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

PHILIPPINES MITIGATION COST-BENEFIT ANALYSIS

-

November 2015

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Forestry Sector Results

November 2015

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ACRONYMS

A&D	Alienable & Disposable Land
ADB	Asian Development Bank
ALU	Agriculture and Land Use
ALU Software	Agriculture and Land Use Greenhouse Gas Inventory Software
AWD	Alternate wetting and drying
BEF	Biomass expansion factor
BRT	Bus Rapid Transit
B-LEADERS	Building Low Emission Alternatives to Develop Economic Resilience and Sustainability
BSWM	Bureau of Soil and Water Management
BW	Aboveground Biomass Stock
BWp	Previous Aboveground Biomass Stock
BWr	Remaining aboveground biomass stock
CADC/CADT	Certificates of Ancestral Domain Claims and Titles
CBA	Cost-Benefit Analysis
CCC	Climate Change Commission
CF	Carbon fraction
CO	Carbon Monoxide
COPD	chronic obstructive pulmonary disease
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CH_4	Methane
DA	Department of Agriculture
DENR	Department of Environment and Natural Resources
EO	Executive Order
FAO	Food and Agriculture Organization
FMB	Forest Management Bureau
FMP	Forestlands Management Project
GBD	Global Burden of Disease
GDP	Gross Domestic Product
GHG	Greenhouse gas
GWP	Global Warming Potential
GHG	Greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
GW	Aboveground Biomass Growth Increment
GWh	Average Job-Years per Gigawatt Hour
GWP	Global Warming Potential
HAC	High activity clay mineral type
ICCT	International Council on Clean Transportation
IEA	International Energy Agency
IER	Integrated Exposure-Response
iFs	Intake fractions
IHME	Institute for Health Metrics and Evaluation

INDC	Intended Nationally Determined Contribution
INREMP	Integrated Environment and Natural Resource Management Project
IPCC	Intergovernmental Panel on Climate Change
IPRA	Indigenous People's Right Act
LEAP	Long range Energy Alternatives Program
LECB	Low Emissions Capacity Building (UNDP Program)
LGU	Local Government Unit
LULUCF	Land Use, Land-Use Change, and Forestry
MAT	Mean Annual Temperature
MAC	Marginal Abatement Cost
MACC	Marginal Abatement Cost Curve
MVIS	Motor Vehicle Inspection System
$MtCO_2e$	Million metric tons of carbon dioxide equivalent
M1	Forest Protection
M2	Forest restoration, reforestation, and afforestation
NAMA	Nationally Appropriate Mitigation Action
NAMRIA	National Mapping and Resource Information Authority
NCIP	National Commission on Indigenous Peoples
NGP	National Greening Program
NIPAS	National Integrated Protected Area Systems
NMVOC	Non-Methane Volatile Organic Compounds
N_2O	Nitrous Oxide
NO_x	Nitrogen Oxides
N/C	Nitrogen/carbon
OECD	Organization for Economic Cooperation and Development
PD	Presidential Decree
PhP	Philippine Peso
$PM_{2.5}$	Ambient fine particulate matter
PNRPS	Philippine National REDD+ Strategy
PSA	Philippines Statistics Authority
REDD	Reduced Emissions from Deforestation and Degradation
RS	Root/shoot ratio
Ton	Metric tons, 1,000 kilograms
TMSD	Tropical Moist Short Dry Season
TRMM	Tropical Montane Moist
TRW	Tropical Wet
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USD	U.S. Dollar
US EPA	U.S. Environmental Protection Agency
VSL	value per Statistical Life
WTP	willingness to pay

VI. FORESTRY

VI.1 EXECUTIVE SUMMARY

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

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

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

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

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

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

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

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

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

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

Table VI. 1 Summarizes the direct costs and benefits of mitigation options, including changes in capital, operating and maintenance (O&M), implementation, and fueling costs as well as GHG emissions. 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 tonne 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.

Table VI. 1. Mitigation Options in the Forestry Sector – Potential and Net Cost

Sector	Sequence Number of Mitigation Option*	Mitigation Option	Incremental Cost (Cumulative 2015-2050) [Billion 2010 USD] Discounted at 5%			Incremental GHG Mitigation potential (2015-2050) [$MtCO_2e$]	Incremental Cost per Ton Mitigation (2015-2050) [2010 USD] *without co-benefits*
			Capital, O&M, Implementation Costs	Cost of Fuel and Other Inputs	Total Net Cost		

Symbol					**A**	*B*	*C*
Formula							*(A*1000)/B=C*
Forestry	23	(M2) Forest Restoration and Reforestation	1.80	-0.94	0.859	405.87	2.12
	25	(M1) Forest Protection	1.94	3.19	5.133	516.91	9.93

*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.

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 VI. 2 summarizes the value of co-benefits that could be monetized for the energy mitigation options. Column J shows the value of these benefits, normalized per ton of GHG mitigation potential. These "co-benefits only" results exclude direct costs; they are combined with direct costs and benefits in Table VI. 3.

Table VI. 2. Monetized Co-Benefits of Mitigation Options in the Forestry Sector

Sequence Number of Mitigation Option	**Mitigation Option**	**Incremental Co-benefits (Cumulative 2011-2050) [Billion 2010,USD] Discounted at 5%**				**Incremental Cost per Ton Mitigation (2011-2050) [2010,USD]** ***co-benefits only*** **[2]**
		Health	Congestion	Income Generation	**Total Co-benefit**	
Symbol		*F*	*G*	*H*	*I*	*J*
Formula					*sum(F,G,H)=I*	*-I/B=J*
23	(M2) Forest Restoration and Reforestation	-0.195	–	7.19	6.995	-17.23
25	(M1) Forest Protection	0.158	–	–	0.158	0.31

Notes: – indicates inapplicability of a given co-benefits category

Table VI. 3 combines the cost per ton without co-benefits (Column B) with the cost per ton of co-benefits (Column J from Table VI. 2).

Finally, Column E indicates the net present value of costs (including fuel savings) and co-benefits for health and traffic congestion. A positive value indicates a mitigation option has net benefits to society in addition to its potential to mitigate GHG emissions. Two mitigation options (Biofuels and Two-Stroke

Replacement) would have costs that outweigh their (non-climate) benefits, indicating that society's willingness-to-pay for GHG mitigation would have to exceed the Cost per Ton Mitigation with Co-benefits (Column D) for these measures to be considered cost effective[1].

Table VI. 3. Net Present Value of Mitigation Options in the Forestry Sector during 2011-2050

Sequence Number of Mitigation Option[1]	Mitigation Option	GHG Mitigation Potential [2011-2050] (MtCO$_2$e)[3]	Cost per Ton CO$_2$e Mitigation [2011-2050] (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]	
		A	*B*	*C*	*D = B+C*	*E = –D * A/1000*
23	(M2) Forest Restoration and Reforestation	405.87	2.12	-17.23	-15.11	6.13
25	(M1) Forest Protection	516.91	9.93	0.31	9.62	-4.97

Abbreviations:
MtCO$_2$e - 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 5%.
[3] The GHG mitigation potential is a total reduction in GHG emissions that is expected to be achieved by the option during 2011-2050.
[4] The co-benefits for the forestry sector include: (i) human health benefits due to reduced air pollution from electricity generation; and (ii) for option M2, sales of commodities generated by forest and agroforestry plantations designated for production.
[5] Negative value indicates net benefits per ton mitigation. This excludes the non-monetized benefits of GHG reductions.
[6] Negative value indicates net loss in social welfare, cumulative over 2011-2050.This loss does not account for the non-monetized benefits of GHG reductions.

Figure VI. 1 shows the MACC for the agriculture mitigation options which indicates a total cumulative abatement potential of 149 MtCO$_2$e if all four mitigation options were implemented. As discussed above, the organic fertilizers' mitigation option results in a negative cost per ton and has significant abatement potential. The AWD mitigation option has the greatest mitigation potential with more than 90 MtCO$_2$e for less than 1 USD per ton of mitigation. The other two mitigation options are smaller in terms of GHG abatement and are less cost effective, with the crop diversification option providing relatively lower mitigation potential for a relatively higher cost, and the bio-digester option providing very little mitigation potential for an extremely high price.

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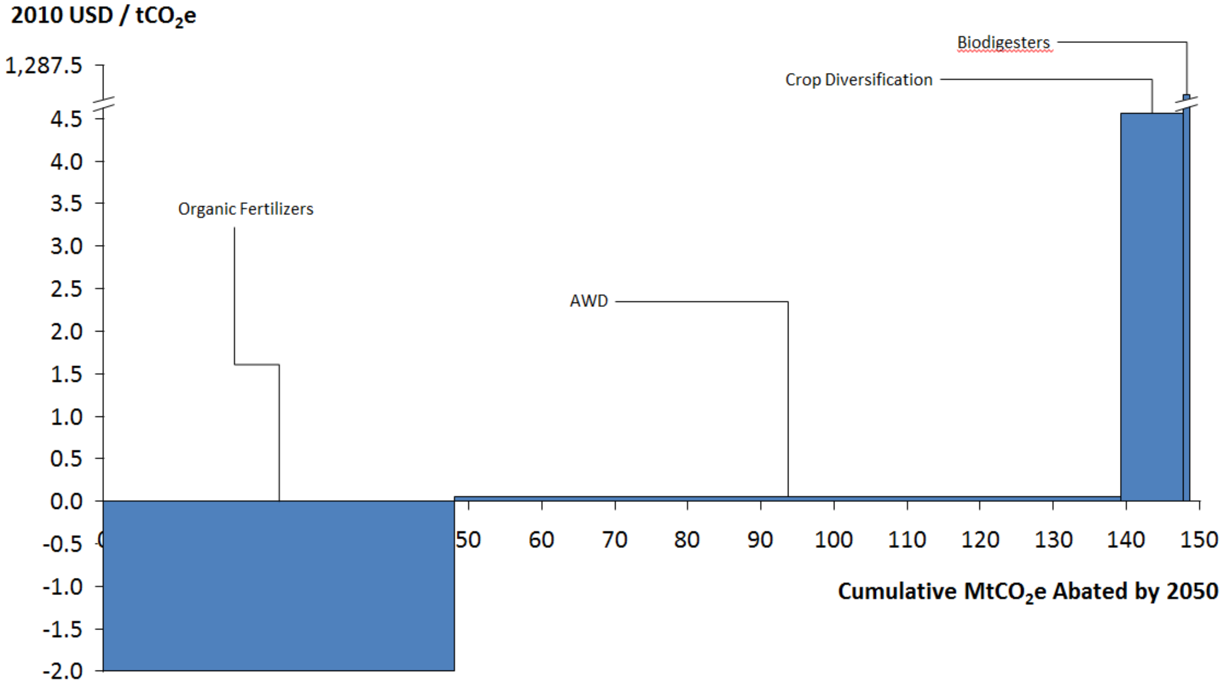
[1] Other mitigation options would still be considered cost effective even if the social cost of carbon-equivalent (expressed in USD per tonne) were zero.

Figure VI. 1. Marginal Abatement Cost Curve for Agriculture Mitigation Options



VI.2 BASE YEAR GHG EMISSIONS

The following subsections provide the 2010 Base Year GHG Emissions and Removals for the forestry sector. The inventory takes into account the gains in carbon from the annual increase in above-ground biomass growth and the losses in carbon due to timber harvesting, fuelwood gathering, deforestation, and disturbances (e.g., forest fires, insects, diseases, and other disturbances).

This report presents the results as of July 2015. It aligns with the numbers that were used by CCC to inform the INDC reported to the UNFCCC in October 2015 (Republic of the Philippines, 2015). Therefore, any data, methods, and stakeholder comments received after July 2015 are not reflected in this report. They may be incorporated in future updates.

It is important to note that because the ALU tool used for the CBA is designed to also analyze GHG emissions and removals for other land-use categories in addition to forest land, including cropland and grassland, some of the figures and tables in this report refer to and include estimates of GHG emissions and removals associated with other land-use categories than forests. When this is the case, we use the broader term "LULUCF" to indicate that results apply to all land-use categories covered by ALU. In contrast, the term "forest" is used to indicate where estimates and results for GHG emissions and removals apply only to the forest land category. Results show that in the 2010 base year, forest lands accounted for 91.35% of the total biomass carbon stock on land use categories analyzed in this report. Therefore, as forests represent the main source of GHG emissions and removals in the Philippines' LULUCF sector, this report focuses on discussing methods, assumptions, and results for forest land.

VI.2.1 Methods and Assumptions

The CBA study adopted the IPCC inventory guidelines (2003 and 2006) which contain widely accepted guidelines for estimating the changes in carbon stocks and GHG emissions from biomass burning in the LULUCF sector. The study team used the Gain-Loss Method described in the IPCC guidelines (2003 and 2006) for determining the annual change in biomass from estimates of biomass gains and losses. The method takes into account the gains in carbon from the annual increase in above-ground biomass growth and the losses in carbon due to timber harvesting, fuelwood gathering, deforestation, and disturbances (e.g., forest fires, insects, diseases, and other disturbances). The CBA used the ALU Software to implement the IPCC methodologies for estimating changes in carbon stock and GHG emissions from biomass burning in the forestry sector. The Study Team used LEAP to determine the energy-related GHG emission impacts of changes in the availability of biomass for heating, cooking, and electricity generation which in turn influences the use of other fuels. The methods and results of the energy-related impacts are discussed in the Energy Report for the CBA (B-LEADERS, 2015).

The Study Team used numerous data sources to develop the 2010 base year emissions estimate for the forestry sector, prioritizing the use of country-specific estimates of activity data as available. The NAMRIA 2010 Land Cover Statistics represents the key data set and was used to define the area in forest lands in 2010 (NAMRIA, 2014). DENR's forest categories and sub-categories were used to further delineate forest lands by type (e.g., closed forest) and tenure (e.g., public lands).

Consistent with the 2000 GHG inventory used for the Philippines' Second National Communication (CCC, 2014), the Study Team used the IPCC Tier 1 approach for estimating emissions from all source categories. However, since the 2010 base year inventory was developed using the ALU Software, and the 2000 GHG inventory did not use ALU, the differences made it difficult to do direct comparison between 2000 and 2010 inventory estimates for these two years difficult. One reason for this is methodology: The 2000 inventory was based on the 1996 IPCC methods and classification. ALU on the other hand used the IPCC's 2000 Good Practice Guidance and the 2003 Good Practice Guidance for LULUCF methods and classification (2000 and 2003).

VI.2.1.1 Land Use in Inventory Year 2010

As the first step in the inventory development, consistent land representation is required in taking into account the Philippine climate, soil types, and land use categories. These factors are known to influence the carbon stocks in aboveground and belowground biomass and in soils. The IPCC methodology for consistent land use representation, as implemented in the ALU Software, requires climate and soil data as inputs. For climate type, using the decision tree in the IPCC 2006 guidelines for climate classification, and by visual classification of elevation, annual rainfall, and mean annual temperature,[2] the entire land

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[2] Elevation Map from the Department of Agriculture's Bureau of Soil and Water Management; Philippines' Annual Rainfall Map from US Department of Energy, National Renewable Energy Laboratory; mean annual temperature in the Philippines is greater than 18C.

area of the Philippines, was categorized into three dominant climate types: tropical moist short dry season (TMSD), tropical montane moist (TRMM), tropical wet (TRW), as shown in Table VI. 4.

Table VI. 4. Climate Type and Percent Total Area of the Philippines

Climate Name	Acronym	Description	Area, ha	% of Total Area
Tropical Moist, Short Dry Season	TMSD	Tropical Region, Elevation < 1000m, Annual precipitation >= 1000mm and Annual precipitation < 2000mm, dry season <= 5 months	6,738,348	22.8
Tropical Montane Moist	TRMM	Tropical Region, Elevation >= 1000m, Annual precipitation >= 1000mm	6,915,673	23.4
Tropical Wet	TRW	Tropical Region, Elevation < 1000m, Annual precipitation >= 2000mm	15,900,136	53.8
TOTAL			**29,554,156**	**100**

For the study, soil types were visually classified based on the Soil Map of the Philippines [DA's Bureau of Soil and Water Management (BSWM)]. The visual analysis revealed three dominant soil types in the Philippines: acrisols, cambisols, and luvisols. These soils are rich in clay and associated with humid tropical climates. Using the IPCC's decision tree for soil classification, with these dominant soils as inputs, all soil types in the Philippines were assumed to be of high activity clay mineral type (HAC), as shown in Table VI. 5.

Table VI. 5. Soil Type of the Philippines and Per Cent of Total Area Allocation

Soil Name	Acronym	Description	% of Land Area
High Activity Clay Mineral	HAC	Lightly to moderately weathered soils dominated by 2:1 silicate clay minerals (IPCC, 2003)	100
TOTAL			**100**

The land use classification for inventory year 2010 was developed using the Philippine 2010 land use/ land cover map by NAMRIA, and the DENR forest categories and tree types. Table VI. 6 presents the land use classification based on the IPCC 6 land use categories. This classification is expanded in Table VI. 7 to incorporate the Philippine climate type, soil type, land use category, DENR category (on forest), and forest sub-categories.

Table VI. 6. Land Use Allocation in 2010, by IPCC Category

IPCC Category	Total Area, ha	% of Total Area
Forest Land	6,839,718	23.143

Grassland	8,617,106	29.157
Cropland	12,442,300	42.100
Wetlands	857,069	2.900
Settlement	709,300	2.400
Other Land	88,663	0.300
Total	**29,554,156**	**100**

Table VI. 7. Land Use Allocation in 2010, by Climate, Soil, Land Use Category/Subcategory[3]

Climate/ Soil Type	Land Use Category	% of Each Land Use	DENR Category	% of Each Land Use	Land-use Subcategory	% of Each Land Use
TRW HAC	Forest Land	23.143	Public Land	93	Closed Forest	27.30
					Open Forest	62.15
					Mangroves	2.98
					Plantation	0.57
			Alienable & Disposable Land	7	Closed Forest	0.97
					Open Forest	4.37
					Mangrove Forest	1.57
					Plantation	0.10
	Grassland	29.157			Fallow	0.09
					Shrubs	40.49
					Wooded Grassland	42.15
					Grassland	17.27
	Cropland	42.100			Annual Crop	50.00
					Perennial Crop	50.00
	Wetland	2.900			Marshland/Swamps	15.00
					Fish Pond	29.00
					Inland Water	56.00
	Settlement	2.400			Built-up	2.30
	Other Land	0.300			Open/Barren	0.30
TMSD HAC	Forest Land	23.143	Public Land	93	Closed Forest	27.30
					Open Forest	62.15
					Mangroves	2.98
					Plantation	0.57
			Alienable & Disposable Land	7	Closed Forest	0.97
					Open Forest	4.37
					Mangroves	1.57
					Plantation	0.10

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[3] Source: Based on consultations with officials from FMB on 6 May 2015, Quezon City, Philippines.

	Grassland	29.157			Fallow	0.09
					Shrubs	40.49
					Wooded Grassland	42.15
					Grassland	17.27
	Cropland	42.100			Annual Crop	50.00
					Perennial Crop	50.00
	Wetland	2.900			Marshland/Swamps	15.00
					Fish Pond	29.00
					Inland water	56.00
	Settlement	2.400			Built-up	2.3.0
	Other Land	0.300			Open/Barren	0.30
TRMM HAC	Forest Land	23.143	Public Land	93	Closed Forest	27.74
					Open Forest	66.16
					Plantation	0.58
			Alienable & Disposable Land	7	Closed Forest	0.77
					Open Forest	4.69
					Plantation	0.08
	Grassland	29.157			Fallow	0.09
					Shrubs	40.49
					Wooded Grassland	42.15
					Grassland	17.27
	Cropland	42.100			Annual Crop	50.00
					Perennial Crop	50.00
	Wetland	2.900			Marshland/Swamps	15.00
					Fish Pond	29.00
					Inland Water	56.00
	Settlement	2.400			Built-up	2.30
	Other Land	0.300			Open/Barren	0.30

VI.2.1.2 Biomass Gains in Inventory Year 2010

To estimate gains in biomass carbon stocks in forest land, grassland, and cropland, the incremental annual growth in aboveground biomass is needed to determine the accumulation of biomass carbon as trees grow over time. This annual growth in aboveground biomass is a function of the age of trees. Younger trees (i.e., < or = 20 years of age) have higher incremental growth in biomass than older trees (i.e. 20 years of age or older). For this reason, the tree age-class distribution has an important bearing on the gains of carbon in forest land, grassland, and perennial cropland, and consequently on GHG emissions/removals estimates.

Since the data on tree age distribution are not available, Table VI. 8, Table VI. 9, and Table VI. 10 provide the assumptions used to determine the tree age range distribution in the 2010 inventory year for forest land, grassland, and cropland, respectively.

Table VI. 8. Tree Age Distribution in Forest Land in 2010[4]

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[4] Source: Based on consultations with officials from FMB on 6 May 2015, Quezon City, Philippines.

Climate/Soil Type	DENR Category	Land-use Subcategory	% of Land Use Subcategory <=20 yrs	% of Land Use Subcategory >20 yrs
TRW HAC	Public Land	Closed Forest	30	70
		Open Forest	80	20
		Mangrove Forest	50	50
		Plantation	80	20
	Alienable & Disposable Land	Closed Forest	30	70
		Open Forest	50	50
		Mangrove Forest	50	50
		Plantation	80	20
TMSD HAC	Public Land	Closed Forest	30	70
		Open Forest	80	20
		Mangrove Forest	50	50
		Plantation	80	20
	Alienable & Disposable Land	Closed Forest	30	70
		Open Forest	50	50
		Mangrove Forest	50	50
		Plantation	80	20
TRMM HAC	Public Land	Closed Forest	30	70
		Open Forest	80	20
		Plantation	80	20
	Alienable & Disposable Land	Closed Forest	30	70
		Open Forest	50	50
		Plantation	80	20

Table VI. 9. Tree Age Distribution in Wooded Grassland in 2010[5]

Climate/Soil Type	Tree Type	Age Range (% of Climate/Soil Type)	
		<= 5 yrs	>5 and <= 8yrs
TRW	Mixed	50	50

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[5] Source: Based on consultations with officials from FMB on 6 May 2015, Quezon City, Philippines.

TMSD	Mixed	50	50
TRMM	Mixed	50	50

Table VI. 10. Tree Age Distribution in Cropland (Perennial Crops) in 2010[6]

Climate/ Soil Type	Unique Management System	Age Range (% of Climate/Soil Type)			
		<= 5 yrs	>5 and <= 8yrs	>8 and <= 30 yrs	> 30 yrs
TRW, TMSD, TRMM	Coconut Plantation	5	5	30	60
	Coffee Plantation	15	40	40	5
	Mango Plantation	10	20	40	30
	Rubber Plantation	5	20	46	29
	Citrus Plantation	20	40	40	-
	Other Plantation	10	25	45	20

VI.2.1.3 Biomass Losses in Inventory Year 2010

Losses in biomass carbon stock are results from timber harvesting, fuelwood gathering, forest disturbance (e.g., forest fires, wind disturbance, and pest and diseases infestation), and deforestation.

In the Philippines, 2.33 million cubic meters of timber were legally harvested and another 1.25 million cubic meters were illegally harvested from forested lands in 2010 (FMB, 2012; Sibucao, 2014; PSA, 2010). This resulted in a total annual timber harvest of 3.58 million cubic meters in 2010, equivalent to a per capita harvest level of 0.04 cubic meters. Based on consultations with FMB officials, the study assumed that 66% of this timber harvested in 2010 was extracted from forest land and 34% from agroforestry/woody cropland.[7]

On fuelwood gathering, it was estimated that the Philippine annual fuelwood harvest varies from a low-end value of 35.46 million cubic meters (Revised Philippine Forestry Master Plan, 2003) to a high-end estimate of 45 to 62 million cubic meters (unpublished FAO Desk Study by Bensel and Remedio, 2002). For the CBA study, given the high level of uncertainty and lack of empirical data on fuelwood gathering, it was assumed that 50 million cubic meters of fuelwood were harvested in 2010. Further, it was assumed that 90% of this total fuelwood removal was extracted from forest land, and 10% from agroforestry/woody cropland.[8]

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[6] Source: Based on consultations with officials from FMB on 6 May 2015, Quezon City, Philippines.

