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

PHILIPPINES MITIGATION COST-BENEFIT ANALYSIS

2018 Update Report – Energy Chapter

January 2018

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ACRONYMS

ALU	Agriculture and Land Use Greenhouse Gas Inventory software
B-LEADERS	Building Low Emission Alternatives to Develop Economic Resilience and Sustainability Project
BSP	Bangko Sentral ng Pilipinas
CBA	Cost-benefit analysis
CCC	Climate Change Commission
CFBC	Circulating Fluidized Bed Combustion
CNG	Compressed natural gas
CO_2e	Carbon dioxide equivalent
DENR	Department of Environment and Natural Resources
DOE	Department of Energy
g	Gram
GDP	Gross domestic product
GHG	Greenhouse gas
HPS	High-pressure sodium
IEA	International Energy Agency
INDC	Intended nationally determined contribution
kg	Kilogram
kW	Kilowatt
LEAP	Long-range Energy Alternatives Planning system
LED	Light-emitting diode
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
m	Meter
MACC	Marginal abatement cost curve
MJ	Megajoule
MSW	Municipal solid waste
MW	Megawatt
MWh	Megawatt-hour
NDC	Nationally determined contribution
NEDA	National Economic and Development Authority
NREP	National Renewable Energy Program
O&M	Operating and maintenance
OSeMOSYS	Open Source Energy Modeling System
PHP	Philippine peso
PSA	Philippine Statistics Authority
PV	Photovoltaic

t	Metric tonne
T&D	Transmission and distribution
TPES	Total primary energy supply
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USD	United States dollar

III. ENERGY

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

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

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

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

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

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

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

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

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

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

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

This report presents the 2017 CBA update for the energy sector (excluding transportation). It provides the following:

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

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

III.2 BASE YEAR GHG EMISSIONS

III.2.1 Updated Methods and Assumptions

CBA results for the energy sector were produced from an integrated model of the Philippines' energy system built on the LEAP platform. LEAP version 2017.0.11.0 was used for the 2017 CBA update. The energy sector model accounts for key dependencies between energy demand and supply that may have a significant impact on emissions – for example, higher final demand for a fuel leading to increased emissions from fuel production, processing, and distribution. This section provides a summary of changes to the model and methods underlying the estimation of base year GHG emissions as compared to the 2015 CBA. Key differences in the determination of base year GHG emissions are as follows:

- Updated discount rate
- Updated currency conversion rates
- Inclusion of latest national energy balance data

III.2.1.1 Discount Rate

The real annual discount rate in the model increased from 5% to 10% to align with the rate used by the National Economic and Development Authority (NEDA) to evaluate potential investments (National Economic and Development Authority 2016). The 10% rate was requested by CCC in the September 2017 workshop. Costs in the model were discounted to 2015 when discounted costs were required.

III.2.1.2 Currency Conversion Rates

Updated exchange and inflation rates were used to convert new cost inputs to the model's base currency, year 2010 U.S. dollars (USD) (Section III.5).

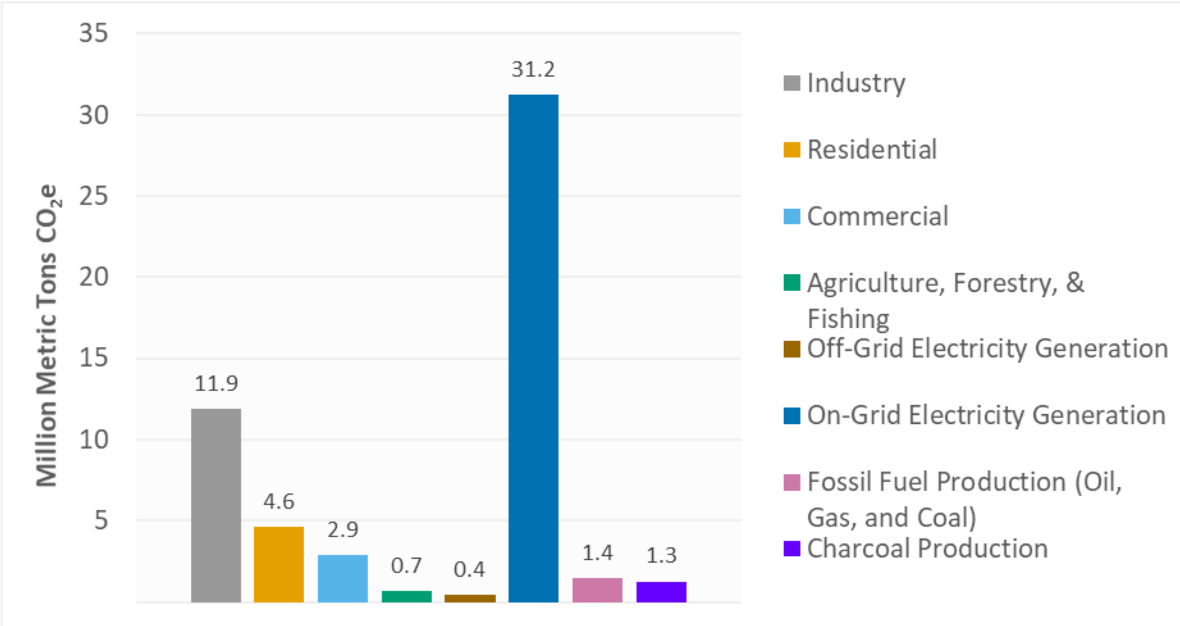
III.2.1.3 National Energy Balances

The model includes historical data on energy demand and supply from the Philippines' national energy balances. For the 2017 CBA update, all such inputs were revised using the latest version of the balances (Department of Energy 2017c). The historical data in the model are from 1990 to 2016; projections start in 2017 and run through 2050.

III.2.2 Results

While the historical period in the energy sector model spans 1990-2016, results for 2010 are singled out in this report because 2010 was the base year for the CBA Study as a whole. Figure III.1 shows modeled GHG emissions from the energy sector in 2010.

Figure III.1: 2010 Base Year GHG Emissions From the Energy Sector



Total emissions from the sector are estimated to be 54.4 million metric tonnes of carbon dioxide equivalent ($MtCO_2e$). The leading contributors are electricity generation (31.7 $MtCO_2e$ from on- and off-grid plants together), industry (11.9 $MtCO_2e$), and the residential sector (4.6 $MtCO_2e$). Combustion emissions from other sources of energy demand and emissions from the production of fossil fuels and charcoal make up the remainder of the total.

III.3 BASELINE PROJECTION TO 2030

III.3.1 Updated Methods and Assumptions

For the energy sector baseline projection, differences in methods, assumptions, and inputs between the 2017 CBA update and the 2015 CBA include the following:

- Mitigation actions undertaken since 2010 excluded from baseline
- Other changes to modeling of final energy demand
    - Change in disaggregation of energy demands in residential sector
    - Updated activity projections
    - Updated wood harvest for energy projection
    - Revised off-grid electricity demand
- Other changes to modeling of energy supply
    - Additional energy supply technologies
    - Updated parameters and methods for modeling electricity generation
    - Updated electricity transmission and distribution (T&D) losses and producer own use
    - Updated inputs for modeling biofuels production
    - Full utilization of oil refining capacity

- Revised modeling of natural gas supply
- Updated resource reserves and yields

III.3.1.1 Exclusion of Mitigation Actions Undertaken Since 2010

The central narrative of the baseline scenario is that no significant new mitigation policies are implemented and historical trends in the major determinants of energy use and emissions continue. However, in the 2015 CBA, mitigation measures implemented between 2010, the study base year, and 2014 were incorporated in the baseline. This lowered the estimated costs and benefits of several mitigation options since these were defined against the baseline.

For the 2017 CBA update, CCC advised the study team to back out any mitigation actions implemented after 2010 from the baseline scenario, and to integrate them into the appropriate mitigation scenarios (discussed further in Section III.4). The resulting changes to the energy sector baseline were as follows:

- **Renewable electricity generating capacity**: On-grid renewable capacity additions occurring after 2010 were removed from the baseline. The affected technologies included landfill gas, wind, solar photovoltaic (PV), small hydro, large hydro, geothermal, and biomass.
- **Cement waste heat to power generation**: Generation of electricity from waste heat in the cement industry was also removed from the baseline.
- **Biodiesel:** The amount of biodiesel in the diesel fuel supply was limited to 2% by volume.

III.3.1.2 Other Changes to Modeling of Final Energy Demand

Modified Disaggregation of Residential Energy Demand

For the 2017 update, households unofficially connected to the main electric grid were modeled separately from households officially connected to the grid. The estimated shares of households unofficially and officially connected were either calculated or obtained from the 2011 Household Energy Consumption Survey (Department of Energy and National Statistics Office 2011) and DOE's Electric Power Industry Reform Act Implementation Status Reports (2015a; 2016a; 2016b). In addition, the short-term projection of household electricity access in the model was revised to reflect DOE's target to achieve 100% electrification by 2022 (2017e).

Table III.1: Updated Structure of LEAP Energy Model (Demand Side - Residential) (changes highlighted in blue)

	Sector	Subsectors
Demand	Residential	Electrified Households
		Unelectrified Households Using Electricity
		Unelectrified Households Not Using Electricity
		Off-Grid Electricity

Updated Activity Projections

Although the activity variables in the final energy demand projection did not change in the 2017 update, sources and values for some of the variables did. Revised sources and values for cement production are given in Table III.2 and Table III.3; sources and values for population, gross domestic product (GDP), and economic value added are in an annex of cross-cutting assumptions in Section III.5.

Table III.2: Data Sources and Projection Methods for Cement Production (updates and changes highlighted in blue)

Variable	Sources of Historical Data	Projection Method
Cement Production	2000-2015: Cement Manufacturers Association of the Philippines (2017)	After 2015, cement production is projected to grow at the same rate as value added by the non-metallic mineral industrial subsector.

