Low Emission Development

GUATEMALA LOW EMISSION DEVELOPMENT STRATEGY

CONTRACT NO. AID-520-C-14-0003

March 2019

This publication is made possible by the support of the American People through the United States Agency for International Development (USAID). It was prepared by the Center for Climate Strategies, under subcontract to RTI international, for the USAID Low Emission Development Project.

GUATEMALA LOW EMISSION DEVELOPMENT STRATEGY

March 2019

RTI International
701 13th Street NW, Suite 750
Washington, DC 20005

DISCLAIMER

This publication is made possible by the support of the American People through the United States Agency for International Development (USAID), under the terms of contract no. AID-520-C-14-00003. The contents of this publication are the sole responsibility of RTI International and its partners, and do not necessarily reflect the views of USAID or the United States Government.

TABLE OF CONTENTS

ACKNOWLEDGMENTS

The Guatemala Low Emission Development Strategy (GLEDS) was developed with assistance by the Center for Climate Strategies (CCS) by a collaboration of representatives of the Ministry of Environment and Natural Resources (MARN), the Ministry of Economy (MINECO), the Secretariat for Planning and Programming of the Presidency (SEGEPLAN), the Ministry of Energy and Mines (MEM), the Ministry of Communications, Infrastructure and Housing (MICIVI), the Ministry of Agriculture, Livestock and Food (MAGA), the National Forestry Institute (INAB), the National Council for Protected Areas (CONAP), Research Triangle Institute (RTI), and the USAID Low Emission Development Project.

Great appreciation is due to the members of the six sector-level working groups (WGs) led by the above-mentioned ministries and agencies who provided valuable insight and time in the review of the work that led to the development of this report. The list of WG participants is provided in Appendix A.

The USAID Low Emission Development Project served as coordinator and technical expert in the development of the GLEDS plan and this report with its team of dedicated professionals: Jonathan Schwarz, Ricardo Roca, Xiomara Lima, Amauri Molina, José Furlan, Jerson Quevedo, Ingrid Schreuel, Luis Alberto Castañeda, Janet de Esquivel, Luis Pedro Utrera, Alejandro Arriola, Silvia Coronado, Milton Diaz and Darlin Sagastume.

Special appreciation is noted to CCS as a key partner and expert of the USAID Low Emission Development Project and its team of professionals, including Tom Peterson, Stephen Roe, Arianna Ugliano, Holly Lindquist, Scott Williamson, and Fan Zhang, who contributed extraordinary amounts of time, energy, and expertise in providing technical analysis, project management and facilitation services for the development of the GLEDS plan and report.

Appreciation is also noted for the following additional members of the GLEDS Team for technical input and review, working group facilitation, and communication support: Oscar Villagrán, Jorge Plauchú, José Manuel Tay, Jean-Roch Lebeau, Alex Guerra, Hugo Vargas, Mario Buch, César Barrientos, Carmina López, José Miguel Miranda, Luis Lepe, Jorge Cabrera, Daniel Manzo, María José Leiva, Raúl Hernandez, Pablo Jimenez and Ana María Palomo; and for the members of the Editorial Committee in charge of planning and reviewing the GLEDS summary version for policy makers: David Barrera (MARN), Pablo Pineda (MINECO) and Silvia Montepeque (SEGEPLAN).

KEY CONCEPTS AND TERMS

TERM	MEANING
Business as usual (BAU)	in action planning, refers to the normal operation of society over time in terms of economic growth, energy use, greenhouse gas (GHG) emissions, and other related factors in the absence of any intervention.
Direct GHG emissions	GHG emissions occurring at the emission source, for example exhaust from the vehicle tailpipe or power plant stack. In some reporting protocols, these are referred to as Scope 1 emissions.
Fixed operations and maintenance (O&M) costs	consist primarily of labor costs, but could also include taxes and other fixed costs. Fixed O&M costs are incurred regardless of the energy produced by a process and are usually assessed per unit of capacity.
GHG emissions	these include all seven GHGs recognized by the United Nations Framework Convention on Climate Change (UNFCCC): carbon dioxide, nitrous oxide, methane, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and nitrogen trifluoride. For GLEDS, the focus is on the first three of these which are represented in the GHG baseline.
Indirect GHG emissions	GHG emissions attributed to an activity (fuel use, industrial process, etc.) but not occurring at the same location (i.e. not direct GHG emissions). These include GHG emissions embodied within a fuel, product, or waste material (see upstream emissions). In corporate GHG accounting, these are referred to as Scope 2 (GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the study boundaries) and Scope 3 emissions (all other GHG emissions that occur outside the study boundaries as a result of activities taking place within the study boundaries).
Levelization	the process of developing a lump sum that has been divided into equal amounts over a specified period of time.
Life-cycle emissions	involves a cradle-to-grave view of GHG emissions associated with an activity (e.g., driving) or use of product (e.g., plastic bottle). Such an assessment includes the extraction and transport of raw materials, manufacture, packaging, freight, usage and recycling or final disposal. It also generally includes the GHG emissions from construction of all facilities within the value chain.
Macro-economic assessment	addresses the indirect or secondary economic impacts on jobs, income, economic growth, productivity, and prices that arise from or in association with the microeconomic direct costs and savings. Such an analysis is also useful to address *distributional impacts,* including differential impacts related to size, location, and socio-economic character of affected households, entities, and communities (often framed as *fairness and equity*).

Term	Meaning
Marginal abatement cost	the marginal abatement cost (MAC) measures the cost of reducing one more unit of GHG emissions relative to a baseline. Marginal GHG abatement costs are generally represented on a MAC curve, where the next highest cost of GHG emission reduction is listed from left to right.
Marginal resource mix	refers to the group of power generation facilities that are the first to be ramped up during periods of increased grid demand or ramped down during periods of reduced grid demand. This group of facilities typically excludes renewables (due to their free energy costs) and plants that are difficult to ramp up or down (e.g. nuclear).
Net present value (NPV)	under the net present value method, the present value of a project's cash inflows is compared to the present value of the project's cash outflows. The difference between the present value of these cash flows is called "the net present value". This net present value determines whether the project is an acceptable investment. The same concept can be applied to the analysis of option alternatives.
Nominal discount rate	in general, a discount rate is a value used to determine the value in today's monetary units of money paid or received at some future time. The selected nominal discount rate is applied to net flows of costs or savings over the GLEDS planning horizon (2019 – 2050) to present those costs/savings at net present value (NPV); see the GLEDS Quantification Memo in Appendix C for more details.
Real discount rate	refers to the discount rate after the rate of inflation has been factored in. For example, when the nominal discount rate is 6% and there is a 2% rate of inflation, then the real discount rate is 1.06/1.02 = 1.0392 or 3.92%.
Renewable energy	energy from sources that are perpetual or that are replenished as quickly as they are used up. Renewable energy includes solar, wind, wave, tidal, geothermal, landfill gas, anaerobic digestion of biomass and other forms of sustainably-sourced biomass, and hydro power.
Upstream emissions	indirect GHG emissions that occur before a product is used for its intended purpose; for example, drilling, refining, and transportation of oil to be used as vehicle fuel; GHG emissions during manufacturing of a product (metal can, glass bottle, steel beam, etc.), as well as extraction, processing and transportation of the raw materials.
Variable O&M costs	include periodic inspection, replacement and repair of system components and consumables, such as water and pollution control materials. Variable O&M costs vary depending on the amount of power (or other product) generated.

ACRONYMS AND ABBREVIATIONS

%	percent
$	US dollar(s)
AFOLU	Agriculture, Forestry, and Other Land Use
AG	Agriculture
AMCG	Guatemala City metropolitan area
AR5	Fifth Assessment Report of the IPCC
BAU	business as usual
BANGUAT	Bank of Guatemala
BOE	barrels (US) of oil equivalent
BRT	bus rapid transit
Btu	British thermal unit
C	(degrees) Celsius
CCS	Center for Climate Strategies
cf	cubic feet
CH_4	methane
CHP	combined heat and power
CI	custom industry
CNG	compressed natural gas
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CONAP	National Council for Protected Areas
COP	Conference of the Parties
CY	calendar year
DG	distributed generation
DGT	General Office of Transportation, Ministry of Communications, Infrastructure and Housing
EPA	(United States) Environmental Protection Agency
ES	Energy Supply
EU	European Union
FS	fuel supply
FOLU	Forestry and Other Land Use

ft	foot
gal	gallon
GDP	gross economic output
Gg	gigagram (one million kilograms)
GHG	greenhouse gas
GJ	gigajoule (one billion joules)
GLEDS	Guatemala Low Emission Development Strategy
GMI	gross mixed income
GNI	gross national income
GOG	Government of Guatemala
GOS	gross operating surplus
GREET	Greenhouse Gases, Regulated Emissions and Energy Use in Transportation (model)
GTM	Guatemala
GWh	gigawatt-hour (one million kilowatt-hours)
GWP	global warming potential
H'	Shannon (energy) Diversity Index
ha	hectare
HDV	heavy-duty vehicle
HFC	hydrofluorocarbon
I	Industry
I&F	Inventory and Forecast
INAB	National Forestry Institute
INEGI	Mexico National Institute of Statistics and Geography
IPCC	Intergovernmental Panel on Climate Change
J	joule
kg	kilogram
km	kilometer
km/L	kilometer perliter
kV	kilovolt
kW	kilowatt
kWh	kilowatt-hour
lb	pound
LDV	light-duty vehicle
LFG	landfill gas

LFGTE	landfill gas-to-energy
LNG	liquefied natural gas
LPG	liquefied petroleum gas
LULC	land use/land cover
m^2	square meter
MAGA	Ministry of Agriculture, Livestock and Food
MARN	Ministry of Environment and Natural Resources
MEM	Ministry of Energy and Mines
MICIVI	Ministry of Communications, Infrastructure and Housing
MINECO	Ministry of Economy
metric ton	1,000 kilograms or 2,205 pounds
MJ	megajoule (one million joules)
MM	million
MSW	municipal solid waste
MW	megawatt (one thousand kilowatts)
MWh	megawatt-hour (one thousand kilowatt-hours)
N	nitrogen
N_2O	nitrous oxide
N/A	not applicable
NDC	Nationally Determined Contribution
NF_3	nitrogen triflouride
NG	natural gas
NOx	oxides of nitrogen
OD	(GLEDS) Option Document
ODS	ozone-depleting substance
OECD	Organization for Economic Cooperation and Development
OS	(GLEDS) Option Scenario
PFC	perfluorocarbon
PJ	petajoule (10^{15} joules)
PM	particulate matter
PM10	particulate matter less than 10 microns
ppm	parts per million
PS	power supply
Q	Guatemalan quetzal(s)

RCI	Residential, Commercial and Institutional
RCP	representative concentration pathway
SEGEPLAN	Secretariat for Planning and Programming of the Presidency
SF_6	sulfur hexafluoride
SO_2	sulfur dioxide
SOx	oxides of sulfur
t	metric ton
Tg	teragram (one million metric tons)
$TgCO_2e$	teragrams of carbon dioxide equivalent
T&D	transmission and distribution
tC	metric tons of carbon
tCO_2	metric tons of carbon dioxide
tCO_2e	metric tons of carbon dioxide equivalent
tCO_2e/MWh	metric tons of carbon dioxide equivalent per megawatt-hour
TJ	terajoule (10^{12} joules)
UNFCCC	United Nations Framework Convention on Climate Change
US	United States of America
USAID	United States Agency for International Development
USD	United States dollar(s)
USEPA	United States Environmental Protection Agency
VKT	vehicle-kilometers traveled
VOC	volatile organic compound
WB	World Bank
WG	(GLEDS) Working group
WM	Waste Management
WTE	waste to energy
WW	wastewater
yr	year

EXECUTIVE SUMMARY

A. INTRODUCTION

This report presents the Guatemala Low Emission Development Strategy (GLEDS) Plan, a portfolio of **43 highly specific mitigation options and investment opportunities for Guatemala that can help the country reduce GHG emissions and simultaneously achieve its economic, energy and environmental/natural resource management priorities.** The GLEDS Plan contains the design of each of the options and the assessment of their direct and indirect impacts against the business as usual (BAU) scenario.

As such, the GLEDS Plan supports **enhancement and implementation of several national development plans and climate change related policies, such as K'atun Nuestra Guatemala 2032, the National Climate Change Law and the Guatemala's Nationally Determined Contribution (NDC)** pursuant to the Paris Agreement at the 21st Conference of the Parties (COP21) under the United Nations Framework Convention on Climate Change (UNFCCC), and the achievement of the GHG emission reduction goals of 11% or 22% with international cooperation support by 2030 set there. The GLEDS Plan is the result of a **multi-year, stepwise, multi-objective, stakeholder-driven, participatory, fact-based and implementation-oriented planning, development and analysis process coupled with local capacity building** (GLEDS Process) **and learning by doing procedures**.

The GLEDS Process was launched in July 2016 and led by the Ministry of Environment and Natural Resources (MARN), the Ministry of Economy (MINECO) and the Secretariat for Planning and Programming of the Presidency (SEGEPLAN) with technical support from the United States Agency for International Development (USAID). The GLEDS Process involved active participation of the Ministry of Energy and Mines (MEM), the Ministry of Communications, Infrastructure and Housing (MICIVI), the Ministry of Agriculture, Livestock and Food (MAGA), the National Forestry Institute (INAB), and the National Council for Protected Areas (CONAP). In addition to the Government of Guatemala (GOG), key players in the GLEDS Process were private sector institutions, associations, businesses, academia, NGOs, and indigenous organizations. **A total of 590 stakeholders actively participated in all implementation of the GLEDS Process.**

B. GLEDS PROCESS METHODOLOGY AND STAKEHOLDER PARTICIPATION

The GLEDS Process was planned, designed and implemented using the **10-step action planning process developed and widely applied by the Center for Climate Strategies (CCS**). The 10-step action planning process is a series of sequential linked steps, each of which includes a series of concepts, techniques, tools and decisions that enable a comprehensive, participatory and fact-based process to develop formal facilitated group agreements on a set of highly specific options for implementation. The 10-step action planning process is summarized in Figure ES.B-1 below.

Figure ES.B-1. CCS Action Planning Process

Step 1	Organization, Visioning & Goals
Step 2	Baseline Development
Step 3	Policy Options Identification
Step 4	Policy Screening & Prioritization
Step 5	Initial Policy Design Specifications
Step 6	Direct (Micro) Impacts Assessment
Step 7	Policy Options Integration and Overlap
Step 8	Indirect (Macro) Impacts Assessment
Step 9	Final Recommendations & Report Transmittal
Step 10	Monitoring, Reporting, Evaluation, & Updating

The 10-Step action planning process is based on the **key principles of transparency, inclusiveness, consensus building and comprehensiveness**, and was highly **customized and adapted for optimal application and implementation within the Guatemalan context (adaptable implementation methodology). It took into account the country's shifting political scene, goals and priorities, as well as the local conditions that most facilitated ameaningful stakeholders' engagement and successful progress toward completion**. Key adaptation and customization efforts and results are highlighted below:

- **Targeted outreach and engagement** to gather political leaders' participation and support; **a concerted effort to engage multiple ministries in both convening and participatory roles**, the **decision of embedding consultants** with sector-level expertise within each of the participating ministries to provide expertise and simultaneously build institutional capacity and facilitate dialog and cooperation.

- To balance the desire for significant stakeholder engagement with limitations on available time, lack of knowledge and initial confidence in a new methodology and policy planning approach, the following steps were taken:

    - **A defined regime of in-person meetings for each sector's working group, along with a defined duration of process and limited duration of each meeting** to ensure participants' understanding of what they were committing to.

    - **Interim meetings and review of deliverables, and an iterative process** wherein inputs were sought for each step and deliverable of the GLEDS Process and **decisions were openly made by the stakeholders**.

    - As knowledge, confidence, and interest in the process increased, **expansion in the number of stakeholders, especially from the private sector who ultimately stepped up and played a key role in the conduct of the GLEDS Process.**

- **Consultations in the interior departments of Guatemala with representatives from municipalities, farmers' organizations, women´s organizations, and indigenous peoples.**

- **Country-specific datasets and customized methodology for multifaceted assessment of each GLEDS Option's prospects for enhancement of the broader Guatemalan economy** to customize the analytical work in order to fill gaps in local technical capacity, data and analytical models through

Key to the success of the GLEDS Process was the **extensive and active participation of over 500 stakeholders from the public and private sectors, including civil society, academic institutions, producers´ organizations and indigenous people's organizations** that were engaged throughout the implementation of the process. The full list of stakeholders is provided in Appendix A.

In order to facilitate stakeholder participation, the following **six sector-level working groups (WGs**) were formed in line with the **six economic sectors** covered under the GLEDS Plan:

- Energy Working Group, led by MEM
- Industry Working Group, led by MINECO
- Transportation Working Group, led by MICIVI
- Agriculture Working Group, led by MAGA
- Forestry and Other Land Use Working Group, led by INAB and CONAP
- Waste Management Working Group, led by MARN

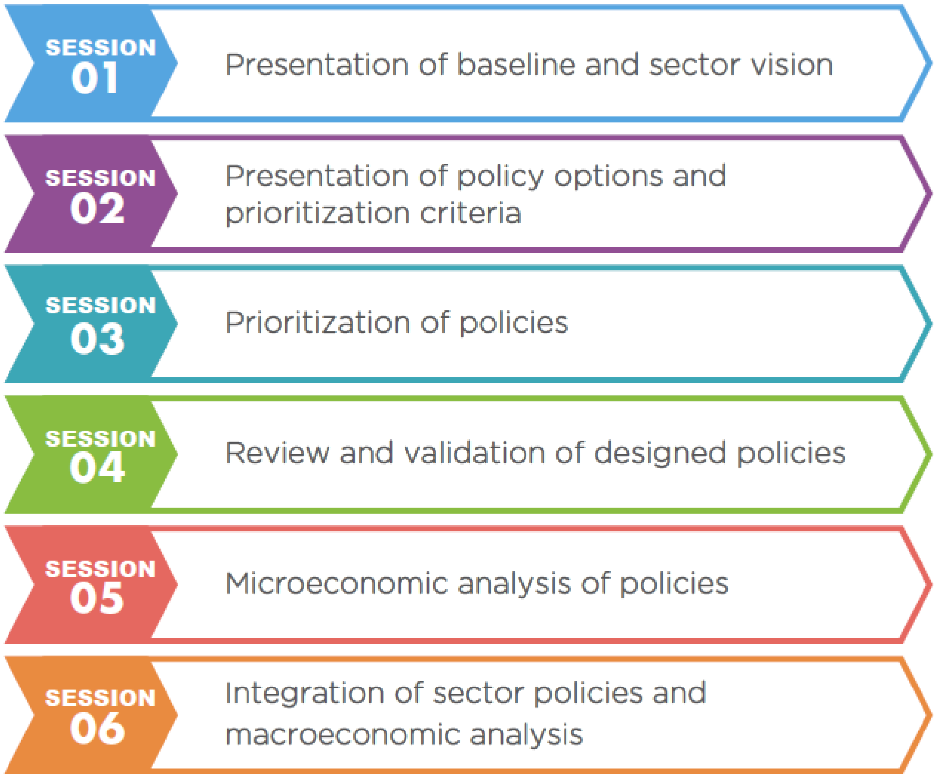
The Agriculture Working Group held two separate sessions - one for Agriculture (crop production) and the other for livestock management - as the related GHG emission sources and mitigation options required specific expertise in each field. In addition to these six sectoral WGs, an urban development working group was established with the purpose of meeting periodically to assess specific urban considerations and impacts of the GLEDS options. It served as a space for dialogue and engagement of urban stakeholders who often deal with issues that are cross-cutting between energy, transportation, green spaces, and urban development.

Participation of different groups of the population in the development of the GLEDS plan has been an important pillar from the beginning of the GLEDS Process. In constructing the membership of various WGs, special attention was placed on securing participation from male and female representatives of more vulnerable groups, particularly representatives from indigenous people and small producers.

The members of the WGs participated to the GLEDS Process through **working group sessions** held during the two years of the GLEDS Plan development. For each WG, five sector-level working sessions and a sixth and final plenary working session were held to openly review, discuss and validate the GLEDS baseline, to screen and prioritize the GLEDS Options, and to review the design of the GLEDS options and the impacts assessment results.

Figure ES.B-2 below illustrates the six working sessions held for each WG.

Figure ES.B-2. Six Sessions of the GLEDS Working Groups



C. GLEDS ENERGY, RESOURCES, AND EMISSIONS BASELINES

The GLEDS Plan was developed based on the Guatemala energy, resource and emission baselines (historic inventory and business as usual forecast) developed as part of the GLEDS Process.

Figure ES.C-1 provides a complete economy-wide accounting of GHG emissions for Guatemala. This figure indicates that the historical (inventory) phase of the baseline is through 2015. This means that historical information was available across most sectors through 2015 to estimate GHG emissions. The BAU forecast period begins in 2016 and continues through the 2050 GLEDS planning period. **Net GHG emissions are expected to increase from 99 teragrams of carbon dioxide equivalent ($TgCO_2e$) in 2015 to 138 $TgCO_2e$ by 2030 and 201 $TgCO_2e$ by 2050**. A teragram (Tg) is equal to one million metric tons. Emissions are shown on a "net" basis, which means that both emissions sources and sinks are included.

Historic and forecasted GHG emissions for the Forestry and Other Land Use (FOLU) sector dominate the baseline. Table ES.C-1 provides some of the annual values used to construct Figure ES.C-1. **By 2015, the FOLU sector was contributing almost 72% of total economy-wide GHG emissions** (71 $TgCO_2e$). This comes from a combination of unsustainable harvests (for both fuelwood and durable wood products) and land conversion (mostly to support an expanding agricultural base). By 2050, under business as usual (BAU) land use, emissions are expected to more than double to 147 $TgCO_2e$.

Chapter III and Appendix B provide additional details of the construction of the GLEDS baseline. This includes not just GHG emissions, but also the underlying energy production/consumption, natural resources consumption/management, and socio-economic baselines.

Figure ES.C-1. Economy-wide Net GHG Emissions Baseline

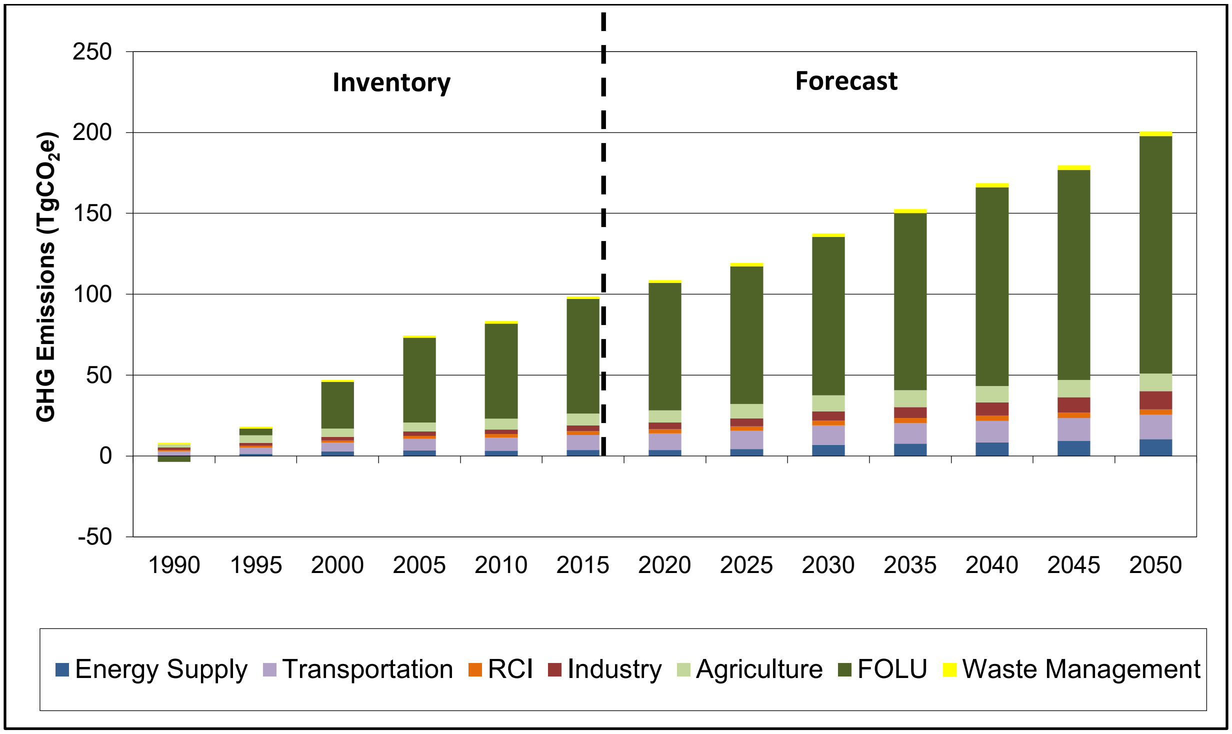


Table ES.C-1. Economy-wide Net GHG Emissions Baseline

Sector	Net Emissions ($TgCO_2e$)							
	1990	2000	2010	2015	2020	2030	2040	2050
Energy Supply	0.32	2.9	3.2	3.6	3.6	6.8	8.5	10
Transportation	2.6	5.3	8.1	9.4	10	12	13	15
RCI	0.72	1.4	2.3	2.4	2.6	2.9	3.2	3.4
Industry	1.7	2.1	2.7	3.5	4.2	5.8	8.1	11
Agriculture	1.9	5.2	6.8	7.3	7.6	10	10	11
FOLU	(3.7)	29	59	71	79	98	123	147
Waste Management	0.87	1.2	1.7	1.7	1.9	2.3	2.7	3.1
TOTAL Net Emissions	**4.4**	**47**	**83**	**99**	**109**	**138**	**169**	**201**

D. GLEDS OPTIONS

The 43 GLEDS options ultimately selected and designed with WG review and comments, and recommended for government adoption are listed in Table ES.B-1 below.

Table ES.B-1. GLEDS Options

ENERGY SECTOR AND URBAN U-3/U-4	
E-1	Management of Permits and Locations to Increase the Potential of Existing Hydroelectric Plants
E-2	Development of Mini- and Micro-Hydroelectric Plants
E-3	Expand the Use of Solar Generation
E-4	Expand the Use of Geothermal Energy
E-5	New Renewable Generation to Reduce System Losses
E-6	Energy Efficiency Codes for Existing Buildings
E-7	Energy Efficiency Standards for Equipment and Appliances
E-8	Energy Audits
E-9	Introduction of Efficient Wood Stoves
U-3	LED Public Lighting in Guatemala City
U-4	Add Energy Efficiency Standards to National Building Code
INDUSTRY SECTOR	
I-1	Energy Efficiency for Furnaces/Ovens
I-2	Energy Efficiency Programs - Boilers and Process Heaters
I-3	Incentives for Renewable Energy
I-4	Improvements to Electrical Energy Efficiency
I-5	Increased Recycling and/or Substitution of Materials
I-6	Improve Heat Recovery
TRANSPORTATION SECTOR AND URBAN U-1/U-2	
T-1	Build MetroRiel Light-rail Route in Guatemala City
T-2	Modernize Private Fleet of Suburban/Extra-urban Commuter Buses
T-3	Improve Regular Transit, Update Fleet, and Expand BRT in Guatemala City
T-4	Construction of Highway Bypasses around the cities of Chimaltenango (department of Chimaltenango) and Barberena (department of Santa Rosa)
T-5	Modernize the Private Light-duty Vehicle Fleet
T-6	Promote the Use of Ethanol in Gasoline
U-1	Establish an Urban Land-Use Component Within the National Urban Development Policy
U-2	Sustainable Urban Mobility Plan for Guatemala City
AGRICULTURE AND LIVESTOCK MANAGEMENT SECTOR	
Agriculture	
AG-1	Sustainable Management of Soils
AG-2	Establishment and Improvement of Agroforestry Systems
AG-3	Establishment of Fruit Plantations
AG-4	Efficient Use of Nitrogen Fertilizers
Livestock	
GAN-1	Improved Pasture Management through Rotational Grazing
GAN-2	Promotion of Silvo-pastoral Systems

GAN-3	Promote Integrated Manure Management at Intensive Animal Production Systems
FORESTRY AND OTHER LAND USE SECTOR AND URBAN U-5	
FOLU-1	Establishment of Sustainable Forest Plantations
FOLU-2	Conservation and Management of Sustainable Natural Forests
FOLU-3	Reforestation of Degraded Lands with Native Species
FOLU-4	Strengthen Institutional Response Capacity in Prevention and Control of Forest Fires
U-5	System of Urban Green Spaces
WASTE MANAGEMENT SECTOR	
Solid Waste	
DS-1	Expansion of Waste Collection and Improvement of Separation Efficiency
DS-2	Re-Use and Recycling of Inorganic Solid Waste
DS-3	Advanced Composting
DS-4	Landfill Gas Capture and Use
Waste Water	
DL-1	Water-Saving Measures in the Residential, Commercial, Institutional and Industrial Sectors
DL-2	Advanced Wastewater Treatment Technologies

The screening and selection of the 43 GLEDS options were conducted by the members of the WGs through a facilitated online Multi-Criteria Analysis (MCA) based on expected performance criteria such as GHG emission reduction, economic growth, competitiveness, creation of new markets, technical feasibility, political feasibility, co-benefits. In addition, a gender analysis was conducted on twelve of the GLEDS options, in order to ensure equal access for men and women and that the options do not negatively affect and widen existing gender gaps.

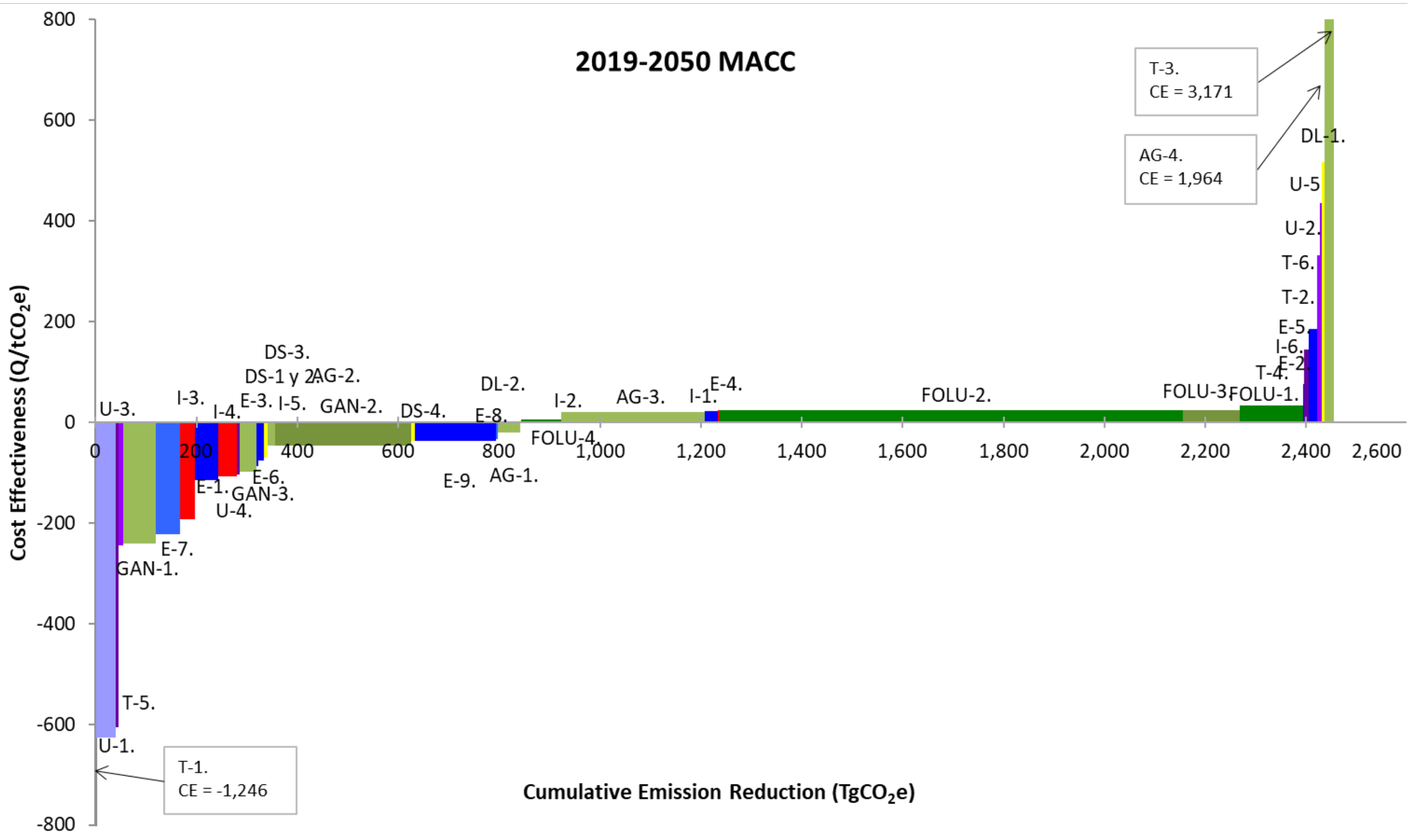
E. IMPACTS OF GLEDS OPTIONS

Direct and indirect impacts of each GLEDS Option were assessed. Direct or microeconomic impacts that can be attributed to implementation of an option include shifts in energy production and consumption, GHG emissions reductions, and costs associated with implementing the options such as costs of equipment, maintenance costs, etc. Indirect or macroeconomic impacts include employment impacts resulting from a change in induced demand for products or services, an increase or decrease in gross domestic product (GDP), and other indirect impacts (changes in price of energy, change in incomes). For the GLEDS Plan, a qualitative approach was developed and applied to address indirect impacts.

Direct (microeconomic) impacts analysis was conducted on each of the 43 GLEDS options. The assessment of each option identified expected changes to BAU energy production/use, resources management, and GHG emissions, and then quantified each of these through the GLEDS planning period (2019-2050). The direct impacts analysis also quantified the expected implementation costs for each option. These included the following types of costs: initial investments, financing, energy, materials, operations and maintenance, and government support costs. Direct impacts were quantified on the basis of implementing a single GLEDS option ("stand-alone analysis"), as well as integrated within and across sectors in order to remove double-counting or adjust for other interactions. A summary of all of this work is shown in the GLEDS marginal abatement cost curve (MACC) in Figure ES.D-1 below. The fully-integrated results for the GLEDS Plan indicate that, **if all options are fully implemented as designed, total 2050 GHG reductions within the country will be 120 TgCO_2e and cumulative in-country reductions for the period 2019-2050 will be 2,454 TgCO_2e. Total direct implementation**

costs are expected to result in over 41 billion 2018Q saved throughout society (approximately US$5.4 billion 2018 value; a negative cost value in the table indicates a net savings to Guatemalan society), while **the cost effectiveness estimated for the entire GLEDS Plan is -17Q/tCO_2e** (approximately US$2.21/t$CO_2$e)**.**

Figure ES.D-1. 2019-2050 Cumulative GHG Marginal Abatement Cost Curve

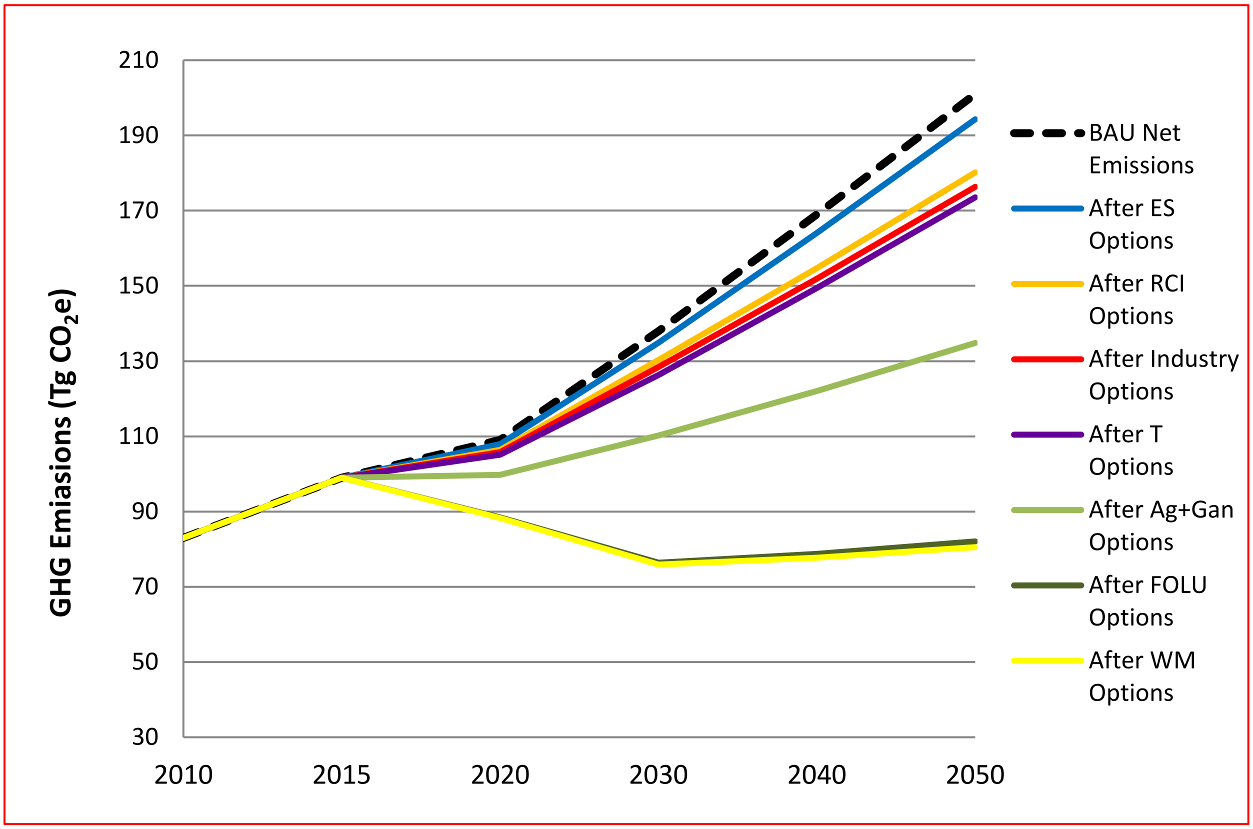


Note: a larger version of this chart can be found in Chapter VII (Figure VII.C-4).

Total cumulative reductions expected from full implementation of the GLEDS Plan are shown on the x-axis of the MACC (over 2,400 TgCO_2e from 2019-2050). GLEDS options are ordered from greatest cost effectiveness (CE) to least cost effective. CE is determined by dividing total implementation costs by the cumulative GHG reductions. For example, option U-1 could be implemented at greater than -600 Q/tCO_2e reduced. Negative values indicate a net savings to society.

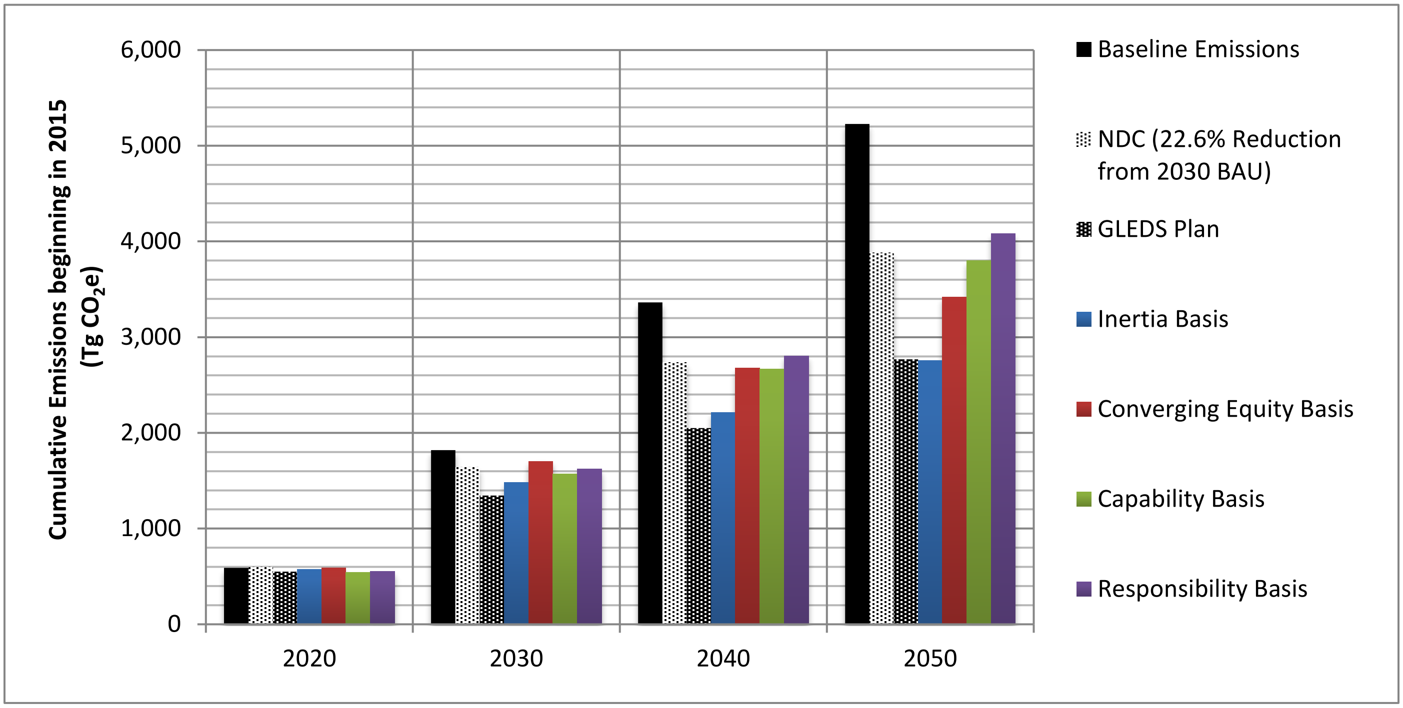
Figure ES.D-1 provides a **summary of the expected reductions against baseline emissions for implementing the GLEDS options.** Each colored line indicates the level of reductions expected for each sector. Hence, the reductions for the Energy Supply (ES) options are first subtracted from the BAU net emissions. Then, the Residential/Commercial/Institutional (RCI) sector options are subtracted from the ES line, and so on. The yellow line indicates the remaining emissions after the Waste Management (WM) sector option reductions have been subtracted. As shown, full implementation of the GLEDS Plan is expected to produce significant reductions against baseline. In particular, reductions from the Agriculture (AG), Livestock Management (GAN) and Forestry & Other Land Use (FOLU) sectors are substantial.

Figure ES.D-1. Expected GHG Reductions from Implementation of GLEDS Options



For national commitments to the Paris Accord, many governments, including Guatemala's, have framed their nationally determined contribution (NDC) in terms of % reductions of GHG emissions during a key forecast year. For Guatemala, the NDC reduction goals are 11%, or 22% with international cooperation support, below 2030 BAU emissions. Another key metric for assessing Guatemala's commitments to international programs, like the Paris Accord, is not annual emissions, but cumulative emissions from a recent historic year through 2050. While country-level emissions budgets have not yet been determined, the GLEDS Baseline Report (Appendix B) offered some possible budget scenarios. Those possible budgets are compared to BAU emissions, emission levels consistent with implementation of Guatemala's NDC, and the GLEDS Plan Scenario in Figure ES.D-2 below**. The GLEDS Plan Scenario is shown to meet all of the possible budgets through 2050, with the only exception being slightly higher than the "inertia basis" budget.** See Appendix B for more details on the meaning and derivation of these possible emission budgets. The context of these can support Guatemalan policymakers in any future international climate change negotiations and agreements.

Figure ES.D-2. Inferred Guatemala GHG Budget Allocation for 2 Degrees C Warming Compared to NDC and GLEDS Plan Emissions



The GLEDS Plan provides for more benefits than just GHG reductions. Significant reductions in fuel and materials (e.g. nitrogen fertilizers) imports and beneficial land use impacts are expected. Table ES.D-1 below summarizes the areas of forest protected or expanded as a result of GLEDS options. As indicated, **nearly 2.5 million hectares (Ha) of forested land will be gained via a combination of preservation and expansion of the forested land base.**

Table ES.D-1. Land Use/Land Cover (LULC) Impacts of GLEDS Plan

LULC IMPACT (THOUSAND HA)	2020	2030	2040	2050
Natural Forest Preserved	61	595	1,122	1,233
Natural Forest Expansion	13	148	262	526
New Forest Plantations	28	227	471	715
Total	**102**	**970**	**1,855**	**2,474**
Note: impacts are as compared to the expected (business as usual) scenario of LULC change.				

The macroeconomic assessment identified certain net effects over the entire collection of GLEDS options:

- **Overall savings exceeds implementation costs.** The 43 options are projected to produce approximately Q500 billion (US$ 65.7 billion) more in savings and in new productivity than in option implementation costs. This represents an average net savings to the economy of nearly Q16 billion (US$ 2.1 billion) per year. This indicates that while implementation requires up-front investment and other costs, the potential return on those investments is significantly larger than the costs involved. In turn, this acts to stimulate the macroeconomy by freeing up funds for reinvestment.

- **Fuel consumption and spending falls significantly**. The 43 options jointly offer a net energy-spending reduction of just over Q325 billion (US$ 42.8 billion)– or Q10 billion (US$ 1.3 billion) per year. This represents significant money freed up for other uses by households, businesses and the government. Given that much energy is derived from imported fossil fuels (either raw or refined), this is also an opportunity to reduce imports. This also acts as a macroeconomic stimulant by freeing up funds for reinvestment.
- **The balance of imports and exports changes for the better**. The 43 GLEDS options are projected to reduce total net imports by approximately Q40-60 billion (US$ 5.2 – 7.9 billion) over the 2019-2050 period, mostly due to substantial reductions in the need to import fuel and fertilizer. This is despite a significant (over Q400 billion, equivalent to US$52.6 billion) increase in spending on imported machinery, equipment, new vehicles and other specialized inputs. This net reduction in imports shifts a share of Guatemalan consumption back to local suppliers and supply chains. This shifts economic benefits to the Guatemala economy.
- **Options present opportunities to stimulate job growth**. Almost all of the GLEDS options anticipate some of their associated implementation costs to come in the form of expanded oversight, management, maintenance or implementation. Labor-intensive activities like these are associated with increases in economy-wide increases in total employment – reflecting both the direct hiring to carry out these activities and the expansion of the job market that results as this new household income is spent on goods and services. This shifts activities toward job creation. In addition, GLEDS options supporting greater levels of technological innovation support jobs with greater incomes and future development of associated industries.
- **Around half of all options stimulate local sectors; however, about 20% seek reductions in scale in certain local-sector activities.** Overall, the 43 GLEDS options provide a net stimulus to local sectors and supply chains within the Guatemalan economy. The construction sector is projected to benefit as options contemplate building new infrastructure or buildings. The growth in the conventional utility sector is projected to shrink as conventional energy generation and the activities that support it are affected by shifts to renewables, efficiency gains, or other goals. The shift to local supply chains also shifts economic benefits to Guatemala.

Overall, the GLEDS options offer significant basis for optimism about the capacity of low-emissions options to stimulate, rather than suppress, economic activity in Guatemala. While not all options offer the same prospects for economic stimulus, many options offer savings or productivity returns greater than their cost of implementation, expend significant money on labor-intense activities, reduce net imports, drive adoption of advanced technologies, and boost activity in key local sectors.

I. INTRODUCTION

This report presents the Guatemala Low Emission Development Strategy (GLEDS) Plan, a portfolio of **43 highly specific mitigation options and investment opportunities for Guatemala that can help the country reduce GHG emissions and simultaneously achieve its economic, energy and environmental/natural resource management priorities.** The GLEDS Plan contains the design of each of the options and the assessment of their direct and indirect impacts against the business as usual (BAU) scenario.

