Initiative for Climate Action Transparency

Building National Mitigation Scenario Modelling Capabilities

Antigua & Barbuda Project

Mitigation Scenario Report

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PREPARED UNDER

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ACRONYMS

AFOLU	Agriculture, Forestry & Other Land Use
CA	Climate Analytics
CCMRVH	Caribbean Cooperative Measurement, Reporting and Verification Hub
CO2	Carbon Dioxide
EV	Electric Vehicle
GACMO	The Greenhouse Gas Abatement Cost Model
GDP	Gross Domestic Product
GHG	Greenhouse gas
GWh	Gigawatt Hour
GWP	Global Warming Potential
ICAT	Initiative for Climate Action Transparency
ICE	Internal Combustion Engine
IMF	International Monetary Fund
kJ	Kilojoules
ktCO2eq	Kilotonnes carbon dioxide equivalent (Unit)
kW	Kilowatts (Unit of Energy)
kWh	Kilowatt Hour
LEAP	The Low Emissions Analysis Platform
LPG	Liquefied Petroleum Gas
MRV	Measurement, Reporting and Verification
MW	Megawatts (Unit of Energy)
NDC	Nationally Determined Contribution
NAP	National Adaptation Plan
NEP	National Energy Policy
OLADE	The Latin American Energy Organization
QA	Quality Assurance
QC	Quality Control
RE	Renewable Energy
SNC	Second National Communication
SPPARE	Sustainable Pathways-Protected Areas and Renewable Energy

1 Introduction

Antigua and Barbuda is a sovereign Small Island Developing State (SIDS) in the Eastern Caribbean. The island is committed to implementing measures to grow its economy in a low carbon and sustainable manner. To assist in achieving this, the country is participating in the Initiative for Climate Action Transparency (ICAT) project.

The Initiative for Climate Action Transparency (ICAT) aims to help countries better assess the impacts of their climate policies and actions and fulfil their transparency commitments. This is executed by increasing the overall transparency capacities of countries, including the capacity to assess the contribution of climate policies and actions on countries' development objectives, and providing appropriate methodological information and tools to support evidence-based policymaking. ICAT capacity development efforts are established to reinforce existing climate measurement, reporting and verification (MRV) systems and knowledge within countries and complement previous or ongoing activities by other initiatives.

The focus of the Antigua and Barbuda ICAT project is to establish a sustainable national economy wide GHG emission projection and mitigation analysis modelling capability. To achieve this focus, in addition to executing introductory and advanced training workshops on mitigation assessment and modelling tools, the project also involved the following:

- Development of a modelling framework and selection of an appropriate modelling tool for Antigua and Barbuda mitigation assessment. The process of this selection was highlighted in the mitigation analysis project output scope report.
- Development of a baseline scenario report to reflect the analysis of available historical data and updated information from the climate analytics LEAP model. This was done for the key assumptions, demand, and transformation sections of the model. In addition, the baseline scenario report also highlighted the business-as-usual scenario projections in the absence of new mitigation policies and actions, incorporating existing actions and policies where applicable.

The next immediate activity is the formulation and documentation of the mitigation scenario, and these are addressed in this report. Some of the major aspects presented are:

- General identified policies and actions
- Policies and actions implemented in the model individual scenarios
- Overall policy scenarios (based on the combination of individual scenarios).

Also included are model updates and preliminary results using both LEAP and GACMO. These are all presented via the following sections:

Section 2 – General updates to the baseline specification report;
Section 3 – General Overview of the Mitigation Scenarios;
Section 4 – Methodology;
Section 5 – Assumptions used in the Mitigation Scenarios;

Section 6 – Preliminary Results;
Section 7 – Specific Data/Assumptions to be Validated;
Section 8 – Suggestions for Improvements; and
Section 9 – Conclusions.

2 General Updates Compared with the Baseline Specification Report

The baseline specification report for the project was submitted in June 2021. In that report, the key assumptions, parameters, and data used to formulate the historical and business as usual projection scenarios were presented. While many of these remain the same, the mitigation scenario preparation benefitted from more detailed analysis and internal QA/QC checks. Owing to these, some of the assumptions, parameters and data have been updated. The major updates are outlined in the list below with respect to specification parameters used within the LEAP modelling framework. It is important to note that these and other assumptions can all be further improved and validated in the future when more data become available.

- The GDP growth rate of 3.9% for 2025 was assumed to remain constant up to 2050 (in the absence of more data). This was previously stated as 1.6% in the baseline specification report. This economic growth assumption can be improved in the future when more related credible information and studies become available. The assumption should also be more deeply informed by climate change impact projections in conjunction with Antigua and Barbuda's National Adaptation Plan (NAP). The updated demographic and economic data can be found in Annex 1.
- In the baseline specification report, it was stated that fuel demand data during the historical period were taken from OLADE's energy balances. However, it was subsequently noticed during the formulation of the mitigation scenarios that for electricity, the OLADE's production data did not correlate well with data from the power plants in Antigua and Barbuda. Owing to this, the OLADE energy balance was used for all fuels but electricity. Electricity data from the United Nations was used as these corresponded well to that of the power plants. The updated demand data can be found in Annex 2 and the associated United Nations data is presented in Annex 3.
- The degree of penetration of some technologies (in both the historical period and baseline projection) was adjusted **based on expert judgement after consultations with the National Coordination Team** after considering the latest census results and their knowledge of Antigua and Barbuda. These adjustments include:
    - firewood cooking in the household sector was changed from 100% saturation[1] to 15% saturation (static in the baseline);
    - charcoal cooking in the household sector was changed from 100% saturation to 15% saturation (static in the baseline);
    - electric cooking in the household sector was changed from 100% saturation to 5% saturation (static in the baseline);
    - LPG water heaters were added to the household sectors with a percentage share of 35% (with solar and electric being adjusted to 30% and 25%, respectively);

[1] Saturation refers to the percentage of households using that particular technology with access to other similar technologies

- LPG water heaters were added to the commercial sectors with a percentage share of 40% (with solar and electric being adjusted to 25% and 35%, respectively); and
- cooking penetrations were adjusted in the commercial sector to include the following technologies (LPG 60%, electricity 30%, and wood 10%).

These are all reflected in Annex 4.

➢ During the preparation of the baseline specification report, as various energy intensity values for different demand technologies were not available for Antigua and Barbuda, these were assumed from previous work in the region (Heaps 2021). These values remain unavailable but are now calculated for Antigua and Barbuda based on the consumption data from OLADE and the United Nations. All the new energy intensities are presented in Annex 5 (residential) and Annex 6 (commercial).

3 Overview of Mitigation Scenarios

The mitigation actions provided by the Government of Antigua and Barbuda were created/adapted from various reports and projects. Some of these include:

- Antigua & Barbuda Nationally Determined Contribution (NDC) 2015,
- Antigua & Barbuda revised NDC 2021,
- The Sustainable Pathways – Protected Areas and Renewable Energy (SPPARE) project,
- The Second National Communication (SNC),
- The third National Communications (TNC),
- The electric school bus project,
- The Sustainable Low-emission Island Mobility Project (SLIM),
- Grid-Interactive Solar PV Systems for Schools and Clinics (GISS),
- The 2015 Biennial Update Report (BUR), and
- The National Energy Policy (NEP).

These highlighted various mitigation actions for Antigua and Barbuda (either in progress or planned) and were mainly based on the development of the updated NDCs. Thirty (30) actions were compiled, and these were separated into two main categories (Appendix 1):

1. Actions ready for inclusion in the modelling mitigation scenarios; and
2. Actions that could not be modelled within the available software tools, either due to their construction or significant lack of data. These actions will likely require more precise specifications are to guide future work and model improvement.

This mitigation scenario report focuses on those actions in category 1 above, which are categorized by sectors, proposed implementation parameters, and completion years (2020-2035), as can be seen in the immediate section below. The full list of mitigation actions can be found in Appendix 1: Table 24.

3.1 Mitigation Actions Considered for Modelling: Energy Sector

Most of the mitigation actions ready for inclusion in the modelling mitigation scenarios were from the energy sector. These actions were divided into three sub-division: energy efficiency, renewable energy, and transport. The energy efficiency subcategory relates to affected changes in the end-use of electricity. This includes changes in equipment used for cooling, lighting, refrigeration, and appliance use. The renewable energy subcategory relates to the supply of electricity from renewable sources both centralised and distributed generation that are connected to the electricity grid. The transport sector relates to energy use in road transport; domestic marine and aviation modes are not considered in these actions.

3.1.1 Energy Efficient Appliances and Lighting

The energy efficiency mitigation strategies or actions for Antigua and Barbuda included in the modelling scenarios are:

- Establish efficiency standards for the importation of all appliances in 2020;
- Adoption of 100% energy-efficient fixtures and appliances in government buildings;
- Replacement of all sodium street lights with LED lighting by 2025; and
- Updating and legislation of building codes in line with a climate-resilient development pathway by 2025,

3.1.2 Renewable Energy Implementation

As demonstrated in the revised NDCs, there appears to be a keen focus on renewable energy generation plans for Antigua and Barbuda, with a desire to achieve an overall 86% renewable energy generation by the year 2030. The overall renewable energy generation national target is supported by the following mitigation actions as shown below:

- 4.125 MW of capacity additions from wind turbines,
- A new modular hybrid power plant with both solar (720kW) and diesel engine (660kW) capacities;
- 100 MW of grid-connected renewable energy generation capacity available;
- 50 MW of grid-connected renewable energy generation capacity owned by farmers;
- 100 MW of new renewable energy generation capacity owned by social investment entities;
- 20 MW of wind-powered energy generation; and
- 100% renewable energy generation for all government operations.

3.1.3 Transport

The main mitigation strategy within the transportation subsector is the ban on the importation of new internal combustion engine vehicles from the year 2028. To accomplish this action, 100% of government vehicles will be expected to be electrified by 2035. In addition, to aid with the GHG emission reduction in this subsector, one mitigation action is the implantation of efficiency standards for fossil fuel vehicle importation by 2021

3.2 Mitigation Actions considered for modelling: Agriculture, Forestry, & Other Land Use (AFOLU)

Within the AFOLU sector, the focus is placed on expanding the capacity for carbon sequestration using natural resources. The two main mechanisms to achieve this include the management and protection of natural resources and reforestation. Due to the lack of inventory data on wetlands, only the reforestation action is considered in the modelling.

3.2.1 Reforestation

Antigua & Barbuda aim to plant 20,000 trees to restore degraded land and increase carbon sequestration. This project is currently ongoing.

3.3 Mitigation Scenarios not Modelled: Energy, AFOLU & Finance Sectors

Several proposed mitigation actions could not be modelled due to the manner in which they have been specified by the government of Antigua and Barbuda or because they required input data that is not currently available. Within the energy sector, such actions included the enhancement of the established sustainable development framework, removal of the fuel surcharge tax on electricity bills, completion of the technical analysis assessing the construction of a waste to energy plant, and the inclusion of back-up and own grid RE systems along with necessary storage infrastructure.

Within the AFOLU sector, one action was excluded (due to data inadequacy). This was the protection of all the remaining wetlands, watersheds, and seagrass bed areas that have carbon sequestration potential. This action is planned for 2030 and can be incorporated into future versions of the models.

Some actions such as waterways protection and biodiversity were excluded, as they are more adaptation oriented.

Two proposed actions within the finance sector were also not modelled. These were:

- The establishment of technical and other support to de-risk GHG reduction investments by Micro, Small and Medium-Sized Enterprises (MSMEs) in Antigua & Barbuda by 2030; and
- A 50% increase in the number of MSMEs that provide energy services aligned with the Paris Agreement Objectives by 2030.

Though these actions are noteworthy, they require further data and expert assumptions for modelling.

The full list of actions considered for modelling can be found in Appendix 1: ***Table 24*** and the list of actions not modelled with explanations can be found in Appendix 2: ***Table 25***.