[7] Based on consultation with FMB officials on July 6-8. 2015 in Clark, Pampanga, Philippines.

[8] B-LEADERS held a consultation session with FMB on August 12, 2015. During that consultation FMB suggested, based on FAOStat data, to reduce the fuelwood assumption from 50 million cubic meters to 12 million cubic

Forest disturbance in 2010 was assumed to be minimal based on experience from the recent past in the Philippines.[9] For the 2010 inventory year, it was assumed that 0.1% of alienable and disposable land, with open forest trees of >20 years of age, was disturbed due to fire. This was estimated to be around 160 hectares of forest area burned in 2010 in the entire country.

To determine the rate of deforestation in 2010, the change in forest area between year 2003 and 2010 was estimated at 1,436,979 hectares and averaged across each year to determine deforestation in 2010. This is equivalent to an annual rate of change of 2.86% or 205,283 hectares of deforested area per year.[10] The study team assumed that 0.24% of the area of public land closed forest with matured trees (>20 years of age), and public land open forest with <20 years and >20 years of age, were deforested in 2010.[11] Further, the Study Team assumed that only 10% of the deforested area was cleared by burning.

VI.2.1.4 Forest Gain-Loss

To estimate the changes in carbon stock in a particular land use category with woody trees, using the Gain-Loss Method, the following emission/stock factors are required:

- Aboveground biomass growth increment of trees (Gw);
- Aboveground biomass stock (Bw);
- Carbon fraction (CF);
- Root/shoot ratio (RS); and
- Biomass fraction left after the disturbances (e.g., fire, wind, pest).

The Study Team assigned the IPCC default values for Gw, shown in Table VI. 11, to different forest types and age ranges. For Bw, the IPCC default values given in Table VI. 12, were used.

Table VI. 11. Aboveground Biomass Growth Increment (Gw) of Trees in Forest in 2010 (dm/ha/yr)

Forest Type	Age Range, Year	Annual Aboveground Biomass Growth Increment (Gw) in Tons of Dry Matter Per Hectare Per Year (dm/ha/yr)

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meters to harmonize the assumption with other analytical studies supported by FMB. Given that this report reflects the methods and assumptions used in the July 2015 version of the CBA which informed the Philippines' INDC, the suggested revision to the fuelwood estimates are not reflected here but may be incorporated in the CBA at a later stage.

[9] Based on 6-8 July 2015 consultation with FMB, Clark, Pampanga, Philippines.

[10] B-LEADERS held a consultation session with FMB on August 12, 2015. During that consultation FMB suggested that the annual change in forest area of 205,283 ha is due to the combined impact of deforestation and forest degradation. On deforestation alone, FMB suggested B-LEADERS use a value of 47,000 hectares in 2010, with 21.85% coming from public land closed forest and 78.15% from plantation in public land (FMB Philippine Forestry Statistics, 2010). Given that this report reflects the methods and assumptions used in the July 2015 version of the CBA which informed the Philippines' INDC, the suggested revision to the deforestation rate is not reflected here but may be incorporated in the CBA at a later stage.

[11] Based on consultation with FMB officials on July 6-8. 2015 in Clark, Pampanga, Philippines.

Closed Forest	<= 20	11
	>20	3
Open Forest	<= 20	11
	>20	3
Mangrove Forest	<= 20	11
	>20	3
Plantation Forest	<= 20	12
	>20	3

Table VI. 12. Aboveground Biomass Stock (Bw) in Forest in 2010 (dm/ha/yr)[12]

Forest Type	Age Range, Year	Aboveground Biomass Stock (Bw) in Tons of Dry Matter Per Hectare Per Year (dm/ha/yr)
Closed Forest	<= 20	280
	>20	348
Open Forest	<= 20	280
	>20	348
Mangrove Forest	<= 20	280
	>20	348
Plantation Forest	<= 20	130
	>20	220

The Study Team assumed that the carbon fraction of dry matter was equal to 0.5 tons C per ton dry matter (IPCC, 2003). The Root:Shoot ratio for all tree types was assumed to be equal to 0.24 (IPCC, 2003 Table 3A.1.8 for Tropical Forest). The Study Team used the IPCC default values for biomass fraction left after fire, windstorms, pests, and diseases, all of which were zero.

VI.2.1.5 Timber Harvesting and Fuelwood Gathering

To account for the losses of biomass carbon due to timber harvesting and fuelwood gathering, the following emission/stock factors are required:

- Wood density (D);

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[12] Source: IPCC, 2003 (Table 3A.1.2 for Naturally Regenerated Forest in Insular Asia with Tropical Wet Climate; and Table 3A.1.3 for Plantation Forest in Asia with Tropical Wet Climate)

- Biomass expansion factor (BEF) for timber and fuelwood;
- Carbon fraction (CF); and
- Biomass fraction left after harvest.

For the wood density of major tree species in the Philippines, a value of 0.42 ton dry matter per cubic meter was assigned based on consultation with DENR-FMB.[13]

The biomass expansion factor for timber and fuelwood was assumed to be equal to 1.5. This is based on the IPCC default value provided in IPCC, 2003 (Table 3A.1.10, for BEF1 in Tropical Forest).

The carbon fraction of dry matter was assumed to be equal to the IPCC default value of 0.5 tons of carbon per ton of dry matter (IPCC, 2003). The Study Team used the IPCC default value for the biomass fraction left after harvest. This value is zero.

VI.2.1.6 Deforestation

To account for the changes in biomass carbon stock due to deforestation, the following emissions/stock factors are required:

- Previous aboveground biomass stock (BWp);
- Root/shoot ratio (RS);
- Carbon fraction (CF); and
- Remaining aboveground biomass stock (BWr).

Deforestation in 2010 was assumed to occur only in closed forest with mature trees (>20 years of age), and open forest with all tree ages. Table VI. 13 shows the assumed BWp values based on DENR-FMB (2014).

The Study Team assumed that the Root:Shoot ratio for all tree types was equal to the IPCC default value of 0.24 (IPCC, 2003 in Table 3A.1.8 for Tropical Forest). The carbon fraction of dry matter was assumed to be equal to 0.5 tons carbon per ton of dry matter (IPCC, 2003).

Based on consultation with DENR-FMB, the remaining aboveground biomass stock was assumed to be equal to 10% of the previous aboveground biomass. [14]

Table VI. 13. Previous Aboveground Biomass Stock (BWp) in Forest in 2010 (dm/ha/yr)[15]

Forest Type	Age Range, Year	Previous Aboveground Biomass Stock (BWp), in tons of dry matter per hectare per year (dm/ha/yr)
Closed Forest	> 20	134
Open Forest	<= 20	75

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[13] Based on consultation with DENR-FMB on July 6-8, 2015 in Clark, Pampanga, Philippines.

[14] Based on consultation with DENR-FMB on July 6-8. 2015 in Clark, Pampanga, Philippines.

[15] Source: DENR-FMB Forest Resource Accounting and Valuation Study (2014).

	>20	75

VI.2.1.7 Biomass Burning

To calculate GHG emissions from biomass burning, the following emissions/stock factors are required:

- Mass of fuel available for burning;
- Combustion efficiency of biomass;
- Carbon fraction;
- Nitrogen/carbon (N/C) ratio; and
- Emission ratios for methane (CH_4), carbon monoxide (CO), nitrous oxide (N_2O), and oxides of nitrogen (NOx).

The mass of fuel for combustion, which includes aboveground biomass, ground litter and dead wood, was assumed to be available only for closed forest and open forest at the rate of 134 and 75 tons of dry matter per hectare, respectively (DENR-FMB, 2014; IPCC Default BEF and FRA data).

The combustion efficiency was set at 20%, based on the IPCC default value for tropical moist primary forest with broadcast burning[16] and drying time of < 6 months (IPCC, 2003 in Table 3A.1.14). The carbon fraction of dry matter was assumed to be equal to 0.5 tons of carbon per ton of dry matter (IPCC, 2003).

The IPCC default value of 0.01 ton N/ton C was assigned for the N/C ratio. Also, the following IPCC default emission ratios for CH_4, CO, N_2O, and NOx were assigned, respectively:

- 0.012 ton CH_4-C/ton C;
- 0.06 ton CO-C/ton C;
- 0.007 ton N_2O-N/ton N; and

0.121 ton NOx-N/ton N (IPCC, 2003 in Table 3A.1.15, p. 3.185).

VI.2.2 Results

This section summarizes the results for the 2010 base year forestry emissions profile and includes graphical presentation of the results.

VI.2.2.1 Biomass C Stocks

Table VI. 14 shows the estimated gains and losses in biomass carbon stocks for the base year 2010. The gains in biomass, brought about by incremental growth of trees, exceeded the losses in biomass due to timber harvesting, fuelwood gathering, and other disturbances (e.g. fire). This resulted in a total net gain in biomass carbon stock of -83,308.29 $GgCO_2e$ or -83.308 million metric tons of CO_2e.

Table VI. 14. Gains and Losses in Biomass Carbon Stocks in 2010 (Gg C)

Subsource	Area (ha)	Gain in Biomass C Stocks	Loss of Biomass C Stocks	Change in Biomass C	Net Biomass Carbon Stock

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[16] Broadcast burning is the controlled application of fire to fuels.

		(Gg C)	(Gg C)	Stocks (Gg C)	(Gg)
Forest Gain Loss	6,838,832	34,268.57	-14,945.73	19,322.84	-70,850.40
Silvipasture	3,632,484	14,135.53	-1,462.58	12,672.95	-46,467.50
Agroforestry/ Perennial Cropland	6,221,150	3,923.65	-1,958.42	1,965.23	-7,205.84
Deforestation	212,793	0	-11,240.58	-11,240.58	41,215.45
Total	16,905,259	52,327.74	-29,607.3	22,720.44	-83,308.29

VI.2.2.2 GHG Emissions from Biomass Burning

Forest fire occurrence in the Philippines is considered to be minimal, being in the tropics with plenty of annual precipitation. Further, controlled burning of biomass is uncommonly practiced in agroforestry and perennial cropland.

As shown in Table VI. 15, the estimated GHG emissions from biomass burning in 2010 is only 74.976 $GgCO_2e$. This amount is very small as compared to the estimated total carbon sequestered by woody trees in the same year, as provided in Table VI. 14.

Table VI. 15. GHG Emissions from Biomass Burning in Forest Land in 2010

Subsource	CH_4 Emissions (Gg CH_4)	CO Emissions (Gg CO)	N_2O Emissions (Gg N_2O)	NOx Emissions (Gg NOx)	Net Emissions from Biomass Burning in CO_2 equivalents (Gg CO_2e)	Net Emissions from Biomass Burning in CO_2 equivalents ($MtCO_2e$)
Forest Gain-Loss	0.018	0.16	0.000	0.005	0.422	0.000422
Deforestation	3.223	28.202	0.022	0.801	74.554	0.074554
Total	**3.241**	**28.362**	**0.022**	**0.806**	**74.976**	**0.074976**
Note: 1 $MtCO_2e$ = 1,000 $GgCO_2e$						

VI.2.2.3 Total Emissions/Removals from Forestry in 2010

Overall, with more gains in biomass carbon stocks in forest land, grassland (silvipasture), and cropland (agroforestry and perennial crops) than GHG emissions from biomass burning, as shown in Figure VI. 2, the Philippines remains a carbon sink in the inventory year 2010.

The total net carbon stock is estimated at **83,233.31 $GgCO_2e$ or 83.233 $MtCO_2e$,** as shown in Table VI. 16.

Figure VI. 2. Base Year 2010 GHG Emissions and Removals in LULUCF Sector (MtCO$_2$e)[17]

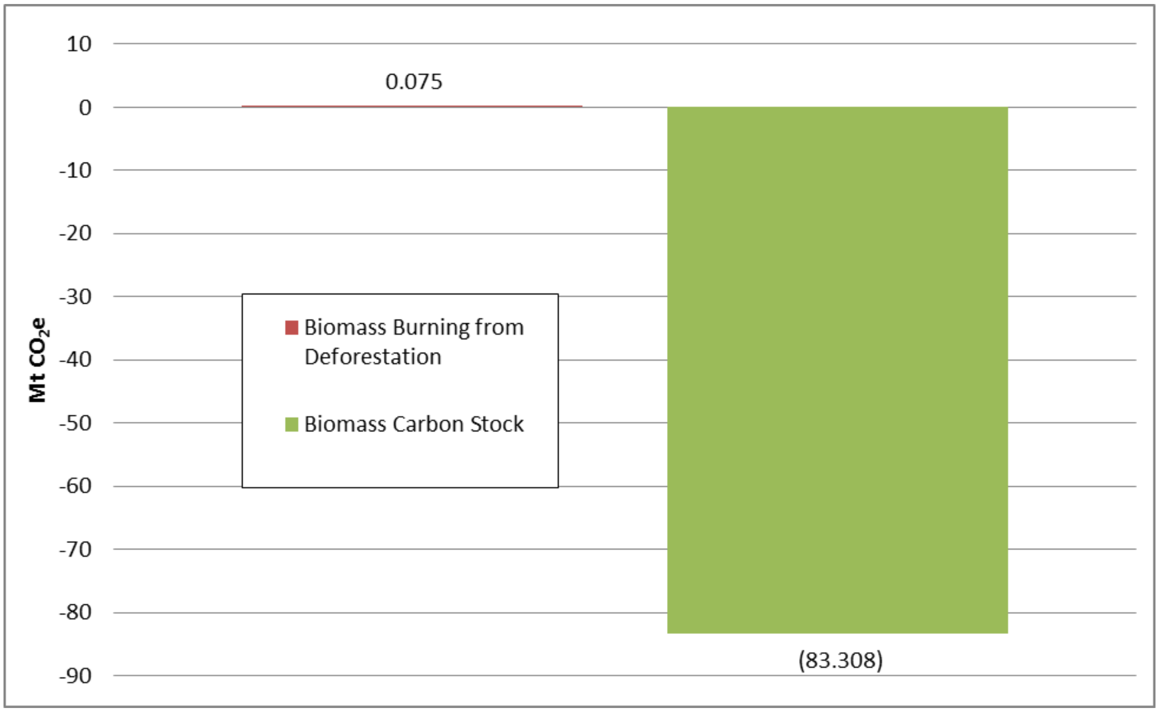

Table VI. 16. Net Carbon Stock in 2010

Category	GgCO$_2$e	MtCO$_2$e
Changes in Biomass Carbon Stocks	-83,308.29	-83.308
Emissions from Biomass Burning (Deforestation)	74.98	0.075
Emissions from Biomass Burning (Forest Gain-Loss)	0.422	0.0004
Net Carbon Stock in 2010	**-83,233.31**	**-83.233**
Note: 1 MtCO$_2$e = 1,000 GgCO$_2$e		

VI.3 BASELINE PROJECTION TO 2050

This subsection describes the estimated annual GHG emissions for 2010 to 2050 for the forestry sector, including the data and key assumptions used for developing this baseline. The baseline describes projected GHG emissions under "business-as-usual" economic activity. It also serves as a standard against which the impacts of current and planned mitigation actions can be measured.

The aims of the CBA are to (i) quantify GHG emissions and removals under an established Baseline Scenario; (ii) assess the impacts of potential mitigation options based on the projected scenario; and (iii)

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[17] Emissions from biomass burning (forest gains-losses) are omitted from this figure due to their relatively small magnitude.

determine the costs and benefits of existing and proposed mitigation actions, regulations, and policies in the Philippines.

In the study, the Baseline Scenario excluded some existing policies that are already being implemented and are likely to contribute to GHG mitigation. Instead, these policies and measures are analyzed as 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 emissions. Table VI. 17 provides a list of current policies related to the LULUCF sector that were not included in the 2010-2050 Baseline Scenario, but were treated as mitigation options in the context of the CBA.

Table VI. 17. Policies and Regulations Not Reflected in the Baseline Scenario

Sector	Policy/Regulation
Forestry	**Executive Order 26 of 2011:** Established the National Greening Program. **Executive Order 23 of 2011:** The moratorium on the cutting and harvesting of timber in the natural and residual forests and creation of the Anti-Illegal Logging Task Force.

VI.3.1 Methods and Assumptions

VI.3.1.1 Land Use under the Baseline Scenario (2010 - 2050)

The baseline projection for land use or land cover data was developed using historical trends from NAMRIA's 2003 and 2010 land cover data and projected these forward to 2050.

For cropland area, the comparison of the two land cover data sets revealed that the total area of cropland has increased from 11.68 million hectares in 2003 to 12.44 million hectares in 2010. This is equivalent to a 6.52% increase in cropland area, or an annual increase of 0.81%. This was assumed to occur mostly in area planted by perennial crops. Taking this into account, alongside the increasing population and demand for food, it was projected that cropland area will increase by 0.81% annually from 2010 to 2020; by 0.2025% annually from 2021 to 2030; then remain at that level until 2050. Further, it was assumed that the increase in cropland area is due to conversion of wooded grassland to cropland.

For the area occupied by forest land, taking into account that some forest-related initiatives (other than those mentioned in Table VI. 17) will lead to reforestation, it was projected that forest land area will increase from 6,839,718 ha in 2010 to 7,421,146 ha in 2050. This increase will come mostly from conversion of grassland into forest land.

Table VI. 18 shows the projected land use allocation under the Baseline Scenario, using the six IPCC land use categories. Table VI. 19 further categorized the forest land area according to climate and soil types, and DENR category and forest subcategory. As described by Table VI. 19, the Baseline Scenario assumes that the area of closed forest will decrease over time while the areas of open forest and mangrove forest will increase as a result of some planting programs/initiatives.

Table VI. 18. Land Use Allocation under Baseline Scenario

Land use	Total Hectares (ha) in 2010	%	Total Hectares (ha) in 2015	%	Total Hectares (ha) in 2020	%	Total Hectares (ha) in 2030	%	Total Hectares (ha) in 2050	%
Cropland	12,442,300	42.10	12,946,213	43.805	13,450,126	45.510	13,994,856	47.353	13,994,856	47.353
Forest Land	6,839,718	23.14	7,175,880	24.280	7,473,920	25.289	7,510,668	25.413	7,421,146	25.110
Grassland	8,617,106	29.16	7,777,031	26.315	6,975,078	23.601	6,393,600	21.634	6,483,122	21.936
Other Lands	88,663	0.30	88,663	0.300	88,663	0.300	88,663	0.300	88,663	0.300
Settlements	709,300	2.40	709,300	2.400	709,300	2.400	709,300	2.400	709,300	2.400
Wetlands	857,069	2.90	857,069	2.900	857,069	2.900	857,069	2.900	857,069	2.900
TOTAL	**29,554,156**	**100**	**29,554,156**	**100**	**29,554,156**	**100**	**29,554,156**	**100**	**29,554,156**	**100**

Table VI. 19. Forest Land Subcategories under Baseline Scenario

Climate /Soil Type	DENR Category	Land-use Subcategory	% in 2010	% in 2015	% in 2020	% in 2030	% in 2050
TRW HAC	Public Land	Closed Forest	27.30	21.89	17.98	15.27	14.37
		Open Forest	62.15	68.68	73.15	76.21	77.23
		Mangrove	2.98	3.55	4.00	4.28	4.35
		Plantation	0.57	0.28	0.17	0.14	0.15
	Alienable & Disposable land	Closed Forest	0.97	0.81	0.70	0.60	0.59
		Open Forest	4.37	3.09	2.28	1.73	1.53
		Mangrove	1.57	1.65	1.70	1.74	1.75
		Plantation	0.10	0.05	0.03	0.02	0.02
TMSD HAC	Public Land	Closed Forest	27.30	21.89	17.98	15.27	14.37
		Open Forest	62.15	68.68	73.15	76.21	77.23
		Mangrove	2.98	3.55	4.00	4.28	4.35
		Plantation	0.57	0.28	0.17	0.14	0.15
	Alienable & Disposable land	Closed Forest	0.97	0.81	0.70	0.60	0.59
		Open Forest	4.37	3.09	2.28	1.73	1.53
		Mangrove	1.57	1.65	1.70	1.74	1.75
		Plantation	0.10	0.05	0.03	0.02	0.02
TRMM HAC	Public Land	Closed Forest	27.74	21.89	17.98	15.27	14.37
		Open Forest	66.16	72.23	77.15	80.49	81.58
		Plantation	0.58	0.28	0.17	0.14	0.15

	Alienable & Disposable land	Closed Forest	0.77	0.81	0.70	0.60	0.59
		Open Forest	4.69	4.74	3.97	3.47	3.28
		Plantation	0.08	0.05	0.03	0.02	0.02

VI.3.1.2 Biomass Gains under Baseline Scenario (2010 – 2050)

Tree age range or distribution is an important set of data to be developed in relation to assigning values for annual incremental growth of trees, and in estimating the projected gains in biomass carbon stocks in forest land, grassland, and cropland.

In the absence of a comprehensive national forest inventory, projecting tree age distribution fora particular land use type is difficult. In the Philippines, there is no forest inventory or other empirical data available for projection of tree age distribution under the Baseline Scenario. As an alternative, forest tree age distribution was developed[18], as shown in Table VI. 20.

VI.3.1.3 Biomass Losses under Baseline Scenario (2010 – 2050)

As mentioned above, losses in biomass carbon stock are brought about by timber harvesting, fuelwood gathering, forest disturbance (e.g., forest fires, wind disturbance, and pest and disease infestation), and deforestation. The Study Team projected biomass losses from these activities to assess their impacts on carbon stocks under the Baseline Scenario.

For timber harvesting, based on the assumptions discussed In section VI.2 Base Year GHG Emissions for the base year 2010, the Study Team assumed that per capita timber consumption will remain steady over the years at 0.0388 cubic meters. With the expected increase in population, it was projected that timber consumption will reach a level of 5.16 million cubic meters in 2050, as shown in Table VI. 21. Further, the Study Team assumed that 66% of the total harvested timber will be extracted from forest land, and 34% from agroforestry/woody cropland.[19]

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[18] Based on 6 May 2015 Consultation with FMB officials.

[19] Based on 6-8 July 2015 Consultation with FMB in Clark, Pampanga.