As such, the GLEDS Plan supports **enhancement and implementation of several national development plans and climate change related policies, such as K'atun Nuestra Guatemala 2032, the National Climate Change Law and the Guatemala's Nationally Determined Contributions (NDCs)** pursuant to the Paris Agreement at the 21st Conference of the Parties (COP21) under the United Nations Framework Convention on Climate Change (UNFCCC), and the achievement of the GHG emission reduction goal of 11%, or 22% with international cooperation support, by 2030 set there. The GLEDS Plan is the result of a **multi-year, stepwise, multi-objective stakeholder-driven, participatory, fact-based and implementation-oriented planning, development and analysis process coupled with local capacity building and learning by doing procedures** (GLEDS Process).

The GLEDS Process was launched in July 2016 and led by the Ministry of Environment and Natural Resources (MARN), the Ministry of Economy (MINECO) and the Secretariat for Planning and Programming of the Presidency (SEGEPLAN) with technical support from the United States Agency for International Development (USAID). The GLEDS Process involved active participation of the Ministry of Energy and Mines (MEM), the Ministry of Communications, Infrastructure and Housing (MICIVI), the Ministry of Agriculture, Livestock and Food (MAGA), the National Forestry Institute (INAB), and the National Council for Protected Areas (CONAP). In addition to the Government of Guatemala (GOG), key players in the GLEDS Process were private sector institutions, associations, businesses, academia, NGOs, and indigenous organizations. **A total of 590 stakeholders participated in the implementation of the GLEDS Process.**

The GLEDS Process covered the following **key economic sectors** in Guatemala:

- Energy, including supply (heat and power production) and demand through residential, commercial, and institutional (RCI) activities
- Industry, industrial processes (I)
- Transportation (T)
- Agriculture and Livestock production (AG)
- Forestry, and Other Land Uses (FOLU)
- Waste Management (WM), including solid waste and waste water

The GLEDS planning period will begin with implementation in 2019 and run through 2050.

II. GLEDS PROCESS METHODOLOGY AND STAKEHOLDER PARTICIPATION

A. ADAPTABLE IMPLEMENTATION METHODOLOGY AND PRINCIPLES

The GLEDS Process was planned, designed and implemented using the **10-step Action Planning Process developed and widely applied by the Center for Climate Strategies (CCS**). The 10-step Action Planning process is a series of sequential linked steps, each of which includes a series of concepts, techniques, tools, and decisions that enable a comprehensive, participatory and fact-based process to develop a set of highly specific options for implementation.

The 10-step Action Planning Process is summarized in Figure II-1 below:

Figure II-1. CCS Action Planning Process

Step 1	Organization, Visioning & Goals
Step 2	Baseline Development
Step 3	Policy Options Identification
Step 4	Policy Screening & Prioritization
Step 5	Initial Policy Design Specifications
Step 6	Direct (Micro) Impacts Assessment
Step 7	Policy Options Integration and Overlap
Step 8	Indirect (Macro) Impacts Assessment
Step 9	Final Recommendations & Report Transmittal
Step 10	Monitoring, Reporting, Evaluation, & Updating

This 10-step Action Planning Process – highly adapted to the Guatemalan context as described in more detailed below - was applied to guide GLEDS planning participants through a process to identify GHG mitigation, natural resource management and other development goals; construct planning baselines; scope, screen, and prioritize GLEDS options; develop GLEDS option designs; analyze the direct impacts and costs or savings of implementing each GLEDS option; assess integration and overlap among GLEDS options; assess the indirect macroeconomic impacts of the GLEDS options; evaluate the overall impact and cost for the full suite of GLEDS options; and deliver and document the final set of GLEDS options to GOG for adoption.

The 10-step Action Planning Process enabled the GLEDS Process to be implemented based on the following key principles:

- **Transparency** of option design, participant viewpoints, and technical analysis (metrics, data sources, methods, key assumptions, and uncertainties)

- **Inclusiveness** through participation of a diverse group of Guatemalan stakeholders that represent a broad spectrum of interests and expertise in Guatemala
- **Consensus-building** though formal, facilitated validation of deliverables and results by the stakeholders at key milestones in the process in order to advance to next steps. Each participant was encouraged to voice any concerns, objections or questions during the process and modifications were undertaken where needed to improve deliverables accordingly
- **Comprehensivene**ss to cover all sectors, levels of government, potential implementation methods, and impact metrics of interest
- **Implementation-oriented** in order to provide the GoG with the level of detail in design specification, analysis, and stakeholder agreement for each option to support next steps on technical analysis, rulemaking, legislation, financing, monitoring, reporting and verification, or other needs.

Preserving a strong focus on the above principles, the 10-Step Action Planning Process was **customized and adapted** for optimal application and implementation within the Guatemalan context, and took into account the country's shifting political scene, goals and priorities, as well as the local conditions that most facilitated a meaningful stakeholders' engagement and successful progress toward completion. Key adaptation and customization efforts and results are highlighted below:

- The first step, regarding organization and goals, took into account the need to ensure alignment with Guatemala's new policy initiatives. These include its NDC as well as the National Climate Change Law, passed in 2013, that mandated a focus on mitigation as well as adaptation and by multiple ministries rather than just MARN. Additionally, the planning and start-up of the GLEDS Process coincided with a phase of significant political turnover in both elected offices and ministry leadership prior to and after the 2015 Presidential election. These conditions required **additional outreach and engagement** to gather political leaders' participation and support; **a concerted effort to engage multiple ministries in both convening and participatory roles**, in order to add expertise, insight and buy-in to the GLEDS Process and its results; the **decision of embedding consultants** with sector-level expertise within each of the participating Ministries to provide expertise and expanded labor capacity to meaningfully participate in the GLEDS Process, as well as to simultaneously build institutional capacity and facilitate dialog and cooperation.

- Key to the success of the GLEDS Process was the large and active stakeholder participation as described in Section II.B below. To balance the desire for significant stakeholder engagement with limitations on available time, lack of knowledge and initial confidence in a new methodology and policy planning approach, the following steps were taken:
    - **A defined regime of in-person meetings for each sector's working group was established along with a defined duration of process and limited duration of each meeting**. Establishing a defined timeframe and clear session objectives for each working group (WG) helped to secure the participation of WG members, as participants understood what they were committing to.
    - **Interim meetings and review of deliverables** were conducted to facilitate understanding and build capacity. Most interim meetings were organized to accommodate requests for additional clarity or review from WG participants.

- **An iterative process was used** (supported by online tools where needed to meet local needs) wherein inputs were sought for each step and deliverable of the GLEDS Process and **decisions were openly made by the stakeholders**. This approach enabled stakeholders to be key players and decision makers in the GLEDS Process rather than being confined to a simple consultative role.

- As knowledge, confidence, and interest in the process increased, **the number of stakeholders was expanded, especially from the private sector who ultimately stepped up and played a key role in the conduct of the GLEDS Process.**

* To incentivize feedback and participation also from groups outside of the capital city, three **consultations were held in the interior departments of Guatemala with representatives from municipalities, farmer organizations, women´s organizations, and indigenous peoples, and support from the Regional Climate Change Networks.** These included: 1) a consultation with different representatives from Petén, Izabal and Las Verapaces; 2) a consultation with representatives from Zacapa, Chiquimula, Izabal, Jutiapa, El Progreso and Jalapa; and 3) a consultation with representatives from Huehuetenango, San Marcos, Sololá, Totonicapán and Quetzaltenango.

* The analytical work performed to develop a comprehensive baseline for the country (as detailed in Chapter III) and to assess the impact of each GLEDS Option (as detailed in Chapter V and VI) was also significantly customized to fill gaps in local technical capacity, data and analytical models:

    - **Country-specific datasets were constructed** with as many Guatemala-specific sources as possible, a comprehensively detailed methodology, and transparent assumptions where needed.

    - Due to the absence of full input-output or computable general equilibrium macroeconomic models appropriate for use in the Guatemalan context or functional at the level of detail required to assess the individual GLEDS Options, a **customized methodology for multifaceted assessment of each option's prospects for enhancement of the broader Guatemalan economy was developed.** The methodology explained in Section IV below applied a literature-based approach to the rigorous quantification of each option's series of expected direct costs, savings, productivity changes, import or export activities, and other direct impacts on financial flows.

B. STAKEHOLDER PARTICIPATION

Key to the success of the GLEDS Process was the **extensive and active participation of over 500 stakeholders from the public and private sectors, including civil society, academic institutions, producers´ organizations and indigenous people's organizations** that were engaged throughout the implementation of the process. The full list of stakeholders in provided in Appendix A.

To facilitate stakeholder participation, the following **six sector-level WGs** were formed:

* Energy Working Group, led by MEM
* Industry Working Group, led by MINECO

- Transportation Working Group, led by MICIVI
- Agriculture Working Group, led by MAGA
- FOLU Working Group, led by INAB and CONAP
- Waste Management Working Group, led by MARN

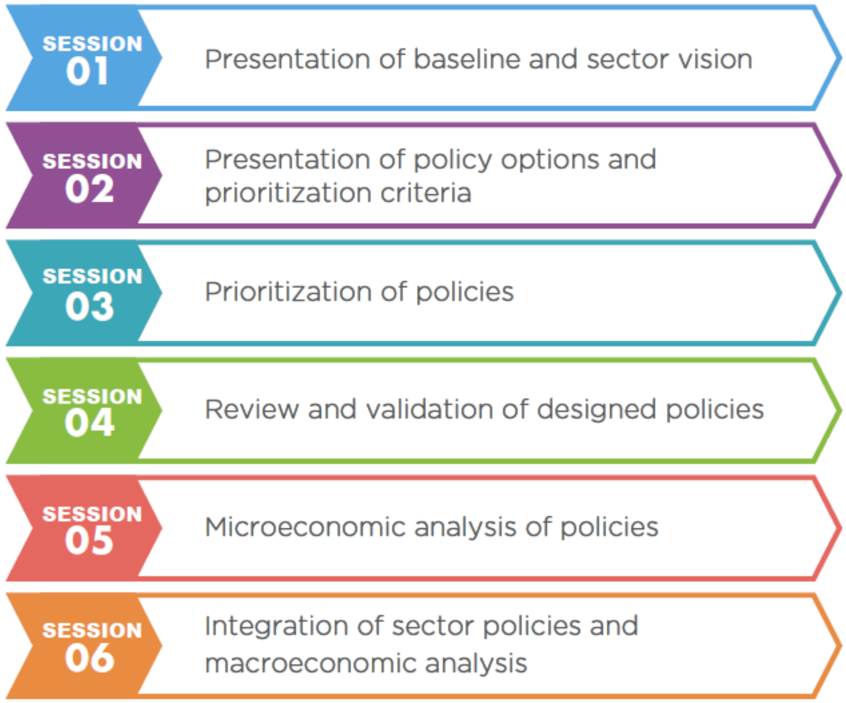
The Agriculture Working Group held separate sessions for agriculture (crop production) and for livestock management respectively, as the emission sources and mitigation options required specific expertise in each field. In addition to these six sectoral WGs, an urban development working group was also established with the purpose of meeting periodically to assess specific urban considerations and impacts of the GLEDS options. It served as a space for dialogue and engagement of stakeholders who often deal with issues that are cross-cutting between energy, transportation, green spaces, and urban development.

The sector-level WGs included full representation of high-level institutional representatives and sector-level technical experts from both governmental agencies, private sector and nongovernmental organizations, as well as representatives from the different indigenous peoples in Guatemala. They provided inputs, reviewed and approved key GLEDS Process deliverables and made key choices and decisions through an open, transparent, fact-based and inclusive decision-making process.

The members of the WGs participated in the GLEDS Process through working group sessions held during the two years of the GLEDS Plan development. For each WG, five sector-level working sessions and a sixth and final plenary working session were held to openly review, discuss and validate the GLEDS baseline, to screen and prioritize GLEDS options for development, to review the design of the GLEDS options and the impacts assessment results.

Figure II-2 below illustrates the six working sessions held for each WG. In the first session, each WG reviewed the GLEDS baseline of energy, resources, and GHG emissions and provided comments back to the technical team. During the second session, each WG was presented with catalogs of mitigation options for their sector (WG members provided comments back on each sector catalog). During the third session, the WG reviewed and commented on the prioritized list of options for inclusion in the GLEDS Plan as resulted by the participatory online multi-criteria analysis (MCA) process the stakeholders conducted as described in Chapter IV. Session four focused on a review of the design of each of the prioritized GLEDS options (WG members were asked to provide their input on the initial design of each option). During session five, the results of the direct (microeconomic) impacts of each GLEDS option were reviewed with each WG (WG members provided input on key methods, inputs and results including implementation costs, energy/resource/emissions impacts). Finally, during session six, a review was conducted on the anticipated macroeconomic impacts for the GLEDS options. As well, the full economy-wide impacts from all GLEDS options were reviewed.

Figure II-2. Six Sessions of the GLEDS Working Groups



Participation of different groups of the population in the development of the GLEDS Plan has been an important pillar from the beginning of the GLEDS process. In constructing the membership of various WGs, special attention was placed on securing participation from male and female representatives of more vulnerable groups, particularly representatives from indigenous people and small producers.

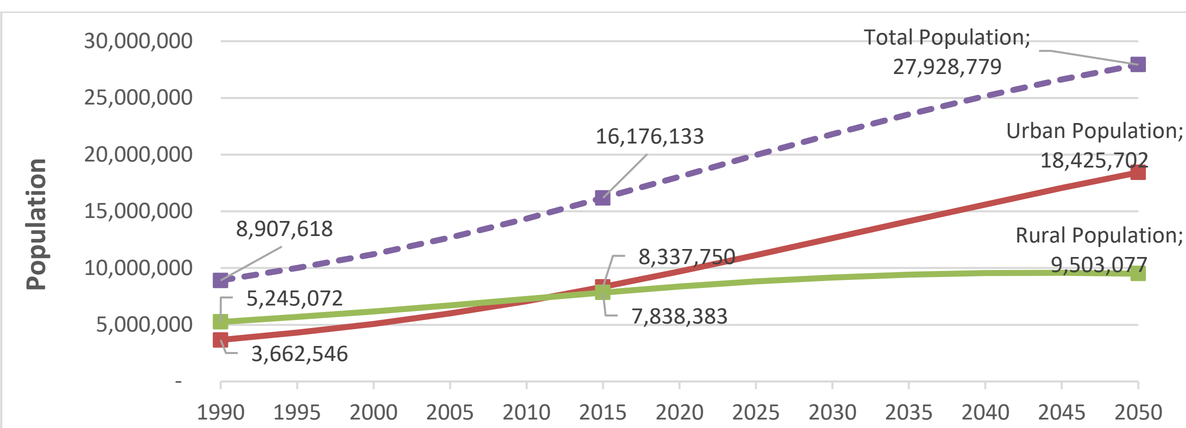
III. BASELINES OF ECONOMIC ACTIVITY, ENERGY USE AND PRODUCTION, RESOURCE CONSUMPTION / MANAGEMENT AND EMISSIONS

This section presents a summary of the GLEDS baseline. The full GLEDS baseline report is provided in Appendix B. The report addresses **historic and expected BAU socio-economic activity for Guatemala, as well as the associated energy production and consumption, resource consumption/management, and emissions of greenhouse gases (GHGs).** Please note that the use of the word "baseline" throughout this report refers to a complete summary of historic (measured) and BAU forecasted (modeled) data. Measured historical data vary by source in terms of the period measured; however, these generally range from 1990 – 2015. In some cases, historical data that did not extend all the way to 1990 were "back-casted" using simple trending analysis to derive a complete historical period.

A. GLEDS SOCIO-ECONOMIC BASELINE

Beginning with population growth, Figure III.A-1 provides the GLEDS baseline. **Total population was estimated to be over 16 million in 2015, and this is expected to grow to almost 28 million by 2050.** Growth in urban populations is expected to account for most of this growth.[1]

Figure III.A-1. Guatemala's Expected Population Growth



[1] Total Population: INE, *XI Censo de Población y VI de Habitación* 2002. Rural and urban population break-outs taken from the World Bank Indicators accessed February 17, 2016. http://data.worldbank.org/data-catalog/world-development-indicators.

Figure III.A-2 provides the GLEDS baseline for overall economic activity (gross domestic product or GDP) and gross national income (GNI). The units are in constant 2015 Quetzals (Q). Historic data through 2015 were extracted from the World Bank (WB) Development Indicators database.[2] The values shown for GDP are "GDP at purchaser's prices". This is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. **Based on WB data from 2005 through 2015, the average annual GDP growth rate has been 3.7%.** Gross national income (GNI) tracks very closely to GDP for Guatemala.[3]

GDP forecasts for 2016 - 2018 were taken from WB Global Economic Prospects Database (3.5%/yr -3.6%/yr).[4] Long-term (2019 - 2050) GDP growth is based on the average annual growth rate from 2016 to 2021 from the International Monetary Fund's World Economic Outlook (3.8%/yr).[5] A deeper understanding of Guatemala's BAU economic development could be obtained with more detailed information on expected levels of future employment and a breakdown of forecasted GDP by economic sector. However, these estimates were not available from WB or the Bank of Guatemala (BANGUAT). See the GLEDS Baseline report for more historic information on the make-up of Guatemala's economy.

---

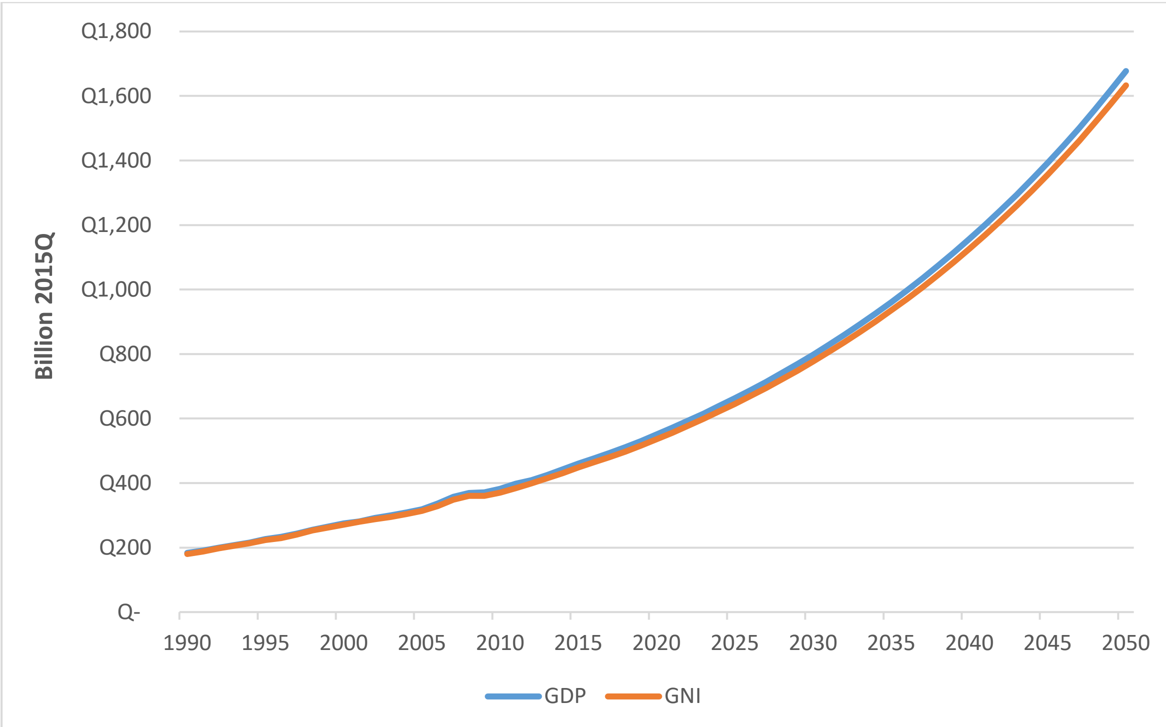
[2] World Bank Development Indicators, accessed October 2016: http://databank.worldbank.org/data/reports.aspx?source=2&country=GTM&series=&period=#. Note that while these data were obtained from WB, they are reported by Guatemalan government agencies. Historical GDP values match those reported by the Bank of Guatemala.

[3] Because of the close historical relationship between GDP and Gross National Income (GNI), GNI was forecasted based on annual GDP growth. GNI (formerly GNP) is the sum of value added by all resident producers plus any product taxes (less subsidies) not included in the valuation of output plus net receipts of primary income (compensation of employees and property income) from abroad.

[4] World Bank Global Economic Prospects, accessed October 2016: http://www.worldbank.org/en/publication/global-economic-prospects#data.

[5] Internal Monetary Fund World Economic Outlook, accessed October 2016: http://www.worldbank.org/en/publication/global-economic-prospects#data.

Figure III.A-2. Guatemala's Expected Economic Growth



Total GDP is derived by the following equation:

$$GDP = GCF + FC + E - I$$

where:
GCF = gross capital formation
FC = final consumption
E = exports
I = imports

Figure III.A-3 provides a breakdown of Guatemala's historic GDP by spending category based on BANGUAT data. Gross capital formation (also known as "gross domestic investment") consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories. Fixed assets include land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. Inventories are stocks of goods held by firms to meet temporary or unexpected fluctuations in production or sales, and "work in progress." Final consumption expenditure (also referred to as "total consumption") is the sum of household final consumption expenditure (private consumption) and general government final consumption expenditure (general government consumption).

As shown in Figure III.A-3, the import values show up as negative values. The final consumption wedge of the chart is essentially pulled down over the top of imports so that the net GDP gets represented on the Y-axis. This chart indicates a substantial increase in spending during the period by households and government which has pushed GDP up from about 150 billion quetzals in 2001 to about 400 billion in 2012. This equates to an average annual growth rate of 9.7%.

An annual average increase in gross capital formation of 6.7% and exports at 8.2% have combined to drive GDP higher during the period of 2001-2012. At the same time, imports have also grown substantially (8.1% annually), which has served as a slight drag on the overall economy. Imports more than doubled during this period, which by 2011 **reduced GDP by almost 150 billion quetzals annually**.

Figure III.A-3. GDP Make-Up by Spending Category

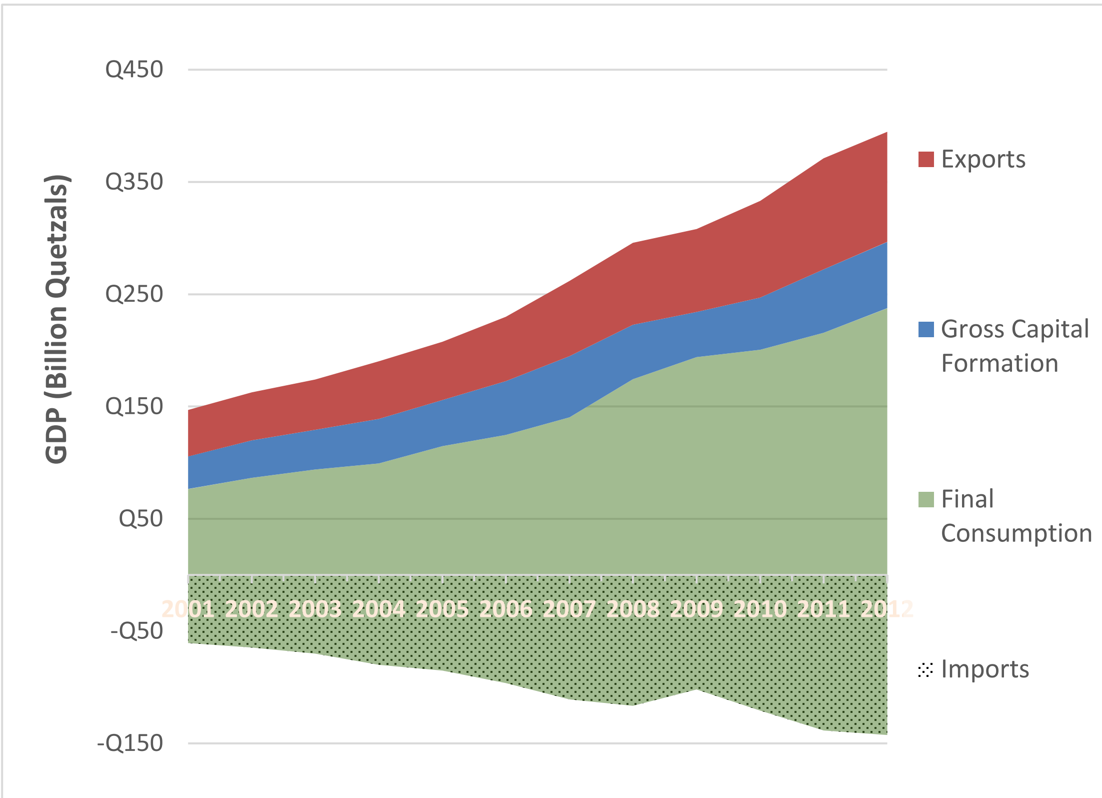


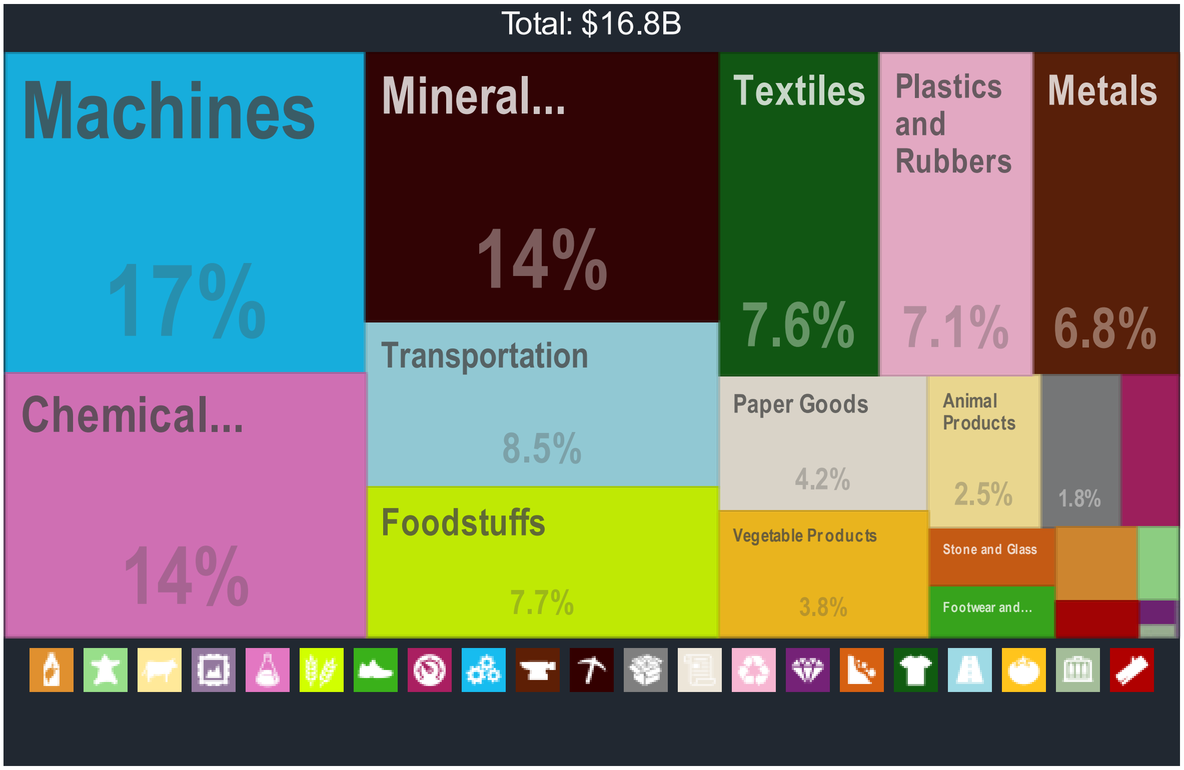
Figure III.A-4 provides a recent breakdown of Guatemala's imports by category. As indicated in the bottom portion of the figure, refined petroleum products, part of the mineral products category (mainly gasoline and diesel fuel), made up a significant portion of imports in 2016 (11% of US$ 16.8 billion).[6] A further breakdown of the import costs of refined petroleum products is provided in the next section.

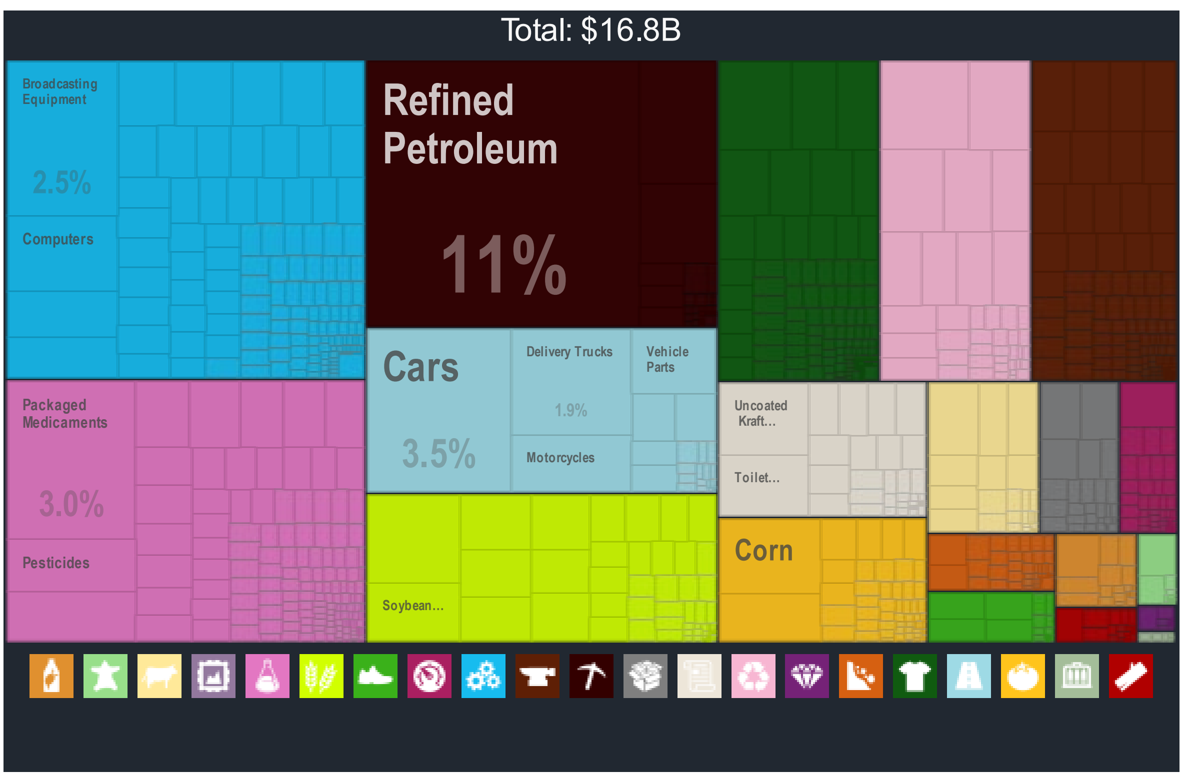
Another notable import for the GLEDS process within the chemical products category is nitrogenous fertilizers. While the import value cannot be seen in Figure III.A-4, it made up over half a percent of imports in 2016 (not an insignificant value; over US$ 90 million). Additional details on

[6] Source: Observatory of Economic Complexity (OEC); https://atlas.media.mit.edu/en/profile/country/gtm/. These data are taken from the BACI International Trade Database2. The original data comes from the United Nations Statistical Division (COMTRADE), but is cleaned by the BACI (Banque de France and CEPII) team using their own methodology of harmonization. CEPII is the French Centre d'Etudes Prospectives et d'Informations Internationales.

the country's imports can be found by exploring the Observatory of Economic Complexity web page.

Figure III.A-4. 2016 Composition of Imports

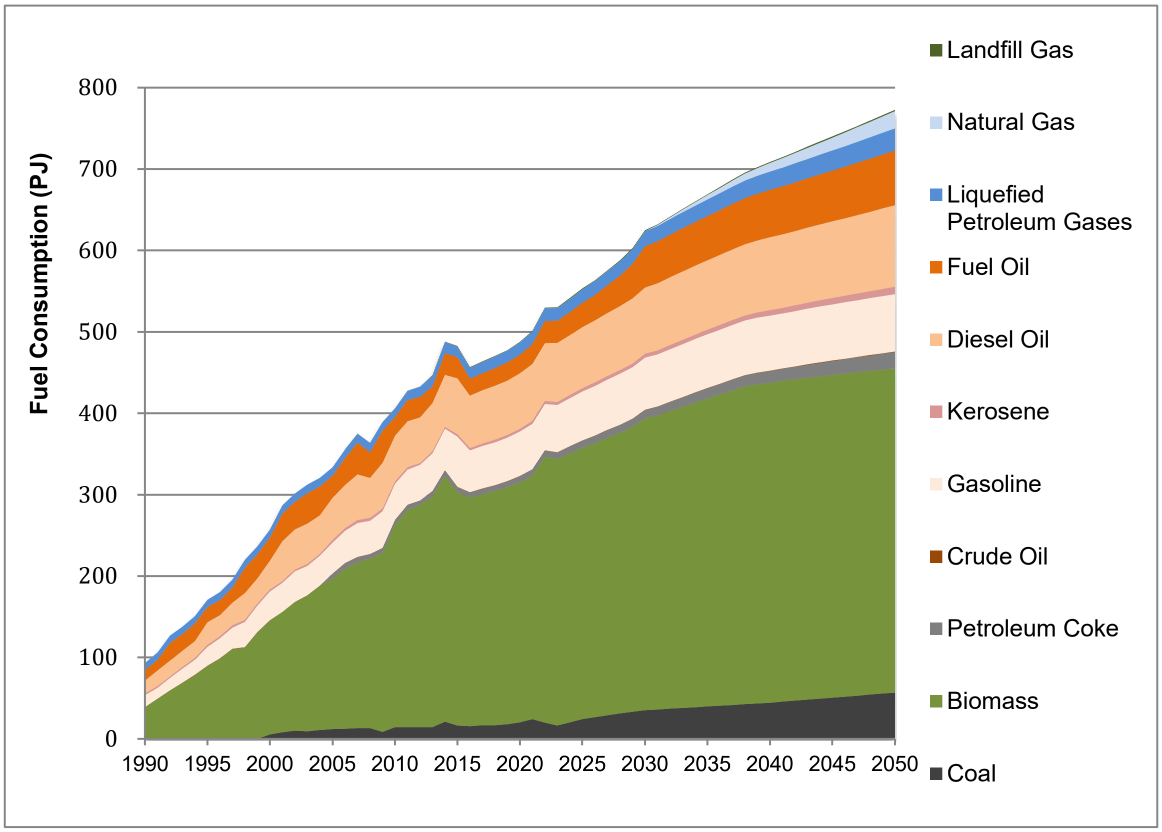




B. GLEDS ENERGY BASELINE

To support the level of anticipated and desired socio-economic growth described above, Guatemala's economy will require energy and other resources. The estimated amounts of primary energy needed to support economic growth are summarized in Figure III.B-1 below. In 2015, a total of about 450 petajoules (PJ) of primary energy was consumed by Guatemala's economy.[7] By 2050, primary energy needs for the country are expected to be about 775 PJ. **Important fossil fuels consumed in the BAU forecast through 2050 are coal, diesel oil, and fuel oil.[8] Biomass consumption, mainly in the residential sector, has been a dominant source of energy and is expected to remain that way through 2050.**

Figure III.B-1. GLEDS Primary Energy Consumption Baseline

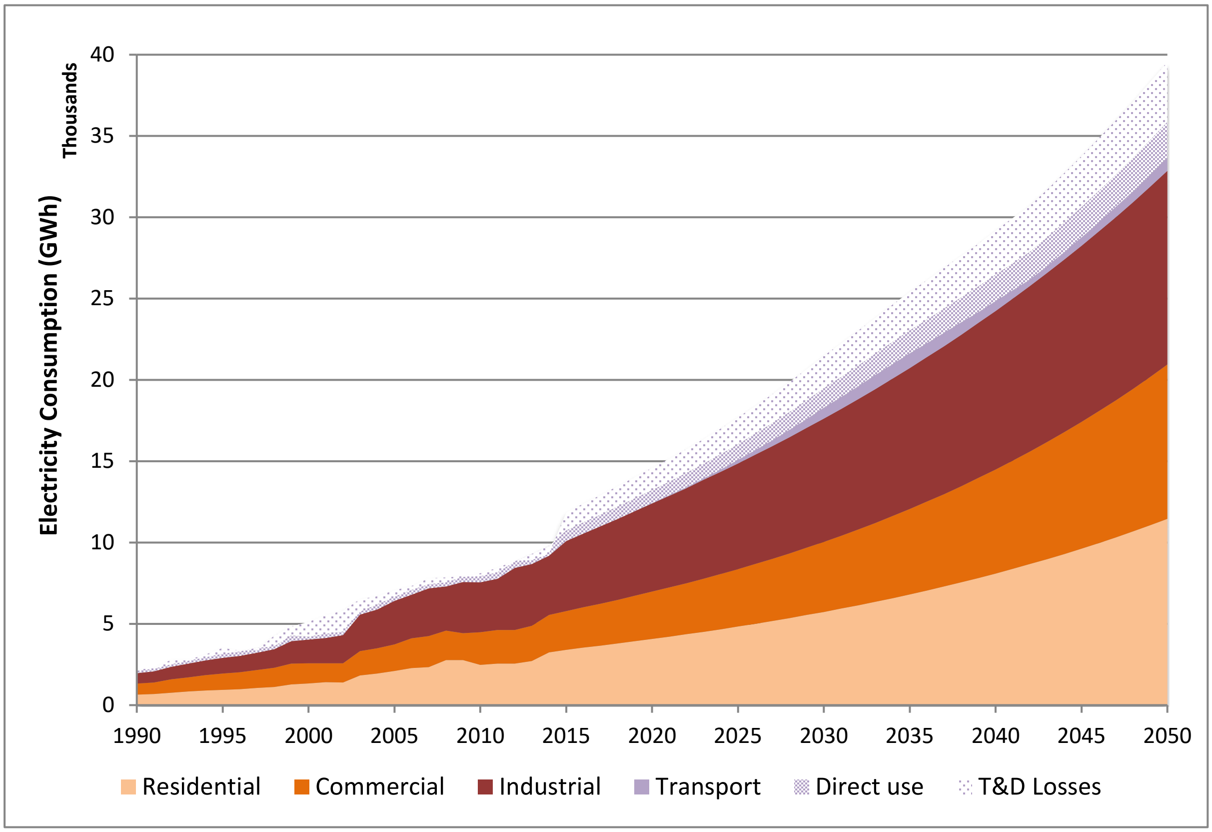


[7] A PJ is 10^{12} joules. A PJ is also equal to 1,000 terajoules (TJ; 10^9 joules), which are the most common unit of energy used in the GLEDS Project

[8] Fuel oil here refers to residual fuel oil, which is also referred to as heavy fuel oil or bunker fuel oil.

Aside from their use as transportation fuels and to drive industrial processes, some of the fossil fuels shown in the figure above are also needed to generate power for the growing economy and population. Figure III.B-2 provides the baseline for electricity demand by sector and also includes the expected losses of power during transmission and distribution (T&D)[9].

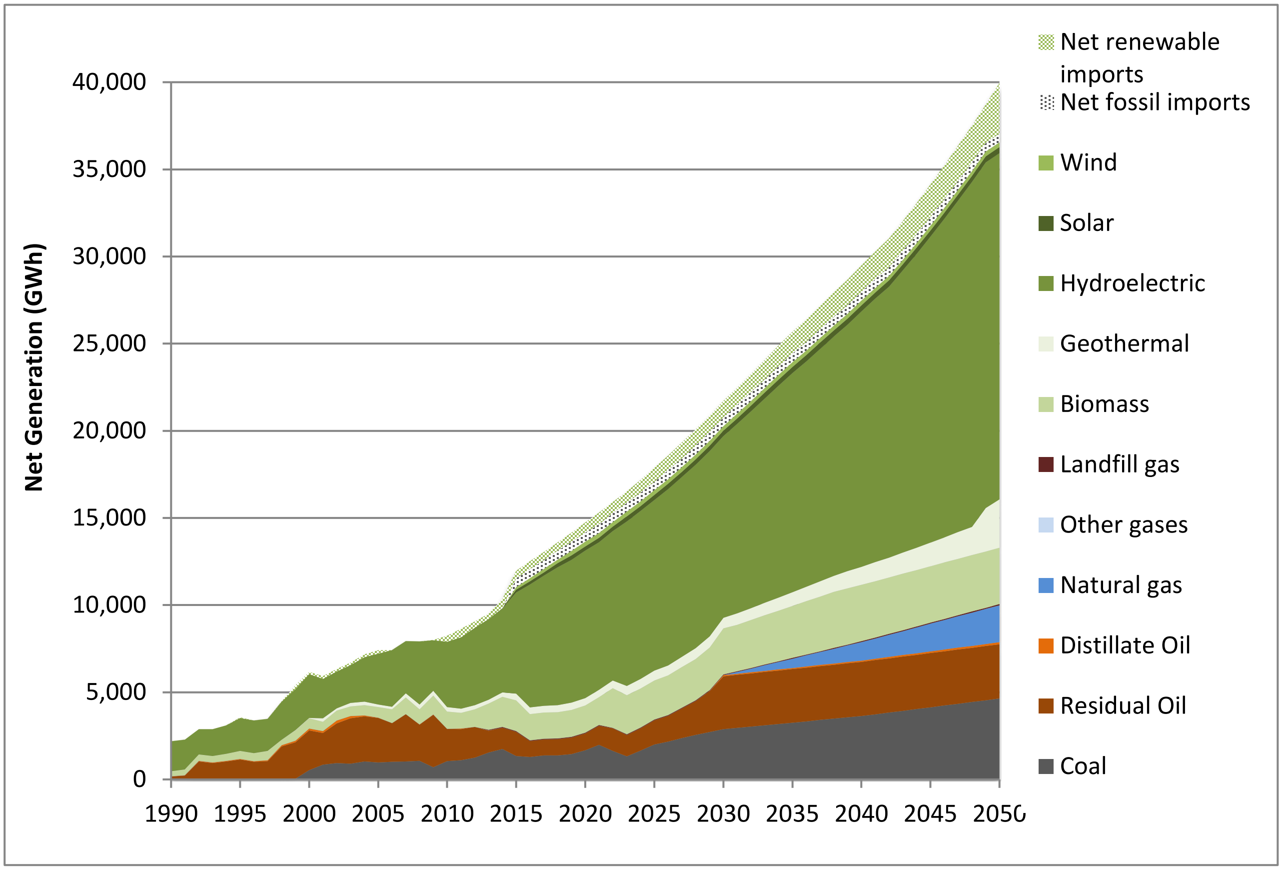
Figure III.B-2. GLEDS Electricity Demand Baseline



[9] T&D losses include both technical and non-technical losses. Losses are an inherent consequence of the operation of any electrical network and arise as power flows through equipment such as cables, overhead lines and transformers. Non-technical losses include theft, non-payment by customers, and errors in accounting and record-keeping.

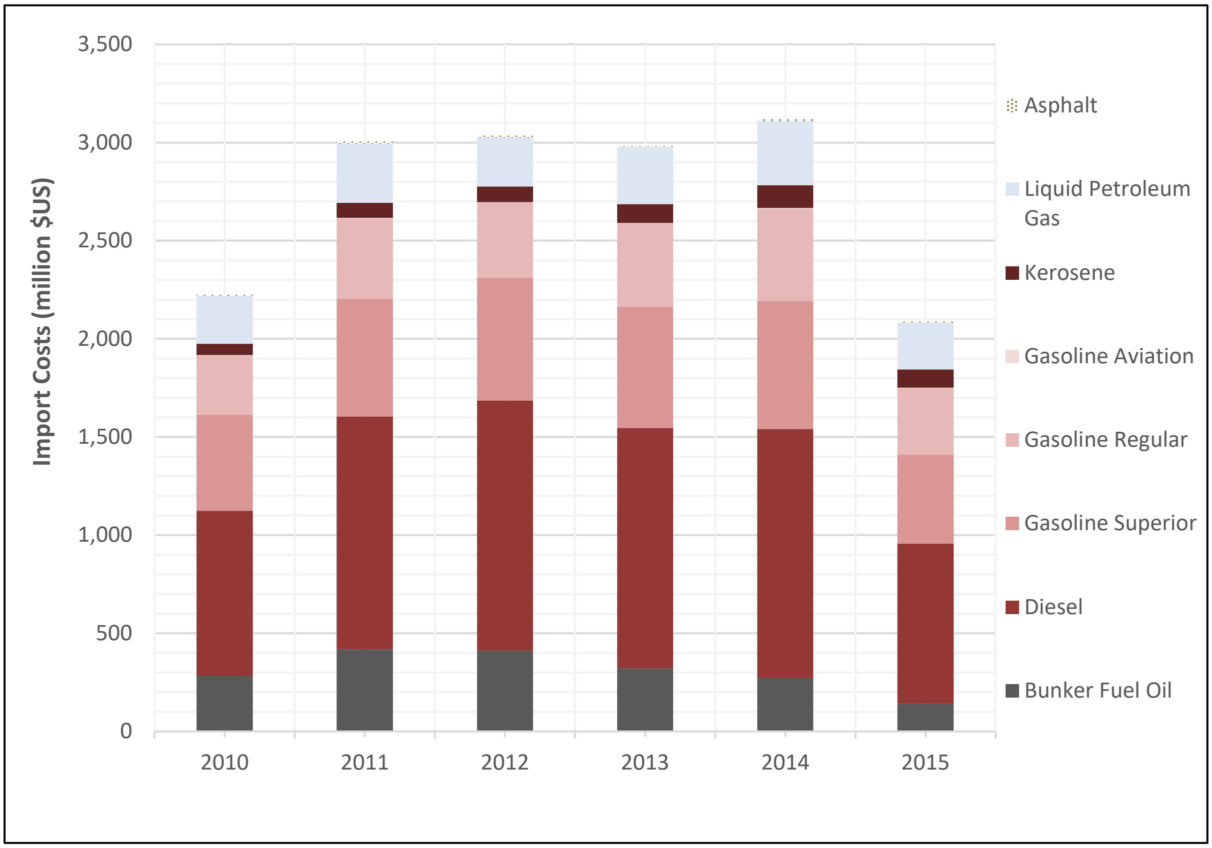
Figure III.B-3 below provides a summary of the historic and BAU forecasted net generation of power required to meet demand, which includes fossil fuels and renewable energy (RE) sources. The most important RE generation resources by far in Guatemala are large-scale hydro-power. Additional important contributions come from biomass power generation (sugarcane bagasse). Geothermal, RE imports, landfill gas, solar and wind have small contributions to net generation in the BAU forecast.