4 Methodological Approach to the Mitigation Scenarios

In consultation with the ICAT in-country National Coordinating Team and the Department of Environment of Antigua and Barbuda, a list of mitigation actions and policies were elaborated. A scenario design workshop was conducted to provide key stakeholders with an opportunity to provide much-needed input into the elaboration and parameterization of Antigua and Barbuda's mitigation policies, actions, and associated mitigation scenarios to complement the proposed government-approved NDC. As a result of this workshop, a list of thirty (30) mitigation actions and policies were proposed for Antigua and Barbuda as highlighted in ***Section 3***.

These thirty mitigation actions were then assessed by the National Coordinating Team and the CCMRVH consultants for mitigation modelling suitability based on data availability and applicability to the selected modelling tools. Ultimately, sixteen (16) mitigation actions were modelled under five (5) categories to quantify the impacts of Antigua and Barbuda's mitigation strategy using both the LEAP and GACMO modelling tools. The remaining fourteen (14) mitigation actions were deemed to have insufficient data to be modelled or they were considered to be closer related to adaptation measures with very limited mitigation potential (as outlined in ***Section 3***).

The Antigua and Barbuda LEAP model in this project build on the previous modelling work associated with the development and updating of the country's NDCs. Many of these updates were outlined in the baseline scenario report and included the addition of the non-energy sector emissions from the 2006 and the 2015 GHG inventory, as well as the addition of historical data from the OLADE 2010-2012 Energy Balance and United Nations database. In addition, the LEAP model was updated with the most recent economic, demographic, and other energy statistics and, to the extent possible, developed to capture the economic and GHG impact of COVID-19.

Forward-looking scenarios were created for all sectors based on the mitigation actions and policies from 2020 to 2030 and 2050 to project GHG emissions over these time frames. The modelled emissions were brought into close alignment with the most recent GHG inventory. Historical emissions and energy demand closely match the official energy statistics and GHG inventories, this indicates that the model is well aligned with Antigua and Barbuda national circumstances.

The forward-looking scenarios developed through this project are intended to assess the impacts of the following:

- A baseline scenario that shows emissions based on currently implemented policies and strategies in Antigua and Barbuda. This illustrates the emissions of Antigua and Barbuda assuming no changes from current policy implementation and considering the demographic and macroeconomic trends. See baseline specification report and ***Section 2*** general updates to this report.
- The sixteen (16) mitigation strategies/actions identified for the modelling were split into five categories and modelled by individual actions and groups. The mitigation scenarios explore the implementation of the different actions, policies, and strategies identified in the various sectors. The macroeconomic and baseline trends were assumed to be the same as the baseline in the mitigation scenarios.
- Combination of scenarios showing the overall mitigation impact of the mitigation strategies modelled in the different categories and overall.

Similarly, to the LEAP model, a GACMO model was developed for Antigua and Barbuda. For GACMO two model versions were developed:

- One using the GHG inventory of 2015 and the OLADE Energy Balance of 2010-2012,
- The other using the updated energy balance of 2019 from LEAP and 2015 inventory data.

To ensure compatibility with the LEAP and GACMO models, the growth trends from the baseline of the LEAP model were used in the GACMO model. The percentage increase was estimated for 2020, 2020-2025, 2025-2030, and 2030-2050 for each relevant sector, subsector, population, and GDP. Future–looking baseline balances were then calculated via the model for the years 2020, 2025, 2030 and 2050. The assumptions for the model were inputted and are described in ***Section 5.2*** below. For GACMO the mitigation options are available within the model. Therefore, the sixteen mitigation actions and policies selected for Antigua and Barbuda were compared with the default mitigation options in the model and the most appropriate default mitigation options utilized in the model for conducting analysis.

5 Assumptions

5.1 Detailed Information on Assumptions in Mitigation Scenarios for LEAP

Information on the assumptions used in the LEAP model to elaborate the mitigation actions and scenarios are described below. For all emission calculations, 2006 IPCC Tier 1 emission factors were used corresponding to the emission factors used for the 2015 inventory for Antigua and Barbuda.

5.1.1 Modelled Action 1: Energy Efficient Equipment

Mitigation Actions modelled:

- Establish efficiency standards for the importation of all appliances by 2020;
- Updating and legislation of building codes in line with a climate-resilient development pathway by 2025, and
- 100% of fixtures and appliances in government buildings will be energy efficient by 2030.

It was assumed that the efficiency standards for both the commercial and residential sectors will be developed specifically for lighting, air-conditioning systems, refrigeration, and other appliances with these measures being grouped for general improvements in energy efficiency. Water heaters are not considered as an appliance in this scenario but are considered for general improvements in the baseline scenario. For the action related to government buildings, since no data was obtained separately, the government buildings were considered as part of the commercial buildings. Though the baseline projections considered some energy efficiency improvements for appliances, for this mitigation scenario further additional improvements were considered. It is assumed that due to the establishment of efficiency standards, an occurrence of a higher uptake/ownership of energy-efficient equipment in the residential and commercial sectors would take place. To estimate the impact of these actions on GHG emissions, assumptions were made about the technical characteristics and uptake rates of more energy-efficient equipment in the future.

Modelled scenario 1.1: Energy Efficient Lighting Equipment

For lighting equipment is it assumed that improvements are made by moving from fluorescent lights to LEDs with an estimated 50% efficiency improvement. If the energy efficiency standards are in place by 2022, it is assumed that a period of 5 years will be needed until full implementation and adoption occur. ***Table 1*** shows the detailed assumptions in the model. The ownership rate for lighting for the residential and commercial sector is assumed to be 100% indicating that all residential and commercial buildings contain some form of lighting equipment. The energy intensity is the amount of energy used to produce lighting output, for the residential sector, this is given per household and for the commercial sector per

GDP measured in eastern Caribbean dollars. It is assumed that the energy intensity is reduced by 50% using more energy-efficient lighting equipment which is labelled as efficiency improvements. The penetration of efficient equipment shows what percentage of residential or commercial buildings are expected to have more energy-efficient lighting equipment and by what year it is assumed to be achieved in the modelling scenarios.

Table 1: Assumptions for Energy Efficient Lighting Equipment

Residential Sector				
Ownership rate	**Current Energy Intensity (kWh/household)**	**Efficiency Improvement**	**Penetration of Efficient Equipment**	
			Baseline scenario	**Mitigation scenario**
100%	361.4	50%	50% by 2040 and 70% by 2050	100% by 2027
Commercial Sector				
Ownership rate	**Current Energy Intensity (kJ/Eastern Caribbean Dollar)**	**Efficiency Improvement**	**Penetration of Efficient Equipment**	
			Baseline scenario	**Mitigation scenario**
100%	18	50%	60% by 2040 and 80% by 2050	90% by 2030

Modelled scenario 1.2: Energy Efficient Refrigeration Equipment

For refrigeration, it is assumed that more efficient equipment will be gradually used with full replacement by 2040 in the mitigation scenario. Since the lifetime of refrigerators is much longer than lighting, it is assumed that 100% penetration of energy-efficient refrigerators will take a longer time (2040 vs. 2027). ***Table 2*** shows the detailed assumptions in the model. The ownership rate for refrigeration is assumed to be 84% in 2010 based on the census data and the model assumes an increased rate to 91.9% in 2019. This indicates that in 2019, 91.9% of households own refrigeration. The energy intensity is the amount of energy used to produce refrigeration output; this is given per household. It is assumed that the energy intensity is reduced by 30% using more energy-efficient refrigeration equipment which is labelled as efficiency improvements. The penetration of efficient equipment shows what percentage of residential buildings are expected to have more energy-efficient refrigeration equipment and by what year it is assumed to be achieved in the modelling scenarios.

Table 2: Assumptions for Energy Efficient Refrigeration Equipment

Residential Sector				
Ownership rate	**Current Energy Intensity (kWh/household)**	**Efficiency Improvement**	**Penetration of Efficient Equipment**	
			Baseline scenario	**Mitigation scenario**
84% in 2010, 91.9% in 2019,	827	30%	30% by 2030 and 50% by 2050	70% by 2030 and 100% by 2040

Modelled scenario 1.3: Energy Efficient Cooling Equipment

For energy-efficient cooling equipment, it was assumed that efficiency will improve by 15% for both residential and commercial applications in the baseline. The mitigation scenario assumes a higher penetration for commercial buildings due to the combined effect of the building code mitigation action. This mitigation action is assumed to increase the penetration of energy-efficient equipment in the commercial sector resulting in 100% penetration of energy-efficient cooling equipment by 2050. ***Table 3*** shows the detailed assumptions in the model. The ownership rate for cooling is assumed to be 5% in 2010 based on the census data, 10% in 2019, 23.3% in 2030 and 60.8% in 2050 for the residential sector and 100% for the commercial sector. The energy intensity is the amount of energy used to produce cooling output, this is given per household in the residential sector and per GDP in eastern Caribbean dollars in the commercial sector. It is assumed that the energy intensity is reduced by 15% using more energy-efficient refrigeration equipment which is labelled as efficiency improvements. The penetration of efficient equipment shows what percentage of residential and commercial buildings are expected to have more energy-efficient cooling equipment and by what year it is assumed to be achieved in the modelling scenarios.

Table 3: Assumptions for Cooling Equipment

Residential Sector				
Ownership rate	**Current Energy Intensity (kWh/household)**	**Efficiency Improvement**	**Penetration of Efficient Equipment**	
			Baseline scenario	**Mitigation scenario**
9% in 2010	7245	15%	10% by 2030 and 30% by 2050	50% by 2030 and 80% by 2050
20% in 2019,				
26.6% in 2030 and 45.8% in 2050				
Commercial Sector				
			Penetration of Efficient Equipment	

Ownership rate	Current Energy Intensity (kJ/Eastern Caribbean Dollar)	Efficiency Improvement	Baseline scenario	Mitigation scenario
100%	50	15%	15% by 2030 by 35% by 2050	60% by 2030 and 100% by 2050

Modelled scenario 1.4: Energy Efficient of other appliances

For other electric appliances (e.g microwaves, toasters, computers) in both residential and commercial sectors, it was assumed that will be an annual increase in the energy efficiency of appliances of 0.5% in the baseline and 2% in the mitigation scenario. ***Table 4*** shows the detailed assumptions in the model. The energy intensity is the amount of energy used to produce output for other electrical appliances, this is given per household in the residential sector and per GDP in eastern Caribbean dollars in the commercial sector. It is assumed that the energy intensity is reduced by 0.5% annually in the baseline using more energy-efficient equipment and by 2% annually in the mitigation scenarios for both residential and commercial sectors.

Table 4: Assumptions for Other Appliances

Residential Sector		
Current Energy Intensity (kWh/household)	**Efficiency Improvements**	
	Baseline scenario	**Mitigation scenario**
1029	0.5% annually	2% annually
Commercial Sector		
Current Energy Intensity (kJ/Eastern Caribbean Dollar)	**Efficiency Improvements**	
	Baseline scenario	**Mitigation scenario**
66	0.5% annually	2% annually

Modelled scenario 1.5: Energy Efficient Equipment

This scenario is a combination of all the scenarios for 'Modelled Action 1' discussed in this section. The effects are combined in this scenario to give the overall reduction in emissions and demand from the energy-efficient equipment action.

5.1.2 Modelled Action 2: Streetlighting Retrofits

Mitigation Action: 100% Sodium Street lights replaced by LED lighting by 2021

Modelled scenario 2.1: Streetlighting Retrofits

This mitigation action assumes all street lighting will be replaced by 2021 and only LED lights will be installed from 2021 onward. ***Table 5*** shows detailed assumptions for the model. The number of streetlights is assumed to be 13,612 in 2019 and is expected to increase with the number of households. The current technology assumes that all streetlights are 150W sodium bulbs and the more efficient technology is 50W LED bulbs. This indicates that the overall improvement in efficiency is 67%. The percentage replacement indicates the percentage of bulbs that are replaced with the more efficient technology in the scenarios. This mitigation action was revised after data was provided which confirmed that all the streetlights are LEDs. Therefore, the action was placed in the baseline and not as a mitigation scenario.

