For Components 1 and 3 under the project Nationally Appropriate Mitigation Actions (NAMAs) for Low Carbon Island Development Strategy for the Republic of Mauritius

(NAMA Project)

MITIGATION STRATEGIES & ACTIONS

AND

MITIGATION SCENARIOS

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List of Acronyms

AFOLU	Agriculture, Forestry and Other Land Use
BAU	Business as usual
BUR	Biennial Update Report
CCM	Climate Change Mitigation
CEB	Central Electricity Board
CO2e	Carbon dioxide equivalent
DLL	Dry Low Land
DOC	Degradable Organic Content
EE	Energy Efficiency
EV	Electric Vehicle
FAREI	Food Agricultural Research and Extension Institute
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GWh	Gigawatt hour
HFC	Hydrofluorocarbon
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use
ktoe	Kilo tonne of oil equivalent
LPG	Liquefied Petroleum Gas
LRS	Light Rail System
MOLTLR	Ministry of Land Transport and Light Rail
MSW	Municipal Solid Waste
MtCO2	Million tonne of carbon dioxide
NAMA	Nationally Appropriate Mitigation Action
NDC	Nationally Determined Contribution
NIR	National Inventory Report
ODS	Ozone Depleting Substances
PA	Paris Agreement
PAX-km	Passenger kilometre
RAC	Refrigeration and Air Conditioning
RE	Renewable Energy
SWMD	Solid Waste Management Division
TNC	Third National Communication
TRMSU	Traffic Road Management and Safety Unit
UNFCCC	United Nations Framework Convention on Climate Change
US$	United States Dollar
WMA	Wastewater Management Authority
WTE	Waste-to-Energy

1.0 Introduction

Component 1 of the NAMA project seeks to 'strengthen national capacity to identify, prioritize and develop mitigation actions to meet NDC targets'. In order to achieve this, it has four outputs of which the second – i.e. Output 1.1 – is 'to strengthen institutional arrangements to coordinate development and implementation of NDC through development of process and procedures as well as clear institutional responsibilities'. Output 1.1 entails two activities:

- ✓ Activity 1.1.1 - Review the institutional arrangements for the development and implementation of mitigation actions and identify gaps; and
- ✓ Activity 1.1.2 – Develop process, procedure and guidelines for mitigation actions identifications, development and implementation for NDC.

This report relates to Activity 1.1.2 by providing a set of guidelines for identifying and prioritizing mitigation actions for NDC formulation. It complements the baseline analysis of mitigation actions,[1] and institutional arrangements for the formulation and implementation of mitigation actions.[2]

The identification and prioritization of mitigation actions is related to the decision of the Conference of Parties 1/CP21.[3] Paragraph 35, invited Parties "*to communicate, by 2020, to the secretariat mid-century, long-term low greenhouse gas emission development strategies in accordance with Article 4, paragraph 19, of the Agreement*". The low greenhouse gas (GHG) development strategies would be published on the UNFCCC website.[4] Article 4 of the Paris Agreement states that Parties[5] should aim to reach global peaking of GHGs as soon as possible, and to undertake rapid reductions thereafter based on the best available science in order to achieve balance between anthropogenic emissions and removals by sinks of GHGs – i.e. net zero carbon emissions – in the second half of this century. Reductions in GHGs are to be carried out on the basis of equity and based on national circumstances[6] so as to support sustainable development and eradication of poverty. The application of paragraph 35 and Article 4 to a small emitter like Mauritius has been carried out to provide an equity-based, effort sharing perspective on long-term GHG emission reductions aligned with the goal of net zero emissions by 2050.[7]

1.1. Approaches used for mitigation assessment

Mitigation assessments can be made based on a combination of three alternatives namely (i) a project- or activity-based approach, (ii) an outcome-based approach, or (iii) a combination of the two. These types of mitigation actions known as '*contribution type'* are depicted in **Figure 1**.

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[1] P Deenapanray (2021) Baseline Analysis of Mitigation Actions – a sectoral perspective, Ministry of Environment, Solid Waste Management and Climate Change, Mauritius.

[2] P Deenapanray (2020) Institutional Arrangements for Climate Governance, Ministry of Environment, Solid Waste Management and Climate Change, Mauritius; P Deenapanray (2021) Draft Guidelines for the implementation of the climate change mitigation provisions of the Climate Change Act 2020 (Energy Industries), Ministry of Environment, Solid Waste Management and Climate Change, Mauritius.

[3] UNFCCC (2021) Report of the Conference of the Parties on its twenty-first session, held from 30 November to 13 December 2015.

[4] The long-term, low-carbon strategies that have been communicated to the UNFCCC are found at: https://unfccc.int/process/the-paris-agreement/long-term-strategies - accessed 19 October 2021.

[5] Article 4(6) states that '*The least developed countries and small island developing States may prepare and communicate strategies, plans and actions for low greenhouse gas emissions development reflecting their special circumstances*'.

[6] Parties should strive to formulate and communicate their long-term low GHG emission development strategies, mindful of Article 2 – i.e. pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels – using the principle of common but differentiated responsibilities and respective capabilities.

[7] PNK Deenapanray (2021) Increasing the ambition of mitigation action in small emitters: the case of Mauritius, Climate Policy 21(4):514-528.

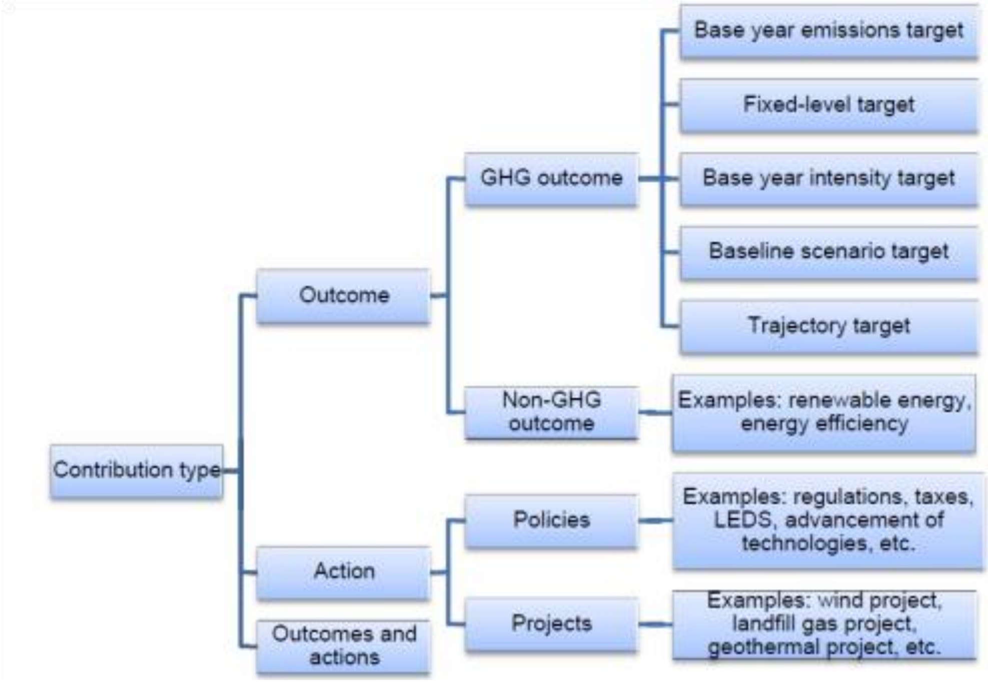

Figure 1. Definition of different types of mitigation contributions.
(Source: WRI & UDP 2015)

In the mitigation analyses, both activity-based (bottom-up) and outcome-based (top-down) approaches have been adopted. The overall level of GHG emission reductions or sequestration has been calculated by developing business-as-usual (BAU) sectoral baseline scenarios or the case when policies would be hindered due to prevailing barriers.

1.2. Structure of the report

This report provides the details concerning mitigation scenarios for Mauritius in energy sector (energy industries and transport); non-energy sector (waste; agriculture; IPPU and AFOLU). As far as practicable, the scenarios have been aligned to existing sectoral policies, strategies and action plans, namely the updated NDC, and have been informed by mitigation actions corroborated by sectoral stakeholders contributing to the NAMA project. As far as practicable, historical emissions have been aligned with the results reported in the biennial update report (BUR). The mitigation assessments are reported in order to: (i) provide the methodology used to develop them, (ii) elaborate the mitigation actions that underpin the mitigation scenarios, and (iii) show the results of GHG emission scenarios. The key underlying assumptions are also provided for transparency. The results are presented for emitting sectors using the IPCC nomenclature.

2.0 Mitigation assessment in the energy sector

This section describes the methods and assumptions that have been used to carry out the mitigation analyses i.e. by calculating the GHG emission reductions against sectoral baseline scenarios for the energy sector. The energy sector is the largest GHG emitting sector in Mauritius. Mitigation analyses have been carried out for the energy industries and transport sub-sectors that are the largest and second largest emitter of GHGs, respectively.

2.1. Energy industries

2.1.1. Modelling approach

Electricity generation and consumption is the largest emitter of GHGs in Mauritius. Baseline and mitigation scenarios for this sub-sector have been developed using a system dynamics model customised for Mauritius. This modelling approach was adopted for mitigation scenario analyses for the energy industries in the Third National Communication (TNC).[8] The model customisation has been carried out through close interactions with the Central Electricity Board (CEB).[9] The baseline emissions analysis has been carried out using the results of the system dynamics model that is able to simulate electricity generation using either an endogenous or an exogenous calculation of GDP. By calibrating the model to replicate historical electricity consumption disaggregated by end-use sectors up until the end of 2021, the model takes into account the impacts of COVID-19 on the power sector. The structure of the model used for mitigation scenario analyses has been reported elsewhere.[10]

The analysis of mitigation scenarios implies the consideration of both (i) underlying trends (e.g. for GDP and population), and (ii) intervention options (e.g. ambition for energy efficiency improvements and transport electrification). Three sets of simulations have been developed to account for uncertainty in relation to (i), especially in relation to the post-COVID economic recovery. In this respect, the following have been considered:

(1) a full and fast recovery, with Gross Domestic Product (GDP) reaching pre-crisis expectations by 2022 as a result of strong GDP growth in 2021 – 2023 (expected to be as high as 12% in 2022);

(2) an intermediate pace of the recovery, with GDP growth reaching pre-crisis levels in 2022 and staying slightly higher thereafter as a result of the push created by economic stimulus measures, with GDP aligning with pre-crisis expectations by 2030; and

(3) a slow recovery, with GDP growth returning to pre-crisis levels by 2024 and staying at that same level thereafter, implying that GDP will not achieve pre-crisis expectations . It will instead grow at the same rate, without making up for losses accrued between 2020 and 2024.

2.1.2. Definition of mitigation actions and scenarios

For each of the above economic growth trajectory, four mitigation scenarios have been simulated to compare four alternative scenarios of emission reductions to a Business-As-Usual (BAU) case. The scenarios are defined as follows:

- Scenario 1: BAU, continuation of historical trends, no additional policy implementation.
- Scenario 2: transport electrification (47,700 electric vehicles (EV) by 2030, in accordance with the High EV growth scenario of the 10 Year Electric Vehicle Integration Roadmap for Mauritius[11]).

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[8] Republic of Mauritius (2016). Third National Communication: Report to the United Nations Framework Convention on Climate Change. Republic of Mauritius, Port Louis.

[9] The NAMA project has purchased a Vensim license to enable CEB to appropriate the model that has been developed by technical assistance.

[10] A.M. Bassi and P.N.K. Deenapanray (2012) Chapter 4 - A green investment analysis using system dynamics modelling - The case study of Mauritius. Small States: Economic Review and Basic Statistics 16 (12): 65-79; P.N.K. Deenapanray and A.M. Bassi (2015) System Dynamics Modelling of the Power Sector in Mauritius, Environmental and Climate Technologies **16**(1), 20-35.

[11] EVConsult and Ecosis Ltd (2020) A 10 year electric vehicle integration roadmap for Mauritius.

- Scenario 3: scenario 2 + energy efficiency (10% across all sectors by 2030, based on the updated NDC document[12]).
- Scenario 4: scenario 3 + Renewable Energy (RE) for power generation (40% by 2030).
- Scenario 5: scenario 4 + coal phase-out by 2030 in favor of the use of biomass (based on the updated NDC document).

Scenario 4 consists of modeling the penetration of renewable energies as per the Renewable Energy Roadmap for the Electricity Sector.[13] In turn, Scenario 5 consists of adding the complete phasing out of coal by 2030.

2.1.3. Results of mitigation scenario analyses

The following sections present results for scenario (2) listed above, while the next section provides comparisons for key indicators across the three groups of scenarios simulated.