Figure III.B-3. GLEDS Net Electricity Generation Baseline



Fossil-based generation grows in the BAU forecast. Coal-based generation grows in its contribution, especially after 2025. Natural gas is also expected to contribute to the power generation mix beginning after 2030. Distillate oil-based generation is expected to remain part of the generation mix through 2050; however, its contributions are not expected to grow after 2030. As further described in the GLEDS Baseline Report (Appendix B), **the country imports coal and finished petroleum products and is expected to continue to import these fuels along with natural gas in the future.** The cost of just the petroleum products imports from 2010-2015 are presented in Figure III.B-4. **Since energy imports create a drag on overall economic activity (e.g. GDP), these rising import needs are another important issue to address in the GLEDS options presented in the next chapter.**

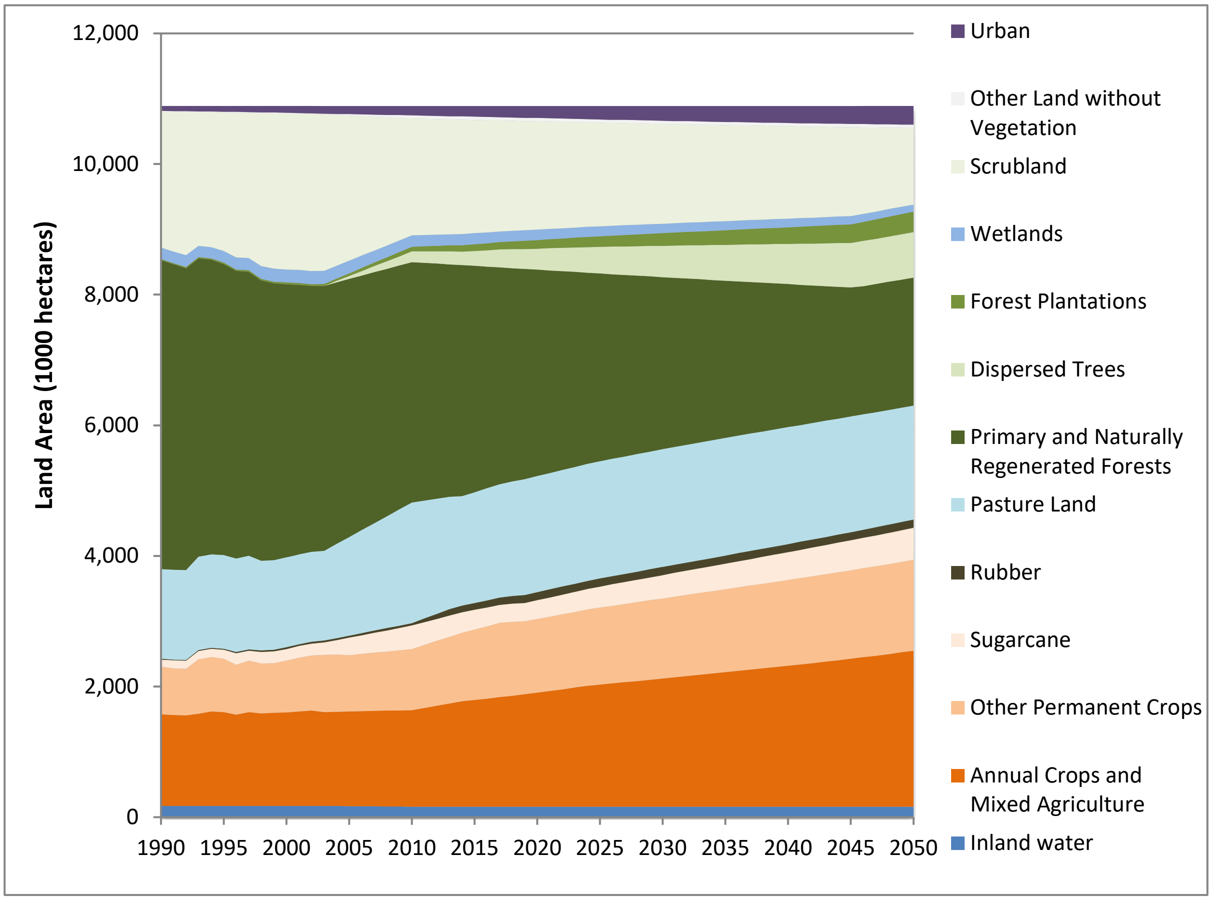
Figure III.B-4. Cost of Petroleum Product Imports



C. GLEDS RESOURCES BASELINE

Another key resource tied to socio-economic growth in Guatemala is land. Figure III.C-1 provides the GLEDS baseline for land use/land cover. This chart indicates that **dramatic changes have occurred in recent history to accommodate population and economic growth, and these are expected to continue through 2050.** What is most noticeable in this chart is the sharp contraction in area for natural and regenerated forests. **Forested lands have been and will continue to be converted to other land uses, mostly in support of expanded crop and livestock production and to a lesser extent to support urban expansion. The area of "dispersed trees", while also a forested land use, indicates a growing area of degraded forest resulting from unsustainable harvesting practices (including use as fuelwood).**

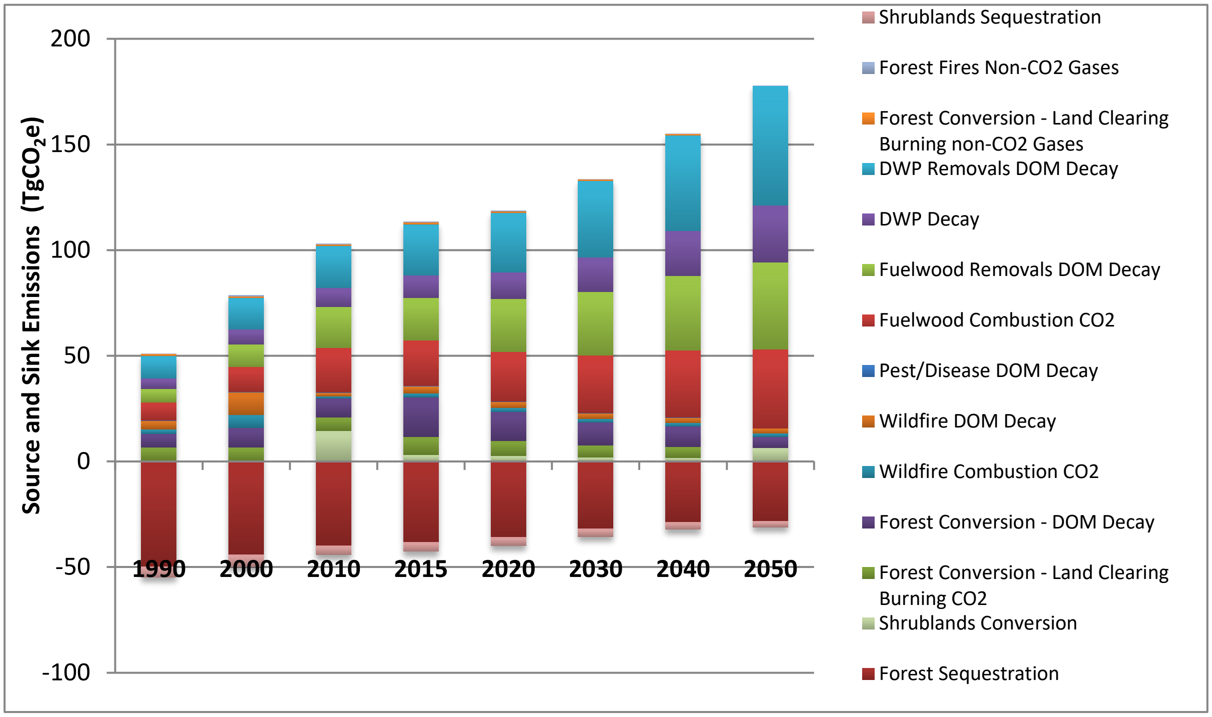
Figure III.C-1. GLEDS Land Use/Landcover Baseline[10]



[10] Note that based on the print size of this figure, some categories, such as "Other Land without Vegetation", "Scrubland", "Dispersed Trees", and "Sugarcane" are either not visible or barely visible. Also, the terms, "shrubland" and "scrubland" are used interchangeable in this report and both refer to a plant community characterized by vegetation dominated by small trees and shrubs, and often also including grasses, herbs, and geophytes.

The GHG impacts resulting from loss of forested area through land conversion and unsustainable biomass harvests are clearly summarized in Figure III.C-2. This figure provides estimates of both carbon sequestration (accumulation) and carbon loss (emission). Although less effort was put into estimating the early historical period (1990-2000) than in later timeframes of the baseline, it is quite likely that the country's forests were net sinks of carbon from the atmosphere prior to the 1990-1995 time-frame.

Figure III.C-2. Net Forest Carbon GHG Emissions



D. GLEDS EMISSIONS BASELINE

Figure III.D-1 provides a complete economy-wide accounting of GHG emissions. This figure indicates that the historical (inventory) phase of the baseline is through 2015. This means that historical information was available across most sectors through 2015 to estimate emissions. The BAU forecast period begins in 2016 and continues through the 2050 GLEDS planning period. **Net emissions are expected to increase from 99 teragrams of carbon dioxide equivalent ($TgCO_2e$) in 2015 to 138 $TgCO_2e$ by 2030 and 201 $TgCO_2e$ by 2050**. A teragram (Tg) is equal to one million metric tons. Emissions are shown on a "net" basis, which means that both emissions sources and sinks are included. Table III.D-1 provides the emissions data in a tabular format for both net emissions and "gross" emissions (gross emissions exclude carbon sinks).

Figure III.D-1. Economy-wide Net GHG Emissions Baseline

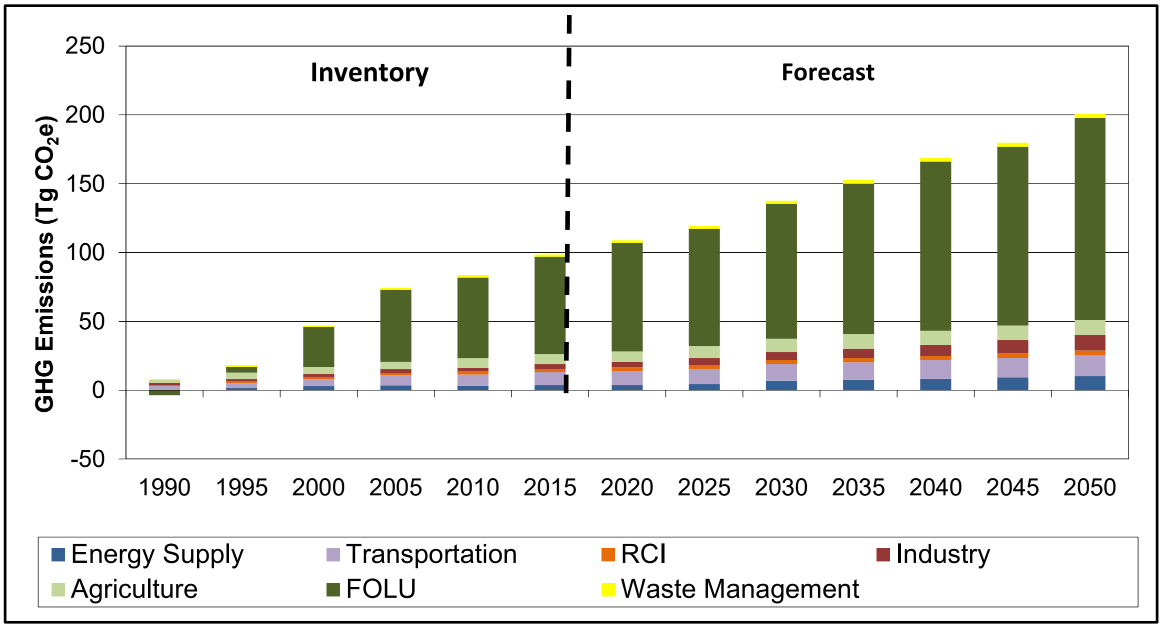


Table III.D-1. Economy-wide GHG Emissions Baseline, Net and Gross[11]

Sector	Net Emissions (Tg CO_2e)							
	1990	2000	2010	2015	2020	2030	2040	2050
Energy Supply	0.32	2.9	3.2	3.6	3.6	6.8	8.5	10
Transportation	2.6	5.3	8.1	9.4	10	12	13	15
RCI	0.72	1.4	2.3	2.4	2.6	2.9	3.2	3.4
Industry	1.7	2.1	2.7	3.5	4.2	5.8	8.1	11
Agriculture	1.9	5.2	6.8	7.3	7.6	9.8	10	11
FOLU	(3.7)	29	59	71	79	98	123	147
Waste Management	0.87	1.2	1.7	1.7	1.9	2.3	2.7	3.1
Total Net Emissions	**4.4**	**47**	**83**	**99**	**109**	**138**	**169**	**201**

Sector	Gross Emissions (Tg CO_2e)							
	1990	2000	2010	2015	2020	2030	2040	2050
Energy Supply	0.32	2.9	3.2	3.6	3.6	6.8	8.5	10
Transportation	2.6	5.3	8.1	9.4	10	12	13	15
RCI	0.72	1.4	2.3	2.4	2.6	2.9	3.2	3.4
Industry	1.7	2.1	2.7	3.5	4.2	5.8	8.1	11
Agriculture	5.0	6.3	8.4	8.5	9.2	10	11	12
FOLU	41	76	88	110	116	132	153	171
Waste Management	1.0	1.4	2.0	2.0	2.3	2.9	3.5	4.1
Total Gross Emissions	**53**	**96**	**114**	**139**	**148**	**172**	**201**	**228**

[11] Note: the general convention for reporting results with an appropriate number of significant digits throughout this plan are to report results greater than 10 with no digits beyond the decimal point; values between 1 and 10 are reported with one value beyond the decimal point; values less than one are reported to two digits beyond the decimal point.

Finally, Table III.D-2 summarizes the contribution of each economic sector to overall emissions growth for the BAU emissions forecast. Two different planning horizons are shown. The first ends in 2030 to indicate near-term growth and comparisons to the country's NDC; and the second ending in 2050, which is the full GLEDS planning horizon. The second and third columns of the table show the contribution of each sector to the growth in economy-wide GHG emissions from 2015-2030 and 2015-2050, respectively. The last two columns provide the annual emissions growth rate for each sector. **The FOLU sector is the key contributor here. About 74% of emissions growth during the GLEDS planning period is expected to come from the FOLU sector as a result of forest land conversion and unsustainable harvesting practices.** Figure III.D-1 presented above provides details on the shrinking forest land base for carbon sequestration during the forecast period and also provides a sense of the size of past and estimated future fuelwood removals. **Energy supply (power generation), transportation (onroad vehicles) and industry are also important sectors contributing to emissions growth.** The GLEDS Baseline Report in Appendix B provides details on the forecasts for each sector.

Table III.D-2. Sector-level Contributions to Net GHG Emissions Growth

Sector	Contribution to Economy-Wide Growth		Sector Annual Growth	
	2015 - 2030 (%)	2015 - 2050 (%)	2015 - 2030 (%/yr)	2015 - 2050 (%/yr)
Energy Supply	8.3%	6.6%	4.3%	3.0%
Transportation	6.8%	5.6%	1.7%	1.4%
RCI	1.4%	1.0%	1.4%	1.1%
Industry	5.9%	7.6%	3.4%	3.4%
Agriculture	6.5%	3.6%	2.0%	1.2%
FOLU	69%	74%	2.2%	2.1%
Waste Management	1.6%	1.4%	2.1%	1.8%

IV. GLEDS OPTIONS SCREENING, SELECTION AND DESIGN

The 43 GLEDS options were screened and selected by the members of the six WGs with CCS' assistance out of sector-based catalogs containing several hundred potential options across all sectors (the "Catalog"). The Catalog was developed in close collaboration between the USAID Low Emission Development Project and the participants of the six WGs and includes options in all six economic sectors that were deemed to have a potential for consideration in Guatemala.

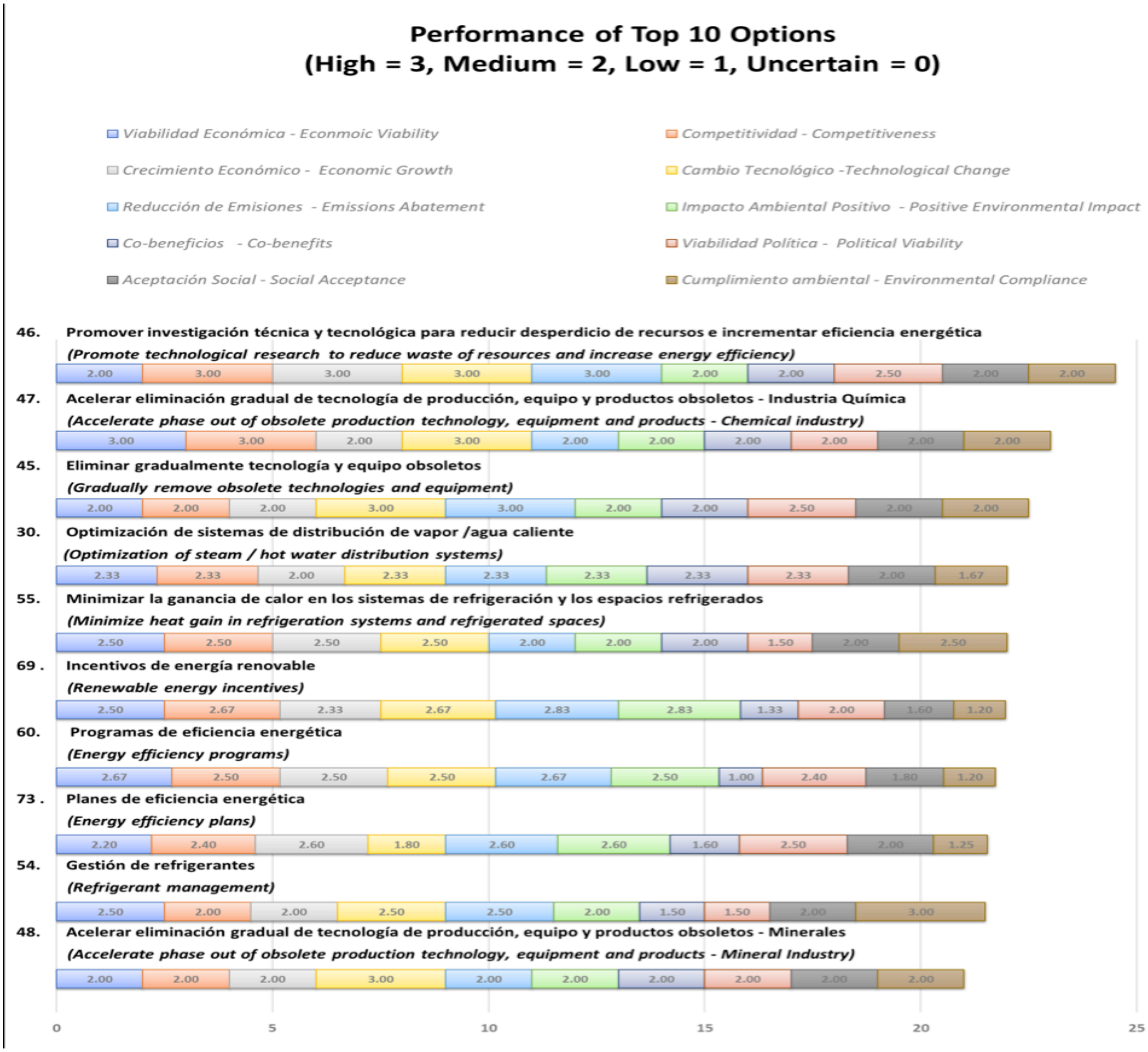
The screening and selection of the 43 GLEDS options was conducted by the members of the WGs through a facilitated online Multi-Criteria Analysis (MCA) process. As a first step in the MCA process, the members of the WGs selected a set of criteria against which they would rank each option. These criteria were:

- GHG emission reduction
- Economic growth
- Competitiveness
- Creation of new markets
- Technical feasibility
- Political feasibility
- Co-Benefits

Based on their expert judgment and best available information for each option in the sector catalog, each criterion was ranked as "high, medium or low" in terms of its expected performance. The ranking was conducted through an online survey system with CCS' assistance, and **the results where then shared and discussed with the WGs to enable them to select, through an open and inclusive process, the top ten priority options in each sector.** In a few cases, some of selected options were then lumped with others to avoid overlap in coverage or analysis.

An example of the MCA process results for the ten top Industry options that ranked highest across the screening criteria is showed in Figure IV.A-1 below.

Figure IV.A-1. Sample MCA Survey Results for the Industry Sector



Following the MCA survey, with CCS's technical assistance the WG packaged the results into individual options for further design and impacts analysis. In some cases, the packaging of MCA results involved bundling individual options from the survey results into a single option for subsequent design and analysis. Table IV.A-1 below provides **the list of the 43 GLEDS priority options** selected by the WGs for further development.

Table IV.A-1. Final List of GLEDS Priority Options

Energy Sector and Urban U-3/U-4	
E-1	Management of Permits and Locations to Increase the Potential of Existing Hydroelectric Plants
E-2	Development of Mini- and Micro-Hydroelectric Plants
E-3	Expand the Use of Solar Generation

E-4	Expand the Use of Geothermal Energy
E-5	New Renewable Generation to Reduce System Losses
E-6	Energy Efficiency Codes for Existing Buildings
E-7	Energy Efficiency Standards for Equipment and Appliances
E-8	Energy Audits
E-9	Introduction of Efficient Wood Stoves
U-3	LED Public Lighting in Guatemala City
U-4	Add Energy Efficiency Standards to National Building Code
INDUSTRY SECTOR	
I-1	Energy Efficiency for Furnaces/Ovens
I-2	Energy Efficiency Programs - Boilers and Process Heaters
I-3	Incentives for Renewable Energy
I-4	Improvements to Electrical Energy Efficiency
I-5	Increased Recycling and/or Substitution of Materials
I-6	Improve Heat Recovery
TRANSPORTATION SECTOR AND URBAN U-1/U-2	
T-1	Build MetroRiel Light-rail Route in Guatemala City
T-2	Modernize Private Fleet of Suburban/Extra-urban Commuter Buses
T-3	Improve Regular Transit, Update Fleet, and Expand BRT in Guatemala City
T-4	Construction of Highway Bypasses around Chimaltenango (department of Chimaltenango) and Barberena (department of Santa Rosa)
T-5	Modernize the Private Light-duty Vehicle Fleet
T-6	Promote the Use of Ethanol in Gasoline
U-1	Establish an Urban Land-Use Component Within the National Urban Development Policy
U-2	Sustainable Urban Mobility Plan for Guatemala City
AGRICULTURE AND LIVESTOCK MANAGEMENT SECTOR	
Agriculture	
AG-1	Sustainable Management of Soils
AG-2	Establishment and Improvement of Agroforestry Systems
AG-3	Establishment of Fruit Plantations
AG-4	Efficient Use of Nitrogen Fertilizers
Livestock	
GAN-1	Improved Pasture Management through Rotational Grazing
GAN-2	Promotion of Silvopastoral Systems
GAN-3	Promote Integrated Manure Management at Intensive Animal Production Systems
FORESTRY AND OTHER LAND USE SECTOR AND URBAN U-5	
FOLU-1	Establishment of Sustainable Forest Plantations
FOLU-2	Conservation and Management of Sustainable Natural Forests
FOLU-3	Reforestation of Degraded Lands with Native Species
FOLU-4	Strengthen Institutional Response Capacity in Prevention and Control of Forest Fires
U-5	System of Urban Green Spaces
WASTE MANAGEMENT SECTOR	
Solid Waste	
DS-1	Expansion of Waste Collection and Improvement of Separation Efficiency

DS-2	Re-Use and Recycling of Inorganic Solid Waste
DS-3	Advanced Composting
DS-4	Landfill Gas Capture and Use
Waste water	
DL-1	Water-Saving Measures in the Residential, Commercial, Institutional and Industrial Sectors
DL-2	Advanced Wastewater Treatment Technologies

For each GLEDS priority option, design parameters were then developed. These included a set of performance goals for each option, as well as the implementation mechanisms needed, both of which are used in the assessment of its impacts. The design parameters were reviewed and discussed by the WGs for final approval. For each option, they include:

- *Description*: introductory description of the option and its intended impact on baseline energy use, resource consumption/management, and/or GHG emissions
- *Level of effort*: quantitative goals
- *Timing:* start and stop dates for the proposed option, as well as any phase-in or ramp-up/down schedules
- *Coverage of implementing or affected parties*: this includes geographic boundaries and the specific types of entities or groups that will be required to implement the option
- *Instruments or mechanisms used to implement the option* defined, at least in general terms, to clarify implementation pathways and address feasibility
- *Causal chains of impacts:* they identify the intended and unintended impacts of the option and include energy consumption/production, natural resource, management practice, follow-on effects on GHGs (increase or decrease), direct monetary cost and savings expected during the implementation of the option.

For each option, an Option Document (OD) template was developed to document and determine the specific approaches used for design, analysis, and implementation. This tool enabled customization of each option as well as consistency across options and sectors.

A gender analysis was carried out for 12 mitigation options in the energy, agricultural, land use change and forestry and transport/urbanism sectors (efficient use of fertilizers, soil management, fruit tree plantations, agroforestry and silvo-pastoral systems, reforestation of degraded areas with native species, solar energy, use of fuelwood efficient stoves, model for territorial urban structure with low emissions and transportation). The gender analysis was carried out in order to define: if the voice (interests, problems, solutions) of the Guatemalan population, in particular the groups and individuals most vulnerable to the effects of climate change, is considered in the definition of the different mitigation options that are the central part of the Low Emissions Development Strategy; whether these mitigation options won´t have negative effects on this population; and if there will be equal access to the benefits from the mitigation options that are included in the Low Emissions Development Strategy. Once the analysis was completed, the results were incorporated into the 12 Option Documents and presented in the session on microeconomic analysis to the LEDS Working Groups. Through the gender analysis exercise of the 12 mitigation options, it has been possible to identify various co-benefits that mitigation technologies and practices may have for men and women (generation of employment; reduction of health problems; increase in productive activities due to access to electricity; reduction of production costs; increase in productivity and competitiveness; and increase in food security), which can be an additional guide in deciding which mitigation options to choose. Finally, it is important to mention that specific considerations regarding indigenous populations were also included in these twelve Option Documents.

All ODs have been included within the sector-level appendices of this report (Appendices D – I).

V. IMPACTS ANALYSIS APPROACH

Direct and indirect impacts of each GLEDS Option were assessed. **Direct or microeconomic impacts that can be attributed to implementation of an option include shifts in energy production and consumption, GHG emissions reductions, and costs associated with implementing the options such as costs of equipment, maintenance costs, etc.** These costs and other impacts occur at the point of option implementation, as well as at points further up the supply value chain (e.g. GHG emission reductions occurring at fossil fuel production facilities as a result of reduction in fuel demand by an end use sector).

Indirect or macroeconomic impacts include employment impacts resulting from a change in induced demand for products or services, an increase or decrease in gross domestic product (GDP), and other indirect impacts (changes in price of energy, change in incomes). For the GLEDS Process, a qualitative approach was developed and applied to address indirect impacts. That approach is detailed below.

A detailed description of the methods used to conduct the analysis of the impacts of implementing the GLEDS options is provided in Appendix C. Much of the focus in Appendix C is on the approach used to conduct direct impacts. However, since the results of the direct impacts analysis were used directly as input to the indirect impacts assessment, the information provided here addresses both.

A. DIRECT (MICROECONOMIC) IMPACTS

Direct impacts of GLEDS options can take many forms depending on the design and implementation of an option. These include: an increase in renewable and low carbon energy (RE) production; a decrease in electricity or resource demand; a decrease in land use conversion or degradation; a decrease in the use of fossil fuel; a decrease in waste generation or increase in reuse; a resulting decrease or increase in GHG emissions, and many others. Direct costs of option implementation can also take on many different forms. Commonly, an initial investment is involved, for example to purchase new technology, acquire land, etc. These initial investments could be made outright using existing public or private funds or they may require financing with programs that are consistent with the lending or investment environment for that sector of the economy. Other ongoing direct costs include operations and maintenance costs for new technology or changes in practices (including labor costs); energy costs; materials costs; and support from government or international sources (e.g. grants, production credits, emission offset credits, etc.). Costs may be fixed or variable, depending on specific needs.

For any direct impact or cost, the following general equation is used to estimate a net impact during each year of the GLEDS planning period (2019 – 2050):

Annual Impact (net change) = OS – BAU

where:

OS = metric value for the new GLEDS option scenario
BAU = metric value for the business as usual forecast (baseline) scenario.

Hence, **the general approach to analysis is to estimate annual streams of energy, resources, emissions, or cost impacts that are expected to occur as a result of implementing the option (OS); and then to do the same for what occurs without the option (BAU). When the BAU value is subtracted from the PS value, a net change occurs**. For example, if energy consumption is lower in the OS scenario, the net result will be a negative value. This works the same for costs. If costs are lower under the OS scenario, then the value of the net change will be negative. This negative value represents a cost savings to society.

Causal chains of impacts and costs have been used to graphically illustrate the intended and unintended impacts and costs resulting from the implementation of an option. Figure V.A-1 below provides an example energy, resources and GHG causal chain. The causal chain begins with an identification of the expected option impacts to energy use/production or resource consumption/management, and then identifies the resulting type of GHG impact for each (each GHG emissions impact is identified in a colored box). GHG impacts can be positive (an increase in emissions above BAU conditions) or negative (a reduction compared to BAU conditions and can be either direct (occurring at the place of option implementation) or indirect (occurring at a different location; e.g. at an upstream location in the production of energy). The example below has 3 GHG impacts identified. Two of these have a star symbol associated with them which indicates that they will be quantified in the impacts analysis. Those without a star symbol are not quantified either because they are not expected to be significant or methods/data do not exist for analyzing them.

In short for this example, the first GHG impact is for reductions of emissions at power plants connected to the grid for which demand has been reduced as a result of new renewable generation sources installed at industrial facilities (this is an indirect impact because it does not occur at the point of option implementation, i.e. the industrial facility). The second impact is another indirect impact. It corresponds to GHG reductions that occur within the fuel supply chain for the power generation facilities, as a result of lower fuel demand for those power plants (e.g. extraction, refining, and transport of residual oil).

Figure V.A-1. Example Energy, Resources and GHG Emissions Causal Chain. (I-3. Incentives for Renewable Energy)

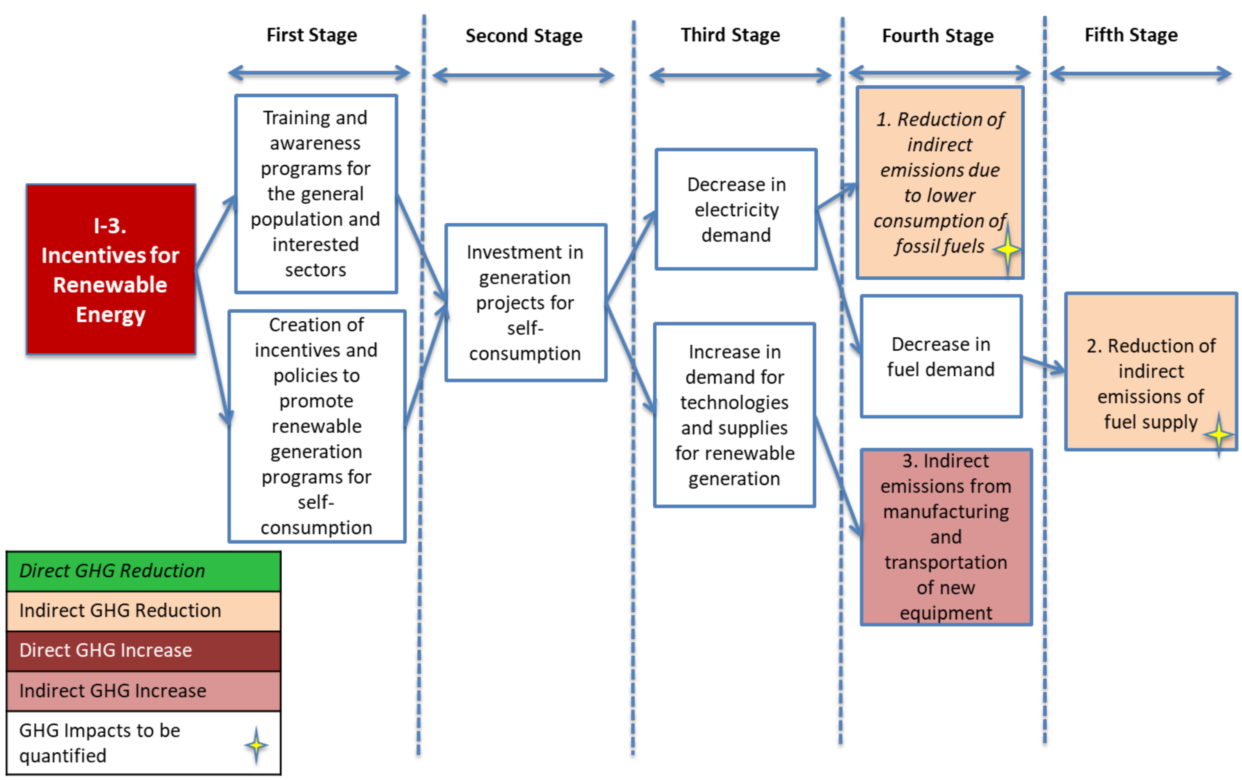
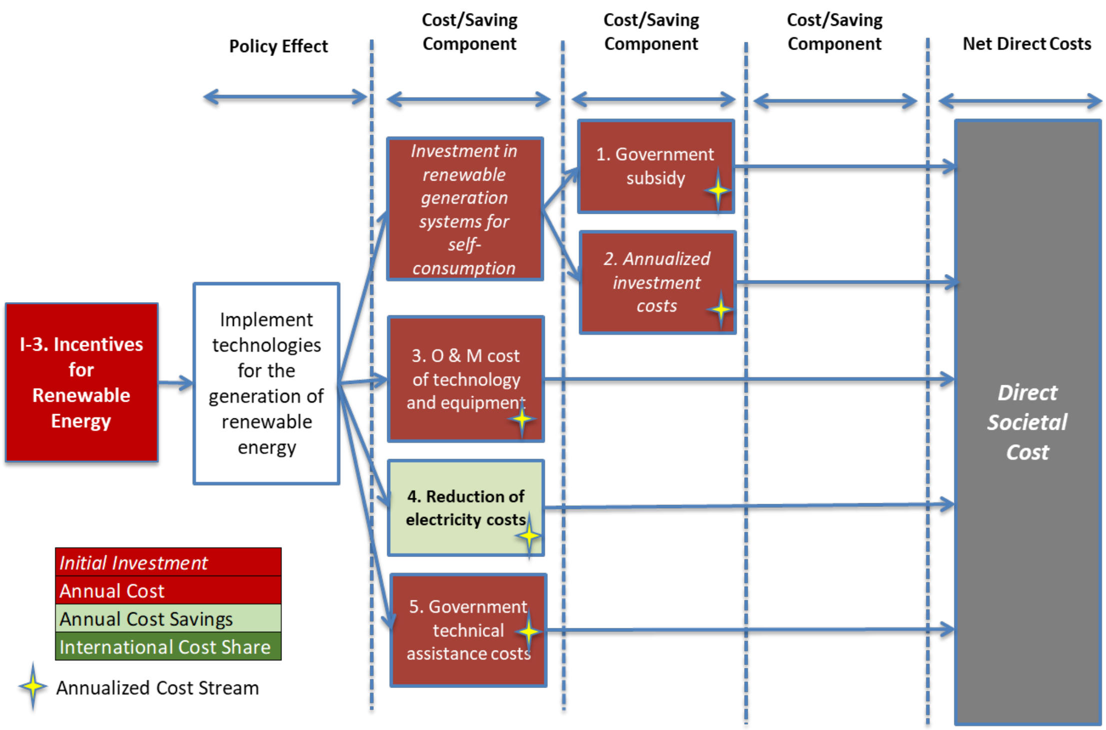


Figure V.A-2 provides an example net societal costing chain for the same option. In a net societal costing chain, each of the option implementation cost components are identified and annualized to result in separate streams of costs/savings which will be added together to derive an estimate of net societal costs. As will be further elaborated below, sufficient separation of these cost components is needed to support macroeconomic assessment. Common cost components are initial investment costs for new technologies, operations and maintenance costs, energy costs, materials costs, technical assistance costs, and government subsidies. Commonly, large initial investment costs will be annualized to account for the way in which these are financed by the implementing entity. Red boxes indicate a cost as compared to BAU conditions, while green boxes indicate a savings as compared to BAU. Like the GHG impacts above, each cost component is numbered, so that they can be tracked through the impacts analysis that follows. A star symbol indicates an annual cost stream that will become part of the net societal cost estimate for the option.

The example net societal costing chain has five cost components. The first two relate to the initial investment costs required for implementing renewable energy projects within the industrial sector. The first box indicates that there is an expected government subsidy to offset some of these initial costs for industry. The second box indicates the remaining initial investment costs that have been annualized per the financing assumptions for the option. Cost component number 3 addresses the operation and maintenance costs for new RE equipment. Cost component number 4 represents the savings to industry from reduced purchases of electricity from the electrical grid. Cost component number 5 covers technical assistance costs for the government needed during option implementation.

Each direct energy, resource, and emissions impact to be analyzed in the direct impacts analysis was identified in the energy/resource/emissions causal chain in the option documents (OD). Similarly, each component of the implementation costs was identified in the net societal costing chains presented in each OD. In addition to the summary table of direct impacts provided in each OD ("Quantification of Estimated Impacts" section), a summary of the net impacts (energy, resources, emissions and costs) at five-year increments is presented in an annex to each OD.

Figure V.A-2. Example Net Societal Costing Chain. (I-3. Incentives for Renewable Energy)



B. INDIRECT (MACROECONOMIC) IMPACTS

Indirect (macro-) assessment is distinct from direct (or micro-) analysis of options, because its purpose is to identify and estimate the *indirect* effects of option-induced changes on the economy as a whole, as well as impacts on different economic sectors, groups of people, and business types and sizes. Typical results from such analyses estimate changes in economy-wide and sector-level employment (jobs), gross domestic product (GDP, or economic growth), personal income, personal consumption expenditures, and even changes in population as people respond to changes in income, cost of living, and the availability of work. These and other outputs of macroeconomic analysis can also offer insights on the impacts on competitiveness of each individual option. Assessments of all these impacts can also be produced for aggregate collections of options, both within and across sectors.

This assessment can be done in a quantitative manner and/or qualitative manner, and in varying degrees. A quantitative approach requires a specialized analytical tool that describes the operation of the economy in question, the interaction of its various sectors internally and with the outside world, and the economy's unique profile of key equilibria, such as supply, demand and prices. **The lack of a full-fledged macroeconomic analytical model (either based on input-output tables or general-equilibrium functionalities) for the Guatemalan economy made it infeasible to conduct a quantitative analysis on the absolute number of jobs an option stimulates, the specific volume of GDP it either drives upward or downward, or the exact scale to which specific sectors of the economy benefit or are burdened as an option is implemented**.

However, based on the financial flows identified in the microeconomic (direct impact) analysis of the GLEDS options, a factor-based macroeconomic assessment of these options was conducted to scope potential jobs, income, and economic growth impacts.[12] This assessment focuses on six factors which have been shown to have a significant effect on estimated growth in GDP and employment and how each option performs against each of them. **The six factors are**:

1. **Overall Net Option Cost vs. Business as Usual** (the option's total collection of costs and savings outperforms the expected net cost of the business-as-usual scenario without the option in place)
2. **Avoided energy spending** (shift to net efficiency, or higher energy savings than use)
3. **Shift in local energy sources** (shifting from imported to local energy sources and production)
4. **Shift in Local supply chains** (expands activity in sectors that buy inputs to production from other local sectors)
5. **Shift in job creation** potential (shifting to more labor intense activities compared to baseline)
6. **Shift in imports** (Net reduction in imports)

The presence of any of these factors as a consequence of option implementation is positively associated with growth in GDP, with the exception of the fifth factor which is statistically associated with growth in economy-wide employment rather than GDP. The presence of the reverse of any of these factors, however, is identified as a cause for concern regarding the option's potential impact on the economy if implemented as designed. For example, an option that envisions additional or substitute spending on a labor-intensive activity like installation of equipment would be positively associated with the "job creation" factor, while an option that achieved savings through reducing an existing labor-intense activity would be negatively associated with the same factor, and that would be identified as a cause for concern. Each of the six factors is independent, an option projected to have multiple streams of spending and saving may have multiple, distinct influences on the economy. Each of the six factors are independent such that a given option may have multiple macroeconomic effects. Factors may also be interactive.

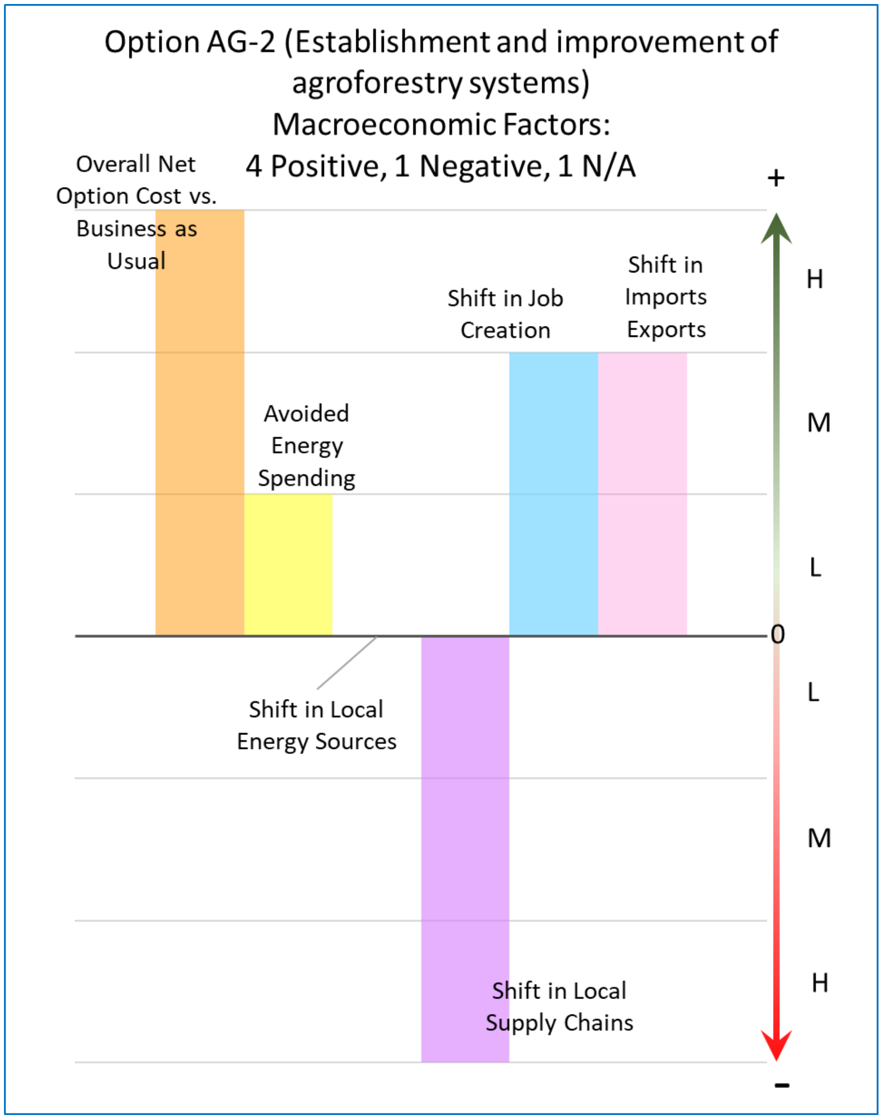
The scale of a specific financial flow estimated in the microeconomic analysis can provide a general scale of positive or negative macroeconomic impact that it drives, but the amount of money involved is still informative as to the likely scale of economic stimulus or risk that financial flow may pose. As a result, based on all financial flows in the microeconomic impact analyses of all 43 GLEDS options, each financial flow was assigned to the top ("high") third, middle ("medium") third, or bottom ("low") third.

The results of the macroeconomic assessment are displayed graphically for each option, with the six factors shown side by side for each option. The size of impact related to each factor is shown through the size of the column as either high, medium or low, and the positive or negative incidence of each factor is shown by the direction (upward or downward) of the column from

[12] The factor-based macroeconomic assessment is based on the study entitled "Summary of Key Factors Contributing to Macroeconomic Impacts of GHG Mitigation Options," by Dan Wei, Adam Rose and Noah Dormady of the USC Sol Price School of Public Policy. www.climatestrategies.us/library/library/download/905.

the midpoint. An example is shown in Figure V.A-3 below for Option AG-2 (Establishment and Improvement of Agro-forestry Systems). In this case, 4 of the six factors are associated with positive macroeconomic effects, one is negative, and the final one is not applicable (change in local fuel consumption). Details of how these factors were evaluated and interpreted for each option can be found in the ODs for each sector (Appendices D-I).

Figure V.A-3. Example Results from the Qualitative Macroeconomic Assessment



By assessing each cost and savings component identified in the direct (microeconomic) impacts analysis for the presence of one or more of these six factors, and identifying whether the cost or savings is positively or negatively associated with the identified factor, this factor based rating process develops a strategic, multi-faceted evaluation of each option's likely unique impact on the economy for design and implementation decisions. It does not, however, estimate the absolute level of change in GDP, jobs, income, imports or exports induced or lost as a result of option implementation.

VI. SECTOR-LEVEL GLEDS IMPACT RESULTS

This chapter presents descriptions of the GLEDS options and summaries of their expected impacts. Options and analysis results are presented separately by economic sector.

A. ENERGY SUPPLY AND DEMAND

1. Sector Overview

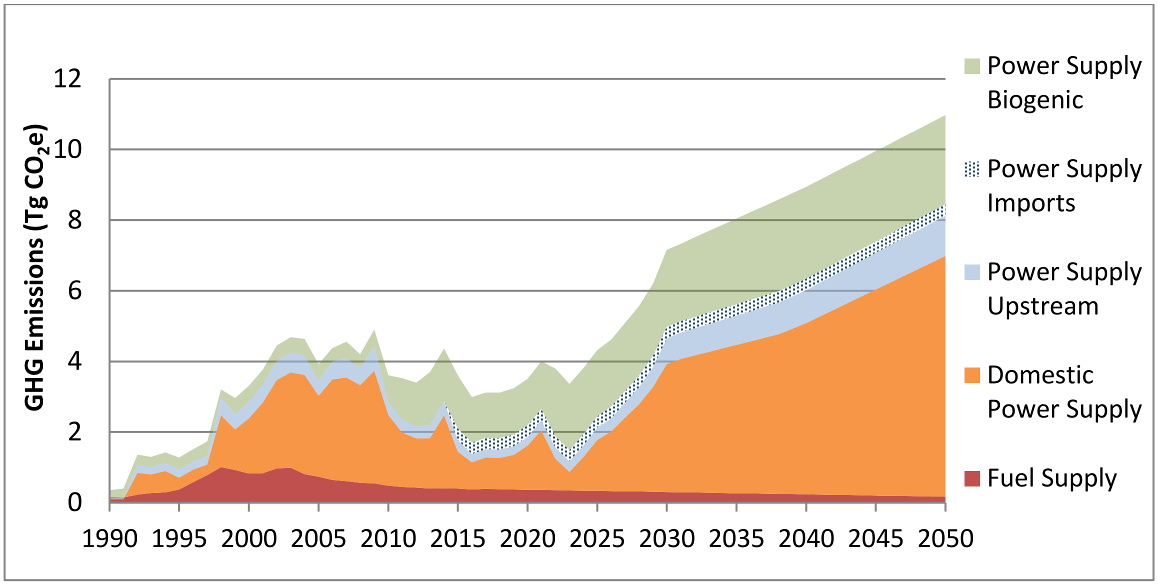
This sector addresses both energy supply (ES) subsector - in particular grid-based electricity supply - and energy demand for the residential, commercial and institutional subsector [(RCI) - including electricity and fuels demand, sometimes referred to commonly as the "buildings" subsector]. Note that energy consumption in industry and transportation are addressed in separate sectors. Figures VI.A-1 and VI.A-2 provide the GHG emissions baselines for each subsector, ES and RCI.

For energy supply, overall GHG emissions are expected to grow dramatically during the GLEDS planning period. Excluding biogenic power supply, GHG emissions (including those from imported power) are expected to increase by a factor of 4 between 2015 (about 2 TgCO_2e) and 2050 (over 8 TgCO_2e). The increase is driven by a combination of growth in electricity demand and a greater future reliance on fossil-based generation (see the GLEDS baseline report in Appendix B for more details).

