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DEPARTMENT OF FORESTRY, FISHERIES AND THE ENVIRONMENT

NO. 4763 **26 April 2024**

DRAFT SECTORAL EMISSION TARGETS REPORT FOR PUBLIC COMMENT

I, Barbara Dallas Creecy, Minister of Forestry, Fisheries and the Environment, hereby publish the draft Sectoral Emission Targets (SETs) Report for public comment. The draft SETs Report details the proposed SETs allocation targets to be adopted by sector departments to support South Africa in meeting its domestic and international commitment to combat climate change and to support the implementation of South Africa's National Determined Contribution (NDC) under the Paris Agreement. The SETs form a key national policy instrument defined in the National Climate Change Policy (2011) that will drive South Africa's transition to lower carbon economy and climate resilience society, and which will anchor the attainment of the National Development Plan (Vision 2030). The draft SETs Report is contained in the Schedule hereto.

Members of the public are invited to submit written comments within 60 days from the date of publication of this Notice in the Government *Gazette* or newspaper, whichever date is the last date, to any of the following addresses:

By post to: **Director-General**: Department of Forestry, Fisheries and the Environment
Attention: Mr Jongikhaya Witi
Department of Forestry, Fisheries and the Environment
Private Bag X447
Pretoria
0001

By email to: SETSComments@dffe.gov.za
Cc: fsherman@dffe.gov.za
Hand delivered at: Environment House, 473 Steve Biko Road, Arcadia, Pretoria, 0083.

Further details and any inquiries, in connection with this Notice or in connection with obtaining a copy of the Socio-Economic Impact Assessment Study (SEIAS) or the Technical SETs Report, can be directed to Mr Jongikhaya Witi to the following contact details: **Phone:** Tel: 012 399 9048 / **Email:** JWITI@dffe.gov.za.

Comments received after the closing date may not be considered.

BARBARA DALLAS CREECY
MINISTER OF FORESTRY, FISHERIES AND THE ENVIRONMENT

forestry, fisheries
& the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

Sectoral Emissions Targets 2025 to 2030

Implementation of South Africa's updated Nationally Determined Contribution

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Abbreviations

APP – Annual Performance Plan

CO_2eq – carbon dioxide equivalence

DALRRD – Department of Agriculture, Land Reform and Rural Development

DFFE – Department of Forestry, Fisheries and Environment

DHS – Department of Human Settlements

DMRE – Department of Mineral Resources and Energy

DPME – Department of Planning, Monitoring and Evaluation

DTIC – Department of Trade, Industry and Competition

DWS – Department of Water and Sanitation

DoT – Department of Transport

EV – Electric Vehicle

FOLU – Forestry and Other Land Use

GHG – Greenhouse Gas

GWP – Global Warming Potential

HFC - Hydrofluorocarbons

IRP – Integrated Resource Plan

IPPU – Industrial Process and Product Use

LEDS – Low Emissions Development Strategy

LULUCF – Land Use, Land-Use Change and Forestry

M+E – monitoring and evaluation

MTEF – Medium Term Expenditure Framework

MTSF – medium term strategic framework

NCCRP – National Climate Change Response Policy

NDC – Nationally Determined Contribution

NEES – National Energy Efficiency Strategy

NEMA – National Environmental Management Act

NIR – national greenhouse gas emissions inventory report

PAMs – Policies and Measures

REDD+ – Reducing emissions from deforestation and forest degradation. The '+' stands for additional forest-related activities that protect the climate, namely sustainable management of forests and the conservation and enhancement of forest carbon stocks.

SETs – Sectoral Emissions Targets

SPLUMA – Spatial Planning and Land Use Management Act

UNFCCC - United Nations Framework Conventions on Climate Change

WEM – With Existing Measures

Executive Summary

Background

The National Climate Change Response Policy (NCCRP) 2011 under Section 6 articulates the key elements in the overall approach to climate change mitigation in South Africa. (Once legislated, the Climate Bill further reinforces the climate mitigation approach in chapter 5.) The policy defines the mitigation goal or the Nationally Determined Contribution (NDC) as the performance benchmark against which the collective outcome of all mitigation actions will be measured. The key mechanism to achieve the NDC is the mitigation system, which is comprised of the Sectorial Emission Targets (SETs).

The draft Climate Change Bill further defines the NDC which will be translated into SETs. SETs are orientated to steer sectors to make transformative changes for achieving long-term climate action. SETs are anchored in sector PAMs governing the programmes and activities that currently or have the potential to make significant impact on greenhouse gas reductions when adequately implemented.

The Minister of Forestry, Fisheries and the Environment (DFFE) is required to allocate SETs to ensure the country meets the stated greenhouse gas (GHG) emission target as published in the NDC. SETs are greenhouse gas emissions reduction targets, either qualitative or quantitative, applicable to sectors or sub-sectors over a period.

Sectors Considered

Seven sectors were identified with Cabinet to focus on for the development of Sectoral Emission Targets (SETs). This includes agriculture, industry, energy, mining, human settlements, transport, and environment. The allocation of SETs is at the level of national government and the following government departments with policy jurisdiction over these sectors is mapped in Table S.0-1 below. SETs will be allocated to these specific line departments.

Table S.0-1: The scope of SETs.

Sector	Line Departments
Agriculture	Department of Rural Development, Land Reform and Agriculture
Industry	Department of Trade, Industry and Competition
Energy	Department of Mineral Resources and Energy
Mining	Department of Mineral Resources and Energy
	Department of Forestry, Fisheries and the Environment
Human Settlements	Department of Human Settlements
	Department of Water and Sanitation
Transport	Department of Transport
Environment and Forestry	Department of Forestry, Fisheries and the Environment

Key Messages

- The draft SETs will assist the country to achieve it's 2030 NDC target.
- The draft SETs will result in an emissions reduction of 27 million tonnes of Carbon Dioxide equivalent ($MtCO_2eq$) in 2030 compared to a business-as-usual scenario including an electricity emissions level equivalent to 125 $MtCO_2eq$ (resulting in 71 $MtCO_2eq$ GHG emissions avoided relative to 2022 emission levels of 196 $MtCO_2$ eq).
- To achieve the high target of the NDC it is required that the IRP 2019 is implemented in the timeframe published.
- The draft IRP 2023 indicates a transition to a lower electricity system by 2030.
- The low target of the NDC (350 Mt CO_2eq) can be achieved with increased investment to implement more ambitious targets in the electricity and transport sectors. The investment is required for increased uptake of non-GHG emitting electricity technologies, increased shift from road to rail transport of freight and passenger, and increased recycling of waste.
- For sectors to transition to a low carbon future, policies and measures either have to be newly developed and/or existing policies and measures need to be enhanced. Qualitative SETs are necessary to guide this process for future SETs updates to be more stringent.

SETs allocation

Table S.0-2 below presents the summary of quantitative targets proposed to be allocated to sectors as categorised by the line department. The qualitative SETs, which are PAMs outcomes that will contribute to creating the enabling environment for a sector to transform to be low carbon over the longer term, are presented in Table S.0-3.