2.1.3.1. Energy demand

Energy demand is forecasted to reach 1,239 ktoe (kilo tonne of oil equivalent) in 2030 in the BAU scenario (**Figure 2**). Compared to 2020, energy demand in 2030 is forecasted to be 30.1% higher. This reflects an average annual growth rate of 2.7%.

The introduction of energy efficiency, electrification of transport, expanded use of renewable energy for power generation and coal phase out investments result in Scenario 5 showing an 11.5% reduction in energy demand in 2030, when compared to BAU. Most the gains in energy efficiency are, on the other hand, achieved in scenario 3, with an 11.8% reduction by 2030. The annual growth rate of demand declines to 1.5% per year, leading to a faster reduction of energy intensity.

The growth rate of energy demand, across all scenarios, is impacted by the COVID-19 pandemic. Covid-19 has led to rapid decline of demand in 2020 and 2021, and the reopening of the economy is pushing demand higher, especially from the year 2022. The growth rate of energy demand, after the full reopening of the economy, is forecasted to be aligned with the growth experienced in the years prior the pandemic. The introduction of energy efficiency investments will instead result in lower energy demand going forward, reflecting a stronger effort relative to what experienced in the past.

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[12] This target is an economy-wide target for electricity end-use efficiency, and it is not accompanied by mitigation actions. With significant inputs from the EEMO, electricity demand scenarios for various end-use-specific energy efficient technologies – i.e. electrical equipment and appliances - have been initiated under the NAMA project. The results are still preliminary and yet to be completed. Hence, mitigation scenario analyses have been developed using the economy-wide target.

[13] Republic of Mauritius, 2019. Renewable Energy Roadmap 2030 for the Electricity Sector, Ministry of Energy and Public Utilities, Port Louis. This approach follows the guidance provided to the Ministry of Environment, Solid Waste Management and Climate Change by the Ministry of Energy and Public Utilities in an email dated 6 June 2021. This approach was corroborated with the CEB.

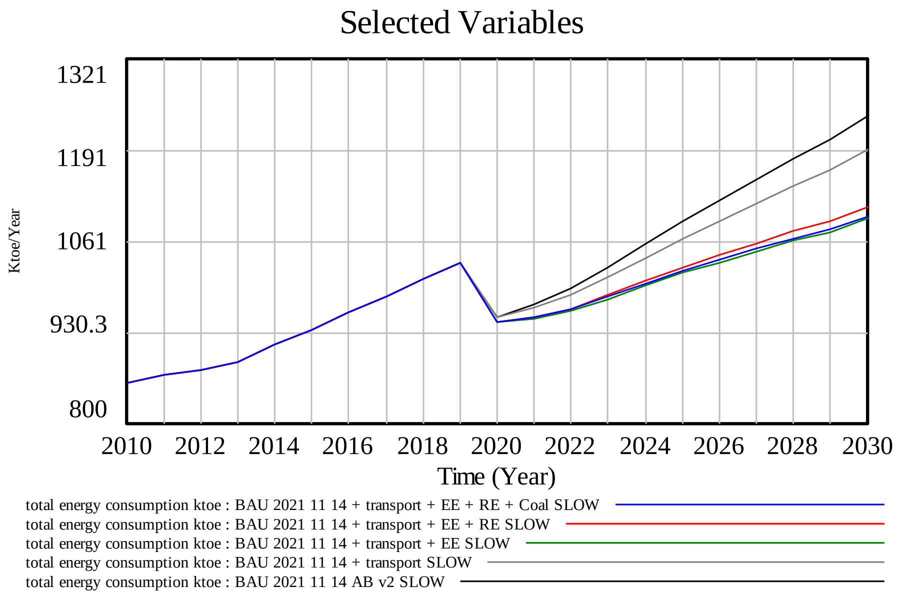

Figure 2. Total energy consumption for the various scenarios.

2.1.3.2. Electricity demand

Electricity demand is forecasted to reach 3,370 GWh in 2030 in the BAU scenario (**Figure 3**). Compared to 2020, energy demand in 2030 is forecasted to be 40.1% higher, indicating that electricity demand is expected to grow faster than other energy sources, at 3.4% per year between 2020 and 2030.

The introduction of energy efficiency, electrification of transport, expanded use of renewable energy for power generation and coal phase out investments result in Scenario 5 showing a reduction of only 1.4% in 2030, when compared to BAU. On the other hand, it should be considered that transport electrification results in an increase in electricity demand of 6.8% that is then fully countered by efficiency improvements. The annual growth rate of demand declines to 3.4% per year. Again, this limited reduction in electricity demand, when compared to the BAU scenario, is due to the effort for transport electrification, affecting 47,000 vehicles by 2030.

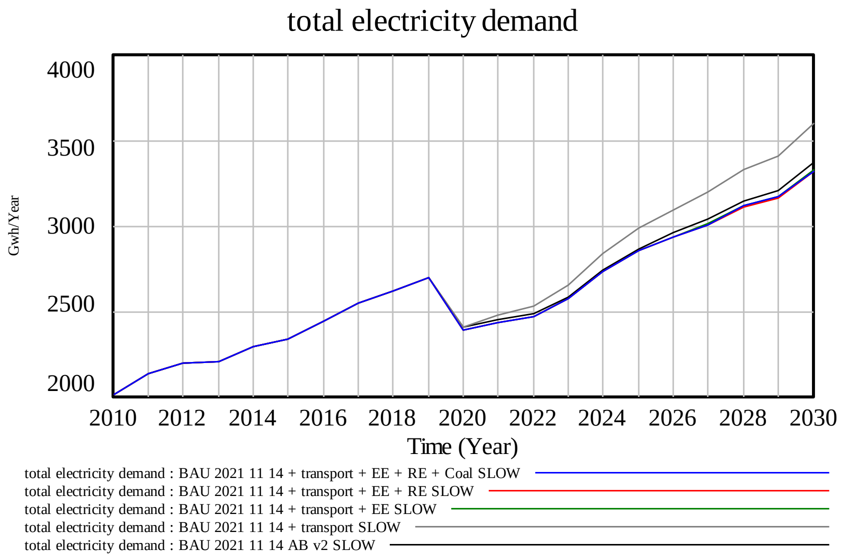

Figure 3. Total electricity consumption associated with the different scenarios.

2.1.3.3. Power generation

Following the trend of electricity demand, power generation is forecasted to reach 3,630 GWh in 2030 in the Scenario 5. This is 26.2% higher than in 2020, with an average annual growth rate of 2.4%.

The main change to power generation is the effort to expand the use of renewable energy, and the phase out of coal. The introduction of renewable energy results in 40% of power generation being from renewables in 2030. This percentage increases to 62.6% in 2030 when the coal phase out (replaced with biomass in co-generation) is considered (**Figure 4**).

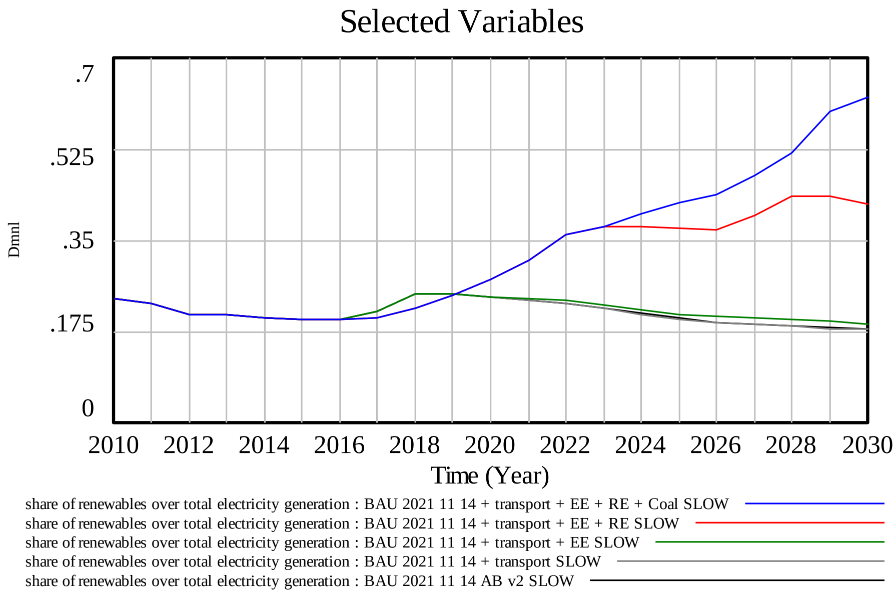

Figure 4. Share of renewable energy in total electricity generation for different scenarios.

2.1.3.4. GHG emissions

The decarbonization measures implemented in the energy sector contribute to significant reductions in GHG emissions as shown in **Figure 5**. By 2030, projections for Scenario 5 indicate a value of 2.88 million tons (Mt) of CO_2, compared to 5.13 $MtCO_2$ in the baseline scenario. The reduction, when comparing the two scenarios, is 44.0% in 2030. This reduction is obtained from renewable energy (21.3%), energy efficiency (6.2%), coal phase out (13.7%) and transport electrification (2.7%).

In the BAU scenario, energy emissions are projected to increase from around 3.94 Mt in 2020 to 4.43 Mt and 5.13 Mt by 2025 and 2030 respectively, with an average annual growth rate of 2.7% between 2020 and 2030. Emissions in Scenario 5 are instead forecasted to decline by 3.0% each year during the same period, and also record a 26.1% decline relative to 2020.

Emission from power generation shows a more marked decline (**Figure 6**). The reduction compared to BAU in Scenario 5 by 2030 is 68.1%, a 48.2% reduction when compared to 2020. The largest portion of the reduction is due to the expansion of renewable energy (58%), followed by the coal phase out (34%).

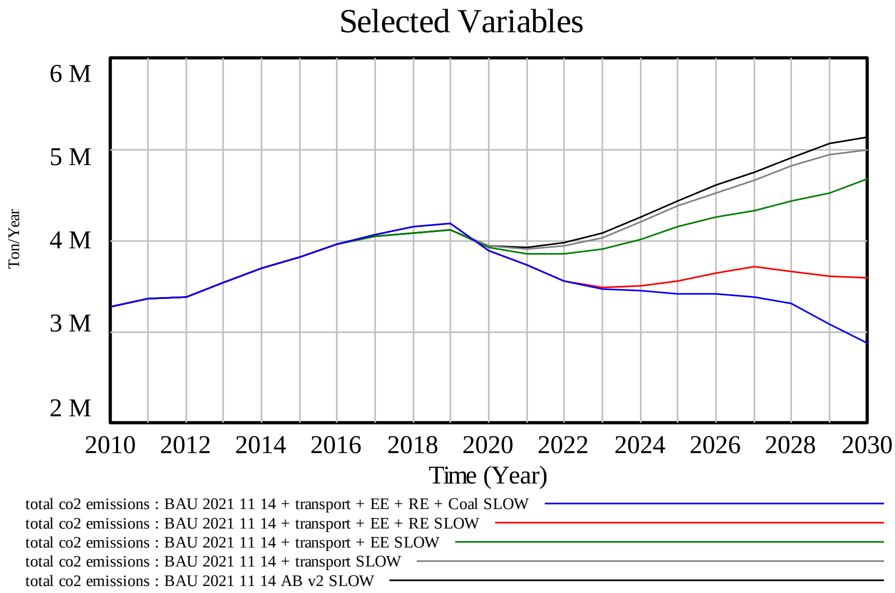

Figure 5. Total energy CO_2 emissions for various scenarios.

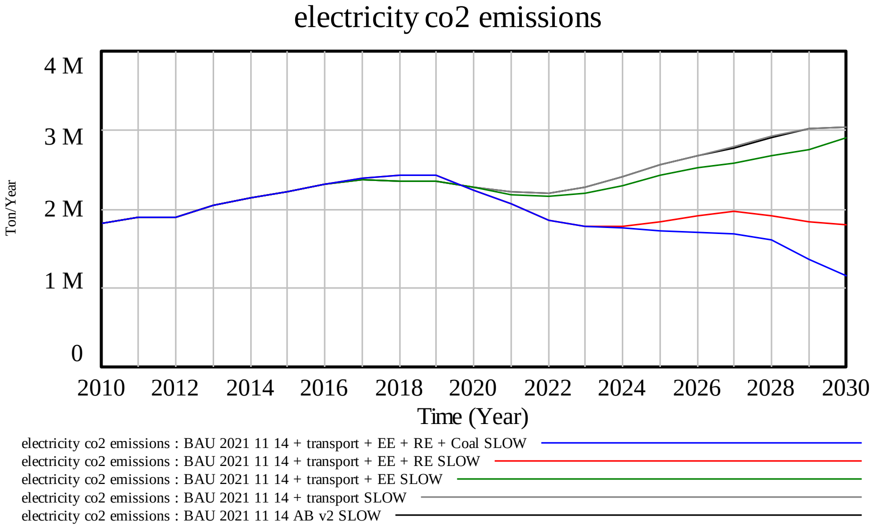

Figure 6. Total power generation CO_2 emissions for various scenarios.

