Zimbabwe Long-term Low Greenhouse Gas Emission Development Strategy (2020-2050)

Foreword

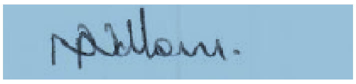
Climate change poses one of the defining challenges of our time and its impacts both nationally and globally are becoming more apparent. In response to the climate challenge, in 1992, countries adopted the United Nations Framework Convention on Climate Change (UNFCCC), as a framework for international cooperation towards achieving stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenetic interference with the climate system. The Kyoto Protocol under the UNFCCC adopted in 1997 mandate developed country parties to undertake economy wide emission reduction actions whilst giving flexibility to developing countries to reduce their emissions on a voluntary basis. The coming to an end of the Kyoto Protocol in 2020 necessitated the need for a new binding agreement to guide future efforts to address climate change, this saw the adoption of the Paris Agreement in 2015. The Paris Agreement calls upon all its Partis to take actions towards reducing greenhouse gas emissions, enhancement of carbon sinks and take action on adaptation within their territories.

Zimbabwe is a Party to the UNFCCC and its subsequent protocols; Kyoto Protocol and Paris Agreement. The Paris Agreement require countries to submit and frequently update their greenhouse gas emission reduction targets through Nationally Determined Contributions (NDCs). Article 4 paragraph 19 of the Paris Agreement also calls upon countries to communicate mid-century low greenhouse gas emissions development strategies to the UNFCCC Secretariat by 2020 to guide countries development pathways in the wake of clime change. The Government of Zimbabwe in response to this call developed the long-term Low greenhouse gas Emission Development Strategy (LEDS) and the attendant Measurement, Reporting and Verification (MRV) Framework for the period 2020-2050. The LEDS will inform subsequent NDC revisions and updates.

This LEDS is in line with Zimbabwe's vision of becoming an upper middle-income economy by 2030. Key strategus that anchor the attainment of this vision include; implementation of renewable energy and energy efficiency initiatives, climate smart agricultural practices, low carbon transport systems, sustainable forest management, solid waste management and sustainable industrial development among others which have been elaborated in this LEDS.

The LEDS was developed through a consultative process that involved the participation of government departments and state-owned enterprises, development agencies, research and academic, private sector, civil society organisations and women and youth organisations. I call upon all stakeholders to embrace the LEDS and maintain the identified climate change mitigation actions that relate to their activities towards a low carbon development pathway.

As I conclude, I would like to acknowledge the technical and final support received from our cooperating partners the United Nations Development Program (UNDP) Russia Trust Fund, UNDP Zimbabwe and GFA Consulting Group who led the development of the LEDS. Last but not least, gratitude goes to all experts and stakeholders who contributed to the developed of this Strategy in support of the Ministry through the Climate change Management Department.



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List of Abbreviations

AC	Air Conditioning
AfDB	African Development Bank
AFOLU	Agriculture Forestry and Other Land-use
AFR	Alternative Fuels and Raw Materials
BAT	Best Available Technology
BAU	Business as Usual
BFS	Blast furnace slag
BF-BOF	Blast furnace to basic oxygen furnace
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BRT	Bus Rapid Transport
BTI	Building Technology Institute
CA	Conservation Agriculture
CAPEX	Capital Expenditure
CCMD	Climate Change Management Department
CCS	Carbon capture and storage
CDM	Clean Development Mechanism
CER	Certified Emission Reductions
CSA	Climate Smart Agriculture
CSI	Cement Sustainability Initiative
CIZ	Commerce, Chamber of Mines, Construction Industry federation of Zimbabwe
CIFOZ	Construction Industry Federation of Zimbabwe
CSP	Concentrated solar power
CIMMYT	International Maize and Wheat Improvement Centre
CZI	Confederation of Zimbabwe Industries
ECA	Export Credit Agency
EMA	Environmental Management Agency
EMS	Environmental Management System
EV	Electric vehicles
FCPF	Forest Carbon Partnership Fund
FeCr	Ferrochromium
GCF	Green Climate Fund
GCI	Green Cooling Initiative
GFEI	Global Fuel Economy Initiative
GHG	Greenhouse Gas
GHGI	Greenhouse Gas Inventory
GoZ	Government of Zimbabwe
GWh	Giga Watt Hour
GWP	Global Warming Potential
ICE	Internal combustion engine
ICRISAT	International Crops Research Institute for the Semi-arid tropics
IDBZ	Infrastructure Development Bank of Zimbabwe
IEA	International Energy Agency

IES	Institute of Environmental Studies
IPPU	Industrial Processes and Product Use
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
KPI	Key Performance Indicators
kVAr	Kilo Volt Ampere Reactive
kWh	Kilo Watt Hour
kW	Kilo Watt
LC	Lifecycle Cost
LFG	Landfill gas flaring
LEDS	Low Emission Development Strategy
LPG	Liquefied Petroleum Gas
LULUCF	Land Use, land Use Change and Forestry
NACAG	Nitric Acid Climate Action Group
NDC	Nationally Determined Contribution
NMT	Non-motorised transport
MAC	Marginal Abatement Cost
MACC	Marginal abatement cost curve
MD	Maximum Demand (
MEPS	Minimum Energy Performance Standard
MICED	Ministry of Industry, Commerce and Enterprise Development
MLAWCRR	Ministry of Lands, Agriculture, Water, Climate and Rural Resettlement
MLGPWNH	Ministry of Local Government, Public Works and National Housing
MIT	Mitigation scenario
MoEPD	Ministry of Energy and Power Development
MRV	Monitoring, Reporting and Verification
MTID;	Ministry of Transport and Infrastructure Development
NCCRS	National Climate Change Response Strategy
NEP	National Environment Policy and Strategies
OPEX	Operational Expenditure
PF	Power factor
PA	Paris Agreement
PBP	Payback-Period
PLR	Prime Lending Rate
PPC	Pretoria Portland Cement
PV	Photovoltaic
RERA	Regional Electricity Regulators Association of Southern Africa
RPC	Reactive Power Compensation
SAZ	Standards Association of Zimbabwe
SDR	Social Discount Rate
SDP	System Development Plan
SE	Standard Error
SIRDC	Scientific Industrial Research and Development Centre
SME	Small to Medium Enterprise
SOC	Soil Organic Carbon
SWDS	Solid Waste Disposal Sites
TD	Transmission and distribution

TNC	Third National Communication
UNDP	United Nation Development Programme
TSP	Transition Stabilisation Programme
UNFCCC	United Nations Framework Convention of Climate Change
WB	World Bank
WBCSD	World Business Council for Sustainable Development
WHR	Waste heat recovery
ZBCA	Zimbabwe Building Contractors Association
ZERA	Zimbabwe Electricity Regulatory Authority
ZEDTC	Zimbabwe Electricity Transmission and Distribution Company
ZimAsset	Zimbabwe Agenda for Sustainable Socio-Economic Transformation
ZIMSTAT	Zimbabwe National Statistics

Executive Summary

Climate change is a defining challenge for humanity. The Government of Zimbabwe (GoZ) is committed to taking urgent action to mitigate and adapt to the effects of Climate Change. As a Party to the United Nations Framework Convention on Climate Change (UNFCCC), the country seeks to contribute to the ambitious global mitigation goals as agreed under the Paris Agreement (PA). Zimbabwe's long-term Low Greenhouse Gas Emission Development Strategy (LEDS) sets the course for reducing emissions, while at the same time ensuring sustainable economic development for the country. It is based on the government's economic planning up to 2050 and covers mitigation measures across the four key sectors of Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and other Land use (AFOLU) and Waste.

Zimbabwe, as a developing country, is projected to experience decades of economic growth with its GDP increasing from 19.6 billion USD in 2020 to 119.1 billion USD by 2050, based on constant prices(a seven-fold increase). Economic development will drive Zimbabwe's business as usual (BAU) emissions of greenhouse gases (GHG), which are projected to increase from 36.6 $MtCO_2e$ in 2020 to 65.3 $MtCO_2e$ in 2050 (a doubling over this period).

Energy. Currently, energy use is the country's largest source of GHG emissions; the sector's emissions are expected to increase to 26.5 $MtCO_2e$ in 2030 and 37.5 $MtCO_2e$ in 2050 with increasing demand for power generation, transport and other uses of fossil fuels. GoZ, private sector and civil society identified 21 mitigation measures including large hydropower projects (Batoka and Devils George) accompanied by other renewable energy measures such as the introduction of solar PV at the commercial and residential scale. Clean generation measures will be complemented by a series of energy efficiency measures reducing electricity demand and the reduction of technical losses in the power system. An important efficiency measure identified is the introduction of fuel economy standards for vehicles, reducing lifecycle costs to consumers as well as emissions and reducing Zimbabwe's dependence on fuel imports. The aggregated set of mitigation measures identified has the potential to reduce the projected BAU emissions from the energy sector from 37.5 to 16.2 $MtCO_2e$ in 2030 (57% reduction).

IPPU. Emissions from these sources represent a relatively small share of Zimbabwe's total national emissions, estimated to total around 0.70 $MtCO_2e$ in 2020. The BAU emissions are based on assuming growth in clinker and cement, fertilizer and ferroalloys production, as well as a return to iron and steel production within the coming decade. BAU emissions are expected to rise to around 1.7 $MtCO_2e$ in 2030 and 2.5 $MtCO_2e$ in 2050. GoZ and stakeholders identified five key mitigation measures, most importantly the reduction of N_2O emissions from fertilizer production and use of alternative fuels in the ferrochromium and iron and steel sectors. Implementing these measures could reduce projected emissions to around 1.4 $MtCO_2e$ by 2050 (44% reduction compared to BAU).

AFOLU. The AFOLU sector is the largest source of GHG emissions after energy use and is estimated to emit 18.8 MtCO_2e by 2020. BAU emissions are projected to peak in around 2034 (at 32.4 MtCO_2e) and fall thereafter to 22.7 MtCO_2e by 2050. Stakeholders identified five mitigation measures to reduce deforestation and emissions from agriculture. Besides stopping net-deforestation by 2030, the most important intervention is increasing the use of conservation agriculture, which increases soil organic carbon as well as revenues from farming and livestock management. Implementation of these measures are estimated to l reduce projected GHG emissions to 14.5 MtCO_2e by 2050 (reduction of 36.2%).

Waste. BAU emission trends in the waste sector are driven by economic development (GDP per capita) and population growth, with GHG emissions expected to increase from 1.18 MtCO_2e in 2020 to 2.62 MtCO_2e by 2050. GoZ and stakeholders have identified two key mitigation measures: capture of landfill gas and increased use of composting, which together have the potential to significantly reduce emissions to just 0.08 MtCO_2e by 2050 (a reduction of over 95% of sector emissions).

Finance& policy amendments. The implementation of all 38 identified mitigation measures is expected to have a significant positive economic impact with a net present value of 7,130 M USD. Their implementation will reduce the costs of power, agricultural and industrial products improving the overall livelihood of Zimbabweans and increasing the country's economic competitiveness. Similarly, the LEDS mitigation actions support SDG achievements beyond the SDG 13 on climate action.

However, at the same time, the successful implementation will depend on the availability of a suitable financing mechanism – total investment needs are estimated at 7,880 M USD, corresponding to 25.4% of the current national GDP. This financing needs to be provided at a low cost of capital for mitigation projects to be viable and bankable.

The successful implementation of the mitigation measures will depend on the availability of a large scale financing facility, providing concessional lending at rates, making the economically viable abatement potential also financially viable. This financing instrument will need to be supported by an enabling framework of new policies and regulations (e.g. fuel economy standards) to incentivise companies and consumers in making purchase decisions minimizing lifecycle costs and GHG emissions.

1 Introduction

The Government of Zimbabwe (GoZ) is committed to taking urgent action to mitigate the causes and adapt to the effects of climate change. As a Party to the United Nations Framework Convention on Climate Change (UNFCCC), the country seeks to contribute to the ambitious goal of limiting temperature rise to 1.5°C above pre-industrial levels as agreed under the Paris Agreement (PA). (UNFCCC, 2015).The GoZ submitted its Intended Nationally Determined Contribution (INDC) to the UNFCCC in 2015 (GoZ, 2015a), and this was approved and advanced to Nationally Determined Contribution (NDC) following the ratification of the PA in 2017.

Zimbabwe's National Climate Policy (GoZ, 2017a) guides the mainstreaming of climate change within national development plans. Action on climate change is supported by several other instruments such as the National Climate Change Response Strategy (NCCRS) (GoZ, 2015b), the National Renewable Energy Policy (GoZ, 2019a) National Bio-fuels Policy (GoZ, 2019b), National Transport Master Plan (2018-2038) (GoZ, 2018a), Forestry Policy (draft), Climate Smart Agriculture (CSA) manual (GoZ-CTCN, 2017) and Climate Smart Agriculture Framework (GoZ, 2018b), as well as the National Environmental Policy and Strategies (GoZ, 2009). The GoZ acknowledges that more work is needed so that all key economic players, including private sector, can participate in climate change mitigation. Zimbabwe's first Nationally Determined Contribution (NDC) is limited to climate change mitigation in the energy sector covering prominently the power and transport sectors, as well as adaptation in agriculture. The NDC targets to reduce energy-related GHG emissions per capita by 33% below the 2030 business as usual (BAU) scenario.

In 2019 GoZ launched the NDC Implementation Framework to guide implementation of the current energy sector focused NDC. Building on these achievements, Zimbabwe Long term Low Greenhouse Gas Emission Development Strategy (LEDS) follows an economy-wide approach. The LEDS covers mitigation in all Intergovernmental Panel on Climate Change (IPCC) sectors (Energy, IPPU, Agriculture, Forestry and Other Land Use (AFOLU), and Waste). The LEDS also provides a framework for developing an economy wide NDC.

Zimbabwe's LEDS does not only address mitigation measures, it places equal emphasis on the country's economic development. Zimbabwe's 2019 Gross Domestic Product (GDP) per capita amounted to USD 2,788 compared, to e.g. USD 6,339 /capita in South Africa or the EU average (USD43,150/capita, all in purchasing power parity). Hence, strengthening the national economy and improving the livelihoods of Zimbabweans is an important priority, as outlined in Vision 2030 (GoZ, 2018c) and Zimbabwe's Transition Stabilisation Programme (TSP) (GoZ, 2018d). The TSP builds on the Zimbabwe Agenda for Sustainable Socio-Economic Transformation (ZimAsset) (2013-2018) (GoZ, 2013).

Against this background, the LEDS explores measures that aim to reduce GHG emissions (or increase carbon sequestration in forests and soils) while contributing to socio-economic development. The LEDS is based on the assessment of 38 sectoral mitigation measures, identified following a comprehensive stakeholder consultation process. These 38 sectoral mitigation measures are, to a large extent, economically viable at a Social Discount Rate (SDR) of 6%. High level modelling of the mitigation measures indicates an aggregated Net Present Value (NPV) of USD7.13 billion. The implementation of these measures will reduce the cost of electricity, reduce costs of agricultural production, reduce fuel consumption and overall provide a significant impulse for economic growth.

While being economically viable, mitigation measures will require an investment volume of USD7.88 billion up to 2030 (corresponding to a third of Zimbabwe's GDP). Both, public and private investments, will be needed to deliver on the climate change mitigation targets. In 2019 the cost of capital was around 15% and hence significantly exceeded the SDR of 6%. The success of Zimbabwe's LEDS will depend, to a large extent, on the availability of a large-scale climate financing facility. This facility should bridge the gap between prevailing lending rates and the SDR enabling private sector investment in economically viable mitigation measures.

2 Methodology

Zimbabwe's LEDS was developed according to the methodology described in the next section.

2.1 Stakeholder Engagement

The Climate Change Management Department (CCMD) in the Ministry of Lands, Agriculture, Water, Climate and Rural Resettlement (MLAWCRR) led the LEDS development with support from the United Nations Development Programme (UNDP). The development of the LEDS employed a participatory approach. The CCMD organised stakeholder consultations during the inception, development and validation phases of the strategy formulation. Stakeholder groups included the responsible ministries (in addition to the Ministry of Energy and Power Development (MoEPD); Ministry of Women Affairs, Community, Small and Medium Enterprise Development (MWACSMED); Ministry of Transport and Infrastructure Development (MTID); Ministry of Local Government, Public Works and National Housing; Ministry of Environment, Tourism and Hospitality Industry; Ministry of Finance and Economic Development (MoFED) and; Ministry of Industry and Commerce. Government departments and agencies that were involved include the Forestry Commission, Environmental Management Agency (EMA), Zimbabwe Energy Regulatory Authority, Rural Electrification Agency, the Infrastructure Development Bank of Zimbabwe (IDBZ) and the Scientific Industrial Research and Development Centre (SIRDC). Local authorities (cities of Harare, Bulawayo and Masvingo), private sector representations and individual companies, as well as various organisations representing civil society (including youth- and women organisations) also participated in the process. The Legal and Transparency, as well as the Mitigation Technical Sub-committees for the implementation of Zimbabwe's NDC provided oversight and guidance of the LEDS development process.

2.2 BAU Modelling

The BAU scenarios developed using GHG data from Zimbabwe's Third National Communication (TNC) to the UNFCCC (GoZ, 2016), and the NDC Implementation Framework (GoZ, 2017b). For each sub-sector, assumptions around future activity growth rates and factors determining change in GHG emissions were applied. In general, population, economic and industrial growth rates were based on the Zimbabwe National Statistics Agency(ZimStat) forecasting model, which represents an outlook for economic growth based on strong recovery:

- The GDP forecast bases on a forecasting approach, which assumes that the country overcomes its current financial crisis and recovers through a series of years with strong economic development. The GDP forecast model bases on population growth, consumer price index and employment data. Annex X provides the GDP forecasts.

- For some sectors, where GoZ conducts detailed planning processes (i.e. development of the electricity demand), the LEDS considers such sector specific planning.

- Population forecasts were based on the medium case growth scenario from ZimStat;
- Detailed approaches to BAU modelling are described within each of the sector-specific chapters and in relevant Annexes of this document.

2.3 Key Assumptions

For modelling the costs and benefits of diesel and gasoline related activities, the obtaining fuel price as provided by ZimStat and a global price forecast model were used. The global price forecast model assumes a modest fuel price increment (i.e. accumulated 16%) up to 2030 and constant prices thereafter.

Since 2016, Zimbabwe has implemented a tobacco tax to support sustainable afforestation and a carbon tax on fossil fuel use. As of 2019, the collected carbon tax amounted to fuel diesel and gasoline[1] use is equivalent to around USD12.24/tCO_2eq.

Moreover, a constant electricity cost of 16 USDc/kWh was assumed. The cost is related to the current price for electricity (10 USDc/kWh, ZERA, 2014) and indirect subsidies related tariffs which are not fully cost reflective (i.e. CAPEX is not fully recovered; see Trimble et al., 2016).

2.4 Mitigation Modelling and Economic Analysis

Climate change mitigation modelling was done using sector specific tools. Over past years, a high cost of capital has led the private sector to invest in emission intensive technologies featuring low capital expenditure (CAPEX), but high operational expenditure (OPEX), for example. the purchase of inefficient passenger cars, with a low asset costs, but high fuel costs.

The alternative GHG mitigation pathway presented in this document is based on a strong climate-financing framework. The underlying assumption is that the LEDS implementation is supported by a national Climate Finance Facility (**Figure 7-5**, which offers debt capital and concessional lending rates based on sustainable and measurable GHG emissions reductions. This would eliminate the gap between the economically viable abatement potential and those measures that may be financially viable/attractive. The Marginal Abatement Cost (MAC) functions were used to prioritize the mitigation options.

The modelling of a mitigation scenario (MIT) is based on brief sectoral studies for i) Reduction of load dependent technical losses in the electricity transmission and distribution system, ii) introduction of Minimum Energy Performance Standards (MEPS), iii) abatement potential in the Solid waste subsector, iv) transport, v) cement and vi) AFOLU. These are presented in Annex I-VII.

[1] Gasoline is generally referred to as petrol in Zimbabwe

2.5 Sustainable Development Impacts and Co-benefits

While the LEDS mitigation actions support Sustainable Development Goals (SDGs) achievements beyond the SDG 13, the SDG impacts of each mitigation action have not been analysed and quantified. There are however clear linkages, exemplified for instance in the energy sector, where fossil fuel based energy production and transport has severe air pollution effects. A shift to cleaner forms of energy has clear health benefits. Similarly, increased uptake of renewable energy also has a positive impact on employment creation, in that the industry offers significant direct and indirect job creation potential across the full value chain.

There is need for an analysis of how to make the transition to a low carbon economy a just and inclusive transition for all. When carbon-intensive industries are phased out, there is need to make sure that cleaner industries are ready to sustain growth and employment and that both positive and negative effects on jobs and livelihoods are considered. While the crafting of the LEDS has been centred on identification of cost-effective, low carbon solutions for reaching the country's ambitious climate targets, the GoZ intends to include a deeper analysis of the social and employment dimensions. , These dimensions will include gender issues, SDG impact and elements of decent work and just transition as an integral part of the development of a LEDS implementation framework.

3 Energy

3.1 Business-as-usual Emissions

Energy use in power generation, transport, manufacturing industry, agriculture buildings accounts for the largest share of national GHG emissions. Emissions totalled around 11.9 $MtCO_2e$ in 2015, of which CO_2 accounted for over 99%. Electricity generation accounted for the largest share of the total, mainly associated with coal and oil combustion - followed by the transport sector emissions, mainly from gasoline and diesel use in road vehicles (Figure 1). Diesel, coal and liquefied petroleum gas (LPG) fuel use in other sectors such as industry, commercial, institutional, residential and agriculture accounted for the remaining share of emissions.

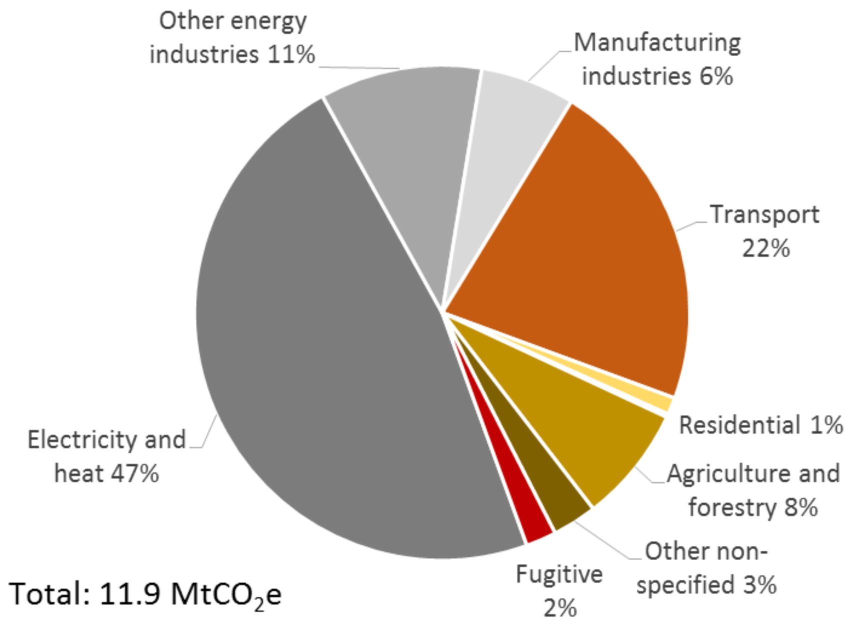

Figure 3-1: GHG emissions from energy use, 2015

Figure 3-2 shows GHG emissions from energy use projected through 2050 under a BAU scenario. Bottom-up detailed energy use and emissions projections were developed separately for each energy-using sector, reflecting a number of assumptions (Goz, 2016). around key drivers and the outlook for growth through 2050 determining changes in economic output, energy supply, technology, economics and policy choices. The approach taken to developing a BAU projection for each contributing sector is summarised in Table 3.1.

Following this methodology, the total emissions are expected to increase significantly over the coming decades, rising to around 26.5 and 37.5 $MtCO_2e$ in 2030 and 2050, respectively. The fastest growth and overall contribution is expected to come from power generation, in particular with the official planned expansion of thermal power generation over the coming decade. Emissions from transport are also forecast to rise significantly as demand for vehicles and transport services increases with economic growth, particularly for passenger cars. Most other sectors are expected to see a steady increase in activity and associated emissions, assuming robust economic growth, industrial output and rising standards of living over the medium and long term.

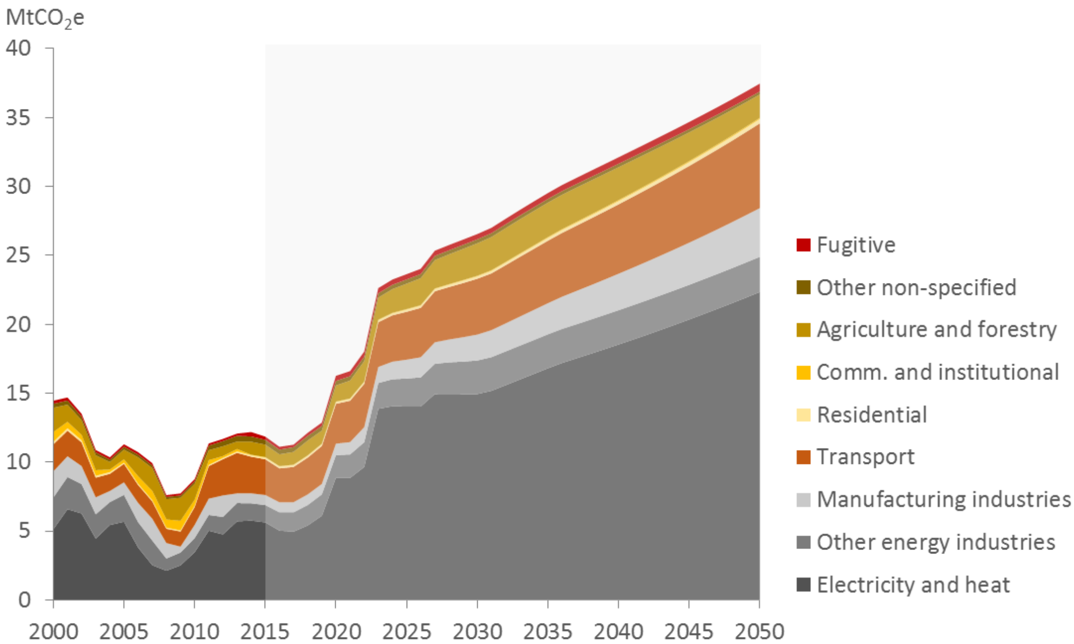

Figure 3-2: GHG Emissions from energy use, historic and projected to 2050 under BAU

Table 3-1: Summary of approach to BAU energy emissions projections according to IPCC category

IPCC sub-sector	IPCC category	Sub-category	Approach	Assumptions
1.A. Fuel Combustion Activities	1. A.1. Energy Industries	1. A.1.a. Electricity and Heat Production	Based on analysis of forecast electricity demand and planned generation through 2038 by power plant (ZETDC, 2017). A counterfactual BAU was developed excluding NDC projects being included, using ZPC plant-level information and data assumptions.	Increased demand and generation to 2050 based on growth trend and final grid mix in 2038.
		1. A.1.c. Manufacture of Solid Fuels and Other Energy Industries	Surrogate approach.	Use of coking coal and other energy use assumed to grow as a function of projected GDP growth and decreasing energy per unit GDP intensity (MJ per USD).
	1. A.2. Manufacturing Industries and Construction		Surrogate approach	Energy demand to grow in most manufacturing sectors as a function of projected GDP growth and decreasing energy per unit GDP intensity.
	1. A.3. Transport	Road	Fuel consumption forecast for different vehicle classes based on transport demand, fuel use and fuel economy assumptions, and detailed vehicle fleet modelling through 2030. Vehicle demand by type linked to GDP per capita growth forecasts using regression analysis from historic data (see Annex IV for details and data	Increased vehicle fleet based on historical trend

IPCC sub-sector	IPCC category	Sub-category	Approach	Assumptions
			sources used).	
		Railways	Forecast coal, diesel and electricity consumption based on data provided by National Railways of Zimbabwe (NRZ) and MTID. Extrapolated to 2050 based on GDP growth trends.	Increased energy demand with increasing GDP
		Aviation	Energy demand assumed to grow in line with GDP growth outlook. Assumes resumption of flight activity over medium term to previous levels of year 2000.	Increased energy demand with increasing GDP
	1. A.4. Other Sectors		Surrogate approach.	Energy demand assumed to grow in line with GDP growth outlook
	1. A.5. Non-specified			Energy use per unit GDP to increase over time
1.B. Fugitive Emissions from Fuels	1. B.1. Solid Fuels	1. B.1.a. Coal Mining and Handling	Modelled according to IPCC Tier 1 guidance assumed (90% surface mining and 10% underground mining); activity data linked directly to projected national coal demand within the same BAU scenarios (i.e. assumes domestic coal meets demand growth).	Increased coal mining with increasing domestic demand

3.1.1 Mitigation Measures

Error! Reference source not found. summarises the mitigation measures identified to contribute to the LEDS, according to each of the key energy sub-sectors. The table provides only a high-level summary, indicating the nature of the mitigation effect; furthermore, some of the options shown comprise several different actions or specific projects (e.g. municipal biogas power projects) grouped together.

The list of options builds upon those identified in Zimbabwe's first NDC. Several of those measures have been extended or scaled-up through to

2050.The table also includes other additional measures considered feasible over the long-term with sufficient technical and financial support. Some of these measures were included as part of the low carbon road transport (see Annex IV), the use of Reactive Power Compensation (RPC, see Annex I), and Minimum Energy Performance Standards for appliances used in buildings (see Annex II).

An important contribution to the LEDS is the assumed expansion of new and as-yet unplanned renewable power generation projects to meet increasing demand through the last 15-20 years of the forecast period. These power generation projects assume the need to balance base load and peaking power whilst moving towards low carbon generation as renewable generation costs fall over time. An equal split between solar Photovoltaic (PV, utility), concentrated solar power (CSP) and hydropower is assumed.

Table 3-2: List of mitigation measures for Zimbabwe LEDS in the energy sector

Sub-sector	**Category**	**Mitigation measure**	Principal mitigation
Energy Industries	Electricity and heat generation	Planned large hydropower (including Batoka and Devil's Gorge).	Replacement of existing and/or planned fossil-fuel generation from grid.
		Planned solar PV micro-grids.	Replacement of generation and GHG emissions from Harare coal plant, and other fossil generation.
		Planned solar PV utility projects.	
		Planned municipal bio-gas power projects.	Displacement of existing coal-fired power on grid.
		Unplanned renewables 2032-2050 (solar PV, CSP, hydro).	Increase in power demand met from renewables from 2032 onwards to reduce grid GHG intensity.
		Reactive power compensation.	Reduced transmission system losses, increasing efficiency of power generation supply.
Manufacturing Industries		Energy efficiency(EE) programme.	Reduced on-site fuel use and grid power.
		Energy efficient electric motors in mining.	Reduced power consumption.
Transport	Road transport	Local biofuel production	Reducing fossil fuel component in the energy mix through blending.
		Fuel economy policy.	Reduction in gasoline and diesel consumption
		Electric- and hydrogen vehicles.	Reduction of gasoline and diesel demand by Internal Combustion Engines (ICE) vehicles through the uptake of electric and hydrogen vehicles.
		Public transport (modal shift).	Reduced carbon intensity of travel system by shifting away from passenger car use to modern buses and non-motorised transport (NMT).
	Railways	Rail refurbishment and electrification.	Displaced diesel consumption (rail + road) by less CO_2-intensive electricity provided from the grid.
Other	Agri-	CSA: Solar pumping for irrigation.	Replacing diesel, gasoline and grid electricity in water pumping.

Sub-sector	**Category**	**Mitigation measure**	Principal mitigation
sectors	culture	CSA: On-farm bio-digesters.	Avoided emissions from manure management.
	Commercial & residential	Solar water heating programme.	Replacing grid electricity consumption.
		Rooftop solar PV for SMEs.	Replacing diesel and gasoline in back-up generators.
		Off-grid solar electrification.	Replacing kerosene (lighting) and diesel/gasoline (gensets).
		Solar LED street and traffic lighting.	Reduced grid electricity for street lighting.
		Replacement of inefficient lighting devices.	Increased energy performance of appliances leading to reduced grid power consumption.
		Minimum Energy Performance Standards.	

Figure 3-3 summarises the estimated emissions reduction potential in 2030 for all the mitigation options identified in Table 3.2. In terms of overall mitigation contribution, electricity supply from the large hydropower projects of Batoka and Devil's Gorge dominate the estimated mitigation potential, accounting for 8.1 $MtCO_2e$ of the total 10.8 $MtCO_2$ potential estimated in 2030 – equivalent to almost 75% of the total effort.

After renewable electricity generation, low carbon transport contributes the largest share of mitigation potential, mainly through a combination of fuel savings and the use of alternative and low carbon fuels and vehicles (see Annex IV).

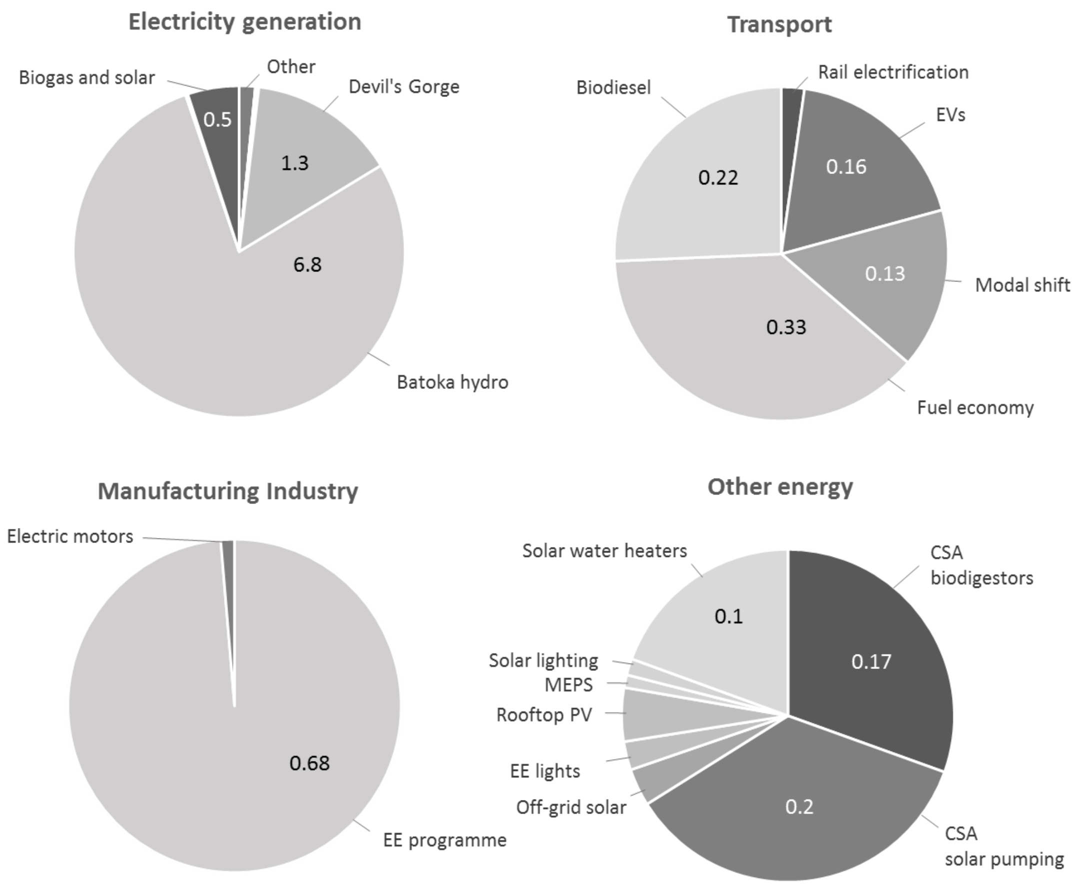

Figure 3-3: GHG emissions mitigation in energy use, 2030 (MtCO_2e)

The contribution from the key mitigation options over the long-term to 2050 is shown in **Figure 3-4**. The projections show that with the implementation of all mitigation measures, total emissions could be limited to around 16MtCO_2e in 2050, compared to 37.5 MtCO_2e under BAU. This represents a more than halving of energy sector emissions. The figure shows that achieving this level of mitigation will be highly determined by the ability of large-scale hydropower to meet future electricity demand, followed by a mix of other renewables meeting incremental demand over the longer-term.

Additional mitigation could be achieved through use of clean coal technologies for thermal power generation and other policy instruments to remove inefficient vehicles, equipment and appliances.

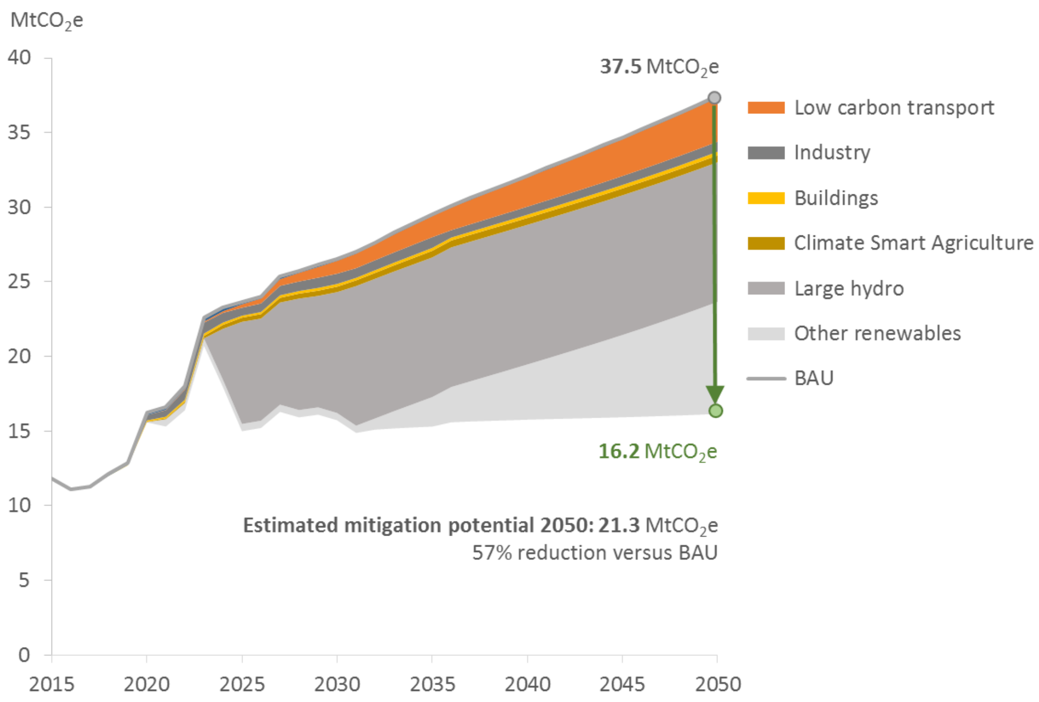

Figure 3-4: GHG emissions projections from energy use under BAU and with mitigation

3.1.2 Economic Analysis

shows the marginal abatement cost curve (MACC) for the energy sector in which each of the identified mitigation options is sorted in ascending order of abatement cost. As described earlier, the costs shown represent the socio-economic costs of abatement, reflecting both costs and benefits to the wider economy.

Some key assumptions for modelling the costs and benefits of mitigation measures were applied specific to the energy sector, including;

- A cost reflective price for electricity generation and supply (cp. ZERA, 2014 and Trimble et al., 2016) of 16 USDc/kWh;
- While the general modelling approach assumes constant prices, international projections for the generation of additional, currently unplanned, renewable energy projects were considered. These unplanned projects will be required to close the gap from 2032 onwards between i) the currently planned generation assets and ii) the increment of the energy demand projected from 2030 onwards. For these projects, international projections for investment costs for utility PV, CSP and hydropower (NREL, 2018)[2] were considered. Moreover, it was assumed that this 'unplanned' generation is provided by small-scale hydropower, PV and CSP in equal shares[3].

