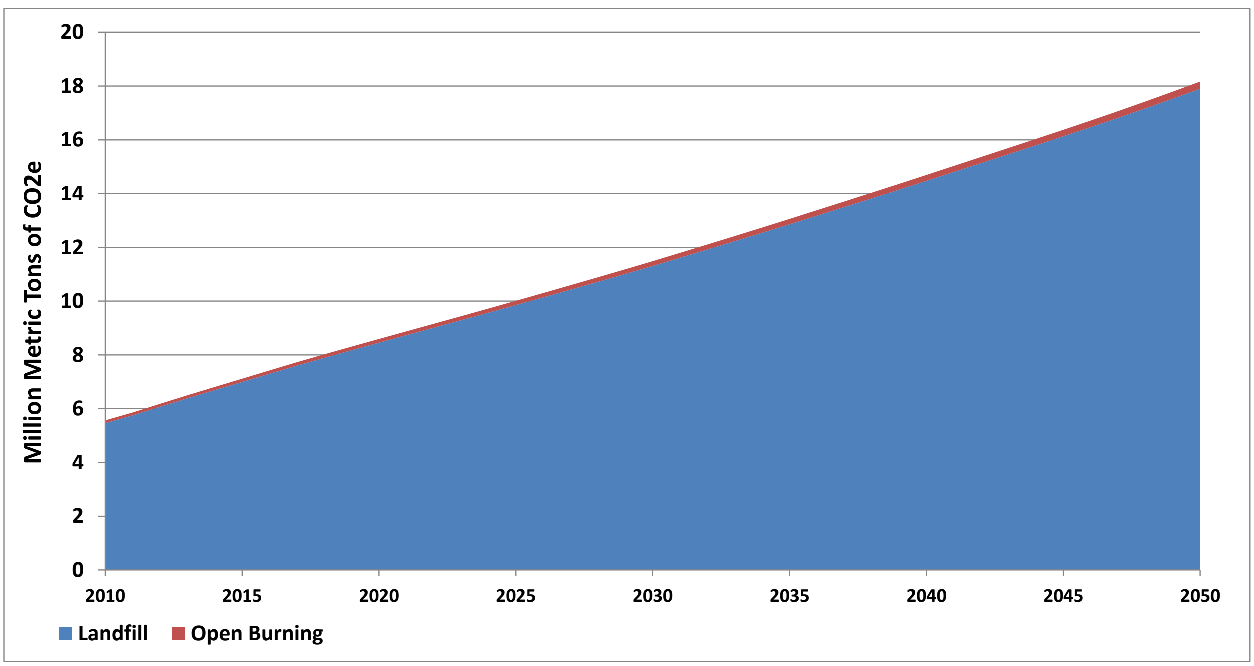


Figure V. 6. 2010-2050 GHG Emissions Baseline for Solid Waste ($MtCO_2e$)



V.3.1.2 Wastewater

Changes in domestic and industrial wastewater methane emissions as well as indirect N_2O emissions from domestic wastewater are driven by changes in national, urban, and rural population over time as well projected changes in the nature and type of economic activity.

V.3.1.2.1 Domestic Wastewater

For the 2018 Update Report the study team updated the projected emissions from domestic wastewater for urban and rural populations using information from the following sources:

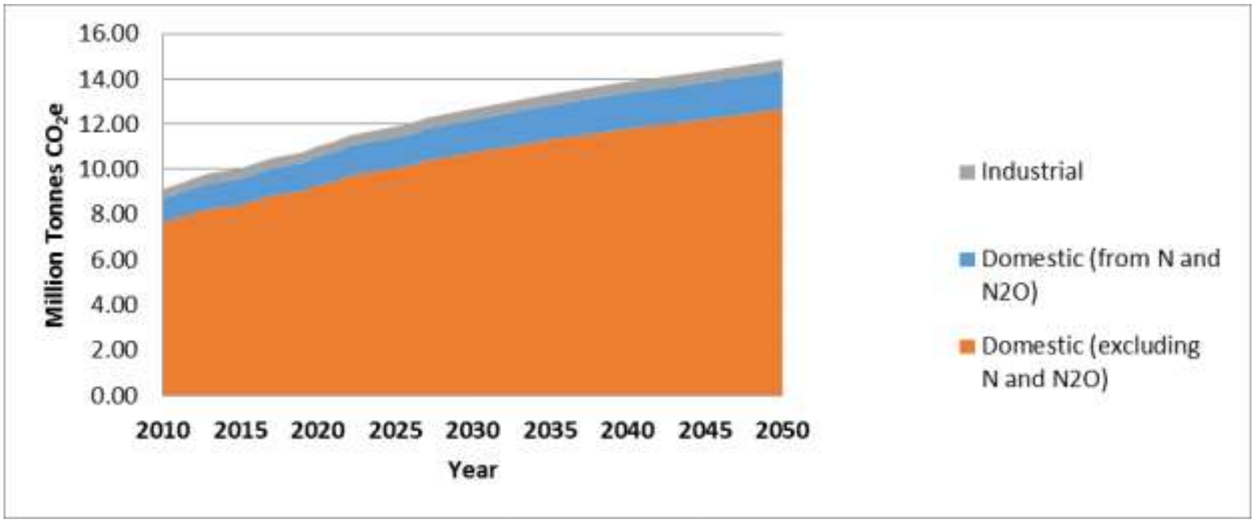
- Rural and urban populations: national population projections for 2010-2050 as presented in *Annex V.5 Cross Cutting Economic Assumptions*.
- Information from the United Nations (United Nations, 2014) on the share of Philippine population living in urban and rural areas from 2010-2050. The Study Team also incorporated the following assumptions to incorporate the available information from the DENR-Ateneo (2016) estimates of urban and rural residents using different types of wastewater collection and treatment pathways from 2010-2030 to complete our baseline calculations:
- The share of the urban population associated with the *Centralized, aerobic treatment* option from Table V.5 remains constant at its 2010 value
- Changes in the the share of the urban population associated with the *Centralized, aerobic treatment* option from the 2010 value in the DENR-Ateneo data are calculated and added to the *Septic tank* option for 2011-2030.
- Resulting values for 2030 for the share of the urban population associated with different collection and treatment pathways are held constant for the years 2031-2050.
- Values for the share of the rural population associated with different collection and treatment pathways are used, as presented without adjustment, in the DENR-Ateneo (2016) data

V.3.1.2.2 Industrial Wastewater

Changes in industrial wastewater over time are driven by the projected changes in the COD loads allocated in each industrial wastewater sector to the available collection and treatment pathways. The Study team used the available DENR-Ateneo (2016) data for industrial wastewater for 2010-2030 and then held the total COD loads and distribution across collection and treatment pathways constant at 2030 values for the years 2031-2050 within each industrial sector.

Figure V. 7 summarizes the results for the wastewater baseline forecast for the 2018 Update Report. The figure shows emissions from wastewater rising from about 7 $MtCO_2e$ in 2010 to 59 $MtCO_2e$ in 2050 with emissions from domestic wastewater, excluding those associated with N and N_2O, accounting for the largest share of these emissions.

Figure V. 7. 2010-2050 GHG Emissions Baseline for Wastewater ($MtCO_2e$)



V.3.2 Results

Figure V.8 and Table V.18 summarize the total waste sector emissions for the 2010 – 2050 baseline.

