CARBON NET ZERO 2050

ROADMAP AND STRATEGIC PLAN

SRI LANKA

AUGUST 2023

MINISTRY OF ENVIRONMENT

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FINAL REPORT

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Carbon Net Zero- 2050 Roadmap and Strategic Plan

ISBN

LIST OF ACRONYMS / ABBREVIATIONS

AFOLU	Agriculture-Forestry-Other Land Use
BAU	Business-as-usual scenario
ccGAP	Climate Change Gender Action Plan
CCS	Carbon Capture and Storage
CCUS	Carbon Capture, Utilization and Storage
CEA	Central Environmental Authority
CEB	Ceylon Electricity Board
CDM	Clean Development Mechanism
CH_4	Methane
CMC	Colombo Municipal Council
CO_2	Carbon Dioxide
CO_2eq	Carbon Dioxide Equivalent
DAPH	Department of Animal Production and Health
DOC	Degradable Organic Carbon
DSM	Demand Side Management
EPL	Environmental Protection License
EPR	Extended Producer Responsibility (EPR)
EU	European Union
FAO	Food and Agriculture Organization
GCV	Gross Calorific Value
GDP	Gross Domestic Product
GHGs	Green House Gases
HVDC	High Voltage Direct Current
IPCC	Intergovernmental Panel on Climate Change
JICA	Japan International Cooperation Agency
LKR	Sri Lankan Rupees
LPG	Liquefied Petroleum Gas
LTGEP	Long Term Generation Expansion Plan
LULUCF	Land use, Land use Change and Forestry
MoE	Ministry of Environment
MoPE	Ministry of Power and Energy
MOU	Memorandum of Understanding
MSW	Municipal Solid waste
MSWM	Municipal Solid Waste Management
NAPPWM	National Action Plan on Plastic Waste Management
n.d.	No Date
NDCs	Nationally Determined Contributions
NEAP	National Environment and Action Plan
NEP	National Environment Policy (NEP)
NEPIO	Nuclear Energy Programme Implementing Organization
NG	Natural Gas

NO_x	Nitrogen Oxides
NSSWM	National Strategy for Solid Waste Management
NSWMC	National Solid Waste Management Center
NTC	National Transport Commission
ORE	Other Renewable Energy
O&M	Operational and Maintenance
PPP	Polluter Pays Principle
PRDS	Petroleum Resources Development Secretariat
RE	Renewable Energy
SBATs	Science Based Actions and Targets
SCP	Sustainable Consumption & Production
SDGs	Sustainable Development Goals
SLAEB	Sri Lanka Atomic Energy Board
SLSEA	Sri Lanka Sustainable Energy Authority
SDG	Sustainable Development Goals
SO_2	Sulphur Dioxide
SW	Solid Waste
SWDS	Solid Waste Dump Sites
SWM	Solid Waste Management
TNC	Third National Communication for Sri Lanka
UDA	Urban Development Authority
UNDP	United Nations Development Programme
US$	United States Dollar
VRE	Variable Renewable Energy
VSSFCW	Vertical Subsurface Flow Constructed Wetland
WtE	Waste to energy
WW	Wastewater
WWTPs	Wastewater Treatment Plants

LIST OF UNITS

g	Gram
Gg	Gigagram
GWh	Gigawatt Hours
kcal	Kilocalories
kg	Kilogram
kJ	Kilojoule
kW	Kilowatt
mg	Milligram
MJ	Megajoule
MT	Metric Tons = tonnes
Mt	Mega tonnes
MW	Megawatt
MWe	Megawatt Electrical

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EXECUTIVE SUMMARY

BACKGROUND

Sri Lanka is an island nation, with a 65,610 km² area and a population of 22.16 million (2021), with the service sector making up 59.7% of GDP, the industrial sector 26.2%, and the agriculture sector 8.4% according to Ministry of Economic Policies and Plan Implementation (2021). In 2020, CO_2 emissions per capita for Sri Lanka had reached a value of 1.13 tonnes through a gradual increase from a value as low as 0.22 tonnes of CO_2 per capita in 1975, according to the Climate Watch (2020), World Resources Institute and the World Bank. Even though Sri Lanka is considered a low-carbon emitting country compared to many other countries in the world, this trend of increasing CO_2 emission is a cause for concern. The Third National Communication of Climate Change in Sri Lanka (TNC) (MoE, 2022), states that the carbon sequestration was higher than the GHG emission in the country up to 2004, and it is reversed from 2005 onwards. According to the Intergovernmental Panel on Climate Change (IPCC), to honour the Paris Agreement and limit global warming to well below 2 degrees Celsius (and pursue efforts to limit that increase to only 1.5 degrees), global carbon emissions should reach net zero by 2050 at the latest. In line with the above thinking, Sri Lanka has, in the updated NDCs of the Ministry of Environment (2021), committed to achieve its Carbon Neutrality by 2050. The development of the 2050 Carbon Net Zero Road Map and Strategic Plan for Sri Lanka is an attempt to realistically set the stage for reducing the GHG emissions and increasing carbon sequestration and storage to achieve carbon neutrality through climate actions covering the following six main thrust areas as identified in the NDCs: viz Energy, Transport, Industry, Waste Management, Agriculture and Forestry. The project is expected to formulate a comprehensive Road Map and a Strategic Plan that will be robust, amenable and easy to implement across the administrative structure of Sri Lanka, with the acceptance of all concerned stakeholders on its effective and meaningful implementation, paying due attention to the gender inclusivity and socio-economic well-being of the community.

APPROACH AND METHODOLOGY

The approach of the study was to predict the GHG emissions from the anticipated activities in the six sectors of concern identified in the NDC's for GHG emission control over the period 2025 to 2050 in the Baseline and Mitigation Scenarios, developed using specific prediction models for each sector. The Baseline Scenario was defined as the future scenario where the predicted emissions in the NDC report for the Unconditional Actions were extended to the year 2050, continuing current trends in population, economy, technology and human behavior. A real GDP growth rate of 3.1% was used for the Baseline scenario, as per the Sri Lanka Government's Climate Prosperity Plan (2022). The Mitigation scenario was developed for each sector, by identifying the appropriate strategies, considering and selecting the appropriate unconditional and conditional mitigation actions identified in the NDC's, and additional interventions to reflect the best case of mitigation, technically, socially and environmentally feasible down the timeline, in each sector. Each sector specialist considered several options/pathways of mitigation actions under this scenario. A preliminary study revealed that it would be possible to achieve net zero emission status by 2050 (even before 2050), if all mitigation actions proposed for each sector by the consultants, which went beyond the NDC actions, were to be implemented as proposed, in a timely manner. Therefore, the Mitigation Scenario was taken as the Net Zero Scenario. The Real GDP growth rate of 4.2% taken from the Sri Lanka Government's Climate Prosperity Plan (2022) was adopted for the Net Zero scenario.

Considering the importance of the need for acceptability of the Road map by the implementing agencies and administrative entities of the government, stakeholder consultation was a key element in the process of development of the Road map and Strategic Plan. Two stakeholder workshops were conducted with invited participants, covering implementing and administrative organizations from each and every sector, as well as members dealing with the gender and social/socioeconomic concerns in the implementing agencies and academia. The first workshop was aimed at opening lines of communication and gathering information on the baseline situation with regard to the existing and planned policies, strategies and action plans as well as staff, technology and infrastructure gaps in the stakeholder organizations and the participants' views on the mitigation actions as proposed in the NDCs. In the second stakeholder meeting, the participants were made aware of the future scenario of emissions, proposed mitigation actions and their views were obtained on the feasibility of proposed actions, new actions that could be considered and the institutional arrangements and new policies/ amendments to policies needed for the implementation of actions, strengths and weaknesses in the system and opportunities for improvement. The workshops were structured as sector wise group discussions, to extract the best ideas and responses form them for the study. In addition, informal interviews were held by the sector specialists, especially the sociology and gender specialist, to gather information on the gender and social analysis. A validation workshop of the proposed Strategic Plan and Road Map was held to a wider cross section of stakeholders, and their valuable comments and recommendations were incorporated into the Final Report. In the case of the Energy Sector, which, in fact is the highest contributor to GHG emissions at present, two optional pathways were considered, one pathway with the introduction of nuclear energy from 2035 and the other aiming at 100% Renewable Energy by 2050 without introduction of nuclear power, due to the uncertainty in the social acceptability of nuclear power in the country, as highlighted by some stakeholders at the validation workshop. Introduction of Green Hydrogen as a Renewable Energy source is also proposed as an option to be seriously considered.

The Policy framework for Climate Change is set by the National Climate Change Policy (MoE, 2014), which was developed to provide guidance and directions for all the stakeholders to address the adverse impacts of climate change efficiently and effectively. There are two important documents that were prepared by the Ministry of Environment and approved by the Cabinet in 2022, pertaining to the Government's Policy, strategies and action plans related to the environment, under the current context of Climate Change adaptation and mitigation. They are the National Environment Policy (NEP) 2022 and the National Environment Action Plan (NEAP) 2022 – 2030, both of which address the Climate Change Mitigation as well as Adaptation to Climate Change impacts. In addition, the Draft Low Carbon Development Strategy for Sri Lanka 2021-2030 has been developed by the Climate Change Secretariat of the Ministry of Environment (MoE, 2021b).

SECTOR WISE PREDICTION OF EMISSIONS FOR THE BASELINE AND MITIGATION SCENARIOS

The current situation with regard to the six sectors that are identified as main contributors to GHG Emissions, their role in the national development and the current status and past trends of GHG emission were analyzed and are given Section 2 of this Report. The Baseline Scenario for each sector was developed using the national level data on population prediction model adopted by the UN World Population Prospect 2022 (UN, 2022), and the real GDP values adopted in the Sri Lanka Climate Prosperity Plan (CPP) Preliminary report (V20, 2022).

THE BASELINE SCENARIO

The sector wise prediction of GHG emissions for the Baseline scenario were developed for the 2025 – 2050 period and is described in Section 3.2 of this Report. The overall situation of the emission predictions for the Baseline scenario is given in Figure 3.21 in the report and reproduced in the Executive Summary as Figure A.

The calculations showed that in the Baseline situation, where only the NDC unconditional actions that do not depend on external inputs such as technology and funding are implemented, by 2050, there will be a net carbon emission quantity of 23.62 Mt per year, resulting from a total emissions quantity of 46.03 Mt per year, while the expected sequestration would amount to 22.41 Mt per year.

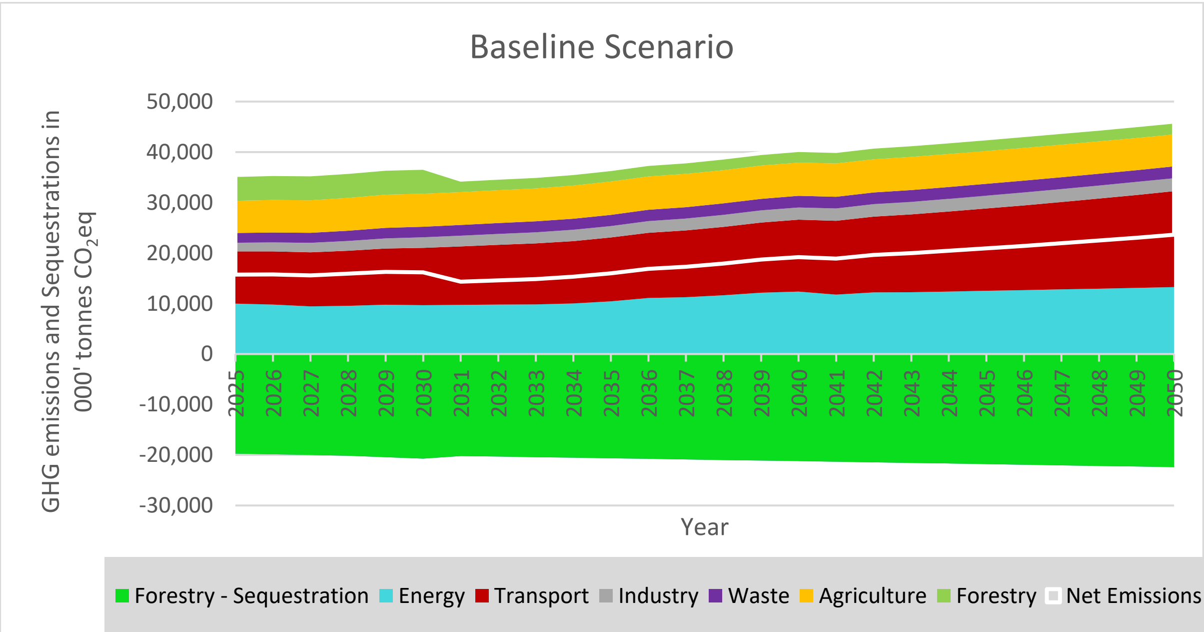

Figure A: The Cumulative Emissions and Sequestration for the Baseline Scenario

(Note: Sequestration is indicated as negative values while the Emissions are indicated as positive values)

THE MITIGATION (NET ZERO) SCENARIO

After identifying the feasible mitigation actions for each sector, using NDC actions as an initial step, and studying literature, research findings and stakeholder consultations to go further to achieve further reductions while being conscious of the impacts of such actions on vulnerable groups and maintaining gender equity, the team was able to model the GHG Emissions for the Best-Case scenario, which is taken as the Mitigation (Net Zero) Scenario.

The sector wise prediction of GHG emissions for the Mitigation (Net Zero) Scenario were developed for the 2025 – 2050 period and is described in Section 3.3 of this Report. The overall situation of the emission predictions for the Baseline scenario is given in Figure 3.30 in the report and reproduced in the Executive Summary as Figure B.

The calculations showed that in the Mitigation (Net Zero) scenario, where the proposed mitigation actions are implemented, by 2050, the country will be able to achieve Net Zero by 2037, and by 2050, there will be a net carbon emission quantity of -8.604 Mt per year, as the total emissions will be reduced to 14.25 Mt per year, while the expected sequestration would amount to 22.85 Mt per year.

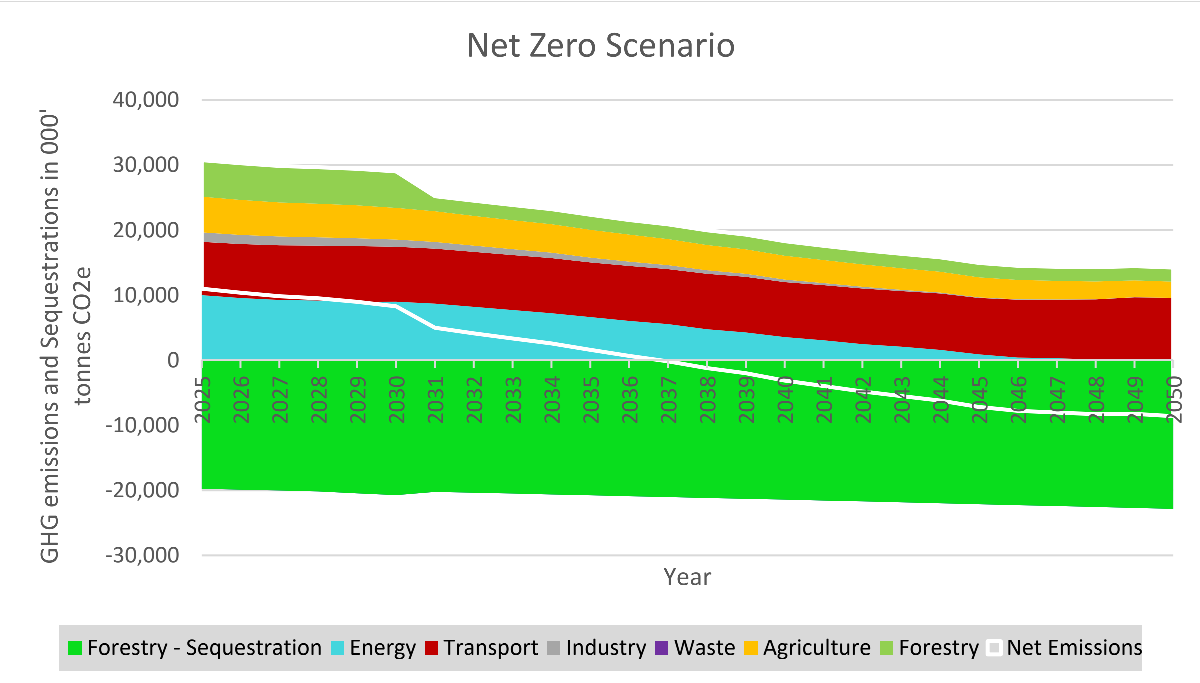

Figure B: The Cumulative Emissions and Sequestration for the Mitigation (Net Zero) Scenario

(Note: Sequestration is indicated as negative values while the Emissions are indicated as positive values)

PROPOSED CARBON NET ZERO FRAMEWORK FOR 2050

Sri Lanka's Carbon Net Zero 2050 Roadmap has the Vision of "A CARBON NEUTRAL PROSPEROUS SRI LANKA".

According to the U.N. Climate Science Panel, man-made carbon dioxide emissions need to reach "net zero" by mid-century to give the world a good chance of limiting warming to 1.5 ^{0}C and avoiding the worst impacts of climate change. Transitioning to a carbon net-zero world is one of the greatest challenges the humankind has faced. Sri Lanka, being a developing country, cannot compromise economic and social development to achieve carbon net zero status. This is an effort to ensure a prosperous and secure country, which is not contributing to the global consequences of climate change caused by anthropogenic GHG emissions.

In order to achieve Carbon Net Zero by the year 2050, the sector wise feasible strategies and actions for reduction of emissions and increasing sequestration or trapping of carbon were studied in detail, so that mitigation actions could be proposed for each sector to achieve the maximum possible reduction in emissions, while maximizing the economic and social development of the country.

FEASIBLE STRATEGIES AND MITIGATION ACTIONS FOR ACHIEVING TARGETS

The feasible strategies and actions for achieving the emission reductions and increased sequestration were identified for each sector in consultation with the stakeholders, and review of literature to find innovative technologies available and methods used locally and overseas. The list of proposed strategies, actions and new technologies is given in Section 4.5 of this Report.

The gender and social impacts of the proposed actions were studied by the sociologist, and corrective action to eliminate any biases against vulnerable groups were suggested to avoid social and gender issues. It is noteworthy that, even though Sri Lanka is listed under the National Focal Points, the country so far has not followed the procedure to nominate a national gender focal point for climate negotiations (UNFCCC, n.d.). The requirement made by UNFCCC to establish gender focal points in relation to climate change under Climate Change Gender Action Plans (ccGAP) has never got implemented in policy planning in Sri Lanka, neither by Ministry of Women and Child Affairs nor by Ministry of Environment.

The issues and constraints for achieving the targets are discussed. The main issues highlighted are the lack of data management systems in most sectors, access to finances, technologies and need for capacity building of staff for implementing the proposed strategies and actions. Several Policy gaps were also identified, which need to be filled for successful implementation of the actions proposed in the Road map.

Following are some identified areas where policy directives are required for implementation of proposed strategies and actions to achieve carbon neutrality. These are described in detail in Sections 4.9.1 to 4.9.6 of the Report.

1. If the pathway with the introduction of nuclear power is to be taken, it is imperative that the following policy directives are initiated immediately:
    a. Promulgation of a new Act and Establishment of a new regulatory body with adequate human and other resources for regulation of Nuclear Power Plants.
    b. Amendment of the existing Sri Lanka Atomic Energy Act No.40 of 2014 to include regulation of nuclear power and strengthen the manpower and other resources.
    c. A clear and strong policy directive is necessary in the nuclear energy sector (similar to government no-coal policy) to incorporate nuclear power as mainstream scenario in the Long-Term Generation Expansion Plan (LTGEP).
2. The draft National Transport Policy which is under review since 2019 needs to be finalized soon and published by a gazette.
3. BOI industry policy (with a priority on investment promotion and economic development concerns rather than promoting low-carbon industry proposals) needs to be amended to promote low carbon industry proposals.
4. Provide sustainability guidelines in setting up individual industry/industry parks with appropriate sustainable economic analysis and incentives to promote the low-carbon industry.
5. National-level recognition of low-carbon industries and their sustainability impacts.
6. Policies for promoting/attracting low carbon options such as Co-generation / tri-generation, district heating/cooling, and benefits should be introduced.
7. The National Waste Management Policy should be amended to
    a. Improve the segregation of MSW at source and increase the number of segregations categories.
    b. Clearly define the purpose of waste-to-energy projects and plan the phasing out of preferential feed-in-tariffs.
    c. Introduce other thermal treatment technologies.
    d. Introduce Land-fill Gas recovery systems.
8. Policies should be introduced to regulate the establishment of new waste-to-energy facilities.
9. Operationalize policy and regulation for siting and implementation of sanitary landfills.
10. Update or introduce the required legislation to facilitate and enforce the implementation of NDCs.
11. Introduce a mechanism for waste generation forecasting with a tracking system to monitor the generation.
12. Introduce legislation to make segregation of waste at the household level mandatory.
13. Introduce or amend necessary legal framework and instruments to initiate Market-Based Instruments (MBIs) and non-market-based instruments to incentivize and promote sustainable consumption patterns.
14. Implement the “Polluter Pays Principle” for mixed waste generators.
15. Conduct awareness and capacity-building programs for behavioral changes in waste generators as well as waste management personnel.
16. Facilitate public-private-partnerships to finance waste sector mitigation actions.
17. Introduce new policies or amend existing policies to

a. include adoption of renewable energy in agriculture and livestock applications.
b. increase land use productivity, improve fertilizer use-efficiency and improve water use efficiency in coconut cultivation.

It was noted at the stakeholder meetings that the agencies responsible for the review of the policy on Irrigation and Land Use and make recommendations to minimize GHG emissions need resources such as finances, manpower, technical knowledge etc. to complete this task.

CARBON NET ZERO STRATEGIC PLAN AND ROAD MAP

The Strategic Plan and Road Map indicating the strategies and actions proposed to achieve the target emission reductions and increased sequestration necessary to achieve carbon Net Zero status as anticipated, before 2050, that was developed, is described in Section 5, and is depicted in Table 5.3.

The Road Map provides the series of strategies to be used and actions proposed to be carried out under each of the six sectors, in the five-year periods from 2025 to 2050. The estimated GHG emission reduction from the baseline emission level at the end of each five-year period due to the particular action/set of actions are also given as milestones, in the progress towards Carbon Net Zero and carbon positivity. The Key Performance Indicators (KPI's) are also indicated to facilitate the monitoring of the proposed actions. Only emission reductions that can be reasonably estimated using available data and predictive tools were taken into consideration in the calculations. Other actions are also indicated, which would be beneficial but would need data, funding and technology inputs, to be taken into the emission reduction calculations at present. These actions are proposed to be carried out in the latter part of the 25-year period under consideration, in anticipation of a more stable economy and better attitudes and conservation practices instilled in the population. The Road Map and Strategic Plan are expected to be used as a base document, with the achievement of milestones being monitored through the KPI's for the actions given for each sector. Thus, any significant deviations from the expected outcomes should be dealt with immediately, with corrective actions, within a short time period, before it is too late and too expensive to be reverted back on track.

NEED FOR INVESTMENTS TO ACHIEVE CARBON NET ZERO

In order to achieve Carbon Net Zero Status in Sri Lanka, a variety of mitigation options have been proposed for each sector, as shown in the above Strategic Plan and Road Map. Detailed calculations of economic benefits achieved by avoided Carbon emissions and the cost of implementation of the proposed actions are provided in the report. Table A gives a summary of the investments needed in the five-year periods from the present to the year 2050, in order to implement the proposed actions. It can be seen that the consultants have proposed actions that need minimum additional funding during the initial period under consideration, in recognition of the fact that the country is going through an economic crisis at the moment, and therefore until funds from external sources are secured, the spending on activities that are aimed at carbon emission reduction will have less priority than the spending on essential commodities.

The Central Bank of Sri Lanka, in their comments on the Draft Final Report of this Road Map, have stated that "Under the current Extended Fund Facility (EFF) of the International Monetary Fund, the Government is committed to maintaining a primary surplus from 2024 onwards. Given the rigid nature of the recurrent expenditure of the Government, curtailment of capital expenditure is more likely in the period ahead, limiting the funds required for green infrastructure projects." It is anticipated that the proposed actions, that are mainly focused on attitude and lifestyle changes towards a low carbon future, would be supported through policy initiatives and supporting incentives very early in the timeline.

The present value of the total investments required to implement the strategic plan is estimated at Rs 44,137 billion, which, at the present exchange rate amounts to approximately US$ 140 billion.

Table A: Investments required for proposed actions in all sectors

Period	Total investment cost (LKR million)
2023 - 2027	69,776
2028 - 2032	2,524,649
2033 - 2037	19,827,476
2038 - 2042	25,731,711
2043 - 2047	33,237,990
2048 - 2050	49,192,499
Present value @ 10%	44,136,870

RECOMMENDATIONS

- It is acknowledged that the proposed action plan does not include any road map for financing the proposed strategic actions. The Central Bank of Sri Lanka, have recommended that in order to facilitate and ensure the timely implementation of the action plans, the key focus should be on alternative financing options than on budgetary allocations. It is recommended that green financing options available locally and internationally should be investigated and approached for funding the investments needed to achieve the desired outcomes.
- The Central Bank of Sri Lanka has already prepared a 'Green Finance Taxonomy' for the Sri Lanka's banking sector, with the aim of promoting lending through the domestic financial system to green projects. Therefore, seeking concessional or priority-based funding for zero carbon projects from the banking sector could be considered as a financing option going forward.
- Implementation of the actions proposed to achieve Carbon Net Zero involves the participation of state as well as private sector institutions, as well as individual citizens, and it is important that a high level of participation is forthcoming from all stakeholders.

- To ensure sustainable growth, investing in research and development becomes vital. This will advance adoption of new technologies in all sectors, such as green hydrogen technologies, in the energy, transport and industrial sectors, leading to increased efficiency, cost-effectiveness, and safety, while minimizing the carbon emissions, which will further attract innovation and drive industry expansion.
- While much effort has been taken to include the opinions of the decision-making officials in the government sector in the development of the strategic plan, through stakeholder consultations, this being a long-term plan, needs to be regularly updated with data available in the future. The government should encourage an open dialogue with all stakeholders and monitor the achievement of the Key Performance Indicators on a regular basis, at least biennially, and review the Strategic Plan and Road Map accordingly.
- As stated in the National Climate Change Policy, it is imperative that the Climate Change is mainstreamed and integrated in the National Development Process. The strategies and actions proposed in the Strategic Plan and Road Map will need to be internalized into the development plans of the relevant institutions, in order to achieve the vision of "A CARBON NEUTRAL PROSPEROUS SRI LANKA".

SECTION 1 - BACKGROUND

1.1 Background and the objective of the study

Sri Lanka is an island nation, with a 65,610 km² area and a population of 22.16 million (2021), with the service sector making up 59.7% of GDP, the industrial sector 26.2%, and the agriculture sector 8.4% according to Ministry of Economic Policies and Plan Implementation (2021). The function of several sectors such as energy, transport, agriculture, industry, forestry, and waste management are emitting large quantities of GHGs, contributing per capita emissions of around 1.02 tonnes/per person.

In 2020, CO_2 emissions per capita for Sri Lanka had reached a value of 1.13 tonnes through a gradual increase from a value as low as 0.22 tonnes of CO_2 per capita in 1975, according to the Climate Watch (World Resources Institute and the World Bank, 2020). Even though Sri Lanka is considered a low-carbon emitting country compared to many other countries in the world, this trend of increasing CO_2 emission is a cause for concern. In the updated Nationally Determined Contributions (NDCs) published by the Ministry of Environment in July 2021, it is stated that 'Despite the low carbon footprint and high vulnerability to climate change, Sri Lanka commits to reducing its GHG emissions'. In these NDCs, the country presents an enhanced ambition which includes 4% unconditional and 10.5% conditional emission reduction commitments with respect to the Business-As-Usual (BAU) scenario.

According to the Intergovernmental Panel on Climate Change (IPCC, 2021), in order to honour the Paris Agreement and limit global warming to well below 2 ^{0}C (and pursue efforts to limit that increase to only 1.5 ^{0}C), global carbon emissions should reach net zero by 2050 at the latest. Over 100 countries have already pledged to do this. However, on its own, reaching net zero in 2050 is nowhere near enough. According to the UNEP, in order to limit global warming to no more than 1.5 ^{0}C, the whole world would need to reduce emissions by 7.6 % per year every single year between 2020 and 2030 (UNEP Press Release 26 November 2019). Even limiting global warming to well below 2 ^{0}C would require annual global reductions of greenhouse gas emissions of 2.6 percent per year. It is important that the action to reduce emissions should start early, rather than wait till the end of the period to achieve the goal, as the short-term impacts could result in climate catastrophes. Thus, the net zero target by 2050 should be complemented by short-term targets too, and all contributing sectors of the economy should be covered.

In line with the above thinking, Sri Lanka has, in the updated NDCs of the Ministry of Environment (2021), committed to increasing the forest cover to 32% by 2030 and reducing greenhouse emissions by 14.5% for the period of 2021–2030 from Power (electricity generation), Transport, Industry, Waste, Forestry, and Agriculture sectors. These targets are determined by considering the achievement of 70% renewable energy in electricity generation by 2030 to achieve Carbon Neutrality in electricity generation by 2050 and assuming there will be no capacity addition of coal power plants in the country. According to the above document, Sri Lanka expects to achieve its Carbon Neutrality by 2050.

The Glasgow Climate Pact called on all countries to revisit and strengthen the 2030 targets in their NDCs by the end of 2022, to align with the Paris Agreement temperature goal. If the overall Carbon neutrality (Net Zero) has to be achieved by 2050 for Sri Lanka, the targets given in the updated NDCs in 2021 have to be further updated, and the strategies and roadmap have to be prepared for achieving these.

The development of the 2050 Carbon Net Zero Road Map and Strategic Plan for Sri Lanka, is an attempt to realistically set the stage for reducing the GHG emissions and increasing carbon sequestration and storage to achieve carbon neutrality through climate actions covering the following six main thrust areas as identified in the NDCs (MoE, 2021 a):

- Energy
- Transport
- Industry
- Waste Management
- Agriculture and
- Forestry

1.1.1 Scope and Objectives

The project is expected to formulate a comprehensive Road Map and a Strategic Plan that will be robust, amenable, and easy to implement across the administrative structure of Sri Lanka with the acceptance of all concerned stakeholders on its effective and meaningful implementation. A well-developed set of policy guidelines anchored on the strategic plan to be developed will cover the Road Map for achieving Carbon Net Zero by 2050, to be given proper statutory acceptance across all levels of the administrative entities of the Government of Sri Lanka.

Carbon net zero refers to the balance between the amount of C produced and the amount removed from the atmosphere, or activities that releases net-zero carbon emissions into the atmosphere. If a country is to reach carbon-net zero, it must primarily reduce its emissions of greenhouse gasses into the atmosphere and increase its carbon dioxide-absorbing ecosystems.

The six sectors mentioned above will be covered in terms of potential carbon emission reduction, enhanced absorption, and sequestration, contributing to the net zero processes. The main concerns and related actions are briefly explained further below.

The Third National Communication of Climate Change in Sri Lanka (TNC) (MoE, 2022), states that the carbon sequestration is higher than the GHG emission in the country up to 2004, and it is reversed from 2005 onwards. The data given in the TNC Report shows that this change has taken place both due to the increase in emissions as well as the decrease in net sequestration of Carbon over the years during the period 2000 to 2010, which was under consideration in the TNC Report. According to the TNC, when considering the emissions excluding the Land Use, Land Use Change and Forestry (LULUCF), in 2010, out of a total of 22.08 Mt emissions, the Energy sector including Transport contributed 64.1% and the agriculture sector contributed 29.5%, while waste and industry (IPPU) sectors contributed 4.4% and 2% respectively. When LULUCF emissions are also included, the profile changes to nearly 50% (49.3%) contribution coming from the LULUCF sector, 32.5% from the Energy sector and 15% from the agriculture sector, while the waste and IPPU contribution contributions are reduced to 2.2% and 1% respectively. However, the transport sector is one of the major GHG emitting sectors in Sri Lanka, and its GHG emissions (7.2 $MtCO_2e$) accounted for 51% of the total GHG emissions from the Energy sector in 2010 according to the TNC (MoE, 2022).

Women are still under-represented in the climate change decision-making process in Sri Lanka as well as in many other parts of the world. Gender inequity is a cross-cutting theme affecting development programs. Ironically, it is well established that the climate change impacts are disproportionately affecting women. Thus, it is important that special attention is paid to ensure that women are included in the educational programs on technologies and mechanisms aimed at attaining Net Zero Carbon, as well as in the implementation of actions. In certain gender-based studies, failure to achieve the set targets has been attributed to women's limited access to timely weather forecast information, limited available options for crop and livelihood diversification, lack of independent sources of income, access to credit or financial institutions for better investment and low decision-making power to apply adaptation measures (World Bank and CIAT, 2015; Huyer, 2016; Milazzo and Goldstein, 2017)

1.2 Link with the National Vision on Climate Change

The National Climate Change Policy of Sri Lanka (MoE, 2014) contains a vision, mission, goal, and a set of guiding principles followed by broad policy statements under Vulnerability, Adaptation, Mitigation, Sustainable Consumption & Production, Knowledge Management and General Statements. Collaborative action at all levels is necessary to transform this policy into a meaningful set of actions to meet the challenges of climate change. The Vision, Mission and Goal of the National Climate policy are defined as follows:

Vision: A future where climate change will have no adverse consequences on Sri Lanka.

Mission: Addressing climate change issues locally while engaging in the global context

Goal: Adaptation to and mitigation of climate change impacts within the framework of sustainable development

The National Climate Policy has the following stated as its objectives:

1. Sensitize and make aware the communities periodically on the country's vulnerability to climate change.
2. Take adaptive measures to avoid/minimize adverse impacts of climate change to the people, their livelihoods, and ecosystems.
3. Mitigate greenhouse gas emissions in the path of sustainable development.
4. Promote sustainable consumption and production.

5. Enhance knowledge on the multifaceted issues related to climate change in the society and build their capacity to make prudent choices in decision making.
6. Develop the country's capacity to address the impacts of climate change effectively and efficiently.
7. Mainstream and integrate climate change issues in the national development process.

Thus, the development of the Road map and Strategic Plan for achieving Carbon Net Zero in a sustainable manner is a mandatory part of achieving the objectives of the National Climate Policy, particularly Objectives 3, 4 and 7,

Sri Lanka, being a party to the Paris agreement has made a commitment of reaching Net Zero status by 2050, in the updated Nationally Determined Contributions (NDCs) submitted to the UNFCCC in 2021, as a mandatory requirement of the agreement. This Roadmap and Strategic Plan are developed to provide a clear vision of the way in which the country must move, in order to reach the goal, as committed to the UNFCCC.

Recognizing the need for responding to the challenges faced by the developing countries which are also the most vulnerable to Climate Change impacts (V20), the member countries of Climate Vulnerability Forum (CVF) have developed Climate Prosperity Plans, which are aimed at designing actionable investment and implementation pathways for climate action.

The Preliminary Report of Sri Lanka's Climate Prosperity Plan 2022 (V20, 2022) outlines a national investment strategy for climate-proofing the nation, and in doing so to secure Sri Lanka's pathway to prosperity in a climate-insecure world. It mentions three goals and three objectives under each goal.

Goal 1 - Unlock domestic energy abundance through renewables, modernization, and sustainable transport

Goal 2 - Financially engineer a climate-secure transportation

Goal 3 - Galvanize climate protection against key risks

These goals and objectives are very much in line with the aspiration of the development of the Roadmap to Net Zero by 2050. For example, the objectives under goal 1 include financing maximized renewable energy and grid modernization potential and connectivity and sustainable transportation by supporting renewable energy-based, resilient mobility network and promoting sustainable lifestyles; goal 2 includes repurposing and reducing the debt-for-climate swaps, carbon financing to value blue carbon, soil carbon, forest carbon, etc.

Implementing these actions will promote the move towards Carbon Net Zero status that is being envisaged in this roadmap, and the actions proposed in the roadmap will play a complementary role in achieving the objectives of the CPP for Sri Lanka.

The Carbon Net Zero 2050 Roadmap has the component of developing mechanisms towards balancing emissions with their input and output rates, with room for path correction, as milestones are traversed in time frame. In other words, the entire Carbon Net Zero 2050 Project is leveraged on a quantifiable platform to count emissions, releases, abatement, and sequestration. Once the Road map and plan are accepted by the stakeholders who would include the parties responsible for implementing the proposed actions and the agencies monitoring the outcomes of the actions, it would provide the pathway for sustainable development of the country, aligned with the United Nations' call for national efforts to control the GHG emissions to keep the global warming well within 2 ^{0}C.

1.3 Approach and Methodology

The process followed in the preparation on this report is given in the Figure 1.1

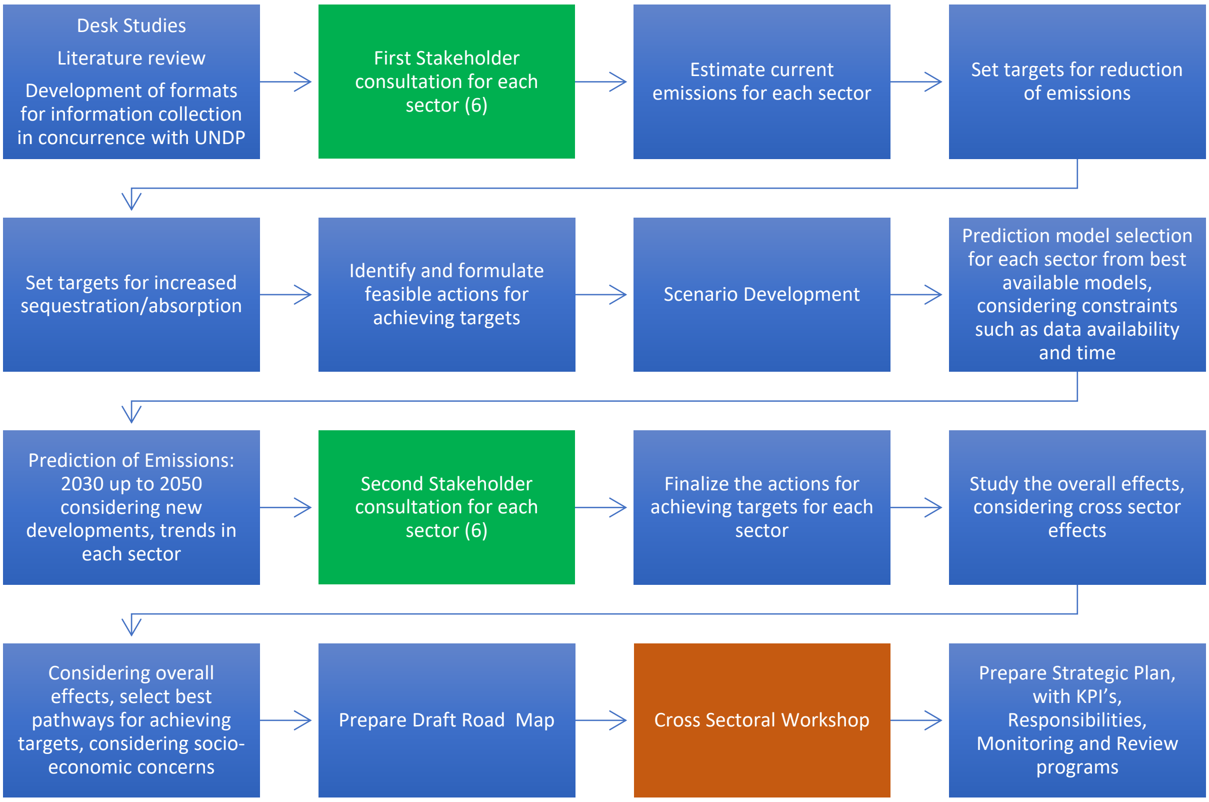

Figure 1.1 : Process Flow Chart

General Methodology

The overall objective of this assignment is to develop a 2050 Carbon Net Zero Road Map with a Strategic Plan for Sri Lanka, in consultation with relevant stakeholders from the respective sectors. The sector specialists for the six sectors studied the current status of GHG emissions and the related policy background in their respective sectors in Sri Lanka and proposed feasible strategies and actions to minimize emissions and increase sequestration/ capture carbon in the period 2025 to 2050, through review of literature, discussions and consultations, and using their expert knowledge in the field. The updated NDC Report (MoE, 2021) provided background information for the study, to understand the past trends and predictions up to 2030. However, the sector specialists reviewed the proposed actions in the NDC report, and selected to carry forward only those that they could reasonably justify as feasible, and proposed some other strategies and actions too, to achieve Carbon Net Zero by 2050. The calculation of emissions in terms of tonnes of CO_2 equivalent were carried out using the IPCC Guidelines (IPCC, 2006) and projections of emissions were carried out using accepted long term forecasting techniques for population and economic growth. The social and gender specialist analysed the situation with respect to social impacts due to the proposed actions and made recommendations to assure social and gender equity and inclusivity in the strategies and actions proposed in the Road Map. An economic analysis was carried out to check the economic viability of the proposed actions for each sector with respect to the value of avoided Carbon, and recommended policy directions for successful implementation of the Road Map and Strategic Plan.

Literature review

- The following documents were used for the base line data as well as for the scenarios development:
  - Nationally Determined Contributions, Ministry of Mahaweli Development and Environment Sri Lanka (2016)
  - Readiness Plan for Implementation of Intended Nationally Determined Contributions (INDCs) 2017-2019, Ministry of Mahaweli Development and Environment Sri Lanka (2016)
  - *Updated Nationally Determined Contributions under the Paris Agreement on Climate Change Sri Lanka,* Ministry of Environment, Sri Lanka

- The following was used as the base documents for the calculation quantities of national level sectoral GHGs emission:
  - IPCC Guidelines for National Greenhouse Gas Inventories, 2006

- The following documents were used as key references for the study:
  - Initial National Communication under the United Nations Framework Convention on Climate Change, MoE (2000)
  - Second National Communication on Climate Change MoE (2011)
  - Draft Low Carbon Development Strategy for Sri Lanka 2021-2030, MoE (2021b),
  - Third National Communication, MoE (2022)
  - Third National Communication of Climate Change in Sri Lanka MoE (2022b)
  - National Environmental Action Plan Pathway to Sustainable Development, 2022-2030: MoE (2022d)

  In addition, a large number of references were used to prepare this document. The list of documents used are given under References in Section 6 of this report.

Consultations:

- The project was initiated with the Kickoff meeting with the Ministry of Environment, Climate Change Secretariat, UNDP on August 16, 2022.

- Several informal interviews with the relevant organization were conducted by the sectoral experts to collect necessary information and their involvement, issues and constrains faced when implementing the NDC and other Climate Change related activities.

Stakeholder meetings

1st Stakeholder Workshop:

The first stakeholder meeting was held on September 23, 2022

The objective of the meeting was to ascertain baselines, sectoral plans, and priorities for emissions reduction and Sequestration opportunities from government proponents for the six identified mitigation sectors, toward achieving carbon net zero by 2050. The agenda and the list of participants are given in Annexure 1.

2nd Stakeholder workshop

The second stakeholder meeting was conducted on November 17, 2022. The aim of meeting was:

a) Briefing the progress of the preparation of the 2050 Carbon Net Zero Road Map and Strategic Plan.
    - Identification of the baseline scenario: Considering the NDC scenario with only unconditional actions as the baseline
    - Calculated emission predictions in the baseline scenario (With graphs showing the predictions up to 2050)
    - Considered scenarios and drivers which are used in the scenario development
    - Mathematical model used for the predictions up to 2050
    - Proposed mitigatory actions with timeline to bring down the emissions and increase storage/sequestration according to your plan
    - Gaps found in the first stakeholder workshop
        - Policy/ Strategy
        - Staff
        - Technology
        - Infrastructure
b) Discussion of the feasibility of the proposed actions and the timeline according to the stakeholders’ opinions
c) New actions and timelines proposed by the stakeholders
d) Available regulatory framework for the implementation of proposed actions and any gaps
e) Identify institutional arrangements and new policies/ amendments to policies needed for the implementation of actions, strengths and weaknesses in the system and opportunities for improvement

f) Conduct a SWOT analysis within the sector for the 2050 Carbon Net Zero Road Map and Strategic Plan.

The agenda and the participant list are given in Annexure 1

Informal interviews – In addition to the stakeholder consultations, informal interviews were held by the sociology and gender specialist. These interviews were conducted with a purposive sample of respondents. Two samples were selected from two locations, urban and rural. The sample was further stratified according to the social class, upper middle and middle class as one and low-income communities as the other. Ten respondents from each sample group were purposely selected to discuss their everyday life and its possible contribution to GHG emissions and the impact of the climatic conditions on their lives.

Validation workshop

This will be conducted after submitting the draft final report

Limitations

The main limitation faced by the consultants was the difficulty in obtaining reliable data required for the estimation of GHG emission from the various sector activities. In most cases, information such as types and age of vehicles in the transport sector, raw material usage in the industry sector, waste volumes and characteristics in the waste sector are either completely missing, unreliable or only partially available, so that the estimation of GHG emissions had high uncertainty. An exception was the Energy sector, where the key organizations such as the CEB, SLSEA and PUCSL have good databases which could be accessed by the sector consultant without difficulty.

Another limitation that was faced by the study team was the fact that information that would be useful for this study was being developed by a few other studies that were undertaken simultaneously, and although there was a fair amount of exchange of information and ideas among the study groups, the findings of the other groups could not be verified, as they were still being processed.

Process followed for the preparation of the report

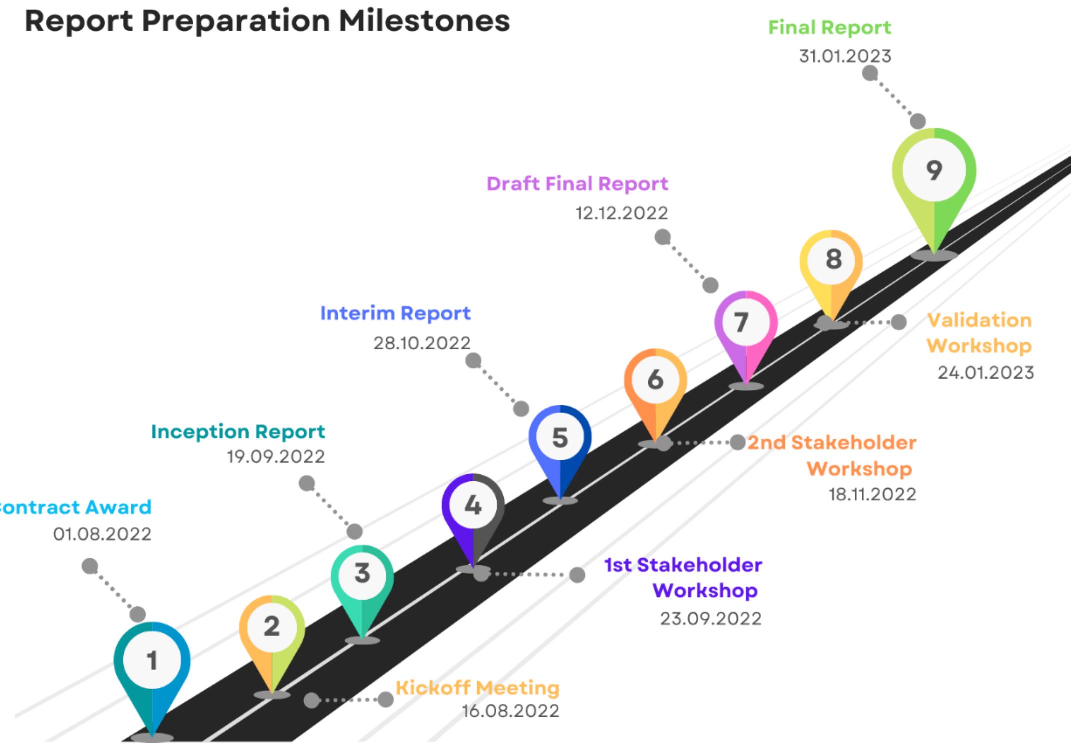

Figure 1.2 : Process Followed for the Preparation of the Report

1.4 Existing policies, strategies and action plans related to achieving net zero status of Sri Lanka

The National Climate Change Policy, as described in Section 1.2, was developed to provide guidance and directions for all the stakeholders to address the adverse impacts of climate change efficiently and effectively.

There are two important documents that were prepared by the Ministry of Environment and approved by the Cabinet in 2022, pertaining to the Government's Policy, strategies and action plans related to the environment, under the current context of Climate Change adaptation and mitigation. They are the National Environment Policy (NEP) 2022, the National Environment Action Plan (NEAP) 2022 – 2030.

In addition, the Draft Low Carbon Development Strategy for Sri Lanka 2021-2030 has been developed by the Climate Change Secretariat of the Ministry of Environment (MoE, 2021b).

- **National Environment Policy (2022)**

The NEP was prepared under the context of Sri Lanka aiming to become a low-carbon, climate-resilient green economy by adopting sustainable development policies.

The Policy identifies 13 Goals that form the basis of the policy objectives, out of which Goal No 8 specifically refers to the country being placed in a path of low-carbon development by implementing appropriate mitigation measures in the priority sectors of Energy, Transport, Industry, Waste and Agriculture-Forestry-Other Land Use (AFOLU) with high Greenhouse Gas (GHG) reduction potential.

Climate Change and Global Environmental Challenges are addressed in the Policy Statements given in Section 4.5 of NEP, which are further elaborated into subsections which broadly cover technical solutions, incentives-positive and/or negative-to create enabling environment for those solutions as well as institutional mechanisms for their implementation. The following five subsections refer to Climate mitigation actions:

4.5.1.5. Commitment towards meeting global GHG mitigation targets will be fulfilled by implementing appropriate mitigation measures in priority sectors with high GHG reduction potential.

4.5.1.6. Measures for reduction of GHG emissions will be selected to maximize co-benefits such as improvement of environmental quality, increased energy security, enhanced food security, reduced dependency on imported fossil fuels and enhanced health benefits by promoting options that include but are not limited to;

- Improving energy efficiency
- Renewable energy
- Integrated transport solutions
- Low and zero-emission vehicles including nonmotorized vehicles
- Integrated solutions of waste management
- Reducing Emissions from Deforestation and Degradation of forests (REDD)
- Adoption of appropriate Climate-Smart Agriculture (CSA) practices with mitigation co-benefits
- Use of traditional methods for food preservation and storage
- Resource-Efficient Cleaner Production (RECP)
- Climate-friendly cooling substances

4.5.1.7. An integrated system for Measurement, Reporting and Verification (MRV) of GHG emissions at national, sector and facility levels will be established to enhance the planning of mitigation efforts and facilitate the reporting of GHG emissions and emission reductions.

4.5.1.8. Prospects for harnessing Carbon Pricing Instruments (CPIs) represented by emission trading schemes and carbon taxes will be explored and necessary measures will be initiated to establish a globally integrated national carbon market for transacting carbon credits.

4.5.1.9. Measures will be initiated to introduce a ‘Climate Change Impact Assessment (CCIA)’ as a part of Strategic Environmental Assessment (SEA) and Environmental Impacts Assessment (EIA) procedures in evaluating investment plans and projects on which climate change is deemed to have significant implications for identifying and quantifying positive and negative contributions of projects to GHG emissions (mitigation impact) and positive and negative contributions to overcome critical impacts of climate change (adaptation impact).

- **National Environmental Action Plan 2022 - 2030**

The National Environment Action Plan (NEAP) 2022-2030 provides the strategies and action plans aligned with the National Environment Policy of 2022, to address environmental challenges of the 21st century and to achieve sustainable development aligned with the UN Sustainable Development Goals (SDGs).

Out of the nine thematic areas in the Action Plan, Thematic Area 3: Climate Action for Sustainability is developed to directly respond to the Thematic Area 4: Climate Change and Global Environmental Challenges of the NEP. It will strive to steer development along a low-emission trajectory, that supports both mitigation and adaptation to climate change, with a strong focus on reaching high income and human development in the next decade.

The action plan for this thematic area includes six strategies and 121 actions to meet the expected objectives for climate change, out of which there are 40 actions related to Energy, Industry, Waste, Transport, Forestry and Agriculture & Livestock sectors under Strategy 3: Reduce greenhouse gas emissions through low carbon development pathways.

In addition to the NEP and NEAP, several other documents prepared by the Climate Change Secretariat of the Ministry of Environment, viz First, Second and Third National Communications on Climate Change in Sri Lanka and the Updated Nationally Determined Commitments (2021) submitted to the UNFCCC, being a mandatory commitment of signatories to the Paris Agreement, also depict strategies and actions related to achieving net zero status of Sri Lanka across all sectors.

The sections 1.4.1 to 1.4.6 provide brief details of existing policies, strategies and action plans pertaining to the sectors, that have a bearing on the status and proposed actions for achieving GHG Emission reduction in the particular sector.

- **Draft Low Carbon Development Strategy for Sri Lanka 2021-2030 (MoE, 2021)**

Further to the Paris Agreement (2016), and to support the NDC Process in achieving its goals, a Zero Carbon Strategy had been proposed all over the world and Sri Lanka is one of the countries who had pledged to achieve this by 2050. To facilitate this process, the Climate Change Secretariat of the Ministry of Environment has prepared a document on Low Carbon Development Strategy which covers the following objectives:

- Promote low carbon technologies in all economic sectors through technology transfer and development.
- Reduction in fossil fuel dependencies through the energy savings, increasing energy efficiency and enhancing use of renewable energy sources.
- Provide efficient and effective sustainable transportation system with minimum GHG emission and improve the local air quality and ensure long life through good health.
- To enable Sri Lanka to effectively contribute to the global goal on mitigation, with a view to achieving sustainable development through the low carbon pathways.

- To build the capacity of key economic sectors and relevant institutions to address low carbon development pathways and promote green jobs.
- Development of afforestation and reforestation to enhance carbon sequestration.
- Cross-cutting issues, including the establishment and implementation of awareness creation programs, establishment of adequate research capacity for various R&D and training institutions, and promoting effective documentation of indigenous knowledge on low carbon development pathways in diverse sectors.
- Poverty reduction - Attracting investment for low carbon economic development and hence increasing GDP

1.4.1 Energy Sector

1.4.1.1 Existing policies in Energy Sector

After almost a decade since the introduction of the first documented energy policy directions in 1997, the government adopted the "Energy Policy and Strategies of Sri Lanka" in 2008. Though there was an energy policy prior to 2008, most of the policies governing the energy sector were more on an ad hoc basis, depending on the vision of the government at the time. One such example was the decision of the government to open grid-connected small hydropower (below 10 MW) sector for private investment in 1992.

The "Energy Policy and Strategies of Sri Lanka-2008" was revised as "National Energy Policy & Strategies of Sri Lanka" by the Extraordinary Gazette No. 2135/61 dated 2019-08-19. The main objective of this policy was to ensure the availability of convenient and affordable energy services for equitable development of Sri Lanka using clean, safe, sustainable, reliable and economically feasible energy supply. This Policy supersedes all previous policies, strategies, plans and guidelines published from time to time. This current Policy is formulated in alignment with the future goals of Sri Lanka, current global trends in energy and the Goal 7 of the Sustainable Development Goals of the United Nations. This policy is expected to realize the vision of Sri Lanka in achieving carbon neutrality by 2050.
The National energy policy stands on following ten pillars, to ensure the equity, security and sustainability in the energy sector in Sri Lanka.

- Assuring Energy Security
- Providing Access to Energy Services
- Providing Energy Services at the Optimum Cost to the National Economy
- Improving Energy Efficiency and Conservation
- Enhancing Self Reliance
- Caring for the Environment
- Enhancing the Share of Renewable Energy
- Strengthening the Governance in the Energy Sector
- Securing Land for Future Energy Infrastructure
- Providing Opportunities for Innovation and Entrepreneurship

The National energy policy and implementing strategies will be in effect until it is reviewed in consideration of any major changes in the external environment. Such policy reviews will be conducted at least once in six years, and this is considered as the apex energy policy in Sri Lanka.

Furthermore, specifically for the electricity sector, as per the Section 5 of Sri Lanka Electricity Act, No 20 of 2009, the Minister of the line ministry has the power to formulate the General Policy Guidelines on the Electricity sector for the Public Utilities Commission. The General Policy Guidelines on the Electricity Industry 2021 (issued in January 2022) set the targets of achieving 70% of electricity generation in the country using renewable energy sources by 2030 and carbon neutrality in power generation by 2050 and has decided to cease building of new coal-fired power plants. The Cabinet of Ministers has approved these two policy elements that shall form the basis of Sri Lanka’s future electricity capacity expansion planning. Further, new addition of firm capacity will be from clean energy sources such as natural gas and nuclear power.

The opening up of the small hydropower sector to private entrepreneurs in 1992 and subsequent energy policy actions in the renewable energy sector and energy efficiency and conservation resulted in the government enacting legislation to establish the Sri Lanka Sustainable Energy Authority (SLSEA) in 2007 as the central institution for renewable resource development, energy efficiency and conservation. As per the SLSEA Act, they are empowered to identify, assess, and develop renewable energy resources, with a view to enhance energy security and thereby derive economic and social benefits to the country. Furthermore, they are the apex body to identify and promote, facilitate, implement, and manage energy efficiency programs for use of energy in the domestic, commercial, agricultural, transport, industrial and other relevant sectors.

1.4.1.2 Strategies and action plans in Energy Sector on achieving net zero status in Sri Lanka

Following key mitigation actions are considered as the strategies to reduce GHG emissions in energy sector.

- Decommissioning of all coal power plants by 2044
- No NG plant additions after 2033
- Nuclear power plants to be introduced starting from 2035. The first addition will be 600 MW in capacity which will be introduced in 2035. The next addition will be in 2040 with a capacity of 1000 MW.
- HVDC inter connection to be introduced by 2034.

Proposed Strategies and action plans in Energy Sector related to the above are given in Table 1 in the Annexure 2.

Given the government's current indecision regarding the development of nuclear power plants in the country, exploring alternative strategies becomes crucial. One promising approach is to focus on achieving 100% indigenous renewable energy generation, complemented by efficient energy storage solutions.

Alternative Strategy:

- Decommissioning of all coal power plants by 2044
- No NG plant additions after 2033
- 100% RE share in the energy sector by 2050.
- HVDC inter connection to be introduced by 2034.

Proposed Strategies and action plans in Energy Sector related to the above are given in Table 1 in the Annexure 3.

However, the Long-Term Green Energy Plan (LTGEP) for the period 2023-2042 has shed light on some significant challenges in realizing an 80% renewable energy (RE) share by 2040. Notably, there have been concerns about RE spillage reaching uneconomical levels, hindering the attainment of the desired 80% RE share. The inability of the projected demand profile to absorb the renewable energy generation has resulted in a considerable amount of renewable energy being curtailed, even at an 80% RE share. This raises valid concerns about the practicality of scaling beyond this threshold, as it leads to a substantial increase in investment costs compared to the Base Case and raises doubts about the sustainability of operational expenses.

In light of these findings, it is evident that careful consideration and innovative approaches are essential for achieving a sustainable and economically viable renewable energy future for the country. Policymakers should strive to strike the right balance between renewable energy integration, efficient energy storage, nuclear power plant policy and the overall energy demand to ensure a successful transition towards a greener and more sustainable energy landscape.

1.4.2 <u>Transport Sector</u>

The lack of a national transport masterplan has been a hindrance to accurately forecasting an Emissions Management and Forecast program in the formation of strategy for Net Zero Carbon. Given the present economic conditions of the country, the implementation of projects that require major capital investments is doubtful for the next 5 years.

Yet, some headway has been cast thanks to the declared NDC's in the sector and national plans that have been formatted at ministry and agency levels of the government. 13 NDCs are proposed covering the key sub sectors in the transport sector: (MOE,2021 (a))

1. Transport sector system improvements.
2. Promote public passenger transport
3. Shift freight to efficient modes
4. Rapid transport for passenger transport
5. Promote non-motorized transport modes
6. Introduce taxes and other instruments to promote public transport

7. Introduce inland water transport modes
8. Modernizing and upgrading of suburban railway
9. Promote electric mobility and hybrid vehicles
10. Improve vehicle fleet efficiency
11. Road infrastructure development
12. Reduce GHG emissions from the marine sector
13. Generic enabling activities

While a more systematic project management and development process must be developed at ministerial and its sub-levels, it is envisaged that the already identified projects would yield significant contributions in emission reduction. The projects that can be implemented within the existing infrastructure & operational capacity will be prioritized for short-term implementation and projects such as LRT and Railway Projects which require large capital investments are to be identified as long-term projects.

The Low Carbon Development Strategy published by the Climate Change Secretariat under the Ministry of Environment outlines some of the strategies that can be implemented to reduce the emissions for the period 2021-2030 which are based on the National Determined Contribution (NDC) report published for the same period.

Sri Lanka Climate Prosperity Plan 2022 (V20, 2022), which has been endorsed by the President of Sri Lanka also outlines similar initiatives for achieving carbon reduction with a special focus on sustainable transportation. It specifies several targets with a time frame up to the year 2040 to achieve these goals. However, majority of these targets are focused only on electrification and promotion of non-motorized travel, as shown in Table 1.1.

Table 1.1 : Targets for Transport Sector in Sri Lanka Climate Prosperity Plan

Target		Year
Electric Mobility	Promotion of electric mobility and hybrid vehicles	2025
	50% of new road vehicles are electric or hybrid.	2030
	90-100% of new road vehicles are electric or hybrid.	2035
	50% of public transportation, including suburban railway, is electrified including through retrofitting.	2030
	100% of public transportation, including suburban railway, is electrified including through retrofitting.	2035
Non-Motorized Travel (NMT)	5km of bike lanes integrated into relevant roads in 10 key urban locations	2025
	50% of relevant roads include bike lane	2030
	90-100% of relevant roads include bike lane	2035
	Promotion of non-motorized transportation in key urban centers	2025
	Share of non-motorized transportation increases to 20% of all road trips	2030
	Share of non-motorized transportation increases to 30% of all road trips	2035

The estimated financing requirements for the proposed initiatives is US $ 2 billion over a 20 - year period. (V20, 2022)

1.4.3 Industry Sector

Following policies and related strategic declarations are in support of industry sector IPPU Net zero achievement either directly or indirectly.

- National policy on industry development (NaPID) and action plan (unpublished and in development / draft stage)
- National environmental policy (NEP) 2022
- National environmental action plan (NEAP) 2022 – 2030
- Draft national policy and strategy on sustainable development (2020)
- National policy on sustainable consumption and production (2019)
- National climate change policy (2014)
- National action plan for "Haritha Lanka" program (2009)
- National Policy and Strategy for Cleaner Production (2005)

In the newly developed NEP and NEAP documents, Industry sector has been selected as one of the main focus areas ("Air, Biodiversity, Climate, Coastal and Marine, Land, Waste, Water, Cities and Industry are the main focus areas reflected", specifically identifying the cement industry process emissions as "activity 3.3.6 - Reduce industrial process GHG in Clinker production in cement industry to reduce 180,034 tCO_2/year is proposed").

Similarly, the NaPID and industry development action plan as well as the NDCs proposes to address the climate change mitigation activities.

Though the above policies and guidelines are well developed, due to the lack of national apex / umbrella policy, proper coordination between policies is a major gap in the country context. Although Climate change, biodiversity loss and plastic pollution are recognized as the three top global environmental issues, in Sri Lanka the priorities given to these issues in national development path is observed insufficient. In addition to the policy gaps, certain ad-hoc initiatives / programs taken at political level never support the relevant priority issues.

1.4.4 Waste Sector

The following National Policies, strategies, and action plans for Sri Lanka provide policy directions for the waste sector.

Existing policies & strategies related to the waste sector
1. National Environment Policy (2022)
2. National Policy and strategy on cleaner production for the health sector (2007)
3. National Strategy for Solid Waste Management (2008)
4. National Climate Change Policy of Sri Lanka (2014)
5. National Policy on Waste Management (2019)
6. National Policy on Sustainable Consumption & Production (SCP) for Sri Lanka (2019)

Action plans related to the waste sector

1. National Environmental Action Plan 2022-2030: Pathway to sustainable development
2. National Action Plan on Plastic Waste Management 2021–2030

The National Environmental Action Plan 2022-2030: Pathway to sustainable development has defined a list of actions related to the waste sector, which is identified as a priority sector to reduce GHG emissions in the path of low-carbon development, by implementing appropriate mitigation measures. One of the main objectives under this Policy Thematic Area (PTA) is to create new partnerships and strengthen the existing ones for mobilization of resources to face global environmental challenges, especially for adapting to climate change impacts and mitigating GHG emissions (NEP, 2022).

In order to optimize the co-benefits of GHG emission reduction measures, including environmental quality improvement, better energy security, improved food security, decreased reliance on imported fossil fuels, and improved health benefits, alternatives in the Waste sector include, but are not limited to:

- Integrated waste transport solutions with low and zero-emission vehicles including non-motorized vehicles
- Integrated solutions of waste management
- Resource-Efficient Cleaner Production (RECP)

1.4.5 <u>Agriculture Sector</u>

The Ministry of Agriculture is one of the main agencies responsible for formulating and executing a coherent policy, which would support implementing a programme to achieve net zero status by 2050 in Sri Lanka.

In the ‘Republic of Sri Lanka Agricultural Policy and Program Review’ made by World Bank Group (1975) on Sri Lanka Agriculture, it has discussed the recent performance of the agricultural sector in Sri Lanka, recent policy actions and plans and identified areas for external financing in support of agricultural development. It is noted that Sri Lanka's agricultural policies aim to increase self-sufficiency in food production, diversify crop production, expand employment opportunities, and improve rural living conditions and social services.

The Government at that time instituted price support programs, productivity centers to improve extension, credit, input supply, and marketing services and legislation to control land use, tenancy, and ownership, and support and subsidy programs to assist the tree crop sub-sector. Additional measures recommended in the report include (i) reduction of the subsidy on fertilizer; (ii) expansion of extension programs; (iii) assessment of draft and mechanical power needs; (iv) improvements in land use; (v) improvement of farm credit programs; (vi) evaluation of taxation, levies, and subsidy systems; and (vii) provision of more foreign exchange.

The current National Agricultural Policy formulated by the Ministry of Agriculture was approved in 2021. Other current policy document that relates to Agriculture is the National Livestock Breeding Policy (DAPH, 2010)

National Agricultural Policy (2021)

The present National Agricultural Policy includes 12 goals to be achieved by 2030 (Ministry of Agriculture, 2021), aimed at doubling the resources-productivity while adhering to sustainable and ecofriendly agricultural practices and doubling the economic profitability of farmers and agri-producers, compared to 2020 values, and others that increase the yield and contribution of Agri-Food systems to the national economy, use of technology, high quality seed and planting materials, eco-friendly inputs, promoting participatory approach in decision making and building an agri-food system in Sri Lanka that is resilient to climatic and other disasters.

Even though climate mitigation actions are not specifically mentioned in the National Agricultural Policy (2021), achievement of these goals, particularly those promoting sustainable and eco-friendly practices and improved productivity would certainly contribute to mitigation of GHG emissions. The strategies and actions under these goals should be carefully developed, to lead to GHG emission reduction, without compromising or delaying the much-needed economic development, food security and climate resilience which far outweigh the need for climate mitigation actions in the context of the minimal contribution to the quantum of global emissions made by Sri Lanka.

The goals of the Paris Agreement cannot be met without transformative changes in the agriculture sector. Incorporating more ambitious, explicit, and directed actions in the agriculture sector in enhanced nationally determined contributions (NDCs) can help make this necessary transition (Ross et al, 2019). This needs going beyond 2030 targeting policies. The Ministry of Agriculture is one of the agencies responsible for formulating and executing a coherent policy, which would support implementing a programme to achieve net zero status by 2050 in Sri Lanka. The present agricultural policy has included following goals to achieve by 2030.

1. Double the resources-productivity (compared to 2020 estimates) by adhering to sustainable and eco-friendly agriculture practices
2. Double the economic profitability of farmers/agri-producers (compared to estimates of 2020)
3. Increase the contribution of the Agri-Food System up to 15% of the National Economy
4. Increase the adoption of technology developed locally along the agri-food value chain, by a minimum of 50% from the present status
5. Increase the high quality and high yielding seed and planting material production locally by 50% of the national requirement

6. Increase the eco - friendly inputs availability in crop production up to 100% of the requirement
7. Supply safe and quality food and feed in compliance with food and feed control regulations of the country
8. Establish a government-regulated food and feed control system supporting certification, standardization, and other logistics
9. Establish farmer/agri-producer groups with Agri-entrepreneurship capacity, coupled with efficient market systems
10. Establish a constituted role and mandatory participation of farmers/agri-producers in the process of decision-making
11. Build an agri-food system in Sri Lanka that is resilient to climatic and other disasters
12. Establish a system of transparent, accountable, responsible and participatory governance is established for decision making

<u>The National Agriculture Policy (2021) - Policy statement 12</u>

Promote adoption of appropriate adaptation and mitigation measures to increase climate resilience of the agriculture systems, where it has included as 12.3. Adhere to the actions related to agriculture identified in the National Adaptation Plan (NAP) for Climate Change and Nationally Determined Contributions (NDC). Thus, the National Agriculture Policy 2021 indicates the importance of strategies such as C net zero Concept to increase climate resilience of the agriculture systems.

National Livestock Breeding Policy (2010)

The Livestock sector has a National Livestock Breeding Policy (DAPH, 2010), where there is no mention made on strategies for reduction of enteric fermentation. However, the Department of Animal Production and Health (DAPH) at the First Stakeholder meeting had the view of the following strategies to reduce GHG emissions:

i. Improve dairy sector productivity by managing herd, herd health, feed and improving animal comfort and welfare;

ii. Improve productivity of Monogastrics by improving genetic, feed efficiency, animal health, comfort and welfare; and

iii. Adopt renewable energy for livestock applications

According to the Ministry of Livestock Development, the DAPH requires formulating a national livestock policy, but due to lack of adequate resources such as finance, manpower and technical knowhow, the task is getting delayed.

1.4.6 Forestry Sector

Sri Lanka submitted its initial NDCs in September 2016 as a country that ratified the Paris Agreement. After going through an intense readiness process in all the sectors in the NDCs, with up-to-date analysis, improved information and data, and an extensive stakeholder consultation process, the updated NDC was submitted in 2021 for the period 2021-2030. It represented a more ambitious, quantified, and robust assessment of the mitigation and adaptation measures for the next decade (2021-2030) informed by the forestry sector which is primarily a mitigation sector due to the trees being able to sequester atmospheric carbon dioxide in their food preparation process (photosynthesis),5 NDC actions were submitted with the primary objective of increasing the forest/tree cover in the country with the target of 32% of the country's land area by 2030.

The National Physical Planning Policy and Plan (2021-2050)

This Plan which is the updated version of the National Physical Planning Policy and Plan (2020-2030) states that all lands in the country cannot be put into economic use; some lands must be protected to fulfil certain objectives that will benefit the country and contribute to sustainable management. These lands include watershed areas, areas with rare ecosystems and ecosystems of exceptional diversity, areas with concentrations of economically important or potentially important species and threatened species, fragile areas that may be easily degraded, and important aesthetic, cultural, historical and recreational areas. The Policy, therefore, recommends that a protected area network be established that will integrate all the areas within the Country that need to be conserved. The areas included in the network will be divided into two categories depending on the level of protection afforded. They will comprise of areas that will be preserved strictly to protect biodiversity, soil, water, historical, cultural, religious and aesthetic values and scenic beauty. These will include all wildlife reserves, all conservation forests identified by the Forest Department, degraded forest areas that will be restored for ecological reasons, areas of archaeological and historical value where there are no development activities;, of natural beauty and natural features of exceptional value, environmentally and hydrological important lands in the hill country, areas where landslides are to be expected, un-utilized lands in areas of high rainfall intensity with slopes of over 60% and highly erodible soils and all natural and man-made water courses and water bodies, as well as their reservations and catchment areas.

The National Watershed Management Policy (2004)

This stresses the need of resolving degradation occurring in the upper watersheds of the country, which has manifested through denuded forest cover. The exposed slopes have become prone to landslides, and the soil profiles are truncated by erosion and poor in fertility, increasing fragmented and uneconomic land holdings worked on by the people, the silting of rivers and reservoirs, and the frequent and costly floods in the coastal plains.

The Land Use Policy (2007)

This aims to ensure suitable land use, food security, economic development and the maintenance of the productivity of the land in the country. It also promotes protection, conservation and sustainable use of the land resource and offers ideal framework that will best meet the needs of the present generation, while safeguarding the needs of the future generation. The Policy is very ambitious and aimed at directing land use in the direction of scientific land use. Mitigation of land degradation has been given high priority in the Policy and suggests enhancing peoples' participation in the sustainable use of land resources, rehabilitation of degraded lands, avoidance of type of land use that constrain sustainable development, preventing encroachment on state lands, creating awareness on scientific land use, implementing effective conservation measures for agricultural land use, rehabilitating marginal and uncultivated lands, protecting environmentally sensitive areas, protecting and conserving land above 1600 m elevation, conserving slopes exceeding 60% situated 1,600 m above mean sea level, using reforestation or agroforestry, and applying appropriate conversion measures in the landslide prone areas.

National Policy on Protection and Conservation of Water Sources, their Catchments and Reservations in Sri Lanka (2014)

This deals with the conservation, protection, rehabilitation, sustainable use and management of the watersheds, while maintaining their environmental characteristics with the involvement of people. The Government Extraordinary Gazette number 1894/3 of 2014/12/22 under the policy on conservation of Water Sources and Water Spouts of 2014 protects and conserves all water sources, their reservations, conservation areas and immediate catchment areas to ensure the existence of the water sources.

Forest Conservation Ordinance and the Fauna and Flora Protection Ordinance (2016)

Natural forests in Sri Lanka are owned, managed and protected by the Forest Department (FD) or the Department of Wildlife Conservation (DWC), and account for about 35% of the total land area of Sri Lanka (MoMD&E, 2016). The FD and DWC are guided by two legal enactments, the **Forest Conservation Ordinance and the Fauna and Flora Protection Ordinance.** Under the Forest Conservation Ordinance of 2009, natural forests coming under the jurisdiction of the Forest Department are designated as Conservation Forests, Reserve Forests or Village Forests and the Ordinance has provision to protect these forests and their produce. The Fauna and Flora Protection Ordinance No 02 of 1937 and subsequent amendments provide for the protection of six categories of natural ecosystems under the jurisdiction of the Department of Wildlife: strict natural reserves, national parks, nature reserves, corridors, and sanctuaries.

Section 13 of the Mahaweli Authority of Sri Lanka Act No.23 of 1979 states that "Notwithstanding the provisions of any other law and without prejudice to the generality of the powers conferred on the Authority by this Act, the Authority shall in or in relation to any Special Area have the power to take such measures as may be necessary for watershed management and control of soil erosion."

Section 22 of the National Environment Act No. 47 of 1980 and subsequent amendments states that the CEA "in consultation with the Council shall, with the assistance of the Ministry charged with the subject of Soil Conservation, recommend soil conservation programmes including therein the identification and protection of critical watershed areas, encouragement of scientific farming techniques, physical and biological means of soil conservation, and short term and long-term research and technology for effective soil conservation".

The National Watershed Management Policy of 2004 provides measures that conserves, protects, rehabilitates, sustainably uses and manages the watersheds, while maintaining their environmental characteristics with the involvement of people. The Government Extraordinary Gazette number 1894/3 of 2014/12/22 under the policy on conservation of Water Sources and Water Spouts of 2014 protects and conserves all water sources, their reservations, conservation areas and immediate catchment areas to ensure the existence of the water sources.

SECTION 2: INTRODUCTION OF THE SECTORS AND THEIR CURRENT STATUS

2.1 Introduction to each sector

2.1.1 Energy Sector

Sri Lanka's primary energy supply was predominantly from biomass (65%) and petroleum (27%) in the early 1980s. Due to the changes in living standards, biomass requirement was gradually reduced, and petroleum requirement gradually increased. The total energy requirement of the country was 509.6 Petajoule in 2019, and the primary energy supply mainly consisted of 223.8 Petajoule of Petroleum, 169.0 Petajoule of biomass, and 58.7 Petajoule of Coal. Accordingly, 55.4% of total energy consumption is from imported fossil fuels (Petroleum + Coal), and the balance is from indigenous resources (SLSEA, 2019). Figure 2.1 shows the distribution of the energy supply in the year 2019, while Figure 2.2 shows the variation of the energy demand by energy sources over the period 1983 to 2019 and Fig 2.3 shows the variation of total energy demand by the various sectors over the same period, as reported by the SLSEA (SLSEA, 2019). Biomass comes in different forms such as fuel wood (unprocessed logs and processed chips), municipal waste, industrial waste, and agricultural waste.

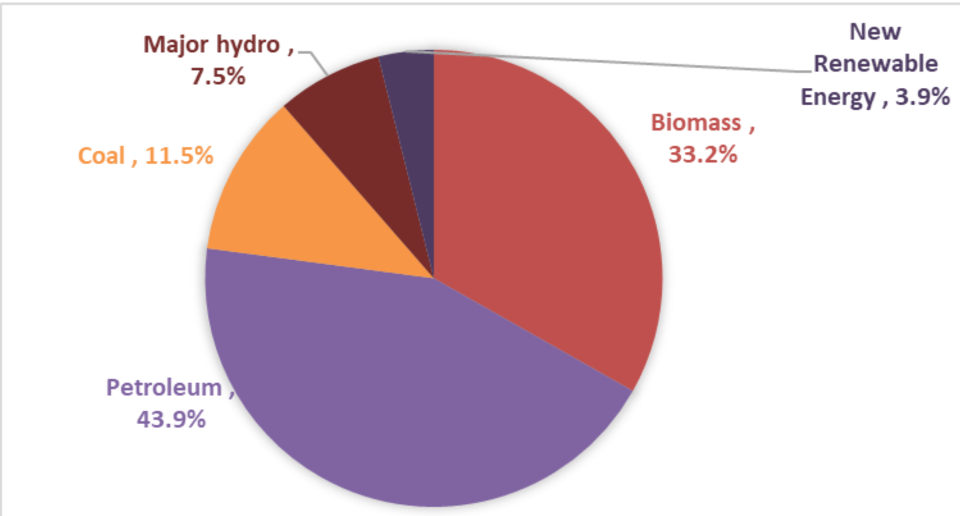

Figure 2.1 : Energy Supply in 2019 (SLSEA, 2019)

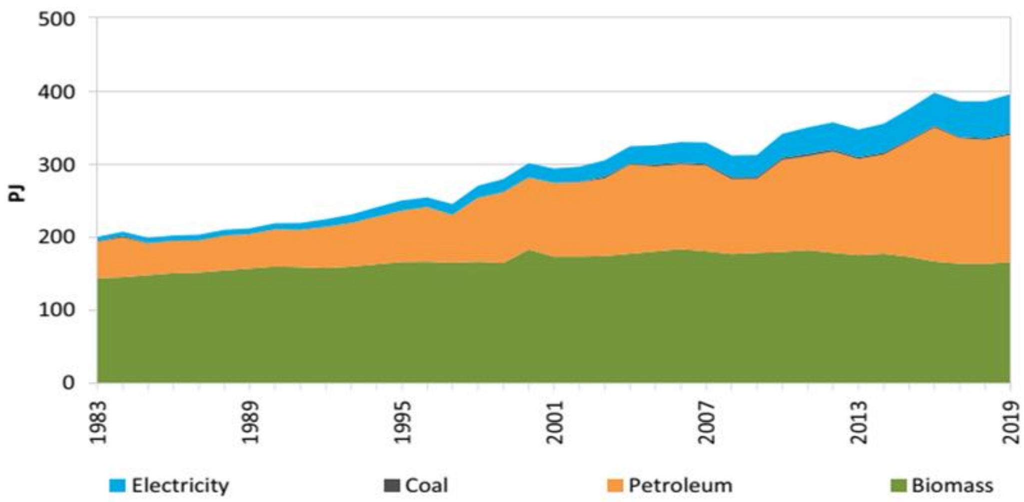

Figure 2.2 :Total Energy Demand by Energy Source

Considering the energy demand side, the main sectors of energy demand are Industry, Transport and Household, commercial and others. Figure 2.3 shows the growth of energy demand by the three sectors mentioned above.

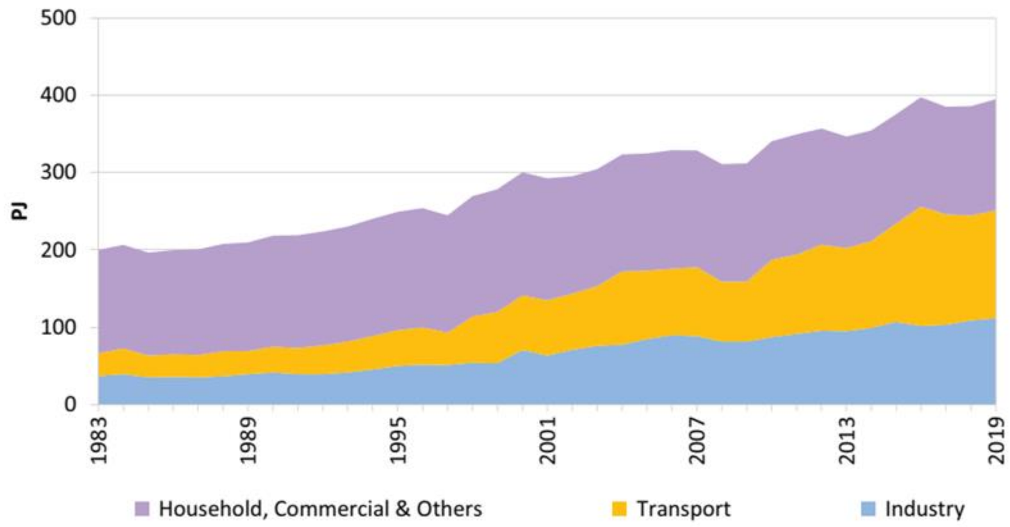

Figure 2.3 : Total Energy Demand by Sectors

The development of the net zero strategy for the energy sector has been done with relative ease due to the availability of several well-researched information sources and data bases. Some of these sources are the Ceylon Electricity Board (CEB), the Public Utilities Commission of Sri Lanka (PUCSL) and the Sri Lanka Sustainable Energy Authority (SLSEA). Useful energy data was also drawn from internationally active emission programs that have also been active in Sri Lanka, such as the Clean Development Mechanism (CDM). Further useful data was extracted from national plans such as the *National Energy Policy and Strategies of Sri Lanka 2019* and the Goal-7 of the Sustainable Development Goals (SDG's) of the United Nations and published in August 2019.