Table S.0-2 Summary table of quantifiable SETs by policy sector

Policy Sector	Target type	Unit	2025	2030	Cumulative (2025-2030) - SET Allocation
DMRE - Electricity	Emission level	MtCO2eq	177.3	124.7	
DMRE - Other	Emission Reductions	MtCO2eq	3.7	11.5	47.9
DALRRD	Emission Reductions	MtCO2eq	0.7	0.6	3.4
DWS	Emission Reductions	MtCO2eq		0.1	0.1
DFFE	Emission Reductions	MtCO2eq	7.0	15.2	76.5
DoT	Emission Reductions	MtCO2eq	0.2	4.5	18.0

Table S.0-3 PAMs included in the Qualitative SETs

Sector	PAM Affected
DMRE - Energy	Energy Efficiency Demand Side Management
DMRE – Minerals	Draft Mine Closure Strategy Derelict and Ownership Mines Programme The Exploration Strategy for the Mining Sector of South Africa and Critical Minerals Strategy Sustainable Development Reporting Guidelines
DALRRD	Conservation of Agriculture Resources Act Climate Smart Strategic Framework Conservation Agriculture Strategy Climate Change Sector Plan Agriculture Sector Implementation Plan
DTIC	Green Hydrogen Commercialisation Strategy Master Plans (various) Industrial finance incentives Strategy for Green Trade Barriers Green (low carbon) Industrial Strategy National Building Standards and Regulations/ SANAS 10400 National Cleaner Production Centre
DHS	Sector Climate Response Strategy, National Housing Code
DWS	Green Drop Report Water and Sanitation Sector Policy on Climate Change
DoT	National Land Transport Strategic Framework 2023 to 2028 White Paper of National Transport Policy White Paper on National Rail Policy Roadmap for the Freight Logistics System in South Africa 2023 Draft Comprehensive Maritime Transport Policy, 2017 White Paper on National Civil Aviation Policy Draft Roads Policy
DFFE	REDD+ Strategy

1 Introduction

Per the forthcoming Climate Bill, the Minister of Forestry, Fisheries and the Environment (DFFE) is required to allocate Sectoral Emissions Targets (SETs) to ensure the country meets the stated greenhouse gas (GHG) emission target as published in the National Determined Contribution (NDC). The SETs Framework that outlines an approach that DFFE would follow when coordinating the process towards allocation and implementation of SETs with the line sector departments, was approved by Cabinet in November 2021. SETs are greenhouse gas emissions reduction targets, either qualitative or quantitative, applicable to sectors or sub-sectors over a period.

The coverage of SETs will include those listed below as defined by Cabinet. The relevant line department proposed to be included in the SETs are presented in the second column.

Table 1-1: The scope of SETs.

Sector	Line Departments
Agriculture	Department of Agriculture, Rural Development and Land Reform
Industry	Department of Trade, Industry and Competition
Energy	Department of Mineral Resources and Energy
Mining	Department of Mineral Resources and Energy
	Department of Forestry, Fisheries and the Environment
Human Settlements	Department of Human Settlements
	Department of Water and Sanitation
Transport	Department of Transport
Environment and Forestry	Department of Forestry, Fisheries and the Environment

Following consultations, the SETs will be refined and subsequently recommended to Cabinet to allocate SETs to line departments. SETs will then be revised and updated in accordance with any changes to the NDC, which is expected every 5 years, while considering our current and projected GHG emissions.

In this communication, the Department of Forestry, Fisheries and the Environment (DFFE) present the Draft Sectoral Emissions Targets (SETs) to 2030 for public consultation.

It should be noted that work is also underway to develop longer term SETs to 2050 that will guide the country towards our goal of net-zero emissions as communicated in the Low Emission Development Strategy 2050.

1.1 National Emissions Profile

The DFFE has completed the drafting of the 9th National GHG Inventory (9th Inventory) for South Africa for the period of 2000 to 2022. The inventory was compiled in accordance with the guidelines provided by the United Nations Framework Convention on Climate Change (UNFCCC) and follows the 2006 Intergovernmental Panel on Climate Change (IPCC) Guidelines for National GHG Inventories (IPCC, 2006) and subsequent refinements[1] and supplements[2]. In the 9th inventory, the emissions for each of the major greenhouse gases (GHGs) are presented as carbon dioxide equivalents (CO_2eq), utilizing the 100-year global warming potentials (GWPs) as outlined in the 2014 IPCC Fifth Assessment Report (AR5) (IPCC, 2014b).

In 2022 the Energy sector was the largest contributor to South Africa's gross emissions (excl. LULUCF) in 2022, comprising 78% of total emissions. This was followed by the agriculture sector (11%), Industrial Processes and Product Use (IPPU) sector (6%) and the Waste sector (4 %).

South Africa's GHG emissions excluding LULUCF stood at 489,748 Gg CO_2eq in 2000, experiencing a decrease of 2.2% by 2022, where emissions totalled an estimated 478,888 Gg CO_2eq (435,700 Gg CO_2eq including LULUCF). The reduction in emissions compared to 2020 is attributed to marginal decreases across all sectors, explained below.

There was an overall decrease in Energy emissions of 2.5%, this is attributed to the decrease in the Residential sector, Aviation as well Petroleum refining, there was also decrease in the IPPU sector in 2022. Despite the overall economic recovery after the COVID-19 pandemic, the IPPU sector's estimated emissions in 2022 were 6.7% lower than those in 2000. This decline is primarily attributed to a significant reduction in metals production (specifically Iron and Steel, and Aluminium) by 39.0%, driven by a decrease in global demand. The chemicals industry also experienced a notable decline of 31.4%.

The agriculture sector accounted for 53,519 Gg CO_2eq emissions, representing 11% of South Africa's total emissions. In 2022, the primary contributor within this sector was the Enteric fermentation category, contributing 36,352 Gg CO_2eq, which constituted 68% of the total agricultural sector emissions, Overall, there has been a decreasing trend in agricultural emissions, with total emissions in 2022 being 9% lower compared to 2000 levels. This reduction can be attributed to a decrease in livestock population numbers.

