REPUBLIC OF RWANDA

Revising Nationally Determined Contribution (NDC) mitigation and adaptation priorities for Rwanda

Final Report

24 March 2020

Prepared by: Gregory Cook (Mitigation lead), Alex Mulisa (Adaptation lead), Innocent Nkurikiyimfura (Energy), Elisée Gashugi (Waste and IPPU), and Svetlana Gaidashova (Agriculture and Forestry)

Task Team Leader: Pablo Benitez Ponce, Senior Environmental Economist, ENB Global Practice

ACKNOWLEDGEMENTS

This report was prepared by a team led by Pablo Benitez (Senior Environmental Economist) of the World Bank and under the expert guidance of Juliet Kabera (Director General of Environment and Climate Change) and Immaculee Uwimana (Climate Change Mitigation officer) at the Ministry of Environment. The main contributing authors are Gregory Cook (Carbon Counts), Alex Mulisa, Innocent Nkurikiyimfura, Elisée Gashugi, and Svetlana Gaidashova.

The team would also like to express its gratitude to the many individuals from within the Government of Rwanda for the provision of data, information and expertise, without which the analysis could not be possible. These include in particular officials and experts from the Ministry of Environment, the Rwanda Environment Management Authority, the Ministry of Agriculture and Animal Resources, the Ministry of Infrastructure, the Ministry of Finance and Economic Planning, National Institute of Statistics of Rwanda, and the Rwanda Agriculture Board. In addition, the team would also like to thank peer reviewers Joern Huenteler, Esdras Byiringiro, Adam Stone Diehl, and Abebaw Alemayehu, and to Sandra Namukaya, Michael John Hammond, and Peter Katanisa for their contributions. Finally, the team would also like to thank the participants in the various consultation sessions including those of the inception and validation workshops conducted in Kigali between February 2019 and November 2019 for their valuable inputs and feedback.

 The study was funded by the NDC Support Facility of the World Bank as part of the NDC Partnership programme.

CONTENTS

ACRONYMS AND ABBREVIATIONS

AFOLU	Agriculture, Forestry and Other Land Use
BAU	'Business as usual'
CBA	Cost-benefit analysis
CCL	CIMERWA Cement Limited Ltd
CDM	Clean Development Mechanism
CFL	Compact fluorescent lamp
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CoK	City of Kigali
CORs	Continuous Operating Reference System
CSA	Climate Smart Agriculture
DDS	District Development Strategy
DRR	Disaster risk reduction
DSM	Demand side management
EDPRS	Economic Development and Poverty Reduction Strategy
EE	Energy Efficiency
EIB	European Investment Bank
EICV5	Fifth Integrated Household Living Survey
EMS	Energy management system
ENR	Environment and Natural Resources
ESSP	Energy Sector Strategic Plan
EV	Electric vehicle
FAO	Food and Agriculture Organization of the United Nations
FIP	Forest Investment Plan
FONERWA	Rwanda's Green Fund
FTE	Full time employees
GCF	Green Climate Fund
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GGCRS	Green Growth and Climate Resilience Strategy
GHG	Greenhouse gas
GoR	Government of Rwanda
GWh	Gigawatt-hour
GWP	Global warming potential
Ha	Hectare
HFC	Hydrofluorocarbon
HH	Household
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use

IWRM	Integrated Water Resources Management
km	Kilometre
kW	Kilowatt
kWe	Kilowatt-electric
L	litre
LAIS	Land Administration and Information System
LCPDP	Least Cost Power Development Plan
LDC	Least Developed Country
LDV	Light duty vehicle
LEAP	Long-Range Energy Alternative Planning
LED	Light emitting diode
LFG	Landfill gas
LPG	Liquefied petroleum gas
M&E	Monitoring and Evaluation
MACC	Marginal abatement cost curve
MIDIMAR	Ministry of Disaster Management and Refugee Affairs
MINAGRI	Ministry of Agriculture and Animal Resources
MINALOC	Ministry of Local Government
MINECOFIN	Ministry of Finance and Economic Planning
MINEDUC	Ministry of Education
MININFRA	Ministry of Infrastructure
MJ	Megajoule
MoE	Ministry of Environment
MRV	Monitoring, Reporting and Verification
Mt	Million tonnes
MW	Megawatt
N	Nitrogen
NAMA	Nationally Appropriate Mitigation Actions
NAP	National Adaptation Plan
NDC	Nationally Determined Contribution
NGO	Non-Governmental Organisation
NISR	National Institute of Statistics of Rwanda
NLUDMP	National Land Use Development Master Plan
NPV	Net present value
NST	National Strategy for Transformation
O&M	Operating and maintenance
ODS	Ozone depleting substances
PA	Paris Agreement
PPCR	Pilot Program for Climate Resilience
PSF	Private Sector Federation
PV	Photovoltaic
RAB	Rwanda Agriculture Board
RBME&L	Results-based monitoring, evaluation and learning

REDD+	Reducing Emissions from Deforestation and Forest Degradation
REG	Rwanda Energy Group Ltd
REMA	Rwanda Environment Management Authority
RHA	Rwanda Housing Authority
RLMUA	Rwanda Land Management and Use Authority
RTDA	Rwanda Transport Development Agency
RURA	Rwanda Utilities Regulatory Authority
RWFA	Rwanda Water and Forestry Authority
SHS	Solar home system
SIDS	Small Island Developing States
SPCR	Strategic Program for Climate Resilience
SREP	Scaling Up Renewable Energy Program
SSP	Sector Strategic Plan
SWDS	Solid waste disposal site
SWH	Solar water heater
t	Tonne
TJ	Tera-joule
TNC	Third National Communication to the UNFCCC
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
USD	United States (US) dollar
WBG	World Bank Group
WtE	Waste to Energy

EXECUTIVE SUMMARY

Introduction

Rwanda submitted its Intended Nationally Determined Contribution (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC) in September 2015 setting out its adaptation and mitigation goals. The INDC formally became the country's first Nationally Determined Contribution (NDC) with the entry into force of the Paris Agreement in 2016.

Rwanda is currently revising its NDC ahead of the 26th Conference of the Parties of the UNFCCC (COP26) in Glasgow. This requires building upon existing work in developing quantifiable mitigation and adaptation targets, and the prioritization of interventions to support these two areas. The World Bank is providing technical assistance to support Rwanda in this process. This report describes the results of technical and economic analysis relating to both the mitigation and adaptation components of the NDC. It covers the following:

- **Mitigation**: An evaluation of greenhouse gas (GHG) mitigation actions based on in-depth assessment of the country's mitigation potential. This has been undertaken using detailed technical and economic analysis and multi-criteria based evaluation involving extensive stakeholder consultation. The development of business as usual (BAU) and alternative GHG pathways through 2030 is used to inform the choice of NDC mitigation targets for Rwanda and support its implementation framework.
- **Adaptation**: Production of quantified targets for adaptation and resilience, criteria-based evaluation of priority interventions, and development of a monitoring and evaluation (M&E) framework for adaptation actions to strengthen national capacity for resource mobilization.

Based on the analysis undertaken, funding requirements and support needs for both conditional and unconditional measures in mitigation and adaptation through 2025 and 2030 are estimated. The work aims to provide a robust technical basis for subsequent actions to strengthen climate change planning and implementation activities in Rwanda.

Mitigation

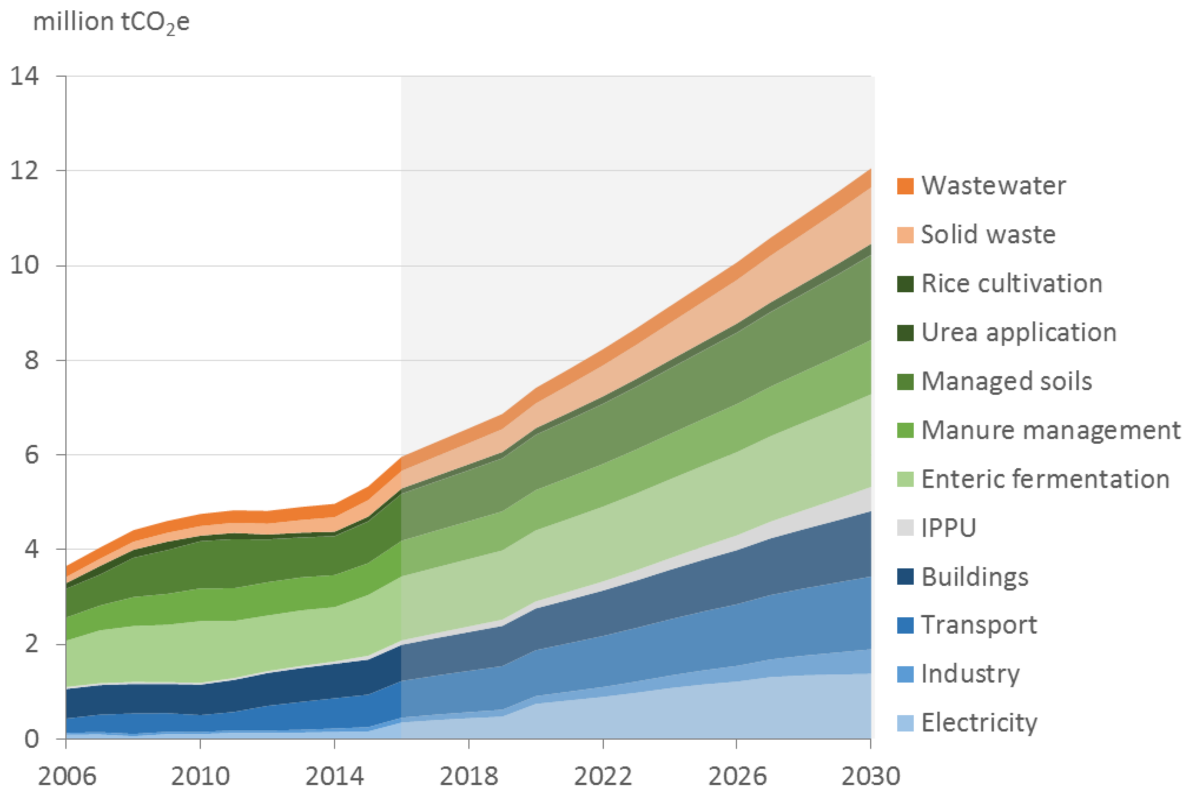
BAU emissions projections

In order to determine Rwanda's mitigation potential and choice of NDC targets, GHG emissions were first projected through 2030 under a BAU scenario according to which NDC mitigation policies and actions are not implemented. The national GHG inventory for the base year was updated according to International Panel on Climate Change (IPCC) reporting guidelines and bottom-up projections made based on updated forecasts of sector-specific activity data and official outlooks for gross domestic product (GDP) and population growth.

At an aggregate level, total emissions are forecast to more than double over the 2015-2030 period, rising from 5.3 million tCO_2e in the base year to 12.1 million tCO_2e in 2030. As shown in the graph below, the most significant growth is forecast within energy use emissions, expanding its share of total emissions from around 31% in the base year to 40% by 2030. The share of emissions from waste generation remains at around 12-13%, whilst agricultural sources decline from 55% to 43%.

The forecast indicates the growing contribution from fossil fuels to national emissions, arising from increasing demand for power generation, road transport and other modern energy uses. At the same time, despite potential for increased productivity, agricultural output in expected to be limited due to land availability, thereby limiting emissions growth from this sector.

Figure ES-1 BAU emissions projections in Rwanda to 2030



Assessment of NDC mitigation options

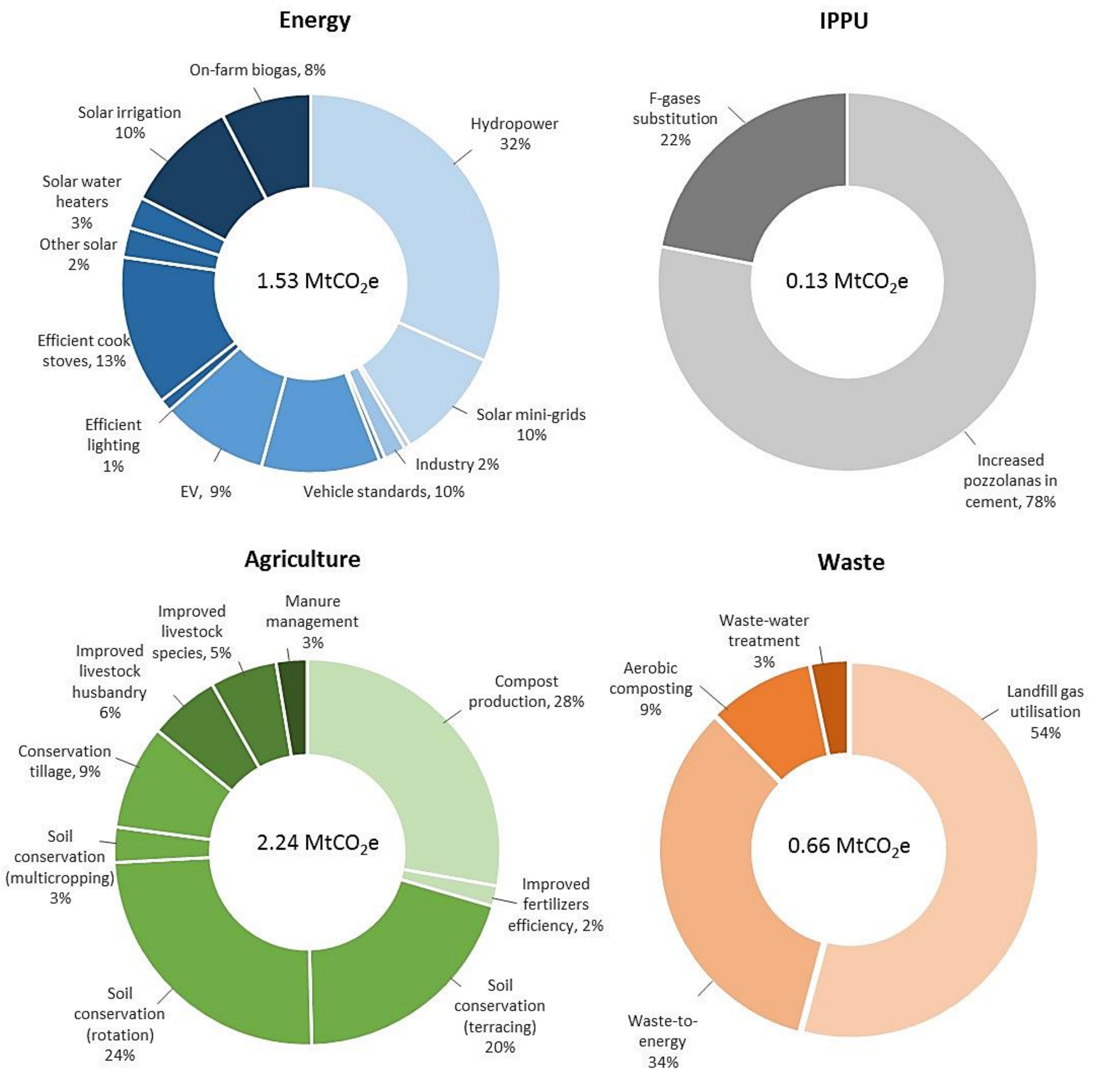
A detailed assessment of GHG mitigation options for Rwanda was next undertaken in order to determine which options are most suitable for inclusion in the NDC. The analysis was undertaken according to a three-step process:

- **Step 1: Identifying mitigation options**. A 'long-list' of potentially suitable emission reduction projects and measures was developed through discussions and consultation with government officials, technical and sector experts, and other stakeholders.
- **Step 2: Assessing the potential**. The identified options were then assessed in terms of their mitigation potential through 2030 compared to the BAU reference scenario and their economic costs and benefits, by undertaking cost-benefit analysis (CBA).
- **Step 3: Evaluating the options**. The quantitative analysis undertaken in Step 2 was complimented by a broader, multi criteria-based, assessment in order to identify those options considered most suitable or feasible to be implemented under the NDC and to determine which will be implemented through domestic efforts alone ('unconditional' projects) and which require international support and finance ('conditional' projects),

including through international market-based approaches e.g. under Article 6 of the Paris Agreement.

The figure below summarises the estimated emissions reduction potential against BAU in 2030 for all mitigation measures assessed from the 'long list'. The total mitigation potential is estimated at around 4.6 million tCO_2e in 2030 against the BAU emissions in the same year of 12.1 million tCO_2e. According to the analysis, mitigation measures identified within the agriculture sector accounts for 49% of the total potential, followed by energy (34% of total), waste (14%), and IPPU (3%).

Figure ES-2 Estimated GHG mitigation potential in 2030 from all measures

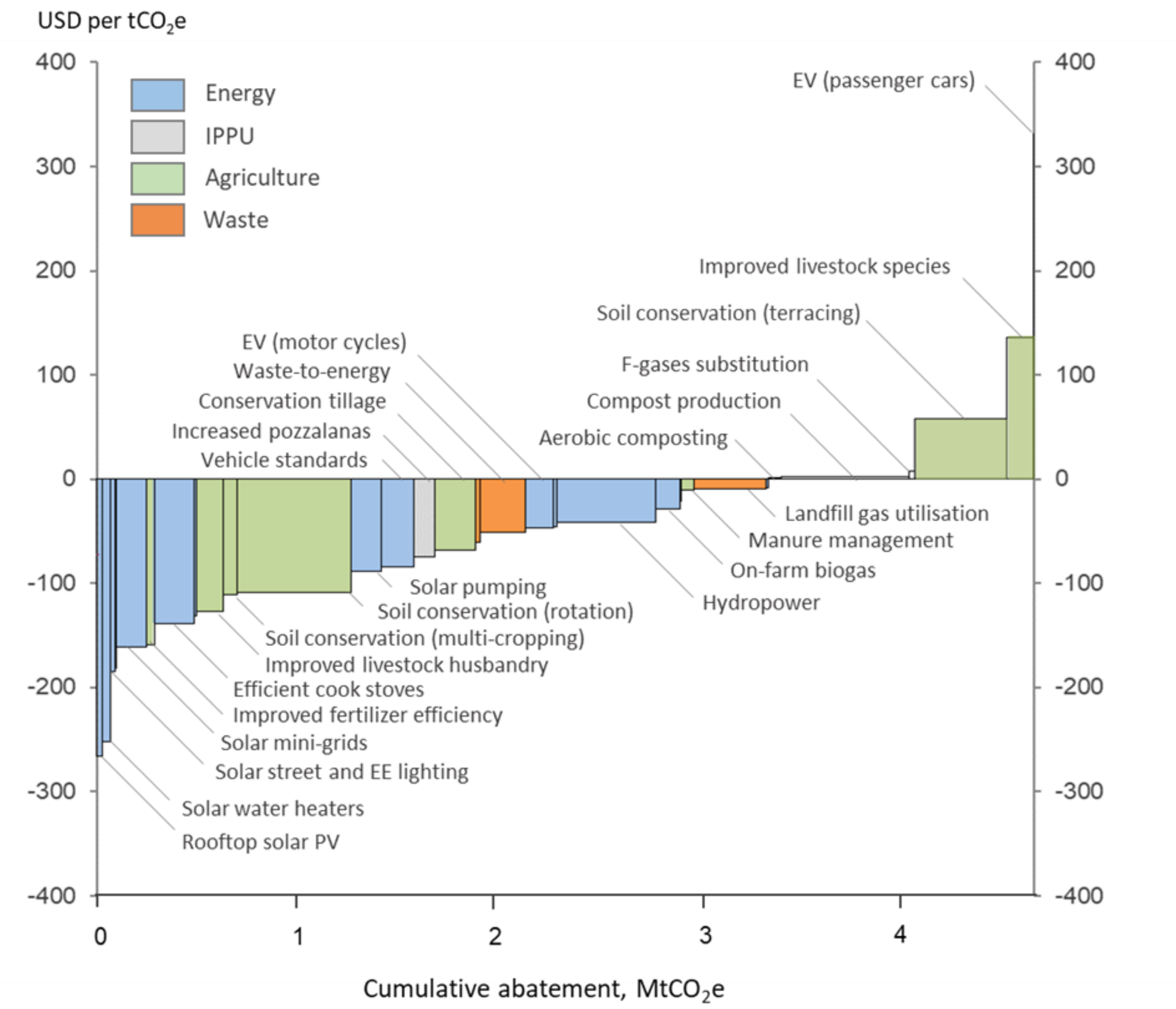


Note: Some mitigation measures are grouped for simplicity

The figure below shows a marginal abatement cost curve (MACC) in which each of the identified NDC mitigation options is sorted in ascending order of abatement cost. The costs represent socio-economic costs of abatement, reflecting both costs and benefits to the wider economy.

Many of the projects shown on the curve – representing around 72% of the total potential - are considered to be achievable with a net socio-economic benefit. This is most noticeable for energy projects, most of which involve the displacement or reduction of imported fossil fuels through increasing the use of indigenous renewable energy and cost-saving demand-side measures. The majority of the waste sector options identified are also considered to be cost-effective on an economic basis, including landfill gas utilisation and waste-to-energy projects which utilise waste materials for economic energy production whilst also delivering wider employment and revenue benefits. Within agriculture, cost-effective options such as crop rotation and improved livestock husbandry can also deliver GHG reductions with important co-benefits such as increasing yields and economic output.

Figure ES-3 Marginal abatement cost curve for all identified mitigation measures in 2030



Development of alternative GHG pathways

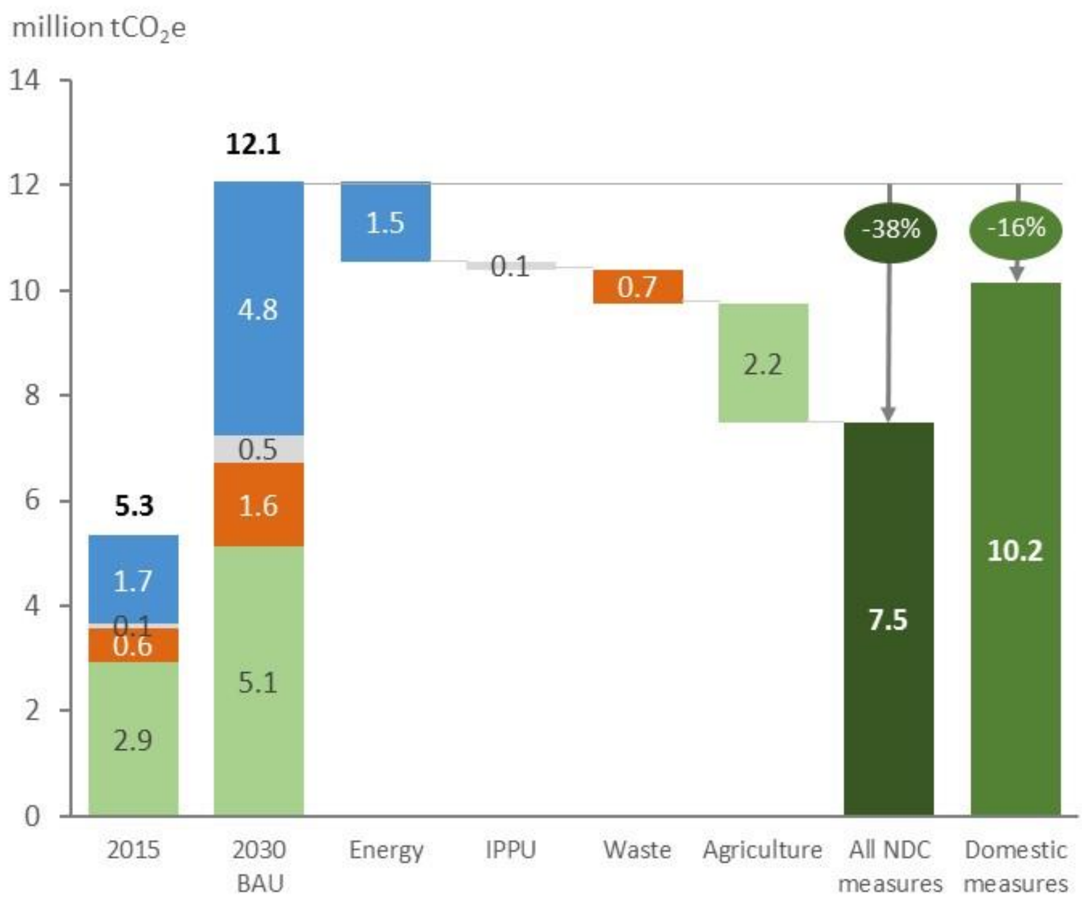
A series of alternative emissions pathways were modelled through 2030 based on the technical analysis of mitigation projects. Two basic NDC mitigation scenarios were modelled:

- **All NDC measures:** Implementation of all identified mitigation options considered suitable as NDC measures, includes both “unconditional” and “conditional” measures, and representing an 'upper end' estimate of how much mitigation potential could be achieved within the NDC sectors through 2030 subject to support.

- **Domestic measures only:** Implementation of unconditional domestically supported projects only, representing those projects already committed within government plans and programmes or considered sufficiently incentivised for private sector implementation to proceed.

The grouping of mitigation options into unconditional and conditional measures was informed by the criteria-based evaluation and through extensive consultation with relevant government departments and agencies as well as through workshops held with non-state actors including civil society and private sector. The BAU and NDC mitigation scenarios are summarised in the figure below, which also shows the contribution of each sector to the total estimated potential based on the technical assessments of all mitigation measures. According to the mitigation pathways, a GHG reduction against BAU of around 16% (domestic measures) and 38% (all NDC measures) is achieved by 2030.

Figure ES-4 NDC emissions reduction scenarios



The ability of Rwanda to achieve these mitigation outcomes will be subject to a range of factors determining both the BAU emissions forecast and the ability of NDC measures to deliver expected reductions. Sensitivity analysis was therefore undertaken, focusing on (a) an alternative lower GDP growth scenario; (b) a reduced outlook for project implementation and mitigation; and (c) inclusion of the Lake Kivu methane power projects, for which international GHG reporting guidance and project emissions data are currently lacking). As expected, the lower mitigation scenario delivers a lower reduction outcome relative to BAU. The lower GDP growth scenario results in a larger emissions reduction achieved relative to BAU. This is because lower growth is assumed to result in reduced economy-wide emissions projected under BAU but not reduced reductions from mitigation projects.[1] Accounting for emissions reductions from the Lake Kivu methane project could have a significant impact on delivering additional reductions, arising mainly from utilisation of methane gas otherwise assumed to be released to atmosphere. This is however subject to a high level of uncertainty around methane formation and release rates, the lack of GHG accounting methodology and project monitoring data.

The results therefore indicate the potential range of mitigation delivered by identified NDC measures according to key uncertainties around baseline and mitigation factors. For domestic measures only, this range is estimated at a 12-18% reduction against BAU in 2030, which is increased to 27-58% for the inclusion of all NDC measures.

Guided by the principle that Rwanda should only adopt targets considered capable of being delivered, the choice of which mitigation target(s) to adopt within the revised NDC should necessarily be informed by a view on which scenario is considered most feasible. In this context, it should be noted that the base case scenario is based on official target assumptions for GDP growth (Vision 2050) and also project outcomes. Overestimating GDP growth has the tendency to *underestimate* mitigation outcomes relative to BAU, while overestimating project success and mitigation outcomes has the tendency to *overestimate* mitigation outcomes relative to BAU. From this, it might reasonably be concluded that the base case represents a feasible forecast of what could be delivered under the first NDC, subject to an enabling domestic policy framework and attracting the necessary international funding and support.

Adaptation

Overview

The adaptation work is aligned with the mitigation analysis, seeking to prioritise adaptation interventions, establish baselines, develop sector-level performance indicators and targets as well as estimating costs for prioritized interventions.

The overall approach to the choice of adaptation indicators considered the following factors as critical: (i) Differentiating between climate change related issues and business-as-usual development, (ii) Basing on Local/sector context to climate vulnerability/resilience assessment, and (iii) Data availability to measure impact. This was conducted using a detailed review and analysis of adaptation and resilience initiatives in Rwanda with related key interventions and indicators. In addition, the consultation with experts from multiple sectors relied on an analytical framework that gained consensus from broad stakeholders. The specific objectives for the consultations were to:

[1] this is a key methodological simplification since some projects will in reality be impacted by reduced demand, and thus mitigation results are likely to be overestimated.

- Check if the information included in the adaptation analytical framework are relevant to the sector;
- Share other internal reports that have consistently informed monitoring and evaluation of sectors;
- Advise on the long term projections to 2025 and 2030 targets;
- Inform and develop consensus on the costing of climate adaptation specific priority actions including outline of sources of finance categorized as “conditional” (supported measures) and “unconditional” (unilaterally funded); and
- Agree on the MRV to report which in the case of adaptation focuses on monitoring and reporting on financial flows to address adaptation/resilience action.

Thus, the overall approach involved extensive review of relevant documents on climate adaptation that have developed over time starting with the Green Growth Climate Resilience Strategy (GGCRS) and associated sector working papers, and also the Strategic Programs for Climate Resilience (SPCRs). It is important to note that this was the basis of the INDC and subsequently the NDC that was ratified under the Paris Agreement.

Adaptation interventions

In total, 24 adaptation interventions were formulated in the context of this WB technical assistance and were built on existing adaptation initiatives and the robust stakeholder consultations. The interventions are classified in eight main sectors selected for Rwanda’s NDC agenda towards 2030 as summarized in the table below.

Table ES-1: NDC selected adaptation interventions by sector

WATER			AGRICULTURE						LAND AND FORESTRY						HUMAN SETTLEMENT		HEALTH	TRANSPORT	MINING	CROSS-SECTORAL			
A National Water Security through water conservation practices, wetlands restoration, water storage and efficient water use	Water resource models, water quality testing, and hydro-related information	Develop and implement a management plan for all Level 1 catchments	Develop climate resilient crops and promote climate resilient livestock	Develop climate resilient postharvest and value addition facilities and technologies	Strengthen crop management practices	Develop sustainable land management practices	Expand irrigation and improve water management	Expand crop and livestock insurance	Development of Agroforestry and Sustainable Agriculture	Promote afforestation / reforestation of designated areas	Improve Forest Management for degraded forest resources	Integrated approach to planning and monitoring for sustainable land use mgt	Harmonised and integrated spacial data management system for sustainable land use	Inclusive land administration that regulate and provide guidance for land tenure security	High density buildings and informal settlement upgrading	Storm water management	Strengthen preventive measures and create capacity to adapt to disease outbreaks	Improved transport infrastructure and services	Climate compatible mining	Disaster risk monitoring	Establish an integrated earlywarning system, and disaster response plans	Capacity building and development for cross-sector NDC implementation	Access to finance
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24

Adaptation indicators

The above adaptation interventions have identified a total of 38 adaptation indicators that are aligned with baselines and adaptation targets that have significantly drawn from existing national initiatives on climate adaptation/resilience analytics. Basing on the experiences in reporting at global level (including expectations of adaptation investment funds) and national level (including projects), the indicators outlined in the report were divided into categories A and B for global and national reporting, respectively. The indicators for reporting on adaptation interventions at global level shown in the table below have the potential to position Rwanda's envisaged robust engagement and efforts at addressing challenges of measurement of climate adaptation/resilience.

Table ES-2: Selected adaptation indicators global level reporting

SN	INDICATORS
1	Water storage per capita
2	Percentage of arable land (to the land area)
3	Number of hectares under irrigation within Integrated Water Resource Management framework
4	Change in land area covered by agroforestry
5	Percentage of forest area (to the land area)
6	Percentage of (i) urban population living in informal settlements, (ii) rural population living in clustered settlements
7	Malaria proportional mortality rate per 1,000 population
8	Percentage of extreme weather events for which advance warning was provided at least 30 minutes in advance
9	Cumulative volume of finance [USD millions] mobilized for climate and environmental purposes

Funding requirements for NDC actions

Extensive analysis and consultations with sector experts were undertaken to produce "conditional" and "unconditional" cost estimates for the mitigation and adaptation measures identified in the report through 2025 and 2030. The total estimated cost for Rwanda's identified NDC mitigation measures through 2030 is estimated at around 5.7 billion USD, and over 5.3 billion USD for adaptation priorities, representing a combined funding requirement of around 11 billion USD.

Table ES-3 below summarises the estimated investment requirements over the two periods. Within mitigation, energy sector projects dominate the period 2020-2025 associated with near term state-funded low carbon energy programmes such as expansion of grid-connected hydropower and solar pumping for irrigation, and projects such as the introduction of electric vehicles requiring international support. The majority of agriculture sector investments are realised within the period 2026-2030 with the scaling up and implementation of domestic fertiliser, crop rotation and livestock programmes as well as those projects requiring additional finance flows.

For both mitigation and adaptation combined, it can be seen that unconditional measures account for around 40% of the total estimated funding requirements, and conditional measures around 60%. In addition to funding, international support in the form of capacity building and technology transfer will also be required.

Table ES-3: Estimated mitigation and adaptation funding needs

USD million	Unconditional	Conditional	Grand Total
Mitigation measures			
2020-2025	1,057	1,754	2,811
2026-2030	953	1,912	2,866
Mitigation Total	**2,010**	**3,667**	**5,677**
Adaptation measures			
2020-2025	916	1,374	2,290
2026-2030	1,229	1,844	3,073
Adaptation Total	**2,145**	**3,218**	**5,364**
Combined Total	**4,155**	**6,885**	**11,041**

Conclusions and recommendations

The technical analysis described in the report provides a basis for Rwanda to submit its revised NDC with targets for mitigation and adaptation, as well as strengthening its implementation planning and framework. The following recommendations are made for implementation of the **mitigation** component of Rwanda's NDC:

- Decision on choice of NDC targets to adopt, based on the technical and economic analysis of mitigation options and estimated reductions from conditional and unconditional components against BAU through 2030.
- Develop an MRV framework for tracking the progress of project implementation and Rwanda's pathway towards achieving the NDC, whilst meeting its international obligations under the Paris Agreement. Such a framework will include developing a set of performance indicators and supporting metrics for monitoring and reporting the progress towards meeting the NDC for the identified prioritized sectors/mitigation actions within each sector and approach to tracking climate finance.
- Elaborate a detailed financing strategy through the revised NDC implementation plan that considers prioritized mitigation measures and guidance on accessing climate finance. This should include overarching strategies and interventions required to address financial challenges and leverage funds from private and international sources, with identification of appropriate sources of funding and support needs matched to the identified actions.
- Request guidance from IPCC regarding GHG accounting from lake methane utilization whilst developing project and emissions data from Lake Kivu power project.

- Establish a detailed implementation plan with a timeline and roadmap of actions through 2025 and 2030, with roles and steps identified within each sector (electricity generation, transport, industry, waste, agriculture) describing how mitigation projects and programs will be embedded within national and regional planning.

The following recommendations are made for implementation of the **adaptation** component:

- Consideration of the selected adaptation indicators for program and projects design, implementation and reporting to funders. Climate action requires performance measures to monitor and report progress for purposes of accountability. It is therefore important that sectors continually improve the relevancy of monitoring and evaluation framework.
- Provide national level adaptation reporting that align and respond to data and information demands at strategic levels including NST and sector strategic plans. National policies and strategies must rely on responsive data to effectively integrate climate adaptation to achieve national sustainable development goals.
- Develop a strategy to evaluate investments in adaptation projects and programs based on reliable metrics to increase likelihood of replication and scale up of proven interventions.
- Design strategic ways to provide capacity building to sectors, including sector experts, to facilitate planning and continuous NDC monitoring in general and in particular on climate adaptation.
- Elaborate a detailed financing strategy through the revised NDC implementation plan that consider the prioritized adaptation interventions and provide guidance for accelerating national access to scalable climate finance. FONERWA has been institutionalized to support a coherent national climate resources mobilization strategy. Notably, the fund is poised to streamline and boost domestic resources and private sector, which is crucial for NDC resources mobilization to fill unconditional resources gap.

1 INTRODUCTION

1.1 Background: the UNFCCC and Paris Agreement

At the 21st Conference of the Parties (COP21) in Paris, on 12 December 2015, Parties to the United Nations Framework on Climate Change (UNFCCC) reached a landmark agreement to combat climate change and to accelerate and intensify the actions and investments needed for a sustainable low carbon future. The Paris Agreement (PA) entered into force in November 2016, following the universal adoption of the Agreement by Parties. Through the PA, developed and developing countries made individual commitments to transition toward a climate-resilient and low-emissions future. Importantly, the Agreement acknowledges that the Sustainable Development Goals (SDGs) ambitions will require a collective and concerted action on climate change, and therefore an ambitious climate action underpin the potential achievement of sustainable development.

It was immediately evident that transitioning the high-level targets into concrete action would require elaborate country level planning and sector coordination, reliable and predictable financial resources to make investments and results impactful. Countries as Parties to the agreement would lead the process of planning, implementing, monitoring, reporting and revising their climate efforts. It was understood and repeatedly communicated that international effort would require developed countries to provide developing countries with technology transfer, capacity building and finance in order to deal with climate change impacts especially adaptation. Additionally, Article 7 of the Paris Agreement cautions against any additional reporting burden for developing country Parties. As such, many Parties will likely communicate adaptation as part of their progress updates on NDC implementation, or as part of their national communications (FAO, 2016).

The Paris Agreement sets the following three long-term goals:

1. to hold global warming to well below 2°C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5°C;
2. to increase the ability to adapt to the adverse effects of climate change and to foster resilience; and
3. to make finance flows consistent with a pathway towards low greenhouse gas emissions and climate-resilient development (Article 2.1).

Parties are required to undertake and communicate efforts to contribute to the achievement of these goals in the form of Nationally Determined Contributions (NDCs) communicated to the UNFCCC (Article 3). NDC's are therefore the centrepiece of the Paris Agreement agreed through an international partnership that forms the foundation for the pathway towards a low-carbon and climate resilient development.

Box 1.1 Nationally Determined Contributions (NDC) under the Paris Agreement

In the lead up to the Paris Climate Conference in 2015, all Parties to the UNFCCC were invited to submit their Intended Nationally Determined Contributions (INDCs) outlining how they will make contributions to both the mitigation of climate change and adaptation to its impacts. Parties have since made submissions to the UNFCCC containing a wide variety of commitments and pledges, including economy wide emissions reductions, intensity reduction targets, and future emission targets set as a deviation from a business-as-usual (BAU) scenario. Most INDCs included a range of technology, sectoral, policy and/or programme specific pledges. With the formal entry into force of the Paris Agreement (PA) on 4 November 2016, these INDCs become binding Nationally Determined Contributions (NDCs) from 2020 onwards.

To ensure increasing levels of ambition to combat climate change, the PA requires that, at a minimum of every five years, Parties submit revised NDCs that represent a progression beyond the Party's then current NDC. The PA also establishes a new 'transparency framework' for action and support, providing the basis for Parties to monitor and report on their progress in implementing their NDCs (Article 13).

The PA also introduced the possibility for new mechanisms to emerge to support the financing of low carbon technology deployment in developing countries (Article 6), including the use of voluntary Cooperative Approaches and a Sustainable Development Mechanism (SDM) to provide a project-based crediting mechanism administered by the UNFCCC. Climate finance is central to the Agreement and the ability of developing countries to reach more ambitious levels of emissions reduction. Recognising this need, Article 9 of the Agreement requires developed country Parties to provide financial resources to assist developing country Parties in achieving mitigation.

The detailed modalities, procedures and guidelines covering all parts of the PA have since been subject to ongoing discussions with the UNFCCC process. In December 2018 in Katowice, Poland, Parties agreed on a Paris Agreement 'rulebook' to put those in place, work which has progressed through 2019 and during the 25TH Conference of Parties to the UNFCCC (COP25) held in Madrid, December 2019. Although several elements of the rulebook are still to be finalised, Parties have now established many of the rules and guidelines detailing how the PA will operate and be implemented in practice.

Source: authors

1.2 Rwanda's national context

1.2.1 Climate impacts and vulnerability

A global warming effect ranging from between 0.8°C to 1.2°C, compared to the pre-industrial revolution, has been largely attributed to human activities (IPCC, 2018). As with many other countries, Rwanda is increasingly experiencing the impacts of climate change. Rainfall has become increasingly intense and the variability is predicted to increase by 5% to 10% (GoR, 2017b). Changes in temperature and precipitation and their distributions are the key drivers of climate and weather-related disasters that negatively affect Rwandans and the overall economy. The main risks/impacts that adversely affect the population include droughts, floods, landslides and storms. These are associated with damages of infrastructures, loss of lives and property including crops, soil erosion, water pollution, etc. (GoR, 2017b; REMA, 2015).

A rise in temperature is predicted across Rwanda in the coming years up to 2050, especially during the dry seasons. An additional seasonal increase of between 0.10 °C and 0.30 °C is projected to be added on annual mean temperature throughout the country expect for the northern region where a decrease of 0.06°C is anticipated. Furthermore, a decreasing trend in mean rainfall and number of rainy days is projected (GoR, 2018a).

This explains that more dry spells are anticipated across the country especially in the eastern region. Climate change will also upset the north-west highlands and south-western districts of Rwanda with rise in rainfall intensities. According to the TNC report, there is high probability that the number of days with extreme temperature will continue to increase by 2050 whereas the days with extreme rainfall will be relatively constant (GoR, 2018a).

The impacts of climate change on Rwanda, however, are disproportionate to its contribution. Rwanda is, in fact, extremely vulnerable to climate change. The National Risk Atlas of Rwanda highlights that the country is highly prone to drought, flood, landslide, earthquake and windstorm (MIDIMAR, 2015). Besides, other activating factors to climate change vulnerability consist of socio-economic drivers such as building in flood prone areas, high population density in prone areas, increased value of assets in flood-prone areas, poor management of soil erosion, etc. (SEI R. a., 2009).

1.2.2 Green Growth and Climate Resilience Strategy

The Government of Rwanda (GoR) is committed to taking urgent action to mitigate and adapt to the effects of climate change. As a Party to the UNFCCC, the country seeks to contribute to the ambitious goal of limiting temperature rise to 1.5^{o}C agreed under the Paris Agreement (UNFCCC, 2015).

Though Rwanda is among the countries with lowest emission per capita (GoR, 2011), it is vulnerable to climate change mainly due to the hilly topography, high population density and dependence on rain-fed agriculture. Therefore, adaptation to climate change is a key concern and a priority for the country. As is true of most African nations, Rwanda's contribution to climate change in the form of greenhouse gas (GHG) emissions is relatively small, although emissions from deforestation, agriculture, and land use, combined with string expected emission growth from expected economic development and energy use, and are significant enough within Rwanda's carbon footprint to demand mitigation response.

In 2011, the country adopted the **Green Growth and Climate Resilience Strategy (GGCRS)** which sets out the country's actions and priorities on climate change and how these with be mainstreamed within economic planning (GoR, 2011). The strategy provides a vision for how Rwanda can tackle climate change through become a climate resilient and low carbon economy, and projects actions to be undertaken to inform Rwanda's strategy for economic development, Vision 2050. The document provides the basis for the subsequent development of its Nationally Determined Contribution (NDC), as described below.

1.3 Rwanda's Nationally Determined Contribution

Rwanda submitted its Intended Nationally Determined Contribution (INDC) to the UNFCCC in September 2015, setting out its adaptation and mitigation goals. With the entry into force of the

Paris Agreement in November 2016, the INDC formally became Rwanda's first NDC. The NDC is built upon the GGCRS, as well as other key national guiding documents including Vision 2050, NST1, Sector Strategic Plans, SPCR, and Sustainable Energy for All (2015-2030).

Rwanda's NDC has two components, as has been elaborated in the GGCRS through the following programmes of actions:

- **Mitigation**: Seven broad programmes of action are identified, covering a wide range of interventions within each of the key sectors. These include low carbon electricity generation from hydropower and solar PV, small-scale generation, and energy efficiency and demand side management (energy); promotion of public transport and vehicle emission standards (transport); resource efficiency and energy demand reductions (industry); implementation of low carbon urban systems (waste); and sustainable forestry, agroforestry and biomass energy (agriculture and forestry).[2]
- **Adaptation**: Priority interventions are identified as Sustainable intensification of agriculture; Agricultural diversity in local and export market; Sustainable forestry, agroforestry and biomass energy; Ecotourism conservation and payment of ecosystem services promotion in protected areas, Integrated water resources management (IWRM) and planning; Integrated approach to sustainable land use planning and management, disaster management; and climate data and projections.

The NDC states that while the GoR will continue to commit significant resources to climate change-relevant strategies, the full implementation of the strategic mitigation actions is conditional on the support of international stakeholders (GoR, 2015a). In addition, Rwanda intends to meet its commitments and/or increase the level of its contribution through the use of international market mechanisms where appropriate, building upon the experience of the Clean Development Mechanism (CDM) and other existing market mechanisms such as Nationally Appropriate Mitigation Actions (NAMAs) and the mechanism for Reducing Emissions from Deforestation and Forest Degradation (REDD+).

Rwanda has since taken steps to align the NDC with existing national policy frameworks and sector strategies such as Vision 2050, the National Strategy for Transformation (NST) and the GGCRS. This will help ensure that national development programming effectively integrates climate action that is in alignment with the sustainable development goals (SDGs).

1.4 Project aims and scope of work

Rwanda is planning to submit its updated NDC to the UNFCCC ahead of the 26th Conference of the Parties (COP26) in Glasgow in November 2020. This requires building upon existing work in developing quantifiable mitigation and adaptation targets, and the prioritization of interventions to support these two areas.

[2] The mitigation contribution is based on estimated emission reductions against a projected 'business as usual' (BAU) baseline for the target year of 2030 based on policies and actions conditional on availability of international support for finance, technology and capacity building. The NDC is economy-wide covering emissions from energy, road transport, industry, waste and agriculture, forestry, and other land use (AFOLU) and covers the three GHGs carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) (GoR, 2015a).

After joining the NDC partnership in 2018, Rwanda through the Ministry of Environment (MoE) as the lead focal institution, requested technical support from the NDC Partnership to help coordinate implementation of Rwanda's NDCs across participating sectors. Following that request, the NDC Support Facility of the World Bank has provided technical assistance to produce targets and evaluate priority interventions to be included in the revised NDC.

The support builds on the World Bank's support for the Strategic Program for Climate Resilience (SPCR), the Forest Investment Plan (FIP), the Scaling Up Renewable Energy Program (SREP), and the forthcoming Climate Smart Agriculture Investment Plan. The main government counterparts for this work are the MoE, Ministry of Agriculture and Animal Resources (MINAGRI), Ministry of Infrastructure (MININFRA), Ministry of Finance and Economic Planning (MINECOFIN), and the Rwanda Environmental Management Authority (REMA).

The scope of technical assistance provided by the World Bank covers both mitigation and climate adaptation aspects of Rwanda's revised NDC to be submitted ahead of COP26:

- **Mitigation**: produce quantified targets for GHG emissions reductions, evaluate priority interventions and develop the implementation roadmap
- **Adaptation**: Produce quantified targets for adaptation/resilience, evaluate priority interventions, develop monitoring and evaluation (M&E) framework for adaptation actions and strengthen national capacity for resource mobilization

This scope of work will help Rwanda to set mitigation and adaptation targets and respective costs for achieving those targets through 2025 and 2030. Once validated by the GoR and key stakeholders, these will be reflected in the revised NDC to be submitted to UNFCCC ahead of COP26.

1.5 Outline of this report

This report presents the results of the technical analysis provided in support of Rwanda's NDC development for both its mitigation and adaptation components. The outline of the document is broadly based around these two components with Sections 3, 4 and 5 covering the mitigation analysis and Sections 6, 7, 8 and 9 covering the adaptation analysis. Estimated funding requirements, and conclusions and recommendations are subsequently presented for both components together. The report is structured as follows:

- **Section 2** outlines the methodology and overall approach to the assessment and scope of analysis for both the mitigation and adaptation components.
- **Section 3** presents the development of a BAU emissions projection under which NDC mitigation actions are not implemented, including analysis of key drivers for future emissions growth.
- **Section 4** describes a technical and economic assessment of GHG mitigation options identified for Rwanda in order to determine which options are most suitable as prioritised mitigation actions within the NDC. Options are quantified in terms of their mitigation and economic potential, and prioritised according to a criteria-based evaluation, before grouping them into either "unconditional" or "conditional" NDC measures.

- **Section 5** describes the results of scenario-based modelling to determine the potential emissions reduction contribution from the identified NDC mitigation options through 2030 compared to BAU.
- **Section 6** sets out the current framework of adaptation and resilience initiatives in Rwanda including the role of adaptation within priority Sector Strategic Plans and the key baseline data and information considered relevant to climate adaptation and resilience.
- **Section 7** addresses some of the key challenges to implementation of adaptation and resilience options at a national and regional policy planning level as well as a project/program level.
- **Section 8** provide an evaluation of adaptation interventions and sets out a framework of indicators.
- **Section 9** proposes a monitoring, evaluation and reporting framework for mitigation and adaptation aligned with the prioritised options, drawing upon stakeholder and expert consultation.
- **Section 10** presents estimates of funding requirements for both mitigation and adaptation components of the NDC through 2025 and 2030, including a breakdown by sector and according to "unconditional" or "conditional" measures.
- **Section 11** provides key conclusions and recommendations for the next stage of work in Rwanda's NDC implementation

A series of technical annexes are appended to the report:

- **Annex A** provides a detailed description of the technical and economic analysis undertaken for the identified NDC mitigation projects.
- **Annex B** describes the criteria-based evaluation for adaptation interventions.
- **Annex C** provides an initial assessment of potential mitigation measures within the forestry sector.[3]

[3] Due to large methodological and data uncertainties in emissions and emission removals estimation and baseline determination, forestry is not included within the scope of the NDC targets

2 METHODOLOGY

This section summarises the methodology and overall approach used in undertaking mitigation and adaptation components of the technical assistance. Further detail is provided in subsequent sections of the report and in the technical annexes.

2.1 Mitigation

The overall objective of the technical support is to assist the GoR in the development of their NDC implementation framework for mitigation. The analysis aimed to address several key questions:

- What are the most feasible BAU and GHG emission reduction pathways through 2030?
- What can be delivered across sectors and programs (GHG emissions mitigation)?
- What are the economic impacts from GHG mitigation actions (costs and benefits)?
- What type of NDC target(s) could be adopted?
- What factors could impact Rwanda's ability to achieve the NDC through 2030?
- What actions, arrangements and funding sources will be needed to implement the NDC?

The support includes a technical analysis phase of work, the results of which will then be used to inform Rwanda's NDC mitigation targets and subsequently a framework for NDC implementation covering policy planning, MRV, and financing aspects. This has been undertaken through a process that integrates an analysis of Rwanda's existing sectoral and climate policy framework, the generation of qualitative information through consultation with government officials, experts and stakeholders, quantitative modelling of mitigation options and scenarios, and the development of actions to help implement the revised NDC and track its progress.

This report describes the technical analysis undertaken. The aim was to develop an evaluation of NDC mitigation actions based on updated information and an in-depth assessment of the country's mitigation potential. This has been undertaken using detailed technical and economic analysis and multi-criteria evaluation of mitigation options. In so doing, the analysis builds on the work undertaken in support of Rwanda's INDC submission in 2015 and other more recent studies including e.g. GHG mitigation estimates made in the context of NAMAs and the Third National Communication (TNC) to the UNFCCC (GoR, 2018a), and a variety of other official data and information sources.

The technical analysis comprises of three main tasks:

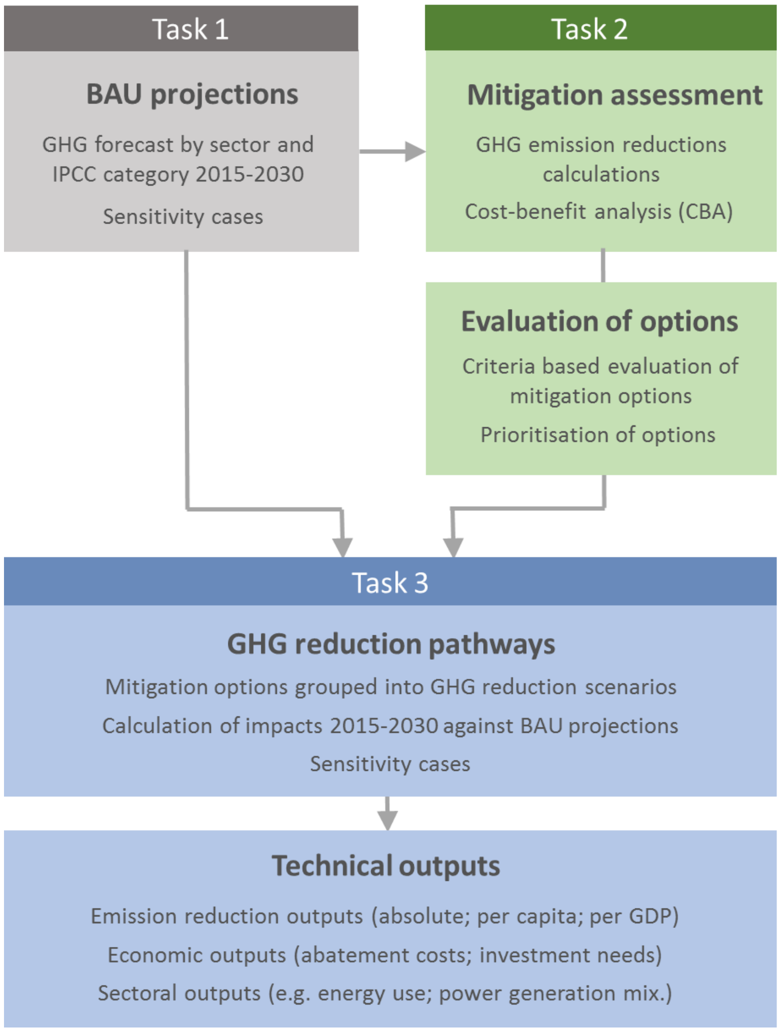
- **Task 1: Develop BAU emissions forecasts**: Based on the national GHG inventory emissions in all IPCC sectors (energy, transport, industry, waste, and agriculture, forestry and other land use; AFOLU) for the base year of 2015, develop a revised BAU baseline scenario through 2030. Variations on the BAU baseline to be developed according to key drivers of national GHG emissions e.g. alternative GDP and/or population projections.
- **Task 2: Assess and prioritise mitigation actions:** Identify and collect information on mitigation options within the NDC sectors based on discussions with in-country officials and experts, quantify their emissions reduction potential through 2030 compared to BAU and undertake an economic cost-benefit analysis (CBA) of each option. In order to prioritize actions and determine which can be supported domestically and which require international

support, undertake multi-criteria-based assessment of the identified measures to determine environmental effectiveness, socio-economic effectiveness and feasibility.

- **Task 3: Develop alternative GHG pathways**: Model alternative GHG pathways based on the identified and prioritised mitigation options against the BAU baseline through 2030 to understand emissions reduction potential across NDC sectors and associated costs and investment needs.

The interaction between these three elements is summarised below in Figure 2.1.

Figure 2.1 Overview of approach to mitigation technical analysis



Source: Authors

2.2 Adaptation

Lessons from the World Bank Action Plan and 2025 Climate Change targets identified the following major areas of focus relevant to Rwanda's NDC implementation in relation to adaptation:

- Boost adaptation financing by increasing access to and effectiveness of additional climate adaptation finance.

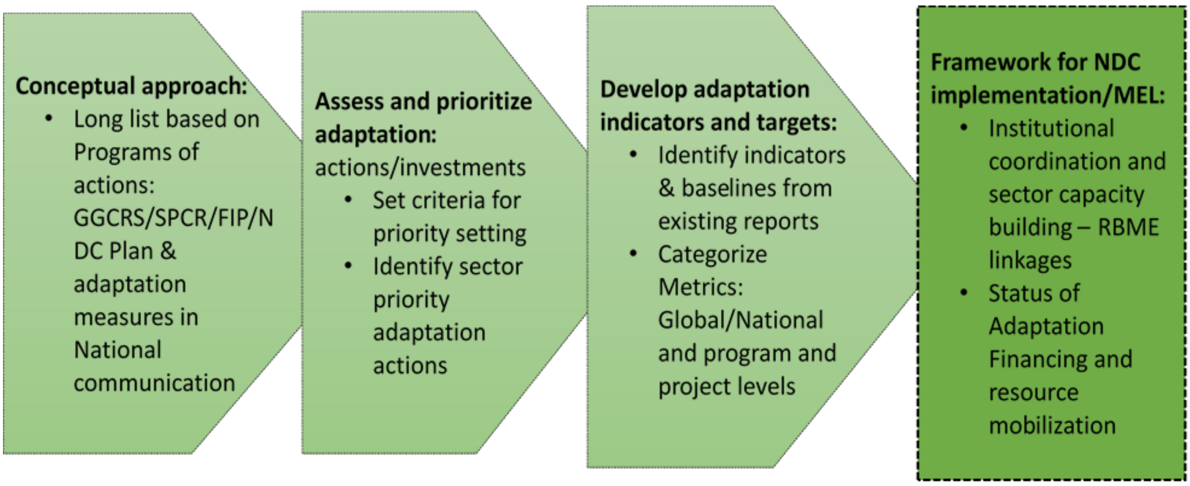
- Drive a mainstreamed, whole-of-government programmatic approach through systematic climate risk management at the country and sector levels and subsequently implemented through sub-national levels.
- Development of an effective and reliable rating system basing on a clear analytical framework to facilitate improved tracking and incentivizing progress on adaptation and resilience.

The commitment to implementing the target on better tracking underpins the focus of this assignment aiming to provide support in the following areas:

- Technical assistance to develop consensus on priority interventions and targets on adaptation to inform Rwanda's revised NDC.
- Support the development and implementation of the Monitoring and Evaluation Framework for adaptation actions partly drawing from and strengthening the Environment and Natural Resources Results Based Monitoring and Evaluation (ENR RBME) and in particular provide capacity development support building on the resilience indicators.
- Support strengthening of national capacity specifically targeting public and private resources mobilization to implement the NDC starting with Deep dive resources US$2.2 Million that the WB through the NDC facility is implementing in partnership with the National Fund for Environment (FONERWA).

The methodology was based on reviewing the existing analytical work carried out in the Green Growth and Climate Resilience Strategy (2011), the Strategic Program for Climate Resilience (2017), the Forest Investment Program (2017), the vulnerability index (National, 2015 and District 2018), Rwanda National Communication to UNFCCC (2018), the Sector Strategic Plans (2017) and the NDC implementation Plan (2017). As shown in Figure 2.2, the methodology considered the development of a long list of adaptation actions, their prioritization, indicators development which will inform the framework for NDC implementation and revised actions/activities.

Figure 2.2 Framework of analysis and scope for the adaptation work



Consultation with experts from multiple sectors was conducted based on the developed analytical framework. The specific objectives for the consultation were:

1. To check if the information included in the adaptation analytical framework is relevant to the sector.
2. Share other internal reports that can be useful for the measurement, reporting and verification (MRV) for sector guidance and validation.
3. Advise on the projected 2025 and 2030 sectoral targets, since the existing ones are primarily drawn from NST 1 that has projections up to 2024 only;
4. Inform and develop consensus on the costing of climate adaptation specific priority actions, including an outline of sources of finance categorized as "conditional" (where the Party would be willing to increase its ambition level given certain conditions were met, otherwise referred to as supported measures) and "unconditional" (unilaterally funded).
5. Agree on the MRV to report which in the case of adaptation focuses on monitoring and reporting on financial flows to address adaptation/resilience action.

The process involved an extensive review of relevant documents on climate adaptation that have developed over time starting with the Green Growth and Climate Resilience Strategy and the associated sector working papers. It is important to note that this was the basis of the INDC and subsequently the NDC that was ratified under the PA. Other documents and reports that were reviewed to significantly inform and influence this assignment were the SPCR along with the Gaps and Needs Analysis, FIP and the NDC implementation plans (2017 & 2018) as well as the national reports on the vulnerability index (2015 and 2019) and the third National communications. The Sector Strategic Plans (SSPs) served as the critical reference documents for sector consultation even considering their scope is remarkably beyond the climate adaptation/resilience.

It is recognized that in order to influence effective mainstreaming of climate adaptation in sector priorities and consequently in a strategic way for national uptake including at the NST and therefore policy levels, clear adaptation metrics including indicators and targets must be generated and agreed upon as measures to guide collection of gender disaggregated data. To achieve this in a systematic way, the assessment ensured priorities were set in a manner that identified adaptation actions even as additional to development targets.

This then helped set adaptation indicators to guide baselines and categories of metrics at global, national/sub-national (to influence SSPs and DDSs) and finally at program and project levels. Only then can it be possible to map out specific capacity needs including those targeting institutional coordination that improve the environmental conditions for design of projects and programs that can attract financing at scale to address Rwanda's sustainable development needs. This served as the context of the analytical framework that consistently influenced the Results Based Monitoring Evaluation and Learning (RBME&L). It was therefore crucial in development of a functional framework for ENR sector in order to serve as a tool for cross sector mainstreaming of climate change adaptation/resilience.

3 BAU Emissions Projections

3.1 Overview and approach

This section describes the development of a BAU GHG emissions forecast for Rwanda. Firstly, an updated inventory of GHG emissions sources covered by the NDC sectors is presented for the base year of 2015 according to International Panel on Climate Change (IPCC) reporting categories (IPCC, 2006). Emissions are then projected from this base year through 2030 under a BAU scenario according to which NDC mitigation policies and actions are not implemented. This projection provides the reference case against which the emissions reduction potential from specific mitigation actions (as described in Section 4) can be estimated under alternative GHG reduction pathways (as described in Section 5). The section concludes with a sensitivity analysis around key drivers influencing future emissions through 2030.

The BAU modelling approach is based on detailed bottom-up activity and GHG projections developed for each emitting sector through 2030. These reflect a number of assumptions determining changes in *inter alia* energy supply and demand, sector output, technology uptake, and policy choices. In so doing, existing government projections and plans were assessed, and experts consulted within relevant ministries, agencies and organisations. These are described in more detail below according to each of the key emitting sectors; energy, IPPU, waste, agriculture. Note that as work is currently ongoing to better quantify national emissions and removals from forestry, these are excluded from the BAU analysis.

The modelling draws heavily upon, and updates, the emissions projections work undertaken as part of the TNC work (GoR, 2018a). These provide long-term emissions projections for Rwanda through 2050 using the Long-range Energy Alternatives Planning System (LEAP) software system developed by the Stockholm Environment Institute (SEI, 2009a) and supplemented by various excel-based calculations. The BAU modelling described in this section departs from the TNC projections in several ways. These include:

1. **Modelling more dynamically linked to GDP growth and other emissions drivers**. Whereas the TNC projections are based on projecting future emissions by extending previous trends from the historic emissions data, the current BAU links future changes more closely to relevant factors driving output and emissions changes, including economic growth, population growth, official agricultural production plans and power expansion planning. As described in the sensitivity analysis further below, two key sources have been used to develop alternative outlooks for GDP growth:

    - National GDP growth forecast aligned with Rwanda's Vision 2050 strategy for economic growth (GoR, 2017a)
    - IMF World Economic Outlook, Rwanda GDP growth outlook (IMF, 2019)

    The former source - representing the GoR official growth outlook - has been used as the base case GDP assumption in the detailed BAU projection described in this section. National population projections have been based on the low, medium and high scenarios contained in the Fifth Integrated Household Living Survey (EICV5) (GoR, 2018b); the medium scenario has been adopted as the base case BAU assumption.

2. **Use of regression analysis**. Extensive use of regression analysis has been undertaken based on latest available data to better understand and inform relationships between certain forecast model parameters (e.g. analysis of vehicle growth by type/class according to GDP and population changes, from historic data).
3. **More detailed characterisation of emitting sectors** to enable more in-depth and robust modelling of factors determining output and corresponding energy use and GHG emissions (e.g. development of detailed road transport fleet modelling).

In addition, the revised BAU projection makes use of more recently available information sources such as e.g. transport and vehicle survey data, official statistics, policy planning documents etc., as described within each sector below. Taken together, and along with some revisions and corrections made to the base year inventory data (see below), these revisions are considered to result in a more robust and accurate basis for developing a BAU scenario. Importantly, they also allow for key drivers such as economic and population growth to be varied within the modelling in order to assess their potential impact upon future emissions (sensitivity analysis).