As the industrial (IPPU) and transport sectors are discussed in separate sections, only the contributions coming from the electricity sector, LPG, and Firewood are evaluated in detail in the energy sector.

The government's recent declaration of a 70% Renewable Energy target by 2030 with no capacity addition of coal power plants has also helped to streamline the emissions management aspects of the Net Zero Carbon development. Quite independently, the Secretary to the Ministry of Power has committed to this goal that was national and international news. At present the Long-Term Generation Expansion Plan (LTGEP) considers achieving 70% RE by 2030 and maintaining 70% RE beyond 2030. Therefore, a further increase of RE component up to 100% by 2050 is not out of place.

Energy conservation through Demand Side Management (DSM) is also considered one of the potential areas of reducing electricity demand and thus reducing the emissions in the sector. Programs such as phasing out the use of incandescent electric lamps and introducing energy efficient equipment are expected to save 2,603 GWh and 5,189 GWh energy respectively, and thus 1,848 Gg and 3,684 Gg CO_2 emission reduction respectively, by 2030 (SLSEA).

It is targeted that a GHG reduction of 25% with 5% unconditionally and 20% conditionally in the electricity sector could be achieved, equivalent to an estimated mitigation level of 9,819,000 tonnes unconditionally and 39,274,000 tonnes conditionally (total of 49,093,000 tonnes) of carbon dioxide equivalent during the period of 2021-2030. This compares to the BAU scenario of the Long-Term Generation Expansion Plan 2013-2032 of Ceylon Electricity Board published in October 2013.

2.1.2 Transport Sector

Transport of Goods and Passengers including Warehousing is one of the major sub sectors that come under services in the Sri Lankan economy which contributed to 23 % of GDP in 2019.

Road density of 1.76 km/km^2 of Sri Lanka is one of the highest in the region with similar economic level. Road transport has become the dominant mode of transport resulting in 94% of passenger transportations and 98% of freight transportation which are moved by roads. Total road network in the country is about 115,000 km, which includes 12,496 km National highways (A & B class roads), 272 km of Expressways which are administered by the Road Development Authority and 18,617 km of Provincial roads managed by the respective Provincial Road Development Authorities. There are about 65,000 km of local authority roads in both the urban and rural sectors. The remaining roads estimated to total 20,000 km are owned or controlled by irrigation and wildlife authorities or other government agencies (NTC, 2021).

The present active vehicle fleet of Sri Lanka is around 6.7 million, of which 54% are motorcycles, 16% are three-wheelers (motor tricycles), 11% motor cars, and 1% buses (MoE, 2021). Vehicle population growth has been substantial over the last decade up to the year 2020. For example, between 2015 and 2019 alone, more than 1.6 million motorcycles have been added to the fleet, which has been the most significant factor for the observed vehicle growth in Sri Lanka. However, with the import restriction in progress, new vehicle registrations are very low. More than 30% of the operated motor vehicles are in the Western Province. Figure 2.4 shows the growth of vehicle numbers per 1000 inhabitants and as a percentage in Asian countries, over the period 2011 – 2018.

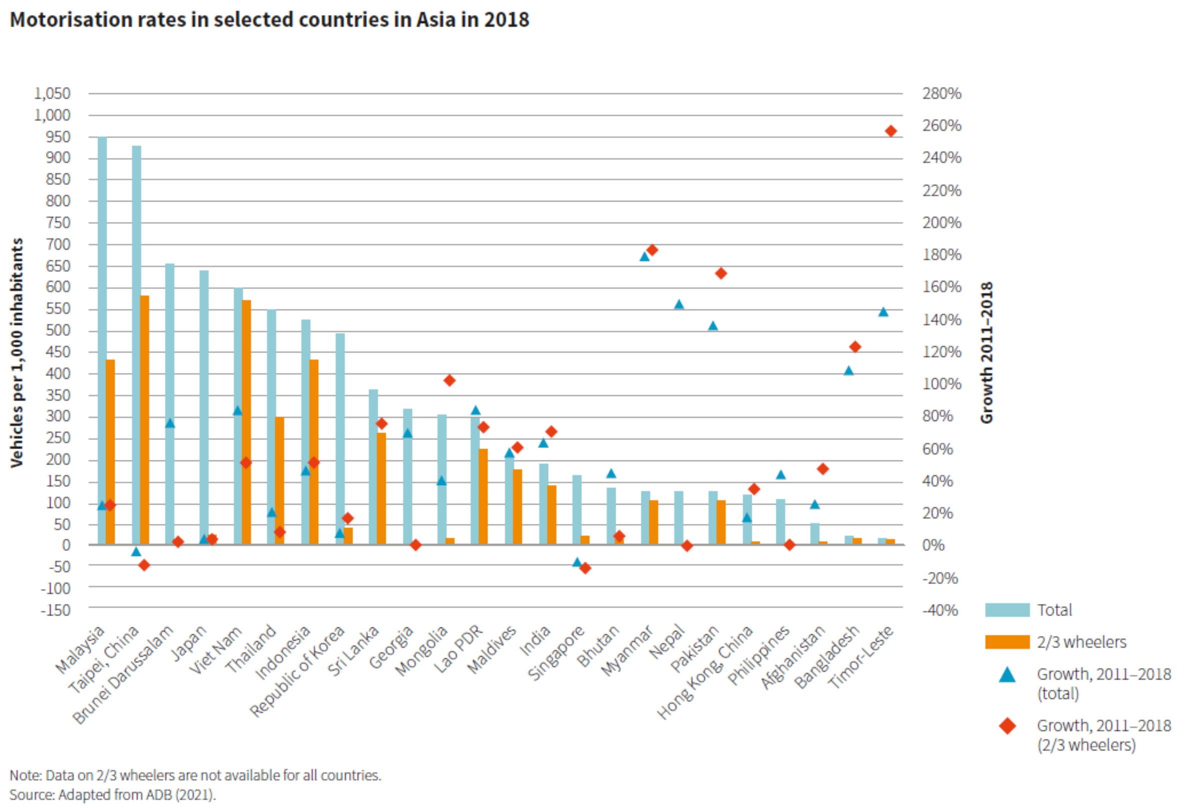

Figure 2.4 : The growth of vehicle numbers per 1000 inhabitants and as a percentage over the period 2011 – 2018 in Asian countries

Source*: Council for Decarbonizing Transport in Asia (2022).*

Sri Lanka Transport Board operates around 7100 buses, which ran approximately 430 million vehicle kilometers per annum and 14.3 billion passenger km, in 2019. A steady decline of around 4% p.a has been observed in the ridership of SLTB buses. Private bus operational fleet was around 19,980 in the year 2019, corresponding to 1085 million vehicle km and 54.2 billion passenger kilometers per year.

The rail network is 1619 km, which operated around 12.5 million train km in 2019 and 7.3 billion passenger kilometers; around 0.5 million goods train km were operated as well.

The modal share based on passenger km is around 37% for buses, 3% for railway and rest for private vehicles.

The active vehicle fleet in SL is shown in Figure 2.5, and it can be seen that the majority are motorcycles.

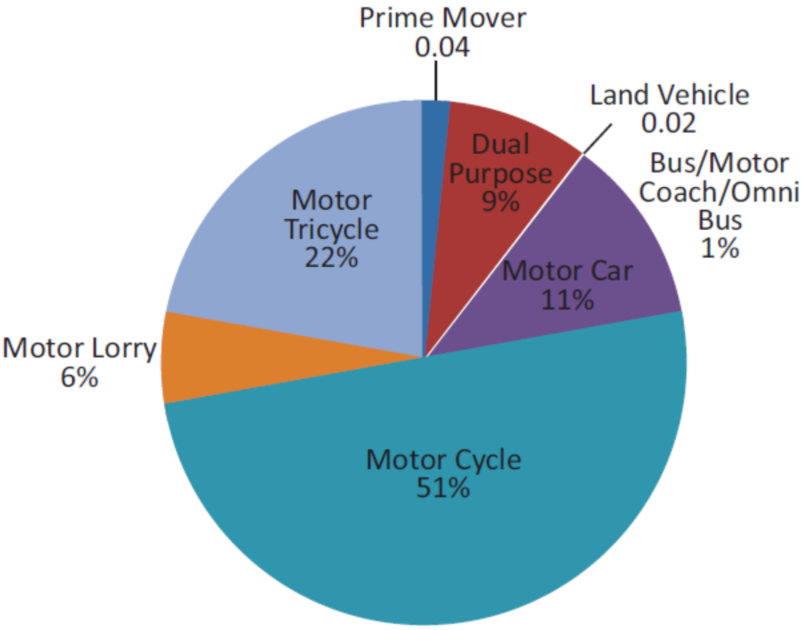

Figure 2.5 : Active vehicle fleet

Figure 2.6 below depicts the composition of the road vehicles, and the majority of the vehicles are being used for private transportation and public transport as a percentage has gone below the freight transport.

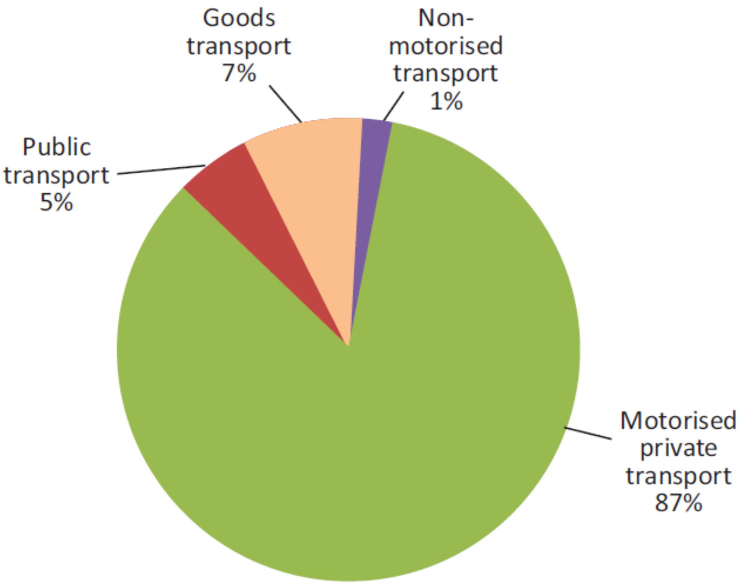

Figure 2.6 : Composition of the Road vehicles

Transport sector accounts for 21% of total emissions, and road transport accounts for three-quarters of transport emissions, road transport accounts for 15% of total CO_2 emissions. 128 kilotonnes of oil equivalent (ktoe)/person in 2016, which is an increase from 91 ktoe/person in 2000. Out of all fossil fuels used in the country, 39% was used for transport in 2016.

Although no major effort has been made to control emission levels, Sri Lanka's emission levels are comparable with Asian region countries considering the GDP and the population, as shown in Figure 2.7 and Figure 2.8. This also reflects the similar issues prevailing in other Asian countries.

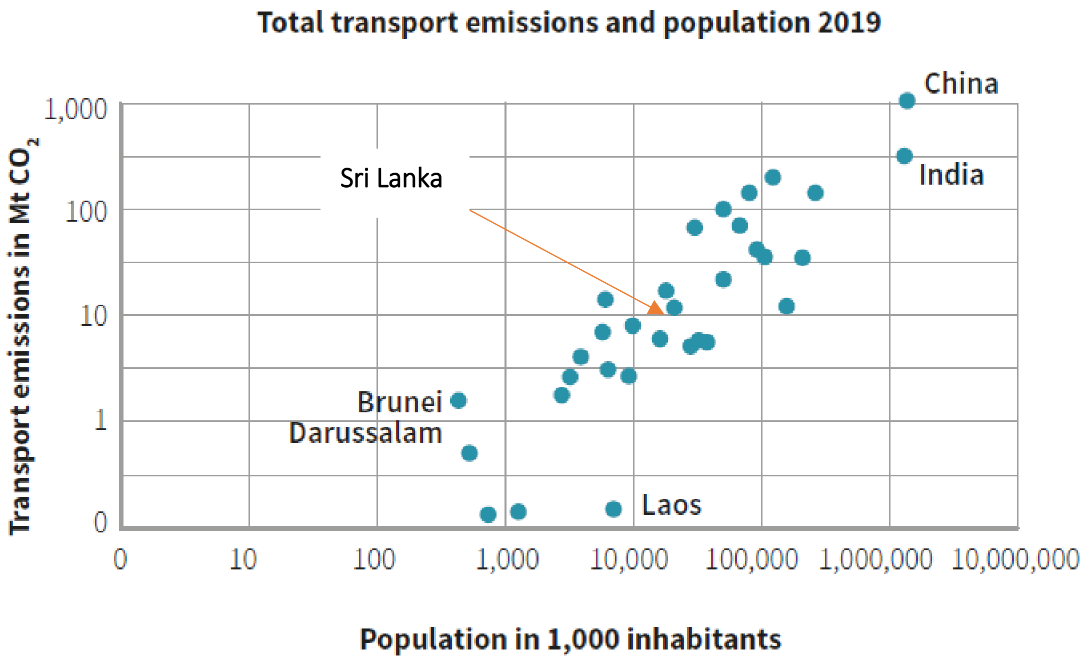

Figure 2.7 : Total Transport Emissions and Population, 2019

Source: Council for Decarbonizing Transport in Asia (2022).

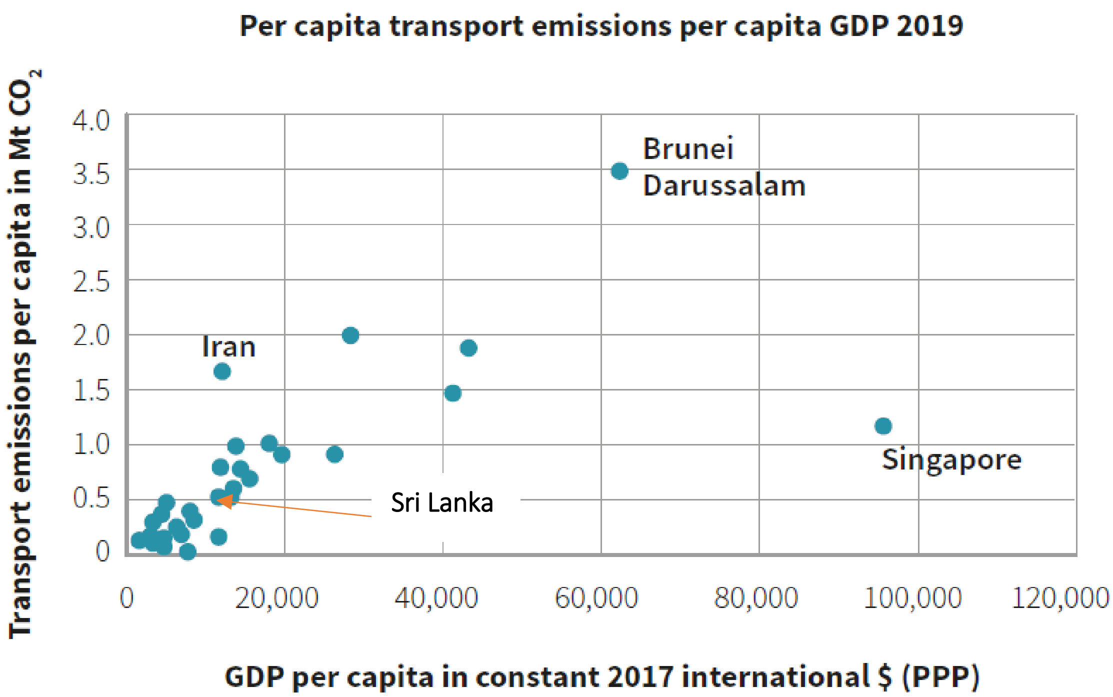

Figure 2.8 : Per capita Transport Emissions/ per capita GDP- 2019

Ref: Council for Decarbonizing Transport in Asia (2022). The Path to Zero: A Vision for Decarbonised Transport in Asia –Overcoming Blind Spots and Enabling Change"

2.1.3 Industry Sector

In the industry sectors, Chemical and physical processes that transform materials releases a significant amount of GHGs, such as CO_2, CH_4, and N_2O, industry sector being one of the major sources of emissions at the global scale. Additionally, apart from above gases HFCs and PFCs often are considered possible sources of emissions in the industrial processes and product use (IPPU) sector. Mainly cement, ceramics, lime, glass, chemicals, metal, solvent applications, surface coatings, wood preservative applications, spirit manufacturing and fluorinate compounds have all been considered as sub-sectors under the IPPU sector to calculate emissions.

However, the national GHG emission picture is significantly different to the global picture, where, as shown in Figure 2.9, the industry sector only represents about 6% in the total emission account, including both industry energy use and process emissions. (TNC, 2021). Out of this 6%, industry sector energy-use related emissions accounts for about 5% and IPPU sector for balance 1%.

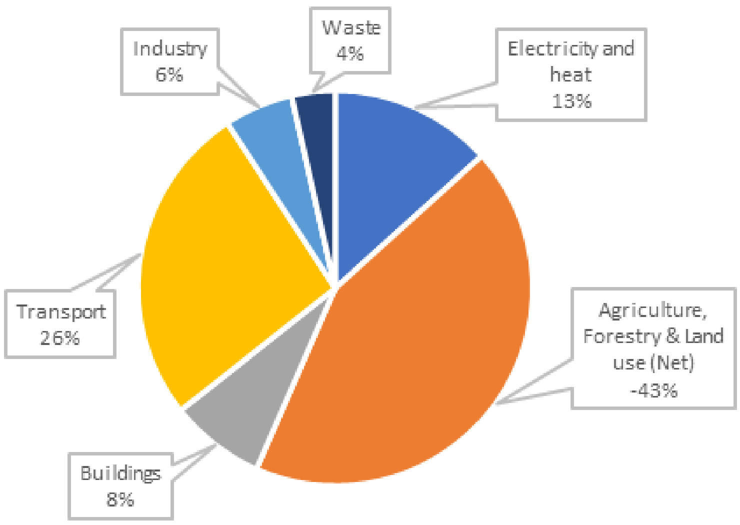

Figure 2.9 : National GHG Emission by economic sector

Source: 3rd National communication (2010 baseline data)

The emission mitigation and sequestration aspect of the industrial sector revolves around the existing industrial processes that have been somewhat taken up by the industry. Most of the current and past initiatives has come from private sector owners. However, again as in the transportation sector, no definitive or clear-cut long-term policies are observable. What is captured in terms of emissions management program for the industry are aspects met in other sectoral (emissions) abatement programs mooted mainly by the private sector owners to ensure sustaining the industry and work force, that is a very laudable effort indeed.

For example, the energy management activity in industry has a direct link to the emissions aspect of this study and provides a cross sectional view of measures and incentives available to the industry for energy savings. The call for fuel switching, power factor corrections, use of time-of-day tariffs all emanate from a study of the energy sector. Hence a clear-cut policy framework for the industrial sector has so far not been cast due to the very nature that many other aspects of sectoral interventions with other sectors being present. The following are some of the areas for emissions abatement and sequestration in the Sri Lankan industry.

- Cleaner production initiatives
- Energy efficiency improvements
- Industry feedstock quality management and circular economic options
- Utilizing green hydrogen and new renewable energy sources

2.1.4 Waste sector

The waste categories such as Municipal Solid waste (MSW), domestic wastewater, industrial wastewater chemical sludge, biological sludge, and sewage mainly emit Green House Gases (GHGs) into the environment, which caused he most important environmental hazards of global warming and the greenhouse effect that pose a threat on a global scale (Karl and Tubiello, 2021).

The waste sector contributes to producing greenhouse gases (GHGs) like carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) from solid and liquid waste categories as well as the waste management sector's vast array of activities.

GHG emission sources from different waste sector activities:

GHG emissions in the waste sector are generated from different treatment and disposal routes that can be categorized as emissions from (Vahk, 2020):

1. Municipal Solid Waste disposal (MSW management practices)
   - Open dumping (SWDS)
   - Landfilling
   - Biological treatment of solid waste (Composting)
   - Incineration and open burning of waste
2. Wastewater treatment and discharge (Industrial WW & domestic WW)
3. Sewage treatment and discharge
4. Chemical & Biological Sludge

Municipal Solid Waste includes garbage, refuse, or a variety of solid material of which the lifetime is over, or is discarded or rejected as useless or unwanted, from human and animal activities which originate from households, commercial establishments, and community actions that are collected by municipalities or other local authorities are considered as MSW. GHG emissions from the waste sector depend on the disposal processes used more or less, and the corresponding GHG emission intensity (GHG emissions per kg disposed of MSW) might reflect the city's waste management level (Liu *et al.*, 2021). MSW can be disposed of in several ways, including open burning, incineration, composting, or utilization as an input to biogas production. However, the majority of MSW ends up in landfills and open dumps where the anaerobic decomposition of organic material releases methane gas (CH_4) (Karl and Tubiello, 2021).

Intergovernmental Panel on Climate Change (IPCC)'s Inventory states that MSW is one of the main sources of anthropogenic CH_4 emissions, which is one of the most important greenhouse effect contributors (Zeng *et al.*, 2014). The GHG emissions from waste collection and landfill activities make a significant contribution; MSW is the fourth largest producer of global emissions of non-CO_2 GHGs that contribute towards global warming and climate change due to their emissions, and it approximately contributes 5.5–6.4% towards global methane (550 Tg) emissions annually (Maria, Góis and Leitão, 2020).

The general stages of MSWM such as collection, separation, treatment, transfer, and disposal all contribute to GHG emissions. There are further GHG emissions associated with waste receptacles, vehicles, and treatment facilities, as well as the transfer of residual waste materials from intermediate stations and treatment facilities to landfills (Skillicorn et al., 2013). GHG emissions in various stages of MSWM practices are indicated in **Figure 2.10.**

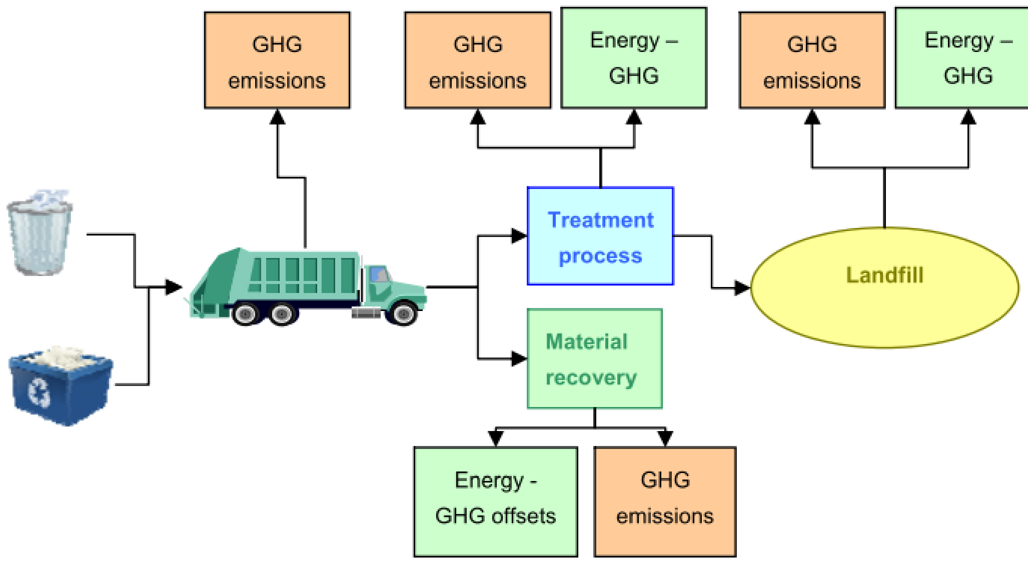

Figure 2.10 : Simplified schematic of the waste management system and GHG emissions (Skillicorn et al., 2013)

Open dumping is the most common practice of MSW disposal which creates numerous environmental and health impacts. Open dumping and landfilling produce CH_4.

Composting is a natural biological process, carried out under controlled aerobic conditions. In this process, various microorganisms, including bacteria and fungi break down organic matter into simpler substances. Compost piles have been found to release CO_2, N_2O, and CH_4.

Literature shows the impact of landfilling and composting on GHG emissions considering streamlined life cycle activities and the decomposition process which reveals that net greenhouse gas emissions for landfills tend to be higher than that for composting facilities (Lou and Nair, 2009).

Incineration and open burning of solid waste produces CO_2, CH_4, and N_2O. The incineration categories include solid and hazardous waste including pharmaceutical waste, waste oil, and industrial sludge. Open burning is the most common practices method of disposal of MSW in rural areas and sub-urban areas which emits 188,600 tonnes CO_2eq in 2022, where there are no proper waste management facilities available.

Municipal and industrial wastewater and their by-products sludge, produce GHG gases that induce global warming (Massoud, 2001). GHGs from wastewater treatment plants (WWTPs) include carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). GHGs from WWTPs can be divided into two categories. The direct emissions produce CO_2, N_2O, and CH_4 from wastewater sources and activities that promote fugitive gaseous emissions related to physical and biochemical processes. Indirect emissions include energy use associated with wastewater transportation, pumping, various treatment processes, effluent disposal, and residual management (Lisowski et al., 2011).

Sewage treatment plants are one of the significant sources of GHG emissions. Sewage treatment includes both industrial and domestic sewage treatment. During the sewage treatment, the anaerobic process produces CH_4 while nitrogen removal produces N_2O. Both CH_4 and N_2O are chemically stable and can stay in the atmosphere for a long period. The Global Warming Potential (GWP) for a 100-year scale of CH_4 and N_2O are 25 and 298 respectively (…).

CO_2 emissions from sewage are not considered in the IPCC 2006 records, however, and the reason posed is that these are of biogenic origin; but this aspect of exclusion should be questioned as national total emissions load is a function of this number as well, quite clearly, the growing number of sewage treatment plants inevitably leads to higher GHG emissions, posing a significant challenge to managing GHG emissions in the waste sector (Xing et al., 2012)

Chemical and biological sludge production during wastewater & sewage treatment in treatment plants has increased dramatically due to rapidly increasing population, industrialization, and urbanization, as well as to higher levels of wastewater treatment (Pilli *et al.*, 2016). Organic matter in sludge is converted to principal greenhouse gases (GHGs) such as CO_2, CH_4, and N_2O, depending on the environmental conditions during sludge treatment and disposal.

2.1.5 Agriculture Sector

Agricultural lands contribute to the greenhouse effect primarily through the emission and consumption of greenhouse gases (GHGs) such as methane, nitrous oxide, and carbon dioxide, as shown in Fig 2.11. In addition to that, green cover helps to reduce the greenhouse effect where, reflectivity or the land surface albedo (LSA) which is the ratio of the upwelling radiant energy relative to the down welling irradiance incident upon a surface of the land reduces by the green cover. In ecological systems, albedo can affect physical and physiological processes of ecosystems, such as energy balance and evapotranspiration by regulating the microclimate conditions of plant canopies and their absorption of solar radiation (Tian et al., 2014).

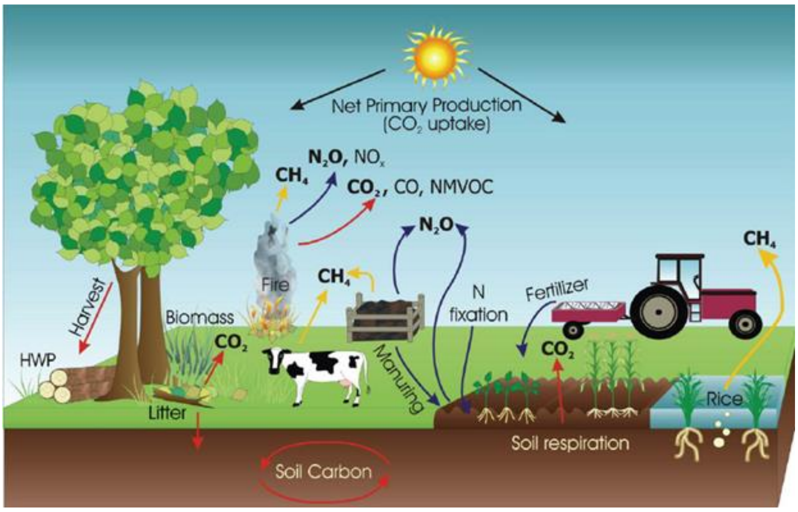

Figure 2.11 : Emission and consumption of greenhouse gases (GHGs) from Agriculture sector

Agricultural land covers approximately 2.6 million hectares or roughly 42% of Sri Lanka’s total land area. The great majority of the land used for food production is owned by about 1.65 million smallholder farmers. With average landholdings totaling less than 2 hectares, smallholder farmers are in charge of almost 80% of Sri Lanka’s total annual crop production.

The agricultural area in Sri Lanka has increased gradually in the past decade. With the end of the internal conflict, previously inaccessible territories have been converted into productive cropland. According to the statistics of Food and Agriculture Organization of United Nations, from 2003 to 2013, rice-harvested areas increased by 30.4% (911,440 to 1,188,230 hectares), while maize-harvested areas more than doubled (27,060 to 67,720 hectares). During the same timeframe, pastureland has not increased significantly, and shifting cultivation (chena) declined, due in part to limited land availability. Home gardens, which contribute to household-level food security in rural Sri Lanka, cover a substantial 14.8% of the total land area

(Punyawardena, 2007). These changing patterns of land use, coupled with the strict enforcement of anti-deforestation laws, have resulted in a decreasing rate of deforestation over the past decade (World Bank; CIAT. 2015).

Agriculture accounts for 25.1% (4.71 million tonnes CO_2e) of the country's total greenhouse gas (GHG) emissions. Out of this, GHG emissions from cropland (mostly rice cultivation and cultivation of organic soils) account for 69.5% of total emissions, while the livestock sector (especially enteric fermentation) accounts for 30.5 % (World Bank and CIAT, 2015).

It could be observed that with the trend of reducing GHG emissions, Sri Lanka can reduce to 61 % of the present level.

To reduce the GHG emissions from the agriculture sector, appropriate management practices must be introduced to minimize CO_2, CH_4 and NO_2 emissions. Further, *Land Surface Albedo* in agricultural lands could be minimized to lower the Surface Albedo and increase the green cover and increase the carbon sequestration and suitable alternative measures must be introduced to minimize CO_2 emissions from agricultural fields. The main emphasis in agricultural sector should be given to GHG emission reduction from rice fields, livestock, and cultivated area of organic soils in the order of importance.

In order to develop necessary mitigation measures carbon dioxide and methane emissions must be quantified for paddy cultivated areas.

Nitrous Oxide (N_2O) is liable for 6% of worldwide anthropogenic GHG emissions; 90% of those emissions are associated with agriculture. Increased N fertilizer usage and animal production are the most significant sources of the projected increase in N_2O. Agricultural soils are the key anthropogenic sources of N_2O and contribute around 60% of human-derived N_2O emissions (Marambe & Nissanka, 2019).

Urea is the major source of supply of nitrogen to crop production in Sri Lanka and urea is imported to Sri Lanka for agricultural use. Around 64% of the imported urea, with a nitrogen content of 46%, is used in paddy cultivation. The recovery of applied nitrogen to wetland paddy is around 20-40%. The agronomic efficiency of nitrogen (additional grain yield per kg N applied compared to without-N) is as low as 10 kg per kg of Nitrogen (Marambe & Nissanka, 2019).

Nitrogen utilization in the tea sector in 2018 includes 100.4 million kg of urea and 27.7 million kg of ammonium sulphate, totaling about 51.88 million kg of nitrogen. The total losses have been estimated at 40% of the applied nitrogen.

The position of Sri Lanka in the agriculture sector, measured based on the Sustainable Nitrogen Management Index (SNMI) in the Environmental Performance Index (EPI) by Pimonenko et al. (2018) is ranked low as 124 among the 180 countries indicating the significant improvement needed by the country in the future in achieving the Sustainable Development Goals (SDGs).

Livestock populations with ruminants emit methane due to the anaerobic digestive process in the forestomachs (fermentation). Milk production from the dairy cow sector in Sri Lanka emits about 2.3 million tons of CO_2e. The emission profile of milk is dominated by methane (93.2 %), while nitrous oxide (N_2O) and CO_2 contribute 1.6 % and 5.2 % of the entire emissions, respectively. Approximately 88% of the emissions from the management of stored manure arise from methane produced by the rumination of cows and 5% of CO_2 emissions related to feed production, transport, and processing contribute a further 5% to total emissions. Ruminants could produce 250 to 500 liters of methane per day counting on various animal and feed-related factors. That would cause about 12% loss of the dietary energy within the ration as methane. In Sri Lanka, cattle and buffaloes are the most abundant livestock groups, while sheep, goats, and swine remain as minors.

2.1.6 Forestry Sector

Forests/trees are unique since only they have the ability to sequester atmospheric carbon dioxide in making their food through photosynthesis. According to the definition of the FAO, Forest is defined as: "land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ. Therefore all natural forests, forest plantations and rubber plantations had been included into the definition of 'Forests'. Trees Outside the Forests (TOF) are all the areas with trees which do not belong to the category of forests In the context of estimations in this report, the ecosystems which are quantifiable such as homegardens, coconut plantations, tea lands, trees in settlements, trees in urban environments including avenue plants) have been considered. Mangrove ecosystems belong to the category of forests in the forest classification but due to their enhanced ability of these ecosystems to sequester atmospheric carbon dioxide compared with the terrestrial tree based ecosystems, mangroves have been taken separately for quantification of carbon.

While healthy forests make a tremendously positive contribution to the balancing of GHG emissions caused by anthropogenic activities, deforestation and forest degradation pose a negative impact, by reducing the net biome production, and hence the carbon sequestration of the ecosystems. However, if the harvested wood is stored in wood products in use which do not degrade over many years, the carbon may be stored in them for long years before being released into the atmosphere, thus not contributing to the GHG emissions in the short term.

Figure 2.12 shows the processes in the carbon cycle with respect to the Forestry sector.

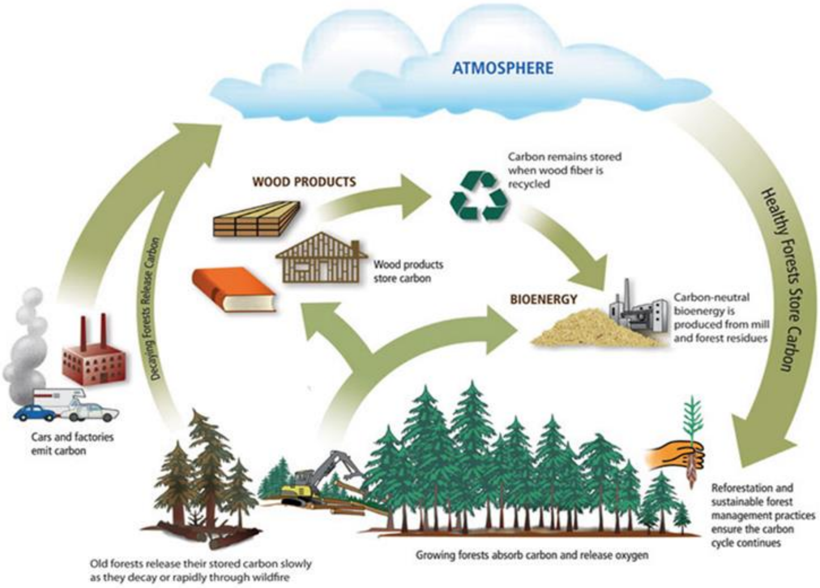

Figure 2.12 : GHG Emissions and Sequestrations from Forestry Sector

Sri Lanka’s Forest cover (which was 29.15% of land area in 2015) is comprised of dense forest, open and sparse forest, savannah, and mangroves. This natural vegetation displays diversity and distribution under Sri Lanka’s three climatic zones; Wet, Dry, and Intermediate. Furthermore, forest-like home gardens and plantations of spices, rubber, timber, etc. also occupy a considerable land extent providing carbon benefits. Sri Lanka is unique in South Asia for its high biodiversity per unit area, and the large extent of high-canopy home gardens. However, over time, forest cover has declined. Some forest cover has been cleared to make way for agriculture and plantations and recently, for larger infrastructure projects (dams, roads, human settlement, etc.). The main concerns for sustenance/protection of natural forests include deforestation, land degradation and soil erosion, illegal felling, wildlife poaching and mining, forest fires and degradation of coastal forests. Aside from the environmental implications, deforestation in Sri Lanka has caused landslides, soil degradation, flooding, loss of biodiversity and their habitats, pollution, etc. It is the primary threat to the survival of Sri Lanka's biodiversity.

Future Outlook & Carbon Sequestration Potential in Forestry Sector

A large number of legislative instruments, policies and strategies and programmes are in place to protect the forest cover. The Fauna and Flora Protection Ordinance (1993), Forest (Amendment) Act, No 65 of 2009, Forest Ordinance 1907 (No. 16 of 1907) as amended up to 2009, Sri Lanka Forestry Sector Master Plan 1995-2020 and its draft extension from 2021-2030National Environmental Act (1980) and its draft revision which is in the process of finalization, National Environmental Action Plan (2022) National Action Plan for combating land degradation in Sri Lanka 2015-2024, National Biodiversity Strategic Action Plan 2016-2022, Forest Conservation and Development Plan, Sustainable Land Management Programme, the National REDD+ Investment Framework and Action Plan are the more recent of these. The current policy framework of the Government provides broad guidelines and directions for sustainable forestry management. It envisions a “Net Carbon Zero Country” and the enhancement of the natural forest cover up to 30% by 2025; 32% by 2030 There is an emphasis on identifying and reforesting suitable lands, re-establishing and enhancing green cover, restoring barren and abandoned lands for agriculture and forestry, planting trees, establishing urban forests, green paths, green roofs and agroforestry systems, establishing parks in urban and semi-urban areas, developing urban vegetation by planting trees along expressways and in industrial premises -all of which can deliver emissions reduction. Forestry has enormous adaptation and disaster mitigation co-benefits. Forests protect catchments and ensure water availability downstream. Forests provide food and fuel for many rural communities and ensure biomass-based renewable energy availability. Nature-based solutions are proposed for many natural hazards, landslides, slope instability, flood, coastal erosion- in place of structures of cement and steel. Examples from Sri Lanka show that mangroves have protected communities from coastal degradation and forests on steep slopes have prevented landslides. Adapting traditional tree and food crops in agro-forestry systems can potentially support resilience (drought tolerance), improve food security (high nutrition fruits/food) and combat human-animal conflicts.

In the NDCs of the country submitted to the UNFCCC in 2021, five NDC actions have been committed in the Forestry Sector; Increase Forest cover of Sri Lanka up to 32% by 2030; Improve the quality of growing stock of natural forests and plantations; Strengthen catchment protection of major rivers and cascade systems, Improve and increase of Trees Outside Forests (TROF) and Generic enabling activities.

According to the updated NDC (2021-2030), 18,000 ha of new forests will be established by 2030 while the existing natural forests and forest plantations will be better protected. In the Net Zero Road Map and Strategic Plan, the Forest Department is hoping to reforest/afforest an additional 200,000 ha of land by 2050. Past Emission Trends in each sector (2010 - 2021)

2.2 Past Emission Trends in each sector (2010 - 2021)

The historical data for the GHG emissions are reported in the Sri Lanka National Communications submitted to the UNFCCC as an obligation under the Paris agreement. Tables 2.1 and 2.2 give the sector wise summary of national emissions for the year 2000 and 2010.

Table 2.1: Summary of national emissions for the year 2000

Source: Sri Lanka second national communication (MoE, 2011)

	CO_2 000' MT	CH_4 000' MT	N_2O 000' MT	Total CO_2e 000' MT
Energy	10,430.01	41.97	0.81	11,562.48
Industry process	492.40			492.40
Agriculture		185.14	2.65	4,709.44
LUCF	10.34	1.67		45.41
Waste		96.82		2,033.22
Total emissions	10,932.75	325.60	3.46	18,842.95

Table 2.2: Summary of national emissions for the year 2010
Reference Sri Lanka's third national communication (MoE,2021a)

Sector	CO_2 emissions	CO_2 Removals	CH_4	N_2O	HFCs	Total
Energy	12,810.00		950.46	393.70		**14,154.16**
IPPU	435.59				12.98	**448.57**
Agriculture	340.45		2,860.62	3,304.60		**6,505.67**
Waste	122.78		527.94	325.50		**976.22**
LULUCF-emissions	21,342.40		112.77	4.96		**21,460.13**
LULUCF-removals		-39,826.30				**-39,826.30**
Net Total	**35,051.22**	**-39.826.3**	**4,451.79**	**4,028.76**	**12.98**	**3,718.45**

2.2.1 Energy Sector

In order to estimate the emissions related to the energy sector, emission factors recommended by the IPCC Guidelines are used. Here, CO_2 and SO_2 emission factors are calculated based on fuel characteristics, while NO_x emissions are based on plant technology.

Table 2.3 gives a list of emission factors for the different plant types and fuel types as per IPCC Guidelines, and Figure 2.13 shows the emission quantities from 2011 -2019 from the power plants, calculated using the emission factors.

Table 2.3: List of the emission factors (IPCC Guidelines-2006)

Plant Type	Fuel Type	GCV	GCV	Sulphur Content	Emission Factors			
		(kcal/kg)	(kJ/kg)	(%)	Particulate (mg/MJ)	CO_2 (g/MJ)	SO_2 (g/MJ)	NO_x (g/MJ)
Internal Combustion Engine	Fuel Oil	10,300	43,124	2-3.5	13.0	76.3	1.709	1.2
	Residual FO	10,300	43,124	2-3.5	13.0	76.3	1.709	1.2
	Auto Diesel	10,500	43,961	1.0	5.0	74.1	0.453	1.2
Gas Turbine	Auto Diesel	10,500	43,961	1.0	5.0	74.1	0.453	0.28
	Natural Gas	13,000	54,428	0	0.0	56.1	0.0	0.1
Combined Cycle	Auto Diesel	10,500	43,961	1.0	5.0	74.1	0.453	0.28
	Naphtha	10,880	45,552	0	0.0	73.3	0	0.28
	Natural Gas	13,000	54,428	0	0.0	56.1	0.0	0.1
Coal Steam	Coal	6,300	26,377	0.6	40.0	94.6	0.455	0.3
Dendro	Dendro*	3,224	13,498	0	255.10	0.0	0.0	0.2

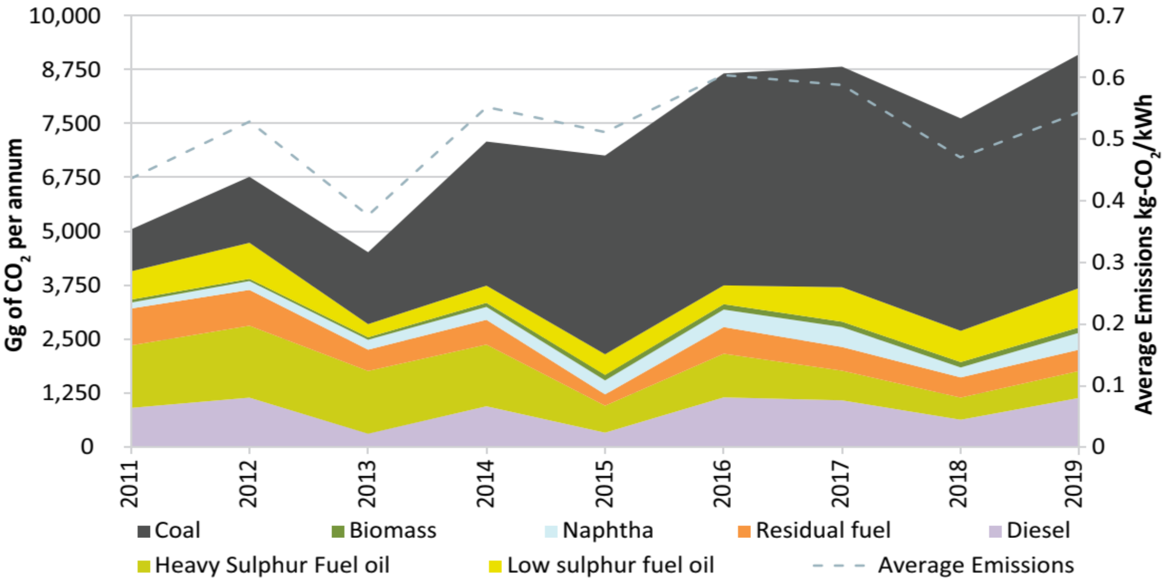

Figure 2.13 : Emissions from Power Plants (SLSEA, 2019)

For the electricity sector, the 'Average Emissions Factor (AEF)' is used to report the carbon footprint. The AEF is calculated by dividing the total emissions from the power sector by the total units of electricity used in the country in a given year. The AEF variation over the past is given in Figure 2.14 (SLSEA, 2019)

Figure 2.14 : Average CO_2 Emission Factor over the past decade

2.2.2 <u>Transport Sector</u>

Most vehicles in Sri Lanka are powered by fossil fuel, mainly auto diesel, and petrol. Some vehicles on roads today are powered by electricity, but the majority are powered by petroleum, and the entire rail transportation is powered using auto diesel. Transport fuel demand for the last few years is depicted in **Table 2.4.** (2020 to 2022 were not considered for the trend analysis due to the temporary economic slump.)

Table 2.4: Transport Fuel Demand

kt	2010	2015	2016	2017	2018	2019
Gasoline	616.5	1,009.0	1,463.1	1,276.8	1,358.7	1,421.5
Auto Diesel	1,433.8	1,815.1	1,902.6	1,605.3	1,568.4	1,606.5
Super Diesel	11.5	46.1	86.6	91.5	101.1	81.6

The estimated past emission trend for the Transport sector as given in the Updated NDC Report is shown in Figure 2.15. Sri Lanka's CO_2 emission in 2021 is 11 million tonnes, as estimated in the NDC report of the Ministry of Environment (MoE, 2021).

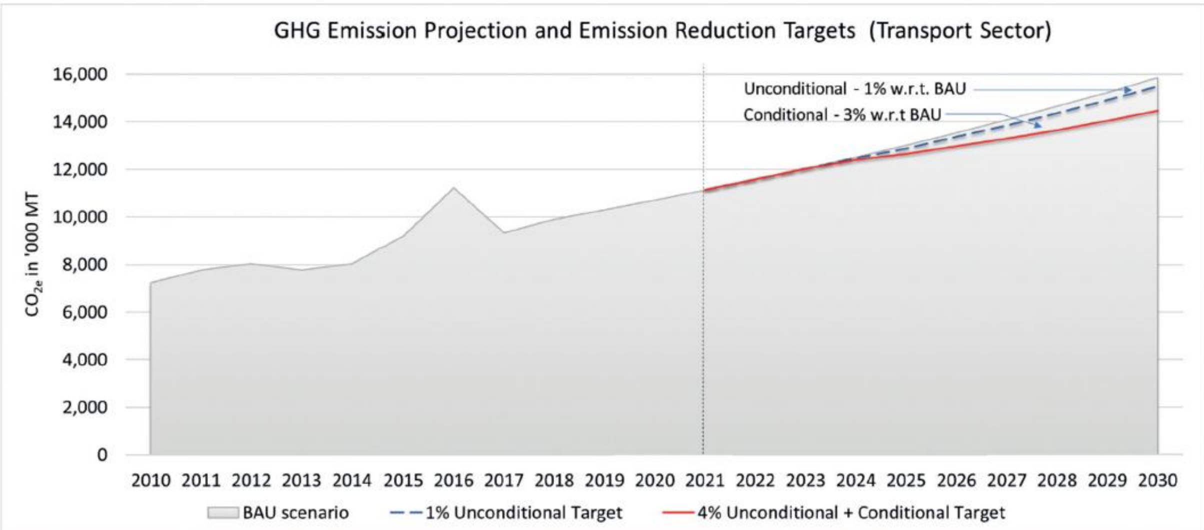

Figure 2.15 : GHG Emission Projection for Transport Sector (MoE, 2021)

Another estimate published by the Knoema.com database gives the CO_2 emissions from transport for Sri Lanka as nine million tonnes in 2021. It also states that CO_2 emissions from transport of Sri Lanka increased from 2 tonnes in 1972 to 9 tonnes in 2021, growing at an average annual rate of 3.81%. (*Sri Lanka CO2 Emissions From Transport, 1970-2022 - knoema.com*, 2022)

According to the World Bank database, CO_2 emission in 2014 from the transport sector was 6.2 million tons, at a growth rate of 5% p. a (the computed growth rate for total CO_2 emission for Sri Lanka from 2011-2016 is 4.8%), the estimated CO_2 emissions for 2021 is 8.8 million tonnes. (*CO2 Emissions From Transport (% of Total Fuel Combustion) | Data*, n.d.)

Calculation of CO_2 emission quantity based on the fuel consumption in the transport sector yields similar results to that of the World Bank estimates.

Table 2.5: Fuel Consumption in Transport Sector

Fuel type	lt(mn. tonnes)	CO_2 emission per liter(tonnes/lt)	CO_2 tonnes
Gasoline	1.4	0.0023	3300
Diesel	1.7	0.0027	4600
Total CO_2 emission in 2019			7900
Est. for 2021 at 5% p.a			8700

CO_2 emission based on Climate Analysis Indicators Tool (CAIT) estimates the CO_2 emission in 2019 in the transport sector to be 10.2 million tonnes (ourworldindata.org, n.d.), with the forecasted value-based linear regression of the previous 10-year data being 11.2 million tonnes. Since this is consistent with estimates used in the Sri Lanka NDC report published in 2021, the data set will be used for the BAU scenario, as shown in Figure 2.16.

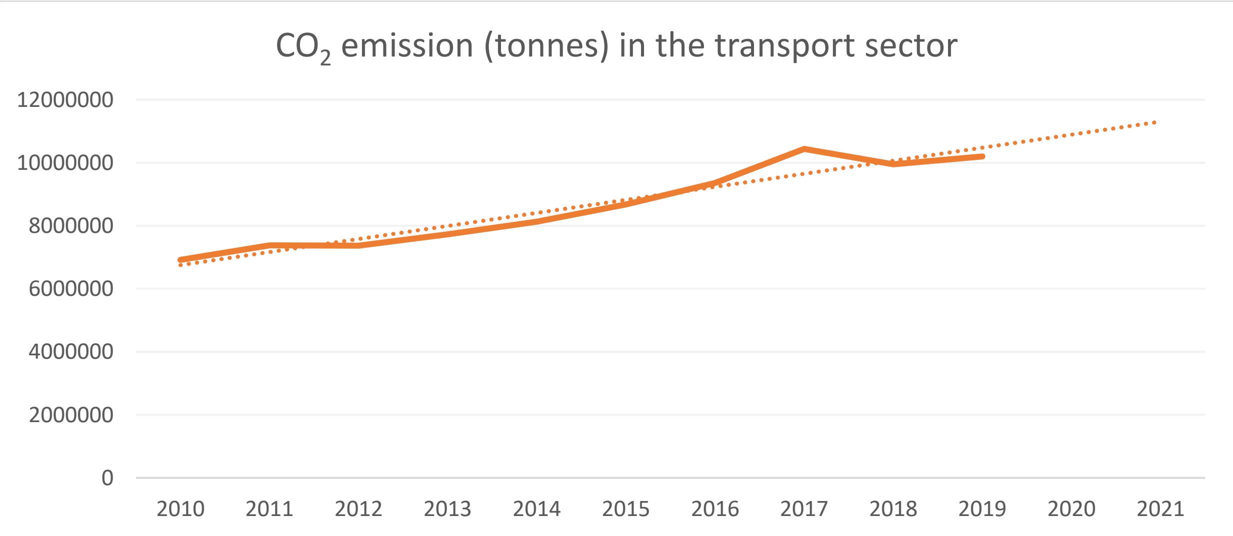

Figure 2.16 : CO_2 emission projection for the transport sector

However, the assumed growth rates in the NDC report would not have materialized under the economic conditions that prevailed in the country during the Covid Pandemic and the economic crisis during 2022. Therefore, suitable estimates based on BAU scenario modelling analysis will be used to derive 2022 values.

2.2.3 Industry Sector

Being a country of low-industrial activity, Sri Lanka does not have many relevant industrial processes (IPs). Accordingly, IP-related emissions are also relatively low. But fulfilling the UNFCCC reporting requirement, CO_2 emissions from the cement industry, lime industry, glass industry, ceramics industry, and Non-Methane Volatile Organic Compounds (NMVOCs) emissions from several other industries, manufacturing surface coatings, solvents, bread production, sugar production and liquor industry producing spirits have been identified for reporting of GHG emissions. The consumption of HFCs and their blends are also accounted for and reported under national GHG inventories. Such reported values for 1994, 2000, and 2010 respectively in the first, second, and third national communications are shown in T**able 2.6.**

Table 2.6: Industry sector related GHG emissions
Ref: MoE (2000, 2011 and 2021a)

Base year	1994	2000	2010
National communication	Initial	Second	Third
IPPU emission 000' $MTCO_2e$	300.55	492.40	447.97

According to **Tables 2.1 and 2.2 (**in section 2.2 of this report**),** industry energy use-related emissions are included in the energy sector. As industry mainly depends on the national grid to provide electricity, their emissions related to industry energy use are totally dependent on the national electricity generation-related emissions. Greening the national grid will have a direct impact on industry energy use emissions. Hence it is obvious that the emissions related to industry energy use totally depend on the low-carbon nature of the power supply.

But as the industry has a substantial potential to improve energy efficiency and renewable energy adoption through energy management strategies or demand management strategies, it is important to estimate the energy demand management-related emission reductions, to be fed into the data pertaining to the energy sector, under demand side management.

Only the Industry Process and Product Use related emissions need to be analyzed separately under the industry sector.

According to the IPCC inventory development guidelines (IPCC, 2006), IPPU (Industry Process and Product Use) is classified as one of the major categories of Greenhouse Gas (GHG) emissions. This covers GHG emissions occurring from industrial processes, from the use of greenhouse gases in products, and from non-energy uses of fossil fuel carbon.

On the other hand, during the NDC development process, the industry sector accounted the emissions from industry energy use related GHG emissions, and IPPU related emissions have not been accounted, due to the limited avenues, unavailability of large scale IPPU emitting industries (such as mineral industries, Chemical industries, primary metal production industries etc.) and poor reliability of data, and the quantity of GHG emissions from the IPPU sector is considered relatively low.

Industry sector total emissions, IPPU emissions and IE emissions for the period 2000 to 2010 are depicted in Figure 2.17

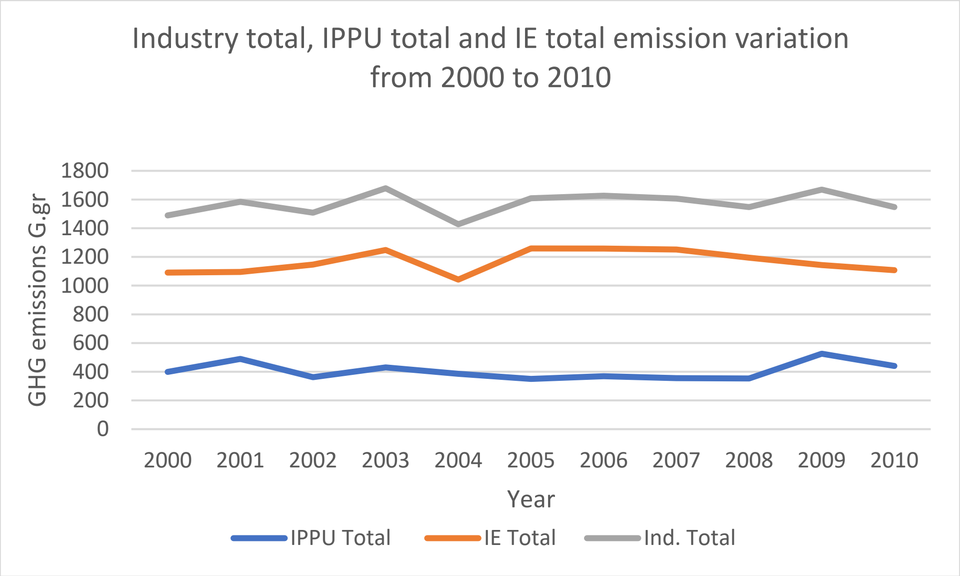

Figure 2.17 : Industry sector total emissions, IPPU emissions and IE emissions for the period 2000 to 2010

As the industry sector primary energy demand is well displayed under the national energy balance, during this national net zero emission strategy development process, industry energy use is directly addressed under the energy sector net zero emission strategy development process. Considering the complete accounting need, the IPPU related emissions are accounted under this strategy development process, though it is a relatively small quantity.

The estimated IPPU emissions reported under the third national communication (TNC) are taken into account as the reference or baseline values.

Accordingly, following national industry related major emission sources are considered:

- Cement industry (INSEE Cement manufacturing company)
- Glass manufacturing industry (Piramal Glass Company)
- Porcelain chinaware industry (Dankotuwa porcelain industry, Noritake Porcelain industry, Midaya Ceramic Industry, Art Decoration International Pvt Ltd, Royal Fernwood Porcelain Limited)
- Floor and wall tile industry (Lanka Tiles, Royal ceramics, Lanka Wall Tiles, Mack Tiles limited)
- Lime manufacturing industries

- Solvents used in national industrial applications
- National bread production in bakery industry

Although there are other minor emission categories relevant to GHG emissions, considering their insignificant values and unreliability of data (especially continuous data from 2000 to 2010) those are not accounted under IPPU emission projections.

The accounted emission (in 1000 tonnes) data for the period from 2000 to 2010 are given in Table 2.7 (Ref; TNC) and depicted in Figure 2.18.

Table 2.7: Industry sector IPPU emissions considered for calculation of past trends

Source: Sri Lanka Third National Communication, MoE (2021a)

Year	Cement	Lime	Glass	Ceramic	Solvent	Bread	Total
2000	196.71	123.6	4.45	2.53	69.83	1.32	398.44
2001	232.91	194.69	4.73	2.18	53.9	1.29	489.7
2002	243.92	71.57	4.28	2.8	37.84	1.3	361.71
2003	272.6	145.59	5.06	3.14	2.74	1.32	430.45
2004	264.05	111.73	5.5	2.88	0.02	1.34	385.52
2005	257.05	83.23	5.8	2.53	0.06	1.35	350.02
2006	250.55	107.9	5.73	3.06	0.06	1.37	368.67
2007	274.59	66.39	2.66	5.44	4.46	1.38	354.92
2008	270.71	64.17	10.21	3.59	2.75	1.39	352.82
2009	322.91	182.91	10.96	6.55	1	1.41	525.74
2010	331.32	85.1	11.5	7.67	2.73	1.42	439.74

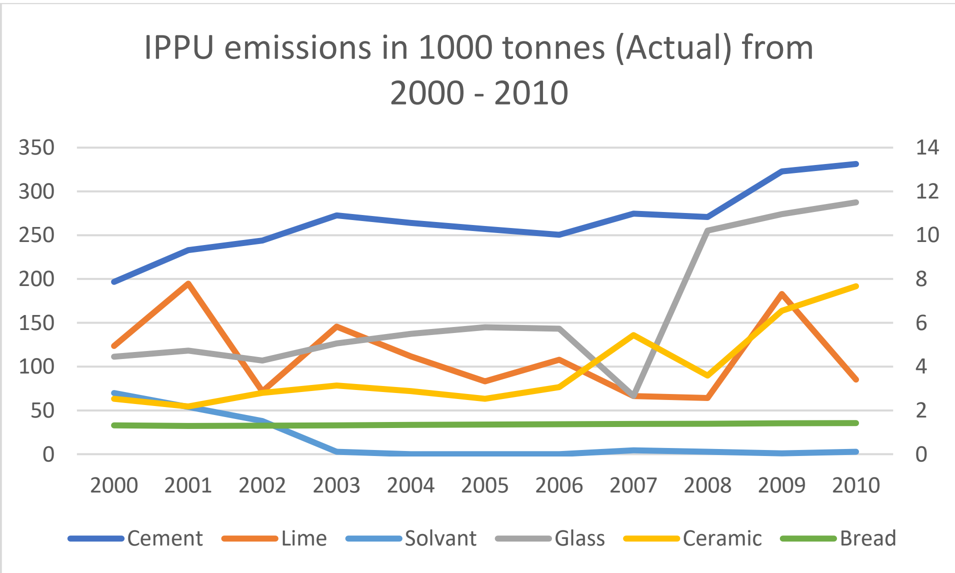

Figure 2.18: IPPU emissions in 1000 tonnes from 2000 -2010

Source: Sri Lanka Third National Communication, MoE (2022)

For the period of 2000 to 2010, IPPU emissions from different industry sub sectors are depicted in Figure 2.19.

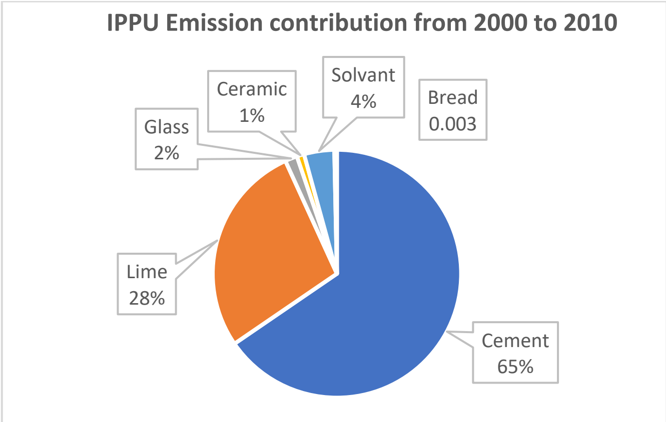

Figure 2.19 : IPPU Emission Contribution of main industrial sectors from 2000 - 2010

According to above analysis, major contributors to the IPPU emissions are Cement, Lime and solvent sectors.

Using the above trends, Annual IPPU emissions estimated for the period 2011 to 2022, as shown in Table 2.8 and Figure 2.20.

Table 2.8: Annual IPPU emissions estimated for the period 2011 to 2022

Year	GHG Emission (1000 tonnes)
2011	745.267
2012	908.6
2013	945.394
2014	1044.126
2015	1006.452
2016	1175.879
2017	1198.456
2018	1254.505
2019	1322.944
2020	1391.383
2021	1459.822
2022	1528.26

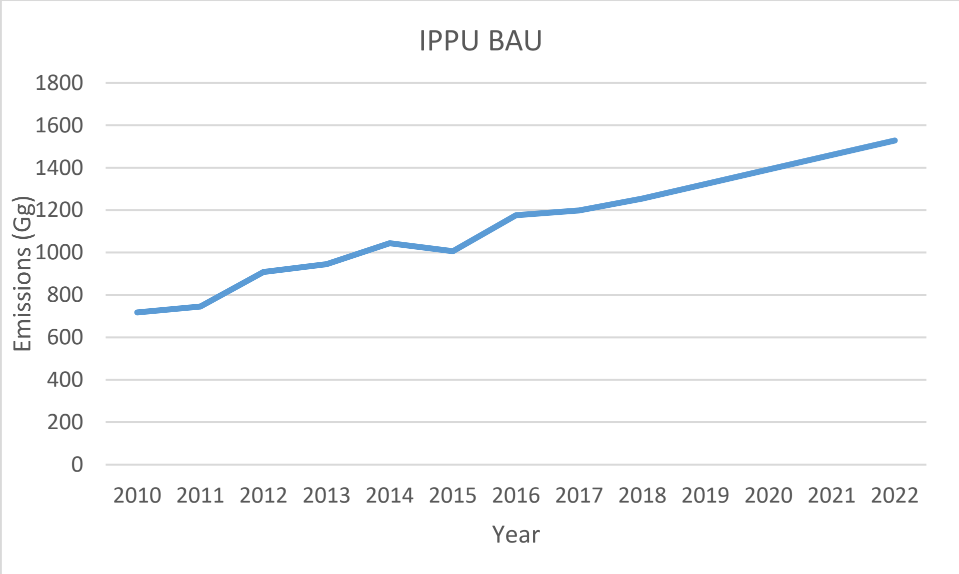

Figure 2.20 : Annual IPPU emissions estimated for the period 2011 to 2022

As IPPUs are not considered in the national NDC development, no NDC commitment based analysis / scenario development could be done for the industry sector.

2.2.4 Waste Sector

Sri Lanka generates approximately 9,000 tonnes of municipal solid waste (MSW) per day with a total volume of 3,500 tonnes (or 40%) produced in the Western Province and 5,500 tonnes (or 60%) produced from the other Provinces (MoE, 2021). Only about 55% in the Western Province and 25% in the other provinces of the generated waste is collected by local authorities. The rest of the waste remains uncollected.

Mainly the waste sector generates CO_2, CH_4, and N_2O gases from solid waste disposal, biological treatment of solid waste (composting), incineration and open burning of solid waste, wastewater treatment, and domestic discharge, as discussed in section 2.1.4 of this report. This prediction was carried out by referring to 2000 to 2010 data from the Third National Communication of Climate Change in Sri Lanka report (MoE, 2022).

The GHG emission trend has an increasing trend from 2010 to 2021 with a steady increase in each category where the emission from wastewater being the highest contributor and the least from composting which is happening at a small scale compared to the other category activities.

a) Emissions from solid waste disposal

The estimated methane emission in SWDSs during the period of 2010-2021 shows an increase from 228,000 CO_2e tonnes to 351,000 CO_2e tonnes of CH_4. Due to a lack of sufficient waste disposal facilities in the country between 2000 and 2010, while six unregulated SWDSs were in operation, waste management was not properly organized during that time.

The MSW generation during the 2010 to 2021 period showed increasing variation due to population growth, urbanization, and economic growth. Inadequate public commitment to waste management, a lack of proper waste segregation and adequate waste collection mechanisms covering the entire island, and practical challenges in the implementation of the 3R principles are some of the fundamental problems with the current waste management practices that also cause this growing trend.

during the 2010 to 2021 time period, the recorded largest disaster in Sri Lanka is the Meethotamulla dumpsite collapsing in 2017which is the biggest dumpsite in Sri Lanka that takes the majority of the garbage from the CMC and suburbs. by the disaster, A total of 1,765 individuals were impacted, 146 homes were destroyed, some infrastructure was damaged, 32 bodies were found in the destroyed region, and 8 more were unaccounted for (Jayathilake et al., 2020).

According to the National Solid Waste Management Center (NSWMC) records in 2020, there are 181 open dumpsites and 2 landfilling sites currently existing in the country.

b) Emissions from composting of solid waste

Composting is regarded as one of the most technically appropriate ways to manage MSW in Sri Lanka, especially given the simplicity of the technology and the nature of Sri Lanka's municipal garbage, which is still mostly organic (Gunaruwan and Gunasekara, 2016). According to the NSWMC data in 2019, there are 175 compost yards existing, with a total of 10011.7 tonnes/day capacity.

The estimated methane emission in composting during the period of 2010-2021 shows an increase from 66,779 CO_2e tonnes/yr to 74,768 CO_2e tonnes/yr of CH_4 as in figure 2-9 where the 2000 to 2010 data from Third National Communication of Climate Change in Sri Lanka (MoE, 2022) was used for the prediction up to 2021.

Composting turns a significant portion of the waste's Degradable Organic Carbon (DOC) into carbon dioxide in the aerobic process. In the compost pile's anaerobic areas, CH_4 is generated and discharged in small amounts and is frequently found at the bottom of heaps.

c) Emissions from open burning of solid waste

The most common practice of disposing of MSW in rural and suburban areas without access to suitable waste management facilities is open burning. Additionally, dry waste, including yard cutting, is openly burned in metropolitan areas too.

The estimated GHG emission in composting during the period of 2010-2021 shows an increase from 127,727 CO_2e tonnes/yr to 163,416 CO_2-eq tonnes/yr of CH_4 as in figure 2-9 where the 2000 to 2010 data from Third National Communication of Climate Change in Sri Lanka was used for the prediction up to 2021.

Most unregulated dumpsites practice open burning of solid waste, which has quite substantial air impacts in the surrounding. This open burning of waste can produce a variety of air pollutants, including NO_X, VOC, SO_X, particulates, CO, CO_2, and methane (APO, 2007). A crucial issue that needs to be addressed is the health risk, in addition to the poisoning of water resources and severe air pollution brought on by the open burning of solid waste.

d) Emissions from wastewater treatment and discharge

The domestic, industrial, and commercial sectors of the economy all contribute to the country's wastewater production. most Industries and industrial zones which produce a large capacity of wastewater located in urban areas had wastewater treatment plants. This wastewater treatment process generates GHG during the treatment process.

The estimated GHG emission in wastewater during the period of 2010-2021 shows an increase from 464,469 CO_2e tonnes/yr to 557,199 CO_2e tonnes/yr of CH_4 where the 2000 to 2010 data from Third National Communication of Climate Change in Sri Lanka was used for the prediction up to 2021. The emission from above activities a,b,c, and d are shown in Figure 2.21

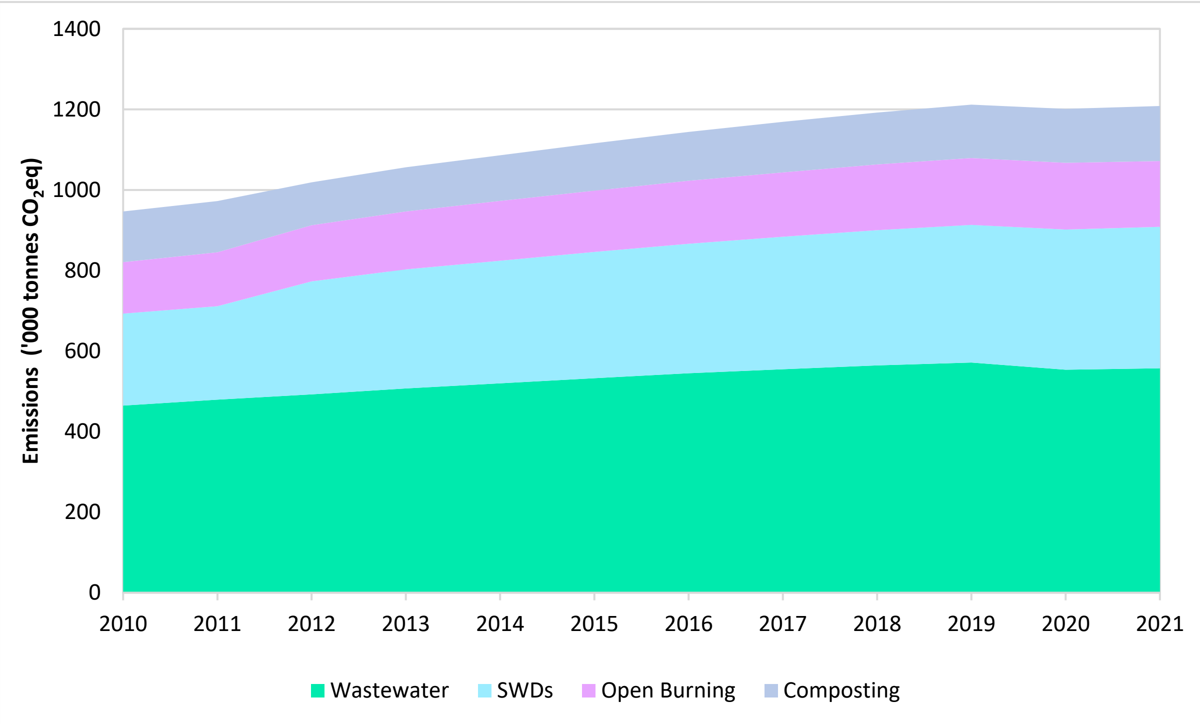

Figure 2.21 : GHG emission prediction from 2010 to 2021

2.2.5 Agriculture Sector

The current emission of main GHGs in agriculture sector as observed in 2019 is shown in **Table 2.9,** with a comparison to the same in 2008.

Table 2.9: Current emission of N_2O and CH_4 from agricultural lands (2019) compared to that in 2008

GHG	Unit	2008	2019
Nitrous Oxide (N_2O)	Mt CO_2eq	2230	2450
Methane (CH_4)	Mt CO_2eq	4500	4180
Carbon Dioxide (CO_2)	Mt CO_2eq	350	180

Source: Climate Watch. 2020. GHG Emissions. Washington, DC: World Resources Institute. *climatewatchdata.org/ghg-emissions*

2.2.5.1 Emission of Methane

Emission variation of CH_4 especially from enteric fermentation from 1990 to 2019 is given in **Figure 2.22.**

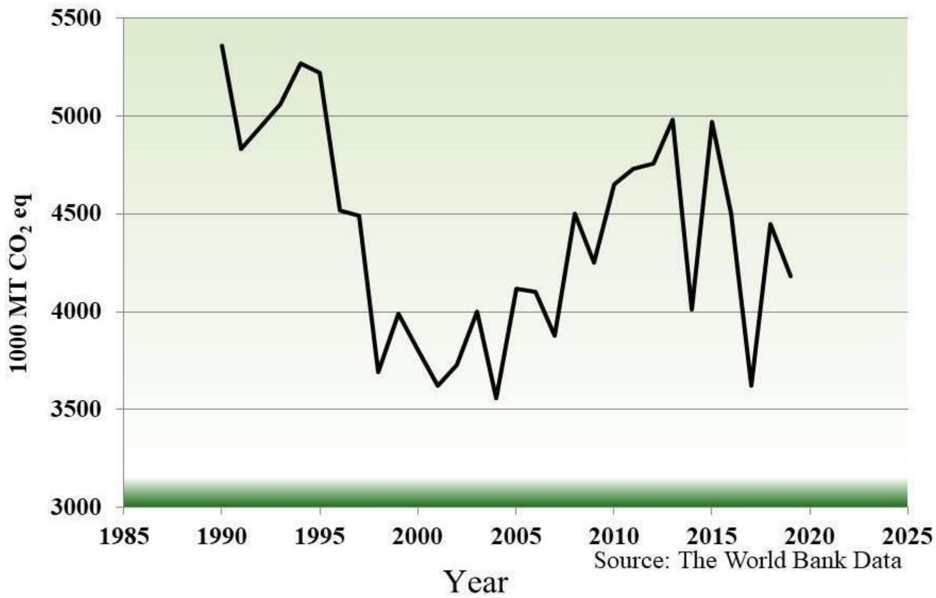

Figure 2.22 : Variation of CH_4 emission from agriculture (1990 – 2019)

Source: Climate Watch. 2020. GHG Emissions. Washington, DC: World Resources Institute. *climatewatchdata.org/ghg-emissions*

2.2.5.2 Emission of Nitrous Oxide

Though Sri Lanka's N_2O emissions fluctuated substantially in recent years, they tended to increase through the 2000 - 2019 period ending at 2,450 thousand tonnes of CO_2eq in 2019.

Synthetic fertilizers and organic after harvesting, and animal manure deposited during grazing are the most common sources that contribute to N_2O emission. N_2O emissions from cropping systems are strongly correlated to increased N fertilization. With the doubling of nitrogen use in South Asia since 1990, there is an excellent potential for enhanced N_2O emissions from the Asian region. The overuse of synthetic N fertilizer generates significant environmental threats. Nitrogen fertilizer, which is not taken by the crop, is either lost as Nitrogen gases, including the greenhouse nitrous oxide gas (N_2O). The emission variation of N_2O during the period from 2000 to 2020 is shown in Figure 2.23

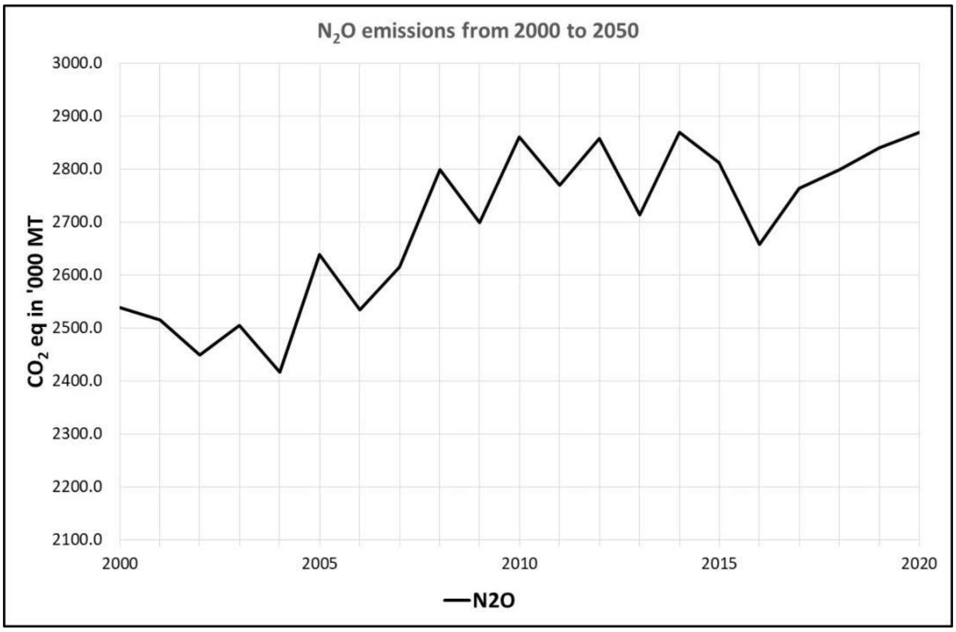

Figure 2.23 : Variation of N_2O emission from 2000 to 2020

Source: Baseline scenario developed for the study adopting NDC data

2.2.5.3 Emission of Carbon dioxide

Carbon dioxide is emitted from agricultural fields due to use of machinery, application of urea, dolomite and gypsum and tillage operations. The total carbon dioxide emissions in the agriculture sector over the period 2000 to 2020 is depicted in Figure 2.24. However, when comparing the total GHG emissions from CH_4, N_2O an CO_2 from agricultural fields in Sri Lanka, it can be seen that the emission of CO2 is negligible compared to other GHGs.

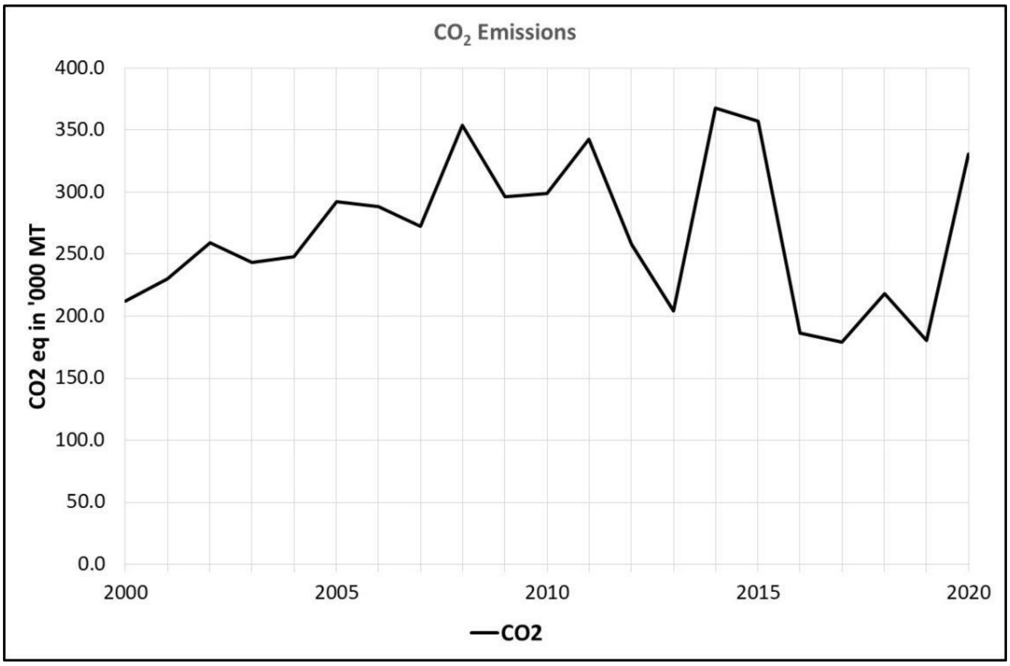

Figure 2.24 : Variation of CO_2 emission from 2000 to 2020

Source: Baseline scenario developed for the study adopting NDC data

2.2.5.4 Carbon sequestration from agriculture sector

<u>Tea Plantations</u>

Carbon sequestration by the plantation sector, which includes coconut, rubber and home gardens has been accounted for under the Forestry Sector. In addition, Tea plantations also have the potential for carbon sequestration, which does not fall under the categories of forests and Trees Outside Forests. However, the sequestration rates in tea plantations are very low (Table 2.10)

Table 2.10: Carbon sequestration from Tea plantations

Region	Kg of C ha^{-1} yr^{-1}
Low country	6,659
Mid country	3,497
Up country	2,344
Uva region	5,085

Source: Wijeratne et al. 2014

Paddy fields

The estimated global average of soil organic carbon stock of rice paddies is 108 tonnes/ha for the 0–100 cm layer. Average soil organic carbon stocks in rice paddies are lower than for mangroves, forests, and wetlands, but substantially higher than for grasslands and croplands, (Yalong Liu et al, 2021)

Results of a study carried out in Sri Lanka (Ratnayake et al 2017) showed that carbon fractions and nutrient availability among different cropping systems varied significantly from one another. Under all cropping systems a higher content of all C fractions was observed in the 0–15 cm layer. Highest dry matter return to soil (147 g/m2) in the rice-rice cropping system as paddy stubble accounted for highest amount of total organic carbon in soil. Change of cropping systems from rice-rice to other annual crops such as rice-tobacco and rice-onion reduced the soil C sequestration to a significant level after 10 years of cultivation. . However, crop rotation change from rice-rice to rice-soybean did not make much difference in the C level (rice-rice; 63.48 tonnes /ha and rice-soybean; 65.18 tonnes/ha) This indicates that C sequestration capacity is species specific and differences are mainly due to remaining crop residues and specific soil tillage practices used for upland crops.