Note that "power supply biogenic" in Figure VI.A-1 below refers to electricity generation from sugarcane bagasse (biomass residue produced during the milling of sugar). The CO_2 emissions from this source are considered biogenic (carbon neutral[13]) and are represented in a transparent wedge for additional understanding of all generation sources. "Power Supply Upstream" refers to emissions in the fossil fuel supply chain (coal, oil and natural gas) for power generators. These are expected to occur mostly outside of the country and are thus also shown in transparent wedges. Guatemala also imports some electricity (patterned wedge), and these imports are presumed to be derived from coal-powered generation facilities. The "Fuel Supply" wedge represents GHG emissions that occur within the country for petroleum extraction and refining.

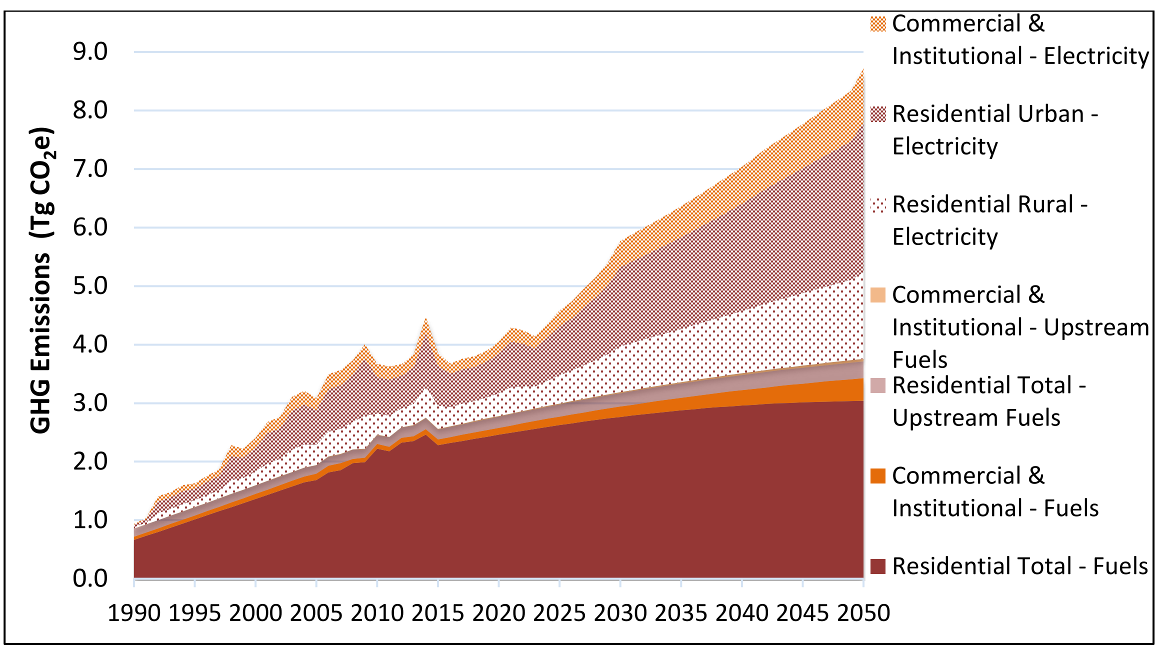
[13] For the GLEDS Plan, biomass derived from sustainable supplies was treated as a carbon neutral source of energy. This means CO_2 emissions were not counted within an estimated of carbon dioxide equivalent emissions. For a sustainable source of biomass for energy combustion, only CH_4 and N_2O emissions were included in the CO_2e GHG emission results. Sustainable forms of biomass in the GLEDS Plan include sugarcane bagasse (which is used to produce electrical power for onsite power use at the sugar mill and as an electrical grid power source). On the other hand, all biomass derived from Guatemala's forests is not considered to be carbon neutral. This is because annual removals of biomass from the forest for energy and other needs exceed the amount of annual biomass sequestered from the atmosphere. So, in all cases, CO_2 emissions are included with CH_4 and N_2O in the CO_2e GHG emission results.

Figure VI.A-1. GHG Baseline for Energy Supply



As indicated in Figure VI.A-2 below, **the dominant sources of GHG emissions in the RCI subsector are residential and commercial/institutional fuel consumption (about 2.5 TgCO_2e in 2015 increasing to about 3 TgCO_2e by 2050). Of these, the residential sector is much larger and is expected to still contribute half of GHG emissions by the end of the GLEDS planning period.** The RCI sector's emissions associated with the consumption of power are also shown on this chart to provide context and a more complete picture of the GHG footprint for the sector. These are shown in patterned wedges and are excluded from any charts that combine emissions from both the ES and RCI sectors. As shown in this chart, **much of the growth after 2025 comes from expected growth in electricity consumption rather than fuels.**

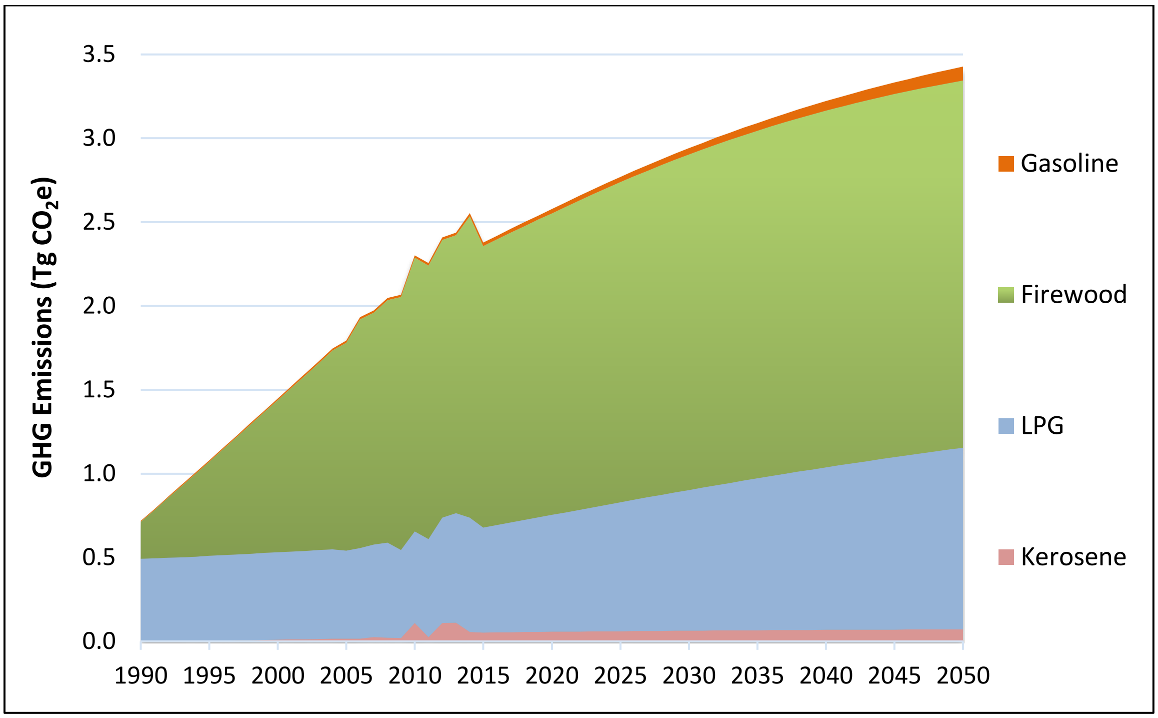
Figure VI.A-2. GHG Baseline for the Residential, Commercial and Institutional Sector



To provide a better understanding of the importance of fuelwood consumption in the RCI sector, Figure VI.A-3 below provides a breakdown of GHG emissions for each of the primary fuels consumed. Liquefied petroleum gas (LPG) and fuelwood are the two main fuels. The CO_2 emissions from fuelwood in this case are not considered carbon neutral, because this biomass is not being sourced sustainably in Guatemala (annual extractions of wood from the forest exceed annual growth of forest biomass).

The appendices of the GLEDS Baseline Report (Appendix B) provide more details and breakdowns of the emissions for the ES and RCI sectors. **Key drivers of future GHG emissions are the expected growth in electricity demand, which in turn is the result of electricity needed to support a growing population, incomes, and economic activity in the residential and commercial sectors**. Also, future generation under BAU conditions, especially after 2030, is expected to feature more coal- and natural gas-based generation.

Figure VI.A-3. Baseline Fuel Consumption GHG Emissions for the RCI Sector



2. Summary of the GLEDS Energy Options

There are eleven GLEDS options for the Energy sector, including five related to Energy Supply, four related to RCI, and two other options that were developed by a subgroup covering urban issues (both address energy efficiency, one for street lighting and one for urban buildings). Each of these options is summarized briefly below and is described in more detail in Appendix E to this report.

E – 1. Management of Permits and Locations to Increase the Potential of Existing Hydroelectric Plants

This option focuses on the **process of repowering, rehabilitation and modernization of hydroelectric power plants currently in operation.** The option is designed to encourage entrepreneurs and operators of these plants to carry out these practices in their facilities in order to increase generation, increase plant capacity, improve reliability, reduce operating and maintenance costs, extend the plant's useful life, and comply with environmental regulations and security. As such, the option offers the opportunity to increase the capacity of electric power generation and improve its efficiency without the need to install or build new hydroelectric plants, which in some cases can present difficulties due to social and environmental issues. **The goal of this option is to increase the hydroelectric capacity and output at existing plants by a total of 285 megawatts (MW) over ten years, with additions at approximately the same annual average rate thereafter.**

E – 2. Development of Mini- and Micro-Hydroelectric Power Plants

The E-2 option promotes investment in mini- and micro-hydroelectric plants to support local grid development projects that benefit rural populations that are isolated from the national electricity system. As such, the option seeks to provide sustainable provision of energy services, the mitigation of climate change by reducing GHG emissions from burning fossil fuels (candles, kerosene) and sometimes biomass fuels for lighting, and/or for the use of diesel power systems in remote areas, and thus reduces the use of scarce fossil resources. Additional benefits include improving scientific and technical knowledge on the repercussions of the use of electricity in productive activities, cost savings from the use of hydro generation when developing local projects, reductions in energy import costs, and improvements in the rate at which access to electric power can be provided to isolated areas. In addition to reducing GHG emissions, relative to the diesel and other systems that would otherwise be used to provide power to remote villages, mini-and micro hydro systems provide opportunities for local economic development, reduce the costs to households of fuels purchased for lighting, and allow the charging of batteries for electronics such as cell phones and entertainment devices. This option has a target of 0.9 MW of mini- and micro-hydro capacity added annually through 2050.

E – 3. Expand the Use of Solar Generation

This option includes the installation of three types of solar photovoltaic generation systems: large systems (greater than 5 MW capacity) connected to the national grid, smaller facilities connected to and supporting local distribution grids, and facilities serving rural areas. Thanks to its geographic features, Guatemala has significant solar radiation during most of the year, which makes the country ideal for the use of this form of energy. The country's average potential is 5.3 kWh/m^2-day of solar radiation.

The development of generation through the use of indigenous resources—in this case solar energy—is part of the energy policy for the years 2013-2027 as published by the Ministry of Energy and Mines of Guatemala and supports the plan's objectives of diversification of the sources of grid electricity, sustainable rural development, and the reduction of GHG emissions. **Targets for this option are an average of just under 17 MW capacity deployed annually, 93 percent of which will be in large installations, and all of which is assumed to displace generation from central station fossil-fueled power plants.**

E – 4. Expand the Use of Geothermal Energy

The goal of this option is to increase installed geothermal generation potential by 300 MW, relative to the baseline, over the years 2026 through 2036, with smaller additions of 5 MW annually thereafter. To enable this more rapid growth in geothermal capacity, the option will support a process that allows redefining rules related to access to concessions in geothermal resource exploitation areas, so that those resources can be exploited through both public and private initiatives. Redefine a time limit of not less than 10 years for the concession of exploration areas for pre-feasibility studies carried out by interested investors is part of these changes in rules. Other elements of the option include compiling and disseminating information about national geothermal potential so as to make such information available to attract investment in the use of geothermal reservoirs for electricity production and thermal use.

E – 5. New Renewable Generation to Reduce System Losses

This option promotes the installation of renewable energy systems at targeted locations on the transmission and distribution (T&D) network in order to support the local T&D network. Adding such generators can help to support voltage and frequency on local networks, and to reduce loading on key T&D lines, thus reducing losses. Under the option, power generation plants with renewable resources (small- and mini-hydro, wind, solar, and biomass-fueled) will be located near the points of connection with main transmission lines. **Targets for the option are to deploy an average of about 13 MW annually through 2050 for grid support, with about two-thirds of the new capacity being hydroelectric, and most of the rest wind power.**

E – 6. Energy Efficiency Codes for Existing Buildings

As a result of the high growth in Guatemala in the construction of buildings for residential, commercial and institutional use, the buildings sector will be a key factor in consumption of electricity and other fuels by 2032. Although other GLEDS options target the **implementation of building energy codes** for new buildings (see U-4, below), **buildings existing as of 2020** will continue to use a large share of the fuels used by the RCI sector for decades. As a result, energy-efficient buildings have great potential to indirectly (via reduction in electricity requirements) reduce GHG emissions in the RCI sector. Efficiency improvements can target air conditioning systems, water heating, and other electricity consumption. **The goal of this option is to save about 1.8 percent of RCI electricity use when the option is fully phased-in.**

E – 7. Energy Efficiency Standards for Equipment and Appliances

As the economy of Guatemala grows, more and more electrical devices are purchased and used. Many of these devices are imported to Guatemala. **Assuring that consumers have the information to select energy-efficient appliances and equipment, and that national and/or regional (multi-country) standards for energy efficiency are sufficiently stringent, are the primary goals of this option.** The growing regional and global trend of using energy labeling systems for electrical appliances equipment, if adopted fully in Guatemala, will allow the best use of the country's energy resources. Without a labeling system, the country's market could quickly become a focus of attraction and concentration of energy inefficient equipment that would not be accepted in markets in neighboring nations. In order to support a system of standards and labeling for appliances and equipment, it is necessary to carry out a market study to identify the consumption ranges of the most widely used electrical equipment in the country, and to provide information so that the general population knows about the energy label systems available to support good decision-making when purchasing electrical appliances and equipment in the residential and commercial services/institutional sectors/markets for those appliance and equipment types most widely used in Guatemala. **The goal of this option is to save 18 percent of RCI electricity use when the option is fully phased-in.**

E– 8. Energy Audits

Option E-8 establishes a program of biannual energy audits for commercial and institutional consumers using larger volumes of electricity. These users are generally relatively easy to identify as they are consumers of electric power that are registered in the category of large users, with demand greater than 100 kW. Under this option, all public and private institutions with electricity demand over the 100 kW threshold undergo energy audits every other year that verify their energy (particularly, electricity) consumption and provide guidance on measures that could be implemented to reduce energy use. Following the audit, consumers will undertake energy efficiency actions to ensure the correct use of energy sources and to improve the management of the use of energy, promoting the reduction of losses and identifying energy savings opportunities. GHG emissions are reduced by reducing requirements for electricity, and consumers realize economic savings through reductions in their electricity bills. **This option targets 25 percent savings by each consumer receiving an audit following the application of audit recommendations.**

E – 9. Efficient Wood Stoves

E-9 is designed to increase the rate of dissemination of high-efficiency wood stoves in rural households in Guatemala. As such, the option is designed to promote and provide implementation mechanisms that increase the rate at which rural households obtain and use wood-saving stoves in homes that use firewood for cooking. Families adopting these high-efficiency stoves reduce the annual consumption of fuelwood, reduce indoor and local pollutant emissions, take advantage of the economic, health, reduced deforestation, and other benefits (such as a reduction in the time required for gathering fuel) associated with the permanent use of higher-efficiency stoves.

The option requires the development of education, promotion, disclosure and purchasing facilities (including financing) to provide conditions for the development of sustained demand for high-efficiency stoves, and support activities for manufacturers, marketers and promoters of stoves in order to have a sufficient supply of stoves to meet demand.

In Guatemala currently, a total of about two million households use firewood for cooking, consuming over 13 million metric tons of firewood and other biomass annually. By switching to higher-efficiency stoves, fuel use can be reduced by 50 percent. **This option targets the dissemination of 100,000 stoves within a 10-year first phase increasing to over 600,000 stoves, or 25 percent of rural households, by 2050.**

Key benefits of the option are reduction of wood consumption, reduction of GHG emissions, improvement in the health of rural household member, especially women and others cooking and tending fires, conservation of forest resources, improved attitudes of families related to improvements in the quality of life, the generation of direct jobs in the manufacture and commercialization of stoves. In addition, the option can change the attitudes of user families through maintaining a sustained relationship between users and program promoters, supervisors and assistance personnel.

U – 3. LED Public Lighting in Guatemala City

This option involves the installation of LED (light-emitting diode) technologies in the public lighting systems of Guatemala, starting with 6 municipalities of the "AMCG", the Área Metropolitana de la Ciudad de Guatemala (Santa Catarina Pinula, San Jose Pinula, Chinautla, Villa Nueva, Villa Canales, San Miguel Petapa), and later, expanding throughout Guatemala. Installations of LED public lighting systems will reduce electricity use and attendant GHG emissions from electricity generation, as well as lowering maintenance costs. This option therefore fits in with Guatemala's existing "Smart City" approach, providing climate mitigation in the context of a series of strategic actions to be developed to strengthen local governments in the management of their networks and public services. The proposed actions will integrate the National Urban Development Policy, currently in the process of formulation by the Vice Ministry of Housing.

Within the framework of the implementation of a Smart City, there are programs aimed directly at reducing energy consumption in the provision of services and urban infrastructures. In different cities, street lighting has been identified as an area with ample potential for energy efficiency improvement. The installation of LED street lighting means savings of up to 70% in the costs of the municipalities and a reduction in the carbon footprint of the cities. The use of LED has great benefits, since it broadens the spectrum of lighting, as it is a high-quality white light with uniform projection. The lamps have very long lifetimes; thus, their maintenance requirements are much lower than the shorter-lived standard bulbs of other technologies that the LEDs replace. LED systems also offer authorities the possibility of optimizing the lighting of certain areas of a city. **Under the option, LED street lighting systems will replace other**

types of street lighting by 2030 in the six municipalities listed above, by 2040 in the rest of the AMCG area, and by 2050 in the remainder of Guatemala.

U– 4. Add Energy Efficiency Standards to the National Building Code

This mitigation option includes the promotion and facilitation of the updating, discussion and adoption of a series of energy efficiency codes for buildings and related construction, as a part of the National Construction Code currently under discussion in Guatemala. The code requirements will be based on the existing manuals of the GGBC (Guatemala Green Building Council) and the Green Architecture Council. The adoption of the National Construction Code as a law of the Congress will require code compliance by builders and developers. Implementation and enforcement of improved and more stringent building energy codes will result in the installation of more energy-efficient building envelopes (walls, windows and doors) as well as more efficient lighting, cooling, ventilation, and water heating systems. These building energy use improvements reduce the electricity and LPG (liquefied petroleum gas) use in new and newly-renovated existing urban buildings, resulting in lowered GHG emissions, reduced energy costs, and in many cases, reductions in other operating costs as well.

This option therefore takes advantage of the great opportunity for countries in the process of urbanization with growing demand for housing and commercial space, to lay the foundations of a construction sector that can decisively contribute to the reduction of GHG and related emissions in the coming decades. To achieve this, a common and effective tool is the local building codes, which set standards of energy efficiency in the type of materials, design and equipment of residential and commercial buildings. Codes can be particularly useful in new buildings, where monitoring is easier and implementation costs are reduced. In addition to taking advantage of green design and technology, new buildings must be integrated into an urban planning scheme oriented towards the global reduction of energy demand. This translates into efficiency improvements in air conditioning systems, water heating and overall electric power and LPG consumption.

3. Option-level and Sector-level Direct Results (Energy, Resources, GHG, Costs and Savings)

Table VI.A-1 below provides a summary of the results of the microeconomic analyses conducted for each of the E options, as well as U-3 and U-4. Negative values are shown in red text (for example, GHG emissions below baseline levels), while positive values are shown in black text (for example, net implementation costs that are above business as usual costs). These results are shown on a "stand-alone" basis, meaning that they were evaluated against BAU conditions assuming that no other options would be implemented. **If all impacts were summed, these "stand-alone" results suggest that in-country annual 2050 GHG reductions would be 25 $TgCO_2e$ and the cumulative reductions for 2019-2050 would be 386 $TgCO_2e$.** There are also some GHG reductions that occur out-of-country emissions for the E sector (and U-3/U-4) options as a result of lower demand for fossil fuels, particularly for electricity generation. GHG reductions for fossil fuel supplies are assumed to occur outside of Guatemala. Including these additional reductions results in a total cumulative GHG reduction impact (inside and outside the country) of 446 $TgCO_2e$.

Table VI.A-1. Stand-alone Direct Impacts for the E Sector (including U-3/U-4)

Option ID	Option Title	*In-Country GHG Impacts*			*Total GHG Impacts*	*Direct Cost (Base Year 2018Q)*	
		Annual CO_2e Impacts		**2050 Cumulative**	**2050 Cumulative**	**NPV 2019-2050**	**Cost Effectiveness**
		2030 Tg	**2050 Tg**	**$TgCO_2e$**	**$TgCO_2e$**	**QMillion**	**Q/tCO_2e**
E-1.	Management of Permits and Locations to Increase the Potential of Existing Hydroelectric Plants	(1.4)	(4.1)	(64)	(79)	-Q10,285	-Q130
E-2.	Development of Mini- and Micro-Hydroelectric Plants	(0.028)	(0.10)	(1.4)	(1.8)	-Q80	-Q44
E-3.	Expand the Use of Solar Generation	(0.26)	(0.79)	(12)	(15)	-Q1,536	-Q102
E-4.	Expand the Use of Geothermal Energy	(0.78)	(2.1)	(36)	(44)	-Q1,499	-Q34
E-5.	New Renewable Generation to Reduce System Losses	(0.51)	(1.6)	(24)	(28)	Q2,822	Q101
E-6.	Energy Efficiency Codes for Existing Buildings	(0.15)	(0.35)	(6.0)	(7.4)	-Q816	-Q111
E-7.	Energy Efficiency Standards for Equipment and Appliances	(1.8)	(3.6)	(64)	(80)	-Q16,881	-Q212
E-8.	Energy Audits	(0.12)	(0.28)	(4.7)	(5.8)	-Q410	-Q71
E-9.	Introduction of Efficient Wood Stoves	(2.7)	(11)	(162)	(162)	-Q5,895	-Q36
U-3.	LED Public Lighting in Guatemala City	(0.17)	(0.64)	(8.8)	(11)	-Q3,190	-Q291
U-4.	Add Energy Efficiency Standards to National Building Code	(0.17)	(0.80)	(2.4)	(12)	-Q1,473	-Q119
	Total	**(8.1)**	**(26)**	**(386)**	**(446)**	**-Q39,244**	**-Q88**

The above summary results are presented on the basis of the "independent" analysis. This means that each option was analyzed independently against the BAU conditions (that is, assuming that it was the only option that would be implemented). These results do not reflect identified overlaps or other interactions with other options. The results that have been adjusted to take into account the overlaps / interactions within this sector are given in the following table.

US$ 1.00 = Q.7.60

If all "stand-alone" impacts results are summed, the net present value (NPV) of direct societal implementation costs are estimated to be -Q39,244 million (in 2018 Q; -US$5,164), meaning that Guatemalan society receives a considerable net *savings* from implementing these options. All of the options except option E-5, provide net societal savings, with E-1 and E-7 providing the bulk figure of the savings offered by all of the options combined as a result of implementing relatively low-cost hydroelectric uprating measures (in E-1) and the low cost of energy efficiency improvements included in E-7. **Overall, the cost effectiveness of the summed set of these 11 options [-88 Q/tCO_2e (in 2018Q); -US$12/t$CO_2$e] indicates a potential for high overall societal savings.**

Table VI.A-2 provides a summary of direct impacts with adjustments made to account for interactions or overlaps among the options in the E sector, including U-3 and U-4. These results provide a more accurate picture of GLEDS option impacts if all options are implemented as designed, although in the case of the options included here, overlaps are minimal. The three options that overlap slightly within the sector are E-6, E-7, and E-8, as some of the audit measures included in E-8 could overlap with E-6 and E-7, but the relatively limited scope of these options (particularly E-6 and E-8) mean that overlaps should be minimal and generally avoidable during implementation.

As shown in Table VI.A-2, because there is little overlap among the policies, the results are very similar to the stand-alone values in Table VI.A-1 (385 TgCO2e compared to 386 TgCO2e for cumulative GHG reductions). **The total societal savings from the options including overlaps are also nearly the same as the stand-alone results at -Q39,203 (-US$2,158) million. The estimated cost effectiveness of all E options (with U-3/U-4) remains at -88 Q/tCO_2**e (in 2018Q; -US$12/t$CO_2$e).

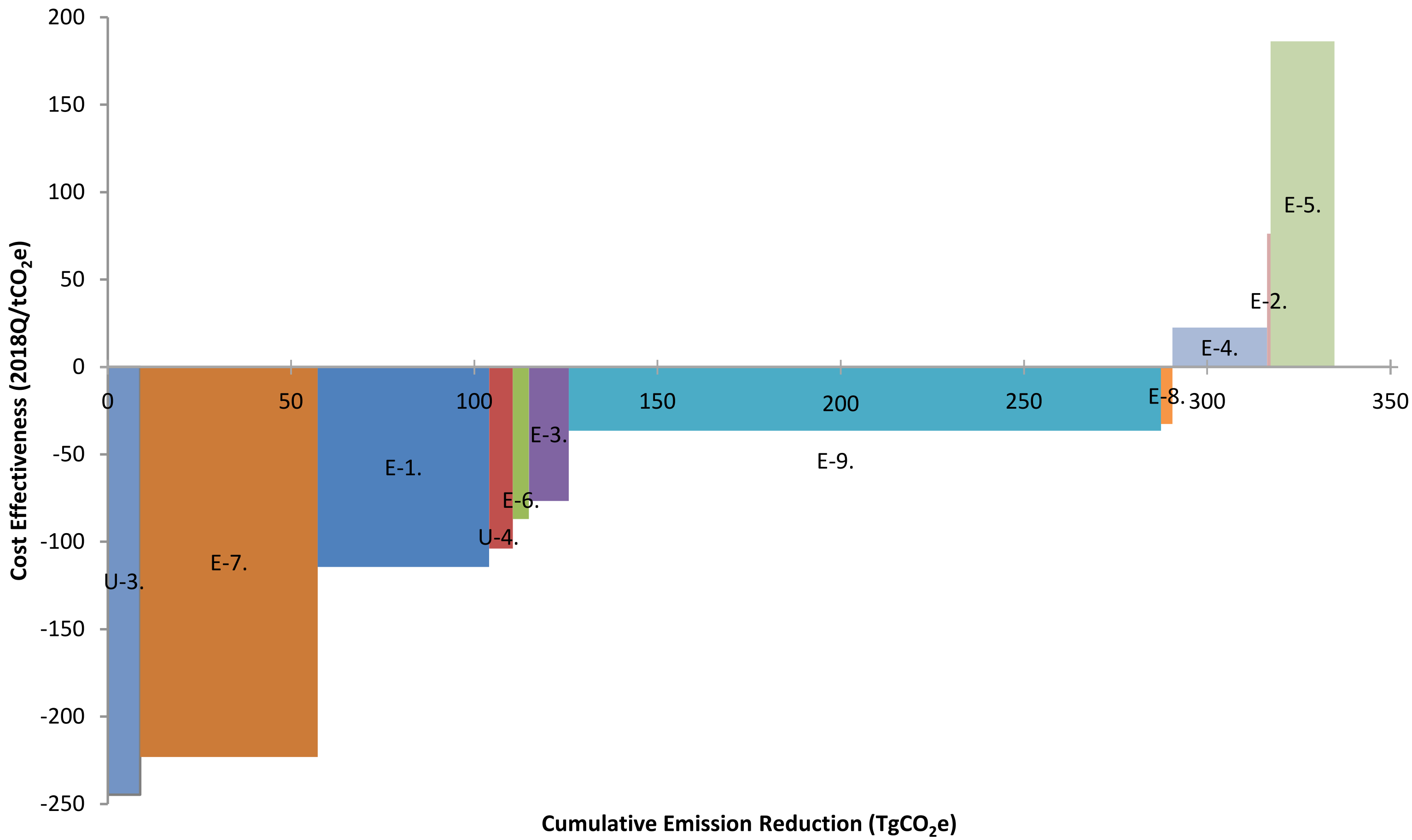
Table VI-A-2. Intra-sector Integrated Direct Impacts for the E Sector

		In-Country GHG Impacts			*Total GHG Impacts*	*Direct Cost (Base Year 2018Q)*	
Option ID	**Option Title**	**Annual CO_2e Impacts 2030 Tg**	**Annual CO_2e Impacts 2050 Tg**	**2050 Cumulative $TgCO_2e$**	**2050 Cumulative $TgCO_2e$**	**NPV 2019-2050 QMillion**	**Cost Effectiveness Q/tCO_2e**
E-1.	Management of Permits and Locations to Increase the Potential of Existing Hydroelectric Plants	(1.4)	(4.1)	(64)	(79)	-Q10,285	-Q130
E-2.	Development of Mini- and Micro-Hydroelectric Plants	(0.028)	(0.10)	(1.4)	(1.8)	-Q80	-Q44
E-3.	Expand the Use of Solar Generation	(0.26)	(0.79)	(12)	(15)	-Q1,536	-Q102
E-4.	Expand the Use of Geothermal Energy	(0.78)	(2.1)	(36)	(44)	-Q1,499	-Q34
E-5.	New Renewable Generation to Reduce System Losses	(0.51)	(1.6)	(24)	(28)	Q2,822	Q101
E-6.	Energy Efficiency Codes for Existing Buildings	(0.15)	(0.35)	(6.0)	(7.4)	-Q816	-Q111
E-7.	Energy Efficiency Standards for Equipment and Appliances	(1.8)	(3.6)	(64)	(80)	-Q16,881	-Q212
E-8.	Energy Audits	(0.11)	(0.25)	(4.2)	(5.2)	-Q369	-Q71
E-9.	Introduction of Efficient Wood Stoves	(2.7)	(11)	(162)	(162)	-Q5,895	-Q36
U-3.	LED Public Lighting in Guatemala City	(0.17)	(0.64)	(8.8)	(11)	-Q3,190	-Q291
U-4.	Add Energy Efficiency Standards to National Building Code	(0.17)	(0.80)	(2.4)	(12)	-Q1,473	-Q119
	Total After Intra-Sector Interactions/Overlaps	**(8.1)**	**(26)**	**(385)**	**(446)**	**-Q39,203**	**-Q88**

US$ 1.00 = Q. 7.60

The results shown in table VI-A-2 have been adjusted for overlays or other interactions between policies in this sector. See the notes next to each set of policy results for a description of the overlaps / interactions that were identified and addressed.
E-1: Basis on which overlap of other SE options are estimated, so by definition, no overlap.
E-2: E-1 covers larger and grid-connected hydro, so no overlap with E-1
E-3: E-3 is solar power, so no overlap with E-1 or E-2.
E-4: E-4 is geothermal power, so no overlap with E-1 through E-3.
E-5: E-5's hydroelectric generation is grid connected, so no overlap with E-2, and is for smaller plants, so no overlap with E-1. E-5 does not include geothermal power, so no overlap with E-4, and includes so little solar PV power that combined with E-3's relatively low rate of capacity, E-5's overlaps with E-3 where considered negligible.
E-6: Basis on which overlap of other RCI options are estimated, so by definition, no overlap.
E-7: E-6 would (or should) by definition be for efficiency improvements beyond standards, so no overlap with E-7
E-8: E-8 should also be largely for improvements beyond standards, so should overlap relatively little with E-7, and the relatively limited scope of both E-6 and E-8 suggests that these options could be implemented in such a way as to limit overlap. We assume that 10 percent of the cost and savings from E-8 overlaps with other RCI options.
E-9: E-9 involves savings in wood fuel use, not electricity, so no overlap with other energy options.
U-3: This option involves acceleration of the replacement of less-efficient lighting technologies with LEDs, but should not overlap with any of the RCI options because it is in the public lighting sector and thus does not seem to be covered by E-7 (RCI-3).
U-4: As this option will include improvements mandated by code, and applies to new buildings (or substantial rennovations), it is unlikely to overlap with any of the RCI options.

Figure VI.A-4. Energy Sector 2019 – 2050 Cumulative GHG MACC



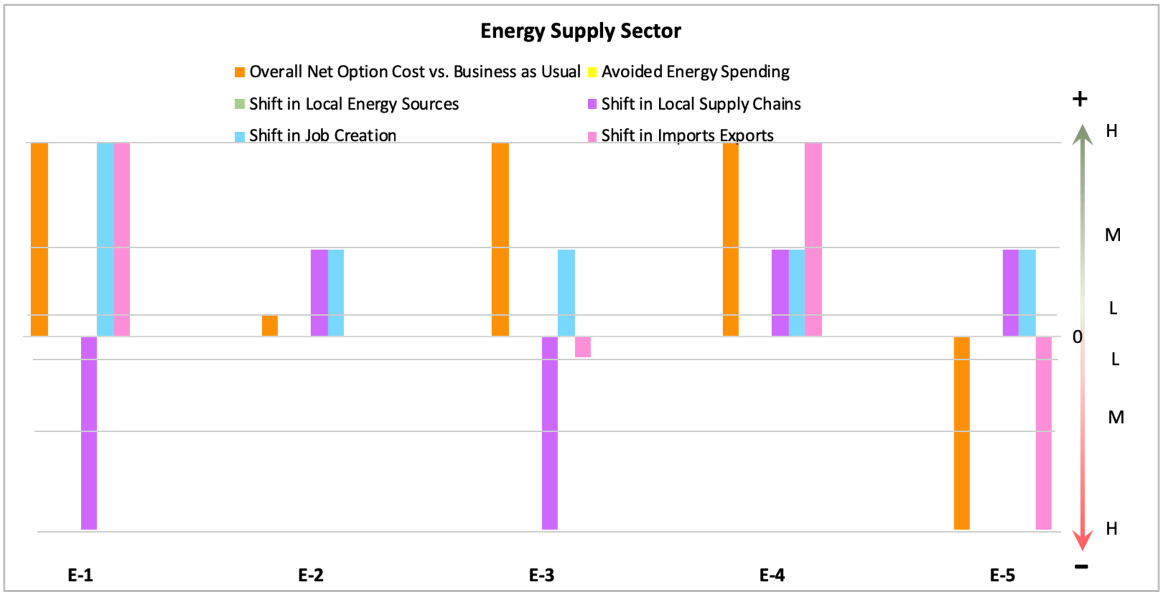
Note: the values represented in this sector-level MACC incorporate interactions and overlaps with options in other sectors ("inter-sector integrated" results). Those results are presented in Chapter VII (summarized values are provided in Table VII.C-6).

Figure VI.A-4 is the marginal abatement cost curve (MACC) for the Energy sector. The cost curve plots the cumulative emission reductions (2019-2050) for each option in the order of most to least cost effective. The values represented in this sector-level MACC incorporate interactions and overlaps with options in other sectors ("inter-sector integrated" results) presented in Chapter VII (summarized values are provided in Table VII.C-6). If all options are fully implemented, cumulative reductions are estimated to be about 330 $TgCO_2e$. Options with negative values for cost effectiveness (CE) are expected to result in net savings to society.

4. Option-level and Sector-level Macroeconomic Performance

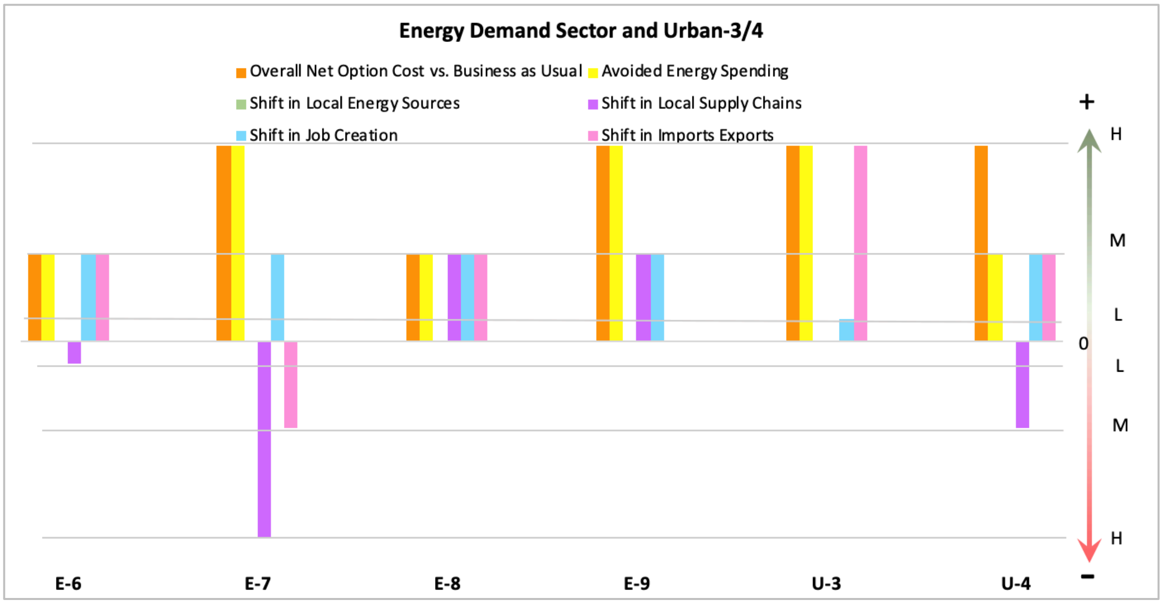
Figures VI.A-5 and VI.A-6 below provide a summary of the outcomes of the macroeconomic impact assessments conducted for each of the E options, as well as U-3 and U-4. The first figure covers the options associated with the supply of energy (E-1 through E-5), while the second figure covers those associated with reducing or changing demand for energy (E-6 through E-9, U-3 and U-4). These outcomes are shown on a "stand-alone" basis, meaning that they were evaluated against BAU conditions in isolation, i.e. without considering influences that might be present due to the implementation of other options.

Figure VI.A-5. Macroeconomic Impact Assessment of Options E-1 through E-5 (Energy Supply)



Overall, the macroeconomic assessment identifies reason to be optimistic about these options' potential to stimulate, rather than burden, Guatemala's economy. **E-1 through E-4 achieve greater savings than costs and stimulate demand for direct labor, with the only real causes for concern being the contraction of the supply chain for conventional electricity production in E-1 and E-3, and a net increase in import spending in E-3 on specialized equipment. E-5 struggles on overall cost vs. savings and does increase net imports (both of which are cause for concern), but still engages significant direct labor and stimulates local sectors.** As a result, while the cost of implementation (particularly the capital investments required) is significant, these options should be considered promising in terms of potential economic impact, particularly if they can achieve the reduction in spending on imported fossil-fuel feedstocks.

Figure VI.A-6. Macroeconomic Impact Assessment of Options E-6 – E-9, U-3 & U-4 (Energy Demand)



As the graphic above shows, the macroeconomic assessment of these six options (all intended to help governments, businesses and residents save on their overall energy use) identifies a significant basis for optimism about the potential to stimulate, rather than burden, Guatemala's economy. **All of the energy demand options produce savings greater than their costs to implement on an economy-wide basis, which is associated with a positive impact on the total amount of activity in the domestic economy. Further, they are all projected to reduce total spending on energy (this is the purpose of these options in the first place), which frees up money for other uses, and to engage at least some direct stimulus of labor-intensive activity, which spurs consumer spending and is associated with job gains not just from the option implementation but economy-wide.**

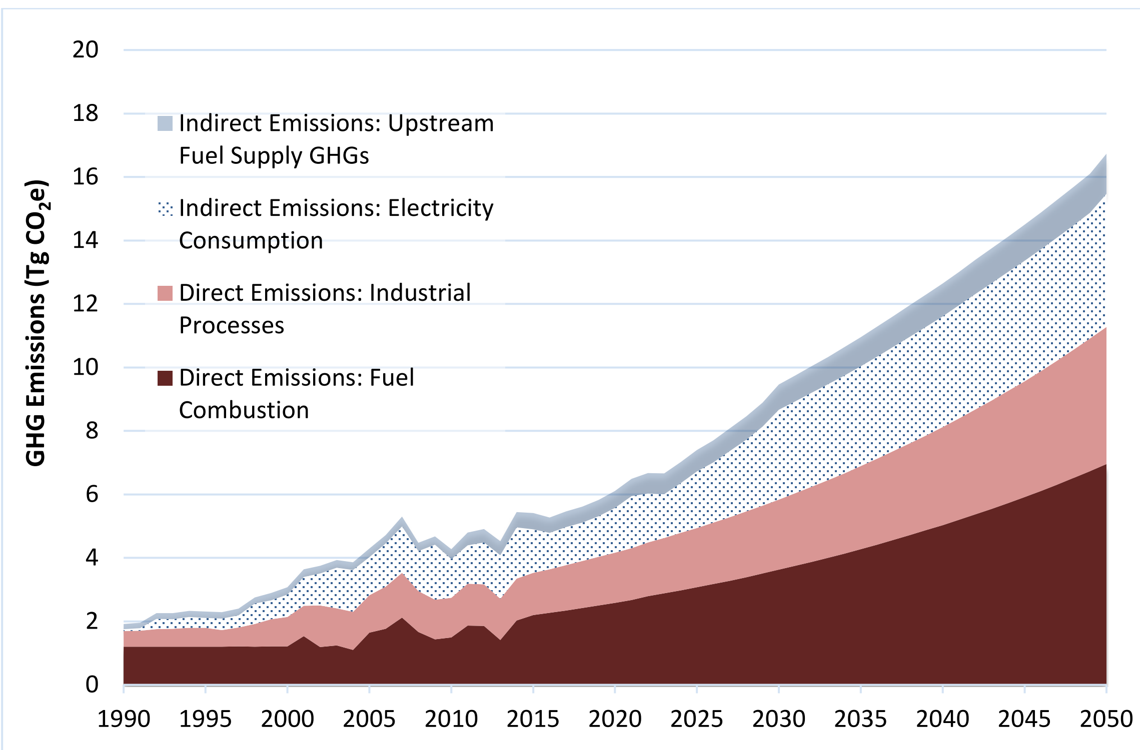
The only real variation across these options has to do with stimulus of local sectors (some options reduce local-sector activity, particularly in the energy-supply sectors) and net exports (in monetary terms, some options require more imports of specialized equipment than they would produce in reduced imports of energy or other goods). Taken as a group, however, these options should be considered promising in terms of potential economic impact, particularly if they can achieve the projected reduction in spending on energy.

B. INDUSTRY

1. Sector Overview

The Industry (I) sector covers energy use within Guatemala's industries, as well as industrial processes with GHG emissions that are not associated with energy use ("non-energy GHGs"). Figure VI.B-1 below provides a summary of GHG emissions from the I sector. This figure provides a full summary of the GHG impact of the country's industrial activities, since it shows direct GHGs from fuel combustion and non-energy GHGs, as well as the indirect GHGs from electricity consumption from the grid and the emissions associated with supply of fuels for electricity production. Direct emissions from fuel consumption and industrial processes are expected to rise sharply from about 3.5 $TgCO_2e$ in 2015 to about 11 $TgCO_2e$ by 2050. Much of this growth is driven by the need for GHG-intensive building materials, like cement, steel and glass, to satisfy building needs for population and economic growth. If GHGs from electricity consumption are also added in, the 2015 carbon footprint for Industry is about 5.5 $TgCO_2e$ and will grow to over 15 $TgCO_2e$ by 2050. The indirect emissions from fuel supply are also shown to provide an indication of the additional GHG emissions associated with supplying the fuels used by industry (most of these emissions occur outside of the country and thus are shown as a transparent wedge).

Figure VI.B-1. GHG Baseline for the I Sector



The GLEDS Baseline Report in Appendix B provides more details and breakdowns of the GHG emissions for the I sector; however, **key subsectors for Guatemala direct emissions are cement and lime production, as well as upstream GHGs from the fuel supply**. These include both fuel use and process emissions. No subsector breakdowns were identified for electricity consumption in the GLEDS baseline. **Key drivers of future GHG emissions are the expected growth in construction of buildings and other infrastructure needed to support a growing population, incomes, and economic activity.**

2. Summary of the GLEDS Industry Options

There are six GLEDS options for the Industry sector described in more detail in the Appendix E.

I-1. Energy Efficiency in Furnaces/Ovens

In some branches of industry, furnaces or ovens are an important source of direct or indirect emissions of greenhouse gases, because in their operation they burn fossil fuels, which produce direct GHGs; indirectly, the fuel supply itself requires energy and uses other processes that produce GHGs during extraction, processing/refining, and transport to the end user. **A reduction in the use of fuel in furnaces/ovens would reduce both direct and indirect GHGs.** There are different types of furnaces/ovens, but all with the same purpose, which is to provide heat to perform some process in a closed space, which allows controlled conditions and greater efficiency compared to combustion processes in open spaces. Industrial furnaces/ovens are used in cooking, drying, calcining, vitrification and curing processes, among others. These sources are thought to represent about one-third of the total sector GHG emissions in 2015.

Among the measures to improve the efficiency in furnaces/ovens are: automated energy management or process controls for the best use of the heat generated; improvements in fuel combustion; and the reduction of thermal losses. The actions implemented under this option are aimed at reducing emissions of GHGs from fuel combustion in industrial furnaces/ovens, while option I-2 addresses fuel use in boilers and process heaters. **The goals for the option are to reduce BAU fuel use by 10% by 2030 and by 25% by 2050.**

I-2. Energy Efficiency Programs – Boilers and Process Heaters

In addition to the furnaces/ovens addressed by option I-1, industrial facilities use other types of equipment that consume fuels, such as boilers and process heaters. Rather than to heat a product directly as in a furnace or oven, boilers and process heaters are used to produce and transfer heat to another medium, usually water or air, which is then use in the process. Among the measures to **improve fuel use efficiency for boilers/process heaters** are: improved/automated energy management systems, reduction of thermal losses (either at the boiler/process heater or in the lines that transfer heat within the plant), and improvements in the efficiency of the fuel burners themselves. While these are similar groupings of technologies as for furnaces/ovens in I-1, the specific technologies and their implementation costs are quite different.

This mitigation option complements I-1 (for industrial furnaces/ovens), I-4 (electrical energy efficiency), and I-6 (heat recovery). **The goals for this option are to reduce BAU fuel consumption by 15% by 2035 and 25% by 2050.**

I– 3. Incentives for Renewable Energy

Guatemala's energy matrix is quite diverse and rich in the use of renewable energy, including hydro, solar and wind power. Renewable energy (RE) has multiple benefits, including environmental, social and economic benefits. It allows countries to diversify their energy matrix, also boosting economic growth and development by attracting investments for generation and distribution projects. At the same time, it reduces the need to import fuels from outside of the country. Renewable energy reduces GHG emissions and supports the decoupling of emissions and economic growth.

This option supports the creation of schemes that encourage the implementation of RE systems within the industrial sector or the purchase of renewable power by means of incentives or facilities for this purpose. While the option is meant to support all forms of RE (hydro, geothermal, wind, solar), for planning and analysis purposes, **the option focuses on wind and solar generation.**

The goals for this option are to produce enough power from RE projects in the Industrial sector to offset 20% of the sector's BAU grid power consumption in 2035 and 35% by 2050. In this way, this option aims to reduce indirect GHG emissions by electricity consumption, which represented approximately 30% of total emissions in 2015 for the industrial sector.

I– 4. Improvements to Electrical Energy Efficiency

This option refers to the implementation of actions to increase energy efficiency in systems powered by electric power in the industrial sector. In multiple studies and audits conducted in companies of different sizes and types, operating conditions have been identified where the way in which energy is used within them is not known in detail and certainty. Areas of focus for this option are on strengthening of technical capacities, application of methodologies and energy management procedures (such as ISO 50001), and the creation of programs to facilitate the acquisition of energy efficient (EE) technologies. The option is oriented towards industrial processes in general and is not limited only to large users of electricity.