[2] 2018 ATB Cost and Performance Summary, NREL. See: https://atb.nrel.gov/electricity/2018/summary.html

[3]Given limitedinformationand lack of a robust and comparable RE assessment and because detailed energy system modelling fell outside the scope of the LEDS development, making an equal split was deemed the

The MACC highlights the large potential for achieving mitigation principally through the introduction of increased renewable supply most noticeably from large hydropower projects such as Batoka and Devil's Gorge to meet Zimbabwe's rising demand for grid electricity. Abatement is also achieved indirectly through the impact that reduced electricity demand has in the electricity generation sector, arising from energy efficiency measures. Importantly, most of the projects are seen to have significant net benefits, shown here as 'negative' abatement costs. This is most noticeable for energy efficiency projects and those involving the re-placement of imported diesel fuel use (Table 3.2).The focus is instead on those options, which can deliver significant cost-effective GHG reductions whilst also offering important co-benefits such as reduced energy imports, green growth and local job creation.

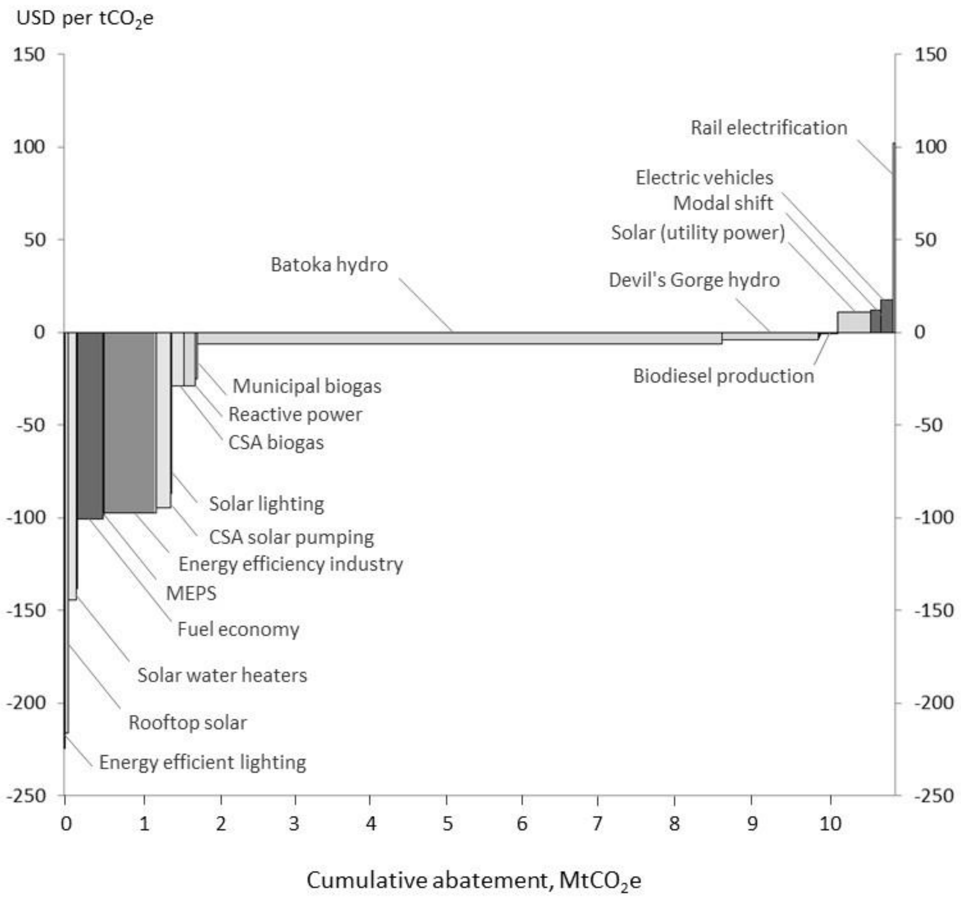

Figure 3-5: Marginal abatement cost curve for energy use, 2030

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most transparent approach. Wind was excluded based on the low resource potential in Zimbabwe, whilst the assumption was that solar will have a larger potential than hydro, given falling unit costs (hence the 2/3 solar compared to 1/3 hydro). Hydro in turn comes with environmental challenges, mainly for large scale hydro. It should be noted that because all Renewable Energy options assume zero emission grid power, the actual split chosen doesn't actually impact the GHG reductions and the LEDS mitigation outlook. The costs would be slightly different depending on the mix, although these become broadly similar going out to 2050.

3.2 Roadmap of Actions

shows a summary timeline for the development and implementation of each of the mitigation measures and actions proposed to implement the LEDS in the Energy sector. The roadmap shows that much of the mitigation effort to be achieved over the long-term through to 2050 will require the formulation and implementation of policies, programmes and investments over the short and medium term. These will be essential in providing the basis and clear direction for subsequent scaling up of low carbon energy use and investment needed to decouple energy consumption from emissions.

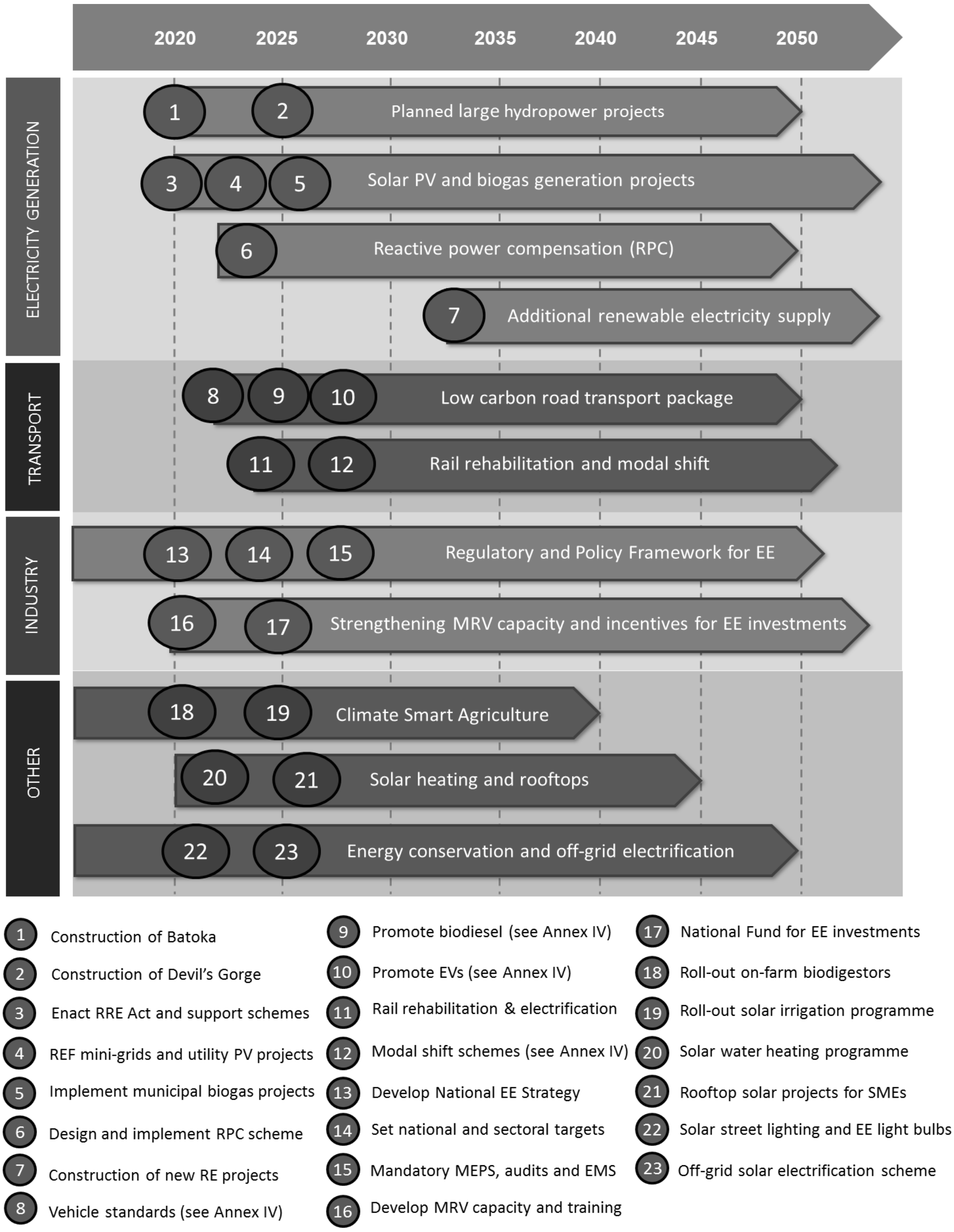

Figure 3-6: Timeline of mitigation actions to support LEDS implementation in the energy sector

4 Industrial Process and Product Use

4.1 Business-as-usual Emissions

Industrial Processes and Product Use emissions include GHG emissions released by a wide range of industrial processes that chemically or physically transform materials and emissions from product use. According to the TNC GHG inventory data, emissions from these sources represent a relatively small share of Zimbabwe's total national emissions, totalling approximately 0.54 MtCO_2e in 2015.[4]

The cement sector accounted for the largest share of total IPPU emissions in 2015, in the form of CO_2 produced during calcination of limestone in cement kilns (Figure 4.1). This sub-sector was followed by release of process CO_2 from ferrochromium smelting and N_2O emissions produced during the production of nitric acid within the country's only nitrogen fertilizer manufacturing plant. A large number of much smaller sources and activities accounted for the remaining share of emissions, including glass production, soda ash use, secondary lead production, and lubricant, paraffin wax and solvent use (other IPPU).

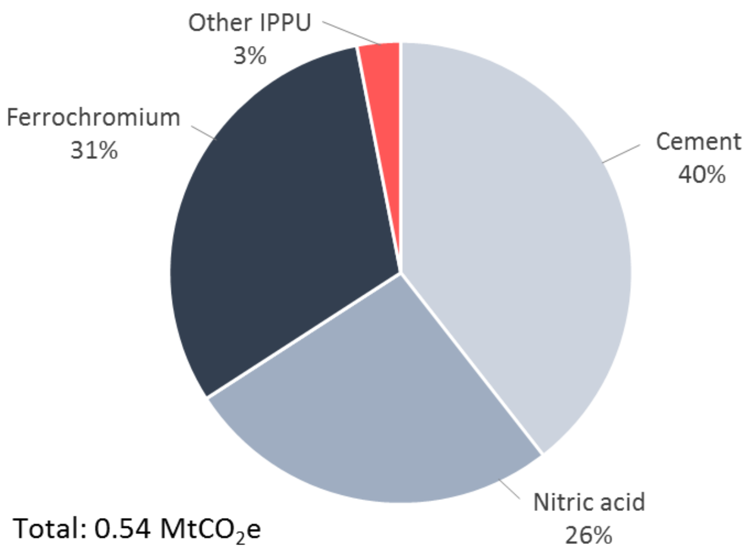

Figure 4-1: GHG emissions from IPPU, 2015

Figure 3-1shows historical GHG emissions from the IPPU sectors well as emissions projected through 2050 under a BAU scenario. The historical data shows how emissions have fallen significantly since 2000. Iron and steel production was a key emitter until around 2008 when the country's only integrated iron and steel works ceased production. Nitric acid production from the nitrogen fertilizer industry has significantly decreased due to operational challenges.

[4] Note that the GHG inventory does not estimate GHG emissions arising from product uses as substitutes for Ozone Depleting Substances (ODS) due to a lack of data

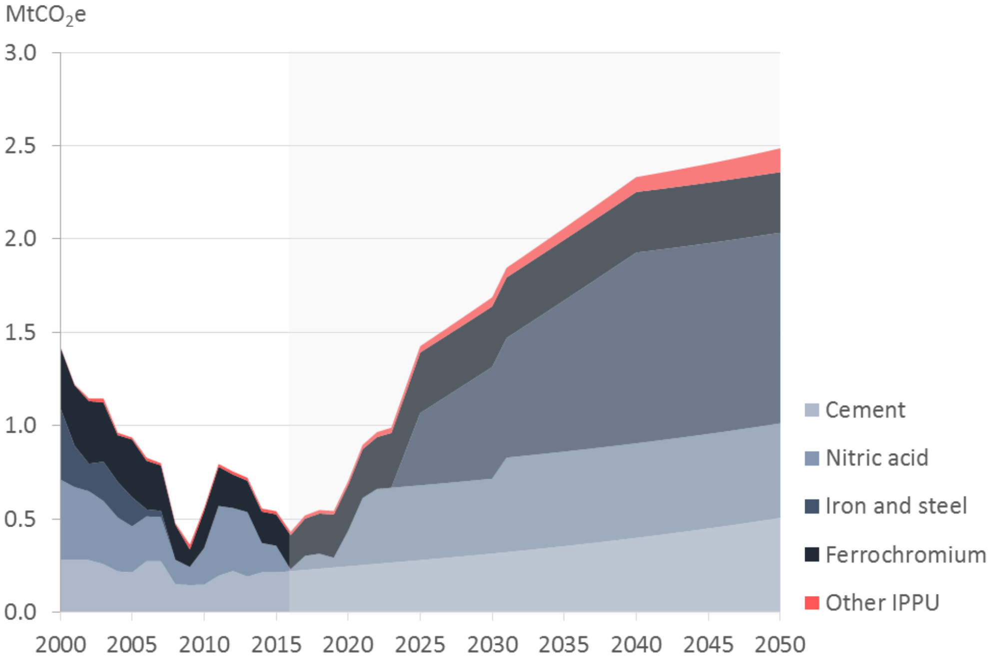

Figure 4.2: GHG emissions from IPPU, historical and BAU projection to 2050 by source

Emissions projections were developed separately for each emitting sub-sector, reflecting assumptions around the forecast outlook for industrial recovery and increased output growth through 2050. The approach taken to developing a BAU projection for each contributing sector is summarised in **Table 4-2.** According to this approach, total BAU emissions are expected to increase significantly over the coming decades, from an estimated 1.7 $MtCO_2e$ in 2030 to 2.5 $MtCO_2e$ in 2050. However, this increase is highly dependent upon the assumption that renewed industrial output and investment can be achieved in the medium-term, in particular within iron and steel and fertilizer production, resulting in activity and emissions returning to early 2000 levels. Over the longer term, most IPPU sectors are expected to have an increase in activity and associated emissions, assuming robust economic growth and industrial output. In the absence of national mandatory GHG reporting requirements for companies, GHG emissions were calculated based on IPCC Tier 1 methodology. Figure 4.2 presents historical and projected BAU GHG emissions from IPPU.

Table 4-1: Summary of assumptions to BAU IPPU emissions projections according to IPCC category

IPCC Sector	IPCC sub-sector	IPCC category	Assumptions
2. IPPU	2.A. Mineral Industry	2.A.1. Cement Production	Clinker production assumed to return to historical levels of around 550kt(early 2000s) by 2025; subsequent annual growth to occur in line with trends at around 2-3% p.a.
		2.A.3. Glass Production	Glass production assumed to return to historical levels of around 20kt(mid 2000s) by 2025; subsequent annual growth occurs in line with trends at around 5% p.a.
		2.A.4b. Other Uses of Soda Ash	Sodium carbonate use assumed to return to early 2000s levels of around 10kt by 2025; subsequent annual growth occurs in line with trends at around 5% p.a.
	2.B. Chemicals Industry	2.B.2. Nitric Acid Production	Assumes target nitric acid production of around 150kt reached by 2024, with subsequent expansion to achieve ammonium nitrate production capacity of 240kt p.a.
	2.C. Metal Industry	2.C.1 Iron & Steel Production	Assumes return to early 2000sproduction levels by 2025, subsequently increasing to 700kt by 2040.
		2.C.2. Ferrochromium	FeCr production assumed to return to early2000 levels of around 250kt by 2025.
	2.D. Non Energy Products	2.D.1 Lubricant Use	Increased non-energy product use linked to manufacturing industry activity within Category 1.A (Energy); assumed to increase as a function of projected GDP growth and decreasing energy per unit GDP intensity.
		2.D.5 Paraffin Wax Use	

Note: Growth rate and industrial output assumptions are based on Zimbabwe National Industrial Development Policy (2019-2023) and expert judgement

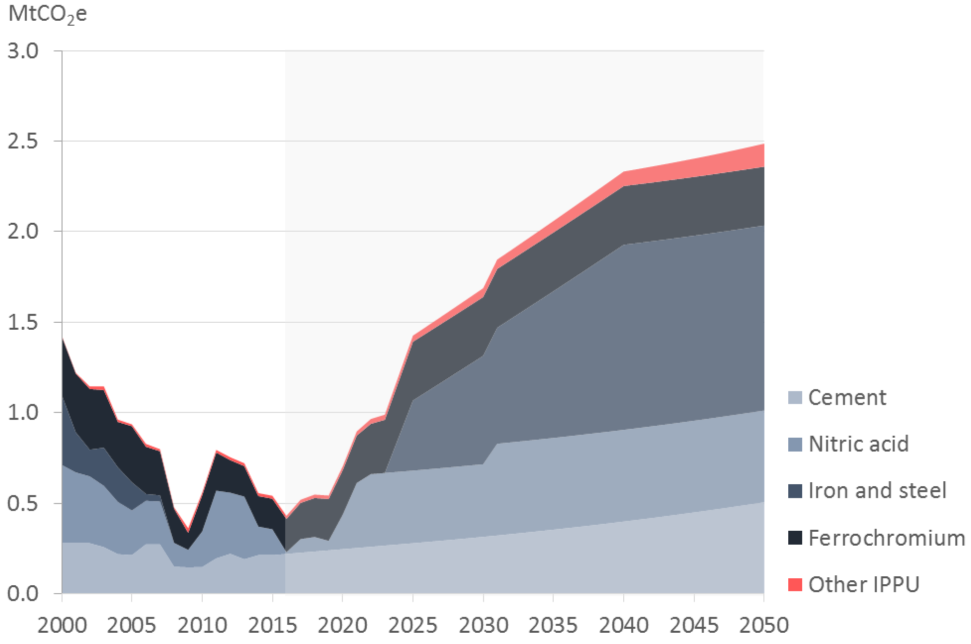

Figure 4-2: Historical and projected GHG emissions from IPPU

4.2 Mitigation Measures

Table 4-2 summarises the mitigation measures identified to contribute to the LEDS, according to each of the key sources of IPPU emissions. Within the cement sector, process CO_2 emissions from the calcination process account for around 60% of total plant emissions. The primary option for reducing these is to substitute the clinker content within cement production with other materials such as fly ash from power generation and blast furnace slag (BFS) from steel production. These materials are currently used in cement production, but experiences globally show that these rates could be increased over time subject to the availability of low cost substitutes and the acceptance of lower clinker products within the market and regulatory framework. These measures are therefore proposed as an important element within a broader package of measures to increase the sustainability of the cement sector in Zimbabwe (see Annex V).

The main GHG emission from fertilizer production in Zimbabwe is nitrous oxide (N_2O).The gas is produced from nitric acid generated during the production of ammonium nitrate fertilizer. Use of nitrous oxide abatement technology is expected to reduce nitrous oxide emissions from ammonium nitrate production by up to 80%. Technical feasibility analysis supported by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) Nitric Acid Climate Action Group (NACAG) has identified the potential to install secondary catalyst technology at the facility, which could result in N_2O emissions abatement of around 80%.

Globally, the iron and steel industry is the largest industrial source of CO_2 emissions due to the energy intensity of steel production and its reliance on carbon-based fuels and reductants (primarily coking coal).[5] Although currently there is low output from the steel industry in Zimbabwe a return to large scale production within the next decade, as assumed in the BAU scenario, based on the integrated blast furnace to basic oxygen furnace(BF-BOF) steelmaking route would result in a large increase in process emissions.

Currently, the main route to reducing non-energy emissions from BF-BOF steelmaking is to substitute coke input with biomass (IPCC, 2006)[6]. Studies estimate that CO_2 emission reductions of up to 1.3 kg/kg steel may be possible with 100% coke substitution (Norgate and Langberg, 2009)[7], equivalent to abatement of around 80-90% of total process emissions. However, technical factors currently limit the use of biomass in large blast furnaces to 20%. The use of a processed type of biomass with better mechanical properties, known as bio-coke, is currently under development and could enable larger substitution rates over the longer-term. Only biomass feedstock from crop residue[8] or sustainably managemed forests will be considered for bio-coke production.

Production of ferrochromium (FeCr) is an energy-intensive industry involving a high consumption of coking coal. The GHG intensity of FeCr production from modern closed furnaces deploying best available technology (BAT) can be up to half as that from older facilities using open furnaces. It is expected that a phased replacement of existing open furnaces in Zimbabwe's ferroalloy sector with modern closed furnace technology employing BAT could deliver significant energy savings and GHG reductions. Similar to iron and steel, there is also the potential to replace the carbon content provided by coking coal with sustainable biomass alternatives such as io-coke, resulting in significant reductions in IPPU emissions. This has been estimated, based on similar assumptions for substitution in steel making.

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[5] Carbon is supplied to the blast furnace mainly in the form of coke produced from metallurgical grade coking coal, but can also be in the form charcoal made from wood or other forms of carbon. Carbon serves a dual purpose in the iron making process, primarily as a reducing agent to convert iron oxides to iron, but also as an energy source to provide heat when carbon and oxygen react exothermically.

[6]Reporting Guidelines for National GHG Inventories: IPPU Chapter (IPCC, 2006).

[7] Environmental and Economic Aspects of Charcoal Use in Steelmaking. In ISIJ International 49(4):587-595. T.Norgate and D.Langberg, 2009.

[8] Biomass from coffee, cotton or tobacco crop residues, straw or cleared invasive allien species like Lantana camara, Water hyacinth will be used

Table 4-2: List of mitigation measures for Zimbabwe LEDS in IPPU

Sector	Category	Mitigation measure	Principal mitigation effect
IPPU	Cement production	Increased clinker substitution with fly ash (up to 16% by 2030, 20% by 2050).	Increasing the content of clinker substitutes within cement products reduces CO_2 emissions associated with clinker production.
		Increased clinker substitution with BFS (up to 16% by 2030, 20% by 2050).	
	Fertiliser (nitric acid production)	Decomposition of N_2O emissions through use of a secondary catalyst.	Selective De-N_2O catalyst results in abatement of approximately 80% of all N_2O emissions produced during nitric acid production.
	Iron and steel	Substitution of coke input to BF/BOF steel making with bio-coke .	Replacement of up to 50% fossil carbon input by sustainable biomass supply (starting at 20% in 2025, rising to 50% by 2040) results in large reduction in IPPU emissions.
	Ferrochromium production	Substitution of coke input to FeCr-production with bio-coke.	Replacement of up to 50% fossil carbon input by sustainable biomass supply (starting at 20% in 2025, rising to 50% by 2040) results in large reduction in IPPU emissions.

Figure 4-3 summarises the estimated emissions reduction potential in 2030 for the IPPU mitigation options identified in the Table 4. In terms of overall mitigation contribution, N_2O decomposition from nitric acid production accounts for half of the estimated mitigation potential of approximately 320ktCO_2e in 2030. Coke substitution within the metals industry (iron and steel and ferrochromium production) account for the majority of the remaining mitigation potential.

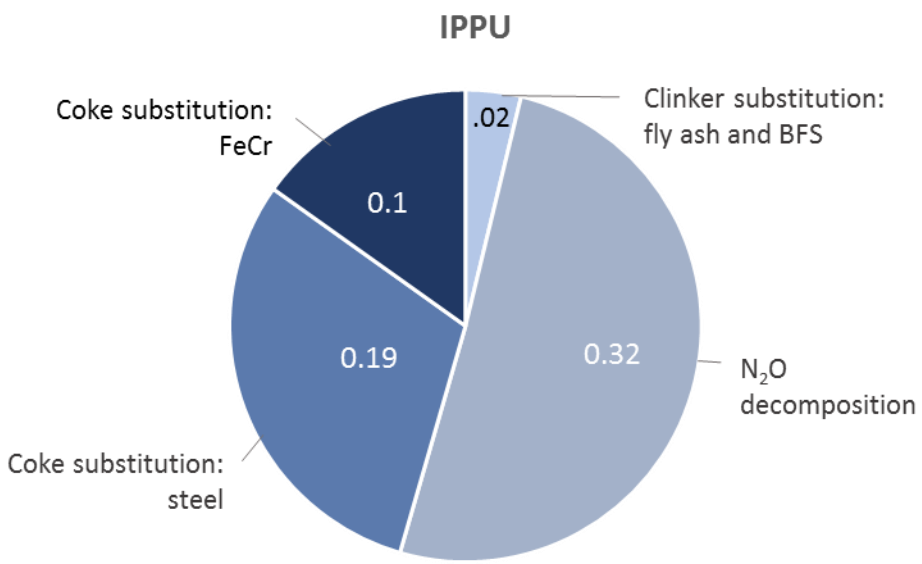


Figure 4-3: GHG emissions mitigation within IPPU, 2030 (MtCO_2e)

The estimated contribution from these key mitigation options over the long-term to 2050 is shown in Figure 4-4 The projections show that with the implementation of all mitigation measures, total emissions could be limited to around 1.3 $MtCO_2e$ in 2050, compared to 2.5 $MtCO_2e$ under BAU representing around half of total IPPU emissions. The future recovery of industrial activity in Zimbabwe over the coming decade will clearly determine the pathway of BAU emissions as well as the feasibility of implementing different mitigation options. Investment in new equipment, plant and practices offers an opportunity to build in low carbon options and cost-effective energy saving technologies.

Subject to accessing finance and (in the case of cement) overcoming non-economic barriers, cost-effective mitigation could be achieved within fertiliser production and cement production based on already well-established abatement technology. The GHG emissions abatement within the metals industry is uncertain. This uncertainty arises from the outlook for these sectors in Zimbabwe, the types of technology used and the inability of the measures such as coke substitution to be economically viable over the coming decades.

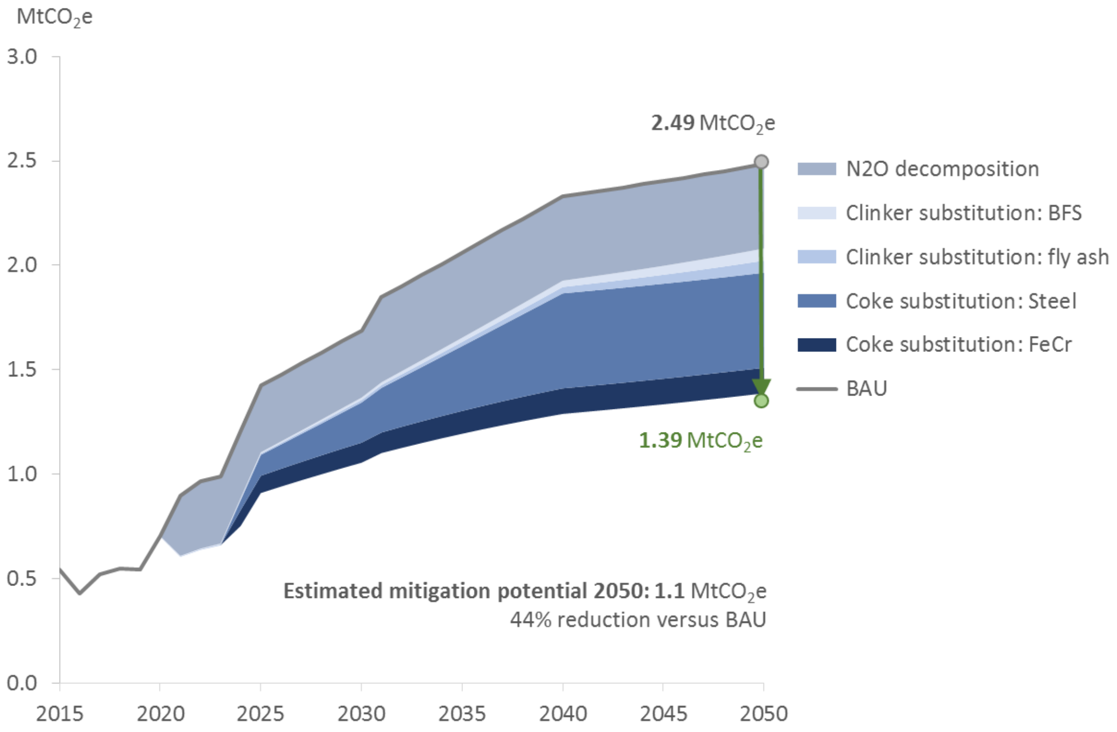


Figure 4-4: GHG emissions projections from IPPU under BAU and with mitigation

4.3 Economic Analysis

Figure 4-5shows the marginal abatement cost curve for the IPPU sector. The figure shows that around half of the mitigation potential could be achieved at low or negative cost. Subject to materials being available and non-economic barriers overcome, clinker substitution can result in a reduction in both industrial process emissions and production costs (see Annex V). Application of secondary catalytic technology to N_2O emissions from nitric acid production is a proven technology delivering large emissions reductions for a relatively low capital cost. The economics of reducing emissions through the use of coke substitution will be largely determined by the relative costs of biomass fuels for example, bio-coke – and metallurgical coking coal.

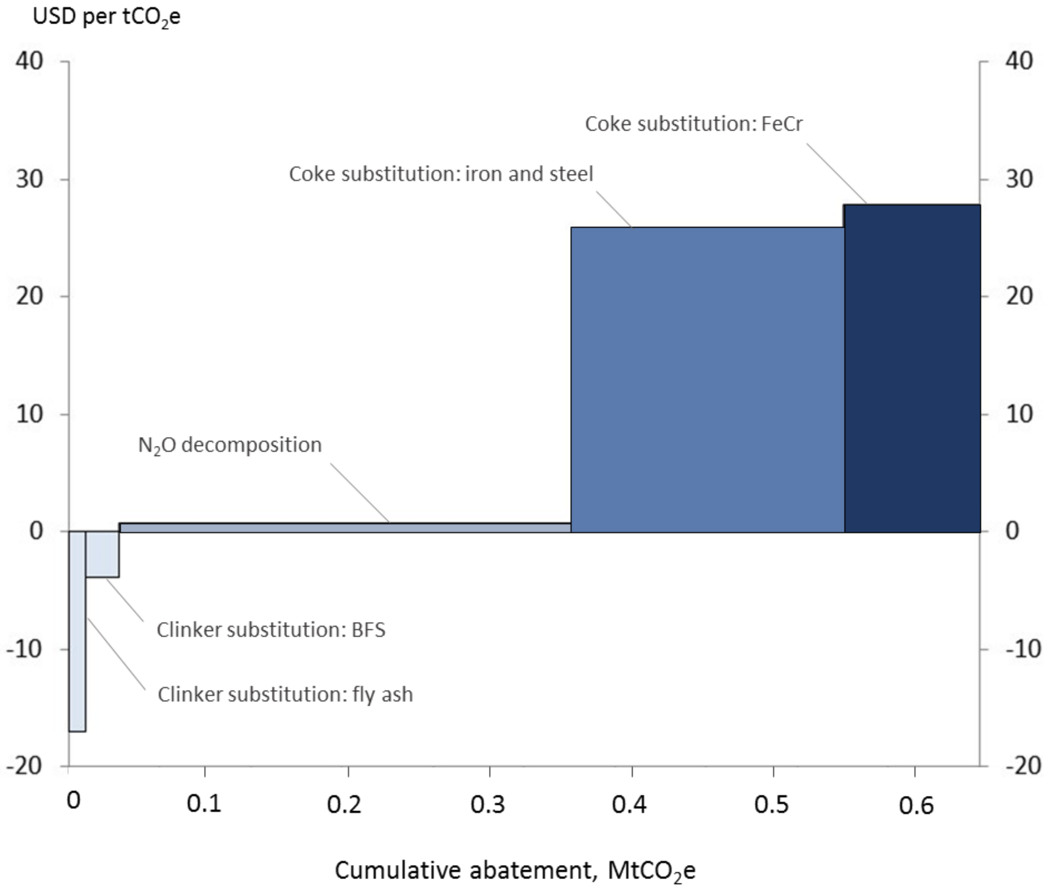


Figure 4-5: Marginal abatement cost curve for IPPU, 2030

4 Roadmap of Actions

Figure4-6 shows a summary timeline for the development and implementation of each of the actions proposed to implement the LEDS in the IPPU sector.

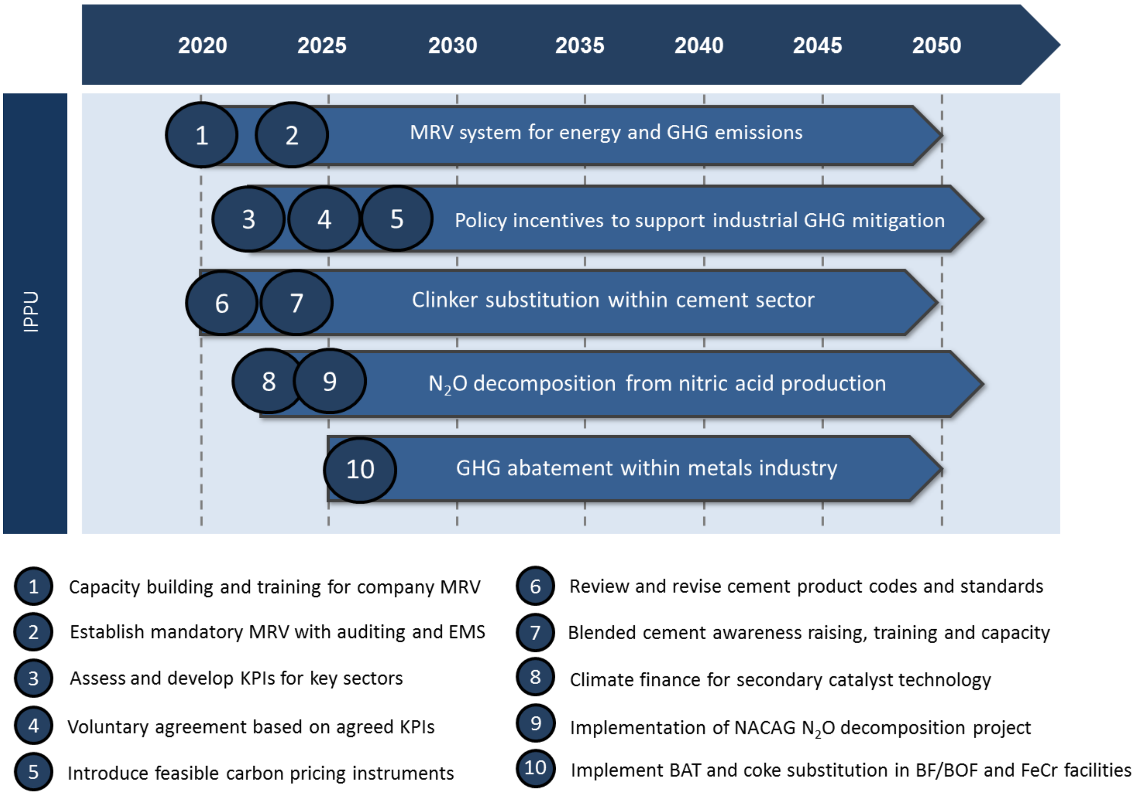


Figure4-6: Timeline of mitigation actions to support NDC implementation within IPPU

Note: MRV = Monitoring, Reporting and Verification; EMS = Energy Management System

5 Agriculture, Forestry and Other Land Use

5.1 Business-as-usual Emissions

The total annual GHG emissions for the country sum up to 22.0 MtCO_2e,which constitutes 0.045% of the global emissions (GoZ, 2015). The TNC reported the total carbon stock, not the stock change. In the TNC enteric fermentation contributed the second highest GHG emissions (19.5%) after the energy industries (24.8%). In the LEDS development, forest loss data obtained from the Global Forest Change (GFW, 2019), as proxy data to estimate emissions from deforestation which employs an efficient algorithm for tiling cloud free Landsat images to produce up to date estimates of conversion from forest to non-forest. It is important to note, that GFW does distinguish between anthropogenic and natural conversion from forest to non-forest.

In 2018, GHG emissions from AFOLU amounted to 15.8 MtCO_2e.The emissions from conversion of forest to non-forest land amounted to 3.20 MtCO_2e, while the agricultural sector contributed 12.59 MtCO_2e (80%) (Figure 5.1).

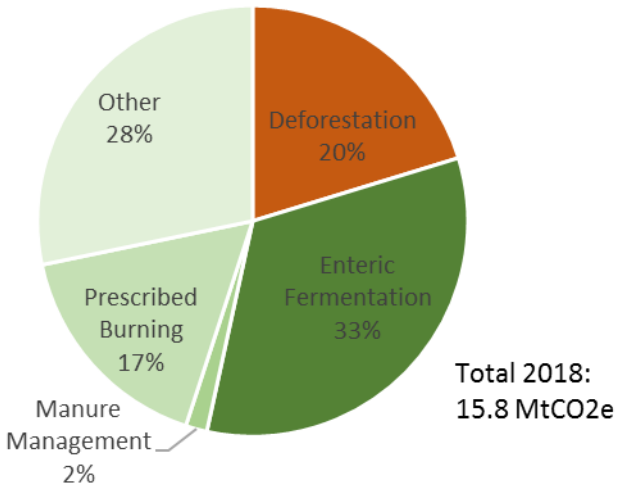


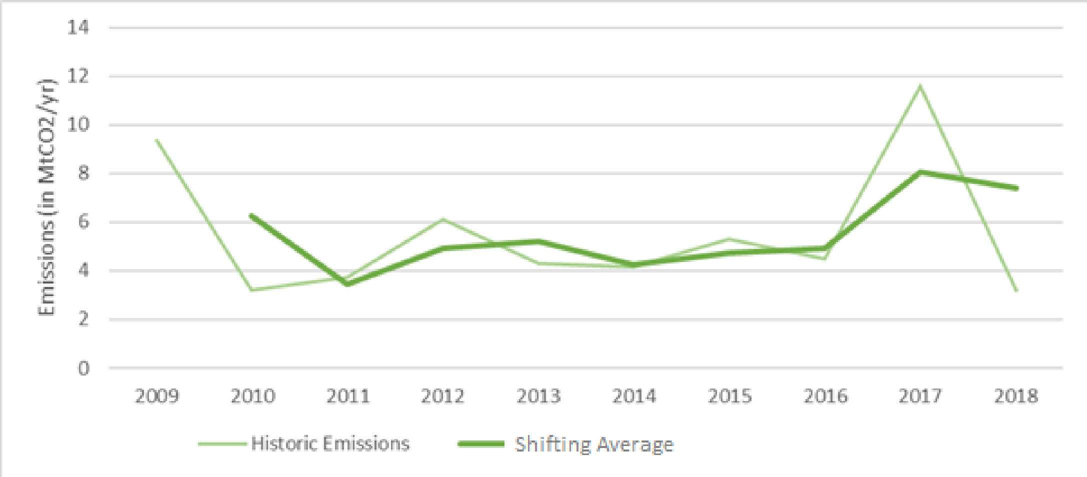
Figure 5-1: GHG Emissions from AFOLU

Emissions from Deforestation

Zimbabwe has not yet taken a final decision on its forest definition, inter alia considering crown cover. The preliminary agreement is to use a crown cover of 10%, which was used for the further analysis.

The emissions from forest degradation are not quantified. While the emissions may be significant, it has proven to be difficult to appropriately quantify the related activity data. For the determination of historic emissions (e.g. reference period of 10 years), very high-resolution imagery is not available. Attempts to quantify the emissions from degradation using Landsat imagery have proven to be inaccurate. Therefore, the emissions from forest degradation are not quantified. GoZ may develop capacities for the monitoring of forest degradation, once higher resolution imagery is available also for the historic reference period.

For the BAU scenario, following the Forest Carbon Partnership Fund (FCPF) methodological Framework, a historic reference period of ten years (i.e. 01/2009 to 12/2018) was applied. The changes shown in Figure 5.2 were attributed to emissions from deforestation, as well as the effects of the improvement in accuracy of the GFW algorithm. As a result, the shifting average approach was used to calculate the ten year average.as the GFW algorithm underwent updates resulting in significant increments in the accuracy. The updates are only applied for new images. This leads to reporting of deforestation, which was not detected before, which may partly explain the jumps in Figure 5.2. Hence, the LEDS development process considers the 10-year average as BAU scenario was considered.



Note :this data does not distinguish between anthropogenic and natural deforestation (cp. Harris et al. 2018) and hence is used as proxy in the absence of a Forest Reference Emission Level.

Figure 5-2: Annual Emissions from Deforestation

The approach taken to developing a BAU projection for each contributing sub-sector is summarized in Table 5.