2.2.6 Forestry Sector

The emissions from the forests including natural forests, forest plantations and rubber plantations which is taken as the 'forests' and the carbon sequestration of the forests is shown in Table 2.11 and Figure 2.25.

Table 2.11: Total Annual Carbon loss due to deforestation and Net Carbon sequestration due to remaining forests from 2010 to 2021

Year	Forest Cover with Forest Plantations and Rubber Plantations (ha)	Annual deforestation rate (ha)	Annual Carbon loss due to deforestation BAU (tonnes/yr) @ 150 tons/yr	A nnual Net Carbon Gain - BAU Scenario (tons/yr)
2010	2,107,202	6,953	1,042,950	3015851
2011	2,103,249	6,953	1,029,000	3050209
2012	2,099,576	6,953	1,029,000	3073207
2013	2,095,247	6,953	1,029,000	3090136
2014	2,088,294	6,953	1,029,000	3082794
2015	2,088,294	5,000	750,000	3365857
2016	2,078,822	5,000	750,000	3372116
2017	2,075,069	5,000	750,000	3378375
	2,070,312	5,000	750,000	3375343

Year	Forest Cover with Forest Plantations and Rubber Plantations (ha)	Annual deforestation rate (ha)	Annual Carbon loss due to deforestation BAU (tonnes/yr) @ 150 tons/yr	A nnual Net Carbon Gain - BAU Scenario (tons/yr)
2018				
2019	2,066,045	5,000	750,000	3376843
2020	2,063,437	5,000	750,000	3393689
2021	2,059,237	7,500	750,000	3395809

Source: Preparatory document of the Updated NDC (2021-2030)

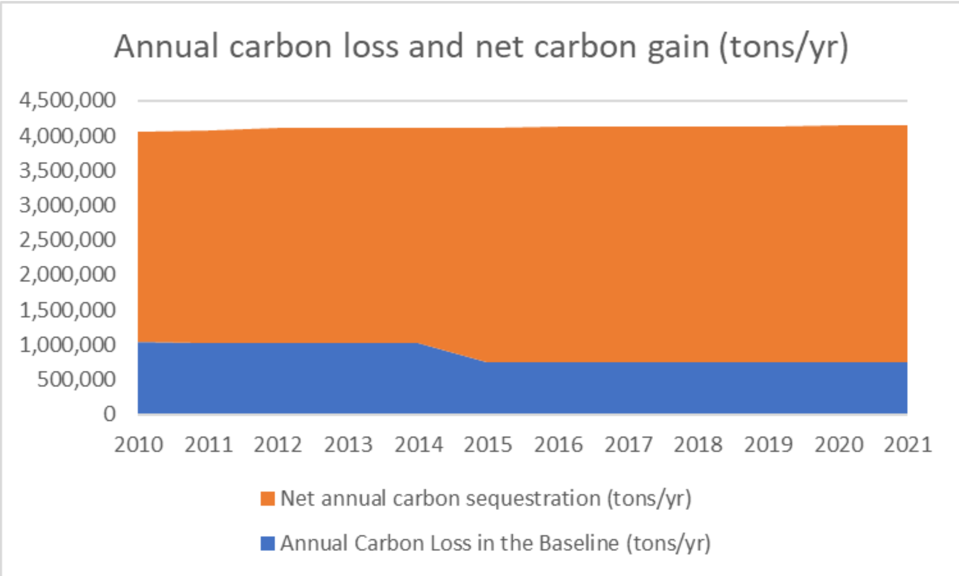

Figure 2.25 : Annual Carbon loss due to deforestation and Carbon sequestration due to remaining forests from 2010 to 2021

SECTION 3 : SCENARIO DEVELOPMENT AND PREDICTION OF EMISSIONS

3.1 Scenario Development and Prediction of Emissions 2025 – 2050

3.1.1 Introduction

Scenarios represent reasonable future circumstances with particular economic, social and environmental characteristics. Different scenarios can be used during the planning of net zero strategies & technologies to identify existing capacities & quantify required resources. At least two scenarios are used as baseline scenario & net zero (Mitigation) scenario for each sector to quantify GHG emissions by 2050 with existing emission reduction approaches & plausible reductions by proposed technologies.

Baseline scenario: a hypothetical reference case of what would have most likely occurred in the absence of a proposed GHG project, using an estimate of GHG emissions, removals, or storage associated with a baseline scenario. The business-as-usual scenario is a crucial point of comparison when it comes to investing, planning, and policymaking. It serves as a reference point against which to assess other scenarios or as a position to begin system analysis.

Mitigation scenario: a hypothetical reference case of what would most likely occur in the presence of proposed GHG project/s. Mitigation scenarios are usually defined as a description and a quantified projection of how GHG emissions can be reduced with respect to some baseline scenario, using an estimate of GHG emissions, removals, or storage associated with a mitigation scenario.

GHG emission reduction: Quantified decrease in GHG emissions between a baseline scenario and the GHG project/ GHG mitigation scenario.

GHG removal enhancement: Quantified increase in GHG removals between a baseline scenario and the GHG project/ GHG mitigation scenario.

GHG project: Activity or activities that alter the conditions of a GHG baseline and which cause GHG emission reductions or GHG removal enhancements.

Baseline is a plausible and consistent description of how a system might evolve into the future in the absence of explicit new GHG mitigation policies. Depending on the selected mitigation scenario different baseline scenarios will require to differentiate GHG reduction or removal enhancement. Sector-wise GHG emission trends & drivers for activity data will be identified using history data. Regression (linear & multiple) models will be used to identify drivers and relationships between the driver & activity data. To reduce the uncertainty of baseline scenarios, multiple baselines are constructed to reflect sensitivity for different aspects, as shown in Figure 3.1.

Demographic trend, economic trends and Evolution of technologies & practices will be considered for identifying driving forces (drivers) for Activity data.

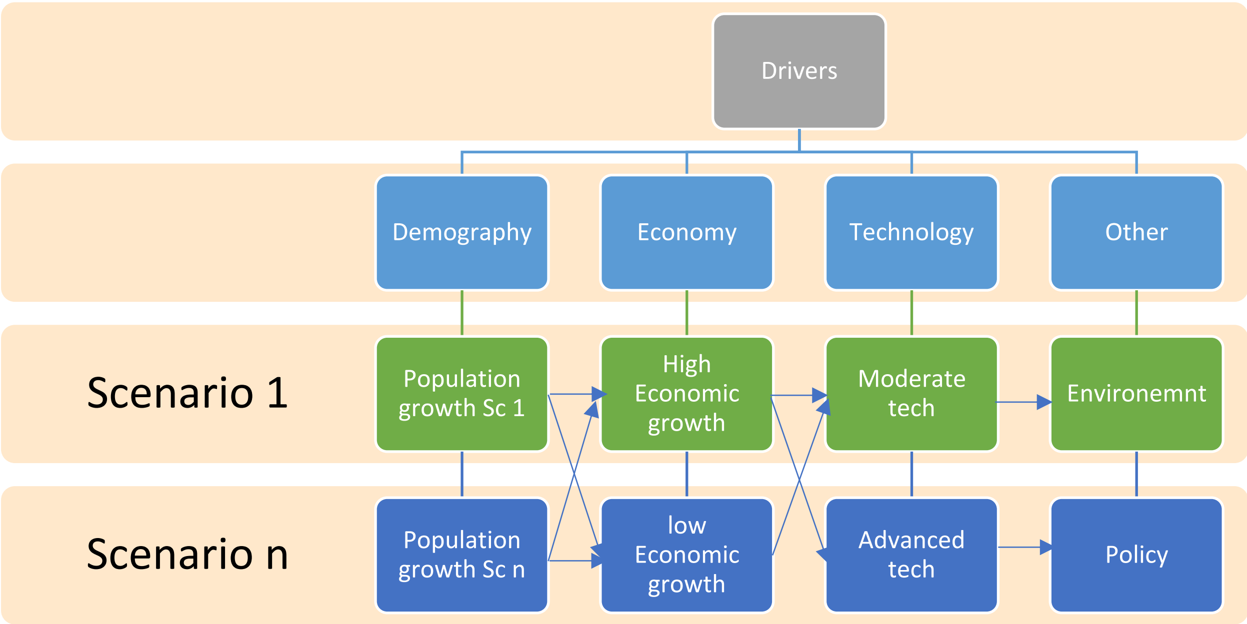

Figure 3.1 : Drivers for development of sector wise modeling of future scenarios

Theoretically, three approaches are used to define baselines:

1. **Economic efficiency case:** assumes perfect allocation of resources: mitigation will always imply economic losses. (High economic development Scenario)
2. **Business as usual case:** a continuation of current trends. (BAU)
3. **Most likely case:** markets and institutions are NOT assumed to behave perfectly. May imply the existence of "no regrets" mitigation options. (NDC Scenario)

In this study, the 'Most likely case', will be used as the baseline scenario.

Figure 3.2 illustrates the way that future emission predictions are developed using econometric prediction models for different future scenarios. The demand for sector activities would be increasing with the time, depending on the population growth and various other drivers identified for the development of the sector considered. Thus, the extension of the historical curve will follow a path which is not necessarily an extrapolation of the historical curve. Under the baseline scenario, the emissions will change with the time, based on the growth of the activity under the normal or most likely case. Under the mitigation scenarios, the emissions will depend on the timing of mitigation actions and the predicted reductions due to the actions in place. In the 'carbon net zero' scenario, the emission curve should take a drastic downward trend, while the GHG emission removal curve (sequestration or trapping) should take an upward trend.

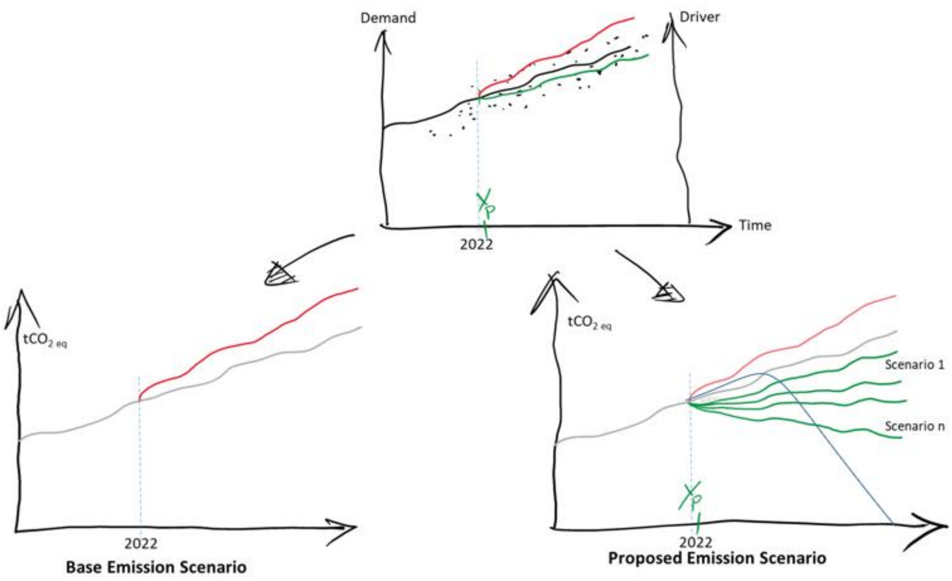

Figure 3.2 : The plausible future emissions calculated based on baseline scenario and scenarios considered with mitigation actions, using econometric modelling

Sector wise activity data, driver-related data & other specific data requirements depend on scope and mitigation activities selected for the analysis. 2000 – 2022 historical time series data (as available) will be used for developing history trends and identifying driving forces. Secondary data will serve the purpose.

$$GHG\ Emission\ = Activity\ Data\ \times Emission\ Factor\ \times GWP$$

Emission factors & GWP values are Based on historical time series data, driver/s can be identified for each activity data or for the sector using regression models. Future activity data will be forecasted using the function derived by the regression model.

$$Activity\ Data\ (unit) = \sum_{i=1}^{n} m_i \times Driver\ _i + C$$

Baseline (Business as Usual – BAU) Scenario Development:

The NDC Implementation Study being conducted concurrently with the present study has got results to show that the emissions during the period 2020 to 2022 follows a path close to the path followed by the emission levels with the implementation of the unconditional NDC actions in the sectors, rather than the BAU scenario taken in the NDC Report. (Figures 1:7.1 to 1:7.6 in the Interim Report of the NDC Implementation Study).

Therefore, the predicted emissions in the NDC report for the Unconditional Actions, extended to the year 2050, continuing current trends in population, economy, technology and human behavior, were taken as the Baseline scenario.

- For Population Predictions, the population data from the UN World Population Prospect 2022 (UN, 2022) as given in Figure 3.3

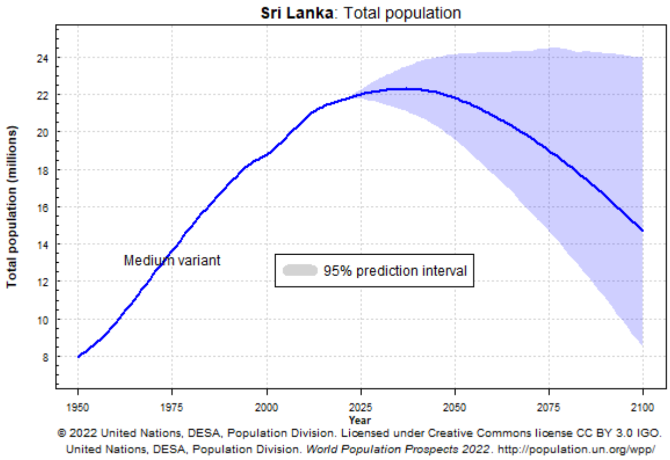

Figure 3.3 : Projected Population for Sri Lanka

- For GDP growth rate, the average values given on Page 46 of the Sri Lanka Climate Prosperity Plan (CPP) Preliminary report (V20, 2022), as shown in Table 3.1 were used:

Table 3.1: Real GDP growth rate comparison within each scenario

Scenario	2022-2030	2030-2040	2040-2050	2022-2050
BAU (Percent)	3.7	2.9	2.8	3.1
CPP (Percent)	4.4	4.3	3.9	4.2
CPP vs BAU	+21.6%	+48.1%	+37.3%	+35.9%

Thus, a Real GDP average growth rate of 3.1% was used for the Baseline scenario.

Mitigation Scenario - Net zero scenario: Actions and strategies to achieve net zero emissions by 2050

A preliminary study revealed that it would be possible to achieve net zero emission status by 2050 (even before 2050), if all mitigation actions proposed for each sector by the consultants, which went beyond the NDC actions, were to be implemented as proposed, in a timely manner. Therefore, the Mitigation Scenario was taken as the Net Zero Scenario.

For each sector, drivers for growth of the sector were identified using available history data using regression analysis, and econometric models are being used to predict the future demand and emissions in the sector activities, with the implementation of mitigation actions proposed for reduction of emissions and increase of carbon stocks (sequestration and carbon storing in biochar etc.).

Each sector considered several options/pathways of mitigation actions under this scenario.

According to the CPP Preliminary report (V20, 2022), the CPP scenario is defined as:

“In the CPP scenario, additional ambition for climate change mitigation was simulated on top of the NDC ambitions, ensuring that net zero emissions are reached in the year 2050. Furthermore, the CPP scenario also assumes the implementation of prosperity measures to achieve targets and objectives outlined in the official target document, such as for example adaptation measures for agriculture production and infrastructure (e.g. roads, buildings, power generation).”

This is the ‘Best case’ scenario, where the Carbon net-zero is achieved and the vulnerability to Climate Change is minimized.

A Real GDP average growth rate of 4.2% will be used for the Net Zero scenario as the average over the period.

Considering the many linkages among the sector actions and impacts, the Net Zero scenario were developed, with interactive sessions among the sector experts and social, gender and economic analysts who have a major role to play in selecting the optimum pathway/s for achieving net zero.

The emissions in this scenario were calculated for each sector, so that the net emissions across the sectors will trend towards zero in the shortest possible time, not later than 2050, while the most economically, socially and environmentally acceptable pathways will be identified for implementation.

3.2 Sector wise Prediction of Emissions for the Baseline Scenario

3.2.1 Energy Sector

For the power sector, CEB has developed the Long-Term Generation Expansion Plan (LTGEP) 2023-2042 which complies with the NDC commitment, with more than 25% reduction in GHG emissions for the period from 2023-2030, compared to the BAU scenario of LTGEP 2013-2032. The unconditional targets have been declared based on the financial and technical capability already available in the country. However, the conditional targets require an external financial and technical support to supplement the domestic capacity. It is forecasted that the electricity peak demand increases on average at 5.3%.

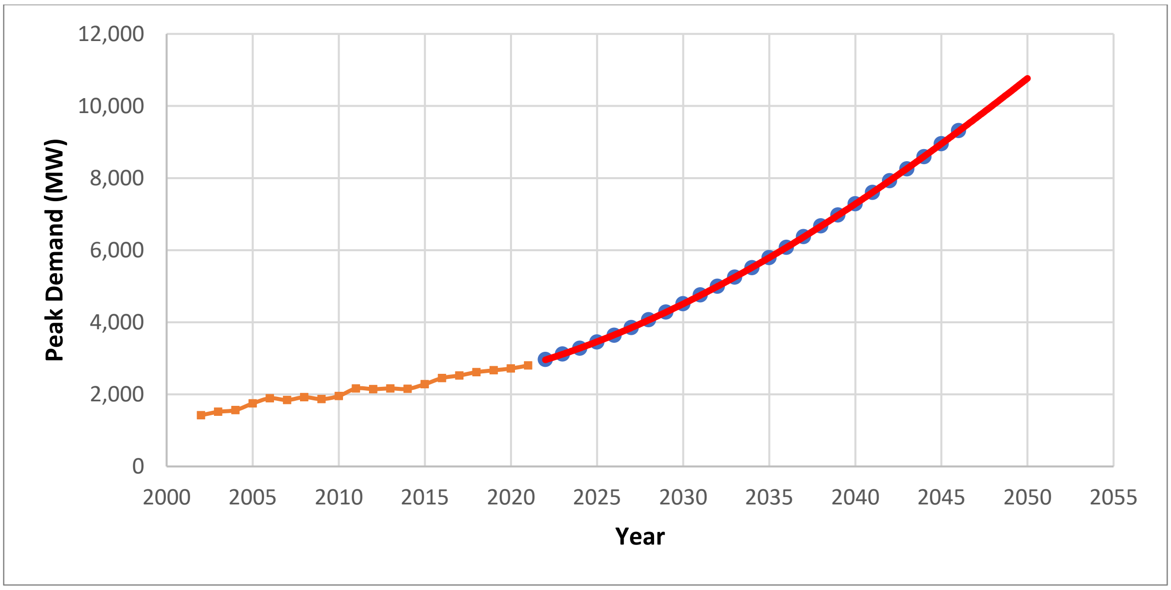

Figure 3.4 : Forecast of Electricity Peak Demand

As per the draft LTGEP 2023-2042, following three scenarios were identified to achieve the general policy guidelines declared by the government (Draft LTGEP 2023-2042). This plan considers power plant additions and retirements only up to year 2042.

Scenario 1: Achieving 70 % RE by 2030, maintaining 70% RE beyond 2030 and no coal fired plant additions throughout the horizon

Scenario 2ieving 70 % RE by 2030, maintaining 70% RE beyond 2030, no coal fired plant additions throughout the horizon and considering cross border interconnection with India

Scenario 3: Achieving 70 % RE by 2030, maintaining 70% RE beyond 2030, no coal fired plant additions throughout the horizon and considering nuclear power development beyond 2040

Based on the forecasted electricity demand up to 2050, the CO_2 emissions of each of the above scenarios are estimated and taken as the baseline scenarios in the power sector.

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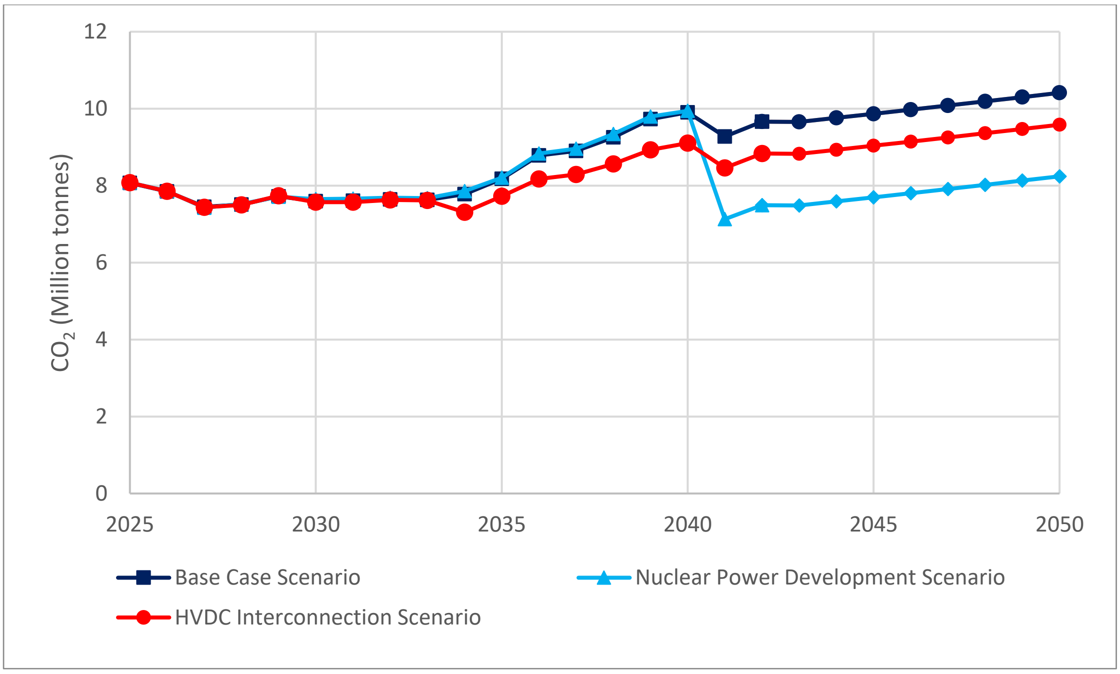

Figure 3.5 : CO_2 Emissions in Baseline Scenarios for Power Sector

The CO_2 emission in the Domestic, Commercial and Other sector (excluding Transport and Industrial sectors) was forecasted by considering forecasted demand of LPG, kerosene, diesel, fuel oil and charcoal. The net emission from firewood and biomass are conceded as net zero. The total CO_2 emission in the Domestic, Commercial and Other sectors is shown in Figure 3.6.

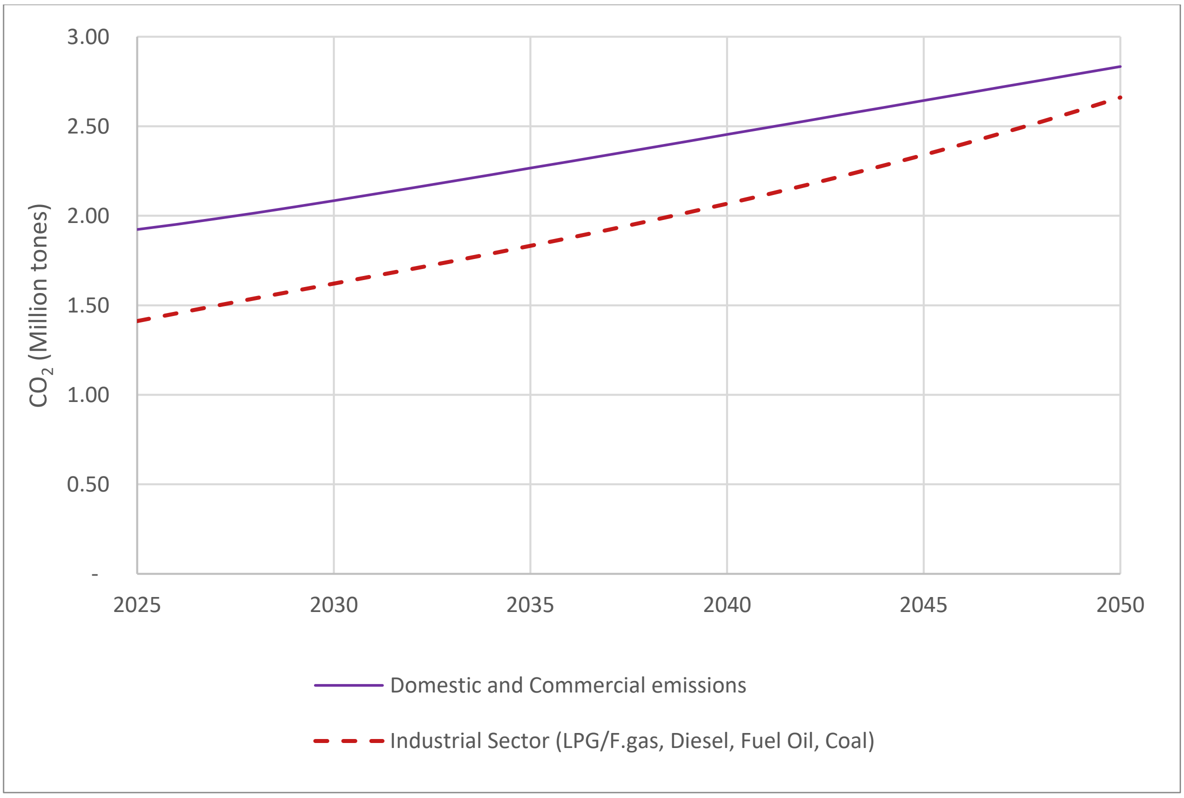

Figure 3.6 : CO2 Emissions in Baseline Scenarios for Household and Commercial Sectors and Industrial Sector

The estimated total CO_2 emissions in the energy sector (excluding fuel used for Transport and Industrial IPPU sectors) for the period of 2025 to 2050 with proposed three baseline scenarios of the LTGEP 2023-2042 are shown in Figure 3.7.

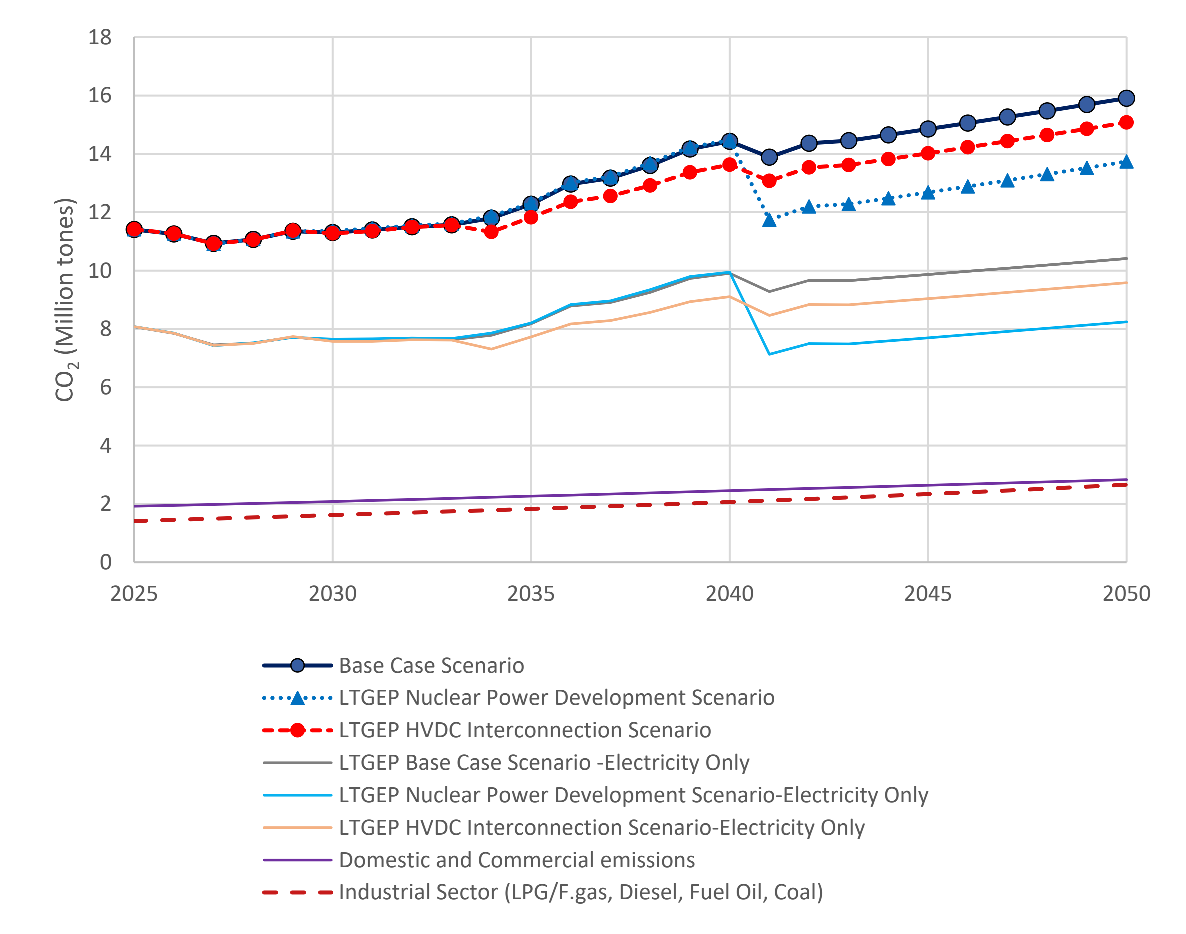

Figure 3.7 : Total CO_2 Emissions in Baseline Scenarios (Excluding fuel used for transport and industrial IPPU sectors)

3.2.2 <u>Transport Sector</u>

Sri Lanka's CO_2 emission by the Transport Sector in 2021 is 11 million tonnes (MoE, 2021), as estimated in the NDC report of the Ministry of Environment. With proposed mitigation measures, it is expected that the implementation of updated NDCs will result in GHG emissions reduction against the BAU scenario by 4.0% in the transport sector (1.0% unconditionally and 3.0% conditionally), equivalent to an estimated mitigation level of 1,337,000 tonnes unconditionally, and 4,011,000 tonnes conditionally (a total of 5,348,000 tonnes) of carbon dioxide equivalent during the period of 2021-2030, as shown in Figure 3.8.

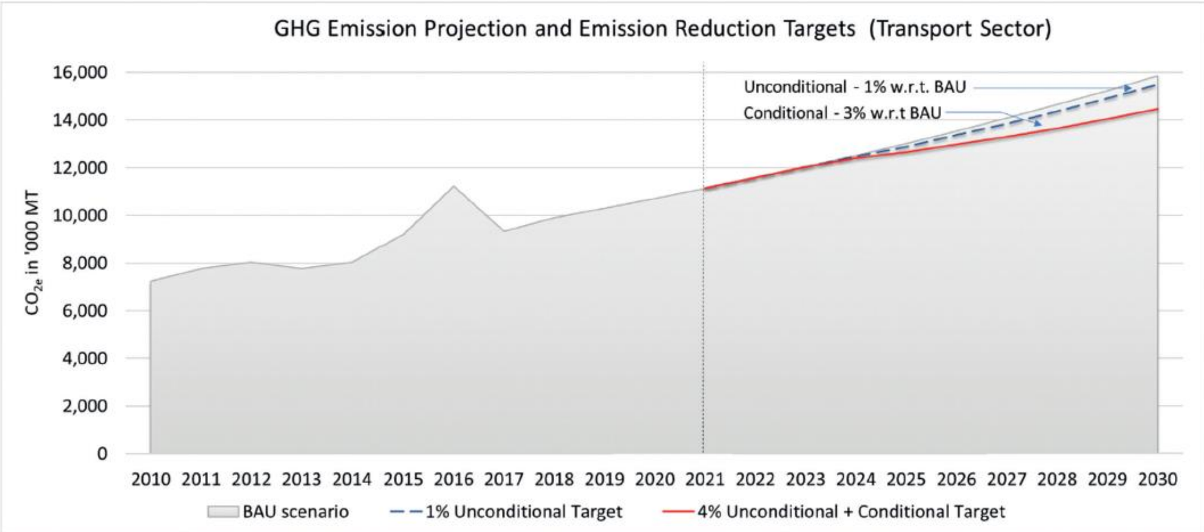

Figure 3.8 : GHG Emission Projection up to 2030

The CO_2 emission level from the transport sector is related to population as well as the GDP of the country since the latter determines the economic activity level of the country. How the transport needs are met to fulfil those economic activities under the existing transport infrastructure, level of motorization and transport policies will determine the level of CO_2 emission level relevant to the transport sector. The NDC implementation study interim report (MoE, 2022) shows no significant difference between the emissions in the BAU case and the implementation of unconditional actions during the period 2020 – 2022. Thus, the BAU scenario is considered as the Baseline, where the population and the economy would grow, while no mitigatory interventions are taken in the future. Therefore, the CO_2 emission rates with respect to the parameters such as GDP and Population are analysed using historical data. Figure 3.9 shows how the CO_2 emission per capita has increased with GDP per capita over the period 2008-2019. A sharp increase in rate is observed during the period 2015-16 when the value increased coinciding with the rapid increase in motorcycles and three-wheeler registrations which was observed during the period. Therefore, the observed relationship is used to forecast CO_2 emission quantities for future population and economic growth (reflected by the GDP) scenarios used in the study.

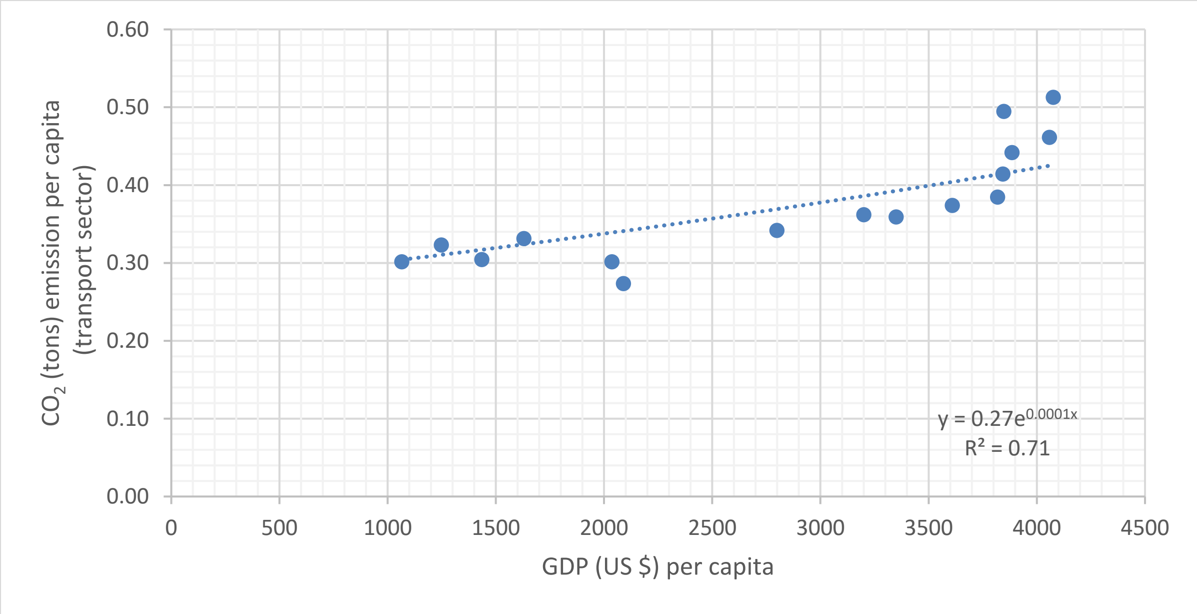

Figure 3.9 : CO_2 emission per capita variation with GDP per capita

3.2.2.1 Baseline scenario CO_2 forecasting for 2050

Sri Lanka has not worked towards generating a transport policy nor a national-level master plan to identify candidate projects that the government has committed to. Regional plans such as the Western Region Megapolis Master Plan (developed in 2015/16) and the COMTRANS study master plan (developed in 2011/12) were not adopted by successive governments. The only strategic level plan that is officially available is the Road Development Authority's Highway Master Plan for 2021-2030, which outlines the highway development needs under the government's economic growth forecast, which was at 6% p.a. Based on the increased transport activity due to the economic growth, the vehicular traffic demand growth rates are adopted to forecast future traffic flows on the road network. The growth rate used in the master plan development is 4% and 3.5% for the period of 2018 – 2025 and 2025 – 2030, respectively (RDA 2021).

According to the World Bank overview, the economic growth forecasts for Sri Lanka for the years 2023 and 2024 are -9% and -4%, respectively. Therefore, the anticipated trip growth rates are unlikely to be applicable until 2025. Hence, the values estimated for 2021 are likely to remain constant up to 2024.

From 2024 to 2050, it is assumed that the GDP growth rate would be equivalent to a 3.1% value based on the project modelling scenario. The population is expected to increase up to 24 million as per the forecasting scenario for the Baseline.

Using the emission per capita and GDP per capita model developed using historical data, the future emission rates per capita can be estimated for the forecasted GDP and population values under the forecasting scenario for the Baseline. For example, in the year 2050, when the GDP increases up to US $ 168 billion, the per capita income for a 24 million population would be

US \$ 7399. At existing emission rates this would give a per capita CO_2 emission rate of 0.79 tonnes.

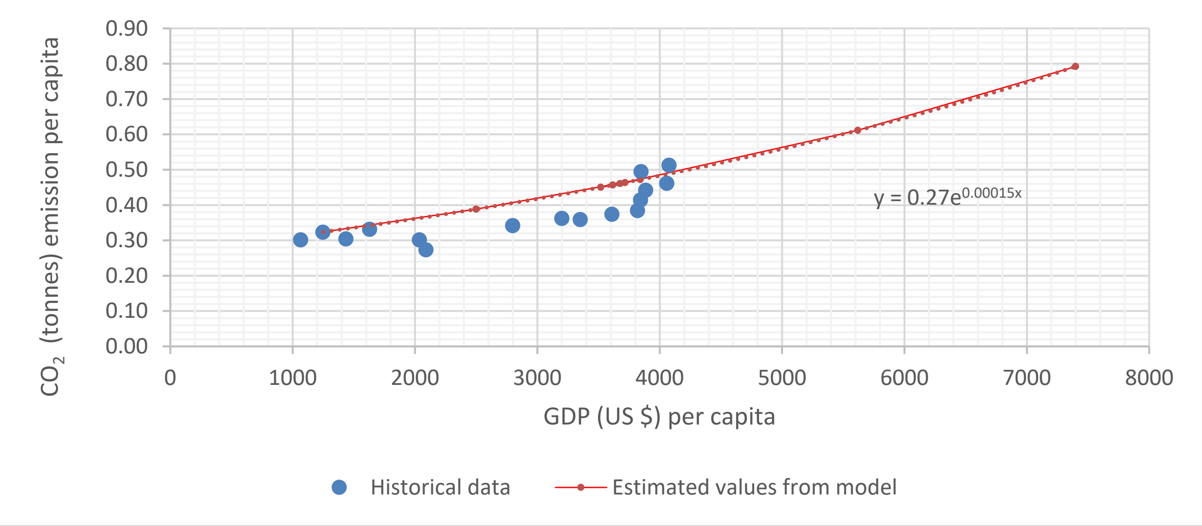

Figure 3.10 : CO_2 estimation from model

Thus, as shown in Figure 3.11, the forecasted CO_2 emission for 2050 is 19 million tonnes.

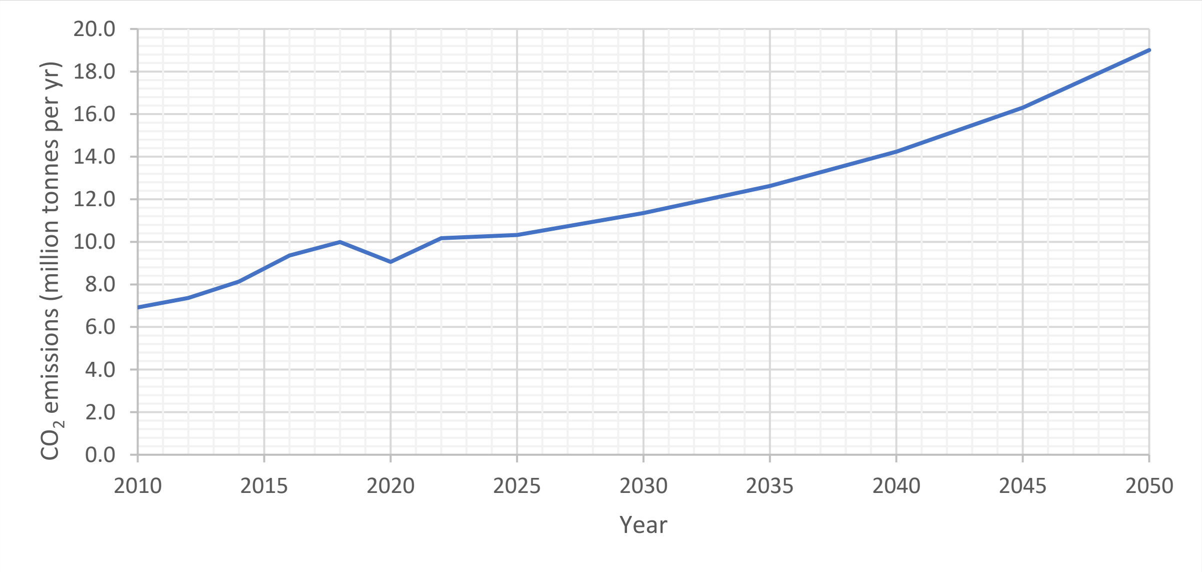

Figure 3.11 : CO_2 estimation for the transport sector

If we use the linear regression analysis-based forecast using the historical data in the Climate Analysis Indicators Tool (CAIT) tool, the forecasted value is 24 million tonnes. Therefore, it can be considered a prudent estimate considering that for close to 4-5 years during this period there is significant reduction in economic activity.

3.2.3 Industry Sector

Considering the national economic development and population growth indices, the total emissions for the Baseline scenario and the mitigation (net zero) scenario were calculated, and depicted in Figure 3.12.

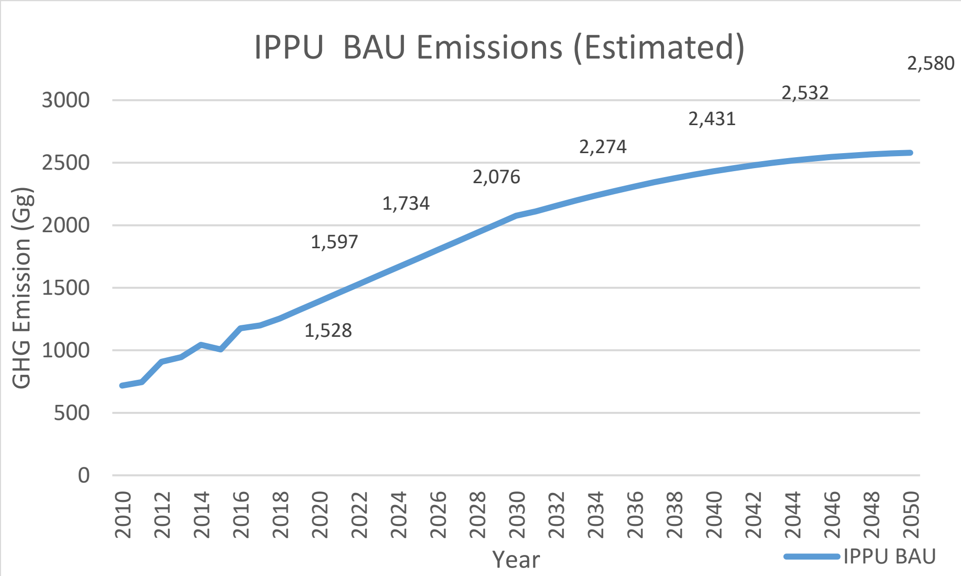

Figure 3.12 : The GHG emissions by the Industry IPPU, predicted for the period 2025 to 2050 under the Baseline Scenario

3.2.4 Waste Sector

The scenarios considered to quantify GHG emissions by 2050 in the waste sector are,

A. **Baseline**: Business-as-usual scenario (BAU) + NDC Unconditional
B. Net-zero (Mitigation) scenario

A. Baseline: Business-as-usual scenario (BAU) + NDC Unconditional

Nationally Determined Contribution (NDC) unconditional actions up to 2030 are considered as the Baseline scenario and NDC unconditional actions were modeled for the prediction up to 2050, as shown in Figure 3.13.

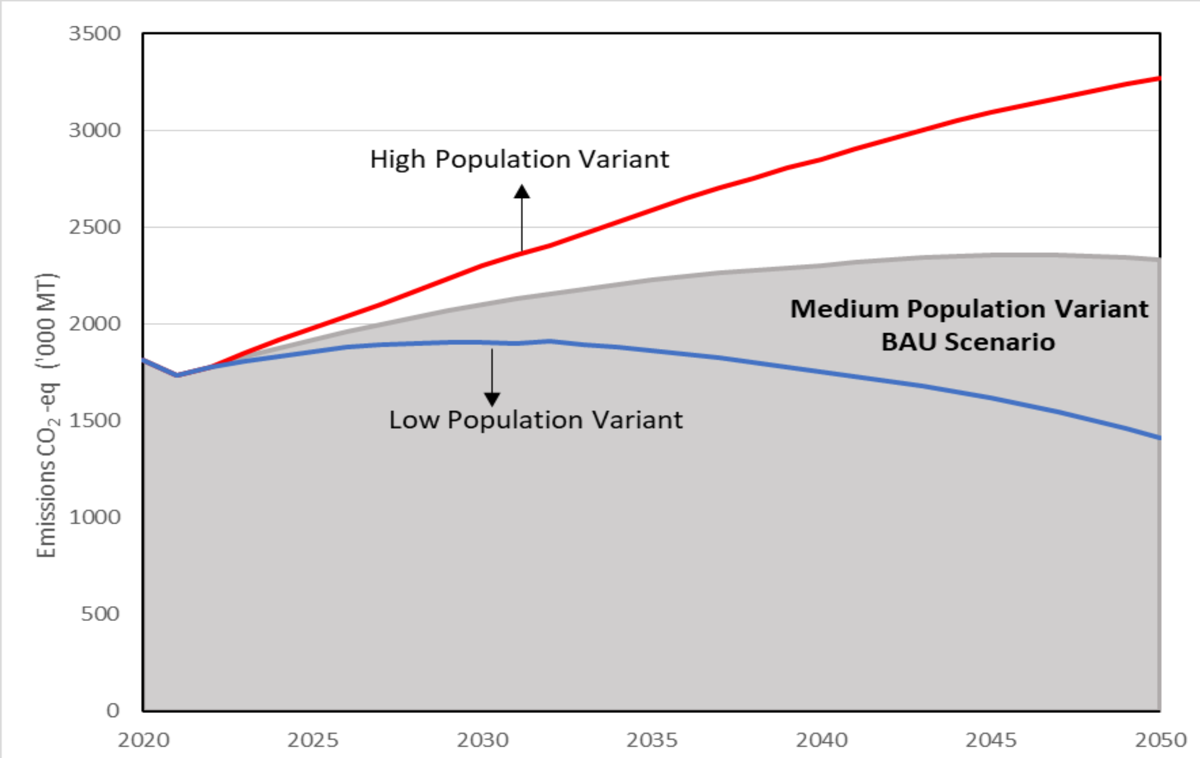

Figure 3.13 : Baseline scenario

Considering the Population Predictions from the United Nations (UN, 2022), three different variations were considered with high medium, and low variations in population in the country with a 3.1% GDP growth rate as given in the Sri Lanka Climate Prosperity Plan Preliminary report. The medium variant population shows a more realistic variation in the GHG emission since the population growth during the latter years during the study period decreased, which as well indicates there could be a natural tendency in the reduction of GHG in the future.

B. Net-zero (Mitigation) scenario

Nationally Determined Contribution (NDC) unconditional and conditional actions up to 2030 are considered as a scenario to understand the pattern of GHG emission if the NDCs' actions were followed promptly. The multiple variant population from the United Nations (UN, 2022) and 3.1% of GDP from CPP were used for the prediction of emissions in the NDC scenario. Figure 3.14 shows the situation of GHG emissions in this scenario.

Here too, the medium variant population shows a more realistic variation in the GHG emissions, since the population growth during the latter years during the study period decreased, which as well indicates there could be a natural tendency in the reduction of GHG in the future. This scenario will be considered to which the proposed mitigatory actions to be incorporated in seeking the net zero emission within the sector.

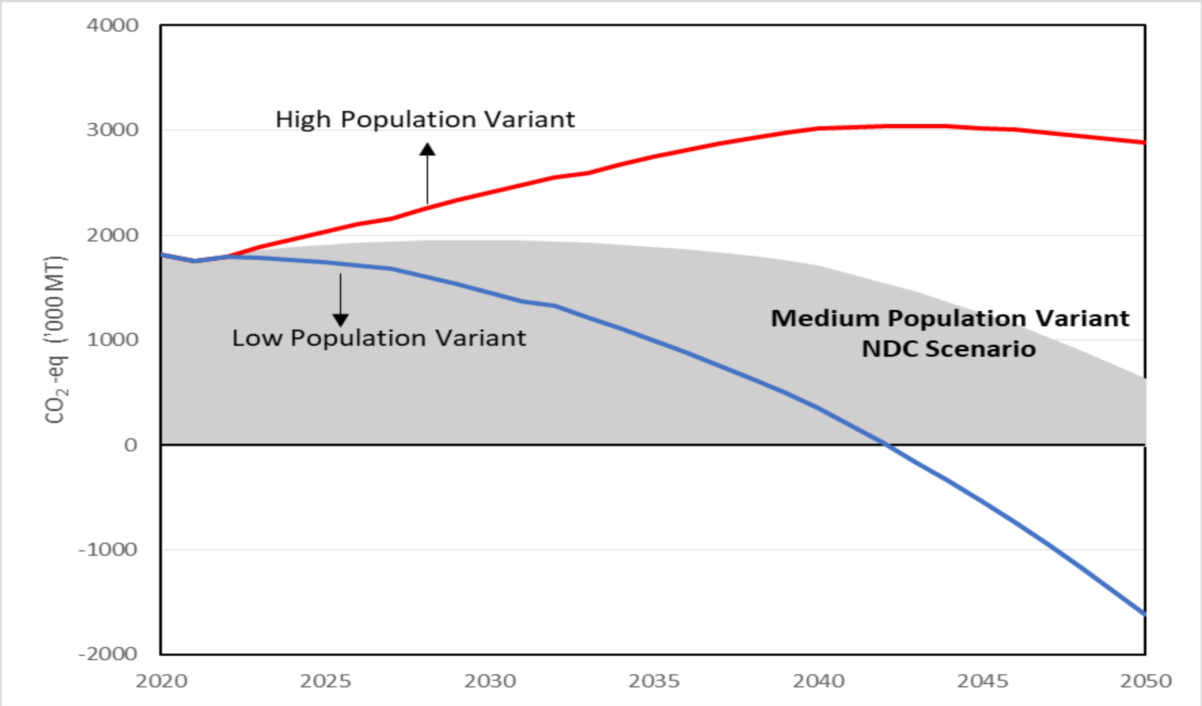

Figure 3.14 : NDC scenario

3.2.5 <u>Agriculture Sector</u>

Emission prediction models for the agriculture sector are limited as many prediction models in agriculture sector are focused to predict yield and production of various crops. Some models found are discussed below with their disadvantages for the present purpose. Prediction of emissions based on NDC approach has been found as the most suitable model scenario development.

FAO EX-ACT Model

The Ex-Ante Carbon-balance Tool (EX-ACT) is an appraisal system developed by FAO (2013b) providing ex-ante estimates of the impact of agriculture and forestry development projects, programmes and policies on the carbon-balance. The carbon-balance is defined as the net balance from all GHGs expressed in CO_2eq that were emitted or sequestered due to project implementation as compared to a business-as usual scenario. The EX-ACT is a land-based accounting system, estimating C stock changes (i.e. emissions or sinks of CO_2) as well as GHG emissions per unit of land, expressed in tonnes of CO_2e per hectare and year. The tool helps project designers to estimate and prioritize project activities with high benefits in economic and climate change mitigation terms. The amount of GHG mitigation may also be used as part of economic analysis as well as for the application for funding additional project components.

Disadvantage – All data required for the model inputs are not available for Sri Lanka.

Machine Learning (ML) models

Machine learning (ML) models are increasingly used to study complex environmental phenomena with high variability in time and space. There are 3 categories of models namely classical regression models, shallow learning models and deep learning models for predicting soil greenhouse gas (GHG) emissions from an agricultural field. Carbon dioxide (CO_2) and nitrous oxide (N_2O) fluxes, as well as various environmental, agronomic and soil data are required as inputs. According to the Hamrani et al. (2020), the rigorous analysis which included statistical comparison and cross-validation for the prediction of CO_2 and N_2O fluxes, confirmed that the Long Short-Term Memory (LSTM) model performed the best among the considered ML models with the highest R coefficient and the lowest root mean squared error (RMSE) values

Disadvantage - One of the fundamental problems of time-series data mining is the representation of the data. Hence, time-series data forecasting without any data clustering requires that one model to be built for each pixel. This requires significant computational effort and validation of a substantial number of models (Vasilakos et al., 2022).

Scenario development

Baseline Scenario – The reference curve has been fixed considering GDP and population change as baseline scenario (Figure 3.15). Two exceptional lowering of emissions was observed in the year 2014 and 2016 and according to DOA it was due to the impacts of an El Nino condition prevailed in Sri Lanka.

NDC 2030 scenario extended to 2050 – The GHG reduction curve established on the assumption that the mitigation strategies mentioned in 2030 report are adopted continuously up to 2050. Figure 3.16.

Mitigation Scenario – This scenario is recommended by this report including following additional changes: Figure 3.17

i. In livestock sector all cattle population and goat and sheep populations were included

ii. A strategy was included to remove paddy straw from all types of paddy fields. The paddy straw provides high C:N ratio and leads to emit more methane if mixed in the soil. Removal of paddy straw from the field and less disturbance to soil through conservation tillage will minimize GHG emission due to microbial activities in the soil.

This improvement could further reduce GHG emission down to 61 %.

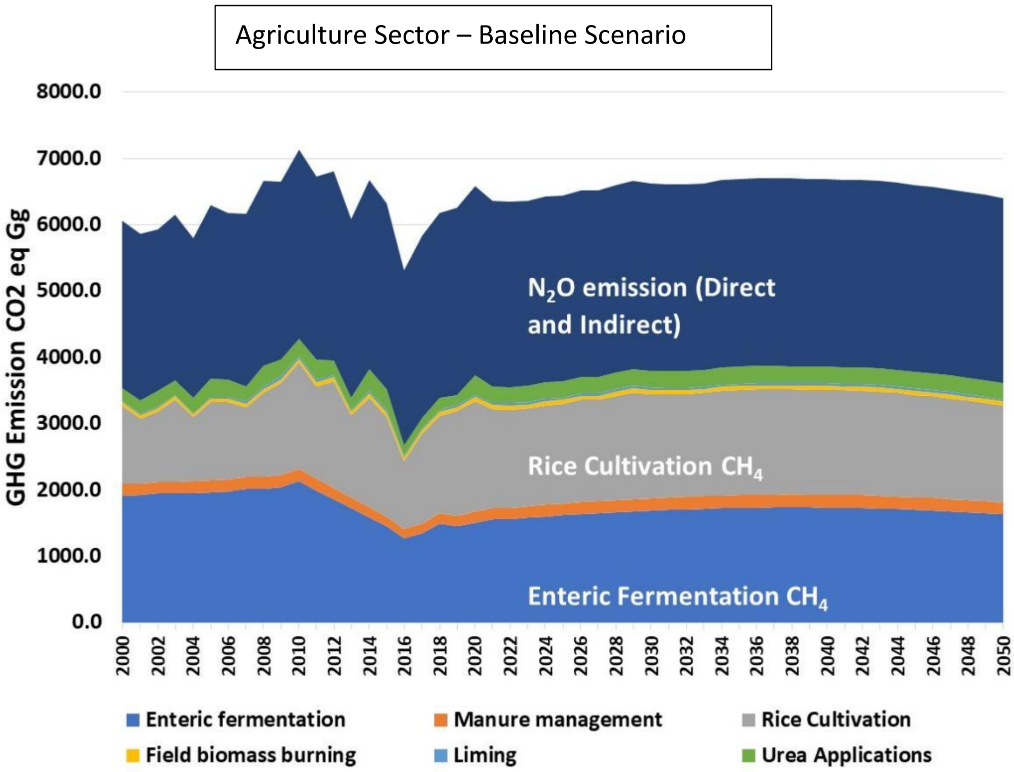

Figure 3.15:The GHG emissions from various activities under Agriculture, contributing to emissions from the Agriculture Sector

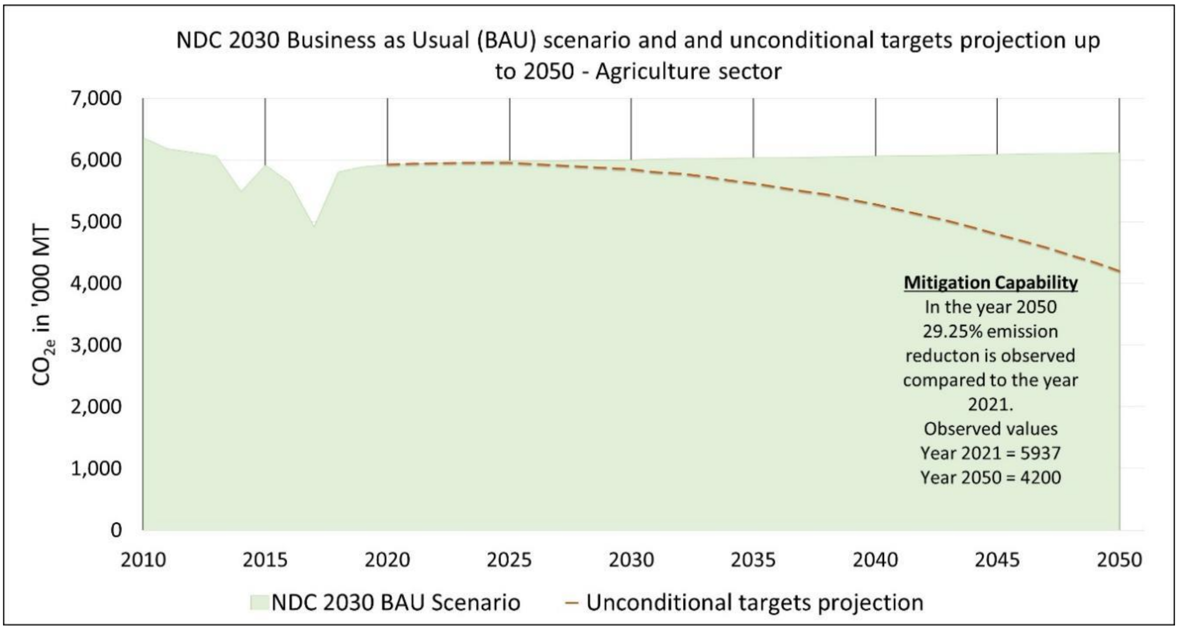

Figure 3.16 : Extrapolated BAU and Unconditional Targets scenarios for the Agriculture sector as per NDC report (MoE, 2021)

However, it was observed that Agriculture sector covered by the updated NDC Sri Lanka needs further improvements prior to be used to predict and forecast selected mitigatory options.

Hence, another scenario was developed with some added detailed parameters to the livestock sector namely, emissions from Neat Cattle local as well as imported breeds were categorized in to milking, not milking, bulls and calves were analyzed in detail. Further to that populations like goats, sheep, swine, chicken and ducks were also analyzed in detail to calculate the GHG emissions to refine the baseline scenario. In addition to that it is proposed to remove paddy strow from paddy fields for various purposes to minimize GHG emissions as mentioned under mitigation activities. In this exercise crop diversification in paddy fields (as recommended in NDC 2030 report) is not much encouraged due to the facts that paddy production should be kept stable and all paddy soils are not suitable for crops like soybean, onion, groundnut etc.

The above refinement is shown in Figure 3.17 and the respective GHG emissions due to methane, carbon dioxide and nitrous oxide is shown in Figure 3.18. This approach helped to increase the mitigation capability of the incremental planning proposed for five-year intervals up to the year 2050 and percentage reduction obtained from the best-case scenario was used to formulate the mitigation planning.

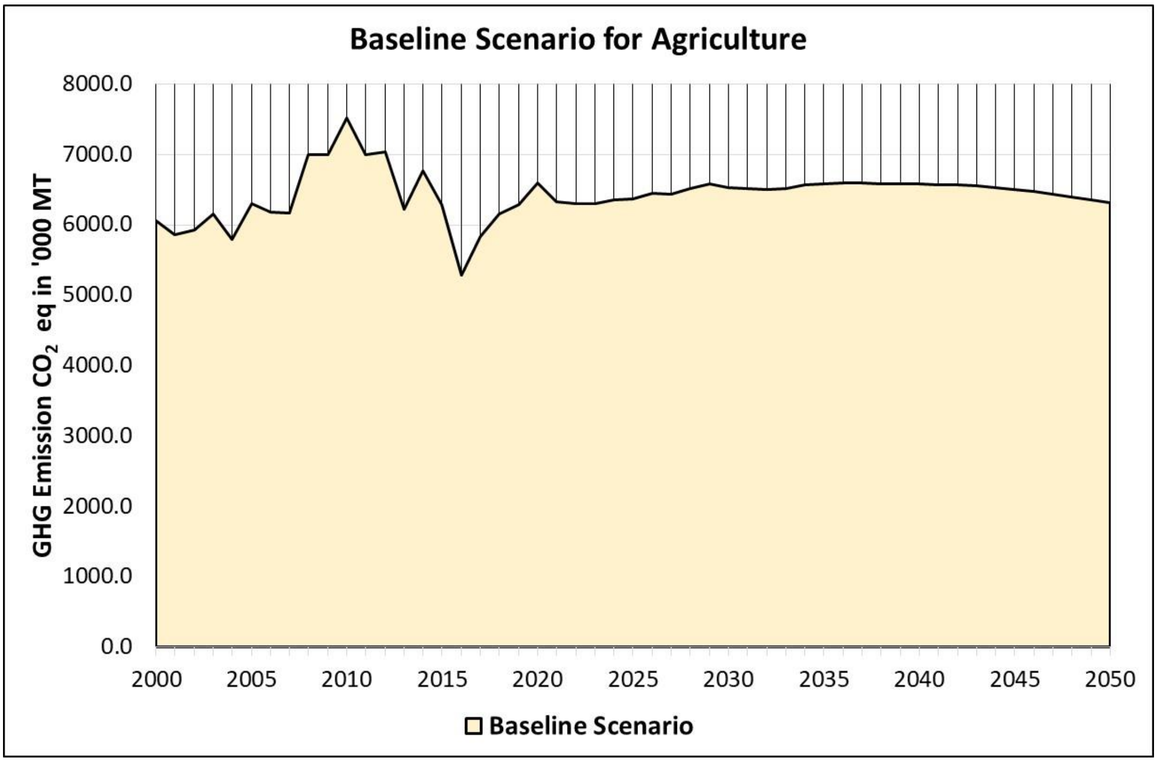

Figure 3.17 :Baseline Scenario developed for the Agriculture

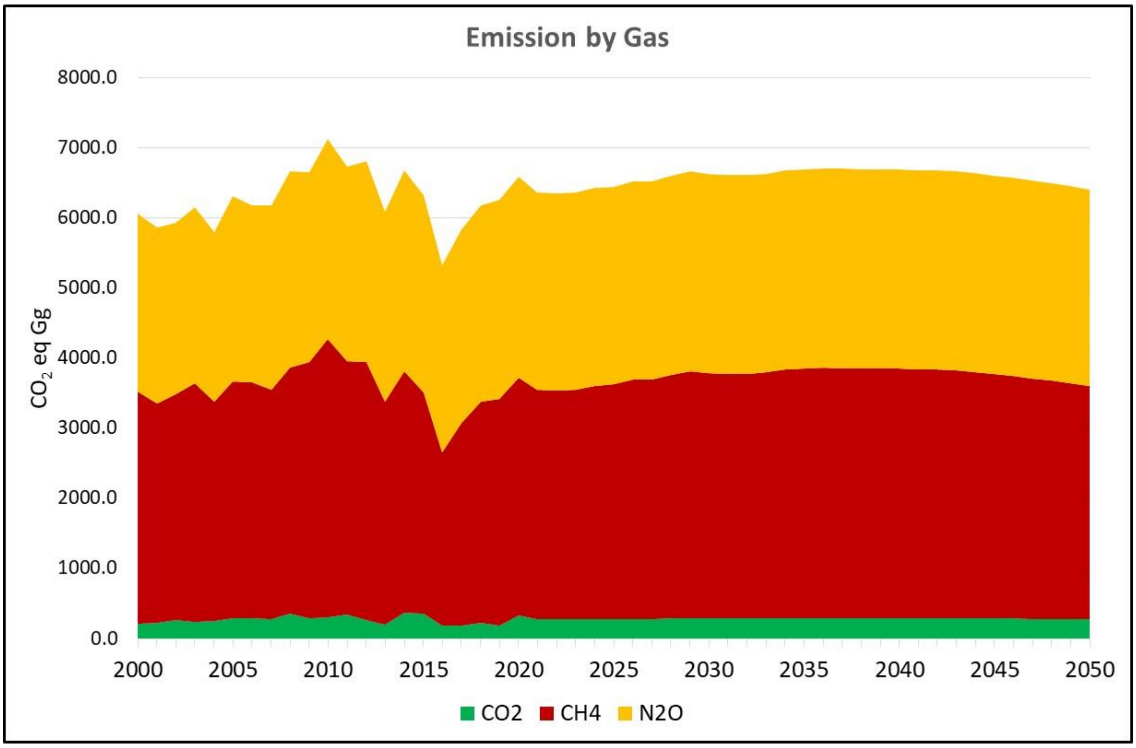

Figure 3.18 :Contributions of CO_2, Methane and N_2O to the total GHG emissions from the Agriculture sector

According to the Figure 3.18 developed on the basis of emission model formulated for the Carbon net zero 2050 study, Methane and Nitrous Oxide gases could be considered as major contributors for the agriculture sector compared to the CO_2 emissions. Hence, it was decided to analyze only CH_4 and N_2O gases as GHG contributors.

Carbon Sequestration from the agriculture sector

The carbon sequestration capacity of tea plantations has not been accounted for in the updated NDC Report (2022) or the TNC (2022). However, these values were calculated for this report, and are given in Table 3.2.

The tea plantations in the low country, mid-country, up country, and Uva have the potential of sequestering 6659, 3497, 2344, and 5085 kg of C ha-1 yr-1 respectively. Potential values for C sequestration were calculated accordingly. These values can be used in C net zero balance exercise.

Other plantation crops and the home garden were not considered under agriculture as these are considered under forestry sector (trees outside the forest)

Table 3.2: Present C sequestration in tea lands

	Low Country	Mid Country	Upcountry	Uva	Total
C sequestration (Kg/ha/year)	6,659	3,497	2,344	5,085	-
Land extent (ha)	13,883	6,358	35,432	25,919	81,592
Baseline C sequestration Mt/ year	92,447	22,234	83,053	131,798	329,532

Source: Wijeratne et al, (2014)

In order to improve the biodiversity in Tea plantations, fruit trees which produce small berries could be introduced. This could be done as land strips having one meter width running along the foot of hills having tea plantations. This will add a separate mini ecosystem to tea lands and will support most of the pollinators which will again support to keep the vegetation cover Gunasena 2016.

However, since the plans or data for enhancement of sequestration are not available for reliable calculations, and these values are not significant compared to the sequestration by the Forestry sector, these were not accounted for the carbon net zero calculations.

3.2.6 Forestry Sector

Baseline Scenario refers to the scenario with the assumption that no mitigation policies or measures will be implemented beyond those that are already in force and/or are legislated or planned to be adopted. In the case of the Forestry sector, this scenario was developed using the following assumptions:

A. Forest cover includes natural forests, forest plantations and rubber plantations according to the definition of forests by FAO.
B. The deforestation rate will be 5000 ha/yr from 2021-2030 as per the Revised Nationally Determined Contributions (NDCs) (Ministry of Environment, 2021). This will continue up to 2050.
C. The new plantings will be 18,050 ha from 2021-2030 according to the Ministry of Environment, (Revised NDC, 2021-2030, Ministry of Environment, 2021) and this will not continue afterwards due to limitations of land.
D. There will be 25,000 ha of reforestation/restoration/afforestation from 2025 and will continue up to 2030. This will also be discontinued afterwards.
E. In home gardens, the annual increase was taken as 1%, while the annual loss was taken as 0.3%
F. In the coconut plantations, the annual loss was taken as 616 ha, while the annual increase was taken as 10,000 ha.

G. In the tea plantations, annual increase was taken as 1800 ha; 40 trees/ha is the density of shade trees.
H. The total urban tree cover of the country is taken as 75,000 ha and the annual loss in general is 300 ha. There is an annual increase of 1% of the extent. It is expected that 100,000 trees will be added to the urban tree repository.
I. The loss of mangrove extent is 0.5% /year, while 100 ha is added annually.

Following Reference values were taken in the calculations:

Emission Factors

a) 150 tons/ha in deforestation and establishment of new forest lands and conversion of home gardens to other non-tree land uses.
b) 100 tons/ha in fragmentation of coconut lands and replanting of coconut lands, removal of mangrove lands, removal of urban forests, replanting of tea lands;
c) Due to the scattered nature of plantings this was not considered in mangroves and urban tree cover.

Carbon sequestration factors

a) Carbon sequestration in natural forests @ 4.6 tonnes/ha
b) Carbon sequestration in new forests: plantations up to 6 years is 3 tons/ha/year while beyond that is a maximum of 9 tonnes/ha/year.
c) Carbon sequestration rate of mature coconut plantations and forest plantations is 9 tonnes/ha/ year; appropriate rates of carbon sequestration (2-9 tons/ha/year) was used according to tree age and the young plants up to 6 years of age is 3 tonnes/ha/year
d) Carbon sequestration rate of home gardens – 4.8 tonnes/ha/year; Carbon sequestration rate of tea plantations, including the shade trees @40 trees/ha - 1.4 tonnes/ha/year; Carbon sequestration rate of mixed trees and other perennials – 4 tonnes/ha/year; Carbon sequestration rate of mangroves – 24.76 tonnes/ha/year.
e) With regards to the urban trees, avenue plants and plants in urban spaces, the number of trees in a hectare was taken as 200 and the carbon sequestration rate was taken as 4 tonnes/ha/year considering the carbon sequestration of a mature tree as 0.02 tonnes/year.

Table 1 in Annexure 3) shows the projected extents of forests (natural forests, forest plantations and rubber plantations), Trees outside the forests (homegardens, coconut plantations, shade trees in tea estates, trees in settlements, trees in urban environments and avenue plants) and mangroves in the Baseline Scenario, estimated annually over the period 2025 to 2050. The estimated Total Carbon Sequestration in Forests, Trees Outside Forests and Mangroves in the Baseline Scenario is shown in Table 2 in Annexure 3).

The Projected Carbon Sequestration for the Baseline scenario in the Forestry Sector is shown in Figure 3.19.

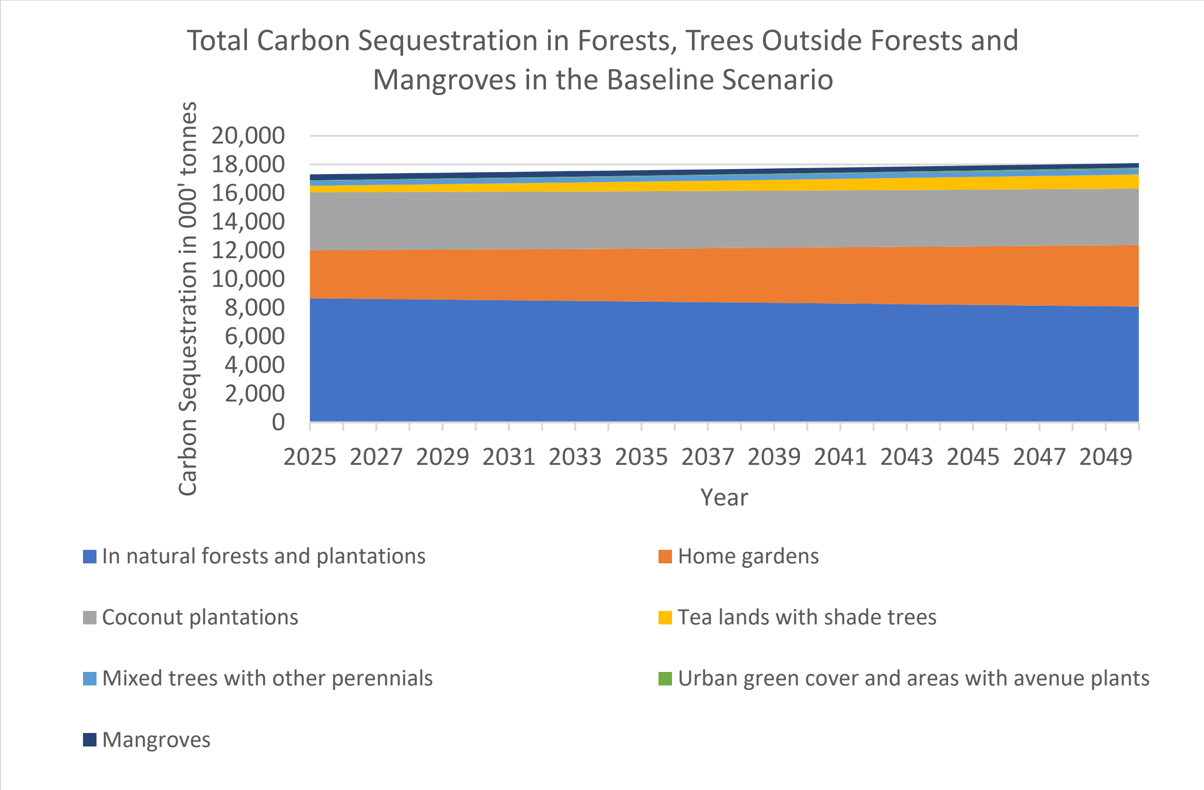

Figure 3.19: Projected Total Carbon Sequestration in Forests, Trees Outside Forests and Mangroves in the Baseline Scenario

The emissions due to deforestation of forests, removal of mangroves and loss of trees outside the forests including coconut plantations and home gardens were taken into consideration. The calculated total GHG emissions from the Forestry sector including forests and trees outside forests (tonnes /yr) in the Baseline Scenario from 2025-2050 is shown in Table 3 in Annexure 3, and Fig 3.20

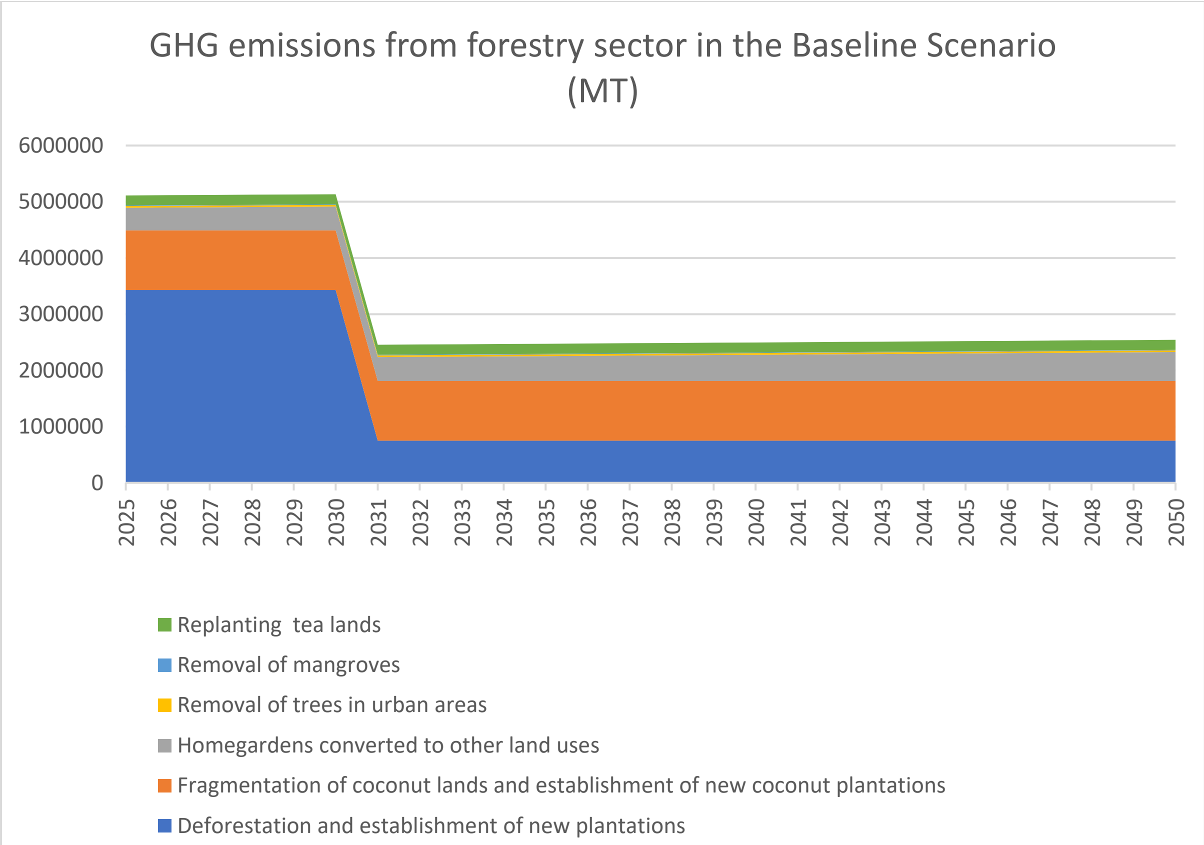

Figure 3.20 : The total GHG emissions from the forestry sector including forests and trees outside forests (tonnes/ha/yr) in the Baseline Scenario from 2025-2050

3.2.7 Overall Net Emissions in the Baseline Scenario

The net emission levels (total emissions - total sequestrations) is shown as a white line graph in Fig 3.21, and this shows an increasing trend throughout the period 2025 to 2050. As seen in Fig 3.21.and Table 3.3, the Baseline scenario would result in a net annual emission quantity of 23,621,843 MT (23.62 Mt) CO_2e by the year 2050. In order to achieve Carbon Net Zero by 2050, this net emissions value has to be reduced by mitigation actions in all sectors, so that the emissions are reduced and sequestrations are increased to balance each other.