Table VI. 20. Projected Forest Tree Age Range Distribution under Baseline Scenario (% by Land-use Subcategory)

Climate/ Soil Type	DENR Category	Land-use Subcategory	2010		2015		2020		2030		2050	
			<=20 yr (%)	>20 yr (%)	<=20 yr (%)	>20 yr (%)	<=20 yr (%)	>20 yr (%)	<=20 yr (%)	>20 yr (%)	<=20 yr (%)	>20 yr (%)
TRW HAC	Public Land	Closed Forest	30	70	50	50	45	55	40	60	30	70
		Open Forest	80	20	80	20	75	25	70	30	50	50
		Mangrove	50	50	50	50	45	55	40	60	30	70
		Plantation	80	20	80	20	75	25	70	30	50	50
	Alienable & Disposable land	Closed Forest	30	70	50	50	45	55	40	60	30	70
		Open Forest	50	50	50	50	45	55	40	60	30	70
		Mangrove Forest	50	50	50	50	45	55	40	60	30	70
		Plantation	80	20	80	20	75	25	70	30	50	50
TMSD HAC	Public Land	Closed Forest	30	70	50	50	45	55	40	60	30	70
		Open Forest	80	20	80	20	75	25	70	30	50	50
		Mangrove	50	50	50	50	45	55	40	60	30	70
		Plantation	80	20	80	20	75	25	70	30	50	50
	Alienable & Disposable land	Closed Forest	30	70	50	50	45	55	40	60	30	70
		Open Forest	50	50	50	50	45	55	40	60	30	70
		Mangrove Forest	50	50	50	50	45	55	40	60	30	70
		Plantation	80	20	80	20	75	25	70	30	50	50
TRMM HAC	Public Land	Closed Forest	30	70	50	50	45	55	40	60	30	70
		Open Forest	80	20	80	20	75	25	70	30	50	50
		Plantation	80	20	80	20	75	25	70	30	50	50
	Alienable & Disposable land	Closed Forest	30	70	50	50	45	55	40	60	30	70
		Open Forest	50	50	50	50	45	55	40	60	30	70
		Plantation	80	20	80	20	75	25	70	30	50	50

Table VI. 21. Projected Timber Harvest under Baseline Scenario (m³)[20]

	2010	2015	2020	2030	2040	2045	2050
Population	92,337,852	101,562,300	109,947,900	125,337,500	137,532,200	142,095,100	147,482,277
Per Capita Timber Harvest (m³)	0.0388	0.0388	0.0388	0.0388	0.0388	0.0388	0.0388
Timber Harvest (m³)	**3,580,000**	**3,554,681**	**3,848,177**	**4,386,813**	**4,813,627**	**4,973,329**	**5,161,880**

Table VI. 22 shows the projected fuelwood gathering under the Baseline Scenario, based on two rates of per capita fuelwood harvest: 0.5415 cubic meters (from 2010 to 2015); and 0.4455 cubic meters (from 2020 to 2050). With the increase in population, the Study Team projected that total fuelwood harvest in 2050 will reach 56.34 million cubic meters. About 90% of the total extracted fuelwood will be gathered from forest land, and 10% from agroforestry/woody cropland.[21]

Forest disturbance was assumed to be very minimal under the Baseline Scenario, with 0.1% of A&D land open forest areas (with trees >20 years), to be disturbed annually due to fire, until 2050.

Table VI. 22. Projected Fuelwood Harvest under Baseline Scenario (m³)[22]

	2010	2015	2020	2030	2040	2045	2050
Population	92,337,852	101,562,300	109,947,900	125,337,500	137,532,200	142,095,100	147,482,277
Fuelwood harvest (m³)	0.5415	0.5415	0.4455	0.4455	0.4455	0.4455	0.4455
Total fuelwood (m³)	**50,000,000**	**46,403,335**	**46,052,355**	**53,459,045**	**51,172,960**	**52,344,127**	**56,340,781**

On deforestation, following the assumptions used in Section VI.2 Base Year GHG Emissions the Study Team assumed that the rate of deforestation in public land closed and open forests, under Baseline Scenario, will decline over the years until 2050, as shown in Table VI. 23, with only 10% of deforested or cleared area that will be exposed to burning.

Table VI. 23. Projected Deforestation Rate Under Baseline Scenario

	2010	2020	2030	2050
Annual rate of change, %	2.86	2.08	1.29	0.50
% of Closed and Open Forest areas	0.24	0.17	0.11	0.04

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[20] Sources: Sibucao, 2014; Sibucao 2013; and FMB 2012

[21] Based on 6-8 July 2015 Consultation with FMB in Clark, Pampanga.

[22] Sources: Bensel and Remedios, 2002; Sibucao et al., 2014

VI.3.1.4 Emission/Stock Factors

All emission/stock factors used for the 2010 base year were also applied in the Baseline Scenario. For the calculation of biomass carbon stock changes, these included emission/stock factors for Gw; Bw; CF; RS; biomass fraction left after the disturbances (e.g. fire, wind, pest); D; BEF for timber and fuelwood; CF; and biomass fraction left after harvest. For biomass burning, these included emission factors for the mass of fuel; combustion efficiency of biomass; carbon fraction; nitrogen/carbon (N/C) ratio; and emission ratios for CH_4, CO, N_2O, and NOx.

VI.3.1.5 Summary of Assumptions under the Baseline Scenario

Table VI. 24 summarizes the key assumptions under the Baseline Scenario that could influence the changes in carbon stock in biomass, as well as the GHG emissions from biomass burning.

Table VI. 24. Key Assumptions under the Baseline Scenario

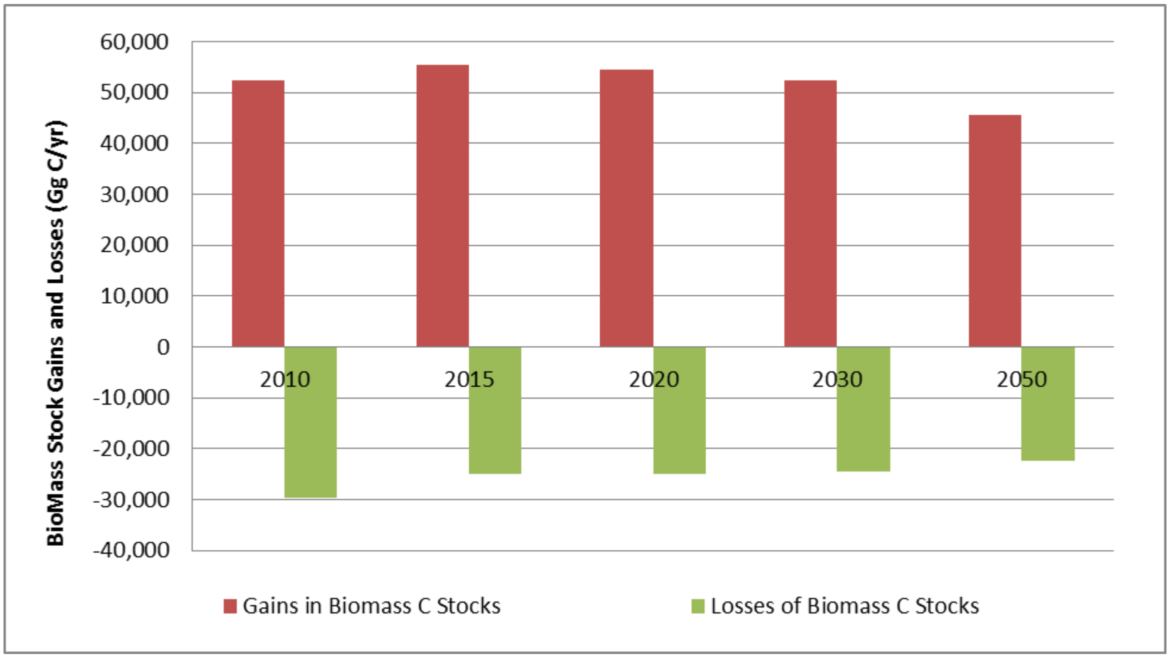
Associated with Gains in Carbon	Associated with Losses in Carbon
1) Closed forest area gradually decreases from 1.63 million ha in 2015 to 1.11 million ha in 2050 2) Open forest area gradually increases from 5.15 million ha in 2015 to 5.85 million ha in 2030, then starts to decrease gradually until it reaches 5.84 million ha in 2050 3) Mangrove area gradually increases from 373 thousand ha in 2015 to 454 thousand ha in 2050 4) Plantation area gradually decreases from 23.31 thousand ha in 2015 to 12.86 thousand in 2050	On Timber Harvest: Assumed to increase from 3.58 million cubic meters in 2010 to 5.16 million cubic meters in 2050 On Fuelwood Gathering: Assumed to increase from 50 million cubic meters in 2010 to 56.34 million cubic meters in 2050 On Deforestation Rate: Assumed to decrease gradually from 2.86% in 2015 to 0.5% in 2050 On Disturbance Rate: Assumed to be minimal at 0.1% of A&D land open forest area (with trees >20 years of age), until 2050.

VI.3.2 Results

VI.3.2.1 Biomass C Stocks under the Baseline Scenario

As shown in Figure VI. 3, the projected gains in biomass carbon exceed the losses in biomass carbon over the study years. Gains in biomass carbon will be mainly brought about by the growth of trees in forest land and grassland, with some gains in biomass carbon in agroforestry and perennial cropland. Losses in biomass carbon will be mainly due to timber harvesting, fuelwood gathering, and deforestation.

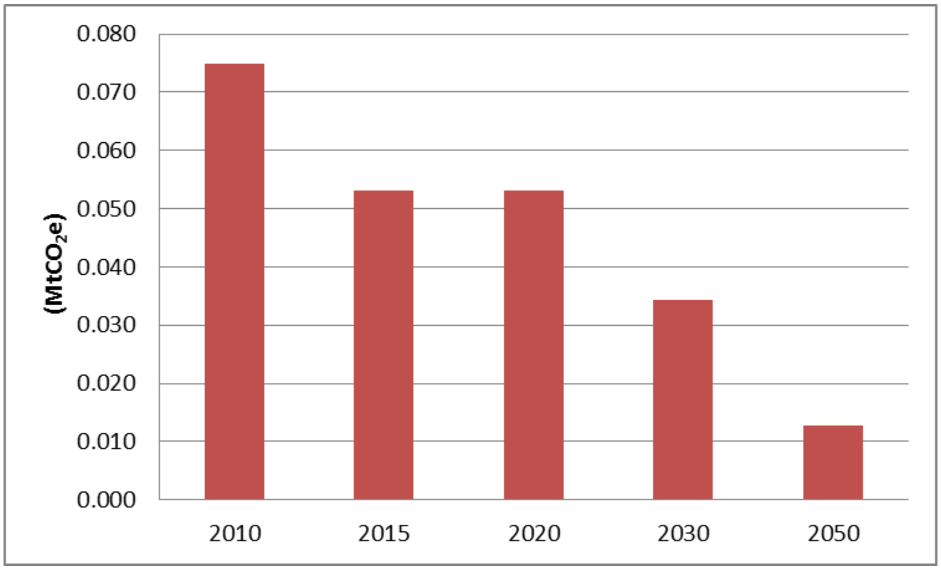
Figure VI. 3. Gains and Losses in Biomass C Stock under the Baseline Scenario (Gg C)



VI.3.2.2 GHG Emissions from Biomass Burning under the Baseline Scenario

GHG emissions from biomass burning under the Baseline Scenario were estimated to be minimal, and were projected to decrease over the years as shown in Figure VI. 4 from 0.0749 $MtCO_2e$ in 2010 to 0.0127 $MtCO_2e$ in 2050.

Figure VI. 4. GHG Emissions from Biomass Burning under the Baseline Scenario ($MtCO_2e$)



VI.3.2.3 Total Emissions/Removals from LULUCF Sector under the Baseline Scenario

Overall, under the Baseline Scenario, the CBA projects that biomass carbon stock will increase over the years, as shown in Figure VI. 5, and the sector will remain a carbon sink until 2050.

The net carbon stock is estimated to peak in 2015 at 111.445 $MtCO_2e$, then gradually decreases to a level of 85.444 $MtCO_2e$ in 2050, as shown in Table VI. 25.

Figure VI. 5. GHG Emissions and Removals under the Baseline Scenario ($MtCO_2e$) [23]

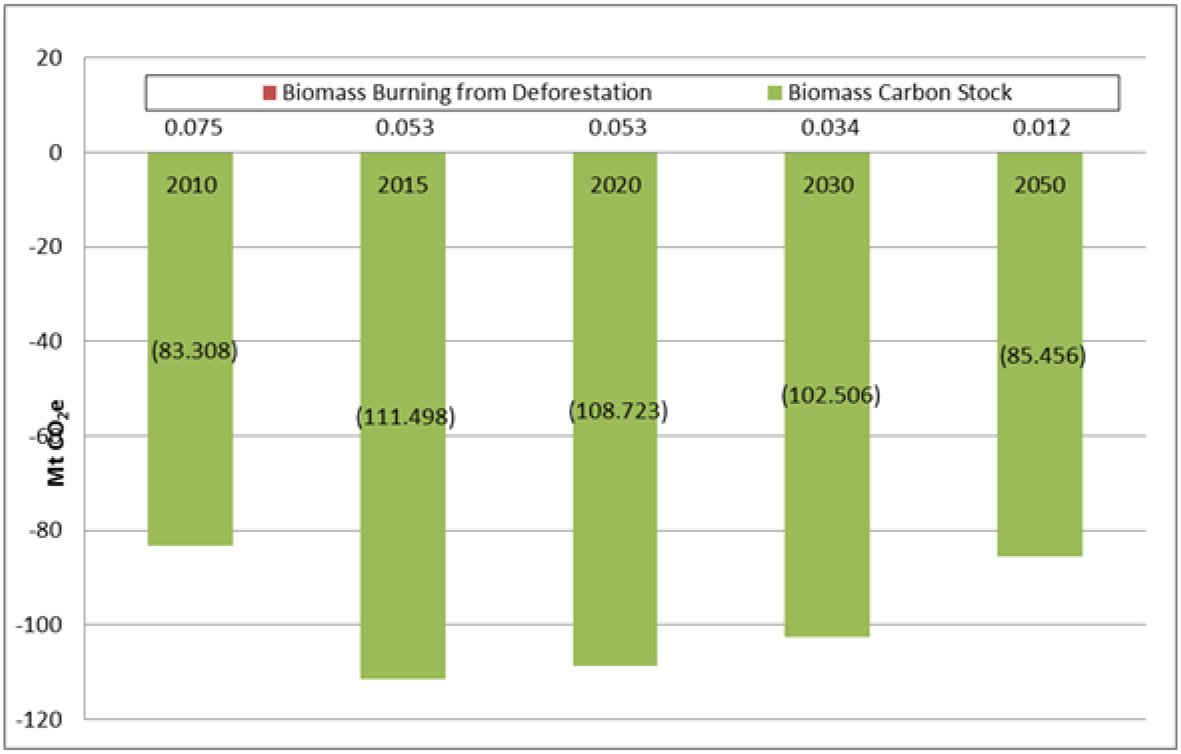


Table VI. 25. Projected Emissions/Removals under the Baseline Scenario ($MtCO_2e$)

Category	2010	2015	2020	2030	2050
Changes in biomass carbon stock ($MtCO_2e$)	-83.308	-111.498	-108.723	-102.506	-85.456
Emissions from biomass burning - Deforestation ($MtCO_2e$)	0.075	0.053	0.053	0.034	0.012
Emissions from biomass burning - Forest Gain-Loss ($MtCO_2e$)	0.000422	0.000347	0.000303	0.000269	0.000280
Net Carbon Stock ($MtCO_2e$)	**-83.233**	**-111.445**	**-108.670**	**-102.472**	**-85.444**

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[23] Emissions from biomass burning (forest gains-losses) are omitted from this figure due to their relatively small magnitude.

VI.4 MITIGATION COST-BENEFIT ANALYSIS

Mitigation options for the LULUCF sector were developed in consultation with FMB, NCIP, and NAMRIA in February 2015. Mitigation options, and the associated assumptions, were confirmed during the stakeholders consultation workshops in April 2015. Additional discussions were also held with FMB to incorporate the targets of the Climate-Resilient Master Plan for Forestry Development for 2015-2028 into the mitigation options. The key to the development of mitigation options for the forest sector was their applicability to the Philippines' national context including alignment with national policies, regulations, and development plans addressing forests.

Table VI. 26 describes the proposed mitigation options for the LULUCF sector. The mitigation options assume that the government will take more intentional actions to plan, implement, and initiate programs to reduce carbon emissions. The major policies and programs addressing the forestry sector include the following:

- Executive Order 26 (2011) – established the National Greening Program;
- Executive Order 23 (2011) – established a moratorium on logging in natural and residual forests and strengthened forest law enforcement;
- EO 263 (1995) – Adoption of community-based forest management as the national strategy for social justice and sustainable forestry;
- EO 318 (2004) – Promotes sustainable forest management in the Philippines;
- National Integrated Protected Area Systems (NIPAS law) in 1992 for those in protected areas;
- Indigenous People's Right Act (IPRA Law) in 1997 for those in ancestral domains;
- Executive Order 881 (2010) – assigned CCC to coordinate the Philippines strategy for REDD+, and designated DENR as the operational implementer of a Philippine National REDD+ Strategy (PNRPS);
- Climate-Resilient Master Plan for Forestry Development (2013);
- Revised Forestry Code (PD 705);
- Forestlands Management Project (FMP) and Integrated Environment and Natural Resource Management Project (INREMP); and
- Other related forestry regulations and programs (e.g., USAID-supported B+WISER Project)

The proposed mitigation options combine subsets of several of these existing and planned programs, with common activities and goals, into two larger mitigation scenarios as described in Table VI. 26.

Table VI. 26. Mitigation Options in the Forestry Sector

CBA Mitigation Option	Description
Mitigation Option 1 Forest Protection: (*Improved forest protection, sustainable management, and enforcement to reduce loss of remaining natural closed and open forests and restored protection areas under EO 23, NIPAS Law, EO 318, IPRA Law, and PD 705*)	Reducing the loss of closed forest and open forest will avoid emissions of CO_2 and non-CO_2 gases from timber harvesting, fuelwood gathering, forest disturbance (e.g., fire), and deforestation. This mitigation option assumes that improved forest protection, management, and enforcement activities will be implemented by the following organizations, agencies or governmental bodies: • Tenure holders in forestlands; • DENR in NIPAs and in untenured forests; • Holders of CADC/CADT in CADT/CADC areas; • Civil and military reservation holders in public forestlands (e.g., Energy Development Corporation for various reservations); and • Local government units in communal forests and watersheds, and those under co-management areas. This mitigation option intersects with the energy sector, due to its impact on the availability of biomass for heating, cooking, and electricity generation. This mitigation option assumes that improved forest protection will *reduce* the supply of biomass for fuel in the energy sector which in turn means that demand for other fuels will increase to meet existing energy needs.
Mitigation Option 2 Restoration and Reforestation: *(Forest restoration, reforestation, afforestation/tree plantations, agroforestry development, and mangrove rehabilitation to restore degraded forests)*	Restoring degraded forests and establishing tree plantations in wooded grasslands, brushlands, and wetlands will increase carbon sequestration in biomass and soils. This mitigation option assumes implementation of specific programs to achieve restoration and reforestation of degraded forests, grassland, and wetlands, including: • The NGP in tenured and non-tenured forests, NIPAs, and some ancestral domains; • River basin/watershed management programs; and • Mangrove rehabilitation program administered by DENR with extension assistance from DA-Bureau of Fisheries and Aquatic Resources. This mitigation option intersects with the energy sector due to its impact on the availability of biomass for heating, cooking, and electricity generation. This mitigation option assumes that forest restoration and reforestation will *increase* the supply of biomass for use in the energy sector thereby reducing demand for other fuels.

VI.4.1 Methods

VI.4.1.1 GHG Mitigation Methods and Assumptions

In order to analyze the GHG mitigation benefits of the two forestry mitigation options, the Study Team developed estimates of changes in the allocations of different types of land cover over time. The allocation translated future potential impacts of policies and programs on forest land that will be covered or occupied by closed forest, open forest, mangrove forest, and plantation land cover until the year 2050. The ALU Software organized the activity data, emission/stock factors, and other assumptions related to changes in the allocation of land cover types, and then calculated associated changes in carbon stocks and GHG emissions from the LULUCF sector.

VI.4.1.2 Land Use Allocation

Table VI. 27 describes the land use allocation under the Forest Protection mitigation option. Similar to the Baseline Scenario, this option assumed a 0.81% annual increase in cropland area from 2010 to 2020, a smaller increase until 2030; cropland then remains at that level until 2050. While the Baseline Scenario assumed a gradual increase in forest land area from 6.84 million ha in 2010 to 7.42 million ha in 2050, under the Forest Protection option there is a more significant increase in forest land area to 7.57 million ha in 2050. This is equal to a 1.97% increase of forest land compared to the Baseline Scenario in 2050. The increase in cropland and forest land areas under this option is assumed to result from conversion of wooded grassland.

The Forest Restoration and Reforestation mitigation option, in contrast, results in a much higher increase of forest land area over the years relative to the Forest Protection option. As shown in Table VI. 28, under the Forest Restoration and Reforestation mitigation option there is an increase of 14.27% in forest land relative to the Baseline Scenario in 2050, which will generally result from the conversion of wooded grassland to forest land. Further, the land use allocation for this option assumed a 5-year survival rate for NGP, INREMP, and other planting programs as listed below:

- NGP plantings (1,571,745 million ha in total): planting to be completed by 2016; 50% five-year survival rate for plantings;
- ADB INREMP (329,780 ha in total): all open forest planted by 2020, all closed forest planted by 2030: 50% five-year survival rate;
- JICA FMP (73,100 ha in total): 70% planted by 2020; 100% planted by 2030; 50% five-year survival rate; and
- Other community-based planting programs (150,000 ha in total): 20% by 2015; 100% planted by 2020: 50% five-year survival rate.

Table VI. 27. Land Use Allocation for Forest Protection mitigation option M1 Scenario

Land use	Total Hectares (ha) in 2010	%	Total Hectares (ha) in 2015	%	Total Hectares (ha) in 2020	%	Total Hectares (ha) in 2030	%	Total Hectares (ha) in 2050	%
Cropland	12,442,300	42.100	12,946,213	43.805	13,450,126	45.510	13,994,856	47.353	13,994,856	47.353
Forest Land	6,839,718	23.143	7,175,880	24.280	7,503,802	25.390	7,673,861	25.965	7,567,443	25.605
Grassland	8,617,106	29.157	7,777,031	26.315	6,945,196	23.500	6,230,407	21.081	6,336,825	21.441
Other Lands	88,663	0.300	88,663	0.300	88,663	0.300	88,663	0.300	88,663	0.300
Settlements	709,300	2.400	709,300	2.400	709,300	2.400	709,300	2.400	709,300	2.400
Wetlands	857,069	2.900	857,069	2.900	857,069	2.900	857,069	2.900	857,069	2.900
TOTAL	**29,554,156**	**100**	**29,554,156**	**100**	**29,554,156**	**100**	**29,554,156**	**100**	**29,554,156**	**100**

Table VI. 28. Land Use Allocation for Forest Restoration and Reforestation mitigation option Scenario

Land use	Total Hectares (ha) in 2010	%	Total Hectares (ha) in 2015	%	Total Hectares (ha) in 2020	%	Total Hectares (ha) in 2030	%	Total Hectares (ha) in 2050	%
Cropland	12,442,300	42.100	12,946,213	43.805	13,450,126	45.510	13,994,856	47.353	13,994,856	47.353
Forest Land	6,839,718	23.143	7,693,391	26.032	8,532,774	28.872	8,569,522	28.996	8,480,001	28.693
Grassland	8,617,106	29.157	7,259,520	24.563	5,916,224	20.018	5,334,746	18.051	5,424,267	18.354
Other Lands	88,663	0.300	88,663	0.300	88,663	0.300	88,663	0.300	88,663	0.300
Settlements	709,300	2.400	709,300	2.400	709,300	2.400	709,300	2.400	709,300	2.400
Wetlands	857,069	2.900	857,069	2.900	857,069	2.900	857,069	2.900	857,069	2.900
TOTAL	**29,554,156**	**100**	**29,554,156**	**100**	**29,554,156**	**100**	**29,554,156**	**100**	**29,554,156**	**100**

These two sets of land use allocation assumptions were further developed, as presented in Table VI. 29 and Table VI. 30, to take into account the respective impacts of ongoing and anticipated forest protection and forest restoration and reforestation programs on the allocation for land use subcategories or forest types. It is important to note that to accommodate the ALU modeling framework, the two mitigation scenarios and their corresponding land allocation assumptions were analyzed as separate and distinct options within the analysis.