Figure V. 8. 2010-2050 GHG Emissions Baseline for Waste by Subsector ($MtCO_2e$)

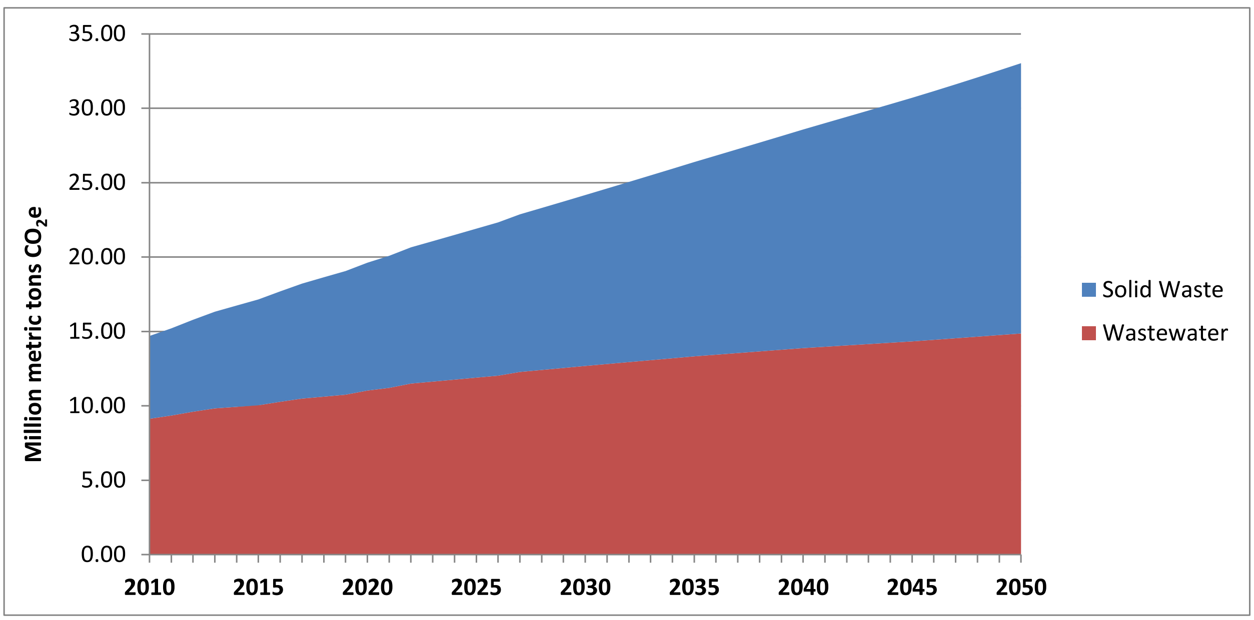


Table V. 18. 2010 - 2050 Baseline for Waste by Source Category ($MtCO_2e$)

Source Category	Year ($MtCO_2e$)				
	2010	2020	2030	2040	2050
Residential Solid Waste	3.54	4.86	6.37	8.08	9.95
Commercial Solid Waste	1.44	2.48	3.34	4.29	5.31
Institutional Solid Waste	0.41	0.94	1.36	1.80	2.26
Industrial Solid Waste	0.06	0.17	0.24	0.31	0.38
Open Burning	0.10	0.14	0.18	0.22	0.27
Solid Waste Subtotal	**5.56**	**8.59**	**11.49**	**14.69**	**18.17**
Domestic Wastewater	7.63	9.30	10.74	11.80	12.67
Indirect Wastewater Effluent	1.07	1.27	1.45	1.59	1.71
Industrial Wastewater	0.43	0.46	0.49	0.49	0.49
Wastewater Subtotal	**9.13**	**11.03**	**12.68**	**13.88**	**14.86**
TOTAL	**14.69**	**19.62**	**24.17**	**28.57**	**33.03**

V.4 MITIGATION COST-BENEFIT ANALYSIS

V.4.1 Direct Cost and Benefits

For the 2018 Update Report, the B-LEADERS team updated the mitigation analysis by adding new mitigation options and updating data and assumptions for some of the existing mitigation options. The updates and results are described in the following subsections.

V.4.1.1 Methods and Assumptions

Table V. 19 and Table V. 20 lay out the definition and key assumptions for each solid waste and wastewater mitigation options, respectively.

Table V. 19. Definitions and Assumptions for Solid Waste Sector Mitigation Options

Mitigation Option	Description	Assumptions
Composting	• Option includes increasing the percentage of biodegradable waste that is composted from 10% in 2015 to 50% in 2050. • Increased composting results in additional biodegradable waste diversion from landfills, reducing CH4	• 120 million tons of additional biodegradable waste is diverted for composting, compared to the baseline, cumulatively by 2050. • By 2050, the national waste diversion rate increases to 41.8% of all waste, compared to 19% in 2050 in the baseline. • The percentage of waste disposed in landfills drops in 2050 to 53%, compared to 76% in the baseline. This also means a lower requirement for new landfill construction compared to baseline. • MRF and Transfer Station Capital Costs: Requirement based on total additional quantity of

Mitigation Option	Description	Assumptions
	emissions and overall disposal requirements.	biodegradable waste processed by composting facilities at MRFs; USD 0.31/ton (2010 USD) (NEDA/NSWMC 2008) • Composting Technology Capital and Operating Costs: Requirement to construct and operate composting facilities within or exclusive of MRFs; assume 70% bioreactor technology, 30% average cost of mix of box, windrow, and vermin composting: o Bioreactor capital cost: USD 19,650 per 1-ton reactor (2010 USD) (ADB, 2003b) o Bioreactor operating cost: USD 11,056 per reactor per year (2010 USD) (ADB, 2003b) o Windrow, box, vermi capital cost: USD 75.79/ton (2010 USD) (Paul et. al., 2008) o Windrow, box, vermin operating cost: USD 40.94/ton of compost product (2010 USD) (Paul et. al., 2008) • Implementation Costs: o Separate collection of biodegradable waste: USD 38.55/ton (2010 USD) (Gerstmayer and Krist, 2012) o Landfill disposal cost savings: USD 13.33/ton (2010 USD) (ADB, 2003b)
Eco-Efficient Cover	• Option includes deployment of eco-efficient soil cover (methane oxidizing cover) at small OD and CDF by 2030.	• Eco-efficient cover is deployed at 50% of small dumpsites by 2030, with a phase-in beginning in 2018. • Small dumpsites are defined as category 1 and 2 sites. Gerstmayer and Krist (2012) indicate that approximately 58% of dumpsite capacity exists in category 1 and 2 dumpsites. • For the portion of small dumpsites that get eco-efficient cover in each year, we assume a 70% emission reduction is achieved (Gerstmayer and Krist 2012). • Cost of biocover per ton of CO_2e mitigated: USD 100 (2010 USD/tCO_2e) (IPCC, 2014) • Option assumes overall utilization of dumpsites for disposal remains the same as baseline (no additional dumpsite closures).
Methane Recovery from Dumpsites for Flaring	• Option includes deployment of methane recovery for flaring at medium OD and CDFs by 2030.	• Assume methane recovery can occur at medium ODs and CDFs. • The percentage of emissions subject to recovery (e.g., percentage of emissions from these facilities) is assumed to be the same as their overall disposal capacity.