3.2 GHG emissions inventory

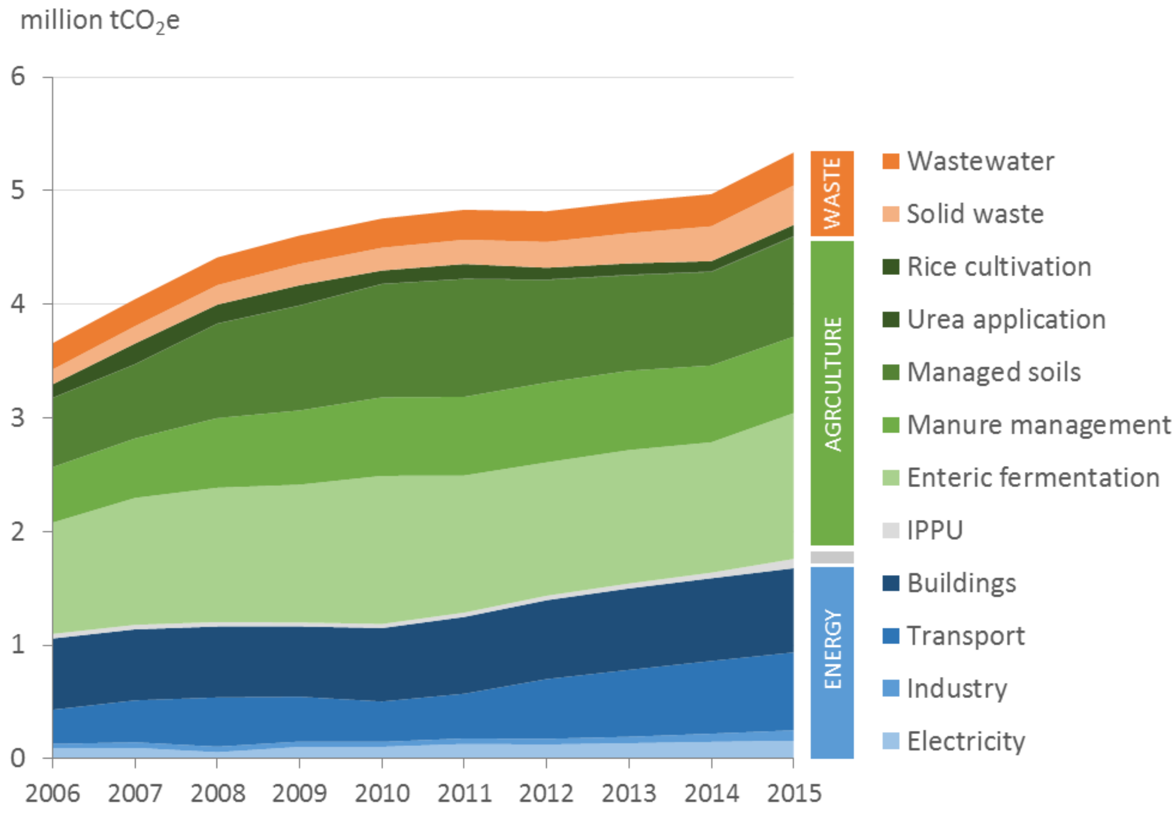
The latest official GHG inventory data, as reported in Rwanda's TNC (GoR, 2018a) covers emissions up to the year 2015. This year was adopted as the common base year for the revised BAU modelling.

Within the resources and time schedule of the technical assistance, a review of the GHG inventory data was undertaken. This resulted in the correction of some errors and inconsistencies[4]. In addition, more recently available information and survey data allowed for actual activity and energy consumption data to replace previously estimated values (described further below according to each sector).[5] The historic and base year data described below are therefore based on this revised dataset which is considered the most recent and accurate information available against which to assess NDC mitigation contributions.

Figure 3.1 shows national GHG emissions for the years 2006-2015 from each of the sectors and activities covered by the NDC, excluding forestry. The series shows that emissions increased significantly over the ten-year period, from around 3.7 million tonnes carbon dioxide equivalent (tCO_2e) to 5.3 million tCO_2e, representing an overall increase of 46%. Emissions from industrial processes and product use (IPPU), waste, and energy use have seen the fastest growth rates over this period - increasing by 102%, 76%, and 58% respectively. Emissions from agriculture, representing the largest contributor to total emissions, increased by around 33% over the same period. The overall trend in emissions growth closely reflects production and output across these sectors, which has seen rapidly increasing industrial output, waste generation and demand for fossil-based energy at the same time as more modest growth in agricultural output e.g. livestock and crop production.

[4] Most noticeably the over-estimation of emissions associated with urea fertiliser application within IPPC reporting category 3.C.3.
[5] These revisions have been described in more detail in a note submitted to the GoR on 6 September 2019.

Figure 3.1 GHG emissions by sector 2006-2015, $MtCO_2e$



Source: Rwanda National GHG Inventory data (September 2019)

GHG inventory data in the base year 2015 is shown in Table 3.1 according to IPCC reporting categories for all GHG emissions sources, and summarised in aggregated form in Figure 3.2.

Total emissions excluding forestry are estimated at 5.33 million tCO_2e for 2015. The agriculture sector accounted for the largest share of the total (2.94 million tCO_2e, 55% of total), followed by energy (1.68 million tCO_2e, 31% of total) and waste (0.64 million tCO_2e, 12% of total). Emissions from IPPU represented just 0.08 milliontCO$_2$e, equivalent to around 2% of total emissions in 2015 (mainly associated with calcination CO_2 emissions from clinker production).

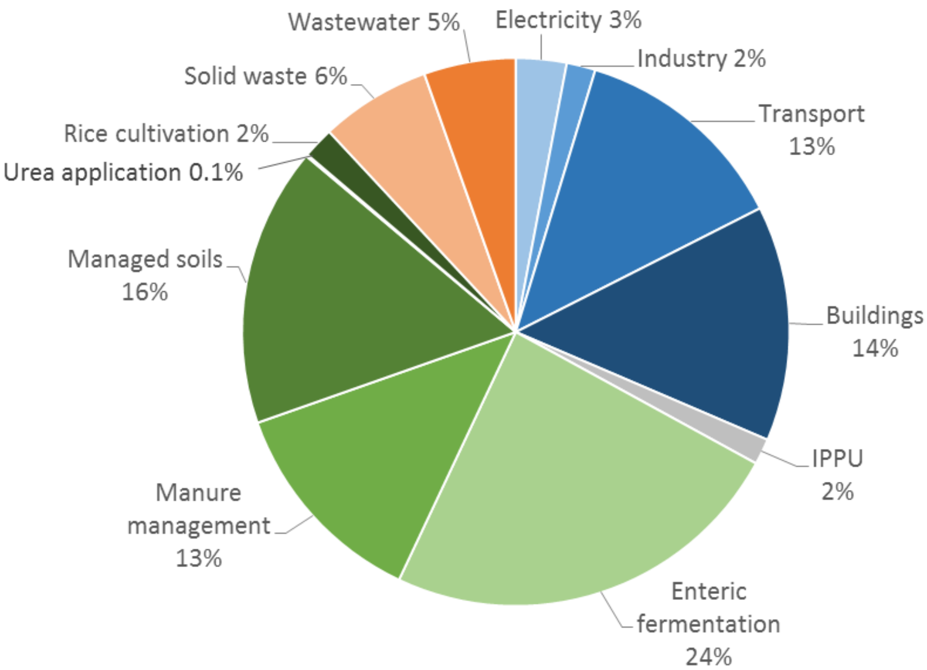
Emissions from livestock, predominantly CH_4 from enteric fermentation in cattle, represented the largest emissions source category in the base year, followed by N_2O emissions from managed soils in crop production. Following these agriculture sources, major sources included CO_2 emissions from fuel combustion for heating and cooking in buildings (LPG, kerosene), which accounted for 14% of the total, and CO_2 emissions from liquid fuel use in road transport (diesel, gasoline), which accounted for 13% of the total. The data shows that fossil fuel combustion in power generation accounted for a small share of overall emissions, reflecting the current relatively low level of power generation per capita in Rwanda and also the dominant share of non-emitting hydropower within the grid mix (as discussed in more detail below).

Table 3.1 GHG emissions by source in 2015, $MtCO_2e$

IPCC Reporting Categories				$GgCO_2e$	$MtCO_2e$
1. Energy	1.A. Fuel Combustion Activities	1.A.1.Energy Industries	1.A.1.a.Electricity and Heat Production	159	0.16
		1.A.2.Manufacturing Industries and Construction		91	0.09
		1.A.3.Transport	1.A.3.b.Road Transport	686	0.69
		1.A.4.Other Sectors	1.A.4.a.Commercial/Institutional	102	0.10
			1.A.4.b.Residential	639	0.64
2. IPPU	2.A. Mineral Industry			69	0.07
	2.C. Metal Industry			2	0.002
	2.D. Non-Energy Products from Fuels and Solvent Use			4	0.004
	2.F. Product Uses as Substitutes for Ozone Depleting Substances			7	0.01
3. AFOLU	3.A. Livestock	3.A.1.Enteric Fermentation		1,284	1.28
		3.A.2.Manure Management		673	0.67
	3.B. Land	3.B.1.Forest Land		-	-
	3.C. Aggregate Sources and Non-CO_2 Emissions Sources on Land	3.C.3.Urea application		6	0.01
		3.C.4.Direct N_2O Emissions from managed soils		540	0.54
		3.C.5.Indirect N_2O Emissions from managed soils		191	0.19
		3.C.6.Indirect N_2O Emissions from manure management		148	0.15
		3.C.7.Rice cultivation		98	0.10
4. Waste	4.A. Solid Waste Disposal			187	0.19
	4.B. Biological Treatment of Solid Waste			159	0.16
	4.C. Incineration and Open Burning of Waste			1	0.001
	4.D. Wastewater Treatment and Discharge			290	0.29
Total emissions Energy				1,677	1.68
Total emissions IPPU				82	0.08
Total emissions AFOLU				2,940	2.94
Total emissions Waste				637	0.64
TOTAL emissions (excluding forestry)				**5,337**	**5.33**

Note: Transport emissions data are available for road transport only; civil aviation, rail and waterborne transport categories are not include due to lack of data and their very small contribution.
Source: Rwanda National GHG Inventory data (as of September 2019); forestry excluded.

Figure 3.2 National GHG emissions by source in 2015, $MtCO_2e$



Total: 5.3 $MtCO_2e$

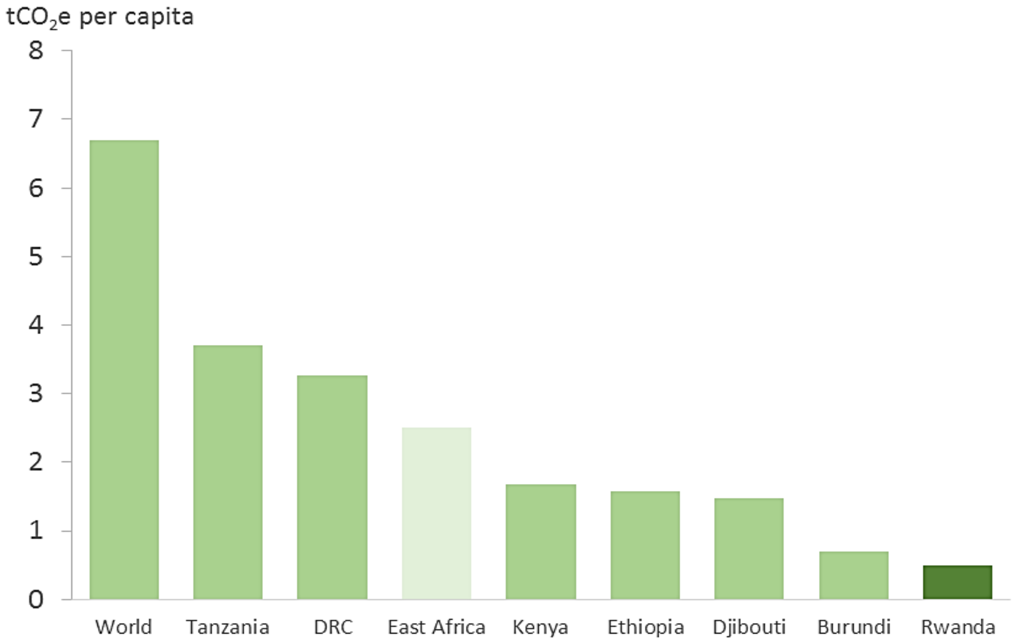
Note: Transport emissions data are available for road transport only; civil aviation, rail and waterborne transport categories are not include due to lack of data and their very small contribution.
Source: Rwanda National GHG Inventory data (as of September 2019); forestry excluded.

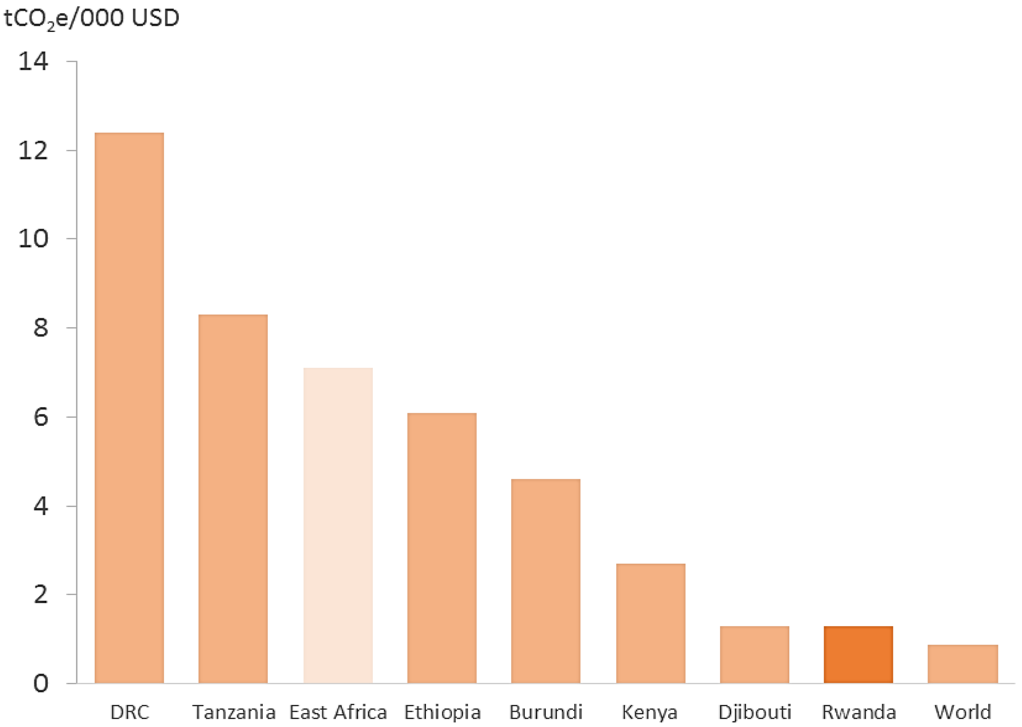
For comparative purposes, Figure 3.3 benchmarks Rwanda's total GHG emissions against other East African countries on a per capita basis, and also emissions intensity of economic output i.e. emissions per unit of gross domestic product (GDP).

The data show that Rwanda has relatively low per capita emissions - around 0.5 tCO_2e - compared to other countries within the region. This figure is around one fifth of the regional average and just thirteenth of the world average, reflecting Rwanda's predominantly agricultural economy based on subsistence farming and low fossil energy demand compared to traditional energy sources such as wood and other biomass. The data also show that Rwanda has a relatively low emissions intensity - around 1.3 tCO_2e per '000 (thousand) USD GDP – which is also around one fifth of the regional average. Although per capita GDP is relatively low in Rwanda at around 750 USD, the low intensity value mainly reflects the importance of non-energy intensive and low emitting sectors within the national economy such as agriculture, tourism and services.

The sections below next describe the BAU development according to each sector, followed by a summary of BAU total emissions through 2030 and sensitivity analysis.

Figure 3.3 Regional comparison of Rwanda per capita and per GDP emissions





Source data: USAID, 2015

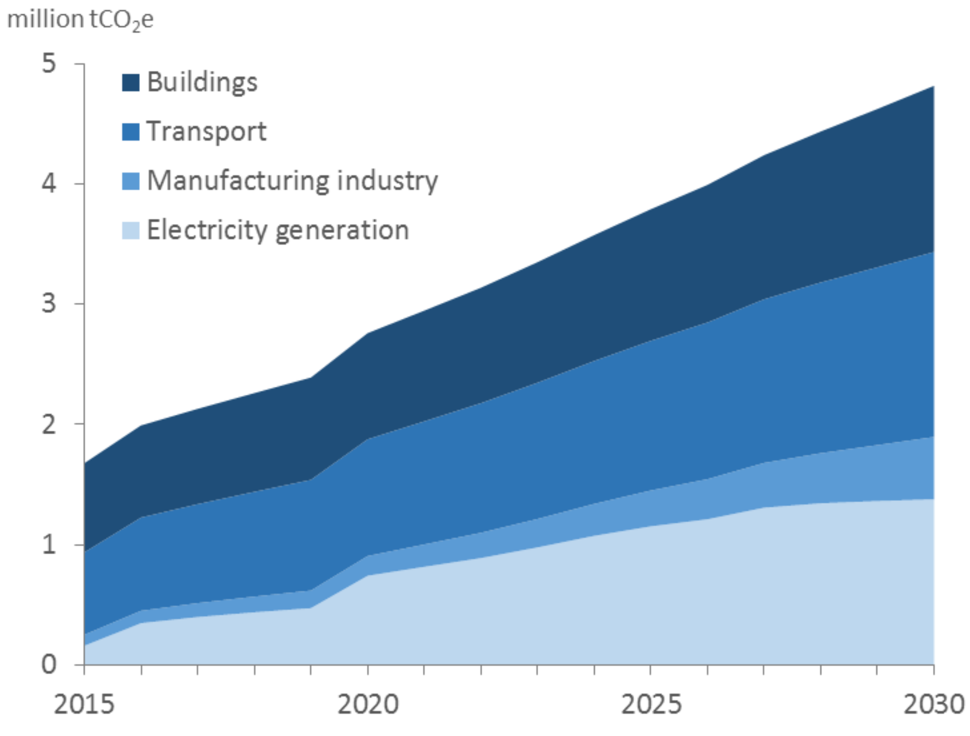
Note: Emissions exclude land use change and forestry

3.3 Energy

Figure 3.4 shows the BAU emissions projection for energy sector emissions through 2030 for the base case (consistent with Vision 2050). Total emissions are forecast to almost treble over the period, rising from around 1.7 million tCO_2e in the base year to 4.8 million tCO_2e in 2030. As shown in the graph, emissions from all sub-sectors are forecast to increase with rapid growth seen in particular from power generation and manufacturing industry. The former reflects the current power system plan which foresees a large expansion of fossil-based generation on the grid, including from new peat and the Lake Kivu methane gas-fired capacity (see below), whereas the latter reflects strong growth assumptions in rapidly expanding sectors such as cement production and construction.

Emissions from road transport are also forecast to rise significantly with increasingly vehicle ownership and assuming low levels of electric vehicle (EV) penetration and an absence of controls on vehicle standards. A more modest increase in emissions from buildings is expected, partly reflecting the large contribution of traditional and low carbon fuels in residential energy use and electricity use in the commercial and public sectors. These sectors however also see increasing emissions in the absence of targeted mitigation policies to increase renewable and off-grid energy use.

Figure 3.4 BAU GHG emissions projection, Energy (base case)



Source: Authors

Table 3.2 BAU GHG emissions projection, Energy (base case)

GHG emissions ($MtCO_2e$)	2015	2020	2025	2030
Electricity generation	0.16	0.74	1.15	1.38
Manufacturing industry	0.09	0.16	0.30	0.52
Construction	*0.02*	*0.03*	*0.05*	*0.07*
Food industry	*0.001*	*0.002*	*0.003*	*0.004*
Non-Metallic minerals	*0.07*	*0.12*	*0.22*	*0.41*
Mining industry	*0.01*	*0.01*	*0.02*	*0.03*
Transport (road transport)	0.69	0.97	1.25	1.54
Motorcycles	*0.31*	*0.42*	*0.53*	*0.66*
Passenger cars	*0.15*	*0.25*	*0.32*	*0.39*
Light duty trucks	*0.07*	*0.09*	*0.11*	*0.14*
Trucks and buses	*0.16*	*0.22*	*0.28*	*0.35*
Other sectors (buildings)	0.74	0.88	1.09	1.38
Residential	*0.64*	*0.71*	*0.78*	*0.86*
Commercial and public	*0.10*	*0.18*	*0.31*	*0.52*
Total	**1.68**	**2.76**	**3.79**	**4.82**

Source: Authors

Table 3.3 below summarises the approach to developing BAU projections for the energy sector across each of the relevant emissions source categories. A more detailed description is provided below for each key category, along with methodological choices, assumptions and data sources.

Table 3.3 Summary of approach to BAU projections, Energy

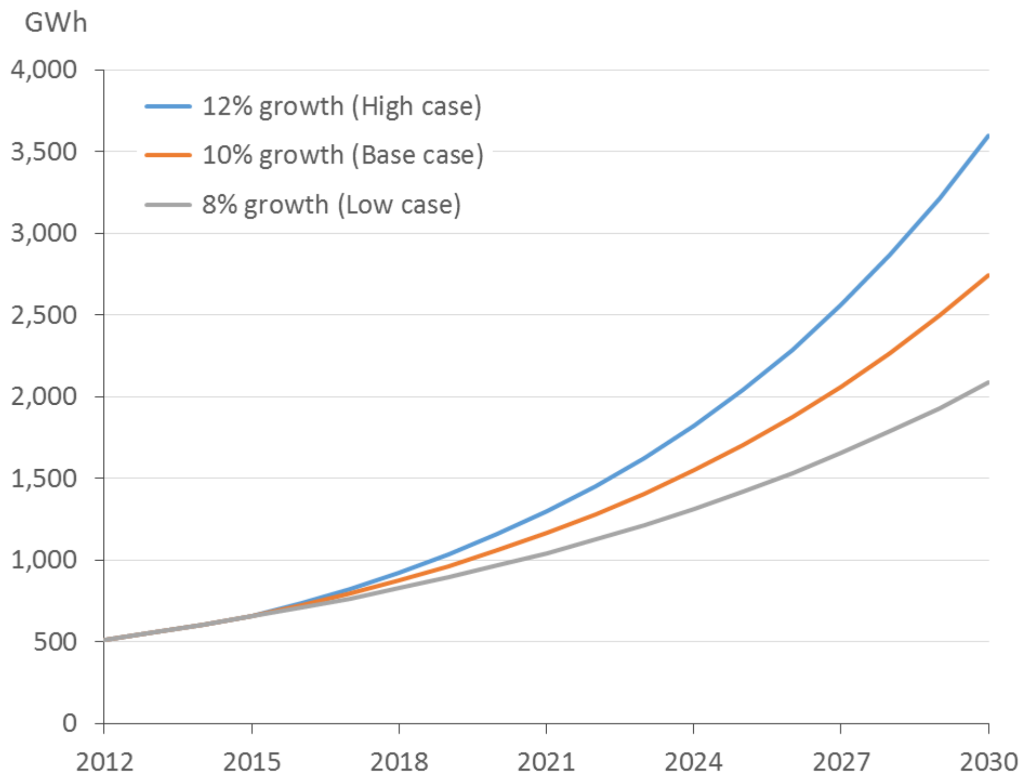
<table>
<tr><th colspan="3">IPCC category</th><th>Description</th></tr>
<tr><td rowspan="7">1.A. Fuel Combustion Activities</td><td>1. A.1. Energy Industries</td><td>1. A.1.a. Electricity and Heat Production</td><td>Based on analysis of forecast electricity demand and planned generation through 2030 as published in the recent Energy Sector Strategic Plan (ESSP) (GoR, 2018c) and the Least Cost Power Development Plan (LCPDP) (REG, 2019). The model developed applying a reserve margin of 15 % (REG, 2019) with all new generation through 2030 met by fossil fuel capacity. GHG emissions calculated in LEAP power generation module based on fuel use, heat rate and other assumptions, through agreement with REG, and application of IPCC 2006 Tier 1 emissions factors.</td></tr>
<tr><td colspan="2">1. A.2. Manufacturing Industries and Construction</td><td>Energy demand linked to official GDP growth outlook (GoR, 2017a) through use of regression analysis within energy-using industrial sectors. GHG emissions modelled within LEAP industry module applying IPCC 2006 Tier 1 emissions factors.</td></tr>
<tr><td>1. A.3. Transport</td><td>1. A.3.b. Road Transport</td><td>Fuel consumption forecast for different vehicle classes based on road vehicle survey information, transport demand, fuel use and fuel economy assumptions, and vehicle fleet modelling through 2030. Supplemented by use of regression analysis to develop correlation between vehicle ownership, and per capita GDP (based on GoR, 2017a; GoR, 2018b).</td></tr>
<tr><td rowspan="2">1. A.4. Other Sectors</td><td>1. A.4.a. Commercial/institutional</td><td rowspan="2">GHG emissions from buildings (commercial, residential and institutional energy use) linked to GDP and population growth (GoR, 2017a; GoR, 2018b) and simulated in the LEAP buildings module. Emissions from residential buildings closely linked to population; emissions from commercial and institutional buildings linked to GDP and historical growth rates.</td></tr>
<tr><td>1. A.4.b. Residential</td></tr>
<tr><td colspan="2">1. A.5. Non-specified</td><td>Energy demand assumed to grow in line with official GDP growth outlook (GoR, 2017a) and based on trends over past decade.</td></tr>
</table>

Source: Authors

3.3.1 Electricity generation

The electricity generation BAU projection was developed based on the planned generation projects as detailed in the least-cost power development plan (LCPDP) (REG, 2019). Development of future renewable energy projects were considered to be NDC mitigation measures and therefore not included within the BAU scenario; existing renewable projects were assumed to continue generating at existing levels through 2030. The projection begins from a 2016 base year and includes generation and GHG modelling from four main fossil fuels: diesel (light fuel oil), residual fuel (heavy fuel oil), peat and methane gas. The power generation demand forecast is included in the LCPDP (REG, 2019), according to which, demand is expected to grow according to three main scenarios: a low growth scenario (8%), medium growth scenario (10 %) and high growth scenario (12%). The BAU 'base case' described in this section is based on the medium growth scenario[6]. According to this scenario, grid electricity generation is expected to more than double from current levels to 2,100 GWh in 2030.

Figure 3.5 National electricity demand projections to 2030 (GWh)



Source: REG, 2019

According to electric power generation plan published by the Rwanda Energy Group Ltd (REG), total available capacity in 2018 was around 154 MW (installed capacity was 216 MW) of which hydropower accounts for around one third (49.5 MW) and fossil based units the remaining two thirds (99 MW) (Table 3.4). Several small solar PV and biomass installations account for around 2 MW, with imports of 3.5 MW.

[6] The other two scenarios were considered within sensitivity analysis, with the 'low growth' scenario adopted to align with the lower GDP forecast as described by the IMF WEO; see Section 3.7.2.

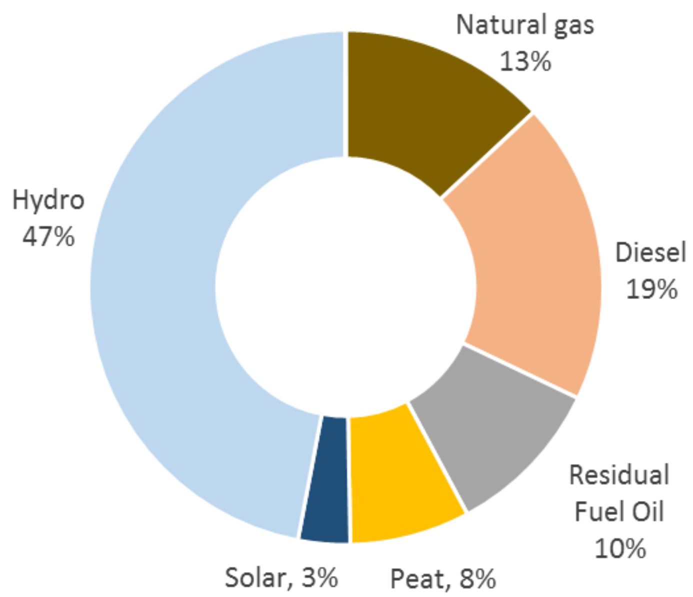
Table 3.4 National installed generating capacity as of 2018

Plant Name	Installed Capacity (MW)	Available Capacity (MW)	Owner	COD	Status	Xstics	Location	Type of Technology
Ntaruka	11.25	2.5875	GoR	1959	Existing	Renewable	Burera	Hydro
Mukungwa I	12.00	6	GoR	1982	Existing	Renewable	Musanze	Hydro
Nyabarongo I	28.00	13.44	GoR	2014	Existing	Renewable	Muhanga	Hydro
Gisenyi	1.20	0.78	Prime Energy	1957	Existing	Renewable	Rubavu	Hydro
Gihira	1.80	1.26	RMT	1984	Existing	Renewable	Rubavu	Hydro
Murunda	0.1	0.045	Repro	2010	Existing	Renewable	Rutsiro	Hydro
Rukarara I	9.5	3.8	Ngali Energy	2010	Existing	Renewable	Nyamagabe	Hydro
Rugezi	2.2	1.1	RMT	2011	Existing	Renewable	Burera	Hydro
Keya	2.2	1.1	Adre Hydro&Energicotel	2011	Existing	Renewable	Rubavu	Hydro
Nyamyotsi I	0.1	0.06	Adre Hydro&Energicotel	2011	Existing	Renewable	Nyabihu	Hydro
Nyamyotsi II	0.1	0.06	Adre Hydro&Energicotel	2011	Existing	Renewable	Nyabihu	Hydro
Agatobwe	0.2	0.07	Carera-Ederer	2010	Existing	Renewable	Nyaruguru	Hydro
Mutobo	0.2	0.09	Repro	2009	Existing	Renewable	Musanze	Hydro
Nkora	0.68	0.34	Adre Hydro&Energicotel	2011	Existing	Renewable	Rutsiro	Hydro
Cyimbili	0.3	0.15	Adre Hydro&Energicotel	2011	Existing	Renewable	Rutsiro	Hydro
Gaseke	0.582	0.5238	Novel Energy	2017	Existing	Renewable	Gakenke	Hydro
Mazimeru	0.5	0.245	Carera-Ederer	2012	Existing	Renewable	Nyaruguru	Hydro
Janja	0.2	0.16	RGE Energy UK ltd	2012	Existing	Renewable	Nyabihu	Hydro
Gashashi	0.2	0.08	Prime Energy	2013	Existing	Renewable	Rutsiro	Hydro
Nyabahanga I	0.2	0.11	GoR	2012	Existing	Renewable	Karongi	Hydro
Nshili I	0.4	0.24	GoR	2012	Existing	Renewable	Nyamagabe	Hydro
Musarara	0.45	0.2205	Amahoro Energy	2013	Existing	Renewable	Nyabihu	Hydro
Mukungwa II	2.5	1.825	Prime Energy	2013	Existing	Renewable	Musanze	Hydro
Rukarara II	2.2	1.155	Prime Energy	2013	Existing	Renewable	Nyamagabe	Hydro
Nyirabuhombohombo	0.5	0.175	RGE Energy UK ltd	2013	Existing	Renewable	Nyamasheke	Hydro
Giciye I	4	1.6	RMT	2013	Existing	Renewable	Nyabihu	Hydro
Giciye II	4	1.6	RMT	2016	Existing	Renewable	Nyabihu	Hydro
Ruzizi II	12.00	10.68	GoR	1984	Existing	Renewable	Rusizi	Hydro
S-total	**97.56**	**49.50**						**Hydro**
Jabana 1	7.8	7.41	GoR	2004	Existing	None Renewable	Gasabo	Diesel
Jabana 2	20	19	GoR	2009	Existing	None Renewable	Gasabo	HFO-Diesel
So Energy	30	28.5	So Energy&SP	2017	Existing	None Renewable	Gaasabo/Musanze	Diesel
S-total	**57.8**	**54.91**						**Diesel**
Gishoma	15	14.25	GoR	2016	Existing	None Renewable	Rusizi	Peat
S-total	**15**	**14.25**						**Peat**
Biomass (Rice Husk)	0.07	0.0665	Novel Energy	2016	Existing	None Renewable	Nyagatare	Biomass
S-total	**0.07**	**0.0665**						**Biomass**
KP1	3.6	3.42	GoR	2008	Existing	None Renewable	Rubavu	Methane
Kivuwatt Phase I	26.4	26.4	Contour Global	2016	Existing	None Renewable	Karongi	Methane
S-total	**30**	**29.82**						**Methane**
Jali	0.25	0.04	Mainz Stadwerke/Local Agency	2007	Existing	Renewable	Gasabo	Solar
GigaWatt /Rwamagana	8.50	1.19	Gigawatt Global	2013	Existing	Renewable	Rwamagana	Solar
Nyamata Solar	0.03	0.01	NMEC Nyamata	2009	Existing	Renewable	Bugesera	Solar
Nasho Solar PP	3.30	0.66	GoR	2017	Existing	Renewable	Kirehe	Solar
S-total	**12.08**	**1.90**						**Solar**
Ruzizi 1	3.50	3.50	Snel Sarl	1957	Existing	Renewable	Rusizi	Imports
S-total	**3.50**	**3.50**						**Imports**
Grand Total	**216.0**	**153.9**						

Source: REG, 2019

The generation mix by technology for 2018 is shown in Figure 3.6. The figure shows that hydropower represents around one half of generation. The use of indigenous fossil fuels such as Lake Kivu methane gas (considered as natural gas fuel combustion in the base case analysis) and peat is growing while the use of imported fossil remains steady. This reflects the national energy policy to reduce imported fossil fuels in the national energy mix.

Figure 3.6 National electricity generation, 2018



Source: REG, 2019

Assuming no new renewable generation (solar PV and hydro) is added under the BAU scenario, all planned thermal power plants (diesel, peat and methane gas) were modelled, and expected installation/retirement dates accounted for in the subsequent generation mix. Table 3.5 shows the planned power generation projects and their estimated commissioning dates, from the LCPDP (REG, 2019). Only projects falling within the first NDC period are included (i.e. committed before 2030).

Table 3.5 Existing and planned generation projects from LCPDP

#	Power Station	Nominal Capacity (MW)	Commissioning date
	Non-renewable power plants		
1	Hakan	80	2020
2	Symbion	50	2022
3	Symbion Extension	25	2022
5	KivuWatt	26.4	2015
6	Jabana 1&2	27.8	2004 and 2009
8	SO-Energy	30	2017
	TOTAL: Non-renewable	**222.2**	
	Solar Power plants		
1	Gigawatt global	8.5	2013
2	Nasho solar	3.3	2017
	TOTAL: Solar	**11.8**	
	Hydro Stations<=5MW		
1	Agatobwe	0.2	2010
2	Base 1	2.9	2020
3	Base 2	2.9	2020

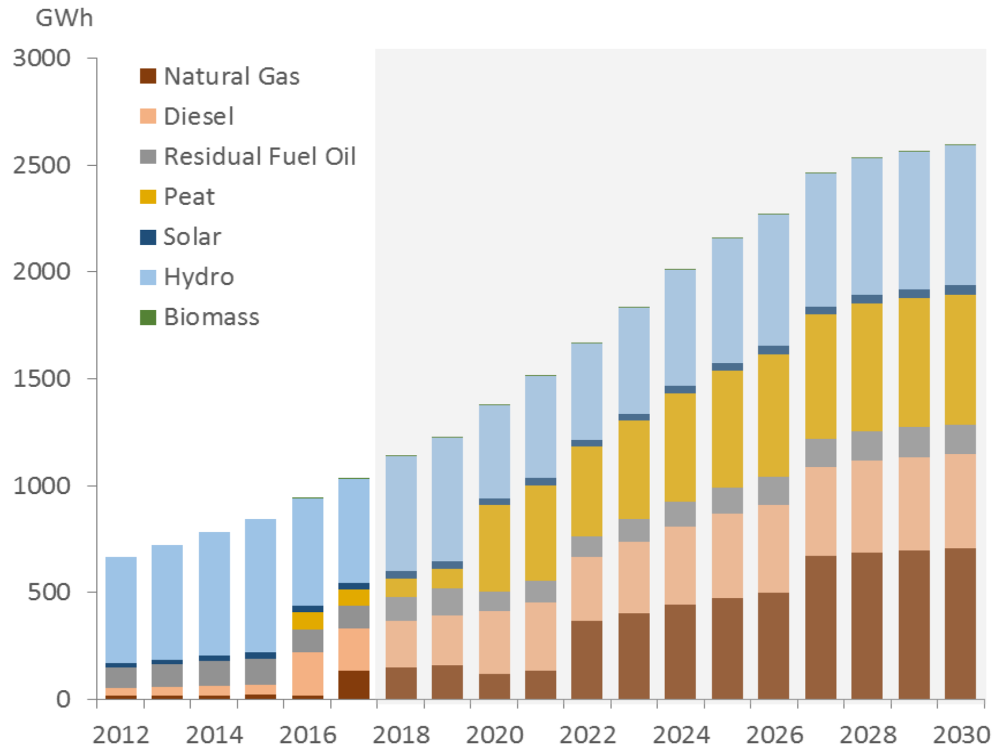
4	Gisenyi	0.7	1957
5	Kabavu	0.1	2022
6	Kavumu	0.4	2018
7	Kigasa	0.2	2017
8	Kore	1.3	2022
9	Mpenge I&III	1.0	2019
10	Muganza	0.3	2022
11	Muhembe	0.3	2018
12	Mukungwa 2	1.0	2013
13	Mutobo	0.8	2019
14	Ngororero	2.7	2018
15	Ntaruka A	2.1	2020
16	Nyirahindwe I&II	1.2	2019
17	Nyirantaruco	1.3	2018
18	Nyundo	4.0	2020
19	Rubagabaga	0.3	2019
20	Rucanzogera	1.6	2022
21	Rugezi	1.1	2019
22	Rukarara V	5.0	2020
23	Rukore	2.0	2022
24	Rwaza I-Muko	2.6	2020
25	Rwondo	2.3	2020
	TOTAL: Hydro Stations<=5MW	**38.3**	
	Hydro Stations>5MW		
1	Bihingore	5.35	2021
2	Giciye III	7.2	2021
3	Nyabarongo II	37.5	2025
4	Rukarara VI	6.7	2020
	TOTAL: Hydro>5MW	**56.75**	
	Regional Projects (hydro)		
1	Rusizi III	48.3	2023
2	Rusumo	26.7	2022

Source: REG, 2019 (page 14)

The electricity generation demand forecast was added in the energy demand module of the LEAP software system, with committed power generation projects added exogenously in the transformation module. The reserve margin was set to 15%; thermal efficiencies were set to 30% for diesel, biomass and residual fuel, and 40% for peat and gas.

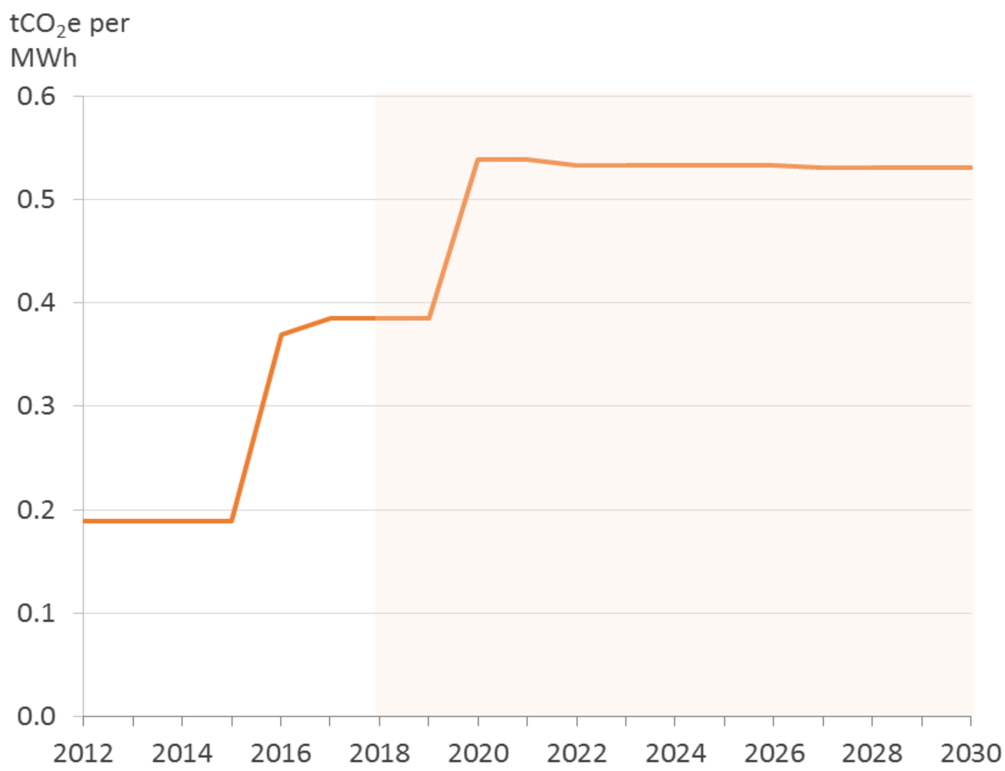
Figure 3.7 shows the resulting generation forecast, based on the medium demand projection chosen for the BAU case. GHG emissions were calculated within the LEAP software based on calculated fuel consumption and Tier 1 IPCC 2006 emissions factors. Figure 3.8 shows the corresponding GHG emissions intensity forecast. The forecast shows how the national grid emissions intensity is expected to increase through 2030 as additional plants are commissioned to meet rising demand, in the absence of NDC mitigation measures such as solar PV and hydropower.

Figure 3.7 National electricity generation forecast, BAU base case (medium demand)



Source: Authors, based on REG, 2019

Figure 3.8 BAU emissions intensity of grid generation, BAU base case (medium demand)



Source: Authors, based on REG, 2019

3.3.2 Manufacturing industries

GHG emissions from manufacturing industries were modelled based on the data published in the TNC (GoR, 2018a). The relationship between GDP growth and historic GHG emissions was analysed for each energy-using industry (non-metallic minerals industries, mining industries, food industries and construction). Emissions were modelled within the industry module of LEAP based on projected fossil energy use, which was assumed to grow at the same rate as national GDP for mining industries, food industries and construction, while emissions from non-metallic minerals industries (cement and clinker) were projected based on assumed production growth. Based on data provided by CIMERWA Cement Limited (CCL), a 13% growth rate was assumed.

3.3.3 Transport

According to the national GHG inventory, road transport was the main contributor to total transport sector GHG emissions in 2015. Due to a lack of data and their relatively small contribution, emissions from other sources including civil aviation, rail and waterborne transport are not reported and have not been estimated as part of the projections. Given road transport's large contribution to Rwanda's energy emissions, a relatively simplified forecast of fuel use and GHG emissions from road vehicles was undertaken using available information from national statistics databases and various in-country and international studies. This improves on the previous approach which applies a simple aggregated forecast of sectoral emissions based on previous trends, with no modelling of vehicle and fleet characteristics or turnover. However, it should be noted that the approach remains relatively simple as it does not capture the impacts from various factors determining travel efficiency (in addition to vehicle efficiency). The approach to developing a BAU forecast for road transport is summarised below.

Step 1: Characterization of existing vehicle fleet. Rwanda's existing vehicle fleet was first characterised according to vehicle type, class, fuel type, and fuel economy. Vehicle numbers were based on official registration data for recent years provided in the National statistical yearbooks (Table 3.6) (NISR, 2014; NISR, 2015; NISR, 2016; NISR, 2017; NISR, 2018). Average fuel economy values (litres per 100 km) for each vehicle class and fuel type were developed, based on estimates including recent analysis undertaken by REMA of fuel economy for road vehicles registered in Rwanda (REMA, 2019), and data from the Rwanda NAMA report. Improvements in average fuel economy rates for future vehicles were estimated based on assumed vehicle efficient metrics provided by the Global Fuel Economic Initiative (GFEI, 2019)[7].

Based on national data for diesel and gasoline consumption in transport, average annual distances for each vehicle category were then developed (km per year). Total fuel consumption for the base year of 2015 was then calculated for each vehicle category, and fuel type within each category (diesel; gasoline), according to:

[7] Equal to an overall assumed improvement of around 15% for all vehicles across the forecast period. This is acknowledged to be a major simplifying assumption, since it does not quantify the potential for decreasing efficiency of travel km arising from urban congestion and poor road quality. As such, the potential for measures to address these factors (i.e. through improved road networks and transport system planning) are also not captured in the methodology, either within the baseline or mitigation scenario(s). This issue is identified as an important area for further and more systematic analysis, including through support to improve national transport modelling and associated GHG impacts modelling.

Fuel consumption = total number of vehicles x fuel economy (l/km) x distance travelled per vehicle (km)

Table 3.6 Estimated vehicle fleet in Rwanda, 2006-2015

Category	2006	2009	2011	2013	2015
Motorcycles	15,224	33,121	49,367	68,846	83,338
Passenger cars	21,693	31,439	37,765	49,720	54,795
Light duty trucks	8,119	11,448	12,974	15,067	15,766
Buses	87	250	469	597	1,020
Microbuses	61	115	144	155	235
Trailers	457	667	733	831	808
Half trailers	89	162	186	188	203
Trucks	1,805	2,490	3,134	3,931	4,502
Other vehicles	96	327	552	814	1,258
Total vehicles	47,631	80,019	105,324	140,149	161,925

Source: based on NISR, 2018

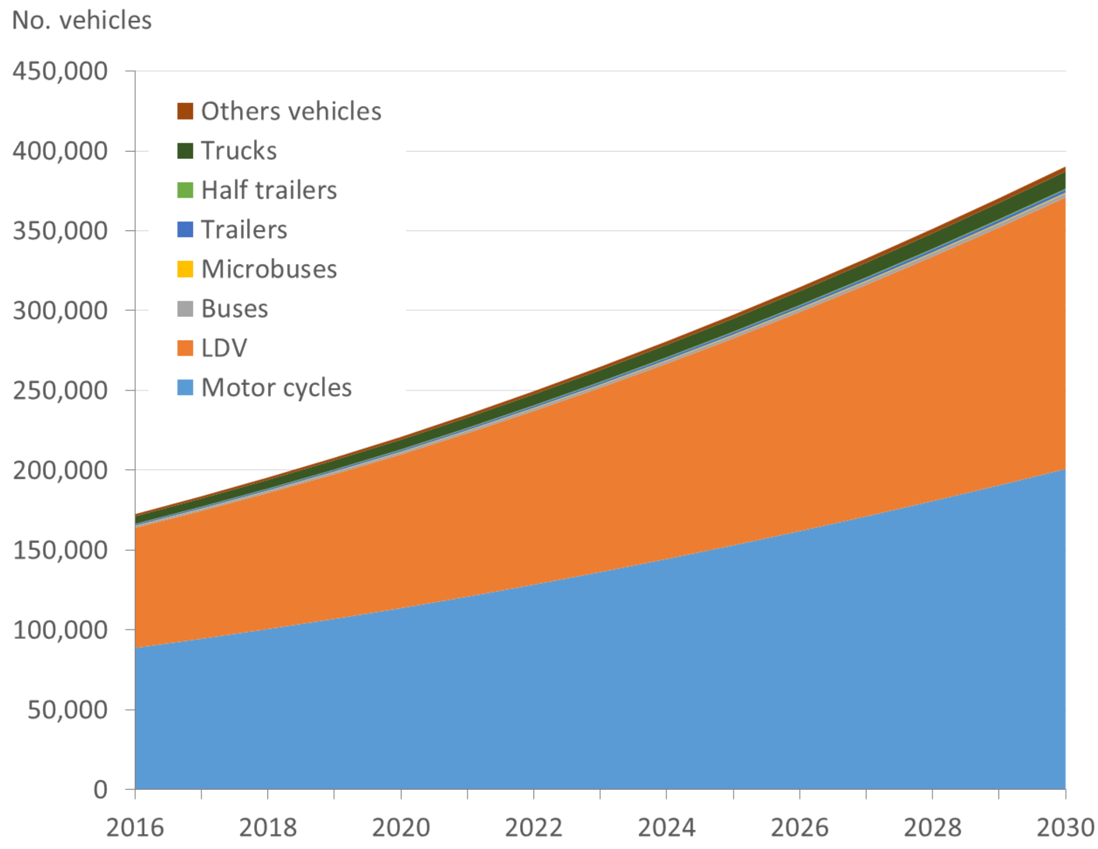
Table 3.7 Fuel economy assumptions for existing and new vehicles

l/100 km	Existing fleet	New fleet
Motorcycles	4.00	3.39
Passenger cars (gasoline)	7.82	6.63
Passenger cars (diesel)	9.26	7.85
Buses	54.00	45.78
Microbuses	44.00	37.30
Trailers	29.00	24.59
Half trailers	15.00	12.72
Trucks	39.50	33.49
Other vehicles	39.50	33.49

Source: based on NAMA and REMA data

Step 2: Vehicle fleet projected through 2030. A forecast was then made of numbers for each vehicle category through 2015-2030. Numbers of new vehicle registrations were estimated based on an increased demand in road transport. Regression models were built and used to analyse the relationship between vehicle numbers and population and GDP per capita; strong correlations were observed between GDP per capita and vehicle ownership per capita, which was applied to future growth projections. An average annual scrappage rate of 5% was assumed, in common with estimated historic scrappage rates in Rwanda, which are also in alignment with typical reported OECD values. From an estimated national fleet of 0.16 million road vehicles in 2016, numbers are projected to increase significantly to around 0.33 million by 2030, of which motorcycles account for 54% and passenger vehicles account for 36%.

Figure 3.9 Projected vehicles numbers by mode 2015-2030

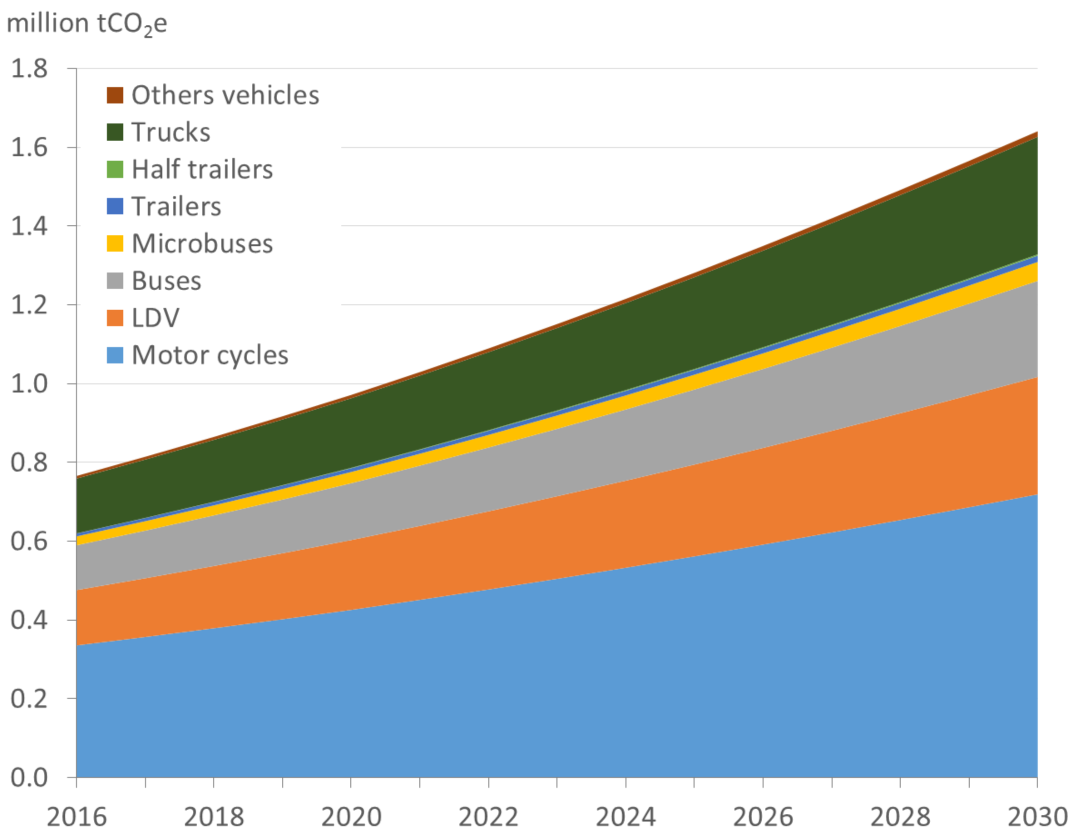


Source: Authors
Note: LDVs include passenger cars and light-duty trucks

Step 3: Estimation of fuel use and GHG emissions through 2030. Based on Steps 1 and 2 described above, fuel use estimates were next calculated for diesel, gasoline in each forecast year and a GHG forecast was made using the IPCC emission factors for mobile emission sources (IPCC, 2006). In the absence of robust alternative assumptions, the existing split between diesel and gasoline usage was assumed to remain the same through the forecast period. Figure 3.10 shows projected total road transport sector GHG emissions by mode through 2030. The outlook estimates total emissions to roughly double from around 0.77 million tCO_2e in the base year of 2015 to 1.64 million tCO_2e in 2030. Whilst this represents a major increase in GHG emissions, it should be noted that the rate of increase is lower than the projections for transport demand and vehicle numbers, largely reflecting assumptions around fuel economy improvements over time.

While the methodology described above is considered an improvement over the previous LEAP forecasting, it should be noted that it remains relatively simplistic resulting in a high degree of uncertainty. A key limitation is that certain types of transport intervention are not quantified, including for example urban transport and road network improvements. These would have the effect of reducing aggregate emissions, although other factors such as increased congestion would similarly increase per km fuel consumption and resulting emissions. Modelling these and other factors, requiring additional resources and data/information collection, is recommended for future improvements in forecasting Rwanda's road transport sector.

Figure 3.10 Projected road transport sector GHG emissions by mode 2015-2030



Source: Authors

Note: LDVs include passenger cars and light-duty trucks

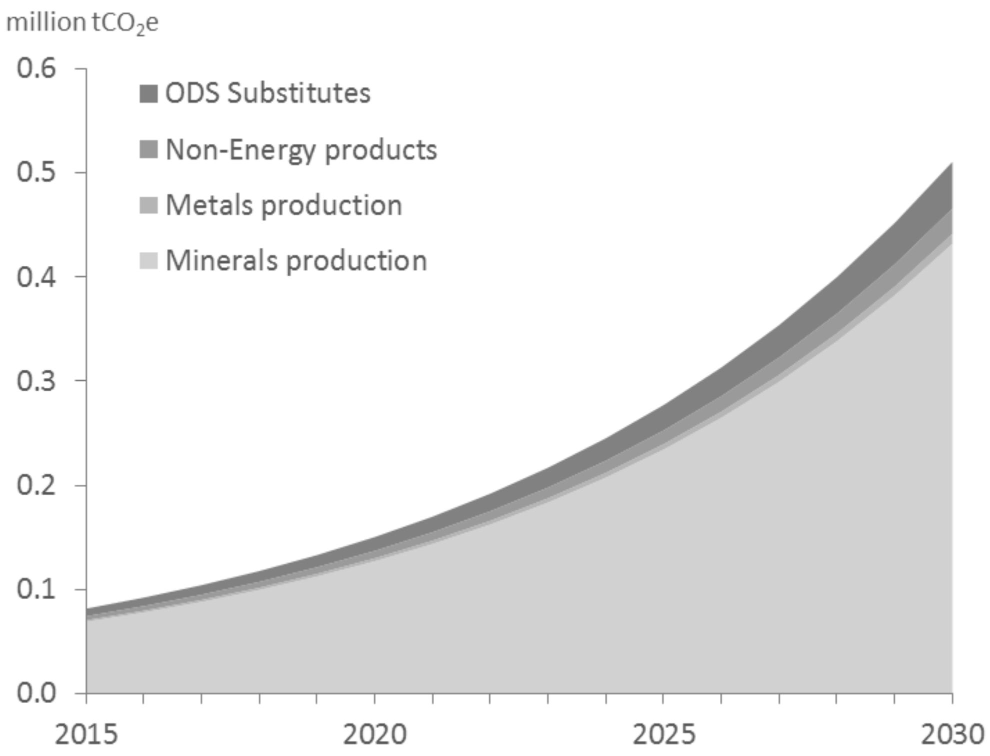
3.3.4 Commercial and residential

GHG emissions projection from energy use in buildings were linked to socio-economic variables GDP and population growth and simulated in the building module of LEAP. Whereas GHG emissions from residential buildings were assumed to grow in line with population for purposes of projecting LPG and wood fuels use, using existing estimates of per capita fuel use included in the TNC, GHG emissions from kerosene and biogas were assumed to grow in line with historical growth trends. GHG emissions from commercial and institutional buildings were assumed to grow as per historic growth rates for diesel and in line with GDP for other fuels.

3.4 Industrial processes and product use

Figure 3.11 shows the BAU emissions projection for IPPU emissions through 2030 for the base case (consistent with Vision 2050). Total emissions are forecast to increase very significantly over the period, albeit from a very low base, rising from around 0.08 million tCO_2e in the base year to 0.51 million tCO_2e in 2030. The graph shows that emissions growth is dominated by the minerals production category (calcination CO_2 emissions from clinker and cement production), with much smaller although growing contributions from other industrial sources. The increase reflects assumptions around ongoing growth from CCL and assumes current rates of clinker substitution and fuel use (see below).

Figure 3.11 BAU GHG emissions projection, IPPU (base case)



Source: Authors

Table 3.8 BAU GHG emissions projection, IPPU (base case)

GHG emissions ($MtCO_2e$)	2015	2020	2025	2030
Minerals production	0.069	0.127	0.235	0.432
Metals production	0.002	0.003	0.005	0.010
Non-Energy products	0.004	0.007	0.013	0.024
ODS Substitutes	0.007	0.013	0.024	0.045
Total	**0.08**	**0.15**	**0.28**	**0.51**

Source: Authors

Table 3.9 below summarises the approach to developing BAU projections for the IPPU sector across each of the relevant emissions source categories. A more detailed description is provided below for each key category, along with methodological choices, assumptions and data sources.

Table 3.9 Summary of approach to BAU projections, IPPU

IPCC category		Description
2. IPPU	2.A. Mineral Industry	Based on forecast cement (clinker) and lime products applying IPCC 2006 emissions factors. Forecast output linked to GDP growth in industrial sector (GoR, 2017a) and informed by CCL facility expansion and renovation, which has almost doubled from 2015 to 2018, based on strong demand from construction sector.
	2.C. Metal Industry	Calculations made using IPCC 2006 guidelines and based on quantity of production. Production output linked to GDP growth forecasts in industrial sector (GoR, 2017a).
	2.D. Non-Energy Products from Fuels and Solvent Use	Calculations made using IPCC 2006 guidelines and based on quantity of production. Production output linked to GDP growth forecasts in industrial sector (GoR, 2017a).
	2.F. Product Uses as Substitutes for Ozone Depleting Substances	Calculations made using IPCC 2006 guidelines and based on quantity of production. Production output linked to GDP growth forecasts in industrial sector (GoR, 2017a).

Source: Authors

3.4.1 Mineral Industry

The mineral industry covers process emissions from the activity data in cement production and lime production. For cement, the baseline emissions associated with cement kiln dust has been calculated using the IPCC 2006 Tier 1 estimation method applying the default calcination emission factor of 0.52 (IPCC, 2016). Similarly, emissions from two type of lime produced in Rwanda - namely high-calcium lime and dolomitic lime - were calculated by using Tier 1 method and their respective emission factors of 0.75 and 0.77 (*ibid*). The baseline projection consistent with Vision 2050 was based on the change of GDP in industry sector which is projected to increase by 13% average growth rate per year (GoR, 2017a). This growth was applied throughout the IPPU sector; the overall share from minerals industry to total IPPU emissions from the mineral sector was assumed constant during the projection period at 84.6% (GoR, 2018a). The expansion of the CCL facility in 2015 and the rising demand of cement from the construction sector as shown in Table 3.10 is expected to maintain BAU emissions from minerals industry at a significantly higher rate level other IPPU sub-sectors.

Table 3.10 Projected clinker and cement production (tonnes)

Item	2015	2020	2025	2030
Clinker	88,090	347,876	531,627	716,200
Cement	125,842	496,966	759,467	1,023,143

Source: MINECOFIN, 2018 and authors

3.4.2 Product Uses as Substitutes for Ozone Depleting Substances

The BAU approach was based on the quantity of hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) used for refrigeration and air-conditioning; mainly R134a, R404a, R 410a, R407c, and R507a and which are also used for mobile air conditioning (GoR, 2018a). The projection, for substitutes of ozone depleting substances (ODS) sub-sector emissions through 2030, was consistent with the expected average increase of industrial sector GDP by 13% (GoR, 2017a). The contributing share to the total IPPU emissions of 8.8% from the substitutes of ODS was assumed constant through 2030 (GoR, 2018a).

3.4.3 Other sources

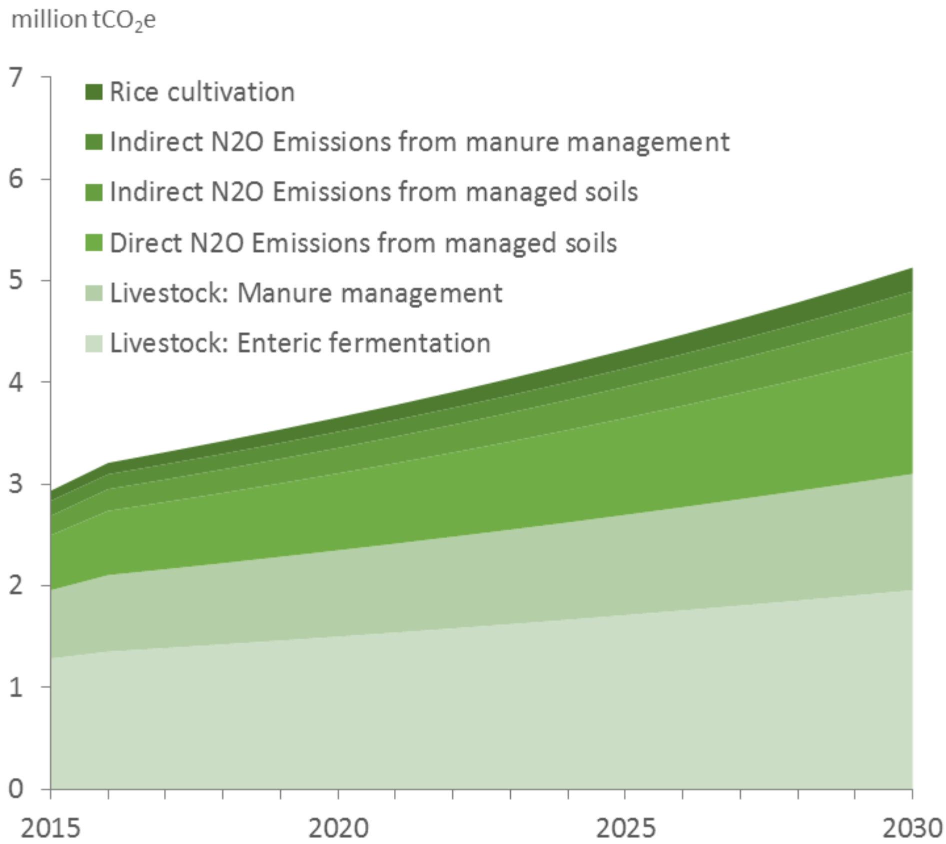
Two other sub-categories were considered, namely emissions from (i) metal industry and (ii) Non-Energy Products from Fuels and Solvent Use. The IPCC 2006 methodology was used during the BAU development and was based on local production data for iron, steel and ferroalloys production (extremely low volumes) as well as the emissions from lubricants and paraffin wax use (GoR, 2018a). Similar to the other IPPU sub-categories, emissions for the base case in these two categories were projected to increase with the GDP average growth from Vision 2050. The current contribution to total IPPU emissions, estimated at 1.86% from the metal industry and 4.74 % from Non-Energy Products from Fuels and Solvent Use was assumed constant throughout 2030 (GoR, 2018a).

