Greenhouse Gas Mitigation Assessment to Inform the update of Eswatini's Nationally Determined Contribution

NDC Climate Action Enhancement Package Support for Eswatini

Activity A301 and 302

Authors:

Gcina Mavimbela, Nosiphiwo Zwane, Mduduzi Mathunjwa, Centre for Sustainable Energy Research, University of Eswatini, Eswatini

Thembinkosi Ndzimandze, Gugu Vilakati, Ministry of Natural Resources and Energy, Eswatini

Jessica Slater, Christopher Malley, Stockholm Environment Institute, University of York, UK

Jason Veysey, Stockholm Environment Institute, Boston, USA

Diego Fernandez Basualto, Sofia Burford Arahuetes, Gerardo Canales Gonzalez, ImplementaSur, Chile

Thabile Ndlovu, University of Eswatini, Eswatini

Armando Rivera, Alessandra Falcucci, Aimable Uwizeye, Timothy Robinson, Food and Agriculture Organization of the United Nations (FAO)

Sizwe Mabaso, University of Eswatini, Eswatini

Samkele Tfwala, Department of Geography, Department of Geography, Environmental Science and Planning, University of Eswatini

Coordination and Oversight:

Catalina Etcheverry, Sandra M. Mazo-Nix, Climate and Clean Air Coalition Secretariat, United Nations Environment Programme

Deliverable prepared for the Climate and Clean Air Coalition (CCAC) under their support to the Climate Action Enhancement Programme (CAEP) of the NDC Partnership.

June 2021

Executive Summary

In 2015, Eswatini produced its first commitment to reduce Greenhouse Gas emissions to mitigate climate change in its Nationally Determined Contribution (NDC). The first NDC did not include a quantitative emission reduction target, but committed to three specific mitigation actions in Energy and Industrial Processes and Product Use sector. As part of the process of updating its NDC, this report summarises a Greenhouse Gas mitigation assessment that was conducted as part of a project funded by the NDC Partnership Climate Action Enhancement Package (CAEP), and implemented by the Climate and Clean Air Coalition and partners. The GHG mitigation assessment aims to evaluate the potential to reduce GHG emissions through the implementation of different policies and measures in Eswatini. This assessment aims to inform the updating of the NDC, and to provide recommendations as to possible GHG reduction targets for Eswatini that are based on an evaluation of specific policies and measures that could achieve them. Compared to Eswatini's 2015 NDC, the GHG mitigation assessment summarised in this report includes a number of updates and additional features that could help to strengthen Eswatini's climate change mitigation ambition, including:

- An economy-wide GHG mitigation assessment has been conducted, quantifying GHG emissions and evaluating mitigation options in the energy, industrial processes (IPPU), agriculture, forestry and land-use (AFOLU), and waste sectors. In the first NDC, no quantitative information on GHG emissions was included in the mitigation commitment.
- The GHG mitigation assessment has updated the estimate of historical GHG emissions, providing the most up-to-date basis for projecting emissions into the future.
- The baseline, or reference projection of GHG emissions in Eswatini to 2030 has been revised, based on key national documents, and accounts for the impact of COVID-19 on Eswatini's economic outlook.
- An extensive assessment of policies and measures has been undertaken. The GHG mitigation assessment evaluates the GHG emission reduction potential of key plans and policies that have been put in place since 2015 to assess how these plans could contribute to reducing GHG emissions in Eswatini.
- The GHG mitigation assessment also evaluates emission reductions of short-lived climate pollutants (SLCPs), such as black carbon, and health-damaging air pollutants that are emitted alongside GHGs. The inclusion of these additional pollutants allows for an evaluation of the local benefits that can be achieved in Eswatini from taking action to reduce GHGs to be evaluated, highlighting important local co-benefits from climate change mitigation.

The GHG mitigation assessment estimates that in 2017, Eswatini emitted 4.5 million tonnes of GHG emissions (CO_2-equivalent emissions). The energy sector, and agriculture, forestry and land use contributed the majority of these emissions (39% and 56%, respectively), followed by Industrial Processes, and Waste. Total GHG emissions in Eswatini were projected to increase by 63% to 7.33 million tonnes in 2030 for a baseline scenario, in which policies and measures to reduce GHGs are not implemented, but Eswatini develops according to socioeconomic forecasts.

A total of 13 mitigation measures were identified across the 4 major GHG source sectors from plans, strategies and policies, including those submitted since the publication of Eswatini's first NDC in 2015 and evaluated in the mitigation assessment. The full implementation of these 13 mitigation measures were estimated to reduce total GHG emissions by 14% in 2030 compared to the baseline scenario, (Figure ES1). As Eswatini did not commit to a quantitative emission reduction target in the 2015 INDC, the results from this GHG mitigation assessment provide a clear basis to increase climate change mitigation ambition in Eswatini, and provide a concrete set of actions through which this increase in ambition can be achieved.

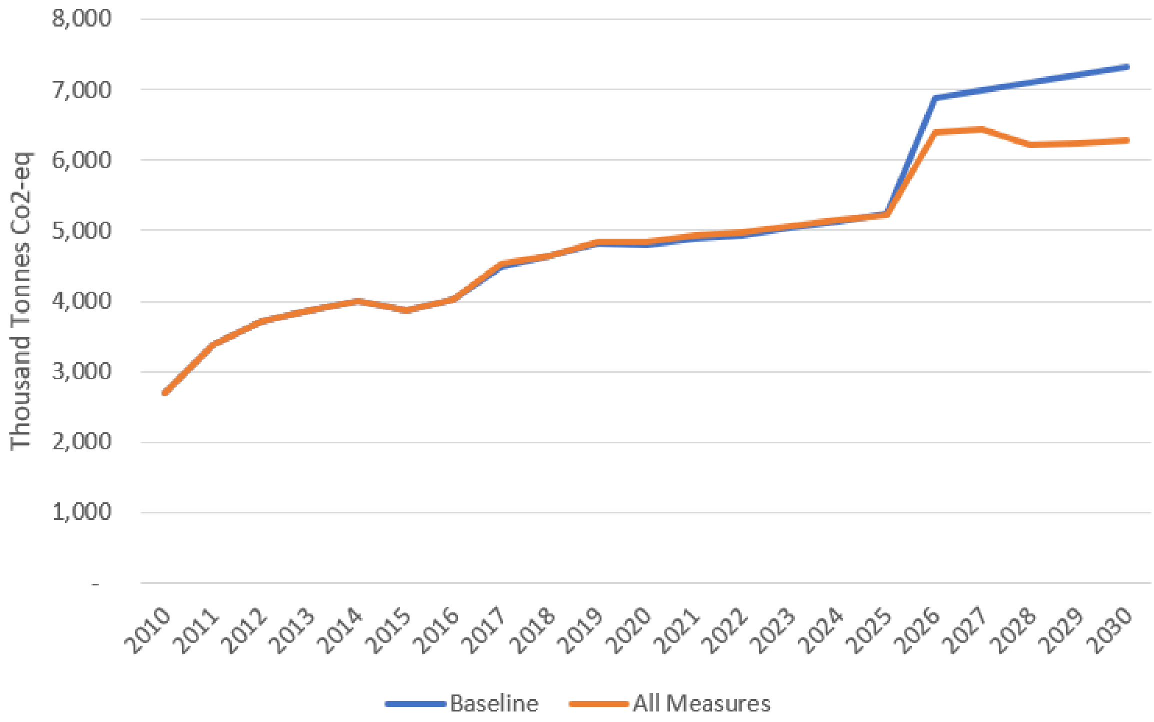


Figure ES1: Reduction in total GHG emissions estimated from the implementation of all mitigation measures in 2030 compared to a baseline scenario.

Table ES1: *Summary of mitigation measures evaluated for GHG emission reduction potential from plans and strategies in Eswatini*

Number	Sector	Mitigation Measure	Source: Plan/Strategy/Regulation
1	Transport	Introduction the commercial use of 10% ethanol blend in petrol by 2030	Eswatini's Intended Nationally Determined Contribution
2	Residential	50% improvement in efficiency of biomass stoves used for cooking	Energy Master Plan 2034
3	Residential	The most inefficient wood-based water heating is replaced by other more efficient options, reducing its share by 13 % by 2034. Reflecting its promotion under the SE4ALL initiative, the share of solar water heating is assumed to reach 50 % of households (25 % with back-up and 25 % without back-up).	Energy Master Plan 2034
4	Residential	100% access to clean energy at household level attained by 2030	Sustainable Energy for All Action Agenda
5	Electricity Generation	To achieve 50% renewables target: biomass-based co-generation: 140-165MW hydro: +40-60MW Solar: +100-120MW Wind: +20-50 MW	National Energy Policy 2018
6	Sugar	15% (95.84 GWh) reduction in electricity consumption in 2034	National Energy Efficiency Strategy and Action Plan
7	Other Agriculture	10% (41.66 GWh) reduction in electricity consumption in 2034	National Energy Efficiency Strategy and Action Plan
8	Industry	10% (38.89 GWh) reduction in electricity consumption in 2034	National Energy Efficiency Strategy and Action Plan
9	Commercial and Public Services	10% (16.67 GWh) reduction in electricity consumption in 2034	National Energy Efficiency Strategy and Action Plan
10	Residential	20% (205.7 GWh) reduction in electricity consumption in 2034	National Energy Efficiency Strategy and Action Plan
11	Ozone Depleting Substances	Implement HFC phase-out with the corresponding schedule for Annex 5 countries (freeze consumption in 2024 compared to average 2019-2021 levels, 10% reduction in consumption compared to 2019-2021 levels in 2029)	Kigali Amendment to Montreal Protocol IPPU Sector NDC update mitigation assessment
12	Livestock	Improvements in productivity of cattle, sheep and goat production through artificial insemination, improved digestibility of feed, and improved manure management	Agriculture Sector NDC update mitigation assessment
14	Solid Waste	Implement best practices in solid waste management considering i) reduction in open burning of waste, ii) increase composting of organic waste, and iii) increase landfill gas recovery at solid waste disposal sites	Waste Sector NDC update mitigation assessment

Contents

1. Introduction

In 2015, Eswatini submitted their Nationally Determined Contribution (NDC) to the United Nations Framework Convention on Climate Change (UNFCCC). All countries are now updating their NDCs to submit to the UNFCCC before the 26th Conference of the Parties (COP) in Glasgow in November 2021. A greenhouse gas mitigation assessment is a key component of establishing a climate change mitigation commitment. Eswatini already has existing data on the magnitude of GHG sources and sinks, most recently updated in 2020 as part of Eswatini's Fourth National Communication. The objectives of this GHG mitigation assessment is to build on and update previous work to provide an up-to-date assessment of the GHG mitigation potential of different mitigation measures, policies and actions in Eswatini, and to provide recommendations as to how it can be incorporated into the revised NDC.