It is important to mention that significant energy savings can be generated through the energy optimization of equipment driven by electric motors, highlighting the pumping systems, and also the air conditioning systems. This option is complementary to I-3, which proposes actions to increase the generation of electricity for self-consumption through renewable sources.

This option aims to reduce indirect emissions from energy consumption, which represented approximately 30% of the total emissions of the industrial sector in 2015. The near-term goal is to decrease the consumption of power in the industrial sector by 12% per year by 2025 below BAU levels. The mid-term and long-term goals are a 25% reduction by 2035 and a 40% by 2050.

I–5. Increased Recycling and/or Substitution of Materials

The generation of solid waste and its current management practices are among the main problems for the environment in Guatemala. The amount of waste coming specifically from the industrial sector has not been studied in detail; however, the GLEDS baseline for the waste sector provides a 2015 reference value of approximately 300,000 tons of industrial waste generated annually. Further, it is expected that most of this waste is deposited in landfills, which would have generated 120,000 tons of CO_2e on an annual basis in 2015.

Some industrial waste can be valued through its introduction as raw or intermediate material in other industrial subsectors within the production chain, or through its energy recovery. The use of waste or recycled products decreases the energy demand and the "upstream" GHG emissions derived from its processes or from the value chain of the products involved. In many cases, these upstream emissions occur outside of Guatemala. Note that these upstream emissions associated with the production and transport of materials that end up in the industrial solid waste stream are not included in the baseline emissions shown in Figure IV.B-1 above (baseline emissions for solid waste management in industry are included in the waste management sector, rather than industry).

Although recycling and material reuse practices are already being implemented in some industries, it is estimated that there is significant potential to be exploited. Therefore, **this option focuses on expanding programs for the reuse and recycling of materials or the replacement of some materials used in specific processes by others with lower generation of GHG emissions. As a result, smaller amounts of waste will be discarded from industry to and sent to final disposal sites. The overall goals of the option are to reduce industrial waste sent to sanitary landfills by 10% by 2025, 30% by 2035 and 40% by 2050.**

I–6. Improve Heat Recovery

In the industrial sector, the efficient use of thermal energy from fossil fuels is important, as indicated by options I-1 and I-2 above. In some industrial processes, residual process heat is available that could be used in other industrial processes, if it can be effectively captured and transmitted. **This option focuses on the recovery of this wasted energy from equipment such as furnaces, boilers and heaters. By recovering this heat, the consumption of fossil fuels is reduced, which in turn reduces GHG emissions from combustion in industry.** Industrial fuel combustion represented approximately 33% of the total GHG emissions of the sector in 2015. This option is complementary to options I-1 and I-2.

Due to the nature of the thermal systems in the industry of the country, the sectors where it is considered that there is a high potential for improvement are those with a high specific consumption of thermal energy. There are likely key opportunities for Guatemala's industry in the future to consider key placement of industries that require process heat (e.g. as low-pressure steam or hot water, construction of cogeneration or trigeneration systems) that could benefit from co-location with large heat generators. This could include, for example, the construction of industrial parks designed for optimal use of heat and materials among industrial partners. This type of approach was not analyzed for the GLEDS process.

The goal of this option is to reduce the fuel consumption of the industrial sector by 20% by means of heat recovery (10% by 2025; 15% by 2035; and 20% by 2050).

3. Option-level and Sector-level Direct Results (Energy, Resources, GHG, Costs and Savings)

Table VI.B-1 below provides a summary of the results of the microeconomic analyses conducted for each of the I options. Negative values are shown in red text (for example, GHG emissions below baseline levels), while positive values are shown in black text (for example, net implementation costs that are above business as usual costs). These results are shown on a "stand-alone" basis, meaning that they were evaluated against BAU conditions assuming that no other options would be implemented. **If all impacts were summed, these "stand-alone" results suggest that in-country annual 2050 GHG reductions would be 7.2 TgCO_2e and the cumulative reductions for 2019-2050 would be 109 TgCO_2e.** There are also some GHG reductions that occur out-of-country emissions for the I sector options as a result of lower demand for fossil fuels. GHG reductions for fossil fuel supplies are assumed to occur outside of Guatemala. These additional reductions result in a total cumulative GHG reduction impact of 149 TgCO_2e.

If all "stand-alone" impacts results are summed, the net present value (NPV) of direct societal implementation savings are estimated to be almost -Q19 billion (in 2018Q; -US$2.5 billion). Implementation costs for the suite of options are driven by the high societal savings for I-3 and I-4. These savings result from implementing renewable power technologies (such as solar and wind) to offset the costs of grid-based electricity, including the avoidance of costs for building new generation facilities during the latter phases of the GLEDS planning period. Option I-5 also results in direct societal savings, while options I-1, I-2 and I-6 result in relatively small direct societal costs. **Overall, the cost effectiveness [-126 Q/tCO_2e (in 2018Q; -US$16.58/t$CO_2$e)] indicates a potential for high overall savings, in particular if Options I-3 and I-4 approach full implementation.**

Table VI.B-1. Stand-alone Direct Impacts for the I Sector

Option ID	Option Title	*In-Country GHG Impacts* Annual CO_2e Impacts 2030 Tg	2050 Tg	2019-2050 Cumulative $TgCO_2e$	*Total GHG Impacts* 2019-2050 Cumulative $TgCO_2e$	*Direct Cost (Base Year 2018Q)* NPV 2019-2050 QMillion	Cost Effectiveness Q/tCO_2e
I-1.	Energy Efficiency for Furnaces/Ovens	(0.11)	(0.24)	(3.7)	(4.3)	Q101	Q24
I-2.	Energy Efficiency Programs - Boilers and Process Heaters	(0.031)	(0.099)	(1.6)	(1.8)	Q16	Q9.3
I-3.	Incentives for Renewable Energy	(1.0)	(3.6)	(52)	(63)	-Q10,869	-Q173
I-4.	Improvements to Electrical Energy Efficiency	(1.0)	(3.1)	(51)	(63)	-Q6,943	-Q111
I-5.	Increased Recycling and/or Substitution of Materials	(0.00076)	(0.062)	(0.52)	(17)	-Q1,105	-Q65
I-6.	Improve Heat Recovery	(0.0044)	(0.026)	(0.36)	(0.39)	Q42	Q106
	Total	**(2.1)**	**(7.2)**	**(109)**	**(149)**	**-Q18,759**	**-Q126**

US$ 1.00 = Q 7.60

The above summary results are presented on the basis of the "independent" analysis. This means that each option was analyzed independently against the BAU conditions (that is, assuming that it was the only option that would be implemented). These results do not reflect identified overlaps or other interactions with other options. The results that have been adjusted to take into account the overlaps / interactions within this sector are given in the following table.

Table VI.B-2 provides a summary of direct impacts with adjustments made to account for interactions or overlaps among the options in the I sector. These results provide a more accurate picture of GLEDS option impacts if all options are implemented as designed. The two options that overlap within the sector are I-3 and I-4. The goals for renewable energy production in option I-3 are specified on the basis of power consumption. Implementation of option I-4 will reduce future power consumption. As a result, the amount of renewable power required to meet the goals of I-3 are lower when both options are implemented. Therefore, the impacts of I-3 have been adjusted to account for the lower levels of renewable power required.

As shown in Table VI.B-2, **the inter-sector integrated in-country GHG reductions for 2050 are lowered to 5.8 TgCO_2e (2019-2050 cumulative reductions are 93 TgCO_2e). Their total societal savings are still significant at more than -Q16 billion (-US$2.1 billion). The estimated cost effectiveness of all I options remains about the same at -125Q/tCO_2e (in 2018Q; -US$16.45/t$CO_2$e).**

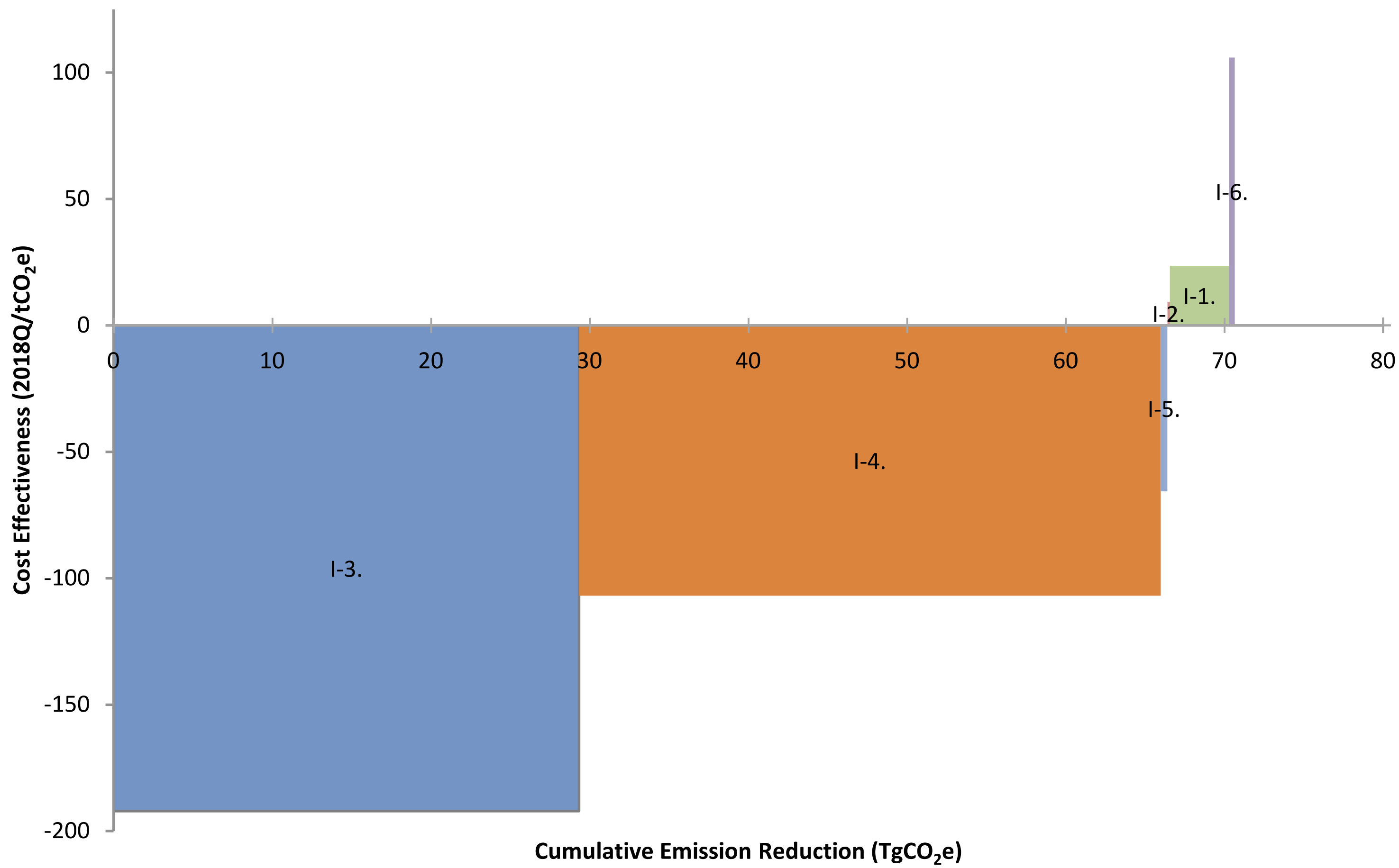
Table VI.B-2. Intra-sector Integrated Direct Impacts for the I Sector

		In-Country GHG Impacts			*Total GHG Impacts*	*Direct Cost (Base Year 2018Q)*	
		Annual CO_2e Impacts		**2019-2050 Cumulative**	**2019-2050 Cumulative**	**NPV 2019-2050**	**Cost Effectiveness**
Option ID	**Option Title**	**2030 Tg**	**2050 Tg**	**$TgCO_2e$**	**$TgCO_2e$**	**QMillion**	**Q/tCO_2e**
I-1.	Energy Efficiency for Furnaces/Ovens	(0.11)	(0.24)	(3.7)	(4.3)	Q101	Q24
I-2.	Energy Efficiency Programs - Boilers and Process Heaters	(0.031)	(0.099)	(1.6)	(1.8)	Q16	Q9.3
I-3.	Incentives for Renewable Energy	(0.89)	(2.3)	(36)	(44)	-Q8,312	-Q190
I-4.	Improvements to Electrical Energy Efficiency	(1.0)	(3.1)	(51)	(63)	-Q6,943	-Q111
I-5.	Increased Recycling and/or Substitution of Materials	(0.00076)	(0.062)	(0.52)	(17)	-Q1,105	-Q65
I-6.	Improve Heat Recovery	(0.0044)	(0.026)	(0.36)	(0.39)	Q42	Q106
	Total After Intra-Sector Interactions/Overlaps	**(2.0)**	**(5.8)**	**(93)**	**(130)**	**-Q16,202**	**-Q125**

US$ 1.00 = Q. 7.60

The results shown in this table have been adjusted for overlaps or other interactions between options in this sector. See the notes next to each set of option results for a description of the overlaps / interactions that were identified and addressed.
I-1: This option only addresses the efficiency of the use of fuel for furnaces, so there is no overlap with I-2, which is directed to process boilers and heaters.
I-2: See note for I-1 above.
I-3: This overlap analysis addresses the reduction in the new renewable energy required for I-3 as a result of the implementation of I-4 that results in reductions in electrical energy through energy efficiency measures in the industry. The I-3 objectives were put in terms of reductions in demand, so there will be less demand as a result of the implementation of I-4.
I-4: See note for I-3 above.
I-6: There is the possibility of some overlap between this option and I-1 and I-2 insofar as thermal systems (for example, steam) become more efficient (leaving less residual heat per unit of fuel consumed). These overlaps would only occur in situations where the elements of both policies apply to the same process and are expected to be insignificant.

Figure VI.B-2. Industry Sector 2019 – 2050 Cumulative GHG MACC



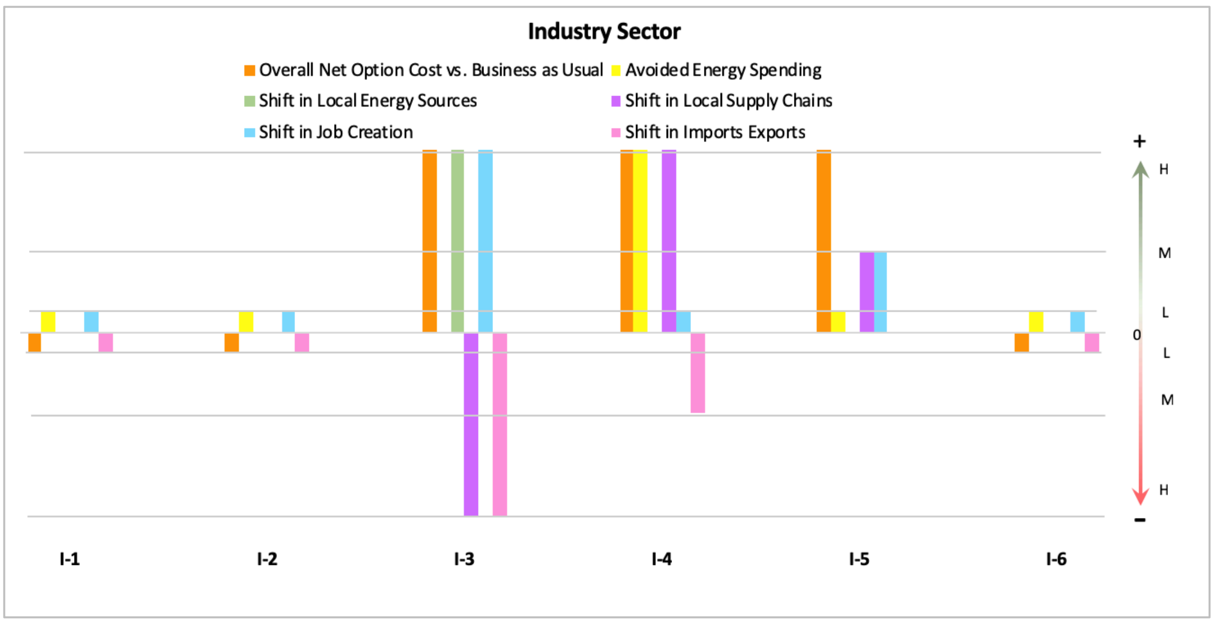
Note: the values represented in this sector-level MACC incorporate interactions and overlaps with options in other sectors ("inter-sector integrated" results). Those results are presented in Chapter VII (summarized values are provided in Table VII.C-6).

Figure VI.B-2 is the marginal abatement cost curve (MACC) for the Industry sector. The cost curve plots the cumulative emission reductions (2019-2050) for each option in the order of most to least cost effective. The values represented in this sector-level MACC incorporate interactions and overlaps with options in other sectors ("inter-sector integrated" results) presented in Chapter VII (summarized values are provided in Table VII.C-6). If all options are fully implemented, cumulative reductions are estimated to be over 70 $TgCO_2e$. Options with negative values for CE are expected to result in net savings to society.

4. Option-level and Sector-level Macroeconomic Performance

Figure VI.B-3 below summarizes the macroeconomic assessment results of the I options. The figure shows that the six I options have been assessed to have very different impacts on key macroeconomic factors relating to economic growth. All options have a mix of positive and negative associations, but some options have significant effects while others are limited to minor impacts. These outcomes are shown on a "stand-alone" basis, meaning that they were evaluated against BAU conditions in isolation, i.e. without considering influences that might be present due to the implementation of other options.

Figure VI.B-3. Macroeconomic Impact Assessment of Options I-1 – I-6 (Industry)



Options I-1, I-2, and I-6 – which focus primarily on industrial programs to recapture or make more efficient the use of heating energy – produce very similar macroeconomic-assessment profiles. Each achieves a modest energy savings and engages labor-intensive activity although in a small amount of (either via government program operations or private-sector operations) to carry out its purpose. These are both positive observations of factors which are statistically associated with GDP and employment growth. However, all three options are also projected to have implementation costs which are higher than the energy or other savings they are able to create. They are also projected to trigger small increases in the total outflow of money from Guatemala to purchase imports. Both of these are negative observations of the factors identified as boosting the local economy. But overall, all the impacts for all factors for these three options are small in every way, and the most salient observation about these three options is that **their potential – and their risk – for economic growth or losses should be considered very minor.**

Options I-3, I-4, and I-5, however, are characterized by large-scale financial flows (measuring tens of billions of Quetzales over the 2019-2050 period). All three are expected to produce net savings that are billions of Qs greater than their costs of implementation, which is a strong positive expression of a factor associated with economic growth. After that, however, they present different profiles of economic impact**.**

I-5, having to do with recycling of industrial materials, shows the most consistently positive set of factors associated with GDP and employment growth. A small net savings on energy while adding spending on recycling efforts and on direct labor involved in those efforts are all positive observations of factors statistically associated with GDP and employment growth.

I-4, which focuses on electrical energy efficiency in industrial settings, has mostly positive observations but does require a significant outlay on imported equipment – driving up the economy's overall volume of spending on imports. Stimulated local construction and significant projected energy savings, however, appear to offer positive influences that are larger in scale the than the potential headwind caused by the import requirement.

I-3 offers the most dramatic mix of positive and negative expressions of factors, with large-scale equipment imports and a significant reduction in utility-sector activity providing notes of caution to offset the benefits of strong energy savings and spending on labor-intense activity.

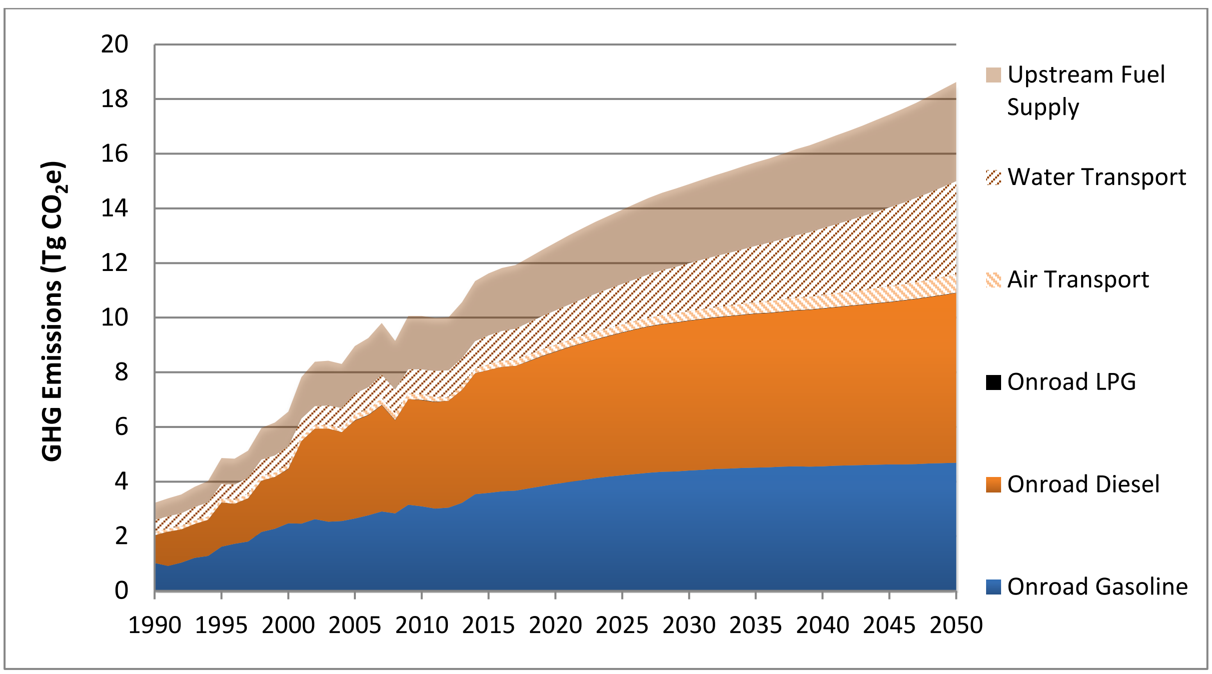
C. TRANSPORTATION

1. Sector Overview

The Transportation (T) sector addresses energy use in onroad vehicles, as well as air and water transport. It should also be mentioned that fuel use in offroad vehicles is also included within the onroad fuel consumption data available during development of the baseline. These offroad uses are likely small in relation to onroad vehicles, but include such things as agricultural and construction equipment (with much of that being diesel and LPG fuel use).

Figure VI.C-1 below provides a summary of the T sector baseline GHG emissions. **Overall, emissions are expected to grow by about 50% by 2050.** Direct emissions for onroad vehicles are expected to grow from around 8 TgCO_2e in 2015 to over 10 TgCO_2e by 2050. Use of electricity to power onroad vehicles begins to enter the baseline late during the planning period; however, as compared to gasoline and diesel, the level of GHG emissions is small (too small to be shown in this chart). **GHG emissions are dominated by onroad vehicle fuel use, including the emissions that could be attributed to upstream processes in fuel supply (extraction, processing and transport of fuels).** Air and water transport GHG emissions are shown in patterned wedges, since the emissions, while attributed to Guatemala, could occur outside the geographic boundaries of the country.

Figure VI.C-1. GHG Baseline for the Transportation Sector



2. Summary of the GLEDS Transportation and Urban Land Use Options

There are eight GLEDS options for the T sector including U-1 and U-2 described in more detail in Appendix F.

T- 1. Build MetroRiel Light-rail Route in Guatemala City

This mitigation option envisions the implementation of a light-rail commuter train ("MetroRiel") in the Metropolitan Area of Guatemala City. The AMCG faces an unprecedented crisis in its urban transport system. Between 1990 and 2010 the on-road fleet doubled, and in recent years it has continued to increase, well beyond the capacity of the region's roadway network (Guatemala City has a capacity of 350 thousand vehicles, and already exceeds 900 thousand). Every day about 1.2 million vehicles enter the city, which is a figure much greater than the capacity that the city can support. This causes congestion which is so severe in many areas that travel speeds fall below 10 kilometers per hour. This pattern of growth is expected to continue: the fleet population will increase at a rate of 7% for vehicles and 20% for motorcycles each year.

According to estimates of the IPCC, transportation contributes approximately 13% of global emissions of GHG, and by 2010 it was estimated to reach 23%. This number is growing rapidly compared to other sectors. It is estimated that by 2050 the contribution of global transport GHG emissions may exceed 30% of the total. In Guatemala, the GHG emissions from transportation in the AMCG are by far the largest in the country.

This option has a direct impact on the GHG emissions by reducing the volume of private cars entering the city. It consists of building a passenger rail transportation system that will bring people from the southern and northern ends of the metropolitan area to the center of the city. This service will deliver a high-quality form of transit, reduce long bus trips and minimize traffic congestion. Also, the service will allow security and comfort for users.

The goals of this option are to modernize the public transport system of Guatemala City through the construction of an urban electric passenger train, and to integrate the new transport system with the existing lines (Transmetro and Transurbano). During the few years after its projected completion and entry into service in 2021, the MetroRiel System is to reach 250,000 passenger trips a day in an electric train from North to South of the municipality of Guatemala. From 2030 to 2050, MetroRiel will continue at the level of 250,000 passenger trips per day.

T - 2. Modernize the Private Fleet of Suburban/Extra-Urban Commuter Buses

This mitigation option refers to the investments in capital needed to update and modernize the current fleet of buses that provide service between cities. The use of more efficient buses is an effective measure to improve air quality and reduce GHG emissions.

The importance of extra-urban transport is clear in terms of the transfer of people between the towns, from a town to the departmental capital and the municipalities to the urban center. The function of the extra urban buses has a commercial importance, since the "parrillero" is home to a large number of small and medium commercial enterprises. These buses are often the means of transport that is used to take the products of the day to the different traditional markets in all the towns.

The extra-urban passenger transport in Guatemala lacks the economic support of the government. An estimated 9,000 extra-urban buses are providing this service in Guatemala, and are operated by private owners. The vehicle removal and scrap programs envisioned in this option (implemented by regulation or incentives) are intended to encourage bus operators to invest in the renewal of fleets. These programs can provide cleaner and more efficient vehicles.

Vehicle updating programs allow the reduction of GHG emissions. In general, old buses are heavier, less aerodynamic and consume more fuel. Consequently, emissions per kilometer are greater than those of new ones. The latter can also be more efficient when transporting more passengers per vehicle. Advanced technology buses, such as hybrids or electric buses, can further reduce air pollution and GHG emissions resulting from older, conventional mass transit vehicles.

The goal of this option is to modernize the extra-urban bus park by means of an incentive from the State for the replacement of the units. As of 2022, replace the fleet of extra-urban buses that operate under the supervision of the General Office of Transportation (DGT) of the Ministry of Communications, Infrastructure and Housing. As of 2030, substitute 50% of the extra-urban buses and start replacing buses with only 5 years of age. In the year 2050, 100% of the fleet will have been replaced, and 50% of the fleet will have been replaced twice with newer and more efficient buses.

T - 3. Improve Regular Transit, Update Fleet and Expand BRT in Guatemala City

Good public urban transport is vital for modern cities to grow and achieve greater density, mixed land uses, and better living standards while lowering the country's carbon footprint. The AMCG faces an unprecedented crisis in its urban transport system. Between 1990 and 2010, the car fleet doubled and in recent years it has continued to increase (Guatemala City has a capacity of 350 thousand vehicles, and already exceeds 900 thousand). The multiplicity of public and private actors involved in the provision of infrastructure, services and regulations of the AMCG hinders the physical integration of the transport system, as well as the integration of fares across public transport services. Each municipality of the AMCG has its own system.

This option aims to modernize the standard bus-transit fleet, and to do so in a way that should also optimize service efficiency, reduce travel times and increase the reliability of schedules through operations and public transport infrastructure and routes. As the city expands its Transmetro BRT service, regular buses and their routes can be optimized to improve trips that take place on both modes. Ensuring both types of vehicles can service all the same locations and platform infrastructure through a vehicle replacement program targeting vehicles service conventional transit routes will enhance the capacity of the two systems to provide faster, easier transit trips to riders in the AMCG area.

This option leads to indirect changes in the average speed of traffic, congestion and delays, as well as to improve the attractiveness of public transport and expand its passenger volume. It can also lead to improvements in the vehicle fleet, which can be evaluated based on the specific fuel efficiency indices of the vehicles, according to their different type and age.

The goal of this option is by the year 2030, to change the old buses of the urban bus fleet of Guatemala City by 100% for new ones more efficient, thanks to the improvement of the transport system derived from the expansion of the BRT and the reorganization of routes and fleets of public transport in the city; and between 2030 and 2050, to maintain the most advanced bus fleet, replacing buses as necessary.

T - 4. Construction of Highway Bypasses around Chimaltenango and Barberena

This mitigation option is focused on existing plans to expand the capacity of commuter roadways, and considers specifically the planned construction of bypass roads around the nearby departmental capitals of Chimaltenango and Barberena.

Roadway capacity programs aim to reduce congestion and pollution through a variety of techniques that expand capacity and reduce bottlenecks, thus improving the flow of motorized traffic. The construction of releases to population centers at critical points is part of the road development plan of the country. The objectives of the Road Development Plan 2008 - 2017 seek to achieve regional integration of the road network, promote economic and social growth through improvement and expansion through land infrastructure, between urban and rural areas, to facilitate the mobilization of people and access to basic social services, expanding and maintaining road infrastructure works in good condition, strengthening urban-rural links through the provision that increases the productivity of rural areas through improved transit of rural roads and appropriate mitigation measures. The expansion of road capacity can improve the flow of traffic and contribute to the benefits of GHG reduction in the short term.

This road section will create an alternative route around, rather than through, the departmental capitals of Chimaltenango and Barberena, thus creating a fast route to move without going through the urban area. Both deliveries that are projected will have a toll that will be managed by a concessionaire company.

The goal of this option is starting in 2019, to reduce the average travel time by four times in the Chimaltenango and Barberena bids. The option has no goals for 2030 and 2050. It seeks to create more capacity for travel during the entire analysis period. The option does not contemplate a change in development patterns or land uses that might accompany decisions to expand capacity along inter-city routes, given that such outcomes depend on independent policy actions.

T - 5. Modernize the Private Light-Duty Vehicle Fleet

This mitigation option envisions a program to apply higher efficiency and air-quality standards to the private vehicle fleet. This program will combine regulatory measures (vehicle regulation) with incentives (tax credits or other fiscal measures) for the purchase and replacement of more efficient vehicles towards individuals, stimulate the renewal of the vehicle fleet, the sale of hybrid and electric vehicles, promote the installations of charging points for electric vehicles, and sensitize the public to the adoption of cleaner vehicles.

The fuel efficiency of vehicles can be significantly improved and GHG emissions can be reduced by means of various technologies that already exist. For on-road vehicles, these technologies include the reduction of aerodynamic drag and rolling resistance, efficient engines including turbocharged, hybrids, improved transmission, on-off systems, engine idling, among others. There are also mitigation opportunities by switching to lower carbon fuels. Plug-in hybrids and all-electric vehicles reduce emissions, particularly if they are charged when the load on the electrical grid is low.

In developed countries, car registration fees are charged annually (or biennially). Registration fees can be charged according to the type of vehicle (automobile, motorcycle or commercial vehicle), year of manufacture, size and type of fuel consumed. You can also apply a sales tax on all vehicles purchased. These taxes can be used to stimulate the purchase of newer and cleaner vehicles. The efficient and optimal consumption of hydrocarbons in the vehicle fleet is presented as a transition measure, since what is sought is the elimination of hydrocarbons, as an energy source in the transport sector.

The goals of this option include by 2028, all vehicles in the country will comply with the Euro 4 norm for air quality and the corresponding GHG emissions levels, and 15% of the vehicle fleet uses electric cars; by 2030, to install charging points for electric vehicles at a level that represents 18% of the vehicle fleet; by 2050, to install charging points for electric vehicles at a level that represents 30% of the vehicle fleet.

T - 6. Promote the Use of Ethanol in Gasoline

This option envisions the implementation of a program to promote the use of advanced ethanol in gasoline in Guatemala. To be considered as advanced ethanol, it must be certified that it can reduce at least 70% of greenhouse gases in its life cycle, compared to fuels derived from petroleum. That program will combine regulatory measures such as a new law to reduce emissions in cars that use gasoline.

According to the Ministry of Energy and Mines (MEM), Guatemala has a capacity of 65 million gallons of Ethanol, of which 80% is exported, and the remaining 20% is used for alcoholic beverages in the country. Ethanol is produced from molasses, a byproduct of sugar production. Guatemala currently has the production capacity to supply the domestic ethanol market with biofuel in a mixture of E10 (10% ethanol and 90% gasoline).

In 2015, MEM (with the support of the Organization of American States) made a pilot plan with 25 vehicles and 5 motorcycles representative of the vehicle fleet using mixtures of ethanol E5 (5% ethanol and 95% gasoline), E7 (7% ethanol and 93% gasoline) and E10 (10% ethanol and 90% gasoline). The results showed that emissions in the exhaust pipe decreased, the one with the greatest impact was the reduction of carbon monoxide (CO) with an average of 79% reduction. By using E10 it was found that the blended fuel improved the power and torque of the engine according to the tests performed. There was no significant variation in fuel efficiency per kilometer, there was no mechanical failure or in the operation of the engine related to the use of the mixtures.

The use of the mixture until E10 does not require modification of the engine of existing on-road vehicles or modifications in the infrastructure to transport, store and dispatch gasoline in the country. This option can also become a key opportunity for economic development in Guatemala, as well as having a positive impact on energy independence, the environment and the health of the population.

The goal of this option is to update current legislation to facilitate the introduction of the use of advanced ethanol in regular and higher gasoline (up to a mixture of E10) as one of the measures for clean energy in the transport sector. In specific, by 2020, all gasoline vehicles in the country use the E10 mixture.

U - 1. Establish an Urban Land Use Component within the National Urban Development Policy

This mitigation option is related to the definition of a series of urban development parameters and instruments that will allow managing the urbanization processes of intermediate cities, under a sustainable and low carbon model. The proposed tools will integrate the National Policy of Urban Development, currently in the process of formulation by the Vice Ministry of Housing. The adoption of the option through the Governing Agreement will give these criteria a binding character for the formulation of urban development plans at the local level.

Urban density is one of the factors that most influence the energy demand of passenger transport and its GHG emissions. A lower urban density is associated with greater energy demand for transport, because the car is used more and the trips are longer. In addition, low density is also associated with higher energy demand for services such as electricity, drainage and drinking water. The compact cities with smaller distances of displacement of the population for the realization of their activities and with a system of efficient public transport, contribute to that the demand for the individual transport is smaller than in the extensive cities. The effects of these measures can be rapid in the areas of growth and contribute to reducing future emissions, for example, by reducing the opening of land in discontinuous areas far from the current edges of the city and sources of employment. These options must be carried out in a coordinated manner with the housing provision options and articulated with the real estate developers, in such a way that the established regulations favor the development of compact cities, but do not restrict the access to land and housing of the strata of lower income. Finally, compact cities are not only linked to energy savings in transport, but also to a lower energy demand per unit of building area and savings in the provision of urban services.

Due to the acceleration of the urban-rural transition process, the intermediate cities of the department of Guatemala are at a key moment in their history to consider themselves as green, resilient and fair cities. To regulate the growth of the expansion area and a denser model, it is necessary to define a series of national parameters that can be applied at the metropolitan and local levels within the framework of urban development and territorial planning.

The goal of this option is to favor more compact and polycentric models of urban growth or urban reorganization, develop low-impact urbanization patterns, with loads and benefits for developers, order the urban expansion and the new growth in contiguity with the consolidated areas in order to guarantee adequate maintenance for the future of the built areas, and incorporate strategic environmental assessment into urban planning processes. From 2030 to 2050, the goal is to reduce 30% of the urban area growth of the nine urbanized cities prioritized by the Urban Agenda of Guatemala, in comparison with the current growth estimates of those cities. The reduction of the urban sprawl in the nine cities will have direct implications in the reduction of the expected VKT in those agglomerations in a BAU scenario.

U - 2. Sustainable Urban Mobility Plan for Guatemala City

This mitigation option refers to the formulation of a sustainable mobility plan for the Metropolitan Area of Guatemala City (AMCG) that frames the transport and urban development actions of Guatemala City. The plan articulates public transport solutions with vehicular transport, non-motorized mobility and urban development model of the city understood as a metropolitan area, emphasizing the development of stops as neighborhood centers.

The role of sustainable mobility in urban planning promotes the development of housing and commercial corridors linked to transport nodes, seeking to promote alternative forms of mobility (walking and cycling) and reduce the number of kilometers traveled, air pollution and the emissions. Priority actions have a structural nature and focus on the road network and public space to reduce the intensity of private traffic of motor vehicles, the promotion of public transport and the active modes of mobility (pedestrian and cyclist).

The main objective is to conceptualize a sustainable mobility plan of the AMCG that includes options, regulatory measures, regulations, incentives and investment projects related to the development and promotion of public transport and non-motorized modes, combined with measures of management of travel demand and land use, which make it possible to reduce the GHG emissions of the sector and that are aligned with the priorities and projections of urban, socioeconomic and environmental management of the city.

The goals of the design of this option are to reorganize urban metropolitan mobility and develop sustainable mobility plans and regulations that regulate all modes of transport, always giving priority to pedestrians and cyclists, improve the security conditions of public transport through better lighting, public surveillance, incorporation of technology and segregated wagons for vulnerable users, create or adapt stations or stops of public transport as neighborhood centers in the framework of urban metropolitan development. By 2030, the target is to reduce by 20% the incidence of private cars in metropolitan mobility compared to current projected trends, and by 2050, to reduce the incidence of private cars by 56% in metropolitan mobility compared to current projected trends.

3. Option-level and Sector-level Direct Results (Energy, Resources, GHG, Costs and Savings)

Table VI.C-1 below provides a summary of the results of the microeconomic analyses conducted for each of the T options as well as for U-1 and U-2. Negative values are shown in red text (for example, GHG emissions below baseline levels), while positive values are shown in black text (for example, net implementation costs that are above business as usual costs). These results are shown on a "stand-alone" basis, meaning that they were evaluated against BAU conditions assuming that no other options would be implemented. **If all impacts were summed, these "stand-alone" results suggest that in-country annual 2050 GHG reductions would be 3.0 TgCO_2e and the cumulative reductions for 2019-2050 would be 68 TgCO_2e**. There are also some GHG reductions that occur out-of-country emissions for the T sector options as a result of lower demand for fossil fuels. GHG reductions for fossil fuel supplies are assumed to occur outside of Guatemala. These additional reductions result in a total cumulative GHG reduction impact of 85 TgCO_2e.

If all "stand-alone" impacts results are summed, the net present value (NPV) of direct societal implementation savings are estimated to be over Q28 billion (in 2018Q; US$3.68 billion). Implementation costs for the suite of options are driven by the high societal savings for U-1, which by itself saves over Q31 billion, while the other options all have net costs that are smaller by an order of magnitude, and which combine to a net cost of approximately Q3 billion together. These savings result from avoidance of costs for building new public infrastructure to serve sprawling growth as a denser planning form takes hold throughout the GLEDS planning period. T-1 and T-5, having to do with implementation of the planned light-rail line for Guatemala City and with requiring higher efficiency and air-quality performance out of light-duty vehicles, are also projected to generate net savings, while the remaining options (dealing with bus transit, bypass construction, ethanol implementation and urban mobility) are projected to cost more than they save over the planning period. **The estimated cost effectiveness of all T options is -331Q/tCO_2e (in 2018Q; US$43.55 /t$CO_2$e).**

Table VI.C-1. Stand-alone Direct Impacts for the T Sector (including U-1/U-2)

		In-Country GHG Impacts			*Total GHG Impacts*	*Direct Cost (Base Year 2018Q)*	
		Annual CO_2e Impacts		**2019-2050 Cumulative**	**2019-2050 Cumulative**	**NPV 2019-2050**	**Cost Effectiveness**
Option ID	**Option Title**	**2030 Tg**	**2050 Tg**	**$TgCO_2e$**	**$TgCO_2e$**	**QMillion**	**Q/tCO_2e**
T-1.	Build MetroRiel Light-rail Route in Guatemala City	(0.0072)	(0.013)	(0.15)	(0.30)	-Q753	-Q2.505
T-2.	Modernize Private Fleet of Suburban/Extra-urban Commuter Buses	(0.19)	(0.34)	(8.6)	(11)	Q1,527	Q144
T-3.	Improve Regular Transit, Update Fleet, and Expand BRT in Guatemala City	(0.019)	(0.020)	(0.54)	(0.67)	Q2,118	Q3,171
T-4.	Construction of Highway Bypasses around Chimaltenango and Barberena	(0.00063)	(0.0050)	(0.23)	(0.28)	Q666	Q2,383
T-5.	Modernize the Private Light-duty Vehicle Fleet	(0.22)	(0.26)	(4.9)	(6.7)	-Q4,101	-Q613
T-6.	Promote the Use of Ethanol in Gasoline	(0.20)	(0.21)	(6.2)	(7.0)	Q2,208	Q314
U-1.	Establish an Urban Land-Use Component Within the National Urban Development Policy	(1.5)	(1.6)	(40)	(50)	-Q31,395	-Q625
U-2.	Sustainable Urban Mobility Plan for Guatemala City	(0.13)	(0.45)	(6.6)	(8.2)	Q1,664	Q202
	Total	**(2.3)**	**(3.0)**	**(68)**	**(85)**	**-Q28,065**	**-Q331**

US$ 1.00 = Q. 7.60

The above summary results are presented on the basis of the "independent" analysis. This means that each option was analyzed independently against the BAU conditions (that is, assuming that it was the only option that would be implemented). These results do not reflect identified overlaps or other interactions with other options. The results that have been adjusted to take into account the overlaps / interactions within this sector are given in the following table.

Table VI.C-2 provides a summary of direct impacts with adjustments made to account for interactions or overlaps among the options in the T sector. These results provide a more accurate picture of GLEDS option impacts if all options are implemented as designed. The transportation sector typically produces options which influence each other in many ways. Options which reduce total demand for travel (such as U-1 and U-2, and also the transit options T-1 through T-3) will lower the baseline GHG emissions against which all other transportation options are working. In the same manner, options that seek to foster the use of cleaner fuels (in this case, T-6 and to a small extent, T-5 with its electric-vehicle component) will also lower the baseline emissions against which other options are making gains (and likely reduce the emissions reduction potential of those options as well). Options improving vehicle efficiency (T-5 in this case) will change the emissions profiles of options seeking to get people out of cars (such as U-1 and U-2, and also the transit options T-1 through T-3), and also change the amount of alternative fuels demanded (in T-6). However, not all options interact: an option changing intra-urban travel behavior may have no effect at all on travel between cities or internationally. An option affecting commercial vehicles and an option affecting personal travel will likely not interact either.

As shown in Table VI.C-2, **the inter-sector integrated in-country GHG reductions for 2050 are still approximately 3.0 TgCO_2e (2019-2050 cumulative reductions are also nearly unchanged, at 84 TgCO_2e).** This is the result of offsetting shifts from the integration. Most options are reduced in effectiveness (causing about a 5% reduction in effectiveness over the entire sector), while T-1 is actually made stronger by other options' implementation. That gain in option strength offsets the reductions in impact of the other options almost exactly, and as a result, the integrated results are very similar to the sum of the stand-alone results. **The total societal savings are still significant at more than -Q27.5 billion (-US$3.6 billion). The estimated cost effectiveness of all T options is -328Q/tCO_2e (in 2018Q; -US$43.16 /t$CO_2$e).**

Table VI.C-2. Intra-sector Integrated Direct Impacts for the T Sector

Option ID	Option Title	*In-Country GHG Impacts* Annual CO_2e Impacts 2030 Tg	2050 Tg	2019-2050 Cumulative $TgCO_2e$	*Total GHG Impacts* 2019-2050 Cumulative $TgCO_2e$	*Direct Cost (Base Year 2018Q)* NPV 2019-2050 QMillion	Cost Effectiveness Q/tCO_2e
T-1.	Build MetroRiel Light-rail Route in Guatemala City	(0.0044)	(0.015)	(0.15)	(0.27)	-Q526	-Q1,964
T-2.	Modernize Private Fleet of Suburban/Extra-urban Commuter Buses	(0.19)	(0.34)	(8.6)	(11)	Q1,527	Q144
T-3.	Improve Regular Transit, Update Fleet, and Expand BRT in Guatemala City	(0.019)	(0.020)	(0.54)	(0.67)	Q2,118	Q3,171
T-4.	Construction of Highway Bypasses around Chimaltenango and Barberena	(0.023)	(0.035)	(0.93)	(1.1)	Q61	Q54
T-5.	Modernize the Private Light-duty Vehicle Fleet	(0.20)	(0.24)	(4.5)	(6.0)	-Q4,007	-Q671
T-6.	Promote the Use of Ethanol in Gasoline	(0.11)	(0.13)	(4.2)	(4.8)	Q1,576	Q331
U-1.	Establish an Urban Land-Use Component Within the National Urban Development Policy	(1.4)	(1.6)	(40)	(49)	-Q30,859	-Q626
U-2.	Sustainable Urban Mobility Plan for Guatemala City	(0.079)	(0.35)	(4.8)	(6.1)	Q2,654	Q435
	Total After Intra-Sector Interactions/Overlaps	**(2.2)**	**(3.0)**	**(69)**	**(84)**	**-Q27,455**	**-Q328**

US$ 1.00 = Q. 7.60

The results shown in table VI.C-2 have been adjusted for overlaps or other interactions between the options in this sector. See the notes next to each set of option results for a description of the overlaps / interactions that were identified and addressed.

T-1: The most efficient fleet of cars (thanks to T-5) and the use of petroleum mixed with ethanol (thanks to T-6) changes emissions by cars in the baseline and in the scenario of option implementation. Oil savings are reduced in this option because of changes in T-5 and T-6.

T-2: This option is not significantly influenced by other options in the transport or urban sectors. This option deals with other types of vehicles and trips than the other options. It also does not change the volume of trips, only the efficiency of the bus.

T-3: This option is not significantly influenced by other options in the transport or urban sectors. This option deals with other types of vehicles and trips than the other options. It also does not change the volume of trips, only the efficiency of the bus.

T-4: The most efficient fleet of cars (thanks to T-5) and the use of petroleum mixed with ethanol (thanks to T-6) changes the emissions by cars in the baseline and in the scenario of option implementation. Oil savings are growing a bit in this option because of the changes in T-5 and T-6. But these deliveries facilitate different trips than those affected by U-1 and U-2, and although U-1 and U-2 are strong options, interaction with T-5 is not expected.