Mitigation Option	Description	Assumptions
		• Category 3 facilities are assumed to comprise 12% of OD/CDF capacity based on Gerstmayer and Krist (2012). • Assume 50% ofCH4 in LFG and a capture efficiency of 50% (IPCC, 2006). • Assume that implementation of potential methane recovery per year given the above assumptions is phased-in between 2018 – 2030, with achievement of the full potential (12% of dumpsites) in 2030. • Capital Cost for Methane Recovery: USD 17 per ton of capacity deploying methane recovery (2010 USD) (USEPA, 2013). Capital cost is applied to the additional dumpsite capacity getting methane recovery capabilities in each year from 2018 – 2030. • Operating Cost for Methane Recovery: USD 3 per ton of capacity deploying methane recovery (2010 USD) (USEPA, 2013). Operating costs are applied to the cumulative quantity of dumpsite capacity with methane recovery in each year (not just the incremental capacity added each year).
Methane Recovery from Dumpsites for Electricity[3]	• Option includes deployment of methane recovery for electricity generation at large ODs and CDFs by 2030. • Option includes the costs of the same methane recovery and flaring system as in the prior option, plus construction and operation of an on-site generation facility as outlined in the CBA Energy Report (B-LEADERS, 2015).	• Assume methane recovery can occur at Category 4 ODs and CDFs. • The percentage of emissions subject to recovery (e.g., percentage of emissions from Category 4 facilities) is assumed to be the same as the overall disposal capacity present in Category 4 facilities. • Category 4 facilities are assumed to comprise 30% of OD/CDF capacity based on Gerstmayer and Krist (2012). • Assume 50% of methane in LFG and a capture efficiency of 50% (IPCC, 2006). • Assume that implementation of potential CH4 recovery per year given the above assumptions is phased-in between 2018 – 2030, with achievement of the full potential (30% of dumpsites) in 2030. • Capital Cost for Methane Recovery: USD 17 per ton of capacity deploying methane recovery (2010 USD) (USEPA, 2013). Capital cost is applied to the additional dumpsite capacity getting methane recovery capabilities in each year from 2018 – 2030. • Operating Cost for Methane Recovery: USD 3 per ton of capacity deploying methane recovery (2010 USD) (USEPA, 2013). Operating costs are applied to

Mitigation Option	Description	Assumptions
		the cumulative quantity of dumpsite capacity with methane recovery in each year (not just the incremental capacity added each year).
Methane Recovery from SLFs for Electricity	• Option includes deployment of methane recovery for electricity generation at large sanitary landfills by 2030. • Option includes the costs of a methane recovery and flaring system, plus construction and operation of an on-site generation facility. For more information see the CBA Energy Report (B-LEADERS, 2015).	• Assume methane recovery can occur at Category 4 SLFs. • The percentage of emissions subject to recovery (e.g., percentage of emissions from Category 4 facilities) is assumed to be the same as the overall disposal capacity present in Category 4 SLF facilities. • Category 4 facilities are assumed to comprise 56% of SLF capacity based on Gerstmayer and Krist (2012). • Assume 50% of CH4 in LFG and a capture efficiency of 50% (IPCC, 2006). • Assume that implementation of potential methane recovery per year given the above assumptions is phased-in between 2018 – 2030, with achievement of the full potential (56% of SLFs) in 2030. • Capital Cost for Methane Recovery: USD 24.46 per ton of SLF capacity deploying methane recovery (2010 USD) (UNFCCC, 2012). Capital cost is applied to the additional SLF capacity getting methane recovery capabilities in each year from 2018 – 2030. • Operating Cost for Methane Recovery: USD 0.0134 per cubic meter of LFG subject to recovery (2010 USD) (UNFCCC, 2012). Operating costs are applied to the cumulative quantity of LFG recovered in each year (not just the incremental quantity recovered each year). • Power Generation: New LFG generation capacity is constructed to utilize the additional fuel. Paralleling NREP, this capacity is deployed into the baseline power model displacing baseline generation and some endogenously built capacity. Electricity demand and total electricity production are not affected. Changes in requirements for fossil fuels impact upstream energy use and emissions from fossil fuel production in keeping with the supply-side model. Capital and O&M costs for LFG power generation can be found in the 2018 Update Report Energy Chapter(B-LEADERS, 2018).
MSW Digestion	• Option includes diversion and collection of biodegradable waste	• This option comprises a limited deployment of MSW plants which are built to U.S. and European technical standards using electrostatic precipitator

Mitigation Option	Description	Assumptions
	for digestion and power generation. • Includes diversion of 1,000 tons per day of biodegradable waste from SLFs by 2025, with a phase-in beginning in 2018.	pollution control technology. • For the MSW Digestion option, sufficient MSW digestion capacity is constructed between 2018 and 2025 to consume 1,000 short tons of organic MSW per day (116 MW). • Each unit of organic solid waste which is consumed for power generation is expected to reduce landfill emissions of CH4 which would otherwise have occurred. • This capacity is deployed into the baseline power model, displacing baseline generation and some endogenously built capacity. Electricity demand and total electricity production are not affected. Capital and O&M costs for MSW Digestion power generation can be found in the 2018 Update Report Energy Chapter (B-LEADERS, 2018).

Details of the mitigation options evaluated for the wastewater sector are presented in Table V. 20. These options are exclusive to domestic wastewater sector. As of the time of this report no mitigation options were identified or evaluated for the industrial wastewater sector.

Table V. 20. Definitions and Assumptions for Domestic Wastewater Sector Mitigation Options

Mitigation Option	Description	Assumptions
Sewerage and Septage	• Option includes expanding septage management in a number of highly urbanized cities (HUCs) and other urban areas outside of the region being addressed by the by Mandamus ruling consistent with the goals of the National Sewerage and Septage Management Program (NSSMP) (DPWH, 2013, 2016)	• Expanded septage coverage will address the domestic wastewater produced by 80% of the urban population in 17 highly urbanized cities (HUCs) and 8 other cities[1]. • The evaluated septage component of the NSSMP involves having domestic wastewater from septic tanks pumped to trucks and taken to newly constructed, centralized, aerobic, treatment facilities for treatment. • It is assumed all additional aerobic treatment facilities required will be constructed and operational starting in 2022. • The emissions impact is evaluated as a switch in 2022 so 80% of domestic wastewater in the targeted areas would treated by a centralized, aerobic treatment facility. • NSSMP target areas do not overlap with the populations addressed by the Mandamus Compliance. • Population estimates for 2015 through 2030 developed from a combination of direct population

Mitigation Option	Description	Assumptions
		estimates for 2010 and 2014 for the covered locations provided by DENR (R. Abad, DENR, September 29, 2017, personal communication) with values for remaining years calculated based on estimated annual population growth rates; for the years 2011, 2012, 2013, 2015; and from regional growth rates at 5-year intervals available from the Philippine Statistical Agency (2016). • Initial cost estimates for implementing the NSSMP septage plan with 80% coverage in the 17 HUCs were provided as a personal communication from DENR (R. Abad, DENR, September 29, 2017, personal communication). This information was used to calculate an initial capital cost-per-covered person (223.02 Ph pesos). This value was used to calculate a total one-time capital cost for the expanded population to be covered in 2022. Details from the initial cost information support allocating the capital cost to plant facilities (80%) and the trucks (20%). Further details specify annual operations costs can be calculated separately as a percentage of the initial capital cost of facilities (21.8%) and the trucks (53%). Annual operations is assumed each year from 2022-2030 for the mitigation scenario[2].
Mandamus Compliance	• Option projects compliance with the Mandamus ruling addressing expanding domestic wastewater collection and centralized treatment in the Manila Bay region.	• Mandamus Compliance is consistent with providing 100% of the population covered by the ruling with access to centralized, domestic wastewater treatment by 2037. • The population assumed covered by the Mandamus Compliance consists of all residents in the National Capital Region, Region III – Central Luzon, and all residents in Cavite within Region IVA – Calabarzon (R. Abad, DENR, September 29, 2017, personal communication). • Estimates of the population in covered areas were developed from a combination of estimates of residents and 5-year average growth rates for the all age populations (Philippine Statistical Agency, 2016). • The emissions impact of the Mandamus Compliance is evaluated assuming that there is a linear progression in the percentage of the affected population whose wastewater is collected and treated by by centralized, aerobic wastewater treatment plants from 2015 to 2037 so that by the

Mitigation Option	Description	Assumptions
		end of 2037 100% of this population is covered by the centralized, aerobic wastewater treatment plants. • The assumed number of new plants required is calculated based on an estimate of urban residents generating 0.12 m^3/wastewater/day (World Bank, 2013) and an average capacity for a new facility of 100,000 m^3/wastewater/day. • Capital costs for a new facility were based on an average cost of 30,624 Ph pesos per m^3/wastewater/day treatment capacity from a review of cost information on 22 treatment facilities developed by provided by Maynilad Water Services Inc. and Manila Company Inc. that was provided following consultations in Manila in July, 2015[2]. • New facilities are assumed to have been constructed and become available when projected increases in wastewater volumes will exceed existing treatment capacity. • Annual operating expenses equal to 17.5% of capital costs are assumed based on cost estimates for implementing the NSSMP sewerage plan provided as a personal communication from DENR (R. Abad, DENR, September 29, 2017, personal communication). • The total capital costs for all new facilities provide the cost base for estimating the annual operations expense.