[1] 2019 Refinement to the 2006 IPCC Guidelines
[2] 2013 Supplements to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands

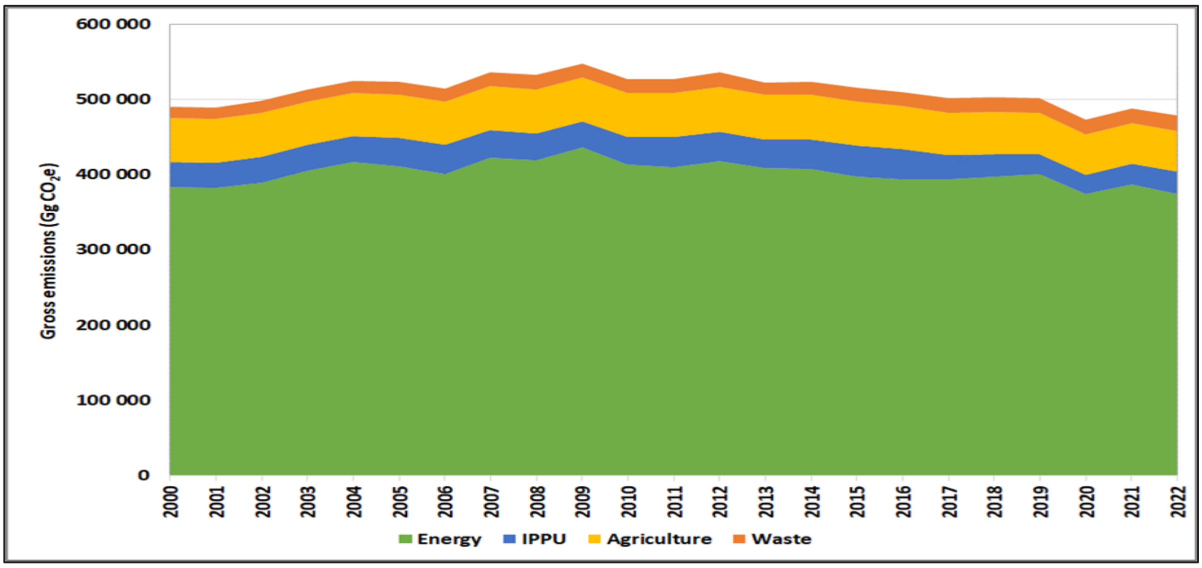


Figure 1-1: National GHG Emissions (excluding LULUCF) for South Africa, 2000 – 2022.

Notable points include a peak in emissions in 2004 at 524 903 Gg CO_2eq, a dip in 2010 with a 3.71% decrease, and a significant decline in 2020 by -5.79%. The emissions increased in 2021 by 3.36% due to post covid economic recovery.

The LULUCF sector was a sink in 2022 with Forest lands being the largest contributor to the sink. All other land categories were a source of emissions in 2022, with Other lands being the largest. The increasing Forest land sink between 2014 and 2022 is due to an observed increasing woodland sink because of an increase in the conversion of grassland to woodland.

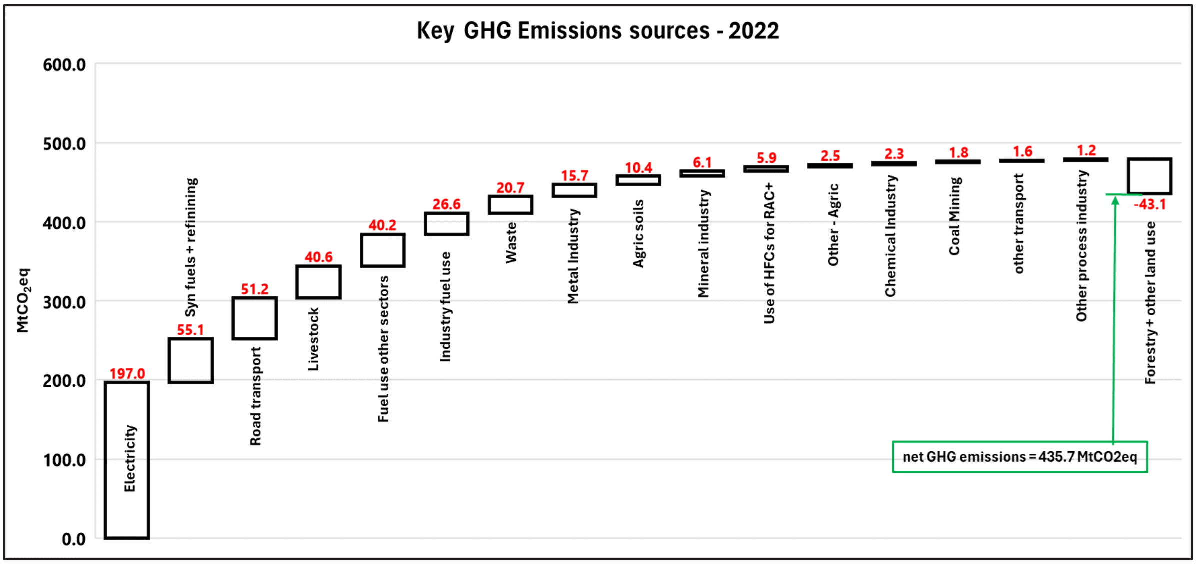


Figure 1-2: key GHG emissions sources based on the 2022 GHG emissions profile.

As per figure 1-2 above, key category analysis applied to the 2022 GHG emissions inventory shows that electricity, synfuels production, road transportation, livestock management and fuel use in the commercial, residential and industry sectors including waste management are some of the biggest contributors to GHG emissions in the country. The analysis also shows that the role forestry and other land use management plays as a sink of GHGs is significant but not sufficient to offset a large share of GHGs largely emanating from fuel combustion, synthetic fuel production and industrial processes and product use. Enhancement of the sinks through sound management of grasslands and their oils, afforestation, reforestation and forest management will help South Africa to achieve its GHG emissions goals.

A closer examination of GHG indicators (see figure 1-3) reveals the following:

- There is a decoupling of economic activity from GHG emissions. The graph above shows that there is an increase of 73% in economic output per unit of GHG emission released.
- Per capita emissions shows a decreasing trend achieving a reduction of 31% in 2022 when indexed relative to 2000 levels.
- GHG emissions per unit of energy supplied to the economy is also declining (35% relative to 2000 indexed levels).
- From the graphic, it is very clear that this decoupling trend was already taking place before the beginning of the COVID pandemic.
- This is informed by several factors such as shift to Electric furnaces for the Iron and Steel sector, decline by primary Aluminium production, decrease in livestock population and increased share of the services sector in the country's GDP.