Table 5-1: Summary of the approach to BAU AFOLU projections per IPCC Category

Sector	Sub-sector	Category	Methodology.	Assumptions
3. Agriculture, Forestry and Other Land Use	3.A Live-stock	3A1 Enteric fermentation	Provided a forecast of the GDP for the agricultural sector.	Increase in agricultural GDP expected for the period 2020-2050
		3A2 Manure Management	The relation GDP agriculture (based on constant prices) and GHG emissions of livestock based on historic data for the period 1990 – 2018 was assessed Considering the correlation coefficient and the GDP forecast up to 2050, livestock populations and GHG emissions from 2020 to 2050 were projected.	Significant correlation exists between agricultural GDP and livestock population up to 2050. No significant change is expected in CH_4 to livestock population relationships between the 1990-2018 and the 2020-2050 period.
	3.B Land	Forest Land converted to other land use	Considering a forest definition with a minimum threshold of crown cover of 10%, historic data for the period 2009 to 2018 was used to derive an average GHG emission estimate per annum.	Future emissions correspond to the historic ten-year average.
	3C Aggregate sources	3C1 biomass burning	Based on historic data for the period 1990 – 2018.	It is assumed that the emissions of agricultural soils depend to a large extent on the intensification of agricultural productivity linked to fertilizer application. Consequently, the development of the emissions of aggregate sources are modelled using ZIMRA's GDP forecast for the agricultural sector.
		3C2 Liming		
		3C3 Urea application		
		3C4-5 direct and indirect emissions from managed soils		
		3C7 Rice cultivation		

Figure 5-3 shows the GHG emissions for deforestation and agriculture from 2000 projected to 2050 under the BAU scenario. Based on forecasts provided by ZimStat, GDP growth projections indicate period of strong growth of agricultural productivity up to 2034. From 2034, the agricultural GDP is projected to slightly decrease to 2050, as the economy's other sectors become more developed.

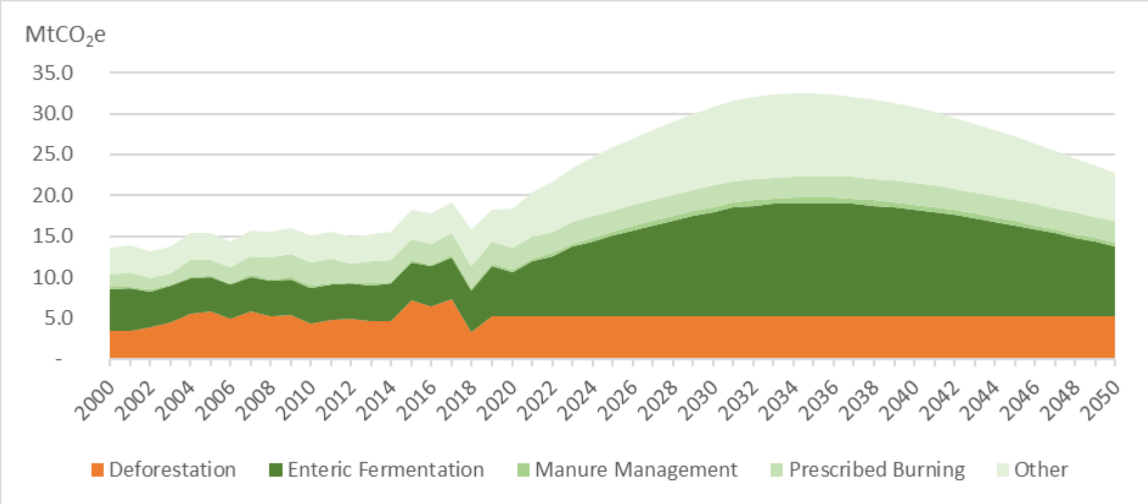


Figure 5-3: GHG emissions from AFOLU, historic and projected under BAU

5.2 Mitigation Measures

Deforestation is one of the most severe environmental problems in Zimbabwe (GoZ, 2017) Annual forest area loss was estimated at 32,000 ha per annum for the period 2009-2018 (based on crown cover of 10%). Furthermore, forest degradation that is largely driven by the same factors causes many environmental problems such as increased soil erosion, depletion of water resources, and changes in microclimates.

Table 5.2 summarizes the mitigation measures identified by stakeholders for the forestry and agriculture sector. The detailed analysis is provided in Annex VI and Annex VII.

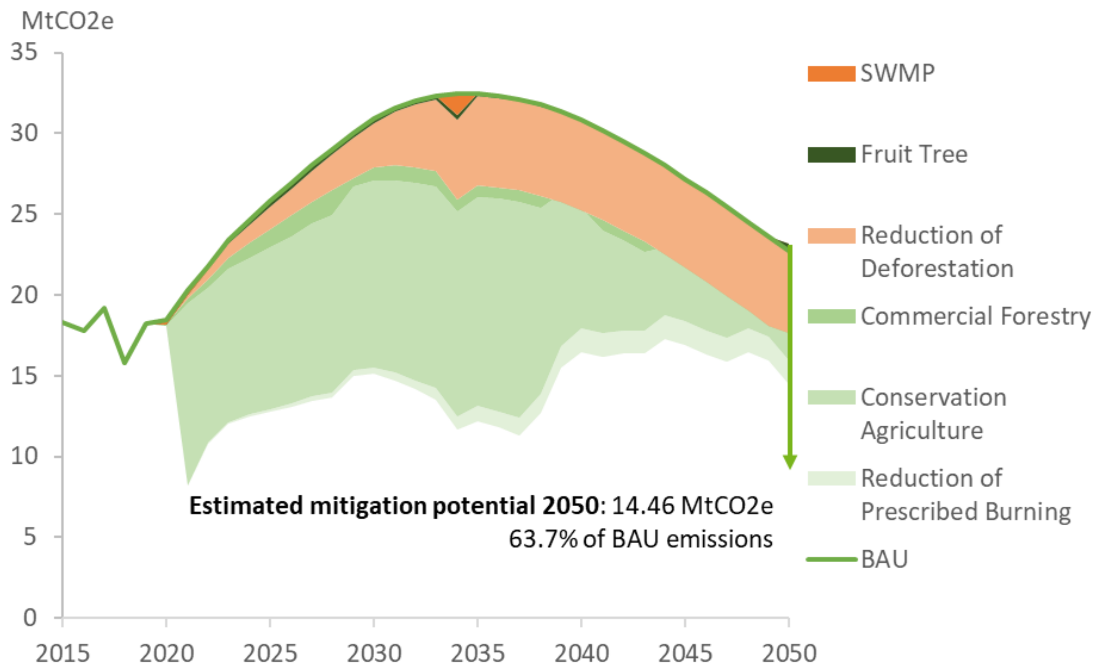


Figure 5-4: Estimated mitigation potential from forestry

Table 5-2: List of mitigation measures for Zimbabwe LEDS in the AFOLU Sector

Sector	Cat-egory	Mitigation measure	Principal mitigation
		Feedstock improvement	Improved feedstock reduces CH_4 emissions from enteric fermentation.
3. Agri-cul-ture, For-estry and Other Land Use	3.A Live-stock	Conservation Agriculture	Increases SOC stock (provided by International Maize and Wheat Improvement Centre (CIMMYT)). Reduced GHG emissions from machinery provided CIMMYT Economic impact of maize mucunaintercropping, provided by International Crops Research Institute for the Semi-arid tropics (ICRISAT).
	3.B Land	Reduction of deforestation	A set of policies and initiatives to reduce net deforestation to 0.5%by 2035: National tree planting programme. Tobacco regulations requiring the use of dedicated energy plantations for tobacco drying. Sustainable tobacco initiatives, implemented by tobacco companies. Tobacco Wood Energy Programme, proposed by the Forest-ry Commission. Reduction of prescribed burning assisting natural Improved enforcement of national forest legislation.
		Fruit Tree planting	Improvement of AGB+BGB carbon stocks in fruit tree plan-tation and provision of alternative income streams to reduce pressure on existing forests.
		Commercial Forestry	Increase planting of commercial forests increases the ABG and BGB carbon stocks; The storage in long term harvested wood products may re-sult in additional GHG emission reductions not quantified.
	3C Ag-gre-gate sourc es	Reduction of prescribed burning	Reduces CH_4 and N_2O emissions from burning biomass in savannah, shrub land and grassland.

Figure 5-4 summarizes the estimated GHG abatement potential by 2030 for all identified mitigation options. The results indicate that conservation agriculture may provide an important contribution to reducing the Zimbabwe's overall emissions. CA is a practice, which has implications on different GHG sources /carbon sinks. It increases SOC stocks, reduces fuel consumption by machinery, through the improvement of animal feed, reduces the emissions from enteric fermentation and may also reduce direct and indirect emissions from fertilizer application.

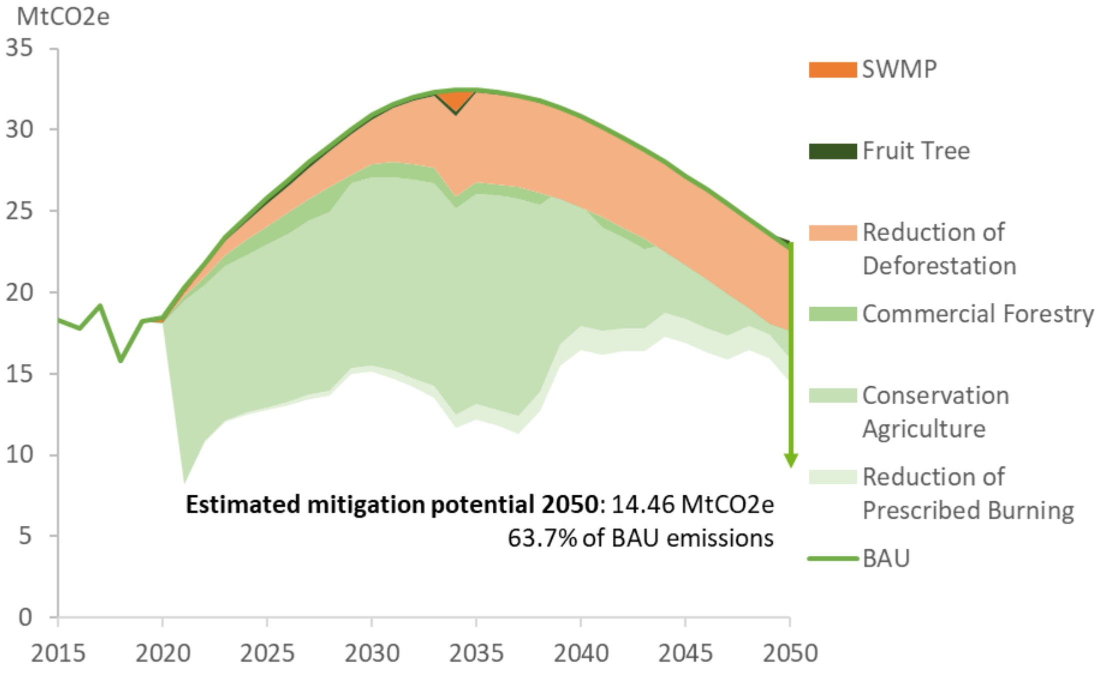


Figure 5.4: GHG emissions projections from AFOLU under BAU and with mitigation

While conservation agriculture is a well proven solution in Zimbabwe, there could be further benefits in the future in transitioning from Conservation Agriculture practices into increasingly regenerative agriculture practices. It is expected that farmers that have already taken up some or the full package of Conservation Agriculture measures will be ready to convert to more effective practices for restoring degraded land. Where relevant, this may include agro-forestry, tree-intercropping, silvo-pasture and improved grazing management strategies for land regeneration and associated increase in SOC stocks along with agro-forestry based carbon sequestration.

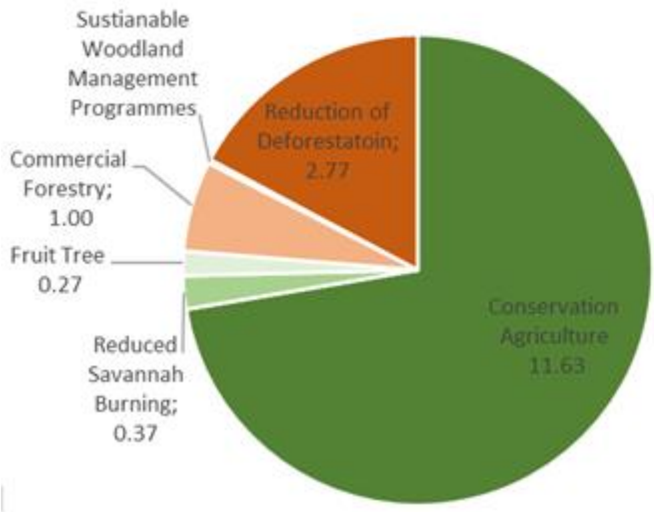


Figure 5-5: AFOLU GHG Abatement by Mitigation Measure

It is important to note that, commercial forestry may easily accommodate biomass energy demand of cement and ferrochromium mitigation measures specified under Chapter 4 and Annex V. The cement sector specifies an average annual energy demand from alternative fuels in the amount of 227.8 TJ, which could be met by 1,142 ha of short-term rotation plantations.

3 Economic Analysis

Figure 5.6 illustrates the marginal abatement cost curve of the AFOLU Sector in which all abatement options are sorted in ascending order of marginal abatement cost. As discussed in Chapter 2, MACCs are based on an economic analysis. Specifically for forestry operations, applying an economic discount rate is a decisive factor.

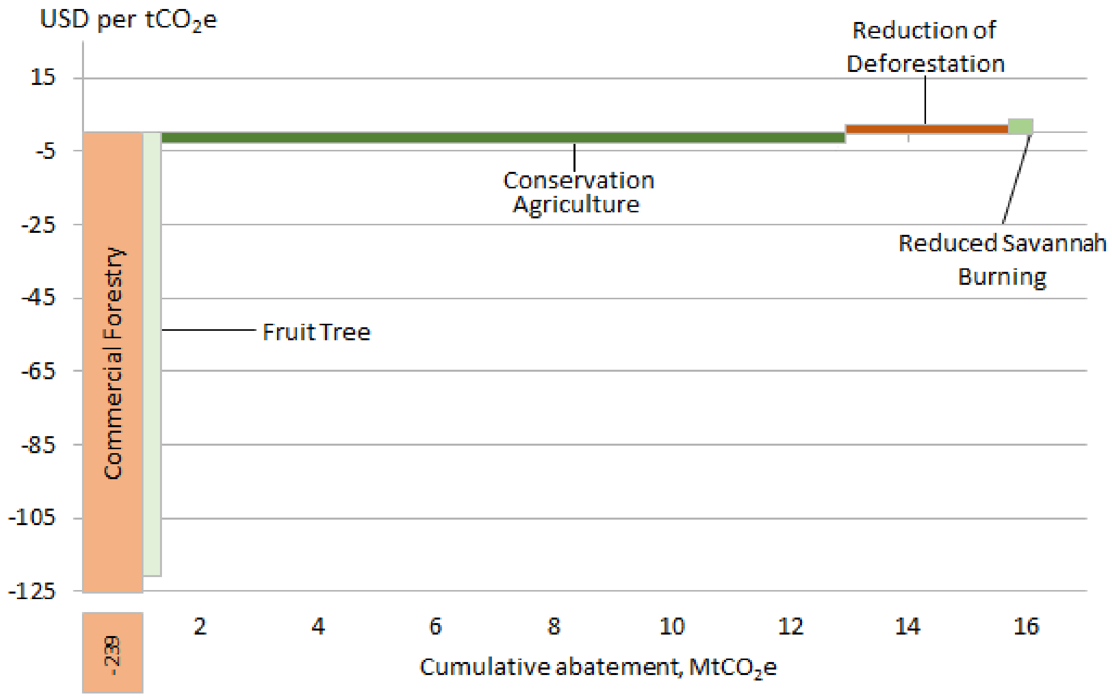


Figure 5-6: Marginal abatement cost curve for AFOLU, 2030

Interestingly, 80.22% of the mapped abatement potential allows reducing GHG emissions while increasing economic wellbeing at a discount rate of 6% per annum. However, it is important to note, that not even the most attractive activity (commercial forestry, with MAC of -239.35 USD) is financially viable with the current lending rate.

5.4 Roadmap of Actions

Figure 5-7shows a summary timeline for the development and implementation of each of the actions proposed to implement the LEDS in the AFOLU sector.

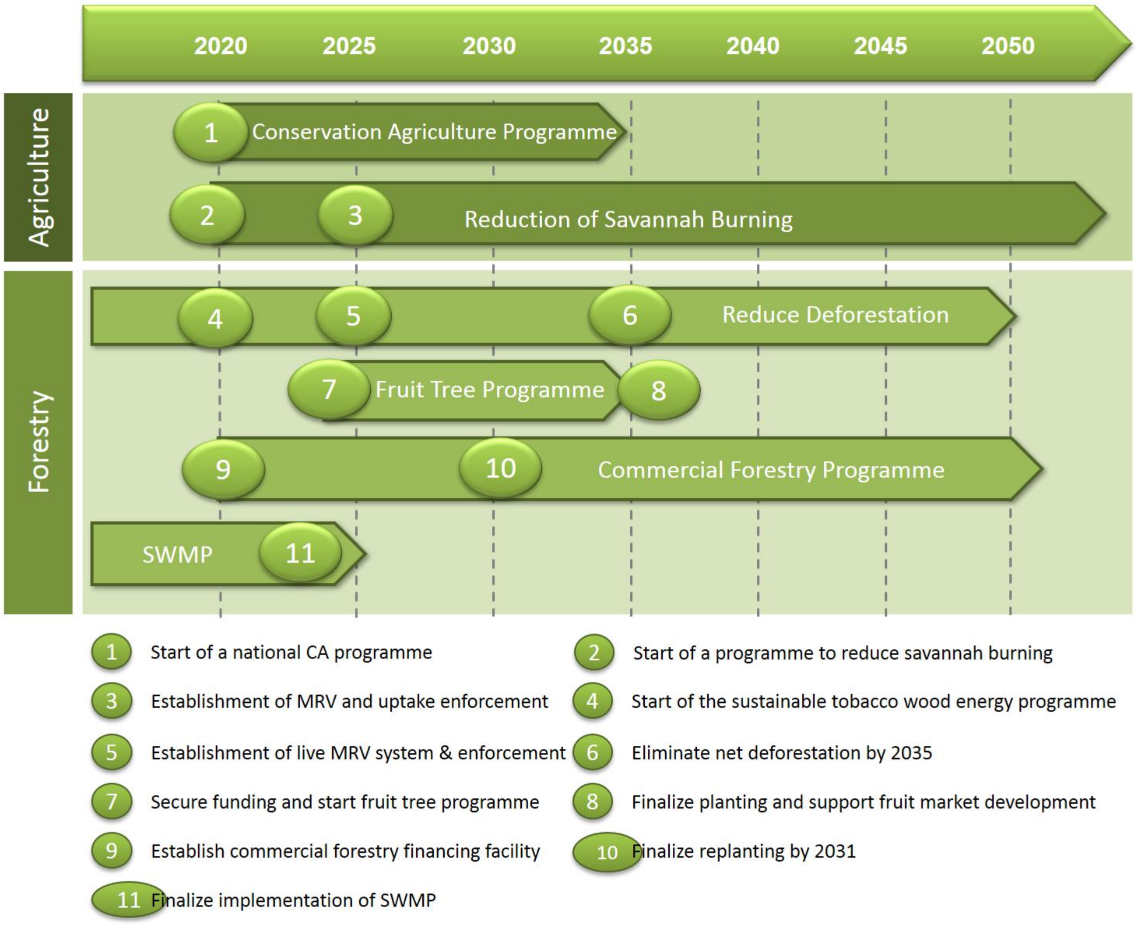


Figure 5-7: Timeline of mitigation actions to support LEDS implementation within AFOLU

6 Waste

6.1 Business-as-usual Emissions

In 2006 the Waste sector contributed 0.75MtCO_2e (3.42%) to the national GHG 22.0MtCO_2e. In Zimbabwe GHG emissions from the Waste sector mainly arise from solid waste disposal sites (SWDS) and wastewater treatment in urban areas. Biological treatment of solid waste, waste incineration and open burning of waste do not contribute much to the GHGs in Zimbabwe, and data on these waste management practices is scanty. The main gases produced from waste handling are CH_4, CO_2 (fossil origin), N_2O, NO_xs and non-methane volatile organic compounds (NMVOCs) (IPCC, 2006). The TNC only covered CH_4 from the Waste sector. Solid waste management was a key category (excluding LULUCF) in 2006 and contributed 2.91%, while emissions from wastewater were 0.53% of the national total (GoZ, 2016). Greenhouse gas emissions from waste incineration and open burning of waste were not estimated in the TNC due to lack of activity data. The main climate change mitigation action cited in the TNC was integrated waste management, and to a lesser extent, waste to energy(GoZ, 2016).

The main policies and strategies that relate to waste management in Zimbabwe include; the National Climate Policy (see Section 3.4), National Climate Change Response Strategy (see Section 3.3.4), National Environmental Policy and Strategies, Integrated Solid Waste Management Plan.

The main activity drivers for waste in Zimbabwe are population growth, urbanization, GDP, unsustainable consumption and poor waste management practices. Waste projections were based on population growth. The mitigation options proposed in this strategy focus on Landfill gas (LFG) flaring and composting. A waste collection rate of 80% was assumed to be achieved in 2020 and later increasing progressively to 100% by 2050. The involvement of corporates and small and medium enterprises remains critical in all aspects of solid waste management.

Under BAU, GHG emissions from solid waste and wastewater are projected to grow from around 1Mt/yr in 2020 to around 2.5Mt/yr in 2050 (Figure 6.1). The emissions from wastewater are minimal and contribute approximately. 0.56% to the total BAU emissions by 2050.

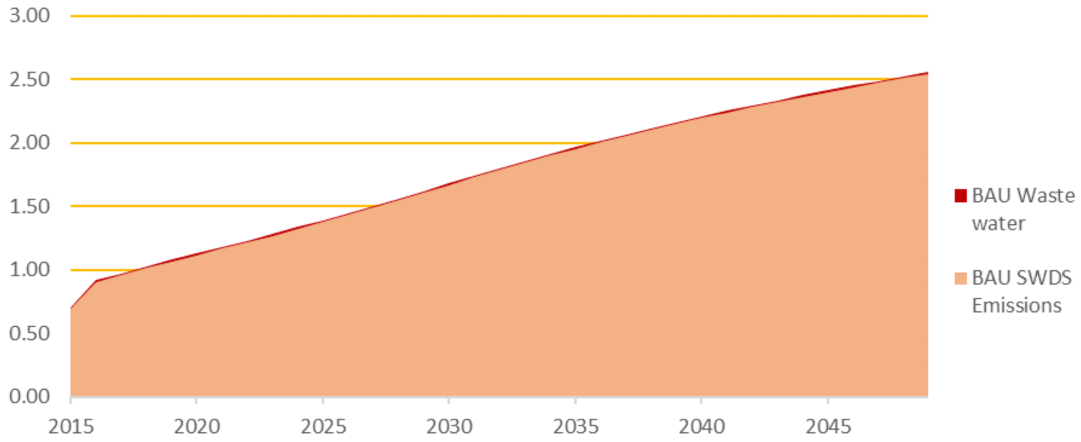


Figure 6-1: GHG emissions from Waste, historic and BAU projection to 2050 by source

2 Mitigation Measures

Mitigation measures identified include LFG flaring and composting of solid waste. Centralized composting facilities employing accelerated composting technologies were recommended taking into account the associated public health benefits. Although solid waste recycling was recommended in the Zimbabwe's Integrated Solid Waste Management Plan of 2014, the option was not considered in the LEDS as a climate change mitigation option in view of its limited effect in reducing GHG emissions from the Waste sector. Methane flaring from wastewater was not considered due to its limited application and unavailability of related data in Zimbabwe. Waste to energy was recommended for the cement industry as off taker. The related mitigation measures are included in the Energy section, Chapter 3.

The Waste sector CDM tool, Version 02.0.0, was used for climate change mitigation modelling for the Waste sector. The tool provides procedures for calculating CH_4 emissions from SWDS or prevented from SWDS[9]. The tool was developed for methane emissions mitigation from existing SWDS. The tool can be applied for mitigation of emissions from LFG flaring or avoided emissions from composting (UNFCCC, 2013). The existing SWDS from Harare, Bulawayo, Mutare and Gweru were considered.

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Methane gas flaring

LFG gas flaring is achieved through the combustion of gases produced from waste decomposition. Over 98% destruction of organic compounds from LFG can be achieved through the use of open or closed flares. Open flame flaring is cheaper and easier to operate, although it presents challenges in the control of the process. Enclosed flares, though expensive, provide better combustion efficiencies and control of LFG flaring.

The Waste sector LEDS mitigation action assumes that LFG flaring will be conducted in the SWDS. It was assumed that 72.6% of the methane generated would be collected and flared. The methane flaring projects will be implemented in one city after

[9] https://cdm.unfccc.int/methodologies/DB/SU1HDJCPVB9QB8D54SGUARSQVLTJUG

the other, starting with Harare in 2020, followed by Bulawayo in 2021, Mutare in 2022 and Gweru in 2023. A positive marginal abatement cost of \$0.74/tCO_2e was obtained from the economic analysis conducted. The positive marginal abatement cost showed that LFG flaring could be justified based on climate change mitigation and not on return on investment.

Composting

The residual emissions from the 72.6% abated through LFG flaring were targeted to be removed through composting, hence, composting targets avoiding generation of CH_4 at SWDS from new waste generated.

Figure 6.2 presents the BAU emissions and mitigation option from flaring and composting. The marginal abatement cost analysis on an internal rate of return (IRR) of 12.75% revealed that composting is financially viable (Figure 6.3).

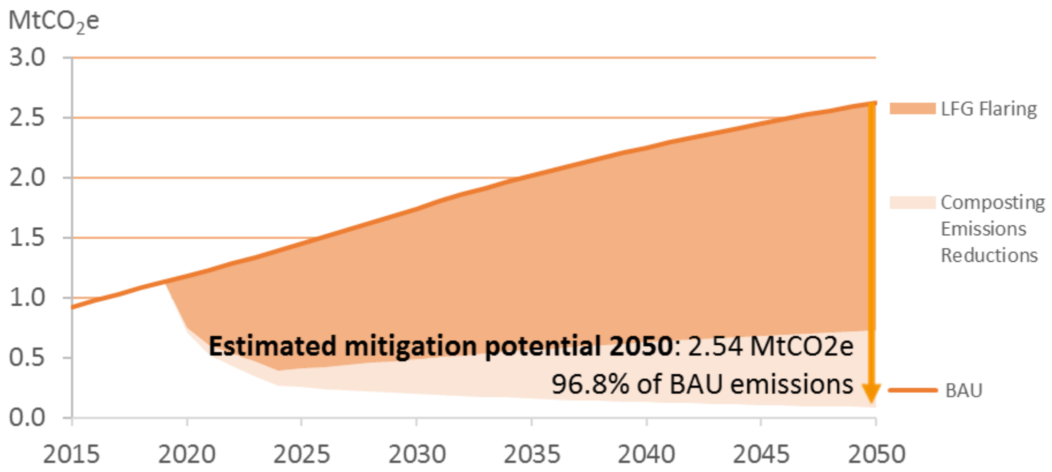


Figure 6-2: GHG emissions projections from waste under BAU and with mitigation

Solid waste recycling

The ISWMP (2014) for Zimbabwe includes the option of recycling. Since recycling addresses waste management activities upstream, the option was not considered in the mitigation analysis in the LEDS.

Recycling assists in removing any contaminants from waste so as to render such waste reusable, or returned to the economic mainstream in the form of raw materials. The environmental concerns on recycling include the need to reduce waste at dumpsites. Financial, economic and social motivation factors for recycling border on reduction in waste handling cost and revenue generation.

3 Economic Analysis

The Waste sector MACC (Figure 6.3) indicates that significant CH_4 emissions can be abated through composting, giving financial gains. Further mitigation can be achieved with flaring, which gives better mitigation option, but with no financial benefits. Flaring can therefore, be justified entirely on climate change mitigation reasons.

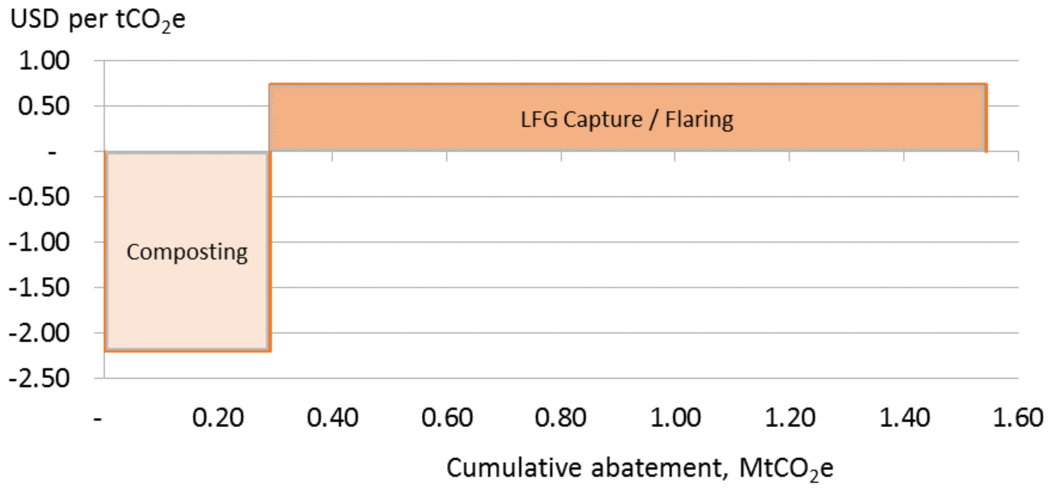


Figure 6-3: Marginal abatement cost curve for Waste, 2030

4 Roadmap of Actions

Figure 6-46.4 shows a summary timeline for the development and implementation of each of the actions proposed to implement the LEDS in the waste sector.

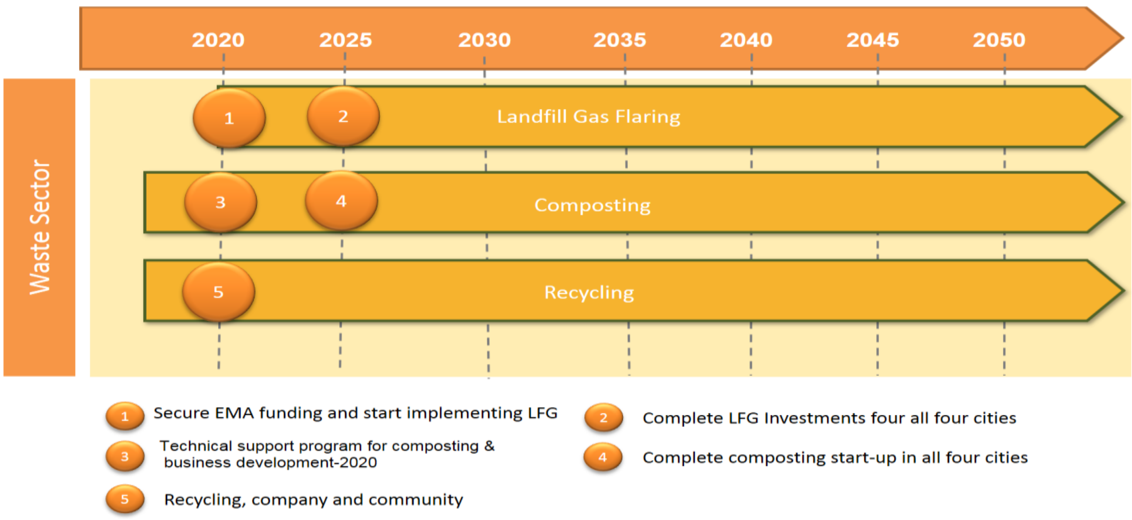


Figure 6-4: Roadmap for the Waste Sector

7 Bringing it all together

7.1 Summary of BAU and MIT Scenarios

Zimbabwe, as a developing country, is projected to experience decades of economic growth with its GDP increasing from 19.6 billion USD in 2020 to 119.1 billion USD by 2050, based on constant prices (ZIMRA, 2019). This corresponds to an increase of 733% over three decades. Economic development is driving Zimbabwe's BAU emission increment.

Since the beginning of its GHG emission inventory reporting in 1998 (Initial National Communication), the GHG intensity of Zimbabwe's economy has been decreasing. This is also reflected in Zimbabwe's BAU emission scenario. **Figure 7-1** illustrates the aggregated BAU scenario up to 2050. The GHG emissions are projected to increase from 36.58 $MtCO_2e$ in 2020 to 65.28 $MtCO_2e$ in 2050. This corresponds to an increase of 207% over three decades.

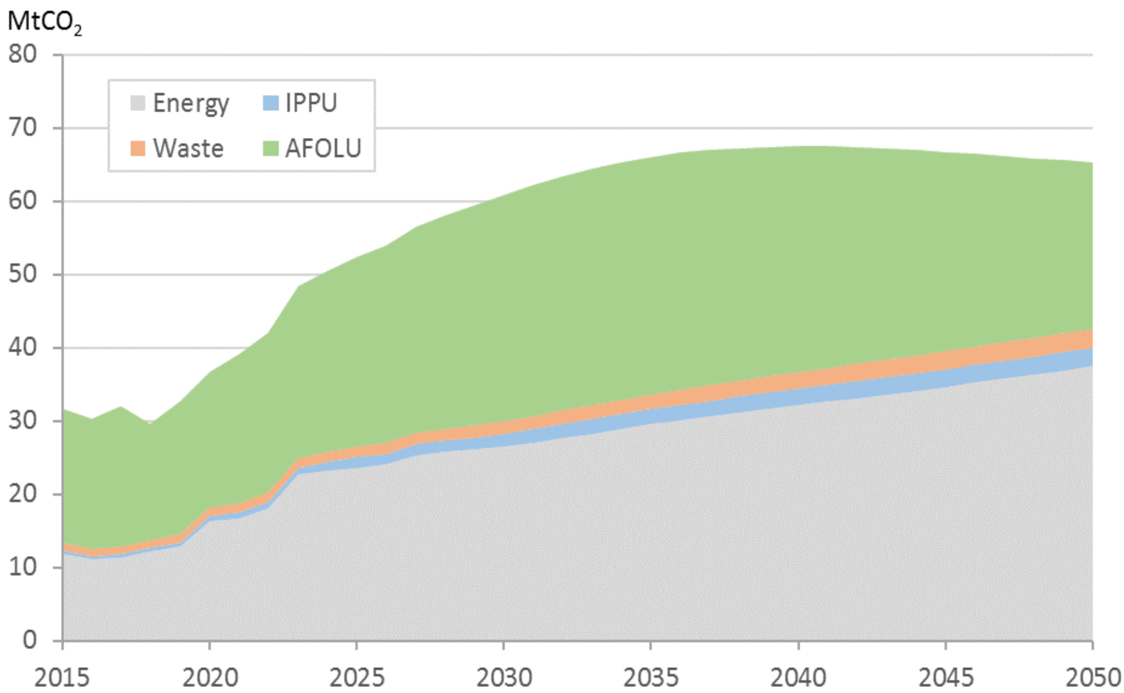


Figure 7-1: Economy wide BAU Scenario

Chapters 3 to 6 describe the mitigation potential from the 38 different mitigation measures identified in the strategy. These mitigation measures have the potential to significantly reduce Zimbabwe's GHG emissions below the BAU scenario despite strong forecast economic growth.

Figure 7-2illustrates Zimbabwe's mitigation potential, aggregated according to the IPCC sector classification. The abatement potential is estimated to be up to 33.2 $MtCO_2e$ by 2050, which corresponds to around 50% of BAU GHG emissions in that year. The largest abatement potential is expected from the AFOLU sector (46.9% of the total abatement potential), followed by the energy sector (44.4%), waste (6.1%), and the IPPU (2.7%).

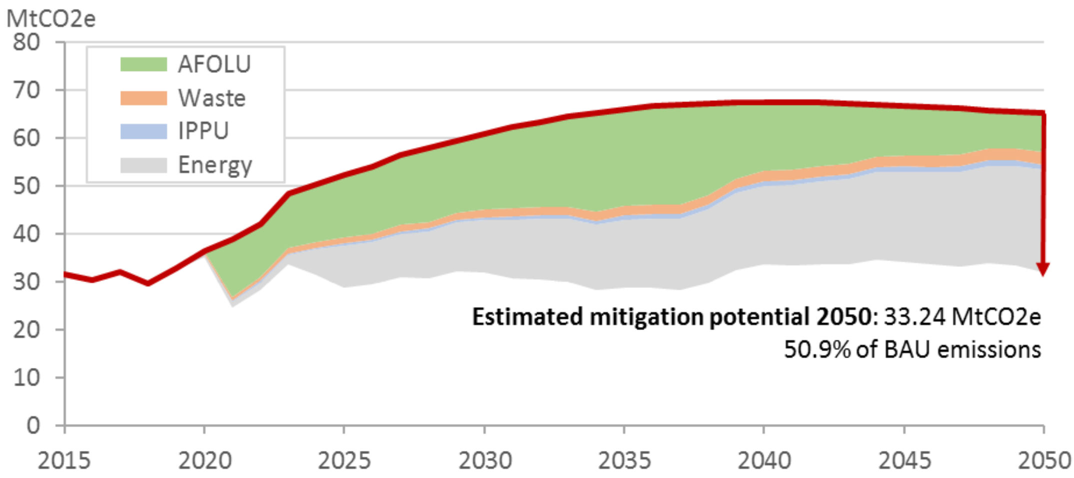


Figure 7-2: Economy wide MIT Scenario

It is equally important to consider the trends of the mitigation contributions by sector over time. The AFOLU abatement potential is driven by Conservation Agriculture, which leads to a substantial soil organic carbon (SOC) increment in the years following the change of management regime. However, as SOC reaches a new dynamic equilibrium state, the annual sequestration rates diminish.

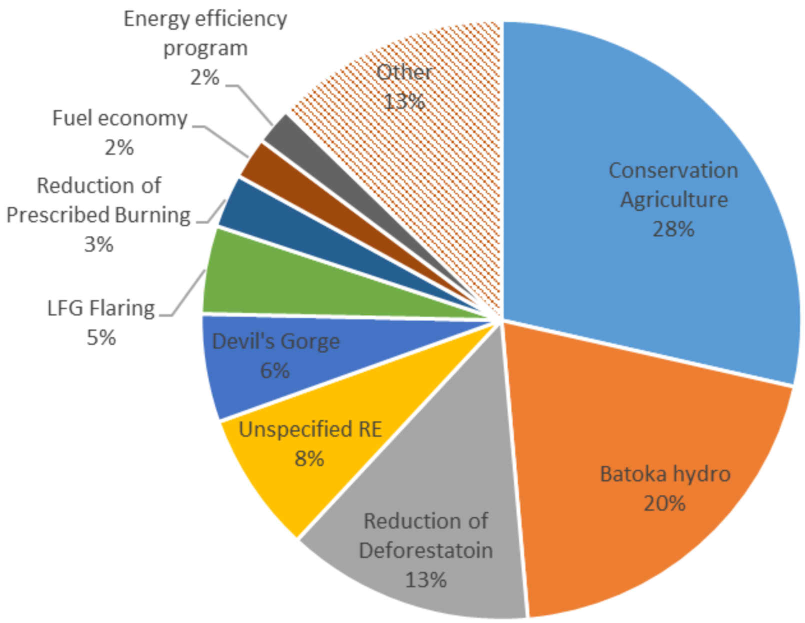
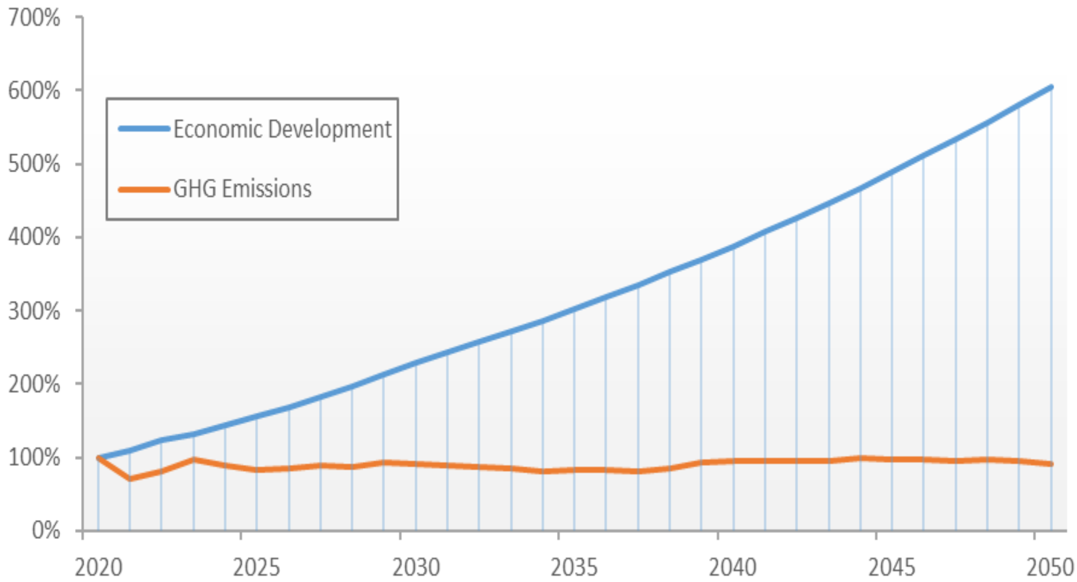


Figure 7-3: Contribution of top ten mitigation options

The energy sector, on the other hand, is dominated by slow turnover rates related to long equipment lifetimes. Mitigation measures such as introducing fuel economy standards for the transport fleet or promoting renewable energy projects face comparably small penetration rates, although their abatement potential increases over time. These policies and mitigation technologies play a central role and may contribute substantially towards decarbonisation in the long-term.