3.5 Agriculture

Figure 3.12 shows the BAU emissions projection for agriculture sector emissions through 2030 for the base case (consistent with the targeted/high output)[8]. Steadier growth is forecast overall, compared to other sectors, rising from around 2.9 million tCO_2e in the base year to 5.1 million tCO_2e in 2030. As shown in the graph, emissions from all sub-sectors are forecast to increase in the absence of specific mitigation measures, with the largest growth expected from N_2O emissions arising from managed land reflecting increased crop production and commodity exports such as tea and horticultural products. Despite assumptions around increased livestock output and productivity, emissions from these sources are expected to rise at comparatively lower rates through 2030.

[8] This reflects a high sector scenario for agricultural output reflecting e.g. growth in fertilizer use, improved soil fertility, increased per Ha yields.

Figure 3.12 BAU GHG emissions projection, Agriculture (base case)



Source: Authors

Table 3.11 BAU GHG emissions projection, Agriculture (base case)

GHG emissions ($MtCO_2e$)	2015	2020	2025	2030
Livestock	1.96	2.35	2.70	3.10
Enteric fermentation	*1.28*	*1.50*	*1.71*	*1.96*
Manure management	*0.67*	*0.85*	*0.99*	*1.14*
Aggregate Sources and Non-CO_2 Emissions Sources	0.98	1.31	1.63	2.04
Urea application	*<0.01*	*<0.01*	*<0.01*	*<0.01*
Direct N_2O Emissions from managed soils	*0.54*	*0.76*	*0.95*	*1.20*
Indirect N_2O Emissions from managed soils	*0.19*	*0.25*	*0.31*	*0.38*
Indirect N_2O Emissions from manure management	*0.15*	*0.16*	*0.18*	*0.21*
Rice cultivation	*0.10*	*0.14*	*0.18*	*0.23*
Total	**2.94**	**3.66**	**4.33**	**5.14**

Source: Authors

Table 3.12 below summarises the approach to developing BAU projections for the agriculture sector across each of the relevant emissions source categories. A more detailed description is provided below for each key category, along with methodological choices, assumptions and data sources. The projections were based on the trends reported in TNC (GoR, 2018a) with use of additional regression analysis from the existing historic data to assess correlations between growth rates and GDP and population data using the MINITAB 18 statistics software (MINITAB 18).[9] Production forecasts, also drawing upon official agricultural outlooks for Rwanda, were then used to model GHG emissions forecasts using AFOLU IPCC Tier 1 emissions factors (IPCC, 2006). Errors observed in the GHG inventory data for both the historic series and BAU base year were corrected as part of the revised BAU analysis.[10]

Table 3.12 Summary of approach to BAU projections, AFOLU

IPCC category			Description
3. AFOLU	3. A. Livestock	3.A.1.Enteric Fermentation	Emissions from livestock calculated based on IPCC Tier 1 emissions factors applied to projected livestock population growth per species (Shapiro et al., 2017) and using regression analysis (MINITAB 18).
		3.A.2.Manure Management	Emissions from manure management were based on IPCC Tier 1 emission factors applied to projected increases in livestock population per species, assuming manure management systems remain unchanged through 2030, (Shapiro et al., 2017). Regression analysis was used.
	3. B. Land	3.B.1.Forest Land	Not included within current analysis (work currently ongoing in parallel to estimate forest land emissions and removals).
	3. C. Aggregate Sources and Non-CO_2 Emissions Sources on Land	3.C.3.Urea application	Projections to 2030 calculated based on IPCC Tier 1 emission factors applied to projected urea utilisation (corrected from GHG inventory and TNC analysis).
		3.C.4.Direct N_2O Emissions from managed soils	Direct N_2O emissions from managed soils linked to crop biomass and projections for 2016-2030 made using regression analysis (MINITAB 18).
		3.C.5.Indirect N_2O Emissions from managed soils	Indirect N_2O emission from managed soils correlated to growth in direct N_2O emissions from managed soils using regression analysis (MINITAB 18).

[9] Historic data on GHG emissions from TNC (2006-2015) (GoR, 2018a) were used to derive regression equations with reported GDP and population in the same period (2006-2015) using MINITAB 18.
[10] Most notably relating to urea application (kilogrammes urea were previously counted in the GHG Inventory as tonnes)

		3.C.6.Indirect N_2O Emissions from manure management	Projections inked to manure management of kraal (livestock enclosures), calculated based on regression analysis showing a high correlation to direct N_2O emissions from managed soils (MINITAB 18).
		3.C.7.Rice cultivation	Emissions calculated based on IPCC Tier 1 emissions factors applied to rice area projections on basis of government's official planned cultivation expansion (MINAGRI, 2013).

Source: Authors

3.5.1 Livestock

The national livestock population is projected to rise through the forecast period. Although the official national policy does not set clear limits on the maximum size of the livestock population per species, subject to available resources, it is assumed populations per species will continue to increase - reflecting government policy aims.

GHG emissions from livestock in Rwanda are dominated by cattle. During the period 2006-2015, cattle population increased by 2.7%, goats by 4.8%, swine by 6% and sheep by 1%. For cattle, to meet official productivity targets, 46% of the current herd is planned to be replaced by cross-breeds, and red meat production is planned to grow from 58,579 tonnes in 2016/17 to 79,586 tonnes in 2021/22, representing an increase by 36% (Shapiro et al., 2017). It is assumed this will be achieved partially through the introduction of meat breeds along with natural population increase, as per historical growth. Based on the current policy focus and historical trends, a 3-4% annual growth in cattle herds was assumed for BAU livestock projections. This results in total cattle numbers rising from around 1.4 million in 2016 to 2.1 million by 2030. Other livestock were assumed to remain at historical growth rates.

3.5.2 Crops

National population growth projections require a doubling of crop productivity by 2050 to sustain basic food requirements (GoR, 2017a). In addition, certain export products such as horticulture are seeing very strong demand.[11] Because expansion of agricultural land has reached its limit in Rwanda, expanding output requires an increase in agricultural inputs in the form of organic and mineral fertilizers, use of improved crop varieties and better agroecosystem management practices, allowing sustainable production and improved nutrient balance in soil. Use of regression analysis from available historic data indicates that emissions from managed soils are not closely correlated with population and GDP. An alternative parameter of crop biomass was instead chosen within the BAU analysis. Crop biomass output was found to have highly significant correlation with direct N_2O emissions from managed soils, while indirect N_2O emissions from soil and manure were found to be strongly related to direct N_2O emissions from managed soils. Thus, regression analysis was performed (MINITAB 18), and regression equations were used to project N_2O emissions for the

[11] The new strategic pan (2019-2024) for the National Agricultural Export Development Board (NAEB) aims at increasing agricultural exports to over USD 1 billion per annum by 2024, from around USD 516 million in 2018. Horticultural product exports are expected to see the largest growth rate, moving to second place after tea. These will have a major impact on increased demand of irrigation (including diesel engine pumping and fertilizer usage).

period 2016-2030. Table 3.13 below shows the projected crop biomass increase through 2030 under the BAU projection.

Table 3.13 Projected increase in crop biomass, BAU 2016-2030

Tonnes	2016	2020	2025	2030
Total crop biomass	7,593,356	9,300,295	11,983,272	15,440,243

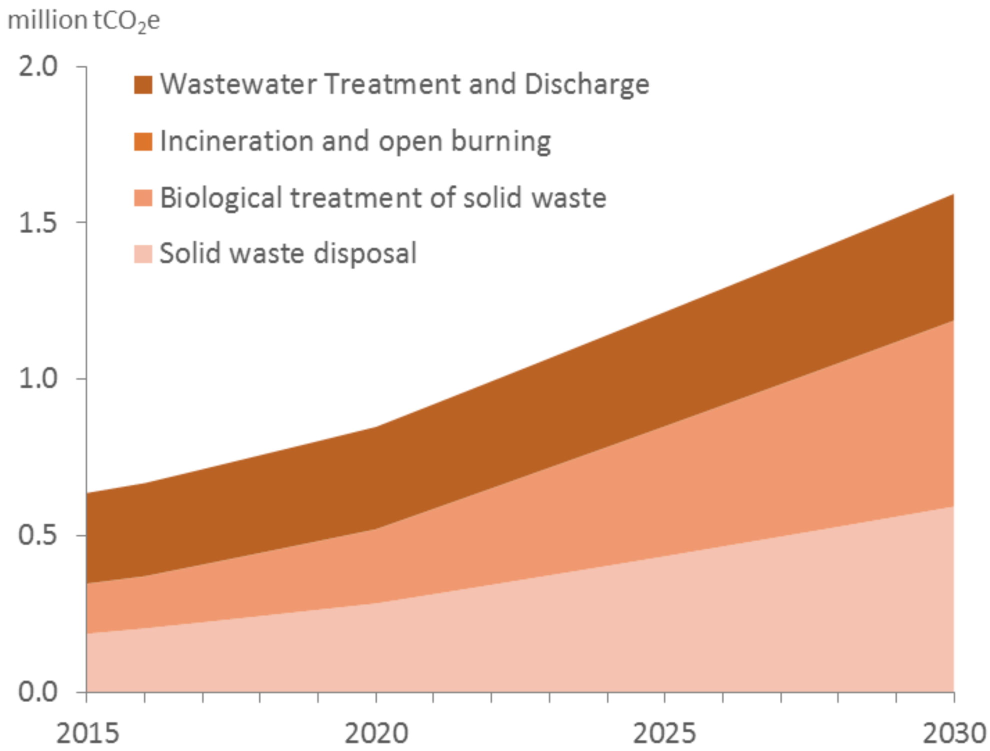
Source: Authors, derived from TNC data (GoR, 2018a)

3.6 Waste

Figure 3.13 shows the BAU emissions projection for emissions from waste through 2030 for the base case (consistent with Vision 2050). A significant increase is forecast, rising from around 0.64 million tCO_2e in the base year to 1.59 million tCO_2e in 2030.

Emissions from all sub-sectors are forecast to increase in the absence of specific mitigation measures, with the largest growth expected from emissions arising from solid waste production, including solid waste disposal sites (reflecting increasing urbanisation rates through 2030) and biological treatment of solid waste (composting). These closely reflect projected population increases and rising per capita waste generation levels, as described further below. The projections assume that current waste practices continue in the absence of targeted actions e.g. investments in landfill gas utilisation. Note that emissions from waste incineration are extremely low, and data and are not visible in the graph, reflecting the prohibition of open burning of waste, the lack of data for open burning of waste and the practice of incineration for mainly clinical waste.

Figure 3.13 BAU GHG emissions projection, Waste (base case)



Source: Authors

Table 3.14 BAU GHG emissions projection, Waste (base case)

GHG emissions ($MtCO_2e$)	2015	2020	2025	2030
Solid waste disposal	0.19	0.28	0.43	0.59
Biological treatment of solid waste	0.16	0.24	0.41	0.59
Incineration and open burning	0.001	0.001	0.002	0.002
Wastewater Treatment and Discharge	0.29	0.33	0.37	0.40
Total	**0.64**	**0.85**	**1.22**	**1.59**

Source: Authors

Table 3.15 below summarises the approach to developing BAU projections for the waste sector across each of the relevant emissions source categories. A more detailed description is provided below for each key category, along with methodological choices, assumptions and data sources.

Table 3.15 Summary of approach to BAU projections, Waste

IPCC category		Description
4. Waste	4. A. Solid Waste Disposal	Base year emissions calculated according to IPCC 2006, Tier 1 methodology with African waste generation assumptions of 0.29 tonnes/capita/year. Emissions projections through 2030 were calculated based on official GDP and population forecasts (GoR, 2017a; GoR, 2018b).
	4. B. Biological Treatment of Solid Waste	Base year emissions calculated according to IPCC 2006, Tier 1 methodology with African waste generation assumptions of 0.29 tonnes/capita/year. Emissions projections through 2030 were calculated based on official GDP and population forecasts (GoR, 2017a; GoR, 2018b).
	4. C. Incineration and Open Burning of Waste	Base year emissions calculated according to IPCC 2006, Tier 1 methodology and incinerated waste generation assumptions. Emissions projections through 2030 were calculated based on official GDP and population forecasts (GoR, 2017a; GoR, 2018b).
	4. D. Wastewater Treatment and Discharge	Base year emissions calculated according to IPCC 2006, Tier 1 methodology. Emissions projection through 2030 were calculated based on official GDP and population forecasts (GoR, 2017a; GoR, 2018b).

Source: Authors

3.6.1 Solid waste

The solid waste category comprises of the following three sub-categories: (i) solid waste disposal site (SWDS), (ii) biological treatment of solid waste, and (iii) waste incineration. Based on national circumstances in waste management, the urban population uses predominantly SWDS while the rural population practises composting; waste incineration is mainly carried out only in hospitals.

IPCC Tier 1 methodologies (IPCC 2006) were applied to calculate base year emissions (GoR, 2018a). The NAMA study assumption of 3% growth in urban population from the base year through 2030 was applied (GoR, 2015b), resulting in an average 35%/65% urban/rural split of population by 2030. Emissions projection through 2030 were calculated by using a multiple regression model using official GDP and population forecasts (GoR, 2017a; GoR, 2018b). The regression results showed strong correlation between the base year emissions, the GDP and the population, with R^2= 0.99 for SWDS, R^2= 0.92 for the biological treatment of solid waste and R^2= 0.99 for waste incineration. Table 3.16 below shows the projected population in urban and rural areas from the base year until 2030.

Table 3.16 Urban and rural population forecasts to 2030

Population (millions)	2015	2020	2025	2030
Urban	2.63	3.05	3.54	4.10
Rural	8.59	9.61	10.62	11.61
Total	11.23	12.66	14.16	15.71

Source: Adapted from GoR, 2018b and GoR, 2015b

3.6.2 Wastewater treatment and discharge

The wastewater sub-sector is divided into: (i) Domestic wastewater treatment and discharge and (ii) Industrial wastewater treatment and discharge. IPCC Tier 1 methodologies (IPCC, 2006) were used to calculate base year emissions (GoR, 2018a). The estimated emissions through 2030 were then calculated by using a multiple regression model with official GDP and population forecasts (GoR, 2017a; GoR, 2018b). The regression results reveal a strong correlation with R^2= 0.99 between the base year emissions from wastewater treatment and discharge, forecast GDP and population.

3.7 Summary and sensitivity analysis

3.7.1 Aggregated BAU results

The bottom-up BAU projections described are aggregated below to produce an economy-wide forecast of BAU emissions through 2030 (Figure 3.14). This represents the BAU baseline projection, consistent with the Vision 2050 outlook, against which the contribution from NDC mitigation actions across each of the key sectors can be quantified.

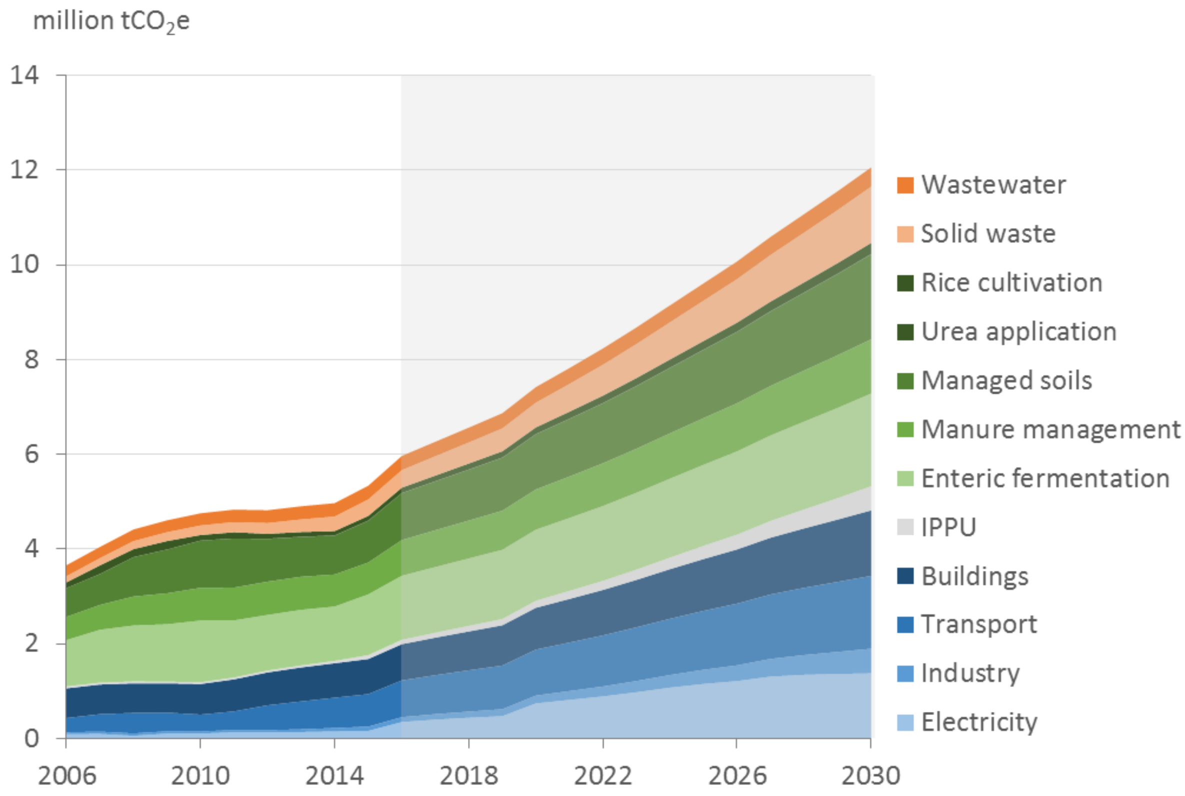
At an aggregate level, total emissions are forecast to more than double over the 2015-2030 period, rising from 5.3 million tCO_2e in the base year to 12.1 million tCO_2e in 2030. The graph shows that this represents an increased rate of growth compared to that seen during the period 2006-2015, closely reflecting the assumptions around economic and population growth and official planning, instead of projections based on past trends.[12] The current projection compares with the TNC projection of around 10.2 million tCO_2e in 2030, representing a doubling from the base year.[13]

As described above, the most rapid growth is forecast within industrial processes and energy use: the former expands its share of total emissions from 2% to around 4%, and the latter from 31% to 40% by 2030. The share of emissions from waste generation remains at around 12-13%, whilst agricultural sources decline from 55% to 43%. Although these do not represent dramatic shifts in emissions sources, they clearly indicate the growing contribution from fossil fuels to national emissions, arising from increasing demand for power generation, road transport services and other modern energy uses. At the same time, despite potential for increased productivity, agricultural output in expected to be limited due to land availability, thereby limiting emissions growth from this sector.

[12] This pattern is consistent with developing countries emissions trajectories; see for example historic Non-Annex B emissions in https://www.carbonbrief.org/what-global-co2-emissions-2016-mean-climate-change

[13] Note that this value is 'corrected' to account for data errors in the TNC reported data (GoR, 2018a).

Figure 3.14 BAU GHG emissions projection, total emissions (base case)



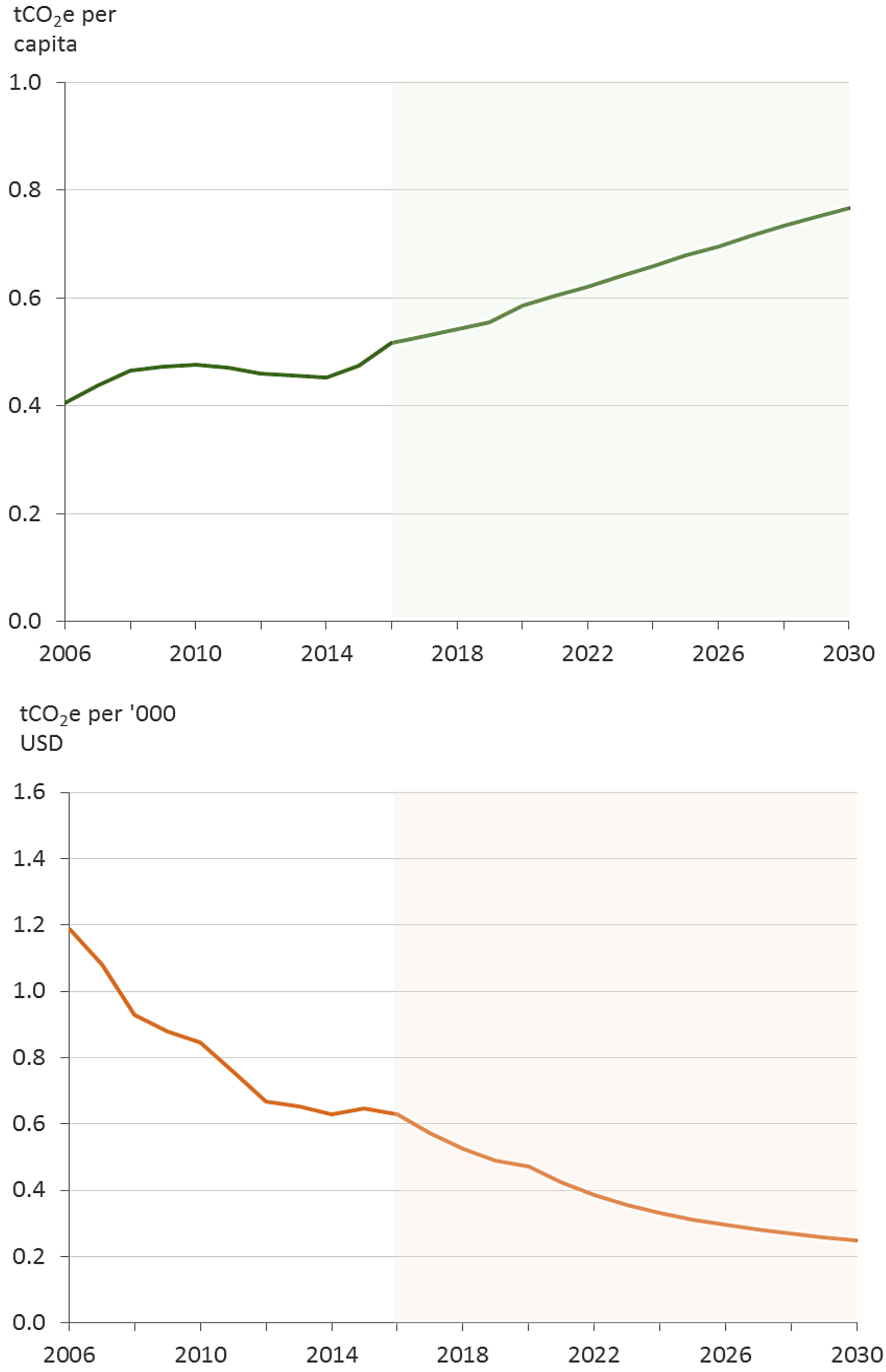
Source: Authors

Per capita and emissions intensity BAU projections are shown below in Figure 3.15. These represent base case forecasts results assuming the GoR official population forecast (medium case) and Vision 2050 economic growth rates, respectively. Per capita emissions can be seen to increase steadily through 2030 according to the BAU projection, broadly in line with previous trends. This pattern is typical for developing countries experiencing strong economic growth and development with rising living standards, reflecting such factors as *inter alia*:

- Increased population growth and urban population, driving e.g. solid waste disposal emissions and energy use in buildings
- Increased demand for transport and vehicles
- Increasing electricity demand, met by mainly fossil-based generation
- Economic, industrial and agricultural growth in line with government strategy and policy aims

Emissions per unit GDP are by contrast forecast to decrease through the same period. Again, this continues broadly in line with historic trends albeit at a reduced rate. This decoupling effect can be attributed to a range of sector-specific factors. For example, agricultural output – which dominates national emissions - is expected to be physically limited beyond a certain level of productivity gain by land availability. Similarly, empirical evidence shows that even with rapid economic growth, road vehicle numbers do not increase at the same rate. The overall factor is that economic growth is forecast to increase at a higher rate than fossil-based energy use, agricultural output and emissions.

Figure 3.15 BAU GHG emissions projection, per capita and per unit GDP (base case)



Source: Authors

3.7.2 Sensitivity analysis

Approach

Changes in production, energy use and GHG emissions through 2030 will be driven by a number of factors. The two most important drivers in the specific context of Rwanda's NDC sectors are considered to be:

- **Economic growth**: Economic growth within key sectors will drive demand for energy, industrial output and services such as road transport and housing. Lower rates of GDP growth over the coming years will therefore tend to restrain demand and output, and GHG emissions levels.
- **Population growth**: Population increases within rural and urban areas will drive demand for road transport, housing, and other services, as well as levels of waste generation and resource use. Lower population growth will tend to restrain demand and GHG emissions levels.

Because the ability to meet a certain NDC goal rests on the future projection of baseline emissions, it was considered important to test the relative significance of these drivers. A sensitivity analysis was therefore undertaken, generating a set of different BAU projections to 2030 reflecting the impact of these factors.

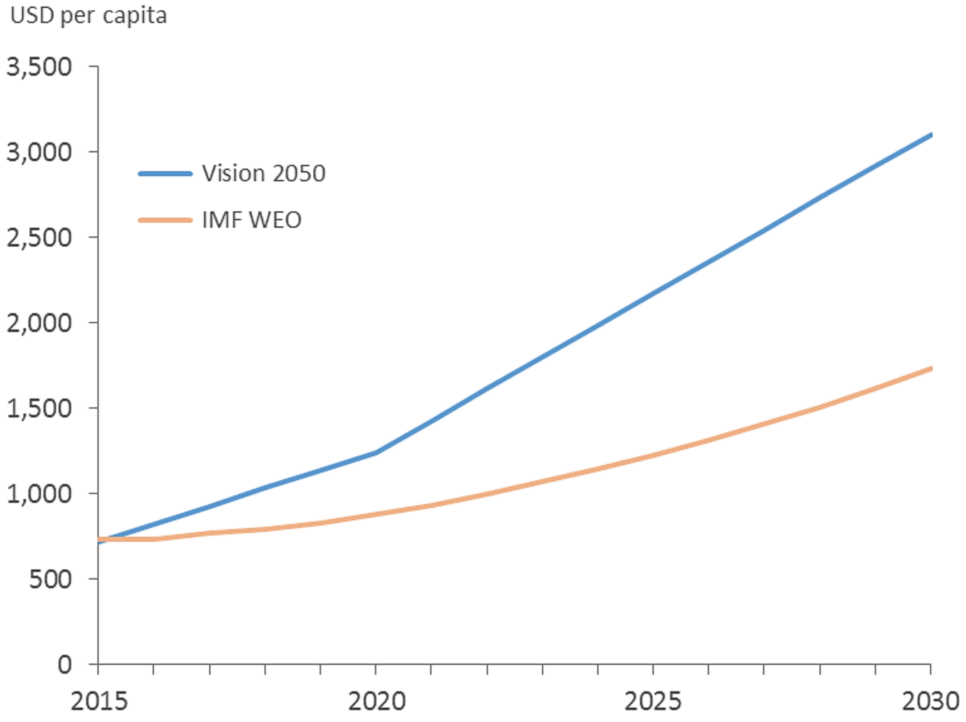
Economic growth outlook

As set out in the country's vision for continued economic development[14], Vision 2050, Rwanda aspires to reach Middle Income Country (MIC) and High-Income Country (HIC) status by 2035 and 2050, respectively. The Vision will be affected through a series of seven-year National Strategies for Transformation (NST1), underpinned by detailed sectoral strategies (World Bank, 2019a). The current NST1 covers the period 2017-2024 (GoR, 2017a). GDP growth assumptions consistent with the Vision have been used as the 'base case' assumption for the BAU emissions projections.

However, given the importance of economic growth to the projections, an alternative and independent outlook for growth in Rwanda produced by the International Monetary Fund (IMF) World Energy Outlook has also been assessed.[15] The two different projections are shown in Figure 3.16 below. It can be seen that the IMF outlook, whilst forecasting strong growth (around 6-7% per annum) is more conservative than the rate of growth envisaged by Vision 2050. As such it provides a useful alternative forecast to the GoR official outlook.

[14] GDP growth averaged 7.5% over the decade to 2018 while per capita GDP grew at 5% annually (World Bank, 2019a).
[15] The IMF WEO outlook is to 2024 only; growth in 2025-2030 has therefore been extrapolated based on the final year growth rate.

Figure 3.16 GDP per capita projections to 2030



Source: Calculated based on Vision 2050 (GoR, 2017a) and IMF World Economic Outlook (IMF, 2019)
Note: WEO projections extrapolated after 2024 based on final year growth rates.

Table 3.17 GDP per capita projections to 2030

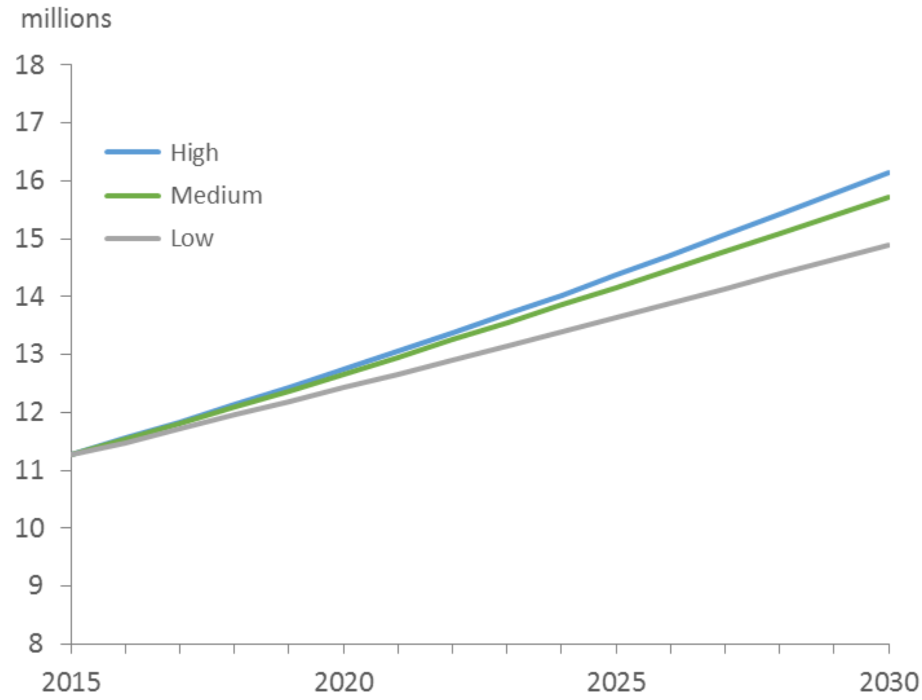
GDP per capita (USD)	2015	2020	2025	2030
Vision 2050	736	1,240	2,172	3,103
IMF WEO	736	879	1,229	1,732

Source: Calculated based on Vision 2050 (GoR, 2017a) and IMF World Economic Outlook (IMF, 2019)
Note: WEO projections extrapolated after 2024 based on final year growth rates.

Population growth outlook

The National Institute of Statistics Rwanda (NISR) publishes population projections based on regulator household surveys and censuses. The most recent of these is the Fifth Integrated Household Living Survey, EICV5, (NISR, 2018). The EICV5 provides detailed projections of population according to low, medium and high scenarios. The medium population scenario has been used as the 'base case' assumption in BAU emissions projections, with the low and high forecasts used as the alternative cases. The three different projections are shown in Figure 3.17 below. The medium scenario predicts a total population growth of around 39% over the period 2015-2030; this rises to 43% under the high scenario and falls to 32% under the low scenario.

Figure 3.17 Rwanda population projections to 2030



Source: Fifth Integrated Household Living Survey; EICV5, (NISR, 2018)

Table 3.18 Rwanda population projections to 2030

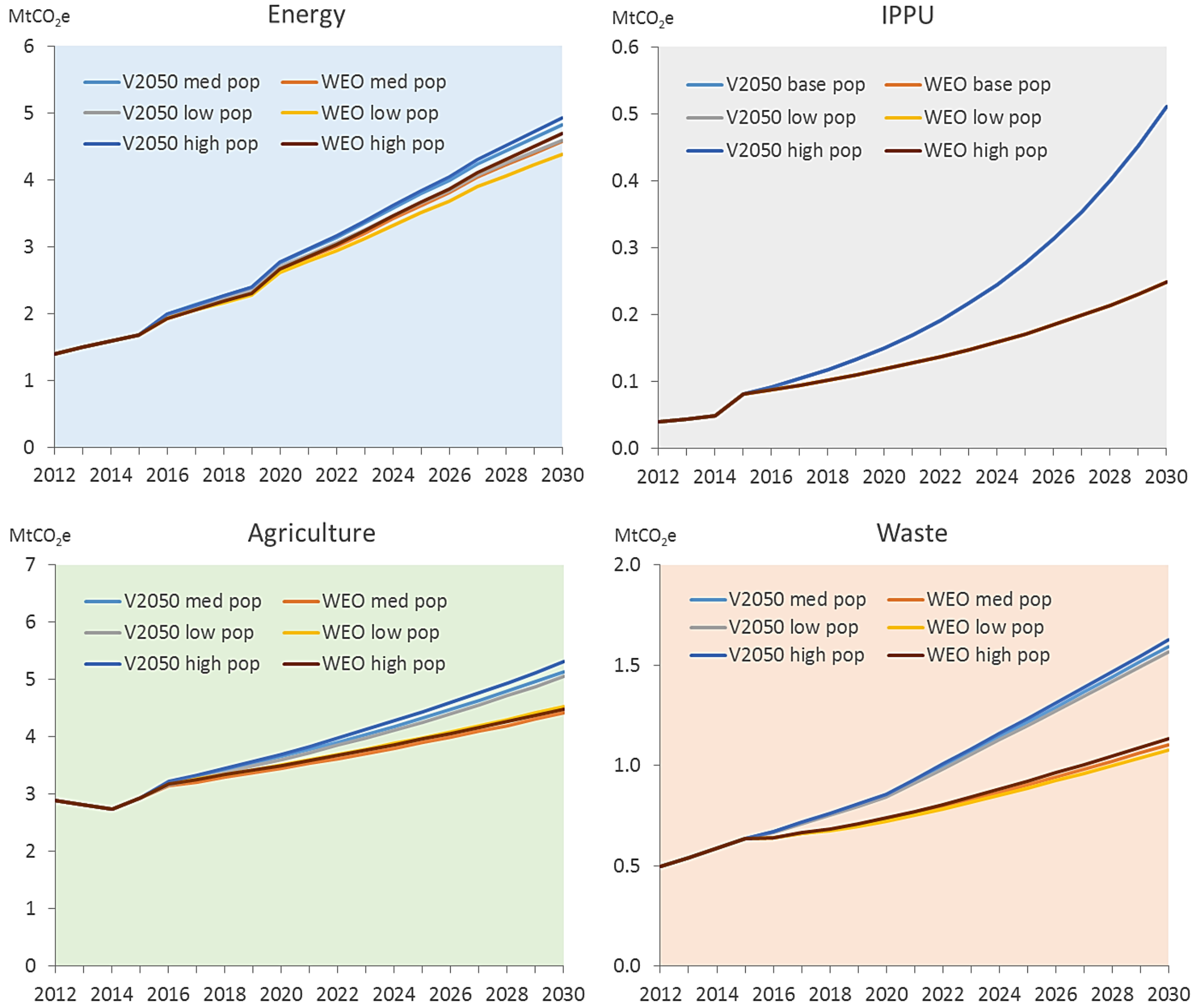
Population (millions)	2015	2020	2025	2030
High case	11.26	12.74	14.37	16.14
Medium case	11.26	12.66	14.16	15.71
Low case	11.26	12.42	13.63	14.90

Source: Fifth Integrated Household Living Survey; EICV5, (NISR, 2018)

Results

The combination of two alternative economic outlooks and three population growth scenarios gives rise to six alternative BAU emissions projections. These are shown below for each of the four key sectors (Figure 3.18). The results show the relative influence of GDP and population assumptions within the BAU modelling across the different activities. In all cases, assumptions around economic growth and production are seen to be a driver of emissions outcomes, most notably within the industrial processes and waste sectors which are closely linked in the modelling to economic growth factors. The effect is less marked within energy use, in part because the official power generation plans, whilst reflecting demand forecasting, are centrally planned and not directly linked to GDP growth assumptions through the period.

Figure 3.18 BAU sensitivity results to 2030 by key sector

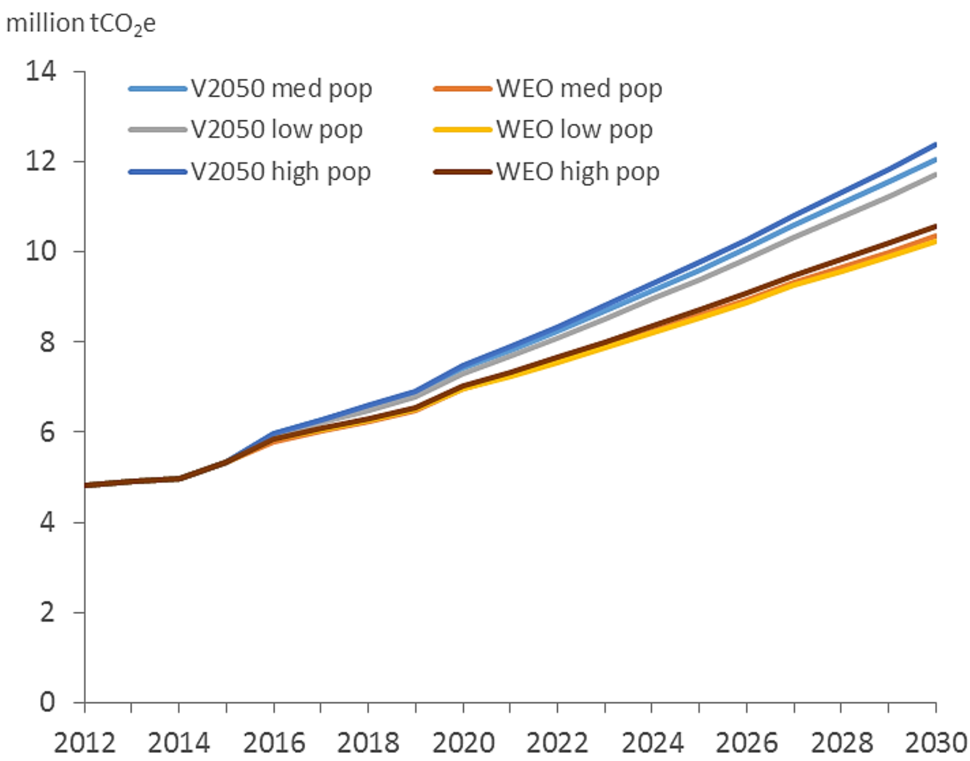


Source: Authors

Figure 3.19 shows the six alternative BAU projections for all emissions sources. The base case BAU results presented throughout this section are shown by the "V2050 med pop" series. The different projections are seen to cluster into two distinct groups according to two alternative GDP assumptions, within which the variations reflect the range of population forecasts. This clearly illustrates the importance of GDP growth assumptions to future BAU emissions, according to the methodological approach. According to the Vision 2050 assumption, emissions are forecast to rise to 12.1 million tCO_2e in 2030; under the economic growth rates envisaged by the IMF WEO source, this falls to 10.3 million tCO_2e, representing a reduction of around 15%.[16] Although noticeable, the impact of population upon emissions is secondary: within the Vision 2050 projections, population variations produce a range in emissions in 2030 of up to 5%, and within the IMF WEO projection a variation of up to 3%.

[16] Based on the medium population forecast.

Figure 3.19 BAU sensitivity results to 2030, total emissions



Source: Authors

Table 3.19 BAU sensitivity results to 2030, total emissions

GHG emissions (million tCO_2e)	2015	2020	2025	2030
Vision2050; high population	5.34	7.47	9.78	12.37
Vision2050; medium population (base case)	5.34	7.42	9.61	12.06
Vision2050; low population	5.34	7.30	9.39	11.72
IMF WEO; high population	5.34	7.03	8.72	10.56
IMF WEO; medium population	5.34	6.96	8.59	10.34
IMF WEO; low population	5.34	6.97	8.55	10.24

Source: Authors

4 ASSESSMENT OF NDC MITIGATION OPTIONS

4.1 Overview

This section describes an assessment of GHG mitigation options for Rwanda, undertaken in order to determine which options are most suitable within the NDC. The analysis was undertaken according to a three-step process:

- **Step 1: Identifying mitigation options**. A 'long-list' list of potentially suitable emission reduction projects and measures was developed through discussions and consultation with government officials, technical and sector experts, and other stakeholders.
- **Step 2: Assessing the potential**. The identified options were then assessed in terms of their mitigation potential through 2030 compared to the BAU reference scenario and their economic costs and benefits - by undertaking cost-benefit analysis (CBA).
- **Step 3: Evaluating the options**. The quantitative analysis undertaken in Step 2 was complimented by a broader, multi criteria-based, assessment in order to identify those options considered most suitable or feasible to be implemented under the NDC and to determine which can be implemented through domestic efforts ('unconditional' projects) and those requiring international support and finance ('conditional' projects), including through international market-based approaches e.g. under Article 6 of the Paris Agreement.

4.2 Identifying mitigation options

The first step of the assessment involved identifying a range of mitigation options from within the each of the NDC sectors for further consideration and quantitative analysis. A bottom-up 'long-list' was developed through close consultation with various stakeholders and experts, based on the following key sources:

- Rwanda's NDC (GoR, 2015a)
- Assessment of NAMAs in Rwanda (GoR, 2015b)
- "Adjusted" list of NDC options, as contained in the Rwanda NDC Implementation Plan (GoR, 2017b)
- Rwanda's TNC to the UNFCCC (GoR, 2018a)

Additional mitigation measures, including those identified from World Bank initiatives/plans and more recent government proposals, were also included. A workshop was held in June 2019 in order to identify and discuss the 'long-list' according to sector-based discussion groups.[17] Guided discussions focused on three elements:

1. **Review of NDC options**: What is the current status of these projects? What is the planned timing? What are the implementation arrangements and needs?
2. **Discussion of additional options**: What other options could be applicable in Rwanda? What are the key challenges? What are the policy gaps and support needs?

[17] Rwanda NDC Implementation Workshop on BAU and mitigation options, held on 18 June 2019, Serena Hotel Kigali

3. **Identifying data sources and gaps**: What are the existing information sources? Where are the key data gaps required for detailed analysis? Discussion of contact points and specific arrangements for follow-up data collection.

A modified ‘long list’ emerging from the workshop discussions was further refined, based on subsequent meetings held between the consulting team and government officials and sector experts though July 2019 - January 2020. The projects identified in the NDC were re-assessed, as well as additional projects and programmes. In some cases, the details, and context, regarding many of the projects were found to have changed since the time of INDC submission. The ‘long list’ of options identified thereby reflects a set of real projects and programmes under consideration, or having been studied, from within government departments and agencies.[18] As such, it represents a bottom-up process of national information gathering rather than an independent technical assessment of Rwanda’s full mitigation potential.

The table below presents the ‘long-list’ of mitigation across each of the sectors. The table indicates which of the identified measures were considered suitable/feasible for quantitative modelling as part of the mitigation technical assessment. Reasons for exclusion included one or more of the following:

1. **Uncertain mitigation effect**: several of the measures identified, including within the NDC, are likely to have valuable cross-cutting and/or ‘enabling’ effects upon mitigation outcomes although there is no clear methodological basis for quantifying possible GHG reductions (e.g. sustainable charcoal use).
2. **Lack of data and complexity**: some of the measures lack the specific data and assumptions considered necessary to undertake mitigation assessment, even at a high-level, and/or require complex calculations unsupported by sufficient information and data (e.g. Eco-park developments; Lake Kivu power project, which is considered as a mitigation project under the sensitivity analysis - see Section 5).
3. **Additionality and inclusion within BAU**: several measures considered as possible mitigation measures are considered to fall within the BAU scenario (e.g. reduction of power grid losses).

It should also be noted that these factors present inherent difficulties in demonstrating and quantifying mitigation effects from projects and programmes against the BAU baseline, which is a requirement of NDC reporting (e.g. transparent MRV). The table is a summary only: several of the measures shown comprise of sub-measures or different projects, each with their own technical and economic assumptions requiring separate assessment.[19] A total of thirty-eight separate mitigation assessments were identified for mitigation assessment (described further below).

[18] As such, the long-list of mitigation options can be considered to be a comprehensive list of mitigation options across Rwanda’s emitting sector but does not represent a technical assessment of the country’s full mitigation potential. Technically possible by highly unfeasible options (e.g. carbon capture storage) were not considered.

[19] Similarly, some of the measures also comprise several different actions or projects grouped together as a ‘package' for convenience.

Table 4.1 Long list of mitigation measures for Rwanda

Sector		Mitigation option	Brief description	Mitigation effect	Source			Mitigation modelling
Sector	Source				A-NDC	NDC	Other	
ENERGY	Electricity generation and distribution	Grid connected large hydropower	Development of 56.75 MW large hydro capacity (capacity > 5 MW), 24.5 MW small and mini hydro projects (capacity <5MW) and 75 MW regional projects by 2030.	Displacement of fossil-based generation (peat, diesel) and CO_2 emissions	✔	✔		✔
		Solar mini-grids	68 MWp of solar mini-grids to be installed in off-grid rural areas by 2030	Displacement of diesel and kerosene for domestic uses	✔	✔		✔
		Solar street lighting	Installaiton of solar lighting installations and panels for street lighting and public spaces	Displacement of fossil-based generation (peat, diesel) and CO2 emissions	✔	✔		✔
		Lake Kivu methane-to-power project	Additional 50 MW of CCGT capacity (Rwanda allocation) to reach total of 80 MW by 2028	Displacement of fossil-based generation (peat, diesel) and CO_2 emissions	✔			
		Reduction of grid losses	Reduction of grid losses from 21% to 15% by 2030	Reduction in fossil-based generation and CO_2 emissions	✔	✔		
	Transport	Improved public transport infrastructure and services in Kigali	Wide range of measures including bus rapid transport (BRT) project, bus lanes, non-motorised transport lanes, and other modal shift projects.	Reduced demand for personal vehicle use; reduced fuel use and CO_2 emissions.	✔	✔		✔
		Vehicle emissions standards and fleet renewal	Range of policies introduced to increase vehicle emissions performance of fleet, including tax incentives and scrappage of older vehicles	Improvement in fuel efficiency of vehicle fleet, reducing fuel demand and CO_2 emissions	✔	✔		✔
		Electric vehicles	Phased adoption of electric buses, passenger vehicles (cars), motorocycles from 2020	Displacement of diesel and gasoline fuel use by grid electricity		✔	✔	✔
		Electric rail between Isaka and Kigali	Implementation of the recently signed agreement to construct an electric rail between Isaka and Kigali.	Displacement of diesel and gasoline fuel use by HGVs and buses by grid electricity		✔		

Note: A-NDC = Adjusted NDC (contained within the Rwanda Detailed NDC Implementation Plan; GoR, 2017b); although no IPPC accounting methodology exists and project data are not available, Lake Kivu is modelled at a high-level as a mitigation option as part of the sensitivity analysis; see Section 5.

Sector		Mitigation option	Brief description	Mitigation effect	Source			Mitigation modelling
Sector	Source				A-NDC	NDC	Other	
ENERGY	Buildings (commercial and residential)	Efficient lighting in buildings	Dissemination of CFL and LED lamps to replace inefficient ones in residential, commercial and institutional buildings	Demand side management: reduced fossil-based generation and CO_2 emissions	✔	✔		✔
		Efficient cook stoves	Dissemination of efficient cook stoves to 80% of rural population and 50% of urban population by 2030	Reduced firewood and fossil energy consumption for cooking (and CO_2 emissions)	✔	✔		✔
		Off-grid solar and rooftop solar PV	Penetration of off-grid solar and rooftop solar PV panels	Displacement of diesel and kerosene for domestic and commercial energy use	✔	✔		✔
		Solar water heaters	Installation of solar thermal water heaters within urban residential buildings	Displacement of grid power and diesel consumption		✔		✔
		Renewable biomass: sustainable charcoal value chain	Increasing average charcoal yields up to 50% by 2030. Development of a sustainable charcoal value chain that can reduce demand of wood in charcoal production.	Reduced fossil fuel and non-renewable biomass consumption, leading to reduced CH_4 , N_2O and CO_2 emissions	✔	✔		
		Clean cooking: LPG for cooking	Clean cooking: Diffusion of LPG for cooking up to 25% in urban areas		✔	✔		
		Renewable biomass: Biogas digesters	Diffusion of biogas digesters, targeted at 3,500 domestic units and 15 institutional units per year (see below)		✔	✔		✔

Note: A-NDC = Adjusted NDC (contained within the Rwanda Detailed NDC Implementation Plan; GoR, 2017b)

Sector		Mitigation option	Brief description	Mitigation effect	Source			Mitigation modelling
Sector	Source				A-NDC	NDC	Other	
ENERGY	Energy use in manufacturing industry	Energy efficiency in agro-processing	A range of energy efficiency measures focused on reducing firewood and electricity consumption in the coffee and tea sector	Reduction in fossil-based generation and CO_2 emissions	✔	✔		✔
		Development of eco-industrial parks	Development of industrial parks at Kigali SEZ (276 Ha) and Bugesera (330 Ha) with companies deploying best practise and green technologies	Increased efficiencies in energy and resource use reducing energy emissions	✔	✔		
		Climate compatible mining	Phasing out of diesel gensets for on-site electricity consumption, to be replaced with grid and/or on-site renewable power production	Displacement of fossil-based on-site generation (diesel gensets) and CO_2 emissions	✔	✔		✔
		Implementation of efficient brick kilns	Phasing out the clamp kilns, and apply energy efficiency measures in brick industries	Reduction of fuel consumption in brick manufacturing and CO_2, CH_4 and N_2O			✔	✔
		Energy reduction in cement production	Waste heat recovery (WHR) and use of rice husks as fuel within clinker production	Reduced energy consumption (peat and fuel oil) and CO_2 emissions		✔		✔
	Energy use in agriculture	Energy use: Solar pumping for irrigation	Use of solar water pumping systems for irrigation to replacing diesel pumps	Displacement of fossil fuel use and associated CO_2 emissions			✔	✔
		Energy use: On-farm anaerobic digestion	On-farm anaerobic digestion of manure for bioenergy (links to biogas digesters above)	Displacement of fossil fuel use and associated CO_2 emissions, and also CH_4 from manure			✔	✔

Note: A-NDC = Adjusted NDC (contained within the Rwanda Detailed NDC Implementation Plan; GoR, 2017b)

Sector		Mitigation option	Brief description	Mitigation effect	Source			Mitigation modelling
Sector	Source				A-NDC	NDC	Other	
IPPU	Non-metallic mineral industries	Increased use of pozzalanas in cement production	Increased share of pozzalanas within cement beyond current cement-to-clinker ratio of 0.7. Introduction of a 2% substitution of clinker with pozzalanas from 2025 to 2029	Reduction in CO_2 emissions from clinker production			✔	✔
IPPU	Process emissions: F-gas	Gradual substitution of F-gases by less polluting substitutes	The calculated level of their consumption expressed in CO2 eq. was set to gradually decrease and not to exceed the following percentages: (a) 2020 to 2024: 95%; (b) 2025 to 2028: 65%; (c) 2029 to 2033: 30%	Gradual reduction of ODS such as HFC-134a, HFC-125, HFC-143a and HFC-32			✔	✔
WASTE	Solid waste	Landfill gas utilisation	Extraction and utilization of landfill gas (LFG) for power generation in connection to semi- or fully- controlled landfills for urban areas	Reduced CH_4 emissions from landfill sites and avoided CO_2 from displacement of fossil-based electricity use.	✔	✔		✔
WASTE	Solid waste	Waste-to-energy (WtE) plants	Development of WtE plants in Kigali and other urban areas through energy recovery options other than LFG.	Avoided CO_2 from displacement of fossil-based electricity use.		✔		✔
WASTE	Solid waste	Integrated solid waste management (ISWM)	Improved efficiency of waste management with reduced emissions to air, water and soil.	Improved waste management reduces CH_4 emissions. Materials and energy recovery from waste reduces CH_4 and CO_2 emissions.			✔	
WASTE	Solid waste	Aerobic composting	Development of commercial scale aerobic composting systems for agricultural and forestry residue, manure, food processing, kitchen and garden waste, and biosolids (organic solids from treated sewage). Rural areas only.	Reduction in CH_4 emissions, since methane-producing microbes are not active in the presence of oxygen.			✔	✔
WASTE	Waste water	Sludge management	Development of sludge management projects within six secondary cities, as described in the Water and Sanitation Sector Strategic Plan 2018-2024.	Reduction in CH_4 emissions and N_2O emisisons.			✔	
WASTE	Waste water	Waste-water treatment and re-use	Energy production from wastewater using waste-to-energy technologies, reducing methane emissions from wastewater and expansion of wastewater treatment plants.	Reduction of CH_4, and CO_2 emissions.	✔	✔		✔

Note: A-NDC = Adjusted NDC (contained within the Rwanda Detailed NDC Implementation Plan; GoR, 2017b)

Sector		Mitigation option	Brief description	Mitigation effect	Source			Mitigation modelling
Sector	Source				A-NDC	NDC	Other	
AFOLU	Agriculture	Improved efficiency of applied fertilizers	Increased use of organic waste in soil fertilizers, supported by target to apply composting within all agricultural households by 2030; more judicious fertilizer use - introduction of site- and crop- specific mineral fertilizer recommendation for all major crops. Promotion of fertigation to enhance fertiliser uptake..	Reduced N_2O emissions from urea fertilizer use. Reduced CH_4 from (avoided) waste sent to disposal.	✔	✔	✔	✔
		Soil and water conservation measures (terracing; crop rotation; multicropping)	Comprises three measures: (1) Installation of 165,000 Ha land protection terracing structures in sloped arable areas to present soil erosion; (2) Continous rop rotation of 600,000 Ha; (3) Multicropping of coffee and bananas of 40,000 Ha.	Prevention of soil erosion, leasing to reduce CH_4 and N_2O emissions and carbon sequestration in soils.	✔		✔	✔
		Conservaton tillage	Reduction in vertical movement of soil, leaving more crop residue on the soil surface, thereby reducing soil erosion.		✔			✔
		Improved livestock husbandary	Promotion of better livestock feed (i.e. legume fodder species) and training in better livestock management.	Reduction in GHG emissions (CH_4) from enteric fermentation		✔		✔
		Improved livestock species and population	Replacement of 10% domestic cows with improved cow species; expansion of fish farming, poultry and other small livestock to increase protein food supply without increasing cows; and change in livestock mix	Reduction in GHG emissions (CH_4) from enteric fermentation		✔		✔
		Improved manure management	Adoption of more efficient manure management systems, includin promotion of collective farms and training	Reduction in GHG emissions from manure management.		✔		✔

Note: A-NDC = Adjusted NDC (contained within the Rwanda Detailed NDC Implementation Plan; GoR, 2017b)

4.3 Assessing the potential

4.3.1 Mitigation potential

Figure 4.1 summarises the estimated emissions reduction potential in 2030 for all mitigation measures assessed from the 'long list' presented in Table 4.1.

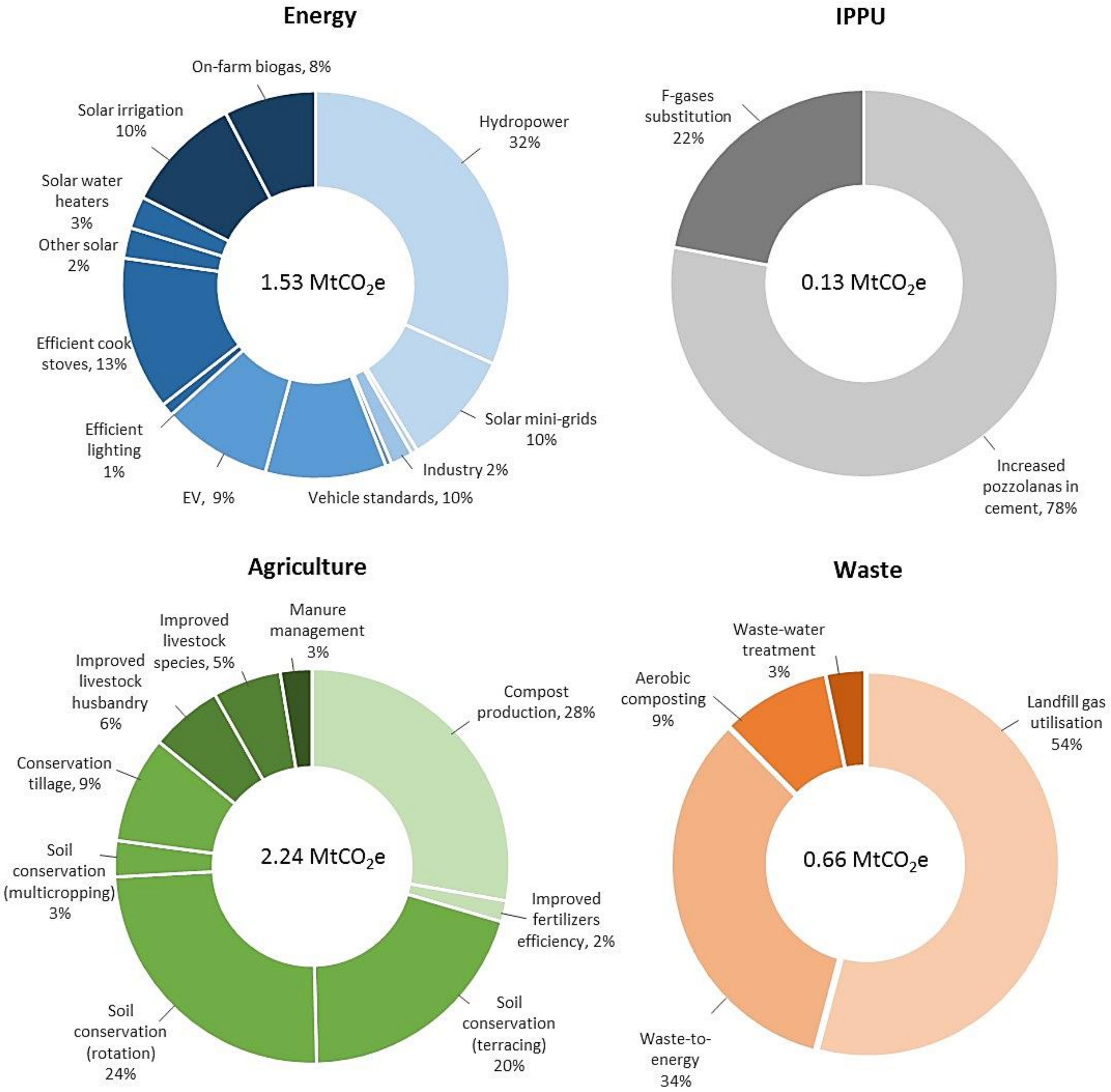
The pie charts indicate the relative contribution made from projects within the key sectors of energy (electricity generation, industry, transport, commercial and residential, and agriculture), waste, IPPU and agriculture against the base case BAU projected emissions described in Section 2. The total mitigation potential is estimated at around 4.6 million tCO_2e in 2030 compared to base case BAU emissions in the same year of 12.1 million tCO_2e. According to the analysis, mitigation measures identified within the agriculture sector accounts for 49% of the total potential, followed by energy (34% of total), waste (14%), and IPPU (3%).

Within agriculture, soil conservation measures – which include terracing, conservation tillage, multi-cropping and crop rotation practices – account for around half of the sector's mitigation potential. The bulk of the remaining mitigation potential includes measures to reduce enteric fermentation emissions from livestock, including the introduction of new species to replace local herds and improved husbandry, and the use of windrow composting.

Within energy use, increased use of renewables to meet increasing energy demand dominates the mitigation potential. Significant emissions reduction potential exists across each of the main sub-sectors. Hydropower, covering large- and small-scale new generation, represents the largest share of the identified GHG reduction potential, followed by the use of solar energy for water heating, pumping for agricultural irrigation and off-grid electricity which together account for around a quarter of all mitigation. Emissions reductions arising from use of electric vehicles and vehicle fuel economy standards are also considered to be potentially significant, although assumptions around the rate of implementation over the coming decade (e.g. new vehicles entering the fleet and development of charging infrastructure) and the rate of electricity grid decarbonisation achieved are key to the net level of abatement achieved.

Within waste, the most significant potential is identified within energy utilisation measures such as landfill gas recovery and direct waste-to-energy (WtE) plants. Mitigation potential from IPPU sources is by comparison relatively limited, with the majority of emissions reductions arising from increased use of clinker substitute for cement production (volcanic pozzolanas), followed by reduction of fluorinated gases (F-gases), in line with the Kigali amendment of the Montreal Protocol on Substances that Deplete the Ozone Layer (UN, 1987).

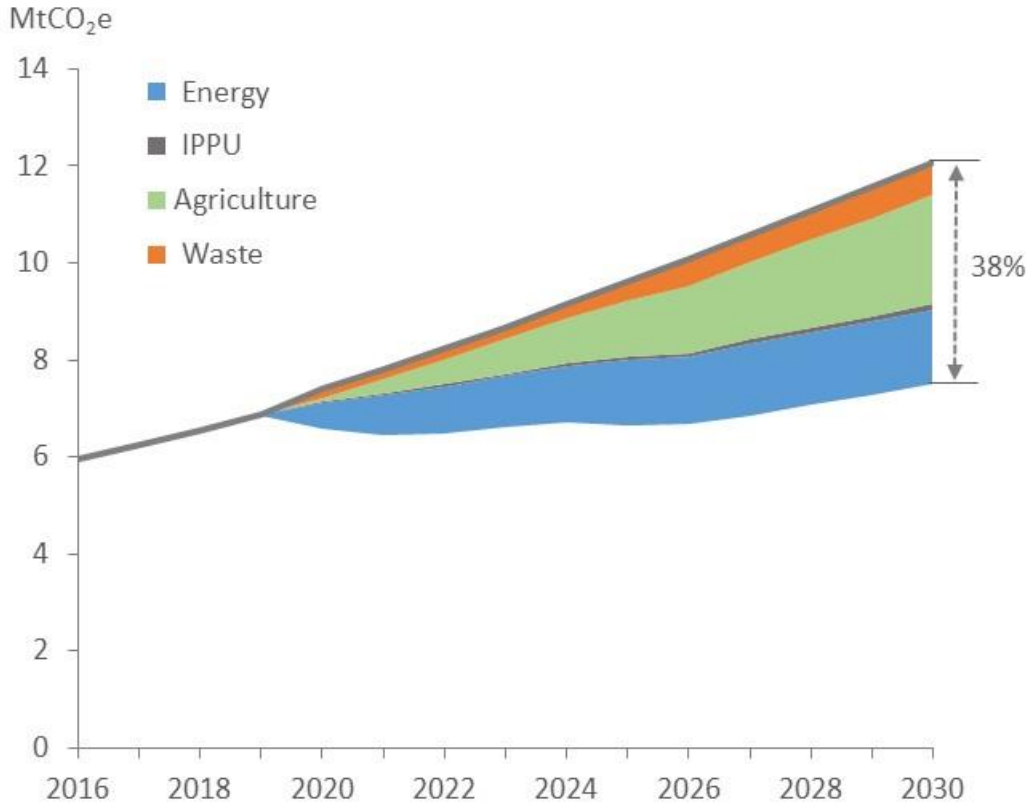
Figure 4.1 Estimated GHG mitigation potential in 2030 from all measures



Source: Authors

The total mitigation potential against the base case BAU projection through 2030 is shown in Figure 4.2 below. The graphs show the relative contribution of each sector, clearly illustrating the dominance of those measures aimed at reducing emissions from agriculture and energy use.