Table 5: Assumptions for Streetlighting Retrofits

Equipment		Streetlights
Number of Streetlights		13,612 in 2019, grows with the increase in households
Current technology		150W Sodium bulbs
Efficient technology		50W LED bulbs (67% improvement)
% Replacement	**Baseline scenario**	0% in 2018, 7% in 2020, 100% in 2021

5.1.3 Modelled Action 3: Renewable Energy Generation

Mitigation Actions:

- 86% renewable energy generation in the electricity sector by 2030;
- 4.125 MW of wind turbines procured and installed by 2021;
- 20 MW of wind-powered energy generation for a new zero GHG emission energy generation technology by 2030;
- modular hybrid power plant installed in Barbuda by 2021;
- 100 MW of renewable energy generation available to the grid by 2030;
- 50 MW of renewable energy generation capacity owned by farmers who can sell electricity to off-takers by 2030;
- 100 MW of renewable energy generation capacity owned by social investment entities by 2030; and
- 100% renewable energy generation for all government operations by 2030.

Modelled scenario 3.1: Wind Power Generation

Mitigation Actions:

- 4.125 MW of wind turbines procured and installed by 2021
- 20MW of wind-powered energy generation for a new zero GHG emission energy generation technology by 2030

These mitigation actions all pertain to wind power generation. It is assumed that the wind power will be installed at its full capacity of 4.125MW in 2021 and 24.125 MW in 2030. ***Table 6*** shows the capacity instalments and years for wind power generation.

Table 6: Wind Power Generation Capacity

Year	Scenario	Wind Generation (MW)
2021	Wind Power	4.125
2030	Wind Power	24.125 (20+4.125)

Modelled scenario 3.2: Solar Power Generation

Mitigation Actions:

- 100 MW of renewable energy available to grid by 2030
- 50 MW of renewable energy generation capacity owned by farmers who can sell electricity to off-takers by 2030
- 100% renewable energy generation for all government operations by 2030
- Building Code updated and passed into law in line with a climate-resilient development pathway including, inter alia, a requirement that all new homes built after 2025 have backup renewable energy generation and storage systems

In this scenario, only solar power generation is considered. It is assumed that 100 MW of renewable energy available to the grid by 2030 represents only utility-scale solar. This scenario is modelled with installed capacity increasing from 2022 until 100 MW is achieved in 2030 and is named *Additional Solar Farms*. The 50 MW of renewable energy generation capacity owned by farmers is considered as distributed generation and will begin in 2022 gradually increasing until 50MW is achieved by 2030. This is modelled under the name *Farmer Distributed Solar*. For 100% renewable energy generation for all government operations by 2030, it is assumed that the government operations consume approximately 20% of the peak demand of 55MW. Therefore, 10MW of solar power installations would be sufficient to cover 100% of their operations. This was modelled under the name *Government Solar*. Since no data was received separately for government operations in Antigua and Barbuda, the assumptions made are expert judgement by the modelling team. In general, it was assumed that due to the newly updated building codes in 2025, the distributed solar generation would grow at 2% annually until 2025, but after 2025 the growth will increase to 5% annually. ***Table 7*** shows the distribution of solar power for 2021, 2025, and 2030.

Table 7: Solar Generation Capacity

Year	Base Year (2019)	2021	2025	2030
Farmer Distributed Solar (MW)	0	0	22.2	50
Government Solar (MW)	0	0	4.4	10
Additional Solar Farms (MW)	0	0	44.4	100
Distributed Solar (MW)	2.5	2.6	2.9	3.5

Modelled scenario 3.3: Barbuda Hybrid Plant

Mitigation Actions:
- Modular hybrid Power Plant installed in Barbuda by 2021 (720kW solar, 660kW diesel)

In this scenario, it is assumed that the modular hybrid plant will be built by 2021 with 720 kW solar and 660 kW of diesel in addition to the 1 MW of diesel currently installed on the island of Barbuda.

Modelled scenario 3.4: Renewable Energy Generation

Mitigation Actions:
- 86% renewable energy generation in the electricity sector
- 100 MW of renewable energy generation capacity owned by social investment entities

This is a combination of all the scenarios for modelled action 3. The effects are combined in this scenario to give the overall renewable energy generation and emission reduction. In this scenario, it is assumed that 100 MW of renewable energy generation owned by social investment entities includes the additional solar farms available to the grid in modelled scenario 3.2 and the 20 MW of wind power in modelled scenario 3.1.

5.1.4 Modelled Action 4: Efficient Transportation

Mitigation Actions:
- Ban on importation of new ICE vehicles by 2028
- 100% of Government vehicles are electric vehicles by 2035
- Establish efficiency requirements for all vehicle importation by 2020

Modelled scenario 4.1: Efficient fuel vehicles

Mitigation Actions:
- Establish efficiency requirements for all vehicle importation by 2020

In this scenario, it is assumed that the established efficiency requirements for all vehicle importation refer to fuel efficiency. In the baseline, it was assumed that the fuel economy of ICE vehicles is unchanged. In the mitigation scenario, it is assumed that the fuel economy of the cars, motorcycles and SUVs vehicles imported beginning in 2022 would have an annual efficiency improvement of 15%. Similarly, a 10% annual improvement is assumed during this period for all other vehicle types.

Modelled scenario 4.2: Electric Transport System

Mitigation Actions:
- Ban on importation of new ICE vehicles by 2028
- 100% of Government vehicles are electric vehicles by 2035

In this scenario, it is assumed that the importation ban on ICE vehicles will take place in 2028, and it will take a further three years for the sale of stock ICE vehicles to cease. It is therefore assumed in the model that all vehicle sales will be electric vehicles by 2031.

Modelled scenario 4.3: Efficient Transportation

This is a combination of all the scenarios for modelled action 4.

5.1.5 Modelled Action 5: Reforestation

Mitigation Actions:

- 20,000 trees planted to restore degraded land and increase CO_2 sequestration by 2021

Reduced Degradation and Reforestation

In this mitigation action, it is assumed that 1,000 trees are planted per hectare to repair degraded land and improve terrestrial sequestration in Antigua and Barbuda. It was assumed that targeted land sequesters carbon at an average rate of 3.67 tCO_2e per hectare (obtained from GACMO model default value) as limited data was provided on the number of hectares and the sequestration rate.

5.2 Detailed Information on Assumptions in Mitigation Scenarios for GACMO

Information on the assumptions used in the GACMO model to prepare the mitigation scenarios are described in this section.

5.2.1 General Assumptions

The following general assumptions in ***TablesTable*** 8 ***– Table*** 11 were used to create the GACMO Model. The actual GACMO model developed for Antigua and Barbuda is provided in Annex 7 and these assumptions are specified in the "assumptions" tab of the model and can be changed as needed. It should be noted that these assumptions were also consistently applied (where applicable) to the LEAP model and were inherited from the GACMO model previously developed for Antigua and Barbuda by Joergen Fenhann of the Danish Technical University for the Introductory Training sessions, except for table 9 which was found from fuel pricing data for Antigua and Barbuda from Global Petrol Prices.

Table 8: Country Settings

Country:	Antigua and Barbuda
Start year (latest inventory):	2012
Currency:	EC
The exchange rate used: 1 US$=	2.7169 per EC
Discount rate =	6.5%

Table 9: Fuel Prices/Heating Values

2020 prices	LPG	Gasoline	Jet Fuel	Diesel Oil	Heavy Fuel Oil	Kerosene
US$/liter	0.65	0.82	0.62	0.99	0.50	0.62
GJ/t	47.3	44.8	44.6	43.3	40.2	44.8

Table 10: Electricity Rates and Grid Emission Factor Information

Electricity		Grid 1	Grid 2
US$/kWh		0.37	NA
	tCO_2/MWh (=kCO_2/kWh)		
Operating margin (OM)		0.8000	
Build Margin (BM)		0.7000	
Combined Margin (CM) Solar & Wind		0.7750	
Combined Margin (CM) Other		0.7500	
Transmission and Distribution Losses (plus Own Use)	20.5%		

Table 11: Emission Factors

kg/GJ	Emission factors	CO_2	CH_4	N_2O
Power plant	Fuel oil	77.4	0.003	0.0006
	Diesel oil	74.1	0.003	0.0006
	Gasoline	69.3	0.003	0.0006
	Jet fuel	71.5	0.003	0.0006
	Kerosene	71.9	0.003	0.0006
	LPG	63.1	0.001	0.0001
Industry	Oil	As above	0.002	0.0006
Residential	Oil	As above	0.010	0.0006

In addition to these, it should be noted that the global warming potentials associated with the second assessment report were used (21 for CH_4 and 310 for N_2O).

5.2.2 Assumptions/Parameters Related to the Development of Mitigation Scenarios in GACMO

The mitigation scenarios for GACMO are embedded in the tool. The mitigation actions developed by Antigua and Barbuda were compared to the mitigation scenarios in the GACMO tool. Although sixteen mitigation actions were considered in the LEAP model, only fourteen actions were considered in the GACMO model (listed below as seven scenarios as some actions are combined into single scenarios). The main reason for this was the embedded mitigation scenarios in GACMO were used rather than creating new scenarios at this time. This can be an area for improvement in the future.

As such, similar to LEAP the improvement in energy efficiency standards were modelled by equipment for lighting, cooling and refrigeration but only for the residential sector. Streetlighting retrofits were modelling similar to LEAP. The renewable energy generation was modelled together to achieve 86% renewable energy by 2030. Only the shift to electrified transport was modelled using stock values from the LEAP model and reforestation was modelled the same in GACMO and LEAP. The resulting seven scenarios modelled were:

- energy-efficient lighting in the household sector;
- energy-efficient refrigeration in the household sector;
- energy-efficient cooling in the household sector;
- street lighting retrofits (energy-efficient street lighting);
- renewable energy generation in the power generation sector;
- electrified transportation; and
- reforestation.

5.2.2.1 *Energy Efficient Lighting in the Household Sector*

Table 12 outlines the parameters associated with energy-efficient lighting in the household sector. The activity data was derived from the LEAP model to ensure consistency. Similarly, the energy intensities for both existing (compact florescent) and efficient (light-emitting diodes) lighting were consistent with that used in LEAP by retaining the following associated assumptions:

- the power rating of CFL – 40W;
- the power rating of LED replacement – 20W;
- number of bulbs per household – 5.5; and
- number of hours per day usage per bulb – 4.5

Table 12: Parameters Used to Model Energy Efficient Lighting in the Household Sector with GACMO

Years	2020	2025	2030	2050
Estimated Number of Households	35,100	36,500	40,300	58,000
Percentage of Household with Lighting	100	100	100	100
Estimated Total Number of Household with Lighting	35,100	36,500	40,300	58,000
Percentage of Efficient LED Bulbs in the BAU	2	14	26	70
Percentage of Efficient LED Bulbs in the Mitigation Scenario	12.5	75.0	100.0	100.0
Number of Efficient LED Bulbs in the BAU Scenario	4,633	28,707	58,072	223,300
Number of Efficient LED Bulbs in the Mitigation Scenario	24,131	150,563	221,650	319,000
Amount of CFLS converted to LEDs (additional LEDs)	19,498	121,855	163,578	95,700

5.2.2.2 *Energy Efficient Refrigeration in the Household Sector*

Table 13 outlines the parameters associated with energy-efficient refrigeration in the Household sector. The activity data were derived from the LEAP model to ensure consistency. Similarly, the energy intensities for both existing and efficient refrigerators were consistent with that used in LEAP by retaining the following associated assumptions:

- the power rating of existing – 200 W;
- power rating efficient replacement – 140 W; and
- number of Refrigerators per Household – 1.