[1] The specific locations were identified in a personal communication from Rolando Abad, DENR, and include the following HUCs: Baguio, Angeles, Olongapo, Lucena, Puerto Princesa, Bacolod, Iloilo City, Lapu-Lapu, Mandaue, Cebu City, Tacloban, Zamboanga City, Cagayan de Oro, Iligan, Davao City, General Santos, Butuan along with the following locations that had submitted applications or letters of intent to participate in the NSSMP as of September, 2017: Puerto Galera, Isabella City, Metropolitan Naga, Zamboanga City, Roxos Palawan, General Santos City, Olongapo City, Cotobato City. These areas do not overlap with the populations targeted by the Mandamus Compliance mitigation option.

[2] These costs incorporate considerable uncertainty as actual costs for a new facility will depend critically, among other factors, on the design capacity of the facility and the associated land costs. As land costs increase there is a general pressure to try and increase the capacity of the treatment facility but the available information does not account for land costs (M. Mulingbayan, Manila Water, September 13, 2017, personal communication).

A key issue in the estimation of mitigation potential and costs per ton is how to account for interactions between mitigation options. Implementing certain options together can lower (or increase) their total effectiveness—for example, an energy efficiency measure will result in greater abatement when the power system is carbon intensive, but less if a renewable power measure is deployed concurrently. Similarly, some mitigation options address the same GHG emission source categories, leading to a potential overestimation of total GHG emission reductions if all the mitigation options analyzed in this report are simply summed up.

The CBA addressed this issue by following the retrospective systems approach in Sathaye and Meyers (1995). In this approach, the GHG emission reduction potential and cost per ton of CO_2e for a given mitigation option were calculated relative to a scenario that reflected the cumulative effect of previously implemented (more cost effective) mitigation options. In the present analysis, the value of an option was represented by its cost per ton of CO_2e mitigation (*excluding* co-benefits), relative to the baseline scenario. Options with low cost per ton of CO_2e mitigation were most cost effective. The advantage of this approach is that it accounts for the interdependence between a given mitigation option and the preceding options analyzed in the CBA. This enables the development of a MACC that illustrates the potential emission reductions that can be achieved if all mitigation options analyzed in this CBA were implemented together.

In brief, this method involves four steps:

- Each mitigation option is first evaluated individually (compared to the baseline scenario), and an initial cost per ton for each is recorded;
- The options are sorted according to their initial costs per ton in ascending order;
- The options are added one at a time and in order to a new combined mitigation scenario, and emissions and costs for the combined scenario are recorded after each addition; and
- The final abatement potential and cost per ton for each option are calculated using the marginal emission reductions and costs incurred after the option was added to the combined scenario. Thus, the first option is evaluated in comparison to the 2010-2030 baseline only, the second option in comparison to the baseline plus the first option, and so forth.

The retrospective approach, which ultimately determines the abatement potential and cost of an option, spans all mitigation options across all sectors. Waste mitigation options were initiated within the overall set or sequence of options based on the retrospective analysis approach, as summarized in Table V. 21. Across all sectors, 50 mitigation options were included in the retrospective analysis, including all of the solid waste and wastewater options described above.

The results presented below in Section V.4.1.2 Results focus on the incremental impacts of the six solid waste mitigation options and the two domestic wastewater mitigation options. However, it is important to understand that those results occur within and are dependent on where an option sits in the overall sequence of 50 options in Table V. 21. The further down the list a mitigation option is placed, the less GHG-intensive the economy will be, thus reducing the potential for achieving additional abatement at a low cost.

Table V. 21. Sequential Order of All Mitigation Options in the Retrospective Analysis Approach

Sector	Mitigation Option Sequence	Mitigation Option Name
Industry	1	Increase Glass Cullet Use
Industry and Energy	2	Cement Clinker Reduction
Transport	3	MVIS
Transport	4	Jeepney Modernization
Transport	5	Congestion Charging
Transport	6	Driver Training
Energy	7	Home Lighting Improvements
Transport	8	CNG Buses
Industry and Energy	9	Cement Waste Heat Recovery
Energy	10	Home Appliance Improvements
Energy	11	Energy Efficient Street Lighting with HPS Technology
Industry and Energy	12	Biomass for Cement Production
Energy	13	NREP Biomass
Agriculture	14	Organic Fertilizers
Energy	15	Advanced New Coal
Waste and Energy	16	MSW Digestion of Organic Waste
Waste and Energy	17	Methane Recovery from Sanitary Landfills for Electricity
Agriculture	18	AWD
Industry	19	Nitric Acid Controls
Industry	20	Kigali Amendment
Forestry and Energy	21	(M2) Forest Restoration and Reforestation
Forestry and Energy	22	(M1) Forest Protection
Waste and Energy	23	Methane Recovery from Large Dumpsites for Electricity
Waste	24	Methane Recovery from Medium Dumpsites for Flaring
Waste	25	Sewerage and Septage
Energy	26	Biomass Co-firing in Coal Plants
Agriculture and Energy	27	Bio-digesters
Energy	28	NREP Geothermal
Energy	29	Nuclear Power
Energy	30	Substituting Natural Gas for Coal
Energy	31	NREP Wind
Transport	32	LDV Efficiency
Energy	33	NREP Large Hydro
Transport	34	Electric MCTC
Waste	35	Eco-Efficient Cover at Small Dumpsites
Energy	36	NREP Small Hydro
Energy	37	NREP Ocean
Transport	38	Biofuels
Agriculture	39	Crop Diversification

Waste	40	Composting
Energy	41	Biodiesel Blending Target
Energy	42	NREP Solar
Waste	43	Mandamus Compliance
Transport	44	Road Maintenance
Transport	45	Buses and BRT
Transport	46	Electric LDV
Transport	47	Two-Stroke Replacement
Transport	48	Euro 4/IV and MVIS
Transport	49	Rail
Transport	50	Euro 6/VI and MVIS

Abbreviations:
AWD = Alternate Wetting and Drying; BRT = bus rapid transit; CNG = Compressed natural gas; HPS = high-pressure sodium; LDV = light-duty vehicle; MCTC = motorcycle/tricycle; MSW = municipal solid waste; MVIS = motor vehicle inspection system; NREP = National Renewable Energy Program.

V.4.1.2 Results

The following section presents the results of the analysis of direct costs and benefits of mitigation options considering two primary questions: the mitigation potential (tons of CO_2e reduced) and the cost-effectiveness (cost per ton of CO_2e) of each discrete mitigation option included in the retrospective analysis.

Table V. 22 provides a description of each of the variables given in the subsequent results tables. Each variable is assigned a symbol (e.g. "A") to allow efficient referencing in the row of formulas provided for each table.