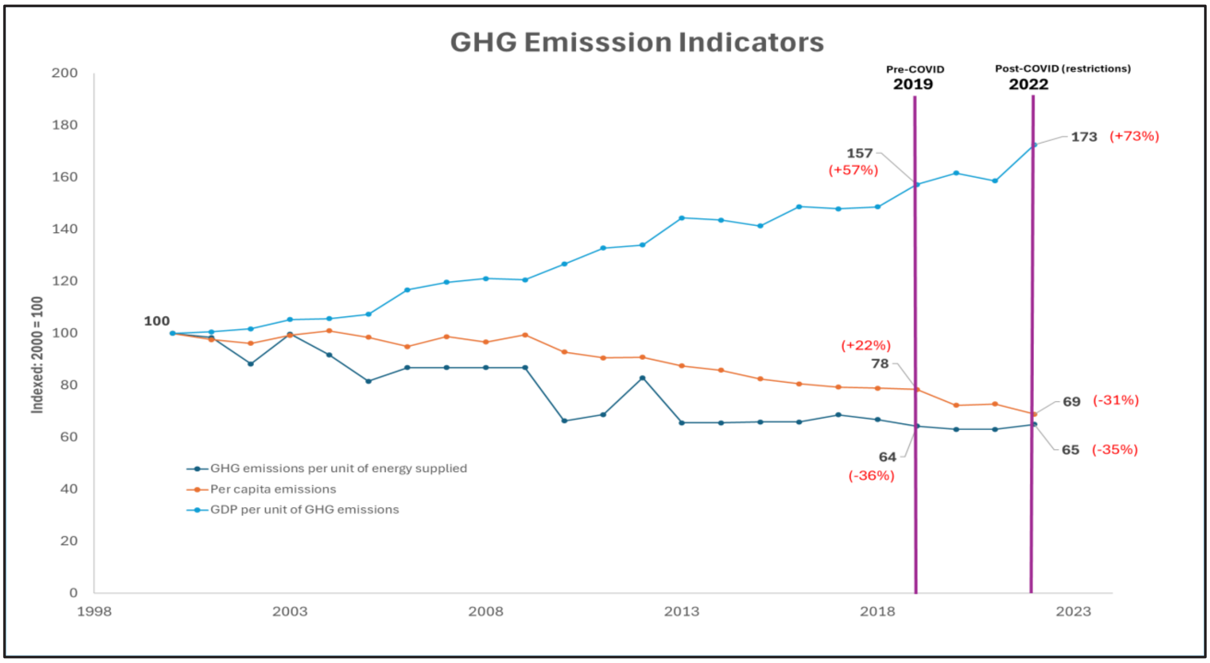


Figure 1-3: key GHG emissions sources based on the 2022 GHG emissions profile.

1.2 Expected Changes in Future Years

It is likely that GHG emissions in the different sectors across the economy will increase and/or decrease over time at different rates. The change in GHG emissions can be affected by several drivers unique to each sector that affect the activities that result in GHG emissions. Some examples of drivers include a change in market demand of a certain material or product that causes the closure of an industry, new technologies that shift the activity of a different sector, behavioural changes at a community or societal level that affects economic activity, global economic dynamics that affects local economic activity, unpredicted policy changes that affects activities of a certain sector. Of the drivers, economic growth and population can have significant impacts. Below we present the sectors that are likely to increase in GHG emissions based on economic growth and population:

Table 1-2: Expected Sector Growth.

Sector	Reason for increase/decrease in emissions
Transport	Increased population will increase the demand for transport. The economic growth will impact the type of transport being used. Uptake of hybrid vehicles to offset high fuel prices will affect GHG emissions trends for road transportation in a positive way.
Industry	Emissions associated with construction related materials produced locally such as cement and mining and quarrying could grow with increased demand in the built environment. Green ammonia production might have GHG emissions implications in Reduction in primary steel production Uncertainty in gas availability in the near future will affect industrial fuel consumption and use of natural gas/SASOL gas as feedstock for some production processes. With loadshedding, and as shown in figure 1-2 above, the is an increase in fuel consumption in the commercial and residential sectors through stand-by generators. This trend is expected to continue for the next three to four years.
Waste water	Increased population would increase the generation of wastewater in both residential and industrial wastewater. Implementation of methane recovery will result in significant emission reductions from wastewater treatment and discharge. However, as per the current implementation plans, real emission savings are to be realised between 2030-2040. Implementation of the Article Six (6) strategy could ensure accelerated implementation of methane recovery projects.
Managed waste	Increased population leading to increased consumption would increase the generation of waste needed to be landfilled. Waste diversion has also increased significantly, thus affecting the amount of biodegradable material available for methane generation.
Biomass burning	Increased population would increase the generation of waste resulting in more biomass burning.
Electricity	Increased population will increase the demand of electricity through increase of household connections and use of appliances in the household

1.3 Climate Change Bill and Low Emissions Development Strategy roadmap summary

The Climate Change Bill represents South Africa's overarching regulatory framework to be promulgated under the National Environment Management Act (NEMA) that will guide the country's transition to achieve the National Development Plan (Vision 2030) and the National Climate Change Policy (2011). The Bill intends to transition the country to a lower carbon economy and climate resilient society in the context of sustainable development. The Bill aims to make a fair contribution to the global effort to stabilise GHG concentrations in the atmosphere through various measures, including a legislated national emissions trajectory, SETs and the allocation of company carbon budgets.

1.4 South Africa's Low Emission Development Strategy 2050

The Low Emission Development Strategy (LEDS) (2050) are national, subnational or supranational strategies for achieving low-emission long-term (often focused on 2050). The Article 4 of the Paris Agreement encourages all Parties to strive to formulate and communicate long-term low greenhouse gas emission development strategies, being mindful of Article 2 and taking into account their common but differentiated responsibilities and respective capabilities, in the light of different national circumstances.

The LEDS are generally described as forward-looking national economic development plans or strategies that encompass low-emission and/or climate-resilient economic growth. A primary goal of LEDS is to double economic growth from emissions reduction - Decoupling economic growth from emissions reduction requires transformational changes in all sectors of the economy, as well as in planning processes.

South Africa's LEDS 2050 represents a blueprint that will support the transition to low carbon economic development resulting in sustained growth in employment and investment, increased financial flows, reduced GHG, and other social, economic, and environmental benefits up to 2050. South Africa's first LEDS (2050) was officially submitted to the UNFCCC Secretariat in September 2020. An updated version will include a defined national vision towards achievement of net zero by 2050, a description of the path going forward to place the country on a coupled low carbon trajectory and socio-economic development path, and a road map of the policies and measures needed to achieve these goals. The SETs will be part and parcel to this road map of policies and measures that guides the country to net zero by 2050.

1.5 Overview of South Africa's Mitigation System and the Role of SETs

The National Climate Change Response Policy (NCCRP) 2011 under Section 6 articulates the key elements in the overall approach to climate change mitigation in South Africa. (Once legislated, the Climate Bill further reinforces the climate mitigation approach in chapter 5.) The policy defines the mitigation goal or the Nationally Determined Contribution (NDC) as the performance benchmark against which the collective outcome of all mitigation actions will be measured. The key mechanism to achieve the NDC is the mitigation system. The mitigation system is informed by the key elements; i) GHG Inventory, ii) NDC, and iii) Greenhouse Gas Emissions Projections of Policies and Measures. The key mechanisms of the mitigation system are the carbon budgets and Sectorial Emission Targets (SETs).

The draft Climate Change Bill further defines the NDC which will be translated into SETs. SETs are orientated to steer sectors to make transformative changes for achieving long-term climate action. SETs are anchored in sector PAMs governing the programmes and activities that currently or have the potential to make significant impact on greenhouse gas reductions when adequately implemented. PAMs act as signals to decision makers and the private sector. They provide the enabling environment for key GHG mitigation levers that are necessary to shift a sector to being low carbon.

DFFE initiated the implementation of SETs in 2021 by developing a framework to outline an approach that DFFE would follow when coordinating the process towards allocation and implementation of SETs. The SETs Framework was approved by Cabinet on 24th November 2021. With this approval, DFFE was permitted to implement the SETs before the Climate Change Bill was legislated.