Table 13: Parameters Used to Model Energy Efficient Refrigeration in the Household Sector with GACMO

Years	2020	2025	2030	2050
Estimated Number of Households	35,100	36,500	40,300	58,000
Percentage of Household with Refrigeration	92	95	96	98
Estimated Total Number of Refrigerators	32,397	34,566	38,527	56,840
Percentage of Efficient Refrigerators in the BAU	3	16	30	50
Percentage of Efficient Refrigerators in the Mitigation Scenario	6.4	38.2	70.0	100.0
Number of Efficient Refrigerators in the BAU	875	5,669	11,558	28,420
Number of Efficient Refrigerators in the Mitigation Scenario	2,073	13,204	26,969	56,840
Number of Additional Efficient Refrigerators	1,199	7,535	15,411	28,420

5.2.2.3 Energy Efficient Cooling in the Household Sector

Table 14 outlines the parameters associated with energy-efficient cooling in the Household sector. The activity data was derived from the LEAP model to ensure consistency. Similarly, the energy intensities for both existing and efficient cooling were consistent with that used in LEAP by retaining the following associated assumptions:

- the power rating of existing – 0.94 kW;
- power rating efficient replacement – 0.8 kW; and
- number of Units per household – 3.

Table 14: Parameters Used to Model Energy Efficient Cooling in the Household Sector with GACMO

Years	2020	2025	2030	2050
Estimated Number of Households	35,100	36,500	40,300	58,000
Percentage of Household with Cooling	22	16	53	100
Estimated Total Number of AC Units	23,061	17,411	64,198	174,000
Percentage of Households with Efficient Cooling in the BAU	1	6	10	30
Percentage of Households with Efficient Cooling in the Mitigation Scenario	4.5	27.3	50.0	80.0
Number of Efficient Cooling in the BAU	208	958	6,420	52,200
Number of Efficient Cooling in the Mitigation Scenario	1,038	4,753	32,099	139,200
Number of Additional Efficient AC Units in the Mitigation Scenario	830	3,795	25,679	87,000

5.2.2.4 *Street Lighting Retrofits*

Table 15 outlines the parameters associated with street lighting retrofits. The activity data was derived from the LEAP model to ensure consistency. Similarly, the energy intensities for both existing and efficient street lighting were consistent with that used in LEAP by retaining the following associated assumptions:

- the power rating of existing – 150W; and
- power rating efficient replacement – 50W.

Table 15: Parameters Used to Model Street Lighting Retrofits with GACMO

Years	2020	2025	2030	2050
Estimated Number of Street lighting	13,600	14,100	15,600	22,500
Percentage of LED Street Lights in the BAU	75	100	100	100
Percentage of LED Street Lights in the Mitigation Scenario	75	100	100	100
Estimated Total Number LED Street Lights in the BAU	10200	14100	15600	22500
Estimated Total Number LED Street Lights in the	10,200	14,100	15,600	22,500
Total Additional Efficient Streetlighting bulbs	0	0	0	0

5.2.2.5 *Renewable Energy Generation*

Table 16 outlines the parameters associated with renewable energy generation. The activity data was derived from the LEAP model to ensure consistency.

Table 16: Parameters Used to Model Renewable Energy Generation Additions with GACMO

Category	2020	2025	2030
Solar Generation (MW) Generation Additions	0.05	17.89	17.91
Wind Generation (MW) Generation Additions	0	0	20

5.2.2.6 *Electrified Transport (Phasing out ICE Vehicles)*

Table 17 outlines the parameters associated with electrified transport. The activity data was derived from the LEAP model to ensure consistency.

Table 17: Parameters Used to Model Electrified Transport with GACMO (vehicle additions)

Types of Vehicles	2020	2025	2030	2050
Electric Cars in Baseline	40	410	1,290	8,980
Electric Cars in Mitigation	40	8,690	31,550	125,270
Electric Buses in Baseline	0	0	50	840
Electric Buses in Mitigation	0	1,010	3,650	12,160
Electric Two - Wheelers in Baseline	250	300	360	490
Electric Two-Wheelers in Mitigation	250	300	360	490
Electric Three-Wheelers in Baseline	0	0	0	0
Electric Three-Wheelers in	0	110	400	1,340
Electric Trucks in Baseline	0	0	0	0
Electric Trucks in Mitigation	0	290	1,030	3,420
Additional Electric Cars	0	8,280	30,260	116,290
Additional Electric Buses	0	1,010	3,600	11,320
Additional Electric Two-Wheelers	0	0	0	0
Additional Electric Three Wheelers	0	110	400	1,340
Additional Electric Trucks	0	290	1,030	3,420

5.2.2.7 Reforestation

The parameters associated with reforestation are noted below. The activity data was consistent with that used for the LEAP model and is based on planting 20,000 trees in 2020. Similarly, the following associated assumptions were consistently used:

- Estimated Number of Trees per Hectare – 1000; and
- Estimated Sequestration rate – 3.7 tonnes CO_2/hectare.

6 Preliminary Results

6.1 <u>Results for LEAP</u>

All LEAP results are sourced from the LEAP model developed for Antigua and Barbuda (Heaps, 2021).

6.1.1 Modelled Action 1: Energy Efficient Equipment

Figure 1 shows the four modelled scenarios for energy-efficient equipment compared with the baseline in the energy sector. These are energy-efficient measures in residential and commercial buildings. This figure demonstrates the reduction in GHG emissions for each of the four mitigation strategies modelled in the energy sector. The greatest reduction is achieved from energy-efficient measures in other appliances and then the energy-efficient measures in cooling. ***Table 18*** shows the baseline emission values in the energy sector and the avoided emissions for each scenario in $GgCO_2eq$ for each mitigation scenario. In ***Figure 2***, the chart shows the combined results of the policies related to energy efficiency in appliances and the potential emission reduction when compared to the baseline scenario for the energy sector in $GgCO_2eq$. This result uses 100-year global warming potentials (GWP), with direct emissions associated with the demand branches and indirect emissions from the transformation (electricity production) branches allocated to the demand. These scenarios are modelled with electricity production changes same as the baseline scenarios. ***Table 19*** shows the potential reduction values for the combined mitigation scenarios in energy-efficient equipment and the baseline.

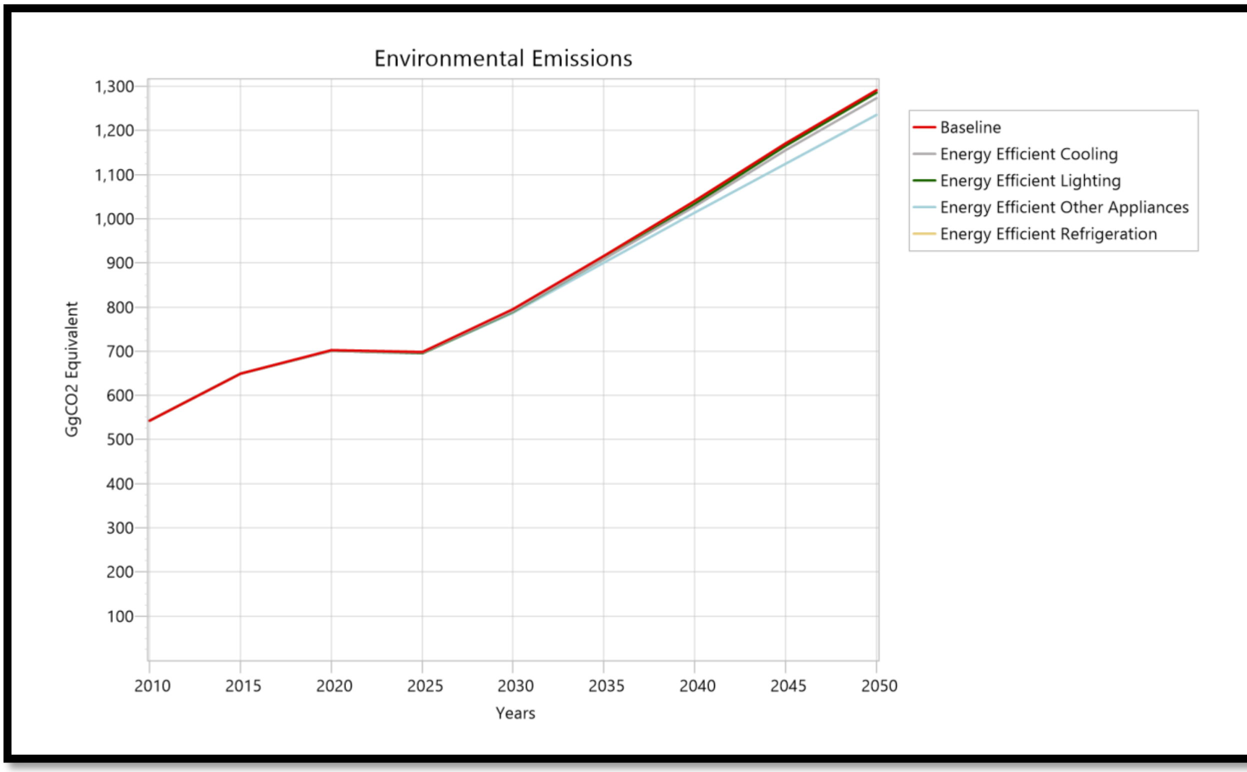

Figure 1: Reduction in GHG emission for Energy-Efficient Cooling, Lighting, Other Appliances and Refrigeration.

Table 18: Information on potential reduction in GHG emissions for the four LEAP scenarios modelled.

Scenario	2010	2020	2025	2030	2035	2040	2050
Baseline (Gg CO_2eq)	542.36	702.07	698.77	794.58	915.69	1040.91	1291.05

Scenario	2010	2020	2025	2030	2035	2040	2050
Energy Efficient Cooling (Gg CO_2eq) avoided	-	- 0.46	-1.69	-3.87	-6.83	-12.28	-17.18
Energy Efficient Lighting (Gg CO_2eq) avoided	-	-0.87	-3.08	-5.13	-6.56	-7.82	-4.84
Energy Efficient Other Appliances (Gg CO_2eq) avoided	-	-1.09	-3.74	-7.53	-14.81	-27.59	-55.31
Energy Efficient Refrigeration (Gg CO_2eq) avoided	-	-0.27	-0.91	-1.86	-3.34	-5.90	-4.91