Figure 7-3 shows the mitigation potentials of the top ten mitigation measures. Conservation agriculture is expected to contribute the largest share with 28%, followed by the Batoka hydro power plant (20%). Other renewable energy projects (Devil's gorge, further RE measures) may contribute another 8% and 6% respectively.

The aggregated mitigation scenario shows the potential to decouple Zimbabwe's GHG emissions from economic development. Zimbabwe has very low GHG emission levels. Per capita emissions are around 1.82 tCO_2e/person compared to the world average of 6.27 tCO_2e/person. **Figure 7-4** illustrates how Zimbabwe's mitigation scenario manages to cater for needed economic development while maintaining the country's total GHG emissions at current levels.



Note: Economic development reflects forecast growth in real GDP

Figure 7-4: Decoupling Economic Development from GHG Emissions under the MIT Scenario

7.2 Financing Strategy

Zimbabwe aims to establish a national low emission development financing strategy in order to achieve low carbon development. This section describes the climate financing strategy framework that supports the ambitious mitigation measures outlined in this strategy.

Climate Financing Strategy Zimbabwe's financial crisis (2015-2019) led to a very high cost of capital (e.g. the prime lending rate amounted to 18% p.a. for 2018). The high costs of capital result in investments being made in GHG intensive technologies. These include the purchase of cheap and inefficient vehicles, investments in diesel and coal power plants and use of energy intensive and inefficient equipment. Such decisions are guided by high discount rates, which lead to investment decisions with low capital expenditure (Capex) while the high operating expenses (Opex) over the equipment lifetime is discounted by high compound interest.

In such an environment, a climate financing framework offering concessional lending for low carbon investments can have significant impacts, including:

- Improving national economic development;
- Improving economic competitiveness in the mid to long-term;
  - Reducing energy use and import dependency; and
  - Reducing GHG emissions.

Against this background, Zimbabwe's LEDS reflected by the mitigation scenarios described in chapters 3 to 6 is closely linked to the development of a Low Emission Development Financing Facility, which offers concessional lending reflecting the SDR. The SDR of 6%, suggested by the World Bank for infrastructure and energy projects in Southern Africa (WB, 2016b), was applied consistently in the analysis.

Zimbabwe's financing strategy is based on the following key elements: also se Figure 7.5):

- **GHG Mitigation Potential.** Abatement options which are predominantly economically viable, in which benefits (e.g. fuel savings, employment benefits) outweigh costs (e.g. costs of equipment, clean technology and infrastructure) were identified. The sectoral MACCs do not therefore represent all technically possible options, but focus more on economically viable abatement options. The sectoral analyses were undertaken from a socio-economic perspective considering a SDR of 6% and the economic cost of fuel and electricity, among other factors.
- **Amendment of Policies.**. It is envisaged that appropriate policies will guide the private sector to invest in mitigation measures. For example, MEPS will prescribe minimum standards for Air Conditioners (ACs) and lighting devices, among others. The private sector would be required to purchase only equipment, which is compliant with these standards (cp. Annex II).
- **Financing Instruments**. To facilitate the implementation of the LEDS, it is essential that a suite of suitable financing instruments is available. These must be designed to reduce the gap between the SDR and the commercial lending rate to a level where it becomes financially attractive for the private sector to invest in mitigation measures instead of continuing with BAU practices. According to the analysis if the lending rate is reduced to below 10%, most projects will become financially attractive (Annex IV).
- **Private Sector Investment**. Combining policy amendments with suitable financing instruments will enable the private sector to invest in economically and financially viable abatement measures. It is therefore envisaged that the bulk of the investment required under the LEDS will be covered by the private sector avoiding further burden on Zimbabwe's national budget.

The implementation of this strategy will create a win/win scenario where investments in mitigation measures will result in reduction of GHG emissions by around 50% against the BAU scenario. In the long term the expected increased competitiveness will result in the overall improvement in economic performance, and environmental and social well-being

Low Emission Development Financing Facility

The vision for funding the implementation of Zimbabwe's LEDS is based on the use of a national, economy wide Low Emission Development financing facility, hosted by the Infrastructure Development Bank of Zimbabwe (IDBZ) and funded by the Green Climate Fund (GCF), with substantial contributions from the GoZ.

As of 2019, the IDBZ was in the process of becoming accredited under the GCF. IDBZ started the accreditation process in 2017, submitted its application to the Green Climate Fund early 2019, and was working on the amendment of its application by the end of 2019. The process is estimated to be completed by July 2020. At the same time, IDBZ is working with a team of consultants on the design of a national financing facility. As shown in Table 7-1.1, the mitigation analysis indicates an accumulated investment need of 6.3 billion USD by 2030 to support the implementation of economically viable abatement activities.

Table 7-1: Summary of Investment Needs

	No	Mitigation Measure	NPV (in M USD)	MACC (in USD/ tCO_2e)	Accumulated Investment Need up to 2030 (in M USD)
Energy	1	On-farm biogas	175.01	-28.98	82.95
	2	Solar pumping for irrigation	517.32	-94.44	378.98
	3	Off-grid solar electrification	88.81	- 138.46	250.89
	4	Energy Efficient lighting	106.68	-224.34	4.00
	5	Rooftop solar (commercial)	128.43	-216.02	40.00
	6	Minimum Energy Performance Standard	39.31	-98.54	18.64
	7	Solar LED street lighting	25.12	-86.69	20.76
	8	Solar water heaters	489.69	-144.45	90.08
	9	Reactive Power Correction	123.96	-28.76	36.06
	10	City of Harare-Mbarebiogas plant	0.15	-26.55	0.26
	11	City of Bulawayo biogas plant	2.91	-24.83	3.30
	12	City of Harare-Firle biogas plant	11.62	-24.79	13.20
	13	Devil's Gorge	238.36	-3.95	2,250.00
	14	Batoka hydro	1,123.65	-6.20	2,600.00
	15	Solar IPPs	- 1.91	4.74	13.28
	16	Rural Electrification Fund micro-grids	-0.14	10.85	2.66
	17	Zimbabwe Power Company solar plants	-96.61	11.02	354.00
	18	Unspecified Renewable Energy projects	N.A.	-1.91	-
	19	Energy efficiency programme	1,779.48	18.24	341.17
	20	Electric motors (mining)	0.83	-8.01	0.32
	21	National Railways of Zimbabwe Rail electrification	-349.47	102.20	801.00
	22	Electric Vehicles	-193.81	17.71	367.37
Energy	23	Public transport	N.A.	12.00	N.A.
	24	Fuel economy	2,051.67	-100.83	510.87
	25	Biodiesel programme	2.94	-0.92	299.70

	No	Mitigation Measure	NPV (in M USD)	MACC (in USD/ tCO_2e)	Accumulated Investment Need up to 2030 (in M USD)
IPPU	26	Clinker substitution: fly ash	12.42	-16.98	0.64
	27	Clinker substitution: Blast Furnace Slag	2.86	- 3.91	9.22
	28	N_2O decomposition	- 2.23	0.70	2.84
	29	Coke substitution: Steel	- 226.21	25.86	-
	30	Coke substitution: FeCr	-81.96	27.86	-
Waste	31	Landfill Gas Flaring	- 31.79	0.74	14.36
	32	Composting Emissions Reductions	25.91	- 2.20	104.51
	33	SWMP	- 2.85	1.37	7.33
AFOLU	34	Reduction of Deforestation	N.A.	0.78	42.48
	35	Fruit Tree planting	437.17	-119.77	- 661.34
	36	Commercial Forestry	183.21	- 239.35	- 123.77
	37	Conservation Agriculture	549.83	- 2.13	3.14
	38	Reduction of Prescribed Burning	N.A.	3.50	1.31
		Total - All Projects	7,130		7,880
		Total – Projects with positive NPV	8,116		6,273

The following institutional setup is envisaged:

- The financing facility is hosted under the IDBZ, which manages the available funds transparently and according to GCF approved standards.
- The facility will comprise loans provided by GCF, Africa Renewable Energy Initiative, the Africa 50 Infrastructure Fund as well as national pension funds
- The financing facility also covers grants which provide funding for
  - i) developing bankable feasibility studies (revolving fund); and
  - ii) high priority mitigation measures, which are not financially viable (e.g. a programme to reduce deforestation, implementation of LFG measures, etc.).
- If mitigation measures fall under IDBZ's core mandate (agricultural investment, energy projects), stakeholders may borrow directly from IDBZ. If mitigation measures do not fall under IDBZ core mandate, borrowing will be arranged through the operations of commercial banks (loans for energy efficient equipment, electric vehicles, etc.). Both pathways will result in long-term tenure.
- The financing facility will be co-funded by the GoZ, which provides the proceeds of the carbon tax and the tobacco tax. Currently the government is collecting a carbon tax of 3USDc/l on gasoline and diesel. This is equivalent to a weighted average carbon tax of 12.24 USD/tCO_2e. The GoZ may increase the carbon tax in the mid and long term. The accumulated tax revenue by 2030 is estimated to 1,282 M USD. This will be complemented by the proceeds of Zimbabwe's tobacco tax, which is expected to contribute 42.48 M USD by 2030 (see Annex X for details on these estimates). The proposed Climate Fund will also be used for co-funding by GoZ.
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Figure 7.5 shows Zimbabwe's Low Emission Development Financing Facility setup

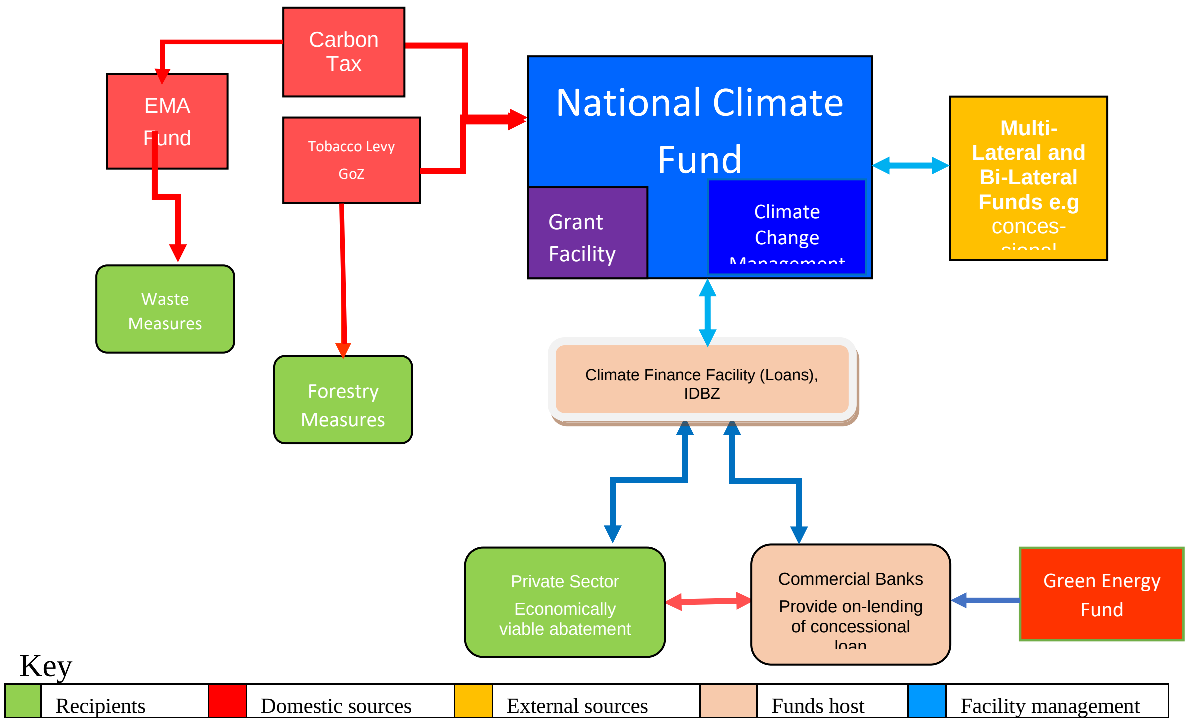

Figure 7-5: Financial Intervention Logic

It is envisaged that the incorporation of a suitable financing facility will trigger economic development and related improvements to the livelihoods of Zimbabweans. List of References

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9 Appendices

Annex I: Reduction of Technical Losses in the Transmission- and Distribution System

This sectoral analysis investigates the emission reduction potential due to Reactive Power Compensation as means to reduce the load dependent technical losses of the transmission and distribution (TD) system. The implementation shall be supported through a regional Article 6 Pilot Programme, which is currently being negotiated between the German Federal Ministry for the Environment and the Government of Zimbabwe and three other Sub-Saharan African countries.

Discussion of Key Parameters

Real power, apparent power and reactive power

Electric power comprises two components, real power (measured in kilo Watts (kW)), which produces work, and reactive power (measured in Kilo Volt Ampere Reactive (kVAr)) necessary to generate magnetic fields specially required for rotating electrical equipment. The two components together constitute the apparent power measured in Kilo Volt Ampere (kVA). The ratio of useful power (in kW) to total power (in kVA) is known as Power Factor (PF) which range from 0 to 1, while typical industrial power factors range from 0.4 to 0.9 (Hofmann et al, 2012).

Apparent power losses due lack of reactive compensation at the demand side

A utility must generate apparent power (kVA), which includes reactive power that increases if customers are operating equipment with a low power factor. Therefore, if the transmission and distribution (TD) system is hampered by high technical losses part of the apparent power is lost.

Information on technical losses in TD systems in Africa is scarce. Tallapragada et al. (2009) conducted a benchmarking exercise of Sub-Saharan Africa (SSA) power utilities. Eleven companies reported their technical losses (i.e. transmission and distribution), and the average amounted to 11.54% of total apparent power. The World Bank (2018) reports total losses averaging 25.48% (including losses due to theft) for 31 out of the 50 SSA countries. In general, low power factors lead to high-energy losses and therefore unnecessary GHG emissions. A common reason for poor power factor is operation of inductive loads such as motors at less than their rated capacity. Power factor correction occurs when customers generate their own reactive power for inductive loads from capacitor banks as depicted in Figure 9-1.

Reactive Power Compensation equipment

The objective of installing Reactive Power Compensation (RPC) equipment at the premises of a Maximum Demand (MD) electricity customer is to reduce the reactive power to be supplied by the TD system thereby reducing the technical losses. Typically, equipment is installed after the utility meter, i.e. downstream. RPC equipment consists of:

- A capacitor bank which stores reactive power, instead of sending back onto the TD system;
- A high-speed switch, e.g. a thyristor control, which allows the dispatch of reactive power downstream as needed.

The capacitor bank and the switch are built into one unit with appropriate cooling (active/passive depending on size of the RPC equipment needed).

Incentives for reactive power compensation

The electricity tariffs of large electricity customers typically include a financial incentive to reduce reactive power demand or for improving power factor through reactive power compensation. Large electricity customers (customers with a peak demand, for example those above 300 kVA) operate under a MD tariff. The tariff foresees payments for i) power consumed (i.e. kWh/month) and ii) a maximum demand charge, which is typically related to the highest power offtake (in kVA) over a defined period, for example a 30-minute period for one month.

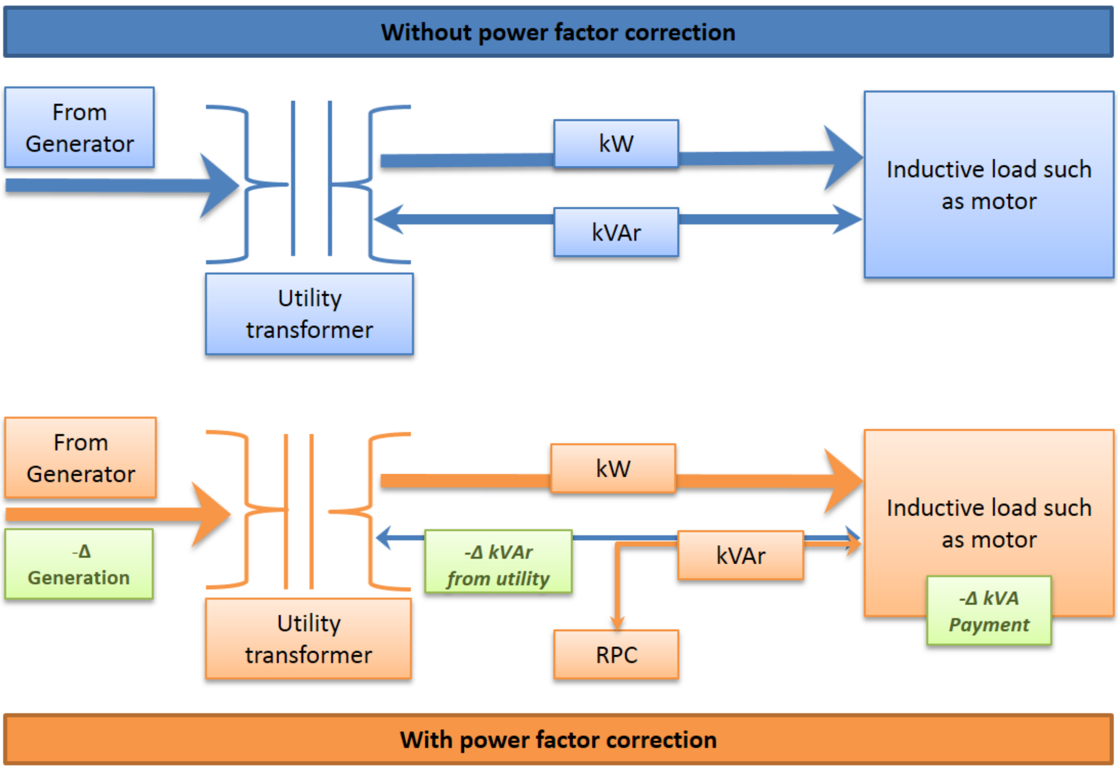


Figure 9-1: Concept of Reactive Power Compensation

Political economy / weak financial standing of utilities leads to lack of investment in TD system

Under optimal conditions power utilities would install RPC equipment at their substations, thus reducing the load and hence the technical losses of the TD system. Investment in , cost-efficient maintenance systems and upgrading of the TD systems is low in SSA. This may be attributed to technical and financial constraints and to some extent due to non-cost reflective tariffs.

A World Bank study (Trimble et al., 2016) investigated cost reflectiveness, comparing the operational and capital expenditures of generation and distribution with the average price of kWh billed for 39 Sub-Saharan African countries from 2010 to 2015. The results indicate that only two countries (i.e. Seychelles and Uganda) operate on cost reflective terms recovering both, operational- and capital expenditures. The cash collected in 19 countries barely covers operational expenditures, but is insufficient to cover any significant new capital layout. Hence, many SSA countries suffer from poor TD infrastructure and resultant technical losses.

GHG accounting elements of an RPC programme

The proposed RPC programme makes use of GHG accounting elements from methods designed and internationally recognized and approved for the UNFCCC Clean Development Mechanism:

- An approved Clean Development Mechanism methodology, AMS-II.T.: Emission reduction through reactive power compensation in power distribution network, Version 1 (CDM EB94, Annex 8) to quantify the baseline emissions and emission reductions due to power factor improvements;
- Based on the grid expansion pathway of the mitigation scenario, the specific grid GHG intensity over time was determined (i.e. tCO_2/MWh, per year).
- A consideration of the forecast of electricity demand as harnessed for Zimbabwe’s power system planning was made, assuming that technical losses and the system’s weighted average power factor remains constant, while the system expands.
- . The GHG reduction potential from RPC intervention was determined by;

i) selecting those interventions which have a Payback-Period (PBP) below the lifetime of the equipment, and

ii) disregarding the cost of finance in the economic analysis.

Applying UNFCCC approved methodologies ensures a consistent, transparent and reproducible estimation of GHG emissions.

Sectoral Abatement Potentials

Data sets and data treatment

For analysing the sectoral abatement potentials, the Zimbabwe Electricity Transmission and Distribution Company (ZEDTC) provided the data for use in analysing sectoral abatement potentials. **Table 9-1**: Overview on Data Set provides an overview on the country data set. In total, RPC interventions at 14,260 customers using 19,923 data points was assessed.

Table 9-1: Overview on Data Set

Distribution Customer	No of Data Points	10,932
	No of Customers	841
Transmission Customer	No of Data Points	107
	No of Customers	14

Where data sets exhibited gaps and/or inconsistencies, the data was treated as follows:

- For all customers, where kWh was available, but kVArh was missing, kVArh was estimated using the average PF;
- For all customers, where kVArh was available, but kWh was missing, kWh was estimated using the average PF;
- For all Medium Voltage (MV) customers, where the data set indicated a load factor above 1, the peak demand was recalculated using a default load factor of 0.6;
- Literature indicates that lowest power factors are around of 0.4 for certain industries (Hofmann et al, 2012). For all customers where the data showed a PF<0.3, this was assumed to be a metering error. Hence, for those customers, thekVArh was calculated based on minimum PF of 0.3, which is conservative;
- Customers which had only peak data were removed from the database. Technical losses

The determination of technical losses is essential for the overall estimation of abatement potentials, as it allows the determination of losses (reactive power) at a given power factor. The TD loss figures for Zimbabwe were made available by Zimbabwe Electricity Regulatory Authority (ZERA).

Table 9-2: Technical transmission- and distribution Losses

Transmission Losses (in %)	Technical Distribution Losses (in %)	Total Technical Losses (in %)
3.27%	15.58%	19.36%

Technical transmission losses of the transmission network amount to 3.3% while the losses of the distribution system amount to 15.58% as shown in Table 9.2. Consequently, 19.36% of reactive power supplied to the final customer is lost(year).

Average power factors

The weighted average PF for distribution customers[10] was 0.85, whereas the weighted average PF for transmission customers[11] was 0.90. The weighted average PF is always higher than the average PF.

Table 9-3: Overview Power Factors in selected Countries

Distribution Customer	Average PF	0.79
	Weighted average PF	0.85
Transmission Customer	Average PF	0.85
	Weighted average PF	0.90

Determining equipment size and costs per customer

Complementing the CDM methodology, the appropriate RPC equipment size (in kVAr) based on a customer's power demand and its power factor was determined as follows:

$$kVAr = kW\left(\tan\left(Arc\cos(Cos\emptyset_{BL,i,y})\right) - \tan\left(Arc\cos(Cos\emptyset_{PJ,i,y})\right)\right)$$

Where:

$kVAr$	Reactive power, in kVAr;
kW	Average power, in kW;
$Cos\emptyset_{BL,i,y}$	Power factor prior to reactive power compensation; i.e. original PF
$Cos\emptyset_{PJ,i,y}$	Power factor after reactive power compensation i.e. target PF.

Equation 9.1: Determination equipment size and costs per customer

Economically available abatement potentials

Technical losses in the transmission and distribution system amount to 19.36% (i.e. without theft). The results indicate that the economically viable RPC potential would lead to reduction of technical, load dependent losses in the amount of 175 GWh/yr. The reduction of energy losses enables the utilities to sell more power using the same generation capacity and the same amount of fuel. In the short term, this could improve power utilities / power distribution company cash flow.

Zimbabwe has a tariff methodology in place which considers system losses to determine cost of electricity.The reduction of technical losses could aid in lowering the cost of electricity or avoid the need to increase electricity tariffs.

Table 9.4 provides a summary of some of the benefits of RPC introduction.

[10] Distribution customers are those, which are directly connected to typical distribution voltage levels of the grid system.

[11] Transmission customers are those, which are directly connected to typical transmission voltage levels of the grid system.

Table 9-4: Savings from TD loss reduction measures

Energy Saving (MWh/yr.)174,776	Energy Cost Saving (USD/yr)	Reduction of MD Charges (SD/yr.) 4,879,	Total Savings	Investment Potential (USD)	Emission Reduction Potential (tCO_2/yr.)
	17,477,600	106,511	22,357,472	15,302,485	

According the results in Table 9.4, the project is economically viable with a simple pay-back period of approximately 0.7 years.

Zimbabwe has a comparatively high prime lending rate, which also may render interventions with short PBP financially unattractive. The prime lending rate indicates the interest rate, at which the premium customer segment may access debt capital from local commercial banks, some of which re-finance elsewhere. Zimbabwe's prime lending rates amounts to 18.0% (RBZ, 2018) per annum. Small and Medium Enterprises (SME) are typically not part of the prime customer lending segment in in Zimbabwe and most SSA countries. The high lending rates make RPC interventions financially unviable. A suitable financing instrument is required to unlock the economically viable RPC potential and realize its full benefits for Zimbabwe.

Financing Strategy

Combining 'push' and 'pull' components to maximize widespread uptake by private sector

The 'push' component' comprises potential amendments of the regulatory framework in Zimbabwe aiming at stimulating subsector-specific investments of the private sector at no cost for the government:

- Adjustment of national Grid Codes about higher mandatory power factor provisions;
- Improvement of the kVA payment structure;
- Introduction of a kVArh related scheme of penalty and reward payments.

Such amendments could lead to cost efficiency, i.e. parity of generation and energy saving costs (**Figure 9-2**). In-country stakeholder consultations showed, that regulatory measures are only acceptable for the private sector and implementable along with financial and technical support (the 'pull'). The fundamental programme funding structure therefore addresses main non-policy barriers to implementation:

- High capital cost that prevents investing in RPC energy efficiency by industries,
- Insufficient competitiveness compared to companies' performance targets and
- Potential lack of awareness- and technical capacity in the country.

The 'pull' component is low cost finance from domestic commercial lenders. Local currency loans are preferred as exposure to Foreign Currency further increases the cost of capital, the burden of which is almost always placed in the borrower. The low-cost finance is made up of a blend of 3 sources

i. carbon (results-based) finance,
ii. export trade cover or risk insurance and
iii. commercial bank debt, which can be augmented with Development Finance Institutions debt as needed.

The blend is essential to achieve the lending rates needed and Export Credit Agency (ECA) support is key as it can significantly reduce the overall cost of funding. ECAs can typically extend up to 85 % of the export contract value for eligible exporters

i. as an exporter (supplier's credit);
ii. through a commercial bank in the form of trade related credit provided either to the supplier or to the importer (buyer's credit); or
iii. directly by another export credit agency of the exporting countries. This allows commercial banks to significantly adjust their risk assessment on the finance and thereby lower the cost of lending well below domestic rates.

Financing instrument structure

Some basic parameters determine the design of the financing instrument. The RPC equipment to be installed must adhere to defined quality standards[12]. and shall have a rated lifetime of 15 years. The financing instrument applied shall enable economically viable investments in RPC installations, while at the same time ensuring rapid uptake of the technology at maximum scale. For this, a financially attractive offer must be made to the MD customers, which allows for loan pay back within a maximum of 6 years from savings accruing from reduced kVA-related maximum demand payments, thus allowing the customer to profit from the installation for the remaining lifetime.

The financing structure required for reducing capital cost applies a blended finance approach:

i. A local development bank sets up and administers a financing vehicle for onlending to stakeholders.
ii. The bank enters into an agreement with a national ECA to reduce the cost of senior funding. ECA conditions depend on the origin of the equipment and services determining the cost of the ECA premium; the amount that is covered (maximum 80% of the export contract value) and on the rating of the recipient country. For all four countries ECA insurance comprising commercial (payment), political (change in government policy) and FX (transfer, convertibility) risks can be secured for a 6-year period.

[12] International standards: IEC 61642, IEC 61000-2-2, IEC 61000-2-4, IEC 61000-2-12, EN 50160 (in Europe), IEEE 519 (USA) and national standard such as NRS 048 in South Africa

iii. A DFI provides first loss funding for the uncovered portion (e.g. 20%). Respective cost of finance is substantially higher than the ECA covered portion of the funding, usually approximately 8% above the cost of ECA backed funding.
iv. In case up-front calculations reveal payback periods of more than 6 years, a carbon finance-based co-financing instrument will be employed, which considers the business case of each individual intervention in order to account for additionally issues and optimize carbon payments.

The proposed carbon finance approach aims to improve on the CDM, where prices for Certified Emission Reductions (CER) were set by supply and demand of CERs under uncertainty about the underlying marginal abatement costs of projects generating the credits. A carbon price of e.g. 10 USD/CER was paid irrespective whether e.g., a HFC-23 abatement project required 0.2 USD/CER (cp. IPCC/TEAP, 2005) or a hydropower project required 10 USD/CER (cp. Rahman et al., 2015) to become financially viable. This resulted in high producer rents for some project types, insufficient carbon incentives for other project types and an overall in a sub-optimal application of carbon finance.

Considering the substantial financing volumes required to achieve the objectives of the Paris Agreement and to implement the SDGs, it is generally understood that private sector involvement is needed with optimal use of public funding. Against this background, the carbon-financing concept is conceived around a sectoral analysis, which estimates the benefits and the costs of each single intervention and determines the marginal abatement costs of individual investments and the amount of carbon finance required to make the mitigation action financially viable, i.e. contribute to reaching a conditional emission mitigation target.

Carbon finance algorithm

The carbon finance algorithm has the following guiding principles:

- The analysis considers solely interventions which are economically reasonable, i.e. the RPC investment leads to net savings for the customer over the equipment lifetime of 15 years.
- Based on the combination of the six-year ECA coverage and DFI first loss funding, the financing vehicle offers average lending rates of around 9%.
- If payback periods including cost of finance, import, transport, installation and service are within the 6-years range, no carbon finance is required.
- In case the PBP for an individual intervention is above the range, the exact amount of carbon payment is determined that reduces the PBP to 6 years.
- This results into a carbon payment scheme, which tailors' individual results-based payments to meet the needs of economic viable interventions and reduce emissions of a whole sector.

The carbon finance needs required for capturing Zimbabwe's economically viable abatement potential is estimated at 3.26 M USD and will cover 333 customers.

Implementation

Energy Savings and GHG Emission Reductions

The RPC programme has the potential to reduce the load dependent technical losses by an accumulated 4,650 GWh by 2030 and 14, 898 GWh by 2050.

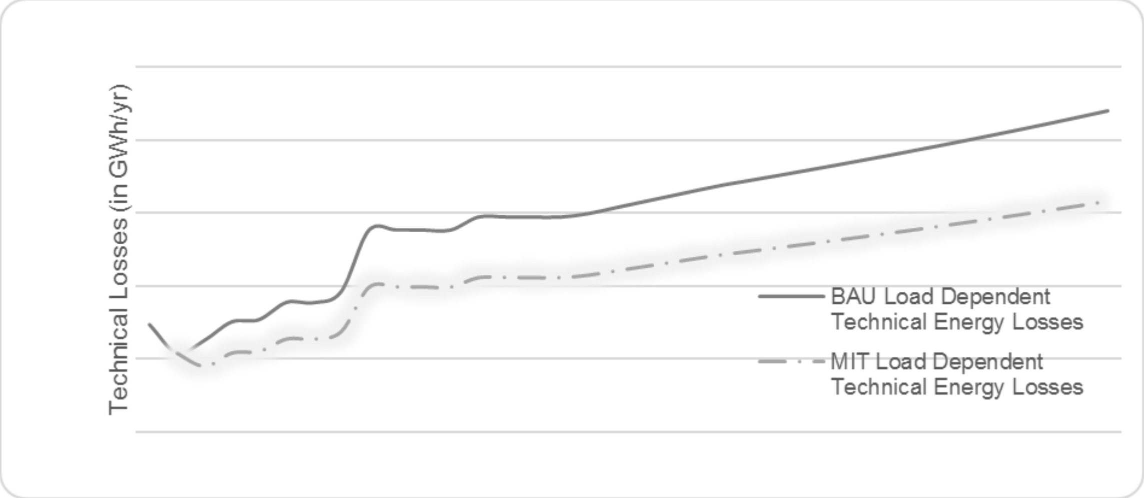


Figure 9-2: BAU and MIT Scenario, technical TD Losses

To estimate the abatement potential, the decreasing GHG intensity of power generation under the MIT scenario was considered.

The energy savings will result in additional, accumulated emission reductions of 4.31 M tCO_2 by 2030 and 11.97 $MtCO_2$ by 2050.

Co-benefits

By applying the blended finance approach, a minimum amount of carbon payments is required for leveraging large-scale private investments with a substantial abatement potential. This is estimated to trigger private sector investments in the amount of 36.06 M USD by 2030 and 53.94 M USD by 2050. Based on the current tariff, these investments will result in reduction of private electricity consumers maximum demand payments by 110.55 M USD by 2030 and 399.20 M USD by 2050. In addition (as technical losses are a parameter to determine the electricity tariff), the reduction of technical losses will reduce the electricity costs / the cost increases. Based on the current price of 10 USDc/kWh, the programme will reduce electricity costs by accumulated 195.95 M USD by 2030 and 1,429.75 M USD by 2050.

Annex II: Minimum Energy Performance Standard

Discussion of Key Parameter

Technology Scope

The model developed by the Green Cooling Initiative (GCI) (refer to Section 2.5) covers 12 equipment types ranging from residential split air conditioners (AC) and other technology options for room cooling (self-contained air conditioners, commercial ducted splits, multi splits) air conditioning in transport and domestic refrigeration. The GCI[13] was established through a project funded by the BMU's International Climate Initiative.

The GCI website provides information on inter alia AC stocks, their energy efficiency, as well as the related electricity consumption. GCI uses a sophisticated model to estimate AC stock and its electricity consumption considering population, GDP, urbanization, electrification and temperature (GCI, 2018).

The proposed model targets energy savings, GHG emission reductions and costs/benefits for ACs and assumes that the scope of MEPS will be extended to other household devices covering all major electricity consuming devices, such as, i) refrigerators and freezers, ii) audio and video equipment, iii) washing machines, iv) tumble dryers, v) washer-dryer combinations, vi) dishwashers and vii) electric ovens.

Time Scope

The GCI model covers a time-period starting with the year 2000 up to 2050. Having a long-term perspective is not only compliant with the requirements of the LEDS process, but equally facilitates an understanding of the expected exponential growth of AC sector in Zimbabwe in the next three decades, which underlines the importance of appropriate policies and financing instruments to guide this development.

Scope of GHG Emissions

The extreme winter and summer temperatures resulting from climate change will increase the demand for heating and cooling. The use of air conditioning systems results in direct and indirect GHG emissions. Direct GHG emissions relate to the production, use and disposal of refrigerants. Typically, AC systems with an installed capacity of 12,000 British Thermal Units (BTU) have small refrigerant loads (less than 1 kg). However, as these refrigerants may feature a high GWP, small loads may also result in a substantial warming impact.

Indirect GHG emissions refer to the emissions related to electricity consumption. In order to provide cooling, AC systems consume electricity. For middle-income countries, it is estimated, that the introduction of cooling will increase the electricity consumption

[13] Can be accessed on the GCI website: www.green-cooling-initiative.org

by as much as 81% (Davis, Gertler, 2015). For each unit of electricity consumed, utilities have to generate power using a combination of renewable and fossil fuel-based power plants. Consequently, operating an AC results in indirect GHG emissions.
Although direct GHG emissions are emitted from ACs, the quantitative analysis in this strategy is constrained to the indirect GHG emissions due to large uncertainties related to;

i) management and disposal of current refrigerants;
ii) replacement of current refrigerants by new refrigerants, which rely on more potent GHGs

Against this background, direct GHG emissions are not considered in modelling. However, the roadmap suggests combining the MEPS with the prescription of using natural refrigerants (no Ozone Depleting Substances, low GWP, such as R290) from 2025 onwards.

Current AC Stock, EC and future development

In order to estimate the current AC stock, its future development and the resulting electricity consumption, the existing model.

Figure 9.3 presents the development of the AC stocks (in million) from 2000 to 2050. The model estimates, that by the end of 2019, the start date of the Paris Agreement, there will be 7,995 devices installed in Zimbabwe. Due to economic development and population growth, it is estimated that the stock increases to 34,129 devices by 2030.

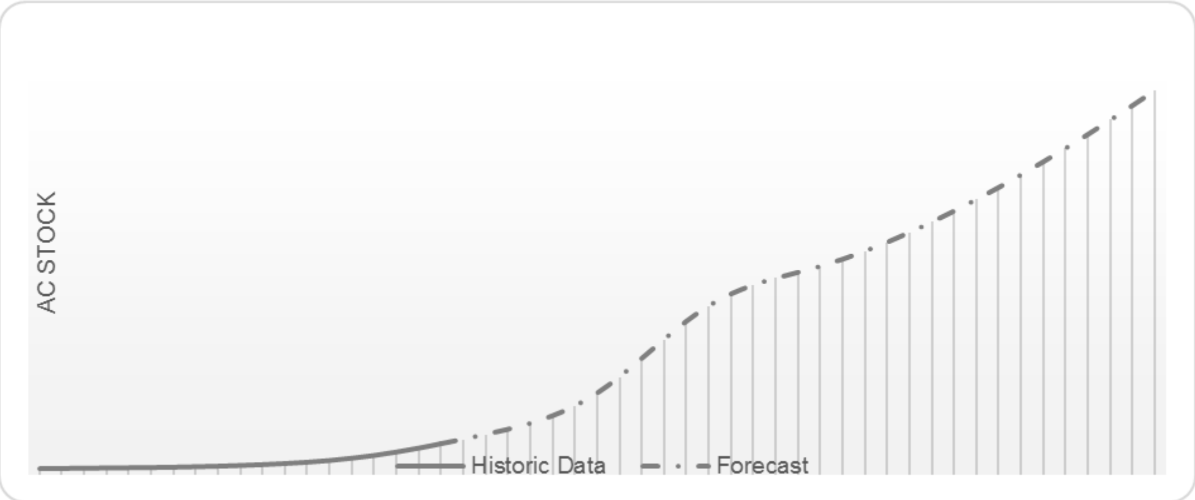


Figure 9-3:AC Stock Development Forecast for Zimbabwe

Economic Analysis

Zimbabwe should guide the investment of the private sector through well-informed regulation regarding economically cost-efficient equipment. Specifically, the energy efficiency of new ACs may be effectively regulated through establishing and maintaining MEPS.

Economic viability determines the best course of action based on governmental discount rate. The private sector, however, may be confronted with much higher financial barriers, for example higher interest rates. Economically viable investments from a macroeconomic perspective may not be necessarily financially viable for a private investment. Carbon finance might be needed to bridge the gap:

Table 9-5 Input parameter for lifecycle cost analysis

Parameter	Value
Electricity price increase (in %, p.a.)	3
Discount rate (in % p.a.)	20
Electricity cost (in USDc/kWh)	10
Electricity cost + Subsidy (in USDc/kWh)	16
Lifetime (in Years)	15

- For the life cycle cost assessment, a SDR of 6% p.a. was used This discount rate was proposed by WB (2016) for economic cost/benefit analyses for the SADC region.
- The annual increase of electricity costs was assumed to amount to 3% p.a.
- The average lifetime of split AC systems is assumed to be 15 years. Lifetime of AC systems is estimated from 15 to above 25 years, depending on maintenance and run-time hours. Therefore, the proposed lifetime is considered conservative.
- For analysis, the electricity price of 10 USDc/kWh (ZEDTC, 2014), and the electricity price including all CAPEX (Trimble et al., 2016) were considered.
- Finally, the average equipment costs for energy efficiency classes 1-10 as determined by a market review for the SADC region, was applied.