Figure 4.2 Mitigation potential from all projects versus BAU projection, 2016-2030



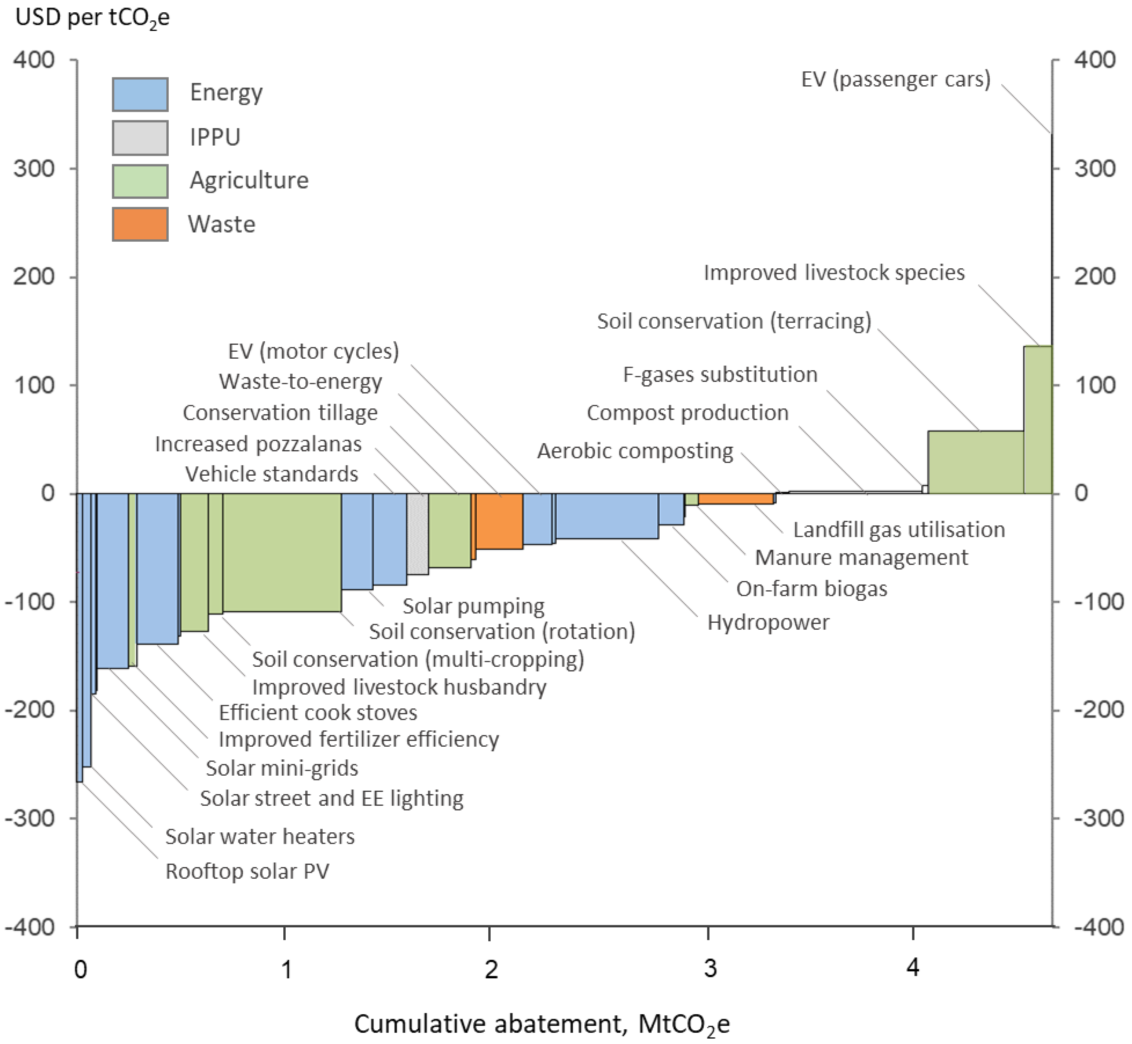
Source: Authors

4.3.2 Mitigation costs and benefits

Figure 4.3 shows a marginal abatement cost curve (MACC) in which each of the identified NDC mitigation options is sorted in ascending order of abatement cost. The costs shown are taken from the NPV values generated by the CBA and therefore represent socio-economic costs of abatement, reflecting both costs and benefits to the wider economy. The MACC presents a useful way of assessing the relative costs and contribution of the mitigation potential for each of the key options assessed, although their use has limitations with results being highly sensitive to input assumptions (see Annex A)[20]. Due to the large number of measures included, a number of smaller options are not indicated. These are however shown within the sector-specific MACCs presented further below.

[20] Mitigation options can interact and overlap according to their specific mix within a scenario seeking to simulate the energy system. This is particularly the case in which supply- and demand-side mitigation measures co-exist: the emissions reductions estimated for a demand-side measure reducing demand for grid electricity must reflect the carbon-intensity of the grid associated with the inclusion of supply-side mitigation projects and not the BAU baseline grid. Otherwise, total emissions reductions shown on the curve would be overestimated. Because the mitigation options were not modelled top-down according to e.g. cost optimization or computable general equilibrium (CGE) type modelling, abatement from supply-side options were calculated before the calculation of mitigation from the (relatively few) relevant demand-side options. For these reasons, CBA and abatement costs were recalculated for each NDC mitigation scenario in order to ensure a mutually consistent suite of options developed as a scenario avoiding overestimation of mitigation potential.

Figure 4.3 Marginal abatement cost curve for all identified mitigation measures in 2030



Source: Authors

The figure highlights the large mitigation potential within the long list of identified options principally through measures within agriculture and energy use. Importantly, many of the projects are seen to be cost-effective with net benefits outweighing net costs, shown here as 'negative' abatement costs - the majority of the abatement potential shown on the curve, around 3.3 million tCO_2e or 72% of the total, is achieved at negative socio-economic cost. This is most noticeable for energy projects. This is consistent with other abatement cost curves globally, reflecting the fact that these include a range of measures involving the displacement of imported fossil fuels through increasing the use of indigenous renewable energy and cost-efficient demand-side interventions (e.g. reducing diesel fuel use in inefficient and polluting generation sets, and diesel and gasoline in road transport). The majority of the waste sector options identified are also considered to be cost-effective on an economic basis, including landfill gas utilisation and WtE projects which utilise waste materials for economic energy production whilst also delivering wider employment and revenue benefits. Within agriculture, cost-effective options such as crop rotation and improved livestock husbandry can also deliver GHG reductions with important co-benefits e.g. through increased yields and economic output.

The higher cost options shown on the curve are seen to fall mainly within the agriculture sector. These include the use of terracing which is assessed to have extremely high investment costs relative to the estimated mitigation potential achieved and the introduction of improved livestock species involving significant compensation for existing herds and capital costs of replacement crossbreed cow species. EV passenger cars are also estimated to be high cost, reflecting the incremental vehicle costs relative to conventional models and significant charging infrastructure costs.

A more detailed description of the economic assessment is provided in Annex A for each sector, including a description of each mitigation measure and the mitigation and CBA analysis assumptions. Investment cost estimates are presented in Section 10 (Funding Requirements).

4.4 Evaluating the options

The identified mitigation options were assessed according to a multi-criteria evaluation framework. This was undertaken partly to assess the suitability of the identified measures within the NDC, and also to help inform the decision of which could be considered 'unconditional' domestically supported measures, and which could be instead considered as 'conditional' on international support.

The above sections describe an economic assessment made for the full list of options, presenting the results of a cost-benefit analysis and estimated abatement costs. Although economic efficiency is a key criterion, mitigation prioritised are typically not optimised solely for cost-effectiveness. This is because the choice of options, and the national policy framework designed to deliver mitigation and adaptation aims, must also respond to other key issues such as e.g. local pollution reduction, energy security, energy access, poverty, and seeking reduced electricity tariffs. A broader evaluation framework is needed.

Suitable mitigation options seek to maximise the following key criteria:

- **Environmental effectiveness**: mitigation actions should achieve real emissions reductions, at the national and global level, whilst minimising indirect environmental impacts and ensuring resilience to climate change impacts.
- **Socio-economic impacts and co-benefits**: mitigation actions should prioritize the most cost-effective options including those with developmental co-benefits and be acceptable to all entities involved taking account of impacts and risks to affected groups including households, businesses, and communities.
- **Feasibility of implementation**: mitigation actions should be feasible to implement in the specific context of the national infrastructure and the legal framework, be in alignment with national policy aims and objectives, and be suitable to international support and climate finance.

A set of criteria was chosen according to these three broad categories, drawing from international literature and guidance on good practice climate policy development (IPCC, 2007). Table 4.2 describes the evaluation criteria used to assess and prioritise each of the identified mitigation options.

Table 4.2 Evaluation criteria for mitigation options

Environmental effectiveness	Contribution towards NDC target	Does the mitigation option offer the ability to deliver significant and/or scaled-up and replicable GHG benefits towards meeting the NDC target through 2030?
	Indirect environmental effects	Are there other (non-GHG) environmental impacts arising from implementation? May include negative impacts (e.g. biodiversity and landscape loss) and positive impacts (environmental co-benefits).
	Adaptation and climate considerations	Are there interactions and alignment with adaptation and climate change vulnerability risks and policy aims?
Socio-economic impacts and co-benefits	Cost-effectiveness	Does the mitigation option deliver GHG reductions cost-effectively i.e. at low or negative economic net cost?
	Welfare and equity	Are there possible changes to welfare within effected groups, including changes to prices and distributional outcomes? May include both negative impacts (e.g. increased costs for low income households) and positive impacts.
	Competitiveness and productivity	What are the potential impacts upon business and the wider economy? May include negative impacts (e.g. increased operating costs and administrative burden) and positive impacts (e.g. increased efficiency, reduced operating costs).
	Green growth and employment	Ability to deliver additional employment and green growth opportunities within the country.
Feasibility of implementation	Alignment with other policy aims	Is the mitigation option in alignment with national policy aims and objectives (e.g. national strategies for economic development, employment, poverty alleviation and energy provision)?
	Legal and regulatory feasibility	Are there potential issues with implementation arising from the legal and/or regulatory framework?
	Suitability to funding and climate finance	Is the mitigation option suited to attracting funding, including both commercial investment and public sector lending and/or international and bilateral climate finance (e.g. suitability of technology or project type)?
	Other implementation challenges	Are there other key challenges, risks and barriers likely to impact the chance of project implementation within a mix of options designed to meet the NDC?

Source: Adapted from various sources including IPCC, 2007

Through discussion exercises within the consulting team, each option was assessed against the criteria and classified according to one of the following:

- **High performance**: clearly performs very well against the criteria, accounting for key uncertainties and the specific real-world context under which the option would be implemented.
- **Medium performance**: performs well against the criteria, although to a lesser extent than above.

- **Mixed or uncertain performance**: there are likely to be mixed outcomes against the criteria or significant uncertainties around the likely performance.
- **Low performance**: performs poorly against the criteria, accounting for key uncertainties and the specific real-world context under which the option would be implemented.

Based on these evaluations, each option was then assessed according to whether it was considered to be a high, medium or lower priority option. This process was undertaken through discussion and expert judgement based on the overall performance within each of the three broad categories, but also noting the benefit of including within the NDC a range of options implemented across multiple sectors and mitigation project types. A formalised scoring or ranking system was not used.

The tables below summarise the results of the evaluation and prioritization process for each of the sectors (energy, IPPU, waste, and agriculture). The colours and symbols shown in the evaluation tables are explained as follows:

EVALUATION CRITERIA	EVALUATION OUTCOME
High performance	High priority mitigation option
Moderate performance	Medium priority mitigation option
Mixed or uncertain performance	Lower priority mitigation option
Low performance	Inappropriate mitigation option

On the balance of the criteria evaluation framework, and informed by some of the additional considerations noted above, the majority of the assessed options were considered to be 'high priority' or 'medium priority' options; no options are considered inappropriate as part of Rwanda's NDC efforts. All measures were also considered to be potentially applicable for implementation before 2030, subject to finance support and overcoming implementation challenges.

The outcome of the initial evaluation and prioritisation can be summarised as follows:

- **Energy:** The large majority of the identified measures are considered to be suitable or highly suitable as NDC actions. All measures are well aligned with national policy aims and goals, including e.g. improving access to modern energy sources, increasing electrification, reducing resource use and fuel import dependence, and developing indigenous low carbon energy - as envisaged within guiding strategies such as the ESSP, Vision 2050, Sustainable Energy for All (2015-2030), National Electrification Plan (NEP) and others. As demonstrated above, most measures are considered cost-effective from a socio-economic perspective, having important co-benefits such as job creation, reduced fossil fuel dependency and socio-economic development. Despite having important benefits, several measures within road transport are considered to be high cost options (e.g. electric passenger cars and public transport bus schemes), although it should be noted that health benefits associated with reduced urban air pollution have not been quantified. Furthermore, the analysis of public transport measures is very simplified and excludes the potential role of e.g. road network improvements and urban decongestion investments which can have significant benefits in terms of fuel and emissions savings. Other measures face significant implementation challenges such e.g. local expertise and capacity to install off-grid systems and access to finance to support energy efficiency investments in industry. Such projects will require support through international funding sources and/or climate finance (discussed further below).

- **IPPU and waste:** All of the measures are considered suitable or highly suitable as mitigation options, and well aligned with government policy priorities and goals relating to industrial, waste and economic development policy. Although making a relatively small contribution in terms of overall emissions reductions, both F-gas reduction and clinker reduction measures within IPPU represent cost-effective mitigation actions consistent with environmentally sustainable industrial practise as well as others e.g. Kigali Amendment to the Montreal Protocol and the national 'Made in Rwanda' policy goal. The identified waste sector measures are similarly considered to be cost-effective and well-aligned with key government policies such as the 2016 National Sanitation Policy and NST1 objectives. A range of technical and financing challenges, as well as the need for increasing local capacity and expertise, will likely require international support to deliver waste-to-energy and landfill gas utilisation projects, however.
- **Agriculture:** As with the other sectors, most of the measures are considered to be suitable as mitigation options and well aligned with key sector policies, for example the national Crop Intensification Program (CIP) and Livestock Intensification Program (LIP). The techno-economic analysis also indicates the significant emissions reduction potential within both crop/soil management and livestock activities, arising largely from enhanced carbon stock retention and a reduction in methane emissions from enteric fermentation. Despite these benefits, several measures such as the introduction of new livestock species and conservation terracing are considered to be high-cost relative to their estimated mitigation levels and face significant funding and other implementation challenges. As such, several agriculture measures will require significant international technical and financial support.

EVALUATION CRITERIA

- High performance
- Moderate performance
- Mixed or uncertain performance
- Low performance

		ENERGY																	
		Electricity			Manufacturing				Transport				Commercial & residential					Agriculture	
		Hydropower projects	Solar mini-grids	Solar street lighting	EE agroprocessing	Climate compatible mining	Efficient brick kilns	EE cement production	Public transport (buses)	Vehicle emissions standards	Electric motorcycles	Electric LDVs	Efficient lighting in buildings	Efficient cook stoves	Off-grid solar electrification	Roof top solar PV	Solar water heaters	Solar pumping for irrigation	On-farm biogas
EVALUATION CRITERIA: Environmental effectiveness	Contribution towards NDC target	High	High	Moderate	Moderate	Moderate	Moderate	High	Mixed	High	High	Low	Moderate	High	Moderate	Moderate	High	High	Moderate
	Indirect environmental effects	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High
	Adaptation and resilience considerations	Mixed	Moderate	Mixed	High	Moderate	High	Mixed	High	Mixed	Mixed	Mixed	Mixed	High	High	Mixed	High	Moderate	High
Socio-economic impacts and co-benefits	Cost-effectiveness	Moderate	High	High	High	Moderate	High	Moderate	Mixed	High	Moderate	Mixed	High	High	High	High	High	High	Moderate
	Equity and welfare	High	High	High	Moderate	Moderate	Moderate	Moderate	Moderate	High	High	Mixed	High	High	High	High	High	High	High
	Competitiveness and productivity	High	High	Moderate	High	High	Moderate	Moderate	Moderate	High	Moderate	Mixed	High	High	High	High	High	High	Mixed
	Green growth and employment	High	High	High	Mixed	Mixed	High	Mixed	Moderate	Moderate	Mixed	Mixed	High	High	High	High	High	High	High
Feasibility of implementation	Alignment with other policy aims	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High
	Legal and regulatory feasibility	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High	High
	Suitability to funding and climate finance	High	High	High	Moderate	Moderate	High	Moderate	Moderate	High	Moderate	Moderate	High	High	High	Moderate	High	High	High
	Other implementation challenges	High	Mixed	High	High	High	High	Mixed	High	High	High	High	High	High	High	Mixed	Moderate	High	High
OUTCOME	Short-term options - 2020-2025			✓	✓	✓		✓	✓	✓			✓	✓	✓		✓	✓	✓
	Medium-term options - 2025-2030	✓	✓				✓				✓	?				✓			
	Unconditional measure (domesticly supported)	■		■	■	■	■	■		■			■	■				■	
	Conditional measure (international support)		■						■		■	■			■	■	■		■

EVALUATION CRITERIA

- ● High performance
- ● Moderate performance
- ● Mixed or uncertain performance
- ● Low performance

		IPPU		WASTE				AGRICULTURE								
								Crops and soil						Livestock		
		Increased pozzalanas in cement	F-gases substitution	Landfill gas utilisation	Waste-to-energy (WtE) plants	Aerobic composting	Waste-water treatment & re-use	Compost production	Improved fertilizer efficiency	Soil conservation - terracing	Soil conservation - rotation	Soil conservation - multicropping	Soil conservation - cons.tillage	Improved livestock husbandry	Improved livestock	Improved manure management
Environmental effectiveness	Contribution towards NDC target	Mixed	Mixed	High	High	Moderate	Mixed	Moderate	Mixed	Moderate	High	High	Moderate	Moderate	High	Mixed
	Indirect environmental effects	Moderate	High	High	High	High	High	High	Moderate	High	Moderate	High	High	High	Mixed	Mixed
	Adaptation and resilience considerations	Moderate	High	Moderate	Moderate	High	High	High	Mixed	High	High	High	High	High	Mixed	Moderate
Socio-economic impacts and co-benefits	Cost-effectiveness	High	Moderate	High	High	Moderate	High	Moderate	High	Low	High	High	Moderate	High	Low	High
	Equity and welfare	High	Mixed	High	High	High	Mixed	High	Moderate	High	High	High	High	High	Mixed	Mixed
	Competitiveness and productivity	High	Moderate	High	High	High	High	High	Moderate	Moderate	Moderate	High	Moderate	High	High	Moderate
	Green growth and employment	High	Moderate	Moderate	High	High	High	High	Mixed	High	Mixed	High	Mixed	High	High	High
Feasibility of implementation	Alignment with other policy aims	High	High	High	High	Moderate	High	High	High	High	High	High	Moderate	High	High	Mixed
	Legal and regulatory feasibility	Moderate	High	High	High	Mixed	High	High	Mixed	High	Mixed	Mixed	High	High	Mixed	Mixed
	Suitability to funding and climate finance	Mixed	High	High	High	Moderate	High	Moderate	Mixed	High	Mixed	High	High	High	Mixed	Moderate
	Other implementation challenges	Moderate	Mixed	Mixed	Moderate	Mixed	Mixed	Moderate	Moderate	Moderate	High	Moderate	High	High	Mixed	Moderate

Short-term options - 2020-2025	✓	✓	✓	✓	✓	✓									
Medium-term options - 2025-2030							✓	✓	?	✓	✓	✓	✓	?	✓
Unconditional measure (domesticly supported)	■	■								■			■		■
Conditional measure (international support)			■	■	■	■	■	■	■		■	■		■	

4.4.1 Unconditional and conditional projects

The above indicates that all the options are potentially suitable as NDC measures. However, as shown from the economic analysis, many of the identified projects will require significant financial support. Developing country Parties to the UNFCCC are asked to identify the 'means of implementation' relating to their NDC mitigation measures, including the scale of international support required. In response, most are communicating their NDC contributions according to two different components:

- **Unconditional contribution**: Those mitigation measures and policies which will be implemented 'unconditionally' through domestic efforts alone (e.g. funded within committed national policy plans and actions); and
- **Conditional contribution**: Additional mitigation measures which could be implemented, but only conditional upon the availability of international support (including funding and other types of support from donors, climate finance and potentially carbon markets).

This approach was taken within Rwanda's INDC, and after discussions with the GoR, it was agreed that this approach would also be used to frame the NDC target(s) for mitigation. This there required classifying each of the mitigation measures as either an 'unconditional' or 'conditional' action.

The multi-criteria evaluation process outlined above provided a basis for the consulting team to discuss and then propose such a grouping of the mitigation measures.[21] In so doing, the following broad considerations were also used to help guide the choices:

1. **Costs and investment levels**: Higher cost projects and those requiring significant investment levels are typically considered more suitable to international support given national budget and resource constraints.
2. **Inclusion within existing national policies and sector plans**: Several projects and measures are already included within national policy planning and budgeted within sector plans: these can therefore be viewed as domestically committed.
3. **Suitability to international support**: Measures are more or less suited to existing and emerging forms of support (e.g. under Article 6 of the Paris Agreement), both in terms of projects types and their likelihood to demonstrate real and measurable, and additional, mitigation outcomes.

The subsequent proposed grouping of conditional and unconditional NDC measures was shared with key stakeholders and government departments for in-depth discussion and validation from October 2019 to January 2020. The resulting classification is shown below.

[21] This discursive approach was intentionally adopted instead of a more structured or formal methodology, based on the judgment of the consulting team and through discussion within the counterpart. This was informed in part by time constraints and also the 'bottom up' nature of the approach to project identification and evaluation, according to which the government had already taken a clear view on which projects were part of centrally budgeted plans and policies, and which required additional support as mitigation interventions. The consulting team acknowledge that other more formalised approaches can be adopted through use of tools, checklists, criteria-based scoring systems etc.

Table 4.3 Unconditional and conditional NDC mitigation measures

	NDC measure	Unconditional	Conditional
ENERGY	Hydropower	✔	
	Solar mini grids		✔
	Solar street lighting	✔	
	EE agro-processing	✔	
	Climate compatible mining	✔	
	Efficient brick kilns	✔	
	EE cement production	✔	
	Public road transport (buses)		✔
	Vehicle emissions standards	✔	
	Electric motorcycles		✔
	Electric cars		✔
	Electric buses		✔
	Efficient lighting in buildings	✔	
	Efficient cook stoves	✔	
	Off-grid solar electrification		✔
	Roof top solar PV		✔
	Solar water heaters		✔
	Solar pumping for irrigation	✔	
	On-farm biogas		✔
AGRICULTURE	Improved fertilizers		✔
	Soil and water conservation (terracing)		✔
	Soil and water conservation (rotation)	✔	
	Soil and water conservation (multicropping)		✔
	Conservation tillage		✔
	Improved livestock husbandry		✔
	Improved livestock species and population	✔	
	Improved manure management	✔	
IPPU	Increased pozzolanas in cement	✔	
	F-gases substitution	✔	
WASTE	Landfill gas utilisation		✔
	Waste-to-energy (WtE) plants		✔
	Aerobic composting		✔
	Waste-water treatment and re-use		✔

5 ALTERNATIVE GHG PATHWAYS

5.1 NDC mitigation scenarios

This section presents alternative GHG emissions pathways through 2030 based on the technical analysis described in the sections above.

The implementation of NDC mitigation measures through the period 2030 will determine the level of emissions reductions achieved against the BAU baseline. Against the BAU emissions baseline, two basic NDC mitigation scenarios were modelled:

- **All NDC measures:** This scenario estimates the emissions reduction pathway achieved through implementation of all the identified mitigation options considered suitable as NDC measures. This includes both unconditional and conditional measures. Because none of the identified options were assessed to be inappropriate, this scenario can therefore be seen as an 'upper end' estimate of how much mitigation potential could be achieved within the NDC sectors through 2030, subject to support.
- **Domestic measures:** This scenario estimates the emissions pathway achieved through implementation of 'unconditional' domestically supported projects only. These represent those projects already committed within government plans and programmes or incentivised sufficiently for private sector implementation to proceed.

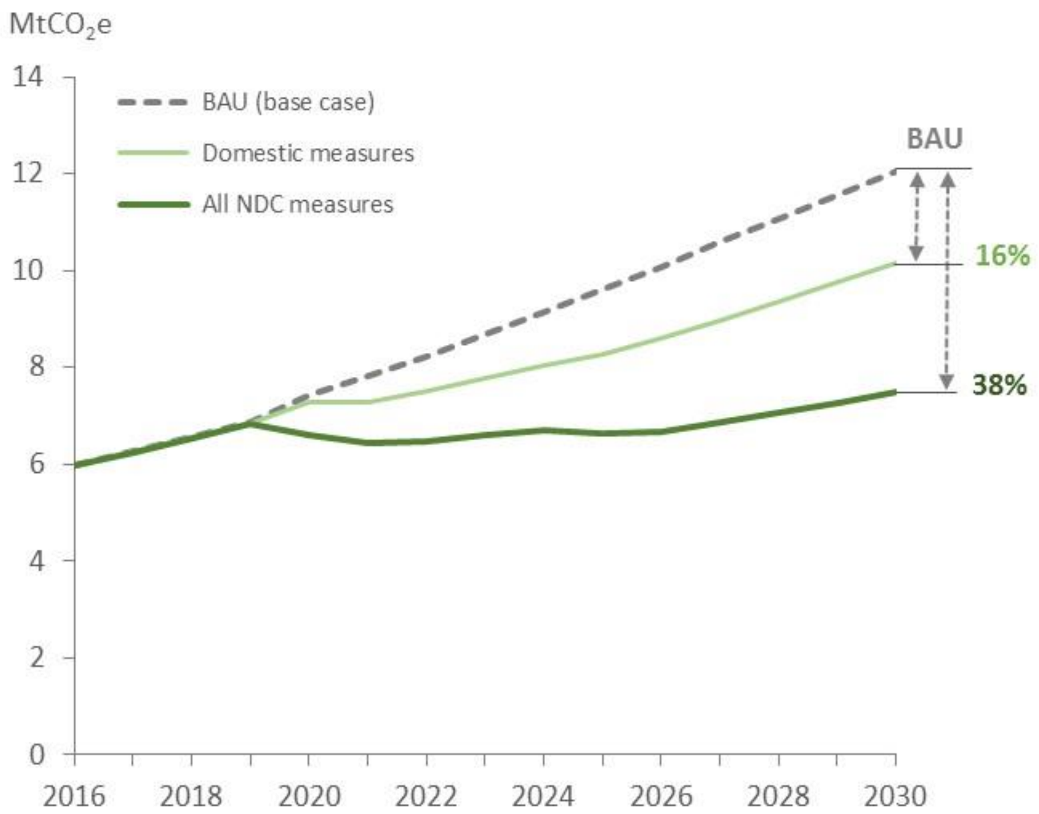
These two mitigation scenarios provide the basis for Rwanda to propose an unconditional and conditional contribution within its revised NDC. Mitigation and investment cost requirements for each scenario were also estimated, followed by sensitivity analysis relating to variations in (a) the BAU emissions forecast and (b) reduced project implementation and mitigation outcomes relative to BAU, as described further below.

5.2 Modelling results

Figure 5.1 illustrates the emission projections for the (base case) BAU baseline and the two alternative NDC mitigation scenarios. The associated values are shown in Table 5.1.

The graph shows emissions more than doubling under the BAU projection from 5.3 MtCO_2e in the base year to around 12.1 MtCO_2e in 2030. According to the alternative GHG pathway which implements the domestically supported unconditional NDC measures, it is estimated that by 2030 emissions would instead rise to around 10.2 MtCO_2e, representing a reduction against BAU of around 16%. The second NDC mitigation scenario, showing the total mitigation potential from both domestic and conditional mitigation measures, sees emissions increasing only slightly over the period, to around 7.5 MtCO_2e, equal to a reduction of 38% by 2030 against the same baseline.

Figure 5.1 NDC emission reduction scenarios against BAU (base case)



Source: Authors

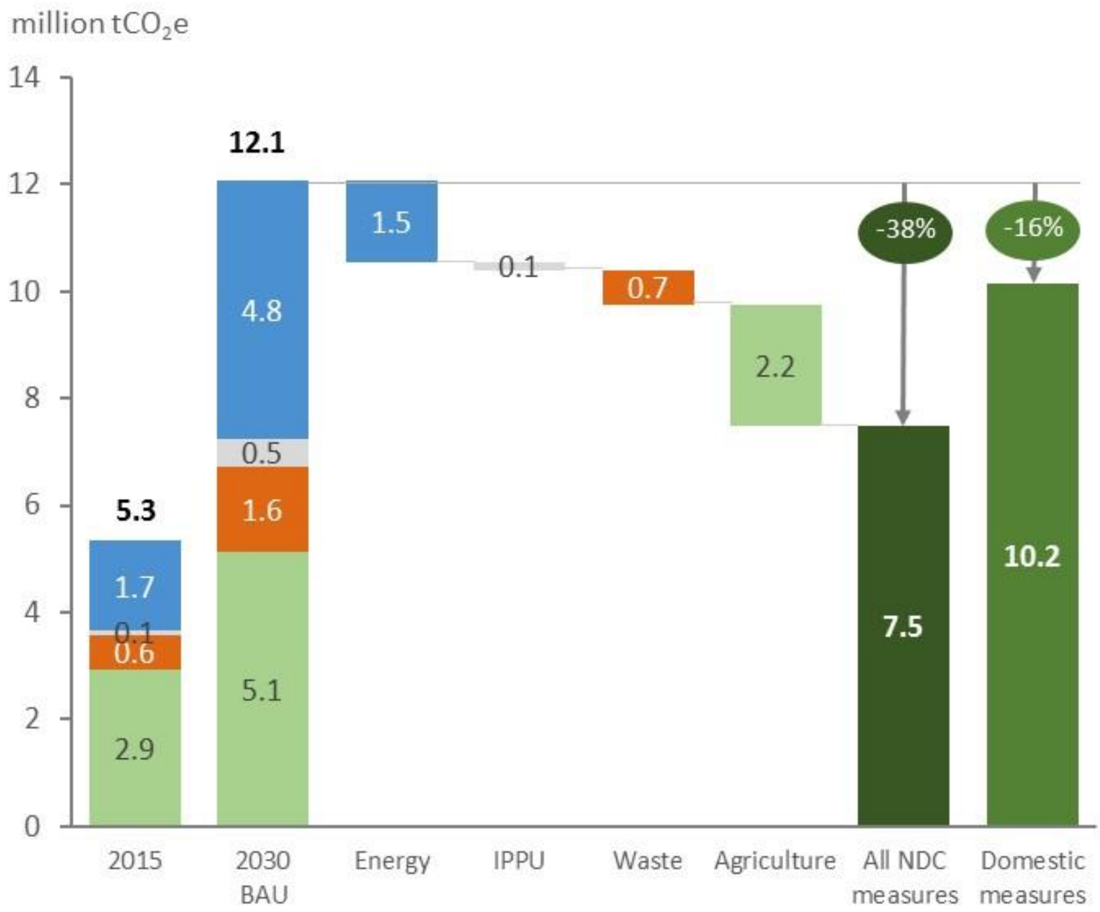
Table 5.1 Emissions projections under NDC scenarios and BAU (base case)

Scenario	2015	2020	2025	2030
Total emissions ($MtCO_2e$)				
BAU reference case (Vision2050)	5.33	7.42	9.61	12.06
Domestic NDC measures	5.33	7.27	8.26	10.16
All NDC measures	5.33	6.59	6.64	7.50
Reduction relative BAU				
Domestic NDC measures	-	2%	14%	16%
All NDC measures	-	11%	31%	38%

Source: Authors

The BAU and NDC mitigation scenarios are summarised in Figure 5.2 below, which also shows the contribution of each sector to the total estimated potential based on the technical assessments of all mitigation measures.

Figure 5.2 NDC emissions reduction scenarios



Source: Authors

5.3 Sensitivity analysis

Sensitivity analysis was undertaken around three key areas of uncertainty with an important impact on future GHG pathways and the levels of mitigation reported under NDC scenarios:

- **Economic growth outlook**. Lower GDP growth has the primary effect of reducing economy-wide emissions growth in the baseline scenario with the potential for defined mitigation measures to achieve greater *relative* mitigation (i.e. in percentage terms)
- **Project implementation and implementation**. Sub-optimal implementation of mitigation measures — whether through project delay, scale-back, cancellations or lower than expected delivery — will result in lower mitigation outcomes.
- **Treatment of Lack Kivu methane power generation**. Due to lack of IPCC reporting guidance and lack of data required to estimate project emissions, the Lake Kivu methane power project has not been assessed as an NDC measure within the base scenario. If

treated as a low carbon project, its inclusion as a conditional project could however deliver significant additional emissions reductions.

Each of these three sensitivity cases is presented below.

5.3.1 Economic growth outlook

Sensitivity analysis was undertaken in order to estimate the impact of a lower GDP growth scenario. As described earlier, future GDP growth is considered to be a major driver guiding sector activity and associated GHG emissions growth through 2030. Developing an assessment of emissions growth and mitigation potential based on an alternative economic outlook is therefore useful in testing the impacts of uncertainty around this key driver.

Figure 5.3 and

Table 5.2 summarise the results of the same two NDC scenarios presented above applying an alternative lower GDP projection. In this case, BAU emissions increase to around 10.3 mtCO_2e in 2030, compared to the value of 12.1 MtCO_2e in 2030 based on Vision 2050 growth assumptions (base case). According to this lower growth forecast, it can be seen that the relative emissions reductions achieved through each of the NDC scenarios is now larger, compared to the base case. This result is largely due to the fact the emissions reductions estimated for most of the identified measures are assumed to be implemented independent of economic growth assumptions in the baseline. For example, assumptions and data inputs around the roll-out and coverage of most government programmes relating to energy use, waste and agriculture are assumed to remain the same independent of economic performance and future demand.[22]

[22] This is recognised as a simplification and limitation within the methodology since implementation and coverage will in many cases respond to changes in factors such as energy demand, household numbers, agricultural output etc. In some cases under a lower growth scenario certain identified measures may not even proceed due to lack of demand e.g. new renewable generating capacity. These dynamic effects have not been captured, with the result that the mitigation potential is likely to be overestimated for this specific sensitivity case.

Figure 5.3 NDC emission reduction scenarios against BAU (lower GDP)

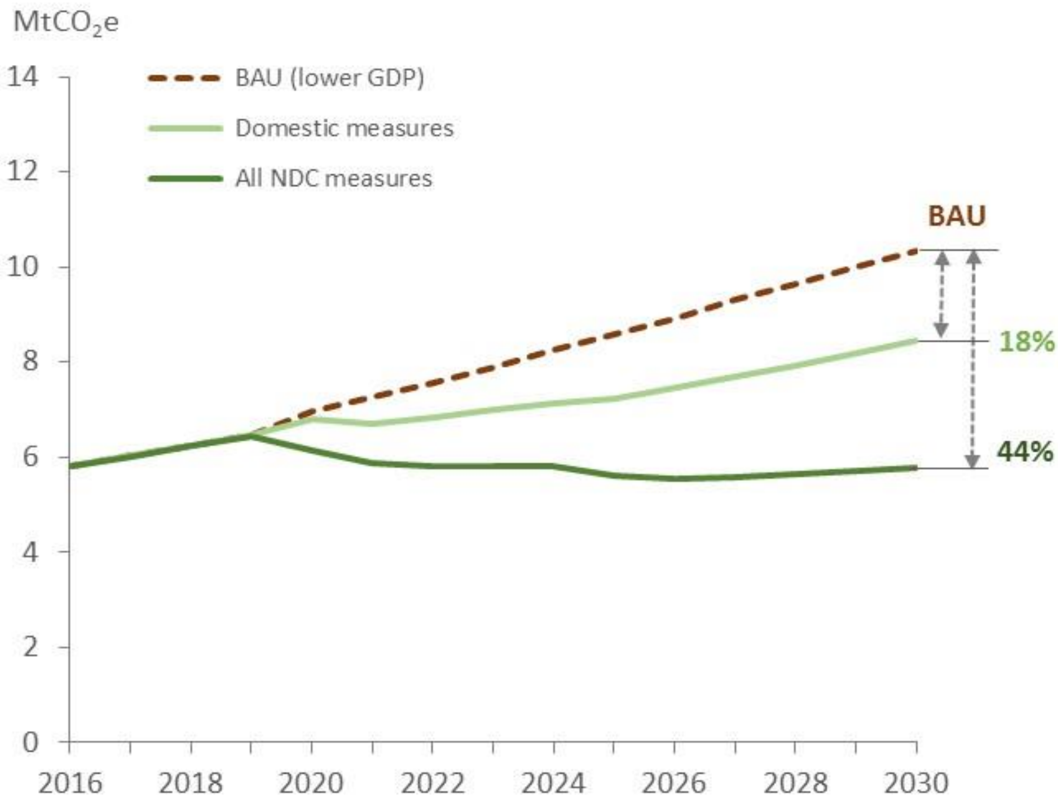


Table 5.2 Emissions projections under NDC scenarios and BAU (lower GDP)

Scenario	2015	2020	2025	2030
Total emissions ($MtCO_2e$)				
BAU reference case (lower GDP)	5.33	6.96	8.59	10.34
Domestic NDC measures	5.33	6.81	7.25	8.44
All NDC measures	5.33	6.13	5.63	5.78
Reduction relative BAU				
Domestic NDC measures	-	2%	16%	18%
All NDC measures	-	12%	35%	44%

As a result, it can be seen that lower than expected economic growth has the effect of achieving greater relative emissions reductions (not absolute emission reductions) compared to the BAU projection through 2030, although caution must be applied given the likelihood of overestimating mitigation potential under this case.[23] In general terms, this indicates a greater

[23] See above footnote.

likelihood of achieving a relative NDC target type (i.e. a % reduction against BAU baseline); an important finding in the event of an official government GDP growth outlook (i.e. as per Vision 2050) being adopted for BAU modelling within the NDC.

5.3.2 Project implementation and mitigation

Sensitivity analysis was next undertaken in order to assess the potential for lower GHG mitigation outcomes arising from delayed, reduced or unsuccessful project implementation through the period 2020-2030.

An assessment was made within each of the sectors concerning the potential for reduced implementation or application rates for NDC programme and projects compared to the base case mitigation scenario. The approach taken was to consider 'realistic' alternative outcomes arising from various challenges including e.g. project delays and funding issues, rather than a 'worst case scenario' approach according to which most or all projects would not be implemented. The assumptions applied are summarised in Table 5.3 below. Reduced implementation assumptions were applied to over half of the identified projects; IPPU options were not considered given the very high certainty these will be realised and following consultation with MINIFRA staff only one measure (Waste-to-Energy) was entirely excluded.

Table 5.3 Summary of lower mitigation scenario

NDC measure		Assumptions
ENERGY	Hydropower	117 MW of planned hydropower projects realised within period compared to 156 MW under base case, reflecting investment challenges and other barriers.
	Solar mini grids	Reduced rate of 50 MWp of solar mini-grids installed in off-grid rural areas by 2030 compared to planned 68 MWp under base case.
	Efficient cook stoves	Programme assumed to achieve only 75% of household penetration rate achieved under base case by 2030.
	Solar pumping for irrigation	Reduced irrigation area of 63,379 Ha achieved by 2030 compared to government target of 84,505 Ha under base case.
AGRICULTURE	Improved fertilizers	Compost application achieved on reduced area compared to base case of 165,000 ha; deep fertilizer placement and biomass management achieved on 25,000 ha.
	Soil and water conservation	New terraces established on reduced area of 110,000 ha; crop rotation achieved on 440,000 ha; coffee-banana multicropping achieved on 15,900 ha; conservation tillage achieved on 180,000 ha.
	Improved livestock husbandry	Improved fodder planted on reduced area of 60,600 ha.
	Improved livestock species and population	Reduced herd replacement rates assumed compared to base case, with improved dairy cows totalling 97,500 animals will replace 195,000 local cows.
	Improved manure management	Improved manure management achieved for a reduced rate of 350,000 cows and 350,000 goats.

WASTE	Landfill gas utilisation	Lower extraction rates for landfill methane gas, increasing to 40% by 2030 compared to base case assumption of 60%.
	Waste-to-energy (WtE) plants	WtE plants are not implemented within the first NDC period due to lack of funding and other barriers.
	Aerobic composting	Decrease in quantity of waste treated by biological treatment/ aerobic composting methods, resulting in a 3% annual increment in composted waste compared to base case assumption of 5% per annum.
	Waste-water treatment and re-use	Reduced rate of urban population connected to wastewater treatment plants projected to be 7% by 2022 compared to base case assumption of 11%, reflecting project pipeline delays e.g. Kigali central wastewater treatment plant in Nyarugenge.

Figure 5.4 and Table 5.4 below show the forecast emissions projections against the BAU baseline according to this alternative lower mitigation pathway. It can be seen that in 2030, mitigation against the baseline is lowered to a 27% reduction for all NDC measures, and 12% for domestic measures only. The associated emissions reductions delivered in 2030 under the lower mitigation scenario and base case scenario are shown by sector in Figure 5.5.

Figure 5.4 NDC emission reduction scenarios against BAU (lower mitigation case)

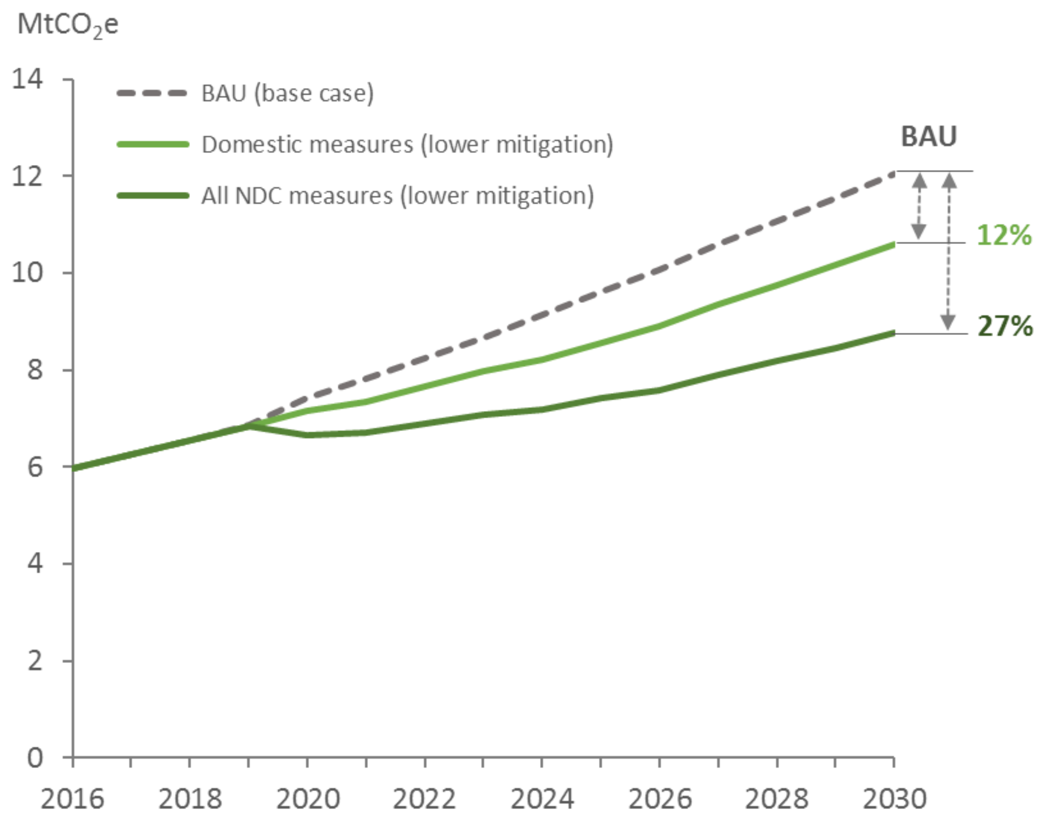
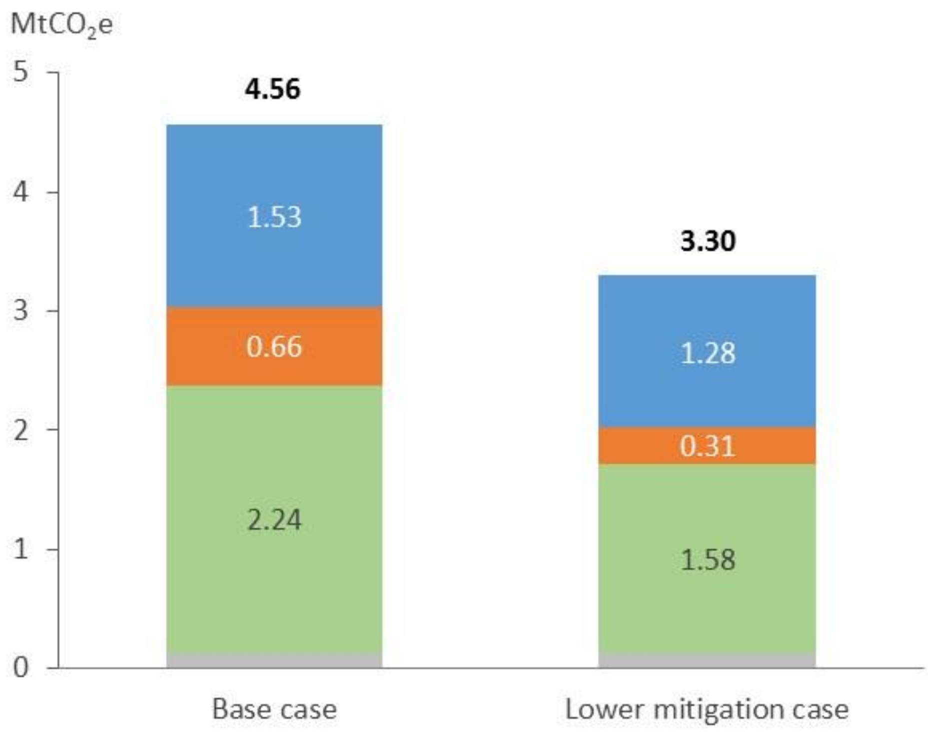


Table 5.4 Emissions projections under NDC scenarios and BAU (lower mitigation case)

Scenario	2015	2020	2025	2030
Total emissions ($MtCO_2e$)				
BAU reference case (Vision2050)	5.33	7.42	9.61	12.06
Domestic NDC measures	5.33	7.16	8.56	10.60
All NDC measures	5.33	6.65	7.41	8.76
Reduction relative BAU				
Domestic NDC measures	-	2%	11%	12%
All NDC measures	-	10%	23%	27%

Source: Authors

Figure 5.5 Annual GHG mitigation versus BAU by sector in 2030 (all NDC measures)



Source: Authors

5.3.3 Lake Kivu methane power generation

Lake Kivu contains large volumes of non-anthropogenic methane which can be extracted for use in grid electricity production and other energy uses. Following a number of pilot projects supported by the World Bank and others, a 26 MW power generation project was developed by ContourGlobal (KivuWatt) and commissioned in late 2015, and there are plans to further expand capacity to around 101 MW (ContourGlobal, 2020). Utilisation of the extracted gas offers the potential to reduce Rwanda's reliance on imported oil to meet its increasing demand for power as well as reducing the risk of a catastrophic degassing event as seen in Cameroon (see Box 5.1).

Box 5.1 Non-anthropogenic methane formation in Lake Kivu

Lake Kivu, located on the border between the Democratic Republic of the Congo and Rwanda, is unique in the world because its deeper waters contain an enormous quantity of dissolved gas: estimates range from 250 billion m³ of carbon dioxide (CO_2) and 50 to 55 billion m³ of non-anthropogenic methane gas (CH_4) (Doevenspeck, M., 2007). This makes the lake one of the largest freshwater reservoirs of dissolved methane on Earth (Morana et al, 2015).

The methane is generated by fermentation processes and by the reduction of volcanic carbon dioxide by the same bacteria (Tietze et al., 1980). It is estimated that 100 to 150 million m³ of methane are generated annually in the lake (Doevenspeck, M., 2007). Like other lakes the waters of Lake Kivu show a stratified structure with stable horizontal homogenous layers which have different physical and chemical properties. Studies show that the highest concentrations of carbon dioxide and methane measured in layers below the depth of 260-270 m where high density gradients prevent any mixing, thus facilitating the gas accumulation (ibid; Pasche et al, 2011; Milucka et al, 2015). Aerobic CH_4 oxidation is the main process preventing the methane from escaping to the atmosphere (Pasche et al, 2011).

Simulations of physical mixing in the lake show that if the current methane production remains stable a dangerous concentration of the gas composition could be reached in about 100 years. However, this time span will diminish if methane production within the sediment continues to increase at the rate measured recently (Schmid et al. 2005). Indeed, one study has reported that methane concentrations in the lake have increased by up to 15% in the last 30 years and that accumulation at this rate could lead to catastrophic outgassing by around 2100 (Pasche et al, 2011). Although studies also indicate a low risk of such an event occurring (Doevenspeck, M., 2007) there remains a concern that Lake Kivu could erupt within the next 100-200 years, releasing large quantities of methane, as occurred in Cameroon at Lake Nyos in 1986 and at Lake Monoun in 1984 with large fatalities. The risk of such an event could have a devastating impact on the entire Lake Kivu catchment area of 10,000 km² (ibid).

In this context, scientists have postulated a controlled degassing of the lake, as has been carried out in Cameroon (Schmid et al. 2003). Extracting Lake Kivu's methane gas for power generation also offers the potential to reduce the risk of an eruption, whilst offering the ability to reduce Rwanda's dependence on imported oil to meet electricity demand. The KivuWatt project, commissioned by ContourGlobal in December 2015, is the only gas/water extraction project currently operating in the world. The first phase of this project is powering three gensets to produce 26 MW of electricity for the local grid. The next phase of this project plans to deploy nine additional gensets at 75 MW to create a total capacity of over 100 MW (ContourGlobal, 2020).

Source: various

In addition to these important benefits, utilisation of lake methane for power generation has the potential to reduce GHG emissions in two principal ways. Firstly, by displacement of oil-fired generation by combustion of methane due to the latter's lower emission factor, and secondly, by utilisation of methane which would otherwise be vented to atmosphere. The first effect is relatively simple to quantify - subject to the assumption of oil-fired generation under the 'baseline scenario' against which any emissions reductions can be quantified. The second effect is more problematic. This is partly because the rate and degree to which Lake Kivu's methane is vented to atmosphere over time is not fully understood or quantified. Limnological studies typically classify Lake Kivu as permanently stratified with much of the dissolved methane stored within lower depths over long periods of time. The KivuWatt project pumps water containing this dissolved methane (and also CO_2) from these lower layers for transportation to shore and subsequent combustion, these activities also resulting in a certain volume of fugitive emissions.

Assumptions around fugitive methane emissions under a counterfactual 'baseline scenario' are therefore not clear, nor are the rate of fugitive methane and CO_2 emissions occurring during the project activity itself (i.e. during the pumping of gas to the surface). Lake Kivu is unique worldwide, and utilisation of lake methane is a novel technology. There are no existing guidelines from the IPCC or other internationally recognised organisation pertaining to emissions accounting for such a project. At the current time, it is understood that additional research involving methane flux characterisation and collection of robust monitoring data will be required to develop suitable accounting guidelines consistent with UNFCCC reporting requirements. This will be needed before such projects can be quantified for purposes of meeting NDC targets (and/or generating "MRV-able" emissions reduction units consistent with the Paris Agreement "rulebook").

Full consideration of these issues is beyond the current scope of work. However, an illustrative calculation has been made in order to estimate the likely scale of GHG reduction potential from Lake Kivu methane utilisation. This is based on the following simple scenario-based assumptions:

- **Project emissions**: Includes CO_2 emissions from combustion of CH_4 at power generation plant plus fugitive emissions of CH_4 arising from the extraction process (fugitive CO_2 emissions not quantified).
- **Baseline emissions**: Includes fugitive emissions from CH_4 released from the lake to the atmosphere plus CO_2 emissions from combustion of fuel oil used to generate the equivalent power generation as per the project (fugitive CO_2 emissions not quantified).

Emissions reductions are calculated as the baseline emissions minus the project emissions. The calculation assumptions and results are summarised in the tables below. The results are shown for the existing KivuWatt project capacity of 26 MW and also its possible expansion to 101 MW. As discussed above, there is high uncertainty around the net rate of fugitive methane emissions in both the baseline and project scenarios[24]. Two simple cases are therefore considered, with net fugitive releases to atmosphere of 25% and 50% of the captured lake methane. The results provide a 'first pass' estimate of the mitigation potential from utilisation of lake methane subject to its recognition under international emissions accounting rules. Notwithstanding the high degree of uncertainty, these are seen to be significant, ranging from around 0.6-0.9

[24] i.e. how much of the utilized methane gas can be treated as fugitive emissions in the baseline, and also how much of the captured methane gas is lost at the surface as releases to atmosphere; in this case only the rate of project fugitive emissions are varied, for simplicity. CO_2 releases represent another emissions source not quantified here.

$MtCO_2e$/year for the existing KivuWatt Phase 1 plant up to 2.4-3.4 $MtCO_2e$/year under KivuWatt Phase 2.[25]

Table 5.5 Lake Kivu methane power production; key assumptions

Parameter	Value	Unit	Source
KivuWatt Phase 1	26.4	MW	ContourGlobal, 2020
KivuWatt Phase 2	101.4	MW	
Average plant availability	80	%	Project assumptions
Annual generation (Phase 1)	185,011	MWh	
Annual generation (Phase 2)	525,600	MWh	
Gas-fired power plant heat rate	7,870	Btu/kWh	US EIA, 2016
	8.30	GJ/MWh	Calculated
Oil-fired power plant heat rate	10,811	Btu/kWh	US EIA, 2016
	11.41	GJ/MWh	Calculated
Natural gas combustion emission factor	54300	$kgCO_2/TJ$	IPCC, 2006
Fuel oil combustion emission factor	72600		
Oxidation factor	1	-	IPCC, 2006
Global Warming Potential (GWP) - CH_4	28	-	IPCC, 2014

Table 5.6 Lake Kivu methane power production; emissions reduction calculations

Parameter	KW Phase 1 (26 MW)		KW Phase 1 (101 MW)	
	Fugitive CH_4 25%	Fugitive CH_4 50%	Fugitive CH_4 25%	Fugitive CH_4 50%
Baseline emissions ($MtCO_2e$ per year)				
Oil-fired power plant emissions	*0.15*	*0.15*	*0.59*	*0.59*
Fugitive methane emissions	*1.10*	*1.10*	*4.24*	*1.10*
Total GHG emissions	1.26	1.26	4.83	4.83
Project emissions ($MtCO_2e$ per year)				
Gas-fired power plant emissions	*0.08*	*0.08*	*0.32*	*0.32*
Fugitive methane emissions	*0.28*	*0.55*	*1.06*	*2.12*
Total GHG emissions	0.36	0.63	1.38	2.44
Emissions reductions ($MtCO_2e$ per year)				
Total GHG emissions	0.90	0.62	3.45	2.39

Source: consultant calculations

[25] The choice of power generation technology in the baseline represents another important area of uncertainty.

5.4 Summary

Table 5.7 summarises the model results for the alternative GHG pathways in terms of reductions against the BAU baseline scenario through the NDC period 2020-2030. For the target year 2030, the base case scenario is estimated to achieve a reduction of 16% for unconditional measures increasing to 38% with conditional measures included. As presented within the sensitivity analysis above, the lower mitigation scenario delivers a lower reduction outcome relative to BAU, while the lower GDP growth scenario results a in higher reduction relative to BAU.

Taken together, the results therefore indicate the potential range of mitigation delivered by identified NDC measures according to key uncertainties around baseline and mitigation factors. For domestic measures only, this range is a 12-18% reduction against BAU in 2030, increasing to 27-58% for all NDC measures subject to inclusion of Lake Kivu methane for power generation.

Guided by the principle that Rwanda should only adopt targets considered capable of being delivered, the choice of which mitigation target(s) to adopt within the revised NDC should necessarily be informed by a view on which scenario is considered most feasible. In this context, it should be noted that the base case scenario is based on official target assumptions for GDP growth and project outcomes. Overestimating the former has the tendency to underestimate mitigation outcomes relative to BAU, while overestimating the latter has the tendency to overestimate mitigation outcomes relative to BAU. From this, it might be reasonably concluded that the base case represents a feasible estimation of what could be delivered under the NDC through 2030, subject to an enabling domestic policy framework and attracting international funding and support.

Table 5.7 Mitigation achieved relative to BAU for alternative GHG pathways

Scenario	2015	2020	2025	2030
Domestic NDC measures				
Lower mitigation scenario	-	2%	11%	12%
Base case scenario	**-**	**2%**	**14%**	**16%**
Lower GDP growth scenario	-	2%	16%	18%
Inclusion of Lake Kivu methane project	-	2%	14%	16%
All NDC measures				
Lower mitigation scenario	-	10%	23%	27%
Base case scenario	**-**	**11%**	**31%**	**38%**
Lower GDP growth scenario	-	12%	35%	44%
Inclusion of Lake Kivu methane project	-	20%	56%	58%

Note: Inclusion of Lake Kivu assumes expansion of current Phase 1 (26MW) to 101 MW under Phase 2 2025-2030; an estimated net fugitive methane release rate of 50% is assumed for conservativesness.

6 ADAPTATION AND RESILIENCE INITIATIVES IN RWANDA

6.1 Policy and legal framework

Rwanda has undertaken a progressive trajectory in efforts to climate-proof its development. It ratified the United Nation Framework Convention on Climate Change (UNFCCC) in 1995, the Kyoto Protocol in 2004, and the Paris Agreement in 2016. Rwanda submitted its National Adaptation Programmes of Actions (NAPA) in 2006. In line with the Paris Agreement, Rwanda submitted its Intended Nationally Determined Contribution (INDC) in 2015 that later became NDC in 2016. Rwanda submitted its initial communication to the UNFCCC in 2005, the second in 2012, and the third in 2018. The objective of the National communication is to build capacity for successful implementation of the convention; general awareness and updates; assist for policy formulation and national planning; update on GHG emission status, mainstreaming scenarios for emission reduction, and update adaptation status and mainstreaming into planning (GoR, 2018a).

The NDC is a commitment towards the implementation of the Paris agreement with mitigation and adaptations actions. In the same framework, Rwanda has joined the NDC partnership and launched a plan during the Africa Green Growth Forum held in Kigali in November 2018. Rwanda has adopted the new Environmental law [26] that takes into account climate change more than the previous Environmental organic law. In addition, recently in June, a new National Environment and Climate Change Policy was enacted with the goal of achieving a climate resilient nation with a clean and heathy environment (MoE, 2019a).

The Green Growth and Climate Resilience Strategy was adopted in 2011 with a time horizon of 2050. The strategy has 14 Programmes of Action (PoA) that include adaptation to climate change in the following programmes:

- PoA 1: Sustainable intensification of agriculture
- PoA 2: Agriculture diversity in local and export markets
- PoA 3:Integrated Water Resources Management (IWRM) and planning
- PoA 4: Integrated Land Use and Management
- PoA 11: Ecotourism, Conservation and Payment of Ecosystem Services
- PoA 12: Sustainable Forest and Agroforestry
- PoA 13: Disaster and Diseases prevention
- PoA 14: Climate data and projections

A recent review of the strategy indicated that it is still valid and relevant to Rwanda’s vision (vision 2020/vision 2050) as well as strategic plan such as National Strategy for Transformation (NST) for the period between 2018 - 2024 (MoE, 2018). Furthermore, in 2019, a new Environment and Climate Change Policy was adopted with remarkable consideration of climate change with clear climate relevant objectives outlined below:

[26] LAW N°48/2018 OF 13/08/2018 ON ENVIRONMENT, Official Gazette no. Special of 21/09/2018

- Greening economic transformation (resource efficiency, low carbon, climate resiliency, circular economy, green technology and procurement, green urbanization and settlements, and green mobility).
- Strengthening meteorological and early warning services (climate and weather services production and mainstreaming into all sectors of Rwanda's socio-economic development, production and access of meteorological, climate and weather services for better planning in all sectors of economy;
- Promoting climate change adaptation, mitigation and response (strengthen mitigation and adaptation in both planning and implementation;
- Strengthening environment and climate change governance (mainstreaming of environment and climate change into all sector policies, national coordination for the management of critical ecosystems, inclusive decision-making and interventions for environment and climate change management, education & awareness of Rwandan society on environment, weather and climate change, and strengthen the institutional framework and coordination mechanisms); and
- Promoting green foreign and domestic direct investment and other capital inflows (strengthening environment & climate financial mechanisms for more efficiency, effectiveness and impact and strengthening climate proofing capital inflow in national economic planning) (MoE, 2019a).

This is a demonstration of the progressive policy relevancy of climate change to Rwanda's economic growth and development that lends the momentum to address climate change in general and adaptation/resilience in particular as a national development challenge that must be addressed by sectors.

6.2 Adaptation in priority Sector Strategic Plans

Priority sectors were identified based on the NDC Partnership Plan that was led by the Ministry of Environment with the support of the NDC Secretariat. The consideration was also based on the focus of the World Bank support in the context of the NDC partnership plan endorsed by the GoR in November, 2018. The following section outlines the status of the sectors and the key baseline data and information that is considered relevant to climate adaptation and resilience as a follow up to inform NDC implementation in Rwanda.

6.2.1 Water Resources / IWRM

Integrated Water Resources Management (IWRM) is the approach adopted to enhance climate change resilience at community level through Catchment Management Committees, among other options. Catchment management committees were established at 35% and available for the catchments of Muvumba, Nyabarongo, Nyabugogo, and Sebeya, water permits issued at 8% with the system accessible online on water portal, while for transboundary basins, two cooperation frameworks were established by the fiscal year 2017/2019 (MoE, 2017a). In addition, a new water law was established on 13/08/2018 and six ministerial orders were developed.

Water resources availability is reported to be 670 m^3 /capita/annum and the water bodies with ambient water quality are at 15% in the year 2017 (MoE, 2017a). Furthermore, by 2016irrigation systems had been developed as part of IWRM approach covering 48,508 hectares (MoE, 2017a), and a map of degraded areas in four priority catchments was available from 2017 (MoE, 2017a). Catchment water balance modelling is in place for Muvumba, Nyabarongo, Sebeya and Nyabugogo were completed (MoE, 2018). In an effort to increase water storage and availability to Rwandans, household level adoption of rain water harvesting has increased and has reached 17% in 2014 (NISR, Integrated Household Living Conditions Survey 4 (EICV 4), Rwanda, 2015).

In the context of adaptation to climate change, the Landscape Approach to Forest Restoration and Conservation (LAFREC) project, funded by the World Bank targets an early warning system for flood management within the Sebeya Catchment. The WB supported project objective is to demonstrate landscape management in the context of environmental as well as climate resilience and livelihood restoration. The following actions are ongoing and by the end of the project (December 2019), the following are targeted:

- 90 Households (HH) in the project area with advanced warning of individual major rainfall or floods;
- Land area converted to enhanced biological protection practices is targeted to reach 3,428 ha by end of the project;
- A total of 70 sub-projects are also expected to support livelihoods;
- Flood hazard mapping for selected flood hotspots will be available by the end of the project; and
- Impact monitoring on land rehabilitation techniques will be produced (World Bank, 2019c)

6.2.2 Agriculture

Rwanda's economy depends primarily on agriculture, which is predominantly rain fed. Land is also vulnerable to heavy rainfall associated with soil erosion and landslides (resulting in the loss of fertility) in North, Western, and Southern province, while Eastern Province is often vulnerable to draught. To reduce land degradation, 110,905 ha of radical terraces, and 923,604 ha of progressive terraces were completed in 2017 (GoR, 2017a). Up to 2015, 41% of farmers used improved seeds on consolidated land to increase up to 635,603 ha in 2017, and irrigation was implemented on 48,508 ha in the same year (GoR, 2017a).

Value addition to the agriculture produce is still a challenge given that in 2014, agro-processing facilities were estimated at 10% with a capacity of 400,000 megatons (MINAGRI, 2016). Crop rotation is implemented by 48% of farmers, 65% of households are using manure, 146,652 MT of compost used in 2018, 197 plant extension doctors trained, 75 plant clinics, 18 on-station research plots. In addition, fertilizer deep placement projects in rice are ongoing. Regarding agriculture diversification in local and export market, 41% of farmers were using improved seeds on consolidated land in 2018 (MoE, 2018). Thus, these improvements in agricultural practices are likely to spur growth of the sector with potential to accelerate penetration of value added products on Rwandan and export markets.