Under the Forest Protection mitigation option Scenario, closed forest area was projected to decrease over time, even with rigorous forest protection activities, to a level of 19.98% of the total forest area in 2050. This represents a higher percentage for area under closed forest than under the Baseline Scenario level of 14.37% in 2050, reflecting the influence of forest protection. In contrast, the open forest land area was projected to slowly increase to a level of 72.35% in 2030 (specifically, forest in public land under TRW-HAC and TMSD-HAC climate/soil types), then gradually decrease to a level of 71.31% in 2050. Compared to the Baseline Scenario, this is 5.92% less in open forest area in 2050.

Areas in mangrove forest are projected to slowly increase over time under the Forest Protection mitigation option until reaching a level of 4.67% in 2050 (for mangrove forest in public land, TRW-HAC and TMSD-HAC climate/soil types). This area is slightly higher than the Baseline Scenario, which has mangrove area at 4.35% in 2050. In contrast, in this scenario, the area under plantation is projected to decrease to a level of 0.15% in 2050, which is the same assumption used for the Baseline Scenario.

Because the Forest Restoration and Reforestation mitigation option scenario does not include forest protection, the closed forest area is projected to decrease over time to a level of 12.57% of the total forest area in 2050. In this case, the projected closed forest area is slightly lower than the Baseline Scenario level of 14.37% in 2050. The area under open forest area is also projected to slowly increase over the years to a level of 67.52% in 2050 (for forest in public land under TRW-HAC and TMSD-HAC climate/soil types). Compared to the Baseline Scenario, this is 9.71% less in open forest area in 2050.

Areas in mangrove forest are projected to slowly increase over time until it reaches a level of 4.07% in 2050 (for mangrove forest in public land, TRW-HAC and TMSD-HAC climate/soil types). This is lower than the Baseline Scenario level of 4.35%. In comparison to the Forest Protection mitigation option Scenario, the plantation forest area under the Forest Restoration and Reforestation mitigation option scenario is projected to increase to a level of 12.34% of total forest area in 2050 (for plantation forest in public land, TRW-HAC and TMSD-HAC climate/soil types).

Table VI. 29. Projected Forest Land Subcategories under the M1 Scenario

Climate/Soil Type	DENR Category	Land-use Subcategory	% in 2010	% in 2015	% in 2020	% in 2030	% in 2050
TRW HAC	Public Land	Closed Forest	27.30	21.89	18.21	19.03	19.98
		Open Forest	62.15	68.68	72.84	72.35	71.31
		Mangrove	2.98	3.55	4.08	4.38	4.67
		Plantation	0.57	0.28	0.17	0.14	0.15
	Alienable & Disposable land	Closed Forest	0.97	0.81	0.70	0.60	0.59
		Open Forest	4.37	3.09	2.28	1.73	1.53
		Mangrove	1.57	1.65	1.70	1.74	1.75
		Plantation	0.10	0.05	0.03	0.02	0.02
TMSD HAC	Public Land	Closed Forest	27.30	21.89	18.21	19.03	19.98
		Open Forest	62.15	68.68	72.84	72.35	71.31
		Mangrove	2.98	3.55	4.08	4.38	4.67
		Plantation	0.57	0.28	0.17	0.14	0.15
	Alienable & Disposable land	Closed Forest	0.97	0.81	0.70	0.60	0.59
		Open Forest	4.37	3.09	2.28	1.73	1.53
		Mangrove	1.57	1.65	1.70	1.74	1.75
		Plantation	0.10	0.05	0.03	0.02	0.02
TRMM HAC	Public Land	Closed Forest	27.74	21.89	18.21	19.03	19.98
		Open Forest	66.16	72.23	76.92	76.73	75.98
		Plantation	0.58	0.28	0.17	0.14	0.15
	Alienable & Disposable land	Closed Forest	0.77	0.81	0.70	0.60	0.59
		Open Forest	4.69	4.74	3.97	3.47	3.28
		Plantation	0.08	0.05	0.03	0.02	0.02

Table VI. 30. Projected Forest Land Subcategories under the M2 Scenario

Climate/Soil Type	DENR Category	Land-use Subcategory	% in 2010	% in 2015	% in 2020	% in 2030	% in 2050
TRW HAC	Public Land	Closed Forest	27.30	20.42	15.75	13.38	12.57
		Open Forest	62.15	64.07	64.08	66.78	67.52
		Mangrove	2.98	3.51	3.77	4.02	4.07
		Plantation	0.57	6.80	12.30	12.22	12.34
	Alienable & Disposable land	Closed Forest	0.97	0.75	0.61	0.53	0.53
		Open Forest	4.37	2.87	1.99	1.52	1.38
		Mangrove	1.57	1.53	1.48	1.53	1.57
		Plantation	0.10	0.04	0.03	0.02	0.02
TMSD HAC	Public Land	Closed Forest	27.30	20.42	15.75	13.38	12.57
		Open Forest	62.15	64.07	64.08	66.78	67.52
		Mangrove	2.98	3.51	3.77	4.02	4.07
		Plantation	0.57	6.80	12.30	12.22	12.34
	Alienable &	Closed Forest	0.97	0.75	0.61	0.53	0.53

	Disposable land	Open Forest	4.37	2.87	1.99	1.52	1.38
		Mangrove	1.57	1.53	1.48	1.53	1.57
		Plantation	0.10	0.04	0.03	0.02	0.02
TRMM HAC	Public Land	Closed Forest	27.74	20.42	15.75	13.38	12.57
		Open Forest	66.16	67.58	67.86	70.80	71.59
		Plantation	0.58	6.80	12.30	12.22	12.34
	Alienable & Disposable land	Closed Forest	0.77	0.75	0.61	0.53	0.53
		Open Forest	4.69	4.40	3.47	3.05	2.95
		Plantation	0.08	0.04	0.03	0.02	0.02

VI.4.1.3 Biomass Gains under Mitigation Options

In order to project gains in biomass carbon stocks in forest land, grassland, and cropland, the study team developed a data on incremental annual growth of tree species. This annual growth increment is a function of tree age range or distribution, which are an important input to the ALU Software.

Given the lack of data from a national-level forest inventory that could support the development of projected tree age distributions, the team assumed that the tree age distribution for both the mitigation option Scenarios is the same[24] as that applied in the Baseline Scenario. Biomass Losses under Mitigation Options

Timber Harvesting

Losses in biomass carbon stock are brought about by timber harvesting, fuelwood gathering, forest disturbance (e.g. forest fires, wind disturbance, and pest and diseases infestation), and deforestation.

Under the M1 scenario, timber harvest under forest protection is projected to decline over the years from 0.0388 cubic meters per capita in 2010 to 0.028 cubic meters per capita in 2050, or equal to a 27.8% decline in timber harvest by 2050 relative to 2010 timber harvest. As shown in Table VI. 31, this resulted in a total timber harvest of 4.13 million cubic meters. Compared to the level of timber harvest projected for the Baseline Scenario, this is an overall reduction of 20% less timber harvested by 2050.

For the M2 scenario, timber harvest is also projected to decline, but at a lower rate as compared to the M1 Scenario. Under M2, timber harvest will remain at the same level of 0.0388 cubic meters per capita until 2020, then start to decline gradually to 0.0335 cubic meters per capita in 2050, which is equivalent to a 13.7% decrease in timber harvest by 2050 relative to the 2010 harvest level. Hence, with the increase in population and higher per capita timber harvest levels than in the M1 scenario, timber harvest under the M2 scenario is projected to reach 6.39 million cubic meters, as shown in Table VI. 32. In comparison to the Baseline Scenario, this is 23% more timber harvested in 2050. Note that timber harvest projections were adjusted to take into account anticipated timber harvests from NGP, INREMP, FMP, and other reforestation programs.

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[24] Based on the May 2015 Consultation with FMB officials.

Table VI. 31. Projected Timber Harvest under the M1 Scenario (m^3)[25]

	2010	2015	2020	2030	2040	2045	2050
Population	92,337,852	101,562,300	109,947,900	125,337,500	137,532,200	142,095,100	147,482,277
Per Capita Harvest Level in Cubic Meters (m^3)	0.0388	0.0341	0.0324	0.0298	0.0280	0.0280	0.0280
Timber Harvest Adjusted for NGP in Cubic Meters (m^3)	**3,580,000**	**3,465,813**	**3,559,563**	**3,728,791**	**3,850,902**	**3,978,663**	**4,129,504**

Table VI. 32. Projected Timber Harvest under the M2 Scenario (m^3)[26]

	2010	2015	2020	2030	2040	2045	2050
Population	92,337,852	101,562,300	109,947,900	125,337,500	137,532,200	142,095,100	147,482,277
Per Capita Harvest Level in Cubic Meters (m^3)	0.0388	0.0388	0.0388	0.0363	0.0347	0.0341	0.0335
Timber Harvest Adjusted for NGP in Cubic Meters (m^3)	**3,580,000**	**3,937,638**	**5,713,456**	**6,002,997**	**6,219,829**	**6,298,425**	**6,389,636**

Fuelwood Gathering

Under the Forest Protection Scenario, fuelwood harvest is projected to decline over the years from 0.5415 cubic meters per capita in 2010 to 0.3056 cubic meters per capita in 2050, or a 43.6% decline in estimated fuelwood harvest by 2050 (relative to estimated 2010 fuelwood harvest level).[27] As shown in

Table VI. 33, with the increase in population, this corresponds to a total harvest of 45.07 million cubic meters of fuelwood by 2050. Compared to the Baseline Scenario, this is a reduction of 20% in fuelwood harvest by 2050.

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[25] Sources: Sibucao, 2014; Sibucao, 2013; and FMB, 2012

[26] Sources: Sibucao, 2014; Sibucao, 2013; and FMB, 2012

[27] Fuelwood harvest estimates shown here are inclusive of charcoal harvest, with quantities expressed in fuelwood equivalent based on energy content.

In contrast, for the Forest Restoration and Reforestation mitigation option Scenario, fuelwood harvest levels will remain at a level of 0.5415 cubic meters per capita until 2015, decrease to 0.4455 cubic meters per capita by 2020, then will remain at that level until 2050 (see Table VI. 34). With the increase in population, fuelwood harvest is projected to reach a level of 58.59 million cubic meters by 2050. This is equivalent to a 4% increase compared to the Baseline Scenario for 2050.

For the two mitigation scenarios, it is assumed that 90% of the total extracted fuelwood and charcoal will be gathered from forest land, and 10% from agroforestry/woody cropland.[28]

Table VI. 33. Projected Fuelwood Harvest under the M1 Scenario (m^3)[29]

	2010	2015	2020	2030	2040	2045	2050
Population	92,337,852	101,562,300	109,947,900	125,337,500	137,532,200	142,095,100	147,482,277
Per capita harvest level in Cubic Meters (m^3)	0.5415	0.4455	0.3874	0.3625	0.2977	0.2947	0.3056
Total Fuelwood and Charcoal in Cubic Meters (m^3)	**50,000,000**	**45,243,252**	**42,598,428**	**45,440,189**	**40,938,368**	**41,875,302**	**45,072,625**

Table VI. 34. Projected Fuelwood Harvest under the M2 Scenario (m^3)[30]

	2010	2015	2020	2030	2040	2045	2050
Population	92,337,852	101,562,300	109,947,900	125,337,500	137,532,200	142,095,100	147,482,277
Per Capita Demand in Cubic Meters (m^3)	0.5415	0.5415	0.4455	0.4455	0.4455	0.4455	0.4455
Total Fuelwood and Charcoal; Adjusted for NGP in Cubic Meters (m^3)	**50,000,000**	**46,403,335**	**48,298,768**	**55,705,458**	**53,419,373**	**54,590,540**	**58,587,194**

Forest Disturbance

Forest disturbance in the two mitigation option scenarios was assumed to be minimal, as in the baseline. This will be equal to 0.1% of A&D land open forest areas (with trees >20 years), of annual disturbance due to fire, until 2050.

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[28] Based on consultations with FMB on 6-8 July 2015 in Clark, Pampanga.

[29] Sources: Bensel and Remedios, 2002; Sibucao et al., 2014

[30] Sources: Bensel and Remedios, 2002; Sibucao et al., 2014

Deforestation

Under the Forest Protection Scenario, the deforestation rate is projected to be less than the Baseline Scenario, so that by 2050 the area of closed and open forests categories which are affected by deforestation is only 0.02%, instead of 0.04% under the Baseline Scenario (

Table VI. 35). Further, it was assumed that only 10% of the deforested or cleared area will be burned.

Under the Forest Restoration and Reforestation mitigation option scenario, the projected deforestation rate is similar to that in the Baseline Scenario, as shown in Table VI. 36.

Table VI. 35. Projected Deforestation Rate under the M1 Scenario

	2010	2020	2030	2050
Annual rate of change, %	2.86	1.87	0.77	0.25
% of closed and open forest areas	0.24	0.16	0.06	0.02

Table VI. 36. Projected Deforestation Rate under M2 Scenario

	2010	2020	2030	2050
Annual rate of change, %	2.86	2.08	1.29	0.50
% of closed and open forest areas	0.24	0.17	0.11	0.04

VI.4.1.4 Grassland Burning under Mitigation Options

Consistent with the assumptions made for the Baseline Scenario, 30% of the total grassland area is projected to be burned until 2050 for both the M1 and M2 Scenarios.

Emission/Stock Factors

All carbon emission/stock factors applied in the M1 and M2 Scenarios were the same as with the emission/stock factors used in the Baseline Scenario. These factors, which are mostly IPCC default values, include factors for Gw; Bw; CF; RS; biomass fraction left after the disturbances (e.g., fire, wind, pest); D; BEF for timber and fuelwood; CF; and biomass fraction left after harvest.

For biomass burning, these include emission factors for the mass of fuel; combustion efficiency of biomass; carbon fraction; nitrogen/carbon (N/C) ratio; and emission ratios for CH_4, C), N_2O, and NO_2.

Summary of Assumptions under the M1 and M2 Mitigation Options

Table VI. 37 summarizes the key assumptions for the M1 and M2 Scenarios that are known to affect the changes in carbon stock and the GHG emissions from biomass burning. These assumptions were important inputs to the ALU Software.

Table VI. 37. Mitigation Options in the Forestry Sector

Scenario	Factors Driving Gains in Forest Carbon	Factors Driving Losses in Forest Carbon
Mitigation 1 (M1):	1) Closed forest area decreases from 1.63 million ha in 2015 to only 1.56	<u>On timber harvest:</u> Assumed to increase

Forest Protection	million ha in 2050 2) Open forest area increases from 5.15 million ha in 2015 to 5.69 million ha in 2030, then starts to decrease gradually until it reaches 5.51 million ha in 2050 3) Mangrove area increases from 373 thousand ha in 2015 to 484 thousand ha in 2050 4) Plantation area decreases from 23.31 thousand ha in 2015 to 12.86 thousand in 2050	from 3.58 million cubic meter in 2010 to 4.13 million cubic meter in 2050 On fuelwood gathering: Assumed to decrease from 50 million cubic meter in 2010 to 45.07 million cubic meter in 2050 On deforestation rate: Assumed to be lesser than the Baseline Scenario, so that by 2050 the per cent of Closed and Open Forests area deforested is only 0.02%, instead of 0.04% under Baseline Scenario On disturbance rate: Assumed to be minimal; equal to 0.1% of A&D Land Open Forest areas (with trees >20 years) that will be disturbed annually due to fire, until 2050
Mitigation 2 (M2): **Restoration and Reforestation**	1) Closed forest area decreases from 1.63 million ha in 2015 to 1.11 million ha in 2050 2) Open forest area increases from 5.15 million ha in 2015 to 5.85 million ha in 2030, then decreases gradually until it reaches 5.84 million ha in 2050 3) Mangrove area increases from 0.38 million ha in 2015 to 0.47 million ha in 2050 4) Plantation area increases from 526.3 thousand ha in 2015 to 1.051 million ha in 2020, then decreases gradually to 1.049 million ha in 2050	On timber harvest: Assumed to increase from 3.58 million cubic meters in 2010 to 6.39 million cubic meters in 2050 On fuelwood gathering: Assumed to increase from 50 million cubic meters in 2010 to 58.59 million cubic meters in 2050 On deforestation rate: Assumed to be of similar level with the Baseline Scenario. On disturbance rate: Assumed to be minimal; equal to 0.1% of A&D land open forest areas (with trees >20 years) that will be disturbed annually due to fire, until 2050

Direct Cost Methods and Assumptions

The costs of forest-based GHG mitigation options include expenses which are incurred by forest management agencies and other stakeholders in order to increase the mitigation of GHG emissions within the forest landscape, relative to the Baseline Scenario.

This section describes key data and assumptions used to estimate the costs of forest mitigation options. It is important to note that, in contrast to many of the other GHG mitigation options evaluated in this effort, the enabling EOs for the forest protection and the National Greening Program (and related reforestation programs) were executed before the study was initiated in 2015. As a result, some of the actual program costs for both mitigation options were incurred *before* 2015, and as such, estimates of these costs have been included in this analysis and expressed in present value terms. Data on biomass removals, costs, prices, and yield were mostly sourced from available local publications, statistical and various technical reports from DENR and from other related agencies, FAO, IPCC, experts, and multi-stakeholder consultations.

In the case of the Forest Protection mitigation option (M1), the two primary components of costs are described below:

- **Opportunity costs:** opportunity costs result from the activities foregone as a result of forest protection, conservation, and sustainable management (e.g., foregone timber harvest, reduction in shifting cultivation and resulting agricultural production). As shown in Table VI. 38 below, opportunity costs associated with forest protection can vary significantly by region and by the type of service(s) and/or products displaced by the forest protection. As a general rule, the opportunity costs for reduced harvest of high-grade timber (e.g., mahogany) are usually the higher-end of the range of opportunity costs for forest protection.

Table VI. 38. Estimates of Opportunity Costs of Forest Protection

Foregone Goods and Services Resulting from Forest Protection	Opportunity Cost Estimates (USD/ha)		
	Brazil [31]	Tanzania[32]	Eastern Paraguay[33]
Timber	24-791/ha	358 to 502/ha	--
Grazing	39-59/ha	--	--
Crops (corn)	39/ha	--	--
Crops (soy)	171/ha	--	~200/ha
Coffee	93/ha	--	--
Crops (all)	--	800-1,400/ha	--

- **Program implementation costs:** typical costs of implementing forest protection and sustainable management programs include (but are not limited to) the costs of agency staff for enforcing policy (e.g., logging ban) and conducting monitoring activities; technical assistance; the use of computers, vehicles, and other equipment; and other costs related to monitoring, tracking, enforcement, and reporting.

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[31] Source:Borner and Wunder (2008).

[32] Source: Fisher et al. (2011).

[33] Source: Naidoo and Ricketts (2006).

Typical costs associated with the second forest mitigation option – forest restoration, reforestation, and afforestation (M2) – include the following:

- **Establishment costs:** the first-year costs of establishing a tree plantation include purchases of seedlings, preparing sites for planting, and early maintenance and protection of young seedlings.
- **Maintenance and protection costs:** these must be incurred on an annual basis in order to ensure the survival of plantations, especially in early years. For commercial tree plantations, there are costs associated with maintenance and subsequent harvests of timber, fuelwood, and non-timber forest products (e.g., cacao, rubber).
- **Program Implementation costs:** other direct costs of forest restoration and reforestation activities include the costs of site monitoring, technical assistance, maintaining records, performance tracking and accounting systems, and other overhead associated with implementation of reforestation and restoration projects (e.g., computer time).

In this analysis, the Study Team first developed estimates of the costs of each mitigation option. Using the cost estimates for the study timeframe of 2011 to 2050, expressed in terms of net present value, the team then calculated the cost of GHG mitigation potential for each mitigation option, i.e., the average cost per ton of avoided CO_2e. In addition, the team developed estimates of income co-benefits for the Forest Restoration and Reforestation mitigation option mitigation option.

When interpreting cost-benefit results for the Forest Restoration and Reforestation mitigation option, it is important to note a distinction between costs which are incurred by (or in the case of benefits, accrue to) public versus private entities. According to best practices in CBA, costs incurred by public agencies should be compared only to benefits also accruing to the public (known as societal benefits); similarly, the appropriate comparison of costs borne by the private sector is to the resulting stream of benefits which accrue to private entities only. Because plantations established under the NGP and other reforestation programs will, for the most part, be managed and maintained by local tenure-holders after Year 3, costs after the third year will be borne by these tenure-holders. Accordingly, some portion of the stream of benefits (i.e., income from harvests of timber, fuelwood, and non-timber commodities) from these plantations should be considered to be private rather than societal benefits.

The assumptions and data sources used to develop estimates of costs of the Forest Protection mitigation option are described in the next section.

Assumptions for Costs of the Forest Protection Scenario (M1)

As described above, the two primary cost elements for forest protection include opportunity costs and the costs of program implementation. The Study Team conducted the opportunity cost calculation by first estimating a reduction in harvests of timber and fuelwood resulting from forest protection activities, relative to the levels of harvest assumed for the Baseline Scenario. The reduction in harvest levels resulting from forest protection was then valued at current prices of timber and substitute products for fuelwood (e.g., liquid petroleum gas, or LPG).

First, in order to generate an estimate of the effectiveness of forest protection at reducing harvest levels in the Philippines, the Study Team evaluated results from studies of existing forest protection and conservation programs across a range of highly forested developing countries (Union of Concerned Scientists, 2014; Gibbs et al. 2010). This review found that in some cases, illegal logging can persist despite a moratorium or other restrictions on logging, due to the fact that opportunity costs of forest protection are often too significant to overcome. In other cases, resources were insufficient to sustain an appropriate level of enforcement of forest protection programs. Moreover, the duration of the performance record for national-level forest protection efforts in other countries is limited. As such, there is a significant uncertainty in our initial estimates of the effectiveness of EO 23 (i.e., logging ban in natural forests) and similar forest protection programs on harvest levels. An additional uncertainty is the level of harvest that would occur in the Baseline Scenario, i.e., in the absence of forest protection activities, which is highly dependent upon economic conditions (especially prices for forest products and substitute products). Results of this analysis are very sensitive to these assumptions. Given the fact that initial estimates of GHG reduction suggest that forest protection could be one of the Philippines' most cost-effective mitigation options, estimates of the forest protection mitigation option would benefit substantially from additional research and evaluation. The single best approach to reducing the uncertainties described here is direct measurement, including regular inventories of forest lands and harvesting levels. Estimates based on econometric modeling of demand for timber and fuelwood in the Philippines would also help reduce uncertainty.

To calculate a value of the estimated reductions in harvest levels associated with forest protection, the Study Team applied prices from recent timber and fuelwood sales in the Philippines. Timber prices were estimated using a weighted average of current prices available, expressed in PhP per cubic meter. Weights for prices were based on the percentage of timber sales for different species types in 2013 relative to total sales. Table VI. 39 shows a weighted average timber price of PhP2,281 per cubic meter, which was then applied to the estimates of the annual reduction in timber harvest over the 2015 to 2050 period. Because the weighted average of timber prices, based on official 2013 timber sales, may not be representative of the types of timber species not harvested resulting from forest protection activities in the future, this creates another uncertainty in the estimate of opportunity costs of reduced timber harvests.