There are three steps to undertaking a GHG mitigation assessment. The first step is the estimating of historic GHG emissions to provide an up-to-date understanding of the national total emissions of GHGs emitted in Eswatini, and to understand the contribution of different source sectors. In addition to estimating the historical GHG emissions, it is necessary in the GHG mitigation assessment to create a baseline or 'business-as-usual' scenario that projects emissions into the future without the implementation of any policies or measures that aim to reduce GHG emissions. The purpose of the baseline scenario is to act as a reference against which the GHG emission reduction potential of mitigation scenarios can be evaluated.

In addition to the baseline scenario, the final part of the GHG mitigation assessment is the development of mitigation scenarios that reflect the implementation of specific policies and measures, and allow the GHG emission reductions to be quantified. The mitigation scenarios can provide the basis for establishing targets (conditional and unconditional) for GHG emission reductions to inform the NDC revision. Within the GHG mitigation assessment for Eswatini's NDC revision, the development of the mitigation scenarios will follow a 'measure-based approach'. A mitigation measure is a specific action undertaken in a specific GHG emission source sector with the goal of reducing GHG emissions from that sector. A measure-based approach to the development of the mitigation scenarios means that any target that is informed by the results from the GHG mitigation assessment is based on the implementation of discrete number of specific mitigation actions. This makes it clear what measures need to be implemented to achieve the climate change commitments made in Eswatini's NDC.

To develop the mitigation scenarios using a measures-based approach requires that a nationally-appropriate set of mitigation measures are identified and evaluated in the GHG mitigation assessment. The GHG mitigation assessment team have reviewed national documents, sectoral plans and strategies, and reports submitted by projects teams working on the NDC revision to identify a set of possible mitigation measures that could contribute to achieving Eswatini's climate change goals. These mitigation measures have been evaluated to identify their GHG emission reduction potential, as well as co-benefits, such as reductions in Short-Lived Climate Pollutant (SLCP) and other air pollutant emissions. It is this evaluation that constitutes the main focus of this GHG mitigation assessment document.

The decision as to which of these mitigation measures should be the basis for Eswatini's updated climate change commitment is a decision for the Ministry of Environment and other stakeholders in

Eswatini. The aim of this document is to provide the necessary information to inform that decision-making process. The specific aims and goals of this document are therefore to:

- Present the updated estimate of historic GHG emissions between 2010 and 2017
- Present an updated baseline scenario showing the change in GHG emissions between 2018 and 2030
- Present GHG emission reduction potentials from the mitigation measures identified from national documents against the updated baseline scenario
- Highlight the co-benefits of implementing the different mitigation measures for reducing other co-emitted pollutants, including short-lived climate pollutants and air pollutants.

Section 2 of this document presents the key information from Eswatini's 2015 Intended Nationally Determined Contribution (INDC). The purpose in highlighting this information is so that the updated GHG mitigation assessment can be placed in the context of the previous submission. Section 3 provides an overview of the methodology used to develop the GHG mitigation assessment. Section 4 presents the historic GHG emissions. Section 5 describes the updated baseline scenario, and Section 6 described the GHG emission reduction potential of candidate mitigation measures for the NDC revision. Finally, Section 7 provides recommendations as to how these measures could be used to inform the NDC update.

2. Eswatini's Intended Nationally Determined Contribution

In 2015, the Government of Eswatini submitted its Intended Nationally Determined Contribution. In Eswatini's INDC, a quantitative emission reduction target for Eswatini was not set, and instead a set of actions were committed to that would reduce Eswatini's GHG emissions. The three actions that are committed to in Eswatini's INDC are:

- Doubling the share of renewable energy in the national energy mix. This includes electricity generation and reduced consumption of non-sustainable biomass.
- Introducing the use of 10% ethanol blend in petrol for use in all vehicles. This is additional to the contribution of doubling the share of renewable energy.
- Phasing out the use of HFCs, PFCs and SF_6 gases.

The doubling of renewable energy in the national energy mix was estimated in Eswatini's INDC to reduce GHG emissions by 0.94 million tonnes CO_2-equivalent emissions, and the replacement of 10% gasoline with ethanol to reduce emissions by 0.03 million tonnes CO_2-equivalent emissions.

The following sections highlight the updated assessment of i) historical GHG emissions, ii) baseline scenario and iii) mitigation scenarios and emission reduction potential. In each subsequent section, the differences between the updated analysis and the INDC are highlighted in blue boxes, to make clear the implications of the updated assessment on revising the NDC.

3. Methodology for GHG mitigation assessment

The greenhouse gas mitigation assessment aimed to estimate emissions of GHG for three scenarios, shown in Figure 1, i) historical emissions between 2010 and 2017, ii) baseline projections of emissions from 2018 and 2030, and iii) emission estimates in 2030 estimated to simulate the implementation of policies and measures that aim to reduce emissions in key source sectors. The key equation used to estimate emissions from all major sources of the pollutants listed above is the multiplication of an *activity* variable multiplied by an *emission factor* (Equation 1). The activity variable quantifies how big a particular sector or process is in a country (e.g. the number of Terajoules of fuel consumed in a particular sector, the number of tonnes of production of a particular mineral, chemical or other product). Emission factors quantify the mass of pollutant emitted per unit of activity (e.g. the kilograms of black carbon emitted per Terajoule of fuel consumed).

$$Emissions = \; Activity \; x \; Emission \; Factor \qquad \text{Eq. 1}$$

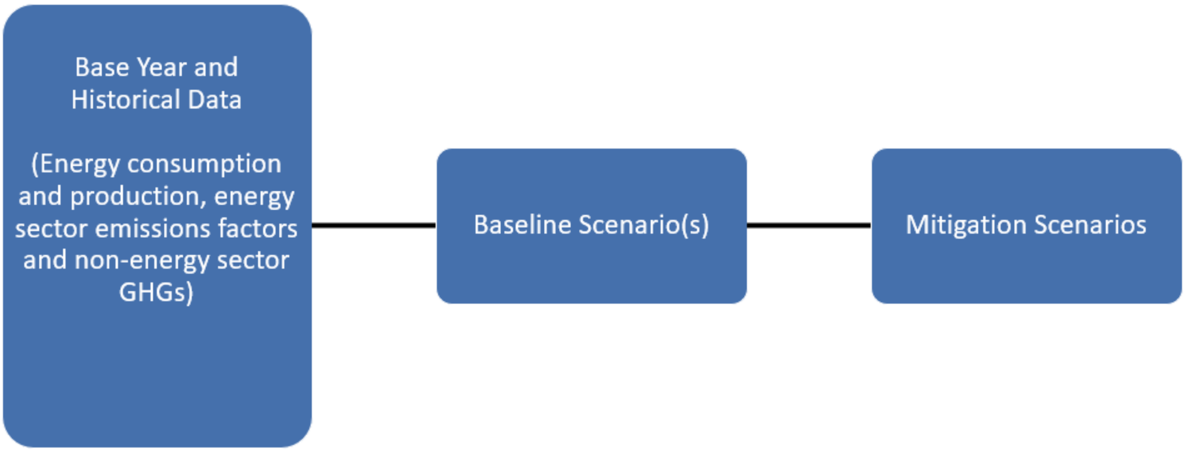


Figure 1: Stages in conducting GHG mitigation assessment

The specific activity data, emission factors and methodologies used to quantify emissions in each source sectors are defined according to international guidelines on the quantification of GHG and air pollutant emissions. Specifically, the methodologies follow the Intergovernmental Panel on Climate Change (IPCC) 2006 emission inventory guidelines. The IPCC 2006 guidelines provide methodologies for the quantification of GHG emissions. They also recommend that for other pollutants, the EMEP/EEA air pollution emission inventory guidebook is used. These methodologies (predominantly the simplest 'Tier 1' methods) were followed to develop this inventory (see Box 1).

The overall GHG mitigation assessment was developed using the Low Emissions Analysis Platform (LEAP, leap.sei.org). The overall LEAP modelling framework is shown in Figure 2. As well as accounting for emissions, LEAP also links energy supply and demand modelling, meaning that interactions between energy supply and demand are taken into account in the development of baseline and mitigation scenarios. For the agriculture, waste and industrial processes and product use sector, the mitigation assessment was conducted using other tools, and the results integrated into LEAP to allow the overall GHG mitigation potential to be assessed.

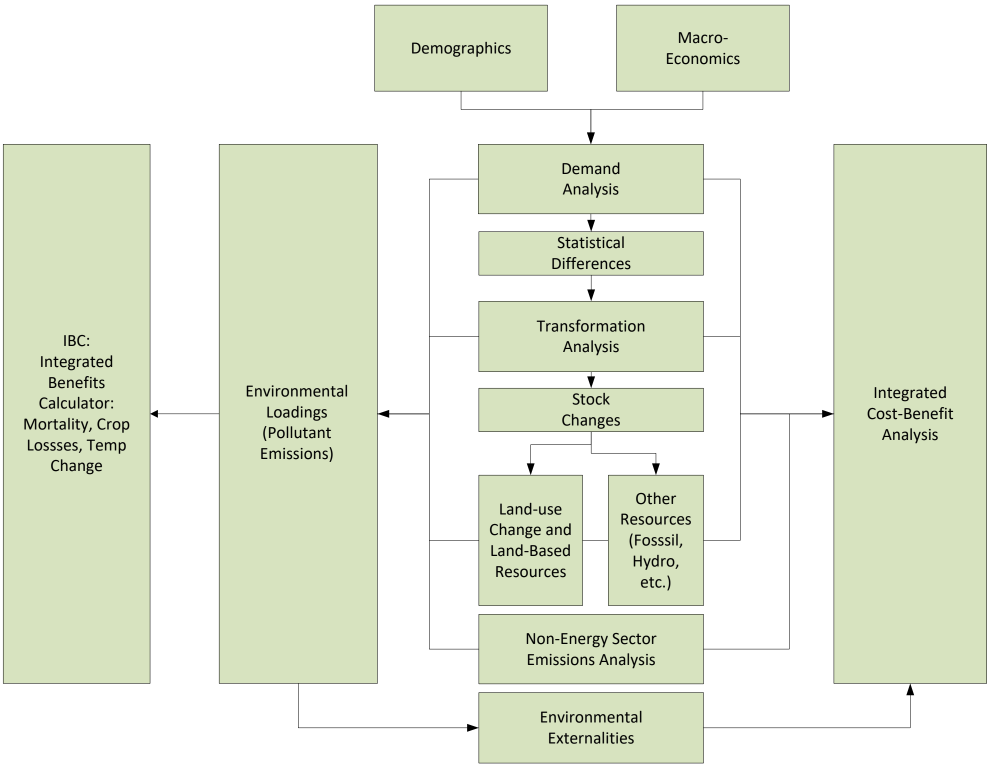


Figure 2: Representation of LEAP modelling framework.

Box 1: Overview of IPCC Guidelines for development of greenhouse gas emission inventories.