Table V. 22. Description of Result Variables

Symbol	Variable	Description
-	Mitigation Option	Mitigation options, evaluated using the retrospective analysis approach.
A	Incremental Cost	Equal to the sum of capital, operating and maintenance (O&M), implementation, fuel, and input costs compared to the mitigation option that preceded it in the retrospective analysis. Represents the net change in costs with implementation of the mitigation option. Negative costs indicate cost savings compared to the prior mitigation option analyzed (e.g., fuel savings).
B	Incremental GHG Mitigation Potential	Potential change in cumulative GHG emissions from 2015-2030 with implementation of the mitigation option relative to the preceding mitigation option. Positive values indicate GHG emission benefits.
C	Incremental 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 relative to the preceding mitigation option. Negative values indicate cost savings as well as GHG emission benefits.

Table V. 23 summarizes the direct costs and benefits of mitigation options, including changes in capital, O&M, implementation, and fueling costs as well as GHG emissions. The assessment is based on cumulative costs expected during the 2015-2030 time period.

Table V. 23. Mitigation Options in the Waste Sector without Co-benefits

Sector	Mitigation Option Sequence [1]	Mitigation Option	Incremental Net Costs (Cumulative 2015-2030) [Billion 2010 USD] Discounted to 2015 at 10%[2]	Incremental GHG Mitigation potential (2015-2030) [$MtCO_2e$]	Incremental Cost per Ton Mitigation (2015-2030) [2010 USD] *without co-benefits*[2]
Symbol			*A*	*B*	*C*
Formula					*(A*1000)/B=C*
Waste	16	MSW Digestion of Organic Waste	-0.02	6.95	-3.40
	17	Methane Recovery from Sanitary Landfills for Electricity	-0.01	11.69	-0.50
	23	Methane Recovery from Large Dumpsites for Electricity	0.03	7.66	3.77
	24	Methane Recovery from Medium Dumpsites for Flaring	0.02	2.79	5.78
	25	Sewage and Septage	0.06	9.12	6.63
	35	Eco-Efficient Cover at Small Dumpsites	0.32	9.45	34.28
	40	Composting	0.51	7.37	68.76
	43	Mandamus Compliance	1.68	16.81	99.87

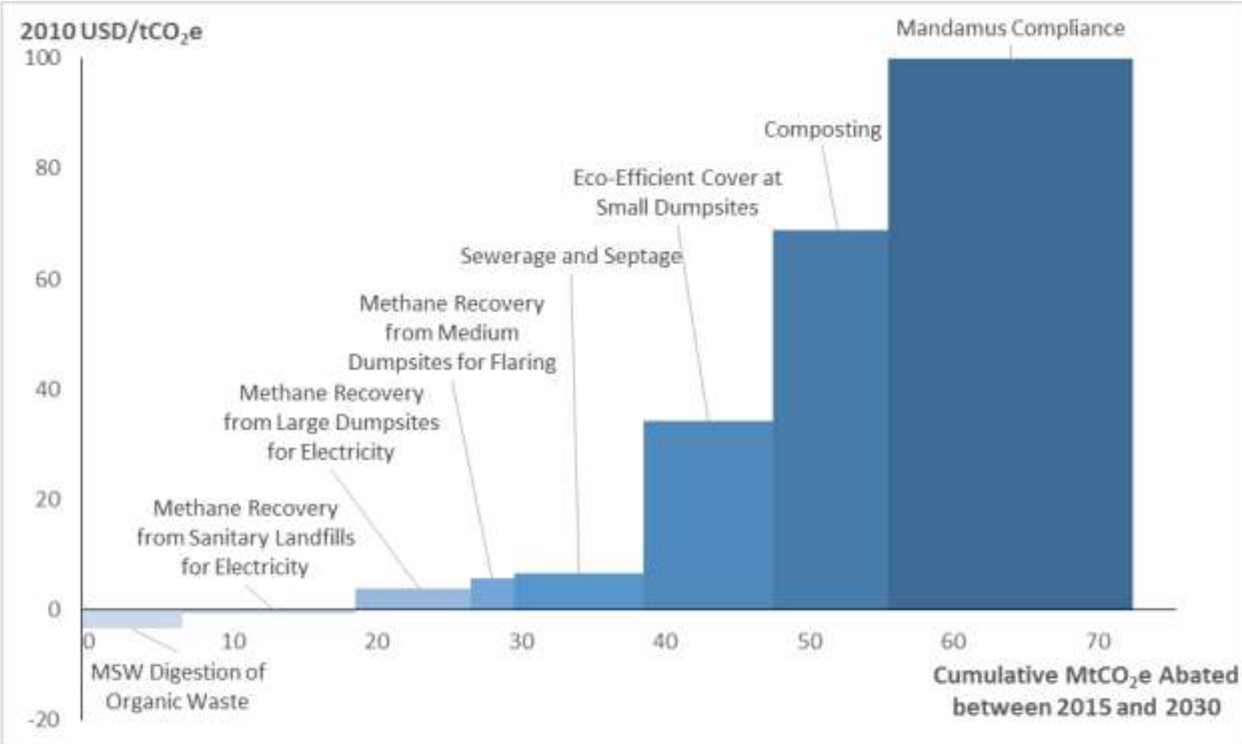
Abbreviations:
$MtCO_2e$ = Million metric tons of carbon dioxide equivalent; GHG = greenhouse gas; USD = U.S. dollar; MSW = municipal solid waste
Notes:
[1] Sequence Number of Mitigation Options refers to the sequential order in which individual mitigation options are initiated as described by the retrospective systems approach.
[2] Values are rounded for presentation and may not equal column C based on the formula and table values.
Column Definitions:
[A] Incremental Costs - Total Net Cost: Equal to the sum of incremental capital, operating and maintenance (O&M), implementation, fuel, and input costs compared to the prior mitigation option using retrospective systems analysis. Represents the incremental net change in costs with implementation of the mitigation option. Negative costs indicate cost savings compared to the business as usual (e.g., fuel savings).
[B] Incremental GHG Mitigation Potential: Potential change in incremental cumulative GHG emissions from 2015-2030 with implementation of the mitigation option. Positive values indicate GHG emissions benefits.
[C] Incremental Cost per Ton Mitigation without Co-benefits: Equal to the total net cost divided by the mitigation potential. Represents the incremental cost per ton of a mitigation option using retrospective systems analysis where costs are calculated using the marginal emission reductions and costs incurred after the option was added to a prior mitigation option. Negative values indicate cost savings as well as GHG emissions benefits.

Figure V. 9 and Figure V. 11 presents the same information in a MACC. The MACC visually illustrates the cumulative abatement potential and costs per ton of the waste sector mitigation options. It shows that implementation of all the waste mitigation options analyzed in the study could result in total cumulative emission reductions of approximately 72 $MtCO_2e$. The negative cost options include the MSW Digestion (waste-to-energy) option and the Methane Recovery from SLFs for Electricity Generation option. If the negative cost mitigation options are implemented (i.e., all those below the horizontal axis), the Philippines can achieve cumulative reductions of 18.7 $MtCO_2e$ from 2015-2030.

These options are especially important as the negative cost implies that a true cost saving to society would be realized by implementing the option as a result of avoided costs or direct benefits from the option.

The MACC presented in Figure V. 9 is based on the direct costs and benefits. It does not capture the indirect market effects highlighted in Section V.4.2 Co-Benefits on co-benefits.