6.2.3 Land Use Management

The high population density puts pressure on natural resources (land for housing, agriculture, wood for domestic use in construction, cooking, infrastructure, etc.). Without proper land use planning and implementation, and with a growing population, the pressures are likely to increase. In addition, Rwanda must increasingly incorporate climate change considerations into land use planning to optimize land allocation to productive uses. By using instruments such as a Spatial Data Guidelines or Policies, cities will be able to use spatial information to integrate climate resilience in their planning processes. It is also essential to monitor and evaluate progress on implementation to facilitate and guide compliance and ensure enforcement measures are reliable. In this framework, Land Administration and Information System (LAIS), National Land Use Development Master Plan (NLUDMP) and 8 sectoral plans including that of the City of Kigali (CoK) were already available in the year 2017 (MoE, 2017a). On the other hand, assessment report done in the same year showed that only 25% compliance of districts to the LUDMP. Rwanda land use portal is operational and LAIS accessible for all 30 Districts with five irembo e-services linked and mobile phone application operational (MoE, 2018). In all, it is important that the impacts of climate change on natural resources is incorporated during land use planning. Climate resilience of natural resources such as land and energy links must serve as critical considerations when developing land use plans (FONERWA, 2017).

6.2.4 Forestry

Though forests mainly contribute to mitigation of climate change as carbon sinks, they also have adaptation benefits, which include erosion control, and reduction or retention of runoff, which can reduce flood and landslide risks. According to the Ministry of Environment (MoE), the targeted forest cover of 30% was reached in the fiscal year July 2018/2019, from the 29.8 % reported in 2016/2017 (GoR, 2017a; MoE, 2019a).

6.2.5 Housing

In 2016, it was reported that 62.60% of urban population live in informal settlements, while less than 20% of the urban population in areas covered by master plans had storm water considerations in 2016 (MININFRA, 2017a). MINALOC has identified grouped settlement, a critical entry point for the Integrated Development Program (IDP) as the main solution to reduce pressure on land for housing. In this regard affordable housing projects are being implemented in the country either by private sector or with support from the Government such as 537 units in Batsinda II and 56 units in Abadahigwa settlement in the suburbs of Kigali City. Moreover, an Affordable Housing Fund was adopted by the Cabinet in 2017 to increase access to affordable housing for the low to middle income groups . The need for affordable housing units is predicted to reach 340,000 by 2024 (MININFRA, 2017b). The current initiative on climate change impacts data and information is crucial in informing planning to achieve the ambitious targets in the housing sector.

6.2.6 Health

In the fiscal year 2016/2017, 308 malaria incidents per 1,000 population were reported and the malaria proportion mortality rate was at 5.7 per 1,000 in the same year. Among children under 5 years, , 80% slept under mosquito nets (LLIN) (MINISANTE, 2018). There is growing evidence that an increasing disease burden, from Malaria in particular, is associated with climate change and its impacts[27].

[27] https://www.irishtimes.com/news/science/scientists-prove-link-between-climate-change-and-malaria-1.1715589

6.2.7 Transport

Climate change adaptation is being mainstreamed in the transport sector by increasing the number of all-weather roads through improving roads from unpaved to paved roads with a focus on national roads. In 2018, from a total length of national roads of 2749km, 1385.5km were paved (50%). Furthermore, Rwanda Transport Development Agency (RTDA) with a grant from the Nordic Development Fund (NDF) signed in 2016 has initiated a project for "Developing Capacity for Climate Resilient Road Infrastructure''. The project is intended to build capacity for all stakeholders involved in road construction and management to mainstream environment and climate change into the whole life cycle of transport infrastructure through vulnerability mapping, training and awareness, and development and testing of manuals, guidelines and standards. Vulnerability mapping is ongoing in collaboration with stakeholders such as MoE, Meteo-Rwanda, RWFA and REMA. The sustainability of this initiative will benefit from establishing an analytical framework that RTDA and its partners can reliably use to monitor and address the impacts of climate change on road infrastructure.

6.2.8 Mining

Model mine concepts and mining standards were recently developed and Strategic Environmental Assessment for mining sector was done, while environmental and social impact assessment and mining licence are mandatory for every mining project[28]. The annual contribution of the mining sector to export revenues was 250 M USD in the fiscal year 2017/18. However, minerals are exported in raw material form (MoE, 2017a). Regarding the water use, it was reported that all mines are complying with rules on efficient use of water in their operations (MoE, 2018). Even with these initiatives, it is important that a framework to monitor and deal with the impacts of climate change in the mining sector be put in place to address critical sustainable development challenges such as soil erosion and water resources management.

6.2.9 Disaster risk reduction

Since the year 2017, routine weather forecasts have supported early warnings for heavy rainfall events and flooding with early weather warning registered for 70% of extreme weather events (MoE, 2017a). Sectoral use of weather related hazards information over 2017 and 2018 was as follows: Agriculture: 30%, Health: 20%, Infrastructure: 50%. In addition, online forms for data requests, CLIMSOFT, an open-source Climate Data Management System improved accuracy in weather forecasting up to 80 % by 2018 (MoE, 2017a).

Furthermore, disaster prone areas in drought, earthquake, landslide and flood were mapped and also the disaster inventory system was put in place with disaster pre-warned at 80% (GoR, 2019). National Contingency plan matrix is in place. District Disaster Management plans are available in 70 % of Districts and various methods were used to train key community groups on disaster preparedness and response (MoE, 2018). In order to reduce the adverse impacts of natural hazards, the Government of Rwanda has provided in recent years a policy framework for Disaster Risk Reduction which include a policy and a law for disaster management. In addition, DRR has been strongly mainstreamed in the first National strategy for transformation-NST1.

[28] https://waterportal.rwfa.rw/sites/default/files/inline-files/Towards%20sustainable%20mining.pdf

6.2.10 Finance for climate resilience

Financial limitation is one of the major challenges among others, which results in gaps for technical and technological capacity, pressure on natural resources linked to high population density. By the fiscal year 2017/18, 99 million USD had been mobilized by the National Fund for the Environment, FONERWA, since 2013/2014 while the target is to mobilize 217.78 million USD by 2023/2024 (MoE, 2017a). However, the later target is considerably underestimated because it does not consider other channels through which climate finance flows to Rwanda such as agriculture, infrastructure, NGOs, etc.

7 CHALLENGES IN ADAPTATION AND RESILIENCE

Challenges to the implementation of adaptation and resilience options are mainly classified at policy/strategic; global/national (sub-national); program and project levels. Both the 2017 and 2018 Rwanda NDC implementation and partnership plans identified the following areas to have broadly captured the demonstrated gaps that need to be addressed and strengthened (GoR, 2018d):

- Institutional and regulatory framework for sector coordination
- Data availability, collection , management, reporting and verification
- Limited financing opportunities for flagship projects implementation
- Institutional and technical capacity among sectors involved in adaptations strategies (government, private sector, and Civil Society Organizations), particularly for developing bankable projects for domestic and external funds mobilization
- Challenges on the operational level focus on metrics, data management, monitoring, reporting and verification.

The following are primary areas of concern in the development of reliable metrics on adaptation and resilience:

1. Unlike mitigation, there is *lack of a well-established standard M&E methodology and indicators for adaptation interventions*. In Rwanda's case, M&E including indicators to track progress have been iteratively developed, revised and refined to inform sector specific development indicators that include those relevant to adaptation and resilience. In addition, various other initiatives including Baseline Vulnerability Index for Rwanda[29], National Communications, and the Strategic Program for Climate Resilience (SPCR) have specifically generated M&E relevant to adaptation. The current M&E developed in the context of WB technical assistance builds on these experiences and initiatives and the robust stakeholder consultations and inputs to inform a useful tool that is practical and realistic in supporting Rwanda's NDC agenda towards 2030.
2. The nature of adaptation as an addition to development interventions makes the *determination of baselines for specific adaptation investment challenging to establish unequivocally*. The current approach worked on the assumption that adaptation interventions can be tracked as a standalone and quantifiable complement to development investments. This approach can realistically facilitate tracking and attribution of adaptation measures either as a standalone as may be the case for rain water harvesting or additional as in the case of soil erosion.
3. *The attribution of adaptation benefits to expected results in the normal lifetime of standard projects and programs* poses unique challenges to selection of interventions. It is therefore important that investments in adaptation projects and programs be evaluated to ensure impacts are appropriated to interventions. Importantly, the evaluations will allow for guiding future interventions including replication and scale up of good adaptation interventions and practices. *There is a problem of attributing*

[29] http://www.climdev-africa.org/sites/default/files/DocumentAttachments/Baseline%20climate%20change%20vulnerability%20index%20for%20Rwanda2.pdf

outcomes in the form of increased resilience directly to specific adaptation investments. It is important to note that adaptation is inherently a complex process cutting across sectors and levels of interventions.

4. *Identifying the best possible proxy outcome indicator* is a key challenge in designing M&E frameworks. In addition, composite indicators such as a vulnerability index and adaptive capacity while useful in broad terms as a guide on national and sub-national vulnerability and resilience, present challenges in mapping and therefore guiding sector specific interventions. Whereas a collaborative multi-sectoral approach is required for robust planning and analysis to reduce vulnerability, in all likelihood it poses challenges in determining sector specific adaptation actions. It is therefore important that the methodology for adaptation M&E responds to sector specific measurements including investments in order to address the attribution problem cited above.

These challenges have been addressed using the following approaches:

- Ensuring consistency in identifying adaptation priority action lists for 2021 and 2030
- Formulating performance indicators with clear metadata that can support consistent monitoring and reporting at strategic levels (UNFCCC, NST and SSPs (ENR RBM)) as well as facilitate tracking progress of NDC implementation.
- Providing reliable support to sectors to generate baselines and to facilitate ongoing monitoring.

In addition to the above, sector specific challenges and gaps on climate change adaptation and resilience have been identified in different sectors through analysis including the comprehensive Gaps and Needs analysis conducted to inform the PPCR process, as outlined below.

7.1 Water Resources

Rwanda is still a water scarce country with 670 m^3 of water per capita per year and 25% of the population are still unable to access safe drinking water. In addition to water scarcity, other challenges were identified: Limited human capacity; high competition among water users; inadequate wastewater management, and water pollution and these are associated with inadequate management of wastewater and agricultural inputs from rural areas (GoR, 2017a; MoE, 2017a). Specifically, the water and sanitation subsector has its own challenges that are affected by gaps in the analytical scope including:

- gaps in water access especially in scattered and unplanned settlements;
- high costs of service provision due to the depletion of water resources;
- gaps in human capacity for planning, operation, and maintenance;
- consolidation and institutional responsibility, the integrated water resources management in Rwanda has been evolving and the recent parliamentary approval of the water board will usher in institutional stability that will lead to effective management of climate related issues such as flooding;
- low level of sustainability of WASH Services, poor quality services, especially in rural areas;

- insufficient water and wastewater treatment and solid waste management, issues in technical and financial capacity among government and private sector and community for investment in water and sanitation sector, and
- weak monitoring systems (MININFRA, 2017a).

7.2 Agriculture

Given that arable land is 48 % of the total Rwandan area (26,338 km2) plot size and land availability are limited. In addition, land fragmentation is also another issue among other constraints that limit the production and profitability of most farmers. Though efforts have been made through terracing and other mitigation measures, land degradation is accelerated by high slopes and high rainfall intensity which are the main drivers of soil erosion. In addition, soil acidity which is observed in three quarters of total arable land is another threat to soil productivity. Pressure on land and other natural resources mainly as a result of population density and growth, exacerbates the challenges of agriculture production.

Furthermore, inadequate agriculture commodity market and value chains limits profitability and food security (MINAGRI, 2017). Unequal distribution of benefits at household and community levels and limited profit to women and youth who are more involved in agriculture activities as well as limited financing alternatives constitutes another limitation. Production and profitability are also constrained by limited skills among farmers with low levels of formal education. Access to finance is a cross-cutting issue that is also felt by the agriculture sector (MINAGRI, 2017). The above challenges are further exacerbated by climate-related factors such as flash floods and extensive soil loss. Thus, improved management of agriculture practice in Rwanda will greatly benefit from efficient planning that can be facilitated by appropriate and targeted analytics that adequately inform climate adaptation and resilience of smallholder farmers, in particular.

7.3 Land Use Management

Annual monitoring of human settlement in both urban and rural area and the population growth is considered one of the key challenges (MININFRA, 2017b). In fact, the urban population compared to the last census is projected to increase from 1.7 million in 2012 up to 4.9 million in 2032, i.e. a rise of 30%. Similarly, the rural population with the same rate of increase over 20 years is projected to rise from 8.7 million in 2012 to 11.4 million in 2032 (GoR, 2018b). Another key challenge to adaptation is that less than 10 % of households are able to afford a formal housing unit, and this has pushed the government to facilitate affordable housing unit as a high level priority.

Furthermore, an increase of un-authorized construction on agricultural land in urban area is still observed and would compromise food security (MININFRA, 2017b). Thus, weak land use planning and compliance need to benefit greatly from reliable analytics that can address competing interests among land users. In fact, land use master plans at districts levels are not harmonized with national land use master plan which makes difficult monitoring of compliance (MoE, 2017a) factors that lead to exposure to climate change impacts. In summary, soil erosion, land degradation, urbanization, pollution, population growth are current major challenges of land use management.

7.4 Forestry

The forestry sector is also constrained by competition with other land users (agriculture, housing, etc.). In addition, unproductive forest management practices like illegal tree felling, poor agroforestry practices, and the predominance of one species, mostly eucalyptus. Differences between demand and production (more demand than production, mainly for fuelwood and construction) are major challenges in the subsector (MoE, 2017a). These inevitably result in deforestation and erosion and soil loss especially in the wake of climate change and its impacts which are increasingly prevalent.

Furthermore, uneven distribution of forest (more in Western province than the rest of the country); poor genetic quality of manmade forest associated with poor productivity; low involvement of private sector in forestry management (low investment financial return), and limited technical skills and capacity are other identified challenges (MINILAF, 2018). Analytics on climate change impacts can help address these areas to improve planning for forestry and agro-forestry management.

7.5 Mining

Identified challenges in mining subsector are mainly related to the limited capacity like in other sectors. Additional sector specific challenges include:

- inadequate and unpredictable finance;
- dominance of small-scale mining which is export-oriented with contribution to soil erosion and loss as well as overall environmental degradation;
- inadequate infrastructure and services;
- limited research and knowledge on mineral availability and professional and technical knowledge, shortage in skilled labour; obsolete technology and processes; inadequate environmental management, including occupational, social, health and safety risks; price volatility of mining produce; and
- illegal mining, etc.

All these factors can be addressed through provision of reliable data and information including climate adaptation and resilience metrics and significantly improve planning and overall sector performance.

7.6 Energy

The energy sector challenges are summarized below according to subsectors:

- **Electricity**: Generation of electricity is constrained by various challenges including those related to climate change impacts such as: achieving correct mix of generation, timely maintenance of infrastructure, high investment cost of electricity generation infrastructure and high investment cost of transmission lines. Concerning access, issues are linked with limited connectivity of remote areas, aligning on- and off-grid power, maintenance, and finance. Energy efficiency is also constrained by limited capacity and awareness among energy utility company, private sector, and end-users, poor quality technologies, coordination of different initiatives, etc. There has already been evidence that climate impacts such as soil erosion causes sedimentation and therefore generation capacity and flash flooding that destroys infrastructure and increases maintenance costs.

- **Biomass**: Deficit in wood supply, gaps in institutional coordination, limited promotion of alternative sources of cooking energy (like Liquefied Petroleum Gas, LPG). These factors are associated with deforestation and soil loss that is accelerated by climate change impacts (MININFRA, 2017c).

7.7 Climate data management

Insufficient modern infrastructure, and limited human capacity to translate climate and weather information into end user products are among the challenges of climate data management. High quality research is another gap that must be addressed to guide monitoring and ensure high quality forecast and early warning system products (MoE, 2017a).

7.8 Health

In the health sector, major issues are related to the capacity gaps particularly at district level (district health units) that limits effective coordination of health services. In addition, gaps in technical skills as well as high turn-over among health personnel is another challenge. An additional challenge is the limited capacity for supply chain management at different levels as well as unsustainable external financing of health sector (MINISANTE, 2018). Both areas can be addressed through strengthened preventive measures including capacity to adapt to disease outbreaks which can benefit from improved analytics on climate change impacts.

7.9 Transport

In terms of adaptation, the transport sector is challenged by lack of all-season roads in rural areas which hampers transfer of agriculture produce from farm gates to the market. Overloading is another challenge that triggers high cost of road maintenance as well as limitation of accessibility especially in case of bridge damages. Unpredictability and delays of public transport services as well as the lack of integrated transport modes are other challenges in the transport sector. Accident and incidents occurrence have also been identified among the challenges (MININFRA, 2017d). Other issues are related to the limitation in infrastructure, and limited analytical information that can facilitate planning for proper storm water management in the face of growing climate change impacts.

7.10 Housing and human settlement

The sector experiences challenges of monitoring demographic growth and movement that is not proportionate to existing housing initiatives. Clear demarcation between urban and peri-urban areas must be well defined to address inconsistency in population projections (e.g. between NISR and WB reports) as well as gaps in land use planning and monitoring. Alignment between Urbanization policy with Human Settlement policy was also another challenge that will likely be addressed through National land use master plan currently under review to improve spatial planning.

Other identified challenges include unregulated construction, both in urban and rural areas that contributes to the depletion of land and other natural resources; conflict with other land uses (especially agriculture); gaps in compliance with land use plans. Additional challenges include limited financing mechanisms in urban development; high cost of land, poor quality construction materials; high speculation of landholders, lack of technical capacity (e.g. limited expertise at national level, urban planners particularly in local governments). (MININFRA, 2017b). Addressing these issues will require improved planning especially in the face of a changing climate that adds to existing challenges. Thus, improving the analytical framework of the sector has the potential to support informed planning to improve sector performance.

8 EVALUATION OF ADAPTATION ACTIVITIES AND INDICATORS

8.1 Overview

A comprehensive review and analysis of adaptation and resilience initiatives in Rwanda to date provides an overview of key interventions, activities and metrics, and indicators that can be crucial in monitoring and reporting on Rwanda's progress in implementing the NDC. This provides an opportunity to align national planning, monitoring and reporting on adaptation actions as well as managing transparency and accountability for purposes of global reporting and tracking finance flows to Rwanda in particular. The key reference documents included various national reports seeking to address the following questions:

- How do the national reports and other initiatives, include national efforts such as NAPs/vulnerability studies/communications (adaptation – challenges)/Green Growth Climate Resilience Strategy (GGCRS)-SPCR/Forest Investment Plan (FIP), relevant to NDC options and analytics on climate adaptation and resilience?
- How adaptation/resilience is reflected in and facilitate delivery on national sustainable development priorities in SSPs and linkages to NST 1?
- RBME&L: What are the opportunities to improve the metrics to serve as a guide to data collection and overall strategic planning, implementation and reporting on NDCs?

The goal is to make informed decisions on practical adaptation actions and to base measures to respond to climate change on a sound, scientific, technical and socio-economic foundation, taking into account current and future climate change and variability (WMO, 2007).

Addressing the above questions will inform the national context and improve over time the options outlined below.

- Identify and develop climate adaptation and resilience analytics of national relevance to report on NST/7-year Government program implementation progress through the sector strategic plans and integrate in ENR MoE RBME/aligned with NISR;
- Facilitate sectors to design climate adaptation and resilience analytics to consistently inform development and review/revision of sector strategies in a way that includes a comprehensive review of climate vulnerability in their sector programs;
- Facilitate Districts to monitor and report (including Imihigo) on sector specific climate adaptation and resilience indicators to increasingly address and reduce vulnerability;
- Develop indicators, baselines and targets as well as metadata at various levels to facilitate progress monitoring and evaluation at projects/programs and enhance capacity for application;
- Align national information with international reporting (UNFCCC) and identify/fill any data gap

8.2 Summary of adaptation activities and their corresponding indicators

The summary of activities, sub-activities and the metrics including indicators, baselines, milestones and targets were selected through extensively rigorous consultations with sector expert teams through various iterative discussions within sectors and in workshops. The workshops had group discussions and plenary sessions of representatives from various sectors that articulated the selected options and metrics that form the summary Tables Table **8.1** toTable 8.8. It is also important to underscore the importance of using evaluation criteria elaborated in Table 8.10 - adapted from the framework applied to mitigation projects - and also used for the mitigation methodology to guide priority adaptation options. The summary table was consequently presented to other stakeholders including civil society organizations and Rwanda Association of Professional Environmental Practitioners (RAPEP) to solicit inputs and promote consultation, consensus, inclusiveness with women's participation in consultations and therefore national ownership of the NDCs deliverables. Tables Table **8.1** to Table 8.8 presents the summary with prioritized sector adaptation interventions, corresponding indicators, baselines and targets characterized as unconditional (domestically supported) and conditional (need for international support) m^3.

Table 8.1 List of adaptation interventions in the water sector and corresponding indicators

Sector: Water					Unconditional	Conditional
Activity name	Adaptation intervention	Selected indicators (with stakeholders) [Sources: 1- NDC, 2- SPCR, 3- SSP and others]				
		Indicators	Baselines	Targets		
Integrated Water Resource Planning and Management [2]	Develop a National Water Security through water conservation practices, wetlands restoration, water storage and efficient water use	(i) Water storage per capita (m^3 per capita) [3]	(i) Water storage capacity per capita (artificial dam) is estimated at 6.89m^3 in 2018 [3];	(i) 10 m^3 per capita storage by 2025 [3]; (ii) 12 m^3 per capita storage by 2030;		✓
		(ii) Renewable water resource availability per capita per annum (m^3 /capita/a) [3]	(ii) Rwanda is still a water scarce country with 670 m^3 of water per capita per year and 25% of the population still unable to access safe drinking water in 2015 [1,3]	(iii) 1000 m^3 /capita/a of renewable resource availability by 2030 [3].		
	Develop water resource models, water quality testing, and improved hydro-related information systems [2]	(i) Percentage of catchments with water balance and allocation models	(i) 30 % of catchments with water balance and allocation models in 2019	(i) 60% and 100% of catchments with water balance and allocation models respectively by 2025 and 2030	✓	
		(ii) Number of hydrological stations	(ii) 43 hydrological stations in 2019	(iii) 100 hydrological stations in 2030		

Sector: Water					Unconditional	Conditional
Activity name	Adaptation intervention	Selected indicators (with stakeholders) [Sources: 1- NDC, 2- SPCR, 3- SSP and others]				
		Indicators	Baselines	Targets		
	Develop and implement a management plan for all Level 1 catchments [3]	Percentage of water bodies with ambient water quality	15% of water bodies with ambient water quality by (2017/18) [3]	45% of water bodies with ambient water quality by 2025		✓

Note: It should be noted that the following indicators were discussed during the consultations and mentioned as good indicators. However, the concerned sectors were not ready to do the monitoring and thus should be considered in the NDC timeline 2025 – 2030:

- *Indicator: Soil erosion and soil loss rate decreased*
- *Baseline: In 2015, soil erosion was 62T/Ha and soil loss at 5.5T/Ha (NISR, 2019b)*
- *Target: Not yet set, policy action not yet in place using NCA indicators*

Table 8.2 List of adaptation interventions in the agriculture sector and corresponding indicators

Sector: Agriculture					Unconditional	Conditional
Activity name	Adaptation intervention	Selected indicators (with stakeholders) [Sources: 1- NDC, 2- SPCR, 3- SSP and others]				
		Indicators	Baselines	Targets		
Climate Resilient Value Chain Development [2]	Develop climate resilient crops and promote climate resilient livestock [3]	(i) Number of climate resilient crop varieties developed (ii) Percentage of farmers adopting resilient crop/ varieties [3] (iii) % of crossbreed livestock at national herd species	(i) In 2019, 40 climate resilient crop varieties released, (PSTA4) (ii) In 2019, 11.8% of farmers use improved seeds varieties (NISR, 2019b) (iii) To be determined	(i) By 2025 and 2030, respectively 100 and 200 climate resilient varieties will be released (based on vision 2050) (ii) By 2025 and 2030, respectively 50% and 90% of farmers will be using improved seeds varieties (iii) To be determined		✓
	Develop climate resilient postharvest and value addition facilities and technologies [3]	(i) Capacity of storage constructed in MT [1, 3]	(i) In 2018, agro processing facilities were estimated at a capacity of 400,000 MT [3]	(i) In 2030, agro processing facilities will increase at a capacity of 1,200,000 MT [3]		✓
	Strengthen crop management practices (disease prevention, diagnostic, surveillance and control) [3]	(i) Number of farmers using surveillance tool (FAW Database, BXW apps etc.)	(i) 2000 farmers using surveillance tools in 2019	(i) 9000 farmers using surveillance tools by 2025 and 18,000 farmers by 2030		✓

Sector: Agriculture						Unconditional	Conditional
Activity name	Adaptation intervention	Selected indicators (with stakeholders) [Sources: 1- NDC, 2- SPCR, 3- SSP and others]					
		Indicators	Baselines	Targets			
	Develop sustainable land management practices (soil erosion control, landscape management) [3]	(i) Area of Land under erosion control measures and used optimally [3] (ii) Percentage of arable land (to the land area)	(i) In June 2017, an estimated 103,918 ha of radical terraces and 913,884 ha of progressive terraces have been implemented [1, 3] TBD (ii) 52% of the national total surface area in 2019 used as arable land	(i) The target is to reach 142,500 Ha of land with radical terraces and 1,007,624 Ha of progressive terraces by 2025 [3]; (ii) Biological soil conservation practices of 150,000 ha by 2025			✓
	Expand irrigation and improve water management [3]	(i) Number of hectares under irrigation within IWRM framework [1, 3]	(i) By 2016, only 48,508 ha (7.5% of land with irrigation potential) had been equipped with irrigation technology [3]	(i) 102,284 Ha to be irrigated by 2025 [3]; (ii) 200,000 Ha to be irrigated by 2030			✓

Sector: Agriculture					Unconditional	Conditional
Activity name	Adaptation intervention	Selected indicators (with stakeholders) [Sources: 1- NDC, 2- SPCR, 3- SSP and others]				
		Indicators	Baselines	Targets		
	Expand crop and livestock insurance	(i) Ha of crops under insurance (by season) (ii) Number of cows under insurance	(i) Crop insured by 2019: - Maize: 247.61 Ha - Rice: 1,588 Ha (ii) Livestock insured by 2019: - Poultry: To be determined - Piggery: To be determined - Cows: 3,496	(i) 37,462 Ha of crops insured by 2025. Including the following: - Maize: 16,244 Ha - Rice: 10,322 Ha - Banana: 928 Ha - Cassava: 975 Ha - Beans: 278 Ha - Irish potato: 2785 Ha - Soybeans: 278 Ha Horticulture: - French beans: 975 Ha - Chili: 500 Ha -Tea: 4177 Ha (ii) 102,284 Ha of crops insured by 2030 (the total irrigated area by 2025, i.e. half of the irrigated area targeted by 2030) (iii) 585,792 livestock insured by 2025. Including the following: - Poultry: 464,100 - Piggery: 23,205 - Cows: 98,487		✓

Sector: Agriculture					Unconditional	Conditional
Activity name	Adaptation intervention	Selected indicators (with stakeholders) [Sources: 1- NDC, 2- SPCR, 3- SSP and others]				
		Indicators	Baselines	Targets		
				(iv) TBD livestock insured by 2030 (Assuming to maintain 585,792 livestock previously insured)		

Note: For soil erosion control, MINAGRI is proposing to revise the efficiency of existing infrastructures, e.g. Terraces, and to design the best soil erosion control measures through a study that will be conducted in partnership with the MoE.

Table 8.3 List of adaptation interventions in Land and Forestry sectors and corresponding indicators

Sector: Land and Forestry					Unconditional	Conditional
Activity name	**Adaptation intervention**	**Selected indicators (with stakeholders)** [Sources: 1- NDC, 2- SPCR, 3- SSP and others]				
		Indicators	**Baselines**	**Targets**		
Sustainable management of forestry and Agroforestry [2]	Development of Agroforestry and Sustainable Agriculture (control soil erosion and improved soil fertility) [2]	(i) Change in land area covered by agroforestry [1]	(i) In 2019, agroforestry is covering 212,214 ha, i.e. 25% of arable land	(i) Agroforestry covering 50% and 80% of arable land respectively by 2025 and 2030		✓
	Promote afforestation / reforestation of designated areas [1]	(i) Hectares of forest restored/ afforested in program area and hectares of protected forest in project/ program area [3]; (ii) Percentage of forest area	(i) In 2019 it is indicated that 724,666 ha (30.4%) of Rwandan dry land was covered by forest;	(i) To have a sustained forest cover of 724,666 ha (30.4%) by 2025 and 2030; (ii) 20,000 Ha of new land area afforested by 2030 (i.e. 10,000 Ha by 2025 and additional 10,000 Ha by 2030)	✓	

Sector: Land and Forestry					Unconditional	Conditional
Activity name	Adaptation intervention	Selected indicators (with stakeholders) [Sources: 1- NDC, 2- SPCR, 3- SSP and others]				
		Indicators	Baselines	Targets		
Wood Supply Chain, Improved Efficiency and Added Value [2]	Improve Forest Management for degraded forest resources [1]	(i) Number of Ha of private forest restored and whose owners are grouped into cooperatives; (ii) Number of Ha of forest plantation whose management is transferred to the private operators; (iii) Change in Forest area degraded/ rehabilitated [1]	(i) 880 Ha of private forest were restored, and owners were grouped into cooperatives by 2019; (ii) 36% (22,148.7 Ha) of public forest plantations allocated to private operators by 2019	(i) 10,000 Ha of private forest will be restored, and owners will be grouped into cooperatives by 2030 (i.e. 5,000 Ha by 2025 and additional 5,000 Ha by 2030); (ii) 60% and 80% of public forest plantations allocated to private operators respectively by 2025 and 2030		✓

Climate-sensitive Integrated Land Use Planning and Spatial Planning [2]	Integrated approach to planning and monitoring for sustainable land use management [1]	(i) NLUDMP that includes comprehensive measures and procedures for sustainable land use practices; (ii) Detailed spatial plans for all districts; (iii) % of compliance of LUDP to the NLUDMP [3]	(i) National land use development master plan (NLUDMP) is being developed	(i) 100% of Land Use Plans (LUP) harmonized with NLUDMP by 2025[3]; (ii) 100% agriculture and premium land protected by 2025 [3]; (Note: premium land includes ecosystems); (iii) Materialization of physical boundaries for Kigali, surrounding districts of Kigali and six secondary cities by 2025; (iv) 100% streamlined coherence between sectors and stakeholders relevant to the use of land by 2025; (v) Spatial/land use planning linked with economic planning by 2030; (vi) To develop and strengthen the Land use monitoring and supervision by 2025; (vii) To develop a land use monitoring index by 2025		✓

Sector: Land and Forestry					Unconditional	Conditional
Activity name	Adaptation intervention	Selected indicators (with stakeholders) [Sources: 1- NDC, 2- SPCR, 3- SSP and others]				
		Indicators	Baselines	Targets		
	Develop a harmonized and integrated spatial data management system for sustainable land use management [1]	(i) Accurate data on exposure to climate vulnerability on HHs and infrastructure in high risk areas reported [3] (ii) Percentage of operational integrated geospatial information framework integrated with environmental and socio-economic statistics	(i) 8 Continuous Operating Reference System (CORs) with 50% of coverage 2017/18) [3]; (ii) low accurate and outdated geospatial data in place	(i) To have an operational and integrated National Spatial Data Infrastructure (NSDI) by 2030 [1]; (ii) To develop updated and accurate geospatial data and tools to guide every planning in the country by 2030		✓
	Inclusive land administration that regulate and provide guidance for land tenure security *(Note: Effective land administration that increase the security of tenure, access to land and create an incentive for landowners to use their land in a sustainable manner)*	(i) Percentage of registered state land optimally used (ii) Up to date land register (iii) Model linking land use/administration in place	(i) 11,4 million parcels registered/8,8 titles issued by 2019	(i) To ensure the security of tenure and access to land for the rational use of land by 2025; (ii) To update the land registration data/ information by 2025	✓	

Table 8.4 List of adaptation interventions in Human Settlements sector and corresponding indicators

<table>
<tr><th colspan="5">Sector: Human Settlements</th><th rowspan="3">Unconditional</th><th rowspan="3">Conditional</th></tr>
<tr><th rowspan="2">Activity name</th><th rowspan="2">Adaptation intervention</th><th colspan="3">Selected indicators (with stakeholders)
[Sources: 1- NDC, 2- SPCR, 3- SSP and others]</th></tr>
<tr><th>Indicators</th><th>Baselines</th><th>Targets</th></tr>
<tr><td>Land Use and Spatial Planning [2]</td><td>High density buildings and informal settlement upgrading [3]</td><td>(i) Percentage of (1) urban population living in informal settlements, (2) rural population living in clustered settlements [3]

(ii) Average share of the built-up area of cities that is open and green space for public use for all (SDG)

(iii) Access to water and sanitation services [3]</td><td>(i) 62.60% of urban population living in informal settlements in 2016 [3]

(ii) 67.9% of rural households are settled in integrated, planned, green rural settlements in 2019 [3]

(iii) The CoK is comprised of more than 30% public space in 2018 [3]

(iv) 87.4% of HH using an improved water source and 86.2% of HH accessing basic sanitation facilities in 2017 [3]</td><td>(i) 47 % of urban population living in informal settlements by 2025 [3]

(ii) 35% of urban population living in informal settlements by 2030

(iii) 80% of rural households settled in integrated, planned, green rural settlements by 2025 [3]

(iv) To have a sustained (with qualitative maintenance) of 30% urban green and public space [3]

(v) 100% of HH using an improved water source and 100% of HH accessing basic sanitation facilities by 2030 [3]</td><td></td><td>✓</td></tr>
</table>

Sector: Human Settlements					Unconditional	Conditional
Activity name	Adaptation intervention	Selected indicators (with stakeholders) [Sources: 1- NDC, 2- SPCR, 3- SSP and others]				
		Indicators	Baselines	Targets		
Storm water and Drainage Management [3]	Storm water management [3]	(i) Percentage of urban population in areas covered by master plans with storm water considerations [3]	(i) Less than 20% of urban population in areas covered by master plans with storm water considerations in 2016 [3]	(i) 90% of urban population in areas covered by master plans with storm water considerations by 2025 [3] (ii) Regular maintenance and upgrading of road and drainage infrastructures [2]		✓

Note: It should be noted that the following indicators were discussed during the consultations and mentioned as good indicators. However, the concerned sectors were not ready to do the monitoring and thus should be considered in the NDC timeline 2025 – 2030:

- *Indicator: Kigali City quick flow (runoff) rate reduced*
- *Baseline: In 2015, storm water as quick flow was 1,356M per hectare (NISR, 2019b)*
- *Target: There is not target yet set*

Table 8.5 List of adaptation interventions in Health sector and corresponding indicators

Sector: Health					Unconditional	Conditional
Activity name	Adaptation intervention	Selected indicators (with stakeholders) [Sources: 1- NDC, 2- SPCR, 3- SSP and others]				
		Indicators	Baselines	Targets		
Vector-based disease prevention [1]	Strengthen preventive measures and create capacity to adapt to disease outbreaks [1]	(i) Malaria proportional mortality rate per 1,000 population [3]	(i) 5.7 Malaria proportional mortality rate in 2016/17 [3]	(i) 3 Malaria proportional mortality rate by 2025 [3] *Note: The following programs are among the initiatives to be carried out in the country:* *Indoor Residual Spraying (IRS), Long Lasting Insecticidal Nets (LLINs), Presidential Malaria initiative (PMI), etc.*		✓

Table 8.6 List of adaptation interventions in Transport sector and corresponding indicators

Sector: Transport					Unconditional	Conditional
Activity name	Adaptation intervention	Selected indicators (with stakeholders) [Sources: 1- NDC, 2- SPCR, 3- SSP and others]				
		Indicators	Baselines	Targets		
Sustainable, climate-resilient roads and bridges [2]	Improved transport infrastructure and services [1]	(i)Environmental and engineering guidelines developed (for climate resilient road infrastructure)	(i) Draft road design manuals are available but without consideration of climate change adaptation	(i) Guidelines developed by 2025 on: - road material stabilization - Seals technology - Gravel roads inspection and maintenance - emergency response to landslide & floods - erosion control - quarry and borrow pits management	✓	
		(i) Reduction of Length of roads vulnerable to flood and landslides	(i) In 2015, the total length of roads vulnerable to landslide was estimated at 979 km (with 165 km for national paved roads, 210 km for national unpaved roads and 604 km for district roads) (MIDIMAR, The National Risk Atlas of Rwanda,, 2015)	(i) To be determined **Note:** Accurate and additional information will be supplemented from a project on Capacity development for Climate Resilient Road Transport Infrastructure currently being conducted across the country with expected end date July 2022		✓

		(i) Length of paved national roads (ii) Number of km of feeder roads rehabilitated (iii) Number of passengers using the public transport each year [1]	(i) In 2017, the total length of urban road was estimated at 421.4 Km [3] (ii) In 2017, the total length of feeder road rehabilitated was estimated at 2060 Km [3]	(i) Establishing Scheduled Bus Routes, Construction of Urban Roads and rural roads rehabilitated, route franchising, and Operationalization of Smart Ticketing System [3]		✓

Table 8.7 List of adaptation interventions in Mining sector and corresponding indicators

Sector: Mining					Unconditional	Conditional
Activity name	Adaptation intervention	Selected indicators (with stakeholders) [Sources: 1- NDC, 2- SPCR, 3- SSP and others]				
		Indicators	Baselines	Targets		
Climate compatible mining [1]	Climate compatible mining [1]	(i) Percentage of companies deploying climate compatible mining [1]	(i) All active mines are complying with water use efficiency in 2017 [1]; (ii) In 2017/18 [3]: (a) Model mines concept has been developed (b) Mining standards developed (c) report for SEA for mining (d) EIA required for each mining license f) Mining law 58/2018	(i) All (100%) mines comply water use efficiency by 2025 and 2030; (ii) Rehabilitation of abandoned mining sites	✓	

Table 8.8 List of adaptation interventions in cross-sectors and corresponding indicators

Sector: cross-sectors					Unconditional	Conditional
Activity name	Adaptation intervention	Selected indicators (with stakeholders) [Sources: 1- NDC, 2- SPCR, 3- SSP and others]				
		Indicators	Baselines	Targets		
DRR program (Disaster preparedness and emergency response) [1]	Disaster risk monitoring	(i) Number of effective city contingency plans developed (ii) Population covered by Disaster risk reduction (DRR) programs [1]	(i) National risk atlas of Rwanda developed in 2015 and Disaster risk maps	(i) Review contingency plans and develop districts disaster management plans [1] (ii) Detailed National risk and vulnerability atlas developed by 2025 [3]	✓	
	Establish an integrated early warning system, and disaster response plans [1]	(i) Percentage of occurred extreme weather events for which advance warning was provided at least 30 minutes in advance [3] (ii) Population covered by DRR programs [1]	(i) 70% occurred extreme weather events are warned in lead time by 2017 [3] (ii) In 2015, around 30,000 households in high risk zone were recorded [1]	(i) 95% occurred extreme weather events are warned in lead time by 2025 and 2030 [3] (ii) Community-based DRR with developed farming techniques, first aid training, public awareness for disease prevention, and relocation of 10,209 households from high risk zones by 2030 [1,3]		✓
Institutional capacity development	Institutional capacity building and development for cross-sector NDC implementation	(i) Number of staff who acquired technical skills to effectively coordinate and report on NDC implementation [3]	(i) MoE staff and focal point in other sectors are available to support coordination across sectors but will need additional technical skills [3]	(i) Sectors effectively coordinated to implement NDC priorities by 2025 and 2030		✓

Sector: cross-sectors					Unconditional	Conditional
Activity name	Adaptation intervention	Selected indicators (with stakeholders) [Sources: 1- NDC, 2- SPCR, 3- SSP and others]				
		Indicators	Baselines	Targets		
Finance (Resources mobilization) [2]	Access to finance	(i) Cumulative volume of finance [USD millions] mobilized for climate and environmental purposes [3]	(i) 99 USD millions mobilized in 2017/18 [3]	(i) 217.78 USD millions to be mobilized by 2025 [3]		✓

8.3 Categorisation of adaptation indicators

Based on the selected adaptation interventions, the consultations with stakeholders and the existing RBME indicators, 42 indicators in total were considered to guide baselines and adaptation targets. In addition, by considering the experiences in reporting at global level (including expectations of adaptation investment funds) and national level (including projects), the indicators were divided into two categories A and B. The category A indicators should be used for reporting on adaptation interventions at global level while category B indicators should be used at national level. In total 9 indicators were selected for category A while 33 indicators belong to category B. Overall, both category indicators are designated to measure progress in the course of developing and implementing adaptation interventions as well as for informing project M&E frameworks seeking funding for implementing those interventions. Table 8.9 below provide the categorisation of selected indicators.

Table 8.9 Categorisation of selected adaptation indicators

SN	INDICATORS	CATEGORY
	Water sector	
1	Water storage per capita	**A**
2	Renewable water resource availability per capita per annum (m^3 /capita/a)	B
3	Percentage of catchments with water balance and allocation models	B
4	Number of hydrological stations	B
5	Percentage of water bodies with ambient water quality	B
	Agriculture sector	
6	Number of climate resilient crop varieties developed	B
7	Percentage of farmers adopting resilient crop/ varieties	B
8	Percentage of crossbreed livestock at national herd species	B
9	Capacity of storage constructed in MT	B
10	Number of farmers using surveillance tool (FAW Database, BXW apps etc.)	B
11	Area of Land under erosion control measures and used optimally	B
12	Percentage of arable land (to the land area)	**A**
13	Number of hectares under irrigation within IWRM framework	**A**
14	Ha of crops under insurance	B
15	Number of cows under insurance	B
	Land and Forestry sectors	
16	Change in land area covered by agroforestry	**A**
17	Hectares of forest restored/ afforested in program area and hectares of protected forest in project/ program area	B
18	Percentage of forest area (to the land area)	**A**
19	Number of Ha of private forest restored and whose owners are grouped into cooperatives	B
20	Number of Ha of forest plantation whose management is transferred to the private operators	B
21	Change in Forest area degraded/ rehabilitated	B
22	National land use development master plan (NLUDMP) that includes comprehensive measures and procedures for sustainable land use practices	B

SN	INDICATORS	CATEGORY
23	Detailed spatial plans for all districts	B
24	% of compliance of land use development plans (LUDP) to the NLUDMP	B
25	Accurate data on exposure to climate vulnerability on households (HHs) and infrastructures in high risk areas reported	B
26	Percentage of operational integrated geospatial information framework integrated with environmental and socio-economic statistics	B
27	Percentage of registered state land optimally used	B
28	Model linking land use/administration in place	B
	Human Settlements sector	
29	Percentage of (1) urban population living in informal settlements, (2) rural population living in clustered settlements	**A**
30	Percentage of urban population in areas covered by master plans with storm water considerations	B
31	Average share of the built-up area of cities that is open and green space for public use for all (SDG)	B
32	Access to water and sanitation services	B
	Health Sector	
33	Malaria proportional mortality rate per 1,000 population	A
	Transport sector	
34	Environmental and engineering guidelines developed (for climate resilient road infrastructure)	B
35	Reduction of length of roads vulnerable to flood and landslides	B
36	Number of passengers using the public transport each year	B
	Mining sector	
37	Percentage of companies deploying climate compatible mining	B
	Cross-sectors	
38	Population covered by Disaster risk reduction (DRR) programs	B
39	Number of effective city contingency plans developed	B
40	Percentage of extreme weather events for which advance warning was provided at least 30 minutes in advance	**A**
41	Number of staff who acquired technical skills to effectively coordinate and report on NDC implementation	B
42	Cumulative volume of finance [USD millions] mobilized for climate and environmental purposes	**A**

8.4 Priority adaptation interventions

Multi-criteria analysis constitutes a decision analysis tool that can serve as a substitute for a single-criterion approach such as cost-benefit analysis and mostly in environmental and social impacts cases that are not easily amenable to monetary values measurements. MCA, appropriately applied can address a comprehensive range of social, environmental, technical, economic, and financial criteria (UNFCCC, 2004). An MCA methodology was adapted as a proposed decision tool for prioritization of interventions particularly as a useful guide during program and project design. A summary of the Identified intervention areas and indicators for Rwanda's NDC developed on the basis of the methodology is explained in Table 8.10. The identified adaptations interventions were then assessed for prioritisation by using the below evaluation criteria. The outcome of the process is reported in Table 8.11 to Table 8.13.

EVALUATION CRITERIA

- High performance
- Moderate performance
- Mixed or uncertain performance
- Low performance

EVALUATION OF OUTCOME

- High priority adaptation option
- Medium priority adaptation option
- Lower priority adaptation option
- Inappropriate adaptation option

Table 8.10 Evaluation criteria for adaptation activities

EVALUATION CRITERIA	Environmental effectiveness	Contribution towards NDC target	Does the adaptation activity offer the ability to adjust to climate change, to moderate potential damages and/ or to deal with consequences towards meeting the NDC target through 2030?
		Indirect environmental effects	Are there other environmental impacts arising from implementation? May include negative impacts (e.g. biodiversity and landscape loss) and positive impacts (environmental co-benefits).
		Mitigation Co-Benefits	Are there interactions and alignment with benefits related to the reduction of greenhouse gases (mitigation) and policy aims?
	Socio-economic impacts and co-benefits	Cost-effectiveness	Does the adaptation activity moderate potential damages with cost effectiveness? i.e. cost implication
		Welfare and equity	Are there possible changes to welfare within affected groups, including changes to prices and distributional outcomes? May include both negative impacts (e.g. increased costs for low income households) and positive impacts.
		Competitiveness and productivity	What are the potential impacts upon business and the wider economy? May include negative impacts (e.g. increased operating costs and administrative burden) and positive impacts (e.g. increased efficiency, reduced operating costs).
		Green growth and employment	Ability to deliver additional employment and green growth opportunities within the country.
	Feasibility of implementation	Alignment with other policy aims	Is the adaptation activity in alignment with national policy aims and objectives (e.g. national strategies for economic development, employment, poverty alleviation and energy provision).
		Legal and regulatory feasibility	Are there potential issues with implementation arising from the legal and/or regulatory framework?
		Suitability to funding and climate finance	Is the adaptation activity suited to attracting funding, including both commercial investment and public sector lending and/or international and bilateral climate finance (e.g. suitability of technology or project type)
		Other implementation challenges	Are there other key challenges, risks and barriers likely to impact the chance of project implementation within a mix of options designed to meet the NDC?

Source: Adapted from Carbon Counts

Table 8.11 Evaluation summary for priority adaptation activities in water and agriculture sectors

EVALUATION CRITERIA

- High performance
- Moderate performance
- Mixed or uncertain performance
- Low performance

			WATER			AGRICULTURE					
			Integrated Water Resource Planning and Management			Climate Resilient Value Chain Development					
			A National Water Security through water conservation practices, wetlands restoration,	Water resource models, water quality testing, and hydro-related information	Develop and implement a management plan for all Level 1 catchments	Develop climate resilient crops and promote climate resilient livestock	Develop climate resilient postharvest and value addition facilities and technologies	Strengthen crop management practices	Develop sustainable land management practices	Expand irrigation and improve water management	Expand crop and livestock insurance
EVALUATION CRITERIA	Environmental effectiveness	Contribution towards NDC target	High	High	High	High	Moderate	High	High	High	High
		Indirect environmental effects	High	High	Moderate	Low	High	High	Mixed or uncertain	Mixed or uncertain	High
		Mitigation Co-Benefits	High	Moderate	High	Mixed or uncertain	Mixed or uncertain	High	Moderate	Moderate	Moderate
	Socio-economic impacts and co-benefits	Cost-effectiveness	Moderate	High	Moderate	High	High	High	High	Moderate	Moderate
		Equity and welfare	High	High	Mixed or uncertain	Moderate	High	Moderate	High	Moderate	High
		Competitiveness and productivity	High	Moderate	High	High	High	High	Moderate	Moderate	Moderate
		Green growth and employment	High	Moderate	High	Moderate	High	High	High	High	High
	Feasibility of implementation	Alignment with other policy aims	High	High	High	Moderate	High	High	High	High	High
		Legal and regulatory feasibility	High	High	Mixed or uncertain	High	High	High	High	Mixed or uncertain	Mixed or uncertain
		Suitability to funding and climate finance	High	High	High	High	High	High	High	Moderate	Moderate
		Other implementation challenges	Mixed or uncertain	Mixed or uncertain	Moderate	Mixed or uncertain	Mixed or uncertain	Moderate	Mixed or uncertain	Moderate	Mixed or uncertain
OUTCOME	Short-term options - 2020-2025		✓	✓	✓	✓	✓	✓	✓	✓	✓
	Medium-term options - 2025-2030		✓	✓		✓	✓	✓		✓	✓
	Not applicable or long-term only >2030										

Note: The use of short term and long-term options for one adaptation intervention consider that two different targets were sets in both terms as details in tables 8.1 to 8.8. Example: Develop a National Water Security through water conservation practices has two targets: (i) 10 m^3 per capita storage by 2025, and (ii) 12 m^3 per capita storage by 2030.

Table 8.12 Evaluation summary for priority adaptation activities in land and forestry and human settlement sectors

EVALUATION CRITERIA

- High performance
- Moderate performance
- Mixed or uncertain performance
- Low performance

		LAND AND FORESTRY						HUMAN SETTLEMENT	
		Sustainable management of forestry and Agroforestry		Wood Supply Chain	Climate-sensitive Integrated Land Use Planning			Urban Land Use	Storm water
		Development of Agroforestry and Sustainable Agriculture	Promote afforestation / reforestation of designated areas	Improve Forest Management for degraded forest resources	Integrated approach to planning and monitoring for sustainable land use mgt	Harmonised and integrated spacial data management system for sustainable land use	Inclusive land administration that regulate and provide guidance for land tenure security	High density buildings and informal settlement upgrading	Storm water management
Environmental effectiveness	Contribution towards NDC target	High	High	High	High	High	High	High	High
	Indirect environmental effects	High	Moderate	High	Moderate	High	High	Moderate	Mixed or uncertain
	Mitigation Co-Benefits	High	High	High	High	High	Moderate	High	High
Socio-economic impacts and co-benefits	Cost-effectiveness	High	Moderate	High	High	High	High	High	High
	Equity and welfare	High	High	High	High	High	High	Moderate	High
	Competitiveness and productivity	High	Moderate	High	High	High	High	High	High
	Green growth and employment	High	High	High	High	Moderate	High	High	High
Feasibility of implementation	Alignment with other policy aims	High	High	High	High	High	High	High	High
	Legal and regulatory feasibility	Moderate	High	High	Moderate	High	High	Moderate	Moderate
	Suitability to funding and climate finance	Moderate	High	High	High	Moderate	Moderate	Moderate	High
	Other implementation challenges	Mixed or uncertain	Mixed or uncertain	Mixed or uncertain	Moderate	Moderate	Mixed or uncertain	Moderate	Moderate

Short-term options - 2020-2025	✓	✓ (light)	✓	✓	✓ (light)	✓	✓	✓
Medium-term options - 2025-2030	✓	✓ (light)	✓	✓	✓ (light)		✓	
Not applicable or long-term only >2030								

Table 8.13 Evaluation summary for priority adaptation activities in health, transport, mining and cross-sectoral

EVALUATION CRITERIA

- High performance
- Moderate performance
- Mixed or uncertain performance
- Low performance

		HEALTH	TRANSPORT	MINING	CROSS-SECTORAL			
		Vector-based diseases	Roads and bridges	Climate compatible mining	DRR program		Capacity development	Resource mobilization
		Strengthen preventive measures and create capacity to adapt to disease outbreaks	Improved transport infrastructure and services	Climate compatible mining	Disaster risk monitoring	Establish an integrated earlywarning system, and disaster response plans	Capacity building and development for cross-sector NDC implementation	Access to finance
Environmental effectiveness	Contribution towards NDC target	High	High	Moderate	High	High	High	High
	Indirect environmental effects	Mixed	Mixed	Moderate	High	Mixed	High	High
	Mitigation Co-Benefits	Mixed	High	High	Moderate	Moderate	High	High
Socio-economic impacts and co-benefits	Cost-effectiveness	High	High	High	High	High	High	High
	Equity and welfare	High	High	Mixed	High	High	High	High
	Competitiveness and productivity	High	High	High	High	High	High	High
	Green growth and employment	Moderate	High	High	Moderate	High	High	High
Feasibility of implementation	Alignment with other policy aims	High	High	High	High	High	High	High
	Legal and regulatory feasibility	Moderate	High	High	High	Moderate	High	High
	Suitability to funding and climate finance	High	High	Moderate	High	Moderate	High	Moderate
	Other implementation challenges	Moderate	Mixed	Moderate	Moderate	Mixed	Moderate	Mixed

Short-term options - 2020-2025	✓	✓	✓	✓	✓	✓	✓
Medium-term options - 2025-2030			✓		✓	✓	
Not applicable or long-term only >2030							

9 MONITORING, EVALUATION AND REPORTING

9.1 Mitigation

9.1.1 Overview

The successful implementation of Rwanda's NDC requires an effective Measurement, Reporting and Verification (MRV) system, enabling the country to monitor the effectiveness of its mitigation actions and facilitating its access to international climate finance. Internationally, the implementation of an MRV system is the basis for understanding the current GHG emission levels, the ambition of the existing efforts, and the progress made in contributing towards the goals of the Paris Agreement.

Monitoring and reporting requirements for Parties to the Paris Agreement are encapsulated within the UNFCCC process by way of new requirements set out in the 'Paris Rulebook'[30] governing implementation of the agreement. Drawing on the Paris Rulebook, Table 9.1 below lists some of the key aspects of an MRV system that will be needed to track progress consistent with NDC implementation.

Table 9.1 MRV systems needed to track NDC implementation

MRV system	Key implementation aspects
GHG emission and reductions	• Assess current GHG emissions for all Intergovernmental Panel on Climate Change (IPCC) reporting sectors and sub-sectors; • Assess Busines-as Usual (BAU) GHGs, where dynamic baselines are considered for NDC modeling; • Assess current progress in reducing GHG emissions towards the overall target (by reviewing the greenhouse gas inventory), and expected future emissions (by reviewing greenhouse gas projections), at national and sectoral levels, to understand the aggregate impact of mitigation actions now and in the future.
Mitigation measures	• Monitor the implementation of the mitigation measures (e.g. implementation of renewable energy generation measures, low carbon transport measures, waste projects); • Assess whether the mitigation measures deliver the targeted impact on GHG emissions; • Assess whether the mitigation measures deliver the expected low emission development impact (e.g. implementation of solar water heating systems in households);
Finance of mitigation measures	• Track climate finance flows for NDC implementation, including international public finance, national domestic budgets and private climate finance, to improve the overall transparency of climate finance flows, and • Assess whether the scale/type of financing requirements for NDC implementation are being addressed.

[30] As contained in Decisions 1 to 20 of the first Conference of the Parties serving as the meeting of the Parties to the Paris Agreement (CMA), held at the Katowice Climate Change Conference in December 2018.

This section outlines the key elements of an MRV framework consistent with these requirements. These actions will allow Rwanda to effectively track progress of mitigation activities identified in the NDC consistent with UNFCCC reporting standards, and carry out ongoing evaluation of whether the country is on course to meet its targets through 2030. It covers the following key elements:

- Reporting requirements under UNFCCC and Paris Agreement
- Tracking progress towards the NDC
- Monitoring international support (climate finance)

A framework of indicators is then proposed for monitoring progress towards meeting the NDC and implementing the mitigation actions described in this document. The indicators, which can be used for international reporting as well as for domestic tracking of NDC implementation, are presented for each of the key emitting sectors.

9.1.2 Reporting requirements under UNFCCC and Paris Agreement

All Parties to the UNFCCC are required to implement a domestic MRV system that can annually quantify national GHG emissions by sources and removals by sinks, and report the specific actions made to identify and implemented mitigation measures. This information is at present compiled by Rwanda and is submitted to the UNFCCC through two channels:

- **National Communications (NCs)** to be submitted every four years, covering measurements of GHG emissions by sources and removals by sinks compiled in accordance with IPCC reporting guidelines (i.e. a National GHG inventory). These should also include a description of steps made to implement mitigation actions in support of the UNFCCC goal, among other aspects (as required under Decision 17/CP.8 and other decisions on implementation details); and
- **Biennial Update Reports (BURs)** to be submitted every two years. These should include an up-dated GHG inventory report from that of the NC, a measurement of mitigation actions and their impacts, reporting on the domestic MRV system and a description of needs and international support received. All non-Annex I countries should have submitted their first BUR by December 2014 and then every two years thereafter (Decision 2/CP.17; Decision 19/CP.18; Decision 9/CP.21).

Rwanda submitted its Third National Communication (TNC) in September 2018, reporting on its national GHG inventory for the year 2015. The country is currently preparing its first BUR and an updated GHG inventory.

The Paris Agreement contains several additional MRV requirements which, when taken together with the existing UNFCCC arrangements, provide an enhanced basis for Rwanda's international reporting requirements relating to the mitigation component of the NDC. New requirements are mainly covered by Article 13, which establishes a new Enhanced Transparency Framework (ETF) through which Parties must regularly account for their NDCs alongside other reporting requirements similar to those contained in NCs, BURs and the International Consultation and Analysis (ICA).

The Paris Rulebook, most of which was agreed in 2018, included Modalities, Procedures and Guidelines (MPGs) for the ETF, covering new MRV requirements for signatory Parties (widely referred to as the "MPGs" under Decision 18/CPA.1 and the Annex thereto). The MPGs require all Parties to submit Biennial Transparency Reports (BTRs) including a National Inventory Report (NIR) by the end of 2024, and every two years thereafter, covering a range of aspects which include, add to and enhance MRV requirements under the UNFCCC, including:

- Provision of information by which to track progress in implementing and achieving NDCs;
- Provision of information on adaptation (see Section 9.2 below);
- Enhanced rules around reporting of annual inventories of GHG emissions and removals; and
- Information on financial, technology development and transfer and capacity-building support received and needed in the future.

In all cases, the MPGs allow for flexibility in implementing MRV for developing countries, recognising their national capacities. However, all Parties are expected to:

- Report information in the BTR on each selected NDC indicator in each reporting year during the NDC implementation period;
- Report GHG emissions and removals data for a reporting year no older than three years before the date of submission of the BTR or NIR (i.e., the vintage of reporting data must not exceed 3 years).

Therefore, under the Paris Rulebook, Rwanda will be required to regularly and systematically monitor and report information on its mitigation actions in a way that provides clarity and allows regular review of the level of progress being made in achieving the mitigation targets specified in the NDC. Information submitted in the BTR and NIR will be used to assess progress in NDC implementation through a Global Stocktake (GST) of efforts made by the UNFCCC, as specified under Article 14 of the PA.[31]

9.1.3 Tracking progress towards the NDC

In addition to the international reporting requirements outlined above, domestic reporting of Rwanda's GHG emissions and efforts taken to reduce emissions will be important to building national transparency around the country's climate response as well as helping to inform good policy-making. Robust NDC monitoring is therefore needed at both the international and domestic levels, to meet the following twin objectives:

Objective 1: Monitoring the effectiveness of policies and programs

This report identifies a large number of NDC mitigation measures covering a wide range of projects, policies and programs across multiple sectors. A successful monitoring system will enable the GoR to not only monitor the GHG emissions and related emission reductions, but also to monitor whether certain measures deliver the expected impacts in terms of expected policy and socio-economic development outcomes, including co-benefits (e.g. clean energy access,

[31] The GST will help determine whether Parties are collectively on track to meet the Paris Agreement's ultimate goal of limiting mean global temperature increases to within 2°C compared to preindustrial levels or, more ambitiously, 1.5°C.

increased public transport investment). Information on key indicator values to demonstrate progress in implementing those actions can therefore be viewed as useful additional information. Reporting information on mitigation actions aggregated at the sector level is also useful, because the indicators used to monitor the impacts of the NDC mitigation measures can help in understanding the changes in sectoral GHG emissions through 2030. To enable transparent MRV and assessment of progress in implementing each measure, the tracking framework will need to include information on (i) measures being implemented for achieving the mitigation target for the current accounting period at that time; (ii) measures planned for achieving the mitigation target for the next NDC accounting period; and (iii) key indicator values to report the impacts/outcomes of the measures being implemented for the current NDC accounting period at that time.

Objective 2: Monitoring of GHG emissions and progress towards NDC target
The nature of Rwanda's target, including the coverage of sectors, will determine the specific information needing to be monitored to track progress of the NDC. At the time of writing, it is understood that the national target will be defined on the basis of achieving a certain percentage (%) reduction in absolute GHG emissions in 2030 with respect to a BAU baseline reference case. The scope of the target is economy-wide, excluding forestry for reasons of data quality. The emissions reduction achieved in each year will therefore be determined by the relative difference between the emissions level achieved through implementation of the NDC mitigation actions in 2030 (actual emissions) and a BAU emissions projection for the same year. This latter projection represents the case under which no actions additional to those already being implemented are taken to reduce GHG emissions.

For NDC mitigation targets expressed as reductions of GHG emissions below BAU, reporting information on the description of the mitigation actions, and on the projections of national GHG emissions with mitigation measures, provides sufficient information on tracking progress in implementing an NDC (Desgain and Sharma, 2016). The use of progress indicators, grouped according to key emitting sectors, are therefore a useful element of the MRV framework needed to track the progress of the NDC. The information required is similar to that which Rwanda is currently required to report under UNFCCC.[32]

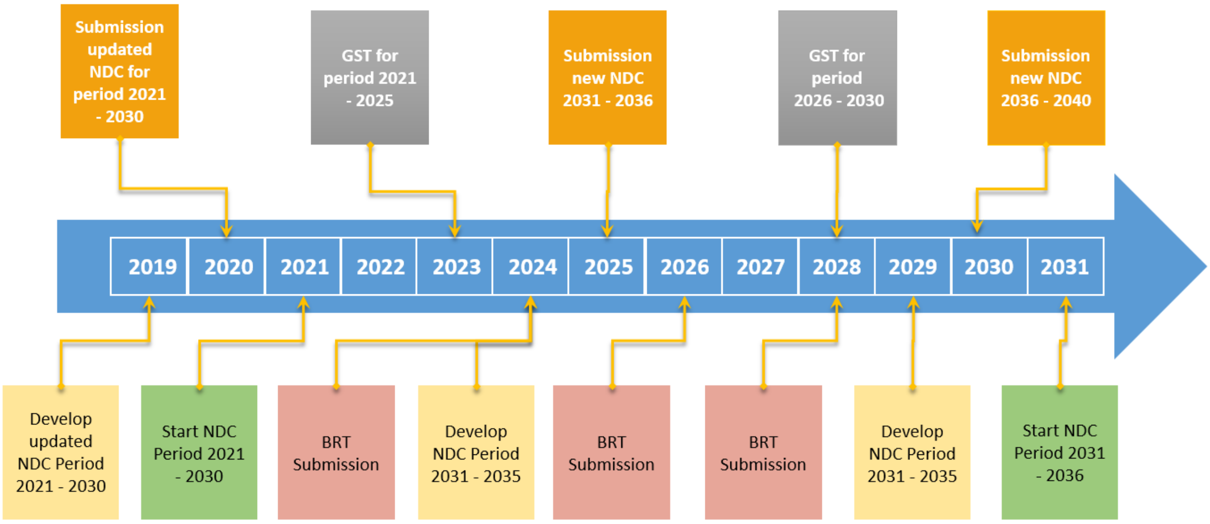
Timeline for MRV of NDC
Rwanda has submitted an NDC for the period to 2030 and is required to communicate or update its NDC in 2020 (i.e. based on the analysis presented in this report), and then every five years thereafter. Rwanda's second NDC will therefore need to be submitted in 2025 (for the accounting period 2031-2035). The 'global stocktake' of all NDCs will take place three years after the start of each accounting period. So for example, during the period 2021-2025, the global stocktake will take place in 2023.