IPCC Guidelines for National Greenhouse Gas Inventories

The IPCC Guidelines for National Greenhouse Gas Inventories are a set of guides that collect methods, and default data that can be used to quantify emissions from all major source sectors. The aim of the IPCC Guidelines is to provide a common set of methodologies, and reporting framework for GHG emissions to facilitate transparency in the quantification and accounting of GHG emissions between countries. The IPCC 2006 Guidelines (i.e. published in 2006), are the most comprehensive set of guidelines. In 2019, a 'refinement' to the IPCC 2006 Guidelines was released which includes updated methodologies and updated default data in some sectors, which, for those sectors updated, supersedes the IPCC 2006 Guidelines.

The IPCC Guidelines aim to be globally applicable, i.e. equally applicable in countries with substantial data resources, and those with substantial data limitations. As such, different methodologies that range in complexity are included in the Guidelines to accommodate the different data availability in different countries. Methodologies are categorised into 3 *Tiers* that reflect methods of increasing complexity and data requirements.

Tier 1 methodologies are the simplest methods, and can be applied with the minimum of data, and often default data is provided for use where no data exists for those sectors. **Tier 2** methodologies have higher complexity, and require more nationally-specific data than is required for Tier 1. Finally, **Tier 3** methods are the most complex, and often require direct measurement of emissions from the source to provide locally appropriate emission factors.

Pollutants Included

The purpose of the GHG mitigation assessment was to characterize the emissions of pollutants that contribute to global temperature increases. However, the sources of greenhouse gases are also sources of air pollutants which impact human health locally. Therefore, the pollutant characterized in this inventory are those that are greenhouse gases, like carbon dioxide and methane, and those pollutants that contribute to the formation of particulate matter (PM), and tropospheric ozone (O_3). These are the two pollutants that have the largest effect on human health, and therefore the pollutants whose emissions are quantified in this emission inventory make the largest contribution to air pollution in Eswatini, as well as Eswatini's contribution to global climate change. The emission inventory of short-lived climate pollutants, greenhouse gases and air pollutants covers 11 pollutants in total, including:

Greenhouse Gases

- **Carbon dioxide (CO_2):** A greenhouse gas with an atmospheric lifetime of hundreds of years, that makes the largest contribution to global climate change.
- **Methane (CH_4):** A greenhouse gas and short-lived climate pollutant with an atmospheric lifetime of approximately 15 years, methane emissions make the second largest contribution to global temperature increases after carbon dioxide. It also contributes to the formation of tropospheric ozone (O_3), which has negative effects on respiratory health.
- **Hydrofluorocarbons (HFCs):** A collection of greenhouses gases used predominantly as refrigerants to replace Chlorofluorocarbons (CFCs) and Hydrochlorofluorocarbons (HCFCs) in the refrigeration and air conditioning sector.

Short-Lived Climate Pollutants

- **Black carbon (BC):** A component of direct particulate matter (PM) emissions that contributes to the negative effects of air pollution on human health. Emissions of black carbon also warm the atmosphere through direct absorption of incoming solar radiation, and through indirect effects such as deposition on snow and ice and cloud interactions. With an atmospheric lifetime of a few days, it is a short-lived climate pollutant. It is mainly emitted through incomplete combustion.

Air Pollutants

- **Particulate Matter ($PM_{2.5}$ and PM_{10}):** Particulate matter (with aerodynamic diameter less than 2.5 µm ($PM_{2.5}$) and 10 µm (PM_{10})) are small solid particles in the atmosphere. They make the largest contribution to air pollution effects on human health through effects on the cardiovascular and respiratory systems. The emissions of $PM_{2.5}$ and PM_{10} calculated here represent the direct emissions to the atmosphere of particulate matter. However, other gaseous pollutants, like Nitrogen oxides, Sulphur dioxide, ammonia and volatile organic compounds, also contribute to the $PM_{2.5}$ and PM_{10} concentrations that people are exposed to, through chemical reactions in the atmosphere that convert gaseous pollutants into solid particles.

- **Nitrogen Oxides (NO_x):** An air pollutant which is a precursor to the formation of particulate matter and tropospheric ozone, NO_x is made up of two pollutants, nitrogen oxide (NO) and nitrogen dioxide (NO_2).
- **Sulphur dioxide (SO_2):** An air pollutant which is a precursor to the formation of particulate matter.
- **Ammonia (NH_3):** An air pollutant which is a precursor to the formation of particulate matter.
- **Organic Carbon (OC):** A component of direct particulate matter (PM) emissions that contributes to the negative effects of air pollution on human health.
- **Non-methane volatile organic compounds (NMVOCs):** A collection of a range of different organic molecules emitted from a range of emission sources. NMVOCs are precursors to the formation of tropospheric ozone and particulate matter
- **Carbon monoxide (CO):** A gaseous air pollutant which contributes to the formation of tropospheric ozone

Source sectors

The emission sources covered in the inventory cover all the major sources of GHGs, SLCPs and air pollutants, with the exception of land-use and land-use change emissions. Emission sources were grouped according to the IPCC source categories. The source sectors covered are described in the table below.

Table 3: Source sectors covered in emission inventory

Source Sector	Sub-sectors
1 - Energy	1A1a Public Electricity and Heat Production
	1A1c Manufacture of Solid Fuels and Other Energy Industries
	1A2 Manufacturing Industries and Construction
	1A3b Road transportation
	1A3c Railways
	1A4a Commercial/Institutional
	1A4b Residential
	1A4c Agriculture, Forestry, Fishing
	1A5 Other
	1B1a Fugitive emissions from coal mining
2- Industrial Processes	2A Mineral Industry
	2D Non-Energy Product Use
	2F Use of ODS Alternatives
	2G Other Product Manufacture and Use
	2H Other
3 – Agriculture, Forestry and Other Land-Use	3A Livestock
	3C Aggregate sources and non-CO2 emission sources on land
	3D Other
4 - Waste	4A Solid Waste Disposal
	4B Biological Treatment
	4C Incineration and Open Burning
	4D Domestic Wastewater Treatment and Discharge

Historical Emissions

The modelling framework highlighted in Figure 2 was used to estimate emissions for historical years between 2010 and 2017. For some sectors, historical activity data was available for a larger number of years (e.g. for some cases from 1990, and in other cases extending to 2018 and 2019). The full range of historical activity data available to characterise emissions was utilised in the GHG mitigation assessment. Table 4 summarises the main data used to estimate emissions in all major source sectors covered in the GHG mitigation assessment.

Table 4: Summary of data source used to estimate GHG emissions for each source sector

Source Sector	Activity Data	Source of Data
1A1a Public Electricity and Heat Production	Historical electricity production Fuel consumption	Energy Masterplan 2034 and Energy Balances 2010-2018;
	Power Plant Capacity, Efficiency and Availability	Energy Masterplan 2034 and sourced from energy supply analysis to update the energy Masterplan (not published)
1A1c Manufacture of Solid Fuels and Other Energy Industries		
1A2 Manufacturing Industries and Construction	Fuel Consumption in Industrial sector	National Energy Balances 2010-2018
1A3b Road transportation	Vehicle registration and number of vehicles in fleet	Fleet data used in inventory;
	Fuel consumption in road transport sector	National Energy Balances 2010-2018;
	Load factors in transport	International Estimates;
	Distances Travelled by the fleet	Reverse engineered from fuel consumption of the fleet and fuel economy of the fleet
1A3c Railways	Fuel consumption in rail sector	Inventory development files (sourced from Eswatini Railways)
1A4a Commercial/Institutional	Fuel consumption in services sector	National Energy Balances 2010-2018
1A4b Residential	Fuel Consumption in household sector	National Energy Balances 2010-2018;
	Number of households	Estimated from population data (Population data is from Eswatini's 2007 and 2017 Census reports); Estimates guided by MNRE work on energy demand analysis to update the Energy Masterplan
	Number of households cooking using different fuels and technologies	

1A4c Agriculture, Forestry, Fishing	Fuel Consumption in agriculture sector	National Energy Balances 2010-208
2.A.3 Glass production	Glass production by type (tonnes), cullet ratio of recycled glass used in each process (%)	Ngwenya glass company
2.A.4.a Other process uses of carbonates: Ceramics	Brick production (tonnes)	Langa bricks company (closed in 2018)
2.D.1 Lubricant use	Lubricants used in the country (tonnes)	Filling stations, garages, sugar industry, Eswatini Railways, Eswatini Revenue Authority (ERA), Ministry of Natural Resources
2.D.2 Paraffin wax use	Paraffin wax consumed in the country (tonnes)	Swazi Candles, ERA
2.D.3 Domestic solvent use	Solvents used in the country (kg) estimated from population statistics (kg per capita)	National population statistics
2.D.4 Asphalt production and use	Asphalt consumed in the country (tonnes) estimated from total length of paved roads	Ministry of Public Works and Transportation
2.F.1 Refrigeration and air conditioning equipment	Annual consumption (production, imports and exports) of refrigerants (kg), quantity of destroyed refrigerants (kg), exports in used equipment (kg), share of HFC in retired equipment being recycled or reclaimed.	Palfridge, refrigerators & air-conditioners' servicing companies, refrigerant distributors, National Ozone Unit, Eswatini Environment Authority, ERA
2.G.1 SF6 from electrical equipment and other uses	Annual consumption of sulphur hexafluoride	Eswatini Electricity Company (EEC)
2.G.3 N_2O from Product use	Annual consumption of nitrous oxide	ERA
2.H.1 Other: Pulp and Paper	Annual production of paper and/or pulp	Swazi Paper Mills (not operative anymore)
2.H.2 Other: Food and beverages industry	Annual production of each type of product: alcoholic beverage production (spirit and beer), sugar, bread, cakes and biscuits, meat, and poultry, as well as animal feed.	Eswatini Sugar Association, ERA

3A Livestock	Number of animals in different production systems Reproductive Data Feed data Manure Management Data	FAO Livestock GHG mitigation assessment
3B Land	GHG sources and sinks	National GHG emission inventory
3C Aggregate sources and non-CO2 emission sources on land	Area of land burned Lime and Urea Application Nitrogen fertiliser applied	National GHG emission inventory
4A Solid Waste Disposal	Population, Waste generation rates, Waste composition, Fraction of waste sent to landfills	Waste GHG mitigation assessment
4B Biological Treatment	Population, Waste generation rates, Waste composition, Fraction of waste composted	Waste GHG mitigation assessment
4C Incineration and Open Burning	Number of clinical beds Population, Waste generation rates, Waste composition, Fraction of waste openly burned	Waste GHG mitigation assessment
4D Domestic Wastewater Treatment and Discharge	Population, Fraction of population using wastewater treatment systems BOD in wastewater	Waste GHG mitigation assessment

For the energy sector analysis, the LEAP dataset that contains the GHG mitigation assessment can be downloaded from the following link: https://drive.google.com/file/d/1ztjAZY-GG_vgBrqbQp4cHBbKk5aRjsj2/view?usp=sharing

For the IPPU, Waste and agriculture sectors, the reader is referred to the individual sectoral reports that were produced as part of the NDC revision process in Eswatini. These reports contain details of the methodologies, data and assumptions that were used to quantify emissions from the IPPU and Waste sectors. These reports are available at:

- IPPU: https://drive.google.com/file/d/1ypgnyepHgYJjG0f55P_dUm8WrTtH1u4t/view?usp=sharing

- Waste: https://drive.google.com/file/d/1ypgnyepHgYJjG0f55P_dUm8WrTtH1u4t/view?usp=sharing
- Agriculture: https://drive.google.com/file/d/1fiVlpzVdPjdRLsEfBI5x6tPZsSNZuvtg/view?usp=sharing

Baseline Scenario Overview

The baseline scenario projects activity in all economic sectors into the future (2030) based on the expected socioeconomic development of Eswatini without any policies interventions. The aim of the baseline scenario is to provide a reference level of emissions against which the policies and measures can be evaluated in terms of their effectiveness at reducing GHG emissions. Assumptions are made as to how the activity in each economic sector are likely to change into the future. The overarching assumption about changes in Eswatini for each of the sectors are summarised in Table 5. Changes in activity variables, such as fuel consumption in the residential sector, industry and services, number of vehicles, electricity generation fleet, etc., were linked to socioeconomic development in Eswatini, such as expected GDP and population growth. The impact of COVID-19 on the economy is explicitly accounted for in the economic projections used to estimate emissions.