Table VI. 39. Weighted Average Price of Timber Sold, 2013[34]

Timber Species	Volume Sold, 2013 (cubic meter)	Weight Based on % of Total 2013 Sales	Retail Price (PhP/cubic meter)	Weighted Avg. Retail Price, 2013 (PhP/cubic meter)
Acacia (*Samanea saman*)	6,416	0.01	11,024	61
Antipolo (*Artocarpus blancoi*)	251	0.00	n/a	
Bagras (*Eucalyptus deglupta*)	15,496	0.01	4,500	60
Benguet Pine (*Pinus kesiya*)	200	0.00	4,000	1
Eucalyptus (*Eucalyptus globus*)	1,830	0.00	n/a	

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[34] Source: Philippine Forestry Statistics, 2013

Falcata (*Paraserianthes falcataria*)	851,629	0.73	1,700	1,242
Gubas (*Endospermum peltatum*)	3,019	0.00	n/a	
Ipil-ipil (*Leucaena leucocephala*)	3,203	0.00	2,458	
Mahogany (*Swietenia macrophylla*)	46,865	0.04	11,024	443
Mangium (*Acacia mangium*)	80,676	0.07	n/a	
Para Rubber (*Hevea brasiliensis*)	6,848	0.01	2,600	15
Yemane (*Gmelina arborea*)	93,043	0.08	5,750	460
Other timber species	56,375	0.05	n/a	
Total (cubic meter)	**1,165,851**	**1**		**2,281**

In addition to the opportunity costs associated with foregone timber harvests, the forest protection mitigation option also results in a reduction in fuelwood harvest relative to the Baseline Scenario. It is assumed that residential demand for fuelwood and charcoal is for cooking, and that the useful energy requirements that would be met by the avoided demand must be satisfied with alternative fuels, such as LPG or electricity. Following Food and Agriculture Organization of the United Nations (2009), three alternatives are considered: LPG, electricity, and kerosene. Sixty-three percent of the affected useful energy is assumed to be met by LPG, 27% by electricity, and 10% by kerosene (Bensel and Remedio 2002). A detailed description of the assumptions, analysis, and resulting impacts on GHG mitigation and the opportunity costs associated with changes in fuelwood use resulting from either forest mitigation options are captured in the results of the Energy Sector report for the CBA (B-LEADERS, 2015).

As described earlier, the second major cost element for forest protection is the cost of implementing forest protection activities. Examples of these costs include (but are not limited to): the costs of agency staff time spent enforcing policies (e.g., logging ban) and conducting monitoring activities; technical assistance; the use of computers, vehicles, and other equipment; and other costs related to monitoring, tracking, enforcement, and reporting on forest protection programs. Based on estimates of DENR appropriations for all forestry programs from 2010 to 2013, the Study Team allocated a portion of these costs to the forest protection option, as shown in Table VI. 40.

Table VI. 40. Estimated DENR Costs of Forest Protection Applicable to Mitigation Option (M1) (2010 USD)[35]

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[35] Source: DENR GAA Appropriations, 2014

Estimated DENR Spending to Support Forest Protection, 2010 to 2013 (PhP)		Annual Avg. Spending, 2010-2013 (PhP)	Annual Avg. Spending, 2010-2013 (2010 USD)
Forest Protection Activities (M1)	4,649,780,000	1,162,445,000	184,015,147

In addition, the Study Team estimated various cost elements of the Philippine Master Plan for Climate Resilient Forestry Development (Master Plan) and allocated a portion of these costs to program implementation for forest protection from 2015 to 2028. Table VI. 41 shows this cost allocation estimate.

Table VI. 41. Master Plan Costs Allocated to Forest Protection (M1) Mitigation Option (Thousand PhP)

Allocation of Master Plan Costs	Cost / Period (PhP '000)		
	2015-2016	2017-2022	2023-2028
Master Plan Costs Allocated to Forest Protection (M1)	6,109,695	11,372,426	7,349,481

The two separate cost elements for the forest protection mitigation option – opportunity costs and program implementation costs – were combined into an estimate of the total implementation program cost from 2015 to 2050. These totals were then used to generate the NPV of costs for Forest Protection mitigation option.

Assumptions for Costs of Forest Restoration and Reforestation Scenario (M2)

The next section describes assumptions and data sources used to develop estimates of costs for the forest restoration and reforestation mitigation option (M2).

Areas in reforestation programs planted with tree species appropriate for timber and fuelwood production (e.g., mahogany and falcata, respectively) are tracked separately in order to estimate the production of timber and fuelwood from plantations on these lands, which are then used to estimate the GHG impacts of biomass removals associated with this mitigation option, as well as the availability of fuelwood for the analysis of energy sector mitigation opportunities as shown in Table VI. 42.

In addition, revenues from the sale of timber and fuelwood lands from NGP plantings are included in the estimate of income co-benefits associated with the Forest Restoration and Reforestation option (described in the next section).

Table VI. 42. Area Planted under the National Greening Program (NGP) and Other Reforestation Programs, 2011 through 2026 (in ha)

Forest Restoration or Reforestation Program	Total Area Planted in Hectares	Area Planted under Timber in	Area Planted under Fuelwood in Hectares

		Hectares	
National Greening Program	1,571,745	393,821	182,118
Integrated Natural Resource Management Program	329,780	32,978	-
Forestlands Management Program	73,100	58,480	14,620
Others (e.g., Community-based Forestry, Private Sector Tenure Holders, Non-Government Organizations)	150,000	75,000	-
Total Area Planted under Forest Restoration and Reforestation Programs	**2,124,625**	**560,279**	**196,738**

The costs of establishing a plantation project for its first three years, including the cost of tree/plant seedlings, preparation of the site for planting, and from year one through three of maintenance and protection for various tree species, are shown in Table VI. 43. These costs are average across all types of tree species planted in the NGP, and expressed on a PhP per hectare basis. The average establishment and maintenance costs of NGP plantings totals to 21,421 PhP per hectare. This average cost per hectare is then applied to all land areas planted under reforestation programs (i.e., including INREMP) to arrive at a total cost estimate of establishment and maintenance of forest restoration and reforestation projects. It is important to note that maintenance costs will need to be incurred after year three to keep these plantations viable, and that these costs will be assumed by the tenure-holders. However, as discussed earlier, because these maintenance costs will be incurred by tenure-holders and not public agencies, total costs presented in this analysis represent only the *public costs* of the forest protection mitigation option.

Table VI. 43. Costs of Establishment and Maintenance of NGP (PhP per ha)[36]

Species/ Commodity	Seedlings			SMP	Social Mobilization				Maintenance and Protection	
	Density (per ha)	Unit Cost	Cost per Ha		Site Preparation	IEC, Transportation, and Mobilization	First Year Maintenance and Protection	First Year Total	Second Year	Third Year
Indigenous	500	12	6,000	450	3,000	1,000	1,000	11,450	3,000	2,000
Fast Growing	500	10	5,000	450	3,000	1,000	1,000	10,450	3,000	2,000

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[36] Source: FMB Technical Bulletin 10

Timber										
Fast Growing Timber	1,000	10	10,000	450	3,000	1,000	1,000	15,450	3,000	2,000
Fuelwood	1,000	6	6,000	450	3,000	1,000	1,000	11,450	3,000	2,000
Coffee (From Seeds)	500	12	6,000	450	3,000	1,000	1,000	11,450	3,000	2,000
Coffee (Luzon) - Clonal Propagation*	500	20	10,000	450	3,000	1,000	1,000	15,450	3,000	2,000
Coffee (Visayas) - Clonal Propagation*	500	18	9,000	450	3,000	1,000	1,000	14,450	3,000	2,000
Coffee (Mindanao) - Clonal Propagation*	500	15	7,500	450	3,000	1,000	1,000	12,950	3,000	2,000
Cacao (Budded)	500	25	12,500	450	3,000	1,000	1,000	17,950	3,000	2,000
Rubber (From Seeds)	500	15	7,500	450	3,000	1,000	1,000	12,950	3,000	2,000
Rubber (Budded)	500	35	17,500	450	3,000	1,000	1,000	22,950	3,000	2,000
Bamboo	500	35	7,000	450	3,000	1,000	1,000	12,450	3,000	2,000
Rattan	500	20	10,000	450	3,000	1,000	1,000	15,450	3,000	2,000
Mangrove (Propagule)	2,500	3	7,500	450	3,000	1,000	1,000	12,950	3,000	2,000
Mangrove (Potted)	2,000	15	30,000	450	3,000	1,000	1,000	35,450	3,000	2,000
Other Fruit Trees (Grafted)	200	25	5,000	450	3,000	1,000	1,000	10,450	3,000	2,000
Urban Greening (Saplings)	400/ha or km	75	3,000	450	3,000	1,000	1,000	35,450	3,000	2,000
Average							**Average cost per ha**	**16,421**	**3,000**	**2,000**

Additional details on the assumptions used to estimate establishment and maintenance costs for the Forest Restoration and Reforestation programs are listed in Table VI. 44 below.

Table VI. 44. Additional Assumptions for Estimating the Establishment and Maintenance Costs for Forest Restoration and Reforestation Mitigation Option[37]

Key Assumptions
- Five-year survival rate of 50% applies to NGP and all other reforestation projects. - INREMP plantings total 329,780 ha, with planting starting in 2016. FMP plantings equal 73,100 ha; with planting beginning in 2014. - Plantings in other community forest lands equal 150,000 ha, starting in 2016. - Costs per ha for establishment and maintenance/protection (years one to three) of INREMP, FMP, and other planting programs based on average costs of NGP plantings, on PhP per ha basis. - Estimate of program implementation costs for 2011 to 2014 based on annual average of Master Plan costs from 2015-2016. - NGP non-timber commodity trees (e.g., mango, rubber), mangroves, and ecological restoration species are not used for timber or fuelwood.

To estimate the costs of implementation for forest restoration and reforestation programs, the Study Team allocated DENR's total appropriations for 2010 to 2013 between this mitigation option and the Forest Protection Mitigation Option. This was also done for the cost of implementation of the Master Plan. The proportion of DENR and the Master Plan costs allocated to the Forest Restoration and Reforestation option is shown in Table VI. 45 and Table VI. 46, respectively.

Table VI. 45. Estimated Costs of DENR Appropriations for Forest Restoration and Reforestation, 2010 to 2013

Estimated DENR Spending to Support NGP, 2010 to 2013 (PhP)		Annual Avg. Spending, 2010-2013 (PhP)	Annual Avg. Spending, 2010-2013 (2010 USD)
Allocation to NGP and Other Reforestation Programs (M2)	10,479,718,000	2,619,929,500	216,327,579

Table VI. 46. Costs Allocated to Forest Restoration/Reforestation from the Master Plan[38] for Climate Resilient Forestry Development

Allocation of Master Plan Costs	Cost / Period (PhP '000)

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[37] Sources: FMB Technical Bulletin 10; expert opinion.

[38] Source: Philippine Master Plan for Climate Resilient Forestry Development, 2014

	2015-2016	2017-2022	2023-2028
Costs Allocated to Forest Restoration and Reforestation (M2)	8,282,923	18,338,367	20,627,160

A key issue in the estimation of mitigation potential and costs per ton is how to account for interactions between the mitigation options. Implementing certain options together can lower (or raise) 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 the total GHG emission reductions if all the mitigation options analyzed in this report are simply summed up.

The CBA addresses 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 are 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 2010-2050 baseline only, the second option in comparison to the baseline plus the first option, and so forth.

The retrospective approach analysis spans all mitigation options across all sectors. Forestry mitigation options were initiated within the overall set or sequence of options based on the retrospective analysis approach, as summarized in Table VI. 47. The sequence order of the forestry mitigation options was specifically noted. The advantage of this approach is that the interdependence between a given mitigation option and every other previous option on the MACC curve is taken into account. Across all sectors, 37 mitigation options were included in the retrospective analysis, including the two forestry mitigation options described above.

The results presented below focus only on the incremental impacts of the two forestry mitigation options included in the retrospective analysis. However, it is important to understand that those results occur within and are dependent on where an option sits in the overall sequence of 37 options. 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 VI. 47. Sequential Order of all Mitigation Options in the Retrospective Analysis Approach

Sector	Mitigation Option Sequence	Mitigation Option Name
Industry	1	Increased Glass Cullet Use
Industry and Energy	2	Cement Clinker Reduction
Transport	3	Motor Vehicle Inspection System (MVIS)
Transport	4	Electric Jeepney
Transport	5	Congestion Charging
Energy	6	Home Lighting Improvements
Transport	7	Driver Training
Energy	8	Home Appliance Standards
Industry and Energy	9	Cement Waste Heat Recovery
Energy	10	Efficient Light-Emitting Diode (LED) Lighting
Industry and Energy	11	Biomass in Cement
Energy	12	National Renewable Energy Program (NREP) Biomass
Industry and Energy	13	Biomass Co-firing
Waste and Energy	14	Municipal Solid Waste (MSW) Digestion
Energy	15	Nuclear Power
Energy	16	National Renewable Energy Program (NREP) Solar
Energy	17	Gas for Coal
Agriculture	18	Organic Fertilizers
Energy	19	National Renewable Energy Program (NREP) Wind
Waste and Energy	20	Methane Recovery from Sanitary Landfill
Agriculture	21	Alternative Wet-Dry (AWD)
Waste	22	Methane Flaring
Forestry and Energy	**23**	**Forest Mitigation 2 – Forest Restoration and Reforestation**
Agriculture	24	Crop Diversification
Forestry and Energy	**25**	**Forest Mitigation 1 – Forest Protection**
Energy	26	National Renewable Energy Program (NREP) Ocean
Energy	27	National Renewable Energy Program (NREP) Large Hydro
Waste	28	Composting
Waste	29	Eco-Efficient Cover
Energy	30	National Renewable Energy Program (NREP) Small Hydro
Energy	31	National Renewable Energy Program (NREP) Geothermal
Transport	32	Biofuels
Energy	33	Biodiesel Target
Transport	34	Buses and Bus Rapid Transit (BRT)
Agriculture and Energy	35	Bio-digesters
Transport	36	Rail
Waste and Energy	37	Municipal Solid Waste (MSW) Incineration

VI.4.2 Results

The following two subsections (Direct Costs and Benefits; and Co-Benefits) present the results of each mitigation option in relation to the baseline and all mitigation options sequenced prior as described in the retrospective analysis approach.

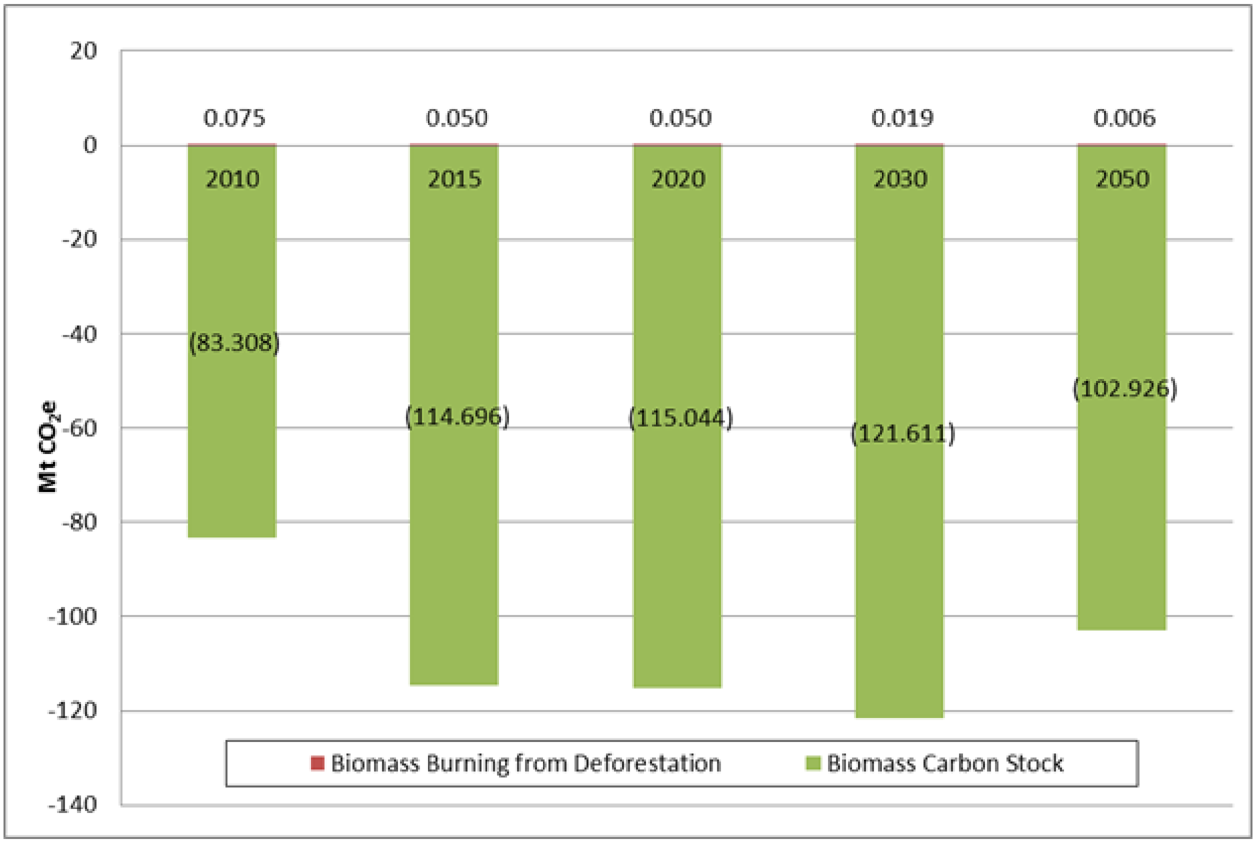
VI.4.2.1 Direct Benefits and Costs

GHG Mitigation Potential

Forest Protection Mitigation Scenario (M1):

Under the Forest Protection Scenario, with the conservation, protection, and sustainable management of forest areas, it is estimated that carbon stocks in the LULUCF sector will continue to increase considerably as shown in Figure VI. 6, with net carbon sequestration peaking in 2030 and declining slightly until 2050. GHG emissions from biomass burning are estimated to be very small, similar to the Baseline Scenario.

Figure VI. 6. GHG Emissions and Removals in the LULUCF Sector under M1 Scenario ($MtCO_2e$) [39]



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[39] Emissions from biomass burning (forest gains-losses) are omitted from this figure due to their relatively small magnitude.

In terms of the net carbon stock (which represents emissions minus removals), the M1 Scenario will increase the carbon stock over the study years, with the highest net carbon stock of 121.6 million metric tons of CO_2e occurring in 2030, as shown in Table VI. 48. In comparison with the Baseline Scenario, the protection and sustainable management of forest to be implemented under this Scenario will increase the baseline carbon sink by 20.45%, which is equivalent to a mitigation potential of 17.476 million metric tons of CO_2e by 2050 Table VI. 49).

Table VI. 48. Projected Emissions/Removals from the LULUCF Sector under the M1 Scenario ($MtCO_2e$)

Category	2010	2015	2020	2030	2050
Changes in Biomass Carbon Stocks	-83.308	-114.695	-115.044	-121.611	-102.926
Emissions from biomass burning – Deforestation	0.075	0.049	0.050	0.019	0.006
Emissions from biomass burning - Forest Gain-Loss	0.000422	0.000236	0.000305	0.000272	.000286
Net Carbon Stock	**-83.233**	**-114.646**	**-114.994**	**-121.592**	**-102.920**

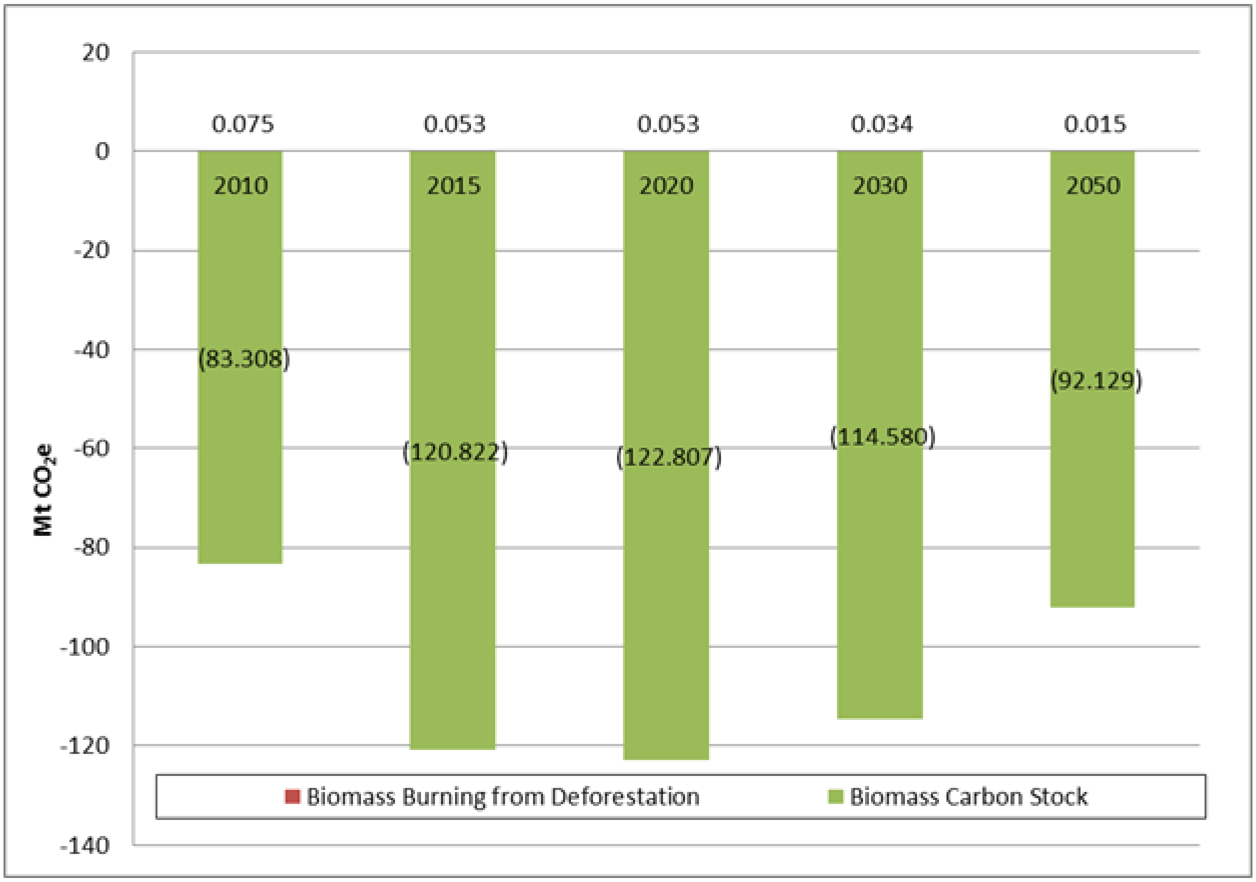
Table VI. 49. Mitigation Potential under the M1 Scenario Compared to the Baseline Scenario ($MtCO_2e$)

Scenario	2010	2015	2020	2030	2050
Baseline	-83.233	-111.445	-108.670	-102.472	-85.444
Mitigation 1	-83.233	-114.646	-114.994	-121.592	-102.920
M1 Mitigation Potential	0.000	-3.201	-6.324	-19.120	-17.476

Forest Restoration and Reforestation Mitigation Scenario (M2):

Under the Forest Restoration and Reforestation Scenario (M2), Figure VI. 7 shows that projected carbon stocks in the LULUCF sector are projected to increase due to forest restoration and reforestation activities, peaking in 2020 at -122.74 $MtCO_2e$ before declining to -114.546 $MtCO_2e$ in 2030 and -92.114 $MtCO_2e$ in 2050. Similar to the M1 Scenario, GHG emissions from biomass burning are also estimated to be very small.

Figure VI. 7. GHG Emissions and Removals in the LULUCF Sector under the M2 Scenario ($MtCO_2e$)[40]



In terms of the net carbon stock, the M2 Scenario is projected to increase carbon stocks in the LULUCF sector to 92.114 million metric tons of CO_2e in 2050 (Table VI. 50). In comparison with the Baseline Scenario, the forest restoration and reforestation activities implemented under this M2 Scenario have the potential to increase the carbon sink by 7.8%, or equivalent to mitigation potential of 6.67 million metric tons of CO_2e in 2050 (Table VI. 51).