Based on the input parameters in Table 12, the Lifecycle Costs (LC) for AC systems were estimated:

- Following the equipment review, the average electricity consumption per equipment class was determined (i.e. normalized, in kWh/kW, per year), ranging from 1 (least efficiency) to 10 (highest efficiency);
- For each class, the average electricity consumption(EC) (i.e. kWh/kW) and the average price (i.e. USD/kW) amongst all products falling in this equipment class was determined. The majority of products range in the lower classes (1-4), while for the ultra-efficient equipment (7-10) only few devices are on the market. If no equipment was available for a class (e.g. class 8 and 9), then linear interpolation was done for the equipment cost and energy consumption. However, it is important to note, that also the least efficient equipment has a significantly lower electricity consumption compared to the existing equipment stock.
- Electricity costs over the lifetime of the equipment (15 years) were estimated considering an annual electricity price increase of 3% and discount the future electricity costs with a discount rate of 6% p.a. The findings are reported under Scenario A;
- The lifecycle costs were determined considering an electricity tariff increase, discount rate and indirect subsidies.

Table 9-6 Life cycle cost analysis for different scenarios

Equip-ment Class	EC (in kWh/kW)	Equipment Price (USD/kW)	Scenario A		Scenario B		Scenario C	
			Electricity Cost	Lifecycle Costs	Electricity Cost	Lifecycle Costs	Electricity Cost	Lifecycle Costs
1	462	143.19	385.24	528.44	329.38	472.57	174.63	318
2	426	142.76	355.71	498.47	304.16	446.92	161.26	304
3	403	193.78	336.07	529.85	287.35	481.13	152.35	346
4	379	174.07	316.43	490.50	270.54	444.61	143.44	318
5	356	185.26	296.72	481.98	253.73	438.99	134.52	320
6	332	196.45	277.08	473.53	236.92	433.37	125.61	322
7	308	207.64	257.44	465.08	220.11	427.75	116.70	324
8	285	237.75	237.80	475.55	203.30	441.05	107.79	337
9	261	267.86	218.09	485.95	186.49	454.34	98.87	349
10	226	297.96	188.63	486.59	161.27	459.23	85.50	356
		Minimum Cost		**465.08**		**427.75**		**304**
		Optimal Equipment Class		**7**		**10**		**2**

Figures 9.4,9.5 and 9.6 illustrate the findings of the analysis. Figure 9-4shows the lifecycle costs per equipment class. LC decreases from 528 USD/kW for the least efficient equipment, to reach a minimum with equipment class 7 (465 USD/kW).

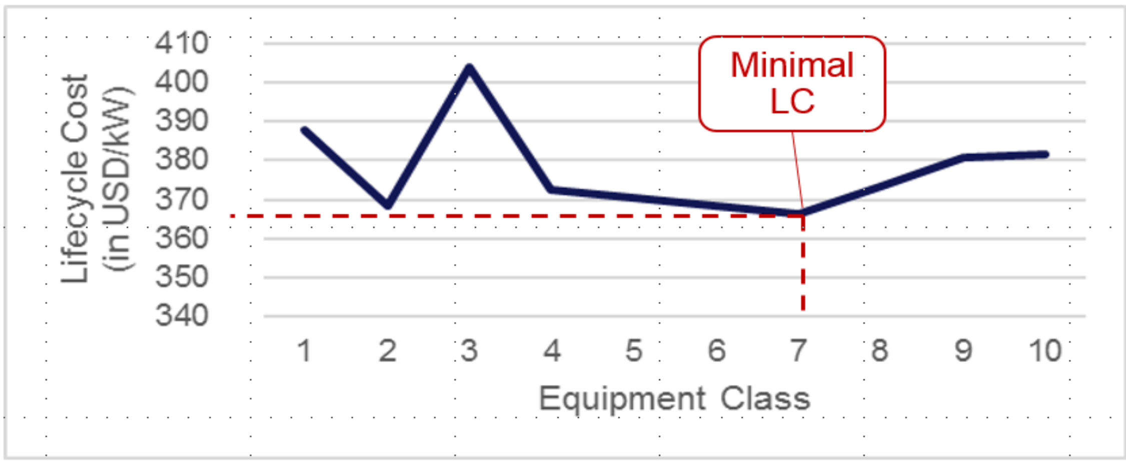


Figure 9-4: LC by Equipment Class considering Tariff Increase and SDR

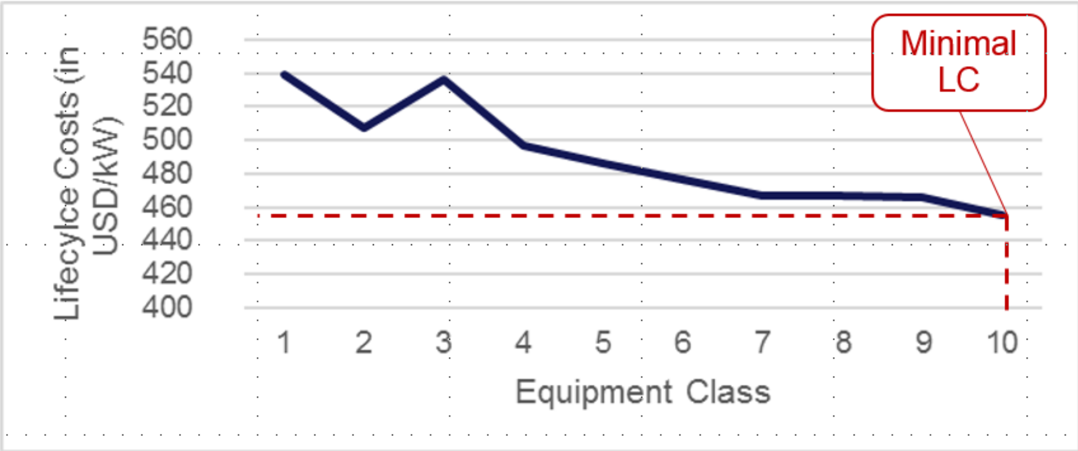


Figure 9-5 LC by Equipment Class considering Tariff Increase, SDR & Subsidies

Thereafter, LC increases with increasing energy efficiency, as the steep price increase moving from energy efficient to ultra-energy efficient equipment overcompensates the reduction of electricity costs.

Expanding the analysis to comprise the consideration of subsidies (i.e. Scenario B) produces a similar result with class 10 equipment having least cost over its lifetime. It is concluded, that from an economic perspective (i.e. SDR of 6% p.a., consideration of electricity subsidies), the optimum is the purchase of class 10 equipment, which may be specified in a Minimum Energy Efficiency Standard. This would result in the reduction of household's electricity cost, reduction of governmental subsidies for electricity and a reduction of GHG emissions.

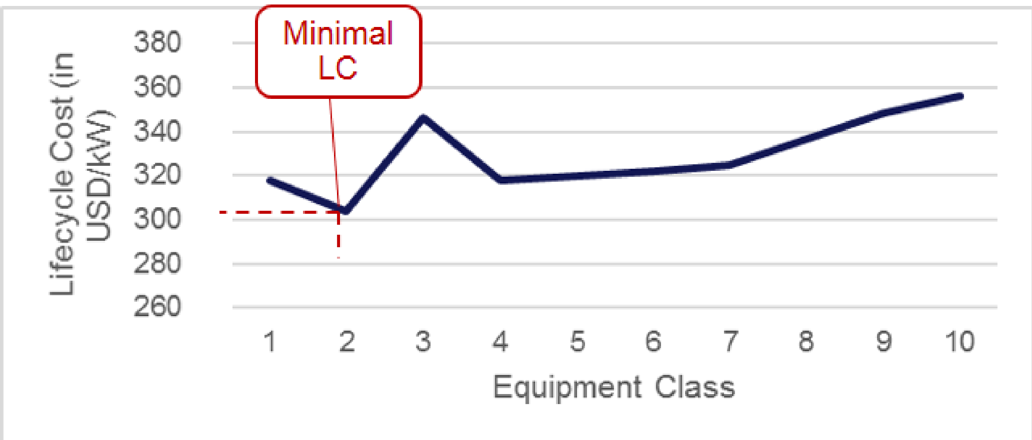


Figure 9-6 LC by Equipment Class considering Tariff Increase and PLR (Scenario C)

However, private consumers or households may access debt capital only at substantially higher interest rates. The Prime Lending Rate (PLR)(i.e. the rates at which the best customer segment of commercial bank may access loans) currently (2019) is around 18% p.a.

Considering a high discount rate and neglecting the indirect subsidies of electricity generation (Scenario C) provides a minimum LC of USD$300/KW for equipment with efficient rating of 2. Under such circumstances, the household chooses the equipment class 2 (being second least efficient technology), leading to minimum lifecycle costs for the household, but high electricity subsidies and large GHG emissions.

Implementation

A successful implementation of energy efficient cooling shall be ensured by a set of policy measures combined with the development of suitable financing instruments.

Policy Measures

For the introduction of MEPS, a stepwise approach is suggested:

- In the first step, MEPS may be introduced in year 2020 forbidding the installation of new equipment with energy efficiency classes 1 to 3. This prohibits the purchase of new equipment with an annual electricity consumption of more than 2,049 kWh/year (i.e. for 12,000 BTU AC system).
- In the second step, in 2023, the standard may be tightened to 1,660 kWh/year (prohibiting energy efficiency classes 4 and 5).
- In the next step, by 2026 all equipment with more than 1,210 kWh/year may be prohibited. This stepwise approach limits the financial burden for the consumers, allows the market to adjust and steadily approaches the economic cost efficient MEPS.

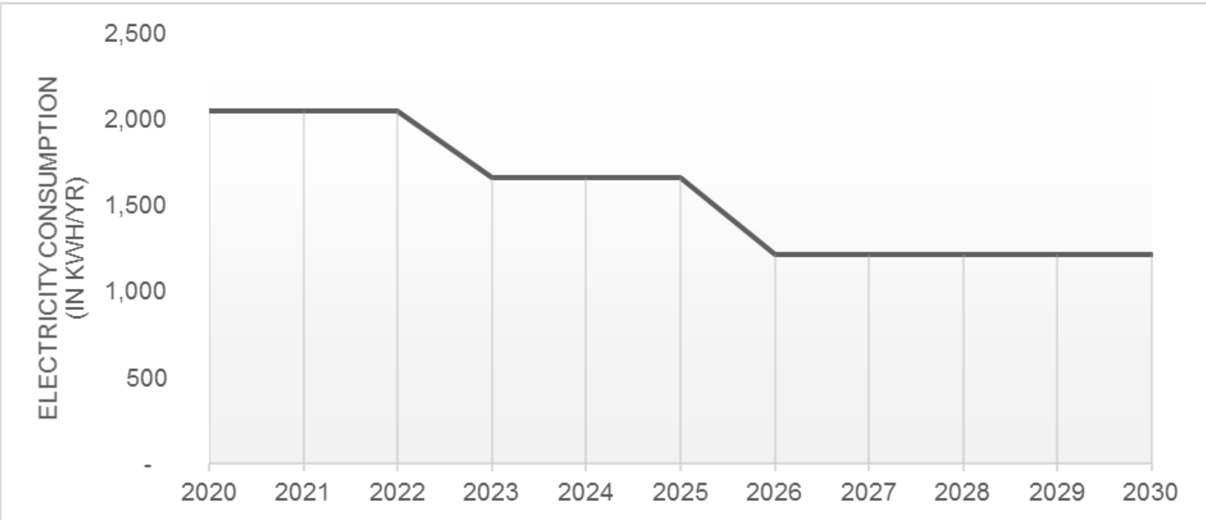


Figure 9-7: Minimum Energy Performance Standard Setting

Energy Saving Potentials

Based on the stock development, and the definition of the economically optimal energy efficiency level (Class 10), the AC electricity demand under a Business as Usual (BAU) and under a mitigation (MIT) scenario with MEPS implementation were estimated. As discussed under section 8.1, the findings were extrapolated from AC systems (which consume approx. 60% of total household electricity demand in developed countries) to a broad MEPS covering all major electricity consuming devices (i.e., i) refrigerators and freezers, ii) audio and video equipment, iii) washing machines, iv) tumble dryers, v) washer-dryer combinations, vi) dishwashers and vii) electric ovens).

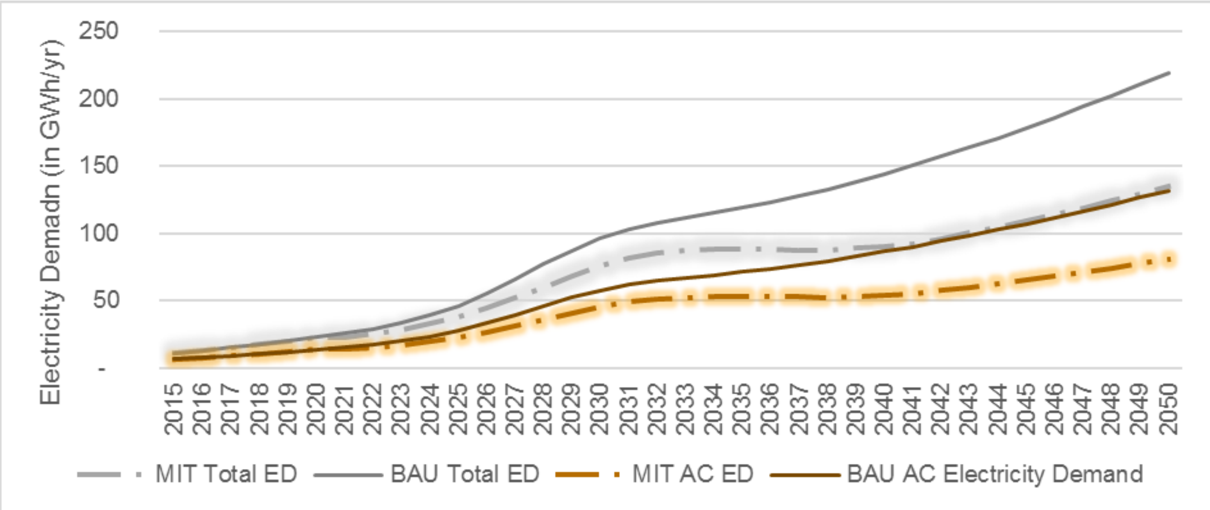


Figure 9-8: Electricity Demand under Business as Usual and under MEPS

The accumulated energy savings potential of a broad MEPS is estimated to 108 GWh by 2030 and 1,167 GWh by 2050.

GHG Abatement Potentials

To estimate the abatement potential, the decreasing GHG intensity of power generation under the MIT scenario were considered. The abatement potential refers to the GHG intensity reduction potential, which is on top of the planned decarbonisation of the power system. Based on this decreasing intensity, the abatement potentials are estimated at 0.045 M tCO_2 by 2030 and 0.399 M tCO_2 by 2050.

Economic Considerations

The estimate to the implementation of the MEPS leads to:

- Additional investments (incremental price from an inefficient to an efficient electric device) of 18. 64 M USD by 2030 and 49.89 M USD by 2050;
- Reduction of household electricity costs by 13.63 M USD by 2030 and 95.53 M USD by 2050;
- Additionally, MEPS may lead to a reduction of indirect subsidies (i.e. lack of full recapitalization of power generation, transmission and distribution infrastructure) of 8.18 M USD by 2030 and 56.12 M USD by 2050.

Overall, considering a SDR of 6%, the NPV of 39.31 M USD was estimated with an IRR of 35%. It is important to note, that this represents the outcome of an economic analysis, not a financial. To implement this potential, Zimbabwe’s climate financing facility has to offer capital at concessional interest rates.

Institutional Aspects

MEPS will be implemented in coordination by a range of institutions. These include the Regional Energy Regulatory Authority (RERA), ZERA and IDBZ. ZERA will establish and maintain national minimum energy performance standards for ACs equipment. ZERA or another appropriate entity will establish a testing centre; the testing centre will test any new AC product, which is produced and imported into the country. Testing will determine the electricity consumption for cooling and heating under standard conditions. The MEPS will be determined using current electricity prices and a national estimate of cooling degree-days to determine lifecycle costs. MEPS will aim to implement economically optimal energy efficiency standard.

The IDBZ in cooperation with commercial banks will establish a climate-financing instrument for funding energy efficient AC systems. This will reduce the lending rate for energy efficient equipment to approx. 7.5% p.a. The reduction of cost of capital will allow realizing the economically viable abatement potential.

Roadmap

The roadmap for implementing the MEPS is presented in Table 9.7.

Table 9-7: High level Roadmap for Minimum Energy Performance Standards

No.	Action	Time-frame	Lead organisation	Cooperating organisations	Potential funding sources	Estimated total costs t0 2050
M1	Establishment of a national energy performance standards for AC systems	Short-term; on-going	ZERA		GEF; UNEP; UNIDO; World Bank; DFID; EU	USD 0.2 million
M2	Development of a regional testing laboratory	Medium-term	RERA	National regulator (SADC), SACREEE	GEF; DFID; EU; Climate finance	USD 2 million
M3	Establish a climate financing instrument for energy efficient AC systems	Medium-long term	IDBZ, commercial banks	Ministry of Energy and Power Development	Climate finance	USD 5 million
M4	Update standards and include regulation of refrigerants, ban refrigerants with a high global warming potential.	Medium to long term	ZERA	Ministry of Energy and Power Development	Government Treasury	USD 0.2 million
M5	Establish MEPS for audio and video equipment, dishwashers, electric oven, refrigerators and freezers, tumble dryers, washer-dryer combinations, washing machines	Long-term	ZERA	Min of Energy Power Development	Government Treasury	USD 0.5 million

Annex III: Low Carbon Waste initiative

Estimate of BAU Emissions

Definitions and Policy Framework

In Zimbabwe the waste definition includes domestic, commercial or industrial material, whether in a liquid, solid, gaseous or radioactive form, which is discharged, emitted or deposited into the environment in such volume, composition or manner as to cause pollution (GoZ, 2002). The definitions used in this study were adopted from the Environmental Management Act Chapter 20:27 and Zimbabwe Integrated Solid Waste Management Plan of 2014 (GoZ, 2014). The following definitions apply:

- **Composting:** The aerobic degradation of organic materials under controlled conditions, yielding a usable soil fertilizer or mulch
- **Landfilling:** The disposal of solid waste at engineered facilities in a series of compacted layers on land.
- **Prevention:** All activities which aim to optimise product design and manufacturing processes so that wastes are not generated in the first place
- **Recycling:** The act of recovering materials from the waste stream and reprocessing them so they become raw materials for new applications.
- **Reduction:** The reduction of waste at source, by understanding and changing production processes to reduce waste.
- **Reuse:** Using an item more than once**.** A product may be reused either for its original purpose, or for some other purpose.
- **SWDS:** Solid Waste Disposal Sites
- **LFG:** Landfill gas

The solid waste composition figures used in this study were obtained from the Integrated Solid Waste Management Plan as shown in Table 9-8.

Table 9-8: Solid waste composition

Waste Stream	Composition by mass (in 1000 tonnes per year)										Total
	Bio-degradable	Paper	Plastic	Textile	Metal	Glass	Electronic	Medical	Rubble	Other	
Residential	346	62	81	32	39	24	3	27	0	1	615
Commercial	76	181	128	24	30	9	13	16	0	8	486
Academic	13	28	20	0	10	0	0	0	0	0	72
Medical	4	7	3	0	0	0	0	19	0	1	34
Industrial	92	129	71	44	29	0	8	0	40	30	443
Grand Total	531	407	303	101	109	33	24	61	40	41	1,650
Share (in %)	32	25	18	6	7	2	1	4	2	2	100

Source: GoZ, 2014

Forecasting BAU emissions from Solid Waste in Zimbabwe
Historical urban waste quantities for the years 1990, 1994 and 2000-2012 were used for BAU modelling. These figures were obtained from the TNC (GoZ, 2015). The GHG considered was CH_4. The historical and projected waste figures are shown in **Figure 9-9**.

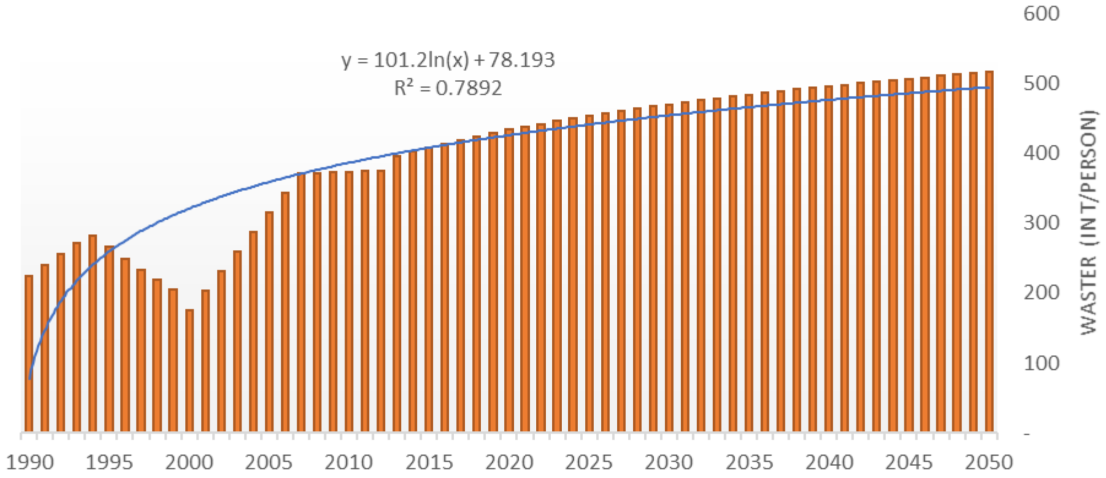


Figure 9-9: Historical and projected waste generated per person

The drop in waste generated per capita experienced from 1997 to 2000 resulted from the economic challenges experienced in the country during that period.

The urban population figures and projections up to 2050 were obtained from ZimStat. Only the urban population was considered since landfilling is done mainly in urban areas in Zimbabwe (GoZ, 2014). Waste collection rates largely respond to the performance of the economy. Table 9.9 presents the forecasted waste collection rates from 2021 to 2050.

Table 9-9: Waste generated and collected

Year	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2035	2040	2045	2050
Waste Generated(Gg)	1892	1911	1930	1949	1967	1984	2001	2017	2032	2048	2114	2173	2225	2271
Waste Collected(Gg)	1551	1606	1660	1715	1770	1825	1880	1936	1992	2048	2114	2173	2225	2271
Collection Rate (in %)	82	84	86	88	90	92	94	96	98	100	100	100	100	100
Urban Waste (t/person)	438	442	446	449	453	457	460	463	466	469	483	495	506	516
Urban Population	4	4	4	4	4	4	4	4	4	4	4	4	4	4

The BAU scenario was developed based on the projected waste figures provided in Table 9-9. Urban population was considered to be the main driver for waste generated in the cities.

BAU GHG Emissions

The CDM tool Version 02.0.0 for waste was used for climate change mitigation modelling for the waste sector (Equation 1). The tool provides procedures for calculating CH_4 emissions from SWDS or prevented from SWDS[14]. The tool was developed for methane

[14] https://cdm.unfccc.int/methodologies/DB/SU1HDJCPVB9QB8D54SGUARSQVLTJUG

emissions mitigation from existing SWDS. The existing SWDS from Harare, Bulawayo, Mutare and Gweru were considered. The cities are the main ones in Zimbabwe. The tool can be applied for mitigation of emissions from LFG flaring or avoided emissions from composting (UNFCCC, 2013).

The CDM tool can also be used to estimate the emissions from a specific disposal site, based on waste disposed in earlier decades and specific decay rates (k_j). The year 2030 was selected for marginal abatement cost analysis. The different types of biodegradable waste generated in urban areas in Zimbabwe are (GoZ, 2014):

- Wood and wood-products
- Pulp, paper and cardboard
- Food waste, beverages and tobacco
- Textiles
- Garden yard- and park waste

The CDM tool can be used for estimating emissions produced on a monthly or yearly basis. Since the data was available on an annual basis, the yearly version of the equation was used. The equation assumes that the contribution of historic waste decreases exponentially over time.

$$BE_{CH4,SWDS,y} = \varphi \cdot (1-f) \cdot GWP_{CH4} \cdot (1-OX) \cdot \frac{16}{12} \cdot F \cdot DOC_f \cdot MCF \cdot \sum_{x=1}^{y} \sum_{j} W_{j,x} \cdot DOC_j \cdot e^{-k_j (y-x)} \cdot \left(1-e^{-k_j}\right)$$

Equation 9.2: Equation for CH_4 estimation

Where, $BE_{CH4,SWDS,y}$ is baseline, project or leakage methane emissions occurring in year, *y* , generated from waste disposal at a SWDS during a time period ending in year *y* (t CO_2e / yr.). Other parameters used in Equation 1 are presented in Table 9-10.

Table 9-10: **Parameters used in Waste Sector modelling**

Parameter	**Definition**	**Selected parameters used in the LEDS model**
x	Years in the time period in which waste is disposed at the SWDS, extending from the first year in the time period (*x* = 1) to year *y* (*x* = *y*).	2020 to 2050 Time horizon for LEDS.
y	Year of the crediting period for which methane emissions are calculated (*y* is a consecutive period of 12 months)	Not Applicable. No registered Mitigation option in Zimbabwe's LEDS under CDM.
DOCf,y	Fraction of degradable organic carbon (DOC) that decomposes under the specific conditions occurring in the SWDS for year *y* (weight fraction)	1.000
Wj,x	Amount of solid waste type *j* disposed or prevented from disposal in the SWDS in the year *x* (t) in Gg	W1 Wood and wood products: 0 W2 Pulp, paper and cardboard: 365 W3 Food, food waste, beverages and tobacco: 468 W4 Textiles: 88 W5 Garden, yard and park waste: 0
φy	Model correction factor to account for model uncertainties for year *y*	0.900
fy	Fraction of methane captured at the SWDS and flared, combusted or used in another manner that prevents the emissions of methane to the atmosphere in year *y*	Not Applicable
GWP(CH_4)	Global Warming Potential of methane	24 (IPCC Second Assessment Report)
OX	Oxidation factor (reflecting the amount of methane from SWDS that is oxidised in the soil or other material covering the waste)	0 (2006 IPCC default)
F	Fraction of methane in the SWDS gas (volume fraction)	0.500 (2006 IPCC default)
MCFy	Methane correction factor for year *y*	0.400 (2006 IPCC default)
DOCj (dry)	Fraction of degradable organic carbon in the waste type *j* (weight fraction)	W1 Wood and wood products=50.00% W2 Pulp, paper and cardboard=44.00% W3 Food, food waste, beverages and tobacco=38.00% W4 Textiles=30.00% W5 Garden, yard and park waste=49.00%
kj (dry)	Decay rate for the waste type *j* (1 / yr.)	W1 Wood and wood products=0.04 W2 Pulp, paper and cardboard-0.04 W3 Food, foodwaste, beverages and tobacco=0.06 W4 Textiles=0.05 W5 Garden, yard and park waste=0.045
j	Type of residual waste or types of waste in the SWDS	W1 Wood and wood products W2 Pulp, paper and cardboard W3 Food, food waste, beverages and tobacco W4 Textiles

Parameter	Definition	Selected parameters used in the LEDS model
		W5 Garden, yard and park waste
e	Constant-Euler's number	2.718

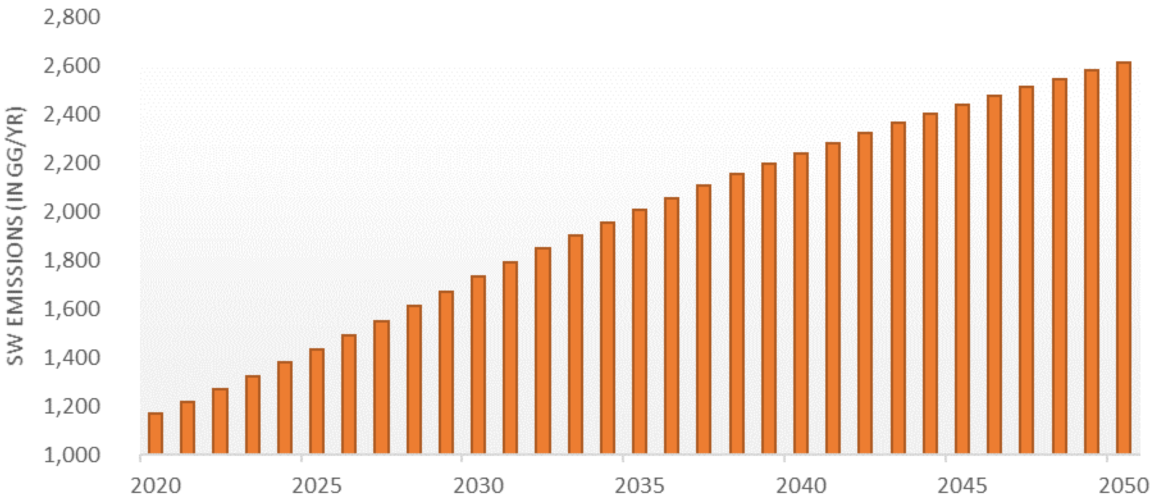


Figure 9-10: Methane emission from solid waste disposal

Discussion results, GHG emissions 2020, 2030 and 2050

Methane emissions from SWDS in Zimbabwe are projected to grow more than 100% from around 1,1000Gg/yr. in 2020 to around 2,500 Gg/yr. in 2050. This significant increase in GHG emissions was considered a factor of increase in urban population.

Policy Framework for Waste Mitigation Measures

Waste policy framework

Zimbabwe developed a number of pieces of legislation governing environmental management in general, and waste management in particular. These include the National Environment Policy and Strategies (NEP) (GoZ, 2009), Environmental Management Act Chapter 20:27 (GoZ, 2002), Statutory Instruments (SI) No. 6 of 2007 (Effluent & Solid Waste Disposal), SI 10 of 2007 (Hazardous Waste Management), and SI 98 of 2010 (Plastic Packaging & Plastic Bottles) (Table 9-11).

Table 9-11: Legislation, policies and strategies on waste management in Zimbabwe

Instrument	Purpose/Focus area on environment and Climate change	Responsible authority (ies)
Renewable Energy Policy (2019)	Promote biogas	Ministry of Energy and Power Development
National Climate Policy (2017)	Promote waste reduction, reuse and recycling; waste to energy.	Local authorities
NCCRS (2014)	Create a Climate Change resilient nation by promoting sustainable development and a climate proofed economy through mainstreaming climate change adaptation and mitigation strategies in socio-economic development at national and sectoral levels through multi-stakeholder engagement.	MAWCLRR
National Environmental Policy and Strategies (2009)	Provide economic instruments to improve resource and energy efficiency Promote use of clean energy sources	Ministry of Environment and Tourism
Industrial Development Policy (2012)	Promote environmentally sustainable industrialisation.	Ministry of Industry and Commerce
Science, Technology and Innovation Policy (2012)	Provide scientific solutions to global environmental challenges.	Ministry of Higher Education, Science and Technology
Constitution of Zimbabwe Chapter 4 Section 73	Environmental rights, prevention of pollution to be guaranteed by the state.	GoZ
Environmental Management Act (Chapter 20:27, 2002)	To provide for the sustainable management of natural resources and protection of the Environment; prevention of pollution and environmental degradation;	Ministry of Environment and Tourism
Urban Councils Act (Chapter 29:15)	Establishment and regulation of local authorities and their function.	Ministry of Local Government, Public Works and National Housing (MLGPWNH)
Public Health Act (Chapter 15:17)	To provide for public health	MHCC

The mitigation actions for solid waste were based on the Integrated Waste management Plan that was developed by the Institute of Environmental Studies (IES) commissioned by EMA in 2014 (GoZ, 2014)

The Integrated Solid Waste Management Plan goals are (GoZ, 2014):

i. Solid waste generation by maximizing resource use at source through sustainable consumption and cleaner production.
ii. Separate solid waste at source.
iii. Reduce biodegradable solid waste through reuse, use of solid waste as feed and composting.
iv. Maximize resource recovery by creating an enabling environment for recovery; expanding markets for recyclables and forging partnerships in the value addition chain for recyclables
v. Restructure and introduce efficient collection of source separated waste streams in all cities, towns and growth points to improve cleanliness and restore the glamour of Zimbabwe.

vi. Invest in and build environmentally sound infrastructure and systems for safe disposal of soil waste as required by legislation.
vii. Educate and raise awareness in all citizens of Zimbabwe to better understand and participate in source separation; resource recovery and conversion; and integrated and sustainable solid waste management.
viii. Promote cleanliness in Zimbabwe where the public, industry and government strive to reduce, reuse and recycle all solid waste materials in order to manage and mitigate the impacts of solid waste on public health and safety, the environment and climate.
ix. Develop a Waste Management Information System to enable long-term measurement of system performance and for use in the design, implementation and monitoring of an effective and efficient system for collection, transportation, recycling, treatment, recovery and disposal of various wastes and for informing policy and planning.
x. Develop a Waste Management Policy and review and assess current legislation to improve implementation.

Figure 9-11 presents Zimbabwe's Integrated Solid Waste Management Plan

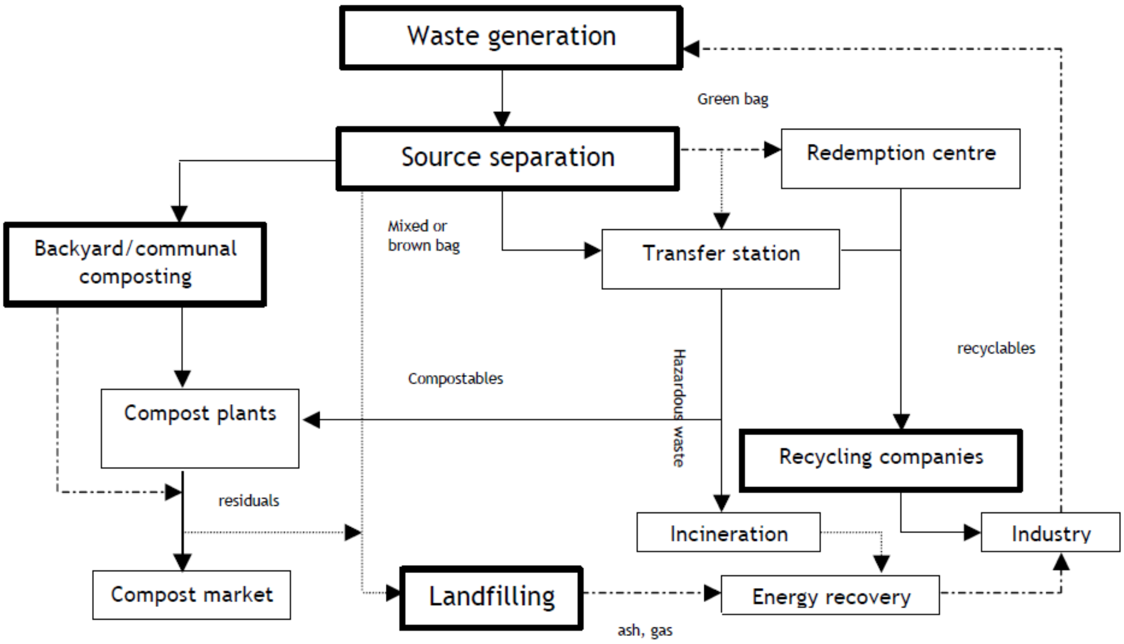


Figure 9-11: Integrated Solid Waste Management System
Source: GoZ, 2014

Based on this policy framework, the following section discusses the abatement potentials and costs / benefits of LFG flaring and composting. Recycling was included since it is covered in the Integrated Solid Waste Management Plan, although it has limited potential to mitigate CH_4 emissions from the Waste sector.

Landfill Gas Flaring

The first abatement option considered was LFG flaring. LFG flaring mitigates climate change through the combustion of CH_4 generated from waste already disposed. Consideration needs to be given to the efficiency of destruction achieved during flaring and, hence, to the environmental impact and possible health risks associated with the combustion products resulting from flaring with systems of differing designs. LFG is an end product of the decomposition of biodegradable wastes in a landfill site (EA, 2002). Typically, LFG comprises a mixture of up to 65% CH_4 and 35% CO_2 by volume, although it includes minor amounts of a range of organic gases and vapours. Combustion is the most common technique for controlling and treating LFG in order to mitigate climate change. Over 98% destruction of organic compounds from LFG can be achieved through the use of combustion technologies such as flares, incinerators, boilers, gas turbines, and internal combustion engines. Methane has a Global Warming Potential (GWP) of 24 and is converted to CO_2 (GWP of 1), resulting in a large greenhouse gas impact reduction. Although combustion reduces the GWP of LFG by oxidising the CH_4 and producing CO_2, there is need to monitor and control the production of secondary emissions, for example, mercaptans, oxides of nitrogen (NOxs) and CO. The two broad technologies on CH_4 flaring are open and closed flaring.

Open flares

Open flame flaring (e.g., candle or pipe flares), is the simplest flaring technology, and it consists of a pipe through which the gas is pumped, a pilot light to spark the gas, and a means to regulate the gas flow. The simplicity of the design and operation of an open flame flare is an advantage of this technology.

Good mixing of air and fuel at the burner shortens the flame and reduces its luminosity. Mixing is improved by good burner design and pre-aeration, which also allow some degree of combustion control through adjustment of the flow of air. Open flares have the advantages of being inexpensive and relatively simple, which are very important factors when there are no emission standards. However, open flares are inefficient, resulting in very poor emissions control compared with those from enclosed flares. The disadvantages include inefficient combustion, aesthetic complaints, and monitoring difficulties. Sometimes, open flame flares are partially covered to hide the flame from view and improve monitoring accuracy. In the general case of diffusion and pre-aerated open flares, there is often a shield around the burner to protect the flame from the wind.

Enclosed flares

Enclosed flares burn CH_4 gas in a vertical, cylindrical or rectilinear enclosure with multiple burners. Some means of combustion control is normally provided, and the enclosure is often insulated to reduce heat losses and allow operation at higher temperatures. In an enclosed flare, the burner or burners are located at the base of a shroud, which is usually, but not always, circular in cross-section. Enclosed flame flares are more complex and expensive than open flame flares. Unlike open flame flares, the amount of gas and air entering an enclosed flame flare can be controlled, making combustion more reliable and more complete. Other enclosed combustion technologies, for instance, boilers, process heaters, gas turbines, and internal combustion engines can also be used. Use of open flaring technologies was considered for LFG flaring.

Zimbabwe LEDS CH_4 flaring mitigation action implementation

The Waste sector LEDS mitigation action assumes that LFG flaring will be conducted in the SWDS in the four cities. It was assumed that 72.6% of the methane generated would be collected and flared. The methane flaring projects will be implemented in one city after the other; starting with Harare in 2020, followed by Bulawayo in 2021, Mutare in 2022 and Gweru in 2023 (see Table 9.12). The funding is expected to come from the Environmental Management Fund managed by EMA.

Table 9-12: CH_4 reduction from SWDS from 2020 to 2050

	Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2035	2040	2045	2050
LFG Reductions	M tCO_2eq	0.44	0.63	0.74	0.87	1.00	1.04	1.08	1.12	1.17	1.21	1.26	1.46	1.63	1.77	1.89

Costs for LFG flaring

The Investment Costs and Operational Expenditure covering 38 cost categories were taken from several CDM LFG projects and have been normalized by area. The size of SWDS were measured for Harare (Pomona Dumpsite) and Bulawayo (Richmond Landfill), while the areas for Gweru and Mutare were estimated. The total area amounts to 141.2 ha. The total cost for mitigation, based on the costs presented in and SWDS areas are shown in **Table 9-13** while **Table 9-14**provides the cost parameters.

Table 9-13: LFG Cost Parameter

Parameter	Value
Investment Cost (in USD/ha)	92,046
OPEX (in USD/yr./ha)	10,179

Table 9-14: Total cost for LFG flaring

		2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2035	2040	2045	2050
CAPEX	M USD	7.4	2.8	1.4	1.4	1.4										
OPEX	M USD	0.8	1.1	1.3	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4
Total Cost	M USD	8.2	4.0	2.7	2.8	2.8	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4	1.4

A 6% SDR was considered for the economic analysis for the LFG flaring mitigation option. The economic analysis is presented in Table 9.15.

Table 9-15: LFG Abatement Cost Analysis

Parameter	Unit	Value
Net Present Value	M USD	31.79
Total GHG Reduction	M tCO_2e	43.06
Abatement Potential 2030	M tCO_2 e	1.26
Marginal Abatement Cost	USD/tCO_2e	0.74

A positive marginal abatement cost of \$0.74/tCO_2e was obtained. The result of the economic analysis showed that LFG flaring can be justified on the basis of climate change mitigation, and not on return on investment.