Table 1 summarises the energy consumption, electricity demand and GHG emissions in relative terms for the five emissions pathways for the three post-2020 economic recovery conditions.

Table 1. Energy consumption, electricity demand and GHG emissions for different economic growth conditions.

	Energy consumption		**Electricity demand**		**CO_2 emissions**	
	2030 relative to 2020	**Relative to BAU**	**2030 relative to 2020**	**Relative to BAU**	**2030 relative to 2020**	**Relative to BAU**
Scenario group 2: medium growth						
Scenario 5: scenario 4 + coal phase-out	16.1%	-11.5%	39.2%	-1.4%	-26.1%	-44.0%
Scenario 4: scenario 3 + RE	17.4%	-10.4%	39.1%	-1.5%	-8.1%	-30.2%
Scenario 3: scenario 2 + energy efficiency	15.7%	-11.8%	39.4%	-1.3%	19.3%	-8.9%
Scenario 2: transport	25.2%	-3.8%	49.6%	6.8%	26.6%	-2.7%
Scenario 1: BAU	30.1%	0.0%	40.1%	0.0%	30.1%	0.0%
Scenario group 3: low growth						
Scenario 5: scenario 4 + coal phase-out	9.3%	-11.6%	33.9%	-1.1%	-30.0%	-45.7%
Scenario 4: scenario 3 + RE	10.5%	-10.6%	33.8%	-1.2%	-12.5%	-32.2%
Scenario 3: scenario 2 + energy efficiency	8.8%	-12.1%	34.1%	-1.0%	13.3%	-11.7%
Scenario 2: transport	17.8%	-4.0%	43.8%	7.1%	23.9%	-2.8%
Scenario 1: BAU	22.7%	0.0%	34.3%	0.0%	27.5%	0.0%
Scenario group 1: high growth						
Scenario 5: scenario 4 + coal phase-out	19.8%	-11.3%	41.5%	-1.5%	-23.7%	-43.0%
Scenario 4: scenario 3 + RE	21.1%	-10.3%	41.3%	-1.6%	-5.0%	-29.0%
Scenario 3: scenario 2 + energy efficiency	19.4%	-11.6%	41.7%	-1.4%	22.9%	-7.6%
Scenario 2: transport	29.1%	-3.7%	52.0%	6.7%	28.6%	-2.7%
Scenario 1: BAU	34.0%	0.0%	42.4%	0.0%	32.1%	0.0%

2.2 Land transport

2.2.1. Modelling approach

This sub-sector is the second largest emitter of GHGs in Mauritius, and it is virtually dependent on imported fossil fuels. The GHG emissions emanating from land transport arise from the combustion of three types of fuels, namely gasoline, diesel oil and LPG in motorised vehicles. The quantity of GHG emissions is not necessarily related to the number of vehicles. It is rather related to the distance that the vehicles travel in any particular year for functional purposes such as carrying passengers and freight. A parametric model has been developed as shown in **Figure 7**. The model is composed of two components:

i) **Passenger mobility** is measured in annual passenger-km travelled (PAX km/capita/year), which is parametrized with *Ysat* = 10 000 km/capita/yr, *k*=-4.27 X 10-4, and x = GDP (constant 1980 US$) per capita, and

ii) **Freight mobility** is measured in tonne of freight/goods km per capita, which is parametrised as a linear relationship to economic growth with a = 0.52, and b = 26.16.

The modelling process consists of four sequential steps, namely: (i) estimating total transport demands for passenger travel and freight transport; (ii) splitting of the passenger and freight transport according to modal share; (iii) calculating the quantities of fuels used by the different modes of transport; and (iv) determining the GHG emissions from the baseline situation and from low-carbon interventions. The details regarding model customization, including description of each of the four steps is available in the published literature.[14]

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[14] PNK Deenapanray, N Khadun (2021) Land transport greenhouse gas emission scenarios for Mauritius based on modelling transport demand, Interdisciplinary Perspectives in Transportation Research **9**, 100299.

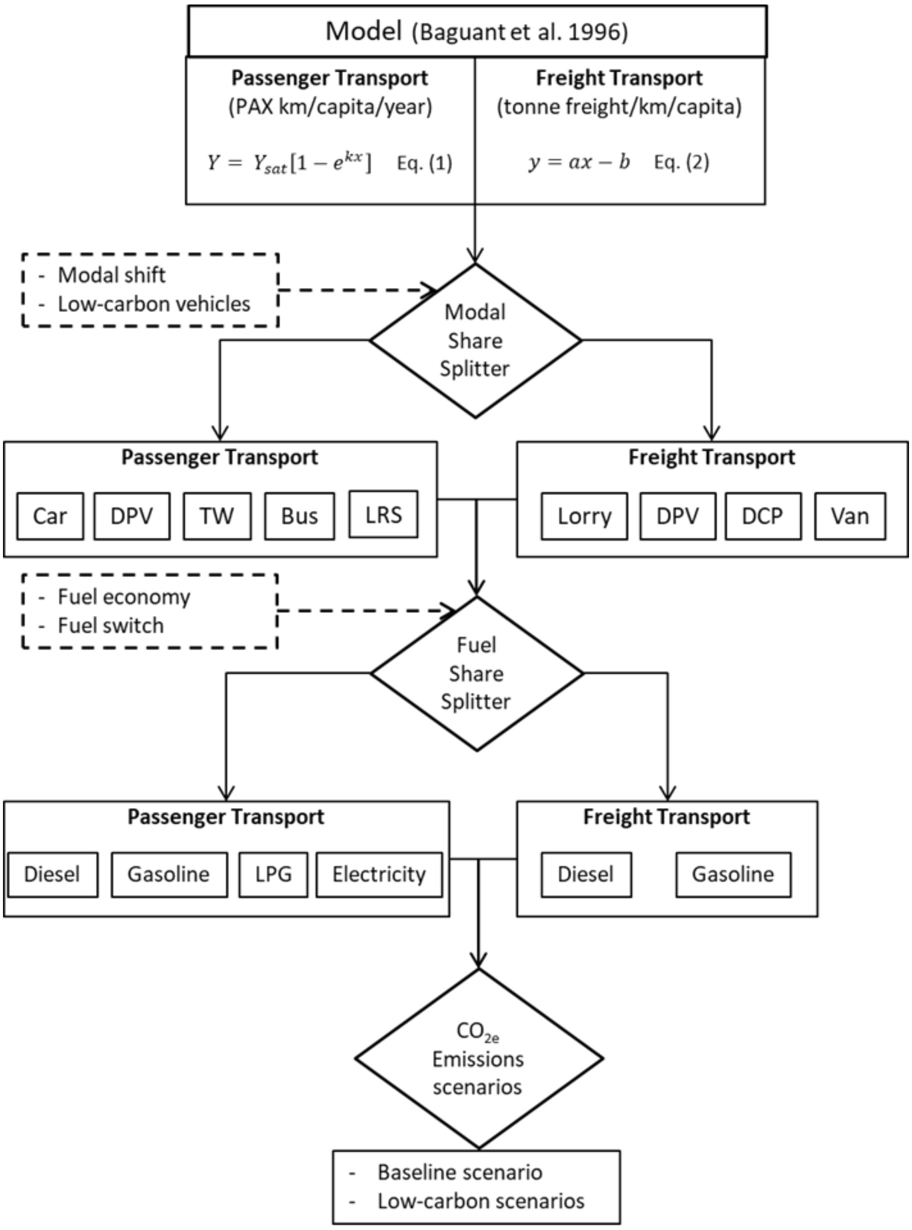

Figure 7. Schematic showing the approach used for land transport mitigation scenario analyses.

The two equations (**Figure 7**) were used to project annual passenger mobility and freight mobility to 2030 using a GDP growth rate of 3.8% per annum. The GDP growth rate for the period 2031 to 2050 is set at 3.0%, based on expert guidance received from stakeholders. The modelling adjusts for the structural break in travel demand in 2020 (down by 26% of expected value) due to the COVID-19 situation. It is assumed that land transport travel demand will be recovered up to 98% of its total value without COVID-19 in 2022.

The parameters used for modelling are given in Annex 1.

2.2.2. Definition of mitigation actions and scenarios

A total of five mitigation scenarios (

Table 2) were defined based on a combination of ongoing government policies or projects that seemed promising and practicable based on the expert judgements of the technical entities operating under the aegis of the Ministry of Land Transport and Light Rail (MOLTLR). The description of mitigation actions given in

Table 2 captures the propositions of stakeholders as well as government policy.

Table 2. Scenarios used for land transport mitigation analyses.

Scenarios	**Description of actions**
Scenario 1: Business as usual (BAU)	Projected travel demand and GHG emissions in the absence of mitigation scenarios described below.
Scenario 2: Vehicle fuel intensity improvements	Improvements in the fuel intensity of vehicles (applied to all vehicles) at the rate of 0.5% per year between 2022 and 2030, decreasing to 0.25% per year after 2030. This scenario was identified for two reasons, namely: (1) technological improvements would result in new vehicles having better fuel economies; and (2) investments in increasing the carrying capacity of road network. The decrease in efficiency gains is related to the rebound effect of a stimulation in passenger transport demand, result in traffic decongestion in the medium-to-long term.[15]
Scenario 3: Efficiency gains at peak travel times (TRMSU scenario)	The TRMSU has identified a number of measures that will help decongestion at peak hours in selected geographic areas. The bundle of actions, including the modeling parameters are given in Annex 2. All the measures were modelled except the one related to 'Telecommuting'.[16]
Scenario 4: A bundle of low-carbon options	A combination of two low-carbon transport technologies has been modelled:[17] i) hybrid cars; ii) electric cars. Hybrid and electric cars are expected to replace conventional gasoline-powered cars. The percentage annual increases of the share of hybrid and electric cars in the total passenger travel demand are listed below. Hybrid and electric cars accounted for 1.43% and 0%, respectively, of total passenger travel demand in 201. The travel demand used for the two technologies are listed in the table below.

Time period	Hybrid (%)	Electric (%)
2020	2.06	0
2025	4.46	1.5
2030	8.31	4.5
2035	13.31	8.25
2040	20.81	13.25
2045	30.81	19.5

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[15] The results in Deenapanray and Khadun (2021) have revealed the influence of the rebound effect. The parameters used are assumptions that are lower than were previously used in order not to overestimate GHG emission reductions. More research is required to quantity the rebound effect arising from efficiency gains in land transport.

[16] Travel demand management through telecommuting is expected to generate relatively high reductions in travel demand, and therefore in fossil fuel combustion. If not implemented, its inclusion in the mitigation analysis for Scenario 3 would give an overestimation of GHG emission reductions that would violate the Conservativeness Principle of carbon accounting.

[17] In Deenapanray and Khadun (2021) the bundle of low-carbon options includes the use of ethanol blends for gasoline-powered cars. This option has not been retained in the present analysis since it was not proposed by stakeholders.

<table>
<tr><td></td><td><table><tr><td>2050</td><td>43.31</td><td>27.0</td></tr></table></td></tr>
<tr><td>Scenario 5: Light Rail System (LRS)</td><td>The LRS is expected to generate model shift away from private cars and buses along the Curepipe – Port Louis corridor. Implementation of the LRS started in 2018 with a first tranche operational between Port Louis and Rose Hill at the end of December 2019. It is assumed that the Curepipe – Port Louis line will be fully operational by the end of 2022. The impact of the LRS on road transport GHG emissions has been modelled taking into account the reduction in car and bus annual distance travelled as follows:
2020: Cars - 109,540,000 km; Buses – 10,547,000 km;
2028: Cars - 107,204,000 km; Buses – 10,836,000 km;
2038: Cars - 115,300,000 km; Buses – 11,330,000 km;
The above data is not publicly available and was obtained by the NTA from the then Ministry of Public of Infrastructure and Land Transport. The above data were first converted into annual car and bus passenger travel demand using the passenger occupancy data given in Annex 1. These car and bus passenger travel demands were then subtracted from the baseline scenario representing a modal shift towards the LRS. The reductions have been kept constant at their 2038 levels for the period 2039 to 2050 because of the unavailability of data. Also, 90% of the reduction in car passenger transport is attributed to gasoline-fueled cars, and the remaining 10% to diesel-fueled cars.</td></tr>
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2.2.3. Results of mitigation scenario analyses

The scenario modelling results are shown in **Figure 8**. In all scenarios recovery of land transport demand is 90% of its expected value without COVID-19 in 2021. All the scenarios are measured against the BAU simulation that shows a monotonic increase. Fuel efficiency gains from Scenarios 1 and 2 are negligible. The penetration of hybrid and electric cars would generate the most GHG emission reductions, but the impacts are more pronounced in the medium-to-long term – i.e. post-2030. The amount of emission reductions produced by the mitigation scenarios, as well as the cumulative effect are summarised in **Table** 3. The reductions are not given for 2020 because of the masking effect of depressed travel demand and hence lower GHG emission due to the COVID-19 situation.