1.6 Defining Sectoral Emission Targets (SETs)

The Draft Climate Change Bill (forthcoming) defines SETs as the greenhouse gas emission reduction goals, either qualitative or quantitative, applicable to sectors or sub-sectors over a period of time. SETs are aligned to the Nationally Determined Contribution, and they will be routinely revised every 5 years in line with future NDC updates. Each national government department will be tasked with developing and implementing Policies and Measures to ensure emissions from within respective sectors or sub-sectors remain within SET allocation. To achieve the desired outcomes, these sector departments would need to align, adjust, upscale and/or develop policies and measures to achieve allocated SETs.

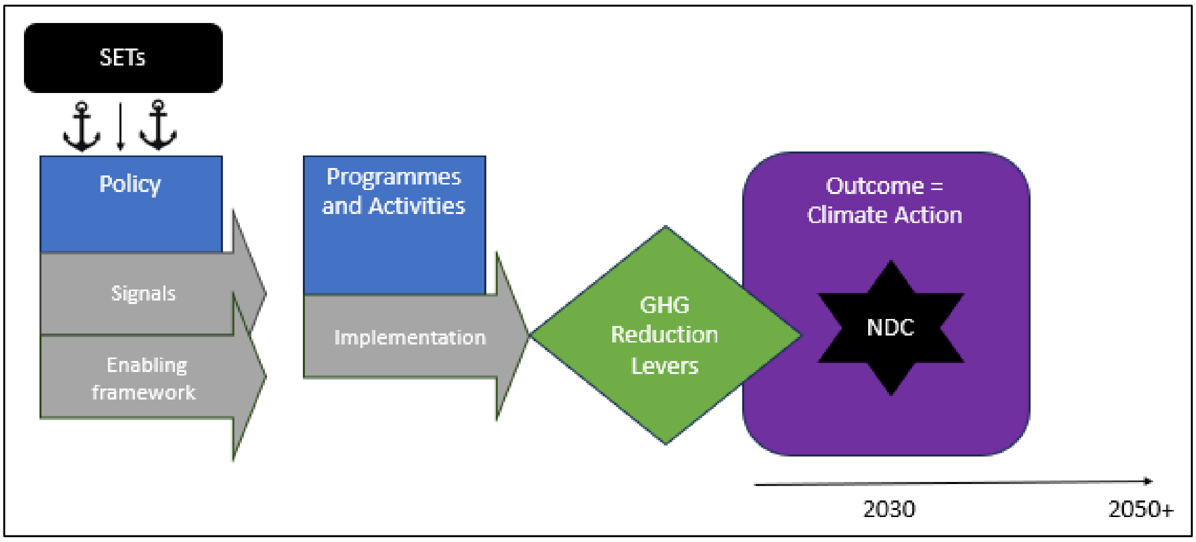


Figure 1-4: SETs are anchored in sector policies to drive long-term transformative change.

Emitting sectors or sub-sectors would need to align, adjust, upscale and/or develop Policies and Measures to achieve their allocated SETs. In addition to PAMs that are being implemented by national government, many sub-national (provincial and local) government departments are undertaking activities that contribute to the national mitigation, adaptation and resilience efforts.

The SETs were developed after consideration of a variety of PAMs that exist under the jurisdiction of line departments. The PAMs can be categorized as regulatory measures, economic measures, support measures, direct government actions and information programmes. These are defined in the accompanying Technical Document.

1.7 Role of spheres of government

The Climate Change Bill makes provision for the provincial and local government spheres to conduct climate change needs and response assessments, and based on this, develop and implement climate change response implementation plan(s) as a component of and/or in conjunction with provincial, metropolitan or district municipality's planning instruments policies and programmes. The effort provided by provincial and local governments may feed into the SETs directly depending on the roles and mandates within each sector and/or may exist outside the SETs. It will be up to the national sector department to determine how other spheres of government feed into the sectoral target. DFFE is embarking on an additional voluntary approach to support local and provincial spheres to elevate their effort on climate change mitigation. Through this initiative, done with the support of the Initiative for Climate Action Transparency (ICAT), DFFE is supporting provinces and local government to develop their respective emissions inventories and GHG emission targets.

2 Methodological Approach

2.1 SETs Allocation Process[3]

SETs will be allocated by government to sector departments. The Cabinet will assign the targets to Ministers of the respective sector line departments who will be responsible for implementing SETs. The progress for achieving SETs will be monitored annually and a final monitoring and evaluation of the SET will take place at the end of the 5-year period by the Department of Monitoring and Evaluation under the Presidency (more information can be found in section 5). DFFE provides the technical guidance and plays coordination role to provide support throughout the processes within government.

2.1.1 Determination of SETs[4]

The process to develop SETs includes a multi-step, evidence-based and collaborative approach within government led by DFFE. DFFE worked closely with sector departments to co-develop Draft SETs to be considered by Government for finalising for allocation. The work included engagements to bring awareness of SETs to line departments, a review of PAMs for each sector to assess the status (including updates and new developments) of PAMs, an in-depth analysis to evaluate the key greenhouse gas mitigation levers of PAMs and the impacts of PAMs on greenhouse gas emissions of the country. The GHG emissions analysis conducted used the DFFE Integrated Climate Change Mitigation Model to assess the GHG impacts and socio-economic impacts of PAMs to 2030 relative to the NDC. Since the development needs of the country cannot be separated from the GHG emission targets, non GHG emissions impacts to the environment, economy and society are also of key consideration in the SETs and key indicators were identified.

The approach to short-listing and the subsequent finalising of the PAMs to be part of draft SETs included analytical tools, including the DFFE Integrated Climate Change Mitigation Model and the multiple engagements made with line departments to get their inputs and recommendations on the above considerations. Figure 2-1 below highlights the process since March 2023. During this process, a policy or measure was framed into an actionable activity (a mitigation lever/progress indicator) based on planned activities of a line department as stated in a certain policy or measure, the MTSF or as verbally discussed in an engagement with a line department. These actionable activities form the basis of a quantifiable or qualitative target that makes up a SET. A SET may include a qualitative target if it was deemed most appropriate to angle the sector policy in a direction that creates an enabling environment for future greenhouse gas reductions.

The sectors of focus for SETs have policy impacts by more than one line department in many cases. The department with current or forthcoming policy that affects sector GHG emissions relevant to that sector was identified and worked with. It is noted that certain sectors have significant interlinkages in terms of greenhouse gas emitting activities such as human settlements and transport, energy and

[3] Annexure C to this document is the SETs allocation framework that was approved by Cabinet in 2021.
[4] Annexure D to this document is a technical report titled "Sectoral Emission Targets – technical Report" that documents the method, assumptions and data used to inform the determination of the SETs.

industry, energy and transport. These are important interlinkages to manage as policies evolve and increase stringency to reduce GHG emissions.

The PAMs agreed upon with sector departments to form a draft SET were assessed for the GHG impacts on the sector and an iterative process was taken to ensure that when these PAMs are implemented the high point of the NDC would be achieved in 2025 and 2030. The full set of PAMs that form the draft SET make up the proposed SETs Scenario as described in the next section. Additional analysis was undertaken to find out what ambition would be needed above and beyond the SETs Policy Package to put the country onto a trajectory of achieving 1.5 degrees. This is the second scenario presented below, the SETs 1.5 Degree Scenario.