Composting

The aerobic decomposing of waste through composting reduces, significantly, the amount of biodegradable waste disposed at the SWDS. Modern, methodical composting is a multi-step, closely monitored process with measured inputs of water, air and carbon- and nitrogen-rich materials, aided by shredding the plant matter, turning the mixture and adding water (Zaļoksnis, 2018). The introduction of worms also assists in speeding up the process. The resultant organic fertiliser can be used in gardens, landscaping, and agriculture. The organic fertiliser improves soil conditioning, in addition to it providing some nutrients and vital humus or humic acids to the soil. Composting reduces the amount of biodegradable waste to less than half of the original quantity.

Composting can be achieved through aerobic or anaerobic digestion. In aerobic digestion, the breaking down of biodegradable material is done in the presence of oxygen under controlled conditions. The carbon content of the material breaks down to CH_4, CO_2 and other gases. Anaerobic composting is the decomposition of organic material in the absence of oxygen. Anaerobic organisms aid the process. Anaerobic decomposition is generally slower than aerobic.
During the composting process, the organic substrate is progressively broken down by a succession of populations of living organisms. Mesophilic and thermophilic bacteria and fungi are the predominant organisms during the initial and the active stages of the compost process. Larger organism like earthworms can be introduced in later stages.

Types of composting technologies
The two broad types of composting are windrow and in-vessel (Hussein et. al., 2018). Windrow systems can be static or turned. In the static version, aeration is accomplished without disturbing the windrow whereas with the “turned” version, aeration involves tearing down and rebuilding the windrow. The many variations between approaches to windrow composting render it difficult to formulate generalisations regarding the economics of the process. However, it can be generalised that turned or static windrow composting should be less costly than in-vessel composting. Current versions of windrow composting differ among themselves with respect to size, degree of mechanisation, and process. The cost of the mechanical turner is a major item in the economics of medium- to large-scale operations. A shed may be required. Sheds would be particularly important if the facility is built relatively close to residential or commercial areas.

Goals underlying the design of an in-vessel reactor are to accelerate the composting process through the maintenance of conditions that are optimum for the microbe's active in composting, and minimise or eliminate adverse impacts upon the ambient environment. The types of in-vessel systems that have been used over the years include Dano drum, or other horizontal drum systems. The Dano reactor is typically less preferred due the high cost. The Eweson system differs from that of the Dano system in that its drum is divided into compartments such that the residence time can be varied throughout the drum.

Factors affecting composting

The main factors affecting composting include nutritional, environmental and operational. Nutritional factors include levels of macronutrients (carbon (C), nitrogen (N), phosphorus (P), calcium (Ca), and potassium (K)) and micronutrients (magnesium (Mg), manganese (Mn), cobalt (Co), iron (Fe), and sulphur (S)) in the material. Environmental factors that affect the compost process are temperature, pH, moisture, and aeration.

Limitations of composting

Composting has been widely accepted as an eco-friendly productive way to manage the waste materials. However, it is a slow process taking several weeks and requiring frequent mixing with possible losses of nutrients (NH_3). Though composting passing through thermophilic stage effectively reduces pathogens, however, absolute removal is very difficult.

Marketing and distribution of compost

Organic fertiliser can find use in agriculture, landscaping, nurseries and residences. The quality of the compost dictates its final use, for example, nurseries require a high-quality product; whereas, a lesser quality material would be suitable for land reclamation or landfill cover. Organic farming is the largest potential market for compost in Zimbabwe. Development of a market for compost involves instilling in potential users an awareness of the utility of the product. To be both effective and efficient, the distribution system must be such that the greatest number of consumers has ready access to the product at the lowest cost.

Additional emission reduction potential from composting

The residual emissions from the 72.6% abated through LFG flaring were targeted to be removed through composting. Considering that LFG flaring applies to both historical waste and projected at the SWDS, the mitigation of CH_4 from composting targets new waste, hence, avoiding generation of CH_4 at SWDS. **Table 9-16** presents CH_4 mitigated through composting from 2020 through 2050.

Table 9-16: CH_4 mitigated through composting

	Year	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2035	2040	2045	2050
Compos-ting ERs	M tCO_2e	0.01	0.03	0.05	0.06	0.06	0.08	0.09	0.11	0.12	0.14	0.15	0.16	0.18	0.19	0.20

Economic Analysis

The economic analysis was performed based on composting plant with the capacity to handle 20,000 mt of biodegradable waste per year. The revenue from the sale of organic fertiliser were estimated at US$ 35 /mt. The revenues were based on the empirical data provided by Zimbabwe Sunshine Group, an organisation involved in waste composting in Harare. The figure was validated by comparing with regional and international figures. The capital and operational costs for composting are presented in Table 9.17.

Table 9-17: Investment and operational costs for composting

	Capacity (t/yr.)	Cost USD
Investment Cost by Plant Capacity	20,000	3,534,737
OPEX (in USD/t)		11

Table 9.18 presents the cash flow for composting, based on the project lifetime of 10 years. The financial analysis indicates that the payback period for composting is 1 year, hence the mitigation would be financially sustainable for the life of the project.

Table 9-18: Cash flow, reinvestment in equipment every 10 years

Parameter	Unit	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2035	2040	2045	2050
Revenues from Compost Sale	M USD	10.35	10.72	11.10	11.48	11.86	12.24	12.62	13.00	13.38	13.77	14.16	14.62	15.02	15.38	15.70
Invest-ment Cost	M USD	52.25	-	-	-	-	-	-	-	-	-	52.25	-	52.25	-	52.25
Compost-ing OPEX	M USD	3.25	3.37	3.49	3.61	3.73	3.85	3.97	4.09	4.21	4.33	4.45	4.59	4.72	4.83	4.93
Net Revenue	M USD	- 45.16	7.35	7.61	7.87	8.13	8.39	8.65	8.91	9.18	9.44	- 42.55	10.02	- 41.95	10.55	- 41.49

The abatement cost analysis presented in Table 9.18 based on an Internal Rate of Return (IRR) of 12.75% intimate that the marginal abatement cost for composting is – US4.22/$mtCO_2e$. The negative marginal abatement cost reveals that composting is financially viable.

Table 9-19: Abatement cost analysis

Parameter	Unit	Value
Net Present Value	M USD	25.91
IRR	%	12.75%
Abatement Potential 2030	M tCO_2 e	0.15
Total Abatement Potential	M tCO_2 e	6.14
Marginal Abatement Cost	USD/tCO_2e	-4.22

R e c y c l i n g

The ISWMP for Zimbabwe includes the option of recycling (GoZ, 2014). Since recycling addresses waste management upstream, the option was not considered in the mitigation analysis. Recycling aims to remove any contaminants from waste so as to render such waste reusable, or returned to the economic mainstream in the form of raw materials. It does not reduce, significantly, biodegradable material disposed at SWDS. The environmental concerns on recycling include the need to reduce waste at dumpsites and promote climate change mitigation. The two main factors for recycling waste can be divided into environmental and economic. Financial, economic and social motivation for recycling borders on reduction in waste handling cost and revenue generation. Formal sector recycling can generate modest profits, but it may not be the case for municipalities. The involvement of the formal private and informal sectors in all aspects of solid waste management has proved to be effective (UN-Habitat, 2012). Mechanisation of the sorting process adds to investment and operational costs, requires good maintenance and a motivated workforce. Recycling happens spontaneously when it is economically viable. Strategies to promote recycling include deposit system or regulations for promoting packaging recycling. Where it is not economically viable, however, it must be subsidised or the cost of alternatives (usually disposal) must be artificially increased. The projected recyclable solid waste is presented in **Figure 9-12**.

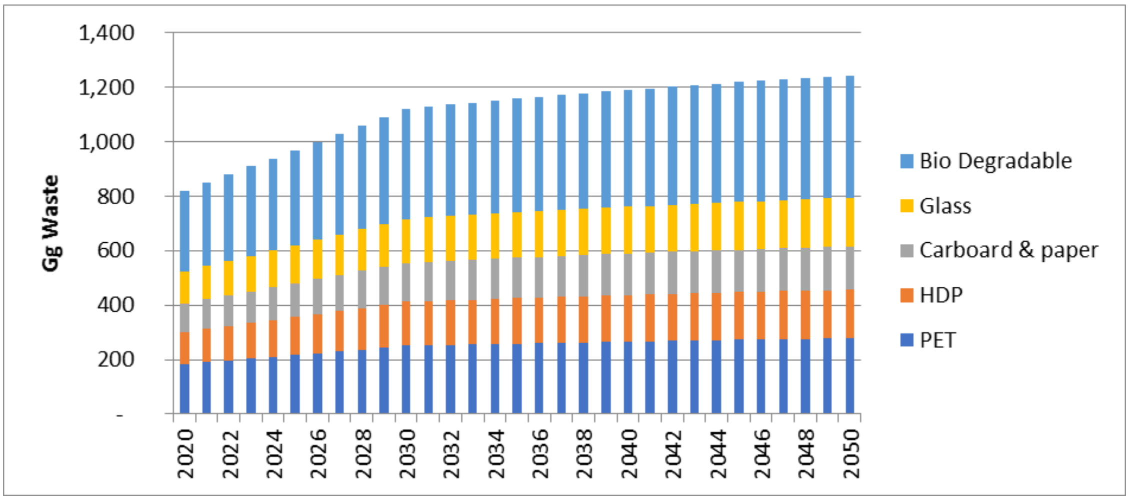


Figure 9-12: Projected Recycle Potentials

The main infrastructure and equipment required for a basic recycling facility include; waste transfer facility, waste sorting and recycling facility, waste compactor, bailing machine, forklift, vehicles, shredders, among others. The prices paid for recycled materials often fluctuate wildly. It is, therefore, common for traders to have the space and working capital that allow them to stockpile material when prices are low. Prices fluctuate with supply and demand. The importation of cheap recyclable material can also affect prices. The recyclables can be sold locally or exported as is or after some semi-processing.

Annex IV: Low Carbon Transport Initiative

Overview

Zimbabwe's National Climate Change Response Strategy of 2015 sets a goal to '*develop climate proofed and environmentally sustainable transport systems that are less carbon intense*' (GoZ, 2015). This goal was subsequently reflected in the Zimbabwe National Transport Master Plan of 2018, which has as one of its key themes or pillars Environmental Sustainability (Theme 2). Noting that road transport is a major contributor to national GHG emissions, the Plan identifies a number of specific measures for the sector, including;

- Enforcement of emission standards for vehicles and using them to assess the emissions of imported vehicles before they are allowed into the country;
- Introduction of an integrated transport system to reduce the carbon footprint caused by the road transport sector;
- Development of an efficient public and mass transport system by introducing larger buses and trains on urban commuter routes to reduce the use of private cars;
- Promotion of the use of non-motorised transport (NMT) such as bicycles and walking to reduce carbon emissions, whilst improving health;
- Incorporating climate change in road designs and transport related infrastructure;
- Moving towards the use of blended fuels for vehicles to reduce GHG emissions; and
- Introducing a transport policy framework that encourages use of transport with low carbon emissions e.g. electric vehicles.

This Annex draws upon this list to describe a package of measures aimed at supporting a low carbon road transport sector as part of the LEDS through 2050. A modelling exercise undertaken to estimate the mitigation potential from these interventions is described, followed by a high-level economic analysis of the package and summary of the types of policies, institutional arrangements and key actions needed for implementation.

GHG mitigation potential

Modelling approach

Transport sector modelling was undertaken to calculate the potential for GHG reductions against a business-as-usual scenario for road transport through 2050. A package of four key mitigation measures was analysed:

- Improved fuel economy of imported internal combustion engine (ICE) vehicles;
- Introduction of electric vehicles (EV);
- Commercial scale domestic biodiesel production and blending; and
- Increased public transport use, with modal shift from passenger car use to modern buses and NMT (e.g. walking and bicycles).

The use of hydrogen fuel and hybrid vehicles was not modelled. Although these options are expected to play an increasing role in low carbon transport over the coming years, they are considered to effectively be variations on the use of EVs (this approach is also taken in the

GFEI's analysis of low carbon vehicle potential through 2050 (GFEI, 2019). The modelling approach and results are described in the next section.

Business as usual scenario

The development of a BAU GHG projection is summarised in the following steps:

Step 1: Characterization of existing vehicle fleet. Zimbabwe's vehicle fleet was first characterised according to vehicle type, class, fuel type, and fuel economy. Vehicle registration data for recent years according to type and class were estimated based on data compiled by the African Development bank (AfDB, 2011)[15] and under the UNEP-supported Global Fuel Economy Initiative (GFEI) in 2017 (Zanamwe Pers.com.)[16] (**Table 9-20**. Average fuel economy values (litres per 100 km) for each vehicle class and fuel type were developed, based on a variety of sources and estimates including recent analysis undertaken by the GFEI of fuel economy for road vehicles registered in Zimbabwe, as well as assumptions around future fuel economy improvements as part of expected technology improvements (GFEI, 2019)[17]. 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 2016 was then calculated for each vehicle category and fuel type within each category (diesel; gasoline), according to:

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

Table 9-20: Estimated vehicle fleet in Zimbabwe, 2000-2016

Category	2000	2005	2010	2015	2016
Motor cycles	191,117	195,711	218,318	278,635	292,567
Passenger vehicles	355,557	509,764	659,442	972,266	1,037,643
Commercial vehicles	86,457	106,272	131,780	168,188	176,597
Buses	*1,678*	*2,531*	*3,542*	*4,521*	*4,747*
Combis	*8,364*	*12,150*	*16,341*	*20,856*	*21,899*
Trailers	*23,048*	*25,142*	*29,375*	*37,491*	*39,365*
HGV (2.3-4.6 Mt)	*17,780*	*23,370*	*30,234*	*38,587*	*40,516*
HGV (4.6-9.0 Mt)	*31,313*	*37,564*	*44,355*	*56,609*	*59,440*
HGV (> 9.0 Mt)	*4,274*	*5,515*	*7,932*	*10,124*	*10,630*
Total number	633,131	811,747	1,009,540	1,419,089	1,506,807

Source: derived from AfDB, 2011 (Annex 5: Road Transport) and UoZ (2017)

Step 2: Vehicle fleet projected through 2050. A forecast was then made of numbers for each vehicle category through 2016-2050. Numbers of new vehicle registrations were estimated

15 African Development Bank Infrastructure Report for Zimbabwe; Annex 5 Road Transport (AfDB, 2011)

16 Motor Vehicle Inventory. Presentation given at GFEI Zimbabwe meeting by N.Zanamwe, University of Zimbabwe, December 2017.

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

based on an increased demand for road transport vehicles. These were projected on the basis of GDP per capita growth (from national medium case GDP and population projections, with regression analysis undertaken to link vehicle ownership rates to GDP per capita from the available historic data). An average annual scrappage rate of 5% was assumed, in common with estimated historic scrappage rates in Zimbabwe, which are also in alignment with typical reported OECD values.

Figure 9-13 shows the resulting estimated projections for road vehicles in Zimbabwe through 2050. It can be seen that from an estimated national fleet of 1.5 million road vehicles in 2016, numbers are projected to increase significantly to around 3.5 million by 2050, of which passenger vehicles (or light duty vehicles, LDVs) account for the large majority.

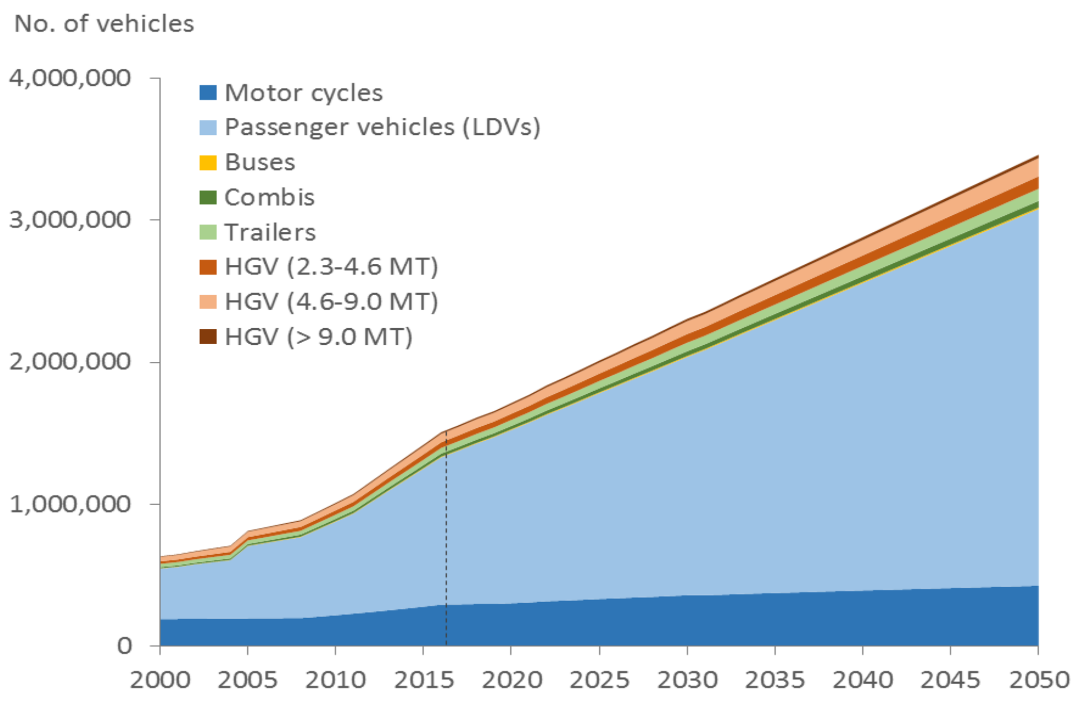


Figure 9-13: Road vehicles by type, historic and projected to 2050 (BAU)

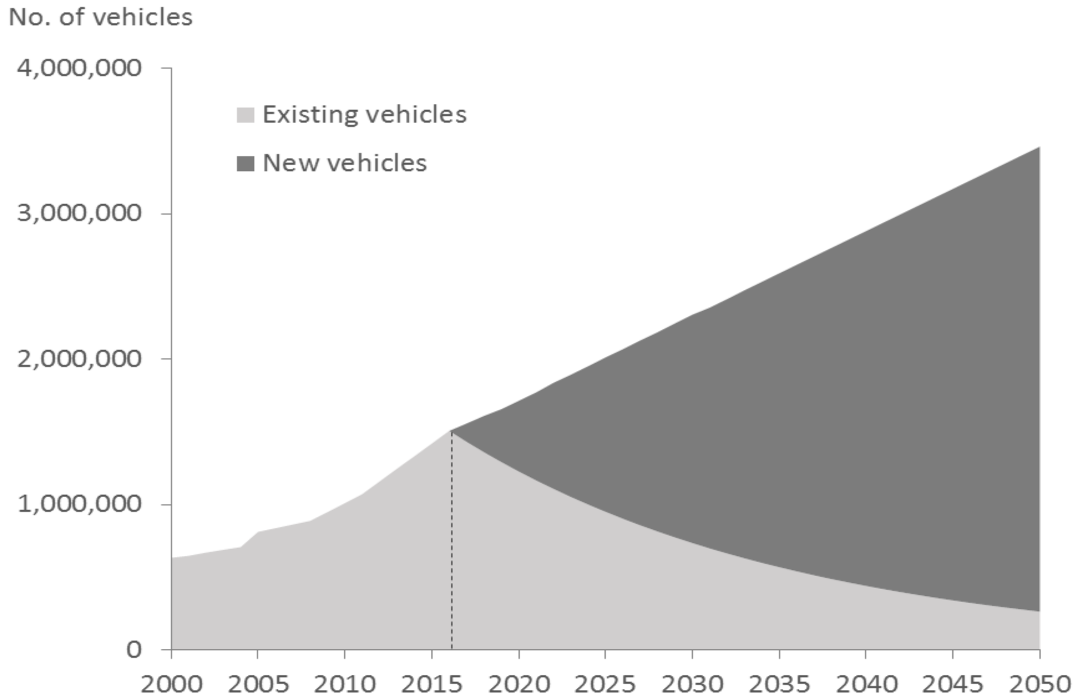


Figure 9-14: Road vehicles, existing versus new stock to 2050

Step 3: Estimation of fuel use and GHG emissions through 2050. Based on Steps 1 and 2, fuel use estimates were next calculated for diesel, gasoline and ethanol in each forecast year. Applying IPCC default emission factors for mobile emission sources (IPCC, 2006), a GHG forecast was made. 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. Current ethanol blending rates from official data sources (which has reached up to 20%, E20, in some cases) were also assumed to remain at existing levels through 2050. Figures 9.15 and 9.16 show projected total fuel use and GHG emissions by transport mode through 2050. The projection estimates total emissions to increase from around 2.3 million tCO_2e in 2015 to almost 5.3 million tCO_2e by 2050. 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 the assumptions around gradual BAU fuel economy improvements over time.

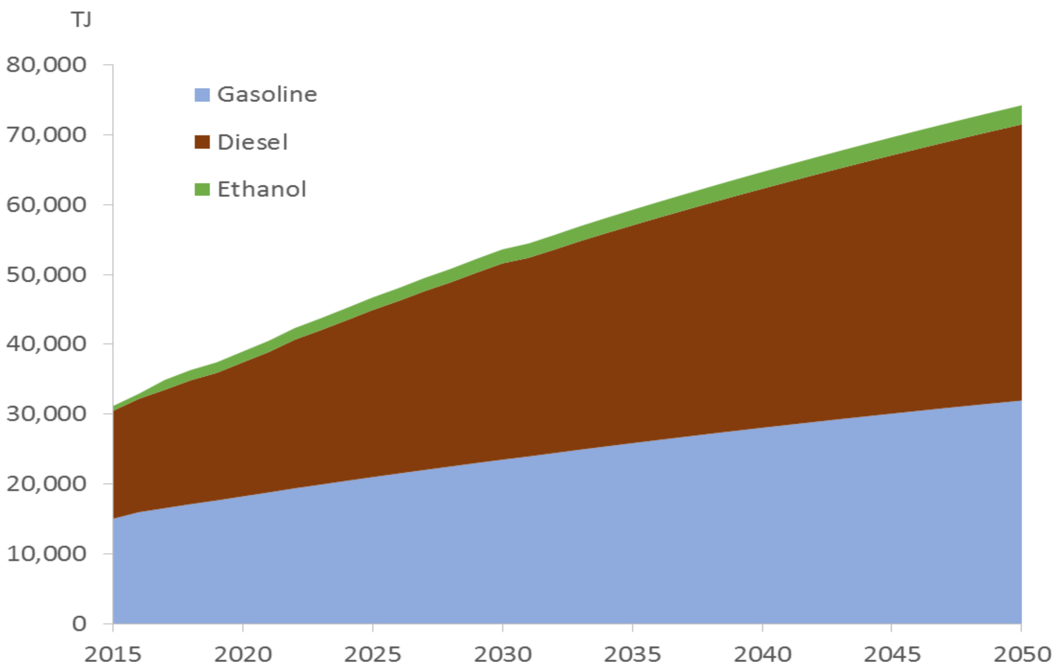


Figure 9-15: Projected fuel use in road transport to 2050 (BAU)

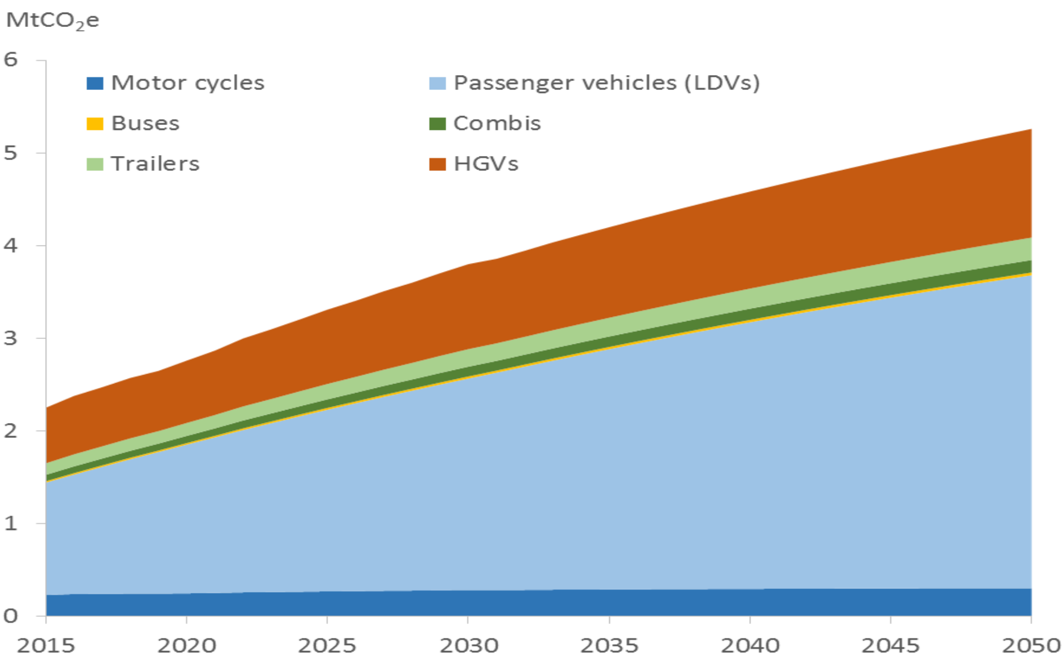


Figure 9-16: Projected GHG emissions from road transport to 2050 (BAU)

M i t i g a t i o n   S c e n a r i o

The four identified GHG mitigation levers were modelled together as a *combined* package within one mitigation scenario. The key assumptions concerning each of the mitigation levers, and the estimated GHG reductions versus BAU, is summarised in the next section.

Fuel economy measures. The potential for improved fuel economy measures for new internal ICE vehicles through 2050 is shown in **Table 9-21**. The values are proposed by the GFEI for four broad vehicles types, based on existing technical analysis undertaken by the International Energy Agency (IEA) and others, and reflect an estimated potential which could be delivered through use of policies and incentivise to drive increasing fuel economy standards for new vehicles within national fleets(GFEI, 2019). The assumed improvement rates are significantly 'front-loaded', reflecting the assumption that improved fuel economy becomes increasingly difficult within ICE technology development through 2050. The values were applied to all new vehicles entering the fleet from 2025 onwards, and the GHG mitigation was calculated through 2050 based on the resulting reduction in fuel consumption. Fuel economy improvements were applied equally to diesel and gasoline vehicle types.

Table 9-21: Fuel economy improvement targets for new road vehicles

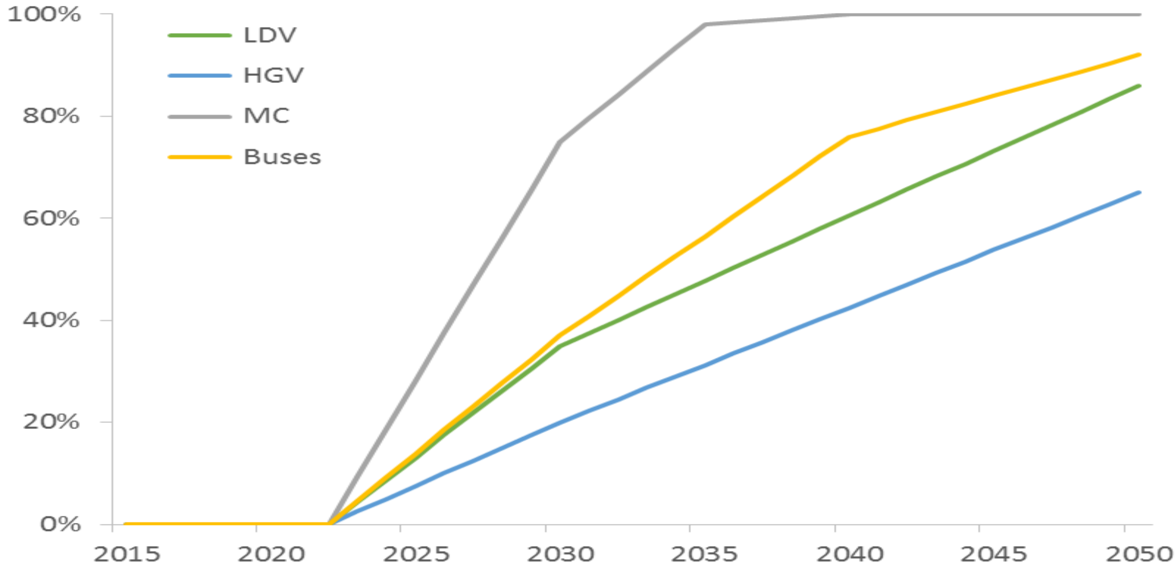
Vehicle type	2025-2030	2030-2035	2035-2040	2040-2045	2045-2050
Motorcycles	2.2% pa	1.9% pa	1.6% pa	1.3% pa	0.9% pa
LDVs	2.9% pa	2.2% pa	1.9% pa	1.4% pa	1.2% pa
Buses	2.6% pa	2.5% pa	2.1% pa	1.8% pa	1.4% pa
HGVs	2.5% pa	2.2% pa	1.9% pa	1.5% pa	1.1% pa

Source: GFEI, 2019

Electric vehicles. The penetration of EVs within the national vehicle fleet was modelled through 2050 according to target potential uptake rates developed by the GFEI reflecting EV policy support (GFEI, 2019). Market penetration curves for new EVs as a share of total new vehicle registrations were developed through 2050 based on these GFEI values assuming EV penetration into Zimbabwe from around 2023 (beyond the existing very small EV numbers) supported by adequate policy incentives. These were applied to all new vehicle classes as direct replacements for ICE equivalents; the resulting growing share of EVs within the cumulative new vehicle fleet from 2016-2050 is shown in Figure 9-17. Emissions mitigation was calculated based on avoided fuel combustion from displaced ICE sales net of power generation emissions associated with annual power demand for the EV fleet. Power generation emissions were calculated by multiplying the total power demand according to vehicle type by the grid emissions factors in each forecast year according to the power generation mitigation scenario (which foresees an increasing reduction in GHG intensity).[18] Average vehicle power demand values from 2020-2050 were taken from GFEI (GFEI, 2019) and are shown in **Table 9-22**.[19]

[18] According to IPCC reporting guidelines, these emissions should be allocated to the electricity and heat generation category; however they are here allocated to transport for the purpose of transparently demonstrating sectoral policy contribution

[19] Note that electricity demand projections for EVs are not linked to national power development system planning



Source: Derived from GFEI, 2019

Figure 9-17: Market penetration rates for electric vehicles (maximum share of new registrations)

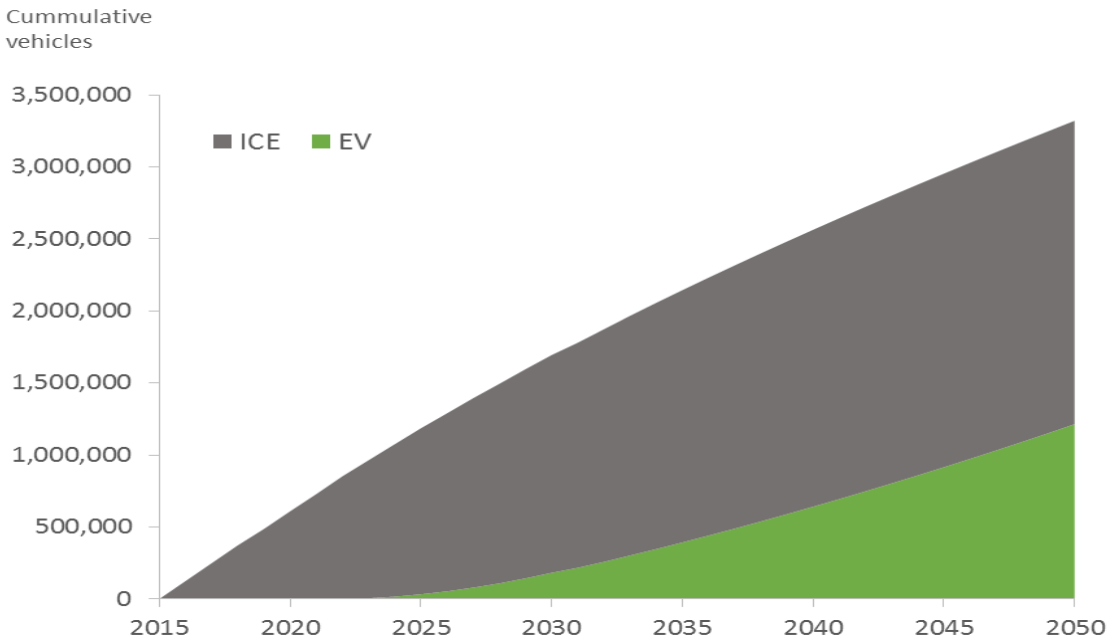


Figure 9-18: Cumulative vehicle sales 2015-2050 (conventional ICE versus EV)

Table 9-22: Average electricity demand from new electric vehicles 2020-2050 (kWh/100 km)

Vehicle type	2020	2025	2030	2040	2050
LDV Passenger car	18.0	18.6	18.6	19.3	19.3
HGV small	26.5	27.4	27.4	28.3	28.3
HGV medium	43.7	45.2	45.2	46.7	46.7
HGV large	88.6	91.6	91.6	94.7	94.7
Motorcycle	4.9	5.1	5.1	5.3	5.3
Bus	48.2	49.9	49.9	51.6	51.6

Source: GFEI, 2019

Biodiesel. Recognising the national dependence on oil product imports, indigenous biofuel production is an objective of ZimAsset and TSP; blending of biofuels in transport fuel use is also a key recommendation within the Zimbabwe National Transport Master Plan. A part of a national biofuels development programme, a biodiesel plant was commissioned in Mount Hampden, near Harare in November 2007 based on production from *jatropha curcas* harvesting and oil production using transesterification. However, the plant remains small-scale due to lack of funding,, despite having an estimated production potential of up to 100 Million litres. Zimbabwe's NDC concluded that reviving the project to achieve commercial scale production would allow national biodiesel blending rates of up to 10% with fossil diesel to be achieved by 2030.

Based on the existing technical analysis in the NDC, increased production and blending of biodiesel with fossil diesel in ICE vehicles was modelled through 2050. As with the NDC analysis, harvesting of jatropha is considered possible after three years, with full commercial-scale production reached after nine years. Output was extrapolated from the NDC analysis whereby *jatropha* production reaches 15,000 Ha and biodiesel fuel product around 100 million litres by 2030. For the LEDS, it was assumed that growth in production is achieved from 2030-2050 sufficient to achieve and maintain an average 15% blending rate within the steadily increasing diesel fuel market[20].

Unlike GHG emissions arising from the production of imported fossil diesel, emission arising from domestic biodiesel production will occur in Zimbabwe. The mitigation potential from biodiesel blending is therefore determined by the displaced fossil diesel *net* of the emissions associated with the biodiesel production process. Energy emissions associated with *jatropha*

[20] Note that this is an average national target assumption, and higher blending rates are possible for certain vehicles

production, covering transesterification, refining, transportation etc. are estimated at 11.3 gCO_2e per MJ fuel based on analysis by Ndong et al, 2009[21].

Public transport/modal shift. Policies and investments aimed at supporting a modal shift away from private vehicle use (mainly passenger cars) to public transport and NMT can be effective in reducing GHG emissions as well as easing congestion leading to greater economic productivity and health benefits. The Zimbabwe National Transport Master Plan proposes a range of measures aimed at increasing the use of transport from modern clean buses, rail, bicycling and walking. Quantifying the impacts of such policies is complex, typically involving the use of advanced transport system models, which are not currently available in Zimbabwe.

Detailed modelling of modal shift potential has not been possible within the scope of the current project. However, a first order estimate of the potential is possible based on some high-level assumptions. It was assumed that a mix of policies and infrastructure projects starting in 2020 can be introduced to drive a modal shift from passenger car usage (defined as passenger km) to modern bus usage (equivalent passenger km) and also non-motorised passenger km (walking and cycling). An equal split between the two modes assumes e.g. covering bus rapid transport (BRT) activities and promotion of cycle lanes, green walkway and pedestrianisation projects. Modal shift programs are typically introduced over medium-long periods. Based on previous experiences in other countries, it was assumed that a total modal shift from passenger car usage to public and NMT alternatives could reach 10% by 2030, 20% by 2040 and 30% by 2050.

GHG mitigation impacts arise from the increased energy efficiency of modern public transport compared to conventional private vehicle travel (in passenger km), and the zero-carbon characteristic of non-motorised transport use. Data was not available to estimate occupancy rates and typical travel distances for different modes in Zimbabwe with any accuracy, hence unit GHG intensity values presented in GFEI (2019) for different transport modes were applied to calculate the decreasing emissions intensity from modal shift relative to BAU through 2050. The following values were assumed

- Passenger car: 204 gCO_2e/km;
- Modern public bus: 82 gCO_2e/km;
- Rail: 60 gCO_2e/km;
- NMT: 0 gCO_2e/km.

Rail rehabilitation and electrification was considered within the Zimbabwe NDC analysis: however, given the lack of available data, the potential for additional rail infrastructure development, including potential for HGV freight km to rail freight km has not been considered here. Increased rail rehabilitation and electrification rates (assuming the GHG intensity of grid supply falls significantly from present levels, as per the mitigation scenario presented in this LEDS) could achieve additional mitigation as diesel consumption from HGVs is displaced by more efficient rail freight energy use.

[21] Life cycle assessment of biofuels from Jatropha curcas in West Africa: a field study (Ndong et al, 2009)

Combined results. The GHG mitigation potential estimated from the combined package of interventions is shown inFigure 9.19. The graph shows that by 2050, the carbon intensity of the road transport system is more than halved under the LEDS low carbon scenario. Under the BAU scenario, emissions are projected to increase to around 5.3 $MtCO_2e$ by 2050. Putting in place the package of low carbon road transport measures is estimated to reduce this level to around 2.4 $MtCO_2e$. The largest contribution to the mitigation effort is expected to come from fuel economy improvements in the vehicle fleet, delivering around 50% of the GHG emissions reductions in 2050, followed by EVs which contribute around 30% of the effort; the use of biodiesel and modal shift account for the remaining 20% of the total mitigation. Note that total decarbonisation of the sector would require additional measures such as *inter alia* mandatory scrappage of all ICE vehicles before 2050 and the development of a zero carbon power supply.

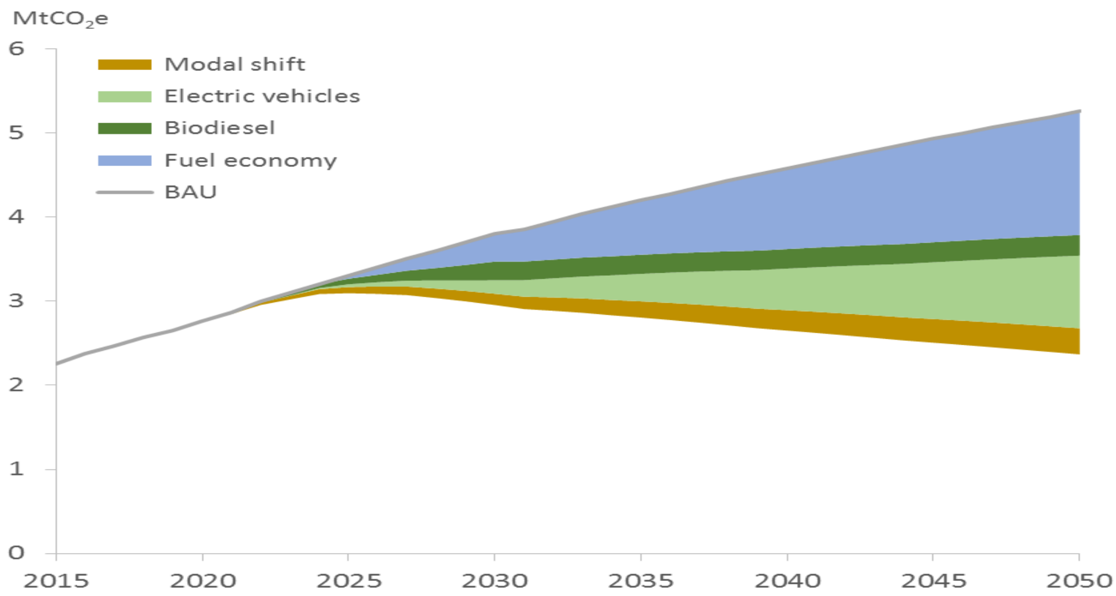


Figure 9-19: GHG mitigation potential in road transport through 2050

Economic Analysis

Abatement costs were calculated for each of the four mitigation measures, based on a simple discounted cash-flow analysis of project costs and benefits (net present value) divided by the total mitigation achieved. The analysis was undertaken on a socio-economic basis applying a discounted factor of 6% over a long-term assessment period of 25 years. The resulting abatement costs are shown in **Table 9-23**, along with the key economic assumptions made.