Table 5: Assumptions about socioeconomic development in Eswatini that informed the development of the baseline scenario

Source Sector	Variable used for baseline projections	Value	Source of Data
1A1a Public Electricity and Heat Production	New installed capacity for electricity generation	Coal Power Plant 2026: 200MW Hydro 2022: 74.5 MW Solar PV 2020: 10 MW	Energy Master Plan 2034
1A2 Manufacturing Industries and Construction	Fuel Consumption in Mining, Manufacturing and Construction sectors	Value Added GDP in Mining, Manufacturing and Construction Sector	Unofficial projections from National Accounts data
1A3b Road transportation	Passenger-km Tonnes-km	GDP per capita growth rates	Unofficial projections from National Accounts data
1A3c Railways	Fuel consumption in rail sector	GDP growth rates	Unofficial projections from National Accounts data
1A4a Commercial/Institutional	Fuel consumption in services sector	Value Added GDP for services sector	Unofficial projections from National Accounts data
1A4b Residential	Number of households	Population	Eswatini Population Projections

			Report 2018-2037
1A4c Agriculture, Forestry, Fishing	Fuel Consumption in agriculture sector	Value Added GDP in Agriculture Sector	Unofficial projections from National Accounts data
2.A.3 Glass production	Glass production	GDP growth	Unofficial GDP projections from National Accounts data
2.A.4.a Other process uses of carbonates: Ceramics	Non applicable (the company shut down)	N/A	N/A
2.D.1 Lubricant use	Lubricant use	GDP growth	Unofficial GDP projections from National Accounts data
2.D.2 Paraffin wax use	Paraffin wax use	GDP growth	Unofficial GDP projections from National Accounts data
2.D.3 Domestic solvent use	Domestic solvent use	Population growth and GDP growth	Eswatini Population Projections Report 2018-2037 and unofficial GDP projections from National Accounts data
2.D.4 Asphalt production and use	Asphalt use	GDP growth	Unofficial GDP projections from National Accounts data
2.F.1 Refrigeration and air conditioning equipment	Annual consumption of refrigerants (kg), quantity of destroyed refrigerants* (kg), exports in used equipment* (kg), share of HFC in retired equipment being recycled or reclaimed* **Even if these values are zero in the baseline, they are considered in the projection.*	GDP growth	Unofficial GDP projections from National Accounts data
2.G.1 SF6 from electrical equipment and other uses	SF6 use	GDP growth	Unofficial GDP projections from National Accounts data

2.G.3 N_2O from Product use	N2O use	GDP growth	Unofficial GDP projections from National Accounts data
2.H.1 Other: Pulp and Paper	Annual production of paper and/or pulp	GDP growth	Unofficial GDP projections from National Accounts data
2.H.2 Other: Food and beverages industry	Annual production of each type of product	GDP growth	Unofficial GDP projections from National Accounts data
3A Livestock	Number of animals Reproductive Data	Livestock Sector Information and Policy Toolkit (LSIPT)	
4A Solid Waste Disposal	Waste Generation	Waste Generation Rate Population Projections	What a Waste 2.0 World Bank Report
4B Biological Treatment	Waste Generation	Waste Generation Rate Population Projections	What a Waste 2.0 World Bank Report
4C Incineration and Open Burning	Waste Generation	Waste Generation Rate Population Projections	What a Waste 2.0 World Bank Report
4D Domestic Wastewater Treatment and Discharge	Population		Eswatini Population Projections Report 2018-2037

Development of mitigation scenarios

Mitigation scenarios represent the implementation of different mitigation actions in different sectors. These mitigation scenarios can reflect the implementation of individual or packages of mitigation measures, taking into account interactions between mitigation measures that might occur (e.g. the combined change in electricity demand and supply). The mitigation measures identified from the analysis of existing plans, strategies and reports are detailed in Section 6.

4. Historical GHG, SLCP and air pollutant emissions in Eswatini 2010-2017

The total emissions of greenhouse gases are shown in Figure 3, and between 2010 and 2017 range between ~2.7 million tonnes CO_2-equivalent emissions in 2010 and 4.5 million tonnes in 2017. The Agriculture, forestry and land use sector was the largest source of GHG emissions, contributing 56% of national total GHG emissions in 2017. The major sources of GHG emissions in the AFOLU sector include livestock, and Forestry and Other Land use. The energy sector emitted approximately 1.7 million tonnes CO_2-equivalent GHG emissions in 2017 (39% of the average 2010-2017 total GHG emissions). The contribution of different energy sectors to GHG emissions is shown in Figure 4. Transport is the largest subsector, contributing 48% of total energy sector GHG emissions in 2017, with road passenger transport making the largest contribution in the transport sector. Fuel consumption in manufacturing industries was the next largest source, followed by Construction and Households (Figure 4).

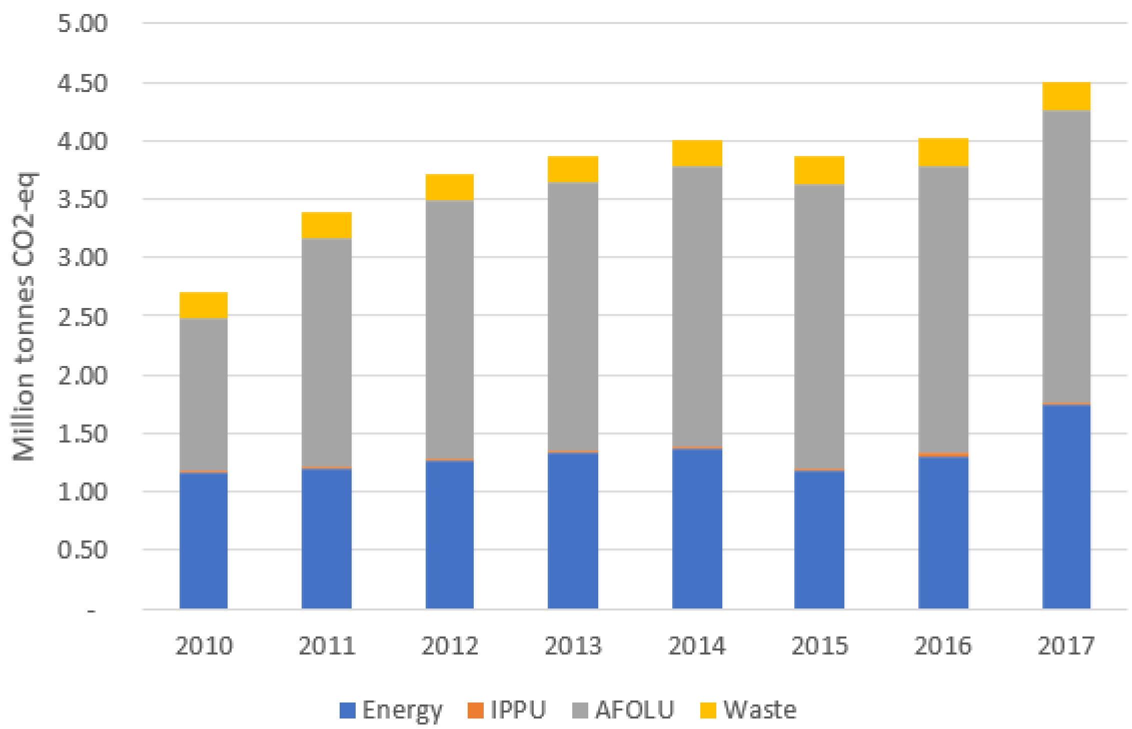


Figure 3: Total GHG emissions in Eswatini between 2010 and 2017 (units: million tonnes CO_2 equivalent emissions).

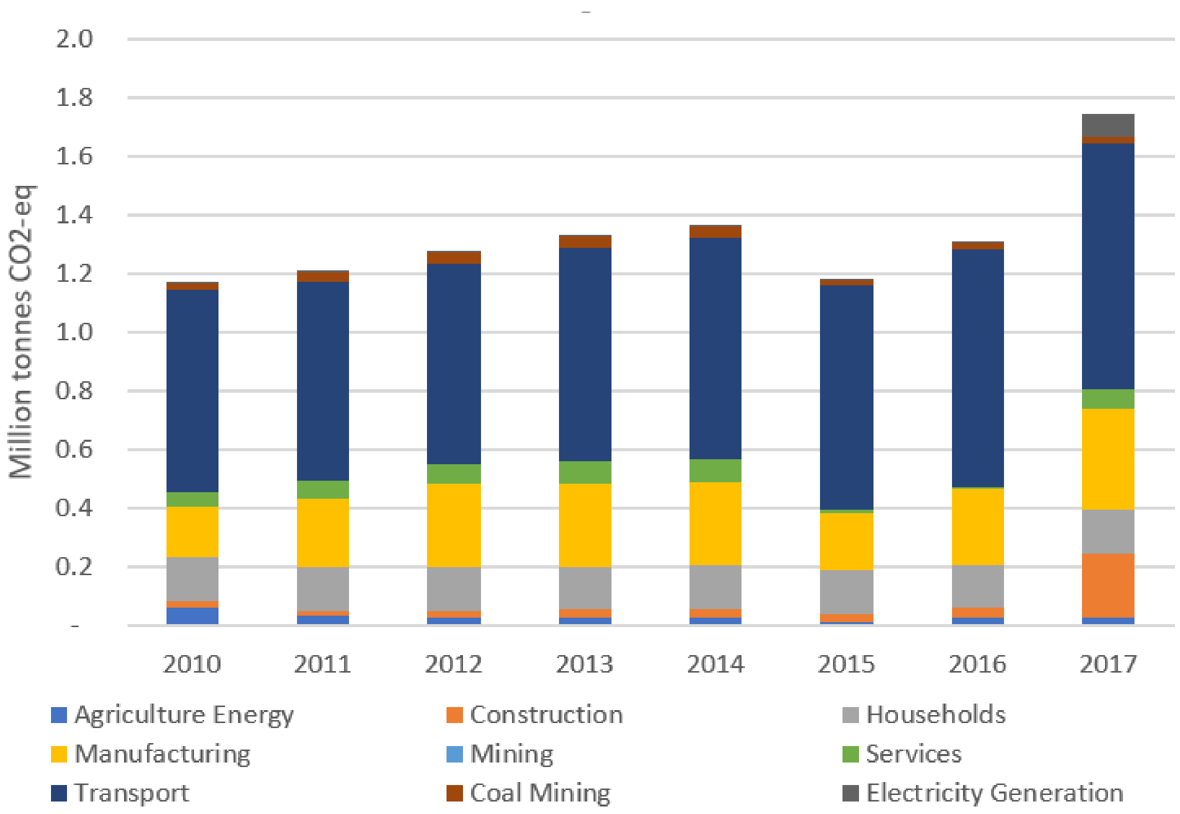


Figure 4: Contribution of sub-sectors to total energy sector GHG emissions between 2010 and 2017 in Eswatini.