Table VI. 50. Projected Emissions/Removals from the LULUCF Sector under the M2 Scenario ($MtCO_2e$)

Category	2010	2015	2020	2030	2050
Changes in Biomass Carbon Stocks	-83.308	-120.822	-122.807	-114.580	-92.129
Emissions from biomass burning – Deforestation	0.075	0.053	0.053	0.034	0.015
Emissions from biomass burning - Forest Gain-Loss	0.00042	0.00034	0.00030	0.00027	0.00029
Net Carbon Stock	**-83.233**	**-120.769**	**-122.754**	**-114.546**	**-92.114**

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[40] Emissions from biomass burning (forest gains-losses) are omitted from this figure due to their relatively small magnitude.

Table VI. 51. Mitigation Potential under the M2 Scenario Compared to the Baseline Scenario (MtCO$_2$e)

Scenario	2010	2015	2020	2030	2050
Baseline	-83.233	-111.445	-108.670	-102.472	-85.444
Mitigation 2	-83.233	-120.769	-122.754	-114.546	-92.114
M2 Mitigation Potential	0.000	-9.324	-14.084	-12.074	-6.670

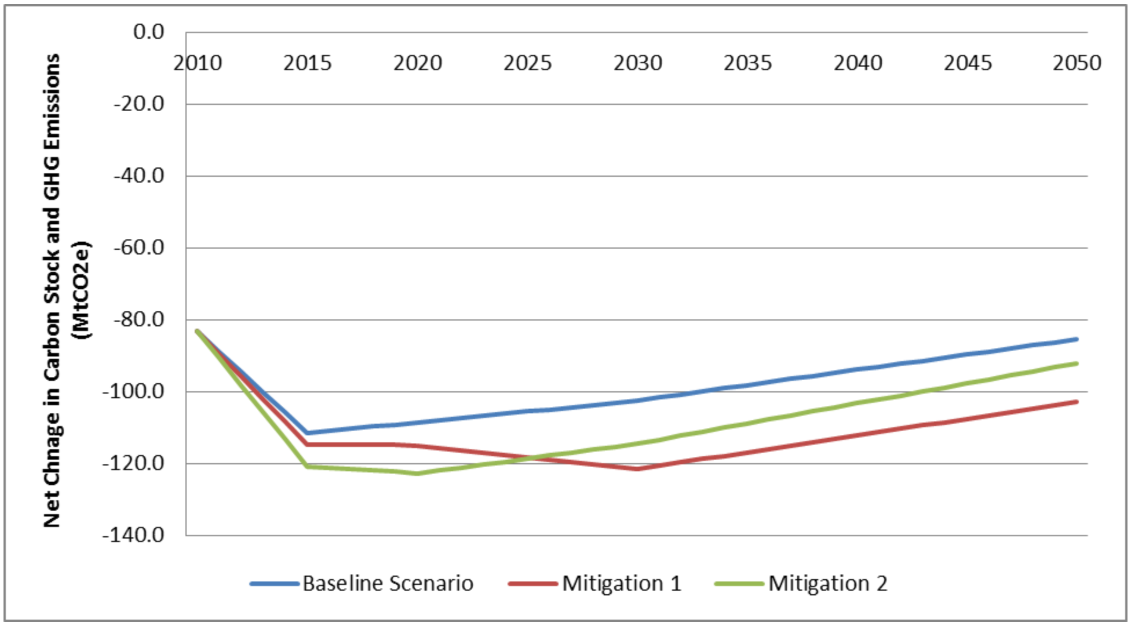
Comparison of Mitigation Potential

A comparison of the mitigation potential of the two measures in the LULUCF sector, with respect to the Baseline Scenario is presented in Table VI. 52 and Figure VI. 8.

Table VI. 52. Comparison of Mitigation Potential between M1 and M2 With Respect to the Baseline Scenario (MtCO$_2$e)

Scenario	2010	2015	2020	2030	2050
Baseline	-83.233	-111.445	-108.670	-102.472	-85.444
Mitigation 1	-83.233	-114.646	-114.994	-121.592	-102.920
M1 Mitigation Potential	**0.000**	**-3.201**	**-6.324**	**-19.120**	**-17.476**
Baseline	-83.233	-111.445	-108.670	-102.472	-85.444
Mitigation 2	-83.233	-120.769	-122.754	-114.546	-92.114
M2 Mitigation Potential	**0.000**	**-9.324**	**-14.084**	**-12.074**	**-6.670**

Figure VI. 8. Comparison of Mitigation Potentials (MtCO$_2$e)



If one has to consider the “timing” of the impact on carbon sink, the M1 option may be of a disadvantage since the full potential to increase the carbon sink can only be realized over a longer timeframe. In comparison, M2 provides greater near-term benefits to the carbon sink. As shown in Table VI. 53, the M2 option has an early lead in increasing the carbon sink in the LULUCF sector. However, over a longer timeframe, the M1 option has the potential to enhance the carbon sink to a greater degree.

Overall, forest protection (Mitigation 1) is projected to have higher mitigation potential than forest restoration and reforestation (Mitigation 2) under the assumptions used in this analysis. In a longer term, the M1 option has the potential to enhance the carbon sink by as much as 2.62 times the amount which the M2 option can provide in 2050 Table VI. 53). However, the combination of the two mitigation options will considerably increase and enhance the carbon sink in the LULUCF sector.

Table VI. 53. Summary of Mitigation Potential ($MtCO_2e$)

Scenario	2010	2015	2020	2030	2050
M1 Potential	0.000	-3.201	-6.324	-19.121	-17.476
M2 Potential	0.000	-9.324	-14.084	-12.074	-6.670
M1/M2 Ratio	**0.000**	**0.343**	**0.449**	**1.584**	**2.620**

Table VI. 54 shows the cumulative net mitigation potential from 2010 to 2050, which substantiates the higher mitigation potential of Mitigation Option 1. Overall, across the time series, Mitigation 1 has a higher net mitigation potential of 1.371 times that of Mitigation 2.

Table VI. 54. Cumulative Net Mitigation Potential ($MtCO_2e$)

Scenario	Cumulative $MtCO_2e$ (2011-2050)
Mitigation 1	527.341
Mitigation 2	384.746
M1/M2 Ratio	***1.371***

Net Costs of Mitigation Options

Table VI. 55 lists the direct costs and benefits of the mitigation options in the forestry sector. As discussed above, the mitigation options used a retrospective systems analysis in which the mitigation options were sequenced according to their initial cost per ton as compared independently to the baseline scenario, then the mitigation options were analyzed again in relation to the baseline scenario and all mitigation options implemented prior in the sequence. As a result, the cumulative mitigation potential of the two forestry mitigation options Table VI. 55 differs slightly from the numbers presented in the above section on GHG mitigation potential.

In this analysis, Mitigation Option 2: Forest Restoration and Reforestation is sequenced as #23 of the 37 economy-wide mitigation options analyzed. Mitigation option 1: Forest Protection is option #25 in the sequence. The results in Table VI. 55 are therefore incremental to the mitigation option that preceded it in the retrospective systems analysis.

Table VI. 55. Mitigation Options in the Forestry Sector – Potential and Net Costs

Sector	Sequence Number of Mitigation Option*	Mitigation Option	Incremental Cost (Cumulative 2011-2050) [Billion 2010 USD] Discounted at 5%	Incremental GHG Mitigation potential (2011-2050) [$MtCO_2e$]	Incremental Cost per Ton Mitigation (2011-2050) [2010 USD] ***without co-benefits***
Symbol			*A*	*B*	*C*
Formula					*(A*1000)/B=C*
Forestry	23	(M2) Forest Restoration and Reforestation	$0.859	405.87	$2.12
	25	(M1) Forest Protection	$5.133	516.91	$9.93
*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.					

Table VI. 55 Column A summarizes the cumulative incremental net costs of each mitigation option, which combines both direct and indirect cost elements. For Forest Protection (M1), the NPV of these direct costs, discounted at five percent and presented in 2010 USD, equals 0.859 billion USD for the 2011 to 2050 timeframe.[41] The net present value of the direct costs of Forest Restoration and Reforestation activities is 5.133 billion USD.

In Table VI. 55 column B, the cumulative GHG mitigation potential of the Forest Protection option totals 516.91 $MtCO_2e$ from 2011 to 2050. As described earlier, the large magnitude of the GHG mitigation potential under this option is attributable to a combination of the reduction in losses of biomass from closed and open canopy forests, combined with the subsequent large accumulation of carbon in those forests as trees age. The protection and conservation of the remaining natural closed and open canopy forest also comes with the conservation of biodiversity and improved resiliency of the head waters of many of the Philippines' watersheds. The GHG mitigation potential of the Forest Restoration and

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[41] Note that for both of these forest mitigation options, some costs were incurred during the period 2011 to 2015 because these programs were initiated after the enabling the EOs took effect in 2011. These early costs were translated into present value terms for 2015, and included in the totals of estimated direct costs.

Reforestation option is considerably lower at a cumulative 405.87 $MtCO_2e$ from 2011 to 2050. Although plantations accumulate carbon at a more rapid rate than older forests, especially in early years, overall carbon accumulation is much lower on average in plantations than in denser, mature closed and open canopy forests.

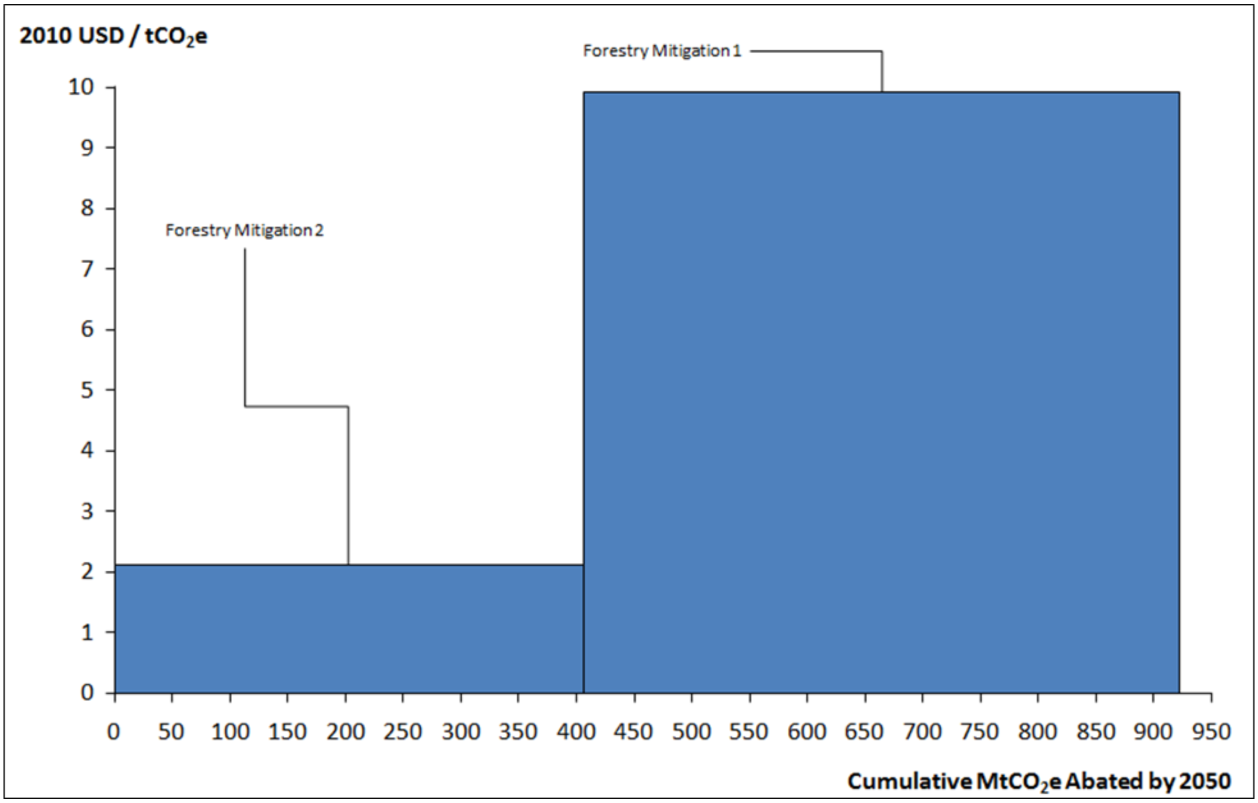
Column C summarizes the cost of mitigation expressed in dollars per ton of CO_2e. For Forest Protection, the *direct* cost of forest mitigation is 9.93 2010 USD per ton, not including the indirect costs incurred for fuels purchased in the energy sector to make up for the loss of fuelwood supplies. For Forest Restoration and Reforestation, the direct cost per ton of GHG mitigation is 2.12 USD.

Due to the linkages between the land use sector and the rest of the economy, however, the impacts of forestry mitigation activities on costs, benefits, and GHG emissions are not limited to the forestry sector, and can result in indirect costs which are incurred as a second-order effect in other sectors of the economy. Because forest mitigation activities can affect the supply of timber, fuelwood, and other non-timber forest products, they can result in interactions with other sectors which can indirectly result in costs, benefits, and GHG emissions incurred by other sectors. The Study Team's analysis shows that incremental changes in the quantity of fuelwood supply associated with the implementation of both forest mitigation options will affect the viability of energy sector mitigation options, such as sustainable biomass and biomass co-firing, and thus result in indirect costs and benefits occurring in the energy sector. Impacts of these mitigation options on the energy sector are described in the Energy Report for the CBA (B-LEADERS, 2015).

VI.4.2.2 Marginal Abatement Cost Curve

Figure VI. 9 shows the marginal abatement cost curve for the forestry mitigation options. As discussed above, both forestry mitigation options result in a positive cost per ton. The Forest Restoration and Reforestation (M2) mitigation option results in significant mitigation potential of more than 405.87 $MtCO_2e$ for 2.12 USD per ton of GHG emissions mitigated. The Forest Protection (M1) option, though resulting in larger net GHG emissions mitigated at 516.91 $MtCO_2e$ relative to M2, also has a relatively higher cost at 9.93 USD per ton of GHG emissions mitigated. Together, the two mitigation options could result in total cumulative emission reductions of about 923 $MtCO_2e$ compared with the 2050 baseline.

Figure VI. 9. Marginal Abatement Cost Curve for Forestry Mitigation Options (2010 USD/MtCO$_2$e)



VI.4.2.3 Co-Benefits Assessment Methods and Results

In this section, the general approaches taken to calculate income generation, human health, energy security, and employment impacts related to the mitigation options for the forestry sector are described and a discussion of the results is provided. The co-benefits analyzed below 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.

Consistent with all the sectoral analyses, the co-benefits have been calculated using the retrospective systems approach described in Sathaye and Meyers (1995), whereby the final emission reduction potential and cost per ton of CO$_2$e for each option are calculated using the marginal emission reductions and costs incurred after the option was added to a prior mitigation option.

The CBA estimated the economic value (i.e., the co-benefit) of the commodities generated by the reforested areas designated for production (under option M2) and of the air quality-related human health impacts of the interactions of the mitigation sector with fuel use for electricity generation in the energy sector (under options M1 and M2). The other impacts were characterized using a series of quantitative indicators as there was insufficient information to estimate their economic value. In subsections below, the methods and results for these impact assessments are described.

Income Generation

Income co-benefits for the forestry sector consist of the potential revenues from forestry and agroforestry production-oriented plantings under the NGP, INREMP, and FMP programs, and other forest project area programs in the M2 mitigation scenario, as previously described. The revenue stream over the 2011 to 2050 time horizon for these programs was estimated.

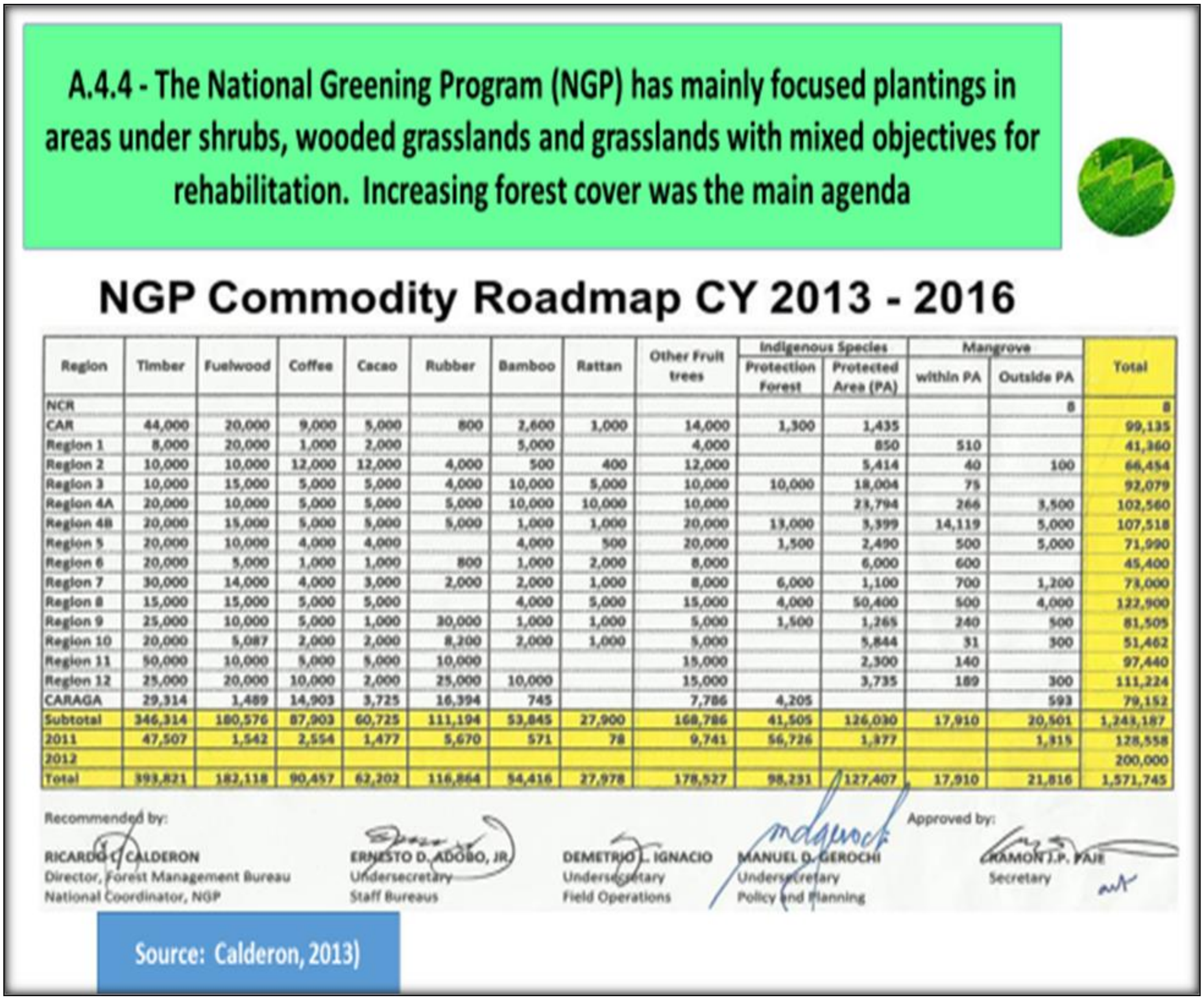
Area Planted for Production

For the NGP plantings, the distribution of plantings between timber, fuelwood, and other agroforestry products is based on information in the NGP Commodity Roadmap presented in Figure VI. 10 (DENR/Calderon, 2013). The NGP Commodity Roadmap provides specific information for how NGP areas were planted in 2011 and the anticipated distribution of plantings for the years 2013-2016. Because the NGP Commodity Roadmap only provides a total area to be planted for 2012, the Study Team used the overall distribution of plantings in the listed categories for these years, 2011 and 2013-2016, and applied that distribution to the area expected to be planted in year 2012.

The additional program efforts and planted areas incorporated in the income co-benefits calculation include:

- ADB-funded INREMP areas, with planned planting of 329,780 ha over 2016-2020 of which 10% (or 33,000 ha) will be planted for timber production;
- JICA-funded FMP area with planned planting of 73,100 ha over 2014-2024 with 80% of the area designated for timber and 20% for fuelwood production, respectively;
- Other projects (by NGOs, grant-funded projects to communities, commercial tenure holders, community tenure holders, holders of reservation areas, etc.) with planned overall planting of 150,000 ha during 2016-2025, of which 50% designated for timber production.

Figure VI. 10. Details of the Timing and Distribution of Actual and Anticipated Plantings under the National Greening Program



A.4.4 - The National Greening Program (NGP) has mainly focused plantings in areas under shrubs, wooded grasslands and grasslands with mixed objectives for rehabilitation. Increasing forest cover was the main agenda

NGP Commodity Roadmap CY 2013 - 2016

Region	Timber	Fuelwood	Coffee	Cacao	Rubber	Bamboo	Rattan	Other Fruit trees	Indigenous Species		Mangrove		Total
									Protection Forest	Protected Area (PA)	within PA	Outside PA	
NCR												8	8
CAR	44,000	20,000	9,000	5,000	800	2,600	1,000	14,000	1,300	1,435			99,135
Region 1	8,000	20,000	1,000	2,000		5,000		4,000		850	510		41,360
Region 2	10,000	10,000	12,000	12,000	4,000	500	400	12,000		5,414	40	100	66,454
Region 3	10,000	15,000	5,000	5,000	4,000	10,000	5,000	10,000	10,000	18,004	75		92,079
Region 4A	20,000	10,000	5,000	5,000	5,000	10,000	10,000	10,000		23,794	266	3,500	102,560
Region 4B	20,000	15,000	5,000	5,000	5,000	1,000	1,000	20,000	13,000	3,399	14,119	5,000	107,518
Region 5	20,000	10,000	4,000	4,000		4,000	500	20,000	1,500	2,490	500	5,000	71,990
Region 6	20,000	5,000	1,000	1,000	800	1,000	2,000	8,000		6,000	600		45,400
Region 7	30,000	14,000	4,000	3,000	2,000	2,000	1,000	8,000	6,000	1,100	700	1,200	73,000
Region 8	15,000	15,000	5,000	5,000		4,000	5,000	15,000	4,000	50,400	500	4,000	122,900
Region 9	25,000	10,000	5,000	1,000	30,000	1,000	1,000	5,000	1,500	1,265	240	500	81,505
Region 10	20,000	5,087	2,000	2,000	8,200	2,000	1,000	5,000		5,844	31	300	51,462
Region 11	50,000	10,000	5,000	5,000	10,000			15,000		2,300	140		97,440
Region 12	25,000	20,000	10,000	2,000	25,000	10,000		15,000		3,735	189	300	111,224
CARAGA	29,314	1,489	14,903	3,725	16,394	745		7,786	4,205			593	79,152
Subtotal	346,314	180,576	87,903	60,725	111,194	53,845	27,900	168,786	41,505	126,030	17,910	20,501	1,243,187
2011	47,507	1,542	2,554	1,477	5,670	571	78	9,741	56,726	1,377		1,315	128,558
2012													200,000
Total	393,821	182,118	90,457	62,202	116,864	54,416	27,978	178,527	98,231	127,407	17,910	21,816	1,571,745

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Source: Calderon, 2013)

Table VI. 56 provides a summary of the distribution of area that is assumed that are planted by year and commodity, through the NGP, INREMP, FMP, and other projects during 2011-2025. Given that the year-by-year information on the INREMP, FMP, and other projects was unavailable, the area planted equally over years falling between the stated milestone years was distributed. Specifically, it was assumed that: INREMP timber plantings will be 6,596 ha annually during 2016-2020; FMP timber plantings will be 6,823 ha annually during 2014-2019 and 3,509 ha annually during 2020-2024; FMP fuelwood plantings will be 1,706 ha annually during 2014-2019 and 877 ha annually during 2020-2024; and other forest projects will plant 7,500 ha of timber annually during 2016-2025. For consistency with the rest of the forestry sector mitigation analysis, it was assumed that the timber plantings consist of 50% fast growing and 50% medium growing tree species. Several additional fruit tree species are introduced in this table, relative to the ones listed in Figure VI. 10. The more refined categorization was based on the detailed NGP planting sites data for 2011-2014 (DENR, 2011).