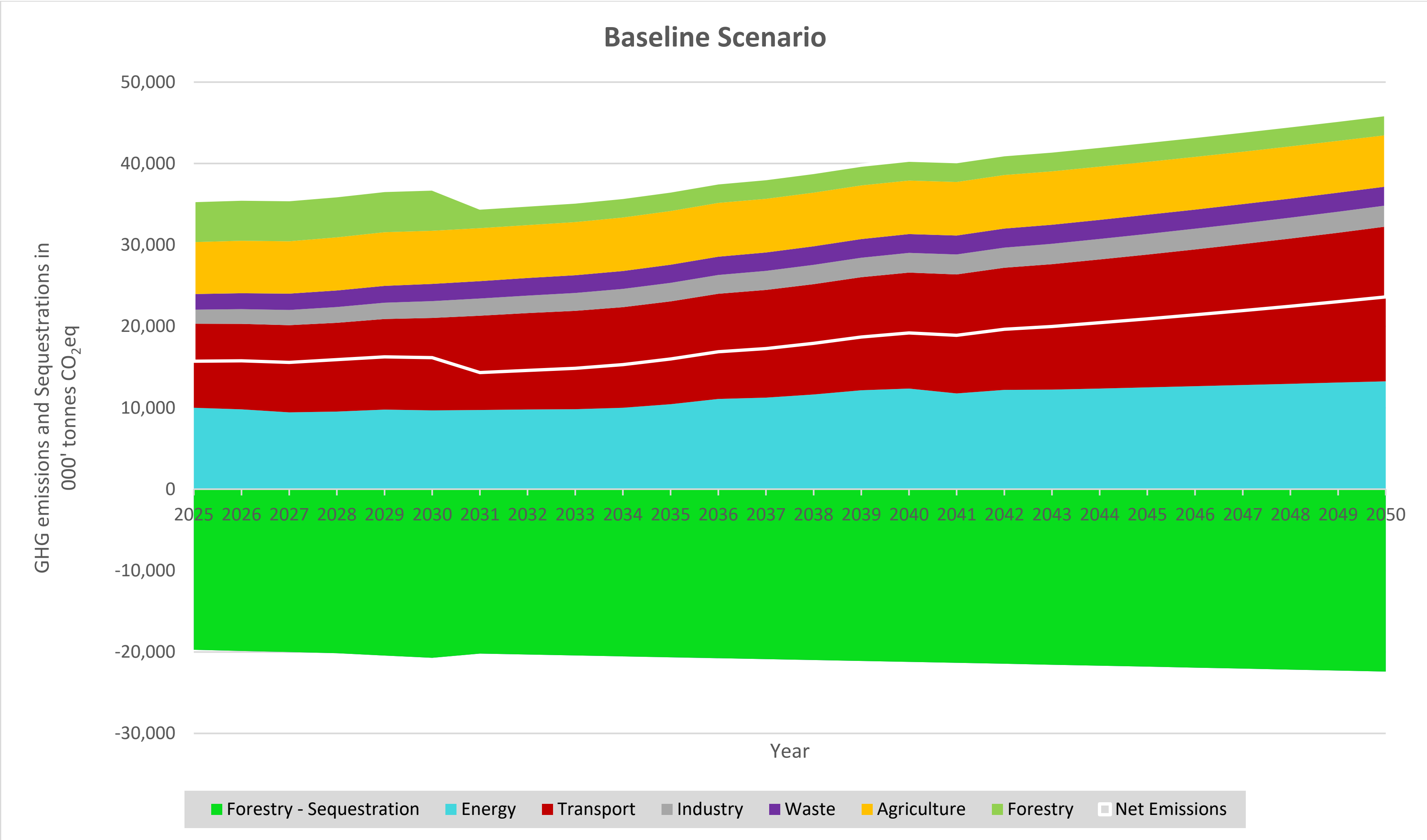

Figure 3.21 : The Predicted Emissions and Sequestration in All Sectors for the Baseline Scenario

Table 3.3: Total Emissions in Mt CO_2e

Sector	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Energy	9.99	9.80	9.43	9.53	9.77	9.68	9.73	9.80	9.82	10.01	10.44	11.09	11.24	11.63	12.15	12.36	11.77	12.19	12.22	12.37	12.51	12.65	12.80	12.95	13.10	13.25
Transport	10.32	10.51	10.71	10.91	11.13	11.35	11.58	11.83	12.08	12.35	12.63	12.92	13.23	13.55	13.88	14.24	14.61	15.00	15.41	15.85	16.31	16.79	17.30	17.84	18.41	19.01
Industry	1.73	1.80	1.87	1.94	2.01	2.08	2.11	2.15	2.20	2.24	2.27	2.31	2.34	2.37	2.40	2.43	2.46	2.48	2.50	2.52	2.53	2.55	2.56	2.57	2.57	2.58
Waste	1.92	1.96	2.00	2.03	2.07	2.10	2.13	2.16	2.18	2.21	2.23	2.25	2.26	2.28	2.29	2.30	2.32	2.33	2.34	2.35	2.35	2.36	2.35	2.35	2.34	2.33
Agriculture	6.45	6.52	6.52	6.60	6.67	6.62	6.61	6.61	6.63	6.68	6.69	6.70	6.70	6.70	6.69	6.69	6.68	6.68	6.66	6.63	6.60	6.57	6.53	6.49	6.45	6.40
Forestry emission	5.11	5.11	5.12	5.12	5.13	5.13	2.46	2.46	2.47	2.48	2.48	2.49	2.49	2.49	2.49	2.50	2.50	2.51	2.51	2.52	2.52	2.53	2.53	2.53	2.54	2.54
Forestry - Sequestration	19.73	19.87	20.00	20.14	20.43	20.72	20.20	20.31	20.42	20.54	20.65	20.76	20.88	20.99	21.11	21.21	21.32	21.44	21.57	21.68	21.80	21.92	22.04	22.16	22.28	22.14
Calculated Net Emissions	15.72	15.76	15.57	15.92	16.26	16.16	14.33	14.59	14.85	15.30	15.99	16.87	17.27	17.91	18.69	19.20	18.80	19.64	19.98	20.44	20.99	21.42	21.94	22.47	23.03	23.62

3.3 The Mitigation Scenario

The Mitigation scenario is one where the GHG emissions are reduced to the lowest possible, and sequestration is increased to the maximum, where relevant, in all six sectors with proposed actions and timeline for the implementation.

As explained in section 3.1.1 of this report, a preliminary study revealed that it would be possible to achieve net zero emission status by 2050 (or even before 2050), if all mitigation actions proposed for each sector by the consultants, which went beyond the NDC actions, were to be implemented as proposed, in a timely manner. Therefore, the Mitigation Scenario was taken as the Net Zero Scenario."

3.3.1 Energy Sector

Rapid decarbonization of the power sector is a crucial step toward achieving net zero, both because the sector currently accounts for about 8,400 tonnes of GHG emissions and because electricity demand is expected to increase as emissions are abated in other sectors via electrification. Power sector policy will in large part determine the speed and extent of the sector's decarbonisation. Therefore, actions need to be taken so that by 2050, all the electricity will come from low carbon sources, subject to security, stability and reliability of supply, bringing forward the government's commitment to a fully decarbonised power system. Therefore, acceleration of deployment of low-cost renewable generation, such as offshore and onshore wind and solar, large-scale nuclear plant and cross border power interconnections are considered as key commitments. Furthermore, generation of green hydrogen can also be considered as an option that can contribute to energy security, lowering emissions and system costs in the future. Following key mitigation actions are considered as the strategies to reduce GHG emissions in the energy sector.

Pathway 1:

- Decommissioning of all coal power plants by 2044
- No NG plant additions after 2033
- Nuclear power plants to be introduced starting from 2035. The first addition will be 2x300 MW in capacity which will be introduced in 2035. The next addition will be in 2040 with a capacity of 1000 MW.
- HVDC inter connection to be introduced by 2034.
- Renewable energy such as biomass, wind and solar will be added throughout the planning time window.
- Coal, NG, Nuclear and energy from HVDC interconnection was considered to support the base load and throughout the planning period the base load is in between 27% to 50% of the total annual generation of electricity.

Pathway 2:

- Considering the government's current uncertainty surrounding the construction of nuclear power plants, it is imperative to explore alternative strategies. A highly promising approach is to strive for 100% indigenous renewable energy generation, bolstered by efficient energy storage solutions.

  However, the Long-Term Green Energy Plan (LTGEP) for the period 2023-2042 has brought to light significant challenges in achieving even an 80% renewable energy share by 2040. A major concern is the potential uneconomical levels of renewable energy spillage, which hinder the realization of the desired 80% RE share. Moreover, the projected demand profile's inability to absorb renewable energy generation has resulted in a considerable amount of curtailed renewable energy, even at an 80% RE share. These observations raise valid concerns about the feasibility of scaling beyond this threshold, as it could lead to a substantial increase in investment costs compared to the Base Case and cast doubts on the sustainability of operational expenses.

  Nevertheless, there is hope for the future, as rapid advancements in RE integration technology and energy storage solutions are expected. These innovations may pave the way for the eventual goal of achieving a 100% renewable energy-powered energy sector in the future. It is crucial for policymakers and stakeholders to invest in research, development, and implementation of these technologies to unlock the full potential of renewable energy and steer the country towards a greener and more sustainable energy landscape. By embracing technological progress and ensuring a conducive environment for renewable energy growth, Sri Lanka can make significant strides towards a cleaner and carbon-neutral future.

As per the LTGEP, following facts are considered in developing net zero strategies,

- No expected addition of major hydro power plants after 2024
- No expected Mini hydro power plants additions after 2039.
- No expected pumped storage to be introduced after 2032.

To avoid renewable energy (RE) curtailment and enhance its economic viability, the introduction of green hydrogen technology holds great promise for Sri Lanka. However, before proceeding, it is crucial to acknowledge that no proper assessment of the hydrogen industry in the country has been conducted yet. Therefore, a detailed feasibility study must be undertaken immediately to lay the groundwork for its successful implementation.

The initial step in establishing a green hydrogen industry would involve strategic investments in renewable energy sources like solar, wind, and hydropower to generate the required electricity. These renewable energy projects should be carefully located to maximize energy production and minimize transmission losses. An indispensable aspect of this endeavor is the establishment of electrolysis plants, where surplus electricity generated from renewables will be used to split water into hydrogen and oxygen. By employing this process, the produced hydrogen will be entirely green, devoid of carbon emissions.

Fostering partnerships between the government and private sectors becomes crucial to support industries. Offering incentives and favorable policies can attract investments in the green hydrogen value chain. Encouraging industrial sectors to transition from conventional fossil fuels to green hydrogen can significantly reduce their carbon footprint and accelerate the country's progress towards achieving carbon net-zero.

To ensure sustainable growth, investing in research and development becomes vital. This will advance green hydrogen technologies, leading to increased efficiency, cost-effectiveness, and safety, which will further attract innovation and drive industry expansion. Public awareness campaigns and educational programs should be launched to promote the benefits of green hydrogen and drive its adoption across various sectors. Engaging the public in this transition will instill a sense of responsibility and foster collective efforts towards achieving carbon neutrality. International collaboration and partnerships will play a pivotal role in knowledge exchange, technology transfer, and accessing global markets for green hydrogen. Drawing insights from successful green hydrogen initiatives in other countries will help fine-tune Sri Lanka's approach.

By implementing a robust green hydrogen industry with unwavering support for industries, Sri Lanka can pave the path towards carbon net-zero, simultaneously fostering economic growth and sustainability for the nation. By considering all above facts, initiating the first project in the year 2032 is considered in the carbon net zero roadmap.

Figure 3.22 shows the predicted GHG emissions for the period 2025 – 2050 under several scenarios that were considered, which includes 3 scenarios considered in the LTGEP, and 2 scenarios studied in this study, viz Proposed Mitigation Scenario for Power Sector Decarbonization and Proposed Mitigation Scenario for Energy Sector Decarbonization, the last being the option that would be most desirable to reach Carbon Net Zero for Sri Lanka.

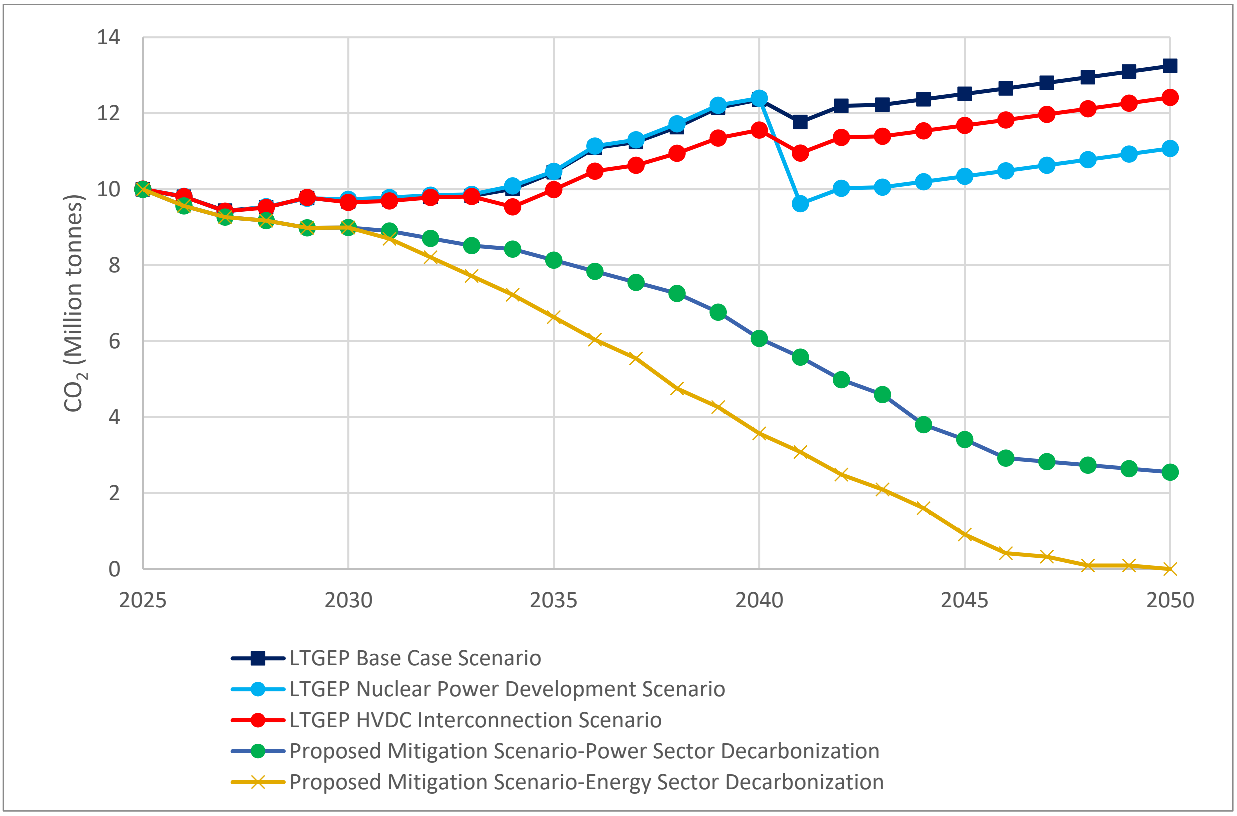

Figure 3.22 : Net Zero Mitigation Scenario in Energy Sector

3.3.2 <u>Transport Sector</u>

The proposed intervention focusses on identifying short term and long-term interventions as well as those that are high capital intensive and low capital intensive. Depending on the government's implementation plan and financing availability, the most feasible actions from these may be chosen.

An overall categorization of the emission-saving projects from the transport sector is given below, details of which is given in the mitigation strategies section.

a. Promote non-motorized transport: increase modal share of walking and cycling for short distance trips
b. Facilitate remote working and e-commerce, e-learning to reduce the travel demand
c. Bus fleet expansion and modernization
d. Pricing strategies for fuel
e. Transport Demand Management in Cities
f. Develop the LRT network
g. E-mobility: electrification of railway, buses and private vehicle fleet.

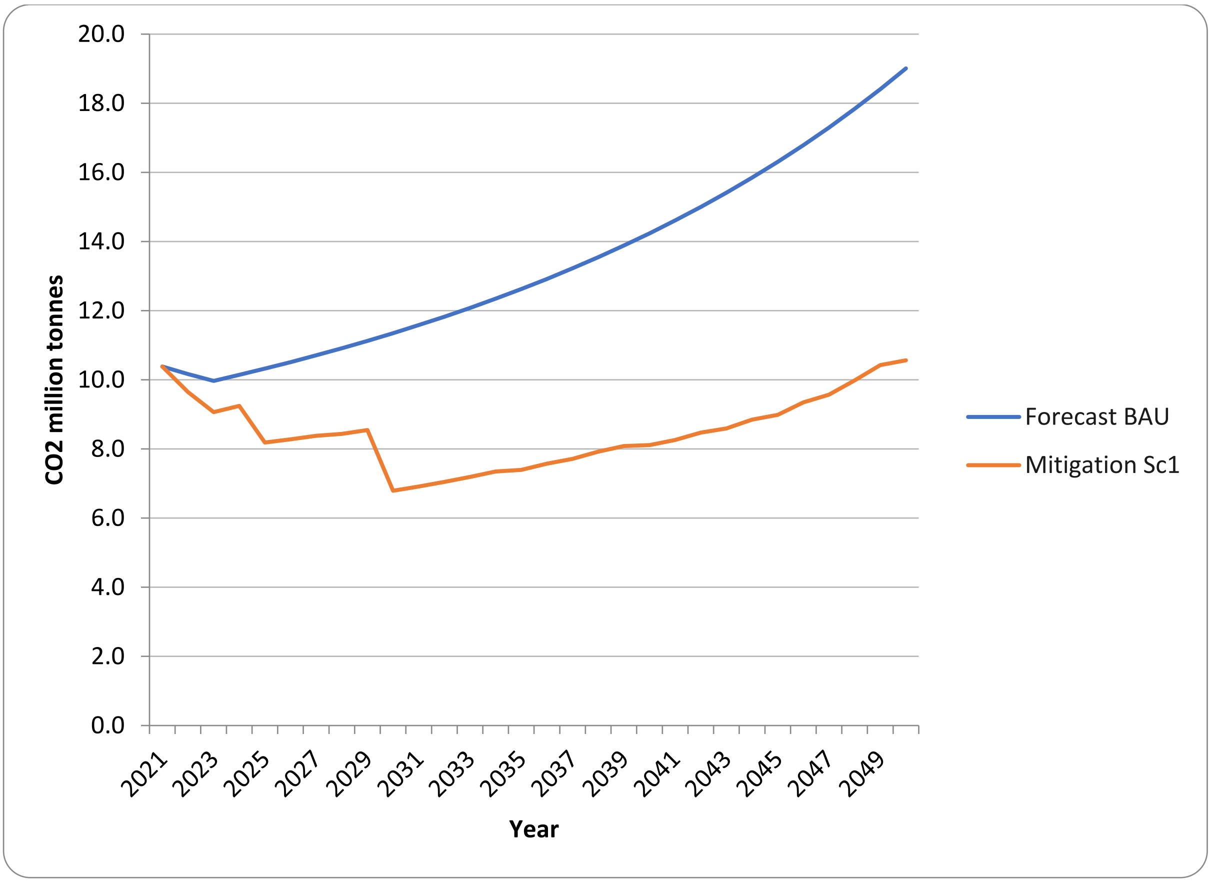

Figure 3.23: The Emissions predicted for the Transport sector under the Baseline and Net Zero scenarios

3.3.3 <u>Industry Sector</u>

As IPPU emissions are highly process specific, very limited opportunities available in reducing emissions (mitigations). Sub sector specific opportunities are listed below;

Cement Industry

Based on the 2000 -2010 cement manufacturing data provided in TNC, 65% of the IPPU emissions are coming from the cement sector (figure 2.aa Page 7).

According to the process studies made during the Greenhouse gas emission reduction from the industries in Asia Pacific (GERIAP 2003 – 2006) at the Puttalam cement manufacturing facility (the only composite cement operation in Sri Lanka) , observed the quality variation of the main raw material lime was not very consistent, due to the geological conditions of the lime query. Hence the industry has taken all possible measures to maintain the process efficiency and product (clinker) quality, which assumed to be the optimum effort to minimize process emissions as well as clinkering process or pyro-processing related energy (coal) and related GHG emissions.

In general application of Cleaner Production (CP) strategies are recommended in minimizing both process and energy use emissions.

As a future emerging and currently emerging option, uses of green hydrogen as a thermal energy source in cement industry for the pyro-processing will be seriously considered as a highly feasible GHG mitigation option, needs to be addressed under the industry energy use.

However, further emission reduction or mitigation potentials or any process specific initiatives to be negotiated and provided by the responsible industry.

In general, subsequent to the maximum effort in minimizing the process-based emissions, remaining emission quantities are recommended to offset with national forestry development plan or "Carbon Capture and Storage" (CCS) strategy or "Carbon Capture, Utilization and storage" (CCUS) strategy appropriate to the industry and viable to the business operation.

Lime industry

Based on the 2000 -2010 lime manufacturing data provided in TNC, 28% of the IPPU emissions are from the lime industry sector (figure 2.aa Page 7).

Currently the main feedstock to the lime industry is dolomite (mixture of $CaCO_3$ and $MgCO_3$) and the main fuel used is firewood logs.

For the GHG inventory development process, the lime production is estimated using the mining licences issued for the purpose by the National Geological Survey and Mines Bureau (GSMB). As there is no post mining quantity assurance process it was assumed that the mining has occurred.

Mined dolomite is subjected to thermal heating process using firewood logs as the source of energy. Dissociation of $MgCO_3$ and $CaCO_3$required 480 ^{O}C and 900 ^{O}C temperatures respectively at the kiln, due to poor thermal efficiencies the expected temperatures are not reached uniformly due to the kiln design and operational inefficiencies. Therefore, the estimated GHG emission values are not highly accurate.

However, the CO2 emission is inherent to the industry and total emission mitigation is unavoidable.

As remedial measures in minimizing emissions adoption of cleaner production technologies are highly recommended. Further, the adaptation of process improvement technologies will provide opportunities to minimize the emissions while product quality improvement.

As GHG mitigation options, Carbon Capture and Storage (CCS), Carbon Capture, Utilization and Storage (CCUS), Forestry or any other offsetting strategies are recommended.

Glass industry

According to the 2000 -2010 glass industry data provided in TNC, 2% of the IPPU emissions are from the glass manufacturing sector (figure 2.aa Page 7).

Use of Soda ash (Sodium carbonate), Dolomite (Sodium Magnesium Carbonate) and Calcite (a carbonate mineral and the most stable polymorph of calcium carbonate) are the main sources of IPPU GHG emissions in the glass industry. In addition to the IPPU emissions, glass industry contributes heavily to the industry energy use related GHG emissions due to its inherent thermal energy requirement for raw material smelting process needs. Use of Green Hydrogen for the industry thermal applications will be one of the potential option in total eliminating of fossil based thermal emissions in the glass industry.

Increasing the percentage of culets of recycled glass will be one of the most feasible options in minimizing the IPPU emissions in the glass industry while reducing the industry energy use emissions due to minimisation of virgin raw material use in the industry. In addition to the GHG reduction it will contribute to the natural resource conservation as well as virgin raw material mining and processing related emissions as well.

According to the position paper published by the “Glass industry Alliance Europe” (Ref: https://www.glassallianceeurope.eu/) “by recycling 74% of the bottles and jars put on the EU market, the glass industry saves about 9 million tonnes of CO2 every year and is at the forefront of the circular economy since decades”.

As circular economy will play a major role in national sustainable economy as well as in national climate mitigation and waste management drives the use of used glass in glass industry is highly recommended.

However, it will be required to consider the feasibilities of this option with the national glass industry stakeholder organisation (Piramal Glass Company Limited).

Ceramic industry

According to the 2000 -2010, Ceramic industry data provided in TNC, 1% of the IPPU emissions are from the ceramic manufacturing (both ceramic tile and porcelain / Chinaware manufacturing sectors (figure 2.aa Page 7).

Calcite and dolomite, which are carbonate are the raw materials used in the ceramic industry which are relevant to the CO_2 emissions when subjected to the thermal curing process in the industry.

Application of cleaner production technologies will be the main option in minimizing the ceramic industry related IPPU emissions. Subsequent to the maximum effort in process efficiency improvement and minimizing the process-based emissions, remaining emission quantities are recommended to offset with national forestry development plan or “Carbon Capture and Storage” (CCS) strategy or “Carbon Capture, Utilization and storage” (CCUS) strategy appropriate to the industry and viable to the business operation.

As ceramic industry consumes substantial volumes of fossil-based energy sources in their kiln operations, there will be a very feasible opportunity use green Hydrogen as a mean of decarbonizing the ceramic industry. Some of the global ceramic industry (https://www.mykonosceramica.com/en/combustion-by-hydrogen-is-achieved-for-the-first-time-in-a-ceramic-kiln/) has taken initiatives towards this option.

Therefore initiatives on green Hydrogen opportunities as a ceramic industry will have decarbonizing the ceramic sector while higher opportunities to approach the global green ceramicware market.

Solvent use

According to the TNC, solvents are used for a variety of purposes including their use as a cleaning agent and in manufacturing surface coatings and dry-cleaning agent, tetrachloroethylene (C_2Cl_4). These are mainly sources of NMVOCs and it's amounting to about 4% of CO_2 out of the total IPPU emissions.

Use of solvents in industry are process specific and mitigation options are very limited. But adoption of Cleaner Production technologies is highly recommended in minimizing solvent based emissions.

Bread manufacturing industry

Bread manufacturing process is contributing to the GHG emissions in two modes; Baking process energy use emissions and fermentation process.

By fuel switching and use of electrical energy with minimized / zero grid emission factor will lead to minimize the emissions from bakery industry.

As fermentation process is a biological process and the emissions are bio carbon, it is proposed not to account the said emissions. As sub sector emissions are relatively very small it is recommended to not consider any specific mitigation measures other than application of Cleaner Production initiatives in emission reduction and other economic benefits.

GHG Emissions from the Industry IPPU Sector in the Mitigation (Net Zero) Scenario

The estimated GHG emissions under the mitigation scenario, when all proposed mitigation actions are implemented over the period 2025 to 2050 are depicted in Figure 3.24.

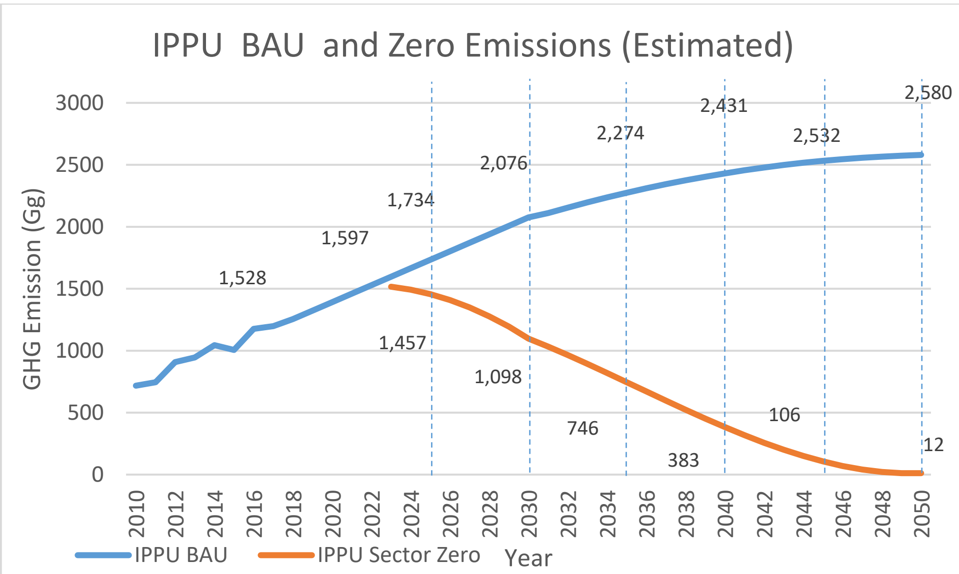

Figure 3.24 : Estimated GHG Emissions from the Industry (IPPU) Sector in the baseline and Mitigation scenarios

3.3.4 Waste Sector

The timeline for the Net Zero Carbon – 2050 was decided considering the development, socioeconomic, and demographic factors. The mitigation actions are spaced into 5 years to execute chronologically to minimize the GHG emission. There are eight mitigatory measures suggested including two from the NDCs which are to be continued until 2050 and beyond.

The mitigatory measures are,

- Daily Cover for Open dumps
- Syngas recovery from open dumps
- Vertical Subsurface flow constructed wetlands (VSSFCW)
- MSW Growth reduction to 50%.
- Mandating 3R practice.
- Electric vehicles for waste collection.
- Waste to energy plants for non-biodegradable waste that remains after all other options.
- Sanitary landfill
- Circular Economy for Redesign, Reuse and Rethink

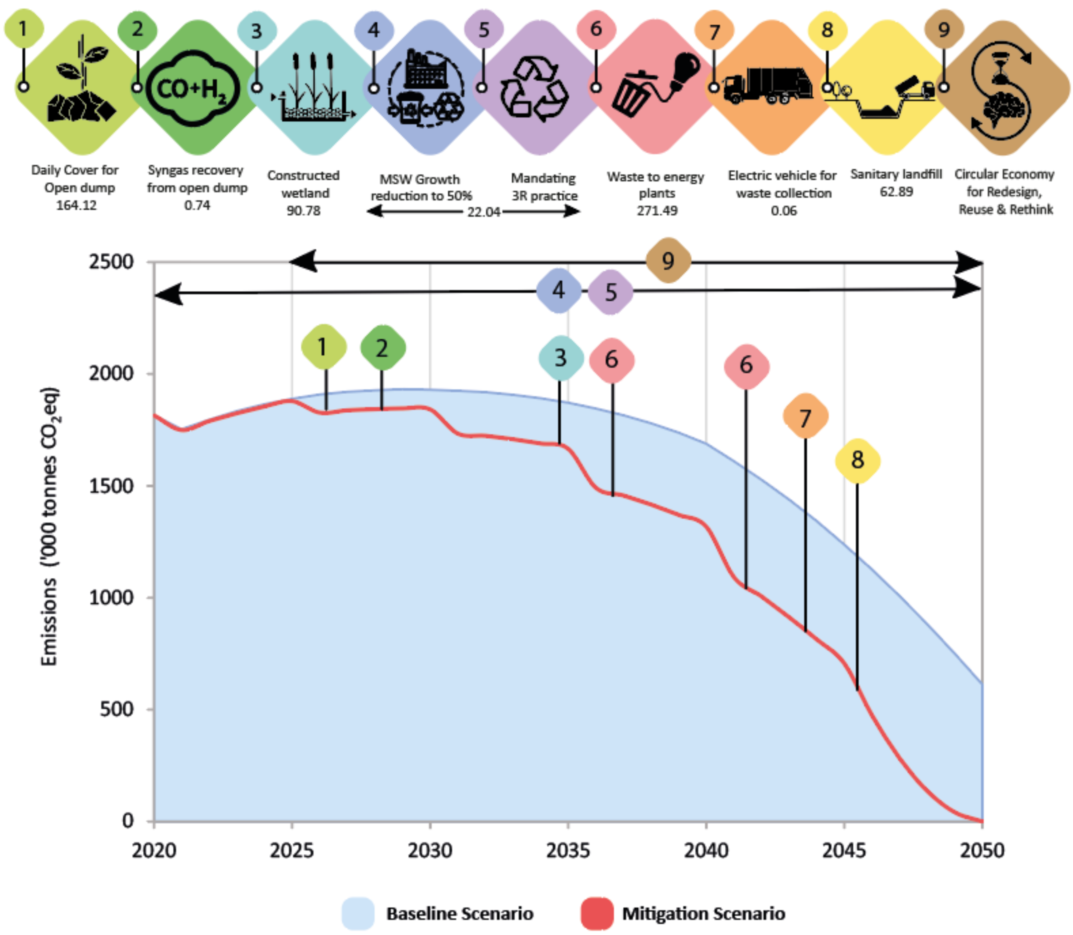

Figure 3.25 : Net zero scenarios with mitigation measures

Prediction Model

This analysis and prediction model is based on demographic and socioeconomic factors such as population and GDP. Waste generation analysis was done using time series data of solid waste generated quantities. The time series analysis model is used to estimate greenhouse gas emissions for the waste sector. Model performance was tested using root mean square error. The results show that forecasting models have a good potential to estimate the national greenhouse gas emission for the waste sector within a reasonable error.

Data gathered from the report of Third National Communication of Climate Change in Sri Lanka (MoE, 2022) were used for the prediction. GHG emissions from 2000 to 2010 of solid waste disposal, composting, incineration and open burning, wastewater treatment, and discharge were used to predict emissions from 2021 to 2050 with the past data and the econometric factors where they show a steady increase in every section indicating mitigation measures are vital to reduce the GHG emissions in every aspect.

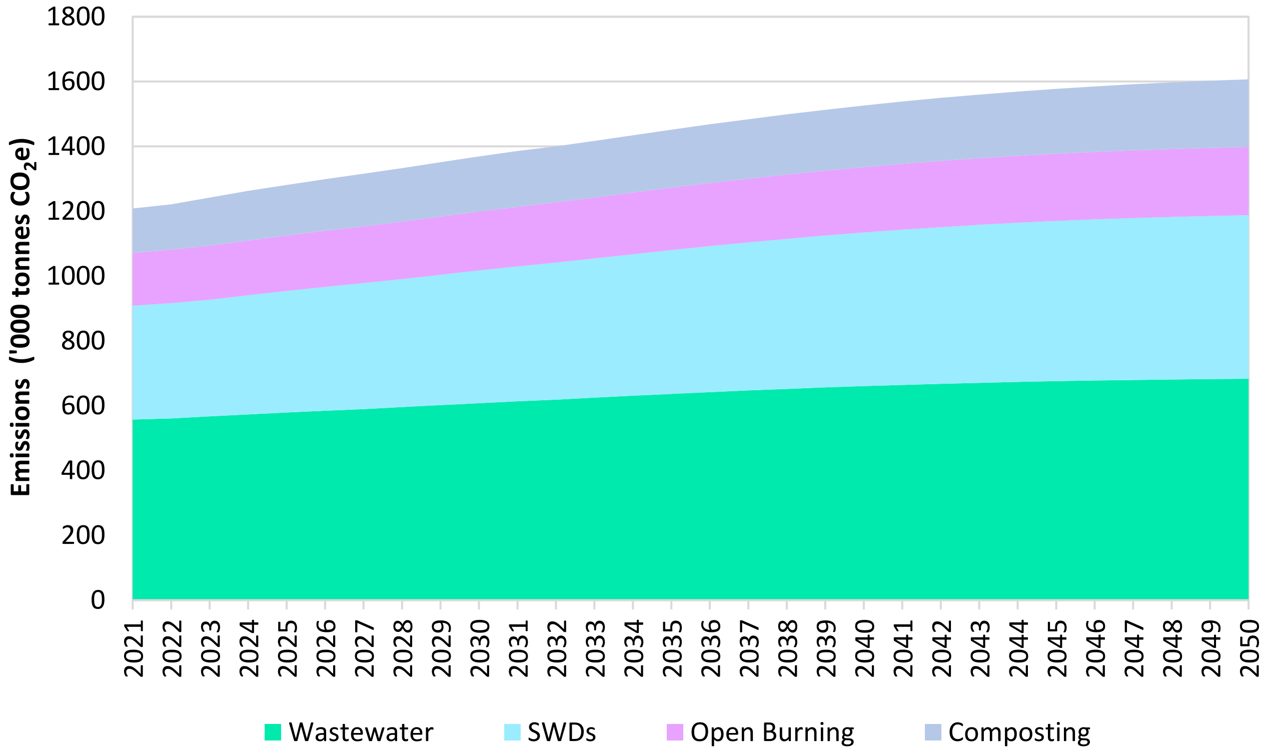

Figure 3.26 : GHG emission prediction from 2021 to 2050

3.3.5 Agriculture Sector

The mitigation actions proposed to reduce GHG emissions from the Agriculture sector r activities include:

a. Reduction of methane and nitrous oxide generation in paddy fields by removal of straw from paddy fields and using them for manufacturing paper and boards used in construction industry, production of biofuels and in the packaging industry
b. Reduction of methane generation from cattle by feed quality improvements, night feeding and supply of water and animal comfort improvement
c. Manure management and soil tillage reduction
d. Reduction of nitrous oxide emissions from agricultural lands by reduction of artificial fertilizer applications.

Mitigation measures were formulated to achieve emission reductions beyond the unconditional target projection up to 2050. Finally, considering the resource availability in relation to the availability of extension services and other human, physical, financial resources, and referring to the World Bank and CIAT report (2015), "Most likely case" was developed for mitigation purposes.

For the livestock sector, only the local and imported neat cattle populations were considered where other local breeds were not accounted, due to the difficulties in applying improved management practices. Calculated values of the mitigated amounts were then fed back into the baseline scenario to obtain the reduced emission values in CO_2 equivalent in '000 MT.

In order to minimize the baseline data variability, over the predictions, only unconditional targets given in NDC Sri Lanka 2030 were extrapolated using a second order polynomial up to the year 2050 Figure 3.15.

Emission reduction from the extended NDC 2030 scenario

It is observed that, when the NDC unconditional targets are extrapolated to 2050 using the model, the actions were capable to reduce GHG emissions by 30 % from the year 2025 (5958 CO_2e in '000 tonnes to 4200 CO_2e in '000 tonnes) to the year 2050.

When the NDC conditional target actions were considered, applicability of these with respect to the field level extension, present economic situation of the country and other facilities, is beyond control and therefore, it was decided to use the Unconditional target, which predicts up to 30 % reduction from the baseline data when developing the NDC 2030 extended scenario up to 2050 for the agriculture sector.

Emission reduction from mitigation scenario

Scenario comparison

As shown in the Figure 3.27, mitigation scenario is capable of reducing GHG emissions by 61% compared to the baseline scenario.

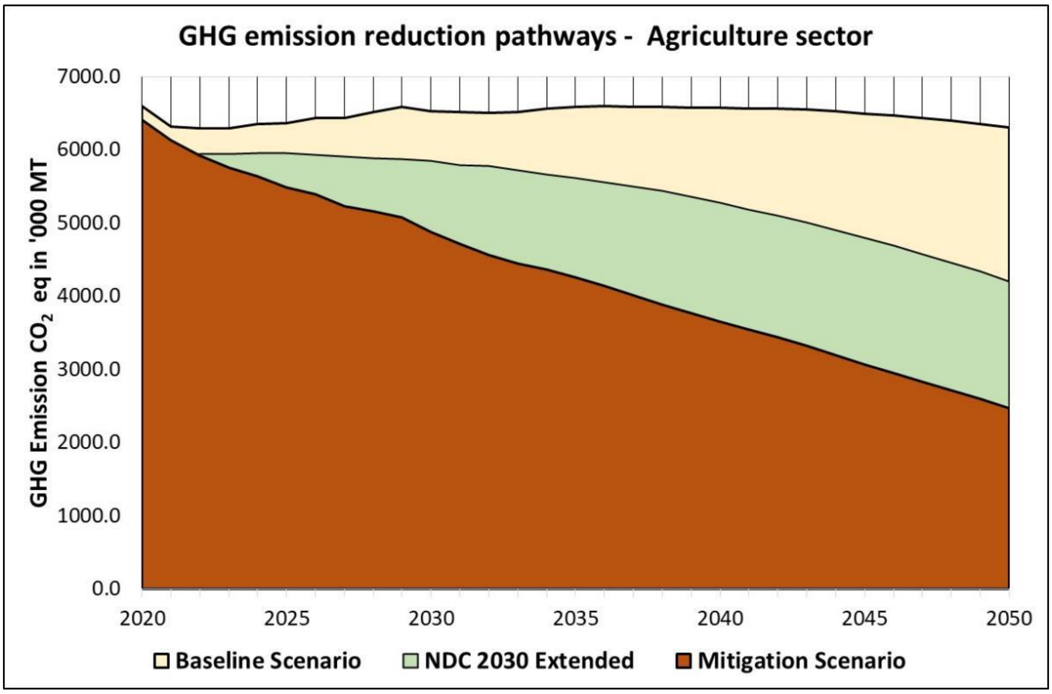

Figure 3.27 : Best case scenario for the agriculture sector

When the following strategies are adopted, GHG emissions could be reduced as illustrated in Figure 3.28

1. Reduce methane emission from paddy fields by removing rice straws and through good management practices
2. Use alternatives to Chemical fertilizer for reducing N_2O emission.
3. Reduce methane emission from livestock by improving feed quality and animal comfort.
4. Reduce N_2O emission in soils due to microbial activities.

GHG emission reduction by strategies

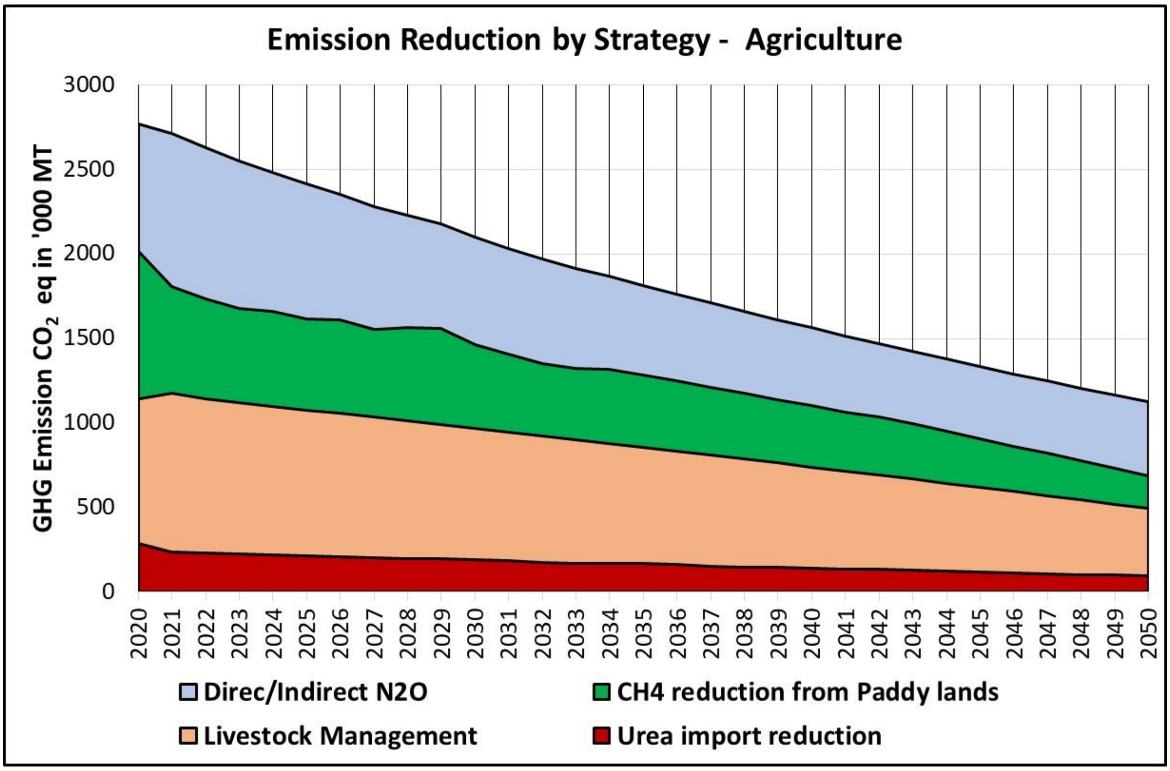

Figure 3.28 : GHG reduction by four strategies

Table 3.4: Emission reduction by different scenarios adopted

Year	Emission reduction in CO_2 eq '000 Mt			Percent emission reduction compared to baseline	
	Baseline scenario	NDC 2030 scenario extended	Improved version	NDC 2030 scenario extended	Improved version
2025 - 2030	35,430	39,361	30,625	9%	20%
2031 - 2035	28,600	33,219	24,405	13%	32%
2036 – 2040	27,140	33,479	23,456	18%	41%
2041 – 2045	25,010	33,248	22,226	23%	49%
2046 - 2050	22,270	32,442	20,667	30%	58%

As shown in the Figure 3.28, model developed for the C Net Zero 2050 was able to reduce 61.1 % GHG emissions from the year 2025 (6374.4 CO_2e in '000 tonnes to 2476.7 CO_2e in '000 tonnes) to the year 2050. compared to the baseline scenario developed for the study and NDC unconditional targets projection, which was able to reduce 29.5 % from the year 2025 (5957.6 CO_2e in '000 tonnes to 4200 CO_2e in '000 tonnes) to the year 2050. This clearly shows the limitations in the agriculture sector to reduce GHG emissions, where basically land and field level extension services are limiting.

GHG emissions from postharvest management practices are also considered in the NDC Sri Lanka 2030 and therefore, C net zero 2050 model was also able to address emissions coming from the postharvest management practices. Further to that, it is proposed to introduce new technologies, like solar and other renewable energy sources to minimize GHG emissions from the agriculture sector.

3.3.6 Forestry Sector

The Mitigation Scenario refers to the scenario with the assumption that all feasible mitigation policies and measures will be implemented, in addition to those that are already in force and/or are legislated or planned to be adopted. In the case of the Forestry sector, this scenario was developed using the following assumptions:

A. Forest cover includes natural forests, forest plantations and rubber plantations according to the definition of forests by FAO.
B. The deforestation rate will be 5000 ha/yr from 2021-2030 as per the Revised Nationally Determined Contributions (NDCs) (Ministry of Environment, 2021) and will be reduced to 1000 ha from 2031-2035; 500 ha from 2036-2040; 100 ha from 2041-2045 and then 0 ha from 2046-2050
C. The new plantings will be 18,050 ha from 2021-2030 according to the Ministry of Environment, (Revised NDC, 2021-2030, Ministry of Environment, 2021) and this will not continue afterwards due to limitations of land.
D. There will be 25,000 ha of reforestation/restoration/afforestation from 2025 and will continue up to 2030. This will also be discontinued afterwards.
E. In home gardens, the annual loss of 0.3% will be stopped while the annual increase of 1% will remain.
F. In the coconut plantations, the annual loss of 616 ha will be stopped, while the annual increase will be 20,000 ha
G. In the tea plantations, annual increase was taken as 1800 ha; 40 trees/ha is the density of shade trees
H. The total urban tree cover of the country of 75,000 ha with the annual increase of 1% will remain and annual loss of 300 ha will be stopped. 100,000 trees will be added to the urban tree repository annually.
I. The loss of mangrove extent is 0.5% /yr will be stopped and there will be 200 ha added annually

Following Reference values were taken in the calculations:

Emission factors

a) 150 tons/ha in deforestation and replanting of new forests
b) 100 tons/ha in establishment of new coconuts and tea plantations; due to the scattered nature of plantings this was not considered in mangroves and urban tree cover

Carbon sequestration factors

a) Carbon sequestration in natural forests @ 4.6 tonnes/ha.
b) Carbon sequestration in new forests: plantations up to 6 years is 3 tons/ha/year while beyond that is a maximum of 9 tonnes/ha/year.
c) Carbon sequestration rate of mature coconut plantations and forest plantations: 9 tonnes/ha/ year; appropriate rates of carbon sequestration (2-9 tons/ha/year) were used according to tree age and the young plants up to 6 years of age is 3 tonnes/ha/year.
d) Carbon sequestration rate of home gardens: 4.8 tonnes/ha/year; Carbon sequestration rate of tea plantations including the shade trees @40 trees/ha: 1.4 tonnes/ha/year; Carbon sequestration rate of mixed trees and other perennials: 4 tonnes/ha/year;
e) Carbon sequestration rate of mangroves – 24.76 tonnes/ha/year.

Table 4 in Annexure 3 shows the projected extents of forests, trees outside forests and mangroves (ha) from 2025-2050 in the Net Zero Scenario, and Table 5 in Annexure 3 shows the corresponding estimated annual Carbon sequestration quantities during the period 2025 to 2050. The Net Carbon Sequestration in Forests, Trees Outside Forests and Mangroves in the Net Zero Scenario (tonnes /year) is given in Figure 3.29

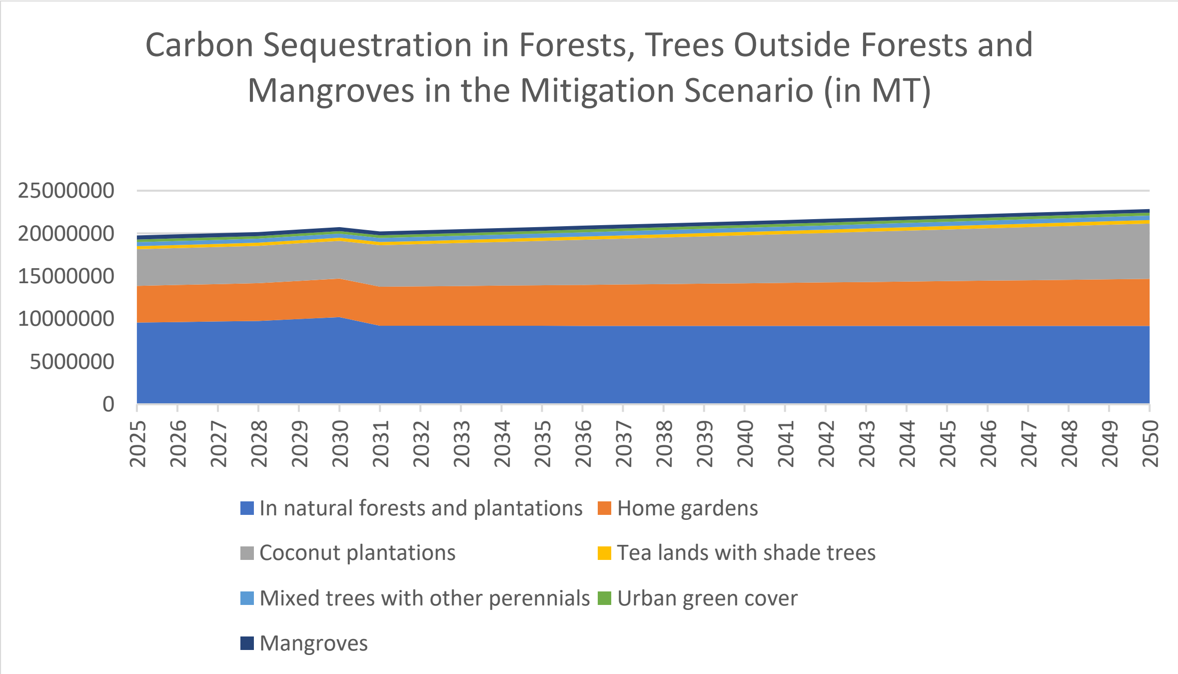

Figure 3.29: Net Carbon Sequestration in Forests, Trees Outside Forests and Mangroves in the Net Zero Scenario (tonnes/ha/yr)

At the same time, the GHG emissions will be caused by the loss of forest cover, Trees outside the Forests and mangroves. Table 6 in Annexure 3 shows the total GHG emissions from the forestry sector including loss of forests and trees outside forests in the Net Zero Scenario from 2025-2050. Please note that it is assumed that there would be no loss in mangroves and urban trees and avenue plants in the Net Zero scenario.

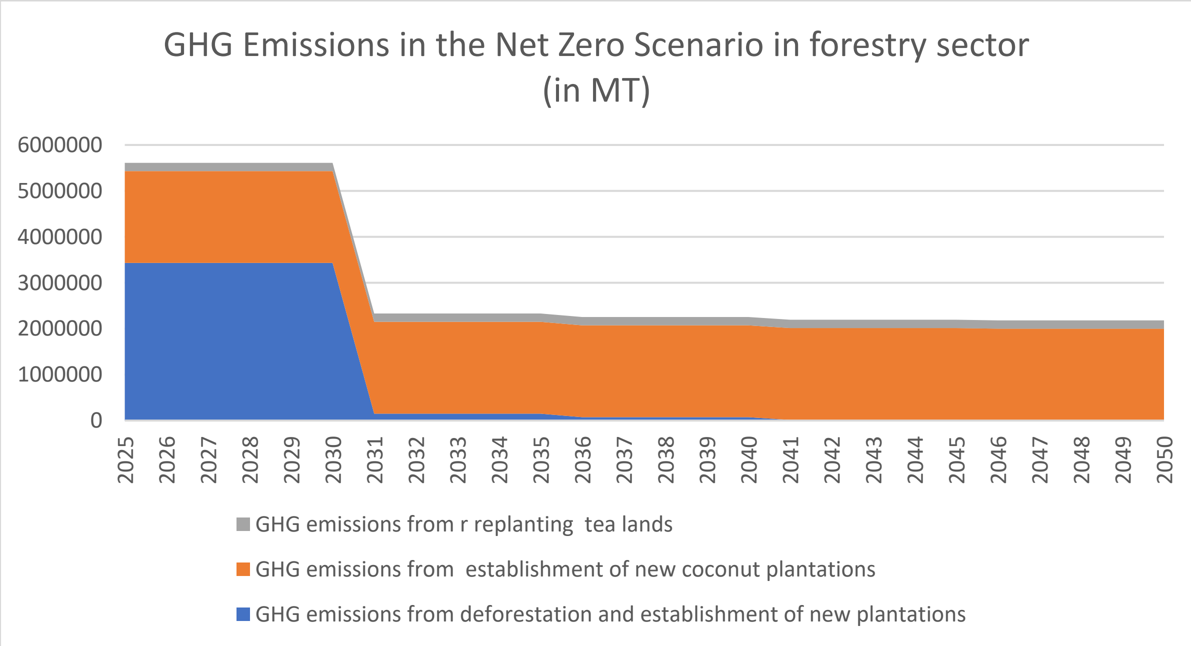

Figure 3.30 : The total GHG emissions from the forestry sector including forests and trees outside forests in the Net Zero Scenario from 2025-2050.(000' Tonnes/yr)

3.3.7 Overall Net Emissions in the Mitigation Scenario

Considering the GHG emissions and sequestration projections as modelled for the period 2025 to 2050 for the six sectors under the selected development, as described in the sections 3.3.1 to 3.3.6 of this report, the Best-Case emission situation that can be expected in the Mitigation Scenario is shown in Figure 3.31, and the emission quantities are given in Table 3.4. The net emission levels (total emissions - total sequestrations) are shown as a white line graph in Figure 3.31, and this shows a decreasing trend throughout the period 2025 to 2050. As seen in Figure 3.31.and Table 3.5, the Mitigation Scenario would result in a net annual emission quantity that would become zero by about year 2037, and will remain negative, the overall situation being carbon positive, or net sequestration, if all the proposed activities are implemented in a timely manner.

The mitigation actions expected to be carried out over the period up to 2050 are described in the section 4.5 of this report. It is however imperative that the policy background is in place, and the institutional capacity, financial provisions, infrastructure, technologies and Research and Development are strengthened as required, in a timely manner, if this prediction is to be made a reality.

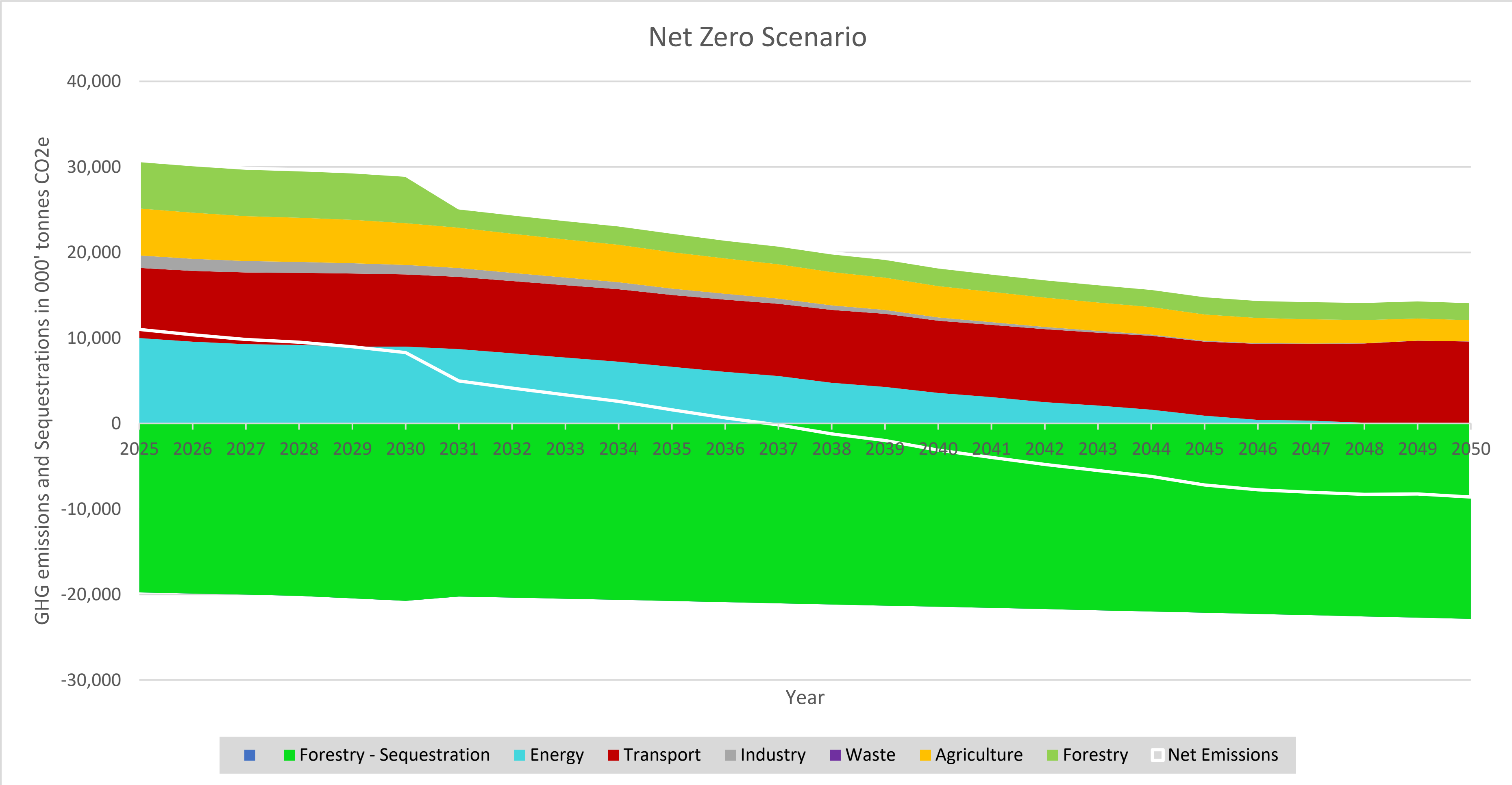

Figure 3.31 : Overall Net Emissions in the Mitigation Scenario

Table 3.5: Total Emissions in million MTCO2eq in Mitigation Scenario

Sector	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050
Energy	9.99	9.56	9.27	9.18	8.98	8.99	8.70	8.21	7.72	7.22	6.63	6.04	5.55	4.76	4.26	3.57	3.08	2.49	2.10	1.60	0.91	0.42	0.33	0.09	0.09	0.00
Transport	8.19	8.28	8.38	8.44	8.55	8.44	8.43	8.44	8.45	8.47	8.39	8.44	8.45	8.53	8.56	8.43	8.45	8.53	8.52	8.65	8.65	8.88	8.98	9.26	9.57	9.58
Industry	1.46	1.41	1.35	1.28	1.19	1.10	1.03	0.96	0.89	0.82	0.75	0.67	0.60	0.52	0.45	0.38	0.32	0.26	0.20	0.15	0.11	0.07	0.04	0.02	0.01	0.01
Waste	1.91	1.88	1.91	1.95	1.98	2.01	1.94	1.96	1.98	2.00	2.02	1.89	1.91	1.92	1.92	1.93	1.80	1.81	1.82	1.82	1.82	1.70	1.63	1.60	1.63	1.72
Agriculture	5.49	5.40	5.24	5.17	5.08	4.88	4.72	4.57	4.45	4.37	4.26	4.14	4.02	3.89	3.78	3.66	3.54	3.44	3.33	3.20	3.07	2.96	2.84	2.72	2.60	2.48
Forestry emission	5.61	5.61	5.61	5.61	5.61	5.61	2.33	2.33	2.33	2.33	2.33	2.26	2.26	2.26	2.26	2.26	2.19	2.19	2.19	2.19	2.19	2.18	2.18	2.18	2.18	2.18
Forestry – Sequestration	19.76	19.86	19.96	20.07	20.33	20.58	20.05	20.15	20.25	20.35	20.44	20.55	20.65	20.75	20.85	20.93	21.03	21.14	21.35	21.45	21.45	21.56	21.66	21.76	21.87	21.97
Net Emissions	10.99	10.40	9.88	9.60	9.09	8.44	5.16	4.36	3.60	2.87	1.92	1.00	0.22	(0.79)	(1.5)	(2.63)	(3.44)	(4.22)	(4.90)	(5.55)	(6.51)	(7.05)	(7.23)	(7.50)	(7.41)	(7.72)

**Note 1 – The emission in 2025 as of the base line scenario is 1.92 million tonnes CO_2eq per year and reduced by 0.01 million tonnes CO_2eq per year due to the mitigatory strategy "MSW Growth reduction to 50% and Mandating 3R practice is currently under practice".*

***Note 2 – The GHG reduction of 0.61 million tonnes CO_2eq by 2050 is from the proposed mitigatory actions, whereas the rest (1.72 million tonnes CO_2eq by 2050) is reduced from the modified actions proposed by the NDC 2030*

SECTION 4 : PROPOSED CARBON NET ZERO FRAMEWORK FOR 2050

4.1 Vision – "A Carbon Neutral, Prosperous Sri Lanka"

4.2 Vision Statement

According to the U.N. Climate Science Panel, man-made carbon dioxide emissions need to reach "net zero" by mid-century to give the world a good chance of limiting warming to 1.5^0C and avoiding the worst impacts of climate change. Transitioning to a carbon net-zero world is one of the greatest challenges the humankind has faced. Sri Lanka, being a developing country, cannot compromise economic and social development to achieve carbon net zero status. This is an effort to ensure a prosperous and secure optimal solution for the country, which is not contributing to the global consequences of climate change caused by anthropogenic GHG emissions.

4.3 Targets for Reduction of Emissions

As discussed in Section 3 of this report, the GHG emissions for each sector under the Baseline Scenario, which is taken as the situation where the current trends would continue up to the year 2025, and the unconditional actions identified in the updated NDC Report (MoE, 2021a) i.e. those that do not need external support, are implemented up to 2030 and beyond, the GHG emissions due to the six identified sectors would result in a net emission quantity of 23.62 Mt/year, as seen in the cumulative graph in Fig 3.21.

The targets for achieving Net Zero were set by the sector experts for each sector, in consultation with the sector stakeholders, considering the technically and administratively feasible actions to mitigate emissions in each sector, provided funds, infrastructure and technological resources were not a constraint for implementation, over the period 2025 to 2050. The emissions and sequestration values for the sectors were calculated using the models described in section 3, and the cumulative emission scenario is shown in Fig 3.30.

The sector-wise target setting is described in this section.

4.3.1 <u>Energy Sector</u>

The vision for the energy sector is to achieve carbon neutrality in the energy sector itself by complete transition of all the energy value chains to net zero by 2050. Therefore, the Target set for the Energy Sector is to reduce the predicted quantity of GHG Emission of 13.246 million tonnes/year of CO_2e to zero by the year 2050. To achieve this overall target, each energy source will be set the targets as given in Table 4.1.

Table 4.1: Targets for emission reduction in the energy sector to achieve Carbon Net Zero by 2050

	Target for Emission Reduction by 2050 (million tonnes CO_2e per year)	Percentage Emission Reduction
Electricity	10.413	100%
Domestic and Commercial Energy	5.494	100%
Total Energy Sector (Excluding fuel used in Transport and Industry IPPU)	15.907	100%

4.3.2 <u>Transport Sector</u>

Transport sector mitigation strategies aims to reduce the emission level by 50% by the year 2050. This is the prudent estimate considering the projects that can be implemented during the time period.

The prediction of emissions for the Baseline Scenario is 19 million tonnes/year in 2050. Thus, the target for emission reduction in the transport sector is 8.4 million tonnes/year in 2050 as described in the section 4.5.2

4.3.3 <u>Industry Sector</u>

Industry sector emissions are in two sources; the industry energy use (both electrical energy and thermal energy) emissions and IPPUs.

Achieving zero emission national electricity grid with renewable energy sources (Wind, Solar, Sustainable biomass) and climate friendly sources (such as nuclear energy) will automatically make the industry sector energy use related emissions zero. Strategies to make the national electricity generation is already addressed under energy sector.

Considering the highest energy value of hydrogen (150 MJ/ kg) and other multiple opportunities offered with green Hydrogen, it is highly recommended to maximize the renewable energy capacity in national grid. With the saturated grid renewable energy more green Hydrogen generation opportunities will be opened. Accordingly, the green hydrogen will provide following zero carbon opportunities;

- Buffering the grid qualities at renewable energy intermittencies,
- Use of green hydrogen as an energy storage to produce electrical energy during power deficiencies in nation grid with fuel cell technologies, and gas turbine-based power gyration,
- Use of green hydrogen as a source of thermal energy in industry thermal energy applications,

- Use of green hydrogen as a fuel in transport industry,
- Use of green hydrogen to produce green ammonia and use as a marine fuel and develop national green nitrogen fertilizer industry.

In addition to above industry energy use emissions national IPPU emissions are relative low in quantity.

Strategies recommended to the zeroing of emissions in IPPUs are discussed in previous chapters.

IPPU sub sector emission zeroing scenario are depicted as below;

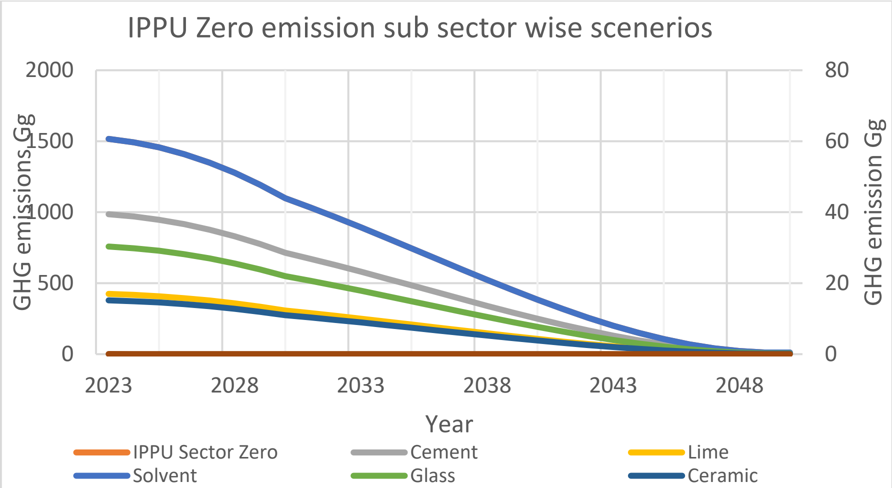

Figure 4.1 : IPPU Zero Emission Sub Sector wise Scenarios

This will be a reduction of 2,568,000 tonnes in 2050, and the estimated reduction is 99.5%

4.3.4 Waste Sector

The waste sector envisages the reduction of GHG Emissions through Syngas recovery from open dumps, MSW Growth reduction to 50% and Mandating 3R practice, Converting the collection and transporting vehicle fleet to electrical vehicles, Waste to energy plants and introduction of Sanitary landfills to replace waste dumps. Table 4.2 shows the targets for reduction in GHG Emissions from these actions.

Table 4.2: Targets for reduction in GHG Emissions in Waste Sector

Strategy	Baseline CO_2e Emissions 2050 (thousand tonnes CO_2eq per year)	Target for Emission Reduction by 2050 (thousand tonnes CO_2eq per year)	Percentage Emission Reduction
Daily Cover for Open dumps	164.11	164.11	100%
Syngas recovery from open dumps	1.48	0.74	50%

Strategy	Baseline CO_2e Emissions 2050 (thousand tonnes CO_2eq per year)	Target for Emission Reduction by 2050 (thousand tonnes CO_2eq per year)	Percentage Emission Reduction
Vertical Subsurface flow constructed wetlands (VSSFCW)	90.78	90.78	100%
MSW Growth reduction to 50%,	22.04	22.04	100%
Mandating 3R practice			
Circular Economy for Redesign, Reuse & Rethink			
Electric vehicles for waste collection	0.06	0.06	100%
Waste to energy plants	271.49	271.49	100%
Sanitary landfill	62.89	62.89	100%
Total in Waste Sector	2,332.66	612.11	26.24%

4.3.5 Agriculture Sector

In order to reduce the greenhouse effect from the agriculture sector, appropriate management practices must be introduced to minimize CO_2, CH_4 and NO_2 emissions. Further to that Land Surface Albino in agricultural lands should be minimized to lower the surface reflectivity and suitable alternative measures must be introduced to minimize CO_2 emissions from agricultural fieldsThe main emphasis in agricultural sector should be given to GHG emission reduction from Paddy fields, livestock and cultivated area of organic soils in the order of importance.

Considering the feasible actions for reduction of GHG emissions, the targets for reduction of emissions from the agriculture sector have been set as given in Table 4.3.

Table 4.3: Targets for reduction of emissions from the agriculture

Strategy	Baseline CO_2e Emissions 2050 (Thousand tonnes CO_2e per year)	Target for Emission Reduction by 2050 (thousand tonnes CO_2e per year)	Percentage Emission Reduction
Paddy fields (due to methane emissions)	1830	1145	62 %
Reduce N2O by reducing urea imports	244	150	61 %

Strategy	Baseline CO_2e Emissions 2050 (Thousand tonnes CO_2e per year)	Target for Emission Reduction by 2050 (thousand tonnes CO_2e per year)	Percentage Emission Reduction
Direct/Indirect N2O reduction	2788	1664	60 %
Methane – Livestock management (neat cattle local, imported, Goats and Sheep)	1251	758	61 %
Total	6113	3717	61 %

4.3.6 Forestry Sector

According to the NDC in forestry, it was stated that the rate of deforestation will be 5000 ha/yr. In the present project to Develop the 2050 Carbon Net Zero Road Map and Strategic Plan for Sri Lanka, it is expected that the rate of deforestation will be further reduced from 5000 to 0 from 2031 to 2050. Accordingly, from the Net Zero Road Map actions and Strategies the target is to reduce 750,000 tonnes per year CO_2 during the period 2025-2050 from deforestation in the baseline scenario.

4.4 Targets for Increased sequestration

4.4.1 Agriculture Sector

The concept of evergreen Agro ecosystems is of multipurpose. Initially based on research conducted in DOA, a green hedge was introduced as a part of agro-forestry system to control soil erosion, enhance soil fertility and to create a micro-climate favorable for crop growth[1] (Dharmasena 1994) This is an alternative to chemical fertilizer as N, P and K are added into the soil by pruning proposed green hedges. Carbon sequestration can be enhanced through this concept especially for croplands with extended fallow periods.

An example for Evergreen Agro-ecosystem Concept is shown in the Fig. 4.2

[1] Dharmasena,P.B., 1994. Conservation farming practices for small reservoir watersheds: a case study from Sri Lanka. Agro-forestry Systems, Kluwer Academic Publishers, Netherlands. 28:203-212

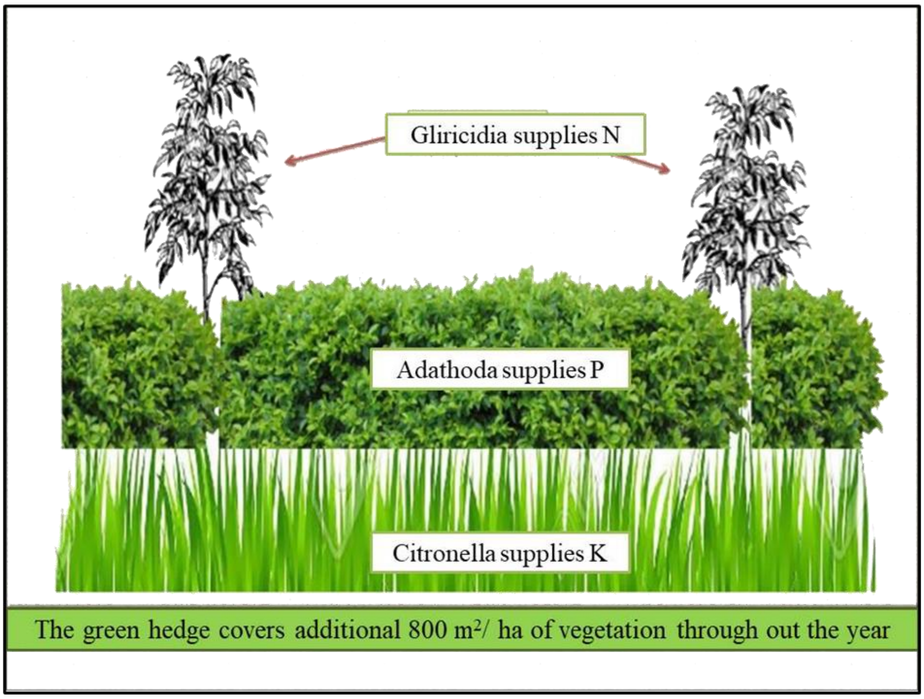

Figure 4.2: Evergreen hedge suitable for paddy fields and rainfed uplands

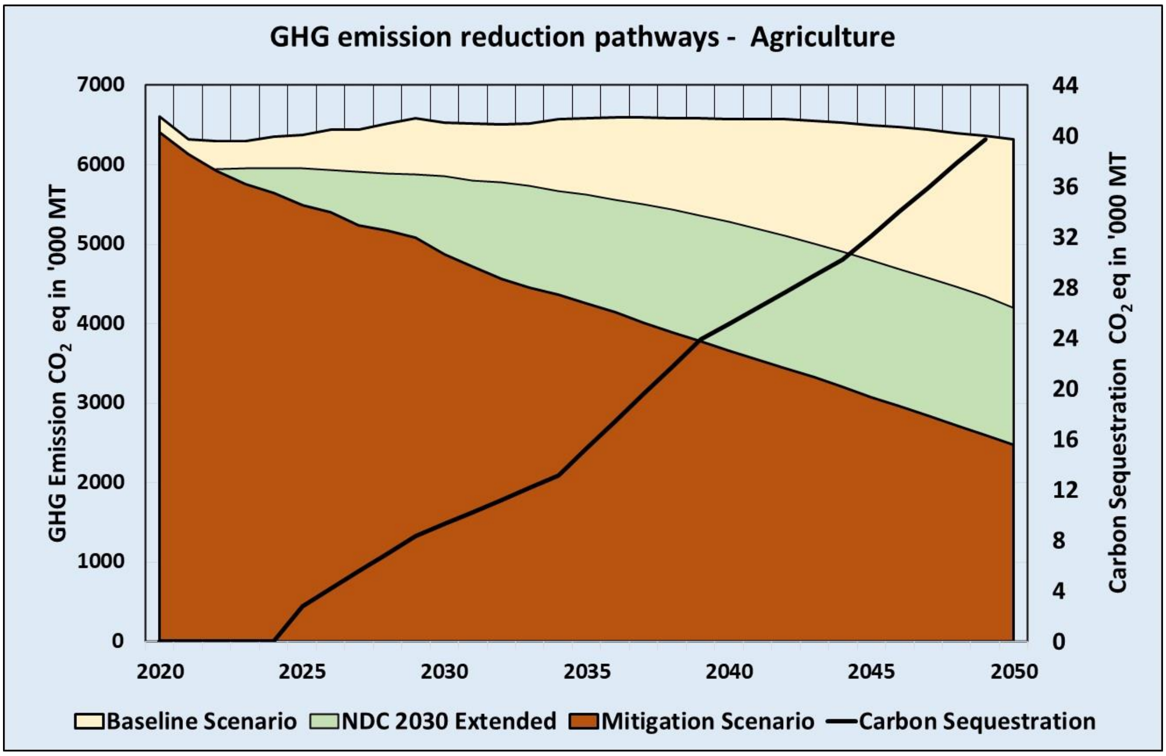

Figure 4.3: GHG emission reduction pathways and Carbon Sequestration in thousand metric tons.

It was observed that introducing evergreen concept in paddy lands and upland rainfed crops covers a very small area and therefore, secondary axis was used to plot the values in the pathways described in the Figure 4.3

4.4.2 Forestry Sector

According to the updated NDC (2021-2030), 18,000 ha of new forests will be established by 2030 to achieve 30.8% of forest cover by 2030. In addition to this, the existing natural forests and forest plantations will be better protected. In the Net Zero Road Map and Strategic Plan, the Forest Department is hoping to reforest/afforest 200,000 ha of land by 2050. This land is included in the land under the category 'Other State Forests' which was vested under the management of Forest Department in the 5/2001 Circular but was cancelled subsequently and these were vested under the custody of Divisional Administrations. However, out of the 500,000 ha, 200,000 ha had been released to the Forest Department for restoration/ reforestation/ afforestation. It is also hoped to increase the contribution of trees outside forests to the GHG mitigation scenario. These include homegardens, coconut plantations, shade trees in the tea plantations, urban trees and avenue trees, trees in settlements and mixed plantations. The rubber plantations had been included in the category of forests according to the classification of FAO. Blue carbon ecosystems such as mangroves, seagrass beds and salt marshes had also been considered as important carbon sinks as they are reported to sequester carbon at rates 4-5 times higher than terrestrial ecosystems. Tables 5 and 6 in Annexure 3 show the net carbon sequestration of forests, trees outside forests and mangroves in Baseline Scenario and Net Zero Scenarios respectively.

Table 4.4: Targets for Land Cover Increasement in Forestry Sector in 2050

Description	Estimated Baseline Area in 2050 (ha per year)	Target for Increased Area by 2050 (ha per year)	Percentage Area Increase against Baseline in 2050
Total forest cover including existing and new plantings	1,921,292	85,357	4.4%
Total trees outside forest including home gardens, coconut planation, and urban green cover with areas of avenue plants	2,451,006	135,811	5.5%
Blue Carbon Ecosystems	13,899	6,568	47.3%

There is no increase in land cover for shade trees of tea plantation and mixed trees with other perennials.

Table 4.5: Targets for Increased Sequestration in Forestry Sector in 2050

Description	Estimated Baseline Sequestrations in 2050 (tonnes CO2e per year)	Target for Increased Sequestrations by 2050 (tonnes CO_2e per year)	Percentage Sequestration Increasement against Baseline in 2050
Total forest cover including existing and new plantings	8,088,665	1,145,605	14.2%
Total trees outside forest including home gardens, coconut planation, tea plantations and urban green cover with areas of avenue plants	9,683,942	1,624,408	16.8%
Blue Carbon Ecosystems	323,292	183,470	50.75%
Total Sequestration	18,095,899	2,953,483	16.3%

There is no increase in sequestations for mixed trees with other perennials while reduction of sequestrations in shade trees of tea plantation.

4.4.3 <u>Waste Sector</u>

Use of Biochar as the Daily Cover for Open dumps

Soil cover is a conventional barrier to mitigate landfill gas emissions from municipal solid waste (MSW) landfills. Methane is a major component of landfill gas, and it is also a more harmful greenhouse gas than carbon dioxide. A daily cover combined with biochar produced from the MSW in the dumpsite can be used to trap GHG emissions by a considerable amount. According to a study carried out by Abraham and Xiao in 2019, 10% of GHG can be absorbed by the daily cover laid on the waste at the dumpsite. Further, the soil mixed with biochar and the MSW will lay a natural platform to improve the composting process within the dump. The daily cover absorption showed an absorption of 164,115.9493 CO_2e tonnes by 2050. This measure can be implemented as early as 2026.

Vertical Subsurface flow constructed wetland (VSSFCW)

According to a study conducted in China in 2011 by Pan et.al, 50% of GHG can be reduced using the VSSFCW rather than the conventional methods. The VSSFCW with an area of 1000m^2 is capable of reducing the GHG emission by 50% compared to the conventional wastewater treatment. The action plan is to implement a centralized system in the western area by 2031, which leads to a GHG reduction of 90,781.26637 CO_2eq tonnes by 2050.

Table 4.6: Sequestration by Waste

	Target for Emission Reduction (Sequestration) by 2050 (tonnes CO_2e per year)
Use of Biochar as the Daily Cover for Open dumps	164,115.95
Vertical Subsurface flow constructed wetland (VSSFCW)	90,781.26

4.5 Feasible Strategies and Mitigation Actions for Achieving Targets

The government should ensure alignment between policies and actions, including public policy and advocacy. The national leadership should ensure this commitment is not undermined by conflicting targets. The national leadership should demonstrate commitment to net zero and the principles provided by:

- Providing strategic direction, oversight, support and sufficient resources to set and achieve targets,
- Incorporating net zero targets into core governance documented information (e.g. national policies, action plans, regulations etc.,),
- Disclosing stakeholder need information and records on climate-related issues, if appropriate to the country and net zero emission targets,
- Publicly committing to achieve targets as soon as possible through communication by the highest level of national leadership,
- Clearly defining national leadership and sub level responsibilities,
- Appointing competent members of the national leadership to take responsibility for net zero actions,
- Ensuring competent persons are appointed to relevant roles and determining the frequency of updates to national leadership on climate-related issues and progress towards targets,

- Designing and implementing incentives for delivering net zero targets with national sustainability benefits,
- Ensuring consideration of actions needed to transition to net zero is prioritized at national level,
- Publicly and regularly communicating transition plans, progress and further action needed.

Once the above principles of good governance are in place, the sector wise strategies and mitigation actions will be effectively implementable.

4.5.1 Energy Sector

Aligned with the national energy policy, it is required to have multiprong approaches in the energy sector to achieve carbon net zero by 2050. The broad strategies are detailed below.

4.5.1.1 Gradual decommissioning of the existing thermal power plants which depends on imported fossil fuel and enhance self-reliance.

It relates to the necessity of a rapid decline in the share of fossil energy in Sri Lanka's primary energy mix. For that decommissioning of existing thermal electricity generation infrastructures, particularly coal power plants and other petroleum-based power plants. It is necessary to continue the government policy on not to construct any new coal power plant in the future. Furthermore, a rapid increase in the share of renewable energy in the electricity generation mix would be a key component in meeting the increasing electricity demand. As per the government policy, it is expected to achieve 70% of electric energy from renewables by 2030. Increasing RE capacity also identified as one of the NDCs in power sector. This includes predominantly solar and wind. Other renewable energy resources have to be exploited based on a priority order arrived at, considering economics, technology and quality of each resource. By considering the energy security, network stability and reliability, it is suggested to integrate variable renewable energy (VRE) with energy storages such as battery storages and pump hydro plants. Therefore, 70% RE share has been assumed to be maintained in the power sector with other carbon net zero power generation options.

4.5.1.2 Development of Nuclear energy resources to the optimum level with sufficient environmental safeguards, by encouraging market demand for such resources

In the absence of fossil, there will not be any other base load zero-carbon technology apart from nuclear energy. Nuclear energy has been very important from the perspective of the country's energy security and has always been an important pillar of future Sri Lanka's energy policy. However, progress on this technology in terms of its penetration into the grid has always lagged. Under net zero carbon scenarios, nuclear-based electricity generation would receive a significant push. The LTGEP proposes nuclear power generation as a scenario. In there, the first nuclear power plant has been proposed in 2041. However, in order to reduce the contribution of fossil fuels and decarbonize the power sector, rapid development of nuclear energy is recognised as critical. As per the draft "Roadmap to establishing a Safe, Secure, Affordable and Reliable Nuclear Power Programme in Sri Lanka" the following nuclear power generation programme is identified in Sri Lanka.

a) Approximately 300 MWe x 02 Units as per the present national grid
b) 1000 -1200 MWe x 02 units (with HVDC interconnection)

However, under the expedited nuclear power generation scenario, it is expected that the share of nuclear energy in Sri Lanka's electricity generation would increase to 7% by 2035 and increase it to about 20% in 2044.