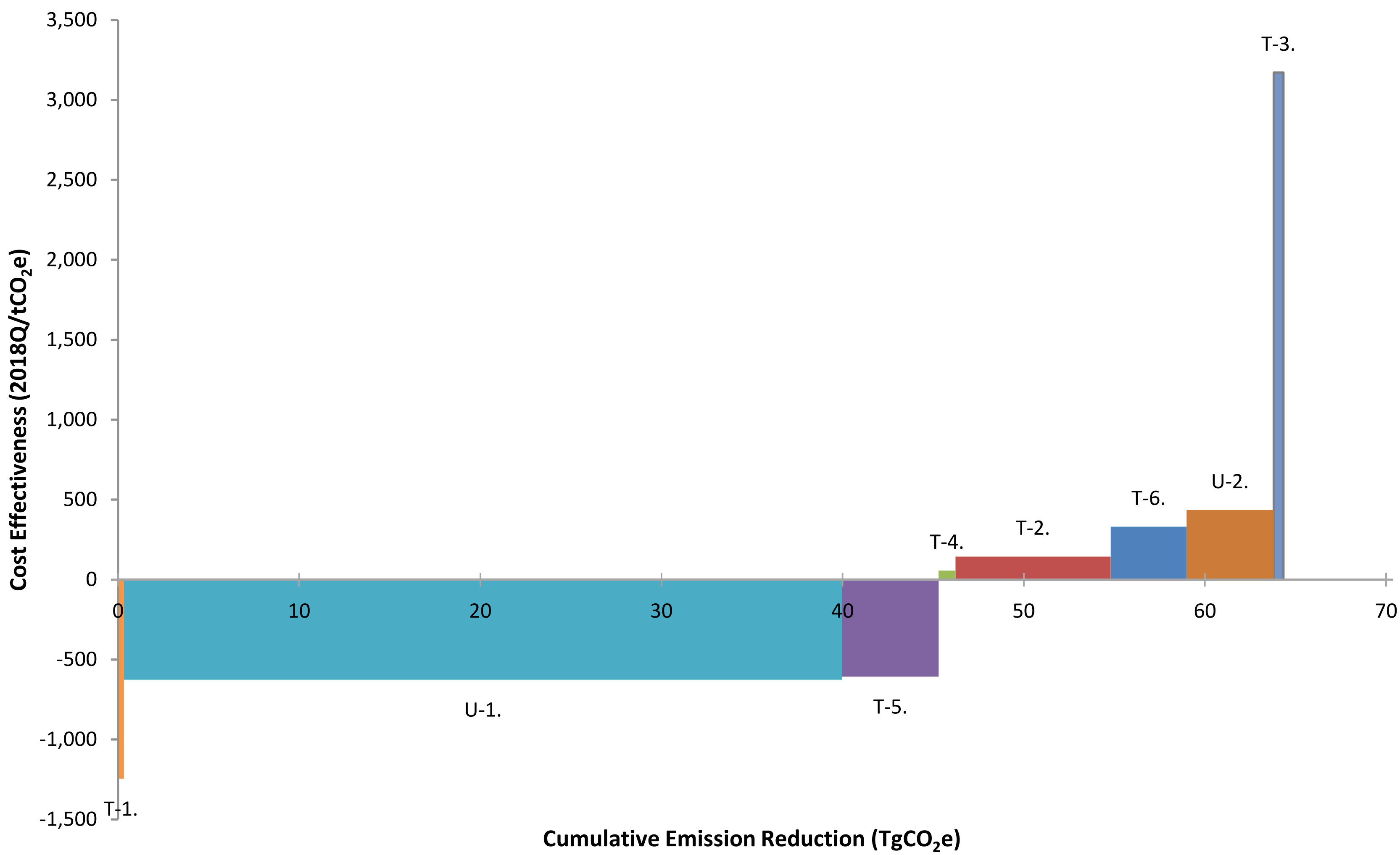
T-5: The impacts of this option are changed by the impact of including ethanol in the fuel, and by the demand reductions for trips thanks to U-1 and U-2, and a little bit by T-1. The baseline of travel, VKT, energy use and emissions is decreased thanks to U-1 and U-2, and emissions per km are also decreased. The impact of the option (which improves efficiency by a percentage) is smaller.

T-6: This option feels the impact of more efficient vehicles (thanks to T-5) and reduced travel volume (thanks to U-1 and U-2, and a bit also by T-1). The total volume of demand for fuel is reduced, and then the impact of mixing ethanol at 10% is smaller.

U-1: The baseline and option scenario both are reduced in emissions thanks to better vehicle efficiency and the mixture of ethanol in the fuel (thanks to T-5 and T-6). This option starts with lower emissions than the baseline, and its reduction (measured as a percentage of the baseline) is less large.

U-2: This option expects that the impact of U-1 (reducing urban sprawl in general) is key to achieving large reductions here in U-2, and then the impact of U-2 is treated as representing the combined impact of U-1 and U-2 in Guatemala City.

Figure VI.C-2. Transportation Sector 2019 – 2050 Cumulative GHG MACC



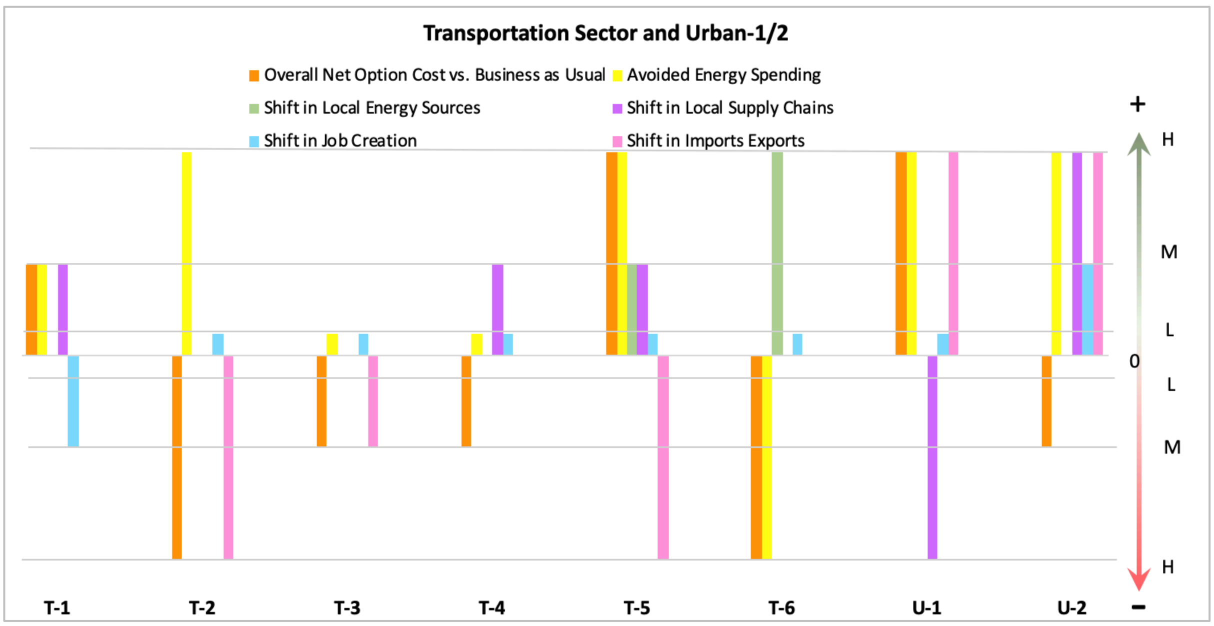
Note: the values represented in this sector-level MACC incorporate interactions and overlaps with options in other sectors ("inter-sector integrated" results). Those results are presented in Chapter VII (summarized values are provided in Table VII.C-6).

Figure VI.C-2 is the MACC for the Transportation sector. The cost curve plots the cumulative emission reductions (2019-2050) for each option in the order of most to least cost effective. The values represented in this sector-level MACC incorporate interactions and overlaps with options in other sectors ("inter-sector integrated" results) presented in Chapter VII (summarized values are provided in Table VII.C-6). If all options are fully implemented, cumulative reductions are estimated to be about 64 $TgCO_2e$. Options with negative values for CE are expected to result in net savings to society.

4. Option-level and Sector-level Macroeconomic Performance

Figure VI.C-3 below summarizes the macroeconomic assessment results of the T and U-1 and U-2 options. These outcomes are shown on a "stand-alone" basis, meaning that they were evaluated against BAU conditions in isolation, i.e. without considering influences that might be present due to the implementation of other options.

Figure VI.C-3. Macroeconomic Impact Assessment of Options T-1 – T-6, U-1 & U-2 (Transportation)



As the graphic above shows, the options described in the T sector present very different economic-impact assessment profiles. These options are quite diverse, ranging from transit expansion to fleet upgrades to fuel switching to urban land-use changes, and so it is not surprising that the impacts on the broader economy would also be quite diverse. Within these eight options are pairs of options focused on similar issues, and considering the macroeconomic assessment in light of these similarities is a helpful way to understand what the results show.

Options T-5 and T-6 both deal with the most familiar aspect of any transportation system: cars and the energy they use. T-5 focuses on requiring vehicles in Guatemala to meet efficiency and air-quality standards, while T-6 focuses on diverting ethanol currently produced for export to use by local cars and trucks as part of a blend with gasoline. **T-5 presents a set of positive observations of factors that are statistically associated with GDP and employment growth** – the reduction in energy use and reduction in energy imports more than offset the expected higher cost of vehicles, and the expenditure to expand electric-vehicle charging infrastructure is expected to be stimulative because the majority of that expense will be concentrated on construction, which is a local rather than imported set of goods and services. **T-6 presents a very positive shift from imported fuels to a domestic supply – the most significant such shift of all the 43 options considered in this assessment– but the slight price premium does produce an increase in economy-wide spending on energy, which is a negative expression of the factor we seek (that of savings on energy spending). However, un-measured by the factors in place is the potential for locally produced ethanol to blunt the economic shocks of rising and falling petroleum prices**, among other strategic benefits associated with relying on domestically produced energy.

Options T-2 and T-3 deal with upgrading the large passenger-bus fleets operating in and around Guatemala's large cities. T-2 focuses on the private bus fleet used for longer trips, while T-3 focuses on the municipal bus fleet used for urban transit service within Guatemala City. Both present similar profiles – the same factors are observed, and in the same directions – but the size of the impacts is different. **T-2 (focusing on privately owned buses) has a larger overall cost, though it also saves more energy as a result. The costs involved are spent on imports, which is cause for concern regarding the option's impact on the broader economy, but the administrative spending on labor and the energy savings achieved through higher bus efficiency offer offsetting positive economic stimuli. T-3 has the same pattern, but at a smaller scale:** modest energy savings and some spending on administration are both positive, but the cost of buses and the need to import them produces both a negative signal regarding import growth and a net cost greater than the savings the option is able to generate.

U-1 and U-2 both have to do with urban designs that improve density and reduce the volume of suburban sprawl. Both options seek to reduce transportation energy requirements involved with living in and around cities, which consequently reduces the volume of imported fuel purchases required to fuel that transportation. Both the **energy savings and the import reductions are positively associated with gains in GDP. They also both involve some administrative work, which is labor-intense and positively associated with economy-wide employment gains.** They differ in whether the option is intended to spark significant construction (as is done in U-2 – this stimulates local sectors but comes at a cost to the broader economy) or reduce the expected volume of construction, specifically to roads (as is expected in U-1, which lowers activity in the construction sector but produces a savings to the broader economy). **Their common factor is the significant savings in auto fuel use, which has unmeasured benefits also in time saved, air quality improved and health benefits as a result.**

T-4 focuses on bypass construction to reduce congestion. The construction activity and government administration are costly, but involve **spending on construction and labor – both positively associated with growth in GDP and economy-wide employment.** The net energy savings is minor, however, as additional travel volume is quickly attracted to the new, free-flowing roadways.

T-1 focuses on the construction of a light-rail line through Guatemala City. As projected, the line would end up producing a net savings on the cost of transportation energy on an economy-wide basis (the electricity required to run the trains would cost less than the savings on avoided motor fuel as people shift from car trips to transit), and the project would drive its expenses primarily to construction. **Both of these shifts – energy savings and stimulus to local productive sectors – are positively associated with gains to GDP. The option's overall cost falls below the savings expected from its implementation, which is a positive sign as well. However, the sector of the economy related to auto maintenance and repair, a labor-intense sector, is expected to grow less than it would in the scenario wherein no option existed. This is a negative observation of a factor – the opposite of what would be associated with employment growth.**

D. AGRICULTURE AND LIVESTOCK

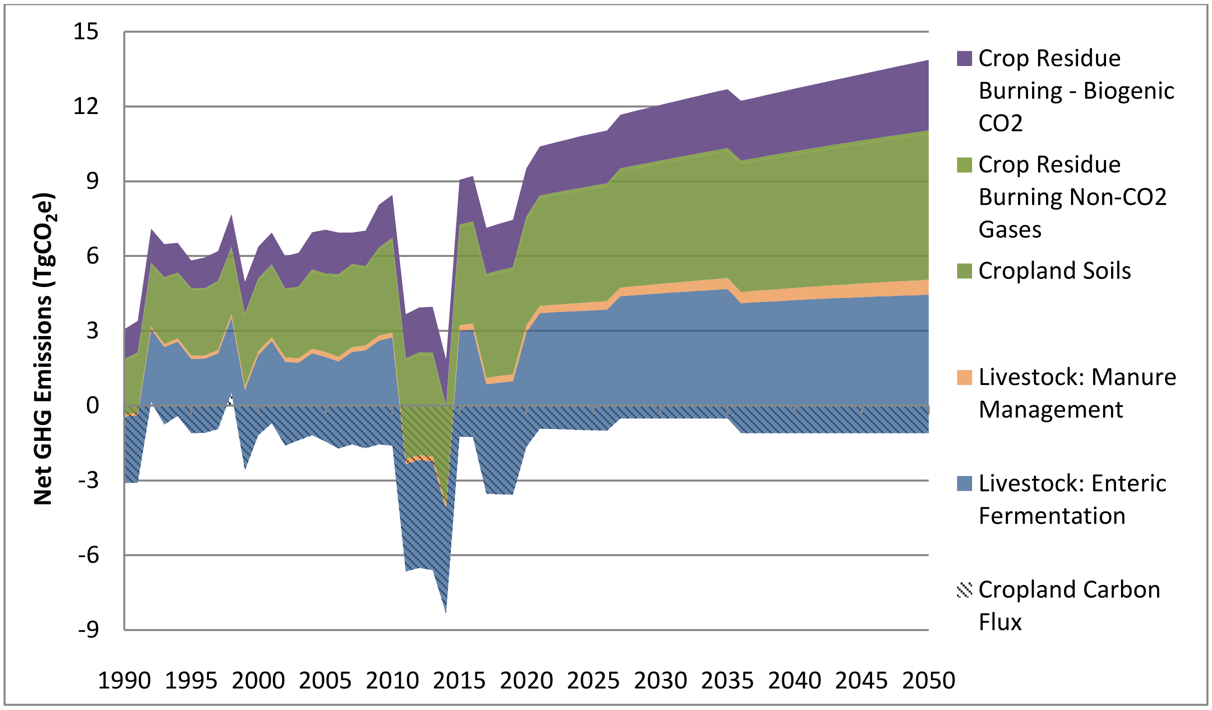
1. Sector Overview

The Agriculture Sector, which includes both the Agriculture (AG) subsector, referring to crop production, and the Livestock management (GAN) subsector (in particular, cattle, pigs and poultry). The GHG emissions addressed in the GLEDS Baseline report in Appendix B cover "non-energy emissions". Due to the availability of data for specific end uses, fuel combustion emissions from agricultural practices, including fossil fuels to power crop cultivation equipment, are included as part of the fuel consumption estimates for the RCI or transportation sectors fuel consumption estimates and cannot be broken out separately. Therefore, the GHG emissions reported for the AG+GAN sector are mainly non-energy methane (CH_4) and nitrous oxide (N_2O) emissions from livestock and crop production. In addition, emissions and sinks of carbon dioxide (CO_2) in agricultural soils and permanent crops are part of this sector. Estimates of carbon sequestration in the biomass of permanent crops have been made and included in the GLEDS baseline; however, data are currently lacking to address carbon sequestration in crop soils.

The primary non-energy GHG sources and sinks for livestock and crop production are as follows: livestock production (CH_4 emissions from enteric fermentation); livestock production – manure management (CH_4 and N_2O emissions from the storage and treatment of livestock manure); crop production, agricultural soils (nitrogen fertilizer application produces N_2O emissions); crop soils (other nitrogen additions produce N_2O emissions including crop residue decomposition and crops that fix nitrogen from the atmosphere); crop production - residue burning (CH_4 and N_2O emissions); cropland carbon - woody perennial crops (CO_2 is sequestered by and stored in woody perennial crops, such as rubber, coffee, oil palm, and fruit and nut trees).

Figure VI.D-1 below provides a summary of the GLEDS baseline for the AG+GAN sector. This summary is shown on a net basis, which means that both GHG emissions and sinks are included. **Key contributors include enteric fermentation (methane emissions from the digestive systems of livestock, mainly cattle), cropland soils (nitrous oxide emissions from nitrogen additions to soils, including chemical fertilizers), and crop residue burning.** Sector emissions are expected to grow from less than 3 $TgCO_2e$ in 2015 to almost 14 $TgCO_2e$ by 2050. As noted above, not shown in the summary due to a lack of detailed fuel use data, energy consumption during crop and livestock production are not shown (these are included within the total consumption estimates of the RCI and T sectors). Key drivers in future emissions are the expected growth in livestock production (in particular, CH_4 emissions from enteric fermentation in cattle) and crop production, including the burning of crop residue). This expansion of the agricultural base is in turn driven by an expanding population with greater income over time (which often shifts diets toward more GHG-intensive production).

Figure VI.D-1. Net GHG Baseline for the AG+GAN Sector



2. Summary of the GLEDS Agriculture and Livestock Options

There are seven AG+GAN options: the first four address the crop production subsector (AG), while the remaining three address the livestock production subsector (GAN). More details are provided in Appendix G.

AG-1. Sustainable Management of Soils

Sustainable management of soils in this option addresses practices related to the management, conservation and restoration of soils, as well as the elimination of crop residue burning. Soil is one of the most important carbon sinks in terrestrial ecosystems, including land dedicated to various crops. A significant source of soil carbon loss is water erosion, since the layers most exposed to this phenomenon are the upper ones, which have the highest carbon content. Soil management also includes the management of fertilization, and there are certain practices that address both objectives. Approaches for nutrient management have been addressed separately in AG-4. Avoiding soil erosion and facilitating its recovery also contributes to maintaining their natural fertility, which generates benefits for producers. Also, by reducing erosion, the sediments that reach the bodies of water decrease, which improves water quality and reduces the risk of river overflow. Therefore, this option contributes to the adaptation to climate change in addition to making contributions in mitigation.

Through the reduction of crop residue burning in the field, some of the carbon contained in this biomass will be incorporated into the soil, which can then increase soil carbon levels (indirectly sequestering carbon from the atmosphere). Also, by reducing crop residue burning, CH_4 and N_2O emissions are reduced.

The overall goals of the option are that, by the year 2030, at least 400,000 hectares are under the implementation of some of the soil conservation practices and that there are 1,000,000 hectares implementing these practices by 2050. The GLEDS baseline indicates a total of approximately 2,500,000 ha of crops that could be covered by this mitigation option by 2050. Therefore, these goals would be addressing 40% of the total area. **Goals for reduced crop residue burning are a 30% reduction of BAU levels by 2030 and 50% reduction by 2050.** For assessing the impacts of soil carbon management, a combination of reduced tilling practices implementation and the use of crop rotations with cover crops are assumed.

AG-2. Establishment and Improvement of Agroforestry Systems

Agroforestry systems can be sources or sinks of greenhouse gases, depending on the uses (trees, crops, cover in paddocks or grazing areas), as well as the way in which they are established. The selection of practices for the establishment and management of Agroforestry Systems (SAF) influences the spatial and temporal flow (emissions or capture) of the carbon and nitrogen reserves in the soil and vegetation. Agroforestry systems can be established and managed to increase CO_2 sequestration in plants and soils, provide soil nitrogen benefits, and generate other benefits.

The practices that have been used the most and that have been mostly accepted in Guatemala for their benefits or services are:

- Alley crops, these include the use of trees to form rows between alleys used generally for annual crops. They are mainly used to improve the soil (eg nitrogen fixation, production and use of organic matter) and / or reduce its loss; they are used in areas with high vulnerability to water erosion, mainly.
- In the dry corridor area and specifically in the municipalities of Jocotán and Camotán in the department of Chiquimula, the use of the system called Kuxu rum has been promoted, which consists of a system that combines the planting of basic grain crops in association with Madrecacao (*Gliricidia sepium*), this system helps maintain moisture and restore soil fertility in hillside lands and without irrigation.
- Trees in line around agricultural plots such as live fences or windbreaks, this last modality helps to protect the soil in areas with high vulnerability to wind erosion.
- Shade trees, in plantations of permanent crops such as coffee, cardamom and cocoa; they can include timber species and species to provide shade, nitrogen fixation and organic matter production (in these two crops the use of Inga species is promoted).

Goals for the option are that by 2030, 131,000 hectares have been established, and by 2050, 220,000 hectares have been established in annual and perennial crop areas under the agroforestry systems approach in areas with national potential. For the purposes of impacts analysis, implementation of agroforestry systems in two crop categories where considered: shade trees in coffee, cardamom, and cocoa; and as alley crops, live fences, or windbreaks in annual crop areas.

AG-3. Establishment of Fruit Plantations

Depending on BAU land use, plantations of woody fruit species have the potential to sequester carbon from the atmosphere and store it in above and below-ground biomass. Gains in soil carbon levels and improvements in soil moisture and fertility are also possible. In this sense, the implementation of this option is intended to increase CO_2 sinks as well as generate co-benefits, including farm incomes.

It is important to indicate that the area proposed in this option corresponds to the area that is reported on the map "Areas suitable for the development of fruit crops of tropical and temperate climate", which was prepared by the Ministry of Agriculture, Livestock and Food 2015. This area is nationwide and is currently used for traditional agricultural crops (especially basic grains) and non-traditional crops (such as sugar cane, bananas, and others). The option should not be implemented in ways that result in conversion of forested lands to fruit plantations, since that would likely produce net GHG emissions.

The goals for this option are to establish at least 109,777 hectares of fruit crops by 2030 and 548,887 hectares by 2050. To reduce the potential for indirect land use change that could occur as a result of option implementation (i.e. clearing of forests to replace lost production of grains or other crops), implementation of other GLEDS options (AG-1 and AG-4) are critical. The other GLEDS options can produce increases in yield that could offset the pressure to convert more land to crop production.

AG-4. Efficient Use of Nitrogen Fertilizers

At least 60% of global gross N_2O emissions evolve from soils, as a result of microbial action on the transforming ammonium into nitrate (nitrification) and nitrate into ammonium (denitrification). Therefore, any addition of nitrogen to the soil, such as nitrogen fertilization (organic or mineral) or nitrogen fixation by leguminous plants, tends to raise N_2O emissions. N_2O has about 300 times the global warming potential of CO_2. As shown in GLEDS baseline in Appendix B), N_2O emissions from nitrogen additions to soils is one of the largest contributors to the agriculture and livestock management sector.

This option focuses mainly on the improvement in application and use of nitrogen fertilizers so that overall applications of nitrogen are reduced. The reduction of nitrogen application to the soil will lead to lower levels of N_2O emissions to the atmosphere. Nitrogen is one of the elements that plants need most to develop and that is why it is one of the three basic components of fertilizers. Therefore, it is not proposed to avoid fertilization but to focus on increasing its efficiency through improving application practices. A complementary activity is the promotion of the use of cover crops that increase organic matter, reduce erosion, return biological diversity to the soil and fix nitrogen (legumes).

This mitigation option is closely related to the option of sustainable soil management (AG-1), and there are activities in both options that could be the same (such as the use of cover crops). **The goals of this option are to increase efficiency in the use of nitrogen fertilizers by 20% by 2030 and 40% by 2050.**

GAN-1. Improved Pasture Management through Rotational Grazing

This option aims to reduce the degradation of pastures, improve animal productivity and, at the same time, contribute to the reduction of GHG emissions occurring during milk and beef production. The components of this mitigation option are the establishment of improved pastures, including the association of grasses and herbaceous legumes, and the use of them under an intensive rotational grazing system.

Intensive rotational grazing consists of using grass (direct consumption by cattle) at the point of equilibrium between production of dry matter and the nutritional quality of it. This requires the division of the grazing area into small paddocks that are used at their carrying capacity [animal units per hectare (UA / ha)]. These paddocks are usually grazed (occupation period) for a day or fraction of a day, which gives the pasture a resting period that allows for total recovery (a return to its optimal state before being grazed again).

Several economic and environmental benefits are achieved with intensive rational grazing of improved pastures in production systems with cattle. These include increased yields of milk and meat per unit area and prevention of vegetation and soil degradation. These benefits, among others, serve to reduce the carbon footprint of milk and beef production systems (i.e. GHG emissions per liter of milk or kilogram of beef produced). Higher animal loads can be managed under rotational grazing systems, which reduces pressure to convert other land uses (especially, forests) to pasture.

The goals for this option are that by 2030, at least 130,000 hectares of improved pasturing using intensive rotational grazing are established. Achieving this goal represents 8 percent of the total pasture area of pastures estimated for 2012. The goal for 2050 is 330,000 hectares.

GAN-2. Promotion of Silvopastoral Systems

The objective of this option is to increase the coverage of trees on farms with cattle, promote biodiversity, increase animal productivity, reduce production costs, increase income and reduce GHG emissions. A silvopastoral system is defined as a natural combination or a deliberate association of one or more woody components (shrubs and / or trees) within a pasture of native and cultivated grass and herbaceous legume species and their use with ruminants and herbivores in grazing.

This option promotes the introduction of trees in different spatial arrangements on farms with cattle, including: i) scattered trees in paddocks; ii) silvopastures (pastures with rows of fodder shrubs, preferably leguminous species, and between these rows, strips of grasses alone or in alternation with strips of herbaceous legumes); iii) grazing in strips or alleys (rows of trees with different spatial arrangements, depending on whether they are timber or fruit species, and strips of grasses alone or in alternation with strips of herbaceous legumes); iv) live fences and wind breaks; v) protection of existing forested areas in livestock farms; and, vi) reforestation of areas previously used as pasture.

The practices identified above have positive impacts on animal productivity (milk/meat per unit area) and, as a result, on the balance of GHG emissions per unit of milk/meat production. Additionally, the introduction of trees in pastoral systems with cattle, or other ruminants, have several co-benefits, such as: i) protection of biodiversity; ii) increased soil fertility; iii) increased water infiltration and retention; iv) increased of income and/or savings from sale and/or non-purchase of wood, poles and firewood; and, v) the shade of the trees reduces the thermal stress of the animals, which, together with the improvement of the quality of the diet due to the consumption of tree forage, cause a better productive performance of the animal production system.

The goals for this option are that by 2030, at least 65,000 hectares of pastureland have been converted to intensive silvopastoral management systems; by 2050 at least 165,000 hectares will have been converted.

GAN-3. Promote Integrated Manure Management in Intensive Animal Production Systems

Integrated manure management comprises a set of practices aimed at getting the most benefit from the use of this resource in livestock production systems, and, at the same time, mitigating GHG emissions. Emissions of both CH_4 and N_2O during manure management are addressed by this option; however, CH_4 emissions are likely to be more significantly affected. These emissions vary depending on the amount and composition of the manure and the type of management and storage conditions of the manure. In general, comparing anaerobic conditions and aerobic conditions, emissions of N_2O are promoted in aerobic conditions, while CH_4 emissions are promoted during anaerobic conditions.

The application of manure management makes more sense in the intensive production systems in confinement, in which large amounts of manure and other organic waste from food provided to animals in feeders are accumulated. This is the case of what happens in cattle dairies and feedlot systems during production of milk and meat, as well as pig and poultry farms.

The goals for the option are that by 2030, at least 10,000 productive units, whether fattening pens or specialized or semi-specialized farms of bovine milk, or poultry and/or pig farms, have adopted composting and/or the use of biodigesters as innovations for the aggregation of value to manure and the mitigation of GHGs from it. By 2050, if the set of factors that stimulate the present innovation is maintained, the minimum expected goal is 20,000 productive units.

In Guatemala, agricultural experts indicate that the practices with the greatest adoption potential are composting and the use of biodigesters. Both reduce the negative impact of manure on the environment and can produce energy and soil amendments as products to raise farm incomes or offset production costs. Based on information on animal populations and emissions in the GLEDS baseline, cattle dairies and feedlot offer the highest GHG reduction potential. Therefore, although the option addresses pigs and poultry, as well, the analysis of option impacts was limited to cattle dairies and feedlots. **The 2050 option goals stated above would represent about 400,000 dairy cattle and 1,800,000 beef cattle (about 24% of the BAU forecasted dairy population and 72% of the beef cattle population).**

3. Option-level and Sector-level Direct Results (Energy, Resources, GHG, Costs and Savings)

Table VI.D-1 below provides a summary of the results of the microeconomic analyses conducted for each of the AG+GAN options. Negative values are shown in red text (for example, GHG emissions below baseline levels), while positive values are shown in black text (for example, net implementation costs that are above business as usual costs). These results are shown on a "stand-alone" basis, meaning that they were evaluated against BAU conditions assuming that no other options would be implemented. **Implementation of five of the seven AG+GAN options are expected to result in net savings to society (those with NPV estimates that are negative). Overall, the "stand-alone" results indicate that in-country annual 2050 GHG reductions would be 39 $TgCO_2e$ and the cumulative reductions for 2019-2050 would be 725 $TgCO_2e$.** There is also a small amount of out-of-country emissions for the AG+GAN sector options as a result of lower demand for nitrogen fertilizers which are assumed to be produced outside of Guatemala. These additional reductions result in a total cumulative GHG reduction impact of 753 $TgCO_2e$.

Net societal implementation costs are estimated to be about Q13.4 billion (in 2018Q; US$ 1.76 billion). Implementation costs for the suite of options are driven by the high implementation costs estimated for AG-4 (Efficient Use of Nitrogen Fertilizers). So, during implementation, some focus should be placed on developing and applying mechanisms for reducing these costs (for example, methods for incorporation of nitrogen fertilizer into the soil). AG-3 has relatively low implementation costs and the remaining options have estimated net societal savings. **Overall, the cost effectiveness [18 Q/tCO_2e (in 2018Q); US$2.37 /$tCO_2e$] is quite low.**

Table VI.D-1. Stand-alone Direct Impacts for the AG+GAN Sector

		In-Country GHG Impacts			*Total GHG Impacts*	*Direct Cost (Base Year 2018Q)*	
		Annual CO_2e Impacts		**2019-2050 Cumulative**	**2019-2050 Cumulative**	**NPV 2019-2050**	**Cost Effectiveness**
Option ID	**Option Title**	**2030 Tg**	**2050 Tg**	**$TgCO_2e$**	**$TgCO_2e$**	**QMillion**	**Q/tCO_2e**
AG-1.	Sustainable Management of Soils	(1.0)	(2.6)	(44)	(45)	-Q946	-Q21
AG-2.	Establishment and Improvement of Agroforestry Systems	(0.87)	(0.24)	(16)	(16)	-Q747	-Q46
AG-3.	Establishment of Fruit Plantations	(4.1)	(21)	(284)	(287)	Q5,877	Q20
AG-4.	Efficient Use of Nitrogen Fertilizers	(0.41)	(1.1)	(17)	(21)	Q42,065	Q1,964
GAN-1.	Improved Pasture Management through Rotational Grazing	(1.5)	(3.9)	(65)	(65)	-Q15,589	-Q241
GAN-2.	Promotion of Silvopastoral Systems	(7.2)	(8.4)	(268)	(268)	-Q12,184	-Q45
GAN-3.	Promote Integrated Manure Management at Intensive Animal Production Systems	(0.87)	(1.7)	(32)	(51)	-Q5,065	-Q99
	Total	**(16)**	**(39)**	**(725)**	**(753)**	**Q13,410**	**Q18**

US$ 1.00 = Q. 7.60

The above summary results are presented on the basis of the "independent" analysis. This means that each option was analyzed independently against the BAU conditions (that is, assuming that it was the only option that would be implemented). These results do not reflect identified overlaps or other interactions with other options. The results that have been adjusted to take into account the overlaps / interactions within this sector are given in the following table.
AG-2: Net reductions in the country become positive at the end of the planning period due to alleged firewood harvests that exceed other GHG reductions.

Table VI.D-2 provides a summary of direct impacts that have been adjusted for interactions or overlaps among the AG+GAN options. While there is a potential for some overlap to occur within some options, **the results of the assessment are that these are not expected to be significant or that the overlap was accounted for in the initial stand-alone analysis described above (so results are the same in both tables).** For example, both AG-1 and AG-4 include the use of cover crops as components of implementation (for example, soil carbon sequestration and costs for establishment of cover crops). All direct impacts and costs were assigned to AG-1 as related to the use of cover crops. GAN-1 and GAN-2 also have the potential for overlap to the extent that some pasture management practices attributed to each could be applied to the same area. For this analysis, it was assumed that the management practices are applied to distinctly separate areas.

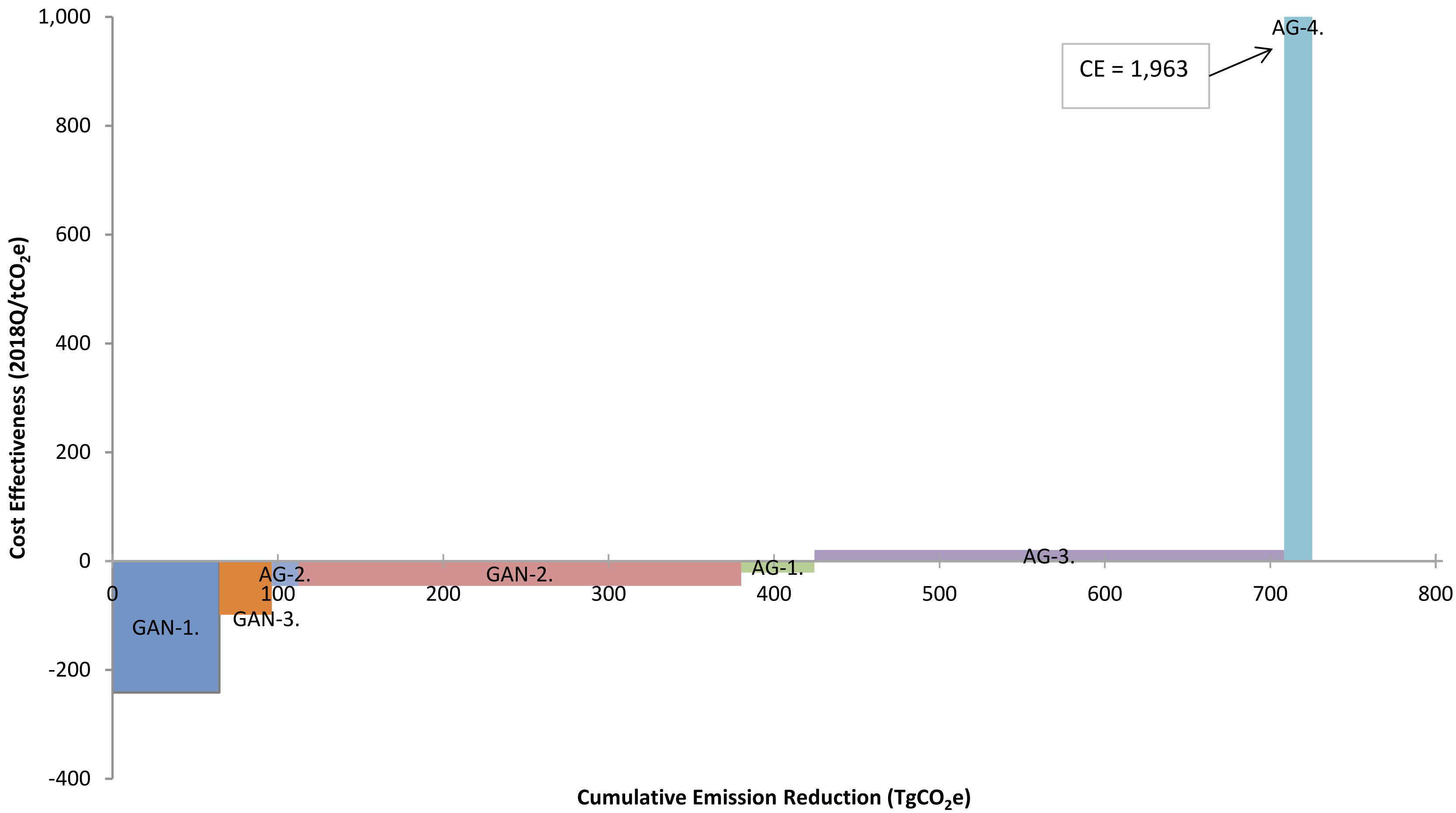
Table VI.D-2. Intra-sector Integrated Direct Impacts for the AG+GAN Sector

		In-Country GHG Impacts			*Total GHG Impacts*	*Direct Cost (Base Year 2018Q)*	
		Annual CO_2e Impacts		**2019-2050 Cumulative**	**2019-2050 Cumulative**	**NPV 2019-2050**	**Cost Effectiveness**
Option ID	**Option Title**	**2030 Tg**	**2050 Tg**	**$TgCO_2e$**	**$TgCO_2e$**	**QMillion**	**Q/tCO_2e**
AG-1.	Sustainable Management of Soils	(1.0)	(2.6)	(44)	(45)	-Q946	-Q21
AG-2.	Establishment and Improvement of Agroforestry Systems	(0.87)	(0.24)	(16)	(16)	-Q747	-Q46
AG-3.	Establishment of Fruit Plantations	(4.1)	(21)	(284)	(287)	Q5,877	Q20
AG-4.	Efficient Use of Nitrogen Fertilizers	(0.41)	(1.1)	(17)	(21)	Q42,065	Q1,964
GAN-1.	Improved Pasture Management through Rotational Grazing	(1.5)	(3.9)	(65)	(65)	-Q15,589	-Q241
GAN-2.	Promotion of Silvopastoral Systems	(7.2)	(8.4)	(268)	(268)	-Q12,184	-Q45
GAN-3.	Promote Integrated Manure Management at Intensive Animal Production Systems	(0.87)	(1.7)	(32)	(51)	-Q5,065	-Q99
	Total After Intra-Sector Interactions/Overlaps	**(16)**	**(39)**	**(725)**	**(753)**	**Q13,410**	**Q18**

US$ 1.00 = Q. 7.60

The results shown in this table have been adjusted for overlaps or other interactions between the options in this sector. See the notes next to each set of option results for a description of the overlaps / interactions that were identified and addressed.
AG-1: There is a potential overlap between AG-1 and AG-4 in that the cover crop is a management method applicable to both. This overlap was addressed during the previous independent analysis by allocating all impacts and costs for the establishment of cover crops to AG-1 only. Then, there is no need for an additional adjustment.
AG-4: See note above for the potential overlap with AG-1. It is assumed that direct impacts and costs are additive.
GAN-1: It is possible that GAN-1 and GAN-2 approach part of the same grazing area. However, to the extent that this occurs, Direct Cost and impacts are still considered additive.
GAN-2: See note for GAN-1 above.

Figure VI.D-2. Agriculture Sector 2019 – 2050 Cumulative GHG MACC



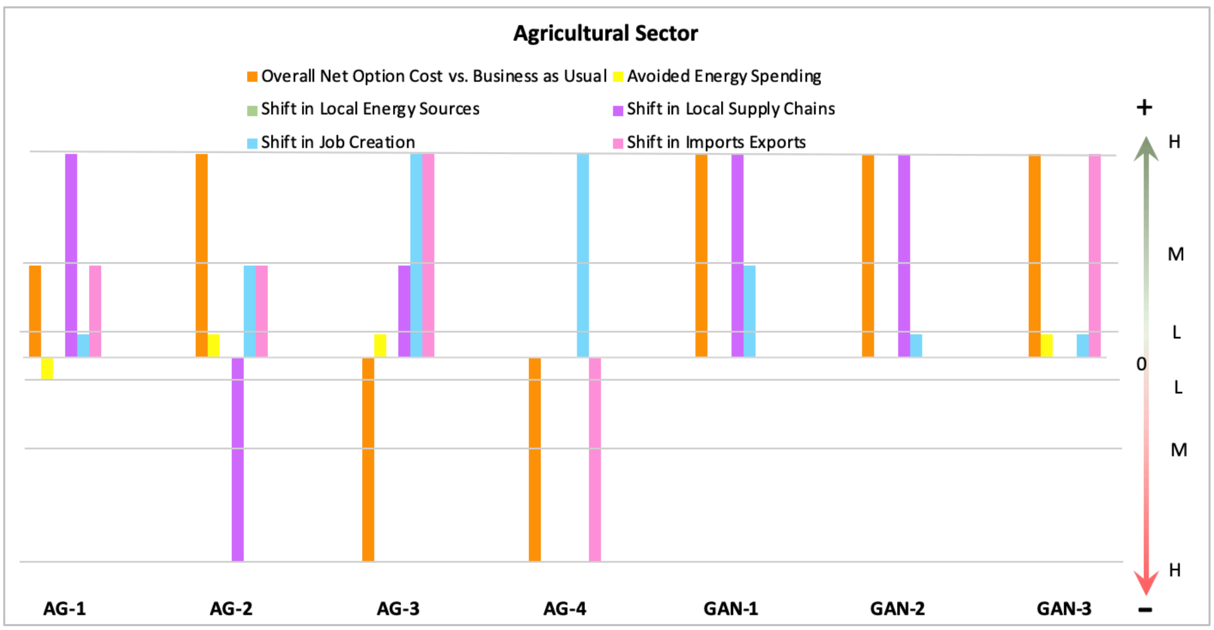
Note: the values represented in this sector-level MACC incorporate interactions and overlaps with options in other sectors ("inter-sector integrated" results). Those results are presented in Chapter VII (summarized values are provided in Table VII.C-6).

Figure VI.D-2 is the MACC for the Agriculture sector. The cost curve plots the cumulative emission reductions (2019-2050) for each option in the order of most to least cost effective. The values represented in this sector-level MACC incorporate interactions and overlaps with options in other sectors ("inter-sector integrated" results) presented in Chapter VII (summarized values are provided in Table VII.C-6). If all options are fully implemented, cumulative reductions are estimated to be about 725 $TgCO_2e$. Options with negative values for CE are expected to result in net savings to society.

4. Option-level and Sector-level Macroeconomic Performance

Figure VI.D-3 below summarizes the macroeconomic assessment results of the agriculture options (AG and GAN subsectors). These outcomes are shown on a "stand-alone" basis, meaning that they were evaluated against BAU conditions in isolation, i.e. without considering influences that might be present due to the implementation of other options.

Figure VI.D-3. Macroeconomic Impact Assessment of Options AG-1 – AG-4, GAN-1 – GAN-3



While the AG+GAN options show different profiles of associated economic-impact factors, there are some commonalities. All four options are projected to significantly reduce demand for nitrogen fertilizers – by either billions or tens of billions of Quetzales over the 2019-2050 period. This spurs observations of a reduction in economy-wide imports in the economic-impact assessments of three of the four options (AG-4 requires even greater spending on imports of equipment than it saves on fertilizer), and help **AG-1 and AG-2 report net savings far greater than net costs – also positively associated with economic growth. They also all show net positive effects for stimulation of labor-intense activities, at varying levels.**

AG-3 is dominated, over and above its significant fertilizer savings, by a large outlay for labor-intensive activity to carry out a more hands-on form of operations. While this labor-intense activity is a positive observation of a factor associated with economy-wide

employment gains, it is also the cost which makes the overall option a significant net expense for the Guatemalan economy to bear.

GAN-1 and GAN-2 are dominated by the expected growth in productivity of meat and milk that they project as a result of the implementation of the better management practices in question. Both options anticipate the production of hundreds of millions of Quetzales in additional value in meat and milk over the 2019-2050 period, and anticipate that no other cost or savings would be more than a few percent of that benefit in scale. As a result, both options **appear very cost-effective and very stimulative to sectors in question**. **They would likely also displace food imports, which could be a further gain, and drive additional spending on labor to implement and maintain the improved practices in question.** GAN-3 primarily achieves its positive profile through a large savings in the purchase of imported fertilizers, in a manner similar to the AG options. This cost saving on fertilizer both lowers the cost of operation in the agriculture sector and reduces the economy's total demand for imports. The import reduction is positively associated with growth in GDP.

E. FORESTRY & OTHER LAND USE

1. Sector Overview

The Forestry and Other Land Use (FOLU) sector addresses net carbon flux across the different land uses, except for Agriculture, including changes in carbon stocks for:

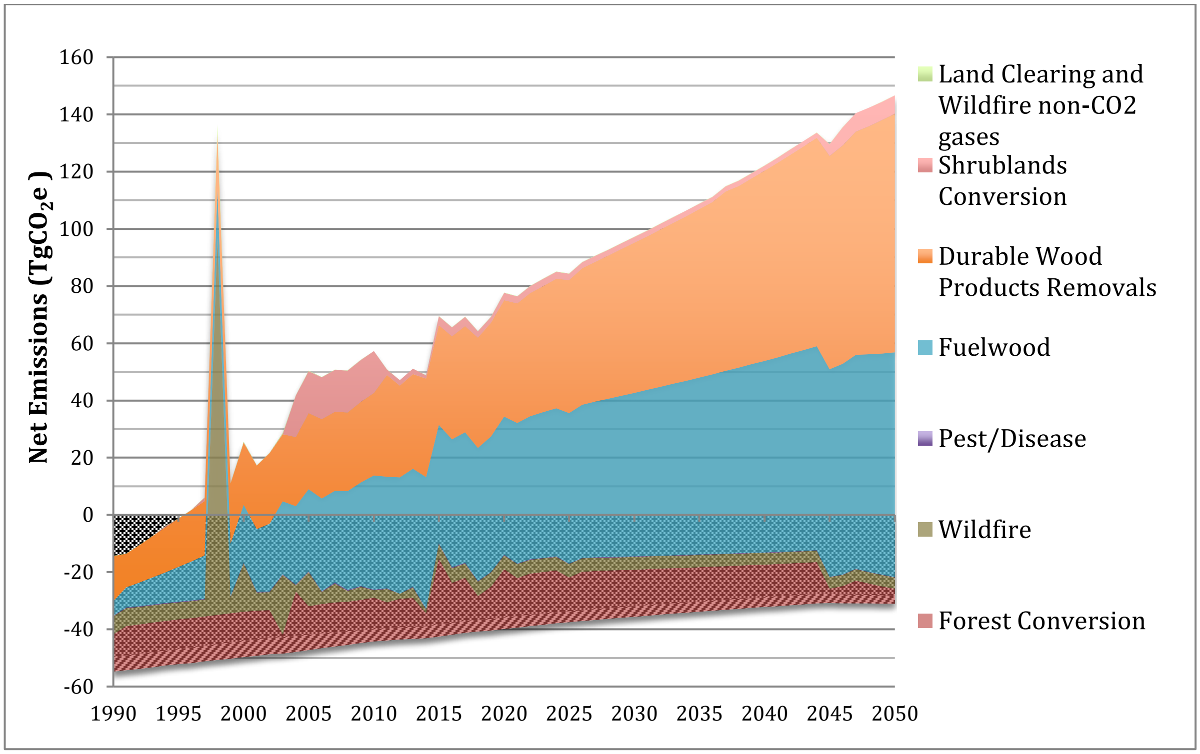
- *Forests Remaining Forests:* net changes in carbon stocks due to sequestration (vegetation growth) and removals (harvesting of wood and losses due to disturbances, such as fires and disease);
- *Other Land Use:* for example, carbon sequestration in shrublands;
- *Land Use Conversion:* net carbon stock changes for land converted from one land use to another, such as forestland converted to agricultural or urban land.

Carbon sequestration in woody permanent crops is accounted for in the Agriculture sector. However, any initial loss of terrestrial carbon that occurs when land use changes from forest to agricultural use is accounted for in the FOLU sector.

As described further in Appendix B, FOLU sector net GHG emissions related to carbon sequestration/loss were estimated using the "Gain-Loss method", which involves estimating the biomass within each carbon pool during each year and then calculating the change from one year to the next. When biomass has accumulated in a pool over the course of a year, then this increase is accounted for as carbon sequestration (a negative emissions flux). On the other hand, when biomass levels decrease within a pool during a year, then this represents an emission to the atmosphere, "a positive emissions flux" (CO_2 release from biomass decay and combustion are examples).

Figure VI.E-1 below provides the FOLU sector net GHG baseline. This net baseline includes both sinks of CO_2 from the atmosphere, as well as GHG emission sources. Net GHG emissions in 2015 were estimated to be around 70 $TgCO_2e$. Emissions are expected to more than double this amount to over 140 $TgCO_2e$ by 2050. T**he largest source of FOLU sector GHG emissions are from wood product and fuelwood removals, which increase significantly over the forecast period. The next greatest source is forest conversion, which ends up decreasing later in the forecast period due to the reduction in forested land available for conversion. Forest sequestration also decreases over the forecast period due to decreased forest area.**

Figure VI.E-1. FOLU Sector GHG Baseline, Net Emissions



Notes: Forest Sequestration and Shrubland Sequestration are negative and occupy the area under the x-axis shown with the striped pattern. Forest Fire Non-CO_2 gases and Pest/Disease Biomass loss are too small to be seen in the chart. The spike in emissions during 1998 is due to significant wildfire activity during that year.