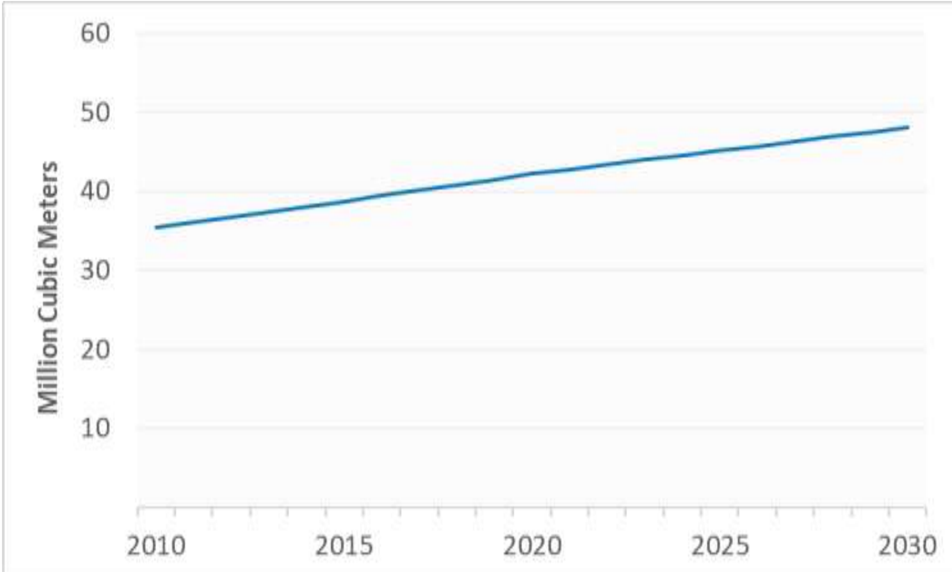
Table III.3: Data and Projections for Cement Production (updated values highlighted in blue)

	Historical Data						Baseline Data						
Year	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Cement Production [Million Tonnes]	-	-	12	12	16	24	27	33	41	49	60	72	87

Updated Wood Harvest for Energy Projection

As in the 2015 CBA, informal consumption of wood in the residential sector was calculated as the total projected harvest of wood for energy from the CBA's forestry modeling minus wood required to satisfy the "formal" wood and charcoal demand in University of the Philippines National Engineering Center (2015). New estimates of the amount of wood harvested for energy were provided by the forestry modeling team (Figure III.2).

Figure III.2: Wood Harvest for Energy, Baseline Scenario



Revised Off-Grid Electricity Demand

Historical off-grid electricity demand during 1996-2016 was determined from National Power Corporation - Small Power Utilities Group (2008) and DOE (2017a). After 2016, following a recommendation from DOE, total off-grid demand was assumed to be 1.6% of on-grid demand.

III.3.1.1 Other Changes to Modeling of Energy Supply

Additional Energy Supply Technologies

The supply side of the energy sector model describes domestic energy production by representing major energy-producing industries. For the 2017 update, additional production technologies were modeled within two industries (Table III.4). On-grid natural gas power plants were separated into "existing" and "new" facilities to model the higher efficiency and reduced operating cost of newer plants. Two electricity storage technologies – lithium ion batteries and pumped hydro – were also introduced. Finally, for natural gas supply, imported liquefied natural gas (LNG) was explicitly modeled.

Table III.4: Updated Structure of LEAP Energy Model (Supply Side) (new processes in blue)

Industry	Fuel & Technology		Capacity Modeled?
Electricity Transmission and Distribution			No
Off-Grid Electricity Generation	Oil	Diesel/Oil	Yes
	Renewables	Small Hydro (≤ 10 megawatts [MW])	
		Solar Photovoltaic	
		On-Shore Wind	
On-Grid Electricity	Coal	Subcritical Pulverized	Yes

<table>
<tr><th>Industry</th><th colspan="2">Fuel & Technology</th><th>Capacity Modeled?</th></tr>
<tr><td rowspan="22">Generation</td><td rowspan="3"></td><td>Supercritical Pulverized</td><td rowspan="3"></td></tr>
<tr><td>Ultrasupercritical Pulverized</td></tr>
<tr><td>Circulating Fluidized Bed Combustion (CFBC)</td></tr>
<tr><td rowspan="3">Oil</td><td>Diesel</td><td rowspan="19">Yes</td></tr>
<tr><td>Oil Combined Cycle</td></tr>
<tr><td>Oil Thermal</td></tr>
<tr><td rowspan="2">Natural Gas</td><td>Natural Gas Combined Cycle (Existing)[2]</td></tr>
<tr><td>Natural Gas Combined Cycle (New)[3]</td></tr>
<tr><td rowspan="7">Renewables Excluding Wastes</td><td>Biomass Combustion</td></tr>
<tr><td>Geothermal</td></tr>
<tr><td>Large Hydro (> 10 MW)</td></tr>
<tr><td>Small Hydro (≤ 10 MW)</td></tr>
<tr><td>Ocean Thermal</td></tr>
<tr><td>Solar PV</td></tr>
<tr><td>On-Shore Wind</td></tr>
<tr><td rowspan="2">Energy Storage</td><td>Lithium Ion Batteries</td></tr>
<tr><td>Pumped Hydro</td></tr>
<tr><td rowspan="4">Wastes</td><td>Agricultural Waste Digestion (Biogas)</td></tr>
<tr><td>Landfill Gas</td></tr>
<tr><td>Municipal Solid Waste (MSW) Digestion (Biogas)</td></tr>
<tr><td>MSW Incineration</td></tr>
<tr><td>Nuclear</td><td>Nuclear</td></tr>
<tr><td colspan="3">Compressed Natural Gas (CNG) Compression</td><td>No</td></tr>
<tr><td rowspan="2">Bioethanol Production</td><td colspan="2">Production from Sugarcane</td><td rowspan="2">Yes</td></tr>
<tr><td colspan="2">Production from Molasses</td></tr>
<tr><td>Biodiesel Production</td><td colspan="2">Production from Copra</td><td>Yes</td></tr>
<tr><td colspan="3">Oil Refining and Storage</td><td>Yes</td></tr>
<tr><td colspan="3">Oil Production and Transport</td><td>No</td></tr>
<tr><td rowspan="2">Natural Gas Transmission and Distribution</td><td colspan="2">Domestic Gas</td><td rowspan="2">No</td></tr>
<tr><td colspan="2">Imported LNG</td></tr>
</table>

[2] Represents existing natural gas generation capacity as of 2016.
[3] Represents new natural gas generation capacity added after 2016.

<table>
<tr><th>Industry</th><th>Fuel & Technology</th><th>Capacity Modeled?</th></tr>
<tr><td colspan="2">Natural Gas Production and Processing</td><td>No</td></tr>
<tr><td rowspan="2">Coal Mining</td><td>Underground Mining</td><td rowspan="2">No</td></tr>
<tr><td>Surface Mining</td></tr>
<tr><td colspan="2">Charcoal Production</td><td>No</td></tr>
<tr><td colspan="2">Biomass Production and Harvesting</td><td>No</td></tr>
</table>

Updated Parameters and Methods for Modeling Electricity Generation

Beyond the new technologies just mentioned, the modeling of electricity generation was modified in several important ways. Existing and committed capacities (including retirements) and historical generation data were updated for both on-grid and off-grid production. On-grid capacity data were taken from Quejada (2017) and DOE (2017d), while on-grid generation data were from DOE (2017c). Off-grid capacity was based on National Power Corporation – Small Power Utilities Group (2017), and off-grid generation was derived from National Power Corporation – Small Power Utilities Group (2008) and DOE (2017a).

Other technical and cost parameters for on and off-grid technologies were revised based on DOE guidance and improved data sources (Table III.5, which also shows parameters for the new on-grid technologies). These changes included an enhancement to account for financing costs in the capital costs of new capacity.

Table III.5: Technical and Cost Parameters of Electricity Generation Technologies (new or updated values in blue)

Technology	Availability Factor [%]	Capacity Credit [%]	Efficiency [%]		Feedstock Fuels	Full Load Hours	Lifetime [yrs]	Capital Cost [2010 USD/kilowatt (kW)]		Fixed Operating and Maintenance (O&M) Cost [2010 USD/kW]		Variable O&M Cost [2010 USD/megawatt-hour (MWh)]	
			2016	2030				2016	2030	2016	2030	2016	2030
On-Grid Technologies													
Agricultural Waste Digestion	80[1]	80[11]	25[1]	25[1]	Animal wastes	N/A	20[1]	3,957[24]	3,558[24]	144[24]	130[24]	4.2[24]	4.2[24]
Biomass	80[2]	70[12]	35[2]	35[2]	Bagasse, coconut residue, rice hull	N/A	30[22]	2,553[2]	2,553[2]	132[2]	132[2]	0.0[2]	0.0[2]
CFBC Coal	80[3]	80[12]	41[14]	41[14]	Coal	N/A	40[23]	1,809[25-28]	1,809[25-28]	40[23]	40[23]	9.3[23]	9.3[23]
Diesel	80[3]	80[12]	110[3]	36[3]	Diesel, biodiesel	N/A	40[22]	1,118[29]	1,118[29]	42[36]	42[36]	17.6[36]	17.6[36]
Geothermal	70[3]	70[12]	10[15]	10[15]	Geo. steam	N/A	40[23]	4,495[30]	4,495[30]	303[32,36]	144[32,36]	0.0[32]	0.0[32]
Landfill Gas	90[4]	90[11]	28[16]	28[16]	Landfill gas	N/A	25[4]	2,177[24]	2,177[24]	23[4]	23[4]	15.0[4]	15.0[4]
Large Hydro	Varies[5]	Varies[12]	35[15]	35[15]	Large hydro	N/A	100[22]	2,134[25]	2,134[25]	48[36]	48[36]	20.1[32,36]	0.0[32,36]
Lithium Ion Batteries	95[6]	30[13]	83[17,18]	90[17,18]	Grid electricity	2.35[17]	10[17]	1,856[17]	1,326[17]	5[17]	5[17]	6.6[17]	6.6[17]
MSW Digestion	80[7]	80[11]	63[7,19]	63[7,19]	Organic MSW	N/A	25[7]	2,730[7]	2,730[7]	19[7]	19[7]	14.7[7]	14.7[7]
MSW Incineration	86[1]	86[11]	30[1]	30[1]	Residual MSW	N/A	15[1]	7,613[24,31]	6,877[24,31]	378[31]	378[31]	8.4[31]	8.4[31]
Natural Gas Combined Cycle Existing	80[3]	80[12]	55[20]	55[20]	Natural gas	N/A	30[23]	1,186[25,32]	N/A	38[36]	38[36]	1.9[36]	1.9[36]
Natural Gas Combined Cycle	80[3]	80[12]	55[20]	61[20]	Natural gas	N/A	30[23]	1,186[25,32]	880[25,32]	40[32,36,37]	19[32,36,37]	1.9[36]	1.9[36]