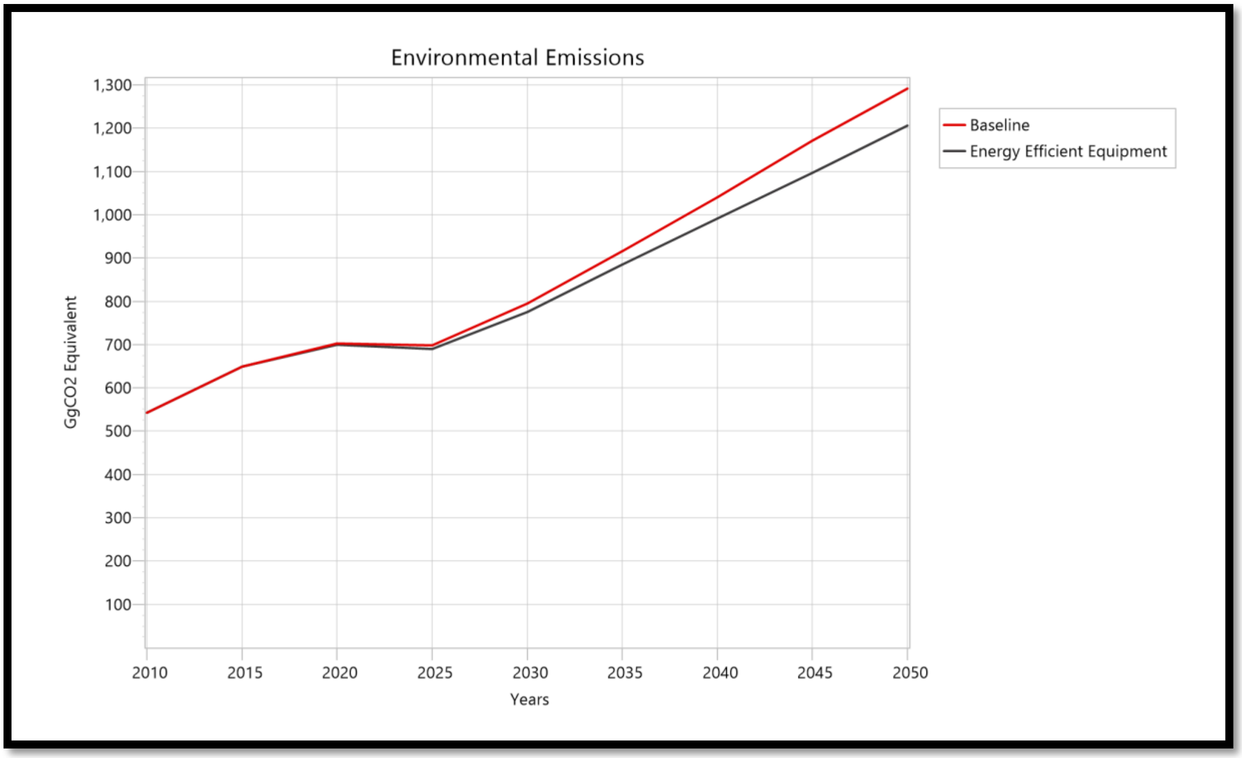

Figure 2: Graph showing a comparison of emissions of baseline vs energy-efficient equipment in GgCO2eq

Table 19: Projected emissions reduction for combined scenarios of Energy efficient Equipment compared to baseline in $GgCO_2eq$

Scenario	2010	2020	2025	2030	2035	2040	2050
Baseline ($GgCO_2eq$)	542.36	702.07	698.77	794.58	915.69	1040.91	1291.05
Energy Efficient Equipment ($GgCO_2eq$) avoided	-	-2.67	-9.41	-18.40	-30.47	-49.36	-84.62

6.1.2 Modelled Action 3: Renewable Energy Generation

Figure 3 shows the relative contributions of various renewable energy strategies to emissions reductions compared to the baseline emissions in the energy sector in $GgCO_2eq$. The scenarios consider wind only, solar only, and the Barbuda hybrid system, which is a combination of solar and diesel***. Figure 4*** shows the combined contributions of the mitigation strategies in renewable energies when compared to the baseline emissions in the energy sector. **Table 20** Table 20 provides a further explanation of the trends in emissions compared to the baseline in ***Figure 4.***

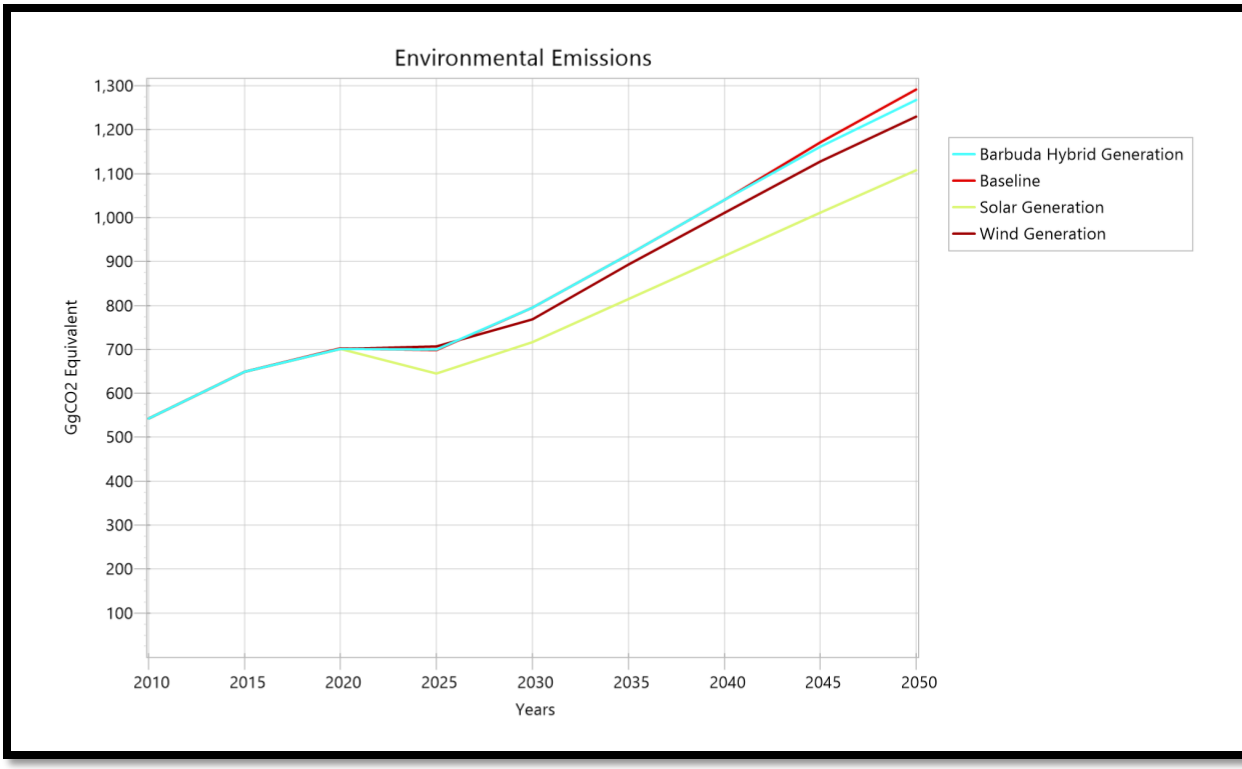

Figure 3: Projected emissions reductions for renewable energy generation scenarios in GgCO2eq

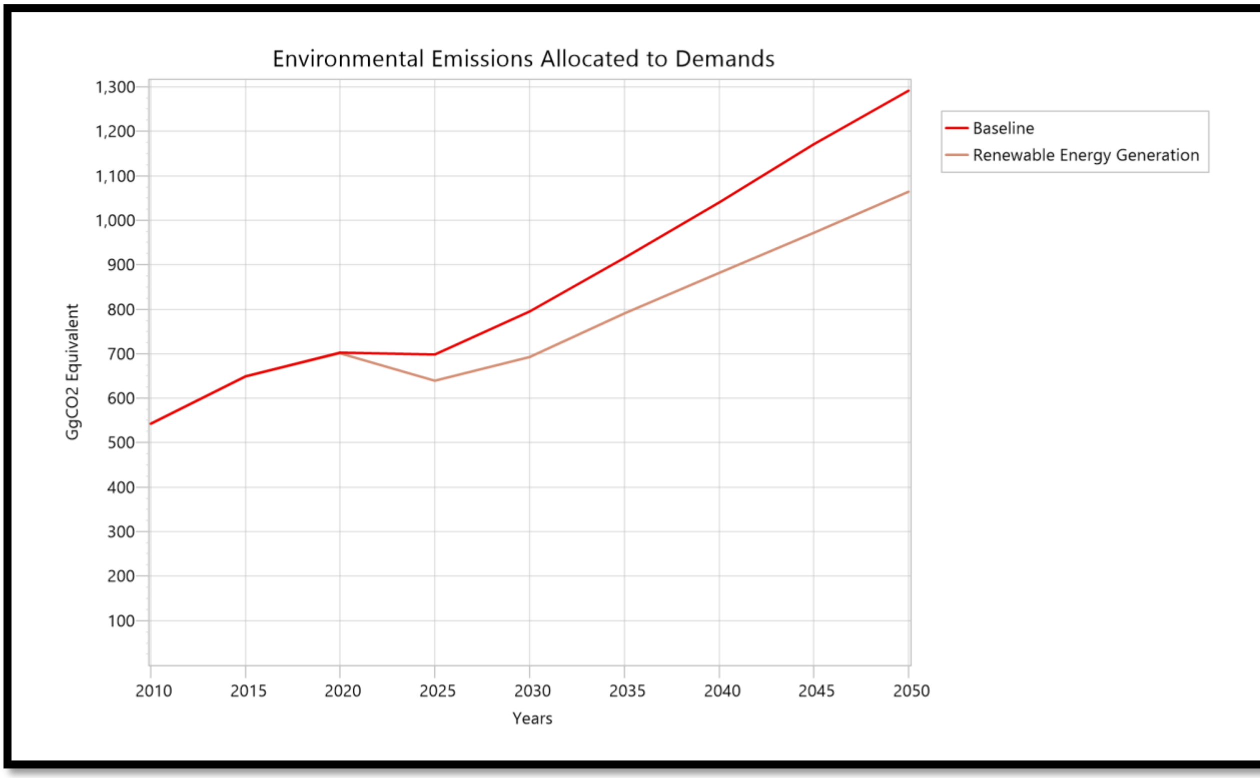

Figure 4: Projected emissions reductions of combined scenarios in renewable energy generation in $GgCO_2eq$

Table 20: Projected emissions reductions relative to baseline for renewable energy scenarios

Scenario	2010	2020	2025	2030	2035	2040	2050
Baseline ($GgCO_2eq$)	542.36	702.07	698.77	794.58	915.69	1040.91	1291.05
Renewable Energy Generation ($GgCO_2eq$)	-	-0.75	-59.59	-102.47	-124.22	-158.10	-227.12

6.1.3 Modelled Action 4: Efficient Transportation

Figure 5 shows the projected emissions for the two modelled scenarios in the transport sector compared to baseline emissions in the energy sector. The ban on the importation of ICE vehicles by 2028 indicates the larger reductions in emissions of the two scenarios. It should be noted that the ban on importation of ICE vehicles is assumed for both new and used vehicles, as there was insufficient data to disaggregate the importation of the two types. This was modelled by eliminating the sale of ICE vehicles in 2031. ***Figure 6*** shows the projected emissions for the combined scenarios in the transport sector when compared to the baseline emissions in the energy sector. **Table 21** elaborates further o the trend and providing emission reduction values in increments of 5 years.