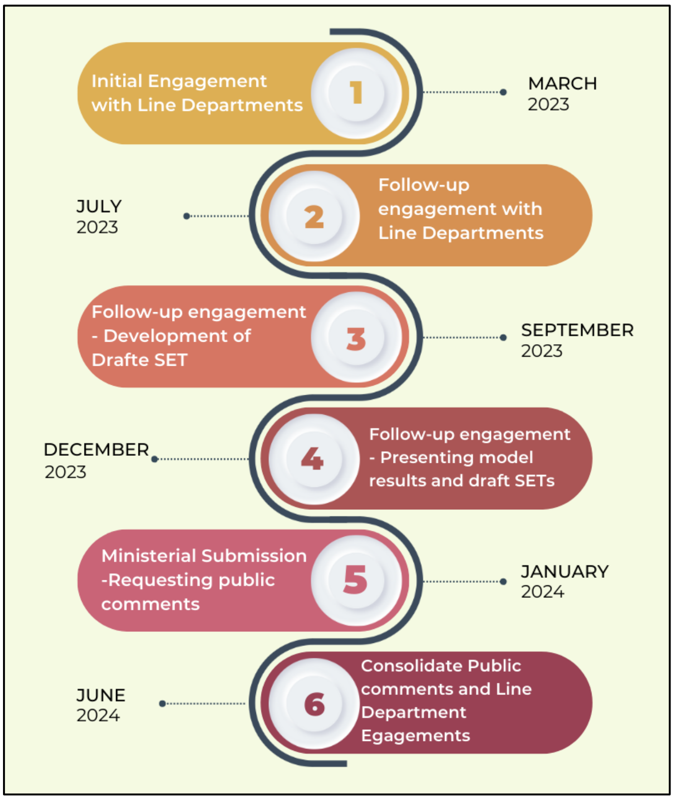


Figure 2-1: Steps undertaken and planned to finalise Draft SETs.

It should be noted that work is concurrently being undertaken to inform the long-term SETs to 2050. Currently in progress is a project to identify possible climate mitigation pathways to 2050 that equally considers socio economic development and net-zero emissions to guide future SETs. This work is necessary to be able to plan and prepare for in order to make the long-term transformative change needed to achieve the country's long term GHG aspirations.

2.2 Analysis Overview

The suite of PAMs that make up the draft Sectoral Emission Targets have been assessed using the DFFE Integrated Climate Change Mitigation Model. The model aggregates the impacts of the selected policies that forms the SETs on the national greenhouse gas emissions. Four scenarios are included:

A.) **With Existing Measures:**
No changes are made across the economy to what already exists in 2022 through to 2050. This scenario is used as the business-as-usual scenario to compare the package of policies that form the SETs. Included in the With Existing Measures (WEM) is the IRP 2019 policy as stated.

B.) **SETs Policy Package:**
The policies that form the SETs in each sector based on engagements with line departments are included in this scenario according to the stated timeline and target in each policy. Qualitative SETs are not included in the quantification of affects since there is no number value to include in the assessment. Certain policies may exist but do not have targets for the stated period (e.g. post-2015 National Energy Efficiency Strategy) and these targets are projected based on stakeholder engagement with sector experts as to what is realistically feasible.

C.) **Realistic PAMs:**
This scenario includes the same package of PAMs as the SETs Policy Package scenario where the implementation is assumed to be 75% of the planned implementation.

D.) **SETs 1.5 Degree Scenario:**
This scenario includes the same package of policies as the SETs Policy Package scenario; however, it includes increased ambition for certain uptake assuming increased investment is available. The sectors that this considers for higher ambition include:

Energy:
- increased uptake of solar PV in various commercial industry sectors
- Additional decommissioning of 1200MW coal power

Transport:
- increased uptake in the modal shift from road freight to rail; and passenger road to rail

Environment
- increased afforestation.
- Increased recycling

The detailed description of the inputs and assumptions for the modelled SETs can be found in the accompanying technical report.

2.3 Model Framework and Key Assumptions

2.3.1 Modelling Framework

The DFFE Integrated Climate Change Mitigation Model is based on a bottom-up approach to estimating greenhouse gases considering the activity data and mitigation potential in key economic sectors (where possible). The model includes a PAMs analysis tool that maps policies to specific activities with defined uptake and/or penetration rates. The uptake and/or penetration rates are based on values given in existing policies and if a value is not available in a policy such as the national energy efficiency strategy, the value is then based on sector expert inputs on what is the most realistically feasible value the sector can achieve in 2030. The model analyses these policies in terms of their aggregated effect across the economy. Some policies may overlap others and care has been taken to exclude any risks of double counting.

The integrated model also includes an economic model, the South African Socio-Economic Model. This is a simulation model used to assesses the socio-economic implications of different scenarios for sectors and the whole economy based on a Social Accounting Matrix (SAM) of South Africa. It uses a set of econometric equations to predict economic behaviour based on the changes to the economy based on the implementation of the PAMs assessed in the scenarios. This model is used to provide investment requirements and employment data.

2.3.2 Data Sources and Key Assumptions

The integrated model uses the National Greenhouse Gas Inventory as the starting point including the same scope and coverage of sectors. The model includes additional disaggregation in some sectors such as energy and industry sectors and this information comes from company data. The socio-economic model includes input assumptions from STATSA. Key assumptions underpinning the model are aligned with government policies and plans, with sector-specific information obtained through stakeholder engagement and literature research where required to fill the gaps. The model has been most recently updated in 2024 with the most current available data.

Key drivers in the model are presented below. Additional information can be found in the accompanying technical report document.

Population: The population projection is aligned with the population projections used for the IRP 2023 and is assumed to follow the United Nations population projection from its Population Division (United Nations, 2022).

GDP: The Statistics South Africa Gross Domestic Product first quarterly release provided updated GDP figured to update historic GDP numbers in the model through to 2022. The GDP projections to 2030 are an output from the socio-economic model within the integrated model.

2.4 Sectoral information and impacts

2.4.1 Mining

The mining sector includes the primary extraction of a variety of minerals ranging from coal to platinum group metals, ferroalloys, manganese, iron ore, chrome, titanium to industrial minerals like clay, limestone and silica. The sources of greenhouse gas emissions are largely CO_2, CH_4 and N_2O from fuel use to conduct operations, the fugitive emissions of CH_4 from underground coal mines and the impact on land sector GHG emissions.

Emissions reductions in the mining sector would be from reducing fuel use or changing technology to use non GHG emitting energy sources, reducing fugitive emissions from coal mines, reducing the disturbance of carbon sinks during mine operations and enhancing the carbon sinks during and after mine rehabilitation. Currently the only policy driving emissions reductions is the Post-2015 NEES. There are no PAMs existing to reduce fugitive emissions from coal mines, reducing the disturbance of carbon sinks and enhancing carbon sinks during and after mine rehabilitation.

The Mining sector also has a role to play in the broader low carbon transition since. Key minerals are needed across the value chains of new technologies, of which will be important to reduce GHG emissions in the other sectors. The Critical Minerals Strategy (in development) by the DMRE will contribute to this development.