Figure 9.1 below summarises the NDC development and MRV cycle under the Paris Agreement. Within this timeline, Rwanda will need to make an ongoing review of its NDC target and the ability to increase the level of ambition. This will be informed by the collection and preparation

[32] For example, the requirements for reporting under the BURs include: Name and description of each mitigation action, including information on the nature of the action, coverage, quantitative goals related to the action, if any, and progress indicators; steps taken or planned to implement the mitigation action; progress with implementing the mitigation actions and the results achieved; and information on the domestic MRV system.

of national statistics, as well as tracking the progress of the mitigation actions described in this report. Importantly, with each successive NDC period, existing NDC actions (at that time) will become part of the BAU baseline thereby ensuring ongoing strengthening of ambition.

Figure 9.1 Rwanda's NDC reporting and tracking cycle



Source: GFA and Carbon Counts, 2019

Rwanda's NDC submissions should include information on the most recent BAU scenario projection, with a base year defined as the start year of the NDC accounting period ongoing at that time (i.e. five years prior to year of NDC submission). The BAU scenario should run until the end of the accounting period for which the NDC is being submitted (*ibid.*) i.e. 2030 for the first NDC; 2035 for the second NDC. The NDC should also include information on the NDC mitigation scenario (as described in this report). For the base year, national GHG emissions will be represented by the estimated national GHG inventory for that year (2015).

9.1.4 Monitoring international support

The Paris Rulebook requires Rwanda to report on financial, technical and capacity building needs, as well as indicating the support received to help meet these needs. Some of these elements are also reported in the BUR. Under Annex III of Decision 2/CP.17, the following items should be monitored and reported:

- Rwanda's national contribution to climate finance (million USD);
- International financial contribution received by Rwanda (million USD);
- Technology development and transfer (activities undertaken); and
- Capacity building (activities undertaken)

In addition, some other elements must be monitored which are not at present fully covered in the BURs. These include the following:

1. **Other voluntary schemes**: in accordance with Article 6.2 of the Paris Agreement, the progress of Nationally Appropriate Mitigation Actions (NAMAs) should be monitored, including those prepared to date.

2. **Internationally Transferred Mitigation Outcomes (ITMOs)**: in accordance with Article 6 and of the Paris Agreement, any emission reductions units generated in Rwanda but subsequently transferred to other Parties need to be monitored and recorded. These emission reductions should not be counted towards fulfilment of Rwanda's NDC, in order to avoid double counting.

These elements should therefore also be included in a framework of indicators used to track Rwanda's NDC implementation, as described below.

9.1.5 Framework of indicators

This section sets out an initial high-level framework of progress indicators for use in tracking and report on implementation of the NDC mitigation component, consistent with the MRV requirements of the UNFCCC and Paris Rulebook.[33]

A series of MRV tables are provided, enabling for monitoring of GHG emissions as well as the effectiveness of mitigation measures within each sector. Indicators are proposed which monitor both the emissions and also non-GHG indicators of progress linked, closely to each of the mitigation actions within each of the key emitting sectors. The choice of indicator has also been informed by existing indicator frameworks applied internationally in the context of climate change, which also support the metrics required under the Paris Rulebook. Simply reporting on emissions and activity data is an overly simplistic approach which cannot always help to assess the effectiveness of a given measure in reaching the NDC. Separate tables of indicators are therefore developed for each of the key sectors covered by the NDC, providing a more detailed framework for tracking progress.

Each of the sector tables is structured as following:

- **Headline indicators**: These include a breakdown by sector of emissions reductions against the BAU baseline. They also include other high-level indicators specific to each sector relating to emissions and mitigation activity.
- **Supporting indicators**: The headline indicators are underpinned by a set of more detailed indicators which track progress in implementing the mitigation measures required to achieve sustainable emission reductions. A series of supporting indicators help quantify the progress in implementing the specific actions within each sector.
- **Other factors**: Various factors will act as drivers of emissions over the coming years, many of which are outside Rwanda's control. No indicators are proposed for these, but they can be tracked as part of a monitoring framework in order to understand, and report on, their influence upon NDC implementation.

Monitoring tables are provided for the four main IPCC reporting categories: Energy; IPPU; AFOLU; and waste (note that AFOLU is at present focused only on agriculture). In addition, an aggregated economy-wide overall NDC progress monitoring template is presented.

[33] It should be noted that developing detailed MRV frameworks for each of the specific mitigation actions identified in this document is also recommended. This would allow for robust and detailed tracking of each measure needed to achieve NDC implementation, and will also be required by project financers/supporters. This falls beyond the scope of the current report.

NDC progress indicators: Aggregated all sectors						
GHG emissions		2015	2020	2021	2022	2023
BAU GHG emissions ($MtCO_2e$)	*Energy*					
	IPPU					
	Agriculture					
	Waste					
	TOTAL					
Current GHG emissions ($MtCO_2e$)	*Energy*					
	IPPU					
	Agriculture					
	Waste					
	TOTAL					
Mitigation from NDC measures ($MtCO_2e$)	*Unconditional*					
	Conditional					
	TOTAL					
Mitigation from NDC measures (% change from BAU)	*Unconditional*					
	Conditional					
	TOTAL					
Other		2015	2020	2021	2022	2023
GDP (million USD)						
Population (millions)						
Finance and mechanisms		2015	2020	2021	2022	2023
Domestic climate finance (million USD)	*Direct*					
	Indirect					
International climate finance (million USD)	*Grants*					
	Other					
Internationally Transferred Mitigation Outcomes ($MtCO_2e$)						
Technology development and transfer (describe activities undertaken)						
Capacity building and strengthening (describe activities undertaken)						
Other voluntary co-operation (describe activities undertaken)						

NDC progress indicators: Energy (electricity generation)						
Headline indicators		2015	2020	2021	2022	2023
BAU GHG emissions ($MtCO_2e$)						
Current GHG emissions ($MtCO_2e$)						
BAU electricity demand (GWh)						
Current electricity demand (GWh)						
BAU emissions intensity of grid supply (tCO_2e/MWh)						
Current emissions intensity of grid supply (tCO_2e/MWh)						
Share of renewables in total electricity supply (%)						
Supporting indicators		2015	2020	2021	2022	2023
Electricity supply		2015	2020	2021	2022	2023
Generation (GWh and % of total)	*Hydropower*					
	Solar/wind					
	Natural gas					
	Peat					
	HFO					
	Imports					
	TOTAL					
Mitigation measures		2015	2020	2021	2022	2023
Hydropower	*Capacity (MW)*					
Off-grid electrification	*# Tier 1 households*					
	# Tier 2 households					
	Solar minigrids (MWp)					
Solar street lighting	*# Solar LED streetlights*					
	# Solar traffic lights					
International finance and support		2015	2020	2021	2022	2023
International contribution to finance mitigation measures (indicate activities and amounts)						
Technology transfer and capacity building activities (indicate activities)						
Other factors						
Development and strengthening of grid infrastructure, including grid losses (indicate key developments)						
Lake Kivu methane gas utilisation and emissions monitoring programme (indicate key developments)						
Rural Energy Strategy development (progress towards goals and milestones achieved)						

NDC progress indicators: Energy (other)						
Headline indicators		2015	2020	2021	2022	2023
BAU GHG emissions ($MtCO_2e$)						
Current GHG emissions ($MtCO_2e$)						
BAU fossil fuel use (% of total energy use)						
Current fossil fuel use (% of total energy use)						
BAU renewable energy use (% of total energy use)						
Current renewable energy use (% of total energy use)						
Supporting indicators		2015	2020	2021	2022	2023
Transport		2015	2020	2021	2022	2023
Average fuel economy for newly registered vehicles (litres per 100 km)	*Buses*					
	LDVs					
	HDVs					
Electric vehicles (EV)	*# EV motorcycles*					
	# EV buses					
	# EV LDVs					
Other activities		2015	2020	2021	2022	2023
Buildings and household energy use	*Rooftop solar (MWp)*					
	# CFL replacements					
	Efficient stoves (# HH)					
	# SWH installations					
Mnaufacturing industry and agriculture	*# Efficient brick kilns*					
	Cement (% non-fossil energy use)					
	# On-farm biodigesters					
	Solar irrigation (Ha)					
International finance and support		2015	2020	2021	2022	2023
International contribution to finance mitigation measures (indicate activities and amounts)						
Technology transfer and capacity building activities (indicate activities)						
Other factors						
E-mobility, modal shift and other public transport progress (indicate key developments)						
Indicators of activity by mode of transport e.g. occupancy rates; average distances (once studies are available)						
Ongoing developments and trends within buildings practices and household and SME energy use (describe)						
Availability and cost of new and low carbon energy technologies and practices						

NDC progress indicators: IPPU						
Headline indicators		2015	2020	2021	2022	2023
BAU GHG emissions ($MtCO_2e$)						
Current GHG emissions ($MtCO_2e$)						
Supporting indicators		2015	2020	2021	2022	2023
Cement production		2015	2020	2021	2022	2023
Clinker substitution	*Pozzolana use (t)*					
	Clinker/cement ratio (%)					
Substitution of F-gases		2015	2020	2021	2022	2023
Substitution of F-gases with low GWP refrigerants	*Imported HFC (kg)*					
	F-gas use (list the gases and amounts in kg)					
	F-gas substitution (%)					
International finance and support		2015	2020	2021	2022	2023
International contribution to finance mitigation measures (indicate activities and amounts)						
Technology transfer and capacity building activities (indicate activities)						
Other factors						
Progress with enabling continued and/or greater use of clinker substitute materials in cement production						
Progress with implementation of MRV system for GHG emissions in industry (indicate developments)						
Substitution of F-gases and progress towards targets under Kigali amendment to Montreal Protocol						

NDC progress indicators: AFOLU (agriculture)						
Headline indicators		2015	2020	2021	2022	2023
BAU GHG emissions ($MtCO_2e$)						
Current GHG emissions ($MtCO_2e$)						
Crop production (total t crop biomass)						
Livestock production (# population)						
Supporting indicators		2015	2020	2021	2022	2023
Crops		2015	2020	2021	2022	2023
Nutrient use efficiency	*Compost application (ha)*					
	Compost application (t/ha)					
	Deep fertiliser and biomass use in rice production (kg/t rice)					
Soil and water conservation	*Terraced land (ha)*					
	Crop rotation (ha)					
	Banana and coffeee multi-crop production (ha)					
	Conservation tillage (ha)					
Livestock		2015	2020	2021	2022	2023
Livestock husbandry and species	*New fodder species production (ha)*					
	New fodder use (# cows)					
	New species (# cows replaced with cross-breeds)					
Manure management	*# new kraals*					
	Manure yields (t/cow)					
International finance and support		2015	2020	2021	2022	2023
International contribution to finance mitigation measures (indicate activities and amounts)						
Technology transfer and capacity building activities (indicate activities)						
Other factors						
Government fertilizer production and distribution policy (decribe progress and outcomes)						
Agricultural and horticultural production, domestic food demand, and export and market developments						
Climactic and other key factors influencing yields and agricultural practices						

NDC progress indicators: Waste						
Headline indicators		2015	2020	2021	2022	2023
BAU GHG emissions ($MtCO_2e$)						
Current GHG emissions ($MtCO_2e$)						
BAU total waste disposal (t)						
Current total waste disposal (t)						
BAU organic waste disposal (t)						
Current organic waste disposal (t)						
Supporting indicators		2015	2020	2021	2022	2023
Solid waste		2015	2020	2021	2022	2023
Landfil gas (LFG) utilisation	*# sites with LFG capture*					
	LFG generation (MW)					
Waste-to-energy (WtE)	*# WtE sites*					
	WtE generation (MW)					
Aerobic composting	*Amount produced (t)*					
	Composting rate (% organic waste composted)					
Wastewater		2015	2020	2021	2022	2023
Wastewater treatment plants (WWTP)	*# WWTP facilities*					
	# households connected to WWTP					
International finance and support		2015	2020	2021	2022	2023
International contribution to finance mitigation measures (indicate activities and amounts)						
Technology transfer and capacity building activities (indicate activities)						
Other factors						
Developments in waste infrastructure investment and management measures (indicate activities developed)						
Development of national and regional waste regulations and enforcement						
Waste recycling progress (e.g. policies and practices; plastic, metals and paper recycling rates)						

9.2 Adaptation

The Monitoring and Evaluation and Reporting framework that includes MRV on financing in the case of adaptation aligns with the adaptation options and the relevant analytics agreed to among various stakeholder consultations. Additionally, an approach has been proposed to organize M&E framework in a way that facilitates reporting at selected levels. The levels have identified indicators that are relevant at global and national (see above).

The national level reporting will respond to data and information demands at strategic levels including NST and sector strategic plans that inform joint sector reviews and other reporting requirements at the prime minister and MINECOFIN levels and Imihigo reporting for sub-national entities in particular. Importantly, these should ideally be guided by the ENR RBME framework which has oversight over cross cutting areas of environment and climate change in the national planning and budgeting framework.

Finally, the selection of indicator driven data will be required for program and projects design, implementation and reporting to funders. This reporting framework demands periodic and timely data collection, analysis and overall management to ensure efficient reporting. Moreover, the clustering will serve as a useful guide to identify targeted resources mobilization from both domestic and external sources. To the extent possible, national and global indicators design features must make a strong case for mobilizing resources and therefore must be smart and results oriented and formulated as outcome and/or impact level indicators.

The general guide to the selection of adaptation indicators has considered the following factors as critical:

- Differentiate between climate change related issues and business-as-usual development. Climate change has been taken seriously in Rwanda as evidenced by the policy prescriptions including Vision 2050, NST and the GGCRS and the regional and global programs to which Rwanda subscribes including NDC, Africa Agenda 2063 and the SDGs. However, significant gaps have been equally evident in how climate change actions in these programs are prioritised for financing that is essential for implementation. The global climate financing agencies are usually overzealous to draw a wedge where it does not even exist or merited between climate change and development. This is especially the case for climate adaptation where "climate rationale" in the case of GCF seriously hampers the ability to direct resources to address the impacts of climate change. It is crucial that climate financing decisions acknowledge the seamlessness of climate adaptation and development even as climate rationale is reasonably pursued in validating finance flows to address the impacts of climate change.
- Local/sector context is crucial to climate vulnerability/resilience assessment. Rwanda has been vigilant in addressing the impacts of climate change starting with the NAPA in 2006 to GGCRS that was approved by Cabinet in 2011. The current efforts are aimed at implementing the PA through the NDCs. Additionally, assessments have been carried out to understand the extent of climate change impacts. Such analyses have included the economics of climate change that measured the economic costs of climate change and made a compelling case for increased financing, the Vulnerability index studies at

various scales; national and sub-national outlining the vulnerability of districts and the design of investment plans including the SPCR and the FIP. The NDC partnership document highlighted the extreme need for inter-ministerial coordination mechanisms. The mechanisms can be used to support coordinated implementation, monitoring and reporting, which can reduce transaction costs and overlapping work, and promote cross-sectoral synergies. The stakeholder engagement that began to robustly involve civil society and private sector presents the potential to use climate action as a driver for sustainable development, in line with countries' ambitions under the 2030 Agenda.

- Consider data availability to measure the impact (to know that change has happened). Rwanda is increasingly making the case for global efforts to support effective climate action through the climate vulnerable countries forum. The stronger case will require continuous improvement of climate analytics that inform national and global reporting for adaptation in particular where harmonized reporting is found wanting. Integration of clear and simplified climate analytics into the ENR RBME will play a significant role in establishing a framework that Rwanda can use to build a reliable and informative database on climate adaptation metrics that systematically guides an ambitious climate action.

The technical support provided to the GoR on climate change analysis has proposed to harmonize the various national reporting initiatives and streamline a reporting structure on climate adaptation analytics. The analytical framework takes into account the need and therefore formats for clustering national and global reporting obligations. Below are the high-level indicators for the proposed reporting arrangements highlighting the source documents (References) that provide information on metadata for the selected indicators. The code classification and sources referenced from the RBME for which MoE is the custodian.

Table 9.2 High level indicators, data sources (metadata) for the proposed reporting

RBME code	Indicator	Source (Metadata)
International and regional good practices (Selected for National communication to UNFCCC)		
07 ECC01	Percentage change in national climate change vulnerability index	Source: Vulnerability Index study report
01 ECC02	Number and Percentage of districts at high risk of suffering major climate change effect	
National framework: (i) NST1; (ii) Sector strategic Plans (SSPs) and District Development Plans (DDSs); and (iii) Programs and Projects		
02 ECC04	Percentage of the rural population living in Green Villages	Source: Green Assessment tool
05 MET06	Average level of satisfaction of major Weather and Climate information institutional users with METEO RWANDA Weather and Climate information	Source: Weather and Climate information Users Survey
LAM20	Percentage of compliance of land use development plans to the NLUDMP	Source: Department of Surveying, land use plans and Mapping, (RLMUA)

RBME code	Indicator	Source (Metadata)
GEM23	Number and % of a) Mines, and b) Processors/Exporters, using appropriate technologies to ensure industry standard recovery rates	Source: Adapted Inspections Process or Mining Sites and Processors Survey/Assessment
WRM05	Water storage per capital	Source: IWRM, Water Monitoring and Development Unit
WRM06	Number (%) of (a) Households, and (b) Institutions with a Rain Water Harvesting (RWH) system installed.	NISR, EICV
FNC10	Proportion of land surface covered by forest [Forest cover]. This excludes agro-forestry area.	RWFA, Forestry department-GIS Report {FMES : IND005}
MET11	Percentage of extreme weather events for which advance warning was provided at least 30 min in advance	METEO RWANDA, Quarterly high impact weather report
FON07	Total amount of finance mobilized for Green Investments (by major category – Climate Change mitigation; Green Energy production etc.)	MOUs and MINECOFIN Reports
-	*Soil erosion and soil loss (To be further elaborated and confirmed)*	*RWFA/IWRM*
-	*Ha of crops under insurance (To be further elaborated and confirmed)*	*MINAGRI*

It is also important to consider additional indicators outlined below that provide examples of High level National/Global indicators for which alignment will be necessary and on-going dialogue and consensus built as Rwanda (Africa Centre for reporting on SDGs) drives the agenda on harmonizing reporting on climate adaptation/resilience at regional and global levels.

- Proportion of the rural population who live within 2 km of an all-season road (SDG indicator 9.1.1);
- Percentage of health centres with at least one food and nutrition outreach programme (MINISANTE or MINAGRI);
- Annual loss due to damage caused by weather-related hazards / number of deaths, missing persons and directly affected persons attributed to disasters per 100,000 population (SDG 13.1.1);
- Number of people with access to improved climate-related early warning information or systems for extreme weather events;
- Change in climate sensitive agricultural production / Proportion of agriculture land protected against erosion (NDC);
- Freshwater withdrawal rate / National Water Security Plan to employ water storage and rain water harvesting, water conservation practices, efficient irrigation established and operational (NDC);
- Change of malaria hazards;

- Specialized support, and amount of support, including finance, technology and capacity-building, for mechanisms for raising capacities for effective climate change-related planning and management (SDG 13.B.1).

10 Funding Requirements

10.1 Overview

According to Article 13 of the Paris Agreement and its associated decisions, developed countries reiterated their previous commitment to channel at least USD 100 billion in annual climate finance to developing countries by 2020. They also agreed to establish a more ambitious climate finance target from 2025. Developing countries are requested to report on the support they have received and any additional needs they have in these areas. For adaptation financing, the GCF has committed to allocate at least half of its resources to adaptation, and half of its adaptation resources to LDCs, SIDS and countries in Sub-Saharan Africa. There is also a particular drive by many bilateral donors to scale up their support for adaptation.

Rwanda's Third National Communication to the UNFCCC highlighted three main challenges in climate finance in Rwanda as: (i) insufficient funds, (ii) limited budget for the implementation of climate action, and (iii) limited involvement of private sector investment in environment and climate change activities. Furthermore, the TNC indicated a need for more bilateral and multilateral financial support (GoR, 2018a). Rwanda has undertaken various initiatives to identify climate finance. These have included a series of Public Environmental Expenditure Review (including climate change), costing exercise for the GGCRS in addition to what information can be gleaned from the costing of SSPs. The gaps and needs analysis to the SPCR made efforts at tracking climate finance.

This section summarises the funding requirements, estimated in real terms (i.e. 2019 USD), for Rwanda's NDC measures for mitigation and adaptation described in this report. It shows that the total estimated cost for Rwanda's identified NDC mitigation measures through 2030 is estimated at around 5.7 billion USD, and over 5.3 billion USD for adaptation priorities, representing a combined funding requirement of around 11 billion USD.

The current technical support provided by the World Bank is seeking to establish a baseline for climate finance that can facilitate a framework for reporting requirements. This includes capturing "unconditional and conditional" resources according to the Paris Agreement framework for 2025 and 2030 respectively. The present analysis made use of extensive consultations with sector experts to generate "conditional" and "unconditional" costing estimates for both mitigation and adaptation measures projected through to 2025 and 2030. This will guide and position Rwanda for strategic resources mobilization to meet the climate action ambition, and help inform a process of tracking climate finance flows towards climate mitigation and adaptation action. This is essential for mobilizing resources for climate action that meets Rwanda's sustainable development ambition.

10.2 Mitigation

Figure 10.1 and

Table 10.1 below show the funding requirements associated with all identified mitigation options described in Section 4, estimated at **5.7 billion USD through 2030**. These represent the capital investment costs required for new plant, installations and equipment.[34] The investment levels for each sector broadly correspond to the estimated mitigation shares across each emitting sector, with agriculture and energy projects accounting for the majority (each accounting for 47% of the total 2020-2030 respectively). Investments in waste facilities account for the bulk of the remaining requirement. In order to achieve the projected mitigation outcomes, around half of the total 5.7 USD billion will be required in the period 2020-2025 and half in the period 2026-2030.

Figure 10.1 Investment requirements for all identified measures through 2030

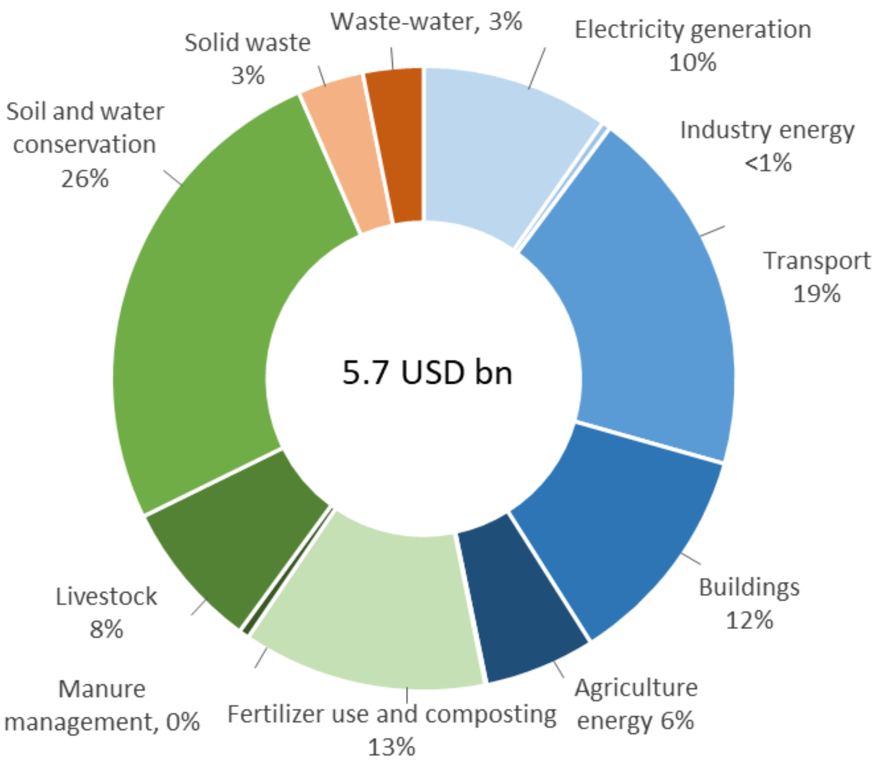


Table 10.1 Investment requirements for all mitigation measures (USD million)

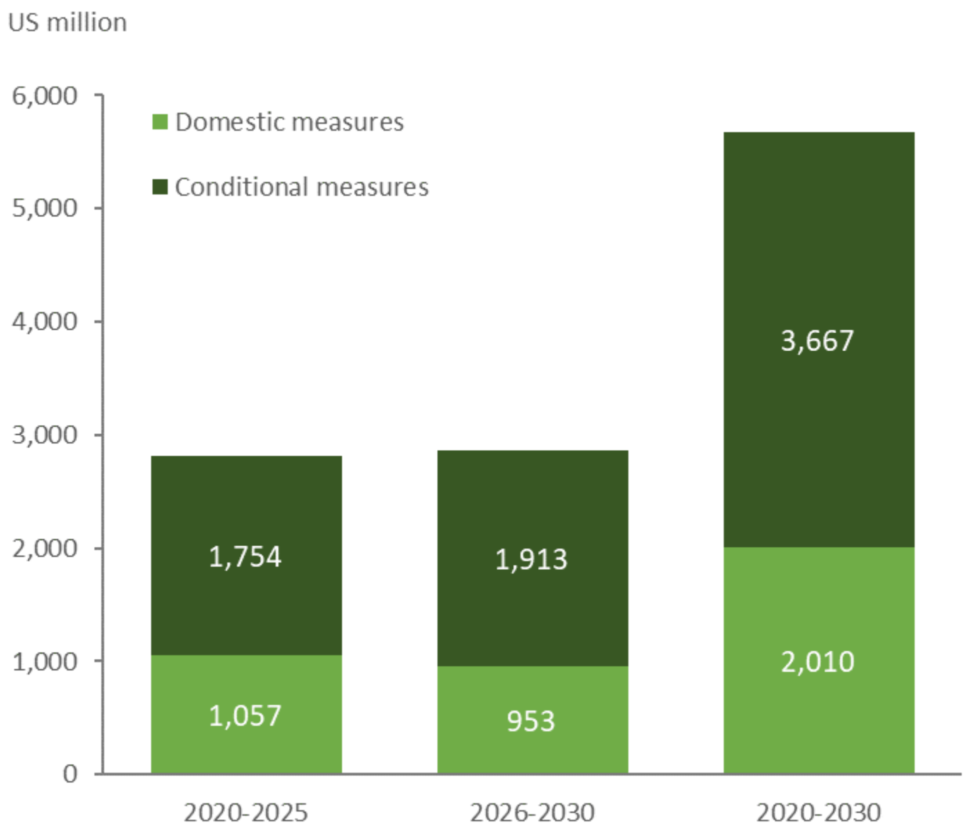
Sector	2020-2025	2026-2030	2020-2030
Electricity generation	495	57	552
Industry energy	6	19	26
Transport	506	585	1,091
Buildings	510	150	660
Agriculture energy	306	20	327
Energy - total	**1,824**	**831**	**2,655**
IPPU - total	**4**	**0**	**4**
Fertilizer use and composting	179	540	719
Manure	15	15	30

[34] Ongoing operating costs are not included

Livestock	206	231	437
Soil and water conservation	299	1,160	1,459
Agriculture - total	**700**	**1,946**	**2,645**
Solid waste	194	0	194
Wastewater	89	89	178
Waste - total	**283**	**89**	**372**
TOTAL	**2,811**	**2,866**	**5,677**

Figure 10.2 shows the estimated funding requirements, now according to the grouping of "unconditional" (domestically supported) and "conditional" measures through to 2025 and 2030. The levels of funding required within each grouping broadly corresponds with the associated mitigation estimates, with conditional measures representing around 65% of the total investment levels estimated to implement all NDC measures.

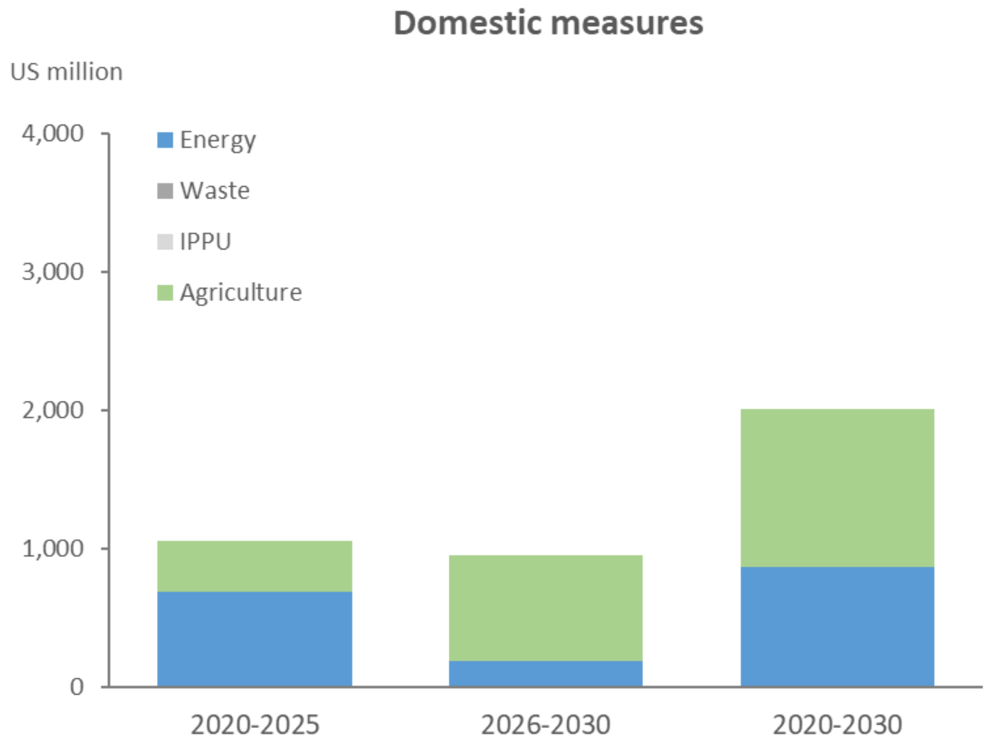
Figure 10.2 Estimated investment requirements for NDC measures

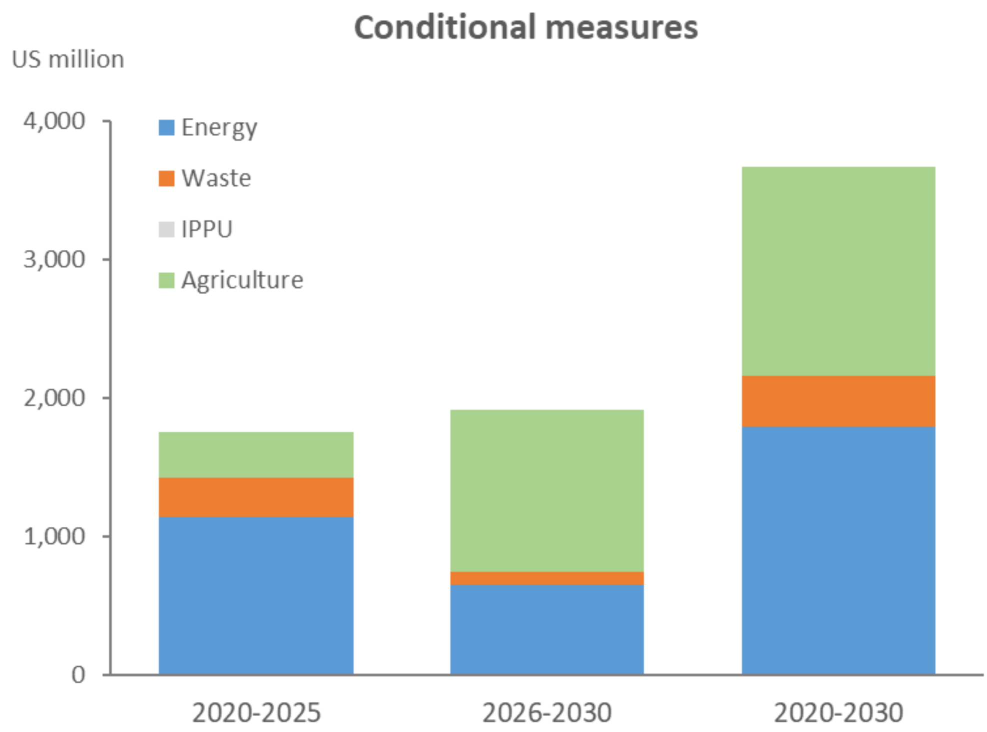


Source: authors

A breakdown by sector for each of the contributions is shown below. Within the domestically supported (unconditional) measures, energy sector investments are seen to dominate the period 2020-2025 associated with near term state-funded low carbon energy programmes such as expansion of grid-connected hydropower and solar pumping for irrigation. The majority of agriculture sector investments are realised within the period 2026-2030 with the scaling up and implementation of fertiliser, crop rotation and livestock programmes. For conditional measures, energy projects also account for most if the investment requirements during the period 2020-2025, along with waste sector projects, with agriculture projects accounting for most of the estimated investment requirements during the period 2026-2030.

Figure 10.3 Estimated investment requirements for NDC measures, by sector





10.3 Adaptation

The cost estimates for adaptation interventions was also made for the two phases, i.e. 2020-2025 and 2025-2030. Estimates were made by referring to different planning documents, among others, the National strategy for transformation (NST 1: 2017-2024), Sector Strategic Plans (SSPs) and the cost of other similar projects. Some interventions will be conditioned by availability of external financial support (conditional) while others may be implemented through internal funding (unconditional) or co-financing (internal and external sources of budget). The total amount of NDC adaptation interventions is estimated at above **5.3 billion USD through 2030**. The consultation with sector experts, considering the existing government initiatives, proposed that the breakdown of adaptation total cost should be estimated at 40% unconditional budget (domestic support) and 60% conditional budget (international support).

Table 10.2 Estimated costs of adaptation interventions

Activity	Intervention	Budget 2020-2025 (USD)	Budget 2026-2030 (USD)	Unconditional	Conditional
IWR planning and management	Develop a National Water Security through water conservation practices, wetlands restoration, water storage and efficient water use	100,000,000	64,308,682		✓
	Develop water resource models, water quality testing, and improved hydro-related information systems	5,000,000	5,000,000	✓	
	Develop and implement a management plan for all Level 1 catchments	180,000,000	180,000,000		✓
Climate Resilient Value Chain Development [2]	Develop climate resilient crops and promote climate resilient livestock	12,029,020	12,029,020		✓
	Develop climate resilient postharvest and value addition facilities and technologies	100,000,000	100,000,000		✓
	Strengthen crop management practices (disease prevention, diagnostic, surveillance and control)	1,500,000	1,500,000	✓	
	Develop sustainable land management practices (soil erosion control; landscape management)	173,086,918	173,086,918		✓

Activity	Intervention	Budget 2020-2025 (USD)	Budget 2026-2030 (USD)	Unconditional	Conditional
	Expand irrigation and improve water management	765,219,726	1,496,264,765		✓
	Expand crop and livestock insurance	18,279,826	91,399,132		✓
Sustainable management of forestry and Agroforestry	Development of Agroforestry and Sustainable Agriculture (control soil erosion and improved soil fertility)	46,033,406	46,033,406		✓
	Promote afforestation / reforestation of designated areas	8,417,567	8,417,567	✓	
Wood Supply Chain, Improved Efficiency and Added Value	Improve Forest Management for degraded forest resources	4,067,245	4,067,245		✓
Climate-sensitive Integrated Land Use Planning and Spatial Planning	Integrated approach to planning and monitoring for sustainable land management	30,000,000	30,000,000		✓
	Develop a harmonized and integrated spatial data management system for sustainable land use management	10,000,000	10,000,000		✓
	Inclusive land administration that regulate and provide guidance for land tenure security	2,500,000	2,500,000	✓	
Land Use and Spatial Planning	High density buildings and informal settlement upgrading	200,000,000	200,000,000		✓
Storm water and Drainage Management	Storm water management	200,000,000	200,000,000		✓
Vector-based disease prevention	Strengthen preventive measures and create capacity to adapt to disease outbreaks	85,000,000	100,000,000		✓

Activity	Intervention	Budget 2020-2025 (USD)	Budget 2026-2030 (USD)	Unconditional	Conditional
Sustainable, climate-resilient roads and bridges	Improved transport infrastructure and services	300,000,000	300,000,000	✓	✓
Climate compatible mining	Climate compatible mining	29,645,336	29,645,336	✓	
DRR program (Disaster preparedness and emergency response)	Establish an integrated early warning system, and disaster response plans	5,000,000	5,000,000		✓
	Disaster risk monitoring	10,000,000	10,000,000		✓
Institutional capacity development	Institutional capacity building and development for cross-sector NDC implementation	3,000,000	3,000,000		✓
Finance (Resources mobilization)	Access to finance	1,500,000	1,500,000	✓	
TOTAL (USD)		**2,290,279,044**	**3,073,752,071**	✓	✓
OVERALL COST (USD)		**5,364,031,115**			60%

10.4 Capacity building and technology transfer

Under the Paris Agreement, developed countries have committed to provide financial support, technology transfer and capacity building to developing countries. Many developing countries will require enhanced capacities to effectively track inflows of bilateral and multilateral resources and support and identify pending gaps and needs. It is critical that the Paris Agreement's capacity building provisions are implemented successfully (Khan, 2017).

The stakeholder consultations undertaken in the course of this technical assistance has brought to the fore clear messages on the urgent need to design strategic ways to build and further develop capacity of sector experts in monitoring and evaluation in general and in particular on climate adaptation. There is evidence of a protracted period within which implementation of programs has created demand for reliable metrics. Such demand has clearly been manifest in the series of poverty reduction strategies including the most recent EDPRS 2 and currently the NST. These key strategies have demonstrated lack of climate adaptation data despite the impacts of climate change such as floods on infrastructure and soil erosion on agricultural productivity. It is important that this WB technical assistance makes a strong case for capacity development particularly in improving analytics around climate change adaptation/resilience.

In the face of advanced IT, there are ample opportunities to bundle M&E systems with IT enabled processes and tools to improve systems and therefore efficiencies for monitoring and reporting.

Rwanda's case of smart phone enabled data management in the health sector and the increasing use of drone technology for data collection are key pointers on how domestication of capacities and technology transfer can fast-track development of reliable M&E systems on climate adaptation. ENR RBME that has been initiated at MoE presents a rare opportunity for the WB technical assistance to build on in streamlining and further developing the analytics on climate adaption and resilience as is evident in the table 6.1 above that has captured the climate adaptation relevant indicators consolidated in the RBME scheme from a wide range of sector documents. However, for this to be useful, a number of deliberate capacity building initiatives will be undertaken at various levels. The following are specific areas to consider for capacity building:

- Institutional development and strengthening;
- Developing human resources through education, training, and research;
- Strong financial support for capacity building targeting Rwanda's compliance in reporting;
- National ownership of capacity building efforts that is aimed to ensure sustainability;
- Networking, partnerships, and sharing of experiences across sectors and beyond;
- Application of Web-based tools to improve capacity building.

There is significant scope to build capacity in cross sector M&E systems including upstream work that is vital to setting up functional M&E systems and frameworks. Investing in M&E systems is crucial to manage progress in implementing climate adaptation. M&E and lesson learning are critical to effective and efficient delivery of project results and sustainable impacts to secure investor confidence that is essential to meet resources mobilization ambition and consequently the national ambition of climate resilient economy by 2050. Identifying capacity building (incl. technical/technology/ resources mobilization) will greatly benefit from:

- Improving the use of existing data and analytical tools bearing in mind that Local/sector context is crucial to climate vulnerability/resilience assessment;
- Differentiating between climate change related issues and business-as-usual development;
- Putting in place measures to facilitate data availability to measure the impact (to know that change has happened).

The consultations have created momentum for ongoing engagement. It is important to recognize that technical knowledge resides with sector specialists and any capacity building and effective application of technology for mainstreaming climate change must draw from that experience and facilitate cross learning among climate change experts and subject matter experts from sectors. It is imperative that this harmony/coherence continually capitalized on to guide successful mainstreaming of climate change into sector priorities.

11 CONCLUSIONS AND RECOMMENDATIONS

11.1 Mitigation

The analysis of mitigation options described in this report show how significant economy-wide emissions reductions can be achieved in Rwanda as part of its NDC efforts. For the target year 2030, the base case scenario is estimated to achieve a reduction against BAU of 16% for domestically supported “unconditional” measures increasing to 38% with “conditional” measures included. The sensitivity analysis shows the level of uncertainty involved in estimating mitigation outcomes and the critical role of assumptions around economic growth, success in project implementation and recognition of Lake Kivu methane power as a mitigation option. For domestic measures only, the results show a range of 12-18% reduction against BAU in 2030, increasing to 27-58% for all NDC measures.

Guided by the principle that Rwanda should only adopt targets considered capable of being delivered, the choice of which mitigation target(s) to adopt within the revised NDC should necessarily be informed by a view on which scenario is considered most feasible. In this context, it should be noted that the base case scenario is based on official target assumptions for GDP growth and also project outcomes. Overestimating the former has the tendency to underestimate mitigation outcomes relative to BAU, while overestimating the latter has the tendency to overestimate mitigation outcomes relative to BAU. From this, it might be reasonably concluded that the base case represents a feasible estimation of what could be delivered under the NDC through 2030, subject to an enabling domestic policy framework and attracting international funding and support.

As shown in the analysis, the estimated funding requirements associated with achieving the identified measures are significant - totaling around 5.7 billion USD through 2030. Accessing climate finance to help drive investment into projects and enabling programs to support mitigation goals across energy, waste, industry and agriculture will be critical. This needs to be accompanied by a roadmap of actions, policies and programs aimed at embedding mitigation priorities within national and regional policy planning. At the same time, a robust framework to monitor, track and review the implementation of NDC actions will be needed to ensure effective delivery and meet reporting requirements under the UNFCCC and Paris Agreement.

In this context, the following recommendations are made for implementation of the mitigation component of Rwanda’s NDC:

- Decision on choice of NDC targets to adopt, based on the technical and economic analysis of mitigation options and estimated reductions from conditional and unconditional components against BAU through 2030.
- Develop an MRV framework for tracking the progress of project implementation and Rwanda’s pathway towards achieving the NDC, whilst meeting its international obligations under the Paris Agreement. Such a framework will include developing a set of performance indicators and supporting metrics for monitoring and reporting the progress towards meeting the NDC for the identified prioritized sectors/mitigation actions within each sector and approach to tracking climate finance.

- Elaborate a detailed financing strategy through the revised NDC implementation plan that considers prioritized mitigation measures and guidance on accessing climate finance. This should include overarching strategies and interventions required to address financial challenges and leverage funds from private and international sources, with identification of appropriate sources of funding and support needs matched to the identified actions.
- Request guidance from IPCC regarding GHG accounting from lake methane utilization whilst developing project and emissions data from Lake Kivu power project.
- Establish a detailed implementation plan with a timeline and roadmap of actions through 2025 and 2030, with roles and steps identified within each sector (electricity generation, road transport, industry, waste, agriculture) describing how mitigation projects and programs will be embedded within national and regional planning.

11.2 Adaptation

Within adaptation, significant work undertaken by sectors has elaborated metrics for indicators, baselines, milestones and the associated metadata. However, the information and data has been highly fluid with significant changes over the years. This has had adverse impact on adaptation relevant analytics and sector priorities. The ability to measure and monitor has also presented its own challenges as has been evident in tracking progress on implementation of GGCRS which has been fraught with lack of consistency and coherency. The current exercise seeks to streamline the measurement and monitoring protocols aimed at consolidation and organizing data and information that can facilitate trend analysis that improves monitoring and evaluation of adaptation strategies, programs and projects.

The above can only be possible through Sector Wide Approach (SWAp) engagement using the national process of Joint Sector Reviews (JSR) scheduled semi-annually across sectors. While these seem to serve as clear avenues to manage adaptation information/data, they are not designed to facilitate detailed analysis. Thus, there is a need to identify sector specific focal groups that can engage in meaningful and focused discussions that are critical to manage the levels of complexity that adaptation metrics and data analysis demands. For this to succeed, clear incentives that include but are not limited to technical training (in-country as well as external) present realistic opportunities for acquisition and application of new knowledge.

Despite growing acknowledgement that climate change impacts have adversely affected food security through soil erosion, loss of property and in the extreme lives of affected populations, infrastructure and energy generation and supply resulting from flooding and sedimentation of water bodies, there is limited link and application of sector specific data to climate adaptation targets. The development paradigm has increasingly dominated data and information management even where it is clearly evident that climate impacts are responsible for the risks. It is essential to approach this work with a level of confidence that climate adaptation and resilience undergird sustainable development. Therefore, this work should lay the foundation for measurement and monitoring of risks with a view to manage the identified risks and foster progress through selection of priority adaptation options that improve the likelihood of catalysing and accelerating resources flow for successful implementation.

The following points provide a summary of the key recommendations that must be considered in order for the adaptation interventions to result into climate action in various sectors to the benefit of national economy:

- Consideration of the selected adaptation indicators for program and projects design, implementation and reporting to funders. Climate action requires performance measures to monitor and report progress for purposes of accountability. It is therefore important that sectors continually improve the relevancy of monitoring and evaluation framework.
- Provide national level adaptation reporting that align and respond to data and information demands at strategic levels including NST and sector strategic plans. National policies and strategies must rely on responsive data to guide policy reforms essential to effective integration of climate adaptation to achieve national sustainable development goals.
- Develop a strategy to evaluate investments in adaptation projects and programs based on reliable analytics to increase likelihood of replication and scale up of proven interventions.
- Design strategic ways to provide capacity building to sectors, including sector experts, to facilitate planning and continuous NDC monitoring in general and in particular on climate adaptation.
- Elaborate a detailed financing strategy through the revised NDC implementation plan that considers the prioritized adaptation interventions and provide guidance for the accelerating national access to scalable climate finance. FONERWA has been institutionalized to support a coherent national climate resources mobilization strategy. Notably, the fund is poised to streamline and boost domestic resources flows including to private sector, which is crucial for NDC resources mobilization to fill the unconditional resources gap.

REFERENCES

AENOR, 2008. Uganda Municipal waste compost program, CDM project 2008/018/CDM/005.1 Uganda. The Spanish Association for Standardization and Certification (AENOR), Kampala.

AFD, 2013. New sanitary landfill in Addis Ababa, Project sheet, Agence Française de Développement (AFD), 22nd July 2019. See: https://www.afd.fr/en/new-sanitary-landfill-addis-ababa.

Amare, T., Terefe, A., Selassie, Y. G., Yitaferu, B., Wolfgramm, B., & Hurni, H., 2013. Soil properties and crop yields along the terraces and toposequece of Anjeni Watershed, Central Highlands of Ethiopia. Journal of Agricultural Science, 5(2), 134.

Bizimana J. & Kannan N., 2011. Economic impact analysis of radical terracing project. Case Study Cyabingo sector in Gakenke District, Bachelor Thesis, Faculty of agricultural engineering and environmental sciences, Higher institute of agricultural and animal Husbandry.

Bizoza A., 2011. Farmers, institutions and land conservation: institutional economic analysis of bench terraces in the highlands of Rwanda.

Bowen, W.T., Diamond, R.B., Singh, U. and Thompson, T.P., 2005. Urea deep placement increases yield and saves nitrogen fertilizer in farmers' fields in Bangladesh. Rice is life: Scientific perspectives for the 21st century.

Bullock, D. G., 1992. Crop rotation, Critical Reviews in Plant Sciences, 11:4, 309-326, DOI: 10.1080/07352689209382349

Chadwick, D., Sommer S., Thorman R., Fangueiro D., Cardenas L., Amon B., and Misselbrook T. (2011). Manure management: Implications for greenhouse gas emissions. Animal Feed Science and Technology 166 (2011): 514-531.

ContourGlobal, 2020. Website information on KivuWatt power generation project. Accessed 10 March, 2020. See https://www.contourglobal.com/innovative-technologies

Desgain, D. and Sharma, S., 2016. Understanding the Paris agreement: analysing the reporting requirements under the enhanced transparency framework. UNEP DTU Partnership.

European Investment Bank (EIB), 2016a. Kigali Central Sewage - Feasibility Study. European Investment Bank. Luxembourg.

EIB, 2016b. Kigali Central Sewerage - Engineering Design and Preparation of Tender. European Investment Bank. Luxembourg.

Eneji, I. S., Obinna, O., & Azua, E. T., 2014. Sequestration and carbon storage potential of tropical forest reserve and tree species located within Benue State of Nigeria. *Journal of Geoscience and Environment Protection*, *2*(02), 157.

Energy Saving Trust, 2017. Guide to charge-point infrastructure for business users. Energy Saving Trust, August 2017.

Energy Water and Sanitation Authority (EWSA), 2014. Residential solar water heating program (SolaRwanda Program). EWSA, 2014.

Fabrizio, A., Tambone, F., and Genevini, P.2009. Effect of compost application rate on carbon degradation and retention in soils. Waste Management, 29(1), 174-179.

FAO, 2016. The agricultural sectors in nationally determined contributions (NDCs); Priority areas for international support. Rome: FAO.

Fawkes, S; Oung, K; Thorpe, D; Zhu, X; de la Rue du Can, S; Farrell, T. Clifford, 2016. Best Practices and Case Studies for Industrial Energy Efficiency Improvement. DTU/UNEP. Copenhagen.

FONERWA, 2017. Strategic Programme for Climate Resilience-SPCR, Gaps and Needs Analysis. Kigali: FONERWA.

GFEI, 2019. Prospects for Fuel Efficiency, Electrification and Fleet Decarbonisation. Working Paper 20. Global Fuel Economy Initiative (GFEI) May 2019.

Girard, P. 2002. Charcoal production and use in Africa: what future? *Unasylva*, *53*(4), 30-35.

Government of Rwanda (GoR), 2011. Green Growth and Climate Resilience: National Strategy on Climate Change and Low Carbon Development. Republic of Rwanda, Kigali.

GoR, 2015a. Intended Nationally Determined Contribution for the Republic of Rwanda. Republic of Rwanda, Kigali.

GoR, 2015b. Rwanda report on Nationally Appropriate Mitigation Actions, sectoral analysis. REMA, Kigali.

GoR, 2017a. 7 Years Government Programme: National Strategy for Transformation (NST1), 2017-2024. Rwanda, Kigali

GoR, 2017b. Detailed Implementation Plan for the Nationally Determined Contributions (NDCs) of Rwanda. Kigali: REMA.

GoR, 2017c. Strategic Programme for Climate Resilience-SPCR. Kigali: Ministry of Environment.

GoR, 2018a. Third National Communication: Report to the United Nations Framework Convention on Climate Change. Republic of Rwanda, Kigali.

GoR, 2018b. The Fifth Integrated Household Living Survey (EICV5): Main Indicators Report 2016/17. Republic of Rwanda, Kigali.

GoR, 2018c. Final Energy Sector Strategic Plan (ESSP). Republic of Rwanda, Kigali.

GoR, 2018d. Rwanda NDC Partnership Plan. Kigali: MoE.

GoR, 2019. Assessment of Climate Change Vulnerability in Rwanda. Kigali: REMA.

Gupta, B. & Sharma, S. (2014). Estimation of biomass and carbon sequestration of trees in informally protected areas of Rajouri, J&K. India. *Int Res J Environ Sci*, *3*(6), 56-61.

Hergoualc'h, K., Blanchart, E., Skiba, U., Hénault, C. & Harmand, J. M., 2012. Changes in carbon stock and greenhouse gas balance in a coffee (Coffea arabica) monoculture versus an agroforestry system with Inga densiflora, in Costa Rica. Agriculture, Ecosystems & Environment, 148, 102-110.

Hoque, N., Roy, A., Beg, M. R. A., & Das, B. K., 2016. Techno-Economic Evaluation of Solar Irrigation Plants Installed in Bangladesh. International Journal of Renewable Energy Development, 5(1).

ICCT, 2014. Costs and Benefits of China 5/V and 6/VI Standards in Guangdong Province. The International Council on Clean Transportation. Working paper 2014-6, June 2014.

IFC, 2013. IFC Jobs Study: Assessing Private Sector Contributions to Job Creation and Poverty Reduction. January 2013. Washington, USA.

IMF, 2019. International Monetary Fund World Economic Outlook Database, accessed April 2019; data extrapolated from 2025 onwards.

Intergovernmental Panel on Climate Change (IPCC), 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. See: https://www.ipcc-nggip.iges.or.jp/public/2006gl/

IPCC, 2007. Fourth Assessment Report of the Intergovernmental Panel on Climate Change. Pachauri, R.K. and Reisinger, A. (Eds.). IPCC, Geneva, Switzerland

IPCC, 2014. Climate Change 2014: Synthesis Report. Contribution of Working Groups II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. Geneva: IPCC.

IPCC, 2018. Global Warming of 1.5^{O}C, Summary for Policymakers. Switzerland: IPCC.

ISAR, 2007. Forest Inventory 2007.

Kagabo, D. M., Stroosnijder, L., Visser, S. M., & Moore, D., 2013. Soil erosion, soil fertility and crop yield on slow-forming terraces in the highlands of Buberuka, Rwanda. Soil and tillage research, 128, 23-29.

Karlsson L & Jönsson T.L, 2012. Pre-feasibility Study of a Waste to Energy Plant in Chisinau, Moldova. Uppsala Universitet, Sweden, Uppsala.

Khan, M., 2017. Capacity Building for Climate Change: Lessons from Other Regimes. AdaptationWatch Weekly Briefing.

Knapp, J. R., Laur, G. L., Vadas, P. A., Weiss, W. P., & Tricarico, J. M., 2014. Invited review: Enteric methane in dairy cattle production: Quantifying the opportunities and impact of reducing emissions. Journal of dairy science, 97(6), 3231-3261.

Kumar, B. M., George, S. J., Jamaludheen, V. & Suresh, T. K. (1998). Comparison of biomass production, tree allometry and nutrient use efficiency of multipurpose trees grown in woodlot and silvopastoral experiments in Kerala, India. *Forest Ecology and Management*, *112*(1-2), 145-163.

Lal, R., 2004. Carbon sequestration in soils of central Asia. Land Degradation & Development, 15(6), 563-572.

Maplecroft, V., 2010. Risk Calculators and Dashboards. Verisk Maplecroft. Retrieved Oct 2010, from https://www.maplecroft.com

MIDIMAR, 2015. The National Risk Atlas of Rwanda. Kigali: MIDIMAR.

MINAGRI, 2013. National Rice Development Strategy 2011-2018, MINAGRI, Kigali, Rwanda.

MINAGRI, 2016. Proposed revisions to the indicators used by MINAGRI to report to the high level dialogue on the GGCRS, . Kigali: Agri-TAF.

MINAGRI, 2017. Strategic Plan for Agricultural Transformation 2018-24, Kigali. Kigali: MINAGRI.

MINECOFIN, 2018. Copy of large industrial production by end December 2018. MINECOFIN, Kigali, Rwanda

MINILAF, 2018. Rwanda National Forestry Policy. Kigali: MINILAF.

MININFRA, 2017a. Water and Sanitation Sector Strategic Plan 2018 - 2024. Kigali: MININFRA.

MININFRA, 2017b. Urbanization & Human Settlement. Sector Strategic Plan for National Strategy for Transformation 2017-24. Kigali: MININFRA .

MININFRA, 2017c. Energy Sector Strategic Plan (ESSP) 2018-2024. Kigali: MININFRA.

MININFRA, 2017d. Transport Sector Strategic Plan for the National Strategy for Transformation (NST1) 2018 - 2024. Kigali: MININFRA .

MINIRENA, 2014. Forest Landscape Restoration Opportunity assessment for Rwanda, MINIRENA – IUCN -WRI, Kigali, Rwanda.

MINISANTE, 2018. Fourth Health Sector Strategic Plan 2018/19 – 2023/24, Rwanda. Kigali: MINISANTE.

MoE, 2017a. Strategic Plan for the Environment and Natural Resources Sector 2018 – 2024, Rwanda. Kigali: MoE.

MoE, 2017b. Gaps and Needs Analysis; Strategic Programme for Climate Resilience (SPCR) for Rwanda. Kigali: MoE.

MoE, 2018. Evaluation of the Green Growth and Climate Resilience Strategy (GGCRS) Implementation, Evaluation report. Kigali: MoE.

MoE, 2019a. National Environmental and climate change policy. Kigali: MoE.

MoE, 2019b. Forward Looking Joint Sector Review 2019-2020. Kigali: MoE.

Murthy et al., 2013. Carbon sequestration potential of agroforestry systems in India, Journal of Earth Science Climate Change 2013, 4:1.

Mutimura, M., & Everson, T. M., 2012. On-farm evaluation of improved Brachiaria grasses in low rainfall and aluminium toxicity prone areas of Rwanda. International journal of Biodiversity and Conservation, 4(3), 137-154.

National Institute of Statistics of Rwanda (NISR), 2012. Rwanda Fourth Population and Housing Census. Thematic Report: Population size, Kigali: NISR & MINECOFIN.

NISR, 2014. Rwanda statistical yearbook 2014, NISR Kigali-Rwanda

NISR, 2015. Rwanda statistical yearbook 2015, NISR Kigali-Rwanda

NISR, 2016. Rwanda statistical yearbook 2016, NISR Kigali-Rwanda

NISR, 2017. Rwanda statistical yearbook 2017, NISR Kigali-Rwanda

NISR, 2018. Rwanda statistical yearbook 2018, NISR Kigali-Rwanda

NISR, 2019a. Seasonal Agricultural Survey 2018. NISR, Kigali, Rwanda.

NISR, 2019b. Rwanda Natural Capital Accounts for Ecosystems. Kigali: NISR, MINECOFIN, MoE.

Nduwamungu J., 2019. Survey in Agriculture, Forestry, Land use change for National Greenhouse gas inventory for the Rwanda Initial Biennial Update report. REMA, Kigali, Rwanda

Ofgem, 2018. Future Insights: Implications of the Transition to Electric Vehicles. See: https://www.ofgem.gov.uk/ofgem-publications/136142

Oversees Development Institute (ODI), 2013. Job Creation Impact Study: Bugoye Hydropower Plant, Uganda. London, UK.

Rajkhowa DJ, Gogoi AK, Yaduraju NT. 2005. Success story on weed utilization. Bulletin, NRC for Weed Science, Jabalpur

Rwanda Environment Management Authority (REMA), 2015. Baseline Climate Change Vulnerability Index for Rwanda. Kigali: REMA.

REMA, 2016. Ozone Depleting Substances Alternative Survey Report, Rwanda. REMA, Kigali.

REMA, 2017. Feasibility Study and Detailed Engineering Designs for a Centralized Sewerage System for Kibagabaga and Kinyinya Catchments in Gasabo District. REMA, Kigali.

Rengsirikul, K., Kanjanakuha, A., Ishii, Y., Kangvansaichol, K., Sripichitt, P., Punsuvon, V. & Tudsri, S. (2011). Potential forage and biomass production of newly introduced varieties of leucaena (Leucaena leucocephala (Lam.) de Wit.) in Thailand. *Grassland science*, *57*(2), 94-100.

Rwanda Agriculture Board (RAB), 2017. Annual Action plan 2017-2018. Kigali, Rwanda.

Rwanda Energy Group (REG), 2019. Rwanda Least Cost Power Development Plan (LCPDP), REG, Kigali-Rwanda. See: http://www.reg.rw/fileadmin/user_upload/LCPDP_REPORT_June_2019.pdf

Rwanda Utilities Regulatory Authority (RURA), 2019. Fuel price data. See https://rura.rw

Schmid, M., Lorke, A., Wuest, A., Halbwachs, M., and Tanyilek, G., 2003. Development and sensitivity analysis of a model for assessing stratification and safety of Lake Nyos during artificial degassing. Ocean Dynamics 53(3):288-301. September 2003.

Schmid, Wehrli, B., A., Wuest, A., and Halbwachs, M., 2005. Weak mixing in Lake Kivu: New insights indicate increased risk of uncontrolled gas eruption. Geochemistry Geophysics Geosystems 6(7). July 2005.

SEI, 2009a. Long-range Energy Alternatives Planning (LEAP). Community for Energy, Environment and Development, Stockholm Environment Institute, 25th April 2009. See: http://www.energycommunity.org/

SEI, 2009b. Economics of Climate Change in Rwanda. Oxford: Stockholm Environment Institute.

Sendege N., 2011. Rice Production in Rwanda. See: www.riceforafrica.net

Shanghai Automobile Co. Limited. Information accessed online September 2019. See: https://www.alibaba.com/product-detail/Brand-new-6730-Coach-Bus-30_60671009920.html?spm=a2700.9099375.35.6.67b157daPTwM4i

Shapiro B.I., Gebru G., Desta S. & Nigussie K., 2017. Rwanda Livestock Development Master Plan, International Livestock Research Institute- FAO, August 2017.

SNV, 2008. Financing domestic biogas in Rwanda. SNV, Kigali-Rwanda

SNV/HIVOS, 2012. Feasibility Study on Domestic Biogas in Zimbabwe. Study undertaken for REA and MEPD. Addis Ababa, Ethiopia.

UNFCCC, 2004. Multicriteria Analysis Methods and tools for assessment application. Retrieved from https://unfccc.int/files/methods_and_science/impacts_vulnerability_and_adaptation/methods_and_tools_for_assessment/application/pdf/mca.pdf

United Nations (UN), 1987. Montreal Protocol on Substances that Deplete the Ozone Layer. United Nations, 1987.

United States Agency for International Development (USAID), 2015. Greenhouse Gas Emissions Factsheet: Greenhouse Gas Emissions in East Africa. December 2015. See: https://www.climatelinks.org/resources/greenhouse-gas-emissions-factsheet-east-africa

United States Environmental Protection Agency (US EPA), 2008. Pre-Feasibility Study for Landfill Gas Recovery and Utilization at the Loma de Los Cocos Landfill Cartagena de Indias, Colombia. Report prepared by SCS Engineers. November 2008, Washington, US.

USAID, 2016. Wage Structure and Labour Costs in Zimbabwe: An Analysis of Flexibility, Competitiveness and Equity. February, 2016.

Van Asten, P. J., Ochola, D., Wairegi, L., Nibasumba, A., Jassogne, L. T., & Mukasa, D., 2015. Coffee-Banana Intercropping: Implementation guidance for policymakers and investors.

WMO, 2007. WMO statement on the status of the global climate in 2007. Geneva: WMO.

World Bank, 2012a. Establishing a Green Charcoal value chain in Rwanda: A feasibility study

World Bank, 2012b. Job Creation through Infrastructure Investment in the Middle East and North Africa. Policy Research Working Paper. The World Bank Middle East and North Africa Region Office of the Chief Economist. August 2012.

World Bank, 2016. Discounting Costs and Benefits in Economic Analysis of World Bank Projects. Technical note produced by Fay, M., Hallegate, S., Kraay, A., and Vogt-Shilb., A. February 2016.

World Bank, 2018. Technical analysis undertaken in support of Zimbabwe NDC Implementation Framework (unpublished). World Bank and Government of Zimbabwe.

World Bank, 2019a. Rwanda overview. Updated 30 September 2019. See: https://www.worldbank.org/en/country/rwanda/overview

World Bank, 2019b. Systematic Country Diagnostic for Rwanda, Report No. 138100-RW. Washington: World Bank.

World Bank, 2019c. Landscape Approach to Forest Restoration and Conservation (LAFREC), implementation status report. Kigali: World Bank.

Annex A – Mitigation project assessments

A-1 Mitigation Project Assessments

A-1.1 Methodological approach

A-1.1.1 Mitigation potential

Emissions reductions arising from mitigation projects can be calculated according to various methodologies. The approach taken with most of the projects was similar to that used in the Clean Development Mechanism (CDM) approved methodologies, according to which annual emission reductions (ER) are calculated on the basis of describing and then quantifying scenarios for baseline emissions (BE) and project emissions (PE) for each year of the mitigation project(s). Thus, mitigation achieved in each year, *n*, was derived for each mitigation measure as follows:

$$\text{Emission reductions } (ER)_n = \text{Baseline emissions } (BE)_n - \text{Project emissions } (PE)_n$$

Where:

Baseline emissions (BE) represent the emissions arising from energy use in the project, activity or sector in the absence of the NDC mitigation action, to deliver a defined outcome or product (e.g. one GWh of grid electricity; unit of industrial output; irrigation pumping power output). These were informed by, and were ensured to be consistent with, the BAU scenario developed for each sector.