2. Summary of the GLEDS FOLU Options

The FOLU sector is the largest source of GHG emissions in the GLEDS baseline; therefore, this sector offers many opportunities for emission reductions. The greatest opportunities for emission reductions include increasing forest sequestration, decreasing forest conversion and disturbances, and decreasing wood removals. Options FOLU-1 and FOLU-3 aim to increase sequestration through expansion of forest plantations, FOLU-2 aims to increase sequestration and reduce forest conversion through forest protection, and FOLU-4 aims to reduce wildfire disturbances. While, FOLU-1 and FOLU-3 aim to reduce removals from natural forests by shifting these removals to forest plantations and FOLU-2 may reduce illegal removals from natural forests through increased protection, none of the FOLU sector options directly address wood product and fuelwood demand. However, option E-9 in the Energy sector aims to reduce fuelwood demand by increasing the usage of efficient wood stoves. In addition to the FOLU options, the Urban sector option U-5, which aims to increase carbon sequestration through expanded urban forest cover, was analyzed within the FOLU sector.

FOLU - 1. Establishment of Sustainable Forest Plantations.

This option promotes the increase of biomass available for uses in the wood industry and for the production of energy (mainly firewood) by increasing forest productivity through the

establishment of forest plantations for industrial and energy purposes. The establishment of plantations according to defined objectives is proposed, among them: wood production, firewood production, and seed production. The species should be considered according to the purposes of the plantations. For timber production, species of commercial value should be considered and for plantations for energy purposes species with rapid growth and resilience should be considered.

The plantations will be submitted to sustainable, integral and efficient forest management according to the purpose of their establishment. They will provide raw material for consumption by the population in terms of wood for industrialization, wood for family uses and for small businesses with products related to wood (rustic furniture, handicrafts, etc.). They will also provide firewood for energy uses in the rural population. The plantations must be established in areas with a productive forestry vocation, areas that are devoid of plant cover and areas with access to extract firewood, which may be municipal. Preferably they should not consider the removal of important vegetation. The plantations are made in areas that are not being economically productive (BAU), but mostly have natural pastures or vegetation called scrub.

Goals for the option are that by 2030, forest coverage shows a gain in its comparative analysis regarding the change in land use, in relation to the estimated parameters for the year 2017 (3,364,000 ha). It is expected that there will be an average increase of 10,000 ha annually during the 2019-2024 period, and an increase to 20,000 ha per year, from 2025 to 2050. By 2050, forest coverage shows a gain in its comparative analysis with respect to the land use change parameters estimated for 2017. An average annual increase of 20,000 ha is expected.

FOLU - 2. Conservation and Management of Sustainable Natural Forests

The sustainable management of forest resources ensures maintaining the provision of goods and services to future generations. Its promotion refers to actions that allow the empowerment of the forestry sector regarding the administration, conservation and rational use of the natural heritage from the point of view of economic, ecological and social benefits that can be obtained. Techniques and practices of sustainable forest management should be implemented in natural forests that promote the reduction of GHG emissions, promote the reduction of deforestation, avoid the loss of organic matter from the soil and prevent the change of land use. Making the forest a source of goods and services that generate economic growth, they conserve resources, especially soil and biodiversity.

Through sustainable forest management, **option goals are that by the year 2030, 100% of the existing natural forest has been conserved at the beginning of the implementation of the option (2019), based on the projections of what exists as reported to the year 2012. For the year 2050 forest cover has increased (150,000 hectares)**, through the management of secondary forests through ecological restoration in lands selected for this purpose, by natural succession processes, in degraded areas in protected areas.

FOLU – 3. Reforestation of Degraded Lands with Native Species

This action promotes the increase of biomass in degraded areas, to recover forest cover under a sustainability approach combining economic and ecological aspects. It is proposed to take actions to restore the natural capital of certain areas, especially river banks, and

others such as areas affected by road construction, mining, overgrazing, selective exploitation, among others. Many of these areas appear in the coverage analysis, such as areas with "shrub and / or herbaceous vegetation", covering 2,557,914 ha. The recovery of these areas would allow the sequestration of carbon with the additional co-benefits of the forests in terms of soil recovery, biodiversity (native species), among others.

Goals for the option are that by 2030, 120,000 hectares of forest cover have been restored in degraded areas, with native species. Especially the areas identified in the coverage study as "shrub and / or herbaceous vegetation," (river banks, protected areas, forest conservation lands). In protected areas and management categories that allow activities of this nature. **By 2050, 330,000 hectares of forest cover have been restored in degraded areas, with native species.**

FOLU – 4. Strengthen Institutional Capacity in Prevention and Control of Forest Fires

The FOLU sector also includes emissions of CH_4 and N_2O from forest fires. Carbon dioxide emissions from forest fires are generally considered carbon neutral and, therefore, are not included in total GHG emissions, (however, the carbon captured in a 50 or more years period can be emitted in just a few months). According to fire records, the calculation of emissions from forest fires in 2015 was estimated at 5.3 $TgCO_2e$.

Institutional strengthening will consider financial, administrative, strategic, regulatory and technical matters as a priority. **A two-dimensional strengthening is proposed, the first for the prevention and regulation of fires, the prescribed burning and burning of crops (*rozas*[14]), and the second for the control and combat of forest fires.** In both cases, knowledge management actions are considered for fire management and combat. Strengthening institutional capacities will allow the protection of Guatemala's natural heritage, reducing ecological imbalance, changing land use, reducing GHG emissions and avoiding the loss of human lives.

Goals for the option are that by 2030, CO_2 emissions due to the incidence of forest fires have been reduced by 50% based on the GLEDS baseline. By 2050, CO_2 emissions due to the incidence of forest fires have been reduced by 90% based on the GLEDS baseline. The implementation of this option starts from the year 2018, in which the new institutions responsible for the issue of forest fires are established.

Urban - 5. System of Urban Green Spaces

This option promotes the definition of the green area system of the metropolitan area of Guatemala City within the framework of the Metropolitan Strategic Plan, to protect the urban green border, establish a green plot, evaluate the gully system, promote reforestation processes of the city, both in public spaces and buildings, as well as the implementation of urban gardens and new green areas in urban expansion areas. A city with a well-planned and well-managed green infrastructure becomes more resilient, sustainable and equitable in terms of nutrition and food security, poverty alleviation, improved livelihoods, mitigation and adaptation to

[14] Nationally employed term for prescribed burning and burning of crops

climate change, risk reduction disasters and ecosystem conservation. Throughout their lives, trees can provide a package of benefits worth two or three times more than investment in planting and care.

The goals of this option are that the forest cover increases by 10% by the year 2030, and by 20% by 2050 under a system of green areas structured and valued by public and private actors.

3. Option-level and Sector-level Direct Results (Energy, Resources, GHG, Costs and Savings)

Table VI.E-1 below provides a summary of the results of the microeconomic analyses conducted for each of the FOLU options. Negative values are shown in red text (for example, GHG emissions below baseline levels), while positive values are shown in black text (for example, net implementation costs that are above business as usual costs). These results are shown on a "stand-alone" basis, meaning that they were evaluated against BAU conditions assuming that no other options would be implemented. **These "stand-alone" results indicate that in-country annual 2050 GHG reductions would be 53 $TgCO_2e$ and the cumulative reductions for 2019-2050 would be 1,249 $TgCO_2e$.** There are no out-of-country emissions for the FOLU sector options, so total emissions are the same as the in-country emissions. **Net societal implementation costs would be Q29.8 billion (in 2018Q; US$3.9 billion)**. Implementation costs for the suite of options is high due to the high costs of forest protection and maintenance for a large area of natural forests and forest plantations. However, **the cost effectiveness [24 Q/tCO_2e (in 2018Q); US$3.16/tCO2e] is relatively low due to the large emission reductions estimated for these options.**

Table VI.E-1. Stand-alone Direct Impacts for the FOLU Sector

		In-Country GHG Impacts			*Total GHG Impacts*	*Direct Costs (base year 2018Q)*	
Option ID	**Option Title**	**Annual CO_2e Impacts 2030 Tg**	**Annual CO_2e Impacts 2050 Tg**	**2019-2050 Cumulative $TgCO_2e$**	**2019-2050 Cumulative $TgCO_2e$**	**NPV 2019-2050 QMillion**	**Cost Effectiveness Q/tCO_2e**
FOLU-1.	Establishment of Sustainable Forest Plantations	(2.5)	(8.5)	(126)	(126)	Q4,310	Q34
FOLU-2.	Conservation and Management of Sustainable Natural Forests	(27)	(32)	(918)	(918)	Q22,392	Q24
FOLU-3.	Reforestation of Degraded Lands with Native Species	(2.2)	(7.8)	(113)	(113)	Q2,767	Q24
FOLU-4.	Strengthen Institutional Response Capacity in Prevention and Control of Forest Fires	(2.7)	(4.6)	(92)	(92)	Q168	Q1.8
U-5	System of Urban Green Spaces	(0.0081)	(0.016)	(0.30)	(0.30)	Q146	Q490
	Total	**(34)**	**(53)**	**(1,249)**	**(1,249)**	**Q29,782**	**Q24**

US$ 1.00 = Q. 7.60

The above summary results are presented on the basis of the "independent" analysis. This means that each option was analyzed independently against the BAU conditions (that is, assuming that it was the only option that would be implemented). These results do not reflect identified overlaps or other interactions with other options. The results that have been adjusted to take into account the overlaps / interactions within this sector are given in the following table.

Table VI.E-2 provides a summary of the microeconomic analysis results accounting for interactions and overlaps with other options within the same sector. The only intra-sector interaction in the FOLU options is for FOLU-4. The increased area of natural forests and forest plantations that would result from the implementation of FOLU-1, 2, and 3 would result in greater wildfire activity and greater costs for preventing and managing those fires in the implementation of FOLU-4. **The integrated results indicate that in-country annual 2050 GHG reductions would be 53 TgCO_2e and the cumulative reductions for 2019-2050 would be 1,237 TgCO_2e. Net societal implementation costs are estimated to be Q29,916 million (US$3,936 million)**, **while the cost effectiveness is estimated to remain at 24 Q/tCO_2e (in 2018Q; US$3.16/t$CO_2$e).**

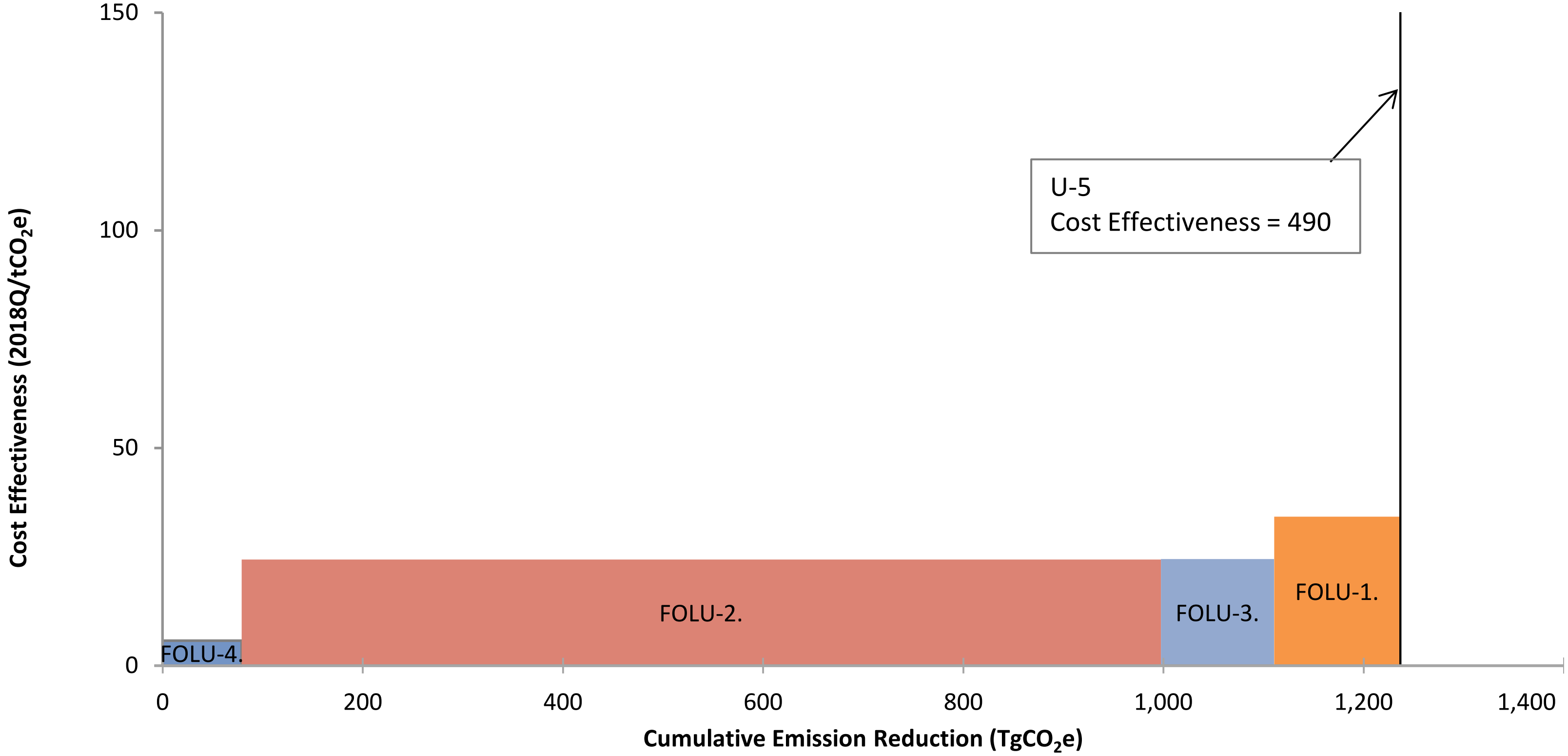
Table VI.E-2. Intra-Sector Integrated Direct Impacts for the FOLU Sector

Option ID	Option Title	*In-Country GHG Impacts* Annual CO_2e Impacts 2030 Tg	2050 Tg	2019-2050 Cumulative $TgCO_2e$	*Total GHG Impacts* 2019-2050 Cumulative $TgCO_2e$	*Direct Cost (Base Year 2018Q)* NPV 2019-2050 QMillion	Cost Effectiveness Q/tCO_2e
FOLU-1.	Establishment of Sustainable Forest Plantations	(2.5)	(8.5)	(126)	(126)	Q4,310	Q34
FOLU-2.	Conservation and Management of Sustainable Natural Forests	(27)	(32)	(918)	(918)	Q22,392	Q24
FOLU-3.	Reforestation of Degraded Lands with Native Species	(2.2)	(7.8)	(113)	(113)	Q2,767	Q24
FOLU-4.	Strengthen Institutional Response Capacity in Prevention and Control of Forest Fires	(2.2)	(4.4)	(79)	(79)	Q302	Q3.8
U-5	System of Urban Green Spaces	(0.0081)	(0.016)	(0.30)	(0.30)	Q146	Q490
	Total After Intra-Sector Interactions/Overlaps	**(34)**	**(53)**	**(1,237)**	**(1,237)**	**Q29,916**	**Q24**

US$1.00 = Q. 7.60

The results shown in this table have been adjusted for overlays or other interactions between options in this sector, see the notes next to each option result set to get a description of the overlays / interactions that were identified and addressed.
FOLU-4: The largest area of natural forest and forest plantations resulting from FOLU-1, 2 and 3, results in a greater possible area for forest fire activity.

Figure VI.E-2. FOLU Sector 2019 – 2050 Cumulative GHG MACC



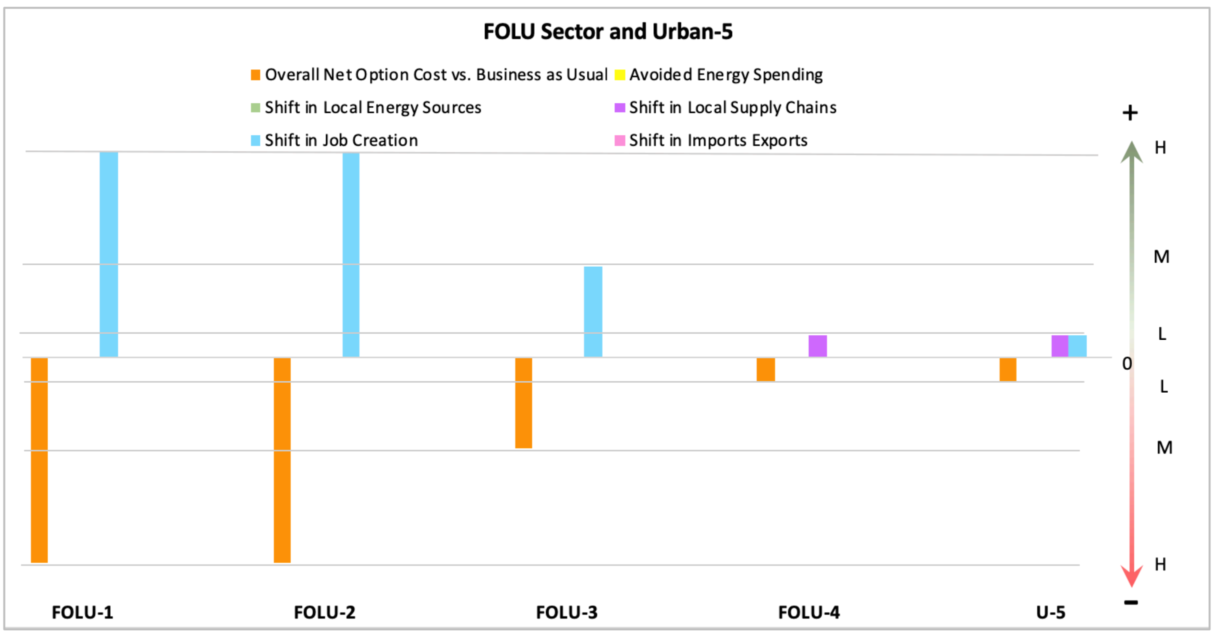
Note: the values represented in this sector-level MACC incorporate interactions and overlaps with options in other sectors ("inter-sector integrated" results). Those results are presented in Chapter VII (summarized values are provided in Table VII.C-6).

Figure VI.E-2 is the MACC for the FOLU sector. The cost curve plots the cumulative emission reductions (2019-2050) for each option in the order of most to least cost effective. The values represented in this sector-level MACC incorporate interactions and overlaps with options in other sectors ("inter-sector integrated" results) presented in Chapter VII (summarized values are provided in Table VII.C-6). If all options are fully implemented, cumulative reductions are estimated to be over 1,200 $TgCO_2e$. Options with negative values for CE are expected to result in net savings to society; however, for the FOLU options, the implementation of these options is expected to result in net societal costs.

4. Option-level and Sector-level Macroeconomic Performance

Figure VI.E-3 below summarizes the macroeconomic assessment results of the FOLU and U-5 options. These outcomes are shown on a "stand-alone" basis, meaning that they were evaluated against BAU conditions in isolation, i.e. without taking into account influences that might be present due to the implementation of other options.

Figure VI.E-3. Macroeconomic Impact Assessment of Options FOLU-1 – FOLU-4 & U-5



The macroeconomic factors assessment of the FOLU options reflects a key element of expected focus of activity under these options: a concentration on new, labor-intensive practices intended to improve the sustainability and use of lands. FOLU-1, FOLU-2 and FOLU-3 all focus on expenditures for people to establish, maintain, administer and protect new practices and new areas of forested land. As a consequence, the profile is fairly straightforward: **these expenditures are stimulative of labor-intense activities, which are positively associated with economy-wide gains in employment. That said, the cost of these expenditures is not offset by any savings or by any increase in productivity, export sale, or other balancing factor, and so the net cost is positive – the program is a cost for the overall economy to bear through taxes or costs of products and services.**

FOLU-4 differs only slightly. It is, like the other three FOLU options, a straightforward outlay on activity to protect forests. **Since that activity is forest fire management (which involves purchases outside of hiring labor), it was assessed as a stimulus to local sectors, rather than simply the hiring of more staff. As with the others, the net cost is not offset by savings or new production, which means that the broader economy must somehow bear the cost of these stimulative activities.**

Finally, **U-5** is similar again, but its costs were a mix of administrative costs (which were characterized as labor-intensive activity) and establishment of urban green spaces (which were characterized as work by a local sector that uses both labor and other materials and machinery). As a result, **small positive instances of local-sector stimulus and labor-intense activity stimulus were both identified. Again, however, the net cost is not offset by savings or new production, which means that the broader economy must somehow bear the cost of these stimulative activities.**

Even though the net cost for all options is positive, the FOLU sector has the largest mitigation impact (over 1,200 $TgCO_2e$) and their implementation provides unmeasured benefits in terms of biodiversity and other ecosystem services such as hydrological regulation, reduction of disaster vulnerability, adaptation to climate change and food security, among others.

F. WASTE MANAGEMENT

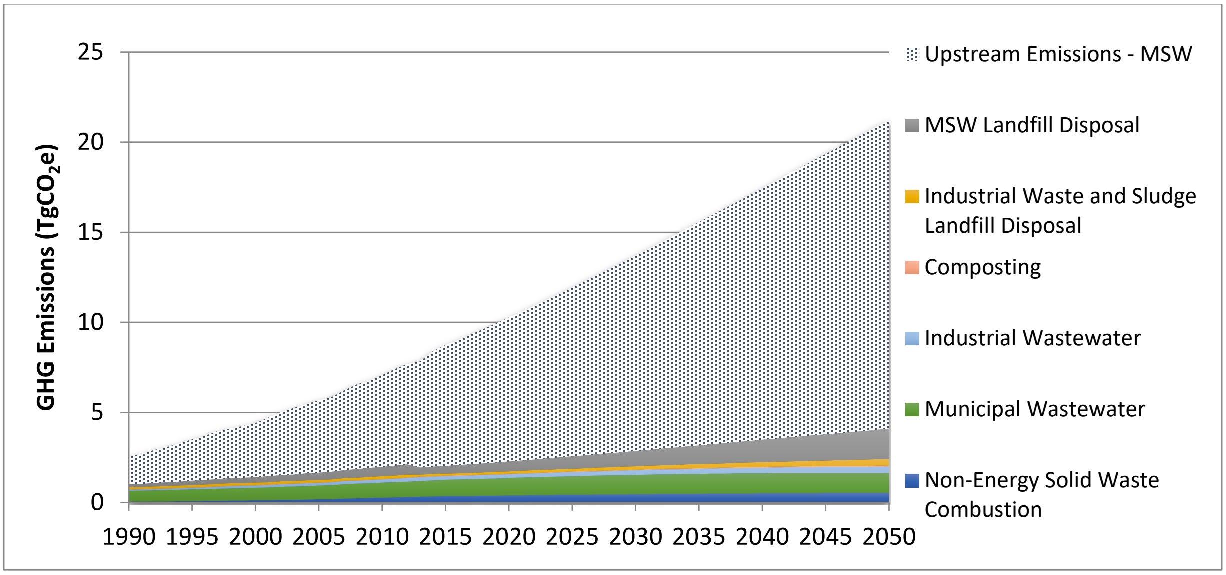
1. Sector Overview

The WM sector is comprised of two subsectors: solid waste management and wastewater treatment. Each of these subsectors can be further broken down into industrial and municipal subsectors. Direct GHG emissions from waste management include:

- Solid waste (SW) management:
  - Landfilling – municipal and industrial landfilling produces landfill gas (LFG) which is made up of roughly half methane (CH_4) and half carbon dioxide (CO_2). The CO_2 in LFG is typically assumed to be derived from biogenic wastes and is therefore assumed to be carbon neutral. Methane in LFG escapes from landfill surfaces and is the primary concern from a GHG perspective. When LFG is combusted, both CH_4 and N_2O emissions are produced (methane is not combusted with 100% efficiency).
  - Solid waste combustion – includes CH_4, CO_2, and N_2O emissions from the combustion of solid waste from residential open burning.
  - Organics management – this category includes composting and anaerobic digestion of solid waste. Both CH_4 and N_2O emissions are produced (CO_2 emissions are considered biogenic and therefore carbon neutral).
- Wastewater management – this subsector addresses CH_4 and N_2O emissions from centralized municipal and industrial wastewater (WW) treatment plants (WWTPs), as well as other WW management methods (e.g. septic systems, latrines, etc.).

When considering consumption-based GHG emissions from the WM sector, upstream emissions from virgin materials acquisition and product processing, manufacturing, and transportation for the products and materials entering the waste stream are also included. Figure VI.F-1, shows the WM sector baseline GHG estimates, with upstream emissions shown in the gray patterned area. As shown in this figure, the upstream emissions from solid waste are significantly higher than the direct emissions from waste management activities. A portion of these upstream emissions are likely to occur inside the country, but for the purposes of options analysis, all of these emissions were assumed to occur outside of the country. Direct GHG emissions were around 2 $TgCO_2e$ in 2015 and are expected to double to over 4 $TgCO_2e$ by 2050. If upstream emissions are also considered, emissions were around 8 $TgCO_2e$ in 2015 and are expected to almost triple to around 21 $TgCO_2e$ by 2050.

Figure VI.F-1. Waste Management Sector GHG Baseline



2. Summary of each of the options

The WM sector includes 4 options directed at solid waste (DS for *desechos sólidos*) and 2 directed at wastewater (DL for *desechos líquidos*) summarized below. Option DS-1 expands solid waste collection services and DS-2 expands and promotes recycling programs. Because expanding collection service without the corresponding expansion of recycling could increase landfilling of waste, resulting in increased GHG emissions, the impacts of these two options were analyzed jointly.

DS - 1. Expansion of Waste Collection and Improvement of Separation Efficiency

The objective of this option is to increase the coverage areas of waste and solid waste collection services at the municipal and industrial levels in a separative manner so that the waste is recycled and reused and minimize the waste in the treatment and final disposal sites.

Up to 2014, 35.2% of the population in the urban area and only 3.2% of the population in the rural area of Guatemala eliminated their waste and solid waste with collection services, whether municipal or private (ENCOVI 2014). From this it can be inferred that most of the population does not have collection coverage (64.8% in the urban area and 96.8% in the rural area and that these wastes and residues remain in clandestine garbage dumps, bodies of surface water, ravines or burn among other practices, thus generating greenhouse gases, mainly methane, nitrous oxide and carbon dioxide. According to the baseline, it was predicted that the solid waste sector will grow close to 201% between 2015 and 2050, with the increase in GHG emissions caused mainly by population growth. At present it is necessary to reduce the generation, as well as to improve the separation from the source, for after the harvest and transport, a minimum of waste / residues are treated and disposed sanitarily, which would reduce the emissions of the GHG associated with the final disposal in landfills.

Goals for this option are to redesign current collection routes and design new routes for geographic areas that do not have coverage in the waste and solid waste collection service to achieve 100% coverage in urban areas and 50% in rural areas, with respect to the current situation, establishing user adhesion mechanisms.

DS - 2. Re-Use and Recycling of Inorganic Waste

This option promotes the reduction of the amount of waste and solid waste from the source of origin and promotes the reuse, transformation and recycling of inert waste that can be valued. Reducing the generation of waste and solid waste reduces the GHG emissions produced in landfills and the GHG emissions associated with their transport.

According to the baseline, it was predicted that the solid waste sector will grow about 230% between 2015 and 2050, with the increase in GHG emissions caused mainly by population growth. The greatest impact on emissions can be achieved through source reductions because it is more efficient to prevent waste than to treat it. This option seeks to change habits of consumption and the re-use and/or recycling of waste and to promote incentives for producers to use reusable and recyclable packaging.

The goals for this option are to reduce solid waste at the source of generation by 25% by 2030, and 50% by 2050, with respect to the projections estimated by the baseline, and to reuse or recycle 50% of recyclable waste by 2030 and 90% by 2050.

DS - 3. Advanced Composting

Through this option, solid waste with potential to be composted will be recovered to reduce the volume and quantity of solid waste and simultaneously obtain an economic benefit from their commercialization. The objective is to achieve the recovery of waste with potential for composting and at the same time promote a market that generates an economic income for people who wish to participate in these programs.

According to the National Surveys of Living Conditions (ENCOVI) the percentage of households that used recycling and composting as a method of eliminating solid waste at the urban level was 1.3% in 2006, 0.9% in the year 2011 and 1.0% in 2014 and at rural level 5.7% in 2006, 2.0% in 2011 and 2.5% in 2014 at rural level. The composition of solid waste in Guatemala, both in the urban area and in the rural area indicates that a high percentage is susceptible to composting (56% urban area and 64% rural area). These residues with the potential to be composted are left in clandestine landfills, municipal dumps, burned in the open, generating greenhouse gases, mainly CH_4, CO_2, N_2O. Also, the high moisture levels of this type of waste generates highly polluting leachates for the environment.

According to studies on the composition of waste, the composition fraction for organic waste in urban areas is 42 and 14% (56%), for food and garden waste respectively, and 48 and 16% (64%) for rural areas. **The goal at the urban level, at landfill and household level, is 30% of organic waste composted by the year 2030, and 50% by 2050. At the rural level there is a goal of 50% by 2030, and 60% by 2050.**

DS - 4. Landfill Gas Capture and Use

The purpose of this option is to design and implement programs for the collection and use of methane in landfills. To achieve this goal, planning and designing landfill gas capture infrastructure is proposed, and when technically and economically viable, building

infrastructure to harvest methane for use in generating heat or electricity. Currently, there is potential for recovery of biogas in the municipal landfills of the urban areas of Guatemala, Quetzaltenango, Escuintla and Alta Verapaz. The landfill of zone 3 of Guatemala City has the potential to recover methane with an efficiency of 80% and is expected to be 27% of the total solid waste discharged by the year 2050.

To achieve the goal of reducing landfill methane emissions by 70% to 90%, this option aims to install 15 MW of landfill gas capacity by 2050 at landfills in Quetzaltenango, Escuintla, Alta Verapaz and other growing cities that generate more than 400 tons of waste/day.

DL - 1. Water-Saving Measures in the Residential, Commercial, Institutional and Industrial Sectors

The purpose of this option is to establish water saving programs in industry, commercial, institutional and residential sectors to reduce the volume of wastewater discharged with the objective of reducing GHG emissions from the liquid waste sector. Reducing water consumption will reduce the consumption of electricity used in the extraction, treatment and distribution of drinking water, and in the treatment of wastewater for reuse and final disposal in the environment. This option guides all actions to save water resources through the application, control and monitoring of existing legislation and the development of cleaner production mechanisms that lead to achieving the stated objective.

By promoting programs to save water in all representative sectors of Guatemalan society, the goal of this option is to reduce the volume of water consumed by various industrial, commercial, institutional and residential activities in the following proportions: 20% in the residential sector, 40% in the industrial sector and 20% in the commercial/institutional sector, with respect to the projections estimated by the baseline.

DL - 2. Advanced Wastewater Treatment Technologies

The purpose of this option is to promote the use of appropriate energy efficient low emission technologies for the treatment of wastewater. The liquid waste sector generates GHG emissions in two ways: directly through fugitive emissions and indirectly through electricity usage for pumping, aeration, etc. The use of appropriate technologies in the treatment of wastewater such as depuration and denitrification, optimal pumping speed, high pumping efficiency, efficient variable speed blowers, optimized aeration control systems and aeration systems, efficient mixing, optimized mixing solutions, improved biogas production, pumping of high efficiency aerobic sludge, and control in filtration will reduce the production of greenhouse gases by the wastewater management sector.

The goal is to reduce GHG emissions generated by the treatment of wastewater projected for the years 2030 and 2050 by 25% and 40% respectively, through the use of technologies appropriate to the environment in wastewater treatment, and have a saving in energy consumption by energy efficiency of 25% by 2030 and 50% by 2050.

3. Option-level and Sector-level Direct Results (Energy, Resources, GHG, Costs and Savings)

Table VI.F-1 below provides a summary of the results of the microeconomic analyses conducted for each of the WM options. Negative values are shown in red text (for example, GHG emissions below baseline levels), while positive values are shown in black text (for example, net implementation costs that are above business as usual costs). These results are shown on a "stand-alone" basis, meaning that they were evaluated against BAU conditions assuming that no other options would be implemented. **These "stand-alone" results indicate that in-country annual 2050 GHG reductions are estimated to be 1.6 $TgCO_2e$ and the cumulative reductions for 2019-2050 are estimated to be 24 $TgCO_2e$**. As explained under the baseline inventory discussion above, upstream emissions for solid waste estimated under the consumption-based inventory are significantly higher than direct emissions for waste management. This high contribution of solid waste upstream emissions can also be seen in the emission reductions for the DS-1 & 2, where the 2050 cumulative emissions are 168 $TgCO_2e$ compared to 7.1 $TgCO_2e$ for direct in-country emissions. Some of these upstream emissions reductions, may occur within the country, but because of the high uncertainty of where they are occurring, they are attributed to out-of-country emissions.

Net societal implementation costs for the WM options are estimated to be -Q8.4 billion (in 2018Q; -US$1.1 billion). For DS-1 & 2 and DS-3, the options result in savings because the reduced costs for landfilling and revenue created from recycling and composting are greater than the increased costs from waste collection and recycling/composting infrastructure. **The cost effectiveness, which is based on total reductions not just in-country reductions, is estimated to be –45 Q/tCO_2e (in 2018Q; -US$5.92/$tCO_2e$)**.

Table VI.F-1. Stand-alone Direct Impacts for the Waste Management Sector

		In-Country GHG Impacts			*Total GHG Impacts*	*Direct Cost (Base Year 2018Q)*	
		Annual CO_2e Impacts		**2019-2050 Cumulative**	**2019-2050 Cumulative**	**NPV 2019-2050**	**Cost Effectiveness**
Option ID	**Option Title**	**2030 Tg**	**2050 Tg**	**$TgCO_2e$**	**$TgCO_2e$**	**QMillion**	**Q/tCO_2e**
DS-1 & 2.	Expansion of Waste Collection and Improvement of Separation Efficiency; Re-Use and Recycling of Inorganic Solid Waste	(0.13)	(0.51)	(7.1)	(168)	-Q10,845	-Q64
DS-3.	Advanced Composting	0.040	(0.19)	(0.98)	(0.98)	-5940	-Q607
DS-4.	Landfill Gas Capture and Use	(0.20)	(0.40)	(7.4)	(7.8)	-Q363	-Q46
DL-1.	Water-Saving Measures in the Residential, Commercial, Institutional and Industrial Sectors	(0.14)	(0.34)	(5.6)	(6.9)	Q3,365	Q484
DL-2.	Advanced Wastewater Treatment Technologies	(0.061)	(0.16)	(2.6)	(2.6)	Q9.3	Q3.6
	Total	**(0.49)**	**(1.6)**	**(24)**	**(187)**	**-Q8,428**	**-Q45**

US$ 1.00= Q. 7.60

The above summary results are presented on the basis of the "independent" analysis. This means that each option was analyzed independently against the BAU conditions (that is, assuming that it was the only option that would be implemented). These results do not reflect identified overlaps or other interactions with other options. The results that have been adjusted to take into account the overlaps / interactions within this sector are given in the following table.

Table VI.F-2 provides a summary of the microeconomic analysis results accounting for interactions and overlaps with other options within the same sector. The only intra-sector interactions among the WM options are between DS-1&2 and DS-3 and between DL-1 and DL-2. The solid waste options overlap because the source reduction component of DS-2 results in less diversion of compostable material from landfills in DS-3. Also, DS-3 reduces the amount of waste that will be collected and deposited in the DS-1. There is a small amount of overlap between the wastewater options DL-1 and DL-2 because DL-1 reduces the amount of wastewater that must be pumped and treated in DL-2, and DL-2 reduces the electricity required to pump and treat water in DL-1. **Integrated results indicate that in-country annual 2050 GHG reductions are estimated to be 1.5 TgCO_2e and the cumulative reductions for 2019-2050 are estimated to be 23 TgCO_2e. Net societal implementation costs for the WM options are estimated to be -Q8,918 million (-US$1,173 million). The cost effectiveness, which is based on total reductions not just in-country reductions, is estimated to be –48 Q/tCO_2e (in 2018Q; -US$6.3/tCO2e)**.

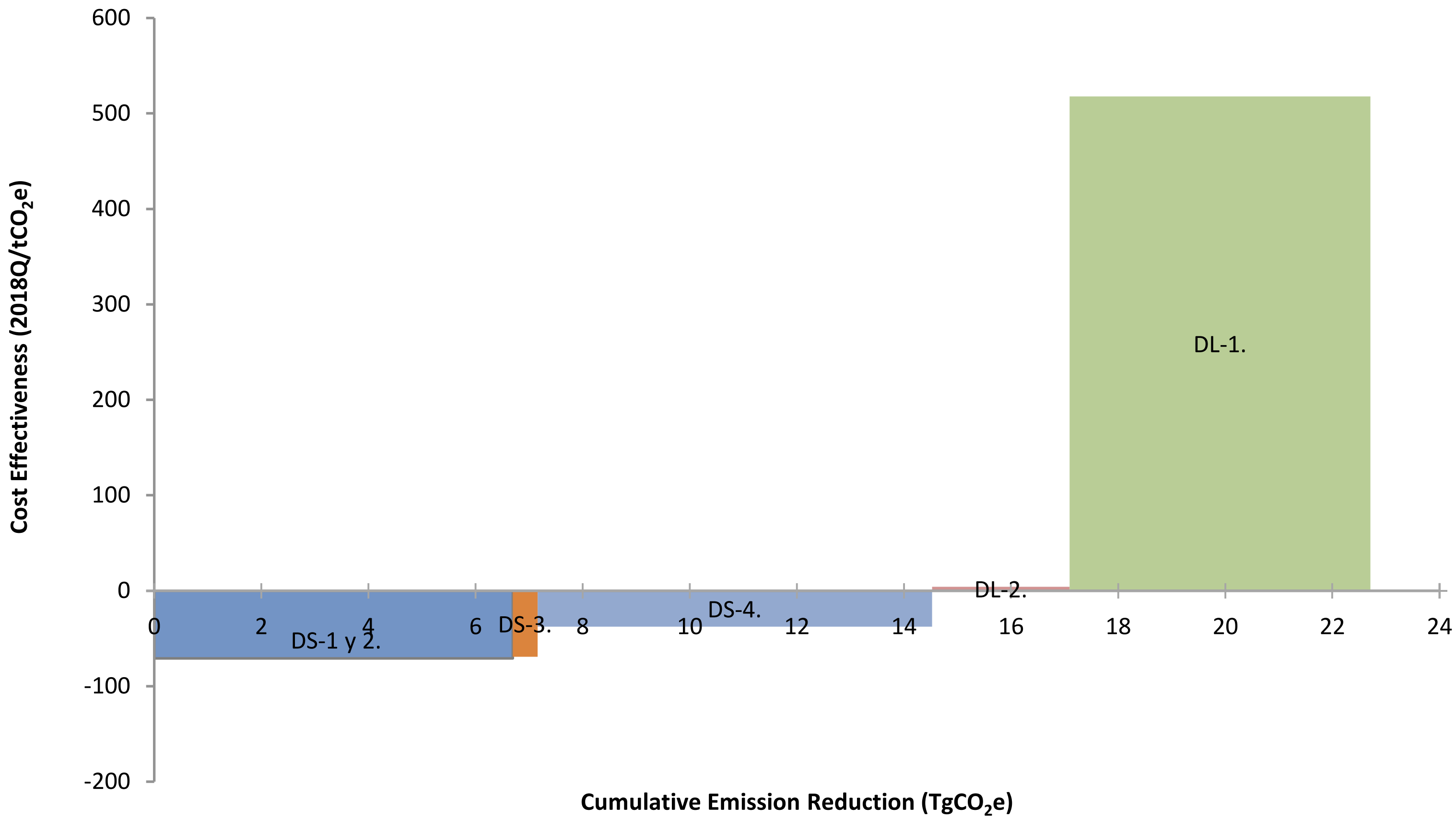
Table VI.F-2. Intra-Sector Integrated Direct Impacts for the Waste Management Sector

Option ID	Option Title	*In-Country GHG Impacts* Annual CO_2e Impacts 2030 Tg	2050 Tg	2019-2050 Cumulative $TgCO_2e$	*Total GHG Impacts* 2019-2050 Cumulative $TgCO_2e$	*Direct Cost (Base Year 2018Q)* NPV 2019-2050 QMillion	Cost Effectiveness Q/tCO_2e
DS-1 y 2.	Expansion of Waste Collection and Improvement of Separation Efficiency; Re-Use and Recycling of Inorganic Solid Waste	(0.094)	(0.57)	(6.7)	(168)	-Q11,894	-Q71
DS-3.	Advanced Composting	(0.0042)	(0.0018)	(0.46)	(0.46)	-Q32	-Q69
DS-4.	Landfill Gas Capture and Use	(0.20)	(0.40)	(7.4)	(7.8)	-Q363	-Q46
DL-1.	Water-Saving Measures in the Residential, Commercial, Institutional and Industrial Sectors	(0.14)	(0.34)	(5.6)	(6.9)	Q3,366	Q485
DL-2.	Advanced Wastewater Treatment Technologies	(0.061)	(0.16)	(2.6)	(2.6)	Q5.2	Q2.0
	Total After Intra-Sector Interactions/Overlaps	**(0.50)**	**(1.5)**	**(23)**	**(186)**	**-Q8,918**	**-Q48**

US$ 1.00 = Q. 7.60

The results shown in this table have been adjusted for overlays or other interactions between options in this sector, see the notes next to each option result set to get a description of the overlays / interactions that were identified and addressed.
DS-1 and 2: DS-1, 2 and 3 overlap because the reduction of the source of DS-1 results in diverting less compostable material from landfills into DS-3. DS-3 reduces the amount of waste that will be collected and deposited in the DS-1.
DL-1 / DL-2: There is a small amount of overlap between DL-1 and DL-2 because DL-1 reduces the amount of wastewater that must be pumped and treated in DL-2. DL-2 reduces the electricity required to pump and treat water in DL-1.

Figure VI.F-2. Waste Management Sector 2019 – 2050 Cumulative GHG MACC



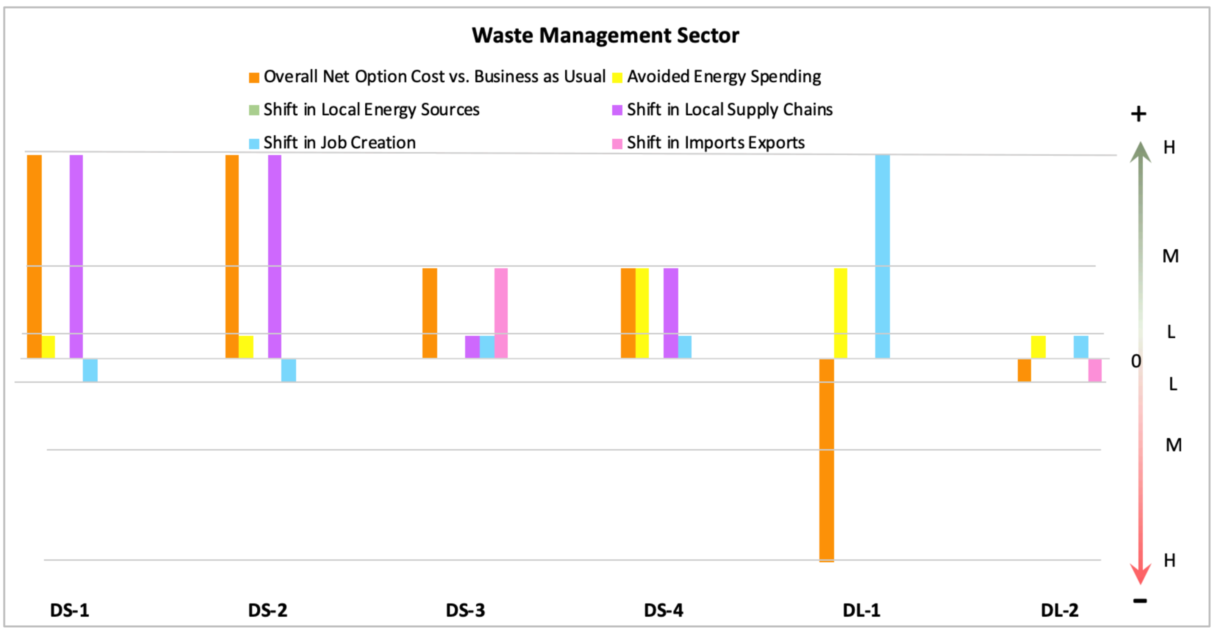
Note: the values represented in this sector-level MACC incorporate interactions and overlaps with options in other sectors ("inter-sector integrated" results). Those results are presented in Chapter VII (summarized values are provided in Table VII.C-6).

Figure VI.F-2 is the MACC for the WM sector. The cost curve plots the cumulative emission reductions (2019-2050) for each option in the order of most to least cost effective. The values represented in this sector-level MACC incorporate interactions and overlaps with options in other sectors ("inter-sector integrated" results) presented in Chapter VII (summarized values are provided in Table VII.C-6). If all options are fully implemented, cumulative reductions are estimated to be about 23 $TgCO_2e$. Note however, that if upstream emission reductions are also considered (i.e. mostly outside of the country), cumulative emission reductions are 186 $TgCO_2e$ (see Table VI.F-2). Options with negative values for CE are expected to result in net savings to society.

4. Option-level and Sector-level Macroeconomic Performance

Figure VI.F-2 below summarizes the macroeconomic assessment results of the WM options. These outcomes are shown on a "stand-alone" basis, meaning that they were evaluated against BAU conditions in isolation, i.e. without considering influences that might be present due to the implementation of other options.