Table 9-23: Abatement costs for low carbon road transport measures in 2030

Measure	USD/ tCO_2e	Key economic assumptions
Fuel economy	-100.83	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 mandatory Euro V standard for ICE vehicle classes (ICCT, 2014). Incremental costs above uncontrolled vehicle types were estimated as $US 54 (motorcycles), $US 361 (passenger cars), $US 2,958 (buses) and $US 2632-5394 (HGV, according to class). Set-up and policy study costs were estimated at $US 5 million, and annual administration and inspection/enforcement costs were estimated at $US 3 million.
Biodiesel blending	-0.92	Capital costs for commercial scale biodiesel production plan estimated at $US 300 million (for target production of 100 million litres p.a.), based on Finealt Engineering, 2016 Clean Development Project (CDM) project design document (PDD).Total operating costs for scale-up estimated at 0.78 $US per litre biodiesel (Finealt Engineering, 2016). Local job creation from production and processing estimated at 3,000 with employment benefits equivalent to to USD 0.05/litre, based on study of *jatropha* production socio-economic benefits (Eijck et al., 2012).
Public transport/ modal shift	12.00	Insufficient data and transport system information was available to undertake robust cost-benefit analysis. Abatement cost therefore taken from an existing study of modal shift implementation in developing country urban area (Bogota), applying bus rapid transit (BRT) system. Midpoint of US$ 10-14/tCO_2e assumed.
Electric vehicles	17.71	Additional capital costs include the incremental cost between an EV and equivalent ICE vehicle purchase, and the charging infrastructure needed to provide for reliable charging. Current costs for equivalent passenger cars e.g. VW Golf (gasoline) and VW eGolf (electric) indicate an incremental cost of around 25-30%. A wide range of market studies (e.g. Deloitte; McKinsey) estimate cost parity may be reached by 2025 principally as a result of rapidly declining battery costs; the year 2028 is assumed as a conservative assumption. It is assumed that wide-spread rapid charging (as opposed to overnight/slow; or fast) will be required for commercial scale EV uptake; a per vehicle capital cost of $US 2,500 is applied, based on a unit cost of GBP 30,000 (USD 37,500) for a 50kW rapid charger supplying 15 vehicles (Energy Saving Trust). Changes in operating costs between an EV and equivalent ICE vehicle are equivalent to vehicle electricity demand per km of travel minus the displaced diesel and gasoline costs per km of travel. Due to a lack of comparative datasets, these assumptions are applied on a unitised basis to all EV vehicles: this is considered reasonable as (a) passenger cars will represent the large majority of new EV vehicles and (b) some vehicle types are expected to face higher relative costs and others lower relative costs compared to passenger cars.

The abatement costs show that undertaking a programme aimed at improving vehicle fuel economy result is highly cost effective: the additional costs arising from the purchase of highly fuel efficient models within each vehicle class are offset by overall fuel savings, as are the set-up and ongoing costs of policy implementation and administration. The inclusion of environmental and health impacts would deliver considerable additional benefits. Despite their ability to deliver cost-effective mitigation, the other measures as described will require larger levels of investment and costs to vehicle users, requiring financial support to enable their uptake.

Policy and Implementation

Policy Measures

Future uptake of electric vehicles to replace ICE vehicles will be largely determined by the rate of technology cost reductions in new models, principally reflecting battery costs. Even with vehicle cost parity, users need access to reliable charging (at home, work, or through public charging points). These represent an additional cost – whether paid for directly by the consumer (home charging), fleet manager (fast or rapid charging for multiple vehicles) or through charging stations. To help bridge the cost difference, a loan facility to incentivise EV and charging purchases is proposed as a climate finance instrument managed by the IDBZ.

Figure 9-20 compares the lifecycle cost on a per km basis for a conventional gasoline ICE passenger car and an equivalent EV model.[22] It is assumed that a fleet operator is assessing the relative financial case between a small fleet of gasoline versus EV vehicles. The first two bars show the costs compared based on a prime commercial lending (CL) basis applying a rate of 15%. It can be seen that although the lower operating costs per km (electricity for EV) are lower than those of the gasoline vehicle, these are insufficient to overcome the total cost of capital. However, if a reduced rate of 6% was applied through a loan facility (LF), the EV fleet now demonstrate lower lifecycle costs.

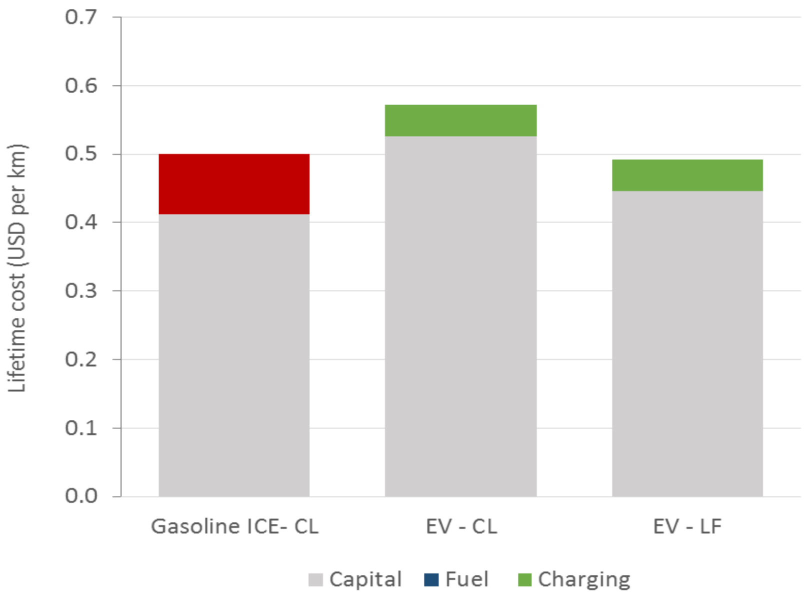


Figure 9-20: Lifetime vehicle cost comparison, Gasoline ICE versus EV (fleet operator)

[22] Assumes finance provided over a five-year period with 15,000 km travel per year. Resale value in year six estimated to be 30% of new sale value (based on 75,000 km mileage).

On this basis, a loan facility to incentivise EV and charging purchases should be made available through a climate finance instrument managed by the IDBZ.

Biodiesel production in Zimbabwe has so far suffered from a lack of funding and policy support. It can however play an important role in reducing fossil energy emissions whilst also helping to create domestic employment and reducing the country’s reliance on diesel imports. Importantly, blended biodiesel offers a way to help mitigation emissions from existing and future ICE vehicles, noting that electrification of the transport system will take several decades. However, the large investment costs (for harvesting, processing, refining and distribution) and long lead times in harvesting biomass pose a challenge to investment. Unlike EVs, biodiesel also face additional ongoing costs versus conventional diesel, as the estimated price required to generate a return to investors is higher than the current pump price for diesel.

Figure 9-21 compares the final pump price for blended biodiesel and conventional diesel (assumed in year 2022). Assuming a 30% margin for production and retail over production costs and biofuels tax exemption, new biodiesel production financed at a commercial lending rate of 15% would retail considerable higher than diesel. Lending at a rate of 6% under a climate finance facility would reduce the price, although the lower level would likely remain insufficient to compete with conventional diesel. Biodiesel would therefore need additional support to incentivise plan investment and commercialise its use. The graph shows the relative impact of increasing the existing carbon tax on transport fuels - here to around $US 0.13/litre, resulting in a final price preference for biodiesel. Carbon pricing could therefore play an important role in supporting biodiesel production – but unless raised to very high levels, would need to be accompanied by the support needed to help finance production plant.

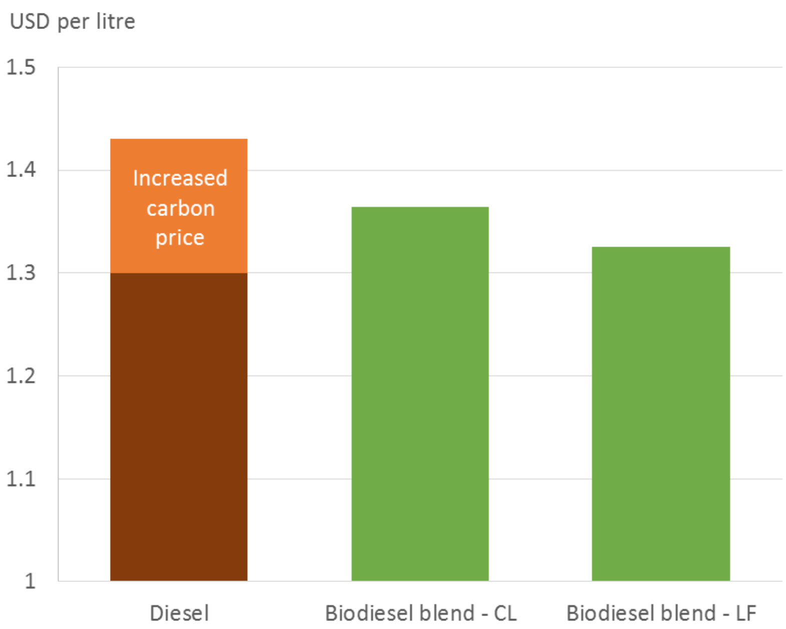


Figure 9-21: Diesel and biodiesel blend pump prices with and without support incentives

A policy package to encourage improvements in vehicle fuel economy should be developed, include the following potential components:

- Development of fuel economy and/or emissions standards for all new vehicle registrations through 2025. Consideration should be given to application of latest Euro engine standards across all vehicle types and classes. A timeline of actions is proposed as:
  - Definition of new emission standards by 2022
  - Phased introduction of the standards from 2022 to 2025
  - Full implementation and enforcement of the standards from 2025
- Strengthen capacity to measure, monitor vehicle emissions, and enforce emissions standards (e.g. setting up a national motor vehicle technical inspection centre).
- Promoting appropriate car maintenance by enforcing vehicle compliance and inspection rules.
- Gradual phase out of kombis and minibuses on trunk routes by replacing them with conventional buses (2022-2025).
- Policy review to assist the private sector to investment in modern fleets, potentially supported through IDBZ loan facility.
- Policy review to assess potential for scrappage of the least fuel-efficient vehicles.
- Fiscal reform to incentivise fuel efficient vehicle, to include the following potential elements:
  - Tax exemptions for imported large fuel efficient buses for public transport
  - Tax levy on imported used cars of 10 years or over.
  - Phased introduction of revenue neutral fee-bate scheme to incentivise purchase of the most fuel-efficient models within each vehicle class/category.

The introduction of an integrated transport system in Zimbabwe would reduce the carbon footprint caused by the road transport sector. This will reduce the number of people using private cars and reduce GHG emissions. A combination of policy development, infrastructure investment, and public awareness campaigns will be required to achieve modal shift from the current carbon intensive transport system to a more sustainable and efficient system over the medium and long term. Key actions will include;

- Introduction of an effective mass public transport system that includes use of big buses and rail transport, replacing kombis on trunk routes in all cities and most towns.
- Establishment of bus priority such as dedicated bus lanes, including construction of dedicated rush hour high speed bus lanes, and scheduled timetables (from 2025 onwards),

- Introduction of regulations promoting use of non-motorized transport (NMT) to reduce carbon emissions and make provisions for non-motorized transport on existing and new road networks, for example, through use of new pedestrian and bicycle lanes.

Roadmap of actions

Table 9-24 presents a roadmap framework of actions proposed to develop a policy framework that promoting a transition to a low carbon transport sector in Zimbabwe. Note that modal shift actions (T6 and T7) area indicated to have economic costs outweighing benefits. However, detailed economic analysis has not been possible and this conclusion is based on an existing study estimating abatement costs from a BRT scheme: inclusion of wider benefits such as reduced air pollution, health benefits and efficiency gains may indicate larger benefits to offset against significant infrastructure investment costs. Similarly, the promotion of EVs may be achievable at overall net economic benefit if assumptions around future capital costs of EVs and charging infrastructure are more favourable and/or the relative costs of electricity versus imported fossil fuels are further reduced over time.

Table 9-24: High level Roadmap for Low Carbon Road Transport

No.	Action	Time-frame	Lead organisation	Cooperating organisations	Potential funding sources	Estimated total costs t0 2050	Economic benefits outweigh costs?
T1	Develop national biofuels policy with financial support for production investment.	Short-term; ongoing	MEPD and MTID	MF; SAZ; MFED; BCSDZ; CZI; EMA; Research Institutions; NGO; IDBZ	Government Treasury; GEF; UNEP; UNIDO; World Bank; DFID; EU; carbon tax on fuels	USD 2 billion	Yes
T2	Promote out-grower schemes and mini processing plants for biofuels production on smallholder farms.	Medium-term; ongoing	MEPD and MOA	Private Sector; Farmer's Organisations; NGOs	Government Treasury; GEF; DFID; EU; private sector; climate finance	USD 50 million	Yes
T3	Strengthen capacity to measure and monitor vehicle emissions and enforce fuel economy standards for new vehicles.	Short-term	MTID; MLAWRCC	MOHA; Government Treasury; motor Industry (traders, retailers); SAZ; MHTESTD; NGOs; fuel Companies; transport operator associations	Carbon tax; import taxes and sales taxes/fees; fines and penalties; motor industry.	USD 5 million	Yes
T4	Implementation of fuel economy standards and support/fiscal incentives.	Medium-long term	MTID; MLAWRCC			USD 1-2 billion	Yes
T5	Develop strategy to promote introduction of EVs to replace imported ICE vehicles, supported by loan facility to support additional costs.	Medium-long term	MTID; MLAWRCC; IDBZ	Motor Industry (traders, retailers); Fuel Companies	Carbon tax; import taxes and sales taxes/fees; climate finance	USD 4-5 billion	No
T6	Introduce regulations and provisions that promote use of non-motorized on existing and new road networks.	Short-term	MTID	MF; MHA; MLGPWNH; MJLPA; CSOs; Media; Local Authorities; Zimbabwe Safety Council	Government Treasury; banks; private sector	USD 50 million	No
T7	Introduce an effective mass public transport system that includes use of large buses and rail transport.	Medium-term	MTID	MF; MLAWRCC; MHA; MLGPWNH; MJLPA; CSOs; Media	Government Treasury; GEF; UNEP; EU; DFID; UNIDO; AfDB; World Bank; banks; private sector; IBDZ	USD 500 million	No

Annex V: Low Carbon Cement Initiative

Overview

The cement sector is a major emitter of industrial GHG emissions, both globally and within Zimbabwe. Emissions include industrial process emissions from calcination during clinker production, as well as energy emissions arising from fossil fuel and electricity consumption. Three main levers exist to reduce direct GHG emissions from the cement industry:

- Lowering the clinker content in cement;
- Increasing the use of alternative fuels and raw materials (AFR) substituting fossil fuel use; and
- Implementing thermal energy and electrical efficiency improvements.

There are currently three major clinker and cement producers operating in Zimbabwe. These include Lafarge, SinoZim and Pretoria Portland Cement (PPC) Zimbabwe. Two other plants, Live Touch and Pacstar also produce cement from sourced clinker. Total clinker production volume was estimated at 376,000 tonnes in 2013. Although aggregated data is not available, production levels in 2018 were estimated to be around 450,000 tonnes per year.

The demand for cement rose by 30% through 2018 due to increased construction activity . The sector is unable to meet demand due to insufficient foreign currency to finance plant repairs and imports of equipment/spare parts. As a result, plants are unable to run at full utilisation due to plant breakdowns. The shortfall is being met through imports from South Africa and other neighbouring countries.

This Annex describes the key elements of a potential low carbon programme for the cement sector. Such a programme would aim to deliver GHG reductions from both GHG emission sources (process emissions and energy emission) whilst also reducing fossil energy use. The programme is described at a very high level only: a key recommendation is that a more detailed programme including specific targets, actions and funding sources be developed. This could can define step-wise goals, KPIs and associated emissions reductions from a BAU baseline case through 2050. This would need to be underpinned by developing an MRV system according to a harmonised sectoral standard to assess progress in CO_2 and energy performance, for example, as developed under the World Business Council for Sustainable Development (WBCSD) Cement Sustainability Initiative (CSI) and through capacity building, awareness raising and improving dialogue among relevant stakeholders.

Although demand for cement is rising, production from existing facilities is hampered by a lack of investment in technology and access to spare parts. Any mitigation programme for the sector should therefore be focused on reducing emissions whilst delivering measurable and cost-effective co-benefits to the industry. For this reason, a realistic low carbon development scenario developed for the cement sector should recognise the need for industrial growth and focus on economic efficiency. Higher-cost or unproven technical options such as carbon capture and storage are not considered within the programme, although could be feasible subject to ongoing developments and support from international climate finance. The scope of the current analysis, only considers mitigation from reducing calcination process emissions. Mitigation from reduced energy use and alternative fuels would deliver additional reductions and should be further assessed as part of a low carbon programme for the sector.

GHG mitigation potential

The cement production process can be divided into two basic steps; first clinker is produced from heating limestone in a kiln to temperatures up to 1,400°C. Then the clinker is milled with other materials to produce powdered cement product. The production of cement gives rise to three principal sources of CO_2:

1. Process emissions associated with de-carbonation of limestone in the kiln (around 525 kg CO_2 per tonne of clinker);
2. Combustion of fuel in the kiln (typically 300-350 kg CO_2 per tonne of cement);
3. Indirect emissions from electricity use for raw materials and clinker grinding, and cement finishing (typically 50 kg CO_2 per tonne of cement).

Process CO_2 emissions associated with limestone calcination thus account for the largest source of sector emissions – equal to around 60% of direct sector emissions. The principal option available to reduce process emissions is through the increased blending of cement with clinker substitutes. Blending reduces the clinker production needed per tonne of cement product. The use of clinker substitutes such as fly ash, blast furnace slag and volcanic ash varies considerably by world region according to the local availability of such materials and varying requirements for product specifications. In addition, significant emissions reductions could be achieved with CCS using post combustion or oxy-firing technology and via the development of alternative low-carbon cement products. These options, however, face considerable uncertainties around their technical and economic viability.

The WBCSD Cement Sustainability Initiative and IEA have developed long-term targets for global cement industry based on the key abatement levers (Figure 9-22). These describe how increasing the use of clinker substitutes, alternative fuel use and energy efficiency measures could deliver 44% of sector mitigation potential cost-effectively.

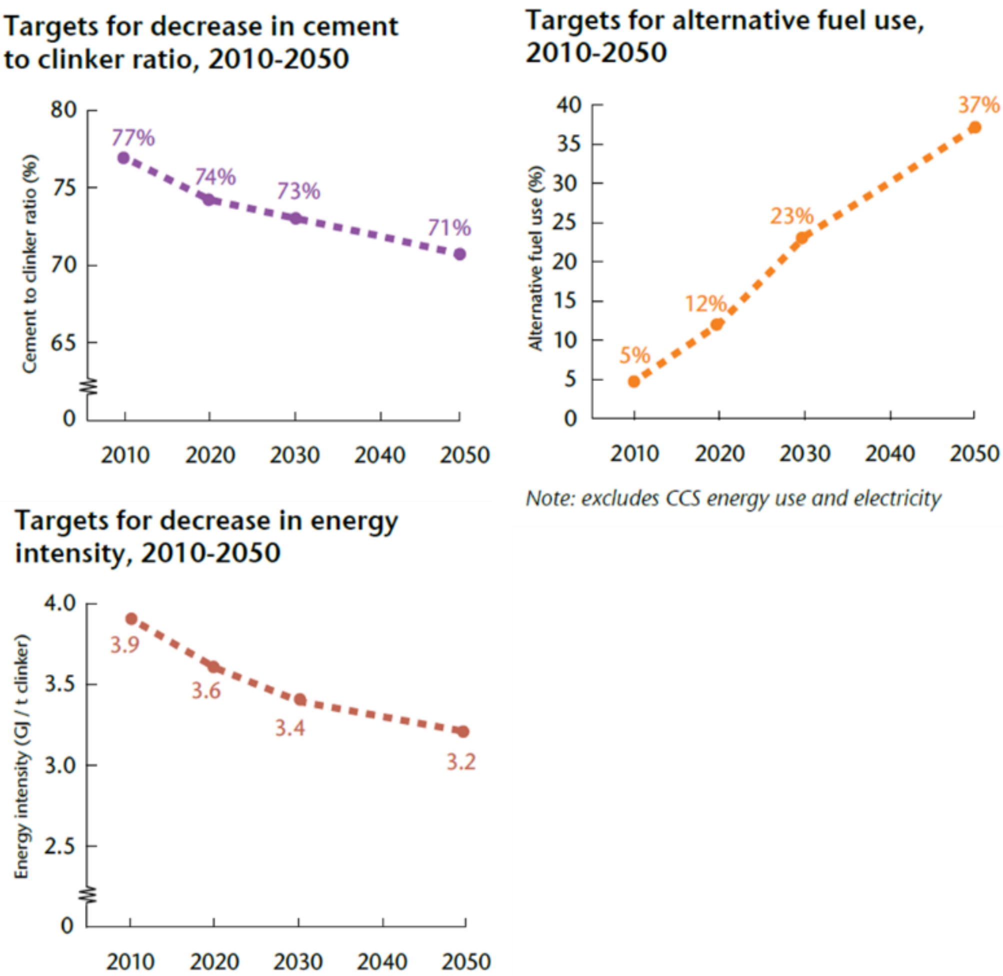


Figure 9-22: Targets for improving sustainability in the global cement industry to 2050

Source: Cement Technology Roadmap (IEA/CSI, 2009)

Various factors, including the local availability of affordable alternative fuels and substitutes, regulatory requirements and standards for the clinker content of cement products, and technology availability will determine what can be achieved in practise.

Table 9-25 presents a series of targets for the Zimbabwe cement sector, based on a series of key performance indicators. The table is based on a framework developed by the EBRD[23] and shows the current performance levels for the sector and targets for what could be feasibly achieved over the medium term, subject to overcoming various barriers. The values shown are aggregated at the sector level based on information provided by each of the key producers.

Table 9-25: GHG emissions KPIs for Zimbabwe cement sector by 2030

Technical aspect	Unit	Current best practice worldwide	Key performance indicators	
			Current	Target
Clinker substitution	% clinker/t cement	<50%	78%	72%
Thermal energy consumption	GJ/t clinker	2.8	4.2	3.8
Electrical energy consumption	kWh/t cement	<80	130	120
Alternative fuels (AF)	% (thermal)	100%	0%	19%
Alternative raw materials (AR)	% (kg/kg raw meal)	100% (small scale industrial)	14%	17%
Specific CO_2 emissions	$kgCO_2$/t clinker	766 (EU ETS)	893	804
Specific CO_2 emissions	$kgCO_2$/t cement	Depends on clinker factor (543, global 10% best)	704	611

Source: based on EBRD, 2016

Figure 9-23 shows sustainability targets for Zimbabwe's cement sector over the longer term to 2050. The specific KPI targets shown in the table are assumed achievable in the medium term (2030) subject to appropriate support. The long-term global targets for energy related emissions as proposed by the WBCSD-CSI and IEA are then applied in year 2050. For clinker content, a steady improvement is assumed based on reaching global BAT-type levels by 2050. The resulting trajectories indicate the potential increase in performance levels that could be achieved by the sector over the next 30 years as part of the national LEDS. It is important to stress that these values are highly indicative only based on initial analysis; as part of a low carbon initiative for the sector. A more detailed assessment and consultation with the industry is required to develop finalised KPI targets.

23 Low-Carbon Roadmap for the Egyptian Cement Industry, EBRD October 2016.

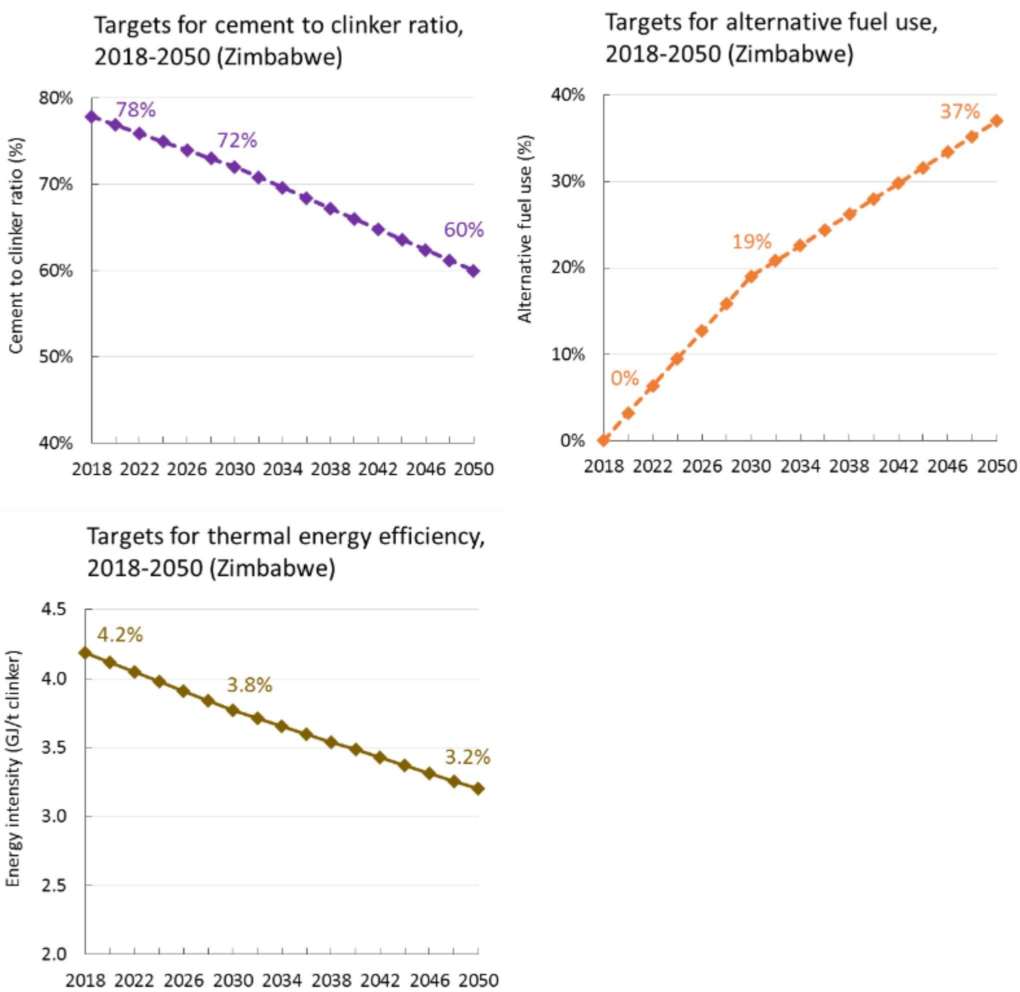


Figure 9-23: Indicative targets for improving sustainability in the Zimbabwe cement industry to 2050

Based on these targets, the sectoral mitigation potential through 2050 compared to BAU can be estimated. This is shown in **Figure 9-24**. The BAU projection shows total cement production emissions comprising of both IPPU process emissions (around 56% of the total) and energy emissions (around 44% of the total). Under the BAU scenario, these rise from just under 0.4 million tCO_2e in 2015 to almost 1 million tCO_2e by 2050. With implementation of the sustainability targets, process and energy emissions are reduced by around 40% compared to the BAU level in 2050. The graph (**Figure 9-24**) shows that clinker substitution delivers the largest reduction, which reduces both process and energy emissions. The associated expected improvements in the GHG intensity of clinker and cement production are shown in Figure 9-25.

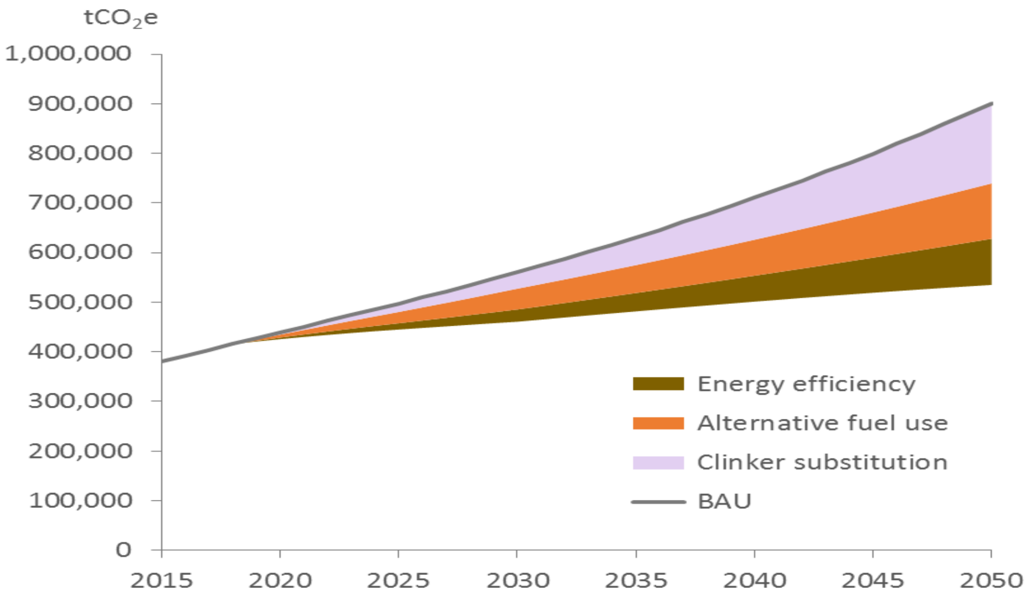


Figure 9-24: Estimated mitigation potential versus BAU in the cement industry through 2050

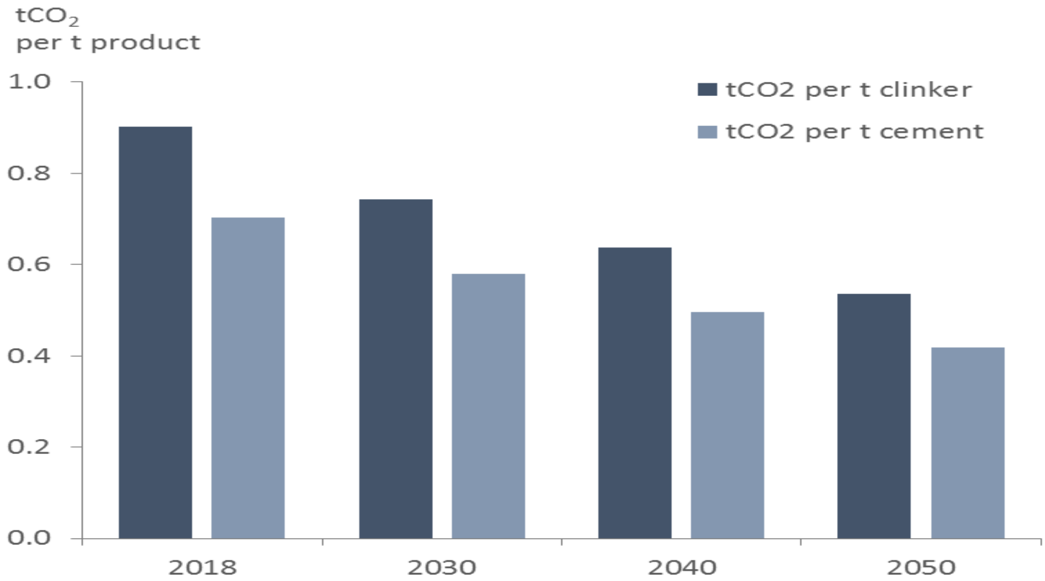


Figure 9-25: Improved GHG intensity of cement and clinker production with mitigation measures

Economic Analysis

Most economic analysis of abatement options in the cement sector indicate that mitigation can be achieved on a cost-effective basis for the three key options in Figure 54

(McKinsey and Company, 2009).[24] This is because capital and material costs are offset by reduced clinker production costs and energy (fuel and electricity) consumption, as follows:

- **Clinker substitution** by alternatives (e.g. fly ash, blast furnace, slag) typically involves capital costs for material handling and material and freight costs; substitution reduces clinker production costs.
- **Increasing use of alternative fuels** and waste (e.g. municipal and fossil-based industrial waste) typically involves capital costs for waste handling and waste fuel costs; use of waste as a fuel reduces fossil fuel costs/imports and potentially also costs to public sector of disposing of domestic and industrial waste.
- **Energy efficiency** and waste heat recovery options give rise to capital costs, which are typically offset in the medium-term by fuel and electricity savings.

Estimating abatement costs for the sector is highly dependent on the technical and logistical circumstances of each production facility and its potential to implement abatement measures. A detailed economic assessment has not been possible due to limited data. However, an economic analysis of the potential to reduce cement process emissions by increasing clinker substitution rates was undertaken.

Abatement costs were calculated for two clinker substitution options: increased use of fly ash (from coal-fired power stations) and increased use of blast furnace slag, BFS (from iron and steel production). Both sources are currently used in the sector and there is potential to increase their use over the medium and long-term, subject to key factors including their future availability and consumer acceptance of lower clinker content products.The GHG emissions reductions are achieved by displacing clinker production emissions. The costs associated with clinker substitution include capital costs for material handling, processing and material purchase costs. Benefits that arise from reduced clinker production costs include energy costs and other fixed and variable cost elements. For the sake of the analysis, and given the high degree of uncertainty around future materials availability, an equal split between fly ash and BFS was assumed.

Abatement costs were calculated for the two clinker substitution measures, based on a simple discounted cash-flow analysis of project costs and benefits (net present value) divided by the total mitigation achieved. The analysis was undertaken on a socio-economic basis applying a discounted factor of 6% over a long-term assessment period of 25 years. The resulting abatement costs are shown in **Table 9-26**, along with the key economic assumptions made. The resulting negative cost values are in line with other published studies, including McKinsey and Company, demonstrating the cost-

[24] Pathways to a Low-Carbon Economy, Version 2.0 of the Global Greenhouse Gas Abatement Cost Curve (McKinsey and Company, 2009).

effectiveness of increasing clinker substitution to reduce emissions within the cement sector(McKinsey and Company, 2009).

Table 9-26: Abatement costs for clinker substitution in 2030

Measure	USD/tCO_2e	Key assumptions
Increased use of fly ash	-16.98	Assumes increased use of fly ash to reach 20% by 2050. Capital costs for fly ash handling capacity estimated at USD 6 per tonne based on existing engineering cost estimates.[25] Material costs of USD 4 per tonne assumed, based on ongoing domestic supply from thermal power generation (sufficient coal-fired generation assumed available through 2050, despite increasing supply from renewables).
Increased use of BFS	-3.91	Assumes increase in use of BFS to reach 20% by 2050. Capital costs for BFS granulation and grinding capacity estimated at USD 80 per tonne based on existing engineering cost estimates.[26] Material costs of USD 9 per tonne assumed, based on ongoing domestic supply from iron and steel production (sufficient supply assumed to be available through 2050, despite current cessation from ZISCO works).
Clinker production cost assumptions		
Item	USD per t	Notes
Labour	1.10	Based on average unit clinker production costs forecast in 2020 for Africa emerging economy producers (VDZ, accessed July 2019)[27] Original values given in EUR and converted to USD assuming 1:1.11 exchange rate as of end of July, 2019
Raw materials	2.20	
Maintenance	2.20	
Depreciation	4.40	
Other	1.10	
Energy	23.00	Calculated based on assumed Zimbabwe fuel and electricity consumption values shown in Figure 9-23
Total	34.00	-

Policy and Implementation

Key challenges and barriers

The cement sector faces a complex combination of economic and non-economic challenges to implementing the types of abatement options in Table 9.26. Key challenges include:

- **Lack of funding and access to equipment:** Each of the major cement companies have undertaken project feasibility studies to implement a range of energy efficiency measures and plant upgrades. Many of these are economically viable given their potential to reduce energy and materials costs. However, a lack of fund-

[25] McKinsey and Company, 2009.

[26] McKinsey and Company, 2009. Analysis estimates a total of €145 per tonne. It is assumed that this would be reduced to half based on existing BFS handing and processing capacity within the cement sector.

[27] See: https://www.vdz-online.de/uploads/media/EU_ETS_Charts_EN.pdf

ing remains an overriding constraint to investing in clean technology within Zimbabwean industries. The current investment climate does not support meaningful foreign direct investment and companies lack the finance to access imported equipment. Major retrofits also lead to plant downtime, which can impact short-term cash flow.

- **Policy and regulatory framework**: In common with many other countries, existing cement product and building codes focus on composition rather than product performance, presenting a barrier to enable the use of higher clinker substitution products. There is also a lack of awareness from consumers regarding the application and performance of lower clinker products
- **Availability of clinker substitute materials:** BFS is currently still available from the ZISCO iron and steel works. However, unless investment is forthcoming to resume production over the coming decade, continued BFS supply will only be available as higher cost imports, thereby limiting and potentially reducing national substitution rates. High quality fly ash is currently available from domestic coal-fired power generation, and is likely to replace BFS for some operators in the coming years.
- **Supply and quality of alternative fuels and waste.** For waste to be used as kiln fuel, waste collection and pre-treatment arrangements and facilities must be developed, potentially based on a supported programme of waste tyre collection. The availability of biomass at a reasonable cost and on a reliable basis will also be needed to achieve an increase in alternative fuel use, which is currently not in practice. The suitability of different available fuel and waste materials also needs to be determined (e.g. relating to calorific value, moisture content, volatiles).

Policy Measures

A series of policy actions and measures will be needed to overcome these barriers and implement a roadmap for increased cement sustainability in the national cement sector contributing to the LEDS. These will need to be developed in consultation with stakeholders. An initial proposal of some key elements is however provided in the next section.

***Cement product qualities and construction practice and codes*.** It is recommended that the Ministry of Local Government, Public Works and National Housing (MLGPWNH) arrange consultations between the cement producers, the Building Technology Institute (BTI), the Standards Association of Zimbabwe (SAZ), the Construction Industry Federation of Zimbabwe (CIFOZ) and the Zimbabwe Building Contractors Association (ZBCA) – and other relevant stakeholders – to explore options to improve the sustainability and carbon footprint of construction and support increased use of clinker substitutes in cement, concrete and construction. There is also a need to raise awareness of low carbon cement production with actions aimed at education, and training of construction workers and managers.

***Development of an enabling regulatory framework for waste*.** A broad framework of waste policy with targeted approaches to different waste products, reflecting the 'waste hierarchy' of reuse and reduction provides a sound basis for waste use in the cement sector. There is therefore a need to review the current legal and regulatory framework to ensure that a sound waste management market is developed with proper infrastructure and a price for waste treatment and disposal, encouraging the cement industry to use waste as a fuel.

Incentives to improve thermal energy efficiency at facilities. It is recommended that the Ministry of Industry and Commerce and the MLAWCRR work to develop reference performance benchmarks for the existing clinker and cement production facilities and for new installation permits. Companies exceeding this level would be required to undertake energy auditing and demonstrate that energy efficiency improvements have been fully assessed. This could be transitioned over time to a mandatory energy auditing and Environmental Management System (EMS) scheme, including for example operation of energy management systems in line with ISO 50001, including staff energy management training, and ISO14000 EMS part of Strategy for Sustainable Development. A financing facility should support proposals from cement companies which demonstrate a clear case for reduced emissions.

Use of voluntary KPIs and sustainability agreement. As part of a wider policy to implement mitigation actions, track improvements and identify abatement opportunities within Zimbabwean industry, it is recommended that the cement sector enter into a voluntary agreement with MLAWCRR to reduce its GHG emissions intensity over time. This could form a wider initiative within industry involving the BCSDZ, the Confederation of Zimbabwe Industries (CZI), Chamber of Commerce, Chamber of Mines, Construction Industry Federation of Zimbabwe (CIFOZ), and others. Development and implementation of voluntary agreements between the government and these industry bodies should be effective as a first step in promoting climate change mitigation and has the benefit of reducing the burden of information and administrative costs from government authorities. Subject to economic growth and industrial recovery over the medium term, such agreements may provide basis for other types of policy e.g. including carbon pricing.