Figure V. 9. 2015-2030 GHG Emissions Abatement Cost Curve for the Waste Sector ($MtCO_2e$)



V.4.2 Co-Benefits

In this section we describe the general approaches taken to calculate income generation, human health, energy security, and employment impacts related to the mitigation options for the waste sector and provide a discussion of the results. Consistent with all the sectoral analyses, these impacts have been calculated using the retrospective systems approach described in Sathaye and Meyers (1995). There are market and non-market co-benefits which can add to the cost-effectiveness of a mitigation option. In the waste sector, we have estimated the following co-benefits:

- *Market co-benefits*: the income generated by sales of the compost product (under the Composting option);
- *Non-market co-benefits*: the economic value of air quality-related improvements in human health (for the MSW Digestion option and the Methane Recovery from SLFs for Electricity option, because these options interact with the energy sector).

The co-benefits that were monetized in this report represent only a subset of the benefits that can be achieved by introducing the mitigation options. However, they are the only ones for which sufficient data were available to quantify and monetize their benefit within the timeframe of the CBA. In addition to the co-benefits listed above, several other impacts of mitigation, such as improvement in energy security, were characterized using a series of quantitative indicators as the available information to estimate their economic value was insufficient.

Within the mitigation options for the waste sector there was insufficient information to evaluate potential co-benefits for the wastewater mitigation options.

In subsections below, we describe the methods and results for these impact assessments.

V.2.2.1 Income Generation

The Composting option includes increases in the segregation of biodegradable waste for the production of compost product, which has a market value. GHG mitigation strategies that result in additional compost materials provide an income co-benefit from the eventual sale of these materials into the marketplace.

The primary market for compost products are in the agricultural sector. By definition, the compost produced by the bioreactor or the composter is a pure organic fertilizer. It has both fertilizing and soil conditioning characteristics, and is highly recommended for enriching soil nutrients in a manner that also enhances soil texture conducive to plant development (ADB, 2003b). A key challenge in the compost market, however, is that agricultural activities, which offer various options to reuse or recycle organic wastes, occur in rural areas. Yet, in cities, the demand for compost products is limited. The pressure to intensify composting as a waste reduction strategy pursuant to RA 9003 is bound to create a situation where it might be challenging to match demand with supply. While enormity of the supply is unavoidable under the situation, the demand has certain limits among compost users (JICA, 2008; ADB, 2003b). In addition, a situation where there is an over-supply of compost is likely to lead to a significant decline in the market price of compost.

This analysis estimates the potential market value of the compost produced (compared to the baseline case), without attempting to characterize the distribution of that income across various involved parties. Further, the analysis does not account for the price changes that are likely to occur due to the shifts in supply of the compost product. To account for the limitations of the compost market size, it was assumed that only 50% of the compost produced can be sold into the market (whereas the remaining 50% of the compost product cannot be sold due to insufficient demand).

Compost is priced on a per-ton basis. The weight of the compost produced from segregated biodegradable waste is estimated based on the assumption that composting technologies can reduce the initial weight of the waste by 50% (NSWMC, 2014). Table V. 24 summarizes the market prices applied to the compost produced.

Table V. 24. Market Price of Compost Products

Compost Product Type	Market Price (2010 USD per Metric Ton)	Source
Bioreactor compost product	87.96	ADB, 2003b
Vermicast compost product	73.73	Paul et al., 2008

Based on the above assumptions, the CBA estimates an income co-benefit potential from compost production of approximately $0.5 billion 2010 USD, cumulative net present value over 2015 – 2050 at 10% discount rate. As noted above, realizing this potential requires significant increases in the diversion of organic waste as well as overcoming market challenges with respect to the overall supply and demand for compost.

V.2.2.2 Air Quality-Related Human Health Impacts

Waste mitigation options that result in the addition of new renewable energy supply to the energy system have the potential to produce human health-related benefits if the new capacity replaces fossil fuel-based power generation that emits local air pollutants. Table V. 25 present the incremental human health impacts for the waste sector mitigation options. The specific results in Table V. 25 are affected by the sequence of options in the retrospective analysis and details of the assumptions incorporated in the LEAP model regarding level of energy demand and dispatch within the electrical system.

Important caveats to interpreting these results would include recognizing that the morbidity impacts of changes in ambient air pollution are not quantified. The direction/sign of any morbidity impact for an option would be the same as the premature mortality results. Annex V.6 presents additional caveats related to the health impact assessment methods that were used.

Table V. 25. Incremental Human Health Impact for Proposed Mitigation Options, Cumulative Impact during 2015-2030

Sector	Mitigation Option Sequence [1]	Mitigation Option Name	Incremental Present Discounted Value (Millions 2010 USD, 10% Discount Rate)	Incremental Cases of Avoided Premature Deaths [2015-2030]	Incremental Cases of Avoided Premature Deaths [2015-2030] (Females)
Waste and Energy	16	MSW Digestion of Organic Waste	-11.7	-30	-10
Waste and Energy	17	Methane Recovery from Sanitary Landfills for Electricity	40.3	90	50
Waste and Energy	23	Methane Recovery from Large Dumpsites for Electricity	36.1	80	40
Waste	24	Methane Recovery from Medium Dumpsites Flaring	No impact on energy sector emissions by design.		
Waste	25	Septage and Sewerage	No impact on energy sector emissions by design.		
Waste	35	Eco-Efficient Cover at Small Dumpsites	No impact on energy sector emissions by design.		
Waste	40	Composting	No impact on energy sector emissions by design.		
Waste	43	Mandamus Compliance	No impact on energy sector emissions by design.		

Abbreviations: USD = U.S. dollar; MSW = municipal solid waste
Notes: [1] Refers to the sequential order in which the mitigation option is introduced in the retrospective analysis.

V.2.2.3 Energy Security Impacts

Increased energy security means that the country's energy system is more resilient to a variety of shocks (e.g., global economic crises, international conflicts, spikes in individual fuel costs). In practice, as energy security within a country's system increases, the adverse impacts from these shocks on the country's economy will be less pronounced. Improvements in energy security can result from several changes in the energy sector, such as increasing combinations of fuel diversity, transport diversity, import diversity, energy efficiency, and infrastructure reliability. For example:

- Energy generation portfolios that are heavily dependent on a limited number of fuel inputs or generation sources can be highly affected by shocks to a single fuel or generation source. In contrast, energy systems that incorporate a relatively diverse mix of fuel inputs and a number of generation sources with redundancy will be less affected by shocks to any single fuel or generation source. Energy security concerns can be alleviated by increasing the diversity of both the source of the fuels (i.e., domestic or imported, including the country of origin), the type of fuel (i.e., oil, gas, solar, renewables), and the mix of technologies used to generate the energy;
- Energy system security is also a function of available fuel supplies/reserves compared to demand. An increase in available fuel supply would increase energy security. Supply can be increased through increased exploration of fossil fuels, increasing investment in renewable fuels, or by encouraging energy efficiency measures to prolong the availability of known existing resources.

A number of indicators may be applied to assess whether a country is becoming more or less energy secure due to implementation of a mitigation option. For this evaluation, the following indicators were computed:

- Energy intensity (energy consumption per unit of GDP);
- GHG intensity (CO_2e emissions per unit of GDP);
- Percentage share of imports in total energy supply; and
- Percentage share of renewable energy in energy supply.

The Study Team calculated these indicators in LEAP using the same retrospective analysis as the one used to assess the mitigation options. Table V. 26 presents the average annual incremental impact of each mitigation option on the four energy security indicators for the period 2015-2030. In reviewing the results it is critical to remember the incremental nature of the analysis, where results for any mitigation option are relative to the suite of those which are assumed to have already been implemented (i.e., all previously listed and lower numbered options). The various waste options generally tend to improve energy security by reducing GHG intensity, increasing the share of renewable energy, and reducing the share of imported fuel. These options have no impact on the energy intensity of GDP.