Figure VI.F-2. Macroeconomic Impact Assessment of Options DS-1 – DS-4, DL-1 – DL-2



The solid waste options vary in their focus, addressing better waste hauling, waste-volume reduction, better composting, and finally, capturing landfill gases. As a result, they rely on different types of actions and expenditures. But there is one common thread: all four of these options identify an opportunity to unlock a source of value that is allowed to disappear in the current waste management system. DS-1 and DS-2 identify the potential to capture and sell a large volume of recyclable materials currently directed to landfills. DS-3, which focuses on composting, identifies compost sales possibilities and fertilizer-cost savings that fully cover the option's expected cost of implementation. Finally, DS-4 projects that methane capture efforts should more than pay for themselves through generation of free electricity that avoids the cost of paying utilities for that energy. **As a result, all of the solid-waste options show a net savings on an economy-wide basis. They also show gains (of varying sizes) to the local sectors that are producing the new materials or energy.**

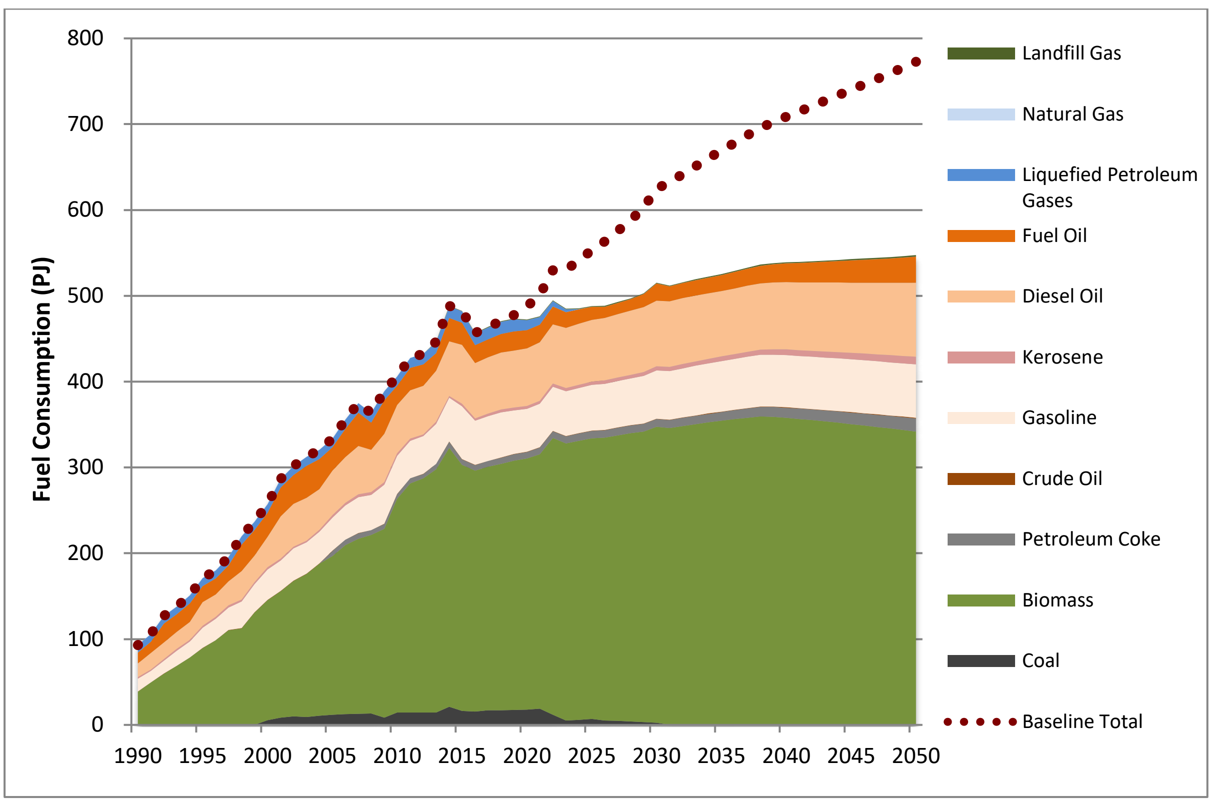
The wastewater options (DL-1 and DL-2) are quite different from each other. **DL-1 anticipates a fairly major expenditure on labor-intense activity to save water – an expenditure over 4 times the value of the electricity saved by the water system as a result**. However, that expenditure is devoted primarily to labor, which is a positive observation of the factor associated with economy-wide employment growth. **DL-2, by contrast, is an option where no cost or savings ever exceeds a few million quetzals per year. Thanks to the small scale of all of its spending and savings, in the context of the overall Guatemalan economy, this option is not expected to have any noticeable positive or negative effect.**

VII. ECONOMY-WIDE (ALL SECTORS) GLEDS IMPACTS

A. ENERGY

The intra- and inter-sector integrated primary energy impacts for all options, including direct fuel use and fuel used for electricity generation, were estimated and compared to the fuel consumption estimated for the baseline. Figure VII-A.1 below shows the estimated fuel consumption under the GLEDS Plan scenario. **Through full implementation of the GLEDS Plan, BAU fuel consumption will be reduced by over 200 petajoules (PJ) annually by 2050 (from 773 PJ to 545 PJ/yr in 2050).** As discussed in the inter-sector integration section below, fuel savings through implementation of **energy efficiency (EE) and renewable energy (RE) options are estimated to offset almost all fossil fuels used for electricity generation**. Figure VII-A.1 shows that the fuels used only for electricity generation in the baseline, coal and natural gas, are estimated to be reduced to zero; with coal completely phased out no later than 2037 and new BAU natural gas capacity not needed. Fuel oil and diesel oil consumption for electricity generation are also reduced by the EE and RE measures.

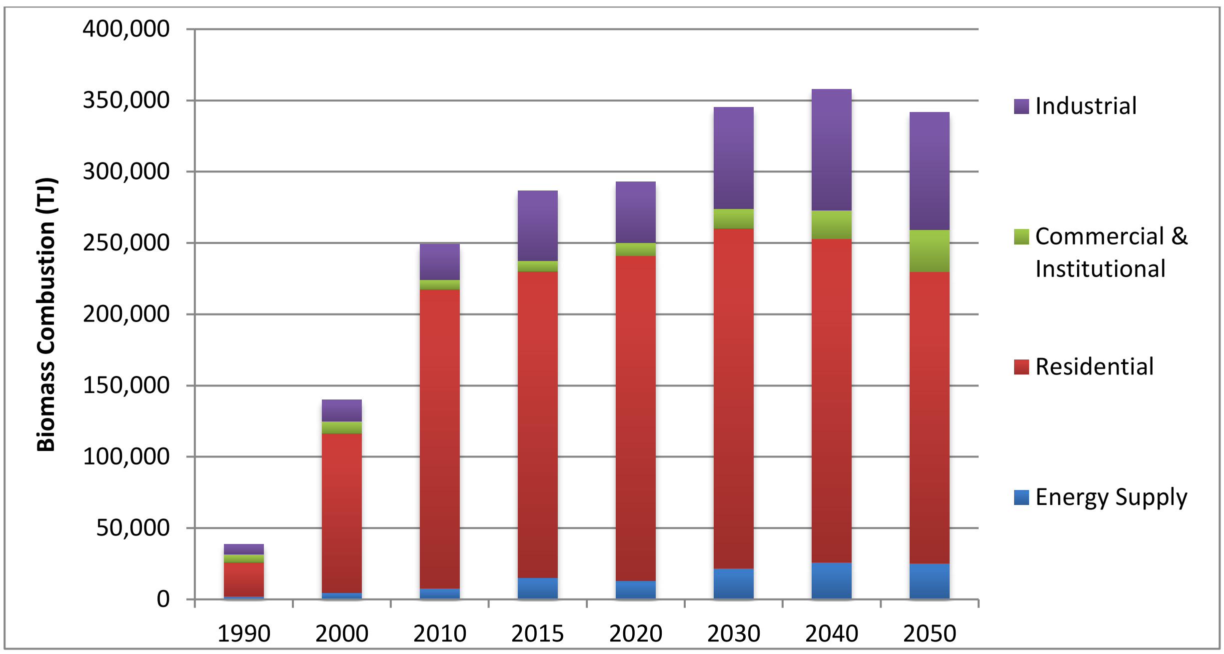
Figure VII.A-1. GLEDS Plan Scenario Primary Energy Consumption Forecast



Biomass consumption is also reduced, mostly through the use of efficient wood stoves from option E-9. Transport sector options reduce the consumption of gasoline and diesel fuel. Consumption of LPG, fuel oil, diesel oil, kerosene, crude oil, and petroleum coke would be reduced through the implementation of Industry options that reduce direct fuel use for process heat generation. Overall LPG consumption in Guatemala is estimated to be completely offset by 2050, due to a combination of the impacts of Industry sector measures and through displacement of LPG use in rural applications through biogas produced through implementation of GAN-3, which promotes the use of manure digestors.

Implementation of the GLEDS Plan would reduce the consumption of biomass for energy end uses from 398 PJ/yr in the BAU case to 342 PJ/yr in 2050 (see Figure VII-A.2)**.** The vast majority of these reductions (>99%) would be from implementation of E-9, which promotes the use of efficient wood stoves in the residential sector. The remaining reductions are from industry measures, including option I-1, which would improve the efficiency of industrial equipment that use biomass fuel, such as kilns and ovens.

Figure VII.A-2. GLEDS Plan Biomass Combustion by Sector

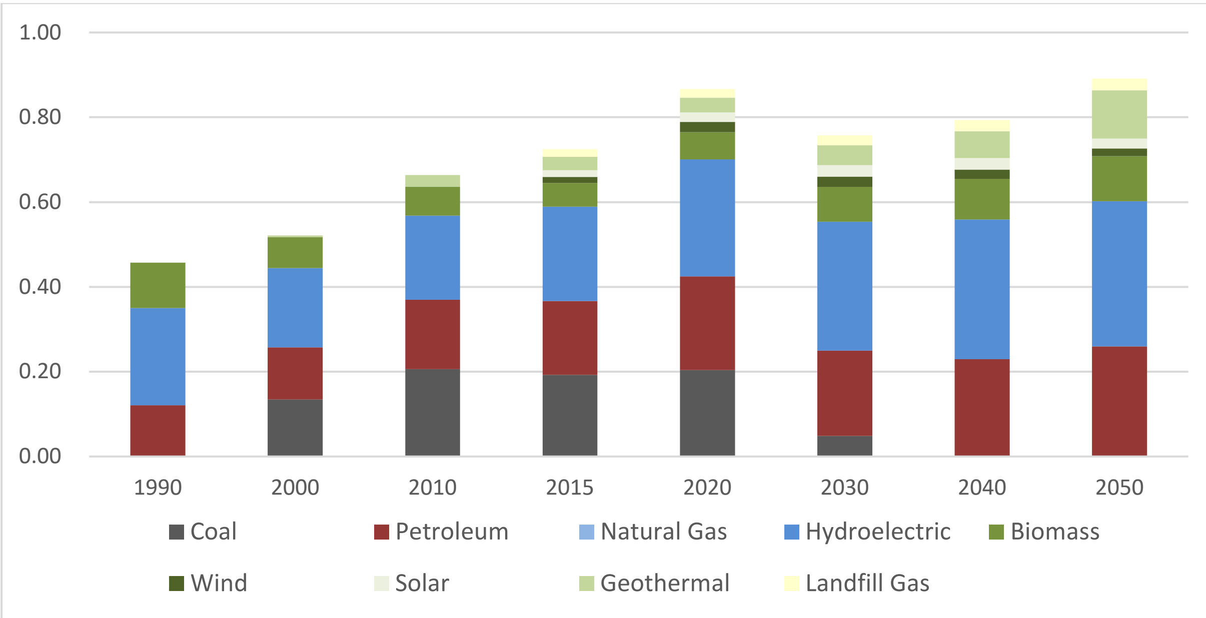


As explained in the Baseline report included in Appendix B, a key indicator of energy security is the diversity of energy supply. This diversity can be measured using the Shannon Diversity Index (H'). H' can be calculated based on the types of fuels in use in any given year; it can also be calculated, for example, based on the source of imports of particular fuels. Under the GLEDS Baseline forecast, H' for diversity by type of fuel was forecasted to grow to a value of 1.18 by 2050 as a result of the increase in the number of types of primary energy forecast to be in use by that year. Because the GLEDS Plan is estimated to result in the complete phase-out of coal and natural gas, the diversity index is expected to drop to 0.89 by 2050, only slightly higher than the current (2018) diversity value (see Figure VII.A-3 below).

Although the GLEDS Plan is expected to reduce the H' measure of energy diversity by fuel, the phase-out of coal and natural gas, as well as LPG, would have the benefit of reducing

reliance on imported fuels, which is another element typically associated with improvements in national energy security. Future analyses of GLEDS Plan impacts on energy security should consider the application of other more complex diversity metrics that capture the security benefit of reducing energy imports.

Figure VII.A-3. Economy-Wide Energy Diversity Index for Guatemala: GLEDS Plan Scenario



B. RESOURCES

The land use/land cover (LULC) impacts estimated for the GLEDS Plan are shown in Table VII.B-1 below. **GLEDS Plan implementation is estimated to result in almost an additional 2.5 million ha of natural forest and forest plantations relative to baseline estimates for 2050. These impacts would be the result of implementation of FOLU options that preserve and expand forests and forest plantations, and of the AG+GAN options, GAN-1 and GAN-2, that improve efficiency of pasture management and create silvopastural systems.** There is a fair amount of uncertainty in these estimates due to the uncertainties associated with how other land uses will be affected by these options. For example, it is not well understood whether forests, shrublands, or other land uses will be better preserved as result of reduced pressure for expansion of livestock pastures.

It is also likely that there is some degree of overlap between the FOLU and GAN options. The direct impacts assessment assumes that these options are implemented on different lands. It is possible, however, that if the GAN options that reduce pressure on forest conversion and option FOLU-2 (strengthening conservation and management of natural forests) are applied in part in the same area, then the protective impacts ascribed to FOLU-2 could be reduced. **A full analysis of the impacts on all land use types would require the use of geospatial analysis to determine the exact locations of at-risk forests, expanding agricultural land by type (pasture, annual crops, and permanent crops), urban expansion, and other land use types that was beyond the scope of this analysis.**

Table VII.B-1. Land Use/Land Cover (LULC) Impacts of GLEDS Plan

LULC Impact (thousand ha)	2020	2030	2040	2050
Natural Forest Preserved	61	595	1,122	1,233
Natural Forest Expansion	13	148	262	526
New Forest Plantations	28	227	471	715
Total	102	970	1,855	2,474
Note: impacts are as compared to the business as usual scenario of LULC change.				

C. GHG EMISSIONS AND DIRECT COSTS AND SAVINGS

1. Inter-sector Integration

Following the sector-level direct impacts analysis, an economy-wide integration of expected GHG impacts was conducted in order to account for interactions and overlaps among options between sectors (an "inter-sector interactions and overlaps" analysis). Some of the areas where overlaps or interactions among options can occur between sectors include:

- **Supply and demand of fuels:** for example, overlaps can occur when options related to biofuel supply are present in the resource sectors (agriculture, forestry, waste management) and options affecting biofuels demand are present in the demand sectors (RCI, Industry, Energy Supply and Transportation). For GLEDS, there were two potential areas of overlap:
  - Use of ethanol as a transportation fuel: The Transportation sector includes Option T-6 addressing the use of Guatemalan-produced ethanol in the transport fuel mix. Since the option is currently designed to re-direct ethanol that is produced under BAU conditions from an export product to its use in the country, then there is no additional demand put on the agricultural system (that is, there is no additional sugarcane production/processing) to fill this need. Therefore, no adjustments were needed to address higher levels of GHG emissions in the agricultural sector to produce more ethanol.
  - Lower demand of forest biomass for fuel use: GLEDS Option E-9 promotes the use of high efficiency biomass cooking stoves as a method to reduce unsustainable forest harvests of fuelwood. This option has potential overlap with measures applied in options FOLU-1 (Establishment and Sustainable Management of Forest Plantations) and FOLU-2 (Strengthening Conservation and Sustainable Management of Natural Forests). As currently designed, however, the two FOLU options focus on maintaining current forest lands as forests, that is, avoiding forest land conversion, and on adding new forest plantations. The FOLU options do not address any changes in wood harvests, which are reduced by the implementation of E-9. Therefore, all of the carbon savings associated with reduced fuelwood consumption for implementing Option E-9 are attributed to that option.
- **Materials management:** as an example, these overlaps/interactions can occur between sectors when options are present that affect waste generation, transport, or management. For the GLEDS, solid waste management options are present in both the Industry sector (I-5) and the Waste Management sector. While in practice, the solid waste streams from industry and municipalities are often co-mingled, these two solid waste streams were assumed to be

kept separate for the purposes of analysis. Therefore, no adjustments were needed to account for overlaps.

As in most similar planning contexts, the key areas where overlapping sector impacts occurred in the GLEDS process was between **electricity supply options and those affecting electricity demand**. The methods for addressing these interactions are provided in Appendix C (Inter-sector integration methodology).

2. Economy-wide GHG emissions and direct costs/savings impacts

The intra-sector adjusted direct GHG reductions and costs results presented in Chapter VI were then adjusted using the revised marginal resource metrics described in Appendix C. **Table VII.C-1** provides a summary of the GLEDS direct impacts analysis for all options following adjustment for inter-sector overlaps and interactions. Fully integrated results are provided for each option, for the total of options within each sector, and finally for the entire GLEDS Plan.

The fully-integrated results for the GLEDS Plan indicate that, if all options are fully implemented as designed, total year-2050 GHG reductions within the country will be 120 TgCO_2e and cumulative in-country reductions for the period 2019-20150 will be 2,454 TgCO_2e. Total direct implementation costs are expected to result in over 41 billion 2018Q saved throughout society (US$5.4 billion 2018; a negative cost value in the table indicates a net savings to Guatemalan society). The column "Total Cumulative Impacts, 2019-2050" indicates the cumulative GHG reductions occurring both within and outside of the country's borders during the planning period. These reductions total 2,732 TgCO_2e for the GLEDS Plan. **When total implementation costs are divided by the total cumulative reductions, the cost effectiveness estimated for the entire GLEDS Plan -17Q/ tCO_2e (-US$2.21/t$CO_2$e).** The marginal abatement cost curve (MACC) for the Plan was then produced based on the values in Table VII.C-1 (see Figure VII.C-4 below).

Table VII.C-1. Fully-Integrated Direct Impact Results

Option ID	Option Title	In-Country 2030 Impacts ($TgCO_2e$)	Total 2030 Impacts ($TgCO_2e$)	In-Country 2050 Impacts ($TgCO_2e$)	Total 2050 Impacts ($TgCO_2e$)	Cumulative Impacts in Guatemala 2019-2050 ($TgCO_2e$)	Total Cumulative Impacts 2019-2050 ($TgCO_2e$)	Net Present Value 2019-2050 (Q2018Million)	Cost Effectiveness (Q2018/tCO_2e)
E-1.	Management of Permits and Locations to Increase the Potential of Existing Hydroelectric Plants	-1.3	-1.6	-2.6	-3.4	-47	-58	-Q6,602	-Q114
E-2.	Development of Mini- and Micro-Hydroelectric Plants	-0.026	-0.034	-0.063	-0.082	-1.0	-1.3	Q100	Q76
E-3.	Expand the Use of Solar Generation	-0.26	-0.31	-0.58	-0.76	-11	-13	-Q1,029	-Q77
E-4.	Expand the Use of Geothermal Energy	-0.7	-0.9	-1.3	-1.7	-26	-32	Q717	Q23
E-5.	New Renewable Generation to Reduce System Losses	-0.48	-0.54	-1.0	-1.3	-17	-20	Q3,765	Q186
U-3.	LED Public Lighting in Guatemala City	-0.17	-0.20	-0.64	-0.84	-8.8	-11	-Q2,682	-Q245
U-4.	Add Energy Efficiency Standards to National Building Code	-0.15	-0.19	-0.44	-0.68	-6.5	-8.9	-Q920	-Q104
Energy Sector Total		**-3.1**	**-3.7**	**-6.7**	**-8.8**	**-117**	**-144**	**-6,650**	**-Q46**

Option ID	Option Title	In-Country 2030 Impacts	Total 2030 Impacts ($TgCO_2e$)	In-Country 2050 Impacts	Total 2050 Impacts ($TgCO_2e$)	Cumulative Impacts in Guatemala 2019-2050	Total Cumulative Impacts 2019-2050	Net Present Value 2019-2050 (Q2018Million)	Cost Effectiveness ($Q2018/tCO_2e$)
E-6.	Energy Efficiency Codes for Existing Buildings	-0.14	-0.17	-0.23	-0.30	-4.4	-5.4	-Q471	-Q87
E-7.	Energy Efficiency Standards for Equipment and Appliances	-1.7	-2.0	-2.3	-3.0	-48	-60	-Q13,298	-Q223
E-8.	Energy Audits	-0.10	-0.12	-0.16	-0.21	-3.1	-3.8	-Q125	-Q33
E-9.	Introduction of Efficient Wood Stoves	-2.7	-2.7	-11	-11	-162	-162	-Q5,895	-Q36
Residential, Commercial, and Institutional Sector Total		**-4.6**	**-5.0**	**-14**	**-15**	**-218**	**-230**	**-Q19,790**	**-Q86**
I-1.	Energy Efficiency for Furnaces/Ovens	-0.11	-0.13	-0.24	-0.28	-3.7	-4.3	Q101	Q24
I-2.	Energy Efficiency Programs - Boilers and Process Heaters	-0.0033	-0.035	-0.010	-0.11	-0.17	-1.8	Q16	Q9.3
I-3.	Incentives for Renewable Energy	-0.85	-1.0	-1.6	-1.9	-29	-35	-Q6,792	-Q192
I-4.	Improvements to Electrical Energy Efficiency	-0.90	-1.1	-2.0	-2.6	-37	-45	-Q4,836	-Q107
I-5.	Increased Recycling and/or Substitution of Materials	-0.00039	-0.27	-0.052	-1.3	-0.42	-17	-Q1,091	-Q66
I-6.	Improve Heat Recovery	-0.0044	-0.0049	-0.026	-0.029	-0.36	-0.39	Q42	Q106
Industrial Sector Total		**-1.9**	**-2.5**	**-3.8**	**-6.2**	**-70**	**-103**	**-Q12,603**	**-Q122**

Option ID	Option Title	In-Country 2030 Impacts	Total 2030 Impacts ($TgCO_2e$)	In-Country 2050 Impacts	Total 2050 Impacts ($TgCO_2e$)	Cumulative Impacts in Guatemala 2019-2050	Total Cumulative Impacts 2019-2050	Net Present Value 2019-2050 (Q2018Million)	Cost Effectiveness (Q2018/tCO_2e)
T-1.	Build MetroRiel Light-rail Route in Guatemala City	-0.0063	-0.010	-0.025	-0.031	-0.32	-0.44	-Q554	-Q1,246
T-2.	Modernize Private Fleet of Suburban/Extra-urban Commuter Buses	-0.19	-0.24	-0.34	-0.42	-8.6	-11	Q1,527	Q144
T-3.	Improve Regular Transit, Update Fleet, and Expand BRT in Guatemala City	-0.019	-0.023	-0.020	-0.024	-0.54	-0.67	Q2,118	Q3,171
T-4.	Construction of Highway Bypasses around Chimaltenango and Barberena	-0.023	-0.028	-0.035	-0.042	-0.92	-1.1	Q65	Q57
T-5.	Modernize the Private Light-duty Vehicle Fleet	-0.21	-0.27	-0.28	-0.35	-5.3	-6.8	-Q4,140	-Q607
T-6.	Promote the Use of Ethanol in Gasoline	-0.11	-0.13	-0.13	-0.15	-4.2	-4.8	Q1,576	Q331
U-1.	Establish an Urban Land-Use Component Within the National Urban Development Policy	-1.4	-1.8	-1.6	-2.0	-40	-49	-Q30,859	-Q626
U-2.	Sustainable Urban Mobility Plan for Guatemala City	-0.079	-0.10	-0.35	-0.45	-4.8	-6.1	Q2,654	Q435
Transportation and Land Use Total		**-2.1**	**-2.6**	**-2.8**	**-3.5**	**-64**	**-80**	**-Q27,613**	**-Q346**

Option ID	Option Title	In-Country 2030 Impacts	Total 2030 Impacts ($TgCO_2e$)	In-Country 2050 Impacts	Total 2050 Impacts ($TgCO_2e$)	Cumulative Impacts in Guatemala 2019-2050	Total Cumulative Impacts 2019-2050	Net Present Value 2019-2050 (Q2018Million)	Cost Effectiveness (Q2018/tCO_2e)
AG-1.	Sustainable Management of Soils	-1.0	-1.1	-2.6	-2.6	-44	-45	-Q946	-Q21
AG-2.	Establishment and Improvement of Agroforestry Systems	-0.87	-0.88	-0.24	-0.26	-16.0	-16.4	-Q747	-Q46
AG-3.	Establishment of Fruit Plantations	-4.1	-4.2	-21	-21	-284	-287	Q5,877	Q20
AG-4.	Efficient Use of Nitrogen Fertilizers	-0.41	-0.51	-1.1	-1.4	-17	-21	Q42,065	Q1,964
GAN-1.	Improved Pasture Management through Rotational Grazing	-1.5	-1.5	-3.9	-3.9	-65	-65	-Q15,589	-Q241
GAN-2.	Promotion of Silvopastoral Systems	-7.2	-7.2	-8.4	-8.4	-268	-268	-Q12,184	-Q45
GAN-3.	Promote Integrated Manure Management at Intensive Animal Production Systems	-0.87	-1.4	-1.7	-2.8	-32	-51	-Q5,065	-Q99
Agriculture and Livestock Sector Total		**-16**	**-17**	**-39**	**-40**	**-725**	**-753**	**Q4,184**	**Q5.6**
FOLU-1.	Establishment of Sustainable Forest Plantations	-2.5	-2.5	-8.5	-8.5	-126	-126	Q4,310	Q34
FOLU-2.	Conservation and Management of Sustainable Natural Forests	-27	-27	-32	-32	-918	-918	Q22,392	Q24

Option ID	Option Title	In-Country 2030 Impacts	Total 2030 Impacts ($TgCO_2e$)	In-Country 2050 Impacts	Total 2050 Impacts ($TgCO_2e$)	Cumulative Impacts in Guatemala 2019-2050	Total Cumulative Impacts 2019-2050	Net Present Value 2019-2050 (Q2018Million)	Cost Effectiveness ($Q2018/tCO_2e$)
FOLU-3.	Reforestation of Degraded Lands with Native Species	-2.2	-2.2	-7.8	-7.8	-113	-113	Q2,767	Q24
FOLU-4.	Strengthen Institutional Response Capacity in Prevention and Control of Forest Fires	-2.2	-2.2	-4.4	-4.4	-79	-79	Q454	Q5.7
U-5	System of Urban Green Spaces	-0.0081	-0.0081	-0.016	-0.016	-0.30	-0.30	Q146	Q490
Forestry and Other Land Use Sector Total		**-34**	**-34**	**-53**	**-53**	**-1,236**	**-1,236**	**Q29,923**	**Q24**
DS-1 & 2.	Expansion of Waste Collection and Improvement of Separation Efficiency ; Re-Use and Recycling of Inorganic Solid Waste	-0.094	-3.9	-0.57	-10	-6.7	-168	-Q11,894	-Q71
DS-3.	Advanced Composting	-0.0042	-0.0042	-0.0018	-0.0018	-0.46	-0.46	-Q32	-Q69
DS-4.	Landfill Gas Capture and Use	-0.20	-0.21	-0.40	-0.43	-7.37	-7.8	-Q295	-Q38
DL-1.	Water-Saving Measures in the Residential, Commercial, Institutional and Industrial Sectors	-0.14	-0.17	-0.34	-0.44	-5.62	-6.9	Q3,594	Q518

Option ID	Option Title	In-Country 2030 Impacts	Total 2030 Impacts ($TgCO_2e$)	In-Country 2050 Impacts	Total 2050 Impacts ($TgCO_2e$)	Cumulative Impacts in Guatemala 2019-2050	Total Cumulative Impacts 2019-2050	Net Present Value 2019-2050 (Q2018Million)	Cost Effectiveness ($Q2018/tCO_2e$)
DL-2.	Advanced Wastewater Treatment Technologies	-0.061	-0.06	-0.16	-0.16	-2.57	-2.6	Q11	Q4.2
Waste Management Sector Total		**-0.50**	**-4.4**	**-1.5**	**-12**	**-23**	**-186**	**-Q8,616**	**-Q46**
Total integrated results for GLEDS plan		**-62**	**-69**	**-120**	**-138**	**-2,454**	**-2,732**	**-Q41,166**	**-Q17**
Although cost estimates are provided to the nearest Q, they should not be understood to be precise to more than 2 significant digits. For example, the NPV of the GLEDS Plan should be understood to be about -41 billion Quetzales (approximately US$5.39 billion). US$1.00 = Q. 7.60									

Figure VII.C-1. 2019-2050 Cumulative GHG Marginal Abatement Cost Curve

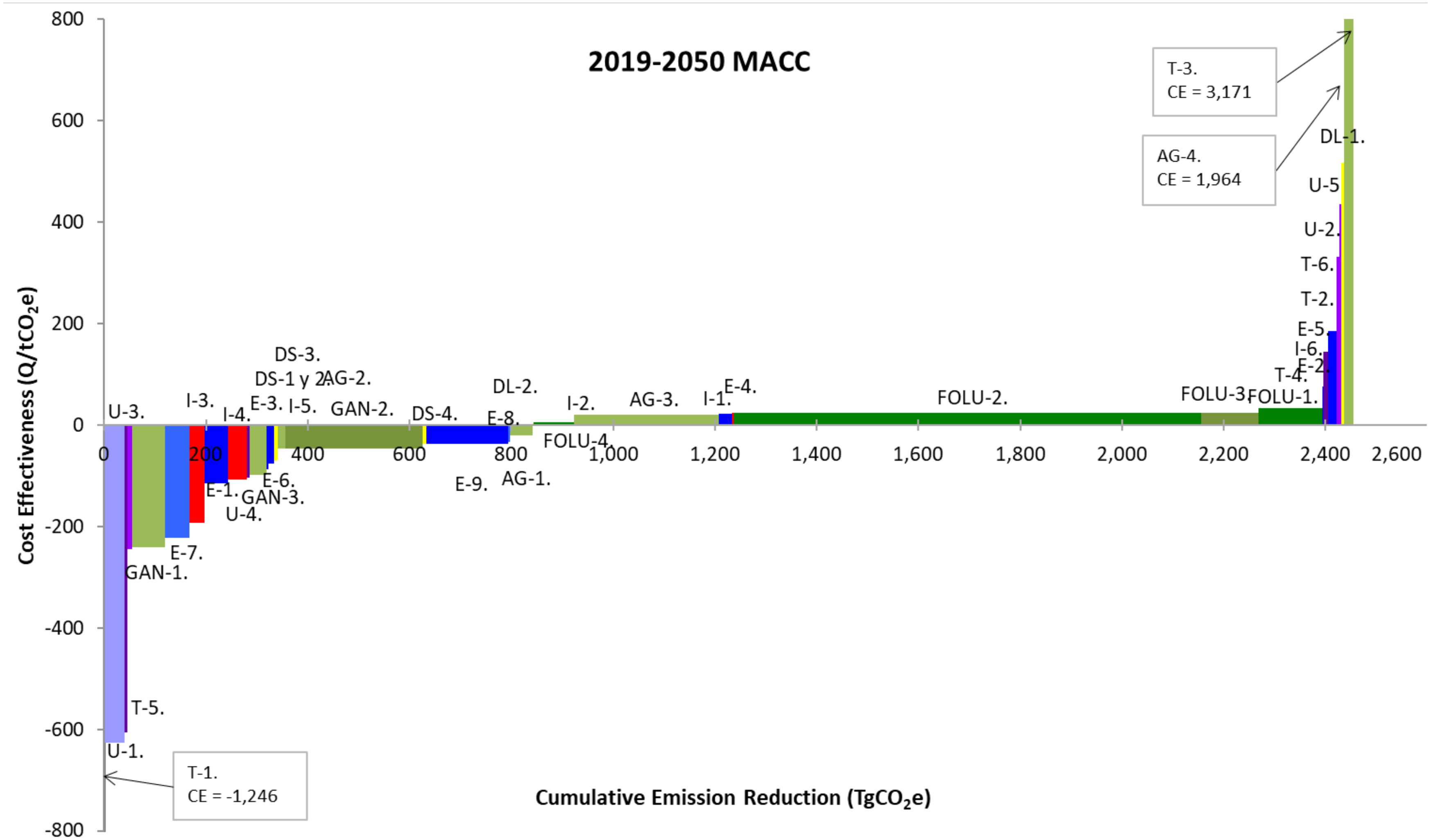
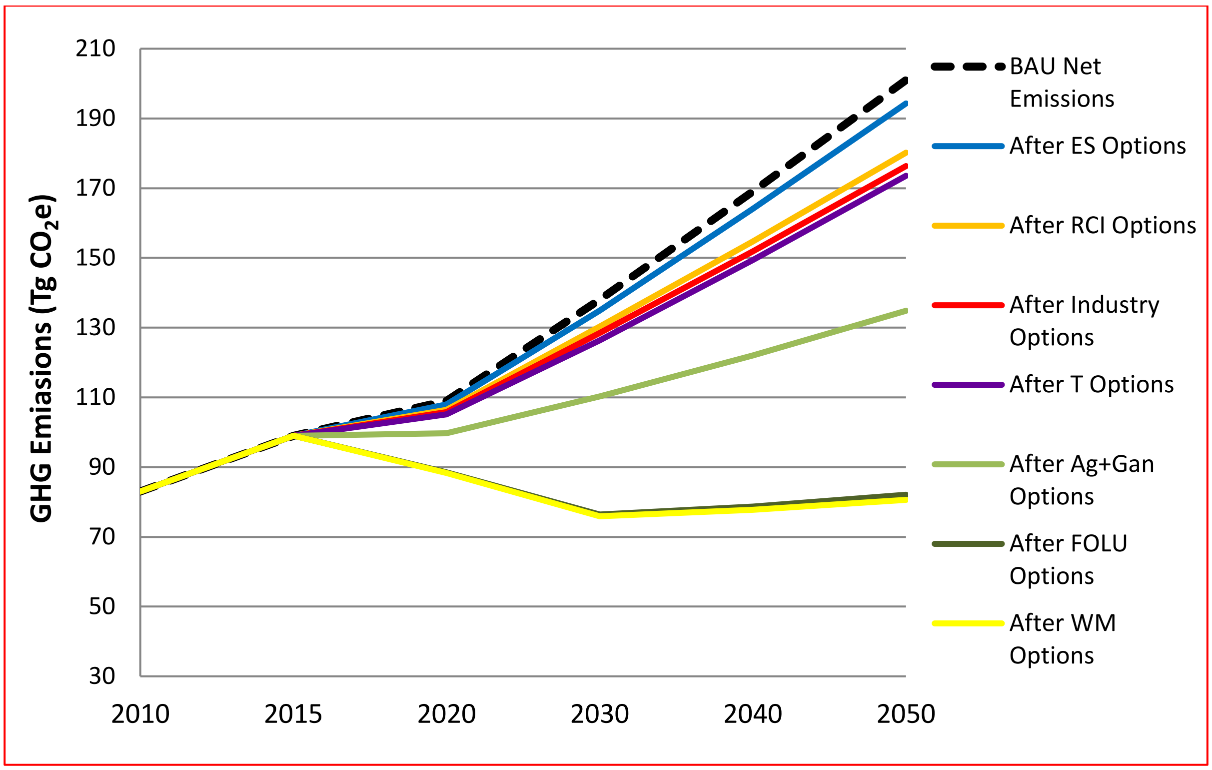


Figure VII.C-1 above shows the MACC for 2019-2050 cumulative emission reductions. The GLEDS options are ordered from lowest to highest cost effectiveness and the bars show cost effectiveness (2018Q/tCO_2e) versus cumulative emission reduction (TgCO_2e). The bars are colored to match the color scheme shown in Table VII.C-1. Taller bars indicate very high or very low cost effectiveness, wider bars indicate larger emission impact over the forecast period. Some bars (T-1, T-3, and AG-4) are too tall to fully show at this scale, so the CE is shown in the corresponding boxes. Some bars may be too thin to see at this scale (e.g. T-1).

Figure VII.C-2 below shows **the expected GHG impacts against baseline for the GLEDS Plan.** Each line underneath the BAU net GHG emissions line indicates the emissions remaining after implementing all options within a specified sector. The reductions from Energy Supply (ES) are subtracted first, followed by those from the Residential/Commercial/Institutional (RCI) sector, and so on. The yellow line at the bottom indicates remaining emissions after implementation of Waste Management (WM) sector options, in addition to all other sectors. Clearly indicated here are the size of the emission reductions achieved with the sets of options from agriculture and FOLU. After 2030, continued population and economic growth will still result in some continued growth in emissions; however, at a much reduced rate. In addition, many of the GLEDS options were designed with implementation schedules that achieve full implementation in the 2030 to 2035 time-frame. Finally, after 2030, GLEDS options are expected to have shifted power generation to cleaner sources, so options that reduce electricity demand will have more muted impacts later in the planning period.

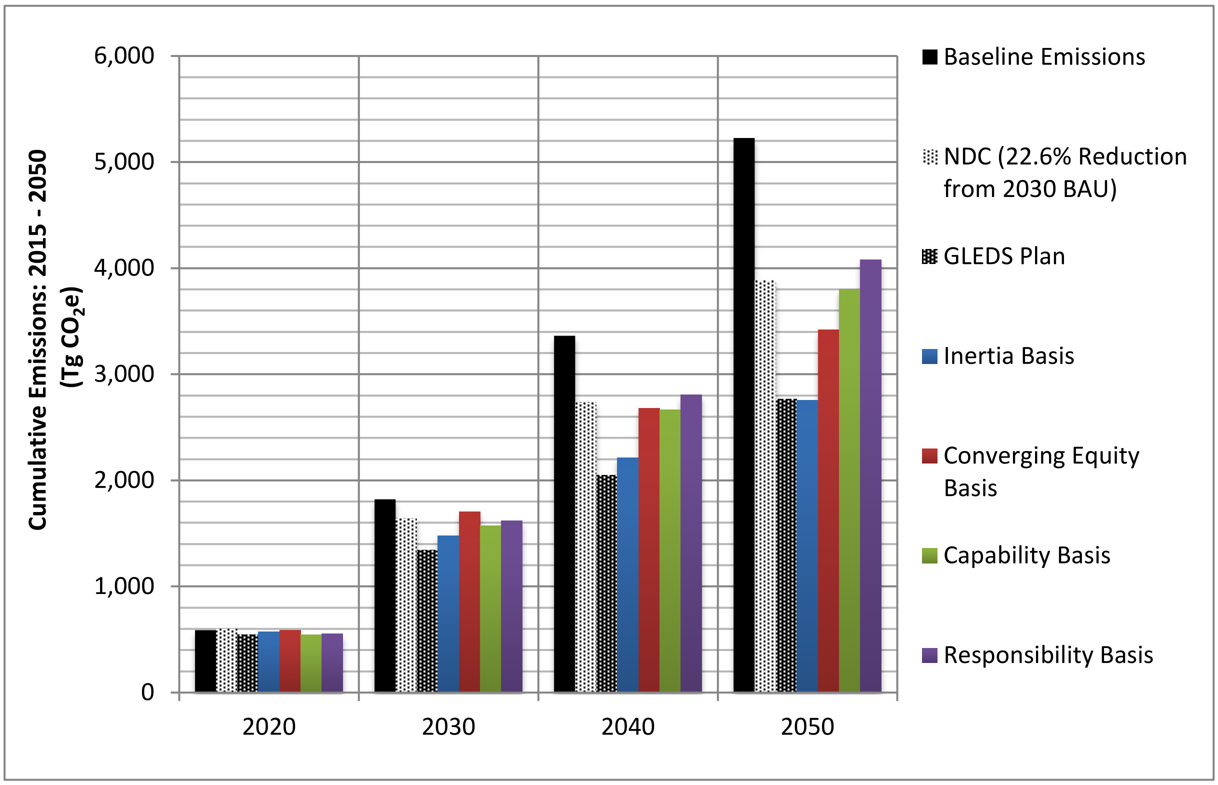
Figure VII.C-2 Expected GHG Reductions from Implementation of GLEDS Options



Cumulative GHG emissions through 2050 within the country are a key metric for use in assessing Guatemala's contribution to global GHG reduction requirements. As shown at the bottom of Table VII.C-1, through implementation of the GLEDS Plan, cumulative in-country reductions are expected to total 2,451 TgCO_2e.

Figure VII.C-3 below is a revised version of the chart previously shown in the Baseline chapter that indicates the possible GHG budgets for Guatemala as part of a global effort to maintain atmospheric GHGs within safe levels (cumulative emissions allowed through 2050). These budgets are compared to estimates based on the country's existing NDC target and the results of the GLEDS Plan. As shown in this chart, **the GLEDS Plan cumulative in-country emissions meet the converging equity, capability, and responsibility basis budgets, and are only slightly above the inertia basis budget in 2050 (2,775 TgCO_2e vs. 2,755 TgCO_2e).** See the GLEDS Baseline Report (Appendix B) for more information on the estimation of these budgets for Guatemala.

Figure VII.C-3. Inferred Guatemala GHG Budget Allocation for 2 Degrees C Warming and Comparison to NDC and GLEDS Plan Emissions



D. MACROECONOMIC PERFORMANCE

Based on the results of all 43 macroeconomic indicator assessments of individual options, as shown in the individual sections of chapter VI relating to each sector, certain net effects over the entire collection of GLEDS options are appropriate to point out:

- ***Overall savings exceeds implementation cost.*** The entire collection of 43 options, when all of the financial flows are summed, **are projected to produce approximately Q500 billion (US$66 billion) more in savings and in new productivity than in option implementation costs.** This is measured cumulatively, over the entire 2019-2050 period, and represents an average net savings to the economy of nearly Q16 billion per year (US$2.1 billion). **This indicates that while the implementation of these 43 options requires a range of up-front investment and other costs, the potential return on those**

investments is significantly larger than the set of costs involved. When discounted to present value (an adjustment to reflect the reduced value of savings or costs that happen far in the future), the net savings over the 2019-2050 period is equivalent to a net savings of over Q78 billion in 2018Q (US$10.3 billion). The indirect effect of these savings is to free up scarce capital for reinvestment and macroeconomic expansion.

This overall result occurs despite significant diversity of individual results from the GLEDS options, however. In fact, of the 43 options, **25 are projected to yield a mix of savings and productivity that are larger than their implementation cost. The other 18 options have a net cost that is positive, meaning that the implementation costs are not fully covered by savings or new productivity.** Options focusing on energy efficiency, solid waste, and agriculture were all or mostly able to show a net savings, while those covering forestry, liquid waste, and transit expansion consistently struggled to recover savings or productivity sufficient to offset their implementation costs. That said, **these options are expected to produce other macroeconomic benefits that are not addressed by the methodology applied.** For example, expansion of forest cover via a combination of forest conservation and reforestation will also provide other ecosystem benefits (e.g. cleaner water, reduced erosion, wildlife habitat). Transit expansion would result in fewer vehicles on the road and improvements to air quality. These ecosystem and other indirect benefits were not monetized and incorporated into the micro- or macro-analyses. Following these, additional benefits, such as any boosts to tourism associated with greater biodiversity or reduced health impacts were also not included.

- *GLEDS options drive significant reduction in fuel consumption and spending***.** The 43 GLEDS options concentrate, in their design, on not only shifting to cleaner energy sources but also reducing overall demand for energy. The individual analyses identify, as a result**, a net energy-spending reduction of just over Q325 billion (US$42.8 billion) in cumulative value over the 2019-2050 period.** This amounts to a net savings on energy costs of nearly Q10 billion (US$1.3 billion) per year. **This represents significant money freed up for other uses by energy consumers (including households, businesses and the government) in the Guatemalan economy. Given that a significant portion of primary energy consumed is derived from imported fossil fuels (either raw or refined), this also reflects a significant easing of a negative pressure on Guatemala's balance of imports and exports.** Based on the analysis cited above, there is a statistically significant relationship between a reduction in spending on energy and projections of GDP growth as a result of implementation. **The indirect effect of these savings is also to free up scarce capital for reinvestment and macroeconomic expansion.**

- *GLEDS options also drive significant shifts to locally produced transportation fuels.* Driven primarily by the blending of locally produced ethanol into the gasoline supply used by vehicles in Guatemala, and to a smaller extent by expansion of the electric-vehicle fleet and supporting infrastructure to allow charging, **the options are projected to shift nearly Q58 billion (US$7.6 billion) in cumulative spending in energy consumption from imported petroleum fuels to locally generated ethanol and electricity.**

- *GLEDS options entail significant overall reduction in imports.* Taken together, the 43 GLEDS options generate a significant reduction in imports. Driven primarily by reductions in demand for the imported fossil fuels needed to power conventional electricity generation, **the GLEDS options are projected to reduce total net imports by approximately Q40-60 billion (US$5.3 – 7.9 billion) over the 2019-2050 period. This is despite a significant (over Q400 billion; US$52.6 billion) increase in spending on imported machinery,**

equipment, new vehicles and other specialized inputs – as well as the financing associated with their purchase – projected as part of the investment needed to implement the set of GLEDS options.

This picture of significant new imports in some areas offset by even larger import reductions in other areas is reflected in the diversity of performance of individual options against this metric. Of the 43 options, **only 26 are identified as affecting net imports and exports.** Of that group, half (13, led by the energy-efficiency options) produce net reductions in imports, while the rest (the other 13, led by the industry sector) produce net increases in imports. **The indirect effect of this shift is also expansion of national economic activity**.

- *Implementation of GLEDS options projected to increase levels of labor-intense activity.* Almost all of the GLEDS options anticipate some of their associated implementation costs to come in the form of expanded oversight, management, maintenance or implementation. **These labor-intensive activities are associated with economy-wide increases in total employment – reflecting both the direct hiring to carry out these activities and the expansion of the job market that results as this new household income is spent on goods and services.**

  In keeping with the overall effect, the individual options are consistently positive with regard to stimulating labor-intensive activity. Of the 43 GLEDS options presented, **39 are projected to include spending on labor-intensive activities while three are expected to reduce such activities below their baseline. Only one option did not have this factor associated with any of its spending or savings impacts. In all, private-sector and public-sector spending on labor-intense activity is projected to grow by a combined Q238 billion (US$31.3 billion) in nominal value over the 2019-2050 period**, with the only projected reductions being in conventional waste management practices (due to collection efficiency and waste-reduction efforts) and auto repair and maintenance (due to reduced driving due to transit expansions). **The indirect effect of this shift is expansion of national employment.**

- *Around half of all options stimulate local sectors; about 20% risk reducing local-sector activity*. **Overall, the 43 GLEDS options provide a net stimulus to local sectors and supply chains within the Guatemalan economy. The most common target of stimulus is the construction sector, as building of new infrastructure or buildings** is projected to result from implementation of the options. **This gain, however, comes from only 21 options, while eight others actually anticipate reductions to local supply chains.** For these eight, the most common target is the conventional utility sector, as conventional energy generation and the activities that support it are expected to carry out less activity as a result of either shifts to renewables, efficiency gains, or other goals. **Fourteen options did not appear to affect local businesses with domestic supply chains – at least not directly. The indirect effect of this shift is expansion of national economic activity.**

Overall, encouraging indications of potential for economic growth are estimated as result of the GLEDS Plan implementation. The complete set of GLEDS options offer significant basis for optimism about the capacity of low-emissions option to stimulate, rather than suppress, economic activity in Guatemala. **Many options offer savings or productivity returns greater than their cost of implementation, as does the entire collection of options when considered together.** The options also expend significant money on labor-intense activities, which is associated with economy-wide job growth, while also reducing net imports (particularly imports of fossil fuels), increasing adoption of advanced technologies, and driving activity to key local sectors.

Not all options offer the same profile, however. Some struggle to return benefits equal to their implementation cost or show cause for concern with respect to their requirement for imports or their dislocation of existing local activity. That said, however, not a single option was entirely negative – all options showed some positive characteristics. **The identification of causes for concern should guide policymakers to address these issues as they further refine the design of each option for optimal environmental and economic impact.**

E. OTHER GLEDS PLAN BENEFITS

A thorough assessment of other benefits or dis-benefits that could be associated with GLEDS options implementation was beyond the resources allocated to the project. Certainly, many ties to other important development issues could be identified. For example, the transformation of Guatemala's electricity system that would result from the implementation of options increasing renewable power production and electrical energy efficiency could be profound. Such a transformation would not only result in reduced GHG emissions and imports of fossil fuels but would also reduce the amount of generation required from hydroelectric plants. The water not needed to produce power could be conserved for other purposes (alternatively, this amount of water would not be needed during future drought years). Air quality improvements are also expected as a result of displacement of fossil-based generation from coal-, oil-, and natural gas-powered plants. Biological diversity would be conserved as a result of lower pressures to convert land from forest or other natural cover to cropland or pasture, and from lower fuelwood harvest levels. All of these benefits would be valuable to further explore in any ongoing work resulting from this Plan.

APPENDIX A. LIST OF LEDS PROCESS PARTICIPANTS

APPENDIX B. GLEDS BASELINE REPORT

APPENDIX C. GLEDS QUANTIFICATION MEMORANDUM AND ELECTRICITY SUPPLY-DEMAND INTEGRATION METHODOLOGY

APPENDIX D. ENERGY SUPPLY AND DEMAND OPTIONS

APPENDIX E. INDUSTRY OPTIONS

APPENDIX F. TRANSPORTATION OPTIONS

APPENDIX G. AGRICULTURE & LIVESTOCK MANAGEMENT OPTIONS

APPENDIX H. FORESTRY & OTHER LAND USE OPTIONS

APPENDIX I. WASTE MANAGEMENT OPTIONS