Table 3. Emission reductions relative to the BAU case, $GgCO_{2e}$ or $ktCO_{2e}$.

Reference	**2022**	**2030**	**2040**	**2050**
Scenario 2 – BAU	5.7	6.7	3.7	4.2
Scenario 3 – BAU	0.0	5.3	6.0	6.7
Scenario 4 – BAU	6.0	34.5	94.7	178.5
Scenario 5 – BAU	3.8	27.5	28.9	28.9
Cumulative effect	15.5	74.0	133.3	218.3

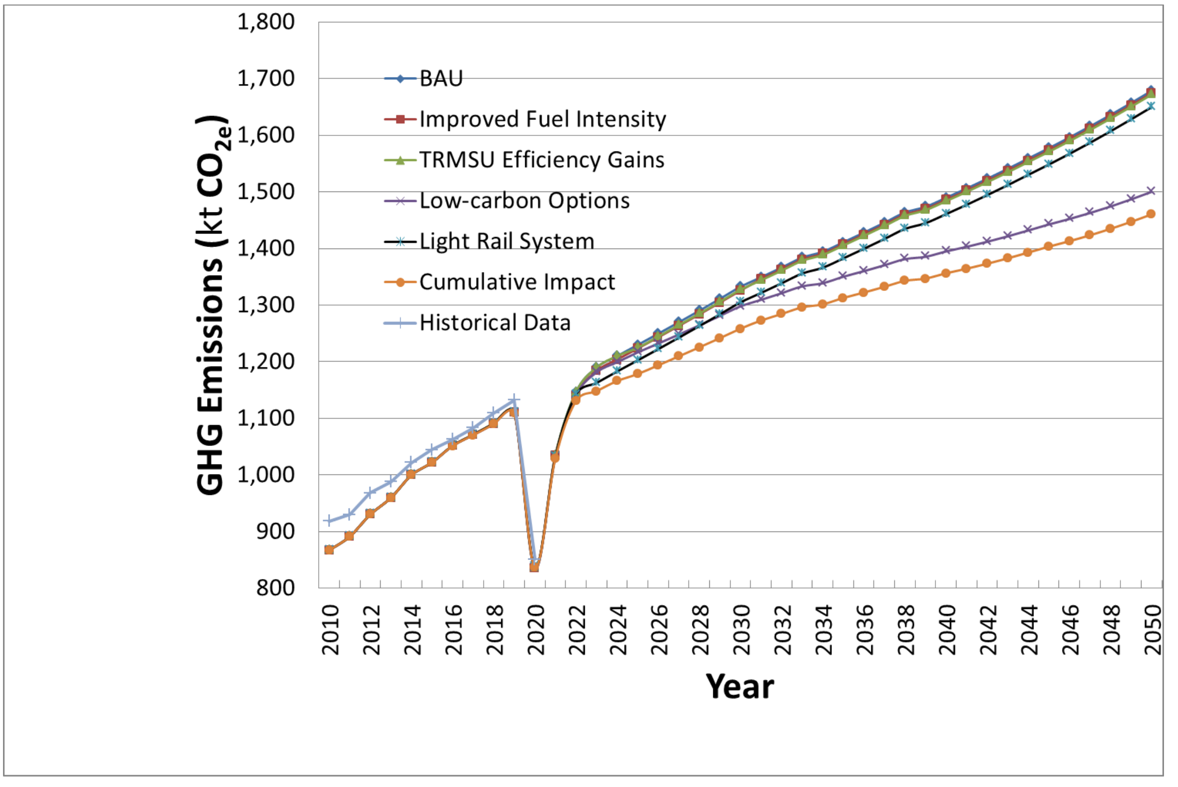

Figure 8. Mitigation scenarios for land transport.

3.0 Mitigation assessment for waste management

This section describes the methods and assumptions that have been used to carry out the mitigation analyses for waste management. It covers the management of solid waste and waste water. The treatment of livestock waste is analysed in the Section 4 on agriculture. Methane emissions are the largest for the solid waste sub-sector.

3.1. Solid waste management

3.1.1. Modelling approach

Emissions from municipal solid waste (MSW) have been modelled by simulating the calculations given in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.[18] Compared to the National Inventory Report (NIR) produced under the TNC, the inventory for GHG emissions from solid waste in the BUR has seen a decrease by around a factor 3. In order to align the mitigation analyses described below with historical data produced in the BUR, all model parameters have been aligned with those used in the BUR up to 2020. For post-2020 analyses, solid waste parameters (e.g. breakdown of solid waste by waste type, degradable organic content (DOC) of waste) provided by the Solid Waste Management Division (SWMD), MOESWMCC were used.[19] The difference between the NIR-TNC and BUR values for solid waste emissions arose mainly due to changes in the values of DOC. The BUR-aligned values are given in **Table** 4.

Table 4. Values of DOC used in mitigation analyses.

Waste type	Food	Garden	Paper	Wood	Textiles	Nappies	Sludge	Industrial
DOC	0.15	0.2	0.4	0.43	0.24	0.24	0.05	0.15

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[18] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf - accessed 18 January 2022.

[19] Selected results of the National Solid Waste Characterisation Study in Mauritius provided by Dr Zumar Bundoo, SWMD.

k (1/yr)	0.4	0.17	0.07	0.035	0.07	0.17	0.4	0.17

Source: BUR inventory – IPCC software

3.1.2. Definition of mitigation actions and scenarios

Five scenarios have been developed for solid waste management as described below:

- Scenario 1: The BAU situation assumes that landfilling and recycling of solid waste will continue and the same pace as it was in 2020. The quantity of waste is assumed to grow at 1.82% per year, which is the projected rate of waste generation assumed by the SWMD to 2030. The same rate of growth is used for the post-2030 timeline;

  The data used for the BAU scenario are given in **Table 5**.

  Table 5. Data used for BAU scenario.

Year	Solid wastes landfilled (tonnes)	Solid wastes composted (tonnes)	Solid wastes recycled (tonnes)	Total solid wastes generated (tonnes)
2010	427802	0	0	427802
2011	414543	5154	0	419697
2012	387926	34785	0	422711
2013	429935	19257	15671	464863
2014	417478	41032	16454	474964
2015	448476	37979	17277	503732
2016	444695	38308	18141	501144
2017	482196	14533	19048	515777
2018	543196	0	20000	563196
2019	537147	0	21000	558147
2020	509085	0	22050	531135
2021	580924	0	23153	604077
2022	598352	0	24130	622482
2023	604335	0	25525	629860
2024	610379	0	26801	637180
2025	616482	0	28142	644624
2026	622647	0	29549	652196
2027	628874	0	31026	659900
2028	635163	0	32577	667740
2029	641514	0	34206	675720
2030	647930	0	35917	683847

  Source: SWMD

- Scenario 2: Increase in the quantity of solid waste that is composted or anaerobically digested as shown in **Table 6**. For modelling purposes, it was assumed that solid waste diverted from the landfill will be comprised of 50% garden waste and 50% food waste.[20]

- Scenario 3: Increase in the quantity of waste that is recycled above the baseline value of 4% as shown in **Table 6**. A mass balance exercise was used to allocate different types of waste for recycling using latest breakdown of recycled waste for 2019/2020.[21] The recycling of inerts was not taken into account in the calculation of avoided methane at landfill.

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[20] This assumption was arrived following discussions with the SWMD in order to keep recyclable and compost waste mutually exclusive (from a mass balance perspective). For instance, paper/carton and textiles wastes can be composted but would rather be recycled.

[21] It is assumed that 38% of paper and 16% of textiles wastes will be recycled.

- Scenario 4: This scenario includes the diversion of 20% of total solid wastes for a waste-to-energy (WTE) project in 2030. For the purposes of calculating avoided methane at landfill, a mass balance exercise was carried out to caculate the amount of organic waste that would be used for WTE. Over and above plastic waste, 3.35 Gg of paper waste and 2.14 Gg of wood waste are assumed from be diverted from landfilling.

Table 6. Pathways for low-carbon solid waste management (% waste).

Year	Solid wastes landfilled (%)	Solid wastes composted/ anaerobically digested (%)	Solid wastes recycled (%)	Solid wastes incinerated (%)
2020	96	0	4	0
2021	96	0	4	0
2022	96	0	4	0
2023	96	0	4	0
2024	83	10	7	0
2025	67	20	13	0
2026	58	25	17	0
2027	54	27	19	0
2028	49	30	21	0
2029	47	31	22	0
2030	27	31	22	20

Source: SWMD

- Scenario 5: Although this is not part of the overall solid waste management strategy that is captured in **Table 6**, enhancing the capture of landfill gas could be contemplated as a mitigation action.[22] The model has been developed to run this scenario as well. However, the post-2020 enhancements in LFG capture are not validated, and hence not reported here.

3.1.3. Results of mitigation scenario analyses

The results of the mitigation scenario analyses are shown in **Figure 9**. Scenario 5 (Enhanced Landfill Gas Capture) is not discussed here. The post-2020 enhancements in LFG capture used in the model are not validated. More discussions with concerned stakeholders will be required for this.

All else being equal, the BAU scenario exhibits a monotonically increasing trend in emissions. For the post-2030 mitigation scenarios, the percentage allocation of wastes given in **Table 6** is frozen at the 2030 values.

Table 7. Summary of emission reductions relative to BAU scenario, ktCO$_{2e}$.

Reference	2020	2030	2040	2050
Scenario 2 – BAU	0.0	36.25	62.62	73.71
Scenario 3 – BAU	0.0	5.80	16.66	23.79
Scenario 4 – BAU	0.0	0.0	3.27	6.33
Cumulative effect	0.0	42.05	82.55	103.83

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[22] B Purmessur and D Surroop (2019) Power generation using landfill gas from new cell at existing landfill, Journal of Environmental Chemical Engineering 7: 103060.

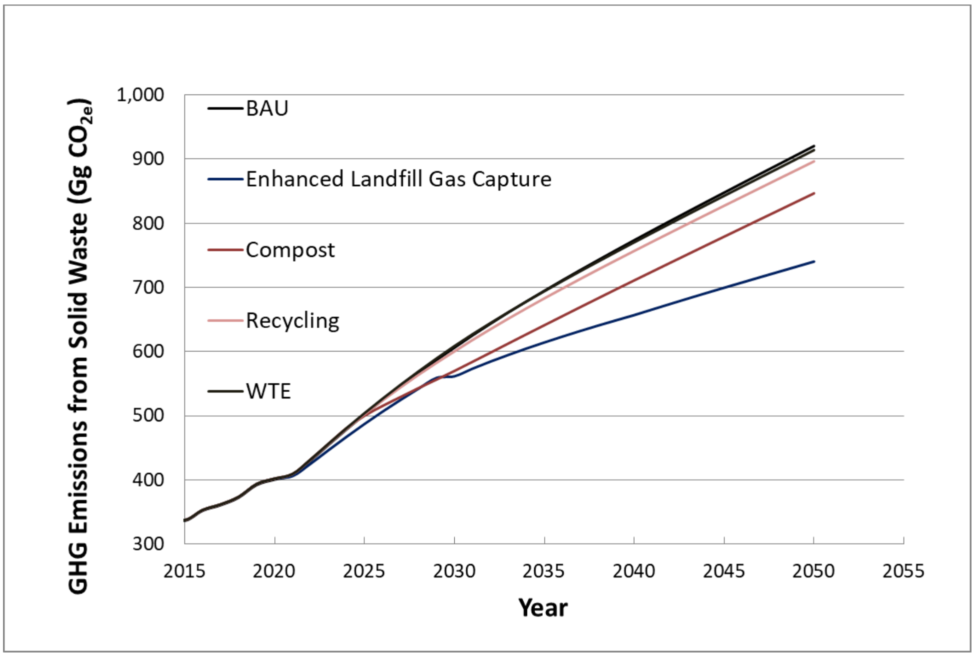

Figure 9. GHG emission scenarios for solid waste management.

3.2. Waste water management

3.1.1. Modelling approach

Emissions from waste water management have been modelled by simulating the calculations given in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.[23] All model parameters and data were obtained from the Wastewater Management Authority (WMA). The modelling approach adopted waste water treatment from sewer and non-sewer technologies (septic tank, latrine and adsorption pit). The total population was allocated to these four technologies. Data regarding the capture of methane from anaerobic treatment of waste water was also provided by WMA. The methane emission factors for four treatment methods are given in **Table 8**. The utilisation of the four treatment technologies differed between the scenarios discussed below.