Table 2-1: Mining Sector: Information on drivers to reduce emissions.

PAM	Assumption / Progress Indicator	Unit
National Energy Efficiency Strategy	Increased efficiency of mining production	Unit energy used / Unit output
Financial Provisioning Regulations	Include carbon sequestration during rehabilitation of mines	t CO_2eq
Monitoring and Management of fugitive emissions from coal mines	Establish monitoring system of fugitive emissions	t CH_4
Critical Minerals Strategy	Role of critical minerals in the low carbon transition are identified. Potential availability of critical minerals is known over a set period	t critical mineral available over a set period

2.4.2 Agriculture

The agriculture sector includes the production crops and livestock that feeds into our food system. The sources of GHG emissions in agriculture are CO_2, CH_4 and N_2O from fuel consumption, N_2O and CH_4 from soils, N_2O and CH_4 from livestock and CO_2 from land disturbances. The agriculture land has the potential to sequester carbon. In 2022 the Livestock sector, specifically enteric fermentation accounted for most of the emissions (40,637 ktCO_2eq) and the Cropland sector contributed 3,509 ktCO_2 to national emissions.

The emissions reductions of the agriculture sector would be from reducing CH_4 and N_2O emissions from livestock, N_2O and CH_4 emissions from agriculture soils, increasing carbon sequestration in soils, CO_2 from land disturbances and CH_4, N_2O and CO_2 from reducing fuel use or changing technology to use non GHG emitting energy sources. Conservation has the potential to sequestrate CO_2, at an estimated rate of 0.02 to 0.07 tCO_2/hectare. Currently the only policy driving emissions reductions is the Post-2015 NEES. The Draft Conservation Agriculture Policy and the Conservation Agriculture Resources Act have the potential to guide widespread adoption of conservation agriculture, there are no specific targets or mechanisms to set targets.

Table 2-2: Agriculture Sector Information: Information on drivers to reduce emissions.

PAM	Assumption / Progress indicator	Unit
National Energy Efficiency Strategy	Increased energy efficiency of agriculture production	Unit energy used / Unit output
Conservation of Agriculture Resources Act	The role of soils in climate mitigation is included in the policy	-
Conservation Agriculture Policy	Finalise policy and align implementation with the policy	-
Livestock emissions research programme	Identify emissions reduction technologies and opportunities in the livestock subsector	t CH_4 and t N_2O reduction potential per technology type

2.4.3 Human Settlements

Human settlements can refer to how we as communities interact with the built environment. It includes residential and commercial buildings, utilities like water and sanitation and overlaps with other key GHG emitting activities such as mobility, waste, energy use and land use. GHG Emissions include CO_2, N_2O and CH_4 from fuel consumption and CH_4 from wastewater. The Commercial and residential sectors accounted for approximately 3.7% of national emissions in 2022.

Emissions reductions in the human settlements would result from reducing the energy use in residential and commercial buildings, reducing the release of CH_4 from wastewater treatment facilities and designing human settlements in a way that reduces the need to travel long distances for work, leisure or other social needs, which in turn will reduce fuel use, and a reduction on the impact settlements have on land use. Key policies that impact emissions reductions in human settlements include the National Housing Code, the Greed Drop Report, Post-2015 NEES and SPLUMA.

Table 2-3: Human Settlements Sector Information: Information on drivers to reduce emissions.

PAM	Assumption/Progress Indicator	Unit
Red Book: The Neighbourhood Planning and Design Guide	Implementation of the planning and design principles to achieve sustainable human settlements	-
Climate Smart Community implementation programme	Development of climate smart communities	Number of climate smart communities developed
Green Drop Report	Inclusion of autogeneration of energy from onsite biodigesters as a criterion for assessments	-

PAM	Assumption/Progress Indicator	Unit
Methane capture at Wastewater Treatment Facilities	Implementation of methane capture technology at wastewater treatment facilities	Number of methane capture installations
Climate Smart Sector Plan for Human Settlements	Inclusion of climate mitigation in the Plan	-

2.4.4 Trade & Industry

The industry sector includes all manufacturing and production in the country. The GHG emissions from this sector include CO_2, CH_4 and N_2O from fuel consumption, CH_4 from fugitive emissions, CO_2 from process emissions, CO_2, CH_4 and N_2O from waste. The industry sector accounted for 13% of national emissions (including FOLU, not including coal-to-liquid/gas-to-liquid) in 2022. More than half of these emissions are a result of process emissions and the remaining 47% are due to energy emissions.

Emissions reductions in the industry sector come from reducing fuel consumption through, for example, improved efficiency, the switch to non-renewable fuels, alternative production processes that can substitute for production processes that result in process emissions, improved management of fugitive emissions and a reduction of waste.

Industry also has a key role to provide for the necessary inputs for other sectors to transition being low carbon. This refers to the scaling up of production of technologies and materials that are needed in other sectors to make the transition. A Green Industrial Strategy would be instrumental to coordinate the needed effort.

Table 2-4: Trade and Industry Sector Information.

PAM	Assumption/ Progress Indicator	Unit
The Green Hydrogen Commercialisation Strategy for South Africa	An implementation strategy is developed	-
Master Plans: Furniture, Sugar, R-CTFL, Poultry, Steel, Automotive, Forestry	The green economy/low carbon opportunities are integrated into the plans	-
Incentive schemes such as the Manufacturing Competitiveness Enhancement Programme, 12 L Tax Deduction of Energy Efficiency Savings, Automotive Incentive Scheme	Reformation of incentives are considered to support the transition of industry to being low carbon	ZAR incentives allocated to low carbon initiatives
Strategy for Green Trade Barriers	Strategy is developed with an implementation plan	-
National Building Regulations and Building Standards Act	The policy is updated to include uptake of energy efficiency in buildings	-
National Cleaner Production Centre and Industrial Energy Efficiency Project	Energy efficiency implementation in industry	Unit energy per production output
Green Industrial Strategy	A sector wide strategy developed to mainstream climate change	
South African Road to Production of Electric Vehicles (The Roadmap)	Increasing availability of EVs for local consumption	Number of EVs produced for local consumption

2.4.5 Transport

In 2022, the transport sector, consisting of domestic aviation, maritime and road subsectors, accounted for 12% of national GHG emissions (including FOLU), of which 11.75% can be attributed to the road transport sector. It is the second largest contributor to emissions after the electricity sector and is largely a result of the emissions of CO_2, CH_4 and N_2O from the combustion of hydrocarbons.

Emissions reductions in the transport sector include retrofitting existing aircraft for improved efficiency, early retirement of aircraft (replaced with newer efficient aircraft) and biofuels in the aviation sector, improved efficiency of internal combustion engines, shifting freight and passenger transport from road to rail and mass transit (passenger), technology swich from internal combustion engines to hybrid electric vehicles, plug-in hybrid electric vehicles, electric vehicles, fuel cell electric vehicles and compressed natural gas and substituting fossil fuel use with biofuels in the road sector, improved efficiency of train locomotives and fuel switching to hybrid diesel, CNG, biofuels and metro rail voltage upgrade in the rail sector, and a set of fuel saving measures in the maritime sector such as propeller upgrade, speed reduction, propeller polishing and wind power applications.