Box 1: Comparison of historical GHG emissions between Eswatini's INDC and the updated GHG mitigation assessment

In Eswatini's INDC, no official estimates of national total GHG emissions are provided as a reference against which a target is set. However, in the introduction to Eswatini's INDC it is stated that *'Estimates put Swaziland's 2010 emission inventory at 0.8 MtCO$_2$ (including the Land Use Land Use Change and Forestry (LULUCF) sector), meaning that Swaziland's emissions represent less than 0.002% of global emissions'*.

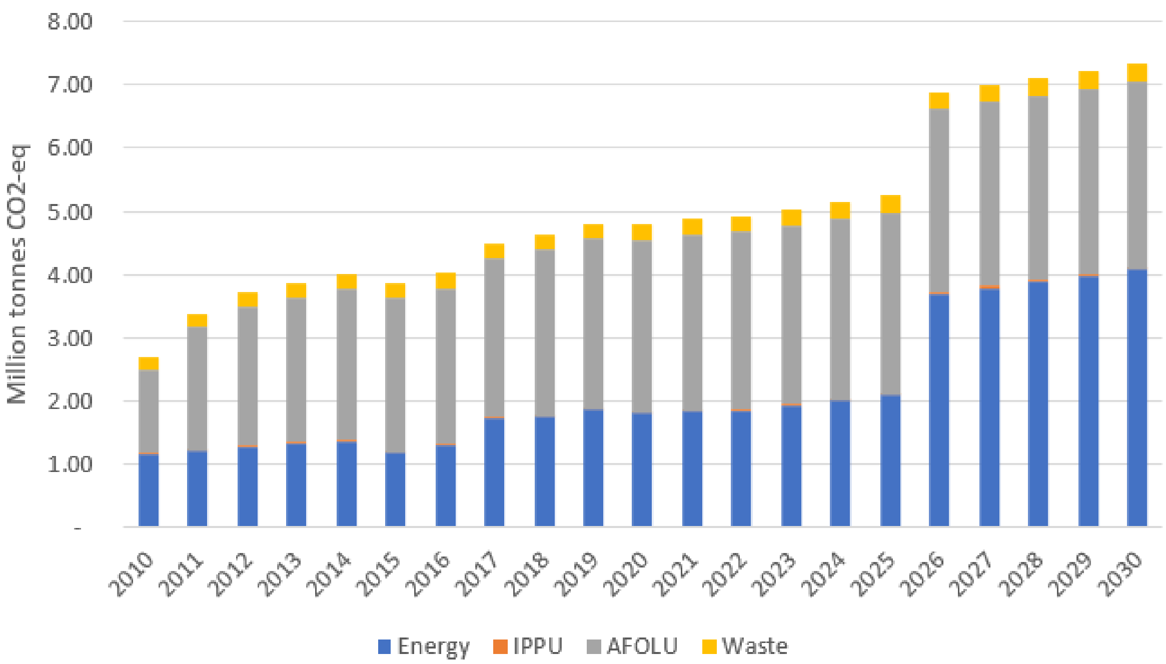
Based on the updated estimate of national total GHG emissions estimated in this GHG mitigation assessment, Eswatini emits a substantial larger amount of GHG emissions than quoted in the INDC. In 2010, the year for which GHG emissions are quoted in Eswatini's INDC, 2.7 million tonnes of GHG emissions were estimated to be emitted in this assessment. This is more than 3 times larger than the value included in Eswatini's INDC.

In addition, since 2010, it is estimated in this GHG mitigation assessment that Eswatini's total GHG emissions have increased. A 67% increase in national total GHG emissions were estimated between 2010 and 2017, with 4.5 million tonnes CO_2-equivalent emissions estimated to have been emitted in 2017.

5. Baseline projections of GHG, SLCP and air pollutant emissions

Having identified the main source sectors of GHGs, SLCPs and air pollutants, as summarised in section 4, the next step is to revise the baseline emission projections to 2030. The purpose of the baseline scenario is to act as a reference against which the mitigation potential of specific policies and measures can be compared. The baseline scenario reflects the expected socioeconomic development in Eswatini without the implementation of specific policies and measures designed to reduce emissions. The objective of this assessment was to estimate the potential for reducing GHG emissions through the implementation of nationally relevant and appropriate mitigation measures in Eswatini. To do so, the first step was to develop a baseline scenario to predict the likely evolution of emissions in the future (2030) without the implementation of additional policies and measures.

The total GHG emissions in the baseline scenario are projected to 2030, in which an estimated 7.33 million tonnes CO_2-equivalent emissions will be emitted (Figure 5). This represents a 63% increase in total GHG emissions between 2017 and 2030. The primary reason for this increase is the construction of a 200 MW coal power plant which is projected to begin generating electricity from 2026. This increases domestic (i.e. excluding emissions from electricity generated in South Africa imported into Eswatini) GHG emissions from electricity generation from 77 thousand tonnes in 2025 to 1,395 thousand tonnes in 2026, after the coal power plant comes online. Socioeconomic development also increase emissions in transport, industry and services sectors. Increase in the intensity of livestock production also increases GHG emissions from the agriculture sector, with a 27% increase in GHG emissions from livestock projected from 2017 to 2030.



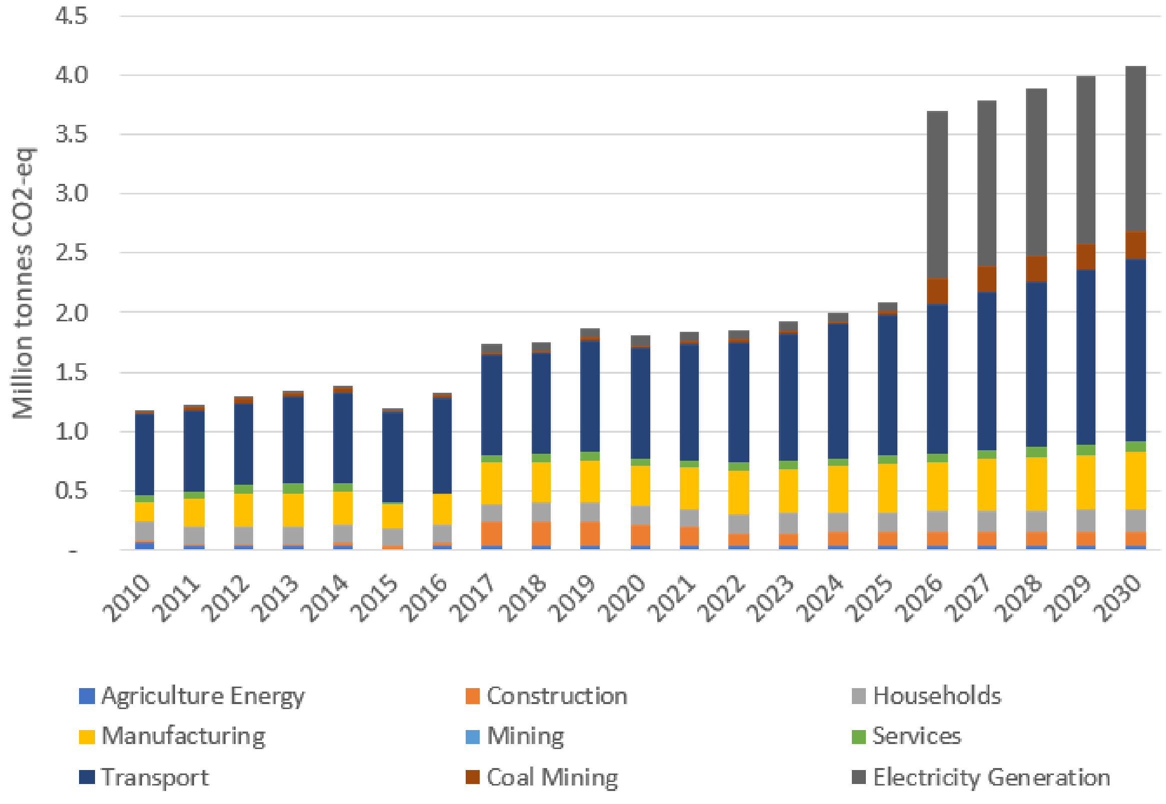


Figure 5: a) Total GHG emission projections from 2010 to 2030 for the baseline scenario (Units: million tonnes CO_2-equivalent emissions), and b) energy sector emission projections from 2010 to 2030 for the baseline scenario.

Box 2: Comparison of baseline GHG emissions between Eswatini's INDC and the updated mitigation assessment

Eswatini's INDC did not specify a quantitative target to reduce GHG emissions, and therefore a baseline projection of emissions was not estimated for any sector. Therefore, the 7.33 million tonnes GHG emissions estimated to be emitted in 2030 does not have a direct comparison in Eswatin's INDC.

6. Mitigation options for GHG mitigation in Eswatini

The historic emission of GHGs, and their baseline projection to 2030 provide an overview of the current contribution that Eswatini makes to global climate change, and how this could change into the future without the implementation of any policies and measures designed to reduce emissions. As outlined in Section 2, in Eswatini's INDC a set of mitigation measures were identified that constituted Eswatini's contribution to mitigate climate change, with no quantitative target

Since the submission of Eswatini's INDC, a substantial number of policies, plans, and strategies have been published that provide substantial opportunities to i) expand the number of sectors considered in the NDC for climate change mitigation, and ii) to increase climate change mitigation ambition in those sectors that are already included. In total 8 plans and strategies were reviewed to extract specific mitigation measures. For a mitigation measure to be modelled in LEAP, it requires two components, a clear, quantitative target (e.g. 30 million households cooking using LPG) and a specific timeline for its implementation (by 2030). Across the 11 documents reviewed, 38 specific mitigation measures were identified. The list of all 38 mitigation measures can be downloaded here: https://drive.google.com/file/d/1w24zimA-iPSM6PogzGSQzTx3AcHAK5gA/view?usp=sharing

Table 6 summarises all documents reviewed in undertaking the GHG mitigation assessment, and the number of mitigation measures identified in each. Of the 38 mitigation measures identified, only a subset (13) were defined in sufficient detail to model quantitatively modelled in the GHG mitigation assessment. Those mitigation measures modelled in LEAP were identified based on expert judgement of those that were most appropriate for the GHG mitigation assessment in Eswatini. Table 7 summarises the mitigation measures modelled in the GHG mitigation assessment for Eswatini.