Table 8. Emission factor of waste water treatment methods.

Treatment method	Anaerobic digester for sludge	Septic system	Latrine	Centralized aerobic system
Emission factor, $kgCH_4/kgBOD$	0.48	0.3	0.06	0

Data for protein intake was obtained from a recent study.[24] The daily protein saturates at 105 g/person/day in 2029 as is reflective of saturation in high income countries. With a total per capita daily protein intake value of 87.1 g/person/day in 2019,[25] linear interpolation has been used to obtain anual protein intake between 2020 and 2028.

3.1.2. Definition of mitigation actions and scenarios

For this sub-sector, two scenarios have been produced as described below.

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[23] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf - accessed 20 November 2021 .

[24] OECD & FAO (2020) OECD-FAO Agricultural Outlook 2020-2029.

[25] https://knoema.com/atlas/Mauritius/topics/Agriculture/Food-Supply-Protein-Supply-gcapitaday/Total-protein-supply - accessed 18 February 2022.

- Scenario 1: The BAU scenario assumes sewer connectivity to continue at the same relatively low pace as witnessed over the past 3-4 years – i.e. ~2,000 households per year. The penetration levels of the four waste wáter treatment technologies is listed in **Table 9**. For lack of visibility after 2030, the technology utilisation levels are frozen at their 2030 values.

Table 9. BAU scenario level of utilisation of four waste water treatment technologies.

Technology	2020	2030	2040	2050
Anaerobic digester	0.02	0.01	0.01	0.01
Septic system	0.94	0.97	0.97	0.97
Latrine	0.03	0.01	0.01	0.01
Aerobic system	0.01	0.01	0.01	0.01

- Scenario 2: This scenario assumes that the level of sewer connectivity that is contingent on large infrastructure investments would remain the same as in the BAU scenario. In this case, the level of utilisation of the four treatment methods would gradually shift towards the lower emission technologies as listed in **Table 10**.

  While the shift towards anearobic digerster of sludge removed and centralised aerobic system has been agreed for mitigation scenario analyses, their exact levels of utilisation remains to be validated. Nevertheless, the utilisation levels used for 2025 are relatively conservative and reflective of discussions that have taken place with the WMA todate.[26]

Table 10. Mitigation scenario level of utilisation of waste water treatment technologies.

Technology	2020	2025	2030	2040	2050
Anaerobic digester	0.02	0.03	0.035	0.06	0.135
Septic system	0.94	0.93	0.92	0.9	0.8
Latrine	0.03	0.02	0.015	0.005	0
Aerobic system	0.01	0.02	0.03	0.035	0.065

3.1.3. Results of mitigation scenario analyses

The results of the scenario modelling are shown in **Figure 10**. Because the emission factor for centralised aerobic system is zero, it has the largest effect on reducing GHG emissions. Based on the utilisation values given in **Table 10**, emission reductions are marginal in 2025 (2.5 $ktCO_{2e}$) and reaching 5.9 $ktCO_{2e}$ in 2030. For all practical purposes – i.e. compared to energy sector and solid waste sub-sector emission reductions, such decreases are not significant.

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[26] The utilisation levels reflect a number of projects that are in the pipeline and that would materialise before 2025.

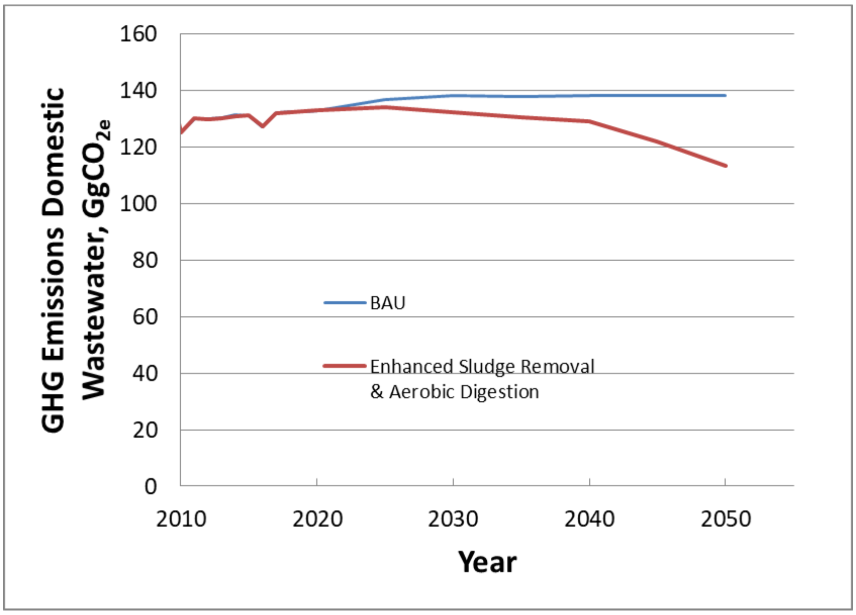

Figure 10. Mitigation scenario analyses for waste water management.

4.0. Mitigation assessment for agriculture and forestry

This section describes the methods and assumptions that have been used to carry out the mitigation analyses for the AFOLU sector. It covers the emissions from the production of crops (sugar and non-sugar), as well as emissions arising from the management of livestock and manure. The agriculture (crops and livestock) is the smallest emissions sub-sector. Scenarios for the enhancement of sinks through afforestation and tree planting are also assessed.

4.1. Agriculture – food crops

4.1.1. Modelling approach

The model for assessing GHG emission reduction scenarios in agriculture has followed the calculations used in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for cropland.[27] Historical emissions have been aligned with the BUR inventory.

4.1.2. Definition of mitigation actions and scenarios

While the process of updating the Strategic Plan 2016 – 2020[28] is ongoing, the approach used in to model mitigation scenarios in agriculture is the continuation of the broad orientations of the existing Strategic Plan. Therefore, the scenarios are the same as those defined in the TNC but with updated trajectories. They are defined as follows:

- Scenario 1: The BAU scenario has been taken as the situation of no implementation of the policies, strategies and actions proposed in the Strategic Plan 2016 – 2020. In this scenario, it is assumed that chemical fertiliser use increases at 2% per year after 2020.

- Scenario 2: There is ongoing effort to decrease sugar cane field burning. The targets are to decrease from 9% of total area cultivated in 2020 to 8% in 2025; 7% in 2035; 6% in 2040; and to 5% in 2050.
- Scenario 3: This scenario consists of reducing chemical inputs in crop production. It is assumed that the reduction starts in 2021 by 1% absolute per year until 2030. At this rate of decrease,

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[27] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_05_Ch5_Cropland.pdf - accessed 18 February 2022.
[28] Ministry of Agro-Industry and Food Security (2016) Strategic Plan 2016 – 2020 for the Food Crop, Livestock and Forestry Sectors.

chemical inputs reach 90% of the value in 2020. Thereafter, the decrease is 5% every 5 years with chemical inputs reaching 80% and 70% of the 2020 value in 2040 and 2050, respectively. This scenario is shown by the curve in dark red, and accounts for direct N_2O emission only.

- Scenario 4: In a biofarming scheme, it is unlikely that the use of chemical fertilizers will be reduced without any substitution. This scenario has been developed for investigating the co-use of compost produced from MSW in food crop cultivation. The amount of compost that is utilised as substitute to chemical inputs is shown in **Table 11**.

Table 11. Amount of compost generated from MSW, Gg.

Year	2024	2025	2026	2027	2028	2029	2030	2035	2040	2045	2050
Compost	2.95	5.98	7.56	8.26	9.29	9.71	9.83	10.42	11.05	11.72	12.43

4.1.3. Results of mitigation scenario analyses

The results of scenario analyses for the crop sub-sector are shown in **Figure 11**. As expected the reduction in the use of chemical fertilisers would produce the largest reductions in GHGs, whereas reducing field burning yields marginal decrease in emissions. Adding compost as a substitute for chemical fertilisers as from 2024 results in a slight increase in emissions. This scenario (lighter blue curve) increases emissions relative to Scenario 3 due to the release of N_2O from the compost. Scenario 4 also includes the increase in manure applied to soil with increasing livestock heads to enhance food security under the policy option. The curve shows the combined effect of reduced use of chemical fertilizers and use of compost, including the calculation of both direct and indirect N_2O emissions.

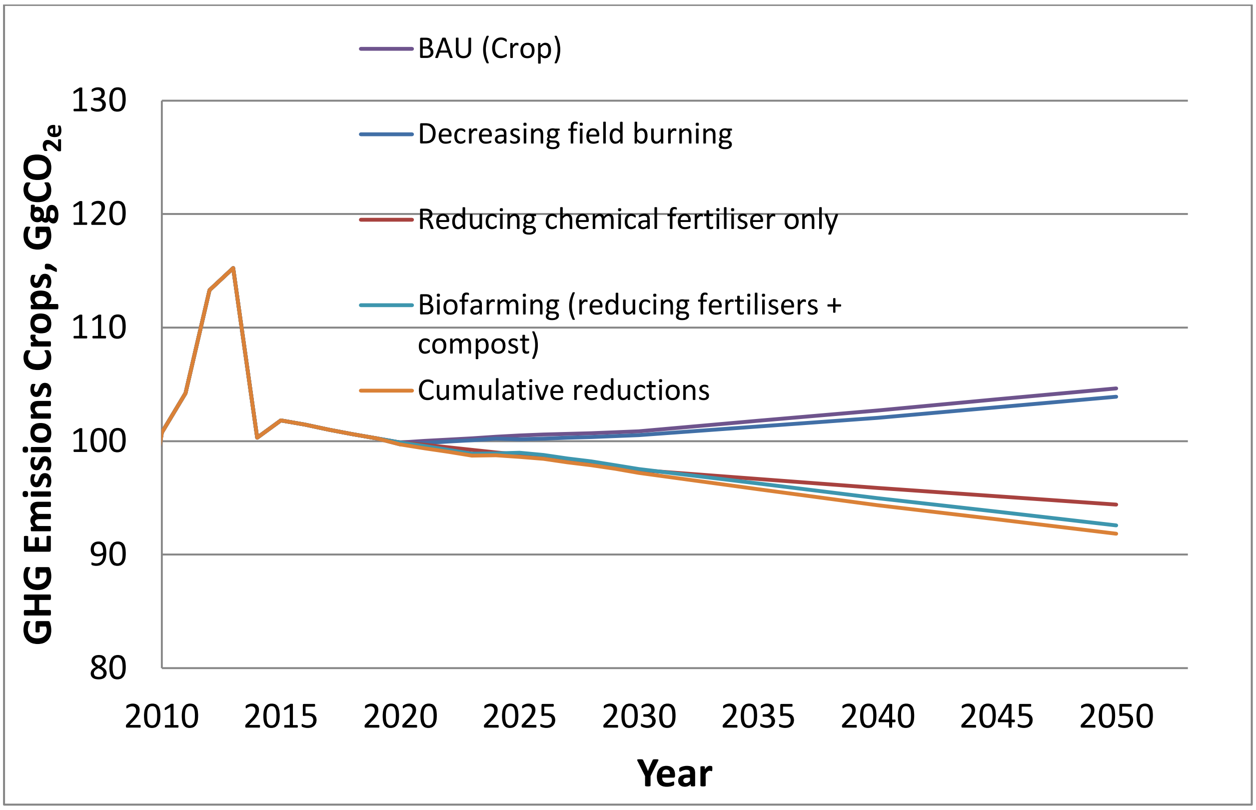

Figure 11. Mitigation scenarios for crops.

The GHG emissions from the different scenarios relative to the BAU is summarised in **Table 12**. As it can be seen, the total GHG emissions in 2030 is only 3 $GgCO_{2e}$ that would increase by a factor of 2.7 by 2050.

Table 12. Summary of GHG emissions reductions relative to the BAU case, $GgCO_{2e}$.

Reference	2020	2030	2040	2050
Scenario 2 – BAU	0.0	0.33	0.63	0.74
Scenario 3 – BAU	0.0	3.42	6.83	10.25
Scenario 4 – Scenario 3	0.0	(0.75)	(1.82)	(2.88)
Cumulative effect	0.0	3.0	5.64	8.11

4.2. Agriculture – livestock

4.2.1. Modelling approach

The model for assessing GHG emission reduction scenarios in agriculture has followed the calculations used in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for livestock and manure management.[29]

4.2.2. Definition of mitigation actions and scenarios

The modelling has considered two main scenarios as described below.

- Scenario 1: The BAU scenenario uses the livestock head counts given in
- **Table** 13. The data for 2015 and 2020 are as provided by the livestock section of FAREI. A quasi-stagnating livestock sector is assumed after 2020. The model assumes that the technological options used for livestock manure management remains unchanged from that used in 2015 (i.e. old technology) up to 2050.