Project emissions (PE) represent the emissions arising from implementation of the NDC action whilst maintaining the equivalent outcome or product as per the *baseline emissions* scenario. These can include *additional* sources of emissions arising from project implementation including, where feasible, so-called 'leakage' emissions in order to allow for a fair calculation of net emissions reductions[35] (e.g. increases in use of electricity or direct energy).

These parameters could be readily defined for most mitigation actions, according to which the counter-factual baseline scenario and baseline emissions (BE) could be easily defined and appropriate assumptions made in order to calculation project emissions (PE) and emissions reductions (ER). These include for example off-grid projects displacing diesel or grid electricity with an equivalent renewable energy (and therefore zero-carbon) supply. It should be noted that the analysis of energy sector projects allows projects to be modelled together as a suite of actions within the energy system as a whole. For example, with increasing supply of hydropower with the energy mix on the grid (under mitigation scenarios), energy efficiency actions resulting in reduced demand for grid power achieve relatively less mitigation, than when compared to a static BAU baseline dominated by fossil-based power. Assessing the mitigation and economic potential of the projects undertaken as a consistent suite of options within the same energy system is essential to developing a credible mitigation scenario and ensuring that emissions reductions are not double counted.

[35] Note that because of the complexities involved and the lack of equivalent analysis in the baseline scenario, life-cycle type assessments were not made

A-1.1.2 Cost-benefit analysis

Economic cost-benefit analysis (CBA) was undertaken for each of the identified mitigation options, in order to assess not only the direct costs for each option (e.g. investment and operating costs) but also the wider socio-economic benefits arising from their implementation. Most mitigation options give rise to a range of costs and benefits, the scope of which is typically determined by whether an *economic* or *financial* analysis is being undertaken. The CBA presented in this section was undertaken from a socio-economic perspective, thereby aiming to reflect economy-wide costs and benefits for each of the options, as opposed to a financial analysis which typically involves appraises projects from a private company's or individual's perspective. The inclusion of wider benefits to the economy such as job creation effects and additional revenue streams to rural communities thus allows for an appraisal of the relative economic performance from mitigation options which is more suited to policymaking and the provision of international support.

Cash-flow analysis of annual costs and benefits was undertaken for each of the identified mitigation options in order to calculate a net project value (NPV). This value represents the difference between discounted benefits and discounted costs as they occur over time. The economic NPV of each project was therefore calculated as:

$$NPV(i,\, n) = \sum_{t=0}^{n} \frac{B_t - Ct}{(1+i)^t}$$

Where:

n = number of periods
t = time period;
B = benefits;
C = costs; and
i = discount rate

For purposes of transparency and simplicity, a common public lending discount rate of 6% was applied to all projects based on guidance for economic appraisal of World Bank projects (World Bank, 2016).[36] Economic time periods were chosen according to each specific project type, with large infrastructure projects or policy programme requiring several implementation stages typically requiring longer appraisal periods (e.g. 20 years) that for simpler and/or smaller projects (e.g. 10 years).

An important limitation to the calculation of NPV and its use in CBA is its high sensitivity to the discount rate. The NPV is a summation of multiple discounted cash flows—both positive and negative—converted into present value terms for the same point in time. As such, the discount rate used in the denominators of each present value (PV) calculation is critical in determining the final NPV value. A small increase or decrease in the discount rate can have a significant effect on the final output.

[36] In practice, certain investments will require finance from private sector organisations and individuals which can be better reflected by higher discount rate; other large infrastructure projects may warrant discount rates of as low as 2-3%.

An extensive range of project data and assumptions were used in undertaking the economic analysis. Information on costs and benefits, and supporting project details and technical information, were requested from relevant government department and stakeholders. Wherever possible this was used in the analysis, although significant information gaps and the need to ensure consistent values for common assumptions meant that in-country data was complimented by a range of assumptions and inputs drawn from the international literature and analogous/regional project case studies and schemes. Key assumptions and data sources used in the cost-benefit analyses are provided in the detailed project descriptions provided further below.

A-1.1.3 Marginal abatement cost curves

The estimated emissions reductions (tCO_2) and economic costs (NPV) for each identified measure were complied into a series of sectoral marginal abatement cost curves (MACC). These present the list of NDC mitigation options sorted in ascending order of cost. As such they can be useful — as part of a broader evaluation process — in prioritising options. They do however have important limitations meaning that their use in informing policy-making and investment choices should be approached with care.

Limitations of MACCs identified in the literature include the following:[37]

1. Do not capture non-market barriers to implementation, including indirect or non-transaction costs.
2. Contain very limited treatment of uncertainties in the underlying analysis and assumptions (e.g. technology economics, learning rates, choice of discount rates, time of retirement for working capital goods).
3. Do not address dimensions other than direct costs, including strategic, operational, or political factors. These may include both ancillary benefits (air and water pollution) or market failures. In general, the MAC curve is unable to capture the wider social implications related to climate change mitigation.
4. Have difficulty capturing interactions between different measures that may limit the total abatement potential. Abatement measures interact, creating synergies and conflicts that mean that the cumulative outcome of two measures may be more than the sum of its parts, or less.

Point (4) is particularly important to the current analysis because mitigation options can often interact and overlap according to their specific mix within a scenario, in particular when seeking to simulate an energy system. This is particularly the case in which supply- and demand-side mitigation measures co-exist: the emissions reductions estimated for a demand-side measure reducing demand for grid electricity must reflect the carbon-intensity of the grid associated with the inclusion of supply-side mitigation projects and not the BAU baseline grid. Otherwise, total emissions reductions shown on the curve would be overestimated.

This has been addressed within the current analysis as follows. Because the mitigation options were not modelled top-down according to e.g. cost optimization or computable general

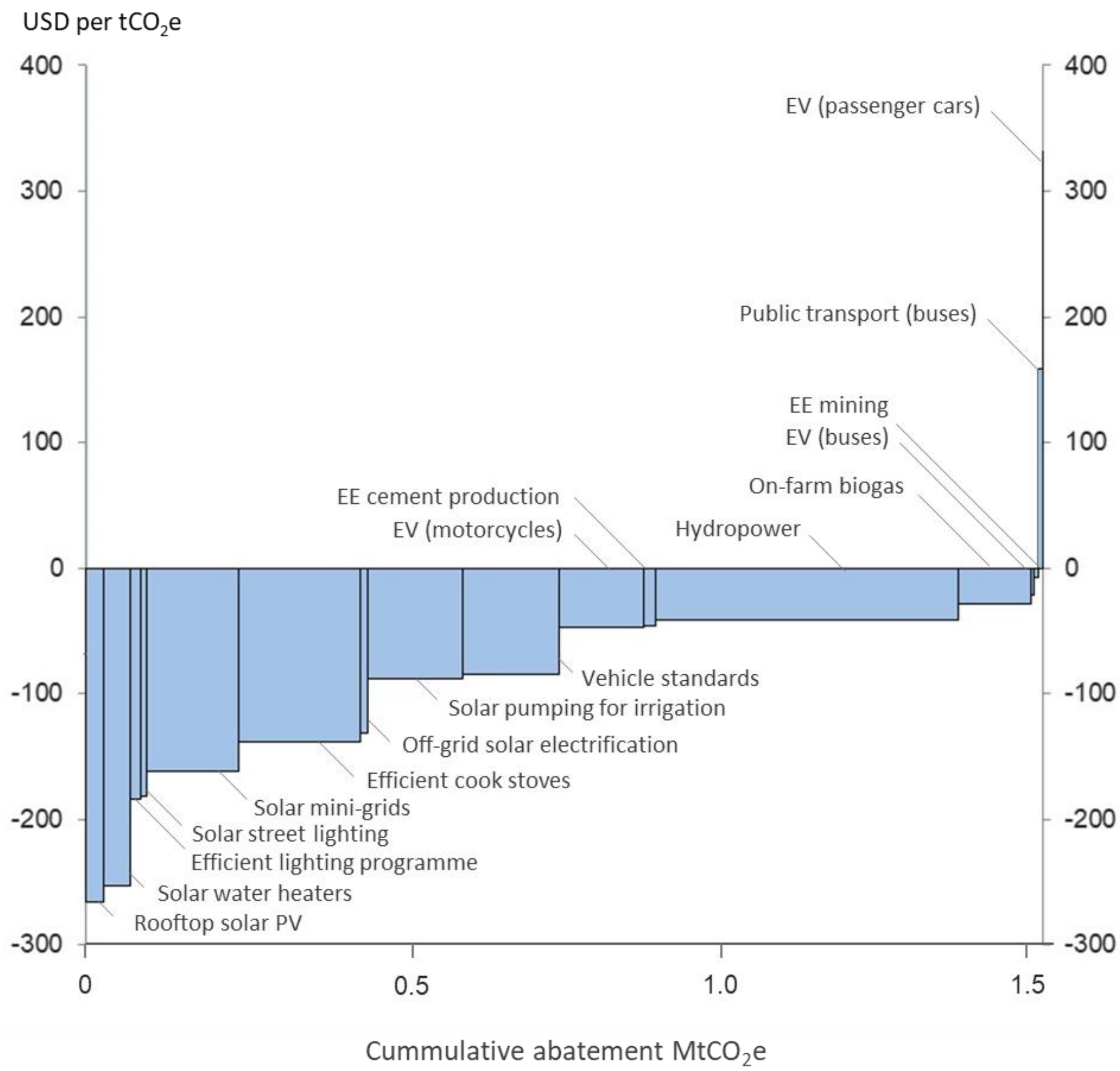
[37] A review of relevant literature with full references is available from: http://planwashington.org/blog/archive/understanding-carbon-reduction-marginal-abatement-cost-curves/

equilibrium (CGE) type modelling, abatement from supply-side options were calculated before the calculation of mitigation from the (relatively few) relevant demand-side options. For these reasons, CBA and abatement costs were recalculated for each NDC mitigation scenario in order to ensure a mutually consistent suite of options developed as a scenario avoiding overestimation of mitigation potential.

A-1.2 Energy

Figure A-1 presents the cost-ordered MACC for all identified measures within energy use for the year 2030. The corresponding data are shown in Table A-1.

Figure A-1 Marginal abatement cost curve for identified measures in 2030, Energy



Source: Authors

Table A-1 Mitigation measures ordered according to abatement costs, Energy

Mitigation option	Sub-Sector	Abatement cost (USD/tCO_2e)	Mitigation 2030 ($MtCO_2e$)
Rooftop solar PV	Buildings	-266.15	0.029
Solar water heaters	Buildings	-252.59	0.041
EE agro-processing	Manufacturing industry	-207.93	0.001
Efficient lighting in buildings	Buildings	-184.30	0.016
Solar street lighting	Electricity and heat	-181.96	0.008
Solar mini grids	Electricity and heat	-161.83	0.146
Efficient cook stoves	Buildings	-138.80	0.195
Off-grid solar electrification	Buildings	-130.91	0.010
Efficient brick kilns	Manufacturing industry	-118.97	0.001
Solar pumping for irrigation	Agriculture	-88.80	0.150
Vehicle emissions standards	Transport	-84.55	0.154
Electric motorcycles	Transport	-46.88	0.136
EE cement production	Manufacturing industry	-46.21	0.019
Hydropower	Electricity and heat	-41.96	0.482
On-farm biogas	Agriculture	-28.98	0.117
Electric buses	Transport	-21.72	0.003
Climate compatible mining	Manufacturing industry	-7.98	0.007
Public transport measures	Transport	158.63	0.008
Electric cars	Transport	331.09	0.001
Total mitigation potential in 2030			1.53

Source: Authors

Table A-2 below provides a summary of the key assumptions and data sources used in the cost-benefit analyses. The subsequent tables describe the assessment of each of the mitigation measures in more detail.

Table A-2 Key assumptions and data sources used in cost benefit analyses, Energy

Parameter	Value	Source	Notes
Energy prices			
Diesel	1.17 USD/litre	RURA, 2019	Final consumer price
Gasoline	1.17 USD/litre	RURA, 2019	Final consumer price
Electricity	0.14 USD/kWh	REG, 2018	Average cost of thermal power generation, sourced from REG [38]
Employment			
Skilled labour cost	3,744 USD per employee per year	Estimate based on MININFRA, 2016	Based on average gross salary reported in National Electrification plan (NEP).
Employment multiplier	3.0	IFC, 2013; World Bank, 2012	Multiplier for indirect job creation; average value assumed within range and other published employment studies.
Electricity generation			
Hydro costs	According to plant schedule from 2020 onwards. Total costs 1.45 billion USD.	REG, 2019	Comprises plant costs, transmission costs and opex.
Direct employment	5 FTE/MW (construction) 2 FTE/MW (operation)	ODI, 2013	Based on job creation impact study of the Bugoye large-scale hydropower project, Uganda.
Off-grid electrification targets	68 MW of solar mini-grids to be installed in off-grid rural areas by 2030 (Tier 1); HH targeted for off-grid electrification through SHS (Tier 2): 1.5 m, equivalent to 250,000 connections per year	Based on MININFRA, 2018 and the data provided by MININFRA	Contained in Final ESSP
Off-grid energy demand	Tier 1: 29 kWh/a Tier 2: 10 kWh/a	MININFRA, 2018	Contained in Final ESSP
Solar minigrids	Capex: 164 million USD (for 68 MWp), of which 48 million USD for battery banks.	MININFRA, 2016	National Electrirication Plan (NEP)
Off-grid capex	Tier 1: 1,250 USD/HH Tier 2: 125 USD/HH	MININFRA, 2018	Midpoints of ranges provided in ESSP
Street lighting capex	USD per unit: Solar traffic lights: 5,000 LED tower lights: 1,495 Solar LED lights: 1,908	World Bank, 2018	Based on estimates provided as part of Zimbabwe NDC technical analysis
Manufacturing Industry			
Agroprocessing (tea and coffee industry)	Boiler economiser capex: 7,300 USD Avoided cost of fuelwood: 12,307 USD/Factory/a Savings in boiler economiser operation: 4,800 USD/Factory/a	Reported in Rwanda press	Values reported from press for implementation of boiler economiser at Kitabi tea factory

[38] This estimate excludes T&D costs, taxes, marketing and other costs

Capex and opex for electric motor replacements in mining sector	Various	Fawkes *et al* (2016); GoR, 2017a	Based on analysis of motor replacement programme in Chilean mining sector: applied to Rwanda mining sector based on estimated energy use.
Modern brick kilns	Cost of modern kiln: 6,111 USD Avoided cost of fuelwood: 15 USD/tonne	Reported in Rwanda press	-
Road transport			
Public transport: modern buses	Capital cost of conventional ICE bus: 11,000 USD Capital cost of modern diesel bus: 40,000 USD	Shanghai Automobile Co Limited, 2019	Analysis based on incremental cost of increasing modern bus fleets
Vehicle fuel economy standards and regulation	Incremental costs above estimated as $US 54 (motocycles), $US 361 (passenger cars), $US 2,958 (buses) and $US 2,632-5,394 (HGV, according to class).	ICCT, 2014	Additional technology (vehicle) costs associated with an improvement of fuel economy in all new vehicle imports (based on GFEI targets) are estimated based on an economic study of mandatary Euro V standard for ICE vehicle classes
	Set-up and policy study costs: $US 5 million; annual administation and inspection/enforcement costs: $US 3 million.	Author estimates, based on previous work	-
Electric vehicles	Capex conventional ICE LDV: 18,000 USD Capex equivalent EV LDV: 23,000 USD (based on VW Golf gasoline and VW eGolf electric model costs). Capex conventional bus: 500,000 USD Capex equivalent E-bus: 750,000 USD.	Ofgem, 2018.	Additional capital costs include incremental cost between an EV and equivalent ICE vehicle purchase, and the charging infrastructure needed to provide for reliable charging.
	Capex conventional ICE motorcycle: 2,741 USD Capex equivalent EV motocycle: 2,960 USD	Data provided directly by Ampersand company.	
	Per vehicle capital cost of $US 2,500 applied, based on a unit cost of USD 37,500 for a 50kW rapid charger supplying fleet of 15 vehicles for EVs and 7,500 applied.	Energy Saving Trust, 2017.	It is assumed that wide-spread rapid charging (as opposed to overnight/slow; or fast) will be required for commercial scale EV uptake.
	Average vehicle power demand values 2020-2030 (kWh/100 km) based on GFEI assumptions.	GFEI, 2019	Based on Global Fuel Economy Inititiave (GFEI) analysis.
Energy use in agriculture			
Solar irrigation system capex	2,000 USD/kWp	Hoque *et al*, 2016	Assumption made on basis of marginal capex requirements to conventional diesel pump system. Average total capex for solar pumpinng assumed to be 3,000 USD/kWp based on Hoque *et al*, 2016.

Solar irrigation system O&M costs	1% of capex	Project team assumption	Operating cost of PV system is negligible (no batteries). Cost of maintenance for pump and distribution is assumed to be similar to diesel-powered system.
Solar irrigation public support programme cost	USD 80 million	Project team Estimate	Government and/or donor support programme relating to awareness, tranidng and finance. Cost estimate based on existing schemes e.g. Practical Action Green Livelihoods Programme in Gwanda.
Solar irrigation labour cost	5% of capex	Project team assumption	Based on authors' knowledge of existing solar irrigation pumping projects in E. Africa and S.E. Asia.
On-farm anaerobic digestion of manure for biogas	Biodigestor capex: 1,260 USD per unit	SNV, 2008	Bsed on the study conducted by SNV on financing domestic biogas in Rwanda
	Govt. support programme: USD 10 million	SNV/HIVOS, 2012	Twice as amount of original programme for 7400 units. Amount for capacity building and awareness. Excludes subsidies.
	O&M cost: 19 USD/unit/year		Based on detailed domestic biogas programme feasibility study.
	Avoided cost of firewood: 168 USD/HH/year		
	Fertilizer replacement cost: 280 USD/HH/year		
	Bio-slurry utilization: 100 USD/HH/year		
	Direct job creation: 700		
Buildings			
CFL bulb capex	USD 3.2 million	GoR, 2018c	1.6 million CFL bulbs at 2 UD per bulb (ESSP target)
CFL demand reduction potential	54,000 MWh/year	GoR, 2018c	Estimated electricity demand reduction (ESSP)
Efficient cook stoves	According to cook stove dissamination program published in ESSP, total cost is 184 million USD.	MINIFRA, 2018	Estimated based on ESSP cost analysis
Rooftop solar systems	Capex: USD 28 million	Based on World Bank, 2018	Of which USD 12 million for battery banks; assumes 7 years useful battery life.
	Annual opex: 1% of capex	Assumption	-
Solar water heating capex	1,300 USD per unit	EWSA, 2014	Assumes 200 l/day SWH system cost published in EWSA (2014)
Solar water heating Govt. support programme	USD 8 million	EWSA, 2014	Assumption based on the previous residential solar water heating program published in EWSA, 2014

ENERGY (electricity)		
Overview	Mitigation measure	**Grid connected hydropower**
	Short description	Development of 56.75 MW large hydro capacity (capacity > 5 MW), 24.5 MW small and mini hydro projects (capacity <5MW) and 75 MW regional projects by 2030.
	Scope of project	Low carbon energy supply
	Timing of project	Gradual construction of both large and small-scale hydro based on the REG plans as published in the Least Cost Power Development plan (LCPDP)
GHG mitigation	Mitigation effect	Displacement of GHG from diesel power generation and new build fossil-based electricity generation.
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.475
	Total project mitigation ($MtCO_2e$)	4.193
Cost-benefit analysis	Description of costs	Costs estimated include planning, construction and operation as detailed in ESSP and LCPDP. Total capital costs estimated at 328 million USD; O&M costs estimated at 3.6 USD/MWh (fixed) and 0.85 USD/MWh (variable).
	Description of benefits	Avoided costs of diesel and fuel oil for power generation (approx. 55 million USD/year over period). Other benefits include job creation (estimated at approx. 45 million USD/year during construction; 18 million USD/year during operation).
	Economic assessment period	20 years
	Discount rate	6%
	NPV of project (Million USD)	175.96
	Notes on economic analysis	Economic cost analysis based on implementation costs published in the ESSP and LCPDP.
	Abatement cost (USD/tCO2e)	-41.96

ENERGY (electricity)		
Overview	Mitigation measure	**Solar minigrids**
	Short description	With a potential of 4.5 kWh per m^2 per day and approximately 5 peak sun hours, solar energy has large potential in Rwanda. The country has already engaged private sector participation into solar solutions as a lighting substitute for remote areas. Currently, 258,414 households have benefited access to electricity with the solar energy through IPPs nationally. Households located far from the planned national grid coverage are encouraged to use mini-grid solar photovoltaics (PVs) to reduce the cost of access to electricity. The Rural Electrification Strategy approved by the cabinet in June 2016 outlines strategies through which Rwanda's households could increase access. 68 MW of solar mini-grids are planned to be installed in off-grid rural areas by 2030. Mini grids will be developed by the private sector with Government playing a key role in identifying sites and establishing a financial incentive framework.
	Scope of project	Rural electrification
	Timing of project	Construction of micro-grids between 2020 and 2024. Operation to last until 2050.
GHG mitigation	Mitigation effect	Displacement of emissions generated by Jabana power plant (HFO)
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.146
	Total project mitigation ($MtCO_2e$)	1.611
Cost-benefit analysis	Description of costs	Total programme costs estimated at around 206 million USD (194 million USD capital costs including battery bank replacements after 7 years; 12 million USD O&M costs).
	Description of benefits	Avoided costs of fossil fuel power generation and transmission infrastructure; employee earnings from solar jobs and indirect jobs. Total economic benefits estimated at up to 54 million USD per year.
	Economic assessment period	15 years
	Discount rate	6%
	NPV of project (Million USD)	260.72
	Notes on economic analysis	Economic assessment does not include transaction costs and administrative costs to government from establishing financial incentive framework and other enabling measures.
	Abatement cost (USD/tCO2e)	-163.83

ENERGY (electricity)		
Overview	Mitigation measure	**Solar LED streetlights**
	Short description	The analysis assumes that approximately 10,000 solar powered LED streetlights will be installed to replace existing High-Pressure Sodium lights. While traffic lights are not separately addressed in the analysis their costs and benefits are included under streetlights.
	Scope of project	Energy efficiency measures
	Timing of project	Beginning in 2019. Ending in 2044 (although may continue).
GHG mitigation	Mitigation effect	Energy efficiency (reduced grid power).
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.008
	Total project mitigation ($MtCO_2e$)	0.100
Cost-benefit analysis	Description of costs	Capital cost of LED streetlights, batteries and installation estimated at around 20 million USD over period; O&M costs (battery replacement) estimated at 8 million USD over period.
	Description of benefits	Avoided cost of grid electricity and conventional light bulb purchase and replacement estimated at around 5-6 million USD/year.
	Economic assessment period	15-year period. While documentation gives no clear indication, we assume the project will last for 25 years (for consistency with other projects).
	Discount rate	6%
	NPV of project (Million USD)	18.23
	Notes on economic analysis	The cost analysis was based on the implementation cost sourced from the ESSP.
	Abatement cost (USD/tCO_2e)	-181.96

ENERGY (road transport)		
Overview	Mitigation measure	**Vehicle fuel economy standards**
	Short description	This project aims at setting vehicle emission standards for new imported road vehicles and enforcement regulations, and integrated national transportation planning.
	Scope of project	Efficient resilient transport system
	Timing of project	Phased in from 2022
GHG mitigation	Mitigation effect	Improved technology and standards for conventional ICE vehicles in road transport, resulting in avoided fossil fuel emissions
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.154
	Total project mitigation ($MtCO_2e$)	0.696
Cost-benefit analysis	Description of costs	Incremental technology costs for efficient vehicle models within each class/type and policy set-up and ongoing administration costs estimated to total around 190 million across period.
	Description of benefits	Avoided costs of imported petro-diesel and gasoline (from increased fuel efficiency) estimated at 285 million across period. Analysis does not quantify potential health benefits i.e. from reduced local pollution.
	Economic assessment period	10 years
	Discount rate	6%
	NPV of project (Million USD)	58.83
	Notes on economic analysis	N/A
	Abatement cost (USD/tCO2e)	-84.55

ENERGY (road transport)		
Overview	Mitigation measure	**Electric vehicles (buses and passenger cars)**
	Short description	Introduction of electric vehicles from around 2020 onwards, reaching up to 0.2% of new vehicle sales by 2023/24 and 8% by 2029/30 for EV cars; and 1% by 2023/24 and 20% by 2029/30 for EV Buses. Requires support to overcome additional capex associated with vehicles and charging points. This project is consistent with the e-mobility initiative, a program that is being developed by the GoR.
	Scope of project	Efficient resilient transport system
	Timing of project	From 2020 onwards
GHG mitigation	Mitigation effect	Displacement of conventional ICE vehicles in road transport, resulting in avoided fossil fuel emissions
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.001 For E-V cars and 0.003 for E-buses
	Total project mitigation ($MtCO_2e$)	0.004 for E-V cars and 0.014 for E-buses
Cost-benefit analysis	Description of costs	Additional capex for EV vehicles, rapid charger infrastructure and electricity costs estimated at 8 USD million for buses and 6 USD million for passenger cars trough period to 2030.
	Description of benefits	Avoided costs of imported diesel and gasoline estimated at 8.8 million for buses and 4 million for passenger cars through period.
	Economic assessment period	15 years
	Discount rate	6%
	NPV of project (Million USD)	-1.22 for E-V cars and 0.29 buses
	Notes on economic analysis	N/A
	Abatement cost (USD/tCO_2e)	331.09 for EV cars and -21.72 buses

ENERGY (road transport)		
Overview	Project title	**Electric motorcycles**
	Short description	This project is part of the ambitious e-mobility program being developed by the GoR. It aims at a phased adoption of electric motorcycles from 2020 with the following targets: 2.3% by 2023/24 and 33% by 2029/30.
	Scope of project	Efficient resilient transport system
	Timing of project	From 2020 onwards
GHG mitigation	Mitigation effect	Displacement of conventional ICE vehicles in road transport, resulting in avoided fossil fuel emissions
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.136
	Total project mitigation ($MtCO_2e$)	2.034
Cost-benefit analysis	Description of costs	Capital and charging costs estimated based on the prices provided by the local companies that are running pilot projects; based on the ambitions reaching up to 38,000 new e-vehicles by 2030, total costs through period are estimated to total over 980 USD million.
	Description of benefits	Avoided costs of imported fuels estimated at over 1.1 USD billion through period. Health benefits not quantified.
	Economic assessment period	10
	Discount rate	6%
	NPV of project (Million USD)	95.36
	Notes on economic analysis	N/A
	Abatement cost (USD/tCO2e)	-46.88

ENERGY (road transport)		
Overview	Mitigation measure	**Public transportation measures (buses)**
	Short description	This project aims at bus promotion as part of public transport development, replacement of minibuses by modern buses and promotion of mass rapid transportation. Additional measures such as improving road networks easing urban congestion have not been assessed within the scope of the analysis due to lack of data and resources. However, depending on the development of sufficient baseline assumptions, these could deliver significant additional benefits in terms of transport efficiency, and associated fuel and GHG savings.
	Scope of project	Efficient resilient transport system
	Timing of project	From 2020 onwards
GHG mitigation	Mitigation effect	Displacement of conventional ICE vehicles in road transport from increased public bus use, resulting in avoided fossil fuel emissions
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.008
	Total project mitigation ($MtCO_2e$)	0.054
Cost-benefit analysis	Description of costs	Capital costs estimated based on the cost of new efficient buses and minibuses; estimated at around 25 million USD for annual purchase of up to 200 new vehicles by 2030.
	Description of benefits	Avoided costs of imported diesel estimated at over 15 million USD through period. Does not quantify potential health benefits from reduced local pollution (considered to be minor).
	Economic assessment period	15 years
	Discount rate	6%
	NPV of project (Million USD)	-8.59
	Notes on economic analysis	N/A
	Abatement cost (USD/tCO2e)	158.63

ENERGY (buildings)		
Overview	Mitigation measure	**Rooftop solar in commercial buildings (grid back-up)**
	Short description	Most of commercial building and institutional buildings in remote areas of Rwanda use diesel generators the main source of electricity. Diesel generators are also used for grid back-up. The project aims at installing cumulative 10 MWp in three years and is aligned with the Rwanda rural electrification strategy.
	Scope of project	Energy efficiency
	Timing of project	Project assumed to begin in 2019 with a few pilots and completed within 3 years.
GHG mitigation	Mitigation effect	Displacement of diesel used in back-up generators
	Estimated mitigation in 2030 ($MtCO_2e/yr$)	0.029
	Total project mitigation ($MtCO_2e$)	0.279
Cost-benefit analysis	Description of costs	Capital costs estimated to total around 40 UDS million through 2030 including battery costs. O&M costs estimated at 3 million through 2030.
	Description of benefits	Displacement of diesel generation costs, grid electricity and creation of new solar jobs estimated to total almost 120 USD million across project assessment period.
	Economic assessment period	10
	Discount rate	6%
	NPV of project (Million USD)	47.02
	Notes on economic analysis	The project is expected to boost employment opportunities, estimated to activate or create new jobs in SMEs for 3,790 men and 4,166 women (due to availability of power during outages).
	Abatement cost (USD/tCO2e)	-168.76

ENERGY (buildings)		
Overview	Mitigation measure	**Energy efficient lighting**
	Short description	Supported by Government subsidy, REG distributed 800,000 CFLs in place of incandescent light bulbs between 2007 and 2014. To further support this initiative, an exemption of VAT on energy saving lamps was introduced in 2013. Benefits of this included a reduction in annual energy demand of 54 GWh and USD 11 million in savings for consumers. Considering the environmental and economic benefits of this previous initiative, a project aiming to further promote the use of efficient light bulbs (LED lamps) was proposed. This is also in line with the Rwanda Green building minimum compliance system.
	Scope of project	Energy efficiency measures under Rwanda Green building minimum compliance system.
	Timing of project	Beginning in 2020. Ending in 2030 (although it may continue).
GHG mitigation	Mitigation effect	Energy efficiency.
	Estimated mitigation in 2030 ($MtCO_2e/yr$)	0.016
	Total project mitigation ($MtCO_2e$)	0.181
Cost-benefit analysis	Description of costs	Total cost of scheme estimated at around 6.4 million USD based on assumed replacement of 1.6 million CFL bulbs through 2030 with CFL unit costs of 2 USD and average lifetime of 7 years.
	Description of benefits	Energy efficiency savings (purchased grid electricity) estimated at around 38 million USD through 2030; avoided cost of standard bulbs estimated at almost 12 million USD through 2030.
	Economic assessment period	15 years
	Discount rate	6%
	NPV of project (Million USD)	33.27
	Notes on economic analysis	N/A
	Abatement cost (USD/tCO2e)	-184.30

ENERGY (buildings)		
Overview	Mitigation measure	**Efficient cook stoves**
	Short description	The type of stove has a significant impact on the amount of fuel required and health of households. Most households (66%) use three-stone cookstoves (a simple cookstove, made by placing a pot on three stones, which are positioned around a fire) or traditional cooking stoves. These normally use firewood. The average household uses around 1.8 tonnes of firewood each year with this type of cookstove. The average monthly consumption per household on firewood is RWF 1,930 (USD 2.27). A Government programme to support the use of improved cooking technologies has been running since the 1980s with 30% household penetration. Private sector led efforts are also distributing cook stoves that are up to three times more efficient than the traditional 3-stone stove and can reduce biomass consumption by anywhere between 68-94%. This will free up the time spent by women and children in collecting firewood. The project aims to halve the number of households using traditional cooking technologies to achieve a sustainable balance between supply and demand of biomass through promotion of biomass efficient technologies. The project aligns with the ESSP targets.
	Scope of project	Energy efficiency
	Timing of project	2019-2030
GHG mitigation	Mitigation effect	Avoided charcoal and firewood consumption
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.195
	Total project mitigation ($MtCO_2e$)	1.896
Cost-benefit analysis	Description of costs	Costs include new stoves, training and monitoring on kiln use (certification), estimated to cost up to 380 million USD through 2030.
	Description of benefits	Avoided costs of charcoal and firewood, and additional job creation.
	Economic assessment period	10 years
	Discount rate	6%
	NPV of project (Million USD)	263.17
	Notes on economic analysis	The economic impact will be achieved progressively with the expansion of improved cookstoves use.
	Abatement cost (USD/tCO2e)	-138.79

ENERGY (buildings)		
Overview	Mitigation measure	**Solar water heaters in the residential sector**
	Short description	A major ongoing initiative is the SolaRwanda Solar Water Heater Program, which promotes the use of solar water heaters, with the aim of reducing the use of electricity from the grid for water heating. The program was initiated in 2009 with the support of development partners and was formally launched in March 2012 with a pilot phase of 100 SWHs. Loans and grants are used to subsidise the cost of purchasing a SWH. Implementation commenced in April 2013 and a total of 2,256 SWHs have been installed. This project focussed on the implementation of the Rwanda Green building compliance system. It aims at encouraging the commercial building to install solar water heaters instead of using electricity.
	Scope of project	The project is part of Rwanda Green building minimum compliance system
	Timing of project	2021-2030 and beyond
GHG mitigation	Mitigation effect	Displacement of electricity consumption
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.041
	Total project mitigation ($MtCO_2e$)	0.24
Cost-benefit analysis	Description of costs	Capital costs include equipment and costs of a implementing a government support programme. Capital costs estimated to total 52 USD million through 203 based on installing 4,000 SWH units per year at unit cost of 1,300 USD. Government support programme cost estimated at 8 million USD. Equipment O&M. estimated to total around 28 million USD through 2030
	Description of benefits	Avoided costs of electricity, plus job creation benefits estimated to total around 180 million USD (156 USD million electricity costs; 24 USD million job creation benefits) through 2030.
	Economic assessment period	10
	Discount rate	6%
	NPV of project (Million USD)	60.03
	Notes on economic analysis	N/A
	Abatement cost (USD/tCO2e)	-252.59

ENERGY (buildings)		
Overview	Mitigation measure	**Off-grid solar electrification (SHS and mini-grids)**
	Short description	Considering the challenges associated with the grid-connected electricity, the government of Rwanda considers the access to off-grid electricity as the primary mean through which the electricity access could be expanded through the country. In recent years, the off-grid electricity has been one of the key achievements of the electricity sector with a growth from 0% to 11%. According to the government plans, the latter access will be increased via solar home systems and solar mini grid.
	Scope of project	Rural electrification
	Timing of project	Universal access to be achieved by 2025.
GHG mitigation	Mitigation effect	Displacement of kerosene used for lighting in rural households, and to a lesser extent, diesel/petrol used in small gensets.
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.010
	Total project mitigation ($MtCO_2e$)	0.075
Cost-benefit analysis	Description of costs	According to REG estimates, a total capital costs of include the solar PV mini-grids and SHS, per REMA estimates. Total amounts to $200 million. Main operating cost is the cost of replacement of solar batteries. While the SHS/mini-grid market is expected to be private sector led, a public support programme to offer training, financing, etc. has been factored in in the cost.
	Description of benefits	Avoided consumption of more basic forms of energy (kerosene, candles, batteries, phone charging services, etc.) and grid electricity, plus job creation benefits estimated to total around 1 billion through 2030.
	Economic assessment period	15 years
	Discount rate	6%
	NPV of project (Million USD)	9.76
	Notes on economic analysis	Other benefits of solar technologies vs other sources (pollution, health, fuel independence, better quality of light, etc.) were not quantified.
	Abatement cost (USD/tCO2e)	-130.91

ENERGY (manufacturing industry)		
Overview	Mitigation measure	**Energy efficient brick kilns**
	Short description	The project aims at replacing the existing traditional kilns by energy efficient brick kilns to reduce the fuel consumption the construction sector. Project is aligned with the GoR policy to reduce the biomass consumption in industries and promote cleaner production.
	Scope of project	Energy efficiency.
	Timing of project	The project is assumed to start in 2020 through 2030 and beyond.
GHG mitigation	Mitigation effect	Energy efficiency.
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.143
	Total project mitigation ($MtCO_2e$)	0.916
Cost-benefit analysis	Description of costs	Total capital cost requirement for replacement energy efficient brick kilns estimated at around 13 million USD through 2030.
	Description of benefits	Avoiding purchase of fuelwood estimated to total over 20 million USD. Additional health benefits from reduced pollution not quantified.
	Economic assessment period	10 years.
	Discount rate	6%
	NPV of project (Million USD)	42.35
	Notes on economic analysis	Health benefits were not estimated. Analysis does not include figures on the costs of establishing the programme and developing a database to monitor the programme.
	Abatement cost (USD/tCO2e)	-46.21

ENERGY (manufacturing industry)		
Overview	Mitigation measure	**Energy efficiency in agro-processing industries**
	Short description	Implementation of energy efficiency equipment and management systems within tea (e.g. tea driers) and coffee.
	Scope of project	Energy efficiency improvement in tea driers
	Timing of project	Ongoing
GHG mitigation	Mitigation effect	Energy efficiency.
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	< 0.001
	Total project mitigation ($MtCO_2e$)	0.007
Cost-benefit analysis	Description of costs	Capital cost grants for improvement equipment estimated at around 2 million through 2030. Ongoing costs of management and operation of programme not estimated.
	Description of benefits	Avoided purchase of fuelwood and electricity estimated to total around 4.3 million through 2030.
	Economic assessment period	15 years.
	Discount rate	6%
	NPV of project (Million USD)	1.39
	Notes on economic analysis	Economic analysis does not include figures on the costs of establishing the programme and developing a database to monitor the programme, for which data estimates are unavailable.
	Abatement cost (USD/tCO2e)	-207.93

ENERGY (manufacturing industry)		
Overview	Mitigation measure	**Energy efficient cement industry**
	Short description	The project aims at replacing fossil fuel use by wood wastes (rice husks and sawdust) within the cement industry. The project is aligned with the GoR policy to reduce the biomass consumption in industries and promote cleaner production.
	Scope of project	Replacement of residual fuel oils by wood wastes.
	Timing of project	The project is assumed to start in 2020.
GHG mitigation	Mitigation effect	Energy efficiency.
	Estimated mitigation in 2030 ($MtCO_2e/yr$)	0.1426
	Total project mitigation ($MtCO_2e$)	0.916
Cost-benefit analysis	Description of costs	Capital and operating costs estimated to total 10.8 million USD through 2030.
	Description of benefits	Avoiding purchase of fossil fuels estimated to be up to 80 million USD through 2030. Potential health benefit impacts were not estimated.
	Economic assessment period	10 years
	Discount rate	6%
	NPV of project (Million USD)	42.35
	Notes on economic analysis	Analysis does not include figures on the costs of establishing the programme and developing a database to monitor the programme.
	Abatement cost (USD/tCO2e)	-46.21

ENERGY (manufacturing industry)		
Overview	Mitigation measure	**Electric motor replacement in mining**
	Short description	The project aims at phasing out the fossil fuel use in the mining industries and to replace it by onsite-generated electricity and/or grid connected electricity. Reduction in diesel consumption will reduce associated GHG emissions and other related air pollutants. The project is aligned with the energy efficiency in industries and the cleaner production program.
	Scope of project	Replacement of existing fossil fuel motors with electric motors in mining companies.
	Timing of project	From 2020 onwards.
GHG mitigation	Mitigation effect	Energy efficiency.
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.011
	Total project mitigation ($MtCO_2e$)	0.056
Cost-benefit analysis	Description of costs	Includes capital costs (via grants for replacement of motors) and O&M costs (management and operation of programme).
	Description of benefits	Avoiding purchase of diesel fuel.
	Economic assessment period	10 years
	Discount rate	6%
	NPV of project (Million USD)	0.31
	Notes on economic analysis	Assessment does not include costs of establishing the programme and developing a database to monitor the programme.
	Abatement cost (USD/tCO2e)	-5.53

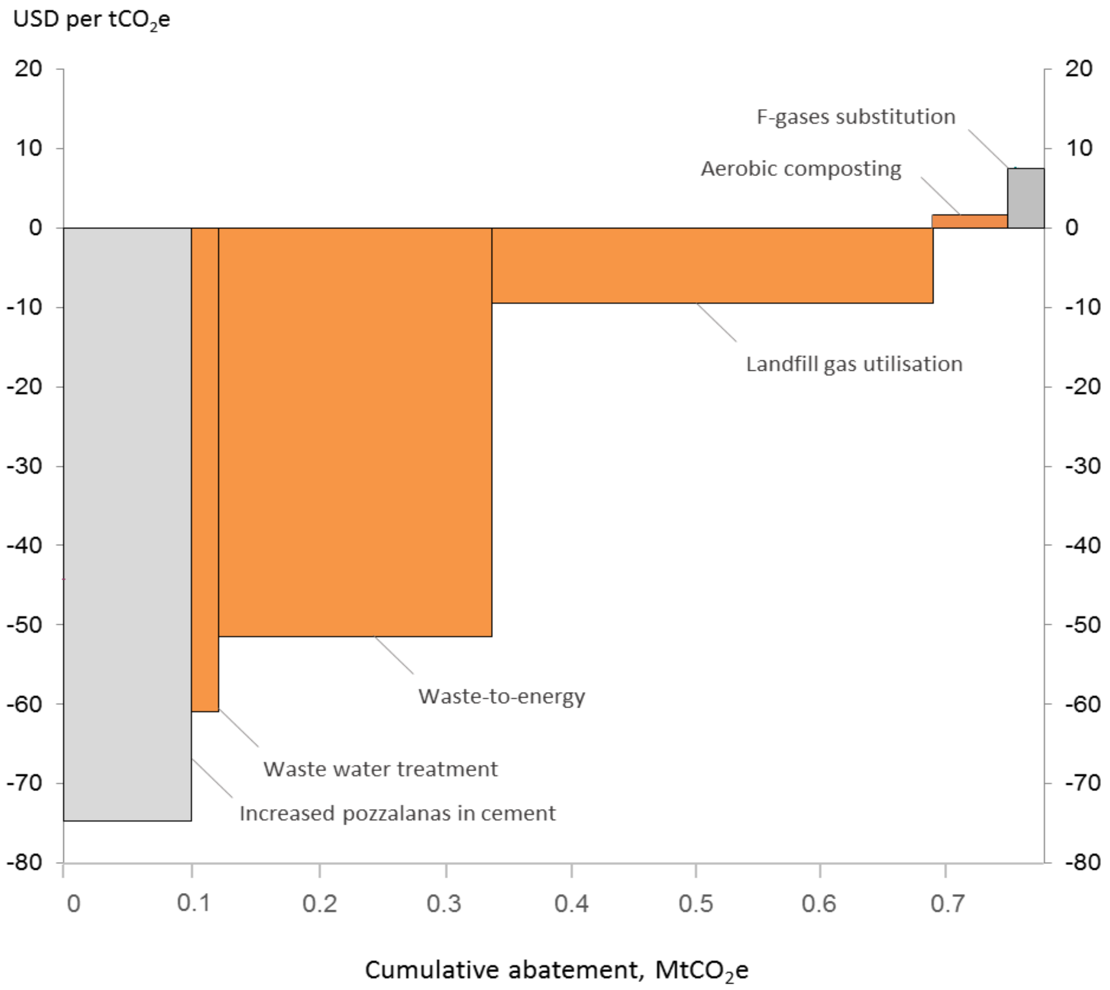
ENERGY (agriculture)		
Overview	Mitigation measure	**Domestic on-farm biogas**
	Short description	The project, which is aligned with ESSP targets, will aim at enforcing the promotion and use of biogas. Biogas utilisation is proposed as potential alternative to biomass. The 2007 National Domestic Biogas programme supported the use of biogas, targeting 9,500 rural households with at least two cows. Since 2007, around 3,700 digesters, based on standard construction design using local materials, have been disseminated. The government provided a 50% subsidy and the remaining provided through local credit institutions. However, recent site visits suggest that use of biogas digesters is limited, with users citing unreliability and insufficient fuel. At the institutional level, there have been 68 installations, with 11 out of 14 prisons reached and the remaining 3 under development.
	Scope of project	29,000 on-farm small-scale biodigesters (capacity 4-20 m^3) to replace (mainly) fuelwood used for cooking; roll-out of government support programme (awareness, training, subsidies)
	Timing of project	Ongoing
GHG mitigation	Mitigation effect	Avoided emissions from manure. Avoided deforestation.
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.117
	Total project mitigation ($MtCO_2e$)	0.869
Cost-benefit analysis	Description of costs	Capital and annual costs estimated based on SNV feasibility studies. Total capex estimated at 37 million USD through 2030 based on reaching cumulative installation of 29,000 biodigesters (at unit cost of 1260 USD); O&M costs estimated at 4 million USD; government support programme 10 million USD.
	Description of benefits	Quantified: Avoided cost of fuelwood, replacement cost of fertiliser, revenue from utilisation of bio-slurry estimated to total almost 120 million USD through 2030. Not quantified: job creation, reduced workload for rural households, health benefits.
	Economic assessment period	10 years
	Discount rate	6%
	NPV of project (Million USD)	33.20
	Notes on economic analysis	N/A
	Abatement cost (USD/tCO2e)	-38.22

ENERGY (agriculture)		
Overview	Mitigation measure	**Solar pumping for irrigation**
	Short description	According to NST1, the national area under irrigation will increase from 48,508 ha (2017) to 102,284 ha in 2024, driven by increasing crop production and exports of tea, horticulture and other products to meet growing international demand. Priority will be given to the scale up of marshland and small-scale technologies for irrigation, considered most cost-effective. This project aims at an irrigation area of 84,505 Ha by 2030.
	Scope of project	Investment in small-scale solar irrigation as opposed to diesel pumps for 84,505 Ha. Public-support programme to create awareness, help farmers finance investment (through credit and/or subsidies) and train technicians). Rwanda Agriculture Board (RAB) implements and Coordinates SSIT countrywide where a subsidy of 50% is given to farmers and funds are earmarked to selected districts while MINAGRI and RAB mobilize farmers to adopt climate resilient methods which include irrigation equipment.
	Timing of project	Implementation/investment over 5 years between 2020 and 2024 (assumption based on NST1).
GHG mitigation	Mitigation effect	Displacement of diesel consumption in small-scale irrigation schemes, targeting 84,505 Ha.
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.150
	Total project mitigation ($MtCO_2e$)	1.202
Cost-benefit analysis	Description of costs	Capital costs include the solar irrigation system equipment (PV modules, mounting structure, pump controller, pump, distribution and water storage) and its installation, compared to the cost of a diesel irrigation system of equivalent performance. Estimated to total around 380 million USD through 2030, including 5-year public-support programme and ongoing O&M costs.
	Description of benefits	Avoided costs of imported diesel fuel (and its transportation to farms), plus job creation benefits estimated to total 625 million USD through 2030.
	Economic assessment period	10 years
	Discount rate	6%
	NPV of project (Million USD)	106.77
	Notes on economic analysis	The economic analysis assumes solar pumps are used throughout the year (as opposed to seasonal use).
	Abatement cost (USD/tCO2e)	-88.80

A-1.3 IPPU and waste

Figure A-2 presents the cost-ordered MACC for all identified measures within the IPPU and waste sectors for the year 2030. The corresponding data are shown in Table A-3.

Figure A-2 Marginal abatement cost curve for identified measures in 2030, IPPU and Waste



Source: Authors

Table A-3 Mitigation measures ordered according to abatement costs, IPPU and Waste

Mitigation option	Sub-Sector	Abatement cost (USD/tCO_2e)	Mitigation 2030 ($MtCO_2e$)
Increased pozzolanas in cement	IPPU; Mineral industries	-74.71	0.104
Waste-water treatment	Waste; Wastewater	-60.93	0.022
Waste-to-energy	Waste; Solid waste	-51.46	0.220
Landfill gas utilisation	Waste; Solid waste	-9.52	0.356
Aerobic composting	Waste; Solid waste	1.68	0.060
F-gases substitution	IPPU; F-gases	7.49	0.029
Total mitigation potential in 2030			0.79

Table A-4 below provides a summary of the key assumptions and data sources used in the cost-benefit analyses. The subsequent tables describe the assessment of each of the mitigation measures in more detail.

Table A-4 Key assumptions and data sources used in cost benefit analyses, IPPU and Waste

Parameter	Value	Source	Notes
Industrial Processes and Product Use (IPPU)			
Clinker reduction from increased use of pozzalanas	Reduced clinker from current 70% ratio clinker to cement: 5% Reduced clinker use due to increased use of non-structural concrete: 20%	CCl, 2019	Considered feasible increase in pozzalana use 2020-2030, and market acceptance of non-structural concrete products, through discussions with industry stakeholders
Cement production costs	Clinker production: USD 75/tonne clinker Pozzalana material cost: USD 6/tonne	CCL, 2019	Pozzalana costs based on weighted average of estimated costs from Rubavu (7,000 FWR/t) and Rusizi (4,000 FWR/t) pozzalana sources.
Substitution of F-gases	F-gas reduction assumptions: 2020-2024: 30% 2024: 2030: 65%	GoR, 2018a	Proposed government reduction targets, as included in TNC
HFC costs	Imported HFC-134a: 9 USD/kg Imported R290: 54 USD/kg	REMA, 2016	HFCs costs at the local market in Rwanda during the November 2016 survey
Waste			
Landfill gas utilisation	Estimated energy available from 2020 to 2030: 38.5 TJ	Calculated, based on GoR, 2018a	Based on TNC calculations of LFG availability applying IPCC 2006 methodology (IPCC, 2006)

	Capital costs: LFG collection and control system: 1 USD million Internal combustion engine power plant: 1 USD million Direct use project: 3 USD million Sanitary landfill: 22 USD million	AFD, 2013; USEPA, 2008	Cost assumptions based on similar project undertaken in Addis Ababa financed by AFD in 2013, and pre-Feasibility Study for LFG Recovery and Utilization at Los Cocos Landfill site, Colombia.
	O&M costs: Power plant: 0.3 USDm/year Gas collection system: 0.1 USDm/year Landfill operaiton: 0.5 USDm/year	USEPA, 2008	
Waste-to-Energy	GHG emission per unit waste in SWDS: 0.38 tCO2e/tonne SWDS waste	Based on GoR, 2018a	Calculated based on the baseline year 2015 for the quantity of waste going to SWDS and their corresponding emissions
	Total capital costs: 161 USD million O&M costs: 8 USD million/year	Karlsson L & Jönsson T.L., 2012	Based on pre-feasibility study of a Waste to Energy plant in Moldova.
	Employment creation: 500 jobs	Assumption	-
Aerobic biological treatment (composting)	Base year composting rate: 20% Annual increase potential: 5% 2030 composting rate: 33%	Assumption	Estimated based on the project implementation requirering capacity building at household level and at large scale
	Production cost, small scale Windrow composting: 20 USD/tonne Capacity building needs and program implementation: 5 USD million	Assumption	Based on cost provided by RAB and estimate of transport costs, and the discussion on capacity building needs
	Compost produced (% of waste handled): 22%	AENOR, 2008	Based on waste composting CDM project 2008/018/CDM/005.1 in Uganda
	Price of compost: 22 USD/tonne	RAB, 2019	Based on 20,000 FRW average cost value provided by RAB
Waste-water treatment and reuse	Urban population connected to the WWTP by 2022: 11.1%	EIB, 2016a; REMA, 2017	Based on feasibility studies of Kigali WWTP, Kibagabaga and Kinyinya Catchments
	Total estimated capital cost of WWTP system: 89 USD million Annual O&M costs: 0.8 USD million	Based on EIB, 2016b ; author estimates	Includes total estimated investment costs, 10% contingency and government support programme
	Benefit assumptions: Sewage tariff: 0.9 USD/m³ Health benefits: 19 USD/person/year Household pit latrine emptying savings: 11 USD/HH/year Annualised replacement costs of HH septic tanks: 11 USD/HH/year Estimated maximum treated sewerage: 12,000 m³ per day Average population per HH: 4	Based on EIB, 2016a; EIB, 2016b, GoR, 2018b.	Calculation of benefits based on EIB local survey data, national census and the WHO estimates for the average economic benefit of improved sanitation. Health benefits include those from introducing piped sanitation to a household which has piped water but non-piped sanitation

INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)		
Overview	Mitigation measure	**Clinker substitution: Increased use of pozzolanas in cement**
	Short description	Clinker substitution recognise the need to lower the carbon in cement production industry. A rational 5% substitution of clinker with pozzolanas from the current 70% (cement-to-clinker ratio) has started to be implemented. The CCL plant envisage to produce the cement of 50% clinker ratio for non-structural application. It is assumed that 20% of the total cement production is used for non-structural concrete use.
	Scope of project	Production of cement by substitution of clinker with pozzolanas alternative to reduce the GHG emission while at the same time reducing the cost of cement production.
	Timing of project	2020-2030
GHG mitigation	Mitigation effect	Reduces CO_2 emissions from the calcination reaction of clinker.
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.104
	Total project mitigation ($MtCO_2e$)	1.183
Cost-benefit analysis	Description of costs	Capital costs estimated at 1.2 million USD; pozzolana material costs estimated to total around 7 million USD through 2030 based on 6 USD/tonne assumption.
	Description of benefits	Use of local materials which results in new job opportunities, GHG reduction in clinker process emissions. In addition, energy related emissions (coal; electricity) will be reduced from the reduction of fossil fuel combustion in clinker production. Thus, the increase of pozzolanas in cement while reducing the clinker-to-cement ratio means lower emissions and lower energy use. Economic benefits from clinker reduction is estimated at 95 million USD through 2030.
	NPV of project (Million USD)	88.41
	Notes on economic analysis	Economic gains are significant from both technical and sustainability perspectives, as well as from an aesthetic point of view. Pozzolana clinker substitute typically costs less than clinker-based cement.
	Abatement cost (USD/tCO2e)	-74.71

INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)		
Overview	Mitigation measure	**Gradual substitution of F-gases by less polluting substitutes**
	Short description	The category 2F emissions will be reduced to comply with the Kigali amendment of the Montreal Protocol on substances that deplete the ozone layer (UN, 2016). 2F gases are mainly imported for refrigeration, stationary air conditioning and mobile air conditioning. By using climate-friendly alternatives to HFCs, emissions are projected to be reduced by 30% in 2020 to 65% in 2030 relative to BAU.
	Scope of project	Gradual replacement of the ODS alternatives that were surveyed in Rwanda on the list of controlled substances as per Annex F of the Montreal Protocol, such as HFC-134a, HFC-125, HFC-143a and HFC-32 (UN, 2016). The study assumes the substitution of existing F-gases with hydrocarbon refrigerants such as R290.
	Timing of project	2020-2030
GHG mitigation	Mitigation effect	Reduction of F-gases, with higher GWP, from refrigeration and servicing sector.
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.029
	Total project mitigation ($MtCO_2e$)	0.303
Cost-benefit analysis	Description of costs	Additional costs associated with importing climate-friendly alternatives to HFCs (R290) estimated to have capital costs of 3.2 million USD and material costs of around 20 million USD through 2030.
	Description of benefits	HFCs are greenhouse gases with high global warming potential (GWP). The solution is to shift to low GWP substitutes. The lower the GWP, the more climate-friendly the substance. Reduced cost of imported HFC R-134a gases estimated at around 17 million USD through 2030.
	NPV of project (Million USD)	-2.27
	Notes on economic analysis	N/A
	Abatement cost (USD/tCO2e)	7.49

WASTE		
Overview	Mitigation measure	**Landfill Gas Utilisation**
	Short description	Generation of electricity power from landfill gas (LFG) collection and their burning applied to sanitary landfills. The project also will improve solid waste collection in urban areas. Approximately 86% of primary energy in Rwanda comes from biomass, in the form of firewood (57%) and charcoal, together with smaller amounts of crop residues and peat (6%). Thus, LFG will provide an alternative renewable energy by capturing a large portion of CH_4 and oxidizes it in combustion.
	Scope of project	The scope of work will include: Landfill sites preparation, waste sorting, landfill gas (methane) generation estimate, landfill gas collection and utilization options, and financial income generation and other government support programmes (awareness, training, subsidies).
	Timing of project	2020-2030
GHG mitigation	Mitigation effect	Reduction of methane (CH_4) emissions from landfill sites and avoided Carbon Dioxide (CO_2) from displacement of fossil-based electricity use. The use of methane landfill gas will reduce methane emissions from 30% to 60% between 2020 and 2030.
	Estimated mitigation in 2030 (MtCO2e/yr)	0.356
	Total project mitigation (MtCO2e)	2.234
.Cost-benefit analysis	Description of costs	Investment for LFG Plants of 6 MW and improved landfills is estimated at 28 million USD. The electricity generation capacity of 3 MWh is estimated from the very beginning of the project from 2020 to 2025 and 6 MWh from 2026 to 2030. The capital costs will be involved in purchasing of materials, design and construction of landfill gas collection system and landfill gas cleaning and treatment system. Operating costs will be focused on landfill gas flaring system, gas storage and compression system, and in LFG utilization system as fuel (estimated at around 9 million USD through 2030).
	Description of benefits	Quantified: Avoided cost of fuel from biomass, compensation cost of electricity demand, revenue from utilisation of landfill gas, and generated additional financial income for the landfill site operations (estimated at over 80 million USD through 2030). Not quantified: job creation, welfare improvements, reduced workload for rural households, health benefits, improved air, water and soil quality, reduction of leachate and improvement of on-site conditions
	NPV of project (Million USD)	21.27
	Notes on economic analysis	It is assumed that this project will boost employment opportunities, activating or creating new jobs. Landfill gas Utilization will meet and contribute to electricity demand and avoided costs of electricity in Rwanda and this will harness economic growth within the country
	Abatement cost (USD/tCO2e)	-9.52

WASTE		
Overview	Mitigation measure	**Waste to Energy (WtE) plants**
	Short description	This project seeks to implement national strategies to recover energy from waste by conversion of non-recyclable waste materials into usable heat or electricity through different processes. The WtE plants will only consider the conversion of non-recyclable waste material from urban area into usable energy. The WtE plant should have a capacity of processing up to 800 tons of solid waste per day and shall be able to generate power capacity of 15 MW per hour by 2020 which will increase to 30 MW in 2025.
	Scope of project	Implementation and establishment of a WtE plant for collection of all wastes for disposal and their transformation into energy by incinerating all wastes, thus preventing future emission from the same waste.
	Timing of project	2020-2030
GHG mitigation	Mitigation effect	Avoided CO_2 emissions from displacement of fossil-based electricity. This project has a high mitigation potential since the technology incinerates all wastes.
	Estimated mitigation in 2030 (MtCO2e/yr)	0.220
	Total project mitigation (MtCO2e)	2.313
Cost-benefit analysis	Description of costs	Assumes investment for WtE plant in urban area with the capacity of 800 tons of solid waste per day and 15 MW of electricity generation with an estimate investment cost of 161 million USD per plant, and other government support programmes and maintenance costs estimated to total around 8 million USD per year.
	Description of benefits	Quantified: WtE electricity generation will translate into revenues per year for job creation and economic growth, estimated at up to around 50 million USD pa. Not quantified: job creation, improved quality of environment, electricity generation, GHG reduction, high public awareness about the efficacy and potency of renewable energy technologies.
	NPV of project (Million USD)	119.01
	Notes on economic analysis	With the increase of urbanization and improvement of living standards, waste to energy project will provide job opportunities, respond to electricity demand and increase the GDP by ensuring access to affordable and clean energy.
	Abatement cost (USD/tCO2e)	-51.46

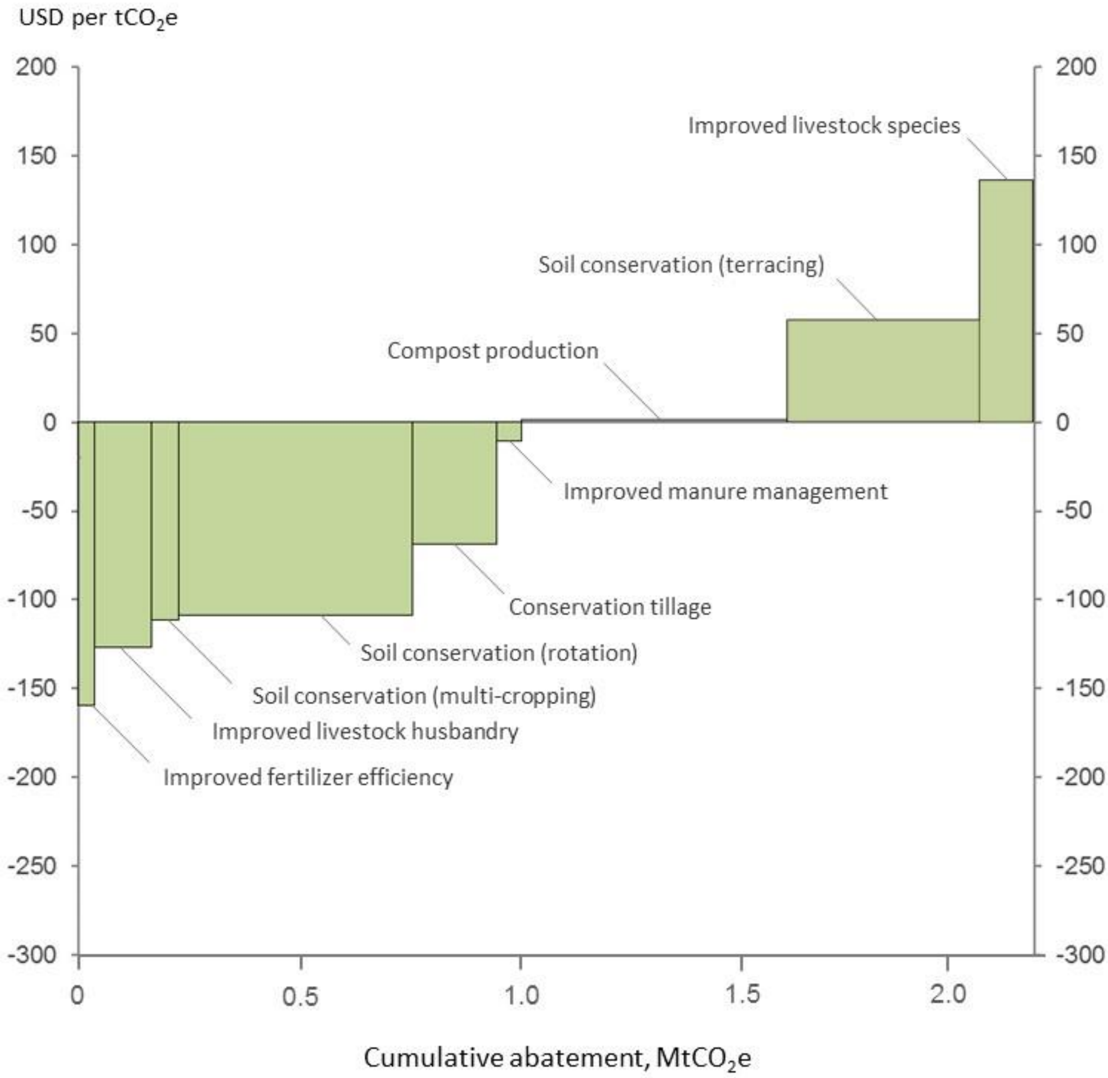
WASTE		
Overview	Mitigation measure	**Aerobic biological treatment (composting)**
	Short description	The project implements the windrow composting method at household level. Organic waste is placed into rows of long piles called windrows and aerated by turning the pile periodically by either manual or mechanical methods. Usually a height of 1.2-2.4 m allows oxygen to flow to the windrow's core.
	Scope of project	The project will be implemented in rural households where solid waste is typically collected into small pits for composting. The project envisages the recovery and reuse of organic waste by neighbouring households, i.e. village/umudugudu in order to restore and maintain soil fertility.
	Timing of project	2020-2030
GHG mitigation	Mitigation effect	The aerobic process of composting does not generate methane because methane-producing microbes are not active in the presence of oxygen (i.e. methane avoidance).
	Estimated mitigation in 2030 (MtCO2e/yr)	0.060
	Total project mitigation (MtCO2e)	0.502
Cost-benefit analysis	Description of costs	At the community level, composting offers an attractive economic advantage because the existing land area for composting will be used. The major cost is labour cost collecting and turning the pile periodically. Labour cost can be reduced by the proximity of households involved in the projects. the assessment assumes a capacity building needs and program implementation cost of 5 million USD and annual costs of up to 6 million based on a unit labour cost assumption of 20 USD/tonne compost.
	Description of benefits	Composting requires relatively simple and scalable technology. In addition to methane gas emissions reduction, composting offers numerous other climate change adaptation co-benefits such as: improving retention of soil fertiliser, reducing compostable waste, enhancing soil buffering capacity and moisture holding capacity, adding a source of organic matter that stimulates biological activity, improving the pool of nutrients, adding a liming effect on the soil, soil structure improvement. Compost sales of up to 7 million USD per year are estimated based on unit price assumption of 22 USD/tonne.
	NPV of project (Million USD)	-0.84
	Notes on economic analysis	Considering the economic and technological context of Rwanda and the country waste management approach in rural areas, the windrow composting is seen as a viable option at household levels.
	Abatement cost (USD/tCO2e)	1.68

WASTE		
Overview	Mitigation measure	**Wastewater treatment and re-use**
	Short description	The proposed project will involve the construction of a sewerage network and wastewater treatment plant (WWTP). The planned projects include: (i) Kigali central WWTP in Nyarugenge and (ii) the Centralized Sewerage System for Kibagabaga and Kinyinya Catchments in Gasabo District, etc. In addition, there are other initiatives of semi-centralized wastewater treatment systems in Kigali.
	Scope of project	In the short term, treating wastewater is the priority while in the long run, reuse of the treated water is targeted to address increasing water scarcity, and increase drought resilience as well as restoring and maintaining soil fertility.
	Timing of project	2020-2030
GHG mitigation	Mitigation effect	Reduction of methane (CH_4) and Nitrogen oxide (N_2O) emissions.
	Estimated mitigation in 2030 (MtCO2e/yr)	0.022
	Total project mitigation (MtCO2e)	0.348
Cost-benefit analysis	Description of costs	Capital costs of 89 million USD per 1 WWTP (178 million USD in total for 2 plants) estimated based on the project of Kigali central wastewater treatment plant. Capital costs will cover the consolidation of basic infrastructures in terms of collection of sewage and operational costs and other costs will be attributed to the functioning of wastewater treatment plant. O&M costs are estimated at around 1.5 million USD per year in total.
	Description of benefits	Quantified: The project has benefits of reduced costs of on-site treatment and emptying of pits/septic tanks. Other benefits include job creation, increased tourism due to cleanliness, increased agriculture production due to wastewater reuse, reduced water footprint, and groundwater recharge (estimated to total around 32 million USD per year). Not quantified: Quantifying the economic benefits of improved river water quality and health is a complex task which would require a collection of substantial amounts of data that is beyond the scope of this project.
	NPV of project (Million USD)	-21.22
	Notes on economic analysis	The project will boost employment opportunities and creating new jobs. The project will promote cost savings from wastewater reuse and will save the costs related to the environment decontamination and health diseases previously due to wastewater discharge.
	Abatement cost (USD/tCO2e)	-60.93

A-1.4 Agriculture

Figure A-3 presents the cost-ordered MACC for all identified measures within the agriculture sector for the year 2030. The corresponding data are shown in Table A-5.