Table 6: Documents reviewed to identify mitigation measures in the GHG mitigation assessment

Document	Year Published	Number of mitigation actions identified
Eswatini's Intended Nationally Determined Contribution	2015	5
Energy Master Plan 2034	2018	4
Sustainable Energy for All Country Action Plan	2014	0
Sustainable Energy for All Action Agenda	2016	14

National Energy Policy 2018	2018	5
Energy Efficiency and Conservation Policy		0
National Energy Policy Implementation Strategy	2018	0
National Energy Efficiency Strategy and Action Plan	2020	7
Waste Sector mitigation assessment for NDC revision	2021	1
IPPU Sector mitigation assessment for NDC revision	2021	1
Agriculture Sector mitigation assessment for NDC revision, which included measures from: • **Ministry of Agriculture -Strategic Plan 2018-2023 (5 mitigation options)** • **Swaziland: good food security practices to share and replicate (3 mitigation options)**	2021	1

In total 13 mitigation measures were identified for inclusion in the GHG mitigation assessment (Table 7). The full implementation of these mitigation measures would reduce total GHG emissions by 14% in 2030 compared to a baseline scenario (Figure 6).

Table 7 lists the GHG emission reduction potential of the individual mitigation measures included in the mitigation assessment. Note that the total GHG emission reduction for the individual measures is smaller than the sum of the emission reduction of all measures. This is due to interactions between individual mitigation measures that reduce the combined GHG emission reduction potential. For example, the implementation of energy efficiency measures can reduce the overall emission reductions from implementing renewable electricity generation measures due to the lower demand for electricity compared to a baseline scenario in which the energy efficiency measures are not implemented. The expansion of renewable energy for electricity generation is the single measure with the largest GHG emissions reduction potential, resulting in a 9% reduction in total GHG emissions in 2030 compared to a baseline scenario individually.

For the measures in the agriculture sector, there is an increase in overall GHG emissions from this sector (2.2% increase in GHG emissions in 2030 compared to a baseline scenario). The agriculture measures included in the GHG mitigation assessment involve an increase in the intensity of production in the agriculture sector (e.g. through genetic improvements, and improvements in the digestibility of the animal feed). The basis for the inclusion of these measures, and the evaluation of their GHG mitigation potential, are comprehensively outlined in the FAO GHG mitigation assessment report for the livestock sector, linked to above. Explaining the effect on GHG emissions from actions in the livestock sector, the FAO report states:

> *The selection of mitigation actions focused on the reduction of the emissions from the main source that is the methane from enteric fermentation in the two most populated species (cattle and goat). For cattle, mitigation actions are aimed at improving productivity with artificial insemination programs, animal health actions, manure management actions, and actions to improve livestock feeding. For goat, mitigation actions focused on animal health and the improvement of the nutritional components of animals.*
>
> *Projections of emission for cattle show an increase in emissions in 15 percent by 2030. This increment occurs because there is an improvement in the fertility rates, animal weights and mortality parameters when the recommended actions were evaluated. These changes caused a considerable increase in the number of animals to 689,582 by 2030, which is 13*

percent more in relation to the 610,740 animals projected in a business-as-usual scenario. However, milk productivity increases 55 percent and meat productivity increases 6 percent in relation to the baseline. The emission factor analysis shows a 27 percent reduction in the milk intensity and a 14 percent reduction in the meat intensity. These changes show an increase in the productive efficiency of livestock. The methane values of both enteric fermentation per animal and manure management per animal show a reduction of 1 and 40 percent respectively, which indicates that there is no increase in emissions from the main source of emission, mainly due to the improvement of the digestibility of the animal feed components. It must be noted that the only source of emissions that has an increase is nitrous oxide from manure management, which has an increase of 7.6 percent by 2030, compared to the baseline.

FAO GHG mitigation Assessment Report for the livestock sector

The FAO GHG mitigation assessment therefore shows that the mitigation measures reduce the emission intensity of milk and meat production in Eswatini, but due to an increase in production, overall emission shows an increase compared to the baseline scenario.

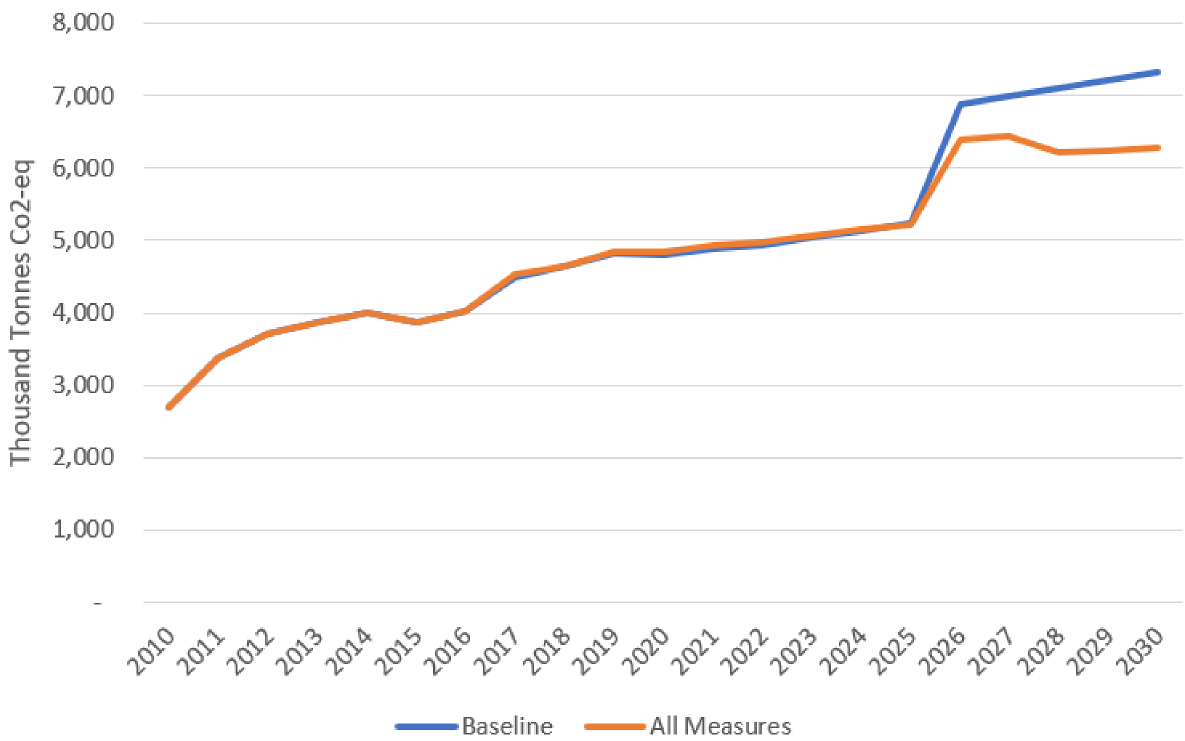


Figure 6: Reduction in total GHG emissions estimated from the implementation of all mitigation measures in 2030 compared to a baseline scenario.

Table 7: Summary of mitigation measures evaluated for GHG emission reduction potential from plans and strategies in Eswatini (baseline 2030 GHG emissions: 7,333 thousand tonnes CO_2-eq emissions)

Number	Sector	Mitigation Measure	Source: Plan/Strategy/Regulation	Percent GHG reductions vs 2030 baseline (%)	Absolute GHG emission reduction 2030 vs baseline (thousand tonnes)
Energy					
1	Transport	Introduction the commercial use of 10% ethanol blend in petrol by 2030	Eswatini's Intended Nationally Determined Contribution	1.35	99.24
2	Residential	50% improvement in efficiency of biomass stoves used for cooking	Energy Master Plan 2034	0.92	67.13
3	Residential	The most inefficient wood-based water heating is replaced by other more efficient options, reducing its share by 13 % by 2034. Reflecting its promotion under the SE4ALL initiative, the share of solar water heating is assumed to reach 50 % of households (25 % with back-up and 25 % without back-up).	Energy Master Plan 2034	0.00	0
4	Residential	100% access to clean energy at household level attained by 2030	Sustainable Energy for All Action Agenda	0.12	8.86
5	Electricity Generation	To achieve 50% renewables target: biomass-based co-generation: 140-165MW hydro: +40-60MW Solar: +100-120MW Wind: +20-50 MW	National Energy Policy 2018	9.08	665.8
6	Sugar	15% (95.84 GWh) reduction in electricity consumption in 2034	National Energy Efficiency Strategy and Action Plan	0.00	0
7	Other Agriculture	10% (41.66 GWh) reduction in electricity consumption in 2034	National Energy Efficiency Strategy and Action Plan	0.00	0
8	Industry	10% (38.89 GWh) reduction in electricity consumption in 2034	National Energy Efficiency Strategy and Action Plan	0.061	4.47

9	Commercial and Public Services	10% (16.67 GWh) reduction in electricity consumption in 2034	National Energy Efficiency Strategy and Action Plan	0.004	0.27
10	Residential	20% (205.7 GWh) reduction in electricity consumption in 2034	National Energy Efficiency Strategy and Action Plan	0.096	7.05
Industrial Processes and Product Use					
11	Ozone Depleting Substances	Implement HFC phase-out with the corresponding schedule for Annex 5 countries (freeze consumption in 2024 compared to average 2019-2021 levels, 10% reduction in consumption compared to 2019-2021 levels in 2029)	Kigali Amendment to Montreal Protocol IPPU Sector NDC update mitigation assessment	0.15	11.36
Agriculture, Forestry and Other Land Use					
12	Livestock	Improvements in productivity of cattle, sheep and goat production through artificial insemination, improved digestibility of feed, and improved manure management	Agriculture Sector NDC update mitigation assessment	2.2% increase in emissions	165 increase in emissions
Waste					
13	Solid Waste	Implement best practices in solid waste management considering i) reduction in open burning of waste, ii) increase composting of organic waste, and iii) increase landfill gas recovery at solid waste disposal sites	Waste Sector NDC update mitigation assessment	0.62	45.26

The emission reduction potential from implementation of mitigation measures in each sector differs. Table 8 summarises the overall reduction in GHG emissions in 2030 for each of the IPCC source categories. In the energy sector, GHG emissions are reduced by 23% in 2030 compared to a baseline scenario from the implementation of the mitigation measures in the energy sector. The IPPU and Waste sector emissions similarly decrease, by 49% and 14%, respectively. As described above, for the AFOLU sector, there is an increase in total emissions due to the increase productivity of the livestock system following the implementation of the mitigation measures.