4.5.1.3 Promote Regional Power Grid Connectivity and Cross-Border Electricity Trade

India and Sri Lanka signed a Memorandum of Understanding (MOU) in 2010 to conduct a feasibility study for the interconnection of the electricity grids of the two countries. This feasibility study was carried out jointly by CEB and Power Grid Corporation of India Limited (POWERGRID). This study proposed an interconnection through 2x500 MW Madurai-New to New Habarana along with 500 MW terminals at both ends as the preferred option in stage I. Therefore, LTGEP proposes the first 500 MW HVDC interconnection in 2034 as a scenario. This can be expanded by adding additional 500 MW HVDC connecting in 2037 totaling 1000 MW regional grid connectivity. This will also facilitate the rapid development of renewable energy and nuclear energy and achieve net zero carbon emission by 2050. This will open the cross-border electricity trading as well.

4.5.1.4 Improving Energy Efficiency and Conversion

Energy efficiency is the practice of using less energy to accomplish the same task or simply eliminating energy waste (Diawuo et al., 2020, Efficiency., 2021, Patterson, 1996). Energy efficiency has a variety of associated benefits including greenhouse gas emission reduction, demand for energy imports reduction, and household and economy-wide level cost lowering. Comparatively, the use of energy efficiency is found to be the cheapest approach to achieving these objectives amongst the available options presently. As per the countries' declared NDCs, energy efficiency, conservation and Demand Side Management (DSM) is also considered one of the potential areas of reducing electricity demand and thus reducing the emissions in the power sector. Programs such as phasing out of the incandescent bulb and introducing energy efficient equipment expect to save 2,603 GWh and 5,189 GWh energy respectively and thus 1,848 Gg and 3,684 Gg CO_2 emission reduction respectively by 2030 (SLSEA). Minimum energy performance standards for LEDs and energy labelling for air conditioners, personal computers, refrigerators, ceiling fans, linear fluorescent lamps/ballasts and induction motors has to be enforced by 2025.

A program should be set up to increase the penetration of efficient, low smoke, low soot biomass cook stoves for households and promote the use of processed, commercialized biomass based fuels in such stoves by making available them widely across the retail market.

These have been considered as a complementary strategy to reduce GHG emission in the energy sector.

4.5.1.5 Energy Transition by Enabling the Continued use of Flexible and Secure Thermal Energy while Reducing Negative Impact to the Environment

The technologies like hydrogen could play a central role in helping to reach net-zero emissions by 2050 by replacing fossil fuel base thermal energy generation by hydrogen based flexible thermal energy. As a complement to other technologies, including renewable powered hydrogen (green hydrogen) has the potential to decarbonize industries, heavy-duty mobility (on and off-road), maritime shipping, and aviation, as well as to support flexible power generation (among other applications). However, before proceeding, it is crucial to acknowledge that no proper assessment of the hydrogen industry in the country has been conducted yet. Therefore, a detailed feasibility study must be undertaken immediately to lay the groundwork for its successful implementation. These have been considered as complementary strategies to reduce GHG emission in the energy sector. Possibility of adopting green hydrogen in Sri Lanka have to be exploited considering economics, technology maturity and adoptability.

Based on above strategies, following mitigation actions are proposed, along the timeline from 2025 to 2050, as shown in Tables 4.9, 4.10 and 4.11, to reduce GHG emissions in the energy sector.

Table 4.7: Proposed renewable energy capacity additions

Year	Renewable Energy additions (MW)							
					Pathway 1: With Nuclear		Pathway 2: Without Nuclear	
	Major Hydro	Pumped Storage	Mini Hydro	Biomass	Wind	Solar	Wind	Solar
2025			25	20	200	505	200	500
2026			25	20	290	500	290	500
2027			25	20	250	500	250	500
2028			25	20	200	520	200	520
2029		350	25	20	250	540	250	540
2030		350	10	20	200	450	200	450
2031		350	10	20	200	450	200	450
2032		250	10	20	150	450	250	550

2033			10	20	150	500	250	650
2034			10	20	150	510	250	850
2035			10	10	150	510	250	850
2036			10	10	150	520	750	850
2037			10	10	150	520	250	850
2038			10	10	150	530	250	1000
2039			10	10	150	530	650	1000
2040				10	150	550	150	1000
2041				20	150	550	150	1000
2042				20	200	570	1200	1000
2043				20	200	570	200	850
2044				30	200	570	200	850
2045				30	200	570	1200	850
2046				30	200	590	200	650
2047				30	200	590	1000	650
2048				30	200	620	200	650
2049				30	300	650	1000	650
2050				30	400	700	400	700

Expected thermal power plant additions (as per LTGEP 2023-2042) and proposed decommissions of thermal power plants to support the GHG emission reduction in the power sector is shown in Table 4.10.

Table 4.8: Proposed additions and decommissions of thermal power plants

	Additions (MW)			Decommissions (MW)		
	Natural Gas	Diesel	Coal	Natural Gas	Diesel	Coal
2025	115				62.4	
2026	200				375	
2027	100					
2033	150			398	191.7	
2035					300	
2041						300
2044						600
2049				795		
2050				100		

The proposed Nuclear and HVDC Connection additions are shown in Table 4.11.

Table 4.9: Proposed Nuclear and HVDC Connection additions

Year	Pathway 1: Nuclear Additions (MW)	HVDC interconnection (MW)
2034		500
2035	600	
2040	1000	
2047		500

With the above actions, the energy mix in the electricity sector is shown in Figure 4.4 and 4.5 for Option 1 (with Nuclear PP) and Option 2 (without Nuclear PP) respectively.

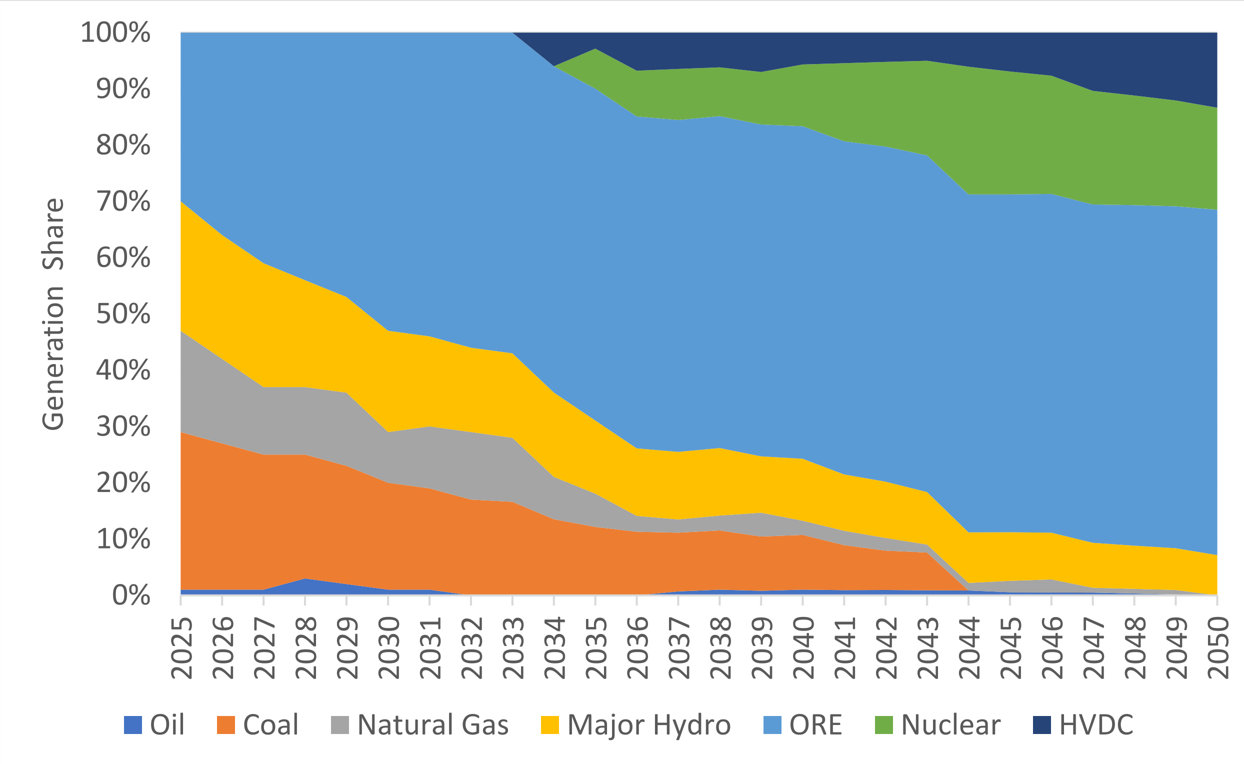

Figure 4.4 : Proposed Generation Share with Pathway 1(With Nuclear PP) to Reduce GHG Emissions in Power Sector

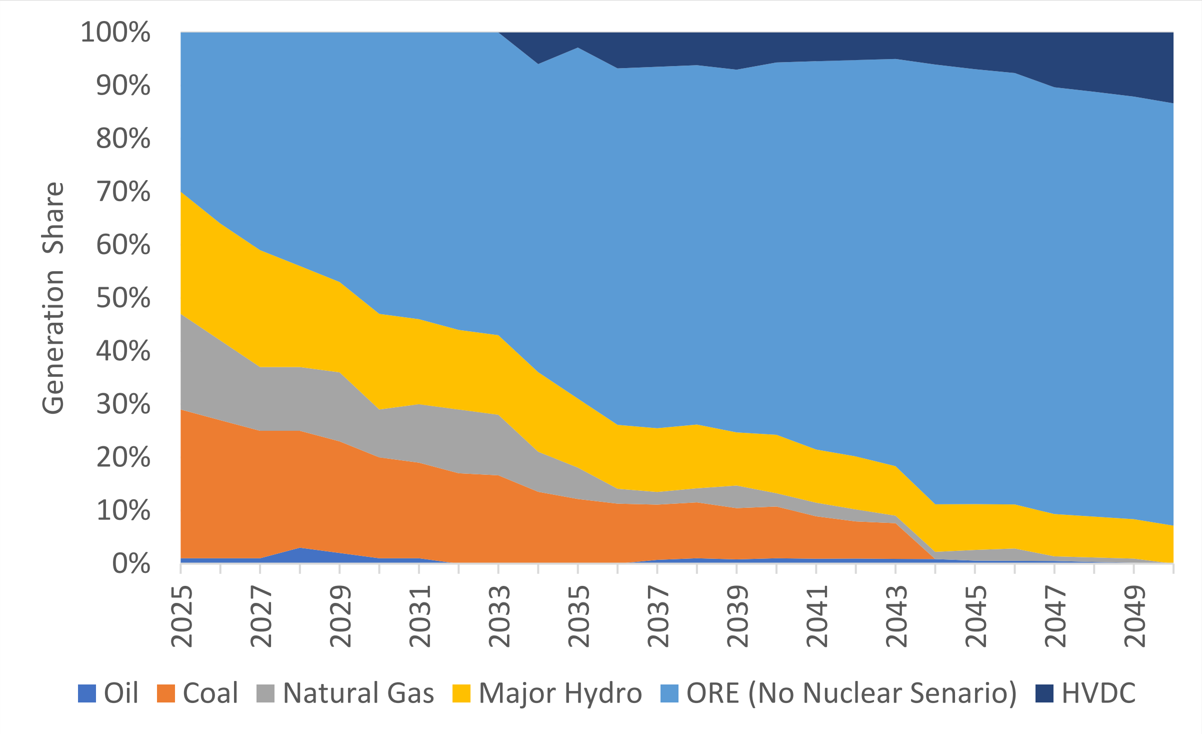

Figure 4.4: Proposed Generation Share with Pathway 2 (Without Nuclear PP) to Reduce GHG Emissions in Power Sector

By considering the trend of the past average capacity factors of the renewable energy, assuming an average capacity factor for renewable power plants between 13-18% during 2025-2050, the expected GHG emissions are estimated and shown in Figure 4.5.

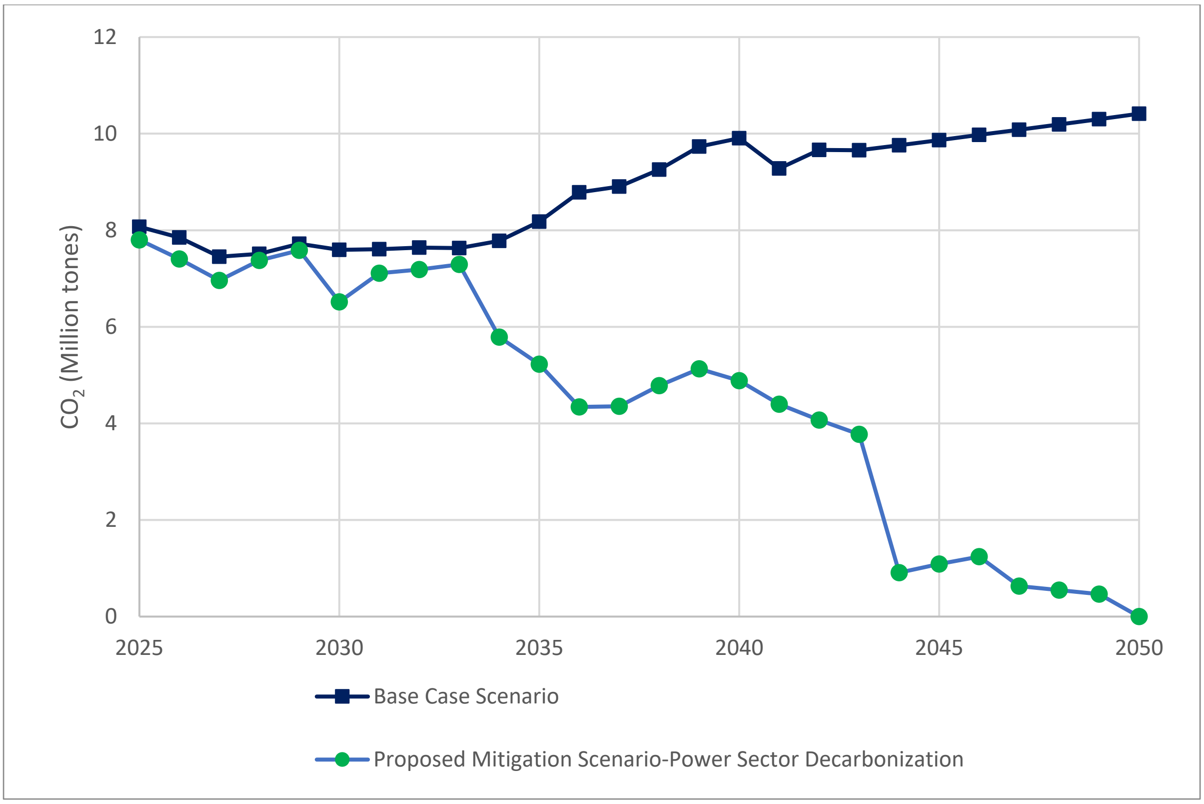

Figure 4.5 : Net Zero Scenario in the Power Sector

It is expected that there will be around 2,833 tonnes of CO_2 emissions in the energy sector by 2050, which can be brought to net zero by implementing the following further actions.

- Dedicated energy plantations for Biomass and counter balancing plantations in existing hydropower catchments and land earmarked for future energy infrastructure,
- Encourage the use of commercial biomass and biomass-based fuel products for industrial thermal applications and households use and eliminate petroleum usage in industrial thermal applications and households.
- Green hydrogen generation to support the decarbonization by flexible power generation,
- By implementing Carbon capture and storage to reduce the rate of increase of CO_2 concentrations due to the combustion of fossil fuels for energy in the domestic, commercial, and other sectors.

If above actions are implemented successfully, it is expected to achieve net zero in energy sector itself.

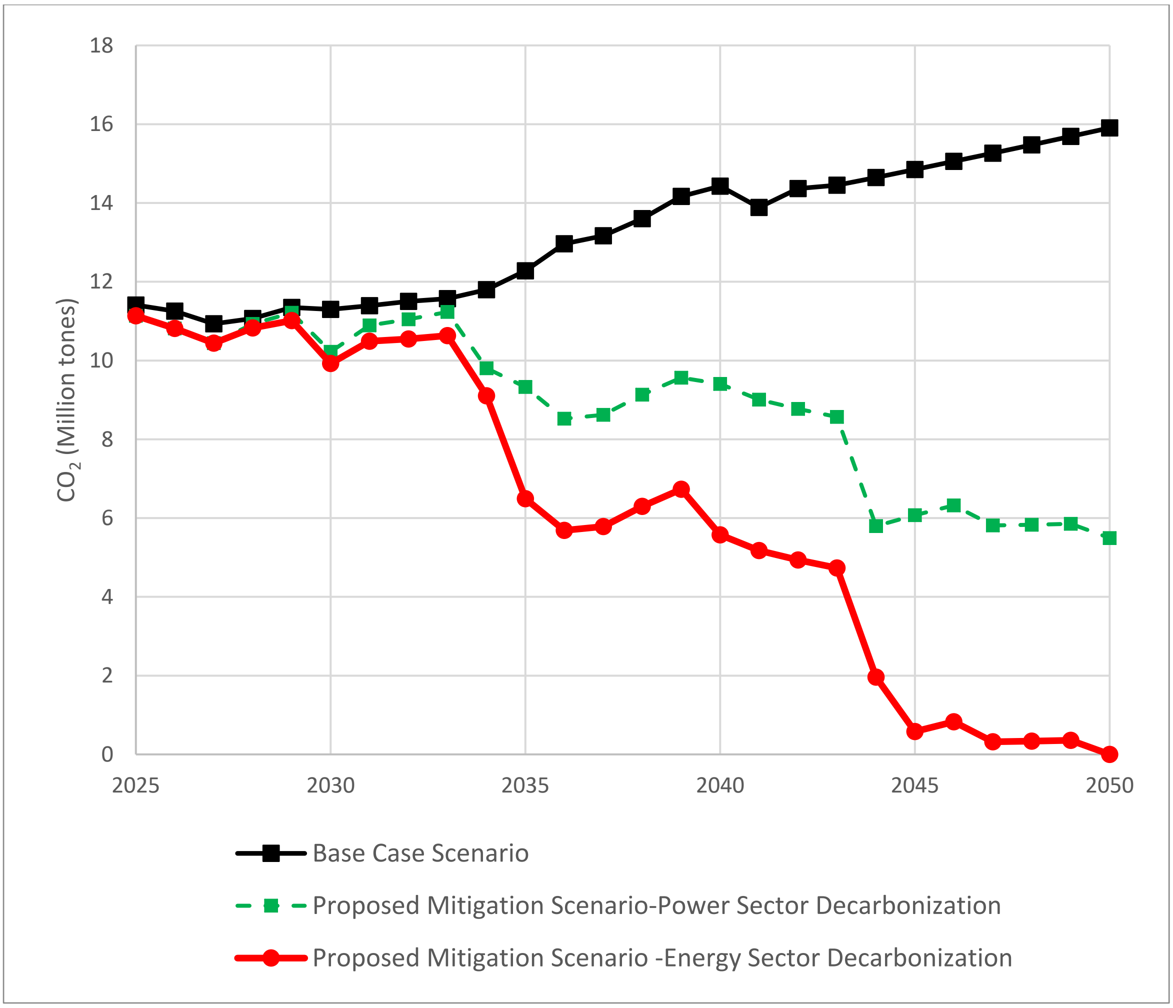

Figure 4.6 : Net Zero Scenario in the Energy Sector

4.5.2 Transport Sector

1. **Improve the pedestrian infrastructure on collector type roads in the country.**

Most of the roads especially B class and Provincial roads lack adequate pedestrian infrastructure to provide safe movement for pedestrians. As a result, most trips that are 'walkable' are diverted to motorized modes. It is evident from the trip characteristics of the Western Province where over 1.2 million trips per day are less than 2 km (JICA, 2014). According to RDA (2020) and Central Bank (2020), Sri Lanka has over 100,000 km of road network and more than 8000 km of B Class Roads and more than 20,000 km of C & D Class Roads.

It can be assumed that nearly 10,000 km of roads require improvements in pedestrian facilities. Moreover, this may include pedestrianization of certain areas such as markets, shopping areas, school zones prioritizing accessibility to pedestrian and discouraging motorized vehicles.

Around 50% of the motorized trips that are less than 2-3 km are expected to be diverted to walking trips as a result. This would result in reduction of CO_2 by 0.11-0.13 million tonnes per year during the analysis period.

Total number of motorized trips 2-3 km in Sri Lanka	5,000,000	
% Reduction in < 2km motorized trips to NMT modes	0.5	
Average distance of trip	2.0 km	
Passenger km per year	5,000,000	pass-km

per day

The amount of CO_2 emissions reduced due to this action is shown in Table 4.12.

Table 4.10: Amount of CO_2 emissions reduced by improving the pedestrian infrastructure on collector type roads

	Passenger km	Veh-km	kg per day
Motorcycle	1,250,000	1,250,000	75,000
Private vehicle	625,000	312,500	71,875
Three-wheeler	3,125,000	1,562,500	156,250
	5,000,000	3,125,000	303,125

At an overall average cost of Rs. 7-8 million per km including street furniture, crosswalks, street lighting where necessary, would cost around Rs. 70-80 billion.

The work can be commenced from around 2025 and completed during a 5 year period ending in 2030.

2. **Promoting cycling**

Promote cycling trips by providing network of cycle lanes in cities linking the major trip attractions and improving road infrastructure and traffic calming measures on local and collector type roads to allow cyclist to share the road with other motorized vehicle users in a safe manner

It is assumed a similar number of motorized trips will divert to cycling and the average trip distance would be around 5-6 km effectively doubling the CO_2 savings calculated for pedestrian infrastructure improvement.

Therefore, the CO_2 savings per annum from cycling infrastructure improvement is approx. 0.25-0.3 million kg per year during the analysis period.

Cost of cycling infrastructure improvement would vary depending in land acquisition requirements, existing carriageway characteristics etc. This would vary from fully separated bicycle lane on major roads as well as cycle lane marked on minor roads including other required lane markings and signage.

Around Rs. 100-150 billion for the project to cover the entire country (XU and Mayuga, 2022). The project could commence around 2050 and be completed over 10-year period.

3. **Promoting remote working**

Nearly 20% of the trips in Western Province are Home-based work trips in Western Province according to the ComTrans study survey by JICA (2014).

Around 4 million similar work trips can be targeted to promote work from home or flexible hours schemes (reduced number of working days).

Assuming a reduction of 25% of working trips under this policy and an average trip length of 10 km the reduction is 10 million passenger-km per day.

This is equivalent to a reduction of 0.58 -0.7 million tonnes of CO_2 per year under the typical modal composition for work trips.

Table 4.11: Amount of CO_2 emissions reduced due to promoting remote working

Mode share of trips shifted to WFH		trip/day	km/day	CO_2 kg/day
PT	0.3*			
Private car	0.4	400,000	4,000,000	920,000
MC	0.15	150,000	1,500,000	69,000
Three-wheel	0.15	150,000	1,500,000	115,000
Total		**700,000**	**7,000,000**	**1,104,000**

* PT (Public Transport) trip reduction is not accounted for CO_2 reduction since those are scheduled services which will be in operation.

4. **Promoting e-commerce and e-learning**

Other type of trips such as shopping, banking, education trips to an extent will also be done using online modes with the advancement of e-commerce and e-learning technologies. There should be incentives for fulfill their needs using these tools and reduce the need to travel.

Around 5 million similar work trips can be targeted. Assuming a reduction of 20% of working trips under this policy and an average trip length of 6 km the reduction is 10 million passenger-km per day.

This is equivalent to a reduction of 0.36 -0.44 million tonnes of CO_2 per year under the typical modal composition for work trips.

5. **Modernizing the bus fleet, introducing low floor buses and introducing new bus routes/frequency in cities to attract private vehicle users to buses**

The bus fleet operated by Sri Lanka Transport Board and Private Bus Operators in Sri Lanka is around 5000 and 20,000 buses respectively. This value has remained stagnant for over a decade while the other modes have increased considerably. Therefore, the bus fleet must be expanded to provide new services for various market segments.

The addition of 5,000 more buses along existing bus routes and selected new routes would improve the travel time reliability and service quality to public transport users. These buses can target certain niche markets such as school services, office transport, nighttime services, rural areas and divert existing private vehicle users. In addition ticketing system, real time bus information systems, bus terminal facilities should be improved in parallel to provide an overall improved user experience.

An addition of 5,000 buses has the potential to reduce up to 8000 passenger km of travel by private modes per bus. This is equivalent to annual saving of 0.62 million kg of CO_2 per year.

The project could commence in the year 2025 and increase the bus fleet in stages by the year 2045. Around Rs. 250-300 billion would need to be spent over the 20-year period to expand the bus fleet and other facilities such as bus bays and facilities at terminals and maintenance cost. (Replacement programs are given with the strategic plan).

6. **Implement a price formula for petrol and diesel to reflect global petroleum prices and exchange rates**

Sri Lanka has not adjusted the fuel prices to reflect changes in the exchange rate and global energy prices for a considerable period. This has made fuel relatively cheaper compared to other commodities which has increased with inflation. It has been found that the long-term price elasticity of fuel is in the range of -0.4. Considering the long-term inflation rates and currency depreciation rates the fuel price may have increased by on average around 6-8% p.a, if so, the fuel demand could have reduced by around 3% compared to current demand. (Price formula must reflect which must be explored during the action plan detailing stage)

Therefore, in the long term, implementation of fuel pricing policy that reflects its actual cost is likely to reduce the fuel consumption by 3%. With a more aggressive pricing strategy that considers the environmental cost of fuel consumption is likely to reduce the demand by 5%.

This will result in a reduction of CO_2 by 1 million tonnes kg by the year 2050.

7. **Transport Demand Management Strategies in Key Cities**

The following measures could be implemented in major cities to discourage private vehicles entering the city area. However, the success of these is dependent on the availability of alternative modes of public transport with sufficient capacity and service quality.

- Parking management: prohibit roadside parking, increase parking fees
- Park and ride system at main corridors for vehicles entering the city
- Congestion charging for selected zones to discourage vehicles entering during peak hours

More than 700,000 trips were recorded to have entered Colombo City area from outside in the ComTrans Study (2014) survey and close to 30% are via private modes. Considering all the main cities in the country, around 500,000 passenger trips per day in private vehicle modes can be potential reduced from entering main cities.

This is equivalent to reducing 4 million veh-km per day and 0.4 million tonnes of CO_2 per year.

This would cost around Rs. 50 billion and projected to be implemented over a period beginning from 2040-2050. If ERP (congestion charging) system is to be implement, that cost has to be separately accounted for considering the implementing area and technology used.

8. Implementation of LRT network in Colombo

The Light Rail Transit Network was proposed as a key project to improve the public transport system in Colombo and the suburbs. Initially the Malabe corridor has been identified to implement the project with expansions to other areas in Colombo also being developed as part of the feasibility study.

Under the present economic context, it is envisaged that the implementation of the LRT is restricted to Malabe Corridor with extension to Kaduwela and further down to Kottawa to integrate with the KV line.

According to the feasibility study the expected emission reduction is around 0.1 million kg CO_2 per annum. However, the actual emission reduction will depend on the ridership level which is also linked to the land use development strategy along the LRT corridor, transport demand management measures, feeder services at the stations linking the trip generation zones in the area etc. It is not prudent to make assumptions in that regard in this study.

The project cost is around Rs. 550 billion and if constructed is more likely to take place after the year 2025 for a period up to 2030.

9. E-Mobility

Public Transport-Rail

Electrification of Urban Rail Tracks

In step number one, the electrification of five main lines within the urban geographical limits is considered, as shown below. This option was considered after looking at the cost of transformation and the frequency of the train that travels within these five lines, as shown in Table 4.14.

Table 4.12: Proposed Railway Electrification Program

Year of Electrification	Railway Line	Rail Distance (km)
2030	KV Line- Fort to Padukka	37.2
2035	Coastal line- Fort to Kaluthara	41.9
2040	Puttalam line- Fort to Ragama	15.6
2045	Northern line – Fort to Polgahawela	73.9
	Mainline -Fort to Polgahawela	

Once electrified, the following savings in terms of engine km (burning diesel fuel) can be expected.

Table 4.13: Train km saving and the electricity requirement for electrification of Railways

Rail Line	Track Length	Train km Saving per Annum	Electricity Requirement (kwh) per Annum
KV line- Padukka	37.18	205,234	1,231,402
Coastal line- Kaluthara	41.87	711,455	4,268,730
Puttalam line- Ragama	15.55	94,420	566,518
Main line –Polgahawela		1,787,353	10,724,120
Northern line - Polgahawela	73.882	572,733	3,436,400
Total	**168**	**3,371,195**	**20,227,169**

Since, on average, a diesel engine travels 2.5 km per litre, diesel savings of 8 million litres can be estimated. In turn, 22 million kg of CO_2 can be reduced per annum from this initiation. At the same time, the Table above shows the electricity required to run the electrified trains in the urban context, which is going to be a demand increase for the energy sector.

Decarbonisation of Long-Distance and Freight Rail

Beyond the urban limits, since the frequency of train travel is less, the electrification of such a long distance may not be prudent. Hence, it is proposed to use hydrogen-fuelled engines to run these trains beyond the urban limits to far distances which is a carbon-free solution provided hydrogen is from abundant renewable energy sources. This initiative is not so new since Germany has already started using hydrogen-driven engines in their trains, and the Indian railway is the next waiting operator expecting a major shift.

The advantage of shifting to hydrogen-driven engines in railways is that sometimes electrification may not be a good solution in remote areas, where breakdowns in the electricity grid are experienced over long periods, even today. On the other hand, this option is just a change in the engines, and there is no cost associated with changing the cabins or upgrading the other infrastructures. Furthermore, operators of trains at less frequency due to lower demand, would not be able to cover the high electrification cost. Thus, a shift to hydrogen-driven engines seems to be the most economical and practical solution for Sri Lanka.

So, in the years 2045 to 2050, we expect all our long-distance trains to be driven using hydrogen engines and assume that more efficient hydrogen engines will be available in such time, than what we have today.

This way, we can fully decarbonise the railway transport, saving about 71,000 tonnes of CO_2.

Public Transport-Buses

Inter-Provincial

In Sri Lanka, there are inter-provincial buses operated by SLTB and the private sector. All private sector buses are registered at National Transport Commission (NTC), and according to the NTC data, there are 3,100+ buses providing long-distance service on a daily basis. On an average day, cumulatively, 0.8 million km are travelled, consuming 0.25 million litres of diesel. Therefore, private buses would emit about 242,000 tonnes CO_2 per year and assuming a similar contribution is from SLTB, the total CO_2 contribution from the interprovincial bus transport could be estimated as 485,000 tonnes of CO_2. (using an emission factor of 2.7 kg per litre disel)

The most practical solution available for the decarbonisation of inter-provincial buses is to introduce electric buses in stages so that the capital cost burden to the government can be spread over the years.

Therefore, the following bus electrification plan is proposed, and subsequent savings on CO_2 as well as additional electricity requirement is also calculated and depicted in Table 4.16 below.

Table 4.14: Bus electrification Plan and Electricity requirement for implementation

Year	*% of Buses Electrified*	*Electric Bus Km per Annum*	*Electricity Requirement (kwh)*
2030	10% of the Interprovincial buses electrified	62,901,384	88,690,952
2035	20% of the Interprovincial buses electrified	125,802,769	177,381,904
2040	50% of the Interprovincial buses electrified	314,506,922	443,454,760
2045	75% of the Interprovincial buses electrified	471,760,383	665,182,140
2050	100% of the Interprovincial buses electrified 1	629,013,844	886,909,520

Note: Total buses considered here (Private+SLTB)

As shown in Table, 887 million units of additional electricity are required for provincial bus electrification, which would, in return, save 485 million kg of CO_2 emissions.

Provincial

Similarly, provincial bus transportation is also provided by the same two operators and assuming a 50:50 share, the following electrification strategy is proposed. Data from Western and Southern Passenger Transport Authorities were received, and calculations were carried out accordingly.

In Western Province, 5,913 private buses are registered, and on average, 4,173 buses are in operation on a daily basis covering 833,687 km. Assuming that SLTB also provides a similar service in the Western Province, it can be estimated that a total of 1.7 million km travelled, burning 476,392 litres of diesel and emitting 1.3 million kg of CO_2 (annually 469 million kg of CO_2).

In Southern Province, 1,239 buses are in operation on a daily basis running 16,993 km. Considering the same assumption as above, the total bus km operated in Southern Province can be estimated as 33,987 km burning 9,710 litres of diesel and emitting 26 million kg of CO_2 (annually 9.6 million kg of CO_2).

Looking at the vast disparity in the operating km in the two provinces, it is difficult to make and estimation for other provinces. However, such an estimation is needed since there is no data obtained so far from such passenger transport authorities. To be on the safe side, Southern province performance is considered for other remaining seven provinces as well.

Thus, the bus electrification plan shown in Fig 4.17 can be proposed to achieve carbon net zero by 2050.

Table 4.15 : Proposed Bus Electrification Plan

Year	% of Buses Electrified	Electric Bus Km per annum	Electricity Requirement (kwh) per year
2030	None	0	0
2037	10% of the Bus Fleet	70,783,063	99,804,119
2043	30% of the Bus Fleet	212,349,189	299,412,356
2047	60% of the Bus Fleet	424,698,378	598,824,713
2050	100% of the Bus Fleet	707,830,630	998,041,188

As shown above, this requires about 998 million units of additional electricity per annum by 2050, saving 546 million kg of CO_2.

Contribution from Private and Freight Vehicles

In the transport sector, the biggest fossil fuel consumption is by private vehicles (including freight vehicles) , burning a total of 3 million tonnes (petrol and diesel) and emitting 9 million tonnes kg of CO_2 annually based on 2020 data. Since vehicle imports are restricted to the country, the number of vehicles would not increase, and this situation can be expected for at least another few years. At the same time, due to the economic crisis and considering the price of a litre of fossil fuel, there will not be any noticeable change in the number of km travelled using private vehicles, and hence it can be prudently assumed that up until 2030, the current scenario will continue.

The only feasible option to decarbonise private vehicle emissions is to replace fossil fuel-based with electric vehicles. This is the vision of some car manufacturing companies as well. For example, Volkswagen will mainly be producing electric vehicles for the next couple of decades, and their plan is to reach net carbon zero by 2050. In similar concepts, if SL wants to be enjoying the same status, the imports must grant only fully electric vehicles so that eventually, our vehicle fleet will be electrified over the 20 years or so beyond 2030. Since freight vehicles are also within this private vehicle category, government subsidies may have to consider electrifying the freight fleet because the capital cost of the vehicle is too high. At the same time, electric charging points, electricity generation to meet additional demands, and the development of other necessary infrastructure are essential for electrification to be a reality.

Sample Calculation:

If we expect a 5,000 million kg reduction of CO_2 emissions by private electric vehicles, the amount of electricity increase can be calculated as follows.

The expected reduction of CO_2 (kg)	5,000,000,000
Number of gasoline litres burnt (assuming 2.3kg of CO_2/litre)	2,173,913,043
Approximate number of km from given litres of gasoline (8km/l)	17,391,304,347
Electricity required to run additional km (0.2 kwh/km)	3,478,260,869

As per the calculation, an additional 3,478 million units of electricity is required to save 5,000 million kg of CO_2.

Considering the past vehicle import rates, it can be assumed that the following numbers (Table 4-18) may apply from 2030 onwards and 5% increase to the base number is expected every year after 2030. It is important to note that all these new imports are electric vehicles and with this we are expecting to replace the existing fleets over a long period of time. In other words, existing fossil-fuelled vehicles will be used for some more time and eventually all fossil-fuelled vehicles will be replaced by electric vehicles in the long run.

Table 4.16: Expected Number of Electric Vehicles Imports by 2030

Cars	80,776
3W	20,063
MC	339,763
SUV Van	16,931
Lorry	7,055
Trailers	1,989
Ambulances	325
Tractors	7,460

Hence we can expect a 1,853 CO2 reduction (million kg) in year 2030 and 3,706 in year 2050.

Table 4.17 : Summary of CO_2 emission reduction by 2050 and additional electricity requirement for transport sector mitigation actions

Activity	CO_2 reduction by 2050 (million kg)	Additional Electricity Requirement (million kw/h)
Railway Electrification	22.8	20.2
Railway- Hydrogen Energy	48.3	0
Inter-Provincial Bus Electrification	485	887
Provincial Bus Electrification	262	438
Private Vehicle Electrification	3,706	4,441

Both maritime and aviation sectors were not specifically addressed in the study mainly due to limited feedback received from state agencies on specific strategies that have been proposed. Moreover, the scope of the study requires identifying relevant stakeholders and specifying implementation timeline and cost, along with the expected emission reduction due to the strategies. In the absence of the specific strategies, reliable estimates of this could not be made. Considering both aviation and maritime emission reduction targets are largely influenced by the goals set by organizations such as International Maritime Organizations and International Civil Aviation Organization and complied with by international shipping and airline companies, it is unclear how the government strategies could influence that to a significant extent. It is also unclear the future ownership status of state owned enterprises such as Sri Lankan Airlines, therefore proposing long term goals is not considered prudent.

4.5.3 Industry Sector

The actions proposed to achieve the NDCs in the Industry Sector are listed below.

1. Promote Resource Efficient Cleaner Production (RECP) practices by conducting energy audits, including low carbon technologies and processes, improving water use efficiency in selected industrial subsectors, and promoting energy-efficient appliances and technologies
2. Establish eco-industrial parks and villages by incorporating the maximum possible green industrial concepts and introducing policy and regulatory regime
3. Adopt the Circular Economy concept for selected industries by conducting a survey to

identify and determine the potential subsectors for the implementation, introducing the life cycle approach, practicing the industrial symbiosis concept, establishing a pilot project on the zero-waste concept, adopting ISO standards for the circular economy concept (ISO/TC 323) and building industry capacity to adopt the circular economy concept

4. Introduce tri-generation facilities in selected industries by carrying out rapid assessments in 10 industrial parks and a detailed assessment in one of the BOI industrial parks for piloting, developing business models and funding options, implementing one Tri-generation facility as a pilot project, and expanding it if it will be successful and making provisions in new developments through policy instruments
5. Encourage GHG reduction of clinker production in the cement industry by making necessary amendments to Sri Lanka Standard Institute (SLSI) standards for cement production
6. Generic enabling activities such as facilitating industries to adopt relevant ISO systems, introducing and promoting suitable tax incentives, facilitating the entry of ISO-certified companies to the Green Public Procurement system of Sri Lanka, facilitating transformational investment and favorable loans, introducing a national policy to address siting of industrial parks and stand-alone industries, ensuring the availability of sustainable biomass and promoting National Green Reporting System (NGRS)
7. In relation to all the itemized proposals above (1-6) enact legislative punitive measures, as found in advanced countries, where *polluters pay dearly* and therefore the inclination to violate the environment is treated with predictable legalized repercussions

According to the NDCs (MoE, 2021), implementation of these activities without hindrances is expected to reduce the GHG emissions by a total of 3,570,000 tonnes (7%) by 2030, out of which 2,088,000 tonnes (4%) will be unconditional and 1,482,000 tonnes (3%) will be conditional. In addition to these actions, other technical options mentioned in Third National Communication of Climate Change in Sri Lanka (MoE, 2022) will be considered and new actions will be developed to achieve net zero carbon emission in Sri Lanka. Qualitative and proportional emission reductions (as%)are shown in below diagrams (Figure 4.5 and 4.6).

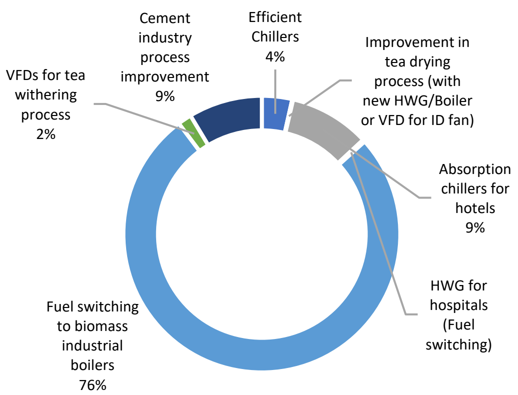

Figure 4.3 : NDCs unconditional and conditional

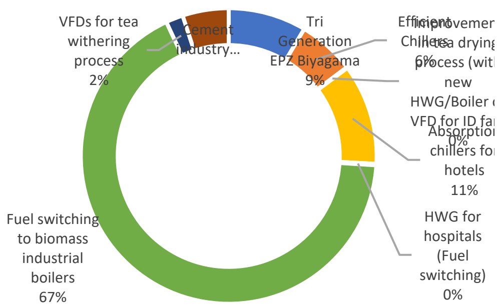

Figure 4.2 : NDCs based unconditional reductions

National Road Map milestones for achieving Carbon Net Zero

Few milestones proposed particularly relevant to Sri Lanka are highlighted as follows;

- Industry process efficiency improvement in reducing industry process (IP) related emissions especially focusing cement and lime industries,

Considering the prevailing national economic crisis situation, prioritizing climate net zero targets will be a challenge. But proper, country specific and specially science-based targets (SBTs) will offer definite national sustainability benefits beyond mere economic benefits. Therefore, in achieving national net zero emissions, it is highly recommended to give the appropriate priority to the strategic options and targets developed on SBTs which are providing simultaneous economic and sustainability (both in short term and long term) benefits.

Based on power sector net zero emission reductions industry sector energy use will be totally a zero-carbon source hence industry energy use related emissions will become zero.

4.5.4 Waste Sector

Waste management is a critical aspect of modern societies as it impacts not only the environment but also human health, social well-being, and economic prosperity. The fast-growing urbanization and globalization trends have led to an exponential increase in waste generation and improper waste management practices, resulting in significant environmental and health impacts. In particular, the waste sector contributes to greenhouse gas (GHG) emissions, which drive climate change. Therefore, reducing waste related GHG emissions has become an urgent priority for both developed and developing countries.

To mitigate the impacts of waste related GHG emissions, various mitigatory actions have been taken at the national and global levels. One of the critical actions is the reduction of waste amount at the source, which is achieved by introducing MSW segregation categories, improving waste collection and transportation, and creating awareness among the public and industrialists. Policy on polluter pay principles to be introduced island wide by the local authorities. Additionally, deposit and refund systems for plastic bottles, glass bottles, aluminium cans, and other waste items have been established to motivate people to reduce waste generation.

Further adoption of the 3R practice (Reduce, Reuse, Recycle) is necessary to reduce waste generation and improve resource efficiency. The circular economy concept has been introduced to promote the redesign, reuse, and rethink of products and materials, which helps in reducing the waste and GHG emissions. To enhance the circular economy, various initiatives have been launched, including subsidies for community-based composting, supporting the production of hybrid fertilizers, and redirecting MSW away from landfills for agricultural use.

GHG emission reduction is enhanced using electric vehicles in waste transportation and waste to energy plants. Establishing sanitary landfills and daily covers for open dumps is another critical action that has been taken to reduce waste related GHG emissions. Additionally, various strategies have been introduced to build a zero-carbon economy, including the introduction of zero-carbon building materials and the offering of national research grants for zero-carbon innovations.

Waste management and GHG emissions reduction are interdependent and require a comprehensive approach that involves the collaboration of various stakeholders, including the government, private sector, civil society, and international organizations. The mitigatory actions mentioned above are critical steps towards achieving a sustainable waste management system and reducing waste related GHG emissions. By implementing these measures, we can create a cleaner, healthier, and more sustainable future for all. According to the National Action Plan on Plastic Waste Management goal 11 there will be non-recyclable remaining at the end stage of the life which accounts for the high caloric input necessary for the plant. The strategic location for the WtE should be identified such that the high amount of waste reaches the plant with minimal transportation. The appropriate land extent must be taken into the account while commissioning the plants. The following strategies are proposed for the waste sector to achieve net zero carbon emission in 2050,

1. Using biochar for daily cover in landfills and open dumps
2. MSW growth reduction 3R practice & promote recycling and use of recycled materials
3. Methane recovery for SynGas production from open dumps and sanitary landfills
4. Constructed wetland for wastewater treatment and reuse treated wastewater for greening
5. Transforming the waste collection garbage trucks into electric trucks
6. Introducing waste to energy plants for other provinces
7. Establishing sanitary landfills for residual wastes

The actions proposed in following strategies are given under table- 4.20 and 4.21

The details of the mitigatory actions are shown in table 4.20

Table 4.18 : Mitigatory Actions for the Waste Sector

No	Mitigatory Actions
1.0	**Using biochar for daily cover in landfills and open dumps**
1.1	Pyrolyzing conversion of municipal solid waste into biochar which supports the circular economy
1.2	Introducing biochar as a renewable energy resource such as carbon fuel cells, porous catalysts, bio-oil, biochar coal, syngas, etc.
1.3	Using biochar for carbon sequestration
2.0	**MSW growth reduction**
2.1	Municipal solid waste & wastewater growth reduction
2.2	Introducing municipal solid waste segregation categories, improving waste collection and transportation problems

No	Mitigatory Actions
2.3	Improving laws, rules, and regulations and formulating economic measures to create motivation for waste reduction
2.4	Establishing polluter pay principles for waste reduction
2.5	Encouraging entrepreneurs to reduce disposable waste container sales and promoting safe reuse containers
2.6	Promoting food waste separation at source, obviously after avoiding the waste as much as possible
3.0	**3R practice & promote recycling and use of recycled materials**
3.1	Mandate 3R practices
3.2	Create awareness among industrialists that improve materials and materials flows like reuse and recycling
3.3	Transform waste into reverse-engineered products
3.4	Mandate recycled content requirements and waste reduction measures
4.0	**Methane recovery for SynGas production from open dumps and sanitary landfills**
5.0	**Constructed wetland for wastewater treatment and reuse treated wastewater for greening**
5.1	Vertical Sub Surface Flow Constructed Wetland (VSSFCW)
6.0	**Transforming the waste collection garbage trucks into electric trucks**
7.0	**Introducing waste to energy plants for other provinces**
8.0	**Establishing sanitary landfills for residual wastes**

Biogas community level from fecal material

Community level Biogas production from faecal material at the community level is a highly effective way to reduce greenhouse gas emissions. When untreated human and animal waste decompose, they release methane, a potent greenhouse gas that contributes significantly to climate change. However, by using anaerobic digestion to convert the waste into biogas, the methane emissions are captured and turned into a renewable energy source. Biogas production not only reduces methane emissions, but it also displaces the use of fossil fuels for cooking, heating, and lighting, further reducing greenhouse gas emissions. This innovative solution not only provides a source of clean energy but also addresses sanitation and hygiene issues, especially in rural areas where access to proper sanitation facilities is limited. Overall, biogas production from faecal material at the community level has the potential to significantly reduce greenhouse gas emissions while promoting sustainable development.

Table 4.19 : Mitigatory Actions for the Waste Sector

No	Mitigatory Actions (unquantifiable/to be quantified in future)
1.0	**Refunds & incentives for proper waste management**
1.1	Supporting deposit & refund systems for plastic bottles, glass bottles, aluminum cans
2.0	**Promote circular economy in supply chains and construction industry**
2.1	Redesign, reuse & rethink for circular economy
2.2	Boosting the energy and resource efficiency of products
2.3	Enhancing the number of recycled materials in products while maintaining their functionality and safety; facilitating remanufacturing and superior recycling
2.4	Limiting single-use and combating premature aging
2.5	Putting a stop to the destruction of durable items that have not sold
2.6	Encouraging business models that allow producers to retain ownership of the product or accountability for its performance over its entire lifecycle
2.7	Rewarding products depending on their various sustainability performance
2.8	Design for deconstruction in such a way that the materials used for construction can be reused in new construction with minimum alterations
3.0	**Efficient waste management**
3.1	Supporting provincial administrative organization to make waste management systems, reuse systems and data management systems
3.2	Restrict outdoor burning and improve the operation of clean development mechanisms
3.3	Addressing the presence of dangerous chemicals in waste
3.4	Addressing the prevalence of microplastics in the environment
3.5	Establishing and standardizing measurement techniques for accidentally released microplastics, particularly from tires and textiles
3.6	Phytoremediation for E-waste contaminated sites
4.0	**Biogas from fecal sludge at community level**
5.0	**Hybrid fertilizer production and Subsidy free community-based composting**
5.1	Redirect MSW away from landfills so that it can be used as a supplement to fertilizer on agricultural fields so, aiding in preserving soil fertility and recycling trash
5.2	Combine agricultural compost with municipal solid waste compost
6.0	**Introducing the waste management activities and the emissions reduction opportunities**
6.1	3R practice as well as saving money, energy, and natural resources related to life cycle management

No	Mitigatory Actions (unquantifiable/to be quantified in future)
6.2	Introduce strategies on the national level to build an economy that keeps materials, products, and services in circulation for as long as possible
7.0	**Promoting zero-carbon innovations**
7.1	Offering National Research Grants for zero carbon innovations
7.2	Introducing zero-carbon building materials
7.3	Introduction of carbon adsorbing materials
8.0	**Community participation, empowerment, and capacity building**

4.5.5 Agriculture Sector

Feasible Strategies

Following strategies are proposed to be adopted in the agriculture sector to reduce GHG emissions:

1. Reduce methane emission from paddy fields by removing rice straws and through good management practices.
2. Use alternatives to Chemical fertilizer for reducing N_2O emission.
3. Reduce methane emission from livestock by improving feed quality and animal comfort.
4. Reduce N_2O emission in soils due to microbial activities.

Following strategies can be adopted to increase carbon sequestration in the agriculture sector:

1. Adopt 'evergreen agro-ecosystem concept' to improve carbon sequestration from paddy fields and rainfed uplands.

Following strategies are also possible to be included in future planning, when information is available to do so:

1. Improve land management practices in agricultural lands to enhance the carbon stock in the soil.
2. Improve crop management practices in tea plantations.

Mitigation Actions proposed to be implemented under the Strategies

Strategy 1. Reduce methane emission from paddy fields by removing rice straws and through good management practices

a. Removal of paddy straw from the paddy field for manufacturing paper, boards and packaging materials and producing biofuel blocks.
b. Reduce post-harvest losses during harvesting and transport to minimize GHG emission from transport and agricultural product residues

c. Establish subsistence and/or polyculture farming to maintain healthier soils
d. Promote diverse cropping systems and a need-based economy
e. Addition of rice straw-derived biochar to lower methane emissions in increased temperature and carbon dioxide conditions, congruent with future climates.
f. Responsible water management such as slower infiltration techniques, breaking up of soil aggregates or alternate wetting and drying (AWD)
g. Policy initiatives to encourage sustainable farming practices and address current subsidies. (Durbin, 2017)
h. Promote rice production in upland areas, in which the fields are not maintained in flooded conditions, generates substantially less methane per hectare and per unit of rice.
i. Adaptation of good management practices for soil and water management particularly large in areas where two or three crops of rice are produced each year. (Wichelns, 2016).
j. or three crops of rice are produced each year. (Wichelns, 2016).

Strategy 2. Use alternatives to Chemical fertilizer for reducing N_2O emission:

a. Integration with organic fertilizers (Organic Farming)
b. Promote slow/controlled N-releasing fertilizers and increase their effectiveness.
c. Deep placement and reduction of frequency of application of N fertilizer,
d. Use of N transformation inhibitors to scale back the hydrolysis of urea to ammonium by soil urease enzyme.
e. The use of nitrification inhibitors to scale back the accumulation of nitrate also will help to reduce GHG emissions.
f. Adjust fertilizer rates to coincide with plant needs.
g. Place fertilizer near plant roots (but not too deep in the soil);
h. Apply fertilizer several times each year, rather than only once.
i. Adopt IPNS (Integrated Plant Nutrition System) approach
j. Adopt Climate Smart Agriculture (World Bank & CIAT, 2015)

Strategy 3. Reduce methane emission from livestock by improving feed quality and animal comfort.

a. Supplement with fodder trees, rice straw, and low-cost concentrate. – Here, lower CH_4 observed with legumes is attributed to lower fiber content and faster rate of passage of feed through the rumen; thus, intakes are higher with legume forages.
b. Use of total mixed ratio – improves productivity and reduces methane emissions.
c. Supplement forage diet with Gliricidia blocks- Promotes high dry matter intake and has a faster rate of passage through the rumen and reduction of CH_4
d. Animal comfort (heat stress management)- Enhanced animal productivity and reduced GHG emission intensity.
e. Use methane for their thermal energy use as well as for power generation especially in larges farms

Strategy 4. Reduce N_2O emission in soils due to microbial activities

a. Manure management from livestock
b. Crop residue management in agricultural fields
c. Management of organic soils to minimize N_2O emission

Strategy 5. Adopt 'evergreen agro-ecosystem concept' to improve carbon sequestration from paddy fields and rain-fed uplands

Main features of the ever-green agro-ecosystems concept can be listed as follows:

- Cultivation of crops with different duration to keep green cover even during the harvesting stage of one crop;
- Cultivation of crops leaving zero fallow period of the land;
- Farming models, which combine seasonal, semi-perennial and perennial crops ensuring the green cover around the year;
- Green manure plants such as gliricidia, adathoda, erithrina, thespesia etc. are grown as hedges with strict frequency of pruning;
- Shade management is adopted to minimize light competition and to maintain the crop land with evergreen situation;
- Live fence is maintained with plants to create a stratification enabling to act as wind barrier as well as favourable micro-climate in the crop field; and
- The farmer should have a field management / self-evaluation schedule for his convenience to ensure the sustainability of the agro-ecosystem

Strategy 6. Improve land management practices in agricultural lands to enhance the carbon stock in the soil

a. Minimize tillage operations.
b. Restore degraded land, improving pasture management.
c. Reduce fallow periods.
d. Add animal manures to the soil.
e. Crop residue management.
f. Use legumes and/or grasses in crop rotations.
g. Convert marginal cropland to perennial grass or agroforestry systems.
h. Use rotational grazing and high-intensity/short-duration grazing.
i. Plant shrubs and trees as shelterbelts.
j. Restore wetlands.

Strategy 7. Improve crop management practices in tea plantations.

a. Introduce shade trees which are having higher carbon sequestration compared to tea bushes
b. Select shade tree species according to the region[2]
c. Adopt proper sustainable land management practices

[2] T. L. Wijeratne, W. A. J. M. De Costa and M. A. Wijeratne, 2014. Carbon Sequestration Potential of Tea Plantations in Sri Lanka as an Option for Mitigating Climate Change; a Step towards a Greener Economy, Conference Paper – Fifth Symposium on Plantation Crop Research

d. Strengthen tea small holding development societies
e. Establish biological hedges (wind barriers and use of tea plant itself without pruning)
f. Establish grass hedges (*Vetiveria zizanioides*, *Cymbopogon winterianus* etc.)
g. Establish cover crops (Ex. Mal Ratakaju (*Arachis pintoi*)

4.5.6 Forestry Sector

According to the updated NDC (2021-2030), 18,000 ha of new forests will be established by 2030 to achieve 30.8% of forest cover by 2030. In addition to this, the existing natural forests and forest plantations will be better protected. In the Net Zero Road Map and Strategic Plan, the Forest Department is hoping to reforest/afforest 200,000 ha of land by 2050. This land is included in the land under the category 'Other State Forests' which was vested under the management of Forest Department in the 5/2001 Circular but was cancelled subsequently and these were vested under the custody of Divisional Administrations. However, out of the 500,000 ha, 200,000 ha had been released to the Forest Department for restoration/ reforestation/ afforestation. It is also hoped to increase the contribution of trees outside forests to the GHG mitigation scenario. These include homegardens, coconut plantations, shade trees in the tea plantations, urban trees and avenue trees, trees in settlements and mixed plantations. The rubber plantations had been included in the category of forests according to the classification of FAO. Blue carbon ecosystems such as mangroves, seagrass beds and salt marshes had also been considered as important carbon sinks as they are reported to sequester carbon at rates 4-5 times higher than terrestrial ecosystems. Tables 5 and 6 in Annexure 3 show the net carbon sequestration of forests, trees outside forests and mangroves in Baseline Scenario and Net Zero Scenarios respectively.

4.6 Overall effects considering the cross-sector impacts

The following list is a summary of the feasible strategies and mitigation actions for achieving targets for the six sectors as described in sections 4.5.1 to 4.5.6:

a) Energy Sector

- Decommissioning coal and diesel power plants
- Addition of natural gas power plants
- Addition of renewable energy such as pumped storage, mini hydro, biomass, wind and solar with integration of energy storage devices such as battery storages and pump hydro plants.
- Nuclear-based electricity generation
- Decommissioning of natural gas power plants
- Adding Cross Border Interconnection of India and Sri Lanka.
- Energy efficiency, Conservation and Demand Side Management (DSM)
- Introduction of green hydrogen
- Introduction of Carbon capture and storage (CCS)
- Dedicated energy plantations for Biomass

a) Transport Sector

- Improving the pedestrian infrastructure on collector type roads in the country
- Promoting cycling
- Promoting remote working
- Promoting e-commerce and e-learning
- Attracting private vehicle users to buses
- Implementing a price formula for petrol and diesel to reflect global petroleum prices and exchange rates
- Prohibition of roadside parking, increase parking fees in cities
- Park and ride systems at main corridors for vehicles entering the city
- Congestion charging for selected zones to discourage vehicles entering during peak hours
- Implementation of LRT network in Colombo
- Electrification of urban rail tracks
- Decarbonisation of long-distance and freight rail with hydrogen fuelled engines
- Introducing electric inter-provincial and provincial buses
- Replacing fossil fuel based private vehicles with electric vehicles
- Introducing electric charging points and necessary infrastructure

b) Industry Sector

- Promoting Resource Efficient Cleaner Production (RECP) practices
- Establishing eco-industrial parks and villages
- Adopting the Circular Economy concept
- Introducing tri-generation facilities
- Substituting clinker with other materials in cement production (Amendment Sri Lanka Standard Institute (SLSI) standards for cement production enabling the increase of ash and other similar materials as substitutes for clinker)
- Implementing polluter pays principle

c) Waste Sector

- Reduction of the waste amount at the source
- Promote recycling and use of recycled materials
- Promote Circular Economy in Supply Chains
- Efficient waste management

- Biochar used as carbon sequestration
- Hybrid fertilizer Production
- Identifying the waste management activities and the emissions reduction opportunities that can be implemented in Sri Lanka
- Promoting zero-carbon innovations

d) Agricultural Sector

- Formulate policies to establish hydrology unit or section or laboratory at all the major plantation research institutes (Tea, Rubber, Coconut etc.) to regain the lost groundwater balance from the central hills.
- Effective Land management practices
- Alter the diets of livestock to reduce methane emissions
- Choosing management practices that enhance productivity
- Manure management practices to reduce methane emission
- Biogas production using manure

e) Forestry Sector

- Establish new forests (afforestation)
- Protection of existing natural forests and forest plantations
- Restoration and reforestation
- Increase the contribution of trees outside forests
- Increase blue carbon ecosystems such as mangroves, seagrass beds and salt marshes

The above six sectors are considered separately for the estimation of current emissions, targets for emission reduction and increased sequestration/absorption, feasible actions for achieving targets, and prediction of emissions. However, there are many linkages among the sectors, which causes impacts on each other when strategies and actions for mitigation are proposed for one sector. Some such linkages that present an additional burden of carbon emissions that need to be mitigated as well as positive impacts on the control measures are shown in Figure 4.7. For example, implementation of LRT network in Colombo, electrification of urban rail tracks, introducing electric inter-provincial and provincial buses, replacing fossil fuel based private vehicles with electric vehicles and introducing electric charging points and necessary infrastructure, all of which are aimed at shifting the transport sector from the use of fossil fuel to electricity, transfers a heavy demand to the energy sector, the emissions of which has to be dealt with by the energy sector. At the same time, activities such as promoting cycling, promoting remote working, promoting e-commerce and e-learning, attracting private vehicle users to buses and implementing a price formula for petrol and diesel to reflect global petroleum prices and exchange rates would reduce the demand for transportation, which would have positive impact on the demand side management for the energy sector.

In addition, some mitigation actions in one sector such as an increase of land used for new forest plantations would reduce the land available for agriculture, transport, and other infrastructure, which in turn may lead to deforestation in other areas, if proper control mechanisms are not in place. The actions used in the development of Figure 4.8 are those used in actions and strategies for Carbon Net Zero scenarios, to show the complexity of the interrelationships within the sectors.

In order to correctly reflect the carbon emission values when considering the overall effects, the sector consultants worked together to share the data and predictions. For example, the reduction in emissions due to actions like electrification in the transportation sector, where the energy source would change from petroleum use to electricity, resulted in the transfer of the emission load from the transport sector to the energy sector, due to the increase in electrical energy demand. Thus, the development of the road map was done interactively among the sectors, to achieve Carbon Net Zero in a holistic manner, rather than working in silos.

Social and gender issues that may arise from the proposed actions need to be effectively mitigated, and actions for assuring gender equity will be incorporated into the Road map. An economic analysis was carried out to find the best pathways for the country's social and economic development, taking this as an opportunity for sustainable development, to rise from the present economic crisis faced by the country.

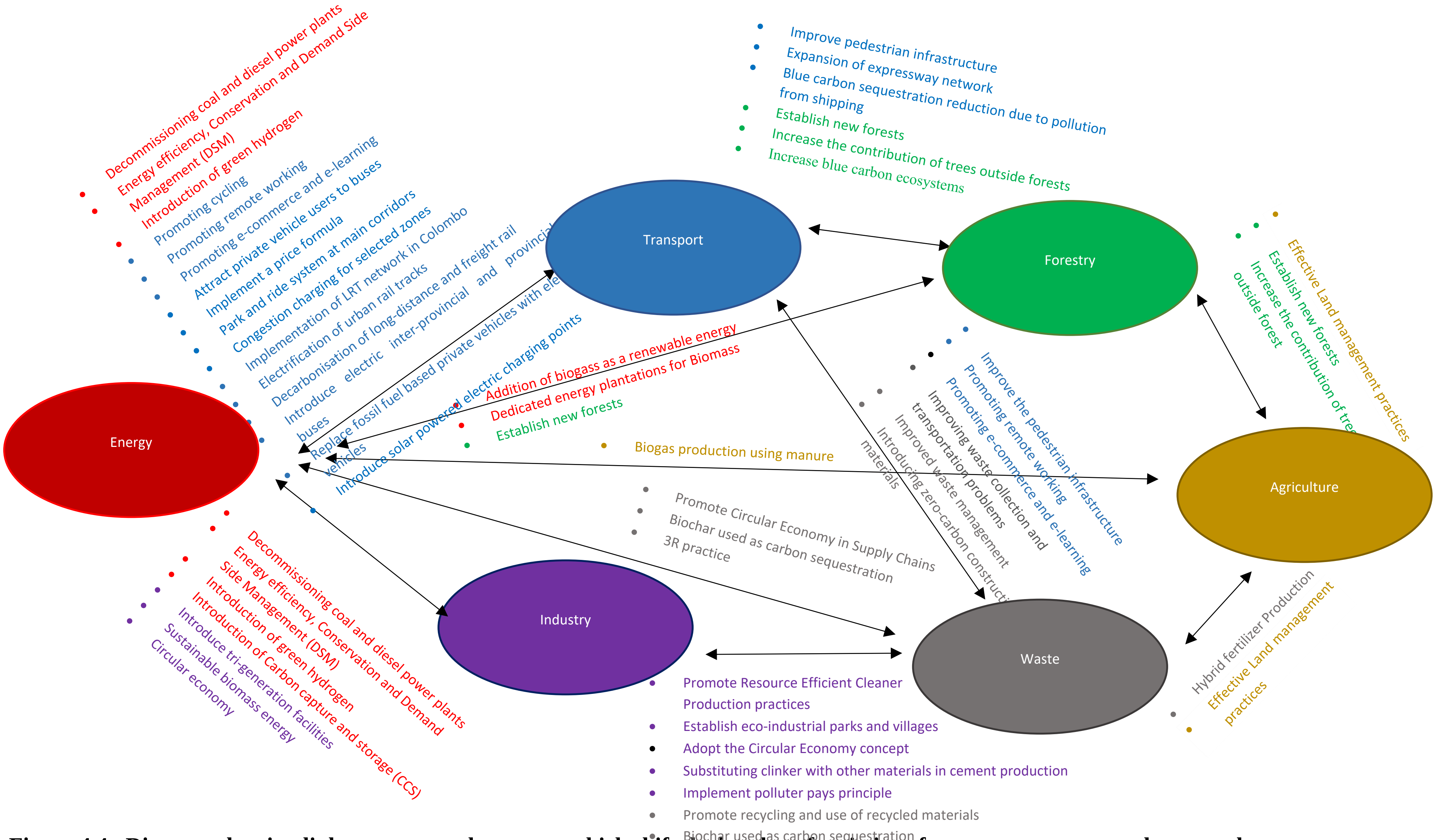

Figure 4.4 : **Diagram showing linkages among the sectors which shift the burden of emissions from one sector to another or reduce emissions from other sectors due to the proposed mitigation actions of one sector.**

4.7 Gender and social inclusion Analysis on actions proposed

Background

A common question raised by many of international endeavors drawn through many national and international treaties, conventions, acts and regulations to counter the negative ecological impacts of development and resulting social repercussions is whether the world can maintain total harmony between the ecological conservation and social and psychological wellbeing of the world population. When the factors that generate socio-economic differences among people are concerned, any particular measure of development does not seem to cater to equity and equality between people who have been divided on the basis of ownership and access to numerous facilities, resources, opportunities etc. placing them in a plethora of social hierarchies. Throughout the last several decades researchers have been searching for fair grounds which can be used as a premise for devising strategies to overcome these social issues pertaining to the maintenance of the balance between environmental conservation and social wellbeing.

"Paris Agreement on Climate change" as one of the key conventions which presents a highly ambitious plan to the world to reach Carbon Net Zero by 2050, addressing the grave issue of global warming, takes the magnitude of the social factors as of high importance in tackling the issue. It envisages that the parties involved in addressing climate change should "*respect, promote and consider their respective obligations on human rights, the right to health, the rights of indigenous peoples, local communities, migrants, children, persons with disabilities and people in vulnerable situations and the right to development, as well as gender equality, empowerment of women and intergenerational equity*" (UNFCCC 2016: 2). (See Annexure 2)

With the eye-opening questions raised in the pioneering text "Women's Role in Economic Development" by Ester Boserup (1970), attention was drawn to the issue of marginalization / exclusion of women in the development process, both as contributors and beneficiaries, catering to the adoption of many international conventions, acts and regulations. Apart from her major concerns on education and employment of women, Boserup (1970) also raised the concern on women's involvement with the environment. In 1988, Vandana Shiva raised a major concern on women's inseparable bond with the environment and the impact of the environmental destruction on the survival of women in her "Staying Alive" (1988) followed by the classic text "Ecofeminism" by Shiva and Maria Mies in 1993 drawing attention to the women's role in the conservation of the environment. Vandana Shiva (1988) critiques modern science and technology as a western, patriarchal and colonial project, which is essentially violent and propagates the same violence against women and nature. Despite many critiques and alternative suggestions, the above texts led the global community to seriously consider the gender aspects of environmental destruction and conservation as well as the global trajectory for development adopted so far.

Ensuring gender equality in all development programmes aiming at sustainability became a major concern since the Beijing Declaration and Platform for Action in 1995. The Paris Convention for Climate Change also deems gender equality as of utmost importance in this whole process towards carbon net zero 2050 planning and implementation including maintaining gender balance in all bodies and delegations constituted under the convention, responding to the differential needs, experiences, priorities and capacities of women and men at all regional, national and local levels.

Population Dynamics and Possible Impact on Carbon Emission

The last population census was carried out in Sri Lanka in 2011, and the final census report was published in 2012. According to this report, the population growth rate in the country in 2011 was 0.7% (Department of Census and Statistics, 2012). From the total population in 2011, 48.4% was male and 51.6% was female, and the sex ratio was 93.8%. The Department of Census and Statistics (2021) has calculated the crude birth rate per 1000 population in 2021 as 12.9, of which 13.5 are male and 12.2 are female. The estimated crude birth rate per 1,000 population in 2025 is 13, while in 2050 it is 10.5 (United Nations, DESA, 2022) showing a declining trend in population. Life expectancy at birth for men in 2025 is estimated to be nearly 73.6 years, while for women, it is 81 years. This shows that the male / female population in Sri Lanka is going to continue almost the same trends in the future. Literature has made evident that female population in general has exhibited a tendency to be more protective towards the environment (Ghaeli, 2019, Castañeda et.al. 2020, Nuber, 2021), so that it is possible to envisage that the potential gender scenario with the declining trend in population and the higher female ratio could have a profound impact in lowering of carbon emissions (see Annexure 1). However, such impact would be meaningful only if the country could reach substantial levels of gender equality allowing female population equal opportunities in entering societal echelons where they would be adequately empowered towards independent decision making.

Policies and Policy Gaps

There are a considerable number of policies and legislations introduced in Sri Lanka by various ministries and departments which have a stake with the subject matter related to the environment. The prime objective of these policies and legislations is conserving the environment and addressing climate change outcomes. However, most of these policies take a deep ecological perspective although some of them occasionally mention their relationship with social factors including gender as having some significance in addressing environmental issues. Nevertheless, those policy-based actions do not seem to pay an adequate concern on gender and social aspects as crucial in their remedial measures.

Review of what could be considered as most relevant policies and legislations in curbing the serious social and gender related repercussions on environment reveal that gender and social aspects of environment including carbon emission either has not been a concern or it only has been given marginal attention. The Ministry of Women and Child Affairs in a Cabinet Memo issued on 15th November 2016 under the title "Establishment of Gender Mainstreaming Programme at Ministerial Level" mentions that "…approval for 53 posts of Gender Focal Points has been obtained when graduate trainees were recruited in 2013" attached to all ministries, on the requirement made by the Commission on the Status of Women (CSW) at its

57th session held in March 2013 in order to curb all forms of violence against women and girls. The memo further says, “The expected targets of our ministry could not be achieved due to lack of support for those officers from the respective ministries they were attached to, lack of proper recognition for this subject and due to lack of proper guidance for those officers to act in relation to gender mainstreaming. At present only six (6) out of those officers remain”.

The establishment of the above-mentioned gender focal points seems to have become a failure despite the grave concern of the country on sexual and gender-based harassment and all forms of violence against women and girls. According to UNFCCC (n.d.), the gender and climate change decision 3/CP.25, paragraph 11, it "Encourages Parties to appoint and provide support for a national gender and climate change focal point for climate negotiations, implementation and monitoring". The UNFCCC secretariat has provided the list of nominated Gender Focal Points under the UNFCCC. Even though Sri Lanka is listed under the National focal points, the country so far has not followed the procedure to nominate a national gender focal point for climate negotiations (UNFCCC, n.d.). The requirement made by UNFCCC to establish gender focal points in relation to climate change under Climate Change Gender Action Plans (ccGAP) has never got implemented in policy planning in Sri Lanka, neither by Ministry of Women and Child Affairs nor by Ministry of Environment. The same lethargy in dealing with gender issues related to aspects of life of people and the country’s development is clearly visible in both these occasions despite the gravity of gender concerns all of the above domains seem to have.

In national policies and strategies related to environment, they have considered traditional knowledge in environmental conservation and preserving biodiversity as an important subject area, and propose strategies for preserving and incorporating traditional knowledge in environmental action. National Environmental Action Plan 2022 – 2030 has taken gender as a priority in planning for climate action. To achieve this goal, NEAP proposes to increase women’s participation in combatting climate change and to incorporate gender aspect “to all the new policies and plans related to climate change” (Ministry of Environment, 2022: 104 – 105) and also specifies the SDG targets (see Annexure 4) and NDCs (see Annexure 3) relevant to this process. NEAP also mentions gender mainstreaming as a noteworthy aspect especially in their agroforestry and woodlot establishment programme. National Environmental Policy and Strategies of 2003, as the first of their priority objectives, mentions the need for balancing social and economic development and environmental integrity to the highest capacity possible (Ministry of Environment and Natural Resources, 2003: 4). National Policy on Sustainable Consumption and Production for Sri Lanka also sees gender, inequality and inclusivity as cross cutting components in addressing SDG 12 (see Annexure 4). Even though the gender and social aspects of environmental action has been made one of the country’s earliest priorities as mentioned in 2003 National Environmental Policy and also in several other policy documents, prevailing national policies do not seem to have given adequate concern to the vitality of social and gender aspects in the process of environmental conservation in general or climate change in particular. This can be seen as a serious gap that need to be considered in 2050 carbon net zero strategies and action plans.

Analysis of the Gender and Social Impact of Proposed Mitigation Actions

Gender and social concerns of the proposed mitigation actions were identified on the basis of the literature review (see Annexures 4) and the analysis in relation to the views expressed by the respondents during the informal interviews (see Annexure 4). Views of the public on their knowledge and everyday experiences with regard to carbon emission becomes highly relevant in understanding the pertinence of these measures in the current socio-economic context of the country.

A stratified sample of 40 individuals purposively selected on the basis of urban/rural difference, gender and social class covering different locations in the country were informally interviewed in order to get their views along aspects related to carbon emission. Main themes included the knowledge and understanding of people on carbon emission, their everyday practices and relevance of those to carbon emissions, the difficulties experienced due to carbon emission as well as the problems they encounter when changing their lifestyles and domestic and livelihood practices despite their contribution to carbon emission. They were also consulted on their indigenous views and suggestions in mitigating atmospheric carbon dioxide increases.

Sample Distribution

Sector/ Social Class	**Gender**	
	Male	**Female**
Rural Upper/ Middle	05	05
Rural Low Income	05	05
Urban Upper/ Middle	05	05
Urban Low Income	05	05
Total	40	

The data collected from each respondent clearly demonstrate the need for obtaining public views in planning for low carbon emission measures for the country. Diversity in people's lives calls for a perspective that balance the social needs of people and the needs of a healthy environment in reaching carbon net zero 2050 goal. The data also pointed to the fact that knowledge and awareness on climate change and other environmental factors were significantly low among the population. The social and cultural practices towards the protection of environment supported in people taking certain protective measure in their daily life, however, apart from a segment of educated population, many were engaged in both environmentally positive and negative activities due to their ignorance.

Lack of alternatives for waste disposal seem to compel women to adopt environmentally destructive practices such as burning polythene even though they were somewhat aware of the harmful effects of this practice. Women seem to engage more in energy saving measures at home as a cost cutting measure since they are often responsible in balancing the household budget. Women commonly did not welcome the practice of work from home, both for themselves and for their husbands, due to family and household issues that cropped up when in such situations. Working from home also seem to cause stress for women and contribute to increased sexual harassment and domestic violence.

Women, more than men, seem to have been engaged in environmental activism and demonstrated a higher concern over the matters related to environment as it directly affects their responsibilities as women. However, women did not seem to have any decision-making power with regard to the matters related to environment, mainly due to low public engagement of women. Their individual contribution in environmentally protective practices at the household level was visible, nevertheless, they did not seem to engage in social and community actions related to the matter mainly due to lack of awareness and patriarchal social relations. Raising awareness among women and elevating them to decision making levels could immensely contribute to the lowering of carbon emission as well as in other environmental conservation activities.

The views of the respondents revealed that the country often experiences situations where expert solutions to problems get ignored or totally rejected by the public due to incompatibilities between these two sectors, experts and lay public. This could be a consequence of the absence of serious enough measures to familiarize the public with the necessary knowledge and/or awareness regarding the gravity of the issue or the potencies of the solutions given, or not considering the ground realities of the society by the experts in drafting solutions to problems they are dealing with. The following section attempts to see the gaps between these two sectors and to identify the need to come to mutually agreeable solutions by the experts in relation to the relevant proposed actions in each sector, as given in Table 4.22.

Feasible Actions for Achieving Targets and their Gender and Social Impacts

It is vital to note that, even though all the proposed actions under each sector are highly necessary to achieve carbon net zero goals, if in any case they have a tendency in unfairly treating any social group, the proposed actions will have a negative impact on sustainable development despite their potential to reach the primary target of attaining carbon net zero. Additionally, any planning that takes gender into account strives towards gender equity and equality in all spheres. Therefore, if a recommended strategy negatively affects a particular gender or social group, it cannot be considered effective from a gender and social standpoint. Gender equality includes engaging women and all gender groups in gender-sensitive planning, which goes beyond merely appointing more women to governing bodies. In that case, although increasing the number of female executives might advance both sustainable development and gender equality, what is more important is that they possess a high level of sensitivity with regard to both gender and social requirements of the society when dealing with sustainable development goals.

Also, even during an economic crisis, it cannot be said with certainty that the use of firewood constituted a permanent change in relation to cooking fuel, with the exception of a small percentage of people. Several gas vendors and companies in Sri Lanka have asserted that they were unable to handle the spike in demand during the crisis, despite the fact that this fact was not statistically supported in the sociological and gender research. Vendors claim that the demand for gas cylinders has surged over the past several months as a result of customers buying extra cylinders and a large number of middle-class consumers purchasing electric cookers (induction, infrared, etc.). Therefore, when considering the situation from the standpoint of the lay community, including the middle-income population, such a plan may not be very effective.

The gender and social impacts, as well as the proposed actions listed below, in Table 4-22, are therefore, intended to address these issues.

Table 4.20: Feasible Actions for Achieving Targets and their Gender and Social Impacts

Sector	Proposed Actions in Carbon Net Zero Roadmap	Gender and Social Impact and possible Mitigation Measures to the Impending Problems
Energy	• Addition of renewable energy such as pumped storage, mini hydro, biomass, wind and solar with integration of energy storage devices such as battery storages and pump hydro plants. • Dedicated energy plantations for Biomass	Before implementing pumped storage as a solution, planners may need to consider its social and gender costs such as the possible shortage of water for the agricultural activities and daily consumption of people living downstream. Water shortage world over contributes to increased vulnerabilities of population, specially women who are socially and culturally considered as primarily responsible for domestic provision of water. The high cost of installing rooftop solar power systems prevent its use at the household level. Introducing an economically feasible solar power system for small-scale industrial and business ventures and households.
	• Energy efficiency, Conservation and	Introducing energy saving equipment, the affordability of the vulnerable population needs to be taken into consideration.

Sector	Proposed Actions in Carbon Net Zero Roadmap	Gender and Social Impact and possible Mitigation Measures to the Impending Problems
	Demand Side Management (DSM)	Make low-cost appliances available. If housing is included in the term “buildings”, low-income groups (also pensioners, disabled, groups without old age financial support) and the 23.4% female headed households in the country have to be taken care of. Concessional provision of material and Cost effective equipment and special provision for small scale industries and female headed cottage industries
	• Introduction of green hydrogen • Introduction of Carbon capture and storage (CCS)	Here, R& D activities need to consider gender and socio-economic vulnerabilities as priority areas
	• Decommisioning coal and diesel power plants • Addition of natural gas power plants • Decommisioning of natural gas power plants after required time	Social impacts due to the loss of employment to the workforce when decommissioning of power plants needs to be mitigated.
	• Nuclear-based electricity generation	The risks associated with possible radioactivity releases have been a major social concern over the years, mainly due to lethality that supposed to be involved in regular or accidental situations and nuclear waste disposal. Therefore, considerable public protest against the use of nuclear energy could be expected. However, scientific investigations into the issue evidence that much of the risk perceptions of citizens are due to misperception and resulting anxiety (Huhtala & Remes, 2017).

Sector	Proposed Actions in Carbon Net Zero Roadmap	Gender and Social Impact and possible Mitigation Measures to the Impending Problems
		Although, the disastrous social impact of nuclear accidents could be very similar to the post-traumatic experiences of the affected population, the fear of chronic anxiety related to the impact of radiation cause individuals, families and communities to much greater worries and low resilience after the disaster. Possible impact of actual radiation and "radiation stigma" that could be both public and self-stigma is very specific to nuclear disasters (Maeda and Oe, 2017). The socioeconomic impact of nuclear disasters could vary according to the economic capacity of the country, worker population and population of the particular geographical area, the organizational strength, disaster preparedness, and the awareness of the public. These varying impacts were particularly visible in well-known nuclear disasters in Chernobyl, Soviet Union and Fukushima, Japan and also related to chemical disaster in Bhopal, India (Maeda and Oe, 2017; Shrivastava, 1987; Chernobyl Forum 2003-2005, 2005). Therefore, large-scale awareness campaigns imparting scientific knowledge to the public and strong precautionary programs to ensure least social cost in accidental events would be immensely important in convincing the country's population about the possible positive contribution of resorting to nuclear energy as an alternative energy source.
	• Adding Cross Border Interconnection of India and Sri Lanka.	Specific gender and social impacts related to these actions need to be studied and mitigated

Sector	Proposed Actions in Carbon Net Zero Roadmap	Gender and Social Impact and possible Mitigation Measures to the Impending Problems
Transport	• Promoting remote working	Travel is one of the most important ways of social interaction and maintaining social relations. The social cost of reducing travel could be highly unhealthy. This needs to be considered in planning
	• Promoting e-commerce and e-learning	• Lack of adequate internet coverage • High cost of data usage • Lower affordability of relevant devices will have a negative impact in promoting online work platforms. In e-commerce, the possible negative impact to the small-scale market-oriented activities due to the above factors should be considered. Learning capacity of the people concerned of necessary technology needs to be improved. In introducing e-learning, individual and family income and the internet coverage should be taken into consideration. Possibility of the learners to abuse the system and falling prey to various abusive and exploitative situations and also the learners becoming victimized due to uncontrolled usage of the system are common pitfalls that could be identified in e learning settings. As a solution sensitizing and improving the knowledge of adults including teachers and parents on various applications to monitor and control the internet access of learners, especially children would be highly necessary. Reduction of spatial movement often gives a feeling of incarceration and prevent imagination, creativity and liberal thinking.