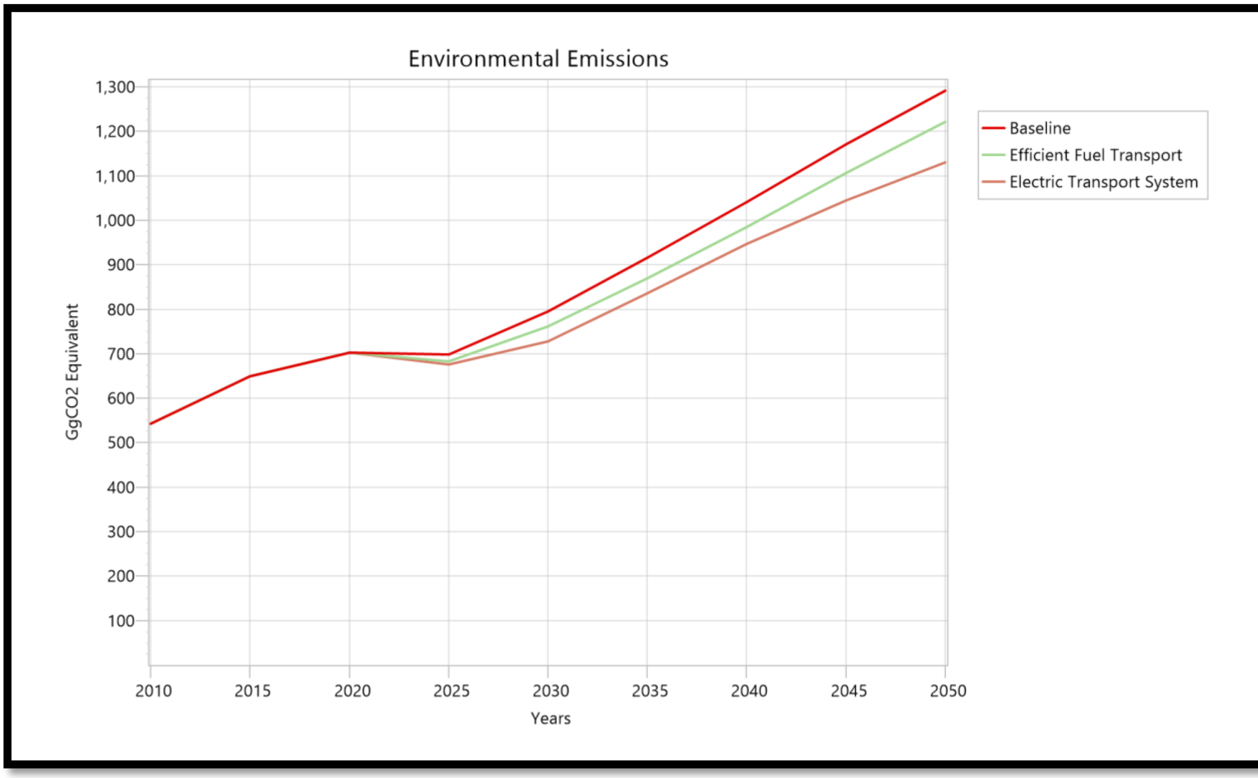

Figure 5: Projected emissions reduction for scenarios in the transport sector

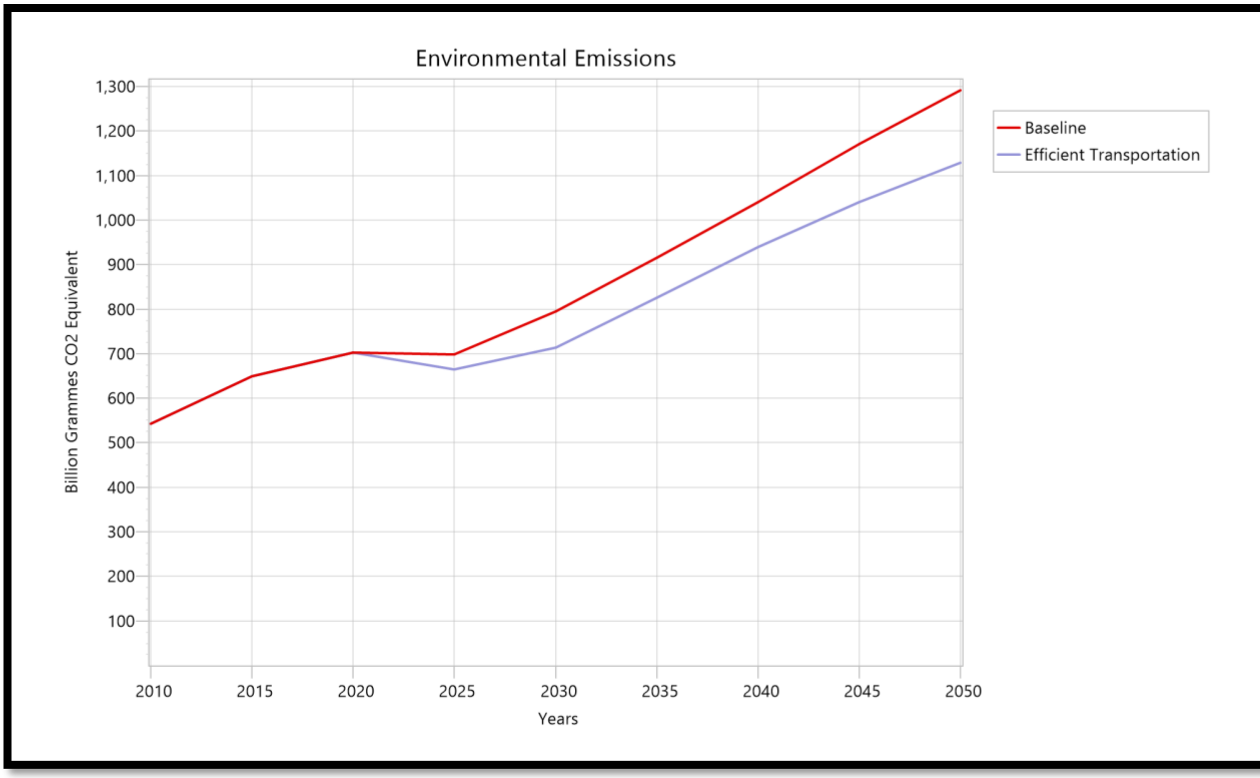

Figure 6: Projected emissions for combined scenarios in the transportation sector

Table 21: Projected emissions for combined mitigation scenarios in the transportation sector and baseline

Scenario	2010	2020	2025	2030	2035	2040	2050
Baseline ($GgCO_2eq$)	542.36	702.07	698.77	794.58	915.69	1040.91	1291.05
Efficient Transportation ($GgCO_2eq$)	-	0.00	-33.38	-80.49	-90.36	-100.98	-162.29

6.1.4 Modelled Action 5: Reforestation

For the increase of sequestration in the modelled scenario for the planting of 20,000 trees, the emissions reductions are extremely small and result in a 0.0734 $GgCO_2eq$ of increase in emission sequestration from 2019 to 2021. This value is too small to be shown in graphs compared to the baseline and in the tables.

6.1.5 Mitigation Scenarios: Future emissions considering all modelled scenarios for Antigua and Barbuda

Sections ***6.1.1*** to ***6.1.4*** compared the mitigation scenarios emission reductions to the baseline emissions in the energy sector. In ***Figure 7*** the projected emission in the mitigation scenarios is compared against baseline emissions for all sectors. Based on this model, in 2025, Antigua and Barbuda can achieve reductions in emissions of approximately 103.38 $GgCO_2eq$ from all sectors when comparing the baseline scenario to the mitigation scenarios. Further reduction in emissions from all the scenarios is further elaborated in **Table 22.**

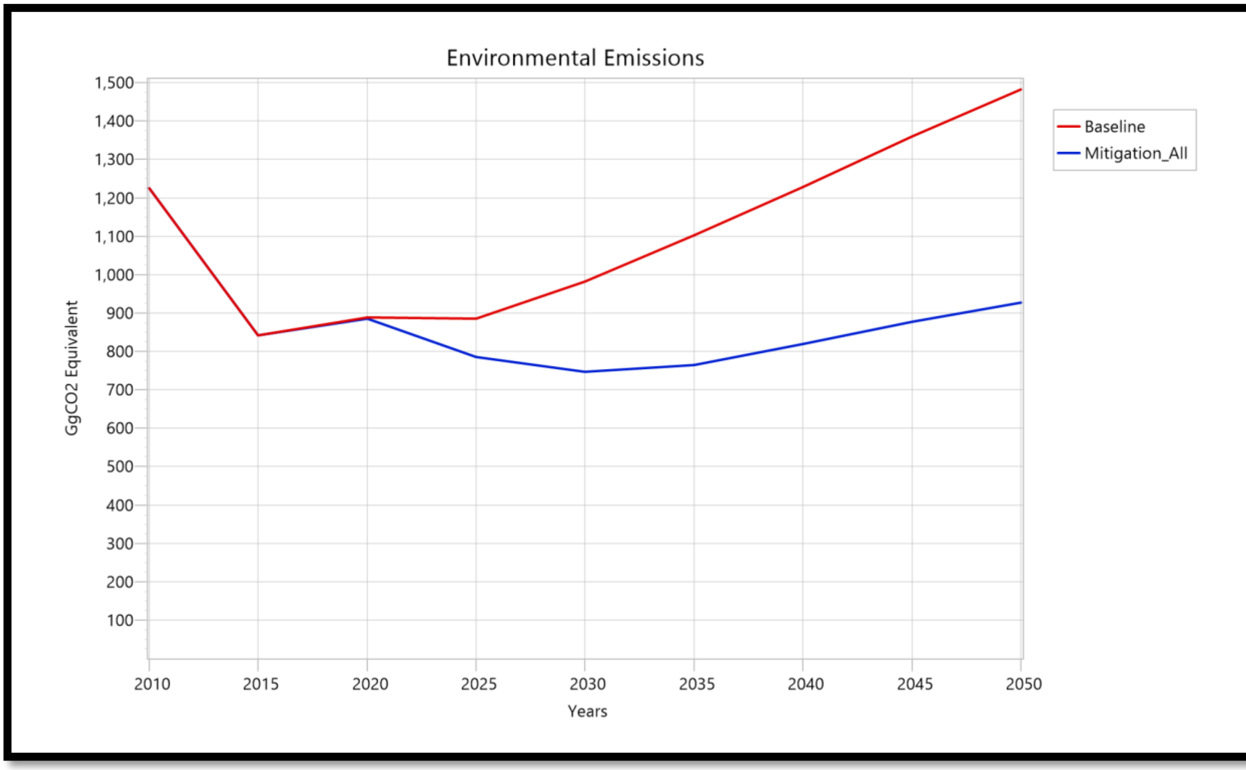

Figure 7: Projected emissions reductions for all mitigation scenarios against baseline emissions for all sectors

Table 22: Projected emissions reductions for all mitigation scenarios

Scenario	2010	2020	2025	2030	2035	2040	2050
Baseline ($GgCO_2eq$)	1275.63	956.86	964.03	1071.8	1208.31	1349.65	1635.57
Mitigation All ($GgCO_2eq$)	1275.63	953.44	860.64	826.19	850.99	913.47	1045.08
Avoided Emissions ($GgCO_2eq$)	-	3.42	-103.38	-245.69	-357.32	-436.17	-590.48

6.1.6 Mitigation Scenarios: Future emissions considering all modelled scenarios for Antigua and Barbuda by major GHG gases

Figure 8, ***Figure 9*** and ***Figure 10*** compare the mitigation scenarios against the baseline emissions reductions for each major GHG gas, carbon dioxide, methane and nitrous oxide respectively. As shown in the figures carbon dioxide represent the greatest reduction in emissions for the mitigation scenarios modelled. For all three gases, the major reductions are due to the mitigation actions modelled in the transportation sector.