MRV system and public GHG reporting. There is currently no requirement for cement companies - or other industrial operators - to undertake MRV of their energy and CO_2 emissions according to a required standard. However, such a system would be needed to track facility and sector level KPIs. It would also help to monitor policy implementation and governmental reporting to the UNFCCC. It is, therefore, recommended to establish a Zimbabwean cement sector energy and GHG MRV approach at the facility and sector level to able to track progress against agreed KPIs. This could be based on the existing WBCSD/CSI global MRV standard and 'Getting the Numbers Right' (GNR) database.

This could be developed through a consultative process between the MIC, MLAWCRR, BCSDZ and SAZ. Based on this MRV system, an annual assessment of KPI progress at the sector level could be undertaken with public disclosure, but ensuring confidential information from each operator. The WBCSD/CSI could potentially facilitate capacity building in designing and developing such a system, and in providing training and knowledge transfer.

Roadmap of actions

Table 9-27 presents a roadmap framework of actions proposed to reduce GHG emissions from the cement sector in Zimbabwe.

Table 9-27: High level Roadmap for Sustainability in Cement Production

No.	Action	Time-frame	Lead organ-isation	Cooperating organisations	Potential funding sources	Estimated costs
C1	Review and revise cement product codes and standards to enable greater use of lower clinker content products	Short term	MLGPWNH SAZ	Cement companies; BTI; SAZ; CIFOZ; ZBCA	MoFED; donor support	< 1 million USD
C2	Blended cement awareness, training and capacity building programmes	Short term	MLAWRCC; MLGPWNH	Cement companies; BTI; SAZ; CIFOZ; ZBCA; consumer groups	MoFED donor support; GEF	1-2 million USD
C3	Technical assistance programme to support biomass suppliers and identify suitable business models	Short term	MLAWRCC; ZERA	MLAWCRR; private sector (biomass suppliers); banks; MoEPD	MoFEDGEF; UNEP; UNIDO; World Bank; DFID; EU	< 1 million USD
C4	Develop incentives for enhancing energy efficiency investments and practices	Short term	MLAWRCC	Cement companies; BCSDZ; MEPD; private sector; banks; MIC	MoFEDGEF; UNEP; EU; DFID; UNIDO; AfDB; World Bank; banks; private sector; IBDZ	Unknown
C5	Develop voluntary agreements with facility and sector KPIs	Short term	; MLAWRCC	Cement companies; BCSDZ; MIC	Cement companies; MoFEDdonor support; WBCSD/CSI	< 1 million USD
C6	Establish MRV system with reporting of energy and GHG emissions	Short term	MIC; MLAWRCC	Cement companies; BCSDZ;	Cement companies; MoFEDdonor support; WBCSD/CSI	1-2 million USD
C7	Studies to determine feasibility of efficient tyre waste collection models.	Short term	MLGPWNH; MLAWRCC	Waste companies; cement companies; municipalities; Financial institutions	MoFEDdonor support; GEF	100-200 k USD
C8	Review and revision of waste framework (e.g. ban landfilling of tyres).	Medium term	MLGPWNH; MLAWRCC	Waste companies; cement companies; municipalities	MoFED	< 1 million USD

Annex VI: Commercial Tree Planting Initiative

This mitigation activity provides an update of the commercial tree planting activity, developed under the WB's NDC Support Project.

Mitigation Potential

Linked to the current economic situation and related difficulties to structure debt capital, the tree plantation establishment has fallen behind the harvesting rate and left areas unplanted in the Eastern Highlands. The total area allocated for plantations is estimated at 140,000 hectares with only 70,000 hectares currently forested. The remaining area is proposed to be reforested by commercial plantations. The trees to be planted include pine and eucalyptus species, namely *Pinuspatula, P. taeda, P elliottii, P. maximinoi, P. tecunuminii, Eucalyptus grandis, E cloeziana, E. camaldulensis, E. pellita,* and *E. urophylla.* The plantations will produce round wood for sawn wood from pines and eucalyptus and utility poles from eucalyptus.

Table 9-28: Planting Schedule Input Parameter

Parameter	Unit	Value
Total Concession Area	ha	200,000
Plantable Areas	ha	140,000
Currently planted	ha	70,000
Factor for actual planting	%	80%

The total forest concession area amounts to approx. 200,000 ha, whereof approx. 140,000 ha are plantable areas. While the historical maximum of planted areas amounts to 110,000 ha, the mitigation action considers the full commercial potential provided that acceptable financing conditions are provided. The net planting area (excluding roads, firebreaks etc.) that the companies will use is expected to total some 70,000 hectares.

Table 9-29: Planting Schedule

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	Total
Pine Sawlogs	3,200	3200	3,200	3200	3,200	3200	3,200	3200	3,200	3200	3,200	2,133	37,333
Eucalyptus Sawlogs	400	400	400	400	400	400	400	400	400	400	400	267	4,667
Eucalyptus Poles	2,400	2400	2,400	2400	2,400	2400	2,400	2400	2,400	2400	2,400	1,600	28,000
Total	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	6,000	4,000	70,000

A planting programme of 6,000 hectares per year for five years is planned. Most of the plantations will be for pine sawlogs (3,200 hectares per year) followed by eucalyptus poles (2,400 hectares per year), and eucalyptus sawlogs (400 hectares per year). It was assumed that the project implementation will start in 2020. The thinning intensity for pine saw wood is assumed to be 40% for the first thinning (year 8), 40% for the second thinning (year 15) and 100% for the final felling (year 25).

For eucalyptus sawwood, the first thinning is planned with an intensity of 40% (year 8) and a final felling after year 20. For eucalyptus poles the trees will be felled after year 10.

The project's GHG impact is related through to establishing and replanting trees after harvests leading to an increment of carbon sequestered in the project area. Even with periodic harvesting and thinning, the average carbon dioxide stock considering both aboveground and belowground biomass in the area under reforestation is significantly higher than what it is currently as degraded unused previous plantation forests covered with grasses.

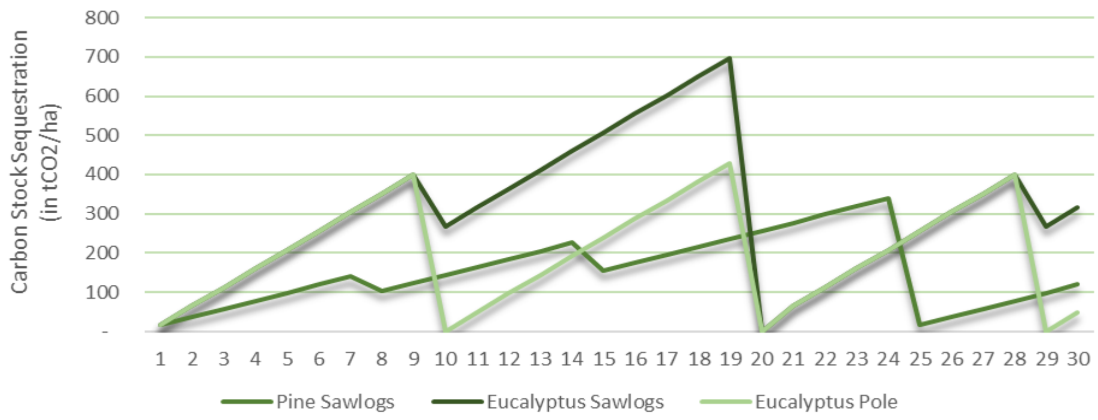


Figure 9-26: Carbon Stock Development under different Management Schemes

The baseline land use is assumed of being grassland with an aboveground biomass of 2.3 tonnes per hectare corresponding to 3.96 tCO_2e/ha. The assessment does not consider carbon stored in wood product pools, though specifically saw wood will enter the long term harvesting product pool storing carbon in boards, furniture and houses well beyond 2050. Furthermore, the accumulation of soil carbon over plantation rotation periods are not considered in the assessment.

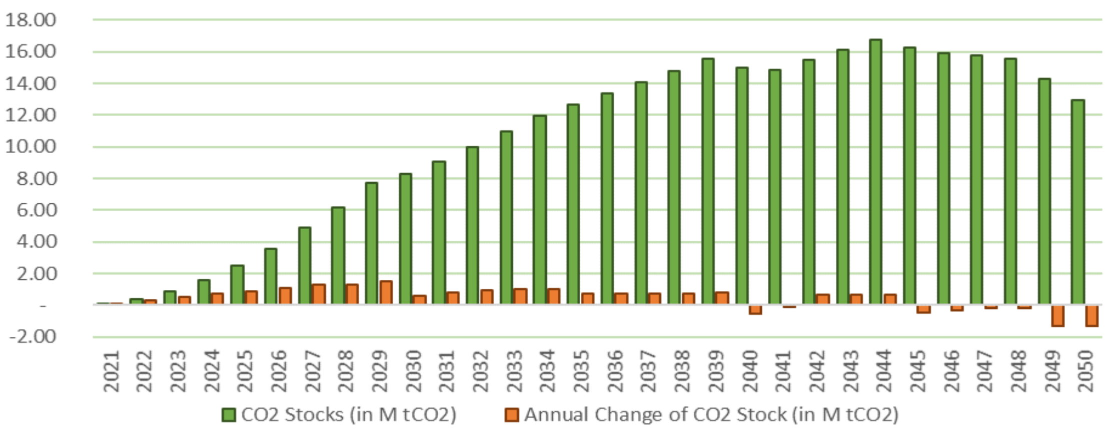


Figure 9-27: Commercial Forestry Carbon Stock Development

In addition to climate change mitigation, the plantations produce valuable round wood that generates a decent cashflow to the project. In addition, plantation projects generally generate employment and additional income in the area of investment for both men and women.

Economic Analysis

The costs of the plantation project provided by Allied Timber include all overhead costs allocated to each hectare planted. The costs of establishing a hectare of plantation is set to USD 1,000 with lower maintenance costs throughout the forest rotation period (see Table E-10 for specific data points used). The costs of harvesting are not included separately in the calculations as the assessment uses net revenues (stumpage prices) from timber harvesting. The benefits to the project are realised through round wood sales revenues. The regimes of the project will produce pine thinnings starting from year 8 after planting (50 m^3/ha) and at year 15 after planting (80 m^3/ha). Eucalyptus will generate thinnings starting at year 10 after planting (126 m^3/ha), and poles from clear-cut at year 10 after planting (315 m^3/ha) and at year 20 after planting (350 m^3/ha from pole regime and 539 m^3/ha from saw log regime). The stumpage prices used for the sales of round wood are presented in Table 9.30

Table 9-30: Stumpage prices

Standing pine prices as clear cut	USD/m3	55
Standing pine prices at thinning	USD/m3	27
Standing eucalyptus prices at clear cut	USD/m3	30
Standing eucalyptus prices at thinning	USD/m3	27

The project's cost-benefit outlay is presented in Figure 9-28. For the first seven years, the mitigation measure is generating solely costs. However, considering future long-term revenues, the commercial forestry activities may be financially attractive in the long run.

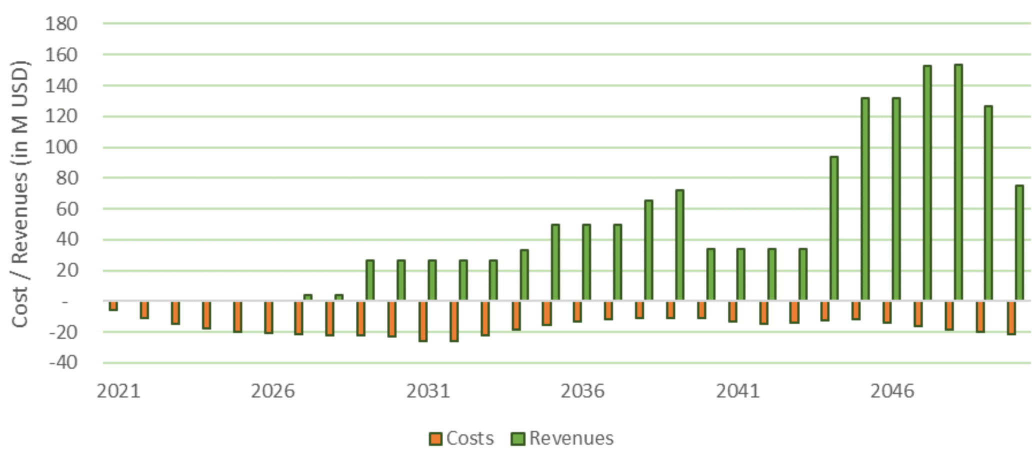


Figure 9-28: Commercial Forestry Cost and Benefits

Considering the costs and benefits in Figure 9.28 and applying a period up to 2050 to assess the costs and benefits of the project, the net present value using a 6 percent discount rate is USD 0.183 billion. The positive NPV for the project indicates that the project is financially viable at a discount rate of 6%.

Table 9-31: Abatement Cost Analysis

Parameter	Unit	Value
SDR	%	6%
Accumulated Climate Financing Need up to 2030	M USD	123.77
Net Present Value	M USD	183.21
IRR	%	13%
Abatement Potential 2030	M tCO_2	0.77
Marginal Abatement Cost	USD/tCO_2	- 239

Due to the long-term nature of commercial forestry, based on current lending rates, commercial forestry would result in a negative NPV. This underlines the importance of a suitable climate-financing instrument for implementing Zimbabwe's LEDS.

Annex VII: Conservation Agriculture Initiative

This section provides an amendment of the Annex F, Mitigation Potential in Agriculture, as produced under the WB's NDC Support Project.

Overview

Zimbabwe has been pursuing a variety of Climate Smart Agriculture (CSA) adaptations including Conservation Agriculture, which includes minimum tillage, crop rotation, and mulching practices (CIAT World Bank, 2017). According to the Zimbabwe Agriculture Investment Plan, a budget was allocated toward improving livestock management and irrigation systems as well as promoting agroforestry and Conservation Agriculture (ZAIP, 2013). Many CSA practices also help mitigate GHG emissions, as it is one of the three pillars of CSA.
Agriculture is the third largest emitter of GHGs in the country (16 %of national emissions), preceded by the Energy (23 %) and Land-Use, Land Use Change andForestry (57 %) sectors. Most of the emissions from agriculture are attributed to the livestock subsector (39 %from enteric fermentation and 28 %from manure depositedon pastures). Savannah burning for agricultural purposes is also a large emitter, about 28 %of the total attributed to agriculture (GoZ, 2016a).

- he subsequent section discusses the mitigation potentials by Conservation Agriculture (CA), including crop rotation, minimum tillage, and improved livestock feed for communal non-dairy cattle.

Mitigation Potential

Conservation Tillage

Conservation tillage involves disturbing the soil as little as possible during the planting process in order to reduce soil erosion and nutrient loss (CIAT World Bank, 2017). Conservation tillage ranges from zero tillage, which leaves the soil undisturbed from planting to harvest, to mulch ripping, which involves some tillage but ensures that crop residues remain on the surface of the ground. In Zimbabwe's clayey and sandy soils, conservation tillage can help reduce the disturbance of soil organic matter and release of soil carbon into the atmosphere. Conservation tillage has widespread effectiveness across Zimbabwe, but different conservation tillage practices are more effective depending on the soil and climate conditions of the region (CSA manual, 2017).

Conservation Agriculture, including zero and minimum tillage, is a key part of the vision of the agriculture sector in Zimbabwe according to the Zimbabwe Agriculture Investment Plan (ZAIP) 2013-2017. The ZAIP allocates $1.5 million (USD 2013) in 2013 to promoting Conservation Agriculture through extension services and advertising about the techniques (ZAIP, 2013). Zero and minimum tillage practices have largely been taken up in Agro-ecological Regions III, IV, and V by farmers growing, sorghum, groundnut and cotton, largely due to provision of training and free or subsidized inputs (CIAT World Bank, 2017).

Improved Feedstock for communal non-dairy cattle

Although livestock management can encompass a wide variety of practices, Zimbabwe's own livestock management priorities include improving livestock husbandry, increasing livestock production, and diversifying livestock. For livestock, improving the quality of livestock feed and avoiding overstocking of livestock in one area can reduce methane emissions and improve livestock health and efficiency overall (CIAT World Bank, 2017). Furthermore, diversifying livestock to include goats and sheep can allow farmers and ranchers security in case of livestock disease or adverse weather conditions (CIAT World Bank, 2017). The main costs of improving livestock management are paying for improved livestock feed, investing in smaller livestock, and accessing information on livestock management (CSA Manual, 2018). Livestock management is particularly applicable in Agro-ecological Regions IV and V of Zimbabwe, where conditions are better for livestock ranching than crop production and drought and extreme heat are more common (CIAT World Bank, 2017).

While the ZAIP focuses largely on improving livestock production, it does provide some support for CSA livestock management practices. Since livestock productivity is important in poverty reduction and livelihoods among smallholders in Regions IV and V in particular, the ZAIP focuses on ensuring and augmenting livestock yield. The ZAIP specifies increasing livestock production and strengthening rural livestock markets as key objectives. However, the budget includes funding for livestock marketing, subsidies or social assistance for livestock rearing inputs, and extension programs to improve livestock husbandry, with the goal of 50 %farmers in Regions IV and V being trained by 2017 (ZAIP, 2013).

However, improved feeding management and reduction in stock size has had a low adoption rate in Zimbabwe to date (CIAT World Bank, 2017). Currently, feed either from home-grown fodder or purchased feed accounts for roughly 10% of the required diet for all communal cattle, with the majority of this feed provided to dairy producing cattle in the dry season (ZimStat, 2015). Improved feed for cattle has been shown to reduce methane emissions significantly and improve cattle health for better milk production, slaughter yield, and birth success rates (GoZ, 2016a;Andeweg and Reisinger 2015).

Crop Rotation

Crop rotation is focused on switching the type of crops planted on a given area from year to year. Crop rotation often includes a nitrogen-fixing crop (i.e. legumes) to improve soil quality. When paired with zero tillage and mulching as part of Conservation Agriculture practices, crop rotation can increase the productivity of water applied to crops (CSA Manual, 2017). In the long run, crop rotation can lead to increased yield and less reliance on fertilizers, as well as contribute to mitigation of greenhouse gases with higher soil carbon retention.

Like conservation tillage, crop rotation is considered a part of Conservation Agriculture, and is a central part of the vision of the agriculture sector in Zimbabwe according to the ZAIP. Crop rotation has a less than 30 %adoption rate among groundnut farmers, but a 30 to 60 % adoption rate among soybean and wheat farmers. Overall, crop rotation practices have largely been taken up in Agro-ecological Regions III, IV, and V, largely due to provision of training and free or subsidized inputs (CIAT World Bank, 2017).

Aggregated CAImpact on SOC

There is a wide range of measurements and estimates on CA impact on Soil Organic Carbon (SOC). Powlson et al (2016) report conduct a metastudy for the Indo-Gangetic Plains and for the semi-arid Sub-Sahran Africa. For the aggregated CA activities (minimum tillage (including residue retention) and crop rotation, the metastudy indicates an annual SOC increment of 1.01 Mg C/ha with a Standard Error (SE) of 0.391. Assuming a normal distribution at 90% confidence interval of the annual SOC will be 0.69 Mg C/ ha.

Though not supported by time series data sets, a strong SOC increment at the start of CA practices is assumed, which decreases over time. Based on IPCC 2006 guidelines, SOC stock change is completed during a time period of 20 years. The stylized SOC increment is illustrated in **Figure 9-29**.

Figure 9-29: Stylized SOC Stock Development

E c o n o m i c   A n a l y s i s

Aggregated impact on agricultural net revenues

Many studies evaluate CA's impacts on yields. However, specifically regarding the retention of crop residues, it seems important to consider trade-offs with animal feed. Homann-Kee, et al. (2014) assessed the economic trade-offs on biomass use in crop-livestock systems in semi-arid Zimbabwe. The findings indicate substituting a third of maize production with mucuna show up to 3.3 t mucuna biomass with an increase in maize production (Table 9-32). It is assumed that 30 % of the mucuna biomass is left as crop residue, while 70% is used as animal feed. Due to the limitations of smallholder households, it is assumed that they achieve only 50% of the researcher managed yield increase resulting in 1,155 kg mucuna /ha available as animal feed.

Table 9-32: CA Impact on Net Revenues

		Conventional Farmer Practice		Maize-Mucana rotation	
		Value	SE	Value	SE
Revenue	Grain	127	104	100	81
	Residue	38	31	31	4
	Mucana BM	0	0	142	20
	Sub-total	166	135	273	105
Var Cost	Ext Input	27	30	27	30
	Draft Power	22	12	22	12
	Manure	11	24	11	24
	Mulch	0	0	46	0
	Total	62	52	106	54
Net Revenue		104	134	167	111

The conversion from conventional agriculture to CA results in significant changes to tractor use and hence, related emissions and costs. Switching to minimal tillage, utility tractors are no longer required and minimum tillage can be achieved with a two-wheel tractor. To assess related costs changes, input parameters were considered in **Table 9-33**.

Table 9-33: Input Parameter - Tractor lifecycle cost analysis

		Utility Tractor	**Two Wheel tractor**
Parameter	Unit	Value	Value
Lifetime Tractor	hrs	10,000	10,000
Average power rating	kw	82	20
Fuel consumption	l/kW	0.30	0.30
Load Factor	dimensionless	40%	40%
Fuel consumption	l/hr	10	2
Diesel Price	USD/l	0.96	0.96
Tractor Cost	USD	25,000	5,000
Tractor Cost	USD	25,000	5,000
Discount Rate	%	6%	6%

Based on the input parameter in **Table 9-34**, the annual costs of a utility tractor and a two wheel-tractor were determined. Based on a lifetime of 10,000 working hours, the utility tractor operates for 14 years, whereas the two-wheel tractor lasts ten years. The discounted cost per working hour are 7.75 USDc and 1.74 USDc respectively.

Table 9-34: Lifecycle Cost Analysis of Utility Tractors and 2 Wheel Tractors

Utility Tractor Lifecycle Cost Analysis											
	Year	1	2	3	4	5	…	10	…	13	14
Work time	Hours	750	750	750	750	750	…	750	…	4,950	1,650
Fuel consumption	Litre	4,950	4,950	4,950	4,950	4,950	…	4,950	…	4,752	1,584
Fuel cost	USD	4,752	4,752	4,752	4,752	4,752	…	4,752	…	750	250
Maintenance cost	USD	750	750	750	750	750	…	750	…		
Tractor cost	USD	25,000					…		…	5,502	1,834
Annual cost	USD	30,502	5,502	5,502	5,502	5,502	…	5,502	…	2,734	860
Discounted annual cost	USD		5,191	4,897	4,620	4,358	…	4,358	…	4,950	1,650
Total discounted cost	USD	77,490									
Discounted cost	USD / hour	7.75									
2-weehled Tractor Lifecycle Cost Analysis											
Work time	Hours	1,125	1,125	1,125	1,125	1,125	…	125			
Fuel consumption	Litre	1,523	1,523	1,523	1,523	1,523	…	169			
Fuel cost	USD	1,462	1,462	1,462	1,462	1,462	…	162			
Maintenance cost	USD	563	563	563	563	563	…	63			
Tractor cost	USD	2,700	-	-	-	-	…	-			
Annual cost	USD	4,724	2,024	2,024	2,024	2,024	…	225			
Discounted annual cost	USD	-	1,910	1,801	1,700	1,603	…	133			
Total discounted cost	USD	17,427					…				
Discounted cost	USD / hour	1.74					…				

Considering the discounted costs, the average discounted costs in **Table 9-34**, the cost savings from changing one hectare (prepared by a tractor) from conventional agriculture to Conservation Agriculture results in cost reductions of 6.01 USD per tractor hour and 5.25 L fuel savings.

Zimbabwe's agriculture is dependent on animal draught power. To produce a realistic estimate on the cost savings and the GHG emission reductions, the actual tractor hour input per hectare in Zimbabwe were determined. The fuel consumption over all farm types amounts to 38.50 M litre diesel fuel corresponding to approx. tractor input of 1.93 hrs per hectare. Consequently, the actual cost saving was 11.60 USD per hectare while the fuel savings correspond to 10.13 L/ha.

Improved Feedstock Potential

Legume production may improve the animal feed, which offers a double benefit:

- The improved diet, especially during the dry season may improve the live weight of animals at time of slaughter;
- The legume feed will replace dry grass, with high fibre content reducing methane emissions from enteric fermentation.

As indicated earlier, the CA may produce approx. 1.65 t of legume feed, whereas 1.16t/ha (70%) is used as animal feed, while 30% remain on site as biomass residue. Cattle, with an average weight over its lifetime of 250kg requires approx. 1.37 t fodder per annum (**Table 9-35**).

During the wet season, animals graze in open rangeland. However, during the dry season of approximately. 6 months, the cows may feed from legume, requiring a legume intake of 0.68t. Consequently, considering the dry season period, one hectare of Conservation Agriculture may feed 1.69 cows. The average emissions from enteric emissions correspond to 0.74 tCO_2e/cow. It is assumed based on a legume feed, these emissions may be reduced by 30%. Considering the dry period, this results in 0.11 tCO_2e per head and (considering that 1 ha of CA may feed 1.69 cows) 0.19 tCO_2 per hectare of CA:

Table 9-35: Calculation of ERs per ha CA

Parameter	Unit	Value
Legume feed	t/ha	1.16
Cattle fodder	Percentage of live-weight, per day	0.02
Average weight over cattle lifetime	Kg	250.00
Cattle fodder	t/yr.	1.37
Legume fodder	t/yr.	0.68
Emission reduction potential	%	0.30
Enteric fermentation emissions	tCO_2e/head	0.73
Emission Reduction Potential	**tCO_2e/ha**	**0.18**

The improved animal feed will not only reduce GHG emissions, but also increase the animal live weight and hence the return per slaughter. The average live weight of communal cattle amounts to 302 kg. With appropriate feed during the dry season, it is estimated that this may be increased to 396 kg/cattle. Considering a percentage of beef to live weight of 53% and a price of 1,114 USD / t beef (producer price), results in an increment of 105.11 USD/slaughter.

Considering that one ha may support 1.69 cows during dry season, and that cow is raised for 4 years results in an average increment of revenues from cattle slaughter of 44.35 USD/ha Conservation Agriculture.

Table 9-36: Calculation of Added Value per Slaughter per ha CA

Parameter	Unit	Value
Life	Years	4.00
Added Value per Slaughter	USD/slaughter	105.11
Added Value per Slaughter	**USD/ha**	**44.35**

Conservation Agriculture Potential

Conservation agriculture may be applied to maize, seed cotton, groundnuts and sorghum cultivation areas. .While CA may contribute to GHG emissions in Agro-ecological Regions I-V, increment in yields are mainly reported in the dryer Regions III to V. The cultivation areas of maize, cotton, groundnuts and sorghum in Regions III to V are estimated to 518,000 ha (**Table 9-38Table 9-37**).

Table 9-37: Estimation of the areas eligible for CA

	III	IV	V
Maize	133,123	70,387	6,305
Seed Cotton	187,808	-	-
Groundnuts	36,282	14,017	473
Sorghum	63,640	14,027	1,0391,039
Total Land Area Eligible for CA	518,100		

It is estimated that at the beginning of 2020, approx. 210,000ha in the Agro-ecological Regions III-V will be under CA. For the expansion, .annual adoption rate was assumed to be 5% p.a. allowing to reach full coverage by 2031.

Table 9-38provides an aggregated summary of potential impacts of CA, considering the regional built-out plan. While estimating the impacts of Conservation Agriculture is complex and associated with high uncertainties, the analysis underlines CA’s potential to reduce GHG emissions while improving the net returns from agriculture.

Table 9-38: Potential Impacts of Conservation Agriculture

	Parameter	Value	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2035	2040	2045	2050
Emission Reductions	Area under CA Mgmt	ha	235,905	261,810	287,715	313,620	339,525	365,430	391,335	417,240	443,145	469,050	494,955	518,100	518,100	518,100	518,100
	SOC Sequestration	M tCO_2	-	27.62	19.19	16.27	14.96	14.31	13.98	13.84	13.79	13.81	13.87	8.25	3.44	1.53	0.20
	Emission Reduction from Fuel Consumption	tCO_2	6,395	7,097	7,800	8,502	9,204	9,906	10,609	11,311	12,013	12,715	13,418	14,045	14,045	14,045	14,045
	Emission Reduction from Enteric Fermentation	tCO_2e	10,997	12,205	13,412	14,620	15,828	17,035	18,243	19,450	20,658	21,866	23,073	24,152	24,152	24,152	24,152
	Total CA Ers	M tCO_2e	0.02	27.64	19.21	16.29	14.98	14.33	14.01	13.87	13.82	13.85	13.91	8.29	3.48	1.57	0.24
Impact Net Revenues	Increment in Net revenues from CA	M USD	14.86	16.49	18.13	19.76	21.39	23.02	24.65	26.29	27.92	29.55	31.18	32.64	32.64	32.64	32.64
	Tractor Cost Reduction	M USD	2.74	3.04	3.34	3.64	3.94	4.24	4.54	4.84	5.14	5.44	5.74	6.01	6.01	6.01	6.01
	Improved Animal Feed	M USD	10.46	11.61	12.76	13.91	15.06	16.21	17.36	18.50	19.65	20.80	21.95	22.98	22.98	22.98	22.98
	Total CA Increment in Net Revenues	M USD	28.06	31.14	34.22	37.31	40.39	43.47	46.55	49.63	52.71	55.79	58.88	61.63	61.63	61.63	61.63

Table 9-39: CA Abatement Cost Analysis

Parameter	Unit	Value
Net Present Value	M USD	701.14
Abetment Potential 2030	M tCO_2	13.91
Total Abatement Potential	M tCO_2	263.22
Marginal Abatement Cost	USD/tCO_2	-2.66

Based on a discount rate of 6%, the NPV is estimated to 701.14 M USD for the period 2020 to 2050. The related GHG abatement potential is estimated at 263 M tCO_2. However, it is important to note, that bulk of the mitigation potential is related to a tC stock change compared to conventional agriculture. If the CA practice would be abandoned, the SOC content would be released and emission reductions annihilated.

Annex VIII: Estimation of Carbon and Tobacco Tax Revenues

This Annex provides a brief summary of the carbon and tobacco tax revenues, considered as GoZ contribution to a national financing facility.

Carbon Tax

Currently the government is collecting a carbon tax of 3USDc/l on Gasoline and Diesel. Considering the different EFs (2.29 tCO_2e/kL and 2.68 tCO_2e/kL) and considering the share of gasoline and diesel in Zimbabwe's total fuel consumption results into a weighted average carbon tax of 12.24 USD/tCO_2e.The assumption is that carbon tax is increased to 50 USD/tCO_2 by 2030 and 125 USD/tCO_2 by 2050, which is the lower bound estimate of the carbon tax required to achieve the Paris Agreement Objectives. Equally, the forecast of the fuel consumption under the MIT transport (Annex IV) was considered. Combining fuel consumption forecasts and projected carbon tax increases allows estimation of carbon tax income over time.

Table 9-40: Carbon Tax Revenue Projections

Parameter	Unit	2020	2021	2022	2023	2024	2025	2030	2035	2040	2045	2050
Gasoline	M litre	570	588	607	623	640	657	735	809	877	941	999
Diesel	M litre	492	515	545	566	589	613	720	799	877	948	1,013
Carbon Tax	USD / tCO_2	18.5	21.7	24.8	28.0	31.1	34.3	50.0	67.0	84.1	101	125.0
Carbon Tax Gasoline	USD/l	0.04	0.05	0.06	0.06	0.07	0.08	0.11	0.15	0.19	0.23	0.29
Carbon Tax Diesel	USD/l	0.05	0.06	0.07	0.07	0.08	0.09	0.13	0.18	0.22	0.27	0.33
Carbon Tax Income	M USD	49	59	71	82	95	108	180	267	366	474	625
Carbon Tax Income by 2030	**M USD**											**1,282**
Carbon Tax Income by 2050	**M USD**											**8,970**

If the tax basis would be widened from fuel to other sectors of the economy, the tax income would increase correspondingly.

Tobacco Tax

The forestry activities of the LEDS will be co-funded by the tobacco tax. The tobacco tax revenue corresponded to 4.6 M Zimbabwe Dollars / 1.84 M USD by 2018. Combining the tax with ZimStat's projections for annual growth of the agricultural sector, GDP will result into a tax revenue of 42.48 M USD by 2030 and 233.94 M USD by 2050.

Table 9-41: Tobacco Tax Revenue Projection

Parameter	Unit	2020	2021	2022	2023	2024	2025	2030	2035	2040	2045	2050
Growth of Agricultural GDP	%	26.0 %	11.8 %	16.6 %	10.1 %	9.3%	8.9%	5.9%	5.9%	5.9%	5.9%	5.9%
Tobacco Tax	M USD	2.09	2.33	2.72	3.00	3.28	3.57	4.96	6.61	8.81	11.4	15.7
Tobacco Tax Income by 2030	**M USD**	**42.48**										
Tobacco Tax Income by 2050	**M USD**	**233.94**										

Annex IX: Emissions from Conversion from Forest Land to Non-Forest.

Table 9-42: GHG Emissions from Conversion of Forest Land to Non-Forest

Forest Cover Loss (in ha)																		
Treecover (in %)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
10	19,158	1.1.1	21,887	30,169	37,175	33,645	43,938	23,552	67,156	27,014	18,957	35,209	22,126	22,769	25,118	23,391	60,114	19,605
15	16,224	19,578	17,948	23,832	30,901	27,727	31,931	17,517	52,278	20,876	16,620	29,897	17,891	18,590	21,433	20,312	50,222	15,873
20	11,384	11,931	10,484	12,830	18,126	18,892	15,329	8,911	29,496	10,812	11,781	19,047	12,269	12,818	15,549	14,502	34,235	9,637
25	10,716	11,013	9,676	11,761	16,539	17,949	13,676	8,029	26,800	9,634	11,125	17,716	11,487	11,923	14,610	13,514	31,770	8,724
30	8,213	8,028	7,321	8,432	11,771	14,905	9,316	5,448	19,427	6,649	9,053	13,821	9,645	9,662	12,280	10,972	26,019	6,568
50	4,223	3,642	4,208	4,398	5,000	9,876	4,251	1,995	8,690	2,356	5,421	7,040	5,976	5,276	7,877	6,105	15,868	3,157
75	990	857	1,110	1,486	1,655	3,800	1,789	859	4,154	953	2,438	3,611	2,754	2,380	3,847	2,483	5,610	1,221
Biomass Loss (in Mt.d.m)																		
Treeco-ver (in %)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
10	1.82	1.91	1.95	2.37	3.07	3.54	2.83	1.66	5.10	1.75	2.03	3.32	2.35	2.28	2.88	2.46	6.31	1.75
15	1.71	1.76	1.79	2.12	2.78	3.32	2.43	1.40	4.53	1.56	1.94	3.09	2.16	2.09	2.71	2.31	5.83	1.56
20	1.46	1.37	1.39	1.57	2.07	2.88	1.66	0.93	3.38	1.09	1.68	2.49	1.84	1.76	2.37	1.98	4.88	1.19
25	1.42	1.32	1.34	1.51	1.97	2.83	1.57	0.88	3.22	1.02	1.64	2.41	1.80	1.70	2.31	1.92	4.71	1.14
30	1.26	1.13	1.19	1.30	1.66	2.64	1.32	0.71	2.76	0.84	1.51	2.15	1.67	1.54	2.15	1.74	4.30	0.99
50	0.88	0.75	0.89	0.97	1.07	2.17	0.91	0.42	1.87	0.48	1.17	1.56	1.32	1.14	1.72	1.28	3.31	0.67
75	0.25	0.21	0.27	0.38	0.42	0.96	0.45	0.22	1.05	0.24	0.62	0.93	0.72	0.61	0.97	0.62	1.39	0.31
CO_2 Emissions																		
Treeco-ver (in %)	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
10	3.34	3.50	3.58	4.34	5.62	6.49	5.18	3.04	9.34	3.20	3.73	6.09	4.31	4.18	5.29	4.51	11.56	3.20
15	3.14	3.22	3.28	3.89	5.10	6.08	4.45	2.57	8.31	2.85	3.55	5.66	3.95	3.83	4.97	4.24	10.69	2.87
20	2.67	2.52	2.55	2.87	3.79	5.29	3.04	1.71	6.19	1.99	3.09	4.56	3.38	3.22	4.34	3.63	8.94	2.19
25	2.60	2.42	2.46	2.76	3.61	5.19	2.88	1.61	5.91	1.87	3.02	4.41	3.29	3.12	4.23	3.51	8.64	2.08
30	2.30	2.08	2.17	2.39	3.04	4.84	2.42	1.30	5.07	1.54	2.77	3.94	3.06	2.83	3.93	3.19	7.89	1.81
50	1.61	1.37	1.64	1.78	1.96	3.97	1.67	0.76	3.43	0.89	2.15	2.86	2.42	2.08	3.16	2.35	6.06	1.22
75	0.45	0.39	0.50	0.69	0.78	1.76	0.83	0.40	1.92	0.44	1.14	1.71	1.31	1.12	1.78	1.14	2.55	0.57

Source GFW, 2019

Annex X: Gross Domestic Product Forecast by Sector

Table 9-43: GDP by expenditure in constant prices

	2010	2015	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
GDP inc Tax on Production & Products	**12,847**	**18,188**	**21,712**	**23,616**	**26,628**	**28,632**	**31,113**	**33,974**	**36,485**	**39,637**	**42,466**	**46,082**	**49,684**
GDP inc Tax on Production	**11,560**	**16,250**	**19,662**	**21,384**	**24,110**	**25,922**	**28,167**	**30,756**	**33,028**	**35,880**	**38,441**	**41,713**	**44,973**
Core activities	7,503	9,296	12,180	13,530	15,854	17,192	19,072	21,139	23,039	25,221	27,246	29,614	31,981
Agriculture and Forestry	1,259	1,564	2,216	2,478	2,890	3,183	3,480	3,789	4,079	4,373	4,674	4,969	5,263
Mining and Quarrying	792	1,153	1,653	1,814	2,655	2,848	3,164	3,376	3,608	3,835	4,076	4,288	4,489
Manufacturing	2,004	2,272	2,562	2,782	3,061	3,324	3,669	4,039	4,460	4,944	5,387	5,998	6,642
Electricity and Water	465	508	561	698	715	731	856	1,123	1,241	1,458	1,609	1,804	1,970
Construction	184	435	590	630	799	882	1,022	1,124	1,251	1,362	1,484	1,598	1,717
Distribution, Hotels and Restaurants	2,798	3,366	4,598	5,128	5,734	6,224	6,881	7,689	8,399	9,249	10,015	10,956	11,900
Supportive services	1,930	2,505	2,802	3,075	3,443	3,751	4,064	4,420	4,730	5,230	5,704	6,428	7,260
Transportation and Communication	1,264	1,530	1,759	1,943	2,225	2,394	2,622	2,860	3,171	3,552	4,025	4,626	5,445
Financial, Banking and Insurance activities	666	974	1,043	1,132	1,218	1,357	1,442	1,560	1,559	1,678	1,680	1,803	1,814
Government Public Administration, Education and Health	1,223	3,083	3,163	3,186	3,198	3,218	3,232	3,251	3,267	3,284	3,301	3,318	3,334
Private Education and Health	91	209	207	210	212	214	216	218	220	222	224	227	229
Administrative and support service activities	498	1,414	1,505	1,505	1,505	1,505	1,505	1,505	1,505	1,505	1,505	1,505	1,505
Education and Training	684	1,499	1,375	1,387	1,396	1,408	1,418	1,430	1,440	1,451	1,462	1,473	1,484
Human Health and Social work activities	132	379	490	503	508	518	525	534	541	550	557	566	573
Households-related services	738	1,077	1,203	1,267	1,267	1,406	1,426	1,555	1,575	1,707	1,724	1,861	1,872
Real estate activities	128	354	440	505	509	646	665	794	816	947	964	1,101	1,112
Other service activities	568	677	716	714	710	712	713	712	712	712	712	712	712
Private households with employed persons	42	45	48	48	48	48	48	48	48	48	48	48	48
Less Fin. Int. Services Indirectly Measured	-49	-87	-97	-105	-113	-126	-134	-145	-145	-156	-156	-167	-168
Taxes on products (subsidies = 0)	1,286	1,938	2,051	2,232	2,519	2,710	2,946	3,218	3,456	3,757	4,025	4,369	4,711
Taxes on production (subsidies = 0)	126	168	203	221	249	268	291	318	342	371	398	432	466

Source: ZIMRA, 2019