Sector	Proposed Actions in Carbon Net Zero Roadmap	Gender and Social Impact and possible Mitigation Measures to the Impending Problems
		Expanding recreational facilities and improving facilities for travel for pleasure (considering the current high cost of travel) could be used in overcoming these negative impacts. Recreational facilities, housing/ quarters, for the working population and green city features would provide sustainable solutions
	• Attract private vehicle users to buses	Convenience to the user is decisive in making such a shift. Bus transportation system should be made orderly, efficient, courteous and convenient to the user.
	• Implementation of LRT network in Colombo	Cost of transportation should be decided considering the affordability of vulnerable populations.
	• Electrification of urban rail tracks • Decarbonisation of long-distance and freight rail with hydrogen fuelled engines • Introduce electric inter-provincial and provincial buses • Replace fossil fuel based private vehicles with electric vehicles • Introduce electric charging points and necessary infrastructure	The actions proposed would be socially beneficial as long as they meet the transportation needs of the ordinary population including low-income travellers and other economically vulnerable groups (pensioners, people with disabilities, and women) Special needs of the above mentioned categories need to be considered in designing and planning.
	• Congestion charging for selected zones to discourage vehicles entering during peak hours	Law enforcement in vehicle emission control. Any cost increase should not overburden vulnerable populations including female breadwinners, elderly, and people with disabilities.

Sector	Proposed Actions in Carbon Net Zero Roadmap	Gender and Social Impact and possible Mitigation Measures to the Impending Problems
	• Prohibit roadside parking, increase parking fees in cities	Shuttle systems to commute from parking places especially designed for old, disable, women and needy population.
	• Improve the pedestrian infrastructure on collector type roads in the country • Promoting cycling	Safe and smooth pavements for pedestrians to walk to short distances and trolleys for convenient shopping Women's clothing could interfere in cycling. Policy decisions on safe dress code is important
	• Implement a price formula for petrol and diesel to reflect global petroleum prices and exchange rates	When revising the public transportation charges according a price formula, the possible impact on low-income populations should be addressed.
	• Park and ride system at main corridors for vehicles entering the city	Introducing reasonable charging systems considering the affordability of daily users.
Industry		All sectors mentioned depend heavily on female population and designing any new measures to reduce carbon emission should consider their possible impact on female working population
	• Promote Resource Efficient Cleaner Production (RECP) practices	Giving concessions for small scale industries and cottage industries which are mainly driven by women and middle-income populations considering their affordability
	• Establish eco-industrial parks and villages	Promoting incorporation of a larger female worker population while considering gender equity as a fundamental premise in this process
	• Adopt the Circular Economy concept	Gender equity also need to be taken into consideration
	• Introduce tri-generation facilities	A social and gender analysis will be highly important in carrying out this study

Sector	Proposed Actions in Carbon Net Zero Roadmap	Gender and Social Impact and possible Mitigation Measures to the Impending Problems
	• Providing strategic direction, oversight, support and sufficient resources to set and achieve targets • Incorporating net zero targets into core governance documented information (e.g. national policies, action plans, regulations etc.,), • Disclosing stakeholder need information and records on climate-related issues, if appropriate to the country and net zero emission targets, • Publicly committing to achieve targets as soon as possible through communication by the highest level of national leadership, • Clearly defining national leadership and sub level responsibilities, • Appointing competent members of the national leadership to	Facilitate entry access to women Such policy and planning level revisions towards carbon net zero targets should be on par with national policy on women (still in the draft form). Gender equality in defining national and sub-level leaderships and also the inclusion of different stakeholder categories including vulnerable groups in decision making levels. In all decision-making bodies, it is highly necessary to have gender focal points and ensure all stakeholder groups are represented.

Sector	Proposed Actions in Carbon Net Zero Roadmap	Gender and Social Impact and possible Mitigation Measures to the Impending Problems
	take responsibility for net zero actions, • Ensuring competent persons are appointed to relevant roles and determining the frequency of updates to national leadership on climate-related issues and progress towards targets, • Designing and implementing incentives for delivering net zero targets with national sustainability benefits, • Ensuring consideration of actions needed to transition to net zero is prioritized at national level, • Publicly and regularly communicating transition plans, progress and further action needed	
	• Substituting clinker with other materials in cement production (Amendment Sri Lanka Standard Institute (SLSI) standards for cement production enabling the increase of ash and other similar materials as substitutes for clinker)	

Sector	Proposed Actions in Carbon Net Zero Roadmap	Gender and Social Impact and possible Mitigation Measures to the Impending Problems
	• Implement polluters pays principle	Identifying the actual polluter is extremely important
Waste	• Reduction of the waste amount at the source • Avoid & Reduce MSW generation Growth from source • Avoid & Reduce Wastewater generation Growth from industries • Introducing MSW Segregation categories, Improving waste collection and transportation problems • Improving laws, rules, and regulations and formulating economic measures to create motivation for waste reduction • Supporting deposit & refund systems for plastic bottles, glass bottles, Aluminium bottles, etc. • Encouraging entrepreneurs to reduce disposable waste container sales and promoting safe reuse containers • Promoting food waste separation at source, obviously after avoiding the waste as much as possible	At the outset, the central government as well as the local government authorities should lay out a systematic waste disposal plan that would convince people of the commitment of the relevant authorities. The most needed community support for the reduction of waste at various levels could more easily be sought after when the public could place trust on the authenticity of official commitment. Awareness raising among women on waste management imparting necessary knowledge on the subject. The management in all relevant sectors should be given the specific knowledge on the reduction of waste. It should be made an important segment of the sectoral management. Develop a local government-level strategic plan with the inclusion of relevant stakeholders and raising awareness among the local community on the waste production and disposal

Sector	Proposed Actions in Carbon Net Zero Roadmap	Gender and Social Impact and possible Mitigation Measures to the Impending Problems
	2. Promote recycling and use of recycled materials • Create awareness among industrialists that improve materials and material flows like reuse and recycling • Waste into reverse-engineered products • Mandate recycled content requirements and waste reduction measures	Programs to encourage communities to recycle and use recycled material, adopting measures such as providing incentives and promoting the use of low-cost recycle material
	3. Promote Circular Economy in Supply Chains • Boosting the energy and resource efficiency of products, addressing the presence of dangerous chemicals in them • Enhancing the number of recycled materials in products while maintaining their functionality and safety; facilitating remanufacturing and superior recycling • Limiting single-use and combating premature aging • Putting a stop to the destruction of durable items that have not sold	• Raise awareness among people about separating waste in the dangers that could have created during waste disposal processes. • Awareness raising campaigns in schools and communities and incorporate such programs into Community-based Organization (CBO) activities. • A system for purchasing and reusing such items. Competitive programs getting people involved in choosing/voting for the best sustainable products

Sector	Proposed Actions in Carbon Net Zero Roadmap	Gender and Social Impact and possible Mitigation Measures to the Impending Problems
	• Encouraging business models that allow producers to retain ownership of the product or accountability for its performance over its entire lifecycle • Products should be rewarded depending on their various sustainability performance • Design for deconstruction in such a way that the materials used for construction can be reused in new construction with minimum alterations	Business ventures to promote to recycle construction material and give adequate publicity to such businesses attracting public attention
	4. Efficient waste management • Supporting provincial administrative organization clustering to make waste management systems, reuse systems • Restrict outdoor burning and improve the operation of clean development mechanisms • Addressing the prevalence of microplastics in the environment • Establishing and standardizing	Establish village-level plastic collection centres/bins and raising awareness among women and school children. Efficient waste collection programs and effective community awareness programs Popularize alternative material

Sector	Proposed Actions in Carbon Net Zero Roadmap	Gender and Social Impact and possible Mitigation Measures to the Impending Problems
	measurement techniques for accidentally released microplastics, particularly from tires and textiles	
	5. Biochar used as carbon sequestration • pyrolyzing conversion of solid waste into biochar which supports the circular economy • Introducing biochar as a renewable energy resource such as carbon fuel cells, porous catalysts, bio-oil, biochar coal, syngas, etc.	Make renewable energy resources and necessary equipment available for easy access in the market for household use
	6. Hybrid fertilizer Production • Redirect MSW away from landfills so that it can be used as a supplement to fertilizer on agricultural fields so, aiding in preserving soil fertility and recycling trash • Combine Agricultural compost with MSW compost	Introduce programs for promoting the use of fertilizer produced out of MSW in market oriented and household agriculture
	7. Identifying the waste management activities and the emissions reduction opportunities that	Receive public support in identifying practical and sustainable waste management activities while benefiting from indigenous knowledge in reducing carbon emissions in everyday activities

Sector	Proposed Actions in Carbon Net Zero Roadmap	Gender and Social Impact and possible Mitigation Measures to the Impending Problems
	can be implemented in Sri Lanka • 3R practice as well as saving money, energy, and natural resources related to life cycle management • Introduce strategies on the national level to build an economy that keeps materials, products, and services in circulation for as long as possible	Implementing awareness raising programs at different levels in the community (schools, CBOs, and higher educational institutions) In national-level planning for a cleaner economy, inclusion of women at the planning level would be highly beneficial
	8. Promoting zero-carbon innovations • Offering National Research Grants for Zero Carbon innovations • Introducing zero-carbon building materials • Introduction of Carbon Adsorbing Materials	Adopting Participatory Research Appraisal (PRA) methods in research projects concerning such new products
Agriculture	• Choosing management practices that enhance productivity • Extending lactation periods of dairy cows; • Using more efficient breeds • Improving reproductive performance; and	Imparting necessary knowledge on methods proposed under this measure to the population involved with the sector, especially to women and younger generations who could be a massive resource pool. Patriarchal domination in the agricultural sector often does not allow women to become decision makers concerning utilization of new methods. Therefore, consultations at the ground level using

Sector	Proposed Actions in Carbon Net Zero Roadmap	Gender and Social Impact and possible Mitigation Measures to the Impending Problems
	• Increasing rates of gain in beef animals so they reach the market sooner	participatory approaches would be important in promoting not only the inclusion of women in decision making, but also deriving indigenous knowledge that can be integrated in moving into new systems
	• **Effective Land management practices** ▪ Reduction in tillage. ▪ Restoring degraded land, improving pasture management. ▪ Reducing fallow periods. ▪ Adding animal manures to the soil ▪ Crop residue management ▪ Using legumes and/or grasses in crop rotations. ▪ Converting marginal cropland to perennial grass or agroforestry systems ▪ Using rotational grazing and high-intensity/short-duration grazing. ▪ Planting shrubs and trees as shelterbelts. ▪ Restoring wetlands	In implementing all these activities, community involvement and support would be highly beneficial to ensure effective results. In gaining community support, the programs need to include visible short-term and long-term benefits to the community.

Sector	Proposed Actions in Carbon Net Zero Roadmap	Gender and Social Impact and possible Mitigation Measures to the Impending Problems
Forestry	• Establish new forests (afforestation) • Restoration and reforestation	Increased women's involvement in identification and implementation process. Achievable through women's societies and CBOs on a voluntary basis and could provide a leisure activity for women without overburdening them
	• Protection of existing natural forests and forest plantations	Inclusion of local communities and women in developing sustainable management of natural forests. Incorporate indigenous knowledge in the planning process Inclusion of local communities and women in all these activities from planning to implementation Awareness raising of the communities and the involvement of Community-based Organizations is highly important Community consultations with affected communities could be used as a major tool in identifying and prioritizing hazards and their impacts
	• Increase the contribution of trees outside forests	Awareness raising among all groups such as local communities, religious congregations, school children and getting their involvement and participation at various levels of the process
	• Increase blue carbon ecosystems such as mangroves, seagrass beds and salt marshes	Benefit from the interest and knowledge women have about their local surroundings in coastal areas in restoration of mangroves Incorporate in the school curriculum and local schools could be integrated in the entire process as part of their field-based studies giving stake to local communities in the process

4.8 Issues and Constraints and Policy Gaps on Achieving Net Zero Status of Sri Lanka

4.8.1 Energy Sector

Successful decarbonization of the energy sector would require alignment of the political and economic forces in a productive manner. In order to support the rapid development of nuclear energy, certain regulatory requirements have to amended. At present the Sri Lanka Atomic Energy Regulatory Council is empowered only for regulation of non-power uses of radiation. Furthermore, development of a firm Government policy is required for the consideration of Nuclear Power as a power source in the future energy mix. Establishment of a Nuclear Energy Programme Implementing Organization (NEPIO) or any other responsible organization is required for the future study/planning activities of the nuclear power programme in Sri Lanka. Following options can be considered to implement regulatory requirements.

- Promulgation of a new Act and Establishment of a new regulatory body with adequate human and other resources for regulation of Nuclear Power Plants.
- Amendment of the existing Sri Lanka Atomic Energy Act No.40 of 2014 to include regulation of nuclear power and strengthen the manpower and other resources

A clear and strong policy directive is necessary in the nuclear energy sector (similar to government no-coal policy) to incorporate nuclear power as mainstream scenario in the LTGEP.

Knowledge of alternative technologies have been increasing in recent years through increased awareness of climate change. However, there is still a significant lack of knowledge regarding low-carbon technologies compared to traditional fossil fuel heating systems among the policy makers, administrators, officers and general public. Industry skills must incorporate a holistic approach to ensure an efficient installation without unintended consequences. Therefore, it is essential to build a competent workforce capable of designing, building, and retrofitting to deliver energy efficient, net zero carbon systems in the energy sector.

Sri Lanka’s potential for cross border energy trade lies with its immediate neighbor, India. The proposal for bilateral energy trade has centered around the proposed India-Sri Lanka High Voltage Direct Current (HVDC) grid interconnection project, aimed to link the national grids of India and Sri Lanka. However, the viability of the project has come under scrutiny on the basis of the limited potential for electricity trade and the high cost that may be incurred in terms of the infrastructure. Public-private partnership (PPP) can be a way forward to move this type of project, where certain amendments to be made to the present electricity act.

Therefore, the willingness at the political level backed by robust analysis is expected to move the aspiration towards faster actions to meet this ambitious, yet achievable target. There are many interesting aspects related to the political economy that must be anticipated and responded to in a strategic way. These include loss of fiscal resources for fossil-dependent states, loss of revenue for certain agencies such as Lanka Coal Company, Ceylon Petroleum corporation and other associated agencies. Dealing with entrenched interest groups and labour unions is expected to be a major political economy challenge that Sri Lankan policymakers would need to face for a net zero transition in the energy sector.

As finance accessibility and sufficiency are among the key challenges for carbon net zero in energy sector, particularly the widespread deployment of RE and other clean energy deployments, it is essential to explore the different and innovative financing schemes and sources available to facilitate such developments. The lack of knowledge and capacity in the sector including the local financial institutions on new opportunities such as Green Financing. is one of the key constraints in the energy sector.

Lack of long-term, consistent, and effective policy and regulation, which exists to drive the energy sector to net zero is the centrepiece of the gaps in policy. The Government and Industry must work together to setting out the policies and programmes required with realistic timescales for implementation, which drives the sector to achieve Net-Zero target. Therefore, there is a need in energy sector for a comprehensive appraisal of the policy and regulatory environment (both sectoral and crosscutting) and introducing relevant revisions in the related policy elements to achieve the Net-Zero target.

Some of the key general and specific areas that should be considered include: (i) Ensuring proper assessment and monitoring of related policy implementations; (iii) Eliminating regulatory barriers and streamlining the associated processes; (iii) Introducing clear policy directives and guidelines on RE resource allocations, speedy project approval procedures for clean energy; (iv) proper and consistent process for RE and other clean energy procurement in power sector; (vi) Introducing power wheeling schemes, particularly for RE.

It is necessary to establish a platform for the market by proposing and implementing standardised market integration and transparency frameworks that facilitate competitive markets. Further, establishment of formal market-based trading arrangements, supported with harmonized and coordinated commercial, regulatory, and legal framework, is required to realize set targets in energy sector. Furthermore, shift from a single buyer to a wholesale model or retail competition for the power sector and electricity trade, is also identified as a policy gap in the energy sector.

4.8.2 Transport Sector

Policy issues

Policy-wise, the transport sector is significantly lagging behind other sectors. There is no national policy for the transport sector of the country, that will guide the strategies and projects that are to be implemented. The draft National Transport Policy which is under review since 2019 needs to be finalized soon and gazetted.

Often, projects on an ad-hoc basis are considered due to the lack of finance available with the government for transport infrastructure development. As a solution, like many other countries, public-private partnerships (PPP) are brought into the discussion. However, the capacity building (amongst relevant state institutions), regulatory and legal requirements, and accurate information availability with respect to costs/demand projects that are necessary for successful PPP implementation have not materialized in the transport sector.

In addition, the integration of transport-related organizations' national development plans is also essential since some individual organizations' decisions might affect the transport needs of the users directly. For example, decisions taken by the UDA on land use changes affect the transport needs of the people in the surrounding area. Thus, with a broader level of consultation of all stakeholders, the development of a national transport plan is key to achieving the objectives of this project. One positive development in this regard is the formation of one ministry, 'Ministry of Highways and Transport' that includes all the major transport sector stakeholders.

Financing

The estimated financial cost of the proposed initiatives is likely to exceed US $ 6-7 bn over 20 year period. Not only that there would be additional fund requirements for operations and maintenance. The government's fiscal capacity to invest at this magnitude must be evaluated considering the other economic issues in the country.

Data Availability

Major shortcoming is the lack of transport sector data including accurate vehicle-kilometer estimation for private vehicle modes at national and provincial levels. Moreover, the trip characteristic data such as trip purpose, mode choice distribution based on passenger kilometers at national level would be useful.

The active vehicle fleet in the country also needs to be accurately estimated, the current data includes the vehicle registrations (cumulative) and the revenue license issued which can be used to estimate the active fleet as a percentage of the total registered vehicles.

The emission levels of different types of vehicles should be accurately evaluated using the Vehicle Emission Test Data and additional validation studies to determine how specific taxing instruments can be implemented to discourage vehicles with poor emission related performances in the long term.

The initiative taken by the National Transport Commission to publish annual report with transport statistics is an encouraging sign, this should be further improved with expanding the data collection and analytics and providing an online tool to access the data.

4.8.3 <u>Industry Sector</u>

Issues and constraints relevant to achieving proposed targets in the industry sector will be analyzed through the following areas (but not limited to) and remedial measures will be proposed.

Immediately recognized issues and constraints relevant to achieving industry net zero targets are as follows:

- Industry sector Policy issues/gaps

- Lack of national industry umbrella policy
- Though some of the existing policies as mentioned in Section 1.4.3 are highly relevant to the industry sector emission reductions, due to long term negligence and lack of updates with respect to climate change mitigation needs, there are major gaps in the policy environment (Ex National cleaner production policy).
- In addition to the existing policies, as Circular Economy is one of the main bridging strategies between climate net zero mechanism and sustainable development, especially in the industry sector, national circular economy policy and action plan covering all national economic sectors will be a major policy need. Though certain policies such as "national policy and strategy on sustainable development" are still given low priority to finalize (since 2019 it is in draft stage). Under the prevailing economic crisis, it will be worth in considering the sustainability opportunities behind these emission mitigation issues (Ex. Optimising the glass cullet recycling in national glass industry and glass industry process emission reduction).
- In addition to the policy gaps, unavailability of a national action plan based national MRVU (monitoring, reporting, verification and update mechanism) is proposed as a major gap in national climate change responses.

- BOI industry policy (with a priority on investment promotion and economic development concerns rather than promoting low-carbon industry proposals)
- Lack of sustainability guidelines in setting up individual industry/industry parks with appropriate sustainable economic analysis and incentives to promote the low-carbon industry,
- National-level recognition of low-carbon industries and their sustainability impacts
- Lack of promoting/attracting low carbon options such as Co-generation / tri-generation, district heating/cooling, and benefits
- Availability of Resources
- Institutional constraints
- Technology/ knowledge

4.8.4 Waste Sector

There are several issues and constraints in achieving the targets and the primary issue would be the unavailability of a centralized data management system which is common for all the responsible authorities. Meanwhile, the so-called database should be organized in such a way that the data are updated in real-time and open to the public, and researchers which enables continuous research with the relevant data.

Moreover, there is no proper waste management and whatever is available is planned and implemented weakly which can be further expedited. There is a lack of commitment by all parties concerned lack of financial resources/assistance and a lack of public awareness. Also, there is a lack of Political will & conflicts of local level politics and a lack of Institutional capability with technical expertise. Unavailability of Suitable lands for waste disposal, weakness of collection system, no proper collection system of recyclable waste, haphazard dumping of SW in unsuitable locations e.g. roadsides, wildlife protected areas Wetlands, flood retention areas, water courses, and no proper environmentally sound waste disposal practices are few issues for MSW disposals.

Furthermore, paying the least attention to SW problems in the majority of LAs, legal provisions and role designation, the overlap of administrative functions at national, regional, and local levels, Outmoded laws and regulations, the weak or total absence of monitoring by civic authorities / civil society and public apathy are some issues where more attention is needed. Medical issues such as health issues (stray dogs, breeding grounds for mosquitoes and flies)and Loss of aesthetic values & scenic beauty, water pollution (both surface and ground water)through leachate and run-off, air Pollution by dioxins, particulates, and hydrocarbon combustion emissions by open burning due to incomplete, odor problems and open dumping of biomedical wastes could cause epidemics.

The ever-increasing demand for land required for solid waste disposal, and the uncontrolled release of landfill gases from dumps and non-engineered landfills are concerning issues. Currently, MSW is disposed of together with hazardous waste, biomedical/ health care waste etc., (Mixed waste) creating huge health and environmental issues and the provision of infrastructure facilities and suitable lands are the main requirements of Local Authorities for integrated solid waste management practices.

While the existing policies, strategies and action plans related to the waste sector, as described in section 1.4.1 aimed at environmental pollution control does help in the actions for reduction of GHG emissions to some extent, there are specific policy instruments that are needed to achieve national net zero targets with the community and institutional involvement. These were identified as gaps during the discussions with the stakeholders at the two meetings held with sector stakeholders.

Policy gaps identified during the 1st stakeholder meeting

1. The National Waste Management Policy should be amended to
    - Improve the segregation of MSW at source and increase the number of segregation categories
    - Clearly define the purpose of waste-to-energy projects and plan the phasing out of preferential feed-in-tariffs
    - Introduce other thermal treatment technologies
    - Introduce Land-fill Gas recovery systems
2. Policies should be introduced to regulate the establishment of new waste-to-energy facilities
3. Operationalize policy and regulation for siting and implementation of sanitary landfills
4. Update or introduce the required legislation to facilitate and enforce the implementation of NDCs

5. Introduce a mechanism for waste generation forecasting with a tracking system to monitor the generation
6. Introduce legislation to make segregation of waste at the household level mandatory
7. Introduce or amend necessary legal framework and instruments to initiate Market-Based Instruments (MBIs) and non-market-based instruments to incentivize and promote sustainable consumption patterns
8. Implement the “Polluter Pays Principle” for mixed waste generators
9. Conduct awareness and capacity-building programs for behavioral changes in waste generators as well as waste management personnel
10. Facilitate public-private-partnerships to finance waste sector mitigation actions

At the second stakeholder meeting, in addition to the gaps in national policies, the following were identified as gaps that need to be addressed for the successful implementation of the mitigation actions proposed for achieving Carbon Net Zero status:

- Staff training
- Availability and access to technology
- Infrastructure
- Institutional framework
- Financial constraints
- Administrative issues
- Research needs
- Baseline data needs
- Future Data gathering mechanisms
- Need for local technology development & transfer of technology

4.8.5 <u>Agriculture Sector</u>

The project plans to establish a Road Map and a Strategic Plan with the acceptance of all concerned stakeholders on its effective and meaningful implementation while developing set of policy guidelines anchored on the strategic plan collaborating all levels of the administrative entities of the Government of Sri Lanka. Further to that, country is planning to achieve the balance between the amount of carbon produced and the amount removed from the atmosphere or activity that releases net-zero carbon emissions into the atmosphere by primarily reducing its emissions of greenhouse gasses into the atmosphere and increase its carbon dioxide-absorbing ecosystems. Climate Analysis Indicators Tool published by the World Bank (WRI CAIT), Sri Lanka's GHG profile in 2011 was dominated by the energy sector (40%), followed by the waste (28%), land use change and forestry (LUCF) (15%), agriculture (14%) sectors and transport sector (20%).

i. Policy issues

If the targets set by the National Agriculture Policy by 2030, it means that resources productivity and economic profitability would increase by 100% and it is comparable to section 2 of the NDC 2030, where it stresses the importance of identifying crops/ varieties with high productivity, adopting good agricultural practices (GAP), increasing the land use productivity, improving fertilizer use-efficiency, improving water use efficiency and promoting precision agriculture. Further, the policy goals set target to increase technology adoption and high quality and high yielding seed and planting material production by 50%.

However, the institutions responsible for such achievements in agriculture mentioned at the First Stakeholder Workshop held on 23rd October 2022, that there are still policy gaps in following NDC 2030 activities.

Institution	Activity	Policy gaps for sub activities
Department of Animal Production and Health	Improve adoption of renewable energy in agriculture	Application of solar power and wind energy Promote grid electricity use
	Adopt renewable energy for livestock applications	
Coconut Cultivation Board	Increase crop productivity	Increase land use productivity Improve fertilizer use-efficiency Improve water use efficiency

At the Second Stakeholder Workshop held on 18th November the Ministry of Agriculture reiterated that although they have resources (finances, manpower, technical knowledge) those are not adequate to review the present policy by 2025. They also have constraints such as lack of coordination among institutions, complexity, and lack of awareness within institutions. They need the support of International Organizations (FAO, UNDP, JICA, and WFP etc.), NGOs, and other organizations such as RRI, CRI, TRI, CCB, DOA, DAD, DEA etc.

Ministry of Livestock Development has also expressed the same concern on resources availability and they also need support of other institutions such as NLDB, Research Institutes, MILCO, Provincial DAPH, Irrigation Dept., Mahaweli, Universities etc.

Ministry of Irrigation and Ministry of Land are responsible for the review of the policy on Irrigation, Land Use and make recommendations to minimize GHG emissions. These Ministries can review the policies by 2025 but they are constrained with resources such as finances, manpower, technical knowledge etc. Supporting agencies are CEA, UDA, Ministry of Environment and they need further support from NBRO and Universities.

ii. Availability of Financial Resources

Some institutions had to curtail their programmes due to restrictions of annual budgetary allocations. Without any external support some programmes would not be possible to implement. However, certain projects support institutes to continue their programmes. This resources constraint has been brought up by the institutes at the first stakeholder workshop of the Carbon net zero project as follows.

Institution	Activity	Financial Constraints for sub activities
Department of Agrarian Development	Improve adoption of renewable energy in agriculture	Promote grid electricity use
Department of Animal Production and Health	Improve adoption of renewable energy in agriculture	Application of solar power and wind energy Promote grid electricity use
Coconut Cultivation Board	Increase crop productivity	Adopt GAP Increase land use productivity Improve fertilizer use-efficiency

iii. Institutional constraints

Main institutes working on NDC undergo several constraints that hinder the success of achievements especially policy gaps, staff, infrastructure and proper technologies. However, the institutes that responded seem to be having not much institutional constraints. As stated by institutions at the 1st Stakeholder Workshop, following institutional constraints for achieving NDC 2030 are faced by them.

Institution	Activity	Institutional constraints for sub activities
Department of Agrarian Development	Reduce post-harvest losses and value addition	Cultivation management Post-harvest management Excess production management
	Improve adoption of renewable energy in agriculture	Promote grid electricity use
Department of Animal Production and Health	Improve adoption of renewable energy in agriculture	Application of solar power and wind energy Promote grid electricity use
Coconut Cultivation Board	Increase crop productivity	Increase land use productivity Improve fertilizer use-efficiency Improve water use efficiency

iv. Technology/ Knowledge

Proper technology, available knowledge base and effective dissemination process are constraints of some institutes in the agricultural sector in achieving NDC goals. It stresses the importance of capacity building for these institutions. This was brought up at the 1st Stakeholder Workshop.

Institution	Activity	Technology/ knowledge requirement for sub activities
Department of Agrarian Development	Improve adoption of renewable energy in agriculture	Promote grid electricity use
Department of Animal Production and Health	Improve adoption of renewable energy in agriculture	Application of solar power and wind energy Promote grid electricity use
Coconut Cultivation Board	Increase crop productivity	Increase land use productivity Improve fertilizer use-efficiency Improve water use efficiency

Productivity of agricultural crops can be increased through Good Agricultural Practices, increasing land use productivity of paddy lands, increasing soil fertility of crop lands, increasing water use efficiency in crop production, integrated farming systems, intercropping and agro-forestry systems approach. However, Agencies such as MoA, MPI, DoA, DEA, EDB are in the opinion that they do not have adequate resources such as finances, manpower, technical knowledge for successful implementation.

Another strategy is to promote crop diversification. Again responsible agencies such as DOA, DEA, Private Sector Organizations and EDB express their concern on inadequacy of resources such as finances, manpower, and technical knowledge for implementing the Carbon Net Zero approach.

As policymakers look toward including strengthened agriculture actions in an enhanced NDC, it is important that they first lay the foundation through enhanced policies, finance, and governance. Doing so will help ensure that proposed mitigation actions are tailored to the country's unique set of circumstances and needs and are aligned with a broader set of food security, equity, and sustainable development imperatives, thus maximizing the chances of successful implementation. This includes the following:

- Scoping the national context – As spatial variability across the country on geography, economy and social aspect, any Carbon net zero should avoid a blueprint approach and carefully consider key characteristics of a country's agriculture sector. This considers national production and consumption trends of crops and livestock, as well as the types and sizes of producers.
- Involvement of Stakeholders – Involving stakeholders even at the beginning to strengthen the legitimacy, quality, and durability of the Carbon net zero targets of 2050. Stakeholders include not only relevant government ministries but also farmers, so that diverse perspectives, needs, and priorities are incorporated. Small-scale agriculture producers, especially women and women's organizations, should be explicitly included, which requires targeted and sustained attention from policymakers. Likewise, it is important to engage stakeholders that will be responsible for the implementation of agricultural climate action.

- Establishing policy coherence – Sri Lanka can consider progress made toward implementing existing goals and policies, and their coherence with other relevant plans, including other climate policies.
- Strengthening measurement, reporting, and verification – In the agriculture sector planning for mitigation, adaptation, and support is foundational for designing C net zero targets. Updated information base provides accessible, understandable, relevant, and timely information and data to inform the design of new climate targets and policies. It deepens the understanding about actions to address climate change to discern what works, what does not, and why. Such effort can also be a useful communication tool for motivating climate change action, both within government and among external stakeholders.
- Identifying opportunities for support – Sri Lanka requires support to fully implement agricultural contributions to achieve C zero targets. This includes access to international climate finance, as well as local support such as improved extension services for farmers, including more widespread use of digital services such as early warnings and seasonal forecasts, and redirecting agricultural support to improve agricultural resilience and reduce emissions. The net zero enhancement process offers an opportunity to identify needs and attract support.
- Ensuring equitable, inclusive governance – It is important to anticipate whether and how proposed activities benefit or harm lives and livelihoods when advancing agricultural climate action. Careful design of incentive structures and finance flows can help facilitate equitable benefit sharing, while safeguard measures and rights-based approaches can help minimize harms.

Following specific aspects are also required to be considered:

1. Settlement policy to manage available land for future human settlements enabling release of more land for cultivation and reforestation. (Gunasena, 2020)
2. National water resource policy to enrich groundwater resource in agricultural lands to enable integrated water resources facilitating the intensification of agriculture on existing lands discouraging opening up of new lands for agriculture and improve agro-ecosystems, while increasing bio-diversity;
3. Development of shallow groundwater to support not only deep-rooted vegetative systems but also encourage shallow rooted bushy type vegetation. Ultimately, this will enhance the entire biodiversity of Sri Lanka and will contribute to carbon sequestration positively. Hence, development of a policy initiative for groundwater recharging will enhance the utilization and replenishment efficiency of surface and subsurface water resources;
4. Policy initiatives to establish fruit gardens and medicinal plant gardens for reforestation activities to safeguard vanishing native fruits and medicinal species while managing above and below soil carbon stocks;

5. It is very clear now that the vegetation of central highlands becomes sparse due to lack of soil carbon stocks and depleting groundwater table. Most of the first order streams within plantations are drying and have been already converted from perennial to seasonal. Therefore, policies must be formulated to establish a Hydrology Unit or section or laboratory in all major plantation research institutes (Tea, Rubber, Coconut etc.) to regain the lost groundwater balance from the central hills; and
6. According to statistical evidences, Sri Lanka is having nearly 5,100,000 families, and most of the families will have land plot having at least 0.3 hectares. Most of the land areas belonging to these families consist of a live fence. Country wide development program could be implemented to upgrade these fencing systems to a fencing ecosystem having fruits, timber and medicinal plants, which need less fertilizer. Necessary policy initiatives must be formulated to establish these live fences wherever possible to increase the carbon sequestration process.
7. Necessary policy initiatives must be drafted and formulated to get the maximum contribution from the Sri Lankan inventors to overwhelm the technology barriers. A comprehensive problem database must be developed with the participation of Sri Lanka Inventors Commission (SLIC) enabling all entrepreneurs to feed their technical problems to a government managed web base/ database, while allowing local and foreign inventors to find those problems and provide appropriate solutions to the burning technical problems. This will boost the agricultural and industrial sectors in Sri Lanka within a short period of time with cost effective local technological solutions.

Most of the development programs were planned by the government or nongovernmental organizations with minimum community participation. Since the community is responsible for the implementation and monitoring of almost all these development plans, the responsibility must be shared with the community to manage the sustainability by blending those programs with the ecosystem services and the resilience of all ecosystems. Hence, necessary policy initiatives must be formulated to bring the appropriate management systems and blend with the community participation appropriately.

4.8.6 Forestry Sector

In order to reach the targets for emission control and enhanced sequestration of carbon, it is essential that the necessary environment and infrastructure are available. Following issues are some of the constraints envisaged to be barriers to achieving the set targets in the sector:

- Sub optimal availability of lands for reforestation/afforestation and land for such purposes are constantly competing with the other non-forest land uses

- The actual implementation on the ground does not follow the plans including National Physical Plan and therefore the areas allocated for forests do not materialize on the ground sometimes

- With regards to trees outside forests and mangroves which provides a significant contribution for carbon sequestration, there are many policy and regulatory gaps, death of institutional responsibilities etc.

- Climate change with special reference to drought which adversely impact the forests

- River catchments and reservations are not in place and mostly used for agricultural practices

- Lack of political will, financial resources, manpower and technology for implementation of mitigation actions.

SECTION 5 : CARBON NET ZERO ROAD MAP

5.1 Pathway for achieving Net-Zero Carbon emissions by 2050

Implementation of strategies and actions set out in Section 4 of this report for the six sectors Energy, Transportation, Industry, Waste, Agriculture and Forestry according to the planned program would drive the country towards achieving Carbon Net Zero status well before 2050, if the necessary policy framework, good governance, funding, infrastructure and institutional set up is provided in a timely manner. This section summarizes the pathways for emission reduction and increased sequestration over the period 2025 to 2050 that need to be followed sector wise, and the lead agencies that should take the responsibility for the implementation of actions.

5.1.1 Energy Sector

Table 5.1: Five year Interval Plan in Energy Sector for Option 1 (With Nuclear PP)

Period	Mitigation Action		Responsibility
2025-2030	Adding following Power Plants for Power Generation		
	Pumped Storage	700 MW	MoPE/CEB
	Mini Hydro	135 MW	MoPE/CEB/SLSEA
	Biomass	120 MW	MoPE/CEB/SLSEA
	Wind	1390 MW	MoPE/CEB/SLSEA
	Solar	3015 MW	MoPE/CEB/SLSEA
	Battery Energy Storage	725 MW/2900 MWh	MoPE/CEB
	Retirement of following Thermal Plants for Power Generation		MoPE/CEB
	Diesel	437.4 MW	
2031-2035	Adding following Power Plants for Power Generation		
	Pumped Storage	700 MW	MoPE/CEB
	Mini Hydro	50 MW	MoPE/CEB/SLSEA
	Biomass	90 MW	MoPE/CEB/SLSEA
	Wind	800 MW	MoPE/CEB/SLSEA
	Solar	2420 MW	MoPE/CEB/SLSEA
	Battery Energy Storage	675 MW/ 2700 MWh	MoPE/CEB
	Nuclear	2x300 MW	MoPE/CEB/ SLAEB
	Adding Cross Boarder Interconnection	500 MW	MoPE/CEB
	Retirement of following Thermal Plants for Power Generation		
	Diesel	191.7 MW	MoPE/CEB
	Diesel/Natural Gas	398 MW	MoPE/CEB

Period	Mitigation Action	Responsibility
	Introduction of Green Hydrogen	SEA/PRDS
2036-2040	Adding following Power Plants for Power Generation Mini Hydro 40 MW Biomass 50 MW Wind 750 MW Solar 2650 MW Battery Energy Storage 515 MW/ 2060 MWh Nuclear 1000 MW Retirement of following Thermal Plants for Power Generation Diesel 300 MW	 MoPE/CEB MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB MoPE/CEB/ SLAEB MoPE/CEB
2041-2045	Adding following Power Plants for Power Generation Biomass 120 MW Wind 950 MW Solar 2830 MW Battery Energy Storage 625 MW/ 2500 MWh Retirement of following Thermal Plants for Power Generation Coal 900 MW	 MoPE/CEB MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB MoPE/CEB
2046-2050	Adding following Power Plants for Power Generation Biomass 150 MW Wind 1300 MW Solar 3150 MW Battery Energy Storage 625 MW/ 2500 MWh Adding Cross Boarder Interconnection 500 MW Retirement of following Thermal Plants for Power Generation Diesel/Natural Gas 895 MW	 MoPE/CEB MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB MoPE/CEB SEA/PRDS

Table 5.2: Five year Interval Plan in Energy Sector for Option 1 (Without Nuclear PP)

Period	Mitigation Action	Responsibility
2025-2030	Adding following Power Plants for Power Generation Pumped Storage 700 MW Mini Hydro 135 MW Biomass 120 MW Wind 1390 MW Solar 3015 MW Battery Energy Storage 725 MW/2900 MWh Retirement of following Thermal Plants for Power Generation Diesel 437.4 MW	 MoPE/CEB MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB MoPE/CEB
2031-2035	Adding following Power Plants for Power Generation Pumped Storage 700 MW Mini Hydro 50 MW Biomass 90 MW Wind 1200 MW Solar 3350 MW Battery Energy Storage 850 MW/ 3400 MWh Adding Cross Boarder Interconnection 500 MW Retirement of following Thermal Plants for Power Generation Diesel 191.7 MW Diesel/Natural Gas 398 MW Introduction of Green Hydrogen	 MoPE/CEB MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB MoPE/CEB MoPE/CEB MoPE/CEB SEA/PRDS
2036-2040	Adding following Power Plants for Power Generation Mini Hydro 40 MW Biomass 50 MW Wind 2050 MW Solar 4700 MW Battery Energy Storage 1175 MW/ 4700 MWh Retirement of following Thermal Plants for Power Generation Diesel 300 MW	 MoPE/CEB MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB MoPE/CEB
2041-2045	Adding following Power Plants for Power Generation Biomass 120 MW Wind 2050 MW	 MoPE/CEB MoPE/CEB/SLSEA

Period	Mitigation Action		Responsibility
	Solar	4550 MW	MoPE/CEB/SLSEA
	Battery Energy Storage	1140 MW/ 4560 MWh	MoPE/CEB
	Retirement of following Thermal Plants for Power Generation		
	Coal	900 MW	MoPE/CEB
2046-2050	Adding following Power Plants for Power Generation		
	Biomass	150 MW	MoPE/CEB
	Wind	2800 MW	MoPE/CEB/SLSEA
	Solar	3300 MW	MoPE/CEB/SLSEA
	Battery Energy Storage	825 MW/ 3300 MWh	MoPE/CEB
	Adding Cross Boarder Interconnection	500 MW	MoPE/CEB
	Retirement of following Thermal Plants for Power Generation		
	Diesel/Natural Gas	895 MW	SEA/PRDS

5.1.2 <u>Transportation Sector</u>

Table 5.2: Five year Interval Plan in Transportation Sector

Year	Actions	Responsible Organizations
2025-2030	Improve the pedestrian infrastructure on collector type roads in the country Construct cycling infrastructure island wide	Urban Development Authority, Road Development Authority, Provincial Road Development Authorities
	Promoting remote working	Ministry of Labour, Ministry of Finance, Ministry of Public Administration
	Modernizing the bus fleet* (up to year 2040)	Ministry of Transport
	Implement a price formula for petrol and diesel to reflect	Ministry of Finance, Ministry of Power and Energy

Year	Actions	Responsible Organizations
	global petroleum prices and exchange rates Transport Demand Management Strategies in Key Cities Implementation of LRT network in Colombo Railway Electrification KV line- Padukka Interprovincial Bus Electrification 10% of the Interprovincial buses electrified Provincial Bus Electrification None	 Local government agencies, Urban Development Authority Ministry of Transport Ministry of Transport Ministry of Finance, Ministry of Transport, National Transport Commission Ministry of Finance, Ministry of Transport, National Transport Commission
2031-2035	Railway Electrification Coastal line- Kaluthara Interprovincial Bus Electrification 20% of the Interprovincial buses electrified Provincial Bus Electrification None Private and Freight Vehicles Electrification (Equivalent to vehicles imports in 2018*1.25)	Ministry of Transport Ministry of Finance, Ministry of Transport, National Transport Commission Ministry of Finance, Ministry of Transport, National Transport Commission Ministry of Transport, Ministry of Finance
2036-2040	Railway Electrification Puttalam line- Ragama	Ministry of Transport

Year	Actions	Responsible Organizations
	Interprovincial Bus Electrification 50% of the Interprovincial buses electrified Provincial Bus Electrification 10% of the Bus Fleet Private and Freight Vehicles Electrification (Equivalent to vehicles imports in 2018*1.5)	Ministry of Finance, Ministry of Transport, National Transport Commission Ministry of Finance, Ministry of Transport, National Transport Commission Ministry of Transport, Ministry of Finance
2041-2045	Railway Electrification Main line –Polgahawela Interprovincial Bus Electrification 75% of the Interprovincial buses electrified Provincial Bus Electrification 30% of the Bus Fleet Private and Freight Vehicles Electrification (Equivalent to vehicles imports in 2018*1.75)	Ministry of Transport Ministry of Finance, Ministry of Transport, National Transport Commission Ministry of Finance, Ministry of Transport, National Transport Commission Ministry of Transport, Ministry of Finance
2046-2050	Railway Electrification Northern line – Polgahawela Interprovincial Bus Electrification 100% of the Interprovincial buses electrified Provincial Bus Electrification 100% of the Bus Fleet	Ministry of Transport Ministry of Finance, Ministry of Transport, National Transport Commission Ministry of Finance, Ministry of Transport, National Transport Commission Ministry of Transport,

Year	Actions	Responsible Organizations
	Private and Freight Vehicles Electrification (Equivalent to vehicles imports in 2018*2)	Ministry of Finance

5.1.3 Industry Sector

Table 5.3: Five year Interval Plan in Industry Sector

Year	Actions	Responsible Organizations
2025-2030	Application of Cleaner production technologies in maximising productivity and the industry efficiencies and minimizing industry losses / waste	Relevant industries / private sector Ministry of industries Ministry of environment / Climate change secretariat BOI IDB Technology service providers Forest Department NGOs and multilateral donor agencies Private sector forest projects
2031-2035	Emission offsetting (by 25%) through forestry projects	
2036-2040	Emission offsetting (by 25%) through forestry projects and CCS projects	
2041-2045	Emission offsetting (by 25%) through forestry projects and CCS / CCUS projects	
2046-2050	Emission offsetting (by 25%) through forestry projects and CCS / CCUS projects	

5.1.4 Waste Sector

Table 5.4: : Five-year Interval Plan in Waste Sector

Year	Actions	Responsible Organizations
2025 – 2030	Daily cover for open dump site with Biochar (Continues until 2050) Expected GHG reduction, In 2026 – 70MT CO_2 – eq	SLLDC WMA-WP LAs

Year	Actions	Responsible Organizations
	In 2050 – 164MT CO_2 – eq	
	3R practice collection and reduction of waste generation at source. These practices are extended from NDC and improved to continue until 2050 Expected GHG reduction, In 2026 – 1.56 MT CO_2 – eq In 2050 – 6.60 MT CO_2 – eq	NSWMSC SLLDC WMA LAs
	Refunds & incentives for proper waste management	LAs
	Promote circular economy in supply chains	SLSEA SLAMERP SLAEA UNDP WMA
	Efficient waste management	LAs
	Hybrid fertilizer production and Subsidy free community-based composting	NSWMSC SLLDC WMA LAs
	Biogas from fecal sludge at community level	LAs BOI
	Introducing the waste management activities and the emissions reduction opportunities	LAs
2031-2035	Recovery of GHG from Open dumpsite to use it for the production of Syn Gas (Synthesis Gas) The implementation level begins at 10 % by 2031 and to be improved to 50 % by 2050 Expected GHG emission reduction In 2031 – 72 MT CO_2 – eq In 2050 – 738 MT CO_2 – eq This process to be continued until 2050 and beyond	NSWMSC SLLDC WMA LAs Private sector
2036-2040	Implementing a centralized Vertical Sub Surface Flow Constructed Wetland (VSSFCW) at a strategic location in the Western province to purify the wastewater biologically and re use the water to enrich the groundwater. Expected GHG emission reduction In 2036 – 4.6 MT CO_2 – eq In 2050 – 4.3 MT CO_2 – eq	CEA LAs CMC BOI Private sector

Year	Actions	Responsible Organizations
	Implementation of Electric vehicle for waste transportation and Route Optimization using Internet of Things (IoT) The vehicles to be charged with renewable energy. Expected total GHG reduction by 2050 1.5 MT CO_2 – eq	NSWMSC WMA LAs
	WtE plant 1 to be implemented strategically at a location Covering Central & North Central province to ensure energy production from waste that were unable to be recycled or reused. GHG reduction In 2036 – 143 MT CO_2 – eq In 2040 – 144 MT CO_2 – eq	Ministry of Power &Energy, LAs, CEB NSWMSC SLLDC WMA LAs Private sector
	Promote circular economy in construction industry	Department of Buildings SLSEA SLAMERP SLAEA UNDP WMA
2041 2045	WtE plant 2 to be implemented strategically at location covering Northern, Easter and North Central Province thus, the transportation of waste to the facility to be optimized. GHG reduction In 2041 – 287 MT CO_2 – eq In 2050 – 271 MT CO_2 – eq Two WtE plants are implemented to replace the Coal plants thus ensuring the net GHG emission reduction in the content of the net gain from moving towards sustainable practices. Moreover, both the WtE plants have to be equipped with Carbon Stacks to further replace the Carbon released to the atmosphere.	Ministry of Power & Energy LAs CEB NSWMSC SLLDC WMA LAs Private sector
	Promoting zero-carbon innovations	NRC
2046- 2050	A Sanitary landfill have to introduced to strategically dispose the unavoidable waste generated and that cannot be used as a fuel to the WtE plants. The expected GHG reduction by the facility is 63 MT CO_2- eq . by 2050.	NSWMSC WMA LAs CEA Private sector

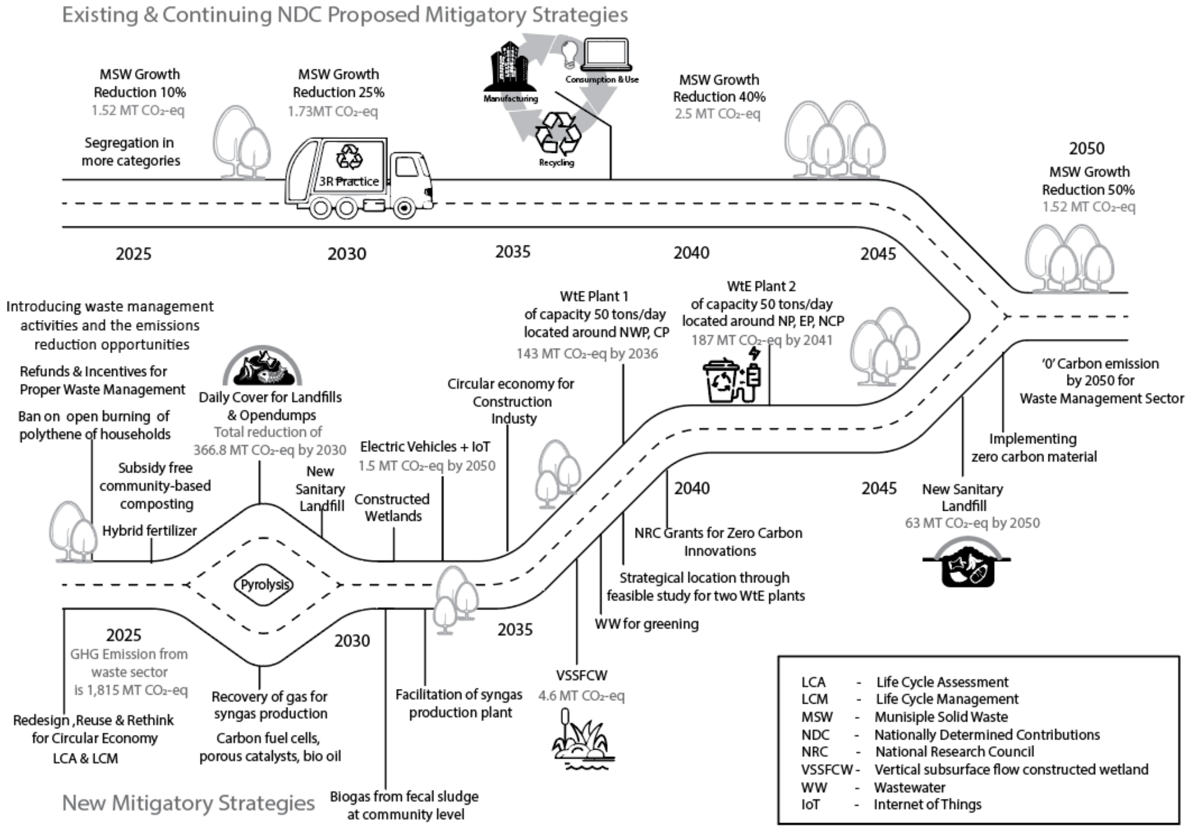

Figure 5.1 : Road Map for Waste Sector

5.1.5 Agriculture Sector

Table 5.5: Five-year Interval Plan in Agriculture Sector

Five-year plan for agriculture sector was developed to implement five main strategies namely, application of mitigatory measures for paddy lands, local and imported neat cattle, goats and sheep, managing soil to minimize direct and indirect N_2O emissions, restricting importation of Urea and carbon sequestration.

Timeline	Activity	Responsible parties
2025-2030	Strategy (i) Paddy land extent target: 147,750 ha (Yala and Maha) a. Removal of straws from paddy fields b. Manufacturing paper and different types of boards d. Production of bio fuel e. Packaging industry Strategy (ii) No. of heads (neat cattle/Goat/Sheep) target: 146,278 a. Feed quality improvement b. Night feeding and supply of water c. Animal comfort improvement (heat reduction, free roaming) Strategy (iii) N_2O reduction Giga tones 0.95 a. Manure management b. Soil tillage reduction Strategy (iv)	Strategy (i) National Paper Company Ltd,, Valaichchenai and Embilipitiya, Durra Building Systems (Pvt) Ltd Strategy (ii) Department of Animal Production and Health, National Livestock Development Board, Market Oriented Dairy Project Strategy (iii) Department of Agriculture Strategy (iv)

Timeline	Activity	Responsible parties
	Reduction of fertilizer: Urea 31,287 Mt a. Reduction of artificial fertilizer application Strategy (v) Lands under carbon Sequestration 2,155 ha	Department of Agriculture Fertilizer Secretariate Fertilizer Cooperation CIC, Bower Strategy (v) Department of Agriculture Department of Agrarian Services
2031-2035	Strategy (i) Paddy land extent target: 197,000 ha (Yala and Maha) a. Export of paddy straw b. Manufacture paper c. Manufacture boards d. Production of bio fuel e. Packaging industry Strategy (ii) No. of heads (neat cattle/Goat/Sheep) target 195,037 a. Feed quality improvement b. Night feeding c. Supply of Drinking water d. Animal comfort improvement (Heat reduction, Free roaming) Strategy (iii) N_2O reduction 1.27 Giga Tones a. Manure management	Strategy (i) Durra Building Systems (Pvt) Ltd Governmental and non-governmental organizations Kankasanthurai and Ambilipitiya paper mills Strategy (ii) Department of Animal Production and Health National Livestock Development Board Market Oriented Dairy Project Strategy (iii) Department of Agriculture

Timeline	Activity	Responsible parties
	b. Soil tillage reduction Strategy (iv) Reduction of fertilizer: Urea 41,716 Mt a. reduction of artificial fertilizer application Strategy (v) Lands under carbon Sequestration 2,155 ha	Strategy (iv) Department of Agriculture Fertilizer Secretariate Fertilizer Cooperation CIC, Bower Strategy (v) Department of Agriculture Department of Agrarian Services
2036-2040	Strategy (i) Paddy land extent target: 246,250 ha (Yala and Maha) a. Export of paddy straw b. Manufacture paper c. Manufacture boards d. Production of bio fuel e. Packaging industry Strategy (ii) No. of heads (neat cattle/Goat/Sheep) target 243,796 a. Feed quality improvement b. Night feeding c. Supply of Drinking water d. Animal comfort improvement (Heat reduction, Free roaming) Strategy (iii) N_2O reduction 1.58 Giga Tones a. Manure management	Strategy (i) Durra Building Systems (Pvt) Ltd Governmental and non-governmental organizations Kankasanthurai and Ambilipitiya paper mills Strategy (ii) Department of Animal Production and Health National Livestock Development Board Market Oriented Dairy Project Strategy (iii) Department of Agriculture

Timeline	Activity	Responsible parties
	b. Soil tillage reduction Strategy (iv) Reduction of fertilizer: Urea 52,146 Mt a. Reduction of artificial fertilizer application Strategy (v) Lands under carbon Sequestration 2,155	 Strategy (iv) Department of Agriculture Fertilizer Secretariate Fertilizer Cooperation CIC, Bower Strategy (v) Department of Agriculture Department of Agrarian Services
2041-2045	Strategy (i) Paddy land extent target: 197,000 ha Yala and Maha) a. Export of paddy straw b. Manufacture paper c. Manufacture boards d. Production of bio fuel e. Packaging industry Strategy (ii) No. of heads (neat cattle/Goat/Sheep) target 195,037 a. Feed quality improvement b. Night feeding c. Supply of Drinking water d. Animal comfort improvement (Heat reduction, Free roaming) Strategy (iii) N_2O reduction 1.27 Giga Tones	Strategy (i) Durra Building Systems (Pvt) Ltd Governmental and non-governmental organizations Kankasanthurai and Ambilipitiya paper mills Strategy (ii) Department of Animal Production and Health National Livestock Development Board Market Oriented Dairy Project Strategy (iii) Department of Agriculture

Timeline	Activity	Responsible parties
	a. Manure management b. Soil tillage reduction Strategy (iv) Reduction of fertilizer: Urea 41,717 Mt a. Reduction of artificial fertilizer application Strategy (v) Lands under carbon Sequestration 2,155 ha	 Strategy (iv) Department of Agriculture Fertilizer Secretariate Fertilizer Cooperation CIC, Bower Strategy (v) Department of Agriculture Department of Agrarian Services
2046-2050	Strategy (i) Paddy land extent target: 98,500 ha (Yala and Maha) a. Export of paddy straw b. Manufacture paper c. Manufacture boards d. Production of bio fuel e. Packaging industry Strategy (ii) No. of heads (neat cattle/Goat/Sheep) target 97,519 a. Feed quality improvement b. Night feeding c. Supply of Drinking water d. Animal comfort improvement (Heat reduction, Free roaming) Strategy (iii) N_2O reduction 0.63 Giga Tonnes a. Manure management	Strategy (i) Durra Building Systems (Pvt) Ltd Governmental and non-governmental organizations Kankasanthurai and Embilipitiya paper mills Strategy (ii) Department of Animal Production and Health National Livestock Development Board Market Oriented Dairy Project Strategy (iii) Department of Agriculture

Timeline	Activity	Responsible parties
	b. Soil tillage reduction Strategy (iv) Reduction of fertilizer: Urea 20,858 Mt a. Reduction of artificial fertilizer application Strategy (v) Lands under carbon Sequestration 2,155	 Strategy (iv) Department of Agriculture Fertilizer Secretariate Fertilizer Cooperation CIC, Bower Strategy (v) Department of Agriculture Department of Agrarian Services

Table 5.6 : Five year plan - Totals

Five year period	**Paddy lands mitigated Hectares**	**Livestock (Number of heads mitigated)**	**Direct and Indirect N2O MT mitigated**	**Urea import restricted MT**
2025/2030	147,750	14,6278	0.95	31,287
2031/2035	197,000	19,5037	1.27	41,717
2036/2040	246,250	24,3796	1.58	52,147
2041/2045	197,000	19,5037	1.27	41,717
2046/2050	98,500	97,519	0.63	20,858

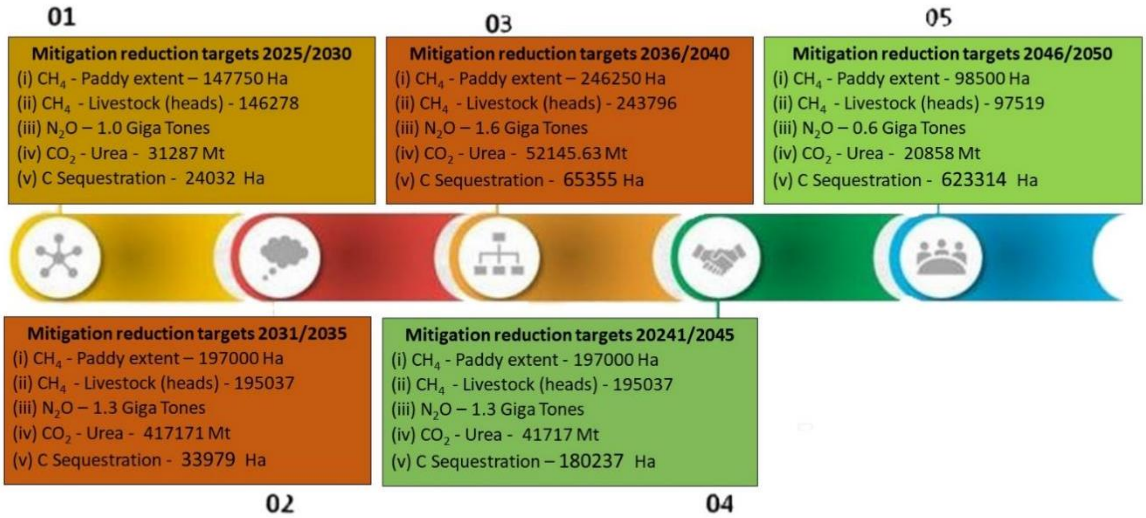

Figure 5.2 : Carbon Net Zero Road Map – Agriculture Sector

5.1.6 Forestry Sector

Table 5.7: Five-year Interval Plan in Forestry Sector

Timeline	Activity	Responsible parties
2025-2030	Deforestation rate would not exceed 5000 ha per year	Forest Department, MASL, RPC, Divisional Administration
	Afforest 1805 (from the already committed area in the NDCs) and 9212 ha (from the 200,000 ha which was retrieved from the areas which were categories under 'Other State Forests' annually	Forest Department, MASL, RPC
	Take measures to reduce the annual loss of homegardens which is now at 0.3% per year	Forest Department, Department of Agriculture, Department of Minor Export Crops, Provincial and District/Divisional Administration
	Planting 80937 ha of coconut plantations per year	Coconut Cultivation Board, Coconut Research Institute, RPCs, Private sector
	Stop the deforestation of mangroves which is 1% per year and plant 100 ha annually	Forest Department, Coast Conservation and Coastal Resource Management Department, IUCN, private sector
	Maintain 40 trees/ha of shade trees in tea plantations and increase the annual tea extent by 15000 ha	Tea Cultivation Board, RPC, SLSPC
	Addition of 1500000 trees in urban and suburban areas per year	UDA, private sector, Forest Department, MASL
2031-2035	Rate of deforestation will be reduced from 5000 ha to 2000 ha	Forest Department, MASL, RPC, Divisional Administration
	Afforest 1805 (from the already committed area in the NDCs) and 9212 ha (from the 200,000 ha which	Forest Department, MASL, RPC

Timeline	Activity	Responsible parties
	was retrieved from the areas which were categories under 'Other State Forests' annually	
	Take measures to reduce the annual loss of homegardens which is now at 0.3% per year	Forest Department, Department of Agriculture, Department of Minor Export Crops, Provincial and District/Divisional Administration
	Planting 80937 ha of coconut plantations per year	Coconut Cultivation Board, Coconut Research Institute, RPCs, Private sector
	Stop the deforestation of mangroves which is 1% per year and plant 100 ha annually	Forest Department, Coast Conservation and Coastal Resource Management Department, IUCN, private sector
	Maintain 40 trees/ha of shade trees in tea plantations and increase the annual tea extent by 15000 ha	Tea Cultivation Board, RPC, SLSPC
	Addition of 1500000 trees in urban and suburban areas per year	UDA, private sector, Forest Department, MASL
2036-2040	Rate of deforestation will be reduced from 2000 ha to 500 ha	Forest Department, MASL, RPC, Divisional Administration
	Afforest 1805 (from the already committed area in the NDCs) and 9212 ha (from the 200,000 ha which was retrieved from the areas which were categories under 'Other State Forests' annually	Forest Department, MASL, RPC
	Take measures to reduce the annual loss of homegardens which is now at 0.3% per year	Forest Department, Department of Agriculture, Department of Minor Export Crops, Provincial and District/Divisional Administration

Timeline	Activity	Responsible parties
	Planting 80937 ha of coconut plantations per year	Coconut Cultivation Board, Coconut Research Institute, RPCs, Private sector
	Stop the deforestation of mangroves which is 1% per year and plant 100 ha annually	Forest Department, Coast Conservation and Coastal Resource Management Department, IUCN, private sector
	Maintain 40 trees/ha of shade trees in tea plantations and increase the annual tea extent by 15000 ha	Tea Cultivation Board, RPC, SLSPC
	Addition of 1500000 trees in urban and suburban areas per year	UDA, private sector, Forest Department, MASL
2041-2045	Rate of deforestation will be reduced from 500 ha to 100 ha	Forest Department, MASL, RPC, Divisional Administration
	Afforest 1805 (from the already committed area in the NDCs) and 9212 ha (from the 200,000 ha which was retrieved from the areas which were categories under 'Other State Forests' annually	Forest Department, MASL, RPC
	Take measures to reduce the annual loss of homegardens which is now at 0.3% per year	Forest Department, Department of Agriculture, Department of Minor Export Crops, Provincial and District/Divisional Administration
	Planting 80937 ha of coconut plantations per year	Coconut Cultivation Board, Coconut Research Institute, RPCs, Private sector
	Stop the deforestation of mangroves which is 1% per year and plant 100 ha annually	Forest Department, Coast Conservation and Coastal Resource Management Department, IUCN, private sector
	Maintain 40 trees/ha of shade trees in tea plantations and	Tea Cultivation Board, RPC, SLSPC

Timeline	Activity	Responsible parties
	increase the annual tea extent by 15000 ha	
	Addition of 1500000 trees in urban and suburban areas per year	UDA, private sector, Forest Department, MASL
2046-2050	Rate of deforestation will be reduced from 100 ha to 0 ha	Forest Department, MASL, RPC, Divisional Administration
	Afforest 1805 (from the already committed area in the NDCs) and 9212 ha (from the 200,000 ha which was retrieved from the areas which were categories under 'Other State Forests' annually	Forest Department, MASL, RPC
	Take measures to reduce the annual loss of homegardens which is now at 0.3% per year	Forest Department, Department of Agriculture, Department of Minor Export Crops, Provincial and District/Divisional Administration
	Planting 80937 ha of coconut plantations per year	Coconut Cultivation Board, Coconut Research Institute, RPCs, Private sector
	Stop the deforestation of mangroves which is 1% per year and plant 100 ha annually	Forest Department, Coast Conservation and Coastal Resource Management Department, IUCN, private sector
	Maintain 40 trees/ha of shade trees in tea plantations and increase the annual tea extent by 15000 ha	Tea Cultivation Board, RPC, SLSPC
	Addition of 1500000 trees in urban and suburban areas per year	UDA, private sector, Forest Department, MASL

5.2 Economic Analysis of Achieving Net Zero Status in Sri Lanka

In order to achieve Net Zero Status in Sri Lanka, a variety of options have been proposed for each sector. Emission reduction (ER) options and sequestration enhancement (SE) options have been proposed under the proposed strategy towards achieving net zero status. It is important to analyze the proposed options to find out their economic viability. Economic viability for each option was assessed based on projected costs for future (up to 2050) and carbon emission savings. World Bank (2017) has proposed Guidelines on value of carbon. Guidance note on shadow price of carbon in economic analysis published by World Bank suggests that shadow price of carbon in US$ per 1 metric ton of CO2 equivalent to be USD 42 (lower estimate) and USD 84 (upper estimate) for the year 2022. Net present value was calculated for each option using a discount rate of 10%.

The following table provides summary of the calculation and provides Net Present Values (NPV) for the energy and transport sectors.

Table 1: Investments required for the Energy sector

Period	Total investment cost (LKR million)
2025 - 2029	2,131,408
2030 - 2034	3,003,414
2035 - 2039	4,112,132
2040 - 2044	5,635,990
2045 - 2050	5,748,165
Present value @ 10%	5,796,452

Table 2: Investments required for the Transport sector

Period	Total investment cost (LKR million)
2030 - 2034	16,334,558
2035 - 2039	20,914,278
2040 - 2044	26,786,734
2045 - 2050	36,145,677
Present value @ 10%	37,052,201

Table 5.8: Net present values of proposed mitigation actions for Energy and Transport sectors

Sector and Mitigation options	Net Present Value (LKR) @ 10% discount rate	
	Value of avoided Carbon (lower estimate)	Value of avoided Carbon (upper estimate
Energy sector		
Proposed Mitigation Scenario 02- Energy Sector decarbonization	-5,105,443,005,555	-4,412,922,592,074
Transport sector Emission reduction options		
1. Railway Electrification	-16,443,331,238	-15,176,037,288
2. Interprovincial Bus Electrification	-97,992,697,344	-70,897,175,975
3. Provincial Bus Electrification	-141,288,818,341	-128,430,869,073
4. Private and Freight Vehicles Electrification	-36,292,770,688,495	-35,828,728,616,907
All four options	-36,548,495,535,418	-36,043,232,699,243

The higher operational and capital costs associated with energy options have resulted in large negative net present values. The proposed renewable energy options however, may generate other local benefits and avoided thermal generations may also lead to significant pollution damage cost savings for the country especially health benefits. There may be additional environmental and social burdens due to some of the proposed energy options such as nuclear power.

Similarly, higher operational and capital costs associated with transport options have resulted in large negative net present values. Individual analysis of all transport options also show negative net present values. There are however, several benefits of transport sector options that have not been estimated. For example, the above calculation has not taken into account the time savings of the commuters, vehicle emission savings etc. associated with the improved rail and other transport modes with electrification. In addition there will be health benefits due to the reduced emission of PM2.5 and other air pollutants from avoided use of fossil fuels in transport.

The following table provides summary of the calculation and Net Present Values (NPV) for the waste sector.

Table 3: Investments required for the Waste sector

Period	Total investment cost (LKR million)
2026 - 2030	15
2031 - 2035	32
2036 - 2040	71,221
2041 - 2045	906
2046 - 2050	38,434
Present value @ 10%	22,722

Table 5.9: Net present values of proposed mitigation actions for waste sector

	Net Present Value (LKR) @ 10% discount rate	
	Value of avoided Carbon (lower estimate)	**Value of avoided Carbon (lower estimate)**
Emission reduction (ER) options and sequestration enhancement (SE) options		
ER option 1: Syngas recovery from open dump	-5,052,744.20	53,115,328.99
ER option 2: Electric vehicle for waste collection	-1,959,271,804.33	-1,940,537,516.89
ER option 3: Waste to energy plants	-24,739,041,603.49	13,887,404,121.78
ER option 4: Sanitary landfill	-18,721,691,991.70	-3,540,883,638.19
SE option 1: Daily Cover for Open dump	12,523,805,993.20	25,079,884,074.14
SE option 2: Vertical Subsurface flow constructed wetland (VSSFCW)	17,526,843,002.79	35,118,949,434.14
All 6 options combined	4,346,928,810.96	25,805,688,533.22

Among the proposed options of waste sector Daily Cover for Open dump and Vertical Subsurface flow constructed wetland (VSSFCW) have resulted in positive net present values. When all options for waste sector are considered together, it has resulted in positive net present values.

The following table provides Net Present Values for the forestry sector.

Table 4: Investments required for the Forestry sector

Period	Total investment cost (LKR million)
2025 - 2029	261,433
2030 - 2034	303,178
2035 - 2039	400,335
2040 - 2044	539,913
2045 - 2050	847,261
Present value @ 10%	641,840

Table 5.10: Net present values of proposed mitigation actions for Forestry sector

Sector and Mitigation options	Net Present Value (LKR) @ 10% discount rate	
	Value of avoided Carbon (lower estimate)	Value of avoided Carbon (upper estimate)
Forests in natural forests and plantations	$1,481,668,327,940.23	3,129,478,180,480
Trees Outside Forests		
Homegardens	816,056,745,585	1,656,563,163,232
Coconut plantations	469,289,070,006	1,637,038,422,127
Tea plantations with shade trees	70,930,596,918	141,838,967,699
Mixed trees with other perennials	64,883,821,812	129,681,864,833
Urban green cover and areas with avenue plants	-56,994,596,077	43,041,161,765
Blue Carbon Ecosystems		
Mangroves	72,657,022,054.15	164,789,655,745
Total for all options	2,832,663,961,588.63	6,302,663,521,836

Among the proposed actions of forestry sector, all actions have resulted in positive net present values except for urban green cover and areas with avenue plants under lower estimate of value of avoided carbon. When all actions for forestry sector are considered together, it has resulted in positive net present value of 2832 LKR billion under lower value of carbon and 6302 LKR billion under upper value of carbon. This analysis however has not taken into account variety of other benefits resulting from increasing forest cover including benefits due to variety of ecosystem services. There are variety of direct and indirect economic benefits associated with homegadens and mangrove forests. Benefits of increased extents of plantations will generate additional direct income.

The following table provides Net Present Values (NPV) for the Agriculture sector.

Table 5: Investments required for the Agriculture sector

Period	Total investment cost (LKR million)
2023 - 2027	69,776
2028 - 2032	131,794
2033 - 2037	186,294
2038 - 2042	233,745
2043 - 2047	274,447
2048 - 2050	181,475
Present value @ 10%	252,647

Table 5.11: Net present values of proposed mitigation actions for agriculture sector

Mitigation actions	Net Present Value (LKR) @ 10% discount rate	
	Value of avoided Carbon (lower estimate)	Value of avoided Carbon (upper estimate)
Emission reduction treatment for neat cattle (both imported and local)	-198,931,253,860.50	-198,882,959,958.46
All actions in agriculture sector including actions to mitigate emissions related to Rice Cultivation, Urea Applications and Direct/Indirect N2O	-198,738,491,541.80	-198,497,416,260.95

The lower emission reductions and higher costs associated with agricultural actions have resulted in large negative net present values. The above analysis assumed actions to mitigate emissions related to Rice Cultivation, Urea Applications and Direct/Indirect N2O as costless.

Summary

The following table provides summary for all sectors, the present values of all costs and benefits for each sector.

Table 5.12: Present values of all costs and benefits for each sector

Sector	Present values (LKR) @ 10% discount rate		
	Costs	Benefit - Value of avoided Carbon (lower estimate)	Benefit - Value of avoided Carbon (lower estimate)
Energy	5,796,452,247,493	691,009,241,938	1,383,529,655,419
Transport	37,052,200,770,104	503,705,234,686	1,008,968,070,861
Waste	17,071,078,646	21,418,007,457	42,876,767,179
Forest	641,839,730,410	3,474,503,691,998	6,944,503,252,245
Agriculture	198,979,539,449	241,047,907	482,123,188

Table 5.13: Net present values of proposed mitigation actions for all actions combined for all sectors

Scenario	Net Present Value (LKR) @ 10% discount rate	
	Value of avoided Carbon (lower estimate)	Value of avoided Carbon (upper estimate)
All sectors combined	-15,696,635,726,157	-12,895,537,785,921
All sectors except transport sector	-1,605,608,533,731.52	1,000,688,710,618.99

The combined analysis resulted in negative net present values. When the transport sector is excluded from the analysis, it resulted in positive net present value of 1000 LKR billion indicating the viability of the remaining sectors under upper estimate of the value of carbon.

It is important to estimate a proper price for the carbon savings to see how the options that are currently economically not viable could be made viable through some type of a resource transfer or through carbon credits.

This analysis provides an initial framework for setting up proper financial mechanisms that need to be realized in order to finance the proposed mitigation measures from international sources.

Table 6 provides details related to investments required for all sectors.

Table 6: Investments required for All sectors

Period	Total investment cost (LKR million)
2023 - 2027	69,776
2028 - 2032	2,524,649
2033 - 2037	19,827,476
2038 - 2042	25,731,711
2043 - 2047	33,237,990
2048 - 2050	49,192,499
Present value @ 10%	44,136,870

Policy recommendations

Net zero pathway requires vast amounts of investment, innovation, skilful policy design and implementation, technology deployment, infrastructure building, international co-operation and efforts across many other areas. Challenge of transforming our energy systems is also a huge opportunity for our economies, with the potential to create millions of new jobs and boost economic growth. Another guiding principle of the Roadmap is that clean energy transitions must be fair and inclusive, leaving nobody behind. Government R&D spending needs to be increased and reprioritised. Critical areas such as electrification, hydrogen, bioenergy and carbon capture, utilization and storage (CCUS) today receive very little or no public R&D funding. Support is also needed to accelerate the roll-out of demonstration projects, to leverage private investment in R&D, and to boost overall deployment levels to help reduce costs.

Some of the changes brought by the clean energy transformation may be challenging to implement, so decisions must be transparent, just and cost-effective. Governments need to ensure that clean energy transitions are people-centered and inclusive. Household energy expenditure as a share of disposable income – including purchases of efficient appliances and fuel bills – rises modestly in developing economies as more people gain access to energy and demand for modern energy services increases rapidly. Ensuring the affordability of energy for households demands close attention: policy tools that can direct support to the poorest include tax credits, loans and targeted subsidies.

Energy transitions have to take account of the social and economic impacts on individuals and communities, and treat people as active participants. The transition to net zero brings substantial new opportunities for employment. Spending on more efficient appliances, electric and fuel cell vehicles, and building retrofits and energy-efficient construction would require a additional workers. But these opportunities are often in different locations, skill sets and sectors than the jobs that will be lost as fossil fuels decline. This requires careful policy attention to address the employment losses. It will be vital to minimise hardships associated with these disruptions, such as by retraining workers, locating new clean energy facilities in heavily affected areas wherever possible, and providing regional aid. Improvements in air quality provide major health benefits also.

For many developing countries, the pathway to net zero without international assistance is not clear. Technical and financial support is needed to ensure deployment of key technologies and infrastructure. Without greater international co-operation, global CO2 emissions will not fall to net zero by 2050.

By 2025, all countries should have a long- term CO2 emissions reduction policy framework in place to provide certainty that the next wave of investment in capacity additions will feature near-zero emissions technologies. Successful strategies are likely to require initial measures such as carbon contracts for difference, public procurement and incentives to encourage private sector procurement. As new technologies are deployed and costs decline, there is likely to be a strong case by about 2030 for replacing these initial measures with others such as CO2 taxes, emissions trading systems and emissions performance standards. Financing support for near-zero emissions capacity additions may also have an important role to play through measures such as low interest and concessional loans and blended finance, as well as through contributions by advanced economies to funds that support projects in emerging market and developing economies.

Strategies should also include measures to reduce industrial emissions through material efficiency, for example by revising design regulations, adopting incentives to promote longer product and building lifetimes, and improving systems for collecting and sorting materials for recycling. There is a strong case for an international agreement on the transition to near-zero emissions for globally traded products by the mid-2020s so as to establish a level playing field. Alternatively, countries may need to resort to measures to shield domestic near-zero emissions production from competition from products that create emissions. Any such policy would need to be designed to respect the regulatory frameworks governing international trade, such as those of the World Trade Organization.

Governments should not overlook the need for measures to spur deployment of already available near-zero emissions technologies in light manufacturing industries. Adopting a carbon price and then sufficiently increasing the price over time – through carbon taxes or emissions trading systems for larger manufacturers – may be the simplest way to achieve that objective. Other regulatory measures such as tradable low-carbon fuel and emissions standards could yield the same outcome, but may involve greater administrative complexity. Technology mandates are likely to be needed to achieve the energy efficiency savings, such as minimum energy performance standards for new motors and boilers. Tailored programmes and incentives for small and medium enterprises could also play a helpful role.

Large proportion of emissions could be saved by behavioral changes which could be directly influenced or mandated by government policy . They include mitigation measures such as phasing out polluting cars from large cities and reducing speed limits on motorways.

To implement carbon pricing, it would benefit from developing the monitoring, reporting and verification structures necessary to implement a robust and comprehensive cap-and-trade-style market. A combination of investments in monitoring systems, data collection networks, and policies to incentivize data accuracy and disclosure could help speed up the potential for carbon markets to play a substantive role in incentivizing emissions reductions

SECTION 6: RECOMMENDATIONS

- It is acknowledged that the proposed action plan does not include any road map for financing the proposed strategic actions. The Central Bank of Sri Lanka, have recommended that in order to facilitate and ensure the timely implementation of the action plans, the key focus should be on alternative financing options than on budgetary allocations. It is recommended that green financing options available locally and internationally should be investigated and approached for funding the investments needed to achieve the desired outcomes. It is imperative that a Road map for financing the proposed actions is also prepared in order to see the successful implementation of the Plan.
- The Central Bank of Sri Lanka has already prepared a 'Green Finance Taxonomy' for the Sri Lanka's banking sector, with the aim of promoting lending through the domestic financial system to green projects. Therefore, seeking concessional or priority-based funding for zero carbon projects from the banking sector could be considered as a financing option going forward.
- Implementation of the actions proposed to achieve Carbon Net Zero involves the participation of state as well as private sector institutions, as well as individual citizens, and it is important that a high level of participation is forthcoming from all stakeholders
- To ensure sustainable growth, investing in research and development becomes vital. This will advance adoption of new technologies in all sectors, such as green hydrogen technologies, in the energy, transport and industrial sectors, leading to increased efficiency, cost-effectiveness, and safety, while minimizing the carbon emissions, which will further attract innovation and drive industry expansion.
- While much effort has been taken to include the opinions of the decision-making officials in the government sector in the development of the strategic plan, through stakeholder consultations, this being a long-term plan, needs to be regularly updated with data available in the future. The government should encourage an open dialogue with all stakeholders and monitor the achievement of the Key Performance Indicators on a regular basis, at least biennially, and review the Strategic Plan and Road Map accordingly. As pointed out by the Ceylon Chamber of Commerce (CCC) in their comments on the Draft Final Report at the validation workshop, a consultative process is essential for ensuring that the plan reflects the needs and interests of the business sector, which is a key driver of growth and innovation in our country. In this regard, they urge the government to establish a more regular and transparent dialogue with the trade Chambers and their members, so that future national plans can follow a due process that incorporates diverse perspectives and feedback from relevant stakeholders.
- As emphasised by the CCC in their comments at the validation workshop of the Strategic Plan and Road Map, appropriate mechanisms that are transparent and effective should be established by the government for collection, analysis and acting on stakeholder feedback, and these should be communicated to the public.

- In the monitoring and regulation of emission, CCC has recommended the use of platforms such as "Carbon Mapper" or citizen engagement apps like "Man Kiwwa" to proactively identify sources of emissions and take prompt action to curb the emissions. It is suggested to launch a Spatial Finance Initiative in Sri Lanka with the support of the Sri Lanka Banks' Association's Sustainable Banking Initiative and Ceylon Chamber of Commerce's ESG Financing Subgroup with the GoSL providing access to the spatial data in an easy to use form to the financial sector to engage constructively with private sector clients to manage their risks.
- As stated in the National Climate Change Policy, it is imperative that the Climate Change is mainstreamed and integrated in the National Development Process. The strategies and actions proposed in the Strategic Plan and Road Map will need to be internalized into the development plans of the relevant institutions, in order to achieve the vision of "A CARBON NEUTRAL PROSPEROUS SRI LANKA". To ensure that this Roadmap is integrated to the strategy of private sector, the CCC is recommending that it is important for Governance and Disclosures of Private Sector to be aligned, and as a first step, GoSL (Climate Change Secretariat) could work with Ceylon Chamber of Commerce to support private sector adoption of Climate and Nature Related Financial Disclosures (TCFD and TNFD), starting with corporates with revenue over LKR 15bn, encouraging them to take a perspective not only of their own operations but of their value chain/business ecosystem and just transition.