Technology	Availability Factor [%]	Capacity Credit [%]	Efficiency [%]		Feedstock Fuels	Full Load Hours	Lifetime [yrs]	Capital Cost [2010 USD/kilowatt (kW)]		Fixed Operating and Maintenance (O&M) Cost [2010 USD/kW]		Variable O&M Cost [2010 USD/megawatt-hour (MWh)]	
			2016	2030				2016	2030	2016	2030	2016	2030
New													
Nuclear	80[3]	80[11]	36[20]	37[20]	Uranium	N/A	60[22]	7,980[23]	7,980[23]	0[23]	0[23]	11.3[23]	11.3[23]
Ocean Thermal	95[2]	95[11]	100[2]	100[2]	Ocean	N/A	20[2]	10,865[2,33]	10,000[2,33]	123[2]	123[2]	0.0[2]	0.0[2]
Oil Combined Cycle	80[3]	80[12]	4[3]	36[3]	Residual fuel oil	N/A	30[23]	803[34]	803[34]	35[38]	14[38]	1.9[38]	1.9[38]
Oil Thermal	80[3]	72[12]	2[3]	36[3]	Residual fuel oil	N/A	40[22]	900[3]	900[3]	8[23]	8[23]	4.0[23]	4.0[23]
Pumped Hydro	98[8]	50[13]	81[17]	81[17]	Grid electricity	10[13]	50[17]	1,828[17]	1,887[17]	4[17]	4[17]	3.8[17]	3.8[17]
Small Hydro	Varies[5]	Varies[12]	35[21]	35[21]	Small hydro	N/A	100[22]	2,884[2]	2,884[2]	65[2]	65[2]	0.0[2]	0.0[2]
Solar PV	Varies[9,10]	0[12]	100[15]	100[15]	Solar	N/A	25[23]	1,583[2,32,35]	1,040[2,32,35]	44[2,32]	8[2,32]	0.0[2]	0.0[2]
Subcritical Pulverized Coal	80[3]	80[12]	35[15]	35[15]	Coal	N/A	40[23]	1,607[34]	1,607[34]	79[23, 36]	40[23, 36]	9.0[36]	9.0[36]
Supercritical Pulverized Coal	80[3]	80[12]	43[20]	43[20]	Coal	N/A	40[23]	1,921[29]	1,921[29]	102[23,36]	33[23, 36]	6.4[36]	6.4[36]
Ultra-supercritical Pulverized Coal	80[3]	80[12]	48[20]	50[20]	Coal	N/A	40[23]	2,300[20]	2,300[20]	46[20]	46[20]	6.4[36]	6.4[36]
Wind (Onshore)	Varies[10]	32[12]	100[15]	100[15]	Wind	N/A	25[23]	1996[2,32]	1,538[2,32]	69[2,32]	46[2,32]	0.0[2]	0.0[2]
Off-Grid Technologies													
Diesel and Oil	80[3]	77[39]	30[3]	30[3]	Diesel, biodiesel, residual fuel oil[8]	N/A	40[22]	500[3]	500[3]	42[29]	42[29]	18[29]	18[29]
Small Hydro	26[5]	26[39]	35[15]	35[15]	Small hydro	N/A	100[22]	2,884[2]	2,884[2]	65[2]	65[2]	0[2]	0[2]
Solar PV	Varies[9,10]	0[12]	100[15]	100[15]	Solar	N/A	25[23]	1,583[2,32,35]	1,040[2,32,35]	44[2,32]	8[2,32]	0[2]	0[2]

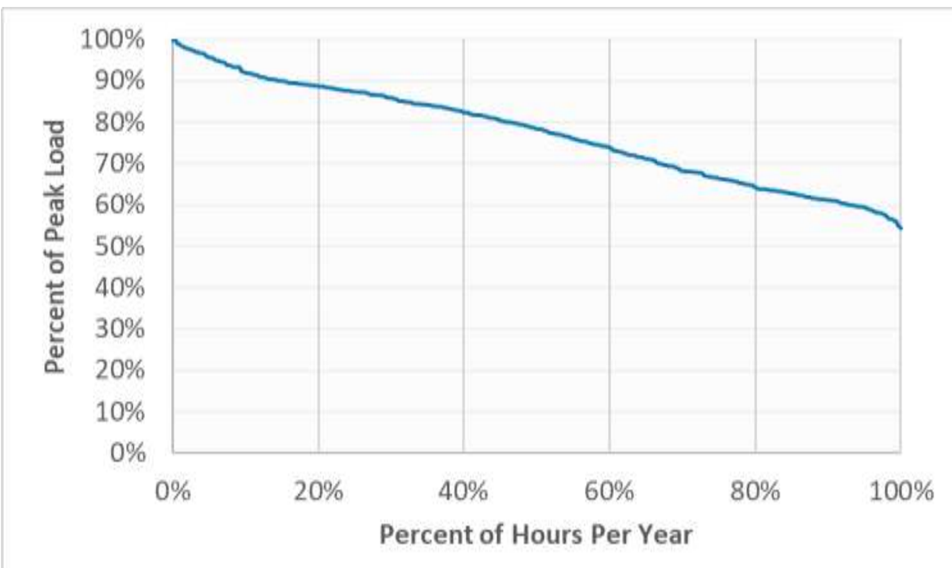
Technology	Availability Factor [%]	Capacity Credit [%]	Efficiency [%]		Feedstock Fuels	Full Load Hours	Lifetime [yrs]	Capital Cost [2010 USD/kilowatt (kW)]		Fixed Operating and Maintenance (O&M) Cost [2010 USD/kW]		Variable O&M Cost [2010 USD/megawatt-hour (MWh)]	
			2016	2030				2016	2030	2016	2030	2016	2030
Wind (Onshore)	Varies[10]	32[12]	100[15]	100[15]	Wind	N/A	25[23]	1,996[2,32]	1,538[2,32]	69[2,32]	46[2,32]	0[2]	0[2]

[1] (Edenhofer et al. 2012)
[2] (Energy Regulatory Commission 2015)
[3] (Department of Energy 2015d)
[4] (Metro Clark Waste Management Corporation 2010)
[5] (Department of Energy 2011a)
[6] (The AES Corporation 2016)
[7] (Endesa Generación, S.A. 2011)
[8] (International Energy Agency Energy Technology Systems Analysis Programme and International Renewable Energy Agency 2015)
[9] (National Renewable Energy Laboratory 2016b)
[10] (National Renewable Energy Laboratory 2016c)
[11] Availability factor used since there are no existing plants of this technology in Philippines.
[12] (Quejada 2017) Capacity credit calculated as dependable capacity divided by rated capacity. A constraint was used so that the capacity credit does not exceed the maximum availability. $NGCC_{new}$ assumed to be the same as $NGCC_{old}$. Oil CC assumed to be same as Oil Thermal. Super- and Ultra Super-Critical Pulverized Coal assumed to be the same as Sub-critical Pulverized Coal.
[13] B-LEADERS assumption.
[14] (International Energy Agency 2010). Average for non-CCS CFBC plants (without biomass co-firing) in Table 3.7b.
[15] (Department of Energy 2017c). Calculated using historical production and fuel inputs in national energy balances.
[16] (Mitsubishi Securities Clean Energy Finance Committee 2004)
[17] (Viswanathan et al. 2013)
[18] (Akhil et al. 2013)
[19] (Spuhler n.d.)
[20] (International Energy Agency 2012) [21] Efficiency for small hydropower assumed to be the same as for large hydropower.
[22] (Quejada 2015)
[23] (Schröder et al. 2013)
[24] (International Renewable Energy Agency 2012)
[25] (Department of Energy 2007)
[26] (Department of Energy 2013a)
[27] (Department of Energy 2013b)
[28] (Department of Energy 2013c)
[29] (B-LEADERS 2015b)

[30] (Fronda et al. 2015)
[31] (U.S. Energy Information Administration 2013)
[32] (National Renewable Energy Laboratory 2016a)
[33] (International Renewable Energy Agency 2014)
[34] (Department of Energy 2012)
[35] (Power Philippines News 2017)
[36] (B-LEADERS 2015a)
[37] (Lantau Group 2013)
[38] Costs assumed to be the same as for new natural gas combined cycle plants.
[39] (National Power Corporation – Small Power Utilities Group 2014). Calculated as dependable capacity divided by rated capacity. A constraint was used so that the capacity credit does not exceed the maximum availability.

The reserve margins for on-grid and off-grid production were changed to 25% (Department of Energy 2017e) and 23% (a B-LEADERS assumption), respectively. To improve the characterization of variable renewable resources and capacity dispatch, the number of subannual time slices considered in the electricity modeling was increased from 24 to 576 – representing a weekend day and a weekday in each month with hourly resolution (2 representative days per month x 24 hours per day x 12 months per year = 576 time slices). A system-wide load curve developed from DOE (2014) (Figure III.3) was used to distribute annual electricity demands over the time slices and to establish power requirements in each slice.

Figure III.3: Load Duration Curve Used in Electricity Modeling



For off-grid generation, a new prioritization scheme was implemented for endogenous capacity additions – i.e., additions made by the model to maintain the reserve margin, after accounting for existing and committed capacity and retirements (Table III.6).

Table III.6: Off-Grid Electricity Production Endogenous Capacity Shares

Technology	Share
Diesel/Oil	94%
Small Hydro	6%

Technology	Share
Solar PV	0%
Onshore Wind	0%

For on-grid production, the simulation methods used in the 2015 CBA for capacity dispatch and expansion (B-LEADERS 2015c) were replaced by least-cost optimization. This technique determines dispatch and capacity expansion by minimizing the net present value of electricity production costs (capital, O&M, and fuel costs for generation and storage) over the modeling period. LEAP uses an open-source algorithm, the Open Source Energy Modeling System (OSeMOSYS), for optimization calculations. OSeMOSYS is produced by a consortium including KTH Royal Institute of Technology and the Stockholm Environment Institute and is provided with the LEAP software package (KTH Royal Institute of Technology 2016). It operates with perfect foresight to achieve a global cost minimum across all modeled years. Further details on OSeMOSYS's code and features are available in Howells et al. (2011) and Moksnes et al. (2015).

As noted in Section III.3.1.1, a further constraint adopted in the on-grid modeling was the exclusion of new renewable generation capacity after 2010. This restriction applied to existing facilities added since 2010, committed capacity, and endogenous capacity that the model might otherwise have added.

Updated Electricity T&D Losses and Producer Own Use

Historical on-grid T&D losses and electricity producer own use were revised based on the latest national energy balances (Department of Energy 2017c). Baseline projections of on-grid T&D losses and own use, as well as variable O&M costs for T&D, were unchanged in the 2017 update.

For off-grid electricity, a nationwide T&D loss rate of 2.14% of gross deliveries to final consumers was applied in all years (Department of Energy 2016d). T&D costs and producer own use rates were assumed to be the same as for on-grid electricity.