Table V. 26. Incremental Changes in Energy Security Indicators due to the Proposed Mitigation Options, Average Annual Incremental Impact during 2015-2030

Sector	Mitigation Option Name	Mitigation Option Sequence [6]	Average Annual Incremental Impact 2015-2030 [1]			
			Change in GHG Intensity of GDP (g CO_2e/2010 USD) [2]	Change in Share of Renewables (%) [3]	Change in Share of imports (%) [4]	Change in Energy Intensity of GDP (MJ/2010 USD) [5]
Waste and Energy	MSW Digestion of Organic Waste	16	-0.8	0.1	-	-
Waste and Energy	Methane Recovery from Sanitoary Landfills for Electricity	17	-1.5	-	-	-
Waste and Energy	Methane Recovery from Large Dumpsites for Electricity	23	-0.9	-	-	-
Waste	Methane Recovery from Medium Dumpsites Flaring	24	-0.3	-	-	-
Waste	Septage and Sewerage	25	-1.0	-	-	-
Waste	Eco-Efficient Cover at Small Dumpsites	35	-1.1	-	-	-
Waste	Composting	40	-0.9	-	-	-
Waste	Mandamus Compliance	43	-2.1	-	-	-

Abbreviations:
GHG = greenhouse gas; GPD = gross domestic product; g = grams; CO_2e = carbon dioxide equivalent; MJ = megajoules; MSW = municipal solid waste
Notes:
- indicates inapplicability of a given indicator category.
[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 grams (g) of CO_2e emissions (economy-wide, including from energy and non-energy sources) per unit of GDP (2010 USD).
[3] Percentage share of RE 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).
[6] Refers to the sequential order in which the mitigation option is introduced in the retrospective analysis.

V.2.2.4 Power Sector Employment Impacts

In this section, we describe the general approach taken to assess power sector employment impacts and caveats to interpreting available option-specific results. The 2018 Update Report does not include any changes to the methodology for estimating these impacts as described in the 2015 CBA report.

Using the parameters described in the 2015 CBA report and the updated power generation projections by source and year calculated using LEAP for the 2018 Update Report, the employment in the power sector for the different mitigation options over the period 2015-2030 was calculated in terms of *job-years*. The incremental impact of each mitigation option on job-years was then calculated by subtracting the calculated job-years for the previous mitigation option from the result for the mitigation option under consideration. Table V. 27 presents our estimates of the incremental change in the power sector employment indicator for each mitigation option.

Table V. 27. Incremental Changes in Power Sector Job-Years for proposed Mitigation Options, Cumulative Impact from 2015-2030

Sector	Mitigation Option Name	Mitigation Option Sequence[1]	Incremental Job-Years Impact (Unrounded Cumulative Job-Years 2015-2030)
Waste and Energy	MSW Digestion of Organic Waste	16	970
Waste and Energy	Methane Recovery from SLFs for Electricity	17	1,413
Waste and Energy	Methane Recovery from Large Dumpsites for Electricity	23	983
Waste	Methane Recovery from Medium Dumpsites Flaring	24	No impact on power sector employment by design
Waste	Septage and Sewerage	25	No impact on power sector employment by design
Waste	Eco-Efficient Cover at Small Dumpsites	35	No impact on power sector employment by design
Waste	Composting	40	No impact on power sector employment by design
Waste	Mandamus Compliance	43	No impact on power sector employment by design

Notes:
[1] Refers to the sequential order in which the mitigation option is introduced in the retrospective analysis.

The potential incremental power sector employment impacts presented in Table V. 27 have a number of important caveats that need to be kept in mind in order to place these results in the proper context. These caveats include:

- Wei et al. (2010) focus on results from the United States. The relevance of their results in the context of the Philippines cannot be assessed;
- The Wei et al., (2010) results focus on development of new generation facilities, their relevance when there is a change in the mix of generation among existing facilities is uncertain; and
- The application of the job-year factors as a constant value over the period of the analysis assumes future changes in technology will not affect these values and that they can be used regardless of the cumulative scale of generation in the Philippine power sector.

The estimated changes in the power sector job-years do not reflect changes in employment of the Philippine economy at large, because gains (losses) in power sector employment may be matched by losses (gains) in employment elsewhere in the economy.

V.4.3 Total Monetized Co-Benefits

Table V.28 combines the cost per ton without co-benefits (Column C) with the cost per ton of co-benefits (Column H from Table V.23).

Table V. 28. Monetized Co-Benefits of Mitigation Options in the Waste Sector

Mitigation Option Sequence [1]	Mitigation Option	Incremental Co-benefits (Cumulative 2015-2030) [Billion 2010,USD] Discounted at 10%				Incremental Cost per Ton Mitigation (2015-2030) [2010,USD] *co-benefits only* [2]
		Health	Congestion	Income Generation	**Total Co-benefit**	
Symbol		*D*	*E*	*F*	*G*	*H*
Formula					*sum(D,E,F)= G*	*-(G*1000)/B=H*
16	MSW Digestion of Organic Waste	-0.01	N/A	N/A	-0.01	1.68
17	Methane Recovery from Sanitary Landfills for Electricity	0.04	N/A	N/A	0.04	-3.44
23	Methane Recovery from Large Dumpsites for Electricity	0.04	N/A	N/A	0.04	-4.71
24	Methane Recovery from Medium Dumpsites for Flaring	0.00	N/A	N/A	0.00	0.00
25	Sewage and Septage	0.00	N/A	N/A	0.00	0.00
35	Eco-Efficient Cover at Small Dumpsites	0.00	N/A	N/A	0.00	0.00
40	Composting	0.00	N/A	0.47	0.47	-63.77
43	Mandamus Compliance	0.00	N/A	N/A	0.00	0.00

Abbreviations:
N/A = indicates inapplicability of a given co-benefits category; USD = U.S. dollar; MSW = municipal solid waste
Notes:
[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.
[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%.
Column Definitions:
[D] Co-benefits: Health: Monetized public health benefits reflect the reduced risk of premature death from exposure to air pollution exposure. 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 SO_2, fine particulates, and NO_x.
[E] Co-benefits: Congestion: Monetized congestion benefits reflect less time wasted on congested roadways. These are specific to the transport sector.
[F] 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.
[G] Total Co-benefits: Sum of valuation of monetized co-benefits.
[H] Incremental Cost per Ton Mitigation: Co-benefits Only: Value of monetized co-benefits (represented as a negative cost) divided by mitigation potential.

V.4.4 Net Present Value of Mitigation Options

The following section presents the NPV results of each mitigation option included in the retrospective analysis. **Table V. 29** shows the cost per ton of CO_2e of each mitigation option with and without co-benefits. Column E of **Table V. 29** indicates the present value of the net benefit stream, which is the difference between the discounted value of cumulative co-benefits and the discounted value of the cumulative costs of a mitigation option. A positive value indicates a mitigation option has net benefits to society in addition to its potential to mitigate GHG emissions.