Table 13. Livestock heads used in BAU scenario: 2015 - 2050.

Livestock	2015	2020	2025	2030	2035	2040	2045	2050
Cow	1,997	1,300	2,000	2,400	2,400	2,400	2,425	2,450
Other cattle	3,901	1,888	1,900	2,100	2,300	2,500	2,750	3,000
Imported beef	7,529	6,311	6,500	6,600	6,700	6,800	6,900	7,000
Goat	26,809	25,165	25,500	25,000	25,000	25,000	24,900	24,800
Sheep	2,752	4,626	5,000	4,000	4,500	4,500	4,500	4,500
Broiler	5,258,667	5,700,000	5,700,000	5,800,000	5,950,000	6,100,000	6,300,000	6,500,000
layer	699,323	785,000	685,000	690,000	710,000	725,000	737,500	750,000
Duck	18,945	18,945	19,500	20,000	21,000	22,000	22,000	22,000
Pig	21,964	20,679	22,000	22,500	22,750	23,000	24,000	25,000
Deer	8,000	8,000	8,500	8,500	8,500	8,500	8,500	8,500

Source: Data for 2015 and 2020 obtained from FAREI

- Scenario 2: A policy scenario that has objective to increase food security is modelled using the livestock head counts given in **Table 14**. Data to 2030 were provided by the livestock section of FAREI and post-2030 values are extrapolations using changes between 2020 and 2030, with the increase in number of livestock heads decreasing between 2040 and 2050. The manure management technology was kept constant at the 2015 values given in **Table 15** over the entire modelling period

Table 14. Livestock heapds used in policy scenario: 2015 - 2050.

Livestock	2015	2020	2025	2030	2035	2040	2045	2050
Cow	1,997	1,300	1,659	2,117	2,517	2,767	3,067	3,317
Other cattle	3,901	1,888	2,409	3,075	3,675	4,275	4,775	5,275

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[29] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_10_Ch10_Livestock.pdf - accessed 18 February 2022.

Imported beef	7,529	6,311	6,587	6,559	6,529	6,499	6,469	6,439
Goat	26,809	25,165	27,600	28,600	29,400	30,000	30,400	30,600
Sheep	2,752	4,626	5,800	6,500	7,000	7,200	7,400	7,550
Broiler	5,258,667	5,700,000	6,300,000	7,500,000	8,000,000	8,500,000	9,000,000	9,000,000
layer	699,323	785,000	820,000	890,000	940,000	990,000	1,040,000	1,040,000
Duck	18,945	18,945	33,000	48,000	60,000	70,000	77,000	80,000
Pig	21,964	20,679	26,000	29,500	32,500	34,000	34,500	35,000
Deer	8,000	8,000	8,500	9,000	9,500	10,000	10,000	10,000

Source: Data for 2015, 2020 and 2025 obtained from FAREI

The policy scenario is run for two cases, namely: (i) freezing manure manegement practices using technologies that existed in 2015, or (ii) new technologies used for the management of manure produced by dairy cows, other cattle and pig husbandry. The manure management technologies are solid storage, aerobic digestion and anaerobic digestion, and their utilisation levels are given in **Table 15**.

Table 15. Technology options for manure management: 2015 - 2050.

	2015	2020	2025	2030	2035	2040	2045	2050
Dairy cow								
Solid storage	0.97	0.9	0.86	0.83	0.76	0.7	0.6	0.49
Aerobic digestions	0.01	0.03	0.05	0.07	0.1	0.13	0.18	0.24
Anaerobic digestion	0	0.05	0.07	0.08	0.12	0.15	0.2	0.25
Other cattle								
Solid storage	0.97	0.9	0.86	0.83	0.76	0.7	0.6	0.49
Aerobic digestions	0.01	0.03	0.05	0.07	0.1	0.13	0.18	0.24
Anaerobic digestion	0	0.05	0.07	0.08	0.12	0.15	0.2	0.25
Pig								
Solid storage	0.5	0.4	0.4	0.4	0.2	-	-	-
Aerobic digestions	0.25	0.3	0.3	0.3	0.35	0.4	0.32	0.25
Anaerobic digestion	0.25	0.3	0.3	0.3	0.45	0.6	0.68	0.75

Source: As used in the TNC (FAREI)

4.2.3. Results of mitigation scenario analyses

The results of mitigation analyses are given in **Figure 12**. Both GHG emissions and emission reductions (with adoption of lower-carbon manure management technologies) are very small in this sub-sector. It is also the sector that exhibits policy-induced increase in total emissions. The BAU scenario reflects a quasi-stagnant sub-sector with emissions increase marginally from 28.6 $GgCO_{2e}$ (or $ktCO_{2e}$) in 2020 to 30.6 $GgCO_{2e}$. The policy scenario (Scenario 2) that is geared towards increasing local production to enhance food security results in an increase in emissions to 35 $GgCO_{2e}$ in 2030 and 41.4 $GgCO_{2e}$ in 2050 with no evolution in lower-carbon manure management technologies. With the adoption of lower-carbon manure management technologies given in **Table 15**, emission in 2030 is virtually unchanged and it is marginally lower at 39.9 $GgCO_{2e}$ in 2050. **Figure 12** also shows that a significant contributor to the increase in emissions in the policy scenario is enteric emissions.[30]

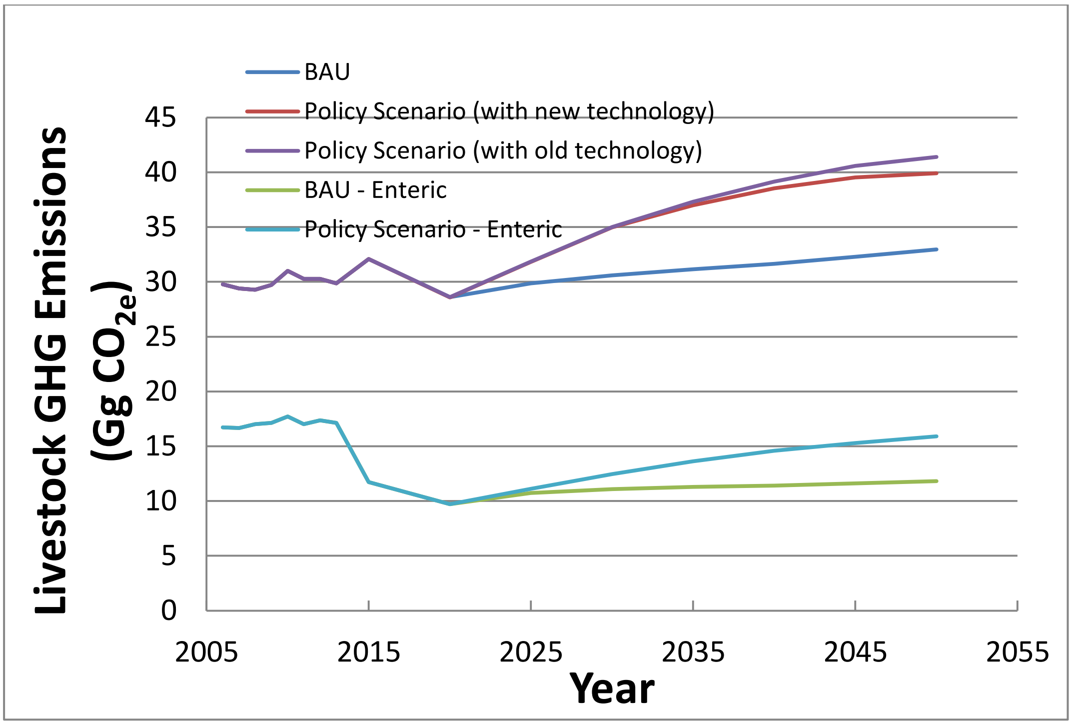

Figure 12. Mitigation scenarios for livestock and manure management.

4.3. Forestry (sinks)

4.3.1. Modelling approach

The model for assessing GHG emission reduction scenarios in agriculture has followed the calculations used in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for forest land.[31]

4.3.2. Definition of mitigation actions and scenarios

While the process of updating the Strategic Plan 2016 – 2020[32] is ongoing, the approach used in to model mitigation scenarios for forestry is the continuation of the broad orientations of the existing Strategic Plan. Therefore, the scenarios are the same as those defined in the TNC but with updated trajectorie. They are defined as follows:

- Scenario 1: The BAU scenario has been taken as the situation of no implementation of the policies, strategies and actions proposed in the Strategic Plan 2016 – 2020. The parameters used for the BAU scenario are given in **Table 16**.

Table 16. Selected parameters used to model the forestry BAU scenario.

	2015	2020	2030	2040	2050
Mangrove forest (ha)	159.4	160.1	160.1	160.1	160.1

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[30] This suggests the scope for managing livestock methane emissions through a combination of adopting species that produce less such emissions and changes in livestock feed.

[31] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_04_Ch4_Forest_Land.pdf - accessed 18 February 2022.

[32] Ministry of Agro-Industry and Food Security (2016) Strategic Plan 2016 – 2020 for the Food Crop, Livestock and Forestry Sectors.

Wood removal (m^3/year)	DLL Eucalyptus	528	478	300	200	100
	WUL pine>20 yr	708	650	550	300	100
Fuelwood removal (m^3/year)	DLL Eucalyptus	1,769	1,204	557	400	100
	WUL pine>20 yr	1,587	1,125	565	350	100

Source: Forestry Services, Ministry of Agro-Industry and Food Security; Digest of Environment Statistics 2019

- Scenario 2: This is the policy scenario arising from the implementation of the Strategic Plan. The tree planting scenario is given in **Table 17**. It includes the government strategy to plan 600,000 over a period of 7 years along the M1/M2 motorways. It is estimated that around 40% of the plants will be of woody biomass that will be effective carbon stocks. It is also assumed that planting will take place between 2022 and 2028. Another assumption is that no new trees were planted in 2021.

Table 17. Parameters used for tree planting scenario.

Parameters	2016	2017	2018	2019	2020	2021	2022 – 2028 (annually)
Area planted (ha)	25	35	51	37	20	0	35
Approximate number of trees	30,100	38,500	56,100	40,700	22,000	0	38,500
Ratio of native to exotic trees	1.17	1.25	1.50	1.75	2	N/A	2

Sources: Forestry Services; Ministry of Environment, Solid Waste Management and Climate Change

- Scenario 3: The scenario consists of investigating the impact of afforesting 1,750 ha of abandoned sugar cane land. It is assumed that all of the 1,750 ha of land is available in the agro-ecological zone of Dry Lowland (DLL). Although there is no formal policy to carry out this scenario, it is added in the analysis as an indicative measure for increase carbon sinks in Mauritius (against a quasi-stagnating baseline). The parameters used for modelling this scenario are given in **Table 18**. The ratio of native species to exotic species is assumed to be 1:1.

Table 18. Parameters used for the afforestation of abandoned sugar cane land.

Time period	Area planted with native tree species (ha/yr)	Area planted with exotic trees (ha/yr)		
		Araucaria	Eucalyptus	Tabebuia
2021-2025	5	1.25	2.5	1.25
2026-2030	20	5	10	5
2031-2035	30	7.5	15	7.5
2036-2040	35	8.75	17.5	8.75
2041-2045	40	10	20	10
2046-2050	45	11.25	22.5	11.25

Source: TNC (area afforested decreased from 5,000 ha to 1,750 ha)

4.3.3. Results of mitigation scenario analyses

Figure 13 shows the results of the three scenarios. The BAU scenario shows marginally increasing carbon stocks for a constant area of forest and crop land. The increase in carbon sink for the Scenario 2 and Scenario 3 relative to the BAU case is given in **Table 19**.

Table 19. Increase in carbon sequestration, $GgCO_{2e}$.