Table 8: Sectoral reductions in GHGs in 2030 compared to a baseline scenario

Sector	2017 GHG emissions (thousand tonnes CO_2-equivalent)	2030 baseline GHG Emissions (thousand tonnes CO_2-equivalent)	2030 measures GHG emissions (thousand tonnes CO_2-equivalent)
Energy	1,741.5	4,082.6	2917.7 (-29%)
IPPU	17.97	23.32	11.94 (-49%)
Agriculture, Forestry and Other Land Use	2,502	2,947	3,112 (+5.5%)
Waste	236.09	281.13	235.86 (-16%)
Total	4,497	7,333	6,289 (-14%)

Figure 7 shows the reduction in GHG emissions from implementation of the mitigation measures, and the remaining GHG emissions after implementation of these mitigation measures. The largest remaining sources of GHG emissions after implementation of all measures considered in this assessment are the agriculture sector. Within the energy sector, transport and electricity generation continue to emit substantial amounts of GHG emissions even after the implementation of all mitigation measures included in Table 7.

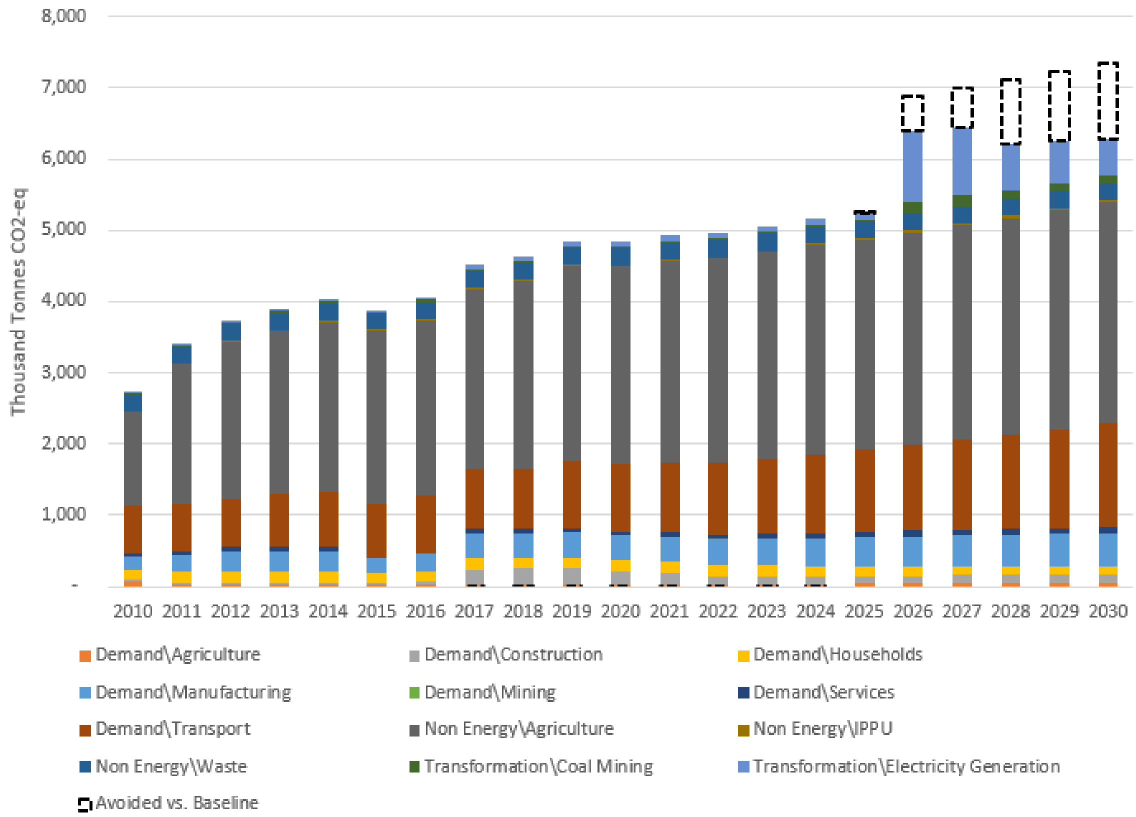


Figure 7: Reduction in GHG emissions from implementation of all measures

Box 3: Comparison of GHG mitigation between Eswatini's INDC and updated GHG mitigation assessment

In Eswatini's INDC, the contribution to reducing climate change was the inclusion of specific mitigation actions, for which indicative GHG reductions were given:

- Doubling the share of renewable energy in the national energy mix. This includes electricity generation and reduced consumption of non-sustainable biomass. (0.94 million tonnes CO_2-eq emissions reduced)
- Introducing the use of 10% ethanol blend in petrol for use in all vehicles. This is additional to the contribution of doubling the share of renewable energy. (0.03 million tonnes CO_2-eq emissions reduced)
- Phasing out the use of HFCs, PFCs and SF_6 gases. (No mitigation potential given)

In this GHG mitigation assessment, a broader set of measures have been modelled that reflect updated plans and strategies in Eswatini since the production of Eswatini's INDC. Collectively, the mitigation measures included in this updated GHG mitigation assessment would reduce total GHG emissions by 14% compared to a baseline scenario, equivalent to 1.04 million tonnes CO_2-equivalent emissions. The overall reduction in GHG emissions is larger than the GHG emission reduction potentials reported in the INDC for the two mitigation measures included.

7. Co-benefits of GHG mitigation for Short-Lived Climate Pollutants an air pollutants

Air pollution and climate change are two of the biggest environmental problems facing the world. Exposure to air pollution from indoor and outdoor sources was associated with 4.9 million premature deaths in 2017 due to respiratory and cardiovascular diseases. It is also linked to other non-fatal health effects, such as difficulties during pregnancy, asthma and emergency room visits. The two pollutants with the greatest impact on human health are fine particulate matter (PM2.5) and ground-level ozone (O3). In 2019, almost 831 premature deaths in Eswatini were associated with exposure to air pollution.

At the same time, emissions of air pollutants are warming the atmosphere. Since pre-industrial times, global average temperatures have risen by 1.1°C, while the Paris Agreement sets the goal of limiting the increase in global average temperatures to "well below 2°C", and ideally to 1.5°C. Current climate change commitments are estimated to lead to a warming of more than 3°C by 2100, so more action is needed to meet the Paris Agreement targets. The consequences of climate change include increased frequency of extreme weather events, such as storms, floods, droughts and heat waves, impacts on agriculture and food security, impacts on human health and biodiversity.

The issues of climate change and air pollution are closely linked because (i) in many cases, greenhouse gases and air pollutants are emitted from the same sources, and (ii) some of the substances contribute to climate change and the adverse effects of air pollution, such as methane, black carbon and ground-level ozone, i.e. short-lived climate pollutants (SLCPs) (Figure 8). These two linkages offer considerable opportunities to design strategies and identify mitigation measures that can simultaneously reduce air pollution and mitigate climate change. Global and regional studies have shown that there is a range of strategies and actions that can be taken to target major sources of SLCPs and simultaneously improve local air pollution while reducing countries' contribution to global climate change.

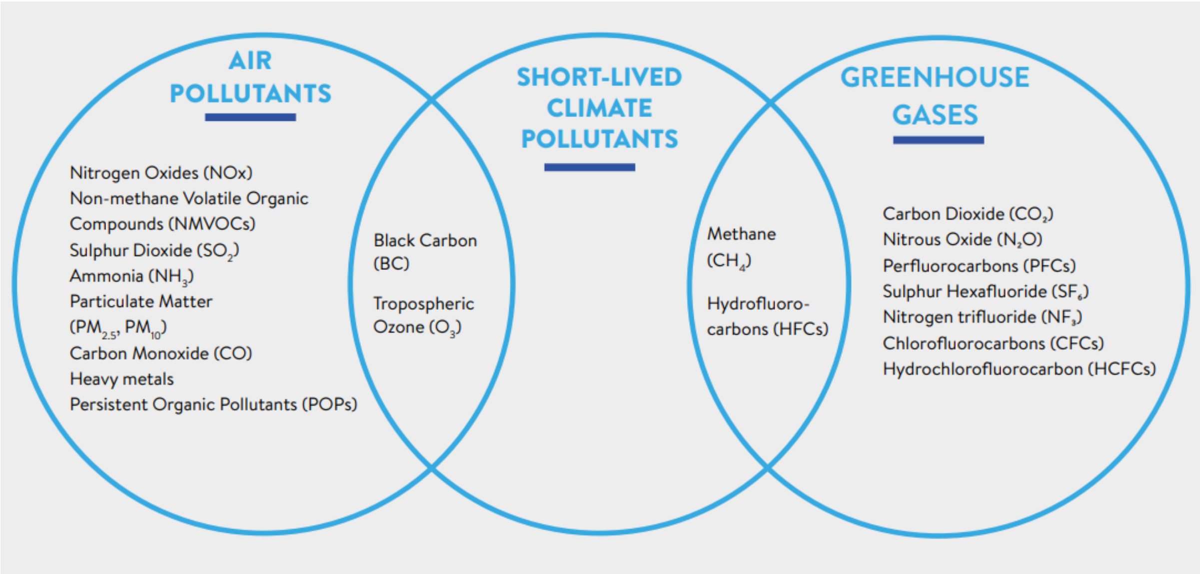


Figure 8: Summary of pollutants that are classified as air pollutants, short-lived climate pollutants and greenhouse gases

Following the findings of the UNEP/WMO Integrated Assessment of Black Carbon and Ground-level Ozone (2011), a broad consensus has emerged on the need and urgency to address the adverse effects of air pollution and climate change simultaneously. Mitigation measures targeting the main sources of black carbon and methane (a precursor of ground-level ozone) were assessed for their impact on air quality and climate. In total, 16 measures that delivered 90% climate benefits were identified from hundreds of assessed measures. Of these, 9 measures targeted black carbon, including in the residential, agricultural, transport and industrial sectors, and 7 measures targeted methane in the agricultural, oil and gas and waste sectors. The assessment concluded that full implementation of these measures would deliver substantial air quality and climate benefits, estimating that 2.4 million premature deaths would be avoided in 2030 compared to the baseline situation, as well as an additional 52 million tonnes of 4 staple crops (rice, wheat, maize and soybeans) due to reduced crop damage caused by ozone exposure. These air quality benefits are felt directly at the local level in the countries and regions where the emission reductions take place. At the same time, implementation of these measures would also avoid a 0.5°C increase in global temperature, which would go a long way to limiting global temperature increase when combined with rapid and ambitious CO2 reductions (Figure 1.1). Black carbon, methane and ground-level ozone, as well as hydrofluorocarbons, have been labelled 'short-lived climate pollutants' because of the relatively short time they spend in the atmosphere once emitted (days to two decades), and their impact on climate and air quality (with the exception of HFCs, which have only a climate impact). This means that actions on SLCPs can quickly produce multiple benefits for air quality and climate change (Shindell et al., 2012).