Updated Inputs for Modeling Biofuels Production

Updated sources and values for technical parameters used to model biofuels production are shown in Table III.7.

Table III.7: Parameters for Modeling Biofuels Production (new or updated values in blue)

Feedstock Fuel	Efficiency [%]	Availability/ Capacity Credit [%]	Lifetime [Years]	Auxiliary Fuel Use
Sugarcane	53.073 kg sugarcane/U.S. gallon ethanol[1]	100[1]	30[1]	0.62 megajoules (MJ) bagasse and 0.004 MJ residual fuel oil / MJ ethanol[3]
Molasses	74.19 kg molasses / 18.6 liters ethanol[1]	100[1]	30[1]	
Copra	1 kilogram (kg) biodiesel : 1.667 kg copra[5]	100[1]	30[1]	0.06 MJ natural gas and 0.10 MJ electricity / MJ biodiesel[5]

[1] B-LEADERS assumption.

[2] Efficiencies are taken from the mean of calculated efficiencies from the 2008-2016 period. Efficiencies calculated using historical production data from National Energy Balances (Department of Energy 2017c) and sugarcane/molasses consumption data from USDA Foreign Agricultural Service (2016).
[3] (Argonne National Laboratory 2015)
[4] (Gopal and Kammen 2009)
[5] (Tan et al. 2004)

In addition to the changes listed in the table, some new data on historical production of biofuels and biofuels production capacity were introduced into the model. Historical bioethanol production was reproduced using data from the national energy balances (Department of Energy 2017c) and process shares from USDA Foreign Agricultural Service (2016). An updated estimate of the capacity of bioethanol plants, including existing and committed facilities, was taken from Informa Economics and DOE (2016) and USDA Foreign Agricultural Service (2016). Historical production of biodiesel was determined from the national energy balances (Department of Energy 2017c).

Full Utilization of Oil Refining Capacity

The only change in the modeling of oil refining was that available refining capacity was assumed to be fully utilized at all times. Any surplus production was assumed to be exported. DOE requested this change in a CBA consultation.

Revised Modeling of Natural Gas Supply

The modeling of natural gas production was updated to reflect an expected decline in domestic production by 2024 due to the depletion of reserves at the Philippines' largest gas field (Department of Energy 2016c). Future natural gas supplies were assumed to be supplemented by LNG imports. LNG terminal and T&D capacity were not modeled, so sufficient capacity to meet delivery requirements was assumed to be deployed as needed. Projected gas prices were based on the source of the gas (domestic or LNG; Section III.5).

Updated Resource Reserves and Yields

The estimates of domestic primary energy potential used in the model – covering both fossil fuel reserves and annual yields of renewable resources – were changed in several cases. Table III.8 summarizes sources and methods for the estimates, and Table III.9 and Table III.10 provide sample values.

Table III.8: Methods for Estimating Natural Resource Availability (updated methods highlighted in blue)

Resource	Method
Crude Oil, Natural Gas, and Condensate, Coal	Estimates of current reserves taken from Quejada (2015). Reserves drawn down during projection as domestic resources are used. Annual additions to coal reserves based on average value of annual coal discoveries, projected through 2040 (Department of Energy 2017b).
Wood	Use of wood for energy based on updated CBA forestry modeling (see Figure III.2).
Rice Hull	Annual availability based on projection of rice production from 2015 CBA agriculture modeling and assumption that 1 t rice produces 0.2 t rice hull.

Bagasse	Annual availability based on projection of sugarcane production from 2015 CBA agriculture modeling and assumption that 1.0 t sugarcane produces 0.3 t bagasse.
Sugarcane	Annual availability of unprocessed sugarcane as input for ethanol production based on projection of sugarcane production from 2015 CBA agriculture modeling and fraction of sugarcane milled for sugar (Sugar Regulatory Administration 2013).
Molasses	Annual availability based on amount of sugarcane milled for sugar and assumption that 1.0 t sugarcane milled yields 0.056 t molasses (Gopal and Kammen 2009).
Copra	Annual availability based on projection of coconut production from 2015 CBA agriculture modeling and yield of copra from fresh coconut reported in Guarte et al. (1996).
Coconut Residue	Annual availability based on projection of coconut production from 2015 CBA agriculture modeling and assumption that 1 kg coconut residue is available per kg of copra produced (Tan et al. 2004).
Animal Wastes	Annual availability based on projections of livestock population from 2015 CBA agriculture modeling and estimates of manure production per head in U.S. Environmental Protection Agency (1999) and Food and Agriculture Organization of the United Nations (1997).
Landfill Gas	Annual availability based on projections from updated waste modeling for 2017 CBA update.
Organic MSW	Annual availability based on projections from updated waste modeling for 2017 CBA update.
Other MSW	Annual availability based on projections from updated waste modeling for 2017 CBA update.
Wind	Annual availability taken from National Renewable Energy Laboratory (2015) for areas of Philippines with average 100-meter (m) wind speeds of at least 6.0 m/s.
Solar	Annual availability taken from National Renewable Energy Laboratory (2015) for areas of Philippines with global horizontal irradiance of at least 5.0 kilowatt-hours/m^2/day.
Small Hydro	Annual availability based on sum of installable micro (1-100 kW) and mini (100 kW - 10 MW) hydro capacity from DOE (2015c).
Large Hydro	Annual availability based on 10+ MW hydro capacity from DOE (2015c).
Geothermal	Annual availability taken from DOE (2011b).
Ocean Thermal	Annual availability assumed to be unlimited.

Table III.9: Historical and Projected Fossil Fuel Reserves, Baseline Scenario [Million Tonnes of Oil Equivalent]
(updated values highlighted in blue)

Fuel	2010	2020	2030	2040	2050
Crude Oil	2.1	-	-	-	-

Fuel	2010	2020	2030	2040	2050
Natural Gas	16.3	0.1	-	-	-
Condensate	8.1	5.9	5.9	5.9	5.9
Coal	111.9	176.1	15.4	-	-

Table III.10: Annual Yield of Renewable Resources, Baseline Scenario [Thousand Tonnes of Oil Equivalent][4]
(updated values highlighted in blue)

Fuel	2010	2020	2030	2040	2050
Animal Wastes	40,439	44,085	47,730	51,376	55,021
Bagasse	931	1,031	1,130	1,230	1,329
Coconut Residue	789	889	994	1,099	1,204
Copra[a]	999	1,126	1,259	1,392	1,525
Geothermal	23,236	23,236	23,236	23,236	23,236
Landfill Gas	3	5	8	8	8
Large Hydro	16,591	13,922	13,922	13,922	13,922
Molasses[b]	166	186	204	222	240
Municipal Solid Waste (Other)[d]	0	0	0	0	0
Municipal Solid Waste (Organic)[d]	0	0	0	0	0
Rice Hull	976	1,214	1,452	1,690	1,928
Small Hydro	1,160	1,160	1,160	1,160	1,160
Solar	1,300,187	1,300,187	1,300,187	1,300,187	1,300,187
Sugarcane[c]	11	4	4	5	5
Wind	87,853	87,853	87,853	87,853	87,853

[a] Represents the biodiesel energy that could be produced from available copra.

[b] Represents the ethanol energy that could be produced from available molasses.

[c] Represents the ethanol energy that could be produced from available sugarcane.

[d] Only used in mitigation scenarios.

III.3.2 Results

Figure III.4 and Figure III.5 show final energy demand and primary energy supply in the baseline scenario.

[4] Wood is not shown because the annual wood harvest for energy is determined directly from the CBA's forestry modelling; thus, it is not necessary to model wood availability *per se*. Ocean thermal is not shown because it is assumed to be effectively unlimited.

Figure III.4: Final Energy Demand (Excluding Transport), Baseline Scenario

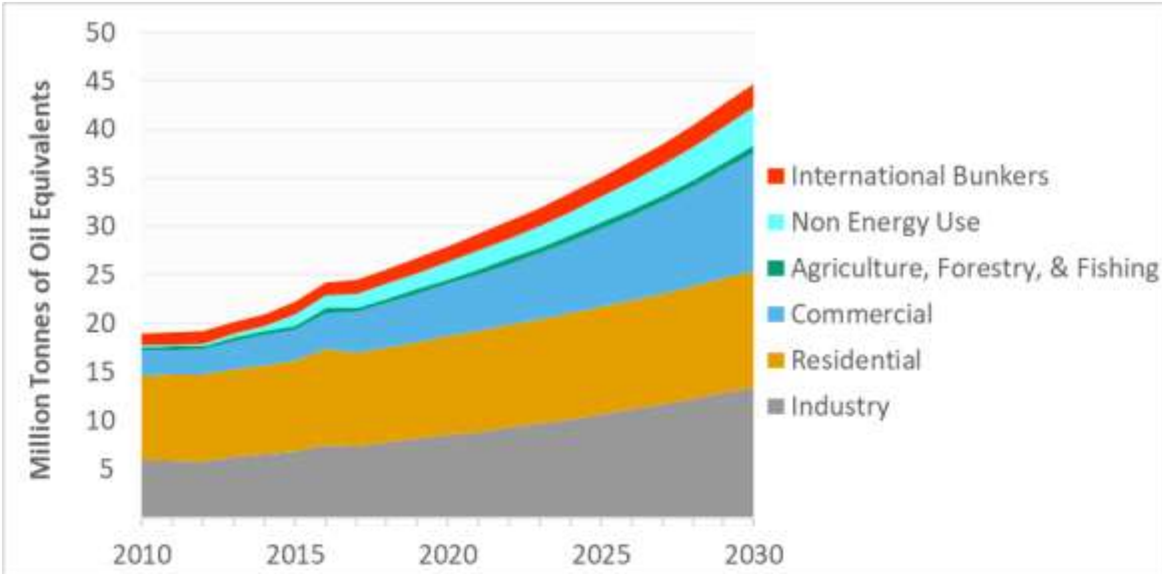
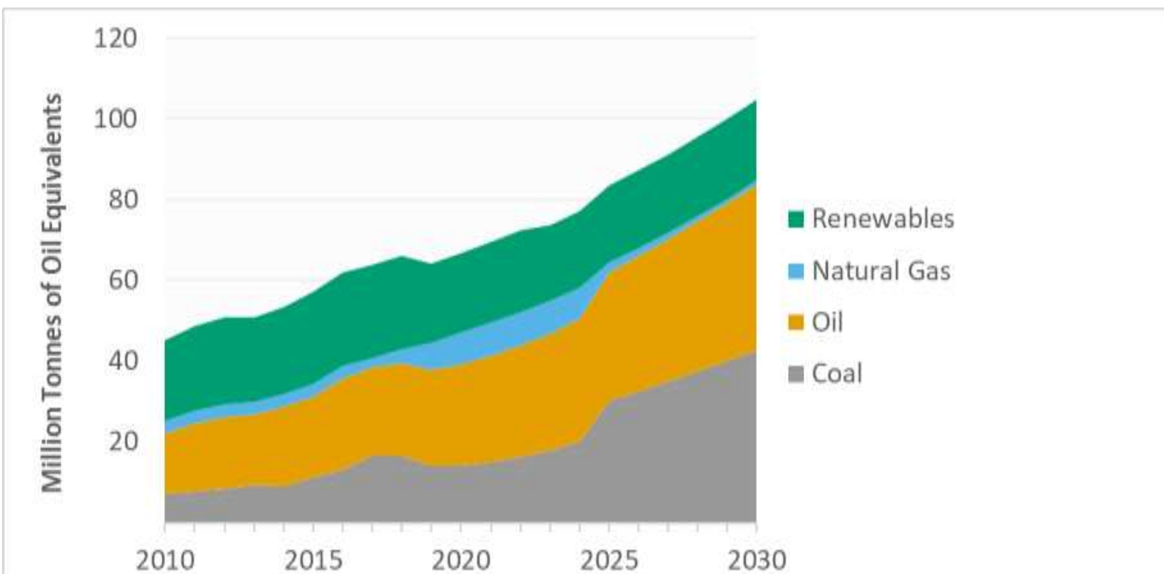