Scenario	2020	2030	2040	2050

Tree planting	-	4.34	4.44	4.68
Afforestation	-	5.20	14.66	27.13

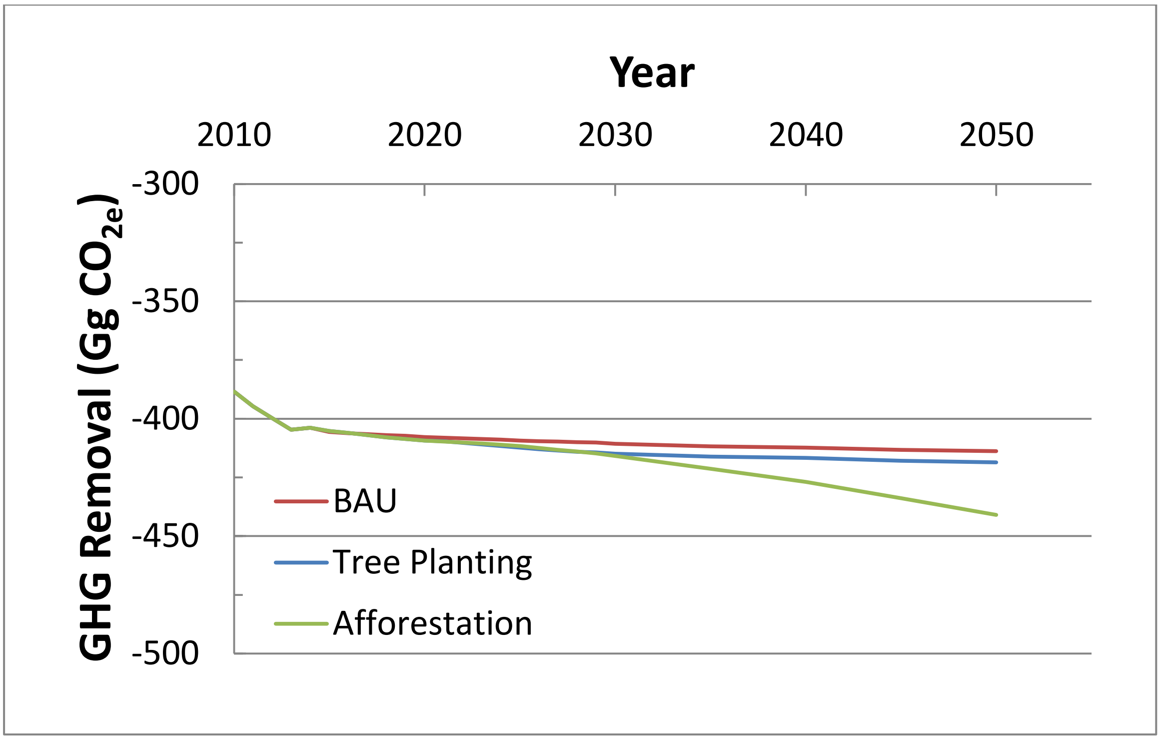

Figure 13. GHG emissions scenarios for forestry.

5.0 Industrial Processes and Product Use (IPPU)

In the NIR-TNC the IPPU sector accounted for less than 1% of national emissions.[33] Provisional IPPU emissions were reported as 48.77 GgCO_{2e} and 51.21 GgCO_{2e} for 2019 and 2020, respectively – i.e. 0.8% and 1% of total emissions, respectively.[34] Hydrofluorocarbons (HFCs) provisionally amounted to 12.05 GgCO_{2e} and 14.76 GgCO_{2e} in 2019 and 2020, respectively. In this sector, CO_2 emissions arise from iron & steel production and lime production. The BUR has revealed a significant increase in IPPU emissions with emissions increasing from 2000 to 2016 (the last inventory year).[35] For this sector, the BUR notes, in contrast to the NIR-TNC, that the most significant emissions category is the Product Use as Substitutes of Ozone Depleting Substances (ODS), represented by stationary refrigerant and air conditioning (RAC) and mobile air conditioning. IPPU-related GHG emissions increased from 70.32 GgCO_{2e} in 2000 311.18 GgCO_{2e} in 2016. Refrigerants used as substitutes for ODS accounted for 90.7% (282.10 GgCO_{2e}) of the total IPPU GHG emissions in 2016. In 2016, the IPPU sector accounted for ~6% of total emissions (excluding LULUCF).

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[33] Republic of Mauritius (2016). Third National Communication: Report to the United Nations Framework Convention on Climate Change. Republic of Mauritius, Port Louis.

[34] Statistics Mauritius (2021) Environmental Statistics 2020.

[35] Republic of Mauritius (2021) National Inventory Report (NIR) to the United Nations Framework Convention on Climate Change, Ministry of Environment, Solid Waste Management and Climate Change, Port Louis.

At the start of the NAMA project, the IPPU sector was not a priority based on results published in the NIR-TNC. Following the NIR-BUR results, it has been added to the suite of NAMA mitigation analyses with focus on the RAC category.

5.1. Modelling approach

The model for assessing GHG emission reduction scenarios in agriculture has followed the calculations used in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories for emissions of fluorinated substitutes for ODS.[36] The baseline analysis is aligned with NIR-BUR.

5.2. Definition of mitigation actions and scenarios

Two scenarios are modelled as follows:

- Scenario 1: The BAU situation is modelled up to 2030 using projections of historical trends in the use of main refrigerants (HFC-32, HFC-125, HFC-134a and HFC-143a) in the RAC sub-sector. This scenario assumes that the policy scenario (i.e. Scenario 2) would not implemented. HFC inventory data for the period 2006 – 2020 have been provided by the National Ozone Unit, MOESWMCC.
- Scenario 2: The policy-induced strategies and actions for the Phase Down / Phase Out of HFCs according to the information given in **Table 20**. The strategies and actions are those reported in the NDC.

Table 20. Action for the Phase Down and Phase Out of fluorinated ODS.

Strategies	Description of actions
Phase down of HFCs	- Freeze imports of HFCs using 2024 as baseline - Reduction will start with refrigerants with high GWP such as R404 A; ammonia and hydrocarbon-based refrigerants such as R290a and R600a will be promoted - Targets: Reduce by 10% (of baseline value) by 2029; 30% by 2035; 50% by 2040; 80% by 2045
Equipment Phase Out	- Policy to ban refrigerators on HFCs as fron 2024 - Policy to ban equipment on HFCs as fron 2029 - The above policies will contribute to the HFC Phase Down targets given above
Environmentally-sound disposal of HFC refrigerants	- Recovery and recycling of HFC refrigerant

Source: National Ozone Unit

5.3. Results of mitigation scenario analyses

[modelling in the process of being completed]

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[36] https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_7_Ch7_ODS_Substitutes.pdf - accessed 15 February 2022.

Annex 1 – Parameters used for modelling land transport demand

Passenger Transport Demand (using motorized vehicles such as two-wheelers, cars, dual purpose vehicle (DPV) and buses, and running on a combination of gasoline, diesel and LPG)			
Number of registered motorised vehicles by type of vehicle	Historical data from 2000 to 2030 provided by the NLTA		
Average distance travelled by vehicles (km/year)	Data provided by NTA based on surveys carried out at road worthiness testing centres was used to calculate demand for passenger land travel from 2010 to 2015. They are as follows: - Autocycle and motorcycle: 5,600 - Cars and DPV: 13,500 - Buses: 38,000		
Allocation of PAX.km by fuel type	Gasoline – 54.93% Diesel – 45.01% LPG – 0.05%		
Allocation of gasoline share of PAX.km by type of gasoline-powered vehicles	Autocycle – 11.31%; motorcycle – 7.36%; cars – 77.79%; DPV – 2.52%; hybrid cars – 1.01%		
Allocation of diesel share of PAX.km by type of diesel-powered vehicles	Cars – 8.46%; DPV – 12.2%; buses – 79.35%		
Allocation of LPG share of PAX.km by type of LPG-powered vehicles	Cars – 94.51%; DPV – 5.49%		
Passenger occupancy	Autocycle and motorcycle: 1; Car and DPV: 1.9; Bus: 35		
Fuel economy by type of vehicle (L/100km)	<u>Gasoline</u> Autocycle: 3.0 Motorcycle: 3.5 Car: 6.6 DPV: 11.5 Car (hybrid): 4.5	<u>Diesel</u> Car: 7.5 DPV: 11.3 Bus: 35	<u>LPG</u> Car: 8.0 DPV: 14.1
Fuel density (kg/L)	0.71	0.85	0.557

Freight Transport Demand (using goods vehicles running on either diesel or gasoline)	
Fuel mix	Diesel used to transport 97% of freight (tonne.km), and remaining 3% transported using gasoline
Fuel intensity	0.0368 L(diesel)/tonne.km; 0.0469 L(gasoline)/tonne.km

Annex 2 – Mitigation actions constituting Scenario 3 in land transport mitigation analyses

1. Uninterrupted Flow along Motorway M2/HOV lane

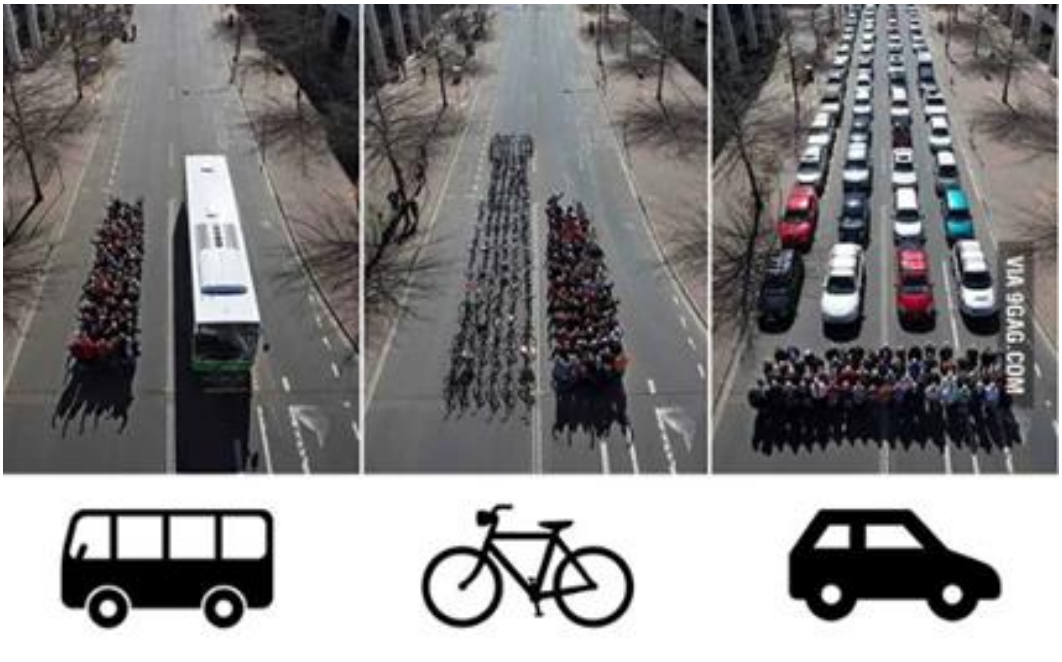
A dedicated bus lane service is helpful in reducing traffic congestion, energy consumption and environmental problems. Separating buses from other vehicles in dedicated lanes protects them from traffic congestion and delays and improves the reliability of services.

An alternative strategy to be adopted is in the re-design of existing road space along the Motorways so that more people could be transported without necessarily having to build new roads or widen existing roads.

Bus lanes have been gaining popularity elsewhere in the world. Bus priority lanes are so termed as they are intended to provide priority travel for buses vis-à-vis other traffic. This is part of the strategy, which is intended to attract more passengers to buses, so that taking cars off the road would ultimately lead to better speeds for all road users. Thus a successful bus lane has the potential for being a win-win situation whereby both the bus passengers as well as the other road users benefit by this exercise.
Buses are often delayed along Motorway M1 and M2 when plying towards Port Louis during morning rush hours as they have to share road space with other vehicles. Introducing dedicated bus lanes may enable buses to avoid traffic jams.
If the bus priority facilities along Motorway M1 and M2 will be carefully planned and implemented they can provide the following benefits:

- Reduction in traffic congestion, fuel use and exhaust emissions [decrease in carbon footprint]
- Reduced travel time [improved journey time]
- Time savings for passengers
- More reliable buses
- Increased public transport patronage
- Make better use of existing road infrastructure

Providing high occupancy vehicle lanes is one of such methods that have been used in other countries. The bus is one such high occupancy vehicle, which has an average occupancy of around 60 passengers compared to 1 or 2 in cars. Thus, a strategy, which can attract people from private transport to public transport, is a means whereby the demand for road space can be reduced since a passenger on a bus takes less road space than one travelling by car or even a motorcycle.



Road Space: Bus vs Bikes vs Cars [69 people]

The proposed bus lanes could operate “full-time” or only during certain hours, such as on Mondays to Fridays between 07:00-09:30. Outside those hours, other vehicles can use the lane. Bus lanes typically allow access to emergency vehicles but may also be opened up to other modes of transport – for example motorcycles, van and taxis.

The Traffic Management and Road Safety Unit already conducted a traffic study along Motorway M2 from Calebasses to Port Louis which is ‘overloaded’ at peak times both in the morning and in the afternoon, which results in jamming concentration where long queues and delays are experienced by drivers. Data collected at the study area included traffic volume composition and turning proportion at the roundabouts, geometry, signal timing, and performance measure, i.e. journey time. Traffic movements, signal timing and journey time were collected during morning peak hour. Analyses were performed by using VISSIM traffic micro-simulation to build a micro-simulation network model.