As outlined above, the GHG mitigation assessment conducted for Eswatini also quantified emissions of SLCPs and air pollutants, and their emission reduction potential. The mitigation assessment showed that there is substantial potential to reduce SLCPs and air pollutants alongside GHGs. Table 9 shows the magnitude of emissions of SLCPs and air pollutant emissions quantified alongside GHGs in this GHG mitigation assessment, while Figure 9 shows the contribution of major source sectors. For black carbon, over half of the 1,500 tonnes emitted in 2017 are emitted from the household sector, due to the burning of solid biomass for cooking. Manufacturing and waste make up the largest remaining sources of SLCPs in Eswatini. The household sector similarly is a major source of other fine particulate matter ($PM_{2.5}$) emissions, while the transport sector is a major source of nitrogen oxides (NO_x) air pollution.

Table 9 also summarises the reduction in SLCP and air pollutant emissions resulting from the implementation of the mitigation measures summarised in Table 7. The full implementation of the mitigation actions included in this GHG mitigation assessment could reduce black carbon emissions by 17% in 2030 compared to a baseline scenario, and result in larger reductions for other key health-damaging air pollutants such as $PM_{2.5}$. The most effective measures to achieve these reductions are those that convert households from cooking using solid biomass to cleaner fuels, or more efficient biomass stoves, due to the majority of Black carbon and $PM_{2.5}$ emissions originating from the residential sector. Table 9 underlines the substantial co-benefits for SLCPs and air pollutants that could be achieved through climate change mitigation actions considered in this assessment.

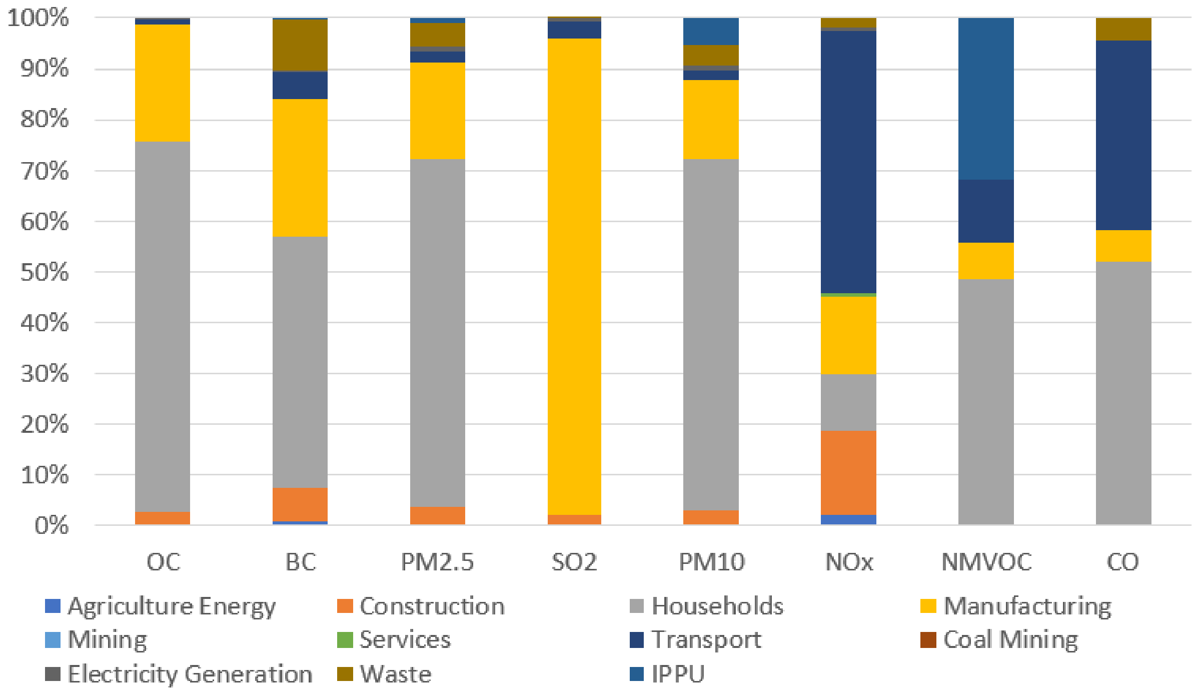


Figure 9: Contribution of major source sectors to SLCP and air pollutant emissions in 2017 in Eswatini

Table 9: SLCP and air pollutant emissions in 2017, and 2030 for Baseline, All Measures scenarios

Scenario	OC	BC	$PM_{2.5}$	PM_{10}	NOx	NMVOC	CO
2017 emissions	3.41	1.53	8.05	9.54	16.3	32.79	123.2
Baseline 2030 emissions	4.25	2.02	10.06	11.91	25.88	43.89	181.79
All Measures 2030 emissions	3.09 (-27.3%)	1.68 (-16.8%)	7.97 (-20.4%)	9.19 (-22.6%)	23.57 (-8.9%)	32.11 (-26.8%)	148.33 (-18.4%)

8. Recommendations for GHG mitigation targets for NDC revision

The assessment of GHG mitigation actions for Eswatini described in above, quantifies the potential to reduce GHG, (and SLCP and air pollutant) emissions from 13 mitigation measures included in existing plans and strategies in Eswatini. Overall, the full implementation of the mitigation measures could reduce GHG emissions by 14% in 2030 compared to a baseline scenario. These same actions were also shown to substantially reduce SLCP and air pollutant emissions, bringing substantial co-benefits from their implementation. This section describes the different possible targets that could be included in Eswatini's revised NDC, that are supported by the GHG mitigation assessment results described above.

Possible Economy-wide GHG emission reduction targets

The GHG mitigation assessment conducted in this work supports an economy wide GHG reduction target for Eswatini of 14% in 2030 compared to a baseline scenario. This 14% reduction is equivalent to 1.04 million tonnes fewer GHG emissions in 2030 compared to a baseline scenario. This 14% reduction target is based on the implementation of the 13 mitigation measures national experts deemed most achievable given the national context. The NDC can contain an unconditional target, which can be achieved without international support, as well as a conditional target that is higher and could be achieved with international support. The level of both an unconditional and conditional target are political decisions beyond the scope of this technical GHG mitigation assessment, but Table 7 summarises the individual GHG mitigation potentials which occur for each mitigation measure, which could be combined in different ways to define unconditional and conditional targets in the NDC update.

Possible Sectoral GHG emission reduction targets

In Eswatini's INDC, submitted in 2015, mitigation measures were included for the energy and IPPU sectors only. The GHG mitigation assessment supports the setting of sectoral GHG reduction targets, both for the energy and IPPU sector, but also for all other major GHG emission source sectors. The possible sectoral targets, supported by the assessment of GHG emission reductions from implementation of the mitigation measures listed in Table 7, are summarized in Table 10.

Table 10: Sectoral reductions in GHGs in 2030 compared to a baseline scenario

Sector	2017 GHG emissions (thousand tonnes CO_2-equivalent)	2030 baseline GHG Emissions (thousand tonnes CO_2-equivalent)	2030 measures GHG emissions (thousand tonnes CO_2-equivalent)
Energy	1,741.5	4,082.6	2917.7 (-29%)
IPPU	17.97	23.32	11.94 (-49%)
Agriculture, Forestry and Other Land Use	2,502	2,947	3,112 (+5.5%_
Waste	236.09	281.13	235.86 (-16%)
Total	4,497	7,333	6,289 (-14%)

Co-benefits from NDC implementation

In addition to the GHG emission reductions that can be used to set targets in Eswatini's updated NDC, a key aspect of this GHG mitigation assessment is that the estimated emission reductions for a wider set of pollutants were included in the analysis. This broader set of pollutants includes black carbon, a short-lived climate pollutant, which impacts climate change and also human health as an air pollutant. The implementation of the 13 mitigation measures included in the GHG mitigation assessment were estimated to reduce black carbon emissions by 16% in 2030 compared to a baseline scenario (Section 7). This represents an additional reduction in Eswatini's contribution to climate change, as well as a co-benefit that will improve the health of Eswatinians through improve air quality. The air pollution in Eswatini will be further improved through the implementation of these 10 mitigation measures, with a 20% reduction in fine particulate matter ($PM_{2.5}$) emissions in 2030 compared to a baseline scenario. These co-benefits from Eswatini's climate change commitment could be included in the revised NDC as additional benefits alongside the GHG reduction

Mitigation measures to achieve possible targets

The possible targets for GHG reductions outlined above are based on the expected reductions in GHG emissions, and enhancement of GHG sinks, that are estimated to occur from the implementation of specific, discrete mitigation actions. Therefore, when updating Eswatini's NDC, we recommend that these mitigation measures are specifically included in the NDC document, to provide clarity as to how the mitigation commitment will be achieved. The 13 mitigation actions that achieve the possible targets highlighted above are listed in Table 11 below.

Table 11: Summary of mitigation measures evaluated for GHG emission reduction potential from plans and strategies in Eswatini

Number	Sector	Mitigation Measure	Source: Plan/Strategy/Regulation
1	Transport	Introduction the commercial use of 10% ethanol blend in petrol by 2030	Eswatini's Intended Nationally Determined Contribution
2	Residential	50% improvement in efficiency of biomass stoves used for cooking	Energy Master Plan 2034
3	Residential	The most inefficient wood-based water heating is replaced by other more efficient options, reducing its share by 13 % by 2034. Reflecting its promotion under the SE4ALL initiative, the share of solar water heating is assumed to reach 50 % of households (25 % with back-up and 25 % without back-up).	Energy Master Plan 2034
4	Residential	100% access to clean energy at household level attained by 2030	Sustainable Energy for All Action Agenda
5	Electricity Generation	To achieve 50% renewables target: biomass-based co-generation: 140-165MW hydro: +40-60MW Solar: +100-120MW Wind: +20-50 MW	National Energy Policy 2018
6	Sugar	15% (95.84 GWh) reduction in electricity consumption in 2034	National Energy Efficiency Strategy and Action Plan

7	Other Agriculture	10% (41.66 GWh) reduction in electricity consumption in 2034	National Energy Efficiency Strategy and Action Plan
8	Industry	10% (38.89 GWh) reduction in electricity consumption in 2034	National Energy Efficiency Strategy and Action Plan
9	Commercial and Public Services	10% (16.67 GWh) reduction in electricity consumption in 2034	National Energy Efficiency Strategy and Action Plan
10	Residential	20% (205.7 GWh) reduction in electricity consumption in 2034	National Energy Efficiency Strategy and Action Plan
11	Ozone Depleting Substances	Implement HFC phase-out with the corresponding schedule for Annex 5 countries (freeze consumption in 2024 compared to average 2019-2021 levels, 10% reduction in consumption compared to 2019-2021 levels in 2029)	Kigali Amendment to Montreal Protocol IPPU Sector NDC update mitigation assessment
12	Livestock	Improvements in productivity of cattle, sheep and goat production through artificial insemination, improved digestibility of feed, and improved manure management	Agriculture Sector NDC update mitigation assessment
14	Solid Waste	Implement best practices in solid waste management considering i) reduction in open burning of waste, ii) increase composting of organic waste, and iii) increase landfill gas recovery at solid waste disposal sites	Waste Sector NDC update mitigation assessment