Table VI. 56. Timing and Distribution of Planting for NGP, INREMP, FMP, and Other Projects Incorporated in the Income Co-benefits Calculation for the M2 Mitigation Option (hectares)

Year	Areas Planted for Production in ha												
	Timber		Fuelwood	Coffee	Cacao	Rubber Tree	Bamboo	Rattan	Jackfruit	Lanzones	Mango	Rambutan	Other Fruit Trees
	Fast growing	Medium growing											
2011	23,754	23,754	1,542	2,554	1,477	5,670	571	78	1,401	1,286	1,303	1,813	3,938
2012	28,709	28,709	26,553	13,189	9,069	17,039	7,934	4,079	3,744	3,435	3,483	4,845	10,522
2013	43,289	43,289	45,144	21,976	15,181	27,799	13,461	6,975	6,070	5,569	5,646	7,854	17,057
2014	46,701	46,701	46,850	21,976	15,181	27,799	13,461	6,975	6,070	5,569	5,646	7,854	17,057
2015	46,701	46,701	46,850	21,976	15,181	27,799	13,461	6,975	6,070	5,569	5,646	7,854	17,057
2016	53,748	53,748	46,850	21,976	15,181	27,799	13,461	6,975	6,070	5,569	5,646	7,854	17,057
2017	10,459	10,459	1,706	-	-	-	-	-	-	-	-	-	-
2018	10,459	10,459	1,706	-	-	-	-	-	-	-	-	-	-
2019	10,459	10,459	1,706	-	-	-	-	-	-	-	-	-	-
2020	8,802	8,802	877	-	-	-	-	-	-	-	-	-	-
2021	5,504	5,504	877	-	-	-	-	-	-	-	-	-	-
2022	5,504	5,504	877	-	-	-	-	-	-	-	-	-	-
2023	5,504	5,504	877	-	-	-	-	-	-	-	-	-	-
2024	5,504	5,504	877	-	-	-	-	-	-	-	-	-	-
2025	3,750	3,750	-	-	-	-	-	-	-	-	-	-	-

Productivity, Yields, and Prices

For these planted areas, the income co-benefit calculation assumes there is a *50% 5-year planting survival rate* and that the *species were re-planted* at the end of their economic lifespan, which is consistent with the assumptions made for the mitigation option analysis earlier in this report. For each species, the production life cycle (maturation, economic life span, and harvest periodicity), yield, and prices were characterized. Table VI. 57 reports these parameters for each species, along with the sources of data. For simplicity, it was assumed that:

- Yields per ha were zero until the species was mature and constant after that;
- Agroforestry species are not harvested for wood at the end of their economic lifespan;
- While productive, the agroforestry species have the same yields as those observed on average at plantations currently used for commercial purposes; and
- Commodity prices were held constant for all species, except timber. Timber price was assumed to grow at 10% per year, which is consistent with the rest of the analysis.

Table VI. 57. Species-specific Assumptions about Productivity and Prices

Species Name	Maturation (years)[1]	Economic lifespan (years) [1]	Productivity per ha[2]	Price (2010 USD)[3][4]	Value per ha (2010 USD)
Timber, fast growing	12	1	150 m3/ha	46 USD/m^3	6,982
Timber, medium growing	22	1	115 m3/ha	46 USD/m^3	5,353
Fuelwood	3	15	25 m3/ha	8 USD/m^3	205
Coffee	3	30	0.74 ton/ha	1379 USD/ton	1,022
Cacao	5	40	0.52 ton/ha	1512 USD/ton	782
Rubber tree	7	30	0.93 ton/ha	1030 USD/ton	960
Bamboo	12	1	150 m3/ha	46 USD/m^3	6,982
Rattan	12	1	150 m3/ha	46 USD/m^3	6,982
Jackfruit	7	25	5.14 ton/ha	260 USD/ton	1,339
Lanzones	4	25	2.82 ton/ha	691 USD/ton	1,944
Mango	8	60	3.97 ton/ha	371 USD/ton	1,476
Rambutan	3	20	2.41 ton/ha	511 USD/ton	1,231
Other fruit trees	5	30	8.68 ton/ha	410 USD/ton	3,565

Notes:

[1] Life cycle assumptions for timber species are based on national consultant information. These assumptions are consistent with those used for mitigation option analysis. Life cycle assumptions for agroforestry species are based on several sources: Department of Agriculture (Year Unknown), GIZ (2012), Watson Brown HSM Ltd (2009). When sources were conflicting, the most conservative assumptions about species productivity (i.e., longer maturation and/or shorter economic lifespan) was relied upon.

[2] Assumptions about productivity (per ha) for timber species are based on consultant information. These assumptions are consistent with those used for the mitigation option analysis. Assumptions about agroforestry species are based on several sources: FAO Statistics Division (2015b) and GIZ (2012).

[3] Data on prices for timber species was obtained from PHIL Forestry Statistics (2013), while data on fuelwood prices was obtained from Department of Environment and Natural Resources (2013). These assumptions are consistent with those used for the mitigation option analysis in the forestry and energy sectors. Data on agroforestry species are based on several sources of latest price information: FAO Statistics Division (2015a) and PAS (2015).

[4] To be consistent with the mitigation option analysis, it was assumed that timber prices will grow at 1% annually, while other prices will stay constant.

Results

Based on these data and assumptions, the species-specific potential revenue streams over 2011-2050 was estimated. The present discounted value (at 5% discount rate) of each revenue stream was computed. These values are reported in Table VI. 58. Overall, the estimated income generation co-benefits for the M2 option were 7.19 billion 2010 USD.

Table VI. 58. Cumulative Forestry and Agroforestry Revenues from Production-Designated Plantings (Billion 2010 USD)

Species Name	Cumulative Revenue over 2011-2050 (discounted to 2015 at 5%, billion 2010 USD)
Timber, fast growing	1.14
Timber, medium growing	0.35
Fuelwood	0.31
Coffee	0.78
Cacao	0.38
Rubber tree	0.77
Bamboo	0.24
Rattan	0.12
Jackfruit	0.22
Lanzones	0.36
Mango	0.23
Rambutan	0.34
Other fruit trees	1.96
Total	7.19

VI.4.2.4 Air Quality-Related Human Health Impacts

The potential marginal impacts on human health associated with the mitigation options in the retrospective analysis is limited to a consideration of impacts on premature mortality associated with exposure to ambient fine particulate matter ($PM_{2.5}$). The potential human health impact of each mitigation option was based on LEAP-generated estimates of the option-specific $PM_{2.5}$ precursor emissions. To assess the premature mortality impact of the air pollutant emissions, the associated ambient $PM_{2.5}$ concentrations was computed and the epidemiological relationships were used to combine this information with estimates of the exposed population sizes and baseline mortality rates. The resulting option-specific impact was quantified in terms of the *incremental change* in the cumulative number of air pollution-related premature deaths (separately for males and females) expected to occur based on the *incremental change* in emissions of air pollutants during 2015-2050. In this framework, a negative value reflects the option resulting in *additional* projected premature deaths. The economic value of the changes in premature mortality was computed using an estimate of the Value per Statistical Life (VSL) and the standard discounting procedures used throughout this assessment. Additional details on estimation of the human health co-benefits are presented in the Appendix.

Table VI. 59 presents the incremental human health impacts calculated for the forestry sector mitigation options. The specific results in Table VI. 59 are affected by the sequence of options and details of the assumptions incorporated in the LEAP model regarding level of energy demand and dispatch within the electrical system (B-LEADERS, 2015). However, the following observations can be made:

- The Restoration and Reforestation option (M2) results in human health disbenefits, because it generates additional fuelwood that can be used as an energy source by households. Given that growing household energy demand is now matched by the available fuelwood and not electricity, there is a year-long delay in the addition of new natural gas power plants. This results in an extra year of electricity generation from coal power plants, which have higher air pollutant emission rates, and increased air pollution-related premature mortality;

- The Forest Protection option (M1) results in human health benefits, because under this option households are expected to replace fuelwood by electricity as an energy source. This increases the electricity demand, which requires additions of new natural gas power plants sooner. In essence, option M1 is "undoing" option M2's impact on the power sector and human health;

- Females are expected to experience slightly less than 50% of the total health benefit (or disbenefit) because their baseline mortality rates are lower than the baseline mortality rates for males.

Table VI. 59. Incremental Human Health Impact of the Proposed Mitigation Options, Cumulative Impact during 2015-2050

Sector	Mitigation Option Sequence	Mitigation Option Name	Incremental Present Discounted Value [2015-2015] (Million 2010 USD, 5% Discount Rate)	Incremental Cases of Premature Death [2015-2015]	Incremental Cases of Premature Death [2015-2015] (Females)
Forestry and Energy	23	Forest Restoration and Reforestation	-195	-210	-72
Forestry and Energy	25	Forest Protection	158	173	Not presented[1]

Notes:

[1] The sampling routine used to calculate this result returned an unstable estimate, so it is not presented. The result would have the same sign as that for the incremental cases while being smaller in magnitude.

Important caveats to interpreting these results 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 result in Table VI. 59;

- Forestry mitigation options will impact the extent to which fuelwood is used by households, thereby affecting indoor and outdoor air quality. While the information was insufficient to quantify the effects of changes in emissions of these sources, several qualitative observations can be made. First, the Restoration and Reforestation option (M2) is expected to increase household fuelwood use, thereby increasing air pollution and generating human health dis-benefits. Thus, the team expect that this option results in greater premature mortality increases than those quantified in Table VI. 59. Second, because fuelwood burning is performed predominantly by females (e.g., cooking), women would likely be disproportionately exposed to the additional fuelwood burning emissions. Thus, option M2 could generate disproportionate dis-benefits for females. Third, the Forest Protection option (M1) will reduce fuelwood use by households, thereby reducing the harmful effects of their exposure to air pollution, which will benefit females disproportionately.

The Appendix presents additional caveats related to the health impact assessment methods that were used.

VI.4.2.5 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 combination 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 VI. 60 presents the average annual incremental impact of the two forestry mitigation options on the four energy security indicators for the period 2015-2050.

Table VI. 60. Incremental Changes in Energy Security Indicators due to the Proposed Mitigation Options, Average Annual Incremental Impact during 2015-2050

	Mitigation Option Name		Average Annual Incremental Impact 2015-2050 [1]			
Sector		Mitigation Option Sequence	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]
Forestry and Energy	Forest Mitigation 2 – Forest Restoration and Reforestation	23	-18.90	36	-28	0.02
Forestry and Energy	Forest Mitigation 1 – Forest Protection	25	-19.10	-127	102	-0.07

Notes:

[1] All indicators are calculated in LEAP. Results reflect the average of annual results from 2015-2050 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 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).

In reviewing the results in Table VI. 60 it is critical to remember the incremental nature of the analysis, the 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). Nevertheless, it is not surprising that the Forest Restoration and Reforestation option (M2), which involved energy generation outside of the formal electric grid, has a positive impact on energy security, because it reduces energy demand.

VI.4.2.6 Power Sector Employment Impacts

In this section, the general approach taken to assess power sector employment impacts and caveats to interpreting available option-specific results is described. The basic indicator used to capture potential employment impacts is the *job-year,* defined as “full-time employment for one person for a duration of one year” (Wei et al., 2010 p. 7). Estimates of the net change in job-years associated with the mitigation options were calculated using results from Wei et al. (2010). Wei et al. conducted a literature review and synthesis of results that quantified the employment impacts of *new* power projects over a defined project lifetime. By accounting for the power generation potential and anticipated use of the project, the Wei et al. (2010) results are expressed in terms of the average number of job-years per GWh. The CBA incorporates the Wei et al. (2010) results using the job-years/GWh factors in Table VI. 61.

Table VI. 61. Average Job-Years/GWh in the Power Sector by Type of Power Generation[42]

Power Generation Technology	Average Job-Years/GWh of Generation*
Solar Photovoltaics	0.87
Landfill Gas	0.72
Large Hydro	0.27
Small Hydro	0.27
Geothermal	0.25
Agricultural Waste Digestion	0.21
Biomass	0.21
MSW Digestion	0.21
MSW Incineration	0.21
Ocean Thermal	0.17
Wind	0.17
Nuclear	0.14
Circulating Fluidized Bed Combustion (CFBC) Coal	0.11
Natural Gas Combined Cycle	0.11
Subcritical Pulverized Coal	0.11
Supercritical Pulverized Coal	0.11
Ultrasupercritical Pulverized Coal	0.11

*** Assumptions:**

- Wei et al. (2010) provided job-years factor for *Small Hydro*. The same factor was assigned to *Large Hydro.*
- *MSW Incineration*, *MSW Digestion*, and *Agricultural Waste Digestion* use the *Biomass* job-years factor.
- *Ocean Thermal* uses the *Wind* job-years factor.
- All *Coal* types have the same job-years factor based on the belief they are a close match for each other.

Using the factors in Table VI. 61 and power generation projections by source and year calculated using LEAP, employment in the power sector for the different mitigation options over the period 2015-2050 was calculated in terms of *job-years*. The incremental impact of each mitigation option on job-years was

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[42] Source: Results based on Wei et al., 2010

then calculated by subtracting the calculated job-years for the previous mitigation option from the result for the mitigation option under consideration.

The scope of this analysis is constrained. In quantifying potential employment impacts from implementing the mitigation options, the net change that would result in the power sector was considered. Employment changes in other sectors or elsewhere in the economy that are directly and indirectly affected with implementation were not accounted for as they are beyond the scope of the analysis. Table VI. 62 presents our estimates of the incremental change in the power sector employment indicator for each mitigation option.

Table VI. 62. Incremental Changes in Power Sector Job-Years for the Proposed Mitigation Options, Cumulative Impact from 2015-2050

Sector	Mitigation Option Name	Mitigation Option Sequence	Incremental Job-Years Impact (Unrounded Cumulative Job-Years 2015-2050)
Forestry and Energy	Forest Mitigation 2 – Forest Restoration and Reforestation	23	**-1,020**
Forestry and Energy	Forest Mitigation 1 – Forest Protection	25	**3,417**

The potential incremental power sector employment impacts presented in Table VI. 62 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;
- 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;
- 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.

VI.4.2.7 Net Present Value

Table VI. 63 summarizes the GHG abatement potential for each forestry mitigation option (Column A), cost per ton of CO_2e mitigation (Column B), and co-benefits per ton of CO_2e mitigation (Column C) for the 2011-2050 analysis period. In addition, for each option, the table presents the net cost per ton of CO_2e mitigation after incorporating the co-benefits (Column D) as well as the NPVexcluding the value of GHG reduction (Column E). As shown in Table VI. 63, the co-benefits per ton of CO_2e mitigated for the Forest Restoration and Reforestation option and the Forest Protection (M1) option are 17.23 2010 USD and 0.31 2010 USD, respectively. Notably, for the option M2, the net cost per ton of CO_2e mitigation, which factors in the co-benefits, is negative. This implies that this option generates social welfare gains even without accounting for the benefits of GHG reductions.

Table VI. 63. Net Present Value of Mitigation Options in the Forestry Sector during 2011-2050

Sequence Number of Mitigation Option[1]	**Mitigation Option**	**GHG Mitigation Potential [2011-2050] ($MtCO_2e$)**[3]	**Cost per Ton CO_2e Mitigation [2011-2050] (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]	
		A	*B*	*C*	*D = B+C*	*E = –D * A/1000*
23	(M2) Forest Restoration and Reforestation	405.87	2.12	-17.23	-15.11	6.13
25	(M1) Forest Protection	516.91	9.93	0.31	9.62	-4.97

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 5%.

[3] The GHG mitigation potential is a total reduction in GHG emissions that is expected to be achieved by the option during 2011-2050.

[4] The co-benefits for the forestry sector include: (i) human health benefits due to reduced air pollution from electricity generation; and (ii) for option M2, sales of commodities generated by forest and agroforestry plantations designated for production.

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

[6] Negative value indicates net loss in social welfare, cumulative over 2011-2050.This loss does not account for the non-monetized benefits of GHG reductions.

APPENDIX 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 VI. 64 shows the data sources and assumptions used to generate these projections, while Table VI. 65 presents historical and projected values in select years that were used in the analysis. Table VI. 66 lists historical exchange rates and inflation rates used for inter-temporal and cross-country currency conversions.

Table VI. 64. Data Sources and Assumptions Used for Projections of Population, GDP, Economic Sector-Specific Value Added, and Fuel Price

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

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

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

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

Table VI. 65. Data and Projections of Population, GDP, Economic Sector-Specific Value Added, and Fuel Price in Select Historical and Baseline Years

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

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

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

Table VI. 66. Historical Exchange Rates and Inflation Rates used to Build the Baseline

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

Notes:

[1] Source: Bangko Sentral Ng Pilipinas (http://www.bsp.gov.ph/statistics/statistics_online.asp -> Online Statistical Interactive Database -> Exchange Rates -> Philippine Peso per US Dollar). Accessed 12 March 2015.

Bankers Association of the Philppines (BAP) reference rate from December 13,1984 to August 3,1992 weighted average rate. Philippine Dealing System (PDS) starting August 14,1992 From: Reference Exchange Rate Bulletin, TD-BSP

[2] Sources:

1990-2011: Bangko Sentral Ng Pilipinas (http://www.bsp.gov.ph/statistics/statistics_online.asp -> Online Statistical Interactive Database -> Prices -> Consumer Price Index, Inflation Rate, and Purchasing Power of the Peso). Accessed 12 March 2015.

2012-2014: http://web0.psa.gov.ph/statistics/survey/price/summary-inflation-report-consumer-price-index-2006100-february-2015. Accessed 12 March 2015.

[3] Sources:

1990-2013: World Bank World Development Indicators (http://data.worldbank.org/indicator/NY.GDP.DEFL.KD.ZG). Accessed 12 March 2015.

2014: US. Bureau of Economic Analysis, Gross Domestic Product: Implicit Price Deflator [GDPDEF], retrieved from

Year	Philippine Peso per US Dollar[1]	Philippine Peso Annual Inflation Rate (%)[2]	US Dollar Annual Inflation Rate (%) [3]
FRED, Federal Reserve Bank of St. Louis https://research.stlouisfed.org/fred2/series/GDPDEF/, March 25, 2015.			

APPENDIX VI.6 HEALTH CO-BENEFITS METHODS

B-LEADERS team estimated the human health co-benefits of the mitigation options according to the basic framework presented in Figure VI. 11:

- Emissions from the LEAP model are converted to outdoor air pollution concentrations. The emissions from the LEAP Baseline case inform the baseline concentration estimates and the predicted change in emissions in each mitigation scenario is translated to air quality change. We focus on concentrations of fine particulate matter ($PM_{2.5}$), which has dominated cost-benefit analyses of reduced air pollution.[43]

- The health benefits of reduced exposure to outdoor air pollution come from reduced risk of morbidity and premature mortality. The risk reductions are calculated using research literature-based epidemiological relationships known as “exposure-response functions”. In this analysis, we estimate the co-benefits associated with reduced risk of premature mortality.[44]

- To express the social benefit of fewer premature deaths in monetary terms, we rely on the concept of the aggregate willingness to pay (WTP) for small reductions in annual mortality risk by a population of a given size. We estimate the WTP is as a product of the number of premature deaths avoided due to a mitigation option and the value per statistical life (VSL), a risk reduction-normalized WTP estimate derived from the research literature.

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

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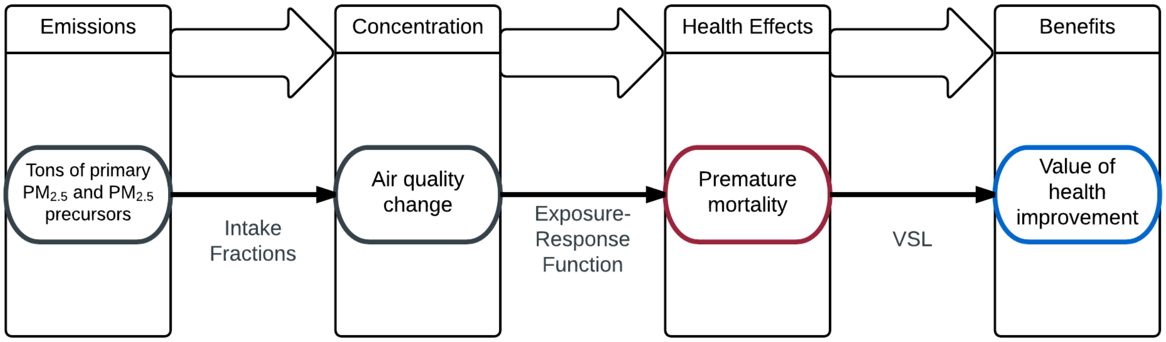
[43] Ozone is another important pollutant, but modeling ozone levels is outside of the scope of this analysis. Furthermore, the Global Burden of Disease (GBD) Study found that deaths attributable to ambient ozone levels were less than 5% the number of deaths attributable to ambient $PM_{2.5}$ levels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

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

Figure VI. 11 General Framework for Health Co-Benefits Calculation



VI.5.1 Emissions

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

ANNEX VI.1.2.1 Transportation sector emissions

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

We followed the same general methods for calculating conventional pollutant emissions for on-road transportation as those described for GHG emissions. We used emission factors from the ICCT Roadmap Model (ICCT 2014). A report by the Asian Development Bank (ADB, 1992) was the only resource providing emission factor information specific to the Philippines, and presents emission factors that do not likely apply to most vehicles currently on the road, and did not include emission factors for methane, nitrous oxide, or black carbon. We used emission factors from the ICCT Roadmap Model, and used the ADB report as a reference to check against the emission factors for uncontrolled vehicles. Where there were large discrepancies between emission factors reported by ADB (1992) for a specific pollutant or mode and those used in the Roadmap, the emission factors were adjusted using a third source, the zero-mile emission rates used in the ICCT India Model (Bansal and Bandivadekar, 2013). In some cases, additional adjustments were made to fill gaps for relevant pollutants and vehicle fuel types. Adjustments by mode, fuel type and pollutant are shown in Table VI. 67.

Table VI. 67. Selection of Road Vehicle Emission Factors

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

KEY:

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

\- No change to ICCT Roadmap Model Emission Factors

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

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

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

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

ANNEX VI.1.2.2 Energy sector emissions

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

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

VI.5.2 Concentrations

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

ANNEX VI.1.2.1 Baseline concentrations

The exposure-response function used to estimate the change in health requires an estimate of the baseline $PM_{2.5}$ concentration and the concentration for each mitigation option. We estimate the baseline ambient $PM_{2.5}$ concentrations using both measured data and modeled data, the latter using the previously discussed modeled emissions from the transportation and energy sectors as a key input. Since the annual average concentration of $PM_{2.5}$ varies significantly between rural areas and urban areas, we model concentrations separately for rural and urban areas. For rural areas, baseline exposure integrates measured concentrations (see Table VI. 68) and changes from the power sector only. The effects of transportation in rural areas are minor and dominated by secondary $PM_{2.5}$ formation, which we are not modeling for transport. For urban areas, baseline exposure is informed by measured concentrations and the contribution of the transportation and power sectors. A single baseline urban exposure is assumed for energy sector impacts, while transportation impacts assume two baselines: one average concentration for major cities in the Philippines and a separate baseline concentration for Metro Manila.