Figure III.5: Total Primary Energy Supply (TPES) (Including Transport), Baseline Scenario



Substantial growth in demand appears across all major sectors, except for the residential sector where the growth is more modest. This is due to a low population growth rate in comparison to GDP growth.

Baseline GHG emissions from the energy sector are reported in Figure III.6 and Table III.11. The fraction of emissions due to electricity generation grows over time: from 25% in 2010 to over 32% in 2030. An expanded deployment of coal and natural gas generation to meet rising electricity demands underlies this phenomenon.

Figure III.6: Baseline GHG Emissions From the Energy Sector

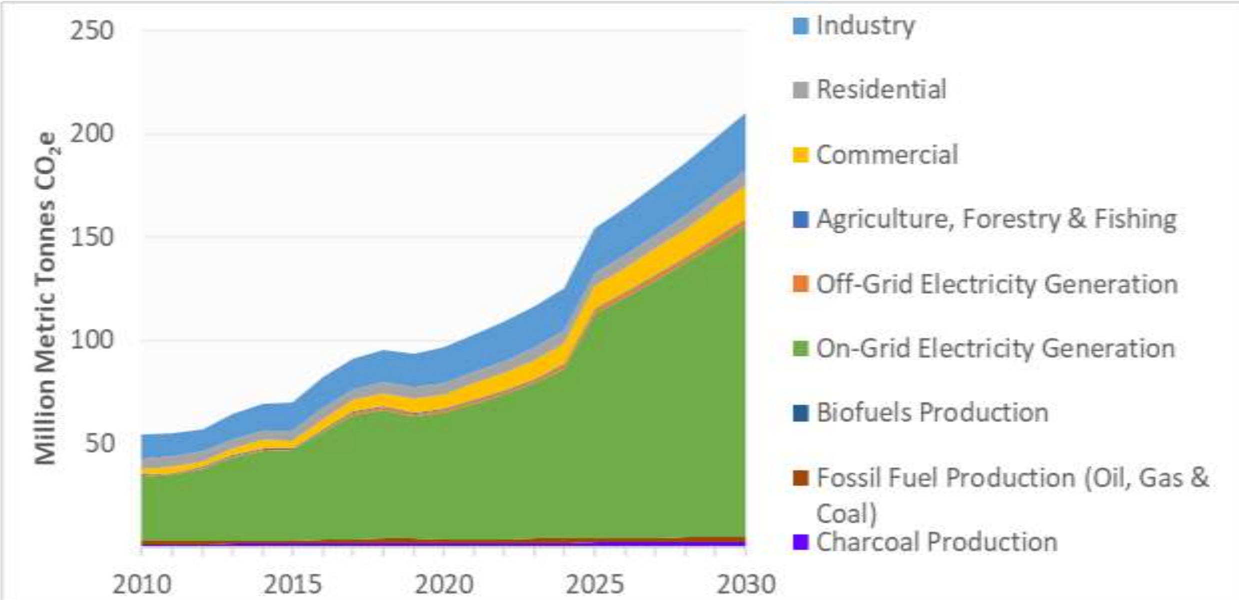


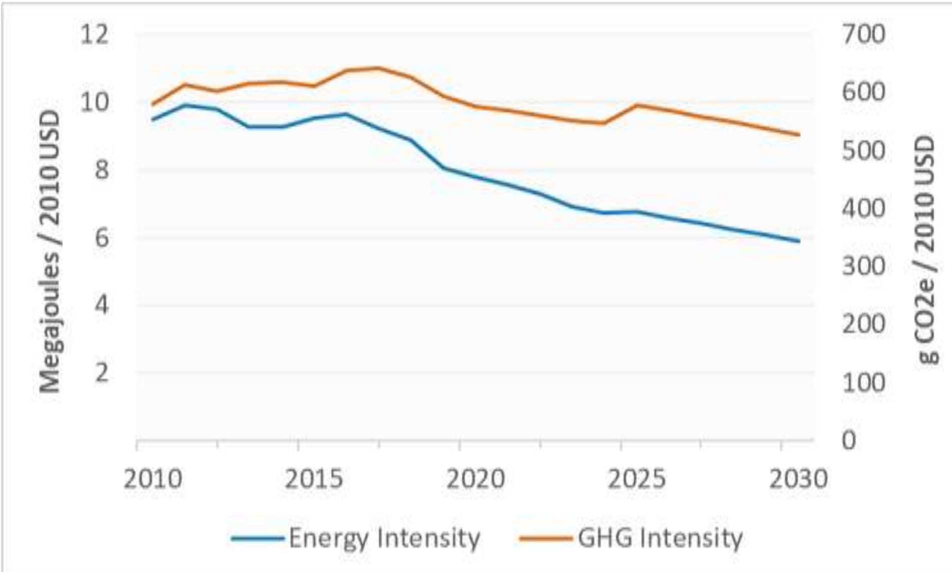
Table III.11: Baseline GHG Emissions from the Energy Sector [$MtCO_2e$]

Sector	2010	2020	2030
Industry	11.91	17.21	**27.64**
Residential	4.61	5.64	**7.24**
Commercial	2.87	7.01	**16.31**
Agriculture, Forestry, and Fishing	0.66	0.73	**0.78**
Off-Grid Electricity Generation	0.45	1.29	**2.30**
On-Grid Electricity Generation	31.21	61.21	**150.68**
Biofuels Production	0.00	0.04	**0.06**
Fossil Fuel Production (Oil, Gas, and Coal)	1.45	1.78	**2.78**
Charcoal Production	1.27	1.90	**2.21**
Total	**54.43**	**96.80**	**210.01**

Total emissions from energy demand and supply (excluding transport) reach 210 $MtCO_2e$ by 2030, nearly four times greater than in 2010. These results are significantly higher than the 2015 CBA Study findings due to an increased assumed GDP growth rate of 7.5% after 2016 (refer to Section III.5 for details). This results in real GDP increasing almost fourfold between 2010 and 2030.

The energy intensity of GDP exhibits a downward trend, dropping from 9.5 megajoules MJ per USD in 2010 to 5.9 MJ/USD in 2030 (Figure III.7). The GHG intensity of GDP also decreases to 527 grams (g) of CO_2e per USD in 2030.[5]

Figure III.7: Energy and GHG Intensities of GDP (Including Transport), Baseline Scenario



III.4 MITIGATION COST-BENEFIT ANALYSIS

III.4.1 Updated Methods and Assumptions

III.4.1.1 Identification and Description of Mitigation Options

Table III.12 lists updates to the CBA energy sector mitigation options based on input from CCC and DOE. Assumptions not explicitly discussed in the table were inherited from the baseline scenario described in Section III.3.

[5] Both of these results include all CBA sectors, not just the energy sector.

Table III.12: New or Updated Energy Sector Mitigation Options Analyzed in CBA (updates highlighted in blue)

Option	Description	Assumptions
Electricity Supply		
National Renewable Energy Program (NREP)	No change to the scenario description.	For renewable technologies covered by NREP, actual (historical) and committed additions of capacity after 2010 were removed from the baseline and incorporated in this option. No other changes were made to assumptions, aside from updates to the technical and cost parameters shown in Table III.5, and updated fuel prices discussed in Section III.5.
Advanced New Coal (**NEW OPTION)**	It is likely that coal will continue to play a significant role in the Philippines' electricity supply through 2050. There are important differences between coal combustion technologies that affect emissions, even in the absence of carbon capture and storage. Advanced coal plants generally incorporate state-of-the-art pollution controls, lowering air pollution and health impacts. They are also more efficient than conventional coal plants, which reduces need for imported coal. This option assumes that all new coal plants constructed in or after 2020 use state-of-the-art ultrasupercritical pulverized coal combustion technology with best available air pollution controls.	Technical: Committed coal plants built after 2020 use the ultrasupercritical technology. Technical parameters of coal generation technologies and other attributes of the power model are not altered. Electricity demand and total production are not affected either. Changes in requirements for fossil fuels affect upstream energy use and emissions from fossil fuel production in keeping with the supply-side modeling outlined in Section III.3.1.1. Cost: Capital and O&M costs for power technologies are described in Table III.5. Projected fuel costs are discussed in Section III.5. No program implementation costs besides capital, O&M, and fuel are modeled.
Substituting Natural Gas for Coal	The implementation of this option was updated to disallow the addition of coal capacity beyond existing and committed capacity. Capacity shortfalls are filled primarily with new natural gas combined cycle capacity.	No changes to assumptions, aside from updates to the technical and cost parameters shown in Table III.5, and updated fuel prices discussed in Section III.5.
Methane Recovery from Sanitary Landfills for Electricity	No change to the scenario description.	Actual (historical) and committed additions of landfill gas capacity after 2010 were removed from the baseline and incorporated in these options. Updated LFG collection rates for power generation under each option are provided in Figure III.8 below (based on the updated CBA solid waste modeling).[6] No other changes were made to assumptions, aside from updates to the technical and cost parameters shown in Table

[6] For a full explanation of the assumptions and modeling underlying the projections of landfill gas availability, see the waste chapter of the 2017 CBA update report.