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
ENERGY SECTOR										
ENERGY SECTOR (Option 1-With Nuclear Program)	Promotion of renewable energy.	Adding following Power Plants for Power Generation	Pumped Storage 700 MW Mini Hydro - 135 MW Biomass-120 MW Wind - 1390 MW Solar - 3015 MW Battery Energy Storagett 725 MW/2900 MWh	Pumped Storage 700 MW Mini Hydro - 50 MW Biomass - 90 MW Wind - 800 MW Solar - 2420 MW Battery Energy Storage 675 MW/ 2700 MWh	Mini Hydro - 40 MW Biomass - 50 MW Wind - 750 MW Solar - 2650 MW Battery Energy Storage 515 MW/ 2060 MWh	Biomass 120 MW Wind 950 MW Solar 2830 MW Battery Energy Storage 625 MW/ 2500 MWh	Biomass - 150 MW Wind - 1300 MW Solar - 3150 MW Battery Energy Storage 625 MW/ 2500 MWh	MoPE/CEB MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB/SLSEA	-Proper renewable energy resource assessment and firm RE development plan. -An agency for facilitating the financing mechanism for green energy projects. - Upgraded transmission network to integrate more REs. -Energy sector market structure to facilitate RE integration. -Expedite land acquisition mechanism for RE projects and transmission network expansions. -Sufficient amount of materials/equipment for RE projects (major components are imported dependent). -Sufficient human resource	-Unavailability of firm RE resource development plan. -Lack of finances and sovereign /treasury guarantee to the energy sector finances. -Policy and statutory bottlenecks for speedy RE additions. -Unavailability of sufficient financing for transmission network upgrade. -Not enough local manufacturing of materials/equipment for RE projects No sufficient human resource/ expert on this area
	GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)		No additional reduction as it is in line with the base case scenario	78	131	1087	1899			
	KPI	Pump hydro added to the system	700 MW	700 MW						

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
		Number of MW of Mini-hydro added to the system.	135 MW	50 MW	40 MW					
		Number of MW of biomass added to the system.	120 MW	90 MW	50 MW	120 MW	150 MW			
		Number of MW of wind PV added to the system	1390 MW	800 MW	750 MW	950 MW	1300 MW			
		Number of MW of solar PV added to the system	3015 MW	2420 MW	2650 MW	2830 MW	3150 MW			
		Capacity of battery storage added to the system.	725 MW/2900 MWh	675 MW/ 2700 MWh	515 MW/ 2060 MWh	625 MW/ 2500 MWh	625 MW/ 2500 MWh			
	Development of Nuclear energy resources to the optimum level with sufficient environmental safeguards, by encouraging market demand for such resources	Adding Nuclear Power Plants for power generation Note: Government should take a firm policy decision on nuclear program. If the nuclear program is not continue, option 2 shall be considered.		Nuclear - 600 MW	Nuclear - 1000 MW				-An agency for facilitating the financing mechanism for green energy projects. -Upgraded transmission network to integrate more REs. -A mechanism to enhance the social acceptance of nuclear energy. -Sufficient human resource	-Policy and statutory bottlenecks for speedy integration of nuclear power plant. -Unavailability of sufficient financing for the project. -An agency to facilitate nuclear energy power plant development and to enhance the social acceptance -No sufficient human resource/ expert on this area
	GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)			1280	3229	5842	3397			
	KPI	Number of MW of nuclear power added to the system		600 MW	1000 MW					

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
ENERGY SECTOR (Option 2-Without Nuclear Program)	Promotion of renewable energy.	Adding following Power Plants for Power Generation	Pumped Storage 700 MW Mini Hydro - 135 MW Biomass-120 MW Wind - 1390 MW Solar - 3015 MW Battery Energy Storage 725 MW/2900 MWh	Pumped Storage 700 MW Mini Hydro - 50 MW Biomass - 90 MW Wind - 1200 MW Solar - 3350 MW Battery Energy Storage 850 MW/ 3400 MWh	Mini Hydro - 40 MW Biomass - 50 MW Wind - 2050 MW Solar - 4700 MW Battery Energy Storage 1175 MW/ 4700 MWh	Biomass 120 MW Wind 2050 MW Solar 4550 MW Battery Energy Storage 1140 MW/ 4560 MWh	Biomass - 150 MW Wind - 2800 MW Solar - 3300 MW Battery Energy Storage 825 MW/ 3300 MWh	MoPE/CEB MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB/SLSEA MoPE/CEB/SLSEA	-Proper renewable energy resource assessment and firm RE development plan. -An agency for facilitating the financing mechanism for green energy projects. - Upgraded transmission network to integrate more REs. -Energy sector market structure to facilitate RE integration. -Expedite land acquisition mechanism for RE projects and transmission network expansions. -Sufficient amount of materials/equipment for RE projects (major components are imported dependent). -Sufficient human resource	-Unavailability of firm RE resource development plan. -Lack of finances and sovereign /treasury guarantee to the energy sector finances. -Policy and statutory bottlenecks for speedy RE additions. -Unavailability of sufficient financing for transmission network upgrade. -Not enough local manufacturing of materials/equipment for RE projects No sufficient human resource/ expert on this area
	GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)		No additional reduction as it is in line with the base case scenario	1,358	3,360	6,929	5,296			
	KPI	Pump hydro added to the system	700 MW	700 MW						
		Number of MW of Mini-hydro added to the system.	135 MW	50 MW	40 MW					

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	**2031 – 2035**	**2036 - 2040**	**2041 - 2045**	**2046 - 2050**			
		Number of MW of biomass added to the system.	120 MW	90 MW	50 MW	120 MW	150 MW			
		Number of MW of wind PV added to the system	1390 MW	1200 MW	2050 MW	2050 MW	2800 MW			
		Number of MW of solar PV added to the system	3015 MW	3350 MW	4700 MW	4550 MW	3300 MW			
		Capacity of battery storage added to the system.	725 MW/2900 MWh	850 MW/ 3400 MWh	1175 MW/ 4700 MWh	1140 MW/ 4560 MWh	825 MW/ 3300 MWh			
	Promote Regional Power Grid Connectivity and Cross-Border Electricity Trade	Adding Cross Border Interconnection		Adding Cross Border Interconnection - 500 MW			Adding Cross Border Interconnection - 500 MW	MoPE/CEB	-Energy sector market structure to facilitate cross border energy trading. -Expedite land acquisition mechanism for the transmission network expansions. -Sufficient human resource	-Policy and statutory bottlenecks for speedy integration of nuclear power plant. -Unavailability of sufficient financing for the project. -No proper Energy sector market structure to facilitate cross border energy trading. -No sufficient human resource/ expert on this area
	GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)			512	1662	1849	2503			
	KPI	Total Capacity additions of cross border added to the system.		500 MW			500 MW			

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	**2031 – 2035**	**2036 - 2040**	**2041 - 2045**	**2046 - 2050**			
	Gradual decommissioning of the existing thermal power plants which depends on imported fossil fuel and enhance self-reliance.	Retirement of following Thermal Plants for Power Generation	Diesel 437.4 MW	Diesel - 491.7 MW Diesel/Natural Gas 398 MW		Coal 900 MW	Diesel/Natural Gas 895 MW		-A proper plan for Decomposition, reuse and recycling the identified plants. -Sufficient human resource -Sufficient machinery and equipment	-Policy and statutory bottlenecks for decommissioning thermal power plants -No sufficient human resource/ expert on this area -No Sufficient machinery and equipment
	GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)		No additional reduction as it is inline with the base case scenario	1081		No additional reduction as it is in line with the base case scenario	2614			
	KPI	Number of MW of thermal plant retirements	Diesel 437.4 MW	Diesel - 491.7 MW Diesel/Natural Gas 398 MW		Coal 900 MW	Diesel/Natural Gas 895 MW			
	Energy Transition by Enabling the Continued use of Flexible and Secure Thermal Energy while Reducing Negative Impact to the Environment	Introduction of Green Hydrogen Introduction of Carbon Capturing and Storage		Introduction of Green Hydrogen				MoPE/SEA/PRDS MoPE/SEA/PRDS	-Proper feasibility study	-No Proper feasibility study

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	**2031 – 2035**	**2036 - 2040**	**2041 - 2045**	**2046 - 2050**			
	GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)					5493	5494			
	KPI	Number of MW of Hydrogen electrolyzes commissioned.								
		Hydrogen production in million metric tons from renewable electricity								
	Increase the share of biomass as a fuel used for cooking by introducing improved biomass conversion devices such as cook stoves and enhancing the commercial supply of biomass.	Increasing the share of biomass	Increasing the share of biomass	Increasing the share of biomass	Increasing the share of biomass					
	GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)		1377	2833	3833					
	KPI	Share biomass for cooking at the end of time period								

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
	Total GHG Emission Reduction by the end of the 5 years of period (1000 tonnes CO2e) Energy Sector		**1377**	**5784**	**8855**	**14271**	**15907**			
TRANSPORT SECTOR										
Transport Sector	Avoiding motorized transportation	**Improve the pedestrian infrastructure on collector type roads in the country**	Pedestrian infrastructure improved in 10,000 km of roads					Urban Development Authority, Road Development Authority, Provincial Road Development Authorities	Feasibility study to prioritize roads for ped improvement	Urban Development Authority, Road Development Authority, Provincial Road Development Authorities
GHG Emission Reduction (1000 tonnes CO2e)			119.90	121.71	123.55	125.42	127.31			
KPI	**No of km of road improved with walking tracks**		10000							
	Avoiding motorized transportation	**Construct cycling infrastructure island wide**	Cycling infrastructure improved along 10,000 km of roads					Urban Development Authority, Road Development Authority, Provincial Road Development Authorities, Ministry of Local Government	Feasibility study to prioritize roads for ped improvement Funding Design standards and guidelines	Technical capacity to get funding from alternative sources – green financing etc.
GHG Emission Reduction (1000 tonnes CO2e)			299.74	304.27	308.87	313.54	318.28			
KPI	**No of km of road improved with improved Cycling infrastructure**		10000							
	Avoiding need for transportation	**Promoting remote working**	100% implementation at the start of 2025					Ministry of Labour, Ministry of Finance, Ministry of Public Administration	Identify the action plan to implement this considering the requirements of each organization	Ministry of Labour, Ministry of Finance, Ministry of Public Administration
GHG Emission Reduction (1000 tonnes CO2e)			688.24	698.64	709.20	719.92	730.80			
KPI	**Survey on the No. of gov/ private institutions willing to implement remote working**		100% of the targeted number of institutions						Identify the action plan to implement this considering the	Policy level decision in coordination with all the ministries

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
			implementing the program						requirements of each organization Identify schemes to incentivize this program	Issue necessary gazette
		E-Commerce and E- Learning	Increase the e-commerce and e-learning activities to a pre-defined target level					Ministry of Trade & commerce, Ministry of Education, ICTA		
			412.94	419.18	425.52	431.95	438.48			
KPI	Market survey on the online transactions online & student e-learning usage & estimate the required increase in volume to achieve the trip reduction target		Achieve the increase in e-commerce/e-learning activities to reach the est trip reduction							
	Promoting public transportation	**Modernizing the bus fleet**	500 buses	1000 buses	2500 buses	5000 buses		Ministry of Transport & Highways	Funding Technical study to identify routes, level of modernization etc.	Technical capacity to get funding from alternative sources – green financing etc.
GHG Emission Reduction (1000 tonnes CO2e)			123.87	185.80	309.67	619.34	619.34			
KPI	**No. of Modernized busses**		500	1000	2500	5000				
	Pricing to reflect environmental cost of fossil fuels	**Implement a price formula for petrol and diesel to reflect global petroleum prices and exchange rates**	Implement from 2023 onwards					Ministry of Finance, Ministry of Power and Energy	Develop a comprehensive fuel price formula	Policy level decision at Ministry of Finance
GHG Emission Reduction (1000 tonnes CO2e			556.37	617.40	694.19	792.40	920.30			
KPI	**Price Formula in Effect**		Fuel Price Formula being gazetted							

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
	Promoting public transportation	**Transport Demand Management Strategies in Key Cities**				Full implementation		Local government agencies, Urban Development Authority	Technical study to identify the most effective TDM	Ensure necessary legislative, land use, and municipality level changes are enacted
GHG Emission Reduction (1000 tonnes CO2e			405.02	411.14	417.35	423.66	430.06			
KPI	**No. of cities with transportation demand management (TDM) strategies**		Identify the TDM strategies for each city	All cities to implement the TDM strategies	Identify additional TDM strategies for each city	All cities to implement the TDM strategies				
	Promoting public transportation	**Implementation of LRT network in Colombo**	Completion of Malabe-Fort line					Ministry of Transport		Funding and identification of implementation agency
GHG Emission Reduction (1000 tonnes CO2e			50.00	53.00	53.00	100.00	100.00			
KPI	**Completion of LRT Network**		Completion of the LRT project							
	E-Mobility	**Railway Electrification**		Coastal line- Kaluthara	Puttalam line- Ragama	Main line – Polgahawela	Northern line – Polgahawela	Ministry of Transport		
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)			1.39	6.19	6.82	22.76	22.76			
KPI	**Completion of Railway Electrification**			Coastal line- Kaluthara	Puttalam line- Ragama	Main line – Polgahawela	Northern line – Polgahawela			
	E-Mobility	**Interprovincial Bus Electrification**	10% of the Interprovincial buses electrified	20% of the Interprovincial buses electrified	50% of the Interprovincial buses electrified	75 % of the Interprovincial buses electrified	100% of the Interprovincial buses electrified	Ministry of Finance, Ministry of Transport, National Transport Commission		
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)			48.52	97.05	242.62	363.93	485.24			
KPI	**The percentage of interprovincial busses electrified**		10%	20%	50%	75%	100%			
	E-Mobility	**Provincial Bus Electrification**	none	None	10% of the Bus Fleet	30% of the Bus Fleet	100% of the Bus Fleet			

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	**2031 – 2035**	**2036 - 2040**	**2041 - 2045**	**2046 - 2050**			
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)			-	-	54.60	163.81	546.04			
KPI	**The percentage of provincial busses electrified**				10%	30%	100%			
		Private vehicles electrification	Approximately 457,000 private vehicles and 16000 freight vehicles per year in 2030	5% / annum increase from the base figure (25% increase for 5 years)	5% / annum increase from the base figure (25% increase for 5 years)	5% / annum increase from the base figure (25% increase for 5 years)	5% / annum increase from the base figure (25% increase for 5 years)			
			1,853.22	2,316.53	2,779.84	3,243.14	3,706.45			
KPI	**No. of electric vehicles imported**		Approximately 457,000 private vehicles and 16000 freight vehicles per year in 2030	5% / annum increase from the base figure (25% increase for 5 years)	5% / annum increase from the base figure (25% increase for 5 years)	5% / annum increase from the base figure (25% increase for 5 years)	5% / annum increase from the base figure (25% increase for 5 years)			
Total GHG Emission Reduction by the end of the 5- year period (1000 tonnes CO2e) Transport Sector			**4,559.20**	**5,230.91**	**6,125.24**	**7,319.88**	**8,445.07**			
INDUSTRY SECTOR										
Industry sector IPPU GHG emission Reduction	**Cement industry** process emission reduction through the Promotion of sustainable consumption at end-user level, Resource Efficient Cleaner Production (RECP) at supplier	Activities relevant to given strategy will be implemented throughout the 25 years period at different scales subjected to the availability of the resource, technology and business environment	Implementation of appropriate cleaner production programmes in cement manufacturing process with especial focus on raw material input optimization. Raw material switching to low /no GHG emission types, Switching from Ordinary Portland Cement to Low Carbon Cement, Clinker factor reduction, Introduce Sustainable consumption (SCP) practices at end user level, Adopting circular economic practices,	INSEE Cement Industry, Ministry of industries. Sri Lanka Sustainable Development Council, Ministry of environment, GSMB, Climate change secretariat, Technology service providers, NGOs and multilateral donor agencies, Forest project owners and Renewable energy project owners with carbon offsetting facilities	Sustainable financial facilities, Technology sharing / updating opportunities, Sustainable development focused human resources development programmes, R&D facilitators / agencies	Mineral / Cement industry focused policy guidelines, Emission management national policies / guidelines, National action plans and MRV system and suitable economic instruments such as taxes and incentives	**Cement industry** process emission reduction through the Promotion of sustainable consumption at end-user level, Resource Efficient Cleaner Production (RECP) at supplier level, new technology adaptation and emission offsetting activities	Activities relevant to given strategy will be implemented throughout the 25 years period at different scales subjected to the availability of the resource, technology and business environment	Implementation of appropriate cleaner production programmes in cement manufacturing process with especial focus on raw material input optimization. Raw material switching to low /no GHG emission types, Switching from Ordinary Portland Cement to Low Carbon Cement, Clinker factor reduction, Introduce Sustainable consumption (SCP) practices at end user level, Adopting	INSEE Cement Industry, Ministry of industries. Sri Lanka Sustainable Development Council, Ministry of environment, GSMB, Climate change secretariat, Technology service providers, NGOs and multilateral donor agencies, Forest project owners and Renewable energy project owners with carbon offsetting facilities

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
	level, new technology adaptation and emission offsetting activities		Emission offsetting project						circular economic practices, Emission offsetting project	
Total GHG Emission Reduction by the end of the 5- year period (1000 tonne CO2e) Industry IPPU Sector; Cement subsector			5059.4963	2896.8589	1708.0553	670.8130	101.5623			
KPI	Cement industry IPPU emission reduction is highly dependent on process, raw material, geography, business environment etc. hence specific quantitative GHG emission reduction potentials are not yet defined by the relevant industry. Therefore the proposed KPIs are highly subjective to the future technological deviations. The proposed KPIs are the % out of total direct CO2e (calculated) reduction relevant to the 2025 – 2050 time horizon.		48%	28%	16%	6%	1%			
	Lime manufacturing industry process emission reduction through Promotion of sustainable consumption at end-user level, Resource	Activities relevant to given strategy will be implemented throughout the 25 years' period at different scales subjected to the availability of resource, technology and business environment	Introducing Consumer level consumption reduction /demand reduction programmes, Adopting Cleaner production and SCP programmes at producer level, R&D activities for alternate materials with low carbon emission factors, R&D programmes with the focus of low emission and circular economic opportunities, Introducing Lime industry productivity improvement programmes					Individual lime industries, Lime producers' consortiums and Co-Op societies, SME Sector related Government ministries & agencies, GSMB, Sri Lanka Sustainable Development Council, Ministry of environment,	Sustainable financial facilities, Technology sharing / updating opportunities, Sustainable development focused human resources development programmes,	Lime industry focused policies, action plans and MRV system and suitable economic instruments such as taxes and incentives

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	**2031 – 2035**	**2036 - 2040**	**2041 - 2045**	**2046 - 2050**			
	Efficient Cleaner Production (RECP) at producer level, new technology adaptation and emission offsetting							Climate change Secretariat, CEA, IDB, Development banks, Technology service providers, Multilateral donor agencies, Forest Project owners and Renewable energy project owners with carbon offsetting facilities		
Total GHG Emission Reduction by the end of the 5- year period (1000 tonne CO2e) Industry IPPU Sector; Cement subsector			**2179.4753**	**1247.8777**	**735.7777**	**288.9656**	**43.7499**			
KPI	Lime production industry IPPU emission reduction is highly dependent on process, geography, business environment etc. hence specific quantitative GHG emission reduction potentials are not yet defined by the relevant industry. Therefore the proposed KPIs are highly subjective to the future technological deviations. The proposed KPIs are the % out of total direct CO2e (calculated) reduction relevant to the 2025 – 2050 time horizon.		21%	12%	7%	3%	0.4%			
	Solvent use process emission reduction through Promotion of sustainable	Activities relevant to given strategy will be implemented throughout the 25 years period at different scales subjected to the availability of resource,	Introducing Consumer level solvent consumption reduction /demand reduction programmes, Adopting Cleaner production and SCP programmes at end-user level, Promotion of 3R strategies in solvent use, R&D activities for alternate solvents with low carbon emission factors, R&D programmes with the focus of low emission and circular economic opportunities, introducing green supply chain based solvent recovery business opportunities					Individual solvent users, Solvent producers / importers / distributors / retailers, SME Sector related Government ministries & agencies,	Sustainable financial facilities, Technology sharing / updating opportunities, Sustainable development focused human resources development programmes,	Solvent use industry / business focused policies, action plans and MRV system and suitable economic instruments such as taxes and incentives

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
	consumption at end-user level, Resource Efficient Cleaner Production (RECP) at end user level, New / Green technology adaptation and Circular economic opportunities	technology and business environment						Sri Lanka Sustainable Development Council, Ministry of environment, Climate change Secretariat, CEA, IDB, Development banks, Technology service providers, Multilateral donor agencies, R&D agencies, Universities, Technical collages		
Total GHG Emission Reduction by the end of the 5- year period (1000 tonne CO2e) Industry IPPU Solvent use sub sector			**311.3536**	**178.2682**	**105.1111**	**41.2808**	**6.2499**			
KPI	Solvent use IPPU emission reduction is highly dependent on process, geography, business environment etc. hence specific quantitative GHG emission reduction potentials are not yet defined by the relevant industry. Therefore the proposed KPIs are highly subjective to the future technological deviations. The proposed KPIs are the % out of total direct CO2e (calculated) reduction relevant to the 2025 – 2050 time horizon.		48.5%	27.8%	16.4%	6.4%	1.0%			

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
	Glass manufacturing industry: Emission reduction through Promotion of sustainable consumption at consumer / end-user level, Resource Efficient Cleaner Production (RECP) at end user level, New / Green technology adaptation and Circular economic opportunities	Activities relevant to given strategy will be implemented throughout the 25 years period at different scales subjected to the availability of resource, technology and business environment	• National level and sub national level Glass product green / sustainable supply chain development, • National level promotion of 3R based supply chains to minimize the use of raw silica sand used glass production, • Adaptation of CP technologies to local glass manufacturing industry, • Maximizing the use of culets in local glass industry • Emission offsetting projects, • Carbon capture and storage (CCS) Carbon capture, storage and use (CCSU) processes.					All glass manufacturing industries in Sri Lanka, Sri Lanka Sustainable Development Council, Ministry of environment, Climate change Secretariat, GSMB, CEA, IDB, Development banks, Technology service providers, Multilateral donor agencies, R&D agencies, Universities,	Sustainable financial facilities, Technology sharing / updating opportunities, Sustainable development focused human resources development programmes,	**Glass manufacturing industry:** Emission reduction through Promotion of sustainable consumption at consumer / end-user level, Resource Efficient Cleaner Production (RECP) at end user level, New / Green technology adaptation and Circular economic opportunities
Total GHG Emission Reduction by the end of the 5- year period (1000 tonne CO2e) Industry IPPU Solvent use sub sector			155.6768	89.1341	52.5555	20.6404	3.1250			
KPI	Glass manufacturing industry IPPU emission reduction is highly dependent on process, geography, business environment etc. hence specific quantitative GHG emission reduction potentials are not yet defined by the relevant industry. Therefore the proposed KPIs are		48.5%	27.8%	16.4%	6.4%	1.0%			

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
	highly subjective to the future technological deviations. **<u>The proposed KPIs are the % out of total direct CO2e (calculated) reduction relevant to the 2025 – 2050 time horizon.</u>**									
	Ceramic Industry material use and process related Emission reduction through Promotion of sustainable consumption at consumer / end-user level, Resource Efficient Cleaner Production (RECP) at end user level, New / Green technology adaptation and Circular economic opportunities	Activities relevant to given strategy will be implemented throughout the 25 years period at different scales subjected to the availability of the resource, technology and business environment	• Introducing Consumer level product consumption reduction /demand reduction programmes (SCP based), • Adopting Cleaner production and SCP programmes at production level, • R&D activities to use alternative materials with low carbon emission factors, • R&D programmes with the focus of low emission and circular economic opportunities, • Introducing Ceramic industry productivity improvement programmes • Emission offsetting projects, Carbon capture and storage (CCS) Carbon capture, storage and use (CCSU) processes.					All ceramic product (Wall tile, Floor tiles, Chinaware / porcelain Industries in Sri Lanka, Ministry of industries. BOI, Sri Lanka Sustainable Development Council, Ministry of environment, CEA, GSMB, Climate change secretariat, Technology service providers, NGOs and multilateral donor agencies, Forest Project's owners and Renewable energy project owners with carbon offsetting facilities	Sustainable financial facilities, Technology sharing / updating opportunities, Sustainable development focused human resources development programmes,	Ceramic industry focused policies & action plans and MRV system and suitable economic instruments such as taxes and incentives

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	**2031 – 2035**	**2036 - 2040**	**2041 - 2045**	**2046 - 2050**			
Total GHG Emission Reduction by the end of the 5- year period (1000 tonne CO2e) Industry IPPU Solvent use sub sector			77.8384	44.5671	26.2778	10.3202	1.5625			
KPI	Ceramic industry IPPU emission reduction is highly dependent on process, geography, business environment etc. hence specific quantitative GHG emission reduction potentials are not yet defined by the relevant industry. Therefore the proposed KPIs are highly subjective to the future technological deviations. The proposed KPIs are the % out of total direct CO2e (calculated) reduction relevant to the 2025 – 2050 time horizon.		48.5%	27.8%	16.4%	6.4%	1.0%			
	Bakery industry / bread production related raw material use and process related Emission reduction through the Promotion of sustainable consumption at consumer / end-user level,	Activities relevant to given strategy will be implemented throughout the 25 years period at different scales subjected to the availability of the resource, technology and business environment	• Introducing Consumer level product consumption reduction /demand reduction / waste minimization programmes (SCP based), • Adopting Cleaner production and SCP programmes at production level, • R&D activities to use alternative materials with low carbon emission factors (such as low carbon yeast strains), R&D programmes with the focus of low emission process in bakery industry					All Bakery Industries in Sri Lanka, Ministry of industries. Sri Lanka Sustainable Development Council, Ministry of environment, CEA, SLSI, ITI, Climate change secretariat, Bakery technology service providers, NGOs and multilateral donor agencies,	Sustainable financial facilities, Technology sharing / updating opportunities, Sustainable development focused human resources development programmes,	Food sector industry focused policies & action plans and MRV system and suitable economic instruments such as taxes and incentives

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	**2031 – 2035**	**2036 - 2040**	**2041 - 2045**	**2046 - 2050**			
	Resource Efficient Cleaner Production (RECP) at producer level, New / Green technology adaptation									
Total GHG Emission Reduction by the end of the 5- year period (1000 tonne CO2e) Industry IPPU Solvent use sub sector			**0.2335**	**0.1337**	**0.0788**	**0.0307**	**0.0047**			
KPI	Bakery industry IPPU emission reduction is highly dependent on process, geography, business environment etc. hence specific quantitative GHG emission reduction potentials are not yet defined by the relevant industry. Therefore the proposed KPIs are highly subjective to the future technological deviations. **The proposed KPIs are the % out of total direct CO2e (calculated) reduction relevant to the 2025 – 2050 time horizon.**		48.5%	27.8%	16.4%	6.4%	1.0%			
Total GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)			**7783.84**	**4456.70**	**2627.77**	**1032.02**	**156.24**			
WASTE SECTOR										

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	**2031 – 2035**	**2036 - 2040**	**2041 - 2045**	**2046 - 2050**			
WASTE SECTOR	Biochar for Carbon Sequestration	Using biochar for daily cover in landfills and open dumps	Daily cover for open dumpsite with Biochar (continues until 2050	Daily cover for open dumpsite with Biochar (continues until 2050	Daily cover for open dumpsite with Biochar (continues until 2050	Daily cover for open dumpsite with Biochar (continues until 2050	Daily cover for open dumpsite with Biochar (continues until 2050	SLLDC, WMA-WP, LAs	-Human resources -Technology -Policy -Strategy -Infrastructure -Resource Assessment -Awareness on the downside of open dump	Budget allocation by Las Necessary equipment for Biochar production (Pyrolizers, conveyors belts, movers, etc) Necessary equipment for operation of open dumps Insufficient human resource/experts Proper data management system Policy on decommissioning open dumps Minimal infrastructure Land extent
GHG Emission Reduction by the end of the 5 years of period (1000 tonnes CO2e)			76.3	95.3	116.2	139.1	164.1			
KPI	Area of open dump to be filled with landcover		15%	25%	40%	55%	75%			
	Waste management	MSW growth reduction with 3R practice & promote recycling and use of recycled materials	3R practice collection and reduction of waste generation at source. These practices are extended from NDC and improved to continue until 2050	3R practice collection and reduction of waste generation at source. These practices are extended from NDC and improved to continue until 2050	3R practice collection and reduction of waste generation at source. These practices are extended from NDC and improved to continue until 2050	3R practice collection and reduction of waste generation at source. These practices are extended from NDC and improved to continue until 2050	3R practice collection and reduction of waste generation at source. These practices are extended from NDC and improved to continue until 2050	NSWMSC, SLLDC, WMA, LAs	-Ban Single use plastics and tetra packs -EPR implementation -Continuous awareness programs -Strategy to monitor segregation -Human resources -Recycling machinery	-Hard plastic recycling -Strong PPP -Infrastructure to reduce mixing after segregation -Mechanical Sorters -Recycler empowerment -Training and Financial support

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)			11.3	13.2	15.2	17.8	22.1			
KPI	No of recycling yards for each province		2 recycling yards for each province	5 recycling yards for each province	1 recycling yard for each district	2 recycling yards for each district	Recycling yards for each LAs			
	GHG Capture	Methane recovery for SynGas production from open dumps and sanitary landfills		Recovery of GHG from Open dumpsite to use it for the production of Syn Gas (Synthesis Gas) - 10% Implementation	Recovery of GHG from Open dumpsite to use it for the production of Syn Gas (Synthesis Gas) - 20% implementation	Recovery of GHG from Open dumpsite to use it for the production of Syn Gas (Synthesis Gas) - 35% Implementation	Recovery of GHG from Open dumpsite to use it for the production of Syn Gas (Synthesis Gas) - 50% Implementation	NSWMSC, SLLDC, WMA, LAs and Private Sector	-Human resources -Technology -Policy -Strategy -Infrastructure for GHG collection & SynGas production	-Unavailable of feasible study in Sri Lanka -Infrastructure to collect the gas -Production plants to SynGas
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)				0.2	0.4	0.6	0.7			
KPI	Production and sale of SynGas			Commissioning of SynGas production plant & Start production	Market and sell the 10 tonnes CO_2e syngas	Sell the 15 tonnes CO_2e syngas	Sell the 20 tonnes CO_2e syngas			
	Phytoremediation & Biochar for Carbon Sequestration	Constructed wetland for wastewater treatment and reuse treated wastewater for greening (VSSFCW)		Implementing a centralized Vertical Sub Surface Flow Constructed Wetland (VSSFCW) at a strategic location in the Western province to purify the wastewater biologically and re use the water to enrich the groundwater				CEA, Las, CMC, BOI, Provate Sector	-Emission accounting principles -Infrastructure for VSSFCW and sludge removal facilities -Storm & Sewer network -Application of night soil	-Unavailable of feasible study in Sri Lanka -Insufficient human resource/ experts -Improper design of storm & sewer network
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)				97.6	95.3	93.1	90.8			

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
KPI	Quantity of treated wastewater reuse Vertical Subsurface Flow Constructed Wetland (VSSFCW)			3 VSSFCW to achieve treated wastewater reuse rate of 50%	5 VSSFCW to achieve treated wastewater reuse rate of 60%	15 VSSFCW to achieve treated wastewater reuse rate of 75%	25 VSSFCW to achieve treated wastewater reuse rate of 90%			
	E-mobility	Transforming the waste collection garbage trucks into electric trucks			Implementation of Electric vehicle for waste transportation and Route Optimization using Internet of Things (IoT)- The vehicles to be charged with renewable energy			NSWMSC, WMA, Las	-Dump Trucks Compactors -Renewable Energy -Charging Stations -IoT implementations	-Financial allocations by the Las -Renewable energy production
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)					0.1	0.1	0.1			
KPI	No of the Garbage trucks converted to electric trucks				100	200	300			
	Energy Production from waste	Introducing waste to energy plants for other provinces			WtE plant 1 is to be implemented strategically at a location covering Central & North Central provinces to ensure energy production from waste that could not recycle or reuse.	Two WtE plants are to be implemented to replace the Coal power plants with carbonstcks , to ensure the net GHG emission reduction in the content of the net gain from moving towards sustainable practices.		Ministry of Power & Energy,CEB, NSWMSC, SLLDC, WMA, LAs and Private Sector	-Human resources -Technology -Policy -Strategy -Infrastructure -Land Capacity Building	-Financial allocations by the Las -Lack of feasibility study in Sri Lanka
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)					144.4	281.1	271.5			
KPI	Parentage of waste treated in waste to energy plants				50%	75%	100%			

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
	Biochar for Carbon Sequestration	Establishing sanitary landfills for residual wastes					A Sanitary landfill is to be introduced strategically to dispose of the unavoidable waste generated (fuel to the WtE plants.	NSWMSC, SLLDC, WMA, CEA, LAs	-Human resources -Technology -Policy -Strategy Infrastructure -Land area in strategical location	-Financial allocations by the LAs -Limited land area
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)							62.9			
KPI	No of new sanitary landfill						Construction of sanitary landfill			
Emission Reduction Not Estimated due to lack of Data										
	Encouragement policies	Refunds & incentives for proper waste management	Refunds & incentives for proper waste management					LAs	-Financial resources -Human resources -Technology and infrastructure -Awareness and education -Regulatory framework	-Financial allocations by the Las -Regulatory framework
KPI	No of automated refund system machines in operation		10	25	50	75	100			
	Material efficiency	Promote circular economy in supply chains and construction industry	Promote circular economy in supply chains					Department of Buildings SLSEA SLAMERP SLAEA UNDP WMA	-Material Recovery and recycling facilities -Reverse logistics system -Data analytic tools -Renewable Energy Sources -Collaborations and Partnerships -Design for Circularity -Consumer education and Engagement	-Data analytic tools -Renewable Energy Sources -Financial allocations by the Las -Design for Circularity -Knowledge gap
KPI	Percentage of companies adopting circular economy practices		10%	20%	30%	40%	50%			

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	**2031 – 2035**	**2036 - 2040**	**2041 - 2045**	**2046 - 2050**			
	Waste managem ent	Efficient waste management	Efficient waste management					LAs	-Financial resources -Human resources -Technology and infrastructure -Awareness and education	-Awareness and education
KPI	No of local authorities implementing waste reduction and recycling program		10	20	30	40	50			
	GHG Capture	Biogas from fecal sludge at community level		Introducing Biogas from fecal sludge at community level				LAs BOI	-Fecal Sludge Collection -Biogas Plant Infrastructure -Expertise and Training -Feedstock Management -Gas Utilization -Financing	-Biogas Plant Infrastructure -Awareness and education -Financial allocations by the Las -Policy and Regulatory Gaps
KPI	No of community Biogass plants			5 communities	10 communities	15 communities	20 communities			
	Value addition to waste	Hybrid fertilizer production and Subsidy free community-based composting	Hybrid fertilizer production from MSW and Subsidy free community-based composting					NSWMSC SLLDC WMA LAs	-Waste collection infrastructure -MSW treatment and processing equipment -Composting infrastructure -Technical expertise -Financial resources -Education and awareness	-Financial resources -Education and awareness
KPI	No of tons of hybrid fertilizer produced per year		500	1000	1500 tons	2000 tons	2500 tons			
	Waste managem ent	Introducing the waste management activities and the emissions reduction opportunities	Introducing the waste management activities and the emissions reduction opportunities					LAs	-Waste management infrastructure -Emissions monitoring equipment -Technical expertise -Financial resources -Regulatory framework -Education and awareness	-Emissions monitoring equipment -Technical expertise -Financial resources -Regulatory framework

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	**2031 – 2035**	**2036 - 2040**	**2041 - 2045**	**2046 - 2050**			
KPI	No. of waste management activities introduced		5	10	15	20	25			
	Research on Carbon Capture	Promoting zero-carbon innovations				Promoting zero-carbon innovations through allowing NRC grants		NRC	-Funding -Technical expertise -Regulatory framework -Partnerships and collaboration -Research And Development -Education and training -Public Policy Support	-Funding -Policy Support Regulatory framework
KPI	No. of NRC grants awarded					Award 2 NRC grants	Award 5 NRC grants			
	Knowledge Building and Awareness	Community participation, empowerment, and capacity building						LAs	-Funding -Technical expertise -Regulatory framework -Partnerships and collaboration -Research And Development -Education and training -Public Policy Support	-Funding -Policy Support Regulatory framework
KPI	No of skill development opportunities provided		3 skills development opportunities	6 skills development opportunities	9 skills development opportunities	12 skills development opportunities	15 skills development opportunities			
Total GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e) Waste Sector			**87.6**	**206.3**	**371.6**	**531.8**	**612.2**			
AGRICULTURE SECTOR										

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
Agriculture Sector	Reduce methane emission from paddy fields by removing rice straws and through good management practices	Export of paddy straw Manufacture paper Manufacture boards Production of bio fuel Packaging industry	Paddy land extent target: 147,750ha	Paddy land extent target: 197,000 ha	Paddy land extent target: 246,250 ha	Paddy land extent target: 197,000 ha	Paddy land extent target: 98,500 ha	National Paper Company Ltd,, Valaichchenai and Embilipitiya, Durra Building Systems (Pvt) Ltd	Incentives extension officers Funding for research and development	Lack of necessary policies
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)			**494**	**696**	**873**	**1024**	**1145**			
KPI	**Annual (yala and maha) paddy extent which produces paddy straws (ha)**		147,750	197,000	246,250	197,000	98,500	Department of Census and Statistics, Department of Agriculture		
	Reduce CH_4 emission from livestock by improving feed quality and animal comfort Reduce methane emission	Feed quality improvement Night feeding and supply of water Animal comfort improvement (heat reduction, free roaming)	Target No. of heads (neat cattle/Goat/Sheep) 146278	Target No. of heads (neat cattle/Goat/Sheep) 195037	Target No. of heads (neat cattle/Goat/Sheep) 243796	Target No. of heads (neat cattle/Goat/Sheep) 195037	Target No. of heads (neat cattle/Goat/Sheep) 97519	Department of Animal Production and Health, National Livestock Development Board, Market Oriented Dairy Project	Funding for Research and Development Incentives for extension workers	Lack of policy initiatives

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	**2031 – 2035**	**2036 - 2040**	**2041 - 2045**	**2046 - 2050**			
	from livestock by improving feed quality and animal comfort.									
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)			**319**	**455**	**573**	**675**	**758**			
KPI	**Number of animals treated**		146278	195037	243796	195037	97519			
	Reduce N_2O emission in soils due to microbial activities	Manure management Soil tillage reduction	N2O reduction 0.95 Giga tonnes	N2O reduction 1.27 Giga tonnes	N2O reduction 1.58 Giga tonnes	N2O reduction 1.27 Giga tonnes	N2O reduction 0.63 Giga tonnes	Department of Agriculture	Funding for Research and development Incentives for extension workers	Lack of necessary policies
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)			**724**	**1014**	**1265**	**1481**	**1664**			
KPI	**Paddy extent for soil N_2O reduction**		69,796	93,061	116,327	93,061	46,531			
KPI	**Number of animals with manure management**		146278	195037	243796	195037	97519			
	Use alternatives to Chemical fertilizer for reducing N_2O emission:	Reduction of artificial fertilizer application	Reduction of fertilizer: Urea 31,287 tonnes	Reduction of fertilizer: Urea 41,717 tonnes	Reduction of fertilizer: Urea 52,146 tonnes	Reduction of fertilizer: Urea 41,717 tonnes	Reduction of fertilizer: Urea 20,858 tonnes	Department of Agriculture, Fertilizer Secretariat, Fertilizer Cooperation, Private sector (CIC, Baurs)	Funding for research and development in organic farming sector Seeds and new variety development for organic farming	Lack of funds and necessary policy initiatives

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	**2031 – 2035**	**2036 - 2040**	**2041 - 2045**	**2046 - 2050**			
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)			**65**	**91**	**114**	**134**	**150**			
KPI	**Reduction of urea import tonnes per year**		31,287	41,717	52,146	41,717	20,858			
Total GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e) Agriculture Sector			**1,602**	**2,256**	**2,825**	**3,314**	**3,717**			
Carbon sequestration	Establishment of green hedges	**Land extent (in '000 ha) covered in green hedges**	2,117	5,013	8,822	12,160	14,471			
		Carbon sequestration in CO_2 Equivalent '000 Mt	-6	-8	-10	-9	-6			
KPI	**Land extent (in '000 ha) covered in green hedges**		2,117	5,013	8,822	12,160	14,471			
Total carbon sequestration by the end of the 5-year period (1000 tonnes CO2e) Agriculture Sector			**-6**	**-8**	**-10**	**-9**	**-6**			
FORESTRY SECTOR										
	Reduce GHG emissions from deforestation and loss of ecosystems in		Limiting the deforestation rate to 5000 ha/yr	Reducing the deforestation rate up to 2000 ha/yr	Reducing the deforestation rate up to 500 ha/yr	Reducing the deforestation rate up to 100 ha/yr	Reducing the deforestation rate to 0 ha/yr	Forest Department	Funds to be used as subsidies for the home gardeners	Poor implementation of the policies, laws and non adherence of the sectoral plans to the National Physical Plan which details the areas to be conserved and areas to be developed.

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
	trees outside forests									
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)				450	675	735	750			
KPI	**Extent of forests removed per year**		5000 ha/yr	2000 ha/yr	500 ha/yr	100 ha/yr	0 ha/yr			
		2. Limiting the fragmentation of the coconut lands	Limit the fragmentation of the coconut lands at the present rate of 1705 ha/yr	Limit to the fragmentation of the coconut lands at the present rate of 1705 ha/yr	Limit to the fragmentation of the coconut lands at the present rate of 1705 ha/yr	Limit to the fragmentation of the coconut lands at the present rate of 1705 ha/yr	Limit to the fragmentation of the coconut lands at the present rate of 1705 ha/yr	Coconut Cultivation Board		Poor implementation of the policies, laws and non-adherence of the sectoral plans to the National Physical Plan which details the areas to be conserved and areas to be developed.
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)			-	-	-	-	-			
KPI	**Extent of coconut plantations removed per year**		1705 ha/yr	1705 ha/yr	1705 ha/yr	1705 ha/yr	1705 ha/yr			
		3. Conservation of mangroves	Conserve the mangroves so that there would not be any removal/loss/degradation	Conserve the mangroves so that there would not be any removal/loss/degradation	Conserve the mangroves so that there would not be any removal/loss/degradation	Conserve the mangroves so that there would not be any removal/loss/degradation	Conserve the mangroves so that there would not be any removal/loss/degradation	**Forest Department** IUCN, CC&CRMD UN IUCN Other NGOs working on mangrove conservation and planting Academia		There is no policy/legislation regards home gardens and therefore no institution is responsible for home gardens
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e)			25	24	23	22	21			
KPI	**Extent of mangrooves removed per year**		0	0	0	0	0			
		4. Ensure that the home gardens will not be fragmented and converted to other land uses	Through Private Public Partnerships ensure that the home gardens will not be fragmented and converted to other land uses	Through Private Public Partnerships ensure that the home gardens will not be fragmented and converted to other land uses	Through Private Public Partnerships ensure that the home gardens will not be fragmented and converted to other land uses	Through Private Public Partnerships ensure that the home gardens will not be fragmented and converted to other land uses	Through Private Public Partnerships ensure that the home gardens will not be fragmented and converted to other land uses	**Department of Agriculture** Forest Department Dept of Export Agriculture	Funds to be used as subsidies for the home gardeners	

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
								Academia		
GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e			423	445	468	492	517			
KPI	**Extent converted to other land uses per year**		0	0	0	0	0			
Total GHG Emission Reduction by the end of the 5-year period (1000 tonnes CO2e) Forestry Sector			**-2,923**	**678**	**1,162**	**1,578**	**1,774**			
	Increase the carbon Sequestration by trees by conservation of existing trees, increasing the quality of natural forests and plantations and increasing the tree cover	1. Conserve the existing natural forests, increase quality of natural forests and plant additional trees	Conserve the existing natural forests Increase the quality of natural forests and plantations. Plant 1805 ha/yr as forest plantations, river and catchment reservations, vacant areas in tea plantations etc. Newly plant/restore 7407 ha of land released under the category 'Other State Forests'	Conserve the existing natural forests Increase the quality of natural forests and plantations. Plant 1805 ha/yr as forest plantations, river and catchment reservations, vacant areas in tea plantations etc. Newly plant/restore 7407 ha of land released under the category 'Other State Forests'	Conserve the existing natural forests Increase the quality of natural forests and plantations. Plant 1805 ha/yr as forest plantations, river and catchment reservations, vacant areas in tea plantations etc. Newly plant/restore 7407 ha of land released under the category 'Other State Forests'	Conserve the existing natural forests Increase the quality of natural forests and plantations. Plant 1805 ha/yr as forest plantations, river and catchment reservations, vacant areas in tea plantations etc. Newly plant/restore 7407 ha of land released under the category 'Other State Forests'	Conserve the existing natural forests Increase the quality of natural forests and plantations. Plant 1805 ha/yr as forest plantations, river and catchment reservations, vacant areas in tea plantations etc. Newly plant/restore 7407 ha of land released under the category 'Other State Forests'	Forest Department, MASL, Ministry of Plantation Industries with special reference to Regional Plantation Companies and SLSPC Private sector, academia, NGOs Private sector, academia, NGOs Coconut Research Institute	Funds for planting, boundary demarcation and protection of existing natural forests and plantations and increasing the quality of the forest Funds for raising forest Funds for raising forest Funds Lands Funds lands Lands, funds	Dearth of funds, Dearth of lands to plant as there is competition between reforestation/afforestation/restoration and short term economic pursuits Dearth of funds, Dearth of lands to plant as there is competition between reforestation/afforestation/restoration and short term economic pursuits Dearth of funds, Dearth of lands to plant as there is competition between reforestation/afforestation/restoration and short term economic pursuits

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	**2031 – 2035**	**2036 - 2040**	**2041 - 2045**	**2046 - 2050**			
Increased carbon sequestration by the end of the 5-year period (1000 tonnes CO_2e)			37	528	845	1,016	1,146			
KPI	**The area of forest plantations**		1805 ha/yr	1805 ha/yr	1805 ha/yr	1805 ha/yr	1805 ha/yr			
	Replanted/restored per year for all land uses		7407 ha	7407 ha	7407 ha	7407 ha	7407 ha			
		2. Total trees outside forest including home gardens, coconut plantation, tea plantations and urban green cover with areas of avenue plants	Increase the coconut lands by 80937 ha/yr Increase the urban/avenue plants by 500000 plants/yr Maintain the annual increase of tea lands which is 15000 ha/yr	Increase the coconut lands by 80937 ha/yr Increase the urban/avenue plants by 500000 plants/yr Maintain the annual increase of tea lands which is 15000 ha/yr	Increase the coconut lands by 80937 ha/yr Increase the urban/avenue plants by 500000 plants/yr Maintain the annual increase of tea lands which is 15000 ha/yr	Increase the coconut lands by 80937 ha/yr Increase the urban/avenue plants by 500000 plants/yr Maintain the annual increase of tea lands which is 15000 ha/yr	Increase the coconut lands by 80937 ha/yr Increase the urban/avenue plants by 500000 plants/yr Maintain the annual increase of tea lands which is 15000 ha/yr	Coconut Cultivation Board Forest Department Ministry of Urban Development UDA Tea Cultivation Board, RPC, SLSPC	Funds for planting, boundary demarcation and protection of existing natural forests and plantations and increasing the quality of the forest Funds for raising forest Funds for raising forest Funds Lands Funds lands Lands, funds	There is competition for land from real estate purposes Pest and diseases in coconut which make the plantations not economically lucrative Lack of space in the urban areas is a significant problem here. There is no policy/regulation to allow the extents of greenery in urban spaces and these needs to be factored in to the UDA act.
Increased carbon sequestration by the end of the 5-year period (1000 tonnes CO_2e)			1,562	1,614	1,669	1,726	1,624			
KPI	**Replanted/restored per year for all land uses**		80937 ha/yr	80937 ha/yr	80937 ha/yr	80937 ha/yr	80937 ha/yr			
	Increased area with urban/avenue plants		500000 plants/yr	500000 plants/yr	500000 plants/yr	500000 plants/yr	500000 plants/yr			
	Increased area with tea lands		15000 ha/yr	15000 ha/yr	15000 ha/yr	15000 ha/yr	15000 ha/yr			
		3. Blue Carbon Ecosystems	Plant 100 ha of mangroves/yr	Plant 100 ha of mangroves/yr	Plant 100 ha of mangroves/yr	Plant 100 ha of mangroves/yr	Plant 100 ha of mangroves/yr	CC&CRMD, IUCN, relevant NGOs, Private sector, Academia		Not all the mangrove areas are not protected and therefore had been succumbed to other land uses. Need to study all the mangroves areas and bring them under protection

Key Topic	Strategy	Activity	Time frame of the Actions					Responsibility	Resources Required	Gap of Resources
			2025 - 2030	2031 – 2035	2036 - 2040	2041 - 2045	2046 - 2050			
Increased carbon sequestration by the end of the 5-year period (1000 tonnes CO_2e)			62	94	125	154	183			
KPI	**Replanted/restored per year for all land uses**		100 ha	100 ha	100 ha	100 ha	100 ha			
Total Increased Carbon sequestration by the Forestry Sector by the end of the 5-year period (1000 tonnes CO2e)			**121**	**380**	**877**	**1,426**	**2000**			

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ANNEXURES

ANNEXURE 1: WORKSHOP AGENDA LIST (23.09.2023)

ANNEXURE 2: LIST OF PARTICIPANTS FOR THE SECOND WORKSHOP – 18.11.2023

ANNEXURE 3: AGENDA OF THE WORKSHOP

WORKSHOP- TO DEVELOP A 2050 CARBON NET ZERO ROAD MAP AND STRATEGIC PLAN FOR SRI LANKA-AGENDA

Date: 23.09.2022

Time: 9.00 am – 2.30 pm

Venue: Nelum, Water’s Edge, Battaramulla

Time	Description
9.00 am - 9.30 am	Registration and Tea
9.30 am - 9.40 am	Welcome address by the Secretary, Ministry of Environment
9.40 am -9.45 am	Remarks by UNDP
9.45 am -9.50 am	The objective of the Workshop by the Director, Climate Change Secretariat, Ministry of Environment
9.50 am -10.00 am	Self-introduction of the team
10.00 am -10.30 am	Introduction to the stakeholders on the outline of the project, theconcepts, the method of work
10.30 am -11.00 am	Refreshment Break and Breaking out into the sector groups
11.00 am -1.30 am	Breakout sessions – led by the sector consultants
1.30 am -1.45 am	Closing session (plenary) followed by lunch

ANNEXURE 4: AGENDA OF THE WORKSHOP

WORKSHOP- TO DEVELOP A 2050 CARBON NET ZERO ROAD MAP AND STRATEGIC PLAN FOR SRI LANKA-AGENDA

Date: 18/ 11/ 2022

Time: 9.00 am – 2.30 pm

Venue: Nelum Hall, Water's Edge, Battaramulla

Agenda

Time	Item
9.00 am – 9.30 am	Registration of Participants
9.30 am - 10.00 am	Welcome Address – Team Leader, Prof. Niranjanie Ratnayake
10.15 am – 1.40 pm Breakout Sessions	
	Breakout sessions for each sector, chaired by the sector specialist, andsupported by the RA's: • Energy **-** Dr. Asanka Rodrigo • Transport **-** Dr. Loshaka and Dr Pasindu • Industry – Mr. Nimal • Waste – Prof. Bandunee • Agriculture – Dr. Dharmasena • Forestry sector: to be chaired by Dr. Dharmasena jointly with Agriculture Sector as Prof. Hemanthi will be overseas. • Economic – Prof. Prashanthi • Social and Gender – Prof Subhangi
10.15 am – 10.45 am	Introductory presentation by the sector expert – Energy, Transport, Waste, Industry, Agriculture and Forestry sector experts please prepare slides to show the following: ➢ Identification of the baseline scenario: Let us take NDC scenario with only unconditional actions as the baseline ➢ Calculated emission predictions in the baseline scenario (With graphs showing the predictions up to 2050) ➢ Considered scenarios and drivers which are used in the scenario development

	➢ Mathematical model used for the predictions up to 2050 ➢ Proposed mitigatory actions with timeline to bring down the emissions and increase storage/sequestration according to your plan ➢ Gaps found in the first stakeholder workshop ✓ Policy/ Strategy ✓ Staff ✓ Technology ✓ Infrastructure
10.45 am – 11.15 am	**Tea Break**
Within the breakout rooms	
11.15 am – 12.00 noon	Discussion of the feasibility of the proposed actions and the timeline according to the stakeholders' opinions
12.00 noon -12.20 pm	New actions and timelines proposed by the stakeholders
12.20 pm – 12.40 pm	Available regulatory framework for the implementation of proposed actions and any gaps
12.40 pm – 1.00 pm	Identify institutional arrangements and new policies/ amendments to policies needed for the implementation of actions, strengths and weaknesses in the system and opportunities for improvement
1.00 pm – 1.20 pm	SWOT analysis
1.20 pm 1.40 pm	Presentation of the outcome of the discussion by the Sectoral Leaders
1.40 pm to 1.45 pm	Vote of Thanks
Lunch	
End of Workshop	

ANNEXURE 5: Proposed Strategies and action plans in Energy Sector

Table 1: Proposed Strategies and action plans in Energy Sector

YEAR	RENEWABLE CAPACITY & GRID-SCALE ENERGY STORAGE CAPACITY ADDITIONS AND RETIREMENTS		THERMAL CAPACITY ADDITIONS and RETIREMENTS	
2022	**Uma Oya Hydropower Plant**	**120 MW**		
	Distribution Connected Embedded Solar	160 MW		
	Grid Connected Partially Facilitated Solar	**94 MW**		
	Mini Hydro	20 MW		
	Biomass	10 MW		
2023	Distribution Connected Embedded Solar	160 MW	**Gas Turbine of Sobadhanvi NG Combined Cycle Plant (Kerawalapitiya)**	**235 MW**
	Grid Connected Partially Facilitated Solar 1	**147 MW**	Short-Term Supplementary Power 2	320 MW
	Wind	**25 MW**	Combined Cycle Power Plant (KPS–2)	163 MW
	Mini Hydro	20 MW	*Retirement of*	
	Biomass	20 MW	*Sojitz Kelanitissa Combined Cycle Plant 3*	(163) MW
2024	Moragolla **Hydropower Plant**	**31 MW**	**New Gas Turbines – Kelanitissa 4**	**130 MW**
	Distribution Connected Embedded Solar	160 MW	**Steam Turbine of Sobadhanvi NG Combined Cycle Plant (Kerawalapitiya)**	**115 MW**
	Grid Connected Partially Facilitated Solar 1	223 MW	**Gas Turbine of Second NG Combined Cycle Plant (Kerawalapitiya)**	**235 MW**
	Grid Connected Fully Facilitated Solar	100 MW	*Retirement of*	
	Wind	**60 MW**	*Kelanitissa Gas Turbines 5*	*(68) MW*
	Mini Hydro	20 MW	*Short-Term Supplementary Power*	*(200) MW*
	Biomass	20 MW		
	Standalone Battery Energy Storage	20 MW/50 MWh		
2025	Distribution Connected Embedded Solar	165 MW	**Steam Turbine of Second NG Combined Cycle Plant (Kerawalapitiya***)*	**115 MW**
	Grid Connected Partially Facilitated Solar	80 MW	*Retirement of*	
	Grid Connected Fully Facilitated Solar (With Battery Energy Storage) 100 MW/400 MWh	260 MW	*CEB Barge Power Plant 7*	*(62) MW*
	Wind (Mannar)6	100 MW		
	Wind	100 MW		
	Mini Hydro	25 MW		
	Biomass	20 MW		
2026	Distribution Connected Embedded Solar	170 MW	IC Engine Power Plant -Natural Gas (Western Region)	200 MW
	Grid Connected Partially Facilitated Solar	70 MW	*Retirement of*	
	Grid Connected Fully Facilitated Solar	260 MW	*Gas Turbine (GT7)8*	*(115) MW*
	(With Battery Energy Storage)	100 MW/400 MWh	*4x17 MW Sapugaskande Diesel 8x9 MW*	*(68) MW*
	Wind	290 MW	*Sapugaskande Diesel Ext Short Term*	*(72) MW*
	Mini Hydro	25 MW	*Supplementary Power*	*(120) MW*
	Biomass	20 MW		
	Standalone Battery Energy Storage	80 MW/320 MWh		
2027	Distribution Connected Embedded Solar	170 MW	Gas Turbine -Natural Gas (Western Region)	100 MW
	Grid Connected Partially Facilitated Solar	50 MW		
	Grid Connected Fully Facilitated Solar	280 MW		
	(With Battery Energy Storage)	100 MW/400MWh		

YEAR	RENEWABLE CAPACITY & GRID-SCALE ENERGY STORAGE CAPACITY ADDITIONS AND RETIREMENTS		THERMAL CAPACITY ADDITIONS and RETIREMENTS	
	Wind Mini Hydro Biomass Standalone Battery Energy Storage MW/400 MWh	250 MW 25 MW 20 MW 100		
2028	Distribution Connected Embedded Solar Grid Connected Partially Facilitated Solar Grid Connected Fully Facilitated Solar (With Battery Energy Storage) Wind Mini Hydro Biomass Standalone Battery Energy Storage MWh	170 MW 40 MW 310 MW 150 MW/600 MWh 200 MW 25 MW 20 MW 200MW/800		
2029	Distribution Connected Embedded Solar Grid Connected Partially Facilitated Solar Grid Connected Fully Facilitated Solar (With Battery Energy Storage) Wind Mini Hydro Biomass Pumped Storage Hydropower	170 MW 20 MW 350 MW 150 MW/600 MWh 250 MW 25 MW 20 MW 350 MW		
2030	Distribution Connected Embedded Solar Grid Connected Partially Facilitated Solar Grid Connected Fully Facilitated Solar (With Battery Energy Storage) Wind Mini Hydro Biomass Pumped Storage Hydropower	170 MW 30 MW 250 MW 125 MW/500MWh 200 MW 10 MW 20 MW 350 MW		
2031	Distribution Connected Embedded Solar Grid Connected Partially Facilitated Solar Grid Connected Fully Facilitated Solar (With Battery Energy Storage) Wind Mini Hydro Biomass Pumped Storage Hydropower	170 MW 30 MW 250 MW 125 MW/500MWh 200 MW 10 MW 20 MW 350 MW	-	
2032	Distribution Connected Embedded Solar Grid Connected Partially Facilitated Solar Grid Connected Fully Facilitated Solar (With Battery Energy Storage) Wind Mini Hydro Biomass Pumped Storage Hydropower	170 MW 30 MW 250 MW 125 MW/500MWh 150 MW 10 MW 20 MW 350 MW		
	Distribution Connected Embedded Solar Grid Connected Partially Facilitated Solar Grid Connected Fully Facilitated Solar (With Battery Energy Storage) Wind	170 MW 30 MW 300 MW	Gas Turbine -Natural Gas *Retirement of* *Gas Turbine of Sobadhanvi NG Combined Cycle Plant (Kerawalapitiya)*	150 MW *(235) MW*

YEAR	RENEWABLE CAPACITY & GRID-SCALE ENERGY STORAGE CAPACITY ADDITIONS AND RETIREMENTS		THERMAL CAPACITY ADDITIONS and RETIREMENTS	
2033	Mini Hydro Biomass	150 MW/600MWh 150 MW 10 MW 20 MW	*Combined Cycle Plant (KPS) Combined Cycle Plant (KPS- 2) Uthuru Janani Power Plant*	*(165) MW* *(163) MW* *(26.7) MW*
2034	Distribution Connected Embedded Solar Grid Connected Partially Facilitated Solar Grid Connected Fully Facilitated Solar (With Battery Energy Storage) Wind Mini Hydro Biomass	180 MW 30 MW 300 MW 150 MW/600MWh 150 MW 10 MW 20 MW	HVDC interconnection	500 MW
2035	Distribution Connected Embedded Solar Grid Connected Partially Facilitated Solar Grid Connected Fully Facilitated Solar (With Battery Energy Storage) Wind Mini Hydro Biomass Standalone Battery Energy Storage	180 MW 30 MW 300 MW 125MW/500MWh 150 MW 10 MW 10 MW 50MW/200MWh	Nuclear power Plant *Retirement of* *West Coast Combined Cycle Power Plant*	500 MW *(300) MW*
2036	Distribution Connected Embedded Solar Grid Connected Partially Facilitated Solar Grid Connected Fully Facilitated Solar (With Battery Energy Storage) Wind Mini Hydro Biomass Standalone Battery Energy Storage	190 MW 30 MW 300 MW 100MW/400MWh 150 MW 10 MW 10 MW 100MW /400MWh		
2037	Distribution Connected Embedded Solar Grid Connected Partially Facilitated Solar Grid Connected Fully Facilitated Solar (With Battery Energy Storage) Wind Mini Hydro Biomass Standalone Battery Energy Storage	190 MW 30 MW 300 MW 100MW/400MWh 150 MW 10 MW 10 MW 100MW/400MWh		
2038	Distribution Connected Embedded Solar Grid Connected Partially Facilitated Solar Grid Connected Fully Facilitated Solar (With Battery Energy Storage) Wind Mini Hydro Biomass Standalone Battery Energy Storage	200 MW 30 MW 300 MW 100MW/400MWh 150 MW 10 MW 10 MW 100MW/400MWh		
2039	Distribution Connected Embedded Solar Grid Connected Partially Facilitated Solar Grid Connected Fully Facilitated Solar (With Battery Energy Storage) Wind Mini Hydro Biomass Standalone Battery Energy Storage	200 MW 30 MW 300 MW 100 MW/400 MWh 150 MW 10 MW 10 MW 100 MW/400 MWh		

YEAR	RENEWABLE CAPACITY & GRID-SCALE ENERGY STORAGE CAPACITY ADDITIONS AND RETIREMENTS	THERMAL CAPACITY ADDITIONS and RETIREMENTS
2040	Distribution Connected Embedded Solar 220 MW Grid Connected Partially Facilitated Solar 20 MW Grid Connected Fully Facilitated Solar 310 MW (With Battery Energy Storage) 115 MW/460 MWh Wind 150 MW Biomass 10 MW Standalone Battery Energy Storage 100 MW/400 MWh	Nuclear Power Plant 1000 MW
2041	Distribution Connected Embedded Solar 220 MW Grid Connected Partially Facilitated Solar 20 MW Grid Connected Fully Facilitated Solar 310 MW (With Battery Energy Storage) 125 MW/500 MWh Wind 150 MW Biomass 20 MW Standalone Battery Energy Storage 100 MW/400 MWh	*Retirement of* *Lakvijaya Coal Power Plant Unit 1 (300) MW*
2042	Distribution Connected Embedded Solar 220 MW Grid Connected Partially Facilitated Solar 30 MW Grid Connected Fully Facilitated Solar 320 MW (With Battery Energy Storage) 125 MW/500 MWh Wind 200 MW Biomass 20 MW Standalone Battery Energy Storage 150 MW/600 MWh	
2043	Distribution Connected Embedded Solar 220 MW Grid Connected Partially Facilitated Solar 30 MW Grid Connected Fully Facilitated Solar 320 MW (With Battery Energy Storage) 125 MW/500 MWh Wind 200 MW Biomass 20 MW	
2044	Distribution Connected Embedded Solar 220 MW Grid Connected Partially Facilitated Solar 30 MW Grid Connected Fully Facilitated Solar 320 MW (With Battery Energy Storage) 125 MW/500 MWh Wind 200 MW Biomass 30 MW	*Retirement of* *Lakvijaya Coal Power Plant Unit 2 and 3 (600) MW*
2045	Distribution Connected Embedded Solar 220 MW Grid Connected Partially Facilitated Solar 30 MW Grid Connected Fully Facilitated Solar 320 MW (With Battery Energy Storage) 125 MW/500 MWh Wind 200 MW Biomass 30 MW	
2046	Distribution Connected Embedded Solar 230 MW Grid Connected Partially Facilitated Solar 30 MW Grid Connected Fully Facilitated Solar 330 MW (With Battery Energy Storage) 125 MW/500 MWh Wind 200 MW Biomass 30 MW	
2047	Distribution Connected Embedded Solar 230 MW Grid Connected Partially Facilitated Solar 30 MW Grid Connected Fully Facilitated Solar 330 MW (With Battery Energy Storage) 125 MW/500 MWh Wind 200 MW	HVDC interconnection 500 MW

YEAR	RENEWABLE CAPACITY & GRID-SCALE ENERGY STORAGE CAPACITY ADDITIONS AND RETIREMENTS	THERMAL CAPACITY ADDITIONS and RETIREMENTS
	Biomass 30 MW	
2048	Distribution Connected Embedded Solar 240 MW Grid Connected Partially Facilitated Solar 40 MW Grid Connected Fully Facilitated Solar 340 MW (With Battery Energy Storage) 125 MW/500 MWh Wind 200 MW Biomass 30 MW	
2049	Distribution Connected Embedded Solar 250 MW Grid Connected Partially Facilitated Solar 40 MW Grid Connected Fully Facilitated Solar 360 MW (With Battery Energy Storage) 125 MW/500 MWh Wind 300 MW Biomass 30 MW	*Retirement of* *New Gas Turbines – Kelanitissa 130 MW* *Steam Turbine of Sobadhanvi NG Combined-Cycle Plant (Kerawalapitiya) 115 MW* *Gas Turbine of Second NG Combined Cycle Plant (Kerawalapitiya) 235 MW* *Steam Turbine of Second NG Combined Cycle Plant (Kerawalapitiya) 115MW* *IC Engine Power Plant -Natural Gas (Western Region) 200MW*
2050	Distribution Connected Embedded Solar 270 MW Grid Connected Partially Facilitated Solar 50 MW Grid Connected Fully Facilitated Solar 380 MW (With Battery Energy Storage) 125 MW/500 MWh Wind 300 MW Biomass 30 MW	*Retirement of* *Gas Turbine -Natural Gas (Western Region) 100 MW*

ANNEXURE 6: Baseline and Mitigation Scenario Calculations of Forestry Sector

Table 1: The projected extents of forests, trees outside forests and mangroves (ha) from 2025-2050 in the Baseline Scenario

Year	Forest cover	New plantings	Total forest cover including existing and new plantings	Home gardens	Coconut plantations	Tea Plantations	Mixed trees with other perennials	Mangroves	Urban green cover and areas with avenue plants
2025	2043962	1805	2045767	892560	467593.8	326509	118000	17868.7323	7514.8
2026	2039067	1805	2040872	901485.6	467118.8	341509	118822.222	17690.0626	8014.8
2027	2034172	1805	2035977	910500.5	466643.8	356509	118822.222	17513.1795	8514.8
2028	2029277	1805	2031082	919605.5	466168.8	371509	119465.556	17338.0653	9014.8
2029	2024382	1805	2026187	928801.5	465693.8	386509	120108.889	17164.7023	9514.8
2030	2019487	1805	2021292	938089.6	465218.8	401509	118822.222	16993.0729	10014.8
2031	2014487	1805	2016292	947470.4	464743.8	416509	119465.556	16823.1597	10514.8
2032	2009487	1805	2011292	956945.2	464268.8	431509	120108.889	16654.9457	11014.8
2033	2004487	1805	2006292	966514.6	463793.8	446509	120752.222	16488.4139	11514.8
2034	1999487	1805	2001292	976179.7	463318.8	461509	121395.556	16323.5473	12014.8

Year	Forest cover	New plantings	Total forest cover including existing and new plantings	Home gardens	Coconut plantations	Tea Plantations	Mixed trees with other perennials	Mangroves	Urban green cover and areas with avenue plants
2035	1994487	1805	1996292	985941.5	462843.8	476509	122038.889	16160.3295	12514.8
2036	1989487	1805	1991292	995801	462368.8	491509	122682.222	15998.7438	13014.8
2037	1984487	1805	1986292	1005759	461893.8	506509	123325.556	15838.7739	13514.8
2038	1979487	1805	1981292	1015817	461418.8	521509	123968.889	15680.4038	14014.8
2039	1974487	1805	1976292	1025975	460943.8	536509	124612.222	15523.6173	14514.8
2040	1969487	1805	1971292	1036234	460468.8	551509	120752.222	15368.3988	15014.8
2041	1964487	1805	1966292	1046597	459993.8	566509	121395.556	15214.7324	15514.8
2042	1959487	1805	1961292	1057063	459518.8	581509	122038.889	15062.6027	16014.8
2043	1954487	1805	1956292	1067633	459043.8	596509	124612.222	14911.9942	16514.8
2044	1949487	1805	1951292	1078310	458568.8	611509	125255.556	14762.8919	17014.8
2045	1944487	1805	1946292	1089093	458093.8	626509	125898.889	14615.2806	17514.8
2046	1939487	1805	1941292	1099984	457618.8	641509	126542.222	14469.1454	18014.8
2047	1934487	1805	1936292	1110984	457143.8	656509	127185.556	14324.4715	18514.8

Year	Forest cover	New plantings	Total forest cover including existing and new plantings	Home gardens	Coconut plantations	Tea Plantations	Mixed trees with other perennials	Mangroves	Urban green cover and areas with avenue plants
2048	1929487	1805	1931292	1122093	456668.8	671509	127828.889	14181.2444	19014.8
2049	1924487	1805	1926292	1133314	456193.8	686509	128472.222	14039.4496	19514.8
2050	1919487	1805	1921292	1144648	455718.8	701509	129115.556	13899.0727	20014.8

Table 2: Total Carbon Sequestration in Forests, Trees Outside Forests and Mangroves in the Baseline Scenario (tonnes /yr)

Year	Forests	Trees Outside Forests					Blue Carbon Ecosystems	Total
	In natural forests and plantations	Home gardens	Coconut plantations	Tea lands with shade trees	Mixed trees with other perennials	Urban green cover and areas with avenue plants (ha)	Mangroves	
2025	8661250.2	3345891.493	4047094.2	457112.6	354000	30059.2	415626.713	17311034.4
2026	8638733.2	3379350.408	4042819.2	478112.6	356466.667	32059.2	411470.855	17339012.1
2027	8616216.2	3413143.912	4038544.2	499112.6	356466.667	34059.2	407356.556	17364899.3
2028	8593699.2	3447275.351	4034269.2	520112.6	358396.667	36059.2	403283.4	17393095.6
2029	8571182.2	3481748.105	4029994.2	541112.6	360326.667	38059.2	399250.975	17421673.9
2030	8548665.2	3516565.586	4025719.2	562112.6	361506.333	40059.2	395258.875	17449887
2031	8525665.2	3551731.242	4021444.2	583112.6	362964.667	42059.2	391306.695	17478283.8
2032	8502665.2	3587248.554	4017169.2	604112.6	364423	44059.2	387394.038	17507071.8

Year	Forests	Trees Outside Forests					Blue Carbon Ecosystems	Total
	In natural forests and plantations	Home gardens	Coconut plantations	Tea lands with shade trees	Mixed trees with other perennials	Urban green cover and areas with avenue plants (ha)	Mangroves	
2033	8479665.2	3623121.04	4012894.2	625112.6	365881.333	46059.2	383520.507	17536254.1
2034	8456665.2	3659352.25	4008619.2	646112.6	367339.667	48059.2	379685.711	17565833.8
2035	8433665.2	3695945.773	4004344.2	667112.6	368798	50059.2	375889.263	17595814.2
2036	8410665.2	3732905.23	4000069.2	688112.6	370256.333	52059.2	372130.78	17626198.5
2037	8387665.2	3770234.283	3995794.2	709112.6	371714.667	54059.2	368409.882	17656990
2038	8364665.2	3807936.625	3991519.2	730112.6	373173	56059.2	364726.192	17688192
2039	8341665.2	3846015.992	3987244.2	751112.6	374631.333	58059.2	361079.34	17719807.9
2040	8318665.2	3884476.152	3982969.2	772112.6	376089.667	60059.2	357468.956	17751841
2041	8295665.2	3923320.913	3978694.2	793112.6	377548	62059.2	353894.675	17784294.8
2042	8272665.2	3962554.122	3974419.2	814112.6	379006.333	64059.2	350356.138	17817172.8
2043	8249665.2	4002179.663	3970144.2	835112.6	380464.667	66059.2	346852.986	17850478.5

Year	Forests	Trees Outside Forests					Blue Carbon Ecosystems	Total
	In natural forests and plantations	Home gardens	Coconut plantations	Tea lands with shade trees	Mixed trees with other perennials	Urban green cover and areas with avenue plants (ha)	Mangroves	
2044	8226665.2	4042201.46	3965869.2	856112.6	381923	68059.2	343384.865	17884215.5
2045	8203665.2	4082623.475	3961594.2	877112.6	383381.333	70059.2	339951.426	17918387.4
2046	8180665.2	4123449.709	3957319.2	898112.6	384839.667	72059.2	336552.321	17952997.9
2047	8157665.2	4164684.207	3953044.2	919112.6	386298	74059.2	333187.207	17988050.6
2048	8134665.2	4206331.049	3948769.2	940112.6	387756.333	76059.2	329855.745	18023549.3
2049	8111665.2	4248394.359	3944494.2	961112.6	389214.667	78059.2	326557.597	18059497.8
2050	8088665.2	4290878.303	3940219.2	982112.6	390673	80059.2	323292.43	18095899.9

Table 3: The total GHG emissions from the forestry sector including forests and trees outside forests (tonnes /yr) in the Baseline Scenario from 2025-2050.

Year	From Deforestation	From the fragmentation of coconut lands	From the removal of home gardens	From the removal of mangroves	Total emissions
2025	750000	161250	402860.591	26803.1	1340913.69
2026	750000	161250	406889.197	26535.09	1344674.29
2027	750000	161250	410958.089	26269.77	1348477.86
2028	750000	161250	415067.67	26007.1	1352324.77
2029	750000	161250	419218.346	25747.05	1356215.4
2030	750000	161250	423410.53	25489.61	1360150.14
2031	750000	161250	427644.635	25234.74	1364129.37
2032	750000	161250	431921.081	24982.42	1368153.5
2033	750000	161250	436240.292	24732.62	1372222.91
2034	750000	161250	440602.695	24485.32	1376338.02
2035	750000	161250	445008.722	24240.49	1380499.22
2036	750000	161250	449458.809	23998.12	1384706.92

Year	From Deforestation	From the fragmentation of coconut lands	From the removal of home gardens	From the removal of mangroves	Total emissions
2037	750000	161250	453953.397	23758.16	1388961.56
2038	750000	161250	458492.931	23520.61	1393263.54
2039	750000	161250	463077.861	23285.43	1397613.29
2040	750000	161250	467708.639	23052.6	1402011.24
2041	750000	161250	472385.726	22822.1	1406457.82
2042	750000	161250	477109.583	22593.9	1410953.49
2043	750000	161250	481880.679	22367.99	1415498.67
2044	750000	161250	486699.485	22144.34	1420093.82
2045	750000	161250	491566.48	21922.92	1424739.4
2046	750000	161250	496482.145	21703.72	1429435.86
2047	750000	161250	501446.967	21486.71	1434183.67
2048	750000	161250	506461.436	21271.87	1438983.3
2049	750000	161250	511526.051	21059.17	1443835.22
2050	750000	161250	516641.311	20848.61	1448739.92

Table 4: The projected extents of forests, trees outside forests and mangroves (ha) from 2025-2050 in the Net Zero Scenario

Year	Forest cover	New plantings	Total forest cover including existing and new plantings	Home gardens	Coconut plantations	Tea Plantations	Mixed trees with other perennials	Mangroves	Urban green cover and areas with avenue plants
2025	2043962	9212	2053174	895245.8	547960.8	326509	118000	17966.9723	9514.8
2026	2039067	9212	2048279	904198.2	547485.8	341509	118822.222	18066.9723	12014.8
2027	2034172	9212	2043384	913240.2	547010.8	356509	118822.222	18166.9723	14514.8
2028	2029277	9212	2038489	922372.6	546535.8	371509	119465.556	18266.9723	17014.8
2029	2024382	9212	2033594	931596.3	546060.8	386509	120108.889	18366.9723	19514.8
2030	2019487	9212	2028699	940912.3	545585.8	401509	118822.222	18466.9723	22014.8
2031	2015487	9212	2024699	950321.4	545110.8	416509	119465.556	18566.9723	24514.8
2032	2011487	9212	2020699	959824.6	544635.8	431509	120108.889	18666.9723	27014.8
2033	2008487	9212	2017699	969422.9	544160.8	446509	120752.222	18766.9723	29514.8
2034	2005487	9212	2014699	979117.1	543685.8	461509	121395.556	18866.9723	32014.8
2035	2003487	9212	2012699	988908.3	543210.8	476509	122038.889	18966.9723	34514.8

Year	Forest cover	New plantings	Total forest cover including existing and new plantings	Home gardens	Coconut plantations	Tea Plantations	Mixed trees with other perennials	Mangroves	Urban green cover and areas with avenue plants
2036	2001487	9212	2010699	998797.4	542735.8	491509	122682.222	19066.9723	37014.8
2037	2000487	9212	2009699	1008785	542260.8	506509	123325.556	19166.9723	39514.8
2038	1999487	9212	2008699	1018873	541785.8	521509	123968.889	19266.9723	42014.8
2039	1998987	9212	2008199	1029062	541310.8	536509	124612.222	19366.9723	44514.8
2040	1998487	9212	2007699	1039353	540835.8	551509	120752.222	19466.9723	47014.8
2041	1998187	9212	2007399	1049746	540360.8	566509	121395.556	19566.9723	49514.8
2042	1997937	9212	2007149	1060244	539885.8	581509	122038.889	19666.9723	52014.8
2043	1997737	9212	2006949	1070846	539410.8	596509	124612.222	19766.9723	54514.8
2044	1997587	9212	2006799	1081554	538935.8	611509	125255.556	19866.9723	57014.8
2045	1997487	9212	2006699	1092370	538460.8	626509	125898.889	19966.9723	59514.8
2046	1997437	9212	2006649	1103294	537985.8	641509	126542.222	20066.9723	62014.8
2047	1997437	9212	2006649	1114327	537510.8	656509	127185.556	20166.9723	64514.8

Year	Forest cover	New plantings	Total forest cover including existing and new plantings	Home gardens	Coconut plantations	Tea Plantations	Mixed trees with other perennials	Mangroves	Urban green cover and areas with avenue plants
2048	1997437	9212	2006649	1125470	537035.8	671509	127828.889	20266.9723	67014.8
2049	1997437	9212	2006649	1136725	536560.8	686509	128472.222	20366.9723	69514.8
2050	1997437	9212	2006649	1148092	536085.8	701509	129115.556	20466.9723	72014.8

Table 5: Net Carbon Sequestration in Forests, Trees Outside Forests and Mangroves in the Net Zero Scenario (tonnes /yr)

	Forests	Trees Outside Forests					Blue Carbon Ecosystems	Total
Year	In natural forests and plantations	Homegardens	Coconut plantations	Tea plantations with shade trees	Mixed trees with other perennials	Urban green cover and areas with avenue plants (ha)	Mangroves	
2025	8698285.2	4297179.635	4770397.2	287327.9	354000	38059.2	444862.234	18890111.4
2026	8675768.2	4340151.431	4766122.2	300527.9	356466.667	48059.2	447338.234	18934433.9
2027	8653251.2	4383552.945	4761847.2	313727.9	356466.667	58059.2	449814.234	18976719.4
2028	8630734.2	4427388.475	4757572.2	326927.9	358396.667	68059.2	452290.234	19021368.9
2029	8608217.2	4471662.36	4753297.2	340127.9	360326.667	78059.2	454766.234	19066456.8
2030	8585700.2	4516378.983	4749022.2	353327.9	361506.333	88059.2	457242.234	19111237.1
2031	8717300.2	4561542.773	4744747.2	366527.9	362964.667	98059.2	459718.234	19310860.2
2032	8698900.2	4607158.201	4740472.2	379727.9	364423	108059.2	462194.234	19360935
2033	8835100.2	4653229.783	4736197.2	392927.9	365881.333	118059.2	464670.234	19566065.9
2034	8821300.2	4699762.081	4731922.2	406127.9	367339.667	128059.2	467146.234	19621657.5

	Forests	Trees Outside Forests					Blue Carbon Ecosystems	
Year	In natural forests and plantations	Homegardens	Coconut plantations	Tea plantations with shade trees	Mixed trees with other perennials	Urban green cover and areas with avenue plants (ha)	Mangroves	Total
2035	8962100.2	4746759.701	4727647.2	419327.9	368798	138059.2	469622.234	19832314.5
2036	8952900.2	4794227.298	4723372.2	432527.9	370256.333	148059.2	472098.234	19893441.4
2037	9098300.2	4842169.571	4719097.2	445727.9	371714.667	158059.2	474574.234	20109643
2038	9093700.2	4890591.267	4714822.2	458927.9	373173	168059.2	477050.234	20176324
2039	9166400.2	4939497.18	4710547.2	472127.9	374631.333	178059.2	479526.234	20320789.3
2040	9164100.2	4988892.152	4706272.2	485327.9	376089.667	188059.2	482002.234	20390743.6
2041	9192720.2	5038781.073	4701997.2	498527.9	377548	198059.2	484478.234	20492111.8
2042	9199070.2	5089168.884	4697722.2	511727.9	379006.333	208059.2	486954.234	20571709
2043	9205650.2	5140060.573	4693447.2	524927.9	380464.667	218059.2	489430.234	20652040
2044	9212460.2	5191461.178	4689172.2	538127.9	381923	228059.2	491906.234	20733109.9
2045	9219500.2	5243375.79	4684897.2	551327.9	383381.333	238059.2	494382.234	20814923.9

	Forests	Trees Outside Forests					Blue Carbon Ecosystems	
Year	In natural forests and plantations	Homegardens	Coconut plantations	Tea plantations with shade trees	Mixed trees with other perennials	Urban green cover and areas with avenue plants (ha)	Mangroves	Total
2046	9226770.2	5295809.548	4680622.2	564527.9	384839.667	248059.2	496858.234	20897487
2047	9234270.2	5348767.644	4676347.2	577727.9	386298	258059.2	499334.234	20980804.4
2048	9234270.2	5348767.644	4672072.2	590927.9	387756.333	268059.2	501810.234	21003663.7
2049	9234270.2	5348767.644	4667797.2	604127.9	389214.667	278059.2	504286.234	21026523.1
2050	9234270.2	5348767.644	4663522.2	617327.9	390673	288059.2	506762.234	21049382.4

Table 6: The total GHG emissions from the forestry sector including forests and trees outside forests in the Net Zero Scenario from 2025-2050.(Tonnes/yr)

Year	From Deforestation	From the fragmentation of coconut lands	Total Emissions
2025	750000	161250	911250
2026	750000	161250	911250
2027	750000	161250	911250
2028	750000	161250	911250
2029	750000	161250	911250
2030	750000	161250	911250
2031	600000	161250	761250
2032	600000	161250	761250
2033	450000	161250	611250
2034	450000	161250	611250
2035	300000	161250	461250
2036	300000	161250	461250
2037	150000	161250	311250
2038	150000	161250	311250
2039	75000	161250	236250
2040	75000	161250	236250
2041	45000	161250	206250
2042	37500	161250	198750
2043	30000	161250	191250
2044	22500	161250	183750
2045	15000	161250	176250
2046	7500	161250	168750

2047	0	161250	161250
2048	0	161250	161250
2049	0	161250	161250
2050	0	161250	161250

ANNEXURE 7: GENDER AND SOCIAL ASPECTS OF CARBON NET ZERO GOAL

Social Aspects of Net Carbon Zero Goal

It has been established that energy efficient and lower – carbon living conditions and work settings have far reached impacts. Health benefits and corresponding increased work hours, higher levels of productivity, subtle benefits such as social inclusion and improved accessibility due to energy efficient building and transport, and increased employment due to the demand for skilled labor in building construction and maintenance are among the key advantages identified as resulting from low-carbon settings (Gouldson, A, et. al.2018). The same study also emphasizes on the substantial role of sustainable cities in lowering the level of carbon emission and its positive consequences on the social and economic lives of the people (Gouldson, A, et.al. 2018). The report stresses the implications of energy-efficient buildings, low-carbon transport and effective solid waste management as having a crucial impact on the well-being of people and sustainable development.