Figure A-3 Marginal abatement cost curve for identified measures in 2030, Agriculture



Source: Authors

Table A-5 Mitigation measures ordered according to abatement costs, Agriculture

Mitigation option	Sub-Sector	Abatement cost (USD/tCO_2e)	Mitigation 2030 ($MtCO_2e$)
Improved fertilizers efficiency	Agriculture	-159.61	0.039
Improved livestock husbandry	Agriculture	-126.91	0.133
Soil conservation (multicropping)	Agriculture	-111.59	0.066
Soil conservation (rotation)	Agriculture	-108.66	0.551
Conservation tillage	Agriculture	-68.74	0.197
Manure management	Agriculture	-10.45	0.058
Compost production	Agriculture	1.83	0.624
Soil conservation (terracing)	Agriculture	57.49	0.451
Improved livestock species	Agriculture	136.34	0.126
Total mitigation potential in 2030			2.24

Source: Authors

Table A-6 below provides a summary of the key assumptions and data sources used in the cost-benefit analyses. The subsequent tables describe the assessment of each of the mitigation measures in more detail.

Table A-6 Key assumptions and data sources used in cost benefit analyses, Agriculture

Parameter	Value	Source	Notes
Soil and water conservation measures			
Nutrient use efficiency (deep fertilizer placement in rice)	30% reduction in fertilizer use; 5% yield increase on rice	Bowen et al. 2005	The rate of fertilizer redution and yield increase was adapted downwards from Bowen et al., 2005.
	Seed cost = 1500 frw/kg	RAB	1ha requires 10kg of seed
	Emission factor urea for CO2 = 0.733; Emission factor N2O = 0.01 for direct emission and 0.100 for indirect emission from soil	IPCC 2006	
Nutrient use efficiency (compost)	Soil C retained in soil 150days after compost application of 50t/ha =4.24Mg/ha	Fabrizio et al., 2009	Proportional estimate – application of 10t/ha compost will retain 0.85Mg C/ha (during 2 cropping seasons). To be conservative, this was considered as single time effect
	One cow produces 10kg dung per day and 2-2.5 tonnes/year.	RAB; our assumption	This would be enough for making 5 tons of compost
	1ha of crops produces 5-20 tons of fresh biomass	Rajkhova et al. 2005 and our assumption	4-5tonnes of fresh crop/weed biomass is required to make 5-5.5 tonnes of compost
Soil conservation (rotation)	Maize and bean production cost data	RAB research programs	-
	Yield increase from rotation: 12.5%	Bullock, 1992	Midpoint of 5-20% yield increase indicated in source
Conservation tillage	Soil C increase 0.02-0.76 Mg/ha per year	Lal et al. 2004	Soil C increase of 0.195tons/ha per year assumed to be conservative

Multi-cropping (banana-coffee)	C soil stock under monocropped coffee: 24-29 Mg C/ha	Hergoualc'h et al, 2012	Assessment has estimated soil C stock as about 20Mg C/ha for monocropped coffee
	Aboveground biomass stock for monocropped coffee: 10.5 Mg/ha	Van Asten et al, 2015	C increase in above ground biomass of banana-coffee estimated at 32/8 years = 4 tons C per year.
	Above ground biomass stock for polycropped coffee: 42.5 Mg/ha		-
	Cost of training programme: 2 million USD/year; Follow up: 1 million USD year	Estimated	-
Terracing	Cost of radical terraces: 694 USD/ha	Bizimana & Kannan, 2011	Study of radical terraces cost-benefit analysis with maize and beans yields.
	Cost of progressive terraces: 378 USD/ha	Bizoza A., 2011	-
	Soil loss on unprotected slopes in Rwanda: 41.5t/ha per year; Soil loss on terrace protected slopes: 18t/ha	Kagabo et al 2013	Soil loss prevention potential on 1ha due to terracing therefore calculated at 23.5t/ha per year.
	Share of radical versus progressive terraces: 33%/67%	RAB, 2017	Taken from annual RAB targets contained in the RAB Annual Action plan 2017-2018, assuming annual area of 15,000ha.
	Maize and Irish potatoes seed costs	RAB research programs	-
	Mean yield for maize	NISR, 2019	Seasonal Agricultural Survey Report, 2018
Livestock			
Livestock husbandry (improved fodder expansion)	New fodder species will be planted on a total of 75,500 ha by 2030.	Assumption	The area for improved fodder will be 75,500ha Improved fodder expansion is assumed along new and old terraces, roadsides and sites identified for forage production.
	Brachiaria yield: 5.6 t/ha of dry matter	Mutimura and Everson, 2012	Yield of dry matter estimated at 4t/ha, and fresh biomass yield about 20t/ha
	Consumption of feed per day for 1 cow: 10 kg	Nduwamungu et al., 2019	2 tons of Brachiaria needed for 1 cow per year; this can be obtained from 0.1ha.
	Proportion of improved fodder in animal feed to improve enteric fermentation reduction: 50% Associated reduction achieved: 5%	Knapp et al. 2014	.
	Cost of establishing fodder: 600 USD/ha; cost of maintenance : 500USD/ha per year Milk cost (revenues): 350Frw/litre	RAB Animal nutrition program	-
Livestock species	Cost of improved cow:1000 USD Cost of local cow: 110 USD Cow maintenance cost: 125,000 FRW Length of milking period: 220 days/year; 10-20 l milk per day	RAB Animal nutrition program	-
Other mitigation measures			

Manure management	30% reduction in N2O emission with covering manure	Chadwick et al. 2011	-
	No emissions in slurry systems	Chadwick et al. 2011	-

AGRICULTURE		
Overview	Mitigation measure	**Nutrient use efficiency** (multiple measures)
	Short description	The project is focused on 2 components: compost production and improved biomass and fertilizer management in rice, with the target to achieve compost production and application on 200,000 ha agricultural land at rate of 5 tons/ha per year by 2030. This quantity may be achieved if about 350,000 rural households will produce each about 3tonnes of compost per year. For rice, the practice of reduced biomass application in fields will be practiced on the whole rice area, and mineral fertilizers will be applied at deep placement, which will improve nutrient use from mineral fertilizers and reduce fertilizer quantities by 30% while assuring same or better yield levels.
	Scope of project	The project will provide training, technical support and follow up of the planned expansion of compost making and application, deep fertilizer placement and reduced organic amendment in rice to provide improved nutrients and thus lead to reduced use of mineral fertilizers alone and reduced carbon addition to soil.
	Timing of project	2020-2030
GHG mitigation	Mitigation effect	Increased compost application will increase C-stock in soil, especially where soils have been cultivated without fallow and rotation. Use of crop biomass for compost production will reduce storage period for manure as it will be used for compost making and it will reduce emissions from manure management
	Estimated mitigation in 2030 (MtCO2e/yr)	0.624 MtCO2e (compost component); 0.038 MtCO2e (rice component)
	Total project mitigation (MtCO2e)	3.431MtCO2e (compost component); 0.352 MtCO2e (rice component)
Cost-benefit analysis	Description of costs	Costs include production and seed costs, training, implementation and monitoring of composting units and rice fields. Estimated at around 700 million USD total (compost) and 700 million USD (rice) through 2030.
	Description of benefits	The new composting units will supply nutrients and generate yield with reduced use of mineral fertilizers per unit area. Other benefits include reduced GHG emissions, improved soil physical structure; increased carbon in nutrient depleted soils, and job creation for composting units management (it can be done for CIP consolidated sites and cooperatives); for rice, reduced organic amendment in form of rice bio-mass application in rice fields will reduce methane emissions; there will be reduced N_2O emissions as mineral N-fertilizer use will be reduced to produce the same or better yields using deep fertilizer placement. Total benefits estimated at 780 million USD (rice) and 713 million USD (compost) through 2030.
	NPV of project (Million USD)	-6.27 M USD (compost component); 56.19 M USD (rice component)
	Notes on economic analysis	For compost, the increased production of compost will generate revenues from compost sale, and economic study on improved crop productivity and return from combined use of compost and mineral fertilizers would be conducted as part of project monitoring. The economic benefits of the project are calculated using the avoided costs of mineral fertilizer use (i.e. lesser mineral fertilizer quantities are used to be applied per unit area) for rice.
	Abatement cost (USD/tCO2e)	1.83 USD/tCO_2e (compost component); -159.61 USD/tCO_2e (rice component)

AGRICULTURE		
Overview	Mitigation measure	**Soil and water conservation** (multiple measures)
	Short description	The project targets to achieve 165,000 ha with establishment of new terraces in addition to the existing ones, introduce regular crop rotation on 660,000ha, introduce coffee into banana systems on 25,000ha and expand conservation tillage on 275,000ha by 2030.
	Scope of project	Project will provide training, technical support and follow up of the planned expansion targets of terracing, crop rotation, coffee-banana and conservation tillage options to sustainably improve soil and water conservation, which will result in stable increase of soil C-stock, and thus, improved crop yields.
	Timing of project	2020-2030
GHG mitigation	Mitigation effect	Reduction of N2O emissions from reduced mineral N-fertilizer use per unit area as it will be used in combination with increased compost quantities and increased rotation with leguminous N-fixing crops; increased C-supply in soil; reduced CO2 emissions from bare soil; increased C-fixation in biomass in coffee-banana systems
	Estimated mitigation in 2030 (MtCO2e/yr)	0.45 MtCO2e for terracing; 0.55 MtCO2e for crop rotation; 0.07 MtCO2e for coffee-banana systems and 0.2 MtCO2e for conservation tillage
	Total project mitigation (MtCO2e)	2.48 Mt CO2e for terracing; 3.03 MtCO2e for crop rotation; 0.16 MtCO2e for coffee-banana systems and 1.18 MtCO2e for conservation tillage
Cost-benefit analysis	Description of costs	Costs include terracing, plants, fertilizer, management, training, implementation and monitoring. Total costs estimated at 3.8 billion USD (terracing), 4.5 billion USD (crop rotation); 378 million USD (coffee-banana systems) and 5 billion USD (conservation tillage) through 2030.
	Description of benefits	New terraces will reduce carbon loss from soil with reduced erosion and improved crop yields; terracing preparation will provide employment for rural community; introduction of regular crop rotation will increase N-fixation in soil; increase yields and biomass production; reduce pests and diseases; coffee-banana intercropping will provide economy of space and improve quality of coffee berries, increase soil carbon and carbon sequestration in banana and coffee biomass, reduce bare soil extent and reduce solar insolation with mulching as essential management practice contributing to soil moisture and increased C addition to soil. Tillage will contribute to increased accumulation of carbon stock in soil and slowing down decomposition of soil organic matter. Other benefits include reduced GHG emissions from agricultural soils, improved physical structure of soil. Total benefits estimated at 3.6 billion USD (terracing), 4.5 billion USD (crop rotation); 415 million USD (coffee-banana systems) and 5.2 billion USD (conservation tillage) through 2030.
	NPV of project (Million USD)	-137.71 for terracing; 328.99 for crop rotation; 17.68 for coffee-banana multicropping; and 81.17 for conservation tillage
	Notes on economic analysis	The economic benefits of the project are based on increased crop production after application of the suggested mitigation options.
	Abatement costs(USD/tCO2e)	55.47 USD/tCO2e for terracing; - 108.66 USD/tCO_2e for crop rotation; -111.59 USD/tCO_2e for coffee-banana multicropping and -68.74 USD/tCO_2e for conservation tillage.

AGRICULTURE		
Overview	Mitigation measure	**Improved livestock husbandry**
	Short description	The target for the proposed project to improve livestock husbandry is to expand fodder species (e.g. Calliandra, Leucaena, Medicago and Brachiaria spp. For different agro-ecologies) using terrace edges and roadsides to reach 75,500 ha and use the production of improved fodder to feed 377,5000 cows.
	Scope of project	The project will support establishment of improved fodder species and the follow up of their expansion.
	Timing of project	2020-2030
GHG mitigation	Mitigation effect	Increase of soil carbon through supply of organic matter through root underground biomass, increased aboveground biomass produced per unit area, and reduced soil losses due to erosion.
	Estimated mitigation in 2030 (MtCO2e/yr)	0.133
	Total project mitigation (MtCO2e)	0.626
Cost-benefit analysis	Description of costs	Costs include planting material, establishment and monitoring of Brachiaria fields. Estimated to total 413 million USD through 2030.
	Description of benefits	Fodder plants will increase soil carbon, provide quality nutrition for cows and goats thus resulting in increase in milk production and improved growth. Besides, planted on roadsides and terrace edges they will reduce soil erosion and runoff thus contributing to soil and water conservation. Economic benefits estimated to total 465 million USD through 2030.
	NPV of project (Million USD)	79.46 M USD
	Notes on economic analysis	The economic benefits of the project are calculated using the increased milk production resulting from improved fodder use.
	Abatement cost (USD/tCO2e)	-126.91

AGRICULTURE		
Overview	Mitigation measure	**Improved livestock species and population**
	Short description	The target for the project is to replace 260,000 local cows with 130,000 improved cows (pure and crossbreed) to achieve reduction in enteric fermentation and increase cow productivity per head.
	Scope of project	The project will provide training, technical support and follow up of the planned replacement of local cows within the set target and thus lead to reduced emissions from enteric fermentation.
	Timing of project	2020-2030
GHG mitigation	Mitigation effect	Main mitigation effect will be through reduction of emissions from enteric fermentation from reduced number of cows while maintaining and improving the production of milk
	Estimated mitigation in 2030 (MtCO2e/yr)	0.126
	Total project mitigation (MtCO2e)	1.034
Cost-benefit analysis	Description of costs	Costs include training, cost of improved cows, compensation for local cow replacement and monitoring; estimated to total almost 2 billion USD through 2030.
	Description of benefits	A higher milk production will be achieved with lower population of cows and lower emissions from enteric fermentation; benefits from increased production estimated to total 1.8 billion USD through 2030.
	NPV of project (Million USD)	-140.92M USD
	Notes on economic analysis	The economic benefits of the project are calculated using the sales of milk, meat and manure from improved cows.
	Abatement cost (USD/tCO2e)	136.34

AGRICULTURE		
Overview	Mitigation measure	**Improved manure management**
	Short description	The target for the project is to promote collective cow keeping and kraals with improved manure management facilities (1000 new kraals) achieve improved manure management in existing farms with more frequent manure removal; use of manure covering and straw for manure storage, and promotion of slurry systems.
	Scope of project	Project will provide training, technical support and follow up of the proposed mitigation options; collective farms with improved manure storage facilities.
	Timing of project	2020-2030
GHG mitigation	Mitigation effect	GHG emissions will be reduced with promotion and expansion of covering of manure, using higher straw quantity in stored manure and by covering manure during storage, and promotion of slurry systems.
	Estimated mitigation in 2030 ($MtCO_2e$/yr)	0.058
	Total project mitigation ($MtCO_2e$)	0.379
Cost-benefit analysis	Description of costs	Costs include farm/kraal construction, training, construction of improved manure storage facilities and monitoring; estimated to total 36 million USD through 2030.
	Description of benefits	The proposed improved manure management options will result in generating better quality of manure with higher nutrients, especially for nitrogen. Manure yield in terms of quantities will also be increased as losses will be reduced. Total benefits from increased sales of manure and milk estimated to total 74 million USD through 2030.
	NPV of project (Million USD)	3.96
	Notes on economic analysis	The economic benefits of the project calculated considering the sales of manure and milk from the cows in new kraals with slurry system.
	Abatement cost (USD/tCO_2e)	-10.45

Annex B – Adaptation project evaluations

B-1 ADAPTATION PROJECT EVALUATIONS

Table B-1 Evaluation summary for prioritisation of water sector interventions

			WATER		
			Integrated Water Resource Planning and Management		
			A National Water Security through water conservation practices, wetlands restoration, water storage and efficient water use	Develop water resource models, water quality testing, and improved hydro-related information management	Develop and implement a management plan for all Level 1 catchments
EVALUATION CRITERIA	Environmental effectiveness	Contribution towards NDC target	Significant adaptation potential in terms of human resources and institutional systems	Significant adaptation potential on reliable data from which policy decisions could be based	Significant adaptation potential for critical catchment restoration
		Indirect environmental effects	(+) Increased number of beneficiaries trained in ways to build climate change resilience	Improved seasonal data at catchment level	May include negative impacts such as biodiversity and landscape loss
		Mitigation Co-Benefits	Significant impact through wetland management and restoration	Moderate impact through policy alignment and improvement	Significant impact through forest management and restoration
	Socio-economic impacts and co-benefits	Cost-effectiveness	Moderately costs effective due to conservation benefits	Usually low cost	Moderately cost effective
		Equity and welfare	(+) impacts on equity and welfare due to vulnerable community involvement	No negative impact on equity and walfare	(-) impacts may arise from the population relocation and land compensation
		Competitiveness and productivity	Positive impacts through increased efficiency & water availability	Increased efficiency on business through the integration of climate change in water planning	Reduced costs from water related disasters
		Green growth and employment	Employment and green growth opportunities including vulnerable population	Moderate employment through the use of models and water quality testing	Job creation: implementation of catchment management
	Feasibility of implementation	Alignment with other policy aims	In line with NST 1 and MoE, 2017 Strategic Plan for the ENR	In line with NST 1 and MoE, 2017 Strategic Plan for the ENR	In line with NST 1, SPCR and MoE, 2017 Strategic Plan for the ENR
		Legal and regulatory feasibility	No legal and regulatory issues anticipated	No legal and regulatory issues anticipated	Potential issues arising with existing activities in catchments
		Suitability to funding and climate finance	Highly suitable to funding and climate finance	Highly suitable to funding and climate finance	Highly suitable to funding and climate finance
		Other implementation challenges	Capacity building of local population related to restoration of wetlands	Potential capacity gap in the use of models and info management	May require land compensation

Table B-2 Evaluation summary for prioritisation of agriculture sector interventions

			AGRICULTURE					
			Climate Resilient Value Chain Development					
			Develop climate resilient crops and promote climate resilient livestock	Develop climate resilient postharvest and value addition facilities and technologies	Strengthen crop management practices	Develop sustainable land management practices (soil erosion control; landscape management)	Expand irrigation and improve water management	Expand crop and livestock insurance
EVALUATION CRITERIA	Environmental effectiveness	Contribution towards NDC target	Significant adaptation for resilient to drought	Modest adaptation potential: capacity of food storage facilities	Modest adaptation potential through disease prevention, surveillance and control	Significant adaptation potential to increase food production in target areas	Significant adaptation especially in drought season	Significant adaptation to offset potential losses due to climate change
		Indirect environmental effects	Loss of native species and biodiversity	Improved agro processing facilities	Positive to determine needed actions in crop management on time	Biodiversity and landscape loss, improved production	Over-extraction, lowering groundwater table, increased productivity	Positive impact in the most affected regions as well as for crop and lvestock
		Mitigation Co-Benefits	Uncertain performance for mitigation	Possible increase in energy consumption and GHG emissions	Proper plant management, including nutrition, reduces GHG emissions	Potential increase of carbon sink surface area	Small effect on crop resilience and carbon sink	Restoration of degraded lands, i.e. Carbon sink
	Socio-economic impacts and co-benefits	Cost-effectiveness	Positive performance due to increased productivity	Cost effective due to the benefits of post harvest and value addition	Positive performance due to increased productivity	Cost-effective due to avoided costs of fertilizers and pollution control (co-benefits)	Moderate positive performance due to increased productivity	Cost-effective due to avoided losses or unpaid farmers debt
		Equity and welfare	Possible changes to prices and distributional of seeds and livestock	Positive changes in equity and welfare due to minimized existing post harvest losses	Positive changes such as farmer education, communications and crop resistance	Positive changes within the affected group from the increased crop yield	Possible increase of market prices due to the cost of water	Reduced poverty and access to new agricultural technologies by farmers
		Competitiveness and productivity	Positive on economy through the promotion of early yielding, drought tolerant, shorter cycle, etc.	Reduced market prices and increased quality of agriculture products	Productivity benefits through reduced plant infestation	Increased crop production costs and increased production efficiency	(+)Productivity benefits, (-) Increased crop production costs	Adaptation insurance could be unaccessible to the poorest farmers
		Green growth and employment	Medium green job creation through seed multiplication & livestock farming business	Green job creation such as agro processing facilities and crop storage in districts	Green jobs creation including youth and women using GIS in agriculture	Green job creation such as radical and progressive terraces	Green job creation through irrigation and land consolidation	Additional employment and green growth due to expanded insurance
	Feasibility of implementation	Alignment with other policy aims	In line with MINAGRI -2017 Strategic Plan for Agricultural Transformation	In line with GGCRS and NST 1	In line with GGCRS and NST 1	In line with GGCRS and NST 1	In line with GGCRS and NST 1	In line with GGCRS and NST 1
		Legal and regulatory feasibility	No legal and regulatory issues anticipated	No legal and regulatory issues anticipated	No legal and regulatory issues anticipated	No legal and regulatory issues anticipated	Possible need of transboundary cooperation to reduce water conflicts	Regulation need to be well established to avoid issues such as insurance on the used fake seeds
		Suitability to funding and climate finance	Highly suitable to funding and climate finance	Possible local funding, such as public sector lending	Highly suitable to funding and climate finance	Highly suitable to funding and climate finance	Moderately suitable to funding and climate finance	Highly suitable to funding and climate finance
		Other implementation challenges	Long term research is required to find sustainable solutions & minimise impacts	Gap in local skills for best applicable technologies in post harvest	Moderate issues related to capacity building in GIS technique	May require massive inputs of labor and strong protection (e.g. To avoid terrace destruction)	Current small surface of consolidated land	Farmers awareness to understand what such an insurance program is trying to achieve

Table B-3 Evaluation summary for prioritisation of land use and forestry sector interventions

			LAND AND FORESTRY					
			Sustainable management of forestry and Agroforestry		Wood Supply Chain	Climate-sensitive Integrated Land Use Planning		
			Development of Agroforestry and Sustainable Agriculture (control soil erosion and improved soil fertility)	Promote afforestation / reforestation of designated areas	Improve Forest Management for degraded forest resources	Integrated approach to planning and monitoring for sustainable land use management	Harmonised and integrated spacial data management system for sustainable land use management	Inclusive land administration that regulate and provide guidance for land tenure security
EVALUATION CRITERIA	Environmental effectiveness	Contribution towards NDC target	Significant adaptation and enhancing ecosystem resilience	Significant adaptation and enhancing ecosystem resilience	Significant adaptation and enhancing ecosystem resilience	Significant adaptation due to the small size of the country and demographic pressure	Significant adaptation due to the small size of the country and demographic pressure	Significant adaptation for sustainable management of lands
		Indirect environmental effects	Reduction in soil losses and increased carbon sequestration and pollination services	To sustain ecosystem but can also alter carbon cycles, forest water, energy, and thus, ecosystem services	Cleaner water and air, rich wildlife habitat, and increased recreational opportunities	Poor planing may include biodiversity and landscape loss	Dissemination of information: increased monitoring capacity	Increased climate change adaptation through environmental protection
		Mitigation Co-Benefits	Carbon sink: contribute to mitigating global warming	Carbon sink: contribute to mitigating global warming	Carbon sink: contribute to mitigating global warming	GHG mitigation in planning, development and management of land resources	GHG mitigation in planning, development and management of land resources	Reduced GHG emissions related to poor land use decisions
	Socio-economic impacts and co-benefits	Cost-effectiveness	Cost effective due to the reduced soil losses, ecosystem services and large community involvement	Moderate cost effective due to the reduced soil losses and ecosystem services	Cost effective due to the reduced soil losses and ecosystem services	Cost effective due to the planning that control land use changes	Cost effective due to data accessibility and information to adaptation to climate change	Highly cost effective due to reduced environmental losses (i.e. Soil loss & erosion)
		Equity and welfare	Increased participation in association activities and improved household welfare	Increased participation in association activities and improved household welfare	Positive impacts on community-managed forest, for instance on firewood	No negative impact on equity and walfare	No negative impact on equity and walfare	No negative impact on equity and walfare
		Competitiveness and productivity	(+) Productivity benefits	(+) Wood productivity benefits, (-) reduced arable land	(+) Improved forest benefits and other ecosystem services	(+) Improved economy through optimal choices on the future uses of land	(+) Improved economy through geospatial data collection and adaptation measures formulation	Increased competition due to land ownership of individuals or groups
		Green growth and employment	Green jobs: Agroforestry plantation and management of forest ecosystem services	Green jobs: Forestation and management of forest ecosystem services	Green jobs: Management of forest ecosystem services	Green jobs and other employments: e.g. infrastructural development	May have a strong impact on green jobs and other employments creation	Increased green jobs due to secured access to land
	Feasibility of implementation	Alignment with other policy aims	In line with GGCRS and the 2018 Rwanda national forest policy	In line with GGCRS and the 2018 Rwanda national forest policy	In line with GGCRS and the 2018 Rwanda national forest policy	In line with GGCRS and NST 1	In line with GGCRS and NST 1	In line with GGCRS and NST 1
		Legal and regulatory feasibility	Land owners issues on agroforestry plantation can be anticipated	No legal and regulatory issues anticipated	No legal and regulatory issues anticipated	No legal and regulatory issues anticipated	No legal and regulatory issues anticipated	Except land compensation, no legal and regulatory issues anticipated
		Suitability to funding and climate finance	Moderately suitable to funding and climate finance	Highly suitable to funding and climate finance	Highly suitable to funding and climate finance	Highly suitable to funding and climate finance	Moderately suitable to funding and climate finance	Moderately suitable to funding and climate finance
		Other implementation challenges	Capacity building of farmers, land ownership challenges to decide on what to plant	Increased urbanisation and population pressure	Increased urbanisation and population pressure	Implementation of sustainable land use practices: require capacity building	Skill development in spacial data management and the accuracy of the system	Pressure on land due to increasing population and climate change

Table B-4 Evaluation summary for prioritisation of human settlements interventions

EVALUATION CRITERIA			HUMAN SETTLEMENTS	
			Urban Land Use	Storm water and drainage
			High density buildings and informal settlement upgrading	Storm water management
	Environmental effectiveness	Contribution towards NDC target	Significant adaptation for sustainable management of lands and to moderate potential damages	Significant adaptation to moderate potential flood damages and for water conservation
		Indirect environmental effects	Minimise risks from climate change impacts in informal settlement	Improve groundwater recharge but poor planing may disturb the natural water cycle
		Mitigation Co-Benefits	Reduced materials in buildings and energy consumption	Strenghten hydropower plants: Energy production
	Socio-economic impacts and co-benefits	Cost-effectiveness	Highly cost effective due to reduced loss of properties and improved quality of life	Highly cost effective: infrastructure protection, flood management
		Equity and welfare	Increased costs or relocation, lost of social network for low income households	Reduced storm water impacts from the affected groups
		Competitiveness and productivity	(+) Competitiveness due to the increased quality of life and value of properties	Reduced maintenance cost for public and private infrastructures
		Green growth and employment	Green buildings construction and related additional implyment	Employment through maintenance and upgrading of road and drainage infrastructures
	Feasibility of implementation	Alignment with other policy aims	In line with GGCRS and NST 1	In line with GGCRS and NST 1
		Legal and regulatory feasibility	Except land compensation, no legal and regulatory issues anticipated	Except land compensation, no legal and regulatory issues anticipated
		Suitability to funding and climate finance	Moderately suitable for funding and climate finance	Highly suitable for funding and climate finance
		Other implementation challenges	Access to finance and funding are the key challenges	Access to finance and funding are the key challenges

Table B-5 Evaluation summary for prioritisation of health, transport and mining interventions

EVALUATION CRITERIA			HEALTH	TRANSPORT	MINING
			Vector-based diseases	Climate-resilient roads and bridges	Climate compatible mining
			Strengthen preventive measures and create capacity to adapt to disease outbreaks	Improved transport infrastructure and services	Climate compatible mining
	Environmental effectiveness	Contribution towards NDC target	Significant adaptation for the expected increase proliferation of the diseases	Significant based on Rwanda's hilly topography and to support the economy	Moderate impact through erosion control, water use efficiency, finance, etc.
		Indirect environmental effects	Disease vector control with insecticides may harm the ecosystem and diversity disruption	Biodiversity and landscape loss during construction, improved infrastructures	Environmental benefits from cleaner production measures
		Mitigation Co-Benefits	No direct mitigation, but there is a reduction of migration of vector born diseases	Reduction of GHG emissions through mass common transport	Reduction of GHG emissions through cleaner production
	Socio-economic impacts and co-benefits	Cost-effectiveness	Cost effective, considering vectors proliferation and the current Malaria incidence in Rwanda	Highly cost effective, mainly in districts prone to flooding and landslides	Highly cost effective due to reduced loss of row materials
		Equity and welfare	Reduced mortality rate, mainly in the vulnerable population	Reduced cost and time of transport and increased welfare: access to markets	Increased investment cost for artisanal and small scale miners
		Competitiveness and productivity	Positive impacts, e.g. increased Life expectancy, efficiency and well-being	(+) Reduced maintenance cost and market easier access to local amenities	Increased efficiency in mining production
		Green growth and employment	Additional imployment from the well-being and the reduced mortality	Green jobs from transport services and additional construction and maintanance employment	Green jobs through cleaner production, infrastructure development, etc.
	Feasibility of implementation	Alignment with other policy aims	In line with health sector policy, GGCRS and NST 1	In line with transport sector policy, GGCRS and NST 1	In line with GGCRS program of actions, Rwanda Mining Policy and NST 1
		Legal and regulatory feasibility	Some disease vector control measures may be governed by law	No legal and regulatory issues anticipated	No legal and regulatory issues anticipated
		Suitability to funding and climate finance	Highly suitable for funding and climate finance	Highly suitable for funding and climate finance	Suitable for private sector funding
		Other implementation challenges	Capacity builiding on measures for vector diseases control	Access to finance and funding are the key challenges	Rehabilitation of abondoned mining as a risk to achieve the target

Table B-6 Evaluation summary for prioritisation of cross-sectoral interventions

EVALUATION CRITERIA			CROSS-SECTORAL			
			DRR program		Capacity development	Resource mobilization
			Disaster risk monitoring	Establish an integrated early warning system and disaster response plans	Institutional capacity building and development for cross-sector NDC implementation	Access to finance
EVALUATION CRITERIA	Environmental effectiveness	Contribution towards NDC target	Significant adaptation to monitor and moderate extreme weather events	Significant adaptation to monitor and moderate extreme weather events	Significant to integrate adaptation priorities in national planning	Very significant to reduce and adapt to impacts of climate change
		Indirect environmental effects	Positive impact through controlling the frequency and intensity of hazards	Loop holes in the plans may increase the severity of the disaster	Positive impact to help sector´s implement their specific NDC activities	Positive impact in the most affected regions and for the high priority actions
		Mitigation Co-Benefits	Indirect GHG reduction through protection of forests, land, hydropowers, etc.	Indirect GHG reduction through protection of forests, land, hydropowers, etc.	Co-benefits in adaptation activities that contribute to reducing GHG emissions	Co-benefits in financed activities that contribute to reducing GHG emissions
	Socio-economic impacts and co-benefits	Cost-effectiveness	Cost effective: the targets include disaster resilence strategy and detailed national risk atlas	Cost effective trough preventing or reducing further damages	Cost effective to meet immediate and long-term planned activities	Cost effective activity enabling all other NDC activities
		Equity and welfare	No negative impact on equity and walfare	Positive changes on welfare of vulnerable population	Enabling activity that induce positive impact on equity and walfare	Enabling activity that induce positive impact on equity and walfare
		Competitiveness and productivity	Increased efficiency on business through reduced damages from hazards	Increased efficiency on business through reduced damages from hazards	Increased competitiveness from the developed capacity	Increased efficiency on business through CC resilience and adaptation
		Green growth and employment	May have a moderate impact on green jobs and risk monitoring employments	Potential green jobs creation in disaster response Planning/ actions	Green jobs creation through NDC projects	Green jobs creation through funded NDC projects
	Feasibility of implementation	Alignment with other policy aims	In line with GGCRS, national vulnerability risk assessment and NST 1	In line with GGCRS, national vulnerability risk assessment and NST 1	In line with GGCRS and NST 1	In line with GGCRS and NST 1
		Legal and regulatory feasibility	No legal and regulatory issues anticipated	Legal and regulatory frameworks are necessary to foster the early warning system	No legal and regulatory issues anticipated	No legal and regulatory issues anticipated
		Suitability to funding and climate finance	Highly suitable for funding and climate finance	Moderately suitable for funding and climate finance	Highly suitable for funding and climate finance	Adaptation finance are still low compared to those funds for mitigation support
		Other implementation challenges	Skill development in disaster risk monitoring at national level	Access to finance and funding are the key challenges	To identify priority capacity building and skills needed for NDC implementation	Lack of finance to cover the costs of adaptation

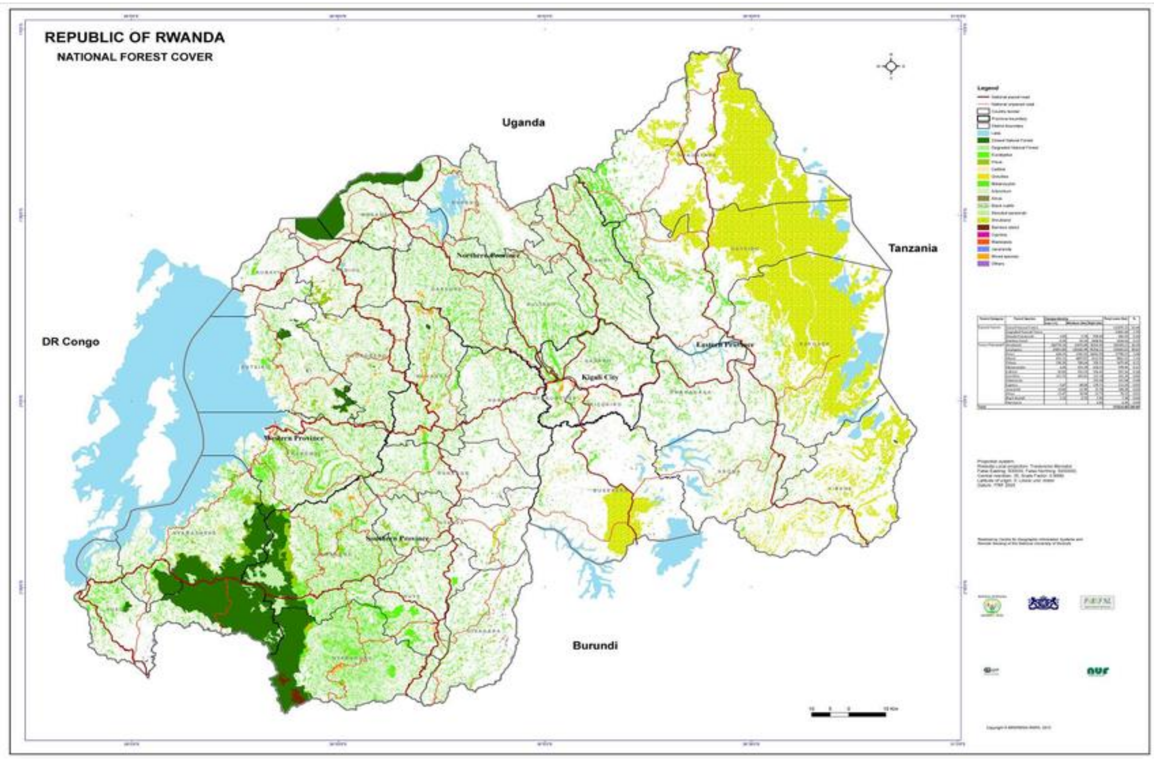
Annex C - Forestry

C-1 MITIGATION POTENTIAL IN FORESTRY

C-1.1 Overview

Forests play a critical role in Rwanda's climate change policy, with a total estimated sequestration potential of 11,359 Gg CO_2e as of 2015 (GoR, 2018a). According to a recent forest cover mapping exercise undertaken in 2018/2019, forests cover over 30.5% of the total national land area, occurring mainly in the southwest and northwest of the country along the Congo-Nil Crest (Figure C-1). The woodland ecosystems in Rwanda comprise of natural highland forests, forest plantations, wooded savanna, and shrub land and bamboo - covering a total of 724,660 Ha (Table C-1).

Figure C-1 Areas dominated by woodland forest ecosystems in Rwanda



Source: Nduwamungu et al., 2013

The area of natural forests has declined since 1990, largely as a result of increased demand for agricultural land and fuel wood plantations. The government has protected the remaining areas of intact natural forest and has led efforts to increase their size through a number of afforestation activities. The current National Forest Policy aims to promote conservation of natural forests, sustainable forest management and appropriate regulatory instruments for efficient biomass supply, enhanced ecosystem services, adoption of agroforestry, and more active involvement of private sector in forest investment (MINILAF, 2018).

Table C-1 Forest area in Rwanda, 2018

Land cover	Area, Ha	Share, %
Natural highland forest	138,910	19.2%
Forest plantation	387,393	53.5%
Wooded savanna	153,785	21.2%
Shrubland	42,313	5.8%
Degraded shrubland	1,647	0.2%
Bamboo	616	0.1%
Total land area	**724,660**	**100%**

Source: Rwanda forest cover mapping 2018/2019, unpublished

The national forest plantations consist mostly of *Eucalyptus* and *Pinus spp*. Planted forests supply almost all fuelwood, with charcoal accounting for about 15.2 % of households' primary energy sources (GoR, 2018a). Bamboo occurs naturally as a lower belt of natural highland forest and has also been planted recently along river belts to protect them from intensive erosion within the hilly landscape. Shrubland and wooded savanna occur within the drier eastern parts of the country, in the region of the Akagera National Park. Rwanda is actively promoting agro-forestry on agricultural land to provide wood for fuel during the transition to more widely available and affordable electricity supply (GoR, 2018a).

Due to increased use of forest resources, standing forest biomass declined from 20,865,594 m^3 in 2007 (ISAR Forest Inventory, 2007) to 7,080,069 m^3 in 2014 (National Forest Inventory, 2015). However, more recently there have been positive changes in afforested areas with increased afforestation over deforestation recorded between 2009 and 2019 (Table C-2).

Table C-2 Deforestation and afforestation area in Rwanda, 2009-2019

Item	Area, Ha
Deforested area	102,106
New planted forest	153,251
No change	571,411
Balance (net afforestation)	51,145

Source: Rwanda forest cover mapping 2018/2019, unpublished.

C-1.2 Mitigation options

Rwanda's climate change mitigation options for forestry can be classified into measures that either:

- Expand forest vegetation and carbon pools in wood products;
- Maintain the existing stands of trees; or
- Substitute fossil fuels and fossil fuel intensive materials with wood derived from renewable sources, e.g., plantations.

Based on the Third National Communication (GoR, 2018a), the following mitigation options have been identified and assessed:

1. Development of agro-forestry for sustainable agriculture
2. Promotion of afforestation and reforestation
3. Rehabilitation and improved forest management of degraded forest resources
4. Efficient wood conversion; and
5. Sustainable biomass energy

Brief descriptions of these options are as follows:

Development of agro-forestry for sustainable agriculture: Agro-forestry technologies would be mainstreamed within national agriculture intensification programmes through increasing tree numbers per hectare on farms and promotion of multipurpose tree species (wood-fodder-stalks-fruits). Both indigenous and exotic tree species would be cultivated in nurseries and distributed to farmers in different agro-ecological zones.

Promotion of afforestation and reforestation would be undertaken in designated areas using improved germplasm and good practices in planting and post-planting (maintenance/tending activities). The focus would be in using quality germplasm, planting trees at optimal times (rainy season) and improving post-planting care and replanting. The priority areas would be steep slopes, roads and settlements. Mixed species planting and seedling availability for indigenous species would be promoted, targeting the increase of mitigation benefits (higher carbon sequestration in multi-species tree communities), biodiversity and ecosystem resilience. More indigenous species planting materials would be produced, disseminated and planted to reduce the current dominance of Eucalyptus. Afforestation and reforestation will increase carbon stock through growth of new forests.

Rehabilitation and improved forest management of degraded forest resources: To increase the existing low productivity of the degraded forest plantations, improved forest management would be applied to increase forest productivity without converting additional land, while public-private partnerships would be promoted. Forest rehabilitation will lead to increased carbon stock through better productivity of the forests.

Efficient wood conversion and sustainable biomass energy: Poor wood conversion efficiency implies that more trees are cut to meet wood demand. Reducing waste of biomass through development of more efficient charcoal value chain and use of improved kilns for charcoal making would be promoted as demand for charcoal increases with urban growth, and charcoal is replacing firewood for use by the urban poor. Use of improved kilns would lead to more efficient use of wood for charcoal production and thus reduce firewood usage (tree use) whilst producing the same quantity of charcoal.

Sustainable forest and landscape management: To reduce soil losses and increase soil protection, bamboo and indigenous tree species would be promoted and planted along river belts and wetland borders. Seedlings would be multiplied and planted in designated areas with conservation status (free wood harvest strictly regulated – prohibited for indigenous tree species and limited to minimal annual thinning for bamboo). Planting trees along rivers and wetlands would sequester significant carbon amounts in growing tree biomass.

A techno-economic assessment is made of each of these measures in order to estimate their emissions reduction potential and cost of abatement. The assessment is undertaken based on the same methodology described in the main body of the report. Project summaries, along with technical and economic assumptions used to assess each of projects are provided below.

C-1.2.1 Agroforestry

Table C-3 Agroforestry - project description

Project title		Agroforestry for wood, fruits and fodder
Overview	Short description	The target for the project is to plant additional 25 trees/ha on 600,000ha of agriculture land; expand new fruit area to 100,000ha; increase agroforestry with fodder species on 50,000ha and with these options to achieve increase of trees on agricultural land from 25 (current number from baseline) to 50.
	Scope of project	Project includes training, seedlings production, planting, and follow up.
	Timing of project	Implementation period is 2020-2030 (11 years)
GHG mitigation	Mitigation effect	The project will lead to GHG mitigation offset through accumulation of carbon in tree biomass and soil due to reduced erosion, accumulation of organic matter from litter and tree roots
	Estimated mitigation in 2030	0.477 MtCO2e/yr for Agroforestry for wood component; 0.495 Mt CO2e/yr for Agroforestry for fruit component and 0.133 MtCO2e/yr for Agroforestry for fodder component
	Total project mitigation to 2030	1.920 MtCO2e for wood component; 2,846 MtCO2e for fruit component; 0.906 MtCO2e/yr for Agroforestry for fodder component.
Cost-benefit analysis	Description of costs	Costs include training, seedling production, planting and follow up.
	Description of benefits	Agroforestry trees will increase carbon stock in soil, provide nutrients via nitrogen fixation, improve soil quality, increase agriculture production, reduce erosion, provide fuelwood, stalks for climbing beans and fodder, produce high market value fruits and nuts.
	NPV of project	- 5.753 M USD for wood component; 120.366 for M USD for fruit component and -4.657 M USD for fodder component.
	Key challenges	Requires substantial investment to achieve the proposed targets.
	Abatement cost	2.996 USD/tCO2e for wood component; -42.292 USD/tCO2e for fruit component and 5.141 USD/tCO2e for fodder component

Table C-4 Agroforestry assumptions

Assumption	Value	Source	Notes
Mean annual increment (Eucalyptus, Pinus)	20-40 t/ha per year	IPCC, 2006	12 t/ha at 100% tree density
Accumulation of C in agroforestry systems	0.141-0.256 tons C /ha per year	Murthy et al., 2013,	Soil C increase estimated as 0.14 tons C/ha /year
Target to increase agroforestry tree density	Increase from 25 to 50 trees/ha	Rwanda Forest Sector Strategic policy 2018-2024.	-
C stock accumulation		Lal et al., 2004	From year 4 to year 8, C stock is assumed to increase at 0.18t/ha per year (half of the further years). Adapted from Lal et al. 2004 (decreased conservatively).
Mean annual increment (MAI) for guava	92kg of C/guava tree	Gupta and Sharma, 2014	Assumed for 20years old tree; total C = 92kg x277trees/ha divide by 20yrs=1.3tons/yr (MAI guava). Tree density (6x6 m spacing) = 277 trees/ha; MAI estimated =1.3tons/ha/yr starting from year 4.
MAI for Papaya	38kg of C/papaya tree (Gupta and Sharma, 2014)	Gupta and Sharma, 2014	Assumed for 20years old tree; total C = 38kg x 833trees/ha divide by 20yrs=1.6 tons/yr (MAI papaya); tree density (3x4m spacing)=833trees/ha; MAI estimated=1.6tons/ha/yr starting from year 3.
MAI for Macadamia	MAI -1m^3 /yr for yr 6-12; 1.7-2m^3 /yr for yr 13-25	Murphy et al., 2012	Tree density 8 x 8 m = 156 trees/ha
MAI Avocado	126kg C/tree	Eneji et al.,2014	Assumed for 20years old tree; total C = 126 x 156 trees/ha=1ton/yr tree density (8x8m spacing=156 trees/ha, MAI estimated 1tons/ha/yr starting from year 4.
Seedling cost	1000fr for papaya and guava; 2000fr for avocado; 4000fr for Macadamia	NAEB and RAB consultation	-
Leycaena leycocephala fresh biomass	MAI = 2.59-13.16 t/ha	Kumar et al., 1998	Median value of 7.9 t/ha applied for MAI of Leucaena spp.

C-1.2.2 Afforestation

Table C-5 Afforestation - project description

Project title		Afforestation (protective new forests on slopes, and urban forests)
Overview	Short description	The project will focus on production and planting of trees in areas identified for protection as degraded lands, steep slopes, and prone to flooding (a total of 42,440 ha) in rural areas with Eucalyptus, Pinus and Alnus spp.; and 2,100 ha to be planted as urban forests with indigenous tree and bamboo spp. For urban forests, the strategy will be using multiple species mix as an option of higher ecological productivity.
	Scope of project	Tree seedlings production, dissemination, planting and follow up with survival data.
	Timing of project	7 years for seedling production and planting, then maintenance and follow until the end of the project (2030).
GHG mitigation	Mitigation effect	A significant carbon sink will be produced, and this will offset GHG emissions through increasing carbon storage in tree biomass and soil.
	Estimated mitigation in 2030	0.348 MtCO2e/yr for protective forests and 0.004 MtCO2e/yr for urban forests
	Total project mitigation to 2030	1.045 MtCO2e for protective forests; 0.015 MtCO2e for urban forests by 2030
Cost-benefit analysis	Description of costs	Costs include training, site preparation, seedling production and tree planting.
	Description of benefits	The newly planted forests will generate sinks, protect soil from erosion or floods and landslides, and produce wood and firewood.
	NPV of project	Protective forests: -13,810 M USD for 2020-2030 period Urban forests: - 1.029 M USD for 2020-2030 period
	Notes on economic analysis	The main economic benefit from newly planted forests will come after 2030 for greater part of the emission reduction, wood harvest, and firewood source. The main economic benefits from newly planted urban forests will be health benefits for urban citizens, as these forests will not produce firewood and will only serve recreational and conservation purposes.
	Abatement cost	Protective forests: 13.22 USD/tCO2e; Urban forests: 70.63 USD/tCO2e

Table C-6 Afforestation - assumptions

Assumption	Value	Source	Notes
Protective forests on very steep and steep slopes	10745+31695=42440 ha	Rwanda Restoration Opportunities assessment, 2014	This will be planted with Pinus spp. (21220ha) And Eucalyptus spp. (21220ha)
Increase in soil C-stock due to afforestation	0.8-1 Mg/ha/year	Johnson et al., 1996 in Lal et al., 2004	Increase of C-stock in soil due to afforestation estimated at 0.8 Mg C per ha per year, starting on 5th year from tree planting.
Min annual increment for native species	0.9-2 m^3 /ha/year		MAI for the native species estimated as 1.2m^3 per ha per year, starting from year 7 to be conservative.
Mean annual increment for Eucalyptus and Pinus on degraded soil	10m^3 /ha per year. Pinus data are 40 m^3 /ha per year in productive forests, no data for degraded forests	IPCC, 2006	MAI for Pinus, Alnus and Eucalyptus for degraded lands estimated as 7 (Pinus) and 7 (Alnus) and 5.5 (Eucalyptus) m^3 per ha per year and , starting from year 7
Cost of establishment of new forest plantation	450 USD / ha	RWFA Forestry department consultation	
Harvest of firewood in new forests	at 8 years :40 tons/ha; at 18 years = 150 tons/ha		Revised downwards from RWFA consultation of 60 and 200 t/ha at 8th and 18th years for the reason of degraded lands and steep slopes topography.

C-1.2.3 Rehabilitation and improved forest management

Table C-7 Rehabilitation and improved forest management - project description

	Project title	Rehabilitation and improved forest management
Overview	Short description	The project aims to promote and perform improved forest management in the existing forest plantations (a total of 273,779 ha)
	Scope of project	Perform improved forest management on a total of 273,779 ha of Pinus and Eucalyptus forests for better productivity
	Timing of project	20 years
GHG mitigation	Mitigation effect	Mitigation effect will be through increase in carbon sink in tree biomass after application of improved forest management to offset GHG emissions.
	Estimated mitigation in 2030	-1.039 Mt CO2e/yr (net increase over 2020-2030 period due to harvesting in early years)
	Total project mitigation to 2030	-2.29 Mt CO2e (net increase over 2020-2030 period due to harvesting in early years)
Cost-benefit analysis	Description of costs	Costs are estimated in USD and include application of improved forest management, training and follow up cost.
	Description of benefits	The Project will result in better tree growth, thus increase in sinks, fuelwood and wood products, reduce soil erosion and have positive effect on climate resilience.
	NPV of project	-209.8 M USD
	Notes on economic analysis	The economic impact will be in achieving more sustainable yields in existing forests; contribute to agro system resilience to climate change.
	Abatement cost	-91.81 USD/tCO2e

Table C-8 Rehabilitation and improved forest management - assumptions

Assumption	Value	Source	Notes
Area identified for restoration	Eucalyptus forests: 255,930 ha; Pinus forests: 17,849 ha	Rwanda Restoration Opportunities assessment, 2014	The project targeted the full area of 273,779 ha
Cost of existing forest rehabilitation and management	1,100 USD/ha	RWFA consultation	Assumes 1,100 USD/ha as forest rehabilitation cost
Harvesting periods: Thinning	7 years for Pinus and 8 years for Eucalyptus		Assumes 7 years for Pinus and 8 years for Eucalyptus from planting to thinning
Harvest at thinning (yr 7 for Pinus; yr 8 for Eucalyptus)	60 - 70 m^3 /ha		Assumes 60m^3 for thinning
Harvest at clear-cut (year 18)	200 m^3 /ha		Assumes 180 m^3 /ha for clear-cut
Mean annual increment of forest plantations in Rwanda	9m^3 /ha per year		Improved management will increase MAI up to 14 m^3 /ha per year (+5m^3 /ha per year).
Price of wood at thinning (firewood)	1m^3 = 5,000 Frw		-
Price of sawn timber: Pinus	1m^3 = 190,000 Frw		-
Price of sawn timber: Eucalyptus	1m^3 = 102,000 Frw		-

C-1.2.4 Efficient wood conversion and sustainable biomass management

Table C-9 Efficient wood conversion - project description

	Project title	Efficient wood conversion and sustainable biomass energy
Overview	Short description	The project aims to expand the use of improved kilns for higher charcoal production.
	Scope of project	Improved charcoal production
	Timing of project	11 years
GHG mitigation	Mitigation effect	Mitigation effect will be through decreased use of wood to produce required quantity of charcoal.
	Estimated mitigation in 2030	0.908 MtCO2e/yr
	Total project mitigation to 2030	4.374 MtCO2
Cost-benefit analysis	Description of costs	Costs are estimated in USD and include trainings and monitoring on kiln use (certification).
	Description of benefits	The Project will provide wood economy for wood used for charcoal production.
	NPV of project	32.22 Million USD
	Notes on economic analysis	The economic impact will be achieved progressively with the expansion of improved kilns use.
	Abatement cost	-35.47 USD/tCO2e

Table C-10 Efficient wood conversion – assumptions

Assumption	Value	Source	Notes
Charcoal demand	120,000 tonnes of charcoal from 850,000tons of wood, 14% efficiency	World Bank, 2012a.	120,000 tonnes per year was demand in Kigali (World Bank, 2012a); Thus with 5% increase in production of charcoal, in 2020 the demand is estimated at 177,295 tonnes
Current wood supply	2,474,000 m³	Unpublished unofficial data from new forest map study, 2019	-
Link between economic development of a country with increased use of charcoal over firewood	5% annual increase in charcoal use estimated	Girard, P., 2002	-
Efficiency of improved kilns	1 tonne of wood will produce additional 75kg of charcoal with improved kilns	Girard, P., 2002	-
Charcoal price	100kg = 12,000frw	RWFA consultation	-

C-1.2.5 Sustainable forest and landscape management

Table C-11 Sustainable forest and landscape management - project description

Project title		Sustainable forest and landscape management
Overview	Short description	The project will focus on production and planting of trees (indigenous and bamboo species) in areas identified as wetland perimeters and riparian buffer forests zones (a total of 80,100 ha).
	Scope of project	Tree planting
	Timing of project	5 years for seedling production and planting, then maintenance and follow up until the end of the project (2030).
GHG mitigation	Mitigation effect	Production of sinks that will offset CO2 emissions in tree biomass and soil.
	Estimated mitigation in 2030	0.596 MtCO2e/yr
	Total project mitigation to 2030	2.349 MtCO2e
Cost-benefit analysis	Description of costs	Costs include seedling production and planting, site preparation and training.
	Description of benefits	The newly planted forests will generate sinks, protect soil from erosion or floods, some of land slides, produce wood and firewood.
	NPV of project	-31.35 USD million
	Notes on economic analysis	The main economic benefit from newly planted forests will come after 2030 for greater part of the emission reduction, wood harvest, and firewood source.
	Abatement cost	13.35 USD/tCO2e

Table C-12 Sustainable forest and landscape management – assumptions

Assumption	Value	Source	Notes
Riparian buffer forests	3152+19586 =22738ha	Rwanda Restoration Opportunities assessment, 2014	This will be planted with native tree species and bamboo.
Wetland perimeters	57362 ha	Rwanda Restoration Opportunities assessment, 2014	This will be planted with native tree species and bamboo.
Tree density	1600 plants/ha	RFRA, Forestry department consultation	Survival rate estimated at 90%, implying that 10% plants will be produced additionally to meet the whole planned area cover.
Increase in soil C-stock due to afforestation	0.8-1 Mg/ha/year	Johnson et al., 1996 in Lal et al., 2004	Increase of C-stock in soil due to afforestation estimated at 0.8 Mg C per ha per year, starting on 5th year from tree planting.
Mean annual increment for native for native species	0.9-2 m^3 /ha/year	IPCC, 2006	MAI for the native species estimated as 1.2m^3 per ha per year, starting from year 7 to be conservative.
Carbon content in trees	0.47	IPCC, 2006	-
Below ground to above ground biomass ratio	0.27 for montane forests	IPCC, 2006	-
Cost of establishing new forest plantation	450 USD / ha	RWFA Forestry department consultation	-
Mean annual increment for bamboo	5m^3	IPCC, 2006	Harvest of firewood in bamboo forests is estimated at 40% of annual increment. Thus, harvest for firewood is estimated at 2m^3 in bamboo forests

C-1.3 Evaluation of options

The options described above have been evaluated based on their emissions mitigation potential and economic viability. The estimated mitigation potential and abatement costs in 2030 are shown in the below table and marginal abatement cost curve (MACC).

Rehabilitation and improved forest management is found to be the most cost-effective option, largely due to the benefits of wood harvesting occurring earlier on, when compared to other projects involving tree planting (e.g. afforestation). However, early wood harvesting removes much of the carbon stocking in the standing tree biomass and the net mitigation balance is calculated to be negative in the first ten years or so.

Fruit tree planting project is found to be the second most cost-effective options and provides significant mitigation with carbon sequestration in tree biomass. Although fruit trees have slower growth than timber plantations, they are not harvested for wood and thus progressively accumulate carbon in standing biomass. Efficient wood conversion using improved kilns is also found to be highly cost-effective, as well as having the highest overall estimated mitigation potential.

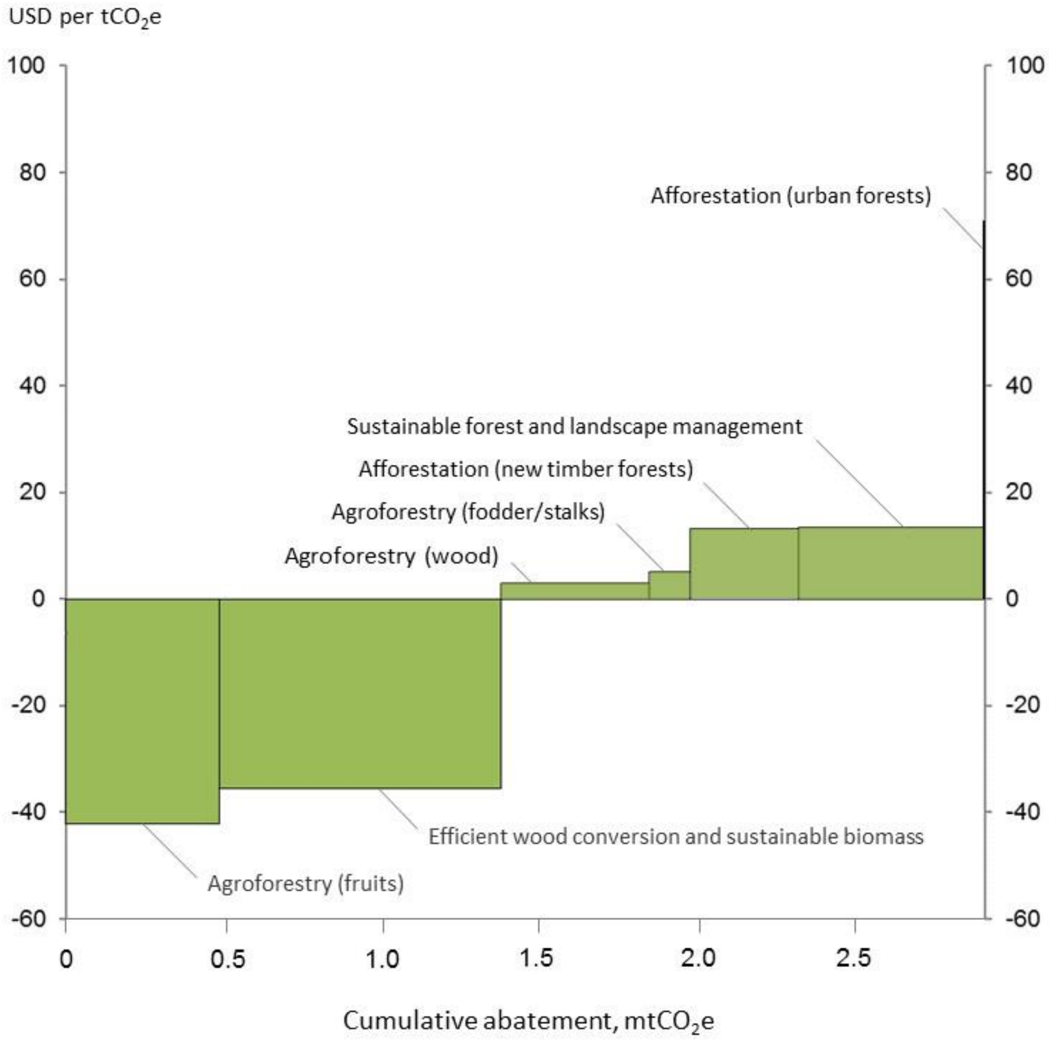
Those projects involving tree planting (i.e. afforestation, sustainable landscape restoration, urban forests) have increased positive cost elements and require investments with their economic harvesting potential being either delayed (afforestation), minimal (landscape restoration), or neither (e.g. urban forests with recreational purpose). However, these projects provide an important basis for long-term mitigation strategies within the forestry sector and should be implemented subject to attracting funding.

Table C-13 Mitigation potential and estimates marginal abatement costs, forestry 2030

Mitigation option	Abatement cost in 2030 ($/tCO2e)	Mitigation in 2030 (MtCO2e)
Rehabilitation and improved forest management	-91.81	*
Agroforestry for fruits	-42.29	0.49
Efficient wood conversion and sustainable biomass management	-35.47	0.91
Agroforestry for wood	3.00	0.48
Agroforestry for fodder/stalks	5.14	0.13
Afforestation (new timber forests)	13.22	0.35
Sustainable forest and landscape management	13.35	0.60
Afforestation in urban forests	70.93	0.004
TOTAL mitigation, 2030	**-**	**2.93**

*Note: Forest rehabilitation is not included due to negative mitigation values through 2030

Figure C-2 Marginal abatement costs of mitigation forestry measures in Rwanda, 2030



Note: Forest rehabilitation is not included due to negative mitigation values through 2030

All of the forestry projects have both a beneficial climate change mitigation and adaptation effect, and each of the proposed mitigation projects can also be implemented as part of national adaptation responses within the NDC. For example, the development of new forests or sustainable management of existing forests and their biomass will lead to increased tree cover, growth and/or productivity and thus improve climate resilience as trees offset solar insolation and create microclimate with cooler and milder environment.