Option	Description	Assumptions
Methane Recovery from Dumpsites for Electricity		III.5, and updated fuel prices discussed in Section III.5.
MSW Combustion	This option was not evaluated in the 2017 CBA update.	This option was not evaluated in the 2017 CBA update.
Nuclear Power	Based on guidance from CCC, this option models the construction of a one-gigawatt nuclear power plant in 2027 (instead of 2025, the year in the 2015 CBA).	No changes to other assumptions, aside from updates to the technical and cost parameters shown in Table III.5, and updated fuel prices discussed in Section III.5.
Industrial Energy Use		
Cement Waste Heat Recovery	No change to the scenario description.	Estimated electricity generation from cement waste heat recovery during 2011-2016 – calculated using Institute for Industrial Productivity and International Finance Corporation (2014) – was removed from the baseline and added to this option.
Residential and Commercial Energy Use		
Forest Protection Forest Restoration and Reforestation	No change to the scenario description.	The decrease or increase in wood harvested for energy based on the latest forestry modeling is provided in Figure III.9. All other technical and cost assumptions remain unchanged from the 2015 CBA.
Cross-Sectoral Energy Use		
Biodiesel Blending Target	No change to the scenario description.	As described in Section III.3.1.1, any historical biodiesel consumption after 2010 in excess of the 2% blending target was shifted to this option. No other changes were made to assumptions.

Figure III.8: Updated Estimates for LFG Collected for Electricity Generation, Baseline and Methane Recovery Scenarios

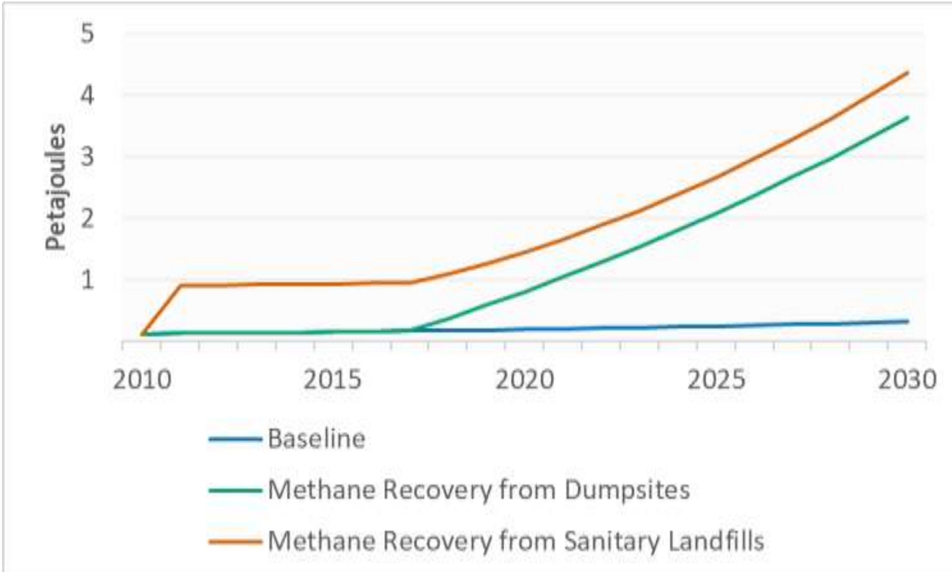
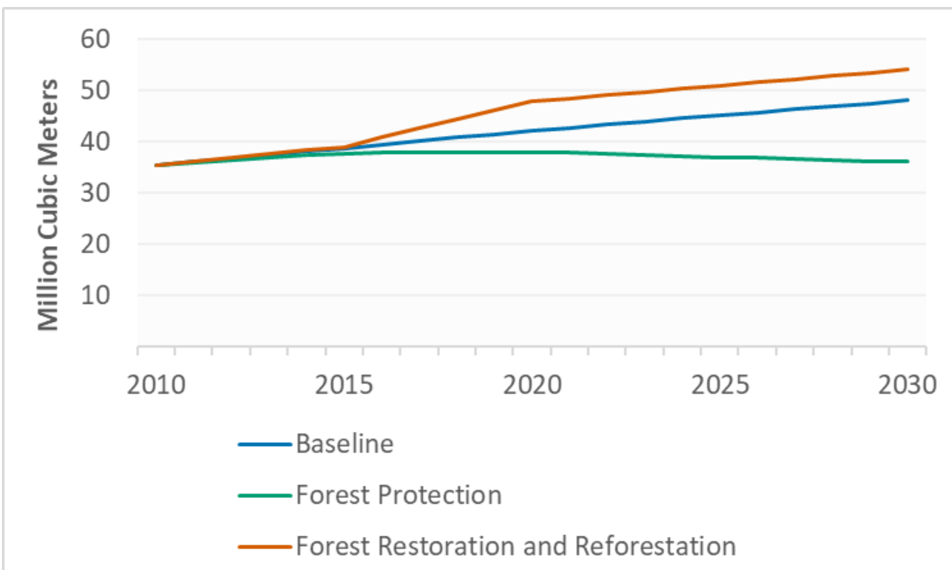


Figure III.9: Updated Estimates for Wood Harvest for Energy, Baseline and Forestry Mitigation Scenarios



III.4.1.2 Costs and Benefits of Mitigation Options

Historical and projected fuel prices were revised for the 2017 CBA update as described in Section III.5. The retrospective systems method of determining incremental impacts of mitigation options (Sathaye and Meyers 1995; B-LEADERS 2015c) continued to be used, but the ordering of options in the retrospective systems analysis changed based on updated assumptions, methods, and inputs. The new ordering is shown in Table III.13.

Table III.13: Full Retrospective Systems Ordering of Mitigation Options, All Sectors

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

Sequence	Sector(s)	Mitigation Option
38	Transport	Biofuels
39	Agriculture	Crop Diversification
40	Waste	Composting
41	Energy	Biodiesel Blending Target
42	Energy	NREP Solar
43	Waste	Mandamus Compliance
44	Transport	Road Maintenance
45	Transport	Buses and BRT
46	Transport	Electric LDV
47	Transport	Two-Stroke Replacement
48	Transport	Euro 4/IV and MVIS
49	Transport	Rail
50	Transport	Euro 6/VI and MVIS

The Energy Efficient Street Lighting with Light-Emitting Diode (LED) Technology option was not included in the retrospective systems analysis due to mutual exclusivity with the Energy Efficient Street Lighting with HPS Technology option.

III.4.1.3 Co-Benefits of Mitigation Options

The methods and assumptions used for assessing co-benefits, including air quality-related human health impacts, energy security impacts, and power sector employment impacts, were the same as in the 2015 CBA.

III.4.2 Results

All results presented in this section were calculated with the retrospective systems method noted earlier.

III.4.2.1 Direct Costs and Benefits of Mitigation Options

Table III.14 and Figure III.10 provide direct cost-benefit results for the energy sector mitigation options.

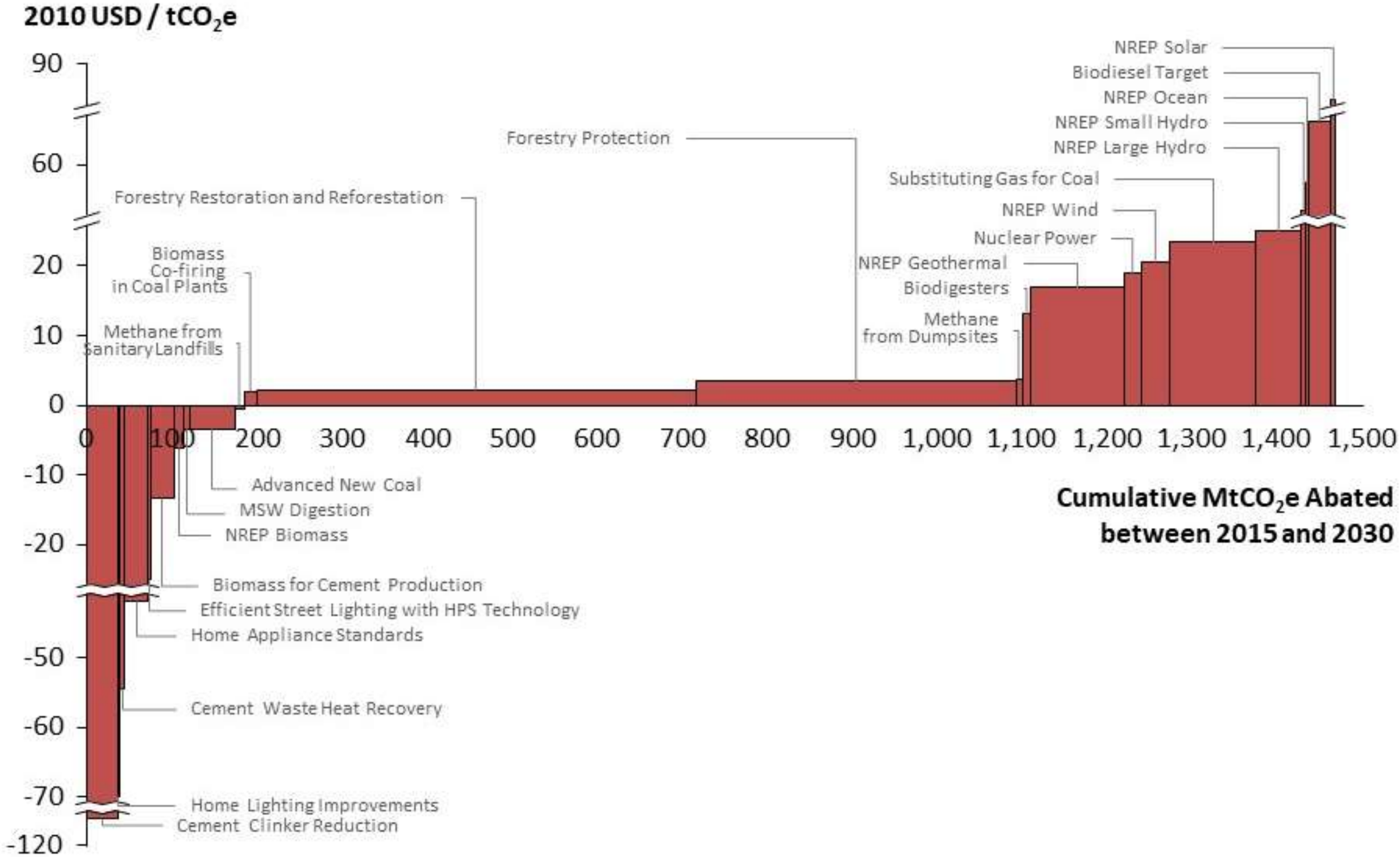
Table III.14: Direct Cost-Benefit Results for Energy Sector Mitigation Options