Research has highlighted the co-benefits of low-carbon futures including its health benefits and resulting quality of life and its contribution to increased productivity, employment generation and reducing socio-economic vulnerabilities. However, the report also deliberates on the unequal consequences such efforts could produce due to demographic factors, geographical location, economy, employment situation etc. (EEA 2021).

Literature also demonstrates that social harmony (ethnicity, religion based), social class, gender, political stability and good governance, social policy and institutional well-being and also domestic life styles have direct and indirect relationships with the carbon emission in a society. Wang et al. (2020), studied "how environmental performance is affected by economic, political and social indicators by using the annual data of 163 developed and developing countries covering the time period of 1996-2016. According to Wang et. al. (2020), ethnic diversity; institutional quality and political freedom play a significant role in decreasing CO2 emissions while energy consumption, GDP growth and financial development are seen as factors contributing to increased environmental degradation".

In a study conducted in Nigeria on the impact of population growth on carbon dioxide emission, Lawal (2019) examines time series data from 1975 to 2016 demonstrating a positive correlation between carbon emission, population and technology while establishing a negative association between affluence and carbon dioxide emissions. The study sees population growth as having only a marginal impact on the level of carbon emission. This finding goes against some other research where population growth, economic development and wealth are seen as factors contributing to higher carbon emissions.

Studies have demonstrated that higher military expenditures cater to increased environmental impacts including greater levels of carbon dioxide emissions (Jorgenson and Clark, 2009; York, 2008, as cited in Ergas and York, 2012). However, Ergas and York in their 2012 study states the nations with higher military expenditure do not necessarily cater to higher carbon emissions but also could be equal with other nations (Ergas and York, 2012).

Using time series data for 37 years from 1974 to 2010 to analyze the causal relationship between environmental pollution, education and economic growth in Bangladesh, Uddin (2014) has shown the presence of statistically significant correlation between carbon dioxide emission and education expenditure. He posits that higher share in GDP for education, via increased literacy and awareness among population, contribute to reduced emissions and resulting sustainable development.

Recent developments in worldwide online education due to Covid pandemic has directed the attention of researchers towards the environmental impact of social changes accompanying this process. Conducting a case study in Chinese universities taking two main elements related to online education, transportation and electricity consumption into consideration, Yin *et al.* (2022) say that online education can significantly reduce lower carbon emission. The study reveals that in the field of higher education alone, if the first calculation result of this study (i.e.,1,459,596.596 tons) is used "the total carbon emissions reduction of college students caused by online education during the half-year is equivalent to the total carbon emissions in 1.296 h in China, 2.688 h in the United States, 5.544 h in India, 12 h in Japan and 3.864 h in European countries of OECD" (Yin et.al., 2022:11).

A study conducted by Benlemlih, Assaf, and El Ouadghiri (2022) provides strong evidence on the positive relationship of low carbon emission and political stability and lesser corruptive practices. Examining data sets from 145 countries worldwide, the researchers have pointed out that in the short run, carbon dioxide emissions become substantially reduced with high political stability.

Drawing information from over 700 research papers, Gouldson et al. (2018), explains that low-carbon measures would cater to a range of achievements including job creation, improved public health, social inclusion, and improved accessibility. The author further claims that green building structure would contribute to as much as a 16 percent increase in worker productivity while playing an important role in the reduction of poverty and inequality, providing job opportunities in the fields of recycling programmes, low carbon waste management projects etc.

Carbon Emission and Gender

Many studies have demonstrated the gendered differences in the contribution to carbon emission and the gendered impact of carbon levels (Lee et.al. 2017; Li et. al. 2019; Castañeda et.al. 2020, Nuber, 2021; WOW, 2021). Researchers also have explicated that women's higher representation in politics as a significant factor in reducing carbon emission (Benlemlih, Assaf, and El Ouadghiri 2022).

Utilizing a large-scale survey of 100,956 respondents across 37 countries Imbulana Arachchi and Managi (2021) shows the existence of a significant contrast between males and females with regard to the knowledge concerning sustainability and energy saving practices. According to this study, in most countries males seem to be more knowledgeable about energy sustainability than females. However, females were found to be more concerned about the importance of energy sustainability than males.

The authors say that male tendency in looking for cause-effect logic and the female tendency in holistic association could be integrated in the decision-making process concerning energy sustainability and energy conservation practices producing better energy conservation models.

A strong connection has been made between women’s participation in the decision-making processes and Lower carbon emission. A survey conducted in Canada has shown that firms comprising a higher female working population demonstrated a higher concern on green gas effects than in firms with a higher male presence (Ghaeli, 2019).

According to IUCN data, women have held 15% top level jobs as ministers of environmental sectors in 2020 compared to 12 percent in 2015 revealing an incremental change over time regarding women’s involvement in decision making related to the environment (IUCN, 2022). IUCN reports also reveal that countries with more women in their parliaments are more likely to ratify environmental treaties and invest in and conserve land for renewable power generation.

According to a fairly large study that took a sample of the 329 largest companies in the United Kingdom into consideration, Liao, Luo and Tang (2015) demonstrated a significant positive association between gender diversity when measured as the percentage of female directors on the board. The study also reveals that the propensity to disclose GHG information and the extensiveness of that disclosure is higher when the female percentage is higher among the Board of directors.

A study conducted by Haque (2017) covering a period of 13 years between 2002 – 2014 examining the effects of board characteristics and sustainable compensation policy on carbon reduction initiatives and greenhouse gas (GHG) emissions of a firm suggested that board independence and board gender diversity have positive associations with carbon reduction initiatives.

IUCN based on studies carried out in West Africa have shown that women have shown a tendency to use agricultural techniques that would better adapt to climate change IUCN (2022), The studies also explicate that women are more likely than men to engage in group decisions catering to better conservation practices and land management extending such contributions to the fields of scientific, business and political decision making.

The Paris agreement takes a holistic view on climate change recognizing climate change as a common concern of humankind. It expects the parties to the agreement to respect, promote and consider their respective obligations on human rights (UNFCCC, 2016) in acting towards addressing climate change.

Article 7 of the Paris agreement requires the parties to follow a country-driven, gender-responsive, participatory and fully transparent approach, taking into consideration vulnerable groups, communities and ecosystems in taking climate action. It also encourages taking into consideration traditional knowledge, knowledge of indigenous peoples and local knowledge systems where appropriate (UNFCCC, 2016). Article 7 also has paid attention to the importance of building resilience of socioeconomic and ecological systems when reaching its goal of sustainable management of natural resources. The success in achieving the carbon net zero goal therefore, would significantly depend on the planning and implementation process at the country level. However, this target would be effective only if and when the country is committed to take a country driven, gender responsive path based on scientific as well as indigenous knowledge that incorporates the total scenario surrounding carbon emission concerning all people of the country including vulnerable communities.

In July 2021, as a signatory to the Paris Agreement, The Ministry of Environment in Sri Lanka published an updated version of the Nationally Determined Contributions (NDCs) to the United Nations Framework Convention on Climate Change (UNFCCC). Being placed at a high rank in the Global Climate Risk Index due to its tropical weather conditions and facing ensuing vulnerabilities despite its low – carbon emission records, Sri Lanka's contribution to environmental conservation becomes a high priority in order to maintain economic and social well-being of its population. The risks become augmented with the increasing urbanization and resulting demand for resources further endangering its already frail ecosystems.

While considering the sectors such as industry, energy, waste, forestry and agriculture as major priorities in the project for lowering carbon emission, the NDC document also has duly paid attention to socio-economic and gender factors. It says that "Investments in mitigation will be prioritized based on emission intensities and the economic, social or environmental co-benefits derived from these actions" (Ministry of Environment, 2021:1) catering to the target of keeping "the country on a low carbon trajectory as it strives for greater economic and social well-being of its people" (Ministry of Environment, 2021: 1).

NDC have considered the significance of considering the gender impacts of any measures taken to lower Net Zero Carbon Emission. In the Chapter 4 of NDCs on Implementing and Monitoring Mitigation, it is recommended that in targeting sustainable development measures it is necessary to conduct "detailed gender and social analyses of the actions and propose any mitigatory steps to overcome risks" and emphasizes that "Gender and sustainable development co-benefit analysis is mandatorily required in Sri Lanka's national planning project format" (Ministry of Environment, 2021:7).

Chapter 5 of NDCs document which discusses the adaptation process" (Ministry of Environment, 2021:25), it considers the mainstreaming of gender and social safeguards into adaptation priorities as an important strategy. While it is recommended that "down-scaled risk assessments and sectoral plans integrate specific needs, vulnerabilities and capacities of women, young children, disabled and elderly populations", it highlights the need for developing gender-responsive strategies "taking into account differentiated needs of men and women within the sector and recommend ways to improve access to knowledge, technology, financing etc. in a way that creates enabling conditions for adaptation". It further cites the importance of "Increased capacities among both men and women, improved technical and Science, Technology, Engineering and Mathematics (STEM) education, more funding for vulnerability analysis at the local level etc., to enable greater engagement and contribution of women, allowing the application of skills and capacities that are gender-specific (Ministry of Environment, 2021: 25).

NDCs also stresses the need to invest in gender-responsive training promoting equal contribution by women and ensuring equal access to benefits. It says that "Gender-responsive NDCs will enable men and women to equally benefit from new technologies, climate-smart production and water management practices that would include better agriculture productivity, food security and incomes, greater resource management efficiency (water, land, food processing and preservation) etc." (Ministry of Environment, 2021: 25) and recommends that the sectors undertake detailed gender analysis in developing ten-year NDC implementation plans. While chapter 7 has substantially been dedicated to the aspect of integrating gender and sustainable development to NDCs, it pays attention to the gender concerns in the entire process in decision making, implementation and monitoring. It has contemplated on the necessity of prioritizing gender and being gender responsive in the efforts to lower GHG emissions while maintaining gender balance at all bodies catering to this cause (Ministry of Environment, 2021: 50).

One of the main concerns of the Paris Agreement is to promote gender equality and women's empowerment and adopt gender-responsive approaches in adaptations of policies and planning and implementation of climate related actions. The UNFCCC Gender Action Plan also recommends gender mainstreaming in all climate change processes. Being on par with these international treaties on climate change, NDCs of Sri Lanka stresses the need to analyze gender disparities from a national development context, "to narrow down existing disparities and identify ways to realize the optimum potential of men and women through climate action" and benefit from the knowledge and capabilities of both men and women in implementing mitigation and adaptation measures (Ministry of Environment, 2021: 50). Placing this process alongside with the national gender equality and women empowerment agenda, National Steering Committee (NSC) has been established to ensure synergies between climate action and other sustainable development goals – including gender equality and women's empowerment" which "are identified as preconditions for the successful implementation of the N and the achievement of the SDGs" (Ministry of Environment, 2021:55). Therefore, the NSCs are expected to ensure that the SDG achievements are not hampered by any mitigation measures taken in climate action in the implementation of NDCs.

NDCs in chapter 5, gender-based actions have been mentioned as a priority only in relation to the livestock sector. NDC recommends the promotion of gender sensitivity in the livestock sector as a major target for the year 2022. No other mentioning of gender-based activity could be identified in the sectoral adaptation of NDCs.

Apparent exclusion of gender and other social sector priorities in natural disasters in the calculations made by different organizations including the World Bank in the predictions made on the potential impacts due to climate change by 2050 has been identified as a gap by the NDC Sri Lanka (Ministry of Environment, 2021: 47). Therefore, it could be estimated that the losses incurred due to climate change by 2050 could be much higher than the currently available estimates. This calls for adequate attention to social and gender issues prevailing in the spheres of climate and environment. In addressing this serious gap in identifying the damages, NDC recommends aligning climate actions with sustainable development goals.

According to the NDC document, effective NDC implementation and investments in mitigation are supposed to be prioritized based on emission intensities and the economic, social or environmental co-benefits derived from these actions. NDCs in Sri Lanka have identified a number of key sectors; viz. agriculture, livestock, fisheries, water, health, biodiversity, coastal and marine, urban planning and human settlements, and tourism for which priority should be given in designing adaptation needs and resilience-building activities with the goal of keeping " the country on a low carbon track as it strives for the greater economic and social well-being of its people (Ministry of Environment, 2021: 1).

When implementing and Monitoring Mitigation NDCs it is mandatory to carry out a gender and sustainable development co-benefit analysis for national planning projects and to conduct environmental and social impact assessments for all projects that involve larger scale land conversion or infrastructures. (Ministry of Environment, 2021:7)

Agreed upon at the United Nations Conference on Sustainable Development in 2012, the Sustainable Development Goals (SDGs) were adopted by the United Nations in 2015 in order to create a global agenda addressing the environmental, political and economic challenges the world has faced hindering the goals of development. The seventeen objectives chosen to be the goals of sustainable development which are to be achieved during the period between 2015 – 2030 consider that for the development to be sustainable, all these aspects including positively responding to the negative impacts of climate change, sustainable management of fragile natural resources, reducing inequalities and promoting peace as priorities that are interrelated and need urgent action.

UN Environment Program has highlighted the importance of addressing environmental issues through each of the SDGs. According to UNEP (2020), SDG 5 which is "Achieve Gender Equality and Empower All Women and Girls" has identified its Target 5.a: as to "Undertake reforms to give women equal rights to economic resources, as well as access to ownership and control over land and other forms of property, financial services, inheritance and natural resources, in accordance with national laws." This target treats the relationship between women and their natural environment in reaching sustainable development and the importance of addressing these issues as a priority concern. Since the rural labour force comprises mainly of women, and their livelihoods are mostly based on natural resources, considering women's relationship to environment as a priority in targeting SDGs become a prime concern in the environmental conservation including climate action. SDG indicators that address the issue of empowerment of women under this scenario would become a clear measurement of the relationship between women's social position and its contribution to environment conservation.

SDGs also attempt to address the prevailing inequalities in countries that would become a significant measure in addressing the environmental and climatic issues related to such inequalities. SDG 10 is particularly designed with the goal of reducing inequality within and among countries. Its target 10.3 claims to "ensure equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and promoting appropriate legislation, policies and action in this regard". This can be considered a central theme in making any development sustainable as the most vulnerable could be reaping the worst impact of environmental degradation and climate change exacerbating the existing vulnerabilities.

Sri Lanka is one of the countries which has shown a clear commitment towards reaching SDGs by 2030. Out of the 17 SDGs, SDG 5: Gender Equality, SDG 8: Decent Work and Economic Growth, SDG10: Reduced Inequalities, SDG 11: Sustainable Cities and Communities and SDG 13: Climate Action are of prime importance in reaching carbon net zero through gender equality and social inclusion. Nevertheless, all SDGs seem to contribute to carbon net zero target directly or indirectly by increasing affordability of the population resulting in increased use of renewable energy sources, reduced dependence on natural resources and active decision making, planning and implementation of ecofriendly development goals.

Even though the above is the positive picture the country is anticipated to accomplish, UN Women (2021) claims,

> "As of December 2020, only 40.9% of indicators needed to monitor the SDGs from a gender perspective were available, with gaps in key areas, in particular: unpaid care and domestic work and information and communications technology skills. In addition, many areas – such as gender and poverty, physical and sexual harassment, women's access to assets (including land), and gender and the environment – lack comparable methodologies for regular monitoring. Closing these gender data gaps is essential for achieving gender-related SDG commitments in Sri Lanka".

According to UN Women (2021), Sri Lanka so far has not been able to achieve the goals of gender equality as envisaged. Women do not seem to have adequately entered into decision making bodies. Women only held 10.89 percent of elected seats in bodies of local government while the representation of women in national parliaments was 5.38 percent of total number of seats as of 2021. Only 25.97 percent of the managerial positions were held by women showing an overall low performance of women's entry into decision making bodies. Moreover, UN Women (2021) reveals that even though a slight increase in number of parliamentary membership of women could be seen, a declining trend is visible in the percentage of women employed in managerial positions. Despite the high performance level shown by Sri Lanka with regard to the presence of "laws and regulations that guarantee full and equal access to women and men aged 15 years and older to sexual and reproductive health care, information and education" which is 89 percent, and equal access to contraceptive and family planning which is 100 percent, low performance of 63 percent has been identified in maternity care which would affect women's health and wellbeing and their upward carrier mobility. Such circumstances which add to women's impaired health and hindered access to opportunities would not produce the anticipated positive input of women in politics (Benlemlih, Assaf, and El Ouadghiri, 2022) and decision-making levels (Ghaeli, 2019; IUCN, 2022) in reducing carbon emissions.

Further to the situation, under SDG 8: Decent Work to Economic Growth, UN Women (2021) reports that the unemployment rate of the country for the people over the age of 15 is increasing for both men and women (4.3%), however, women's unemployment rate (6.9%) is comparatively higher than that of men (3%).

It has been further revealed that the country has experienced an age-standardized mortality rate of 63 deaths per 100,000 population which is attributed to household air pollution (UN Women, 2021) is a consequence of low health and wellbeing due to many factors including overcrowding, lack of enough space, use of fossil fuel and energy sources, use of excessive amounts of firewood in smaller and closed environments etc. The report also says that the proportion of population with primary reliance on clean fuels and technology is only 31 percent. Lower use of renewable energy sources could be attributed to poverty and the high cost of installing solar power systems and other renewable energy sources, low awareness and lack of formal initiatives in popularizing sustainable household energy sources.

Gender and social scenario under these circumstances does not seem to reap the probable contribution that a larger and empowered female population or an educated population could have to the lowering of carbon emission unless specific attempts are made to uplift the socio-economic status of the underprivileged and vulnerable groups and attain gender equality with a focus on the reduction of carbon emission practices during the everyday lives of the country's population.

One of the major issues that have been highlighted with regard to gender and environmental concerns in SDGs is that although SDGs have paid substantial attention to the significance of the gender as well as the environment in achieving sustainability in development, they have not considered the inseparable link between these two factors. UN Policy brief 002 of UNEP (2018) referring to the absence of gender disaggregated data says that "The SDG Global Indicator Framework is gender blind in SDGs 6, 7, 9, 12, 14 and 15". All these indicators are concerned with environmental factors or possible pollutants of the environment, thus revealing the failure of the policy making level to capture the need to see the synergies between gender and environment. Such an approach at the level of policy could lead the countries to ignore this vital relationship and the capacity to utilize it for the protection of environment.

Summary of the views provided by the respondents

- Speaking of their experience with climate change, all the respondents shared that they encountered some consequences of carbon emission, including irregular temperature and rain patterns. In addition to this, rural people often experience the scarcity of water due to the drying of lakes, droughts, loss of vegetation etc. However, except for a few educated respondents, others did not understand the relationship between climate change and carbon emission.
- However, they could see the connection between human activities that can increase climate change, such as deforestation, vehicle emission, improper disposal of garbage, and industrialization and improper disposal of factory waste into the natural ecosystems.
- Three rural respondents including two males and a female with middle income highlighted the fact that there is a dire need for an effective waste collecting system in rural areas. They were of the view that lethargic attitude of the concerned authorities in collecting waste from rural areas lead people to adopt environmentally harmful activities such as burning of non-biodegradable waste.
- Respondents from the rural sector largely pointed out the problems concerning the disposal of chemical waste into the waterways and its impact on the increase of kidney disease in rural settings.
- Other than a few respondents from a rural low-income background who possessed less knowledge on solar energy, both urban and rest of the rural respondents prefer shifting to solar energy if it can be affordable. Dry zone respondents claimed that their climate with high temperatures would provide a perfect ground for generating solar energy. They suggested the introduction of loan scheme for this purpose enabling them to use this freely available source of renewable energy.
- It is important to mention here, even though the suggestion came from one respondent, who is a middle-income male in urban settings, that in order to make solar energy a popular source of renewable energy, it is highly important to focus on people’s infrastructure, including proper roofing, to plant solar panels. According to him, if the government does not prioritize this issue, the urban low-income population living in substandard housing will be unable to reap the benefits of renewable energy, despite receiving government assistance to use solar energy. Another urban middle-income male pointed out that even though he prefers using solar energy, the average lifetime of a solar panel would be 10–12 years. He stated that the approximate cost needed to plant a small solar panel would be nearly 1,500,000–2,000,000 LKR which is not affordable by many middle-class people including himself.
- Rural middle-class respondents in agriculture claimed that they do not have a clear idea on the ability to use solar energy in agricultural activities are less knowledgeable about introducing this initiative to agricultural activities. They are eager to reap the benefits of the newly introduced green agricultural techniques if the government can properly implement this initiative with correct guidelines for using solar-energy driven agricultural appliances.

- However, they stressed the negative repercussions they reaped due to the ineffective decisions taken by the government in completely banning chemical fertilizers and introducing organic fertilizer as an alternative in 2021. According to one rural middle-income farmer and one rural middle-income female engaged in agriculture, this sudden decision caused them to face a slew of problems, including receiving low-quality organic fertilizer, losing more than half of their harvest, losing income, going into debt, etc. According to their experience-based knowledge, organic fertilizer could be more effective for home-based plantations but when it comes to large scale, it is not quite practical. However, they were aware of the environmental destruction that could cause by chemical fertilizers.
- Their suggestion was that if the government could provide high-quality organic fertilizer, they could use it for approximately 70% of the crop, along with 30% for chemical fertilizer according to their experience. They did not see the possibility to totally convert to organic fertilizers at the moment, as it is impossible to kill weeds and pests in a paddy field just with organic agricultural products. They suggested that a gradual shift to decrease the use of chemical fertilizers would be far more effective.
- Both rural and urban people talked about their practices that might contribute to climate change. The main activities mentioned by the urban population was the burning of plastics and the heavy use of polythene. Furthermore, a small number of rural respondents blame the urban middle-income population for their unhealthy practices, such as dumping waste in rural forestry areas and engaging in construction and industrial activities that may worsen environmental degradation.
- People in general have less knowledge about the 3R concept, but some of their practices indicate that they follow some environmentally friendly actions although they were unaware of the related technicalities. Using reusable bags, categorizing waste before disposing of it, reducing food waste by buying what we need, composting food waste, donating unused food to the needy or shelters, and reusing or recycling items such as old clothes, cloth grocery bags, and containers are some of the practices they mentioned, often practiced as meritorious deeds and cultural practices.
- They also engage in some energy-efficient practices such as working more with electricity during the day, limiting the number of light bulbs, and ironing or washing clothes at once a week. One urban middle-income respondent said that he regularly rides a bicycle for short-distance travel as both an exercise and to reduce vehicle emissions. A rural low-income female claimed that her family members use a bicycle to travel to the city a cost cutting method. Respondents from rural settings often claimed that they use firewood to cook, however, they did not have any understanding of the contribution of the practice to carbon emission. They were of the view that the use of fire wood is an environmentally protective activity.
- However, one rural low-income female had a different conception of canal-based transportation systems. In her view, this could increase water pollution in rural waterways.
- In general, the rural population saw rural living as a healthy measure in conserving nature. Urban population did not see it as an alternative that many urban people would

not be able to revert back to mainly due to their established social networks and career opportunities.

- One rural middle-class female talked about the importance of the concept of "think green before shopping."
- Often, rural respondents were of the view that it is the urban population that pollute the environment resulting in climate change.
- Nevertheless, urban residents claim that they are aware of climate change and its consequences, and thus take more environmentally protective measures.
- In general, every respondent knows the impact of polythene on environmental degradation. Even if so, people, especially women, seem to burn polythene, as measure of destroying waste. They were of the view that it is less environmentally harmful if all polythene bags could be collected and burn once a week or so.
- Speaking of environmental movements, five respondents claimed that they have engaged in environmental activism.
- Respondents from both genders and social classes in both rural and urban areas, were unanimous on the need for an efficient transportation system in the country.
- All the respondents strongly agree on the need for reforestation and increasing forest cover in both rural and urban areas. They blamed the forest-based businesses as the main reason for deforestation. Urban respondents emphasized the responsibility of the government to initiate programs for increasing forest cover in urban areas.
- Working from home to reduce carbon emission was not applicable for the very large rural population due to the nature of their livelihoods. Those who engaged in while collar jobs also were not pleased with the idea mentioning that it is not possible to entirely depend on technology as paper work is still largely practiced. Respondents also stated that it is not easy for them to work from home due to stressful family environment, overworking in relation to gender roles at home, and to the difficulty in detaching entirely from domestic social relations and responsibilities during working hours. One urban middle-income male who is also working in an IT related field said that working from home could be more expensive in terms of high electricity and data expenses, and he prefers to travel to his workplace instead. Only four respondents from the total sample preferred working from home since it could be more cost effective.

Suggestions by the respondents

Urban

- Including practice-based knowledge about environmental conservation and climate change into the school education system
- Government intervention to increase forest cover in urban areas
- The government's proper implementation of the 3Rs.
- Government intervention is needed to promote affordable solar energy.
- A better government action plan to reduce carbon emissions, beginning with households and progressing to large factories

- The government should take the necessary action to promote electric cars.

Rural

- Urban settings should be greener.
- Rural waste management should be effective. Government intervention is crucial.
- Proper garbage collection and dumping plans

ANNEXURE 8: SUPPORTING DATA OF THE ECONOMIC ANALYSIS

1. Energy sector

The proposed actions for energy sector results in carbon emission savings which have been converted into monetary estimates using available social cost of carbon emissions from the World Bank. The following figure shows the net benefits, which are negative.

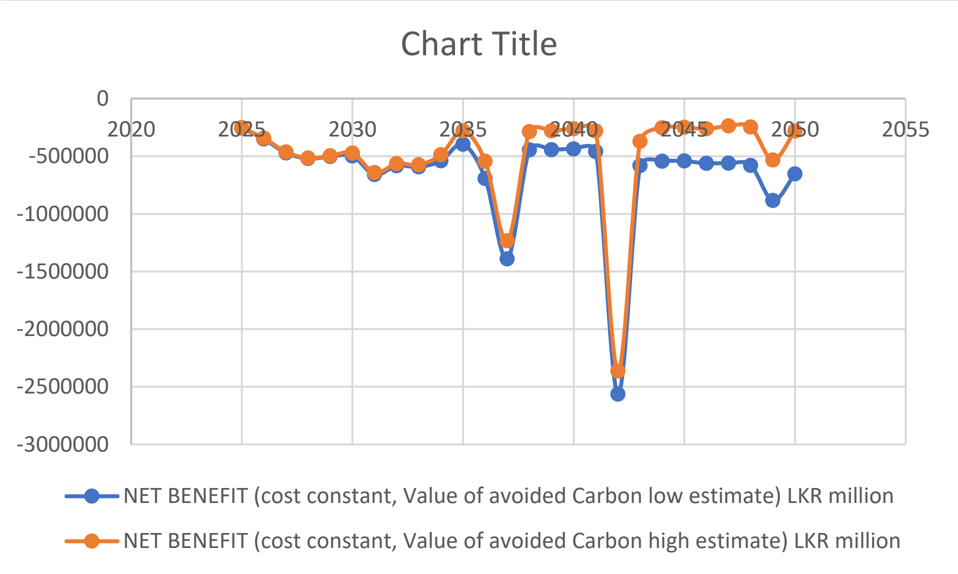

Figure 1. Net benefits from Proposed Mitigation Scenario 02- Energy Sector decarbonization

Above figure indicates that net negative benefits are resulted from the proposed actions for the energy sector due to the high cost of the action. The economic analysis of the action has resulted in net present value as follows for different prices used. The following table provides details.

Table : Net present values of Proposed Mitigation Scenario 02- Energy Sector decarbonization under different prices of avoided carbon and cost escalations

Context	**Net present value (LKR) @ 10% discount rate**
Net benefit (cost constant, Value of avoided Carbon low estimate)	-5,105,443,005,554.94
Net benefit (cost constant, Value of avoided Carbon high estimate)	-4,412,922,592,073.77

It is necessary therefore to arrange financing mechanisms in order to implement the decarbonisation energy actions for Sri Lanka.

2. Transport Sector

The following emission reduction (ER) actions are proposed under the net zero status in the transport sector.

ER action 1: Railway Electrification

ER action 2: Interprovincial Bus Electrification

ER action 3: Provincial Bus Electrification

ER action 4: Private and Freight Vehicles Electrification

The following section provides details of costs and benefits of each action.

ER action 1: Railway Electrification

Railway electrification results in some emission savings. The following figure illustrates the savings for the period from 2030 to 2050.

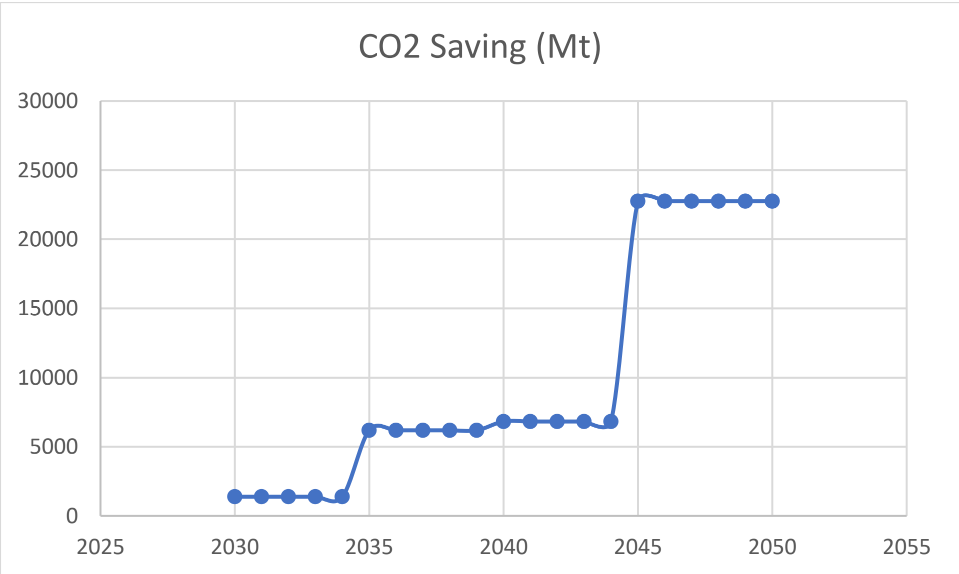

Figure 2: CO2 savings from Railway electrification for the period 2030 to 2050

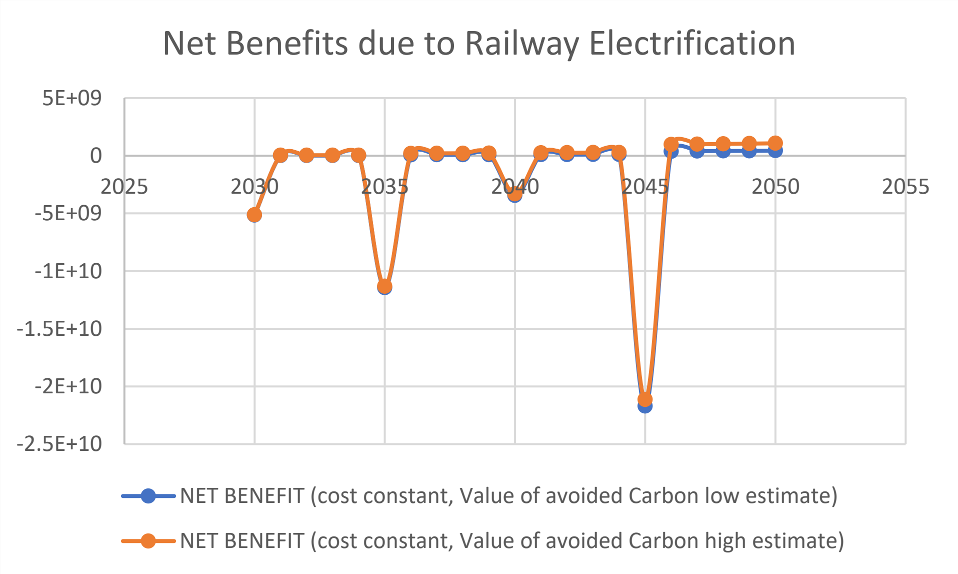

Figure 3: Net Benefits due to Railway Electrification

Above figure indicates that net negative benefits are resulted from the action due to the high cost of the action. The economic analysis of the action has resulted in net present value as follows for different prices used. The following table provides details.

Table : Net present values of using Electric vehicle for Railway Electrification under different prices of avoided carbon

Context	Net present value (LKR) @ 10% discount rate
Net benefit (cost constant, Value of avoided Carbon low estimate)	-16,443,331,238.02
Net benefit (cost constant, Value of avoided Carbon high estimate)	-15,176,037,288.13

The higher operational and capital costs associated with railway electrification makes this action a non beneficial action. The above figure illustrates the higher costs associated with the Railway Electrification. The action results in carbon emission savings which have been converted into monetary estimates using available social cost of carbon emissions from the World Bank.

It is important to estimate a price for the carbon savings to see how this action could be made viable through some type of a resource transferor carbon credits. However, the above calculation has not taken into account the time savings of the commuters, vehicle emission savings etc associated with the improved rail service. In addition there will be health benefits due to the reduced emission of PM 2.5 and other air pollutants.

Similar trends are observed with other actions, which are Interprovincial Bus Electrification, Provincial Bus Electrification and Private and Freight Vehicles Electrification as well.

The following table provides details.

Table: Net present values of proposed Emission reduction **mitigation actions for Transport sectors**

Mitigation actions	**Net Present Value (LKR) @ 10% discount rate**	
	Value of avoided Carbon (lower estimate)	**Value of avoided Carbon (upper estimate**
1. Railway Electrification	-16,443,331,238	-15,176,037,288
2. Interprovincial Bus Electrification	-97,992,697,344	-70,897,175,975
3. Provincial Bus Electrification	-141,288,818,341	-128,430,869,073
4. Private and Freight Vehicles Electrification	-36,292,770,688,495	-35,828,728,616,907
All four actions	-36,548,495,535,418	-36,043,232,699,243

It is therefore essential to find out mechanisms to finance the proposed mitigation measures from international sources.

3. Waste sector

The following emission reduction (ER) actions and sequestration enhancement (SE) actions are proposed under the net zero status in the waste sector.

ER action 1: Syngas recovery from open dump

ER action 2: Electric vehicle for waste collection

ER action 3: Waste to energy plants

ER action 4: Sanitary landfill

SE action 1: Daily Cover for Open dump

SE action 2: Vertical Subsurface flow constructed wetland (VSSFCW)

The following table provides details related to the level of operation and associated unit costs.

Table: Activities/ sub activities, their levels of operation and costs per unit for waste sector

Activity /Sub activity	Level of operation (annual)	Cost per unit
Emission reduction action 1: Syngas recovery from open dump	2031 (10% to 50% by 2050) 71.95 tonnes CO_2eq	0.126 $/Nm^3
	2035 – 628.91 tonnes CO_2eq	
	2040 – 1,464.71 tonnes CO_2eq	
	2045 – 2,598.84 tonnes CO_2eq	
	2050 – 3,463.97 tonnes CO_2eq	
Emission reduction action 2: Electric vehicle for waste collection	2036 – 136.7 tonnes CO_2eq	Electric Compression Garbage Truck US$ 98800-135460
	2040 – 628.83 tonnes CO_2eq	
	2045 – 492.21 tonnes CO_2eq	
	2050 – 355.42 tonnes CO_2eq	
Emission reduction action 3: Waste to energy plants	2036 – 1 No 143,517 tonnes CO_2eq 2041 – 1 No	US$95 million (KCHT Power Station Muthurajawela -2019) 630 tonnes of waste
	2040 – 720,756 tonnes CO_2eq	
	2045 – 1,421,816 tonnes CO_2eq	
	2050 – 1,373,142 tonnes CO_2eq	
Emission reduction action 4: Sanitary landfill	2046 – 118,544 tonnes CO_2eq	The sanitary landfill site at Aruwakkalu is designed to accommodate a capacity of about 5,000,000 tonnes of mixed MSW for 15 years at the cost of around US$ 101 million.
	2050 – 738,404 tonnes CO_2eq	
Sequestration enhancing action 1: Daily Cover for Open dump	2026 – 70,352 tonnes CO_2eq	Rs 2/kg of biochar
	2030 – 366,838 tonnes CO_2eq	
	2035 –437,709 tonnes CO_2eq	
	2040 – 538,461 tonnes CO_2eq	
	2045 – 649,058 tonnes CO_2eq	
	2050 – 769,773 tonnes CO_2eq	
Sequestration enhancing action 2: Vertical Subsurface flow constructed wetland (VSSFCW)	2031 – 4,736 tonnes CO_2eq	Rs. 35 000/Unit Operation Cost
	2036 – 23,463 tonnes CO_2eq	
	2040 – 22,919 tonnes CO_2eq	
	2045 – 22,376 tonnes CO_2eq	
	2050 – 21,832 tonnes CO_2eq	

Emission reduction action 1: Syngas recovery from open dump

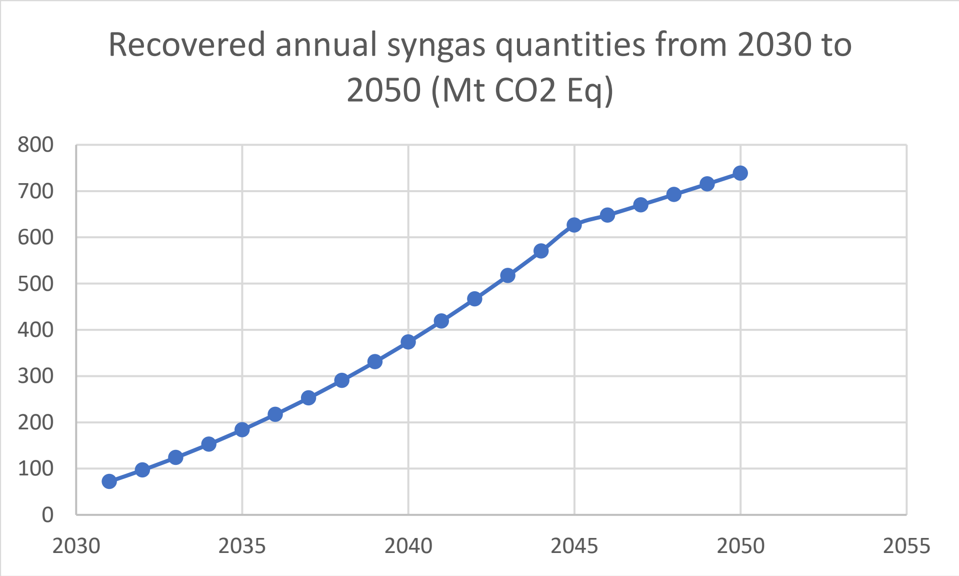

Figure 4 : Recovered annual syngas quantities from 2030 to 2050

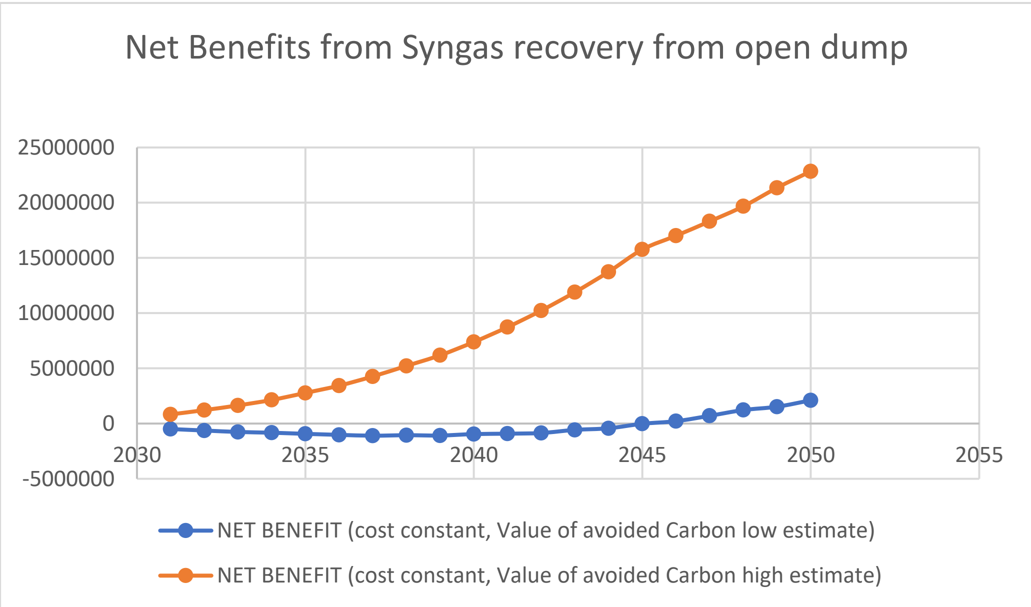

Figure 5 : Net Benefits from Syngas recovery from open dump

Above figure indicates that only the higher estimate of value of avoided carbon shows net positive benefit. The economic analysis of the action has resulted in net present value as follows for different prices used. The following table provides details.

Table : Net present values of syn gas recovery under different prices of avoided carbon and cost escalations

Context	Net present value (LKR) @ 10% discount rate
Net benefit (cost constant, Value of avoided Carbon low estimate)	-5,052,744.20
Net benefit (cost constant, Value of avoided Carbon high estimate)	53,115,328.99
Net benefit (cost 2% increase, Value of avoided Carbon low estimate)	-6,313,657.42
Net benefit (cost 2% increase, Value of avoided Carbon high estimate)	51,854,415.77

Emission reduction action 2: Electric vehicle for waste collection

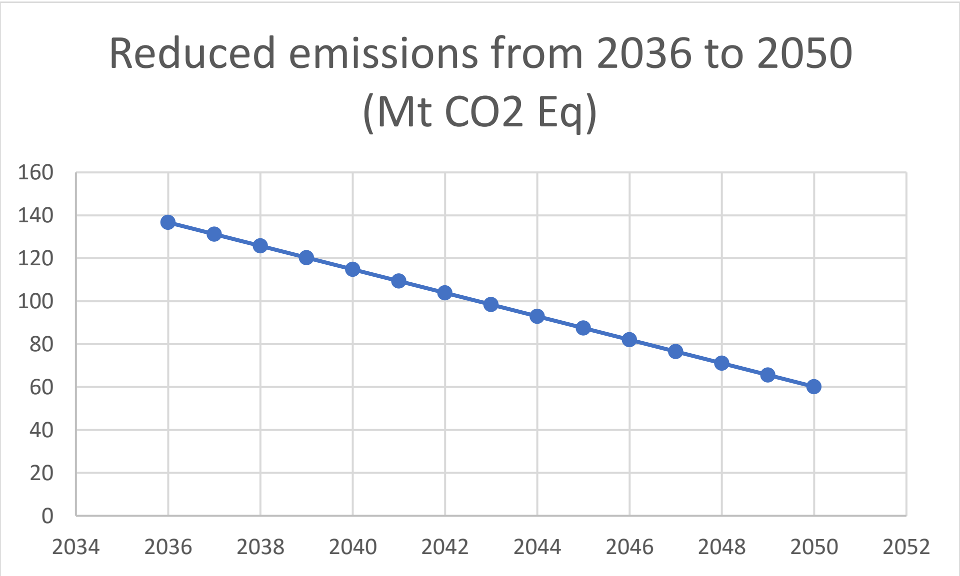

Figure 6 : Reduced emissions due to electric vehicle for waste collection

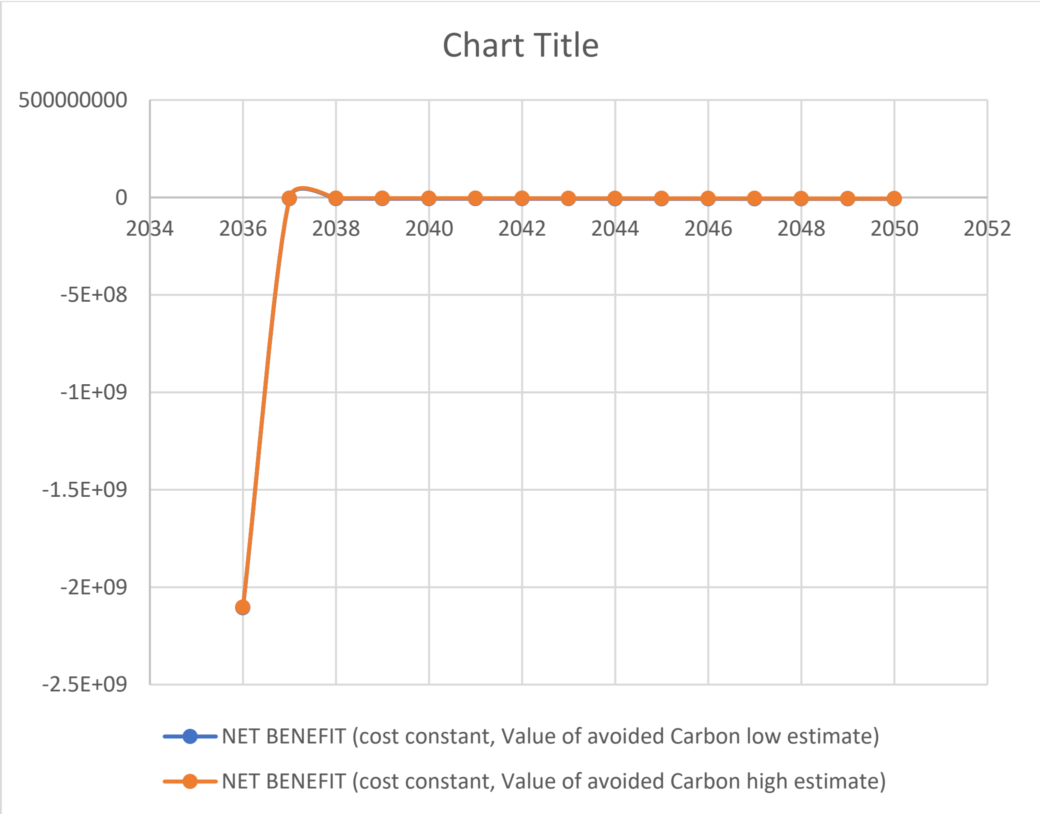

Figure 7 : Net Benefits due to electric vehicle for waste collection

Above figure indicates that net negative benefits are resulted from the action due to the high cost of the action. The economic analysis of the action has resulted in net present value as follows for different prices used. The following table provides details.

Table : Net present values of using Electric vehicle for waste collection under different prices of avoided carbon and cost escalations

Context	**Net present value (LKR) @ 10% discount rate**
Net benefit (cost constant, Value of avoided Carbon low estimate)	-1,959,271,804.33
Net benefit (cost constant, Value of avoided Carbon high estimate)	-1,940,537,516.89
Net benefit (cost 2% increase, Value of avoided Carbon low estimate)	-2,005,534,129.59
Net benefit (cost 2% increase, Value of avoided Carbon high estimate)	-1,986,799,842.15

Emission reduction action 3: Waste to energy plants

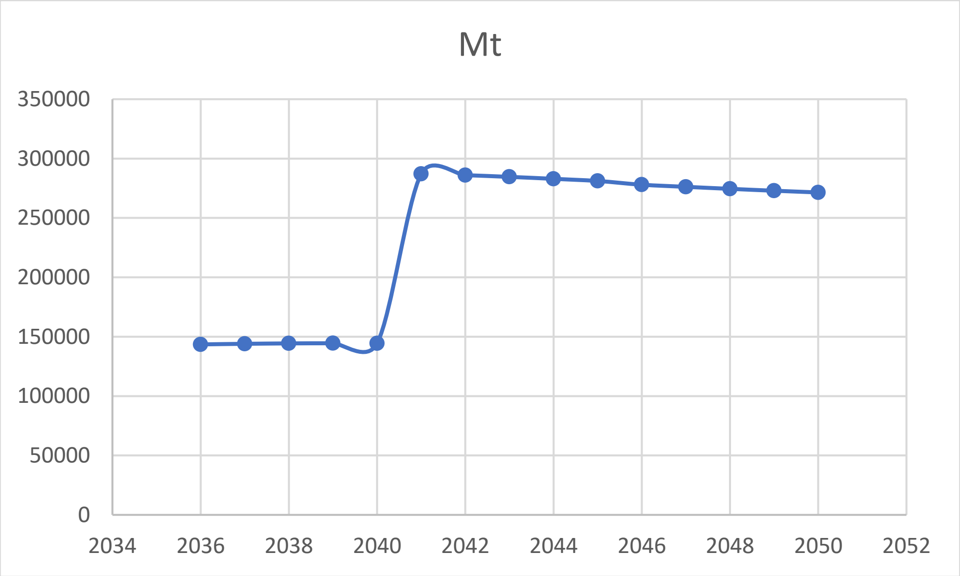

Figure 8 : Reduced emissions due to Waste to energy plants

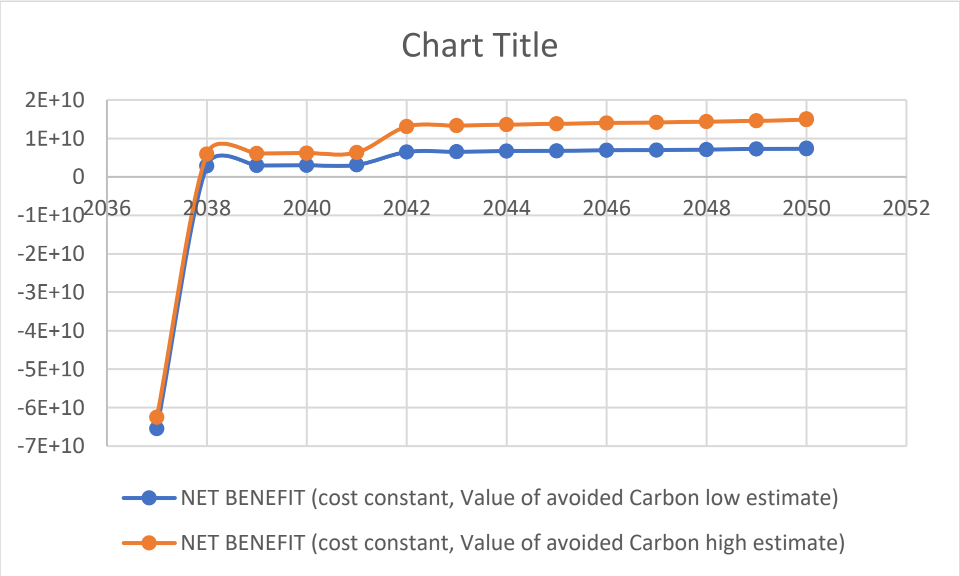

Figure 9 : Net Benefits due to Waste to energy plants

Above figure indicates that from 2038, there are net positive benefits. However, the economic analysis of the action has resulted in net present value only for high carbon prices. The following table provides details.

Table : Net present values of using waste to energy plants under different prices of avoided carbon and cost escalations

Context	Net present value (LKR) @ 10% discount rate
Net benefit (cost constant, Value of avoided Carbon low estimate)	-24,739,041,603.49
Net benefit (cost constant, Value of avoided Carbon high estimate)	13,887,404,121.78
Net benefit (cost 2% increase, Value of avoided Carbon low estimate)	-26,003,572,571.55
Net benefit (cost 2% increase, Value of avoided Carbon high estimate)	12,622,873,153.72

Emission reduction action 4: Sanitary landfill

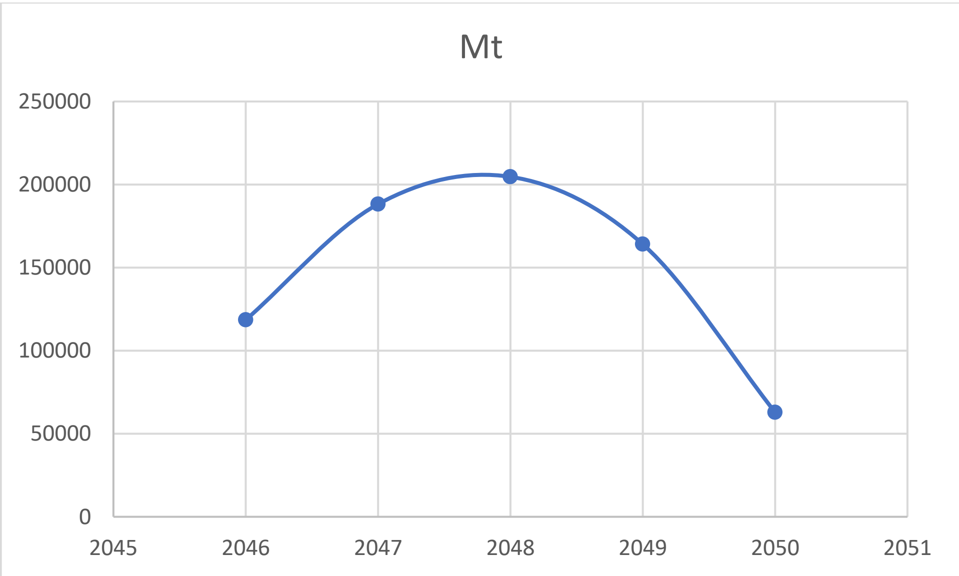

Figure 10 : Reduced emissions due to Sanitary landfill

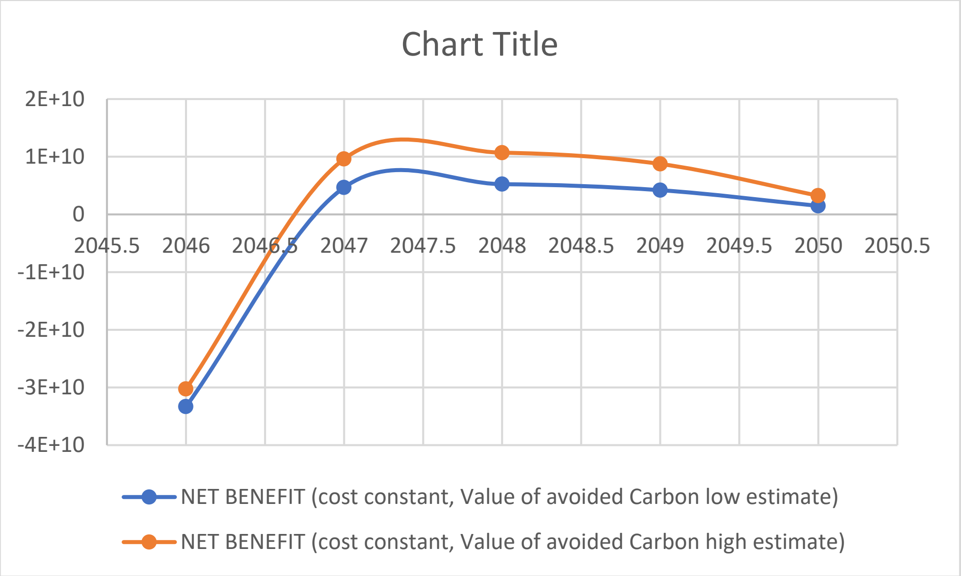

Figure 11 : Net Benefits due to Sanitary landfill

Above figure indicates that from 2047, there are net positive benefits. However, the economic analysis of the action has resulted in net negative present values. The following table provides details.

Table : Net present values of sanitary landfill action under different prices of avoided carbon and cost escalations

Context	**Net present value (LKR) @ 10% discount rate**
Net benefit (cost constant, Value of avoided Carbon low estimate)	-18,721,691,991.70
Net benefit (cost constant, Value of avoided Carbon high estimate)	-3,540,883,638.19
Net benefit (cost 2% increase, Value of avoided Carbon low estimate)	-19,399,266,201.12
Net benefit (cost 2% increase, Value of avoided Carbon high estimate)	-4,218,457,847.60

Sequestration action 1: Daily Cover for Open dump

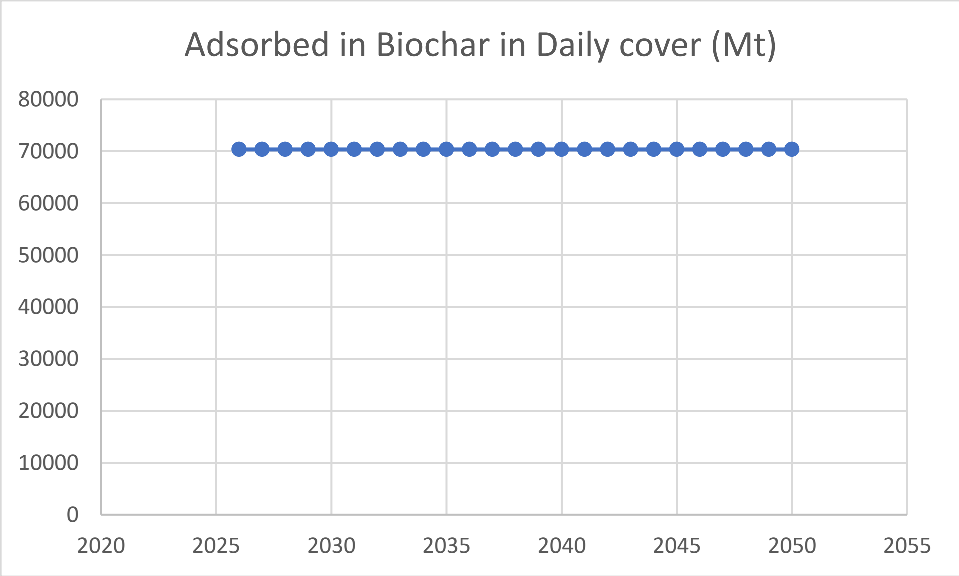

Figure 12: Reduced emissions due to daily cover using biochar

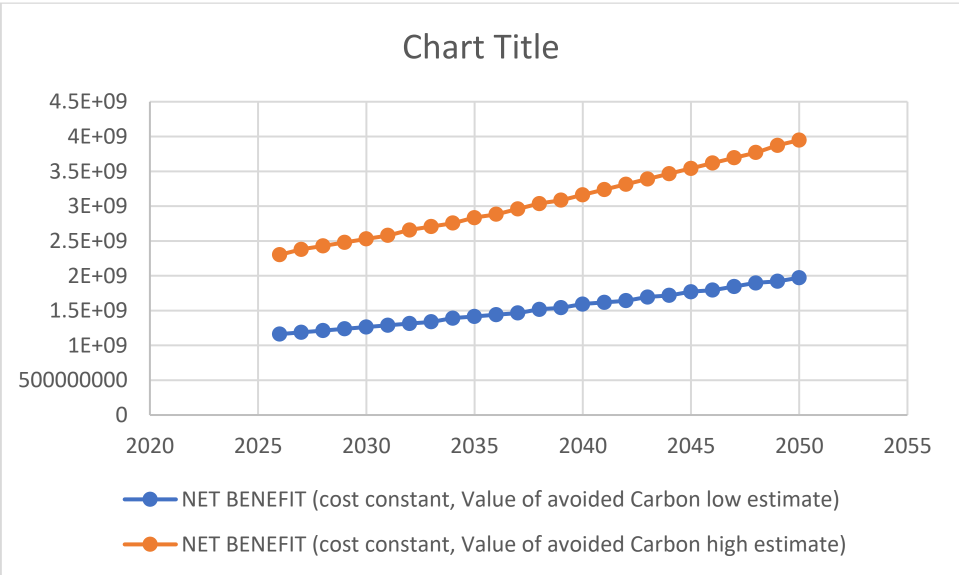

Figure 13: Net Benefits due to daily cover using biochar

Above figure indicates that the action has resulted in net positive benefit. The economic analysis of the action has resulted in net present value as follows for different prices used. The following table provides details.

Table : Net present values of using daily cover using biochar under different prices of avoided carbon and cost escalations

Context	**Net present value (LKR) @ 10% discount rate**
Net benefit (cost constant, Value of avoided Carbon low estimate)	12,523,805,993.20
Net benefit (cost constant, Value of avoided Carbon high estimate)	25,079,884,074.14
Net benefit (cost 2% increase, Value of avoided Carbon low estimate)	12,519,270,960.56
Net benefit (cost 2% increase, Value of avoided Carbon high estimate)	25,075,349,041.49

Sequestration action 2: Vertical Subsurface flow constructed wetland (VSSFCW)

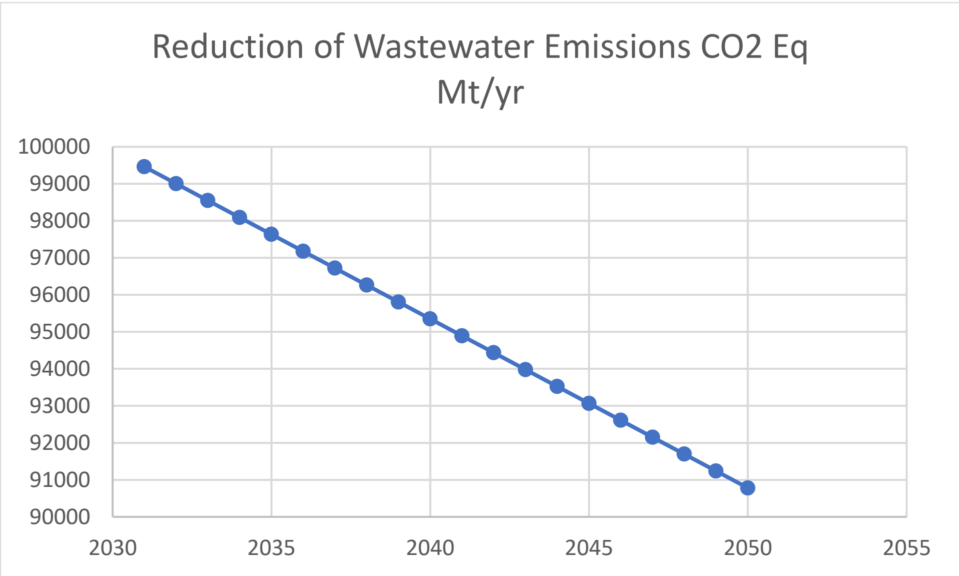

Figure 14: Reduced emissions due to Vertical Subsurface flow constructed wetland (VSSFCW)

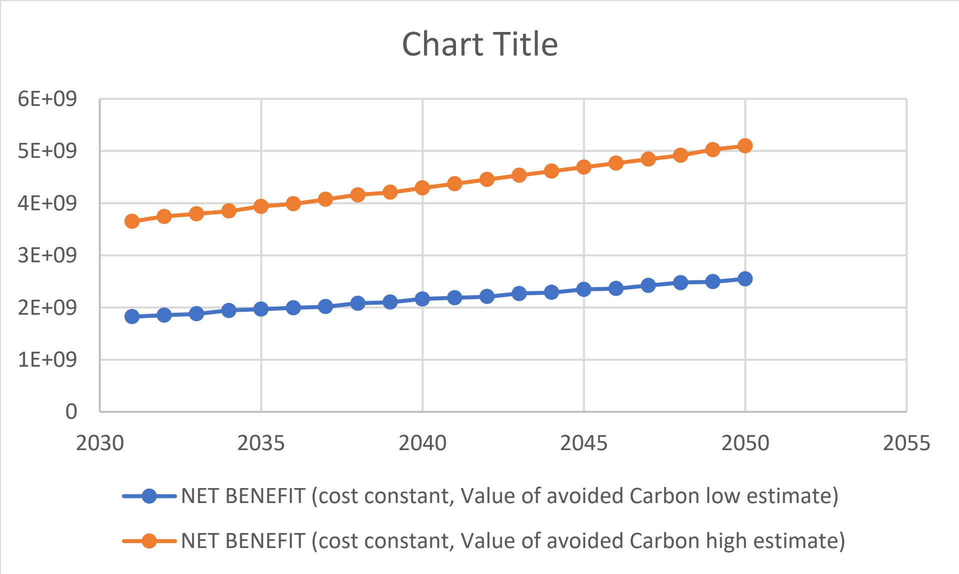

Figure 15 : Net Benefits due to Vertical Subsurface flow constructed wetland (VSSFCW)

Above figure indicates that the VSSFCW action has resulted net positive benefit. The economic analysis of the action has resulted in net present value as follows for different prices used. The following table provides details.

Table : Net present values of Vertical Subsurface flow constructed wetland under different prices of avoided carbon and cost escalations

Context	**Net present value (LKR) @ 10% discount rate**
Net benefit (cost constant, Value of avoided Carbon low estimate)	17,526,843,002.79
Net benefit (cost constant, Value of avoided Carbon high estimate)	35,118,949,434.14
Net benefit (cost 2% increase, Value of avoided Carbon low estimate)	17,526,773,785.74
Net benefit (cost 2% increase, Value of avoided Carbon high estimate)	35,118,880,217.09

Summary of the economic analysis of waste sector is provided in the following table.

Table: Net present values of proposed mitigation actions for waste sector

	Net Present Value (LKR) @ 10% discount rate	
	Value of avoided Carbon (lower estimate)	**Value of avoided Carbon (lower estimate)**
Emission reduction (ER) actions and sequestration enhancement (SE) actions		
ER action 1: Syngas recovery from open dump	-5,052,744.20	53,115,328.99
ER action 2: Electric vehicle for waste collection	-1,959,271,804.33	-1,940,537,516.89
ER action 3: Waste to energy plants	-24,739,041,603.49	13,887,404,121.78
ER action 4: Sanitary landfill	-18,721,691,991.70	-3,540,883,638.19
SE action 1: Daily Cover for Open dump	12,523,805,993.20	25,079,884,074.14
SE action 2: Vertical Subsurface flow constructed wetland (VSSFCW)	17,526,843,002.79	35,118,949,434.14
All 6 actions combined	4,346,928,810.96	25,805,688,533.22

Among the proposed actions of waste sector Daily Cover for Open dump and Vertical Subsurface flow constructed wetland (VSSFCW) have resulted in positive net present values. When all actions for waste sector are considered together, it has resulted in positive net present values.

4. Forestry sector

Net Carbon Sequestration in Forests, Trees Outside Forests and Mangroves in the Net Zero Scenario (tonnes /yr) is given in the following figure.

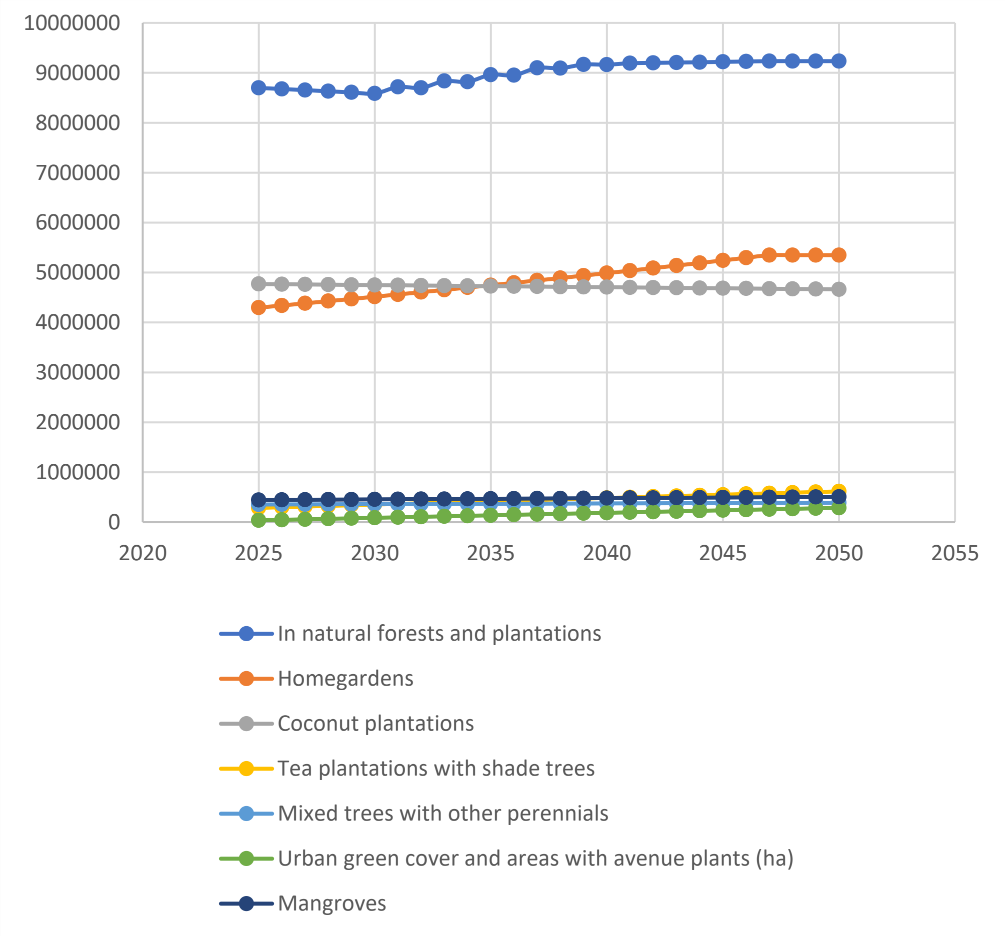

Figure 16: Net Carbon Sequestration in Forests, Trees Outside Forests and Mangroves in the Net Zero Scenario (tonnes /yr)

The following table provides Net Present Values for the forestry sector.

Table: Net present values of proposed mitigation actions for Forestry sector

Sector and Mitigation actions	**Net Present Value (LKR) @ 10% discount rate**	
	Value of avoided Carbon (lower estimate)	**Value of avoided Carbon (upper estimate)**
Forests in natural forests and plantations	$1,481,668,327,940.23	3,129,478,180,480
Trees Outside Forests		
Homegardens	816,056,745,585	1,656,563,163,232
Coconut plantations	469,289,070,006	1,637,038,422,127
Tea plantations with shade trees	70,930,596,918	141,838,967,699

Sector and Mitigation actions	**Net Present Value (LKR) @ 10% discount rate**	
	Value of avoided Carbon (lower estimate)	**Value of avoided Carbon (upper estimate)**
Mixed trees with other perennials	64,883,821,812	129,681,864,833
Urban green cover and areas with avenue plants	-56,994,596,077	43,041,161,765
Blue Carbon Ecosystems		
Mangroves	72,657,022,054.15	164,789,655,745
Total for all actions	2,832,663,961,588.63	6,302,663,521,836

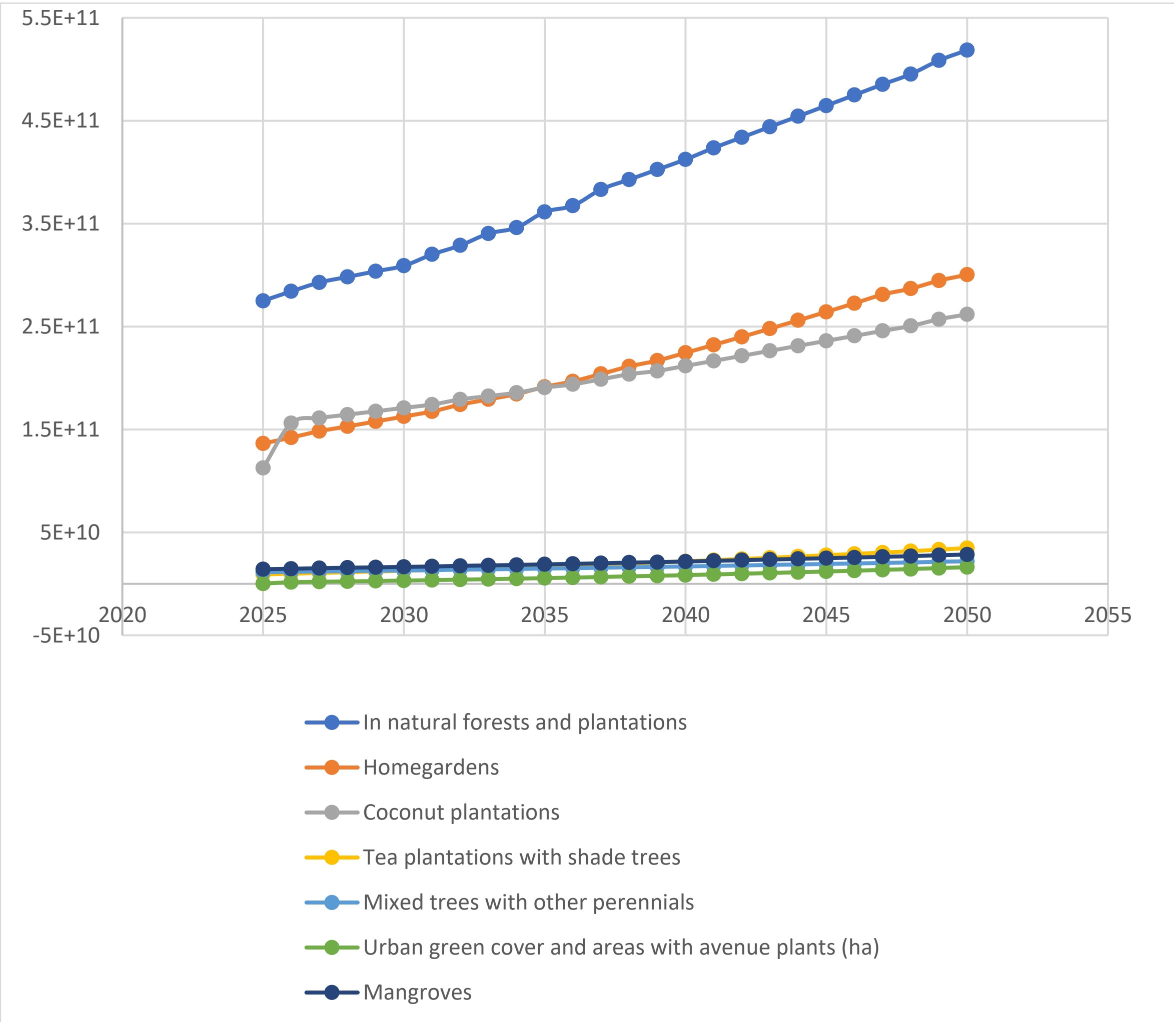

Figure 17: Net benefits of proposed mitigation actions for Forestry sector under upper estimate of carbon

Among the proposed actions of forestry sector, all actions have resulted in positive net present values except for urban green cover and areas with avenue plants under lower estimate of value of avoided carbon. When all actions for forestry sector are considered together, it has resulted in positive net present value of 2832 LKR billion under lower value of carbon and 6302 LKR billion under upper value of carbon. This analysis however has not taken into account variety of other benefits resulting from increasing forest cover including benefits due to variety of ecosystem services. There are variety of direct and indirect economic benefits associated with homegadens and mangrove forests. Benefits of increased extents of plantations will generate additional direct income.

5. Agriculture sector

The following figure illustrates the mitigated CO2 emissions due to the actions proposed by the sector.

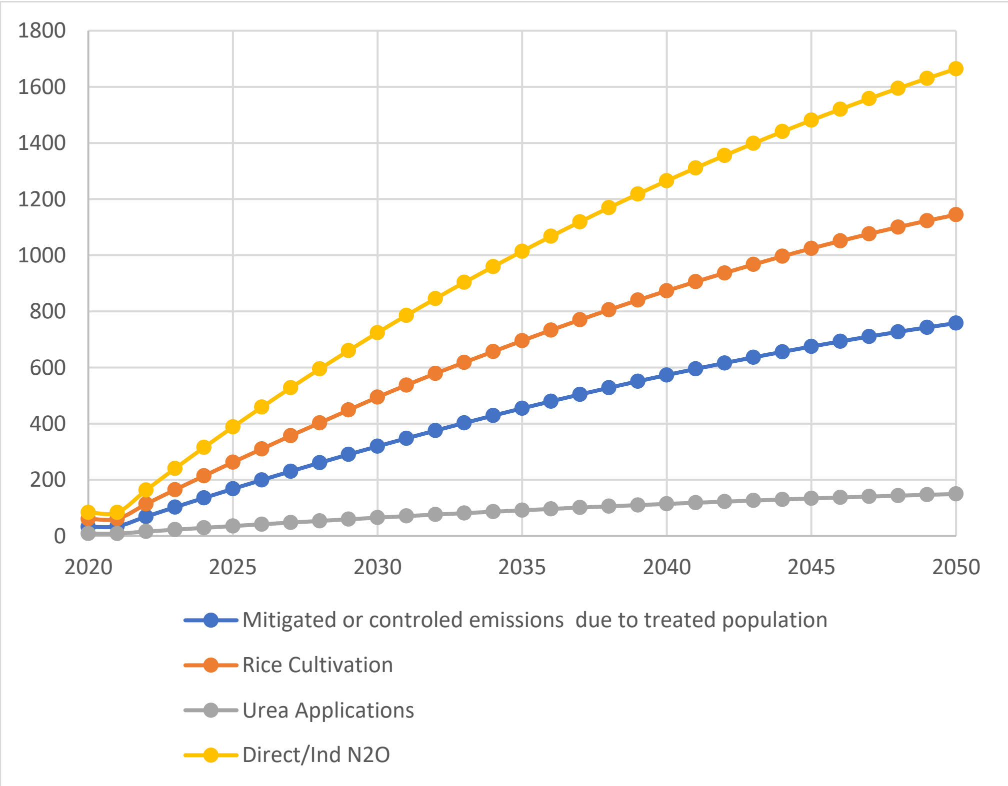

Figure 18: Mitigated CO2 emissions due to the actions proposed by the agriculture sector

The following table provides Net Present Values (NPV) for the Agriculture sector.

Table: Net present values of proposed mitigation actions for agriculture sector

Mitigation actions	Net Present Value (LKR) @ 10% discount rate	
	Value of avoided Carbon (lower estimate)	**Value of avoided Carbon (upper estimate)**
Emission reduction treatment for neat cattle (both imported and local)	-198,931,253,860.50	-198,882,959,958.46
All actions in agriculture sector including actions to mitigate emissions related to Rice Cultivation, Urea Applications and Direct/Indirect N2O	-198,738,491,541.80	-198,497,416,260.95

The lower emission reductions and higher costs associated with agricultural actions have resulted in large negative net present values. The above analysis assumed actions to mitigate emissions related to Rice Cultivation, Urea Applications and Direct/Indirect N2O as costless.

Summary

The following table provides summary for all sectors, the present values of all costs and benefits for each sector.

Table: Present values of all costs and benefits for each sector

Sector	Present values (LKR) @ 10% discount rate		
	Costs	**Benefit - Value of avoided Carbon (lower estimate)**	**Benefit - Value of avoided Carbon (lower estimate)**
Energy	5,796,452,247,493	691,009,241,938	1,383,529,655,419
Transport	37,052,200,770,104	503,705,234,686	1,008,968,070,861
Waste	17,071,078,646	21,418,007,457	42,876,767,179
Forest	641,839,730,410	3,474,503,691,998	6,944,503,252,245
Agriculture	198,979,539,449	241,047,907	482,123,188

Table: Net present values of proposed mitigation actions for all actions combined for all sectors

Scenario	Net Present Value (LKR) @ 10% discount rate	
	Value of avoided Carbon (lower estimate)	**Value of avoided Carbon (upper estimate)**
All sectors combined	-15,696,635,726,157	-12,895,537,785,921
All sectors except transport sector	-1,605,608,533,731.52	1,000,688,710,618.99

The combined analysis resulted in negative net present values. When the transport sector is excluded from the analysis, it resulted in positive net present value of 1000 LKR billion indicating the viability of the remaining sectors under upper estimate of the value of carbon.

It is important to estimate a proper price for the carbon savings to see how the actions that are currently economically not viable could be made viable through some type of a resource transfer or through carbon credits.

This analysis provides an initial framework for setting up proper financial mechanisms that need to be realized in order to finance the proposed mitigation measures from international sources.