Table V. 29. Net Present Value of Mitigation Options in the Waste Sector

Mitigation Option Sequence [1]	Mitigation Option	GHG Mitigation Potential [2015-2030] ($MtCO_2e$)[3]	Cost per Ton CO_2e Mitigation [2015-2030] (2010 USD)[2]			Net Present Value Excluding Value of GHG Reduction (Billion 2010 USD)[2,6]
			without co-benefits	co-benefits only[4]	with co-benefits[5]	
		B	*C*	*H*	*I = C+H*	*J = –I * B/1000*
16	MSW Digestion of Organic Waste	6.95	-3.40	1.68	-1.72	0.01
17	Methane Recovery from Sanitary Landfills for Electricity	11.69	-0.50	-3.44	-3.94	0.05
23	Methane Recovery from Large Dumpsites for Electricity	7.66	3.77	-4.71	-0.94	0.01
24	Methane Recovery from Medium Dumpsites for Flaring	2.79	5.78	0.00	5.78	-0.02
25	Sewage and Septage	9.12	6.63	0.00	6.63	-0.06
35	Eco-Efficient Cover at Small Dumpsites	9.45	34.28	0.00	34.28	-0.32
40	Composting	7.37	68.76	-63.77	4.99	-0.04
43	Mandamus Compliance	16.81	99.87	0.00	99.87	-1.68

Abbreviations:
$MtCO_2e$ = Million metric tons of carbon dioxide equivalent; GHG = Greenhouse gas; USD = U.S. dollar; MSW = municipal solid waste
Notes:
[1] Refers to the sequential order in which the mitigation option is introduced in the retrospective analysis.
[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 industry sector include human health benefits due to reduced air pollution from electricity generation.
[5] Negative value indicates net benefits per ton mitigation. This excludes the non-monetized benefits of GHG reductions.
[6] 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 carbon dioxide-equivalent 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.

ANNEX V.5 CROSS-CUTTING ECONOMIC ASSUMPTIONS

The sector-specific baseline projections are based on the common set of projections for the Philippine economy characteristics. Table V. 30 shows the data sources and assumptions used to generate these projections, while Table V. 31 presents historical and projected values in select years that were used in the analysis. Table V. 32 lists historical exchange rates and inflation rates used for inter-temporal and cross-country currency conversions.

Table V. 30. Data Sources and Assumptions Used for Projections of Population, GDP, Economic Sector-Specific Value Added, and Fuel Price

Characteristic	Sources of Historical Data	Projection Method
Population	1990-2015: Philippine Statistics Authority. Philippine Population Surpassed the 100 Million Mark (Results from the 2015 Census of Population). https://psa.gov.ph/content/philippine-population-surpassed-100-million-mark-results-2015-census-population.	2016-2020: Projection is taken from Philippine Statistics Authority and Inter-Agency Working Group on Population Projections. Projected Population, by Age Group, Sex, and by Single-Calendar Year Interval, Philippines: 2010 - 2020 (Medium Assumption). https://psa.gov.ph/sites/default/files/attachments/hsd/pressrelease/Table4_9.pdf. 2021-2045: Projection is taken from Philippine Statistics Authority and Inter-Agency Working Group on Population Projections (2015a). Projected Population, by Age Group, Sex, and by Five-Calendar Year Interval, Philippines: 2010 - 2045 (Medium Assumption). https://psa.gov.ph/sites/default/files/attachments/hsd/pressrelease/Table1_8.pdf. 2045-2050: Population is assumed to grow at the average annual rate established for 2035-2045.
GDP	1990-2010: Philippine Statistics Authority and Inter-Agency Working Group on Population Projections (2015a). Projected Population, by Age Group, Sex, and by Five-Calendar Year Interval, Philippines: 2010 - 2045 (Medium Assumption). https://psa.gov.ph/sites/default/files/attachments/hsd/pressrelease/Table1_8.pdf. 2011-2016: Philippine Statistics Authority (2017a). Annual National Accounts (1998 -	GDP growth rate increased to 7.5% based on guidance from CCC on 26 September 2017.

Characteristic	Sources of Historical Data	Projection Method
	2016). http://psa.gov.ph/nap-press-release/data-charts.	
Value Added by Industrial Sectors	1990-1997: Based on percent share of GDP 1998-2016: Manufacturing and Total data from Philippine Statistics Authority (2017a). Annual National Accounts (1998 -2016). http://psa.gov.ph/nap-press-release/data-charts.	All value added variables projected based on trends in their historical share of GDP. Projected shares in each year are multiplied by GDP to obtain projected value added.
Value Added by Commercial Sector	1990-1997: Based on percent share of GDP 1998-2016: Philippine Statistics Authority (2017a). Annual National Accounts (1998 -2016). http://psa.gov.ph/nap-press-release/data-charts.	All value added variables projected based on trends in their historical share of GDP. Projected shares in each year are multiplied by GDP to obtain projected value added.
Value Added by Agriculture, Forestry, Fishing	1990-1997: Based on percent share of GDP 1998-2016: Agricultural, Hunting, Forestry, & Fishing data from Philippine Statistics Authority (2017a). Annual National Accounts (1998 -2016). http://psa.gov.ph/nap-press-release/data-charts.	All value added variables projected based on trends in their historical share of GDP. Projected shares in each year are multiplied by GDP to obtain projected value added.
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 historically.
Coal Sub bituminous	Historical coal prices per metric tonne taken from free-on-board Newcastle/Port Kembla price, World Bank. "World Bank Commodity Price Data (The Pink Sheet): Annual Prices (Real), Coal, Australian", updated 2/2/2017. <http://pubdocs.worldbank.org/en/226371486076391711/CMO-Historical-Data-Annual.xlsx>, accessed 2/3/2017. Conversion from mass-based to energy-based cost uses 4490 kcal/kg (energy content of sub-bituminous coal used in this model), which more closely matches energetic cost of coal taken from other Philippine national sources, rather than 6300 kcal/kg fom World Bank source.	IEA (2016), World Energy Outlook 2016, 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). 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.	IEA (2016), World Energy Outlook 2016, IEA, Paris. (Current Policies scenario)
Nuclear	IPCC AR5 WG3 Annex III	Assumed same as the constant price historically.
Crude Oil	Fuel price data provided by DOE to B-LEADERS project, 2015 (USAID	IEA (2016), World Energy Outlook 2016, IEA, Paris. (Current

Characteristic	Sources of Historical Data	Projection Method
	Request_historical prices-03.04.2015.xls)	Policies scenario)
Bagasse	Assumed to be equal to wood on an energy basis.	Assumed same as the constant price historically.
Animal Wastes	Assumed to be equal to wood on an energy basis.	Assumed same as the constant price historically.
Coconut Residue	Assumed to be equal to wood on an energy basis.	Assumed same as the constant price historically.
Rice Hull	Assumed to be equal to wood on an energy basis.	Assumed same as the constant price historically.
Wood	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 historically.
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
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

Characteristic	Sources of Historical Data	Projection Method
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. http://www.cleanskies.org/wp-content/uploads/2013/04/driving-natural-gas-report.pdf. Figure 5.
Charcoal	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 historically.
LNG	Provided by DOE to B-LEADERS project, 2015 (USAID Request_historical prices-03.04.2015.xls). 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.	IEA (2016), World Energy Outlook 2016, IEA, Paris. (Current Policies scenario)

Table V. 31. 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	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 (Millions 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

Year	Historical Data						Baseline						
	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Mining	783	849	829	1,972	2,854	2,046	2,755	3,799	5,218	7,147	9,760	13,296	18,073
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/GJ)													
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
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

Year	Historical Data						Baseline						
	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
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 V. 32. 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	12.3	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

Notes:

[1] Source: Bangko Sentral Ng Pilipinas (2017). Exchange Rates and Foreign Interest Rates - Daily, Monthly (Average and End-of-Period) and Annual. http://www.bsp.gov.ph/PXWeb2007/database/SPEI/ext_accts/exchange_en.asp.

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Year	Philippine Peso per US Dollar[1]	Philippine Peso Annual Inflation Rate (%)[2]	US Dollar Annual Inflation Rate (%) [3]
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ANNEX V.6 HEALTH CO-BENEFITS METHODS

There are no changes to Annex V.6 in the 2018 Addendum.

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