Mitigation Option	Abatement Costs (Cumulative 2015-2030), Discounted to 2015 at 10% [Billion 2010 USD]	GHG Mitigation Potential (Cumulative 2015-2030) [$MtCO_2e$]	Cost per Tonne Mitigation, Without Co-benefits [2010 USD/tCO_2e]
Advanced New Coal	-0.18	53.44	-3.38
Biodiesel Blending	1.71	25.82	66.29

Mitigation Option	Abatement Costs (Cumulative 2015-2030), Discounted to 2015 at 10% [Billion 2010 USD]	GHG Mitigation Potential (Cumulative 2015-2030) [$MtCO_2e$]	Cost per Tonne Mitigation, Without Co-benefits [2010 USD/tCO_2e]
Target			
Bio-digesters	0.12	9.50	13.08
Biomass Co-firing in Coal Plants	0.03	13.80	1.96
Biomass for Cement Production	-0.36	27.19	-13.28
Cement Clinker Reduction	-4.19	36.03	-116.29
Cement Waste Heat Recovery	-0.30	5.53	-54.54
Energy Efficient Street Lighting with HPS Technology	-0.07	2.75	-24.96
(M1) Forest Protection	1.32	376.93	3.50
(M2) Forest Restoration and Reforestation	1.14	516.73	2.20
Home Appliance Improvements	-1.17	27.94	-41.81
Home Lighting Improvements	-0.18	2.57	-69.96
Methane Recovery from Large Dumpsites for Electricity	0.03	7.66	3.77
Methane Recovery from Sanitary Landfills for Electricity	-0.01	11.69	-0.50
MSW Digestion of Organic Waste	-0.02	6.95	-3.40
NREP Biomass	-0.07	11.66	-6.17
NREP Geothermal	1.86	110.13	16.87
NREP Large Hydro	1.33	53.14	24.98
NREP Ocean	0.16	2.74	57.41
NREP Small Hydro	0.29	5.48	53.49
NREP Solar	0.51	6.00	84.89

Mitigation Option	Abatement Costs (Cumulative 2015-2030), Discounted to 2015 at 10% [Billion 2010 USD]	GHG Mitigation Potential (Cumulative 2015-2030) [$MtCO_2e$]	Cost per Tonne Mitigation, Without Co-benefits [2010 USD/tCO_2e]
NREP Wind	0.70	34.26	20.55
Nuclear Power	0.37	19.50	19.06
Substituting Natural Gas for Coal	2.37	101.26	23.37

Figure III.10: Energy Sector MACC



III.4.2.2 Co-Benefits of Mitigation Options

Table III.15 presents the incremental human health impacts calculated for the energy sector mitigation options, and Table III.16 shows the average annual incremental impact of each option on four energy security indicators. Table III.17 provides estimates of changes in direct power sector employment due to the options.

Table III.15: Incremental Human Health Impacts for Energy Sector Mitigation Options, Cumulative 2015-2030

Mitigation Option	Incremental Present Value, Discounted to 2015 at 10% [Million 2010 USD]	Incremental Cases of Premature Death Avoided	Incremental Cases of Premature Death Avoided (Females)
Advanced New Coal	6,272.4	14,190	5,400
Biodiesel Blending Target	26.3	50	30
Bio-digesters	24.6	50	0
Biomass Co-firing in Coal Plants	191.2	420	160
Biomass for Cement Production	0.0	0	0
Cement Clinker Reduction	6.7	20	10
Cement Waste Heat Recovery	8.2	20	10
Energy Efficient Street Lighting with HPS Technology	11.8	30	10
(M1) Forest Protection	-15.1	-40	-10
(M2) Forest Restoration and Reforestation	-9.4	-10	-20
Home Appliance Improvements	319.4	740	280
Home Lighting Improvements	20.6	50	20
Methane Recovery from Large Dumpsites for Electricity	36.0	80	40
Methane Recovery from Sanitary Landfills for Electricity	40.3	90	50
MSW Digestion of Organic Waste	-11.7	-30	-10
NREP Biomass	20.4	40	10
NREP Geothermal	577.7	1,080	410
NREP Large Hydro	583.9	1,010	380
NREP Ocean	22.8	30	10
NREP Small Hydro	75.9	140	50
NREP Solar	-6.9	-50	-30
NREP Wind	434.7	720	270
Nuclear Power	43.2	90	50

Mitigation Option	Incremental Present Value, Discounted to 2015 at 10% [Million 2010 USD]	Incremental Cases of Premature Death Avoided	Incremental Cases of Premature Death Avoided (Females)
Substituting Natural Gas for Coal	-2,441.8	-5,800	-2,230

Table III.16: Incremental Changes in Energy Security Indicators for Energy Sector Mitigation Options, Average Annual Impact During 2015-2030

Mitigation Option	Average Annual Incremental Impact 2015-2030[a]			
	Change in GHG Intensity of GDP [g CO_2e/2010 USD][2]	Change in Share of Renewables in TPES [%][3]	Change in Share of Imports in TPES [%][4]	Change in Energy Intensity of GDP [MJ/2010 USD] [5]
Advanced New Coal	-5.4	0.2	0.4	-0.1
Biodiesel Blending Target	-3.0	0.6	-	-
Bio-digesters	-1.2	0.3	-0.1	-
Biomass Co-firing in Coal Plants	-1.7	0.3	-0.1	-
Biomass for Cement Production	-3.2	0.5	-	-
Cement Clinker Reduction	-4.6	0.1	0.1	-
Cement Waste Heat Recovery	-0.8	-	0.1	-
Energy Efficient Street Lighting with HPS Technology	-0.3	-	-	-
(M1) Forest Protection	-48.2	-1.5	1.2	-0.1
(M2) Forest Restoration and Reforestation	-78.1	1.1	-0.9	0.1
Home Appliance Improvements	-2.9	0.1	0.2	-
Home Lighting Improvements	-0.3	-	-	-
Methane Recovery from Large Dumpsites for	-0.9	-	-	-

Mitigation Option	Average Annual Incremental Impact 2015-2030[a]			
	Change in GHG Intensity of GDP [g CO_2e/2010 USD][2]	Change in Share of Renewables in TPES [%][3]	Change in Share of Imports in TPES [%][4]	Change in Energy Intensity of GDP [MJ/2010 USD] [5]
Electricity				
Methane Recovery from Sanitary Landfills for Electricity	-1.5	-	-	-
MSW Digestion of Organic Waste	-0.8	0.1	-	-
NREP Biomass	-1.6	0.4	-0.2	-
NREP Geothermal	-14.0	8.8	-6.2	0.7
NREP Large Hydro	-7.3	1.8	-1.5	0.1
NREP Ocean	-0.4	0.1	-	-
NREP Small Hydro	-0.8	0.2	-0.1	-
NREP Solar	-1.0	0.2	-0.2	-
NREP Wind	-5.0	0.6	-0.4	-
Nuclear Power	-1.8	-	0.4	-
Substituting Natural Gas for Coal	-10.8	0.2	3.5	-

Notes:

[1] All indicators are calculated in the LEAP model. Results reflect the average of annual results from 2015-2030 that compare the indicator value for a given mitigation option relative to the value for the previous mitigation option.

[2] GHG intensity is measured as gCO_2e emissions (economy-wide, including from energy and non-energy sources) per unit of GDP (2010 USD).

[3] Percentage share of renewable energy in total primary energy supply.

[4] Percentage share of imports in total primary energy supply.

[5] Energy intensity is measured as total megajoules of primary energy supply (indigenous production of primary energy + energy imports - energy exports) divided by GDP (2010 USD).

Table III.17: Incremental Changes in Power Sector Job-Years for Energy Sector Mitigation Options, Cumulative 2015-2030

Mitigation Option	Incremental Job-Years Impact (Unrounded Cumulative Job-Years 2015-2030)
Advanced New Coal	713
Biodiesel Blending Target	0
Bio-digesters	1,505

Mitigation Option	Incremental Job-Years Impact (Unrounded Cumulative Job-Years 2015-2030)
Biomass Co-firing in Coal Plants	239
Biomass for Cement Production	0
Cement Clinker Reduction	-191
Cement Waste Heat Recovery	325
Energy Efficient Street Lighting with HPS Technology	-248
(M1) Forest Protection	627
(M2) Forest Restoration and Reforestation	-328
Home Appliance Improvements	-3,576
Home Lighting Improvements	-328
Methane Recovery from Large Dumpsites for Electricity	983
Methane Recovery from Sanitary Landfills for Electricity	1,413
MSW Digestion of Organic Waste	970
NREP Biomass	3,183
NREP Geothermal	33,134
NREP Large Hydro	30,727
NREP Ocean	931
NREP Small Hydro	2,983
NREP Solar	17,566
NREP Wind	10,706
Nuclear Power	841
Substituting Natural Gas for Coal	-39,042

III.4.2.1 Summary of Monetized Costs and Benefits

Table III.18 shows the monetized co-benefits of each mitigation option in the energy sector.
Table III.19 combines direct costs and benefits of the energy sector mitigation options with their monetized co-benefits to arrive at co-benefits-adjusted abatement costs per tonne and net present values. The tables do not include the option excluded from the retrospective systems analysis: Energy Efficient Street Lighting with LED Technology.