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

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

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

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

There are limited data reporting measurements of $PM_{2.5}$ in the Philippines for use as $C_{Measured,2010}$ in Equation 1 above. Three measurements were available monitoring sites for the year 2010 (Cities Act 2010), shown in Table VI. 68 and two additional studies provided supplementary measurements from previous years. A value of 35 µg/m^3 was assumed for Manila, an average of monitoring data and concentrations reported in supplementary studies (Cities Act 2010, Oanh et al. 2012). For urban areas where there was no measurement data, a default value of 15 µg/m^3 was assumed. For rural areas, a $PM_{2.5}$ concentration of 9.5 µg/m^3 was taken from Oanh et al. (2012).

Table VI. 68. Urban and rural measurements of $PM_{2.5}$ concentrations (µg/m^3)

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

ANNEX VI.1.2.2 Converting emissions to concentrations using intake fractions

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

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

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

Equation 3 shows that intake fraction is specific to a population of size P, with breathing rate Q. Once the value of the intake fraction has been calculated, and the population and breathing rate are known, the equation can be re-arranged and solved to directly give the relationship between total emissions E and concentration C. We keep this ratio of unit of concentration per unit emissions fixed over time, and use it to calculate the air pollution concentration for each mitigation option.[45]

ANNEX VI.1.2.3 Transport sector intake fractions

The set of intake fractions (iFs) used for on-road vehicles were developed for major urban areas worldwide, and include 30 specific to the Philippines (Apte et al. 2012). These intake fractions apply only to conserved pollutants like primary $PM_{2.5}$, not pollutants that undergo significant transformation in the atmosphere, like NOx and SO_2. We used these emission factors for the 18 largest cities in the Philippines, as we had reliable population projections for these cities. As described above, the intake fractions were divided by the relevant city populations (Angel et al. 2010, as cited in Apte et al. 2012) and a breathing rate of 5292.5 m^3/year to derive the ratio of unit concentration per unit emissions for each city, shown in Table VI. 69. Variation in these values across cities occurs due to differences in city size, as well as meteorological factors such as average wind speed. In a city with a larger footprint, emissions are distributed over a larger area and so the ratio of concentration to emissions is lower. For example, the ratio is lowest in Metro Manila, which has a footprint of about 900 km^2 compared to an average of 100 km^2 across the other cities (Angel et al. 2010). However, a low ratio should not be understood to indicate a low impact; in fact, because of the large share of emissions and the large population in Manila, it is modeled to have the largest share of transportation-related health impacts.

Table VI. 69. Concentration-to-emissions ratio used for 18 largest cities in the Philippines

City	Concentration-to-emissions ratio (ug/m^3 change per kiloton emitted)

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

Metro Manila	1.4
Lipa City	14.3
Butuan	19.8
Batangas City	9.5
Iligan	25.2
Cotabato	8.4
Baguio City	5.6
Angeles City	3.3
Mandaue City	11.2
Basilan City (including City of Isabela)	11.2
Lapu-Lapu City	11.2
Iloilo City	11.9
Bacolod	6.8
General Santos City	7.0
Cagayan de Oro City	10.5
Zamboanga City	17.4
Cebu City	2.5
Davao City	5.3

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

ANNEX VI.1.2.4 Energy sector iFs

For the energy sector, three iFs are used, one for primary $PM_{2.5}$ (6×10^{-7}), one for secondary $PM_{2.5}$ from SO_2 (2 x 10-7), and one for secondary $PM_{2.5}$ from NO_2 (6×10^{-8}). These iFs are based on a study of exposure to energy sector emissions in the US from (Levy et al. 2003). The resulting concentration-to-emissions ratios are shown in Table VI. 70. The concentration change is assumed to occur throughout the country.

Table VI. 70. Concentration-to-emissions ratio used for the energy sector

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

ANNEX VI.1.2.5 Disaggregating national transportation emissions to urban areas

As the on-road intake fractions only apply to urban areas, the emissions outputs from the LEAP model must also be scaled to the urban level. The share of national emissions occurring in Metro Manila ($Share_{MM}$) was estimated for each mode based on the national share of vehicle registrations within the national capital region. Less information on registration share was available for the 17 remaining cities. The cumulative share of national emissions occurring in those cities and excluding Metro Manila (urban share without Manila, or $Share_{UR\text{-}M}$) was estimated from the share of population and highway infrastructure in urban areas following a methodology applied and described previously by Chambliss et al. (2013).The urban share for Metro Manila and the combined share across the other 17 cities are given in Table VI. 71. $Share_{UR\text{-}M}$ is further subdivided across each of the 17 cities based on population.

Table VI. 71. Share of national emissions in Metro Manila and aggregate of 17 largest cities in the Philippines (excluding Metro Manila)

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

VI.5.3 Health Impacts

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

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

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

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

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

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

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

VI.5.4 Valuation

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

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

Equation 4. Benefit transfer equation

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

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

APPENDIX VI.6 REFERENCES

ANNEX VI.6.1 General

Asian Development Bank (ADB). (2015). Low-Carbon Scenario and Development Pathways for the Philippines. Technical Report Submitted Under Asian Development Bank TA-7645. 2015.

Berkman International, Inc., GHG Management Institute, and International Institute for Sustainable Development. (2015). Revised First Interim Report: Sub-Contract for the Development of Nationally Appropriate Mitigation Actions (NAMAs). Report to United Nations Development Program.

Building Low Emission Alternatives to Develop Economic Resilience and Sustainability (B-LEADERS) Project (2015): Philippines Mitigation Cost-Benefit Analysis: Energy Sector Results.

Climate Change Commission (2014). Second National Communication to the United Nations Framework Convention on Climate Change: Philippines, December 2014.

Intergovernmental Panel on Climate Change (IPCC) (2006)2006 IPCC Guidelines for National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change. 2006 Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds).

Intergovernmental Panel on Climate Change (IPCC) (2003). Penman J., Gytarsky, M., Hiraishi T., Krug T., Kruger D., Pipatti R., Buendia L., Miwa K., Ngara T., and Tanabe K. (Eds). Good Practice Guidance for Land Use, Land-Use Change and Forestry. Institute for Global Environmental Strategies, Hayama, Japan

Sathaye, J., & Meyers, S. (1995). Greenhouse Gas Mitigation Assessment: A Guidebook. Springer Netherlands.

The United Nations Framework Convention on Climate Change (UNFCCC) (2006). Training Handbook on Mitigation Assessment: Module 5.1 – Mitigation Methods and Tools in the Energy Sector. 2006.

Wei, M., S. Padtadia, and D.M. Kammen. Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US?. Energy Policy 38(2) 919-932.

ANNEX VI.6.2 Forestry

Bensel, T.G. & Elizabeth M. Remedios (2002). "Woodfuel consumption and production in the Philippines: a desk study," FAO Bangkok, unpublished report.

Borner, J. and S. Wunder (2008). “Paying for avoided deforestation in the Brazilian Amazon: from cost assessment to scheme design,” International Forestry Review 19(3): 496-511.

Carandang, A., L. Bugayong, P. Dolom, L.Garcia, M. Villanueva, and N. Espiritu, 2012. Analysis of Key Drivers of Deforestation and Forest Degradation in the Philippines. Forestry Development Center, University of the Philippines Los Banos - College of Forestry and Natural Resources. Funded by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

Climate Change Commission. (2011). Current Status of the Climate Change Mitigation and Adaptation. Manila: Republic of the Philippines. Retrieved from http://www.conference.tgo.or.th/download/2011/workshop/190811/PPT/07_ASEAN.pdf.

Climate Change Commission. (2011).The Philippines Climate Change Action Plan 2011-2028. Manila: Republic of the Philippines.

Department of Agriculture. (Year Unknown) Philippine Agribusiness Investment Opportunities by Department of Agriculture (http://www.dole.gov.ph/files/Philippine%20Agribusiness%20Investment%20Opportunities%20by%20Department%20of%20Agriculture%20.pdf)

Department of Environment and Natural Resources (DENR), 2013 Philippine Forestry Statistics, Table 4.10 MONTHLY RETAIL PRICES OF FUELWOOD AND CHARCOAL: 2013 (http://forestry.denr.gov.ph/PFS2013.pdf)

DENR, 2011. National Greening Program (Agroforestry). Retrieved from: (1) http://ngp.denr.gov.ph/index.php/example-pages/articles/152-the-commodity-roadmap-and-the-ten-most-planted-species and (2) http://ngp.denr.gov.ph/index.php/site-map/ngp-commodity-road-map-2013-2016

DENR, 2011. Executive Order 23: Towards a Greener Philippines," http://www.denr.gov.ph/news-and-features/features/93-eo-23-renewing-hopes-for-sustainable-forestry-in-the-philippines-.html

DENR, Forest Management Bureau (FMB), 2013. Revised Master Plan for Forestry Development (2013-2028). http://forestry.denr.gov.ph/MPFD.htm

DENR, Forest Management Bureau (FMB) (2013). Philippine Master Plan for Climate Resilient Forestry Development.

DENR GAA Appropriations, 2014.

Department of Agriculture, Bureau of Soil and Water Management. Elevation Map of the Philippines http://www.apipnm.org/swlwpnr/reports/y_ta/z_ph/phmp231.htm

Department of Agriculture, Bureau of Soil and Water Management. Soil Map of the Philippines http://www.apipnm.org/swlwpnr/reports/y_ta/z_ph/phmp231.htm

Food and Agriculture Organization (FAO) Statistics Division 2015a. Annual Producer Prices for Philippines. Retrieved on 09 June, 2015

FAO Statistics Division 2015b. Crop Yields for Philippines. Retrieved on 09 June, 2015

FAO Statistics Division 2015a. Annual Producer Prices for Philippines. Retrieved on 09 June, 2015

FAO Statistics Division 2015b. Crop Yields for Philippines. Retrieved on 09 June, 2015

FAO, 2009. State of the World's Forests. ftp://ftp.fao.org/docrep/fao/011/i0350e/i0350e01.pdf

FAO, 2010. http://www.fao.org/docrep/w7730e/w7730e0c.htm

FAO, 2010. FRA 2010 – Country Report, Philippines. FAO, Rome ,Italy.

FAO, 2009. “Criteria and Indicators for Sustainable Woodfuels: Case Studies from Brazil, Guyana, Nepal, Philippines and Tanzania.” http://www.fao.org/docrep/012/i1321e/i1321e08.pdf).

Fisher, B. et al. (2011). Implementation and opportunity costs of reducing deforestation and forest degradation in Tanzania, Nature Climate Change, Vol. 1: 161-164

FMB, 2015. Consultation on 6-8 July 2015, Clark, Pampanga.

Forest Trends, April 2011. BASELINE STUDY 3, VIETNAM: Overview of Forest Governance and Trade. Available at: http://www.euflegt.efi.int/documents/10180/23308/Baseline+Study+3,%20Vietnam/73bea271-0a2e-4ecb-ac4e-f4727f5d8ad9

Gibbs, H. et al. (2010). “Tropical forests were the primary source of new agricultural data in the 1980s and 1990s,” Proceedings of the National Academy of Sciences 107(38): 16732-16737.

GIZ.2012. Economic-analysis-agroforestry-crops-Panay.pdf

Grieshop, Andrew P., Julian D. Marshall, and Milind Kandlikar. 2011. “Health and Climate Benefits of Cookstove Replacement Options.” Energy Policy 39 (12): 7530-42. doi:10.1016/j.enpol.2011.03.024.

Iowa State (2008). Biomass Measurements and Conversions. https://www.extension.iastate.edu/agdm/wholefarm/pdf/c6-88.pdf

Kindermann, G. et al. (2008). “Global cost estimates of reducing carbon emissions through avoided deforestation,” Proceedings of National Academy of Sciences 105 (30): 10302–10307.

Klassen, Arthur. Dec. 2010. Domestic demand: the black hole in Indonesia’s forest policy. ETFRN News 52.

Lasco, R. et al. (2013). “Lessons from Early REDD+ Experiences in the Philippines,” International Journal of Forestry Research, Vol. 2013, 12pp.

Lasco, R. et al. (2013). “Reducing emissions from deforestation and forest degradation plus (REDD+) in the Philippines: will it make a difference in financing forest development?” Mitigation and Adaptation Strategies for Global Change (2013) 18:1109–1124.

Lasco, R. et al. (2011). “An Assessment of Potential Benefits to Smallholders of REDD+ Components in the Philippines,” Annals of Tropical Research, 33(1): 31–48.

Naidoo, R. and T. Ricketts (2006). “Mapping the Economic Costs and Benefits of Conservation,” PLoS Biology 4(11): 2153-2163.

NAMRIA (2014). Land and Forest Cover data.

New Forests - September 2012. “Hardwood Timber Supply & Demand in Asia: An Opportunity for Hardwood Plantation Investment,” V1.2

PAS. 2015. Fruits: Farmgate Prices by Geolocation, Commodity, Period and Year. Retrieved on June 7, 2015 from http://countrystat.bas.gov.ph/?cont=10&pageid=1&ma=K20PRFPC

Prasetyo, E., (2013). “Converting or Conserving the Forests: A Cost-Benefit Analysis of Implementing REDD in Indonesia,“ Columbia University, School of Public and International Affairs, May 2013.

Phelps, J. et al., (2013). “Agricultural intensification escalates future conservation costs,” Proceedings of the National Academy of Sciences 110 (19): 7601–7606.

Philippine Agricultural Statistics. 2015. Fruits: Farmgate Prices by Geolocation, Commodity, Period and Year. Retrieved on June 7, 2015 from http://countrystat.bas.gov.ph/?cont=10&pageid=1&ma=K20PRFPC

Philippine Forestry Statistics, 2013. Table 4.02, QUARTERLY DOMESTIC PRICES OF LOCALLY PRODUCED LOGS, PLANTED: 2013 http://greenwoodresources.com/wp-content/uploads/2014/06/Long-TermOutlookforTimberPrices.pdf

Philippine Statistics Authority. http://web0.psa.gov.ph/statistics/census/population-and-housing

Sibucao, Alejandrino Jr. et al. (2014) "Philippine Forest Resource Accounting and Valuation (FRAV) Study". FMB-DENR- Timber Harvest 2010 and Deforestation Rates.

Sibucao, Alejandrino R. Jr. et al. (2013). "Determining the Supply and Consumption of Wood in the Philippines Using Roundwood Equivalent (RWE) Analysis."

Stenberg, L. and M. Siriwardana, (2008). “Deforestation in the Philippines: An economic assessment of government policy responses,” Environment Research Journal 2 (4): 335-377.

Suarez, R. and P. E. Sajise, (2010). “Deforestation, Swidden Agriculture and Philippine Biodiversity,” Philippine Science Letters (3)1: 91-96.

Union of Concerned Scientists (2014). “Deforestation Success Stories: Tropical Nations Where Forest Protection and Reforestation Policies Have Worked,” Authored by Boucher, D. et al. June 2014.

U.S. Department of Energy, National Renewable Energy Laboratory; Philippines Annual Rainfall Map.

Watson Brown HSM Ltd, 2009 (http://www.wb-hsm.com/NaturalRubber.htm)

The World Bank, April 2009. Forest Carbon Partnership Facility: Estimating the Costs of REDD at the Country Level, Version 2. Authored by B. Bosquet and S. Pagiola.

ANNEX VI.6.3 Health Impacts Co-Benefits

Anenberg, S. C., Shindell, D., Amann, M., Faluvegi, G., Klimont, Z., Janssens-Maenhout, G., ... & West, J. J. (2012). Global air quality and health co-benefits of mitigating near-term climate change through methane and black carbon emission controls.

Angel, S., Parent, J., Civco, D., Blei, A., and Potere, D. (2010). A Planet of Cities: Urban Land Cover Estimates and Projections for All Countries, 2000-2050. Lincoln Institute of Land Policy Cambridge, MA. Retrieved from http://www.alnap.org/pool/files/1861-1171-angel-iii-final.pdf

Apte, J. S., Bombrun, E., Marshall, J. D., and Nazaroff, W. W. (2012). Global Intraurban Intake Fractions for Primary Air Pollutants from Vehicles and Other Distributed Sources. Environmental Science & Technology, 46(6), 3415–3423. http://doi.org/10.1021/es204021h

Asian Development Bank (ADB) (2015). 43207-013: Market Transformation through Introduction of Energy-Efficient Electric Vehicles Project. Accessed 18 Mar 2015 at http://adb.org/projects/details?proj_id=43207-013&page=overview

Asian Development Bank (1992) Final Report for Vehicle Emission Control Planning in Metro Manila, July, ADB T.A. No. 1414-Philippines

Bansal, G, and Bandivadekar, A (2013). India's vehicle emissions control program. The International Council on Clean Transportation. Retrieved from http://theicct.org/indias-vehicle-emissions-control-program

Burnett, R. T., Pope, C. A., III, Ezzati, M., Olives, C., Lim, S. S., Mehta, S., … Cohen, A. (2014). An Integrated Risk Function for Estimating the Global Burden of Disease Attributable to Ambient Fine Particulate Matter Exposure. Environmental Health Perspectives. http://doi.org/10.1289/ehp.1307049

Castillo, J. (2010). Estimación de los beneficios en salud asociados a la reducción de la contaminación atmosferica en Bogotá, Colombia. Universidad de Los Andes, 26.

Chambliss, S., Miller, J., Facanha, C., Minjares, R., and Blumberg, K. (2013). The impact of stringent fuel and vehicle standards on premature mortality and emissions. The International Council on Clean Transportation.

Cities Act (2010). Clean Air Asia Database; Philippines Air Quality Profile 2010 Edition, Clean Air Initiative for Asian Cities.

Cohen, D.D., Stelcer, E., Santos, F.L., Prior, M., Thompson, C., and Pabroa P. (2009). Fingerprinting and source apportionment of fine particle pollution in Manila by IBA and PMF techniques: A 7-year study. X-Ray Spectrometry 38(1): 18-25.

Crawford-Brown, D., Barker, T., Anger, A., & Dessens, O. (2012). Ozone and PM related health co-benefits of climate change policies in Mexico. Environmental Science & Policy, 17, 33–40. doi:10.1016/j.envsci.2011.12.006

Department of Environment and Natural Resources (DENR) (2011). Tracking Greenhouse Gases: An Inventory Manual.

Doucouliagos, H., Stanley, T. D., and Viscusi, W. K. (2014). Publication selection and the income elasticity of the value of a statistical life. Journal of health economics, 33, 67-75.

Garg, A. (2011). Pro-equity Effects of Ancillary Benefits of Climate Change Policies: A Case Study of Human Health Impacts of Outdoor Air Pollution in New Delhi. World Development, 39(6), 1002–1025. doi:10.1016/j.worlddev.2010.01.003

Hammitt, J.K. and Robinson, L.A. (2011). The Income Elasticity of the Value per Statistical Life: Transferring Estimates between High and Low Income Populations. Journal of Benefit-Cost Analysis 2(1): 1. Retrieved from http://www.bepress.com/jbca/vol2/iss1/1

Hoveidi, H. (2013). Cost Emission of Pm10 on Human Health Due to the Solid Waste Disposal Scenarios, Case Study; Tehran, Iran. Journal of Earth Science & Climatic Change, 04(03). doi:10.4172/2157-7617.1000139

Humbert, S., Marshall, J. D., Shaked, S., Spadaro, J. V., Nishioka, Y., Preiss, P., … Jolliet, O. (2011). Intake Fraction for Particulate Matter: Recommendations for Life Cycle Impact Assessment. Environmental Science & Technology, 45(11), 4808–4816. http://doi.org/10.1021/es103563z

International Energy Agency (IEA) (2012). Energy Technology Perspectives 2012. Organisation for Economic Co-operation and Development, Paris. Retrieved from http://www.oecd-ilibrary.org/content/book/energy_tech-2012-en.

Institute for Health Metrics and Evaluation (IHME) (2013). Global Burden of Disease Study 2010. Philippines Global Burden of Disease Study 2010 (GBD 2010) Results 1990-2010. Seattle, United States. Retrieved from http://ghdx.healthdata.org/record/philippines-global-burden-disease-study-2010-gbd-2010-results-1990-2010

Intergovernmental Panel on Climate Change (2015). Intergovernmental Panel on Climate Change Database on Greenhouse Gas Emission Factors (IPCC-EFDB). Retrieved from http://www.ipcc-nggip.iges.or.jp/EFDB/main.php.

International Council on Clean Transportation (ICCT) (2014). Global Transportation Roadmap Model. Retrieved from http://www.theicct.org/global-transportation-roadmap-model

Levy, J. I., Wilson, A. M., Evans, J. S., & Spengler, J. D. (2003). Estimation of primary and secondary particulate matter intake fractions for power plants in Georgia. Environmental science & technology, 37(24), 5528-5536.

Lim, Stephen S., et al. (2013). A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. The Lancet 380(9859): 2224-2260.

Lindhjem, H., Navrud, S., Braathen, N.A., and Biausque, V. (2011). Valuing Mortality Risk Reductions from Environmental, Transport, and Health Policies: A Global Meta-Analysis of Stated Preference Studies. Risk Analysis 31(9).

Manila Observatory (2010). Philippine Greenhouse Gas Inventory for the Year 2000.

Marshall, J. (2007). Urban land area and population growth: a new scaling relationship for metropolitan expansion. Urban Studies 44(10):1889-1904

Miller, J., Blumberg, K., and Sharpe, B. (2014). Cost-Benefit Analysis of Mexico’s Heavy-duty Emission Standards (NOM 044). The International Council on Clean Transportation. Retrieved from http://www.indiaenvironmentportal.org.in/files/file/ICCT_MexicoNOM-044_CBA.pdf

Minjares, R., Wagner, D., and Akbar, S. (2014). Reducing black carbon emissions from diesel vehicles : impacts, control strategies, and cost-benefit analysis. Washington DC ; World Bank Group. Retrieved from http://documents.worldbank.org/curated/en/2014/04/19342185/reducing-black-carbon-emissions-diesel-vehicles-impacts-control-strategies-cost-benefit-analysis

Oanh, NTK, Pongkiatkul, P, Cruz, MT, Ngheim, DT, Phillip, L, and Zhuang, G. (2012). Monitoring and Source Apportionment for Particulate Matter Pollution in Six Asian Cities. Integrated Air Quality Management: Asian Case Studies 97.

Organization for Economic Cooperation and Development (OECD) (2011). "Valuing Mortality Risk Reductions in Regulatory Analysis of Environmental, Health and Transport Policies: Policy Implications", OECD, Paris. Retrieved from: www.oecd.org/env/policies/vsl

Rabl, A. (2011, November 26). How to use The ExternE methodology in China. Retrieved from https://www.google.com/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0CB0QFjAA&url=http%3A%2F%2Fwww.amse-aixmarseille.fr%2Fsites%2Fdefault%2Ffiles%2F_valorisation%2Fcontrats%2Fpaper_4.1_rabl.pdf&ei=hritU9r6EcXdoATfh4GwDg&usg=AFQjCNFANDlVqrCaUVCTyXL4NJd-xojfFg&sig2=gbkGVvbWSrQALOkkPr7Htw

Sakulniyomporn, S., Kubaha, K., & Chullabodhi, C. (2011). External costs of fossil electricity generation: Health-based assessment in Thailand. Renewable and Sustainable Energy Reviews, 15(8), 3470–3479. doi:10.1016/j.rser.2011.05.004

U.S. Environmental Protection Agency (U.S. EPA) (2014). Web Factor Information Retrieval System (WebFIRE). http://epa.gov/ttn/chief/webfire/index.html.

U.S. Environmental Protection Agency Science Advisory Board (U.S. EPA SAB). (2004). Advisory Council on Clean Air Compliance Analysis Response to Agency Request on Cessation Lag. Letter from the Health Effects Subcommittee to the U.S. Environmental Protection Agency Administrator. December

World Bank (2015). GNI per capita, PPP (current international $). World Bank, International Comparison Program database. Retrieved May 2015 from http://data.worldbank.org/indicator/NY.GNP.PCAP.PP.CD

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