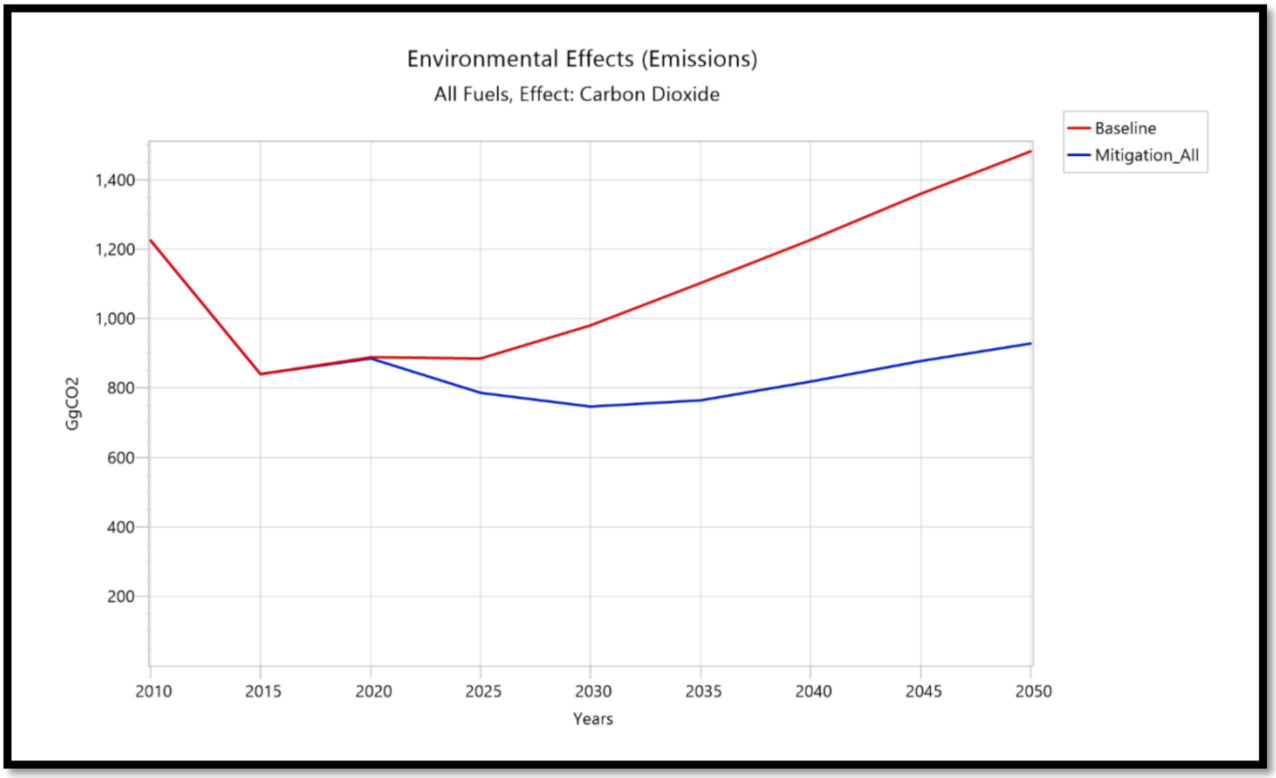

Figure 8: Projected emissions reductions for mitigation scenarios compared to baseline for carbon dioxide

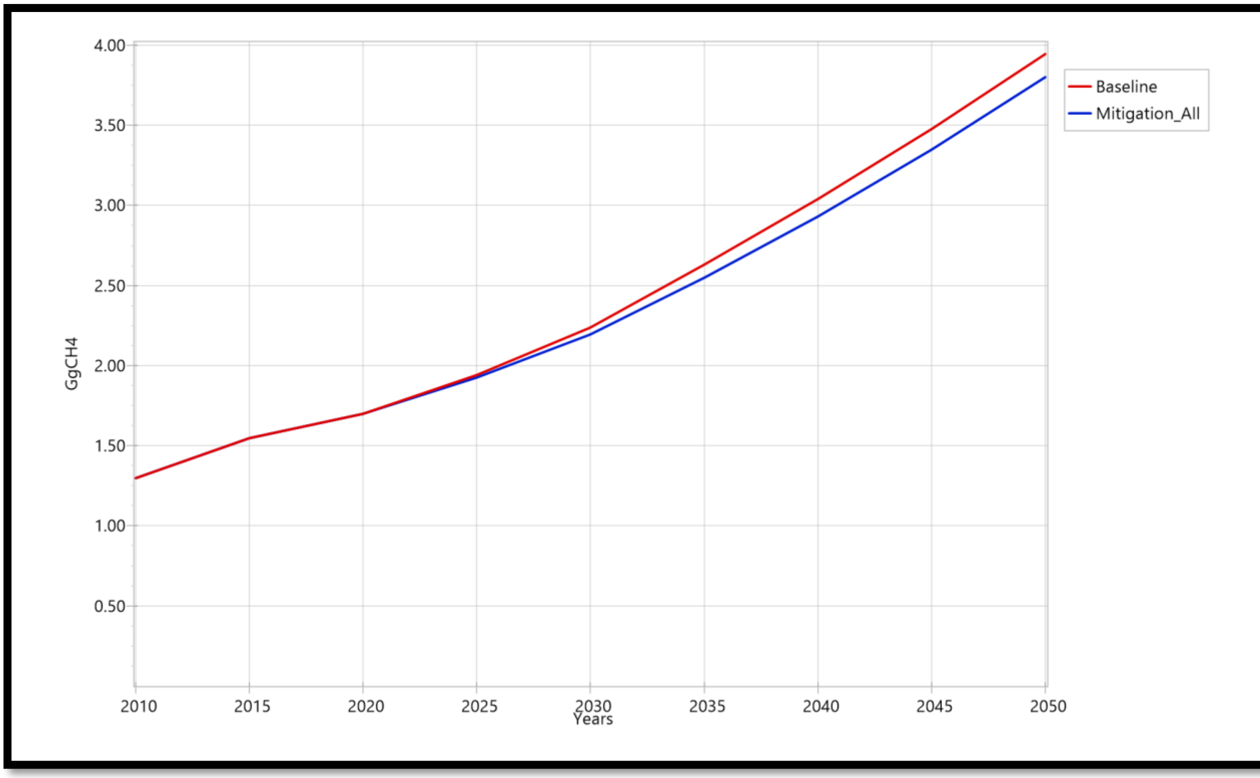

Figure 9: Projected emissions reductions for mitigation scenarios compared to baseline for methane

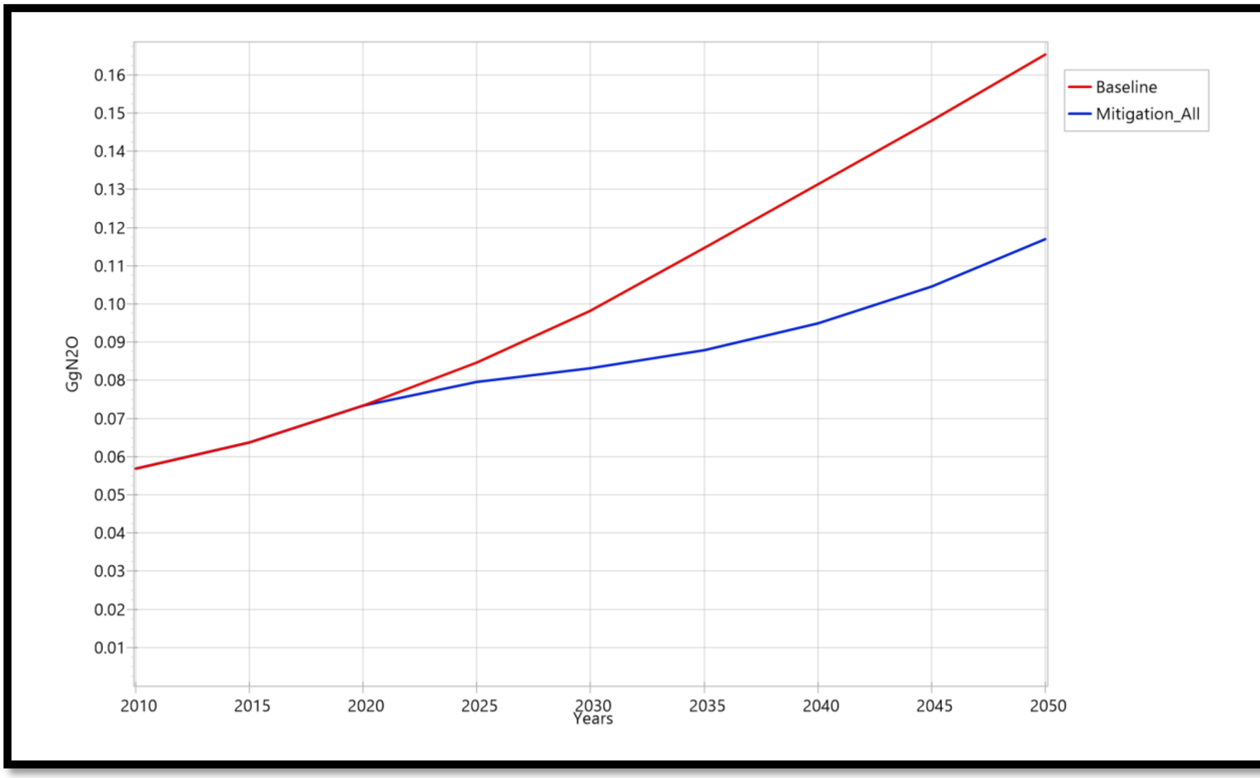

Figure 10: Projected emissions reductions for mitigation scenarios compared to baseline for nitrous oxide

6.2 Results for GACMO

The results for GACMO are available for the years 2020, 2025 and 2030 in Annex 7 where all 7 mitigation scenarios elaborated in the model are listed in section 5. However, in this report, only the results for 2030 are presented and explained.

6.2.1 GACMO Results for 2030

The results for all associated mitigation options can be seen in ***Table 23*** (please note electrified vehicles are disaggregated). From this table, it can be seen that the largest mitigation potential emanates from RE generation from wind (approximately 39 kt/year), followed by RE generation from solar (approximately 25.33 kt/year), electric buses (approximately 24 kt/year) with the other actions following with less GHG reduction impact.

Interestingly, all of these actions can achieve economic savings for Antigua and Barbuda (except transport electrification for buses and trucks and forest generation) as in that case the associated costs are higher. It should be noted that GACMO illustrates results as revenue rather than cost, with a negative revenue indicating a cost. In the table below, these were all changes to abatement cost, so a negative cost indicates that revenue can be earned from the option.

Table 23: Mitigation Actions Analysed in GACMO (2030)

Reduction option	Abatement Cost US$/ton$CO_2$	Emission reduction in 2030 per option kt/year
Assisted forest regeneration (2020)	3.71	0.07
Efficient residential air-conditioning	-119.47	13.88
Wind turbines, onshore with 24 storage	-86.95	38.75
Solar PVs, large grid with 24h storage	-65.32	25.33
Efficient refrigerators	-49.84	5.09
Electric cars	-630.21	16.22
Electric three-wheelers	-329.25	0.07
Electric 12m buses	1466.92	23.61
Electric heavy trucks	67919.08	0.61

6.3 Comparison of the Results LEAP and GACMO

Antigua and Barbuda's BUR-1 illustrated a total GHG emission level of 851.9 Gg CO_2e in 2015. This reported value corresponded well with the results from the LEAP model (821.8 Gg CO_2e). Though results from the GACMO model was not available for 2015 (as GACMO only produces results for set years), the corresponding figure from the GACMO model for 2012 was also comparable (900 Gg CO_2e). The higher value from GACMO for the earlier year was mainly due to higher LULUCF emissions. An area of further work should be to better calibrate historical baseline model emission estimates with reported GHG inventory estimates.

7 Specific Data/Assumptions for Validation

Due to data limitations, there were many areas where expert judgement was required to elaborate both the LEAP and GACMO models. Consequently, a validation workshop will be held toward the end of September to examine key input data and assumptions used. These key assumptions are summarized below.

With respect to the formulation of the baseline:

- gradual uptake of efficient lighting in the household from 0% in 2019 to 50% in 2040 and 70% in 2050;
- gradual uptake of cooling in households from 10% of households in 2019 to 97.2% in 2050 (with growth rate increasing with time);
- gradual uptake of efficient cooling in the household sector from 0% in 2019 to 10% in 2030 and 30% in 2050;
- gradual uptake of water heating at 35% of households in 2019 with gradual growth to 40% in 2030 and 50% in 2050;
- distribution of water heating technology in the household sector amongst LPG (35%), electric (35%) and solar (30%) in 2019 with solar expected to grow to 35% in 2030 and 40% in 2050 at the expense of electric heaters;

- gradual uptake of refrigeration from 92.3% in 2019 with gradual growth up to 98% in 2050 (with growth rate increasing with time);
- gradual uptake of efficient refrigeration in the household sector from 0% in 2019 to 30% in 2030 and 50% in 2050;
- an increase in efficiency of all other appliances in the household sector of 0.5% per annum;
- the use of electricity production data from the United Nations rather than OLADE's energy balance as these corresponded better with historical electrical production in Antigua and Barbuda;
- Using the number of households as the demand driver for the household and agricultural sectors; and
- Using GDP as the demand for the commercial and industrial sectors

With respect to the mitigation scenarios:

- 30% of streetlights would be retrofitted in 2021;
- 20,000 trees were planted in 2020 or are planned to be planted in 2021;
- 2028 ban of ICE vehicles would indicate that by 2031, all sales of ICE would cease but this doesn't represent the stock of vehicles;
- by 2030 100% lighting will be efficient LEDs in the residential sector and 90% in the commercial sector
- by 2030, 50% of all air conditioning systems in the residential sector will be efficient and 60% would be efficient in the commercial sector.