Table III.18: Monetized Co-Benefits of Mitigation Options in the Energy Sector

Sequence Number of Mitigation Option[1]	Mitigation Option	GHG Mitigation Potential (Cumulative 2015-2030) ($MtCO_2e$)	Incremental Co-benefits (Cumulative 2015-2030) [Billion 2010 USD] Discounted to 2015 at 10%				Cost per Tonne Mitigation, Co-benefits Only[2] [2010 USD/tCO_2e]
			Health	Conges-tion	Income Genera-tion	**Total Co-benefit**	
Symbol		*A*	*B*	*C*	*D*	*E*	*F*
Formula						*E=B+C+D*	*F =-E*1000/A*
15	Advanced New Coal	53.44	6.27	N/A	N/A	6.27	-117.37
41	Biodiesel Blending Target	25.82	0.03	N/A	N/A	0.03	-1.02
27	Bio-digesters	9.50	0.02	N/A	N/A	0.02	-2.59
26	Biomass Co-firing in Coal Plants	13.80	0.19	N/A	N/A	0.19	-13.85
12	Biomass for Cement Production	27.19	0.00	N/A	N/A	0.00	0.00
2	Cement Clinker Reduction	36.03	0.01	N/A	N/A	0.01	-0.18
9	Cement Waste Heat Recovery	5.53	0.01	N/A	N/A	0.01	-1.48
11	Energy Efficient Street Lighting with HPS Technology	2.75	0.01	N/A	N/A	0.01	-4.28
22	(M1) Forest Protection	376.93	-0.02	N/A	N/A	-0.02	0.04
21	(M2) Forest Restoration and Reforestation	516.73	-0.01	N/A	3.9	3.93	-7.61
10	Home Appliance Improvements	27.94	0.32	N/A	N/A	0.32	-11.43
7	Home Lighting Improvements	2.57	0.02	N/A	N/A	0.02	-8.01
23	Methane Recovery from Large Dumpsites for Electricity	7.66	0.04	N/A	N/A	0.04	-4.71
17	Methane Recovery from Sanitary Landfills for Electricity	11.69	0.04	N/A	N/A	0.04	-3.44
16	MSW Digestion of	6.95	-0.01	N/A	N/A	-0.01	1.68

Sequence Number of Mitigation Option[1]	Mitigation Option	GHG Mitigation Potential (Cumulative 2015-2030) ($MtCO_2e$)	Incremental Co-benefits (Cumulative 2015-2030) [Billion 2010 USD] Discounted to 2015 at 10%				Cost per Tonne Mitigation, Co-benefits Only[2] [2010 USD/tCO_2e]
			Health	Conges-tion	Income Genera-tion	**Total Co-benefit**	
Symbol		*A*	*B*	*C*	*D*	*E*	*F*
Formula						*E=B+C+D*	*F =-E*1000/A*
	Organic Waste						
13	NREP Biomass	11.66	0.02	N/A	N/A	0.02	-1.75
28	NREP Geothermal	110.13	0.58	N/A	N/A	0.58	-5.25
33	NREP Large Hydro	53.14	0.58	N/A	N/A	0.58	-10.99
37	NREP Ocean	2.74	0.02	N/A	N/A	0.02	-8.33
36	NREP Small Hydro	5.48	0.08	N/A	N/A	0.08	-13.85
42	NREP Solar	6.00	-0.01	N/A	N/A	-0.01	1.14
31	NREP Wind	34.26	0.43	N/A	N/A	0.43	-12.69
29	Nuclear Power	19.50	0.04	N/A	N/A	0.04	-2.21
30	Substituting Natural Gas for Coal	101.26	-2.44	N/A	N/A	-2.44	24.11

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

[1] Sequence Number of Mitigation Options refers to the sequential order in which individual mitigation options are initiated as described by the retrospective systems approach. In the retrospective systems approach, mitigation options are compared to the baseline as stand-alone options and then ranked or sequenced according to their cost per ton of mitigation (without co-benefits) from lowest cost per ton of mitigation to highest cost per ton of mitigation. Then the incremental cost and GHG mitigation potential of mitigation options is calculated as compared to the baseline and all prior sequenced mitigation options. The advantage of this approach is that the interdependence between a given mitigation option and every other previous option on the MACC is taken into account.

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

Column Definitions:

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

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

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

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

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

Table III.19: Net Present Value of Mitigation Options in the Energy Sector during 2015-2030

Sequence Number of Mitigation	Mitigation Option	GHG Mitigation Potential (Cumulative	Cost per Tonne Mitigation (2010 USD/tCO_2e)[2]	Net Present Value Excluding Value of GHG Reduction

Option[1]		2015-2030) (MtCO₂e)[3]	Co-benefits only[4]	Without co-benefits	With co-benefits[5]	(Billion 2010 USD)[6]
	Symbol	*A*	*F*	*G*	*H*	*I*
	Formula				*F+G = H*	*I = -H*A/1000*
15	Advanced New Coal	53.44	-117.37	-3.38	-120.75	6.45
41	Biodiesel Blending Target	25.82	-1.02	66.29	65.27	-1.69
27	Bio-digesters	9.50	-2.59	13.08	10.49	-0.10
26	Biomass Co-firing in Coal Plants	13.80	-13.85	1.96	-11.89	0.16
12	Biomass for Cement Production	27.19	0.00	-13.28	-13.28	0.36
2	Cement Clinker Reduction	36.03	-0.18	-116.29	-116.47	4.20
9	Cement Waste Heat Recovery	5.53	-1.48	-54.54	-56.02	0.31
11	Energy Efficient Street Lighting with HPS Technology	2.75	-4.28	-24.96	-29.24	0.08
22	(M1) Forest Protection	376.93	0.04	3.50	3.54	-1.33
21	(M2) Forest Restoration and Reforestation	516.73	-7.61	2.20	-5.41	2.80
10	Home Appliance Improvements	27.94	-11.43	-41.81	-53.24	1.49
7	Home Lighting Improvements	2.57	-8.01	-69.96	-77.97	0.20
23	Methane Recovery from Large Dumpsites for Electricity	7.66	-4.71	3.77	-0.94	0.01
17	Methane Recovery from Sanitary Landfills for Electricity	11.69	-3.44	-0.50	-3.94	0.05
16	MSW Digestion of Organic Waste	6.95	1.68	-3.40	-1.72	0.01
13	NREP Biomass	11.66	-1.75	-6.17	-7.92	0.09
28	NREP Geothermal	110.13	-5.25	16.87	11.62	-1.28

Sequence Number of Mitigation Option[1]	Mitigation Option	GHG Mitigation Potential (Cumulative 2015-2030) ($MtCO_2e$)[3]	Cost per Tonne Mitigation (2010 USD/tCO_2e)[2]			Net Present Value Excluding Value of GHG Reduction
			Co-benefits only[4]	Without co-benefits	With co-benefits[5]	(Billion 2010 USD)[6]
Symbol		*A*	*F*	*G*	*H*	*I*
Formula					*F+G = H*	*I = -H*A/1000*
33	NREP Large Hydro	53.14	-10.99	24.98	13.99	-0.74
37	NREP Ocean	2.74	-8.33	57.41	49.08	-0.13
36	NREP Small Hydro	5.48	-13.85	53.49	39.64	-0.22
42	NREP Solar	6.00	1.14	84.89	86.03	-0.52
31	NREP Wind	34.26	-12.69	20.55	7.86	-0.27
29	Nuclear Power	19.50	-2.21	19.06	16.85	-0.33
30	Substituting Natural Gas for Coal	101.26	24.11	23.37	47.48	-4.81

Notes:

[1] Refers to the sequential order in which the mitigation option is introduced in the retrospective analysis. In this analysis, mitigation options are compared to the baseline as stand-alone options, and then ranked according to their cost per tons mitigation (excluding co-benefits) from lowest cost per ton mitigation to highest cost per ton mitigation. The cost and GHG mitigation potential of a given mitigation option is calculated relative to a scenario that embeds all options with lower cost per ton mitigation.

[2] The incremental costs and co-benefits expected to occur in years other than 2015 were expressed in terms of their present (i.e., 2015) value using a discount rate of 10%. Equal to the total net cost divided by the mitigation potential. Represents the cumulative cost per ton of a mitigation option if implemented relative to the prior mitigation option using retrospective systems analysis. Negative values indicate cost savings as well as GHG emissions benefits.

[3] The incremental GHG mitigation potential is a total reduction in GHG emissions that is expected to be achieved by the option during 2015-2030.

[4] The co-benefits for the energy sector include human health benefits due to reduced air pollution from electricity generation.

[5] Negative value indicates net benefits per tonne mitigation. This excludes the non-monetized benefits of GHG reductions.

[6] The values reported are calculated using the full precision of the values for GHG Mitigation Potential in tCO_2e (A). Total co-benefits minus total net cost reflects the present value to society of a mitigation option relative to the prior mitigation option, including changes in costs (e.g. capital, fuel, and other inputs) and co-benefits such as public health, but excluding climate benefits. A true net present value would include a valuation of climate benefits based on the social cost of CO_2e in the Philippines times the mitigation potential. A negative value indicates net loss in social welfare, cumulative over 2015-2030. This loss does not account for the non-monetized benefits of GHG reductions.

III.5 ANNEX: CROSS-CUTTING ECONOMIC ASSUMPTIONS

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

Table III.20: Data Sources and Projection Methods for Population, GDP, Economic Sector-Specific Value Added, and Fuel Prices (changes highlighted in blue)

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

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

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

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

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

Table III.21: Historical and Projected Values for Population, GDP, Economic Sector-Specific Value Added, and Fuel Prices

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

Year	Historical Data						Baseline						
	1990	1995	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Construction	6,266	6,796	7,504	7,625	12,220	17,117	26,463	38,594	56,089	81,258	117,392	169,173	243,253
Electricity Gas Water Supply	3,622	3,929	4,828	6,139	7,128	8,217	10,742	14,412	19,266	25,676	34,122	45,233	59,830
All Commercial	49,832	54,049	67,958	86,076	110,009	148,352	218,565	321,104	470,097	686,067	998,455	1,449,464	2,099,538
Agri Crops Product	7,245	7,858	9,216	10,323	13,307	14,340	17,835	23,008	29,579	37,907	48,444	61,755	78,550
Livestock and Poultry	3,622	3,929	4,725	5,174	5,590	5,965	7,098	8,657	10,521	12,747	15,400	18,559	22,317
Agri Services	979	1,062	1,172	1,314	1,634	1,842	2,419	3,142	4,066	5,247	6,751	8,665	11,097
Forestry	98	106	192	129	54	54	52	63	76	91	109	130	155
Fishing	2,545	2,761	3,098	3,436	3,993	3,667	4,006	4,838	5,822	6,984	8,355	9,970	11,871
Fuel Prices (2010 USD/gigajoule)													
Biomass	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Coal Sub bituminous	2.55	2.28	1.76	2.89	5.26	3.13	4.02	4.33	4.68	4.83	4.98	5.14	5.30
Natural Gas	1.46	1.46	1.46	6.54	8.89	15.40	13.99	13.62	13.26	13.26	13.01	12.76	12.52
Nuclear	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
Crude Oil	5.13	5.13	5.13	8.67	12.49	14.86	12.12	15.09	18.77	20.13	21.57	23.13	24.79
Bagasse	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Animal Wastes	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Coconut Residue	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Rice Hull	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
Wood	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84

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

Table III.22: Historical Exchange Rates and Inflation Rates

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

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

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

2012-2014: PSA (2015b)

2015: PSA (2016)

2016 : PSA (2017)

[3] Source: World Bank (2017)

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