Grade Separated Model at Terre Rouge Roundabout

Grade Separated Model at Riche Terre Roundabout

The study has also analyzed the impact on traffic flow on Motorway M2 by providing an overpass at Bois Marchand to cater for an uninterrupted flow for traffic coming from A4 road from the region of Arsenal and Balaclava to join Motorway 2 to ultimately proceed towards Port Louis.

Moreover, the micro-simulation exercise has further analysed the traffic flow on Motorway M2 by controlling traffic movements at Jin Fei Intersection and Roche Bois intersection and at Trou Fanfaron and Places D'Armes with an adaptive traffic signal control system.

The simulation results show that in general, the performance of Motorway M2 is greatly improved by offering an acceptable Level of Service both during morning and afternoon peak hours by the implementation of the following measures:

- Provision of an overpass at Bois Marchand;
- Provision of a grade-separated junction at Terre Rouge roundabout;
- Provision of an adaptive traffic control system at Jin Fei roundabout;
- Provision of a grade-separated junction at Riche Terre roundabout;
- Provision of a grade-separated junction at Cocoterie roundabout;
- Provision of an adaptive traffic control system at Roche Bois roundabout;
- Provision of a grade-separated junction at Quay D roundabout;
- Provision of a coordinated adaptive traffic control system at Trou Fanfaron and Place D'Armes together with some traffic restraints measures.

Key Engineering Parameters:

- Distance of HOV lane from Jin Fei to Quay D roundabout = 3.5km
- Traffic volume on this segment of M2 = 2055 vph
- Journey time under present traffic situation = 1899 seconds
- Journey time with road improvements = 851 seconds
- Gain in journey time = 17 mins
- Project implementation time = year 2025 [assumed]

2. Implementation of Adaptive Traffic Control System [ATCS]

Currently all traffic signal installation in Mauritius operates on a single timing plan. In that, regardless of the change in traffic demand at the intersection, the traffic signals provide the same fixed amount of green times. This type of traffic signal operation is very inefficient and results in traffic congestion during peak periods.

Traffic congestion in urban/rural areas across Mauritius has grown tremendously over the last ten years. This increase in traffic congestion has been simultaneous with increase in urban population. Adding more lanes to existing highways and building new roads have been the traditional response to urban congestion. There have been many studies where different adaptive control systems have been evaluated. Most of the field evaluation studies that have been conducted on adaptive systems have concentrated on addressing the ability of these systems to provide benefits in terms of reductions in travel times, intersection delays, and the number of stopped vehicles. These field evaluations have primarily used the "before" and "after" technique. Evaluation of SCOOT deployments has reported an average reduction of 12% in intersection delay over fixed time plans SCATS has been deployed in Oakland County Michigan. Reported improvements in travel times were 7%-32% during different times of the day and compared to previous conditions which consisted only time based control with little to no effort in maintaining signal timings.

Moreover, results have been reported that coordination of fixed time systems produces journey time savings of around 12% to 22%, reductions in fuel consumption of 3% and crash reductions of about 13% [Holyrokd and Hillier, 1969, Robertson et al, 1980; Camkim and Lowrie, 1972]. More sophisticated traffic adaptive coordination systems have been shown in evaluations to provide additional benefits in terms of further reductions in intersection delays of around 12% to 27%, and reductions in fuel consumption of up to 11% depending on network geometry [Hunt et al, 1982; Luk, Sims and Lowrie, 1982].
Likewise, SCOOT has been demonstrated to yield improvements in traffic performance of the order of 15% compared to fixed timing systems [Institute of Transport Studies, University of Leeds, U.K, 2015].
In response to the above, the TMRSU intends to use high speed broadband technology to support the implementation of an island wide Intelligent Transport Systems.

To improve the efficiency of the traffic signal operations requires enabling traffic signals to automatically adjust their green times based on actual traffic demand. This new system requires storing several signal timing plans at each signalized intersection and having timing plans automatically selected based on the time of day or actual traffic demand. One cost-effective measure is to make use of Adaptive Traffic Control System. Even though it is a significant investment, the Adaptive Traffic Signals is worth the cost because of the benefits they produce, such as:

- reducing travel time and stop frequency,
- reducing the number of rear-end collisions,
- increasing customer satisfaction,
- reducing the costs of congestion thereby saving fuel and time, and
- reducing vehicle emissions.

A traffic survey has been carried out on a segment of Labourdonnais street in Port Louis between two signalized junctions. [**Refer figure below**]

Reference point A: signalized junction Labourdonnais St./Volcy Pougnet St.
Reference point B: signalized junction Labourdonnais Street/St. George St./Wellington St.
Distance between point A and B = 192 m
Traffic volume from point A to point B during morning peak = 770 vph [pcu] (comprising of car =520, bus =10, van= 80, lorry = 8 and motorcycle = 116).

The travel time between the two reference points for the different categories of vehicles are summarized in Table 1 below.

Table 1: Travel Time between reference points during AM peak

SN	Type of Vehicles	Time at A	Time at B	Time Taken
1	Car	07:33:11	07:34:117	0:01:06
2	Car	07:37:05	07:37:53	0:00:48
3	Car	07:38:24	07:39:04	0:00:40
4	Car	07:42:10	07:43:05	0:00:55
5	Car	07:48:33	07:49:00	0:00:27
6	Car	07:58:26	07:58:59	0:00:33
7	Car	08:03:34	08:04:05	0:00:31
8	Car	08:12:09	08:13:45	0:01:36
9	Car	08:14:17	08:17:13	0:02:56
10	Car	08:16:54	08:19:49	0:02:55
11	Car	08:21:09	08:24:02	0:02:53
12	Car	08:24:06	08:26:14	0:02:08
13	Car	08:25:22	08:26:53	0:01:31
14	Car	08:26:51	08:28:58	0:02:58
15	Car	08:28:48	08:30:46	0:01:58
Average time taken for a car to travel between the two signalised junctions				**95 seconds**
16	Motorcycle	07:34:54	07:35:20	0:00:26
17	Motorcycle	07:40:41	07:41:26	0:00:45
18	Motorcycle	07:45:38	07:46:26	0:00::48
19	Motorcycle	07:50:14	07:51:15	0:01:01
20	Motorcycle	08:02:17	08:02:54	0:00:37
21	Motorcycle	08:08:33	08:09:06	0:00:33
22	Motorcycle	08:15:18	08:15:59	0:00:41
23	Motorcycle	08:23:04	08:23:58	0:00:54
24	Motorcycle	08:26:08	08:27:21	0:01:13
Average time taken for a motorcycle to travel between the two signalised junctions				**46 seconds**
25	Double Cab	07:39:59	07:40:20	0:00:21
26	Double Cab	07:51:40	07:52:48	0:01:08
27	Double Cab	07:54:59	07:56:18	0:01:19

28	Double Cab	08:00:40	08:01:33	0:00:53
29	Double Cab	08:05:09	08:06:24	0:01:15
30	Double Cab	08:10:32	08:12:33	0:02:01
31	Double Cab	08:13:39	08:15:06	0:01:27
32	Double Cab	08:20:21	08:22:11	0:01:50
Average time taken for a double cab to travel between the two signalised junctions				**77 seconds**

Travel time gain for the different category of vehicles if the junctions were coordinated with an Adaptive Traffic Control System will be as follows:

Vehicle Category	**Average Travel Time [sec] with fixed traffic signals**	**Average Travel Time [sec] with ATCS**	**Gain in Travel Time [sec]**
Car	95	81	14
Motorcycle	46	39	7
Double Cab	77	65	12

Note: Journey time savings assumed to be 15%

Project implementation schedule:

2022 – 2023: Port Louis

2023 - 2024: Upper Plaine Wilhems

2024 – 2025: Zone 1 [Pamplemousses/Riviere du Rempart/Flacq]

2025 – 2026: Zone 3 [Grand Port/Savanne]

2026 – 2027: Lower Plaine Wilhems

3. Active Transportation

Cycling used to be a popular means of transport in Mauritius some decades ago. But now this activity is only being seen in a few villages of the island. Even so, cycling is becoming less and less popular. The Ministry is committed to make cycling as popular as it was in the past, by promoting cycling as a transportation option to get to work, school, or for fitness and recreation.

The Ministry possesses the designs for four locations, namely Rose-Hill, Vacoas, Grand-Baie and Flacq. The cycling networks for Rose-Hill and Vacoas are focused on providing cycling access to the Metro station in addition to the town centre to encourage people towards a modal shift from cars to cycling and LRT.

The cycling networks of Grand-Baie and Flacq are focused on providing cycling access to the centres so as to encourage modal shift from cars to cycling for short trips.

The cyclist network master plan is as follows:

Location	Total Length [km]
Rose Hill	36
Vacoas	32
Grand Baie	38
Flacq	10
Total	**116**

The project will be implemented in phases as follows: [Phase 1]

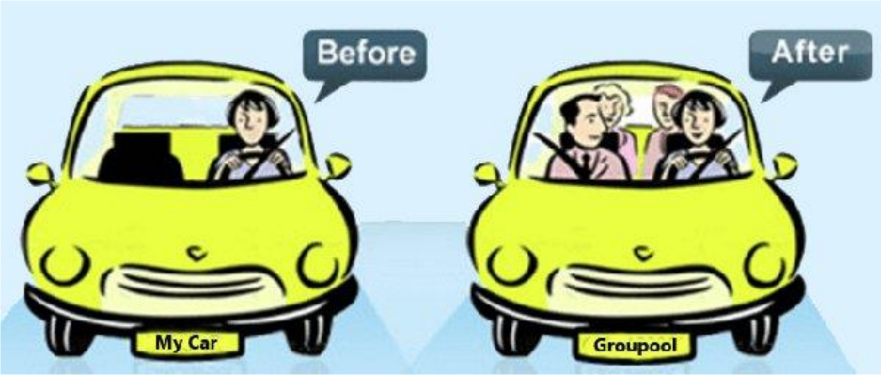
Location	Total Length [km]	Implementation Year
Rose Hill	5.2	2021-2022
Vacoas	4.8	2022-2023
Grand Baie	4.5	2023-2024
Flacq	5.1	2024-2025
Total	**19.6**	

Key Parameters:

- Length of cycle track for Rose Hill = 5.2 km
- Bus passengers from Camp Levieux Area to Rose Hill = 1200/day
- Bus passengers from Camp Levieux Area to Rose Hill = 438,000/yr
- Assuming 25% of passengers as leisure [no baseline carbon] and 75% commuting [with baseline]

4. Carpooling

Carpooling service is helpful in reducing traffic congestion, energy consumption and environmental problems. Carpooling is indeed the concept whereby vehicles are available within a community or locality for individuals to hire on a club basis, or a carpool is a system in which several people share rides to work, school or other destinations.



To be able to identify the significant factors that can influence the acceptability and effectiveness of a carpooling policy in Mauritius, a stated preference questionnaire survey will be undertaken. Data to be collected from the survey will be analysed with a view to make significant inferences.

By reducing fuel consumption, a number of studies have found that carpooling can reduce greenhouse gas (GHG) emissions. Using a simulation model, Herzog et al. (2006) forecasts that individually carpoolers reduce personal commute GHG emissions by approximately **4% to 5%** after joining an employer trip reduction program.

A study by Jacobson and King (2009) estimates savings of 7.2 million tons of GHG emissions annually in the U.S., if one additional passenger were added to every 100 vehicles. The study also estimates a savings of 68.0 million tons of GHG emissions annually in the U.S., if one passenger were added to every 10 vehicles (Jacobson and King 2009). In another study, the SMART 2020 report estimates that employing information and communication technology (ICT), such as app-based carpooling to optimize roadway performance could abate 70 to 190 million metric tons of carbon dioxide emissions (Global e-Sustainability Initiative, 2008).

Key Parameters:

- Chosen study location: Plaine Magnien to Port Louis on Motorway M1
- Length of study section = 45km
- Working days = 5 days only/week
- Holidays [assume 6 weeks]
- Volume of traffic on Motorway M2 from Plaine Magnien heading towards Port Louis during AM peak: car = 860 vph, bus =43 vph, van = 230 vph, lorry = 49 vph.

5. Travel Demand Management [Teleworking]

In general, teleworking reduces the emissions from daily commuting, if daily kilometres travelled could be reduced by a higher share of employees who work from home, as well as an increase in working days from home. Our study shows that the home office could reduce commuter travel, and thus contributes to reducing emissions from passenger transport. However, it also becomes clear that increased opportunity to work at a home office could only be one component in a combination of measures toward limiting CO2 emissions.

Key Parameters:

- No. of public servants = 80,000
- Two days WFH
- Three days at work/office
- Assume 2/3 of public servants travel by car and 1/3 travel by public transport
- Average distance travelled = 45 km