8 Suggestions for Model Improvements

8.1 Data Improvements

For the mitigation actions modelling in LEAP, several assumptions were made when preparing the baseline and mitigation specification reports. These can be updated with better data. These areas include but are not limited to the following:

- Data related to historical fuel use in the industrial, commercial, and residential sectors
- Streetlighting data
- Transmission & Distribution losses in the electrical grid
- Electricity use in the industrial, commercial, and residential sectors
- Non- energy sector emissions for more comprehensive time series
- Levels of ownership for appliances in the commercial and residential sector
- Costing information for technologies, operations, and maintenance specific to Antigua and Barbuda

8.2 Recommended Future Work

Antigua and Barbuda submitted an original list of 30 mitigation actions, out of these mitigation actions, 14 were not modelled due to lack of precision or data to properly represent the scenarios. In addition to these actions, there are other areas suitable for modelling mitigation actions. Some of these areas for consideration in the future are:

- Transitioning to more efficient water heating
- Improvements in transmission and distribution losses
- Improvement in the energy efficiency of electricity generators
- Transitioning to more efficient ovens
- Improvements in the domestic aviation sector
- Improvements in the industrial sector

In addition, an important component of demand projections in the models is energy intensity. Though these values were estimated using energy balance data and related assumptions, it is reasonable to say that the model can be enhanced from "bottom-up" estimations of energy intensities. For this, further studies need to be conducted in Antigua and Barbuda on different demand technologies such as cooking, water heating, cooling, refrigeration, etc. to better establish energy intensities. This study would not only benefit mitigation assessments and modelling but can also give a good indication of areas where the country lies in these areas compared to other similar states.

9 Conclusion

By building the model for Antigua and Barbuda within LEAP and GACMO, the model is readily available for future updated mitigation assessments. In addition, in-country experts were trained on using LEAP and GACMO to ensure that the government retains the capacity to use the models as this was the purpose of the project. Finally, a stakeholder validation workshop was held to review and validate the assumptions, analysis and conclusions of the Antigua and Barbuda LEAP and GACMO models with the associated feedback being incorporated in this report.

10 List of Annexes

The following listed Annexes are also submitted to accompany this report.

- Annexe 1 – Demographic and Economic Data for Antigua and Barbuda
- Annexe 2 – Demand Data for Antigua and Barbuda
- Annexe 3 – United Nations Data for Antigua and Barbuda
- Annexe 4 – Expert Judgement Areas
- Annexe 5 – Energy Intensities (Household)
- Annexe 6 – Energy Intensities (Commercial)
- Annexe 7 – GACMO Model
- Annexe 8 – LEAP Model
- Annexe 9 – GACMO Mitigation Tables
- Annexe 10 – Non-Energy Analysis
- Annexe 11 – Olade Energy Balance
- Annexe 12 – Antigua and Barbuda BUR 1
- Annexe 13 – GACMO Growth Factors
- Annexe 14 – APUA Meeting (August 13th)
- Annexe 15 – Grid Emission Factor Data
- Annexe 16 – GHG Inventory (2006)

11 References

Heaps, C. (2021). *LEAP: The Low Emissions Analysis Platform. [Software version: 2020.1.34].* Stockholm Environment Institute. Massachusetts: Stockholm Environment Institute. Retrieved from https://leap.sei.org

12 APPENDIX 1 – Full List of Mitigation Actions

Mitigation Actions for Antigua and Barbuda

Table 24: Mitigation Actions for Antigua and Barbuda

No	Sector	Mitigation Action/Strategy	Completion Year	Modelled
1	Energy	Establish efficiency standards for the importation of all appliances	2020	Yes
2	Energy	100% Sodium Street lights replaced by LED lighting	2021	Yes
3	Energy	Overall Target: 86% renewable energy generation in the electricity sector.	2030	Yes
4	Energy	4.125 MW of wind turbines procured and installed	2021	Yes
5	Energy	Modular hybrid power plant installed in Barbuda	2021	Yes
6	Energy - Transport	Ban on importation of new ICE vehicles	2028	Yes
7	Agriculture, Forestry, Other Land Use	100% Remaining wetlands, watershed areas, and seagrass bed areas with carbon sequestration potential are protected as carbon sinks: Approx. 43216 tCO_2 potential carbon sequestration per year	2030	No
8	Agriculture, Forestry, Other Land Use	20,000 Trees planted to restore degraded land and increase CO_2 sequestration	2021	Yes
9	Energy	100 MW of renewable energy generation capacity available to the grid.	2030	Yes
10	Energy	50 MW of renewable energy generation capacity owned by farmers who can sell electricity to off-takers	2030	Yes
11	Energy	100 MW of renewable energy generation capacity owned by social investment entities	2030	Yes
12	Energy	20MW of wind-powered energy generation for a new zero greenhouse gas emission energy generation technology	2030	Yes
13	Energy	100% renewable energy generation for all government operations	2030	Yes

No	Sector	Mitigation Action/Strategy	Completion Year	Modelled
14	Energy	100% of fixtures and appliances in government buildings will be energy efficient	2030	Yes
15	Energy - Transport	Change in fiscal policies on fossil fuel to enable the transition to 100% renewable energy sources for the transport sector	2025	No
16	Energy Transport	100% of Government vehicles are electric vehicles	2035	Yes
17	Energy Transport	Establish efficiency standards for all vehicle importation.	2020	Yes
18	Energy	Building Code updated and passed into law in line with a climate-resilient development pathway including, inter alia, a requirement that all new homes built after 2025 have backup renewable energy generation and storage systems	2025	Yes
19	Energy	Enhance the established enabling legal, policy and institutional environment for a low carbon emission development pathway to achieve poverty reduction and sustainable development.	None	No
20	Energy	Elimination of the fuel surcharge tax on electricity bills	2030	No
21	Energy	Finalize the technical studies with the intention to construct and operationalize a waste to energy (WTE) plant targeting 20,000 homes.	2025	No
22	Energy	100% of female-headed households have all barriers removed to access backup renewable energy generation and storage systems	2030	No
23	Energy	20% increase in the number of women-led businesses implementing renewable energy and adaptation interventions	2030	No
24	Energy	100% of Water supply infrastructure powered by own grid-interactive renewable energy sources	2030	No
25	Energy	30,000 or 50% of pre-2020 homes to have backup RE systems for at least 4-6 hours of energy	2030	No
26	Energy	Education, health, food supply and/or storage, and energy shelter facilities powered by own grid-interactive RE sources; GISS: Grid-Interactive Solar PV Systems for Schools and Clinics; Sustainability Energy Facility / Caribbean Development Bank (SEF/CDB) project	2030	No
27	Agriculture, Forestry, Other Land Use	100% of Waterways are protected to reduce risks of flooding and health impacts	2030	No

No	Sector	Mitigation Action/Strategy	Completion Year	Modelled
28	Agriculture, Forestry, Other Land Use	Expansion of protection and sustainable use of globally significant biodiversity in protected areas and surrounding communities by 3035 hectares	2021	No
29	Finance	Establish dedicated technical and other support for de-risking GHG reduction investments by MSMEs in Antigua & Barbuda	2030	No
30	Finance	50 % increase in the number of MSMEs that provide energy services aligned with the objective of the Paris Agreement [SIRF Fund; Entrepreneurial Development Programme Fund	2030	No

13 APPENDIX 2 – Mitigation Actions not modelled

Table 25: Mitigation Actions not considered for Antigua and Barbuda models

No	Sector	Mitigation Action/Strategy	Completion Year	Modelled	Further Explanations
1	Agriculture, Forestry, Other Land Use	100% Remaining wetlands, watershed areas, and seagrass bed areas with carbon sequestration potential are protected as carbon sinks: Approx. 43216 tCO_2 potential carbon sequestration per year	2030	No	No data provided in Inventory on Wetlands
2	Energy - Transport	Change in fiscal policies on fossil fuel to enable the transition to 100% renewable energy sources for the transport sector	2025	No	Insufficient information on what are the changes in the fiscal policies and how will it enable the transition.
3	Energy	Enhance the established enabling legal, policy and institutional environment for a low carbon emission development pathway to achieve poverty reduction and sustainable development.	None	No	Insufficient information on what enhancement will be done to enable the low carbon emission
4	Energy	Elimination of the fuel surcharge tax on electricity bills	2030	No	Not considered a mitigation action by itself, but might be a consequence of other actions.
5	Energy	Finalize the technical studies with the intention to construct and operationalize a waste to energy (WTE) plant targeting 20,000 homes.	2025	No	The study is an enabling factor that will provide information on the mitigation action. Once the study is completed then the technical information can be included in the model
6	Energy	100% of female-headed households have all barriers removed to access backup renewable energy	2030	No	Data not provided in a disaggregated manner to allow for the modelling of female-

No	Sector	Mitigation Action/Strategy	Completion Year	Modelled	Further Explanations
		generation and storage systems			headed households vs males. In addition, information on the existing barriers is important.
7	Energy	20% increase in the number of women-led businesses implementing renewable energy and adaptation interventions	2030	No	Similar to the above, disaggregation of women-led businesses vs male businesses is important for this action to be considered
8	Energy	100% of Water supply infrastructure powered by own grid-interactive renewable energy sources	2030	No	Data is required on the consumption of electricity in the water sector to be able to model this action.
9	Energy	30,000 or 50% of pre-2020 homes to have backup RE systems for at least 4-6 hours of energy	2030	No	Insufficient data on the current levels of pre-2020 homes with RE systems. More details on the back RE systems are required.
10	Energy	Education, health, food supply and/or storage, and energy shelter facilities powered by own grid-interactive RE sources; GISS: Grid-Interactive Solar PV Systems for Schools and Clinics; Sustainability Energy Facility / Caribbean Development Bank (SEF/CDB) project	2030	No	Disaggregated data is required for the different sectors to be able to model the RE systems n these facilities. Information is also required on the size of the system that will be installed.
11	Agriculture, Forestry, Other Land Use	100% of Waterways are protected to reduce risks of flooding and health impacts	2030	No	Considered an adaptation action. To be considered for mitigation, GHG impact needs to be defined.
12	Agriculture, Forestry, Other Land Use	Expansion of protection and sustainable use of globally significant biodiversity in protected areas and	2021	No	Considered an adaptation action. To be considered for mitigation, GHG

No	Sector	Mitigation Action/Strategy	Completion Year	Modelled	Further Explanations
		surrounding communities by 3035 hectares			impact needs to be defined.
13	Finance	Establish dedicated technical and other support for de-risking GHG reduction investments by MSMEs in Antigua & Barbuda	2030	No	This is considered an enabling activity for the reduction in GHG emissions. More information on how this activity is expected to reduce GHG emissions is required
14	Finance	50 % increase in the number of MSMEs that provide energy services aligned with the objective of the Paris Agreement [SIRF Fund; Entrepreneurial Development Programme Fund	2030	No	Similar to the above. This is considered an enabling activity for the reduction of GHG emissions. More information on how it is expected to reduce GHG emissions is required.