Table 2-5: Transport Sector Information.

PAM	Assumption / Progress Indicator	Unit
National Land Transport Strategic Framework 2023 to 2028	Behavioural change of passengers to use low carbon transport options Technology shift to low carbon technology in transport systems Reduction in fuel use in the fuel system	Number of passengers on low carbon transport options per transport type Number of low carbon vehicles on the road per technology type TJ of fuel reduced in the transport sector
White Paper of National Transport Policy		
White Paper on National Rail Policy		
National Transport Master Plan 2050		
Roadmap for the Freight Logistics System in South Africa 2023	Shift of freight from road to rail	Kms freight transported on rail
Draft Roads Policy	Development of an investment strategy and implementation plan to ensure GHG emission mitigation measures are implemented	Number of climate mitigation opportunities implemented
Draft Comprehensive Maritime Transport Policy, 2017	Develop an implementation strategy to deploy energy efficient technologies and other climate mitigation opportunities are implemented across the maritime sector	
White Paper on National Civil Aviation Policy	Make alternative fuels available for the aviation industry Reduce fuel use across the aviation sector Develop market-based measures for the aviation sector	

2.4.6 Energy

The energy sector is defined by the supply and demand of fuel use for energy use. Fuels may be GHG emitting (non-renewable fuels) or non-GHG emitting. The energy sector is by far the most significant contributor, accounting for 86% of national emissions in 2022 (including FOLU). The GHG emissions include CO_2, CH_4 and N_2O from fuel consumption and CO_2 and CH_4 from fugitive emissions.

Emissions reductions in the energy sector would result from a reduction of fuel consumption, a fuel switch to non-renewable fuels and improved management of fugitive emissions. Given the significant volume of GHG emissions emitted from electricity generation, which is currently fuelled by coal, the electricity subsector is a key focus to reduce national GHG emissions. Key efforts to reduce electricity sector emissions include the decommissioning of existing coal power plants and building new power generation that is fuelled by non-renewable fuels.

Table 2-6: Energy Sector Information.

PAM	Assumption/ Progress Indicator	Unit
Integrated Resource Plan	Amount of non-GHG emitting technology installed Amount of non-GHG emitting power generated Amount of GHG emitting capacity decommissioned	MW of per technology MWh per technology
Integrated Energy Plan	The plan is updated considering the future uptake of low carbon fuels	TJ low carbon fuels supplied
National Energy Efficiency Strategy	Update of the energy efficiency strategy across the economy	Unit energy used / Unit output
Solar Water Heaters	Solar water heaters installed in the residential sector to substitute for electrical or gas fired water heaters	Number of SWH installed
Demand Side management	Increased management of electricity usage across commercial, government and residential sectors	Total MWh energy demand

2.4.7 Environment & Forestry

The environment sector is classified by the greenhouse gas emitting and carbon sequestration activities that fall under policy framework of the Department of Forestry, Fisheries and the Environment (DFFE). It includes the management of carbon stocks and carbon sequestration in non-agricultural lands, company carbon budgets, solid waste management and the management of hydrofluorocarbons (HFCs).

Emissions reductions in the environment sector would come from enhancing carbon sequestration in disturbed ecosystems such as grasslands and indigenous forests, managing fires, reducing the emissions of solid waste into the atmosphere and reducing the emissions of HFCs into the atmosphere.

Table 2-7: Environment and Forestry Sector Information.

PAM	Assumption	Unit
National Waste Management Strategy	30% waste diverted from landfill sites	tonne waste type diverted
HFC Phase Down	45% decrease in consumption	Unit consumed per HFC type
Afforestation	5400 ha of temporary unplanted areas planted. 15 000 ha approved for afforestation. 200 000 trees planted outside forests footprint	T CO_2eq sequestered
REDD+ Strategy	Development of the strategy and implementation plan	-
Wildfires	Increased management of wildfires / lower temperature burns	Number of fires suppressed Number of managed cooler fires
Rehabilitation of wetlands	Increasing the carbon sequestration	T CO_2eq sequestered
Restoration of thicket		
Indigenous species cultivated		
Protection of Wetlands	Carbon stock protected	T Carbon stock protected
Land area conservation		

3 Sector Allocation

The 2030 Sectoral Emission Targets (SETs) build the foundation for a structured and coordinated approach to reduce greenhouse gas emissions by considering the key activities, or levers, and policy signals needed to achieve our climate goals as a country. The SETs have two purposes. First, they identify the key policies that are linked to key GHG mitigation levers across the economy, that if implemented as stated the country can achieve the 2025 and 2030 NDC targets as submitted to the UNFCCC in September 2021. Secondly, the SETs lay down the initial stepping stones to carry the momentum towards a low GHG emission economy. The SETs will contribute to the development of the subsequent NDC updates beyond 2030. These SETs will be updated with each 5-yearly update of the NDC which will move the economy to net-zero at a pace and speed given the socio-economic needs and context of the country.

The SETs are presented in the below tables per sector disaggregated per each PAM that contributes to the sector target. The quantitative SETs are presented in both the end of the period target for 2030 and they are annualised per year up to 2030. The targets are communicated in terms of GHG emissions reductions in carbon dioxide equivalence (CO_2eq). The qualitative SETs are presented as an objective to be completed by 2030.

Below we present two plausible options (figure 3-1) for SETs for energy, industry, transport, human settlements, agriculture, minerals and environment sectors. The first option represents the identified PAMs by government to reduce emissions by 2030 to within the NDC range of 420 Mt CO_2eq and 350 Mt CO_2eq based mostly on an existing pipeline of PAMs. The second option represents a more ambitious set of targets that can be achieved with increased investment in the energy and transport sectors to achieve our low NDC target of 350 Mt CO_2eq.

Table 3-1: Quantifiable SETs Allocations.

PAM	Unit	2025	2026	2027	2028	2029	2030	Cumulative (2025-2030)
Agriculture, Land Reform and Rural Development								
Agriculture PAMs (ERs[5])	$MtCO_2eq$	0,74	0,61	0,53	0,38	0,55	0,57	3,37
Water and Sanitation								
Methane capture (ERs)	$MtCO_2eq$	0,00	0,00	0,00	0,00	0,00	0,06	0,06
Mineral Resources and Energy								
Electricity Sector (ELs[6])	$MtCO_2eq$	177,35	165,85	157,72	157,95	148,95	124,73	
NEES (ERs)	$MtCO_2eq$	3,28	3,95	5,09	6,58	6,80	7,07	32,78
Electrification Strategy (ERs)	$MtCO_2eq$	0,22	1,10	1,73	1,28	1,51	2,98	8,83
SWH (ERs)	$MtCO_2eq$	0,22	0,37	1,54	1,42	1,35	1,41	6,31
Forestry, Fisheries and Environment								
CT+CB (ERs)	$MtCO_2eq$	5,54	8,03	10,37	11,95	12,09	10,45	58,41
NWMS (ERs)	$MtCO_2eq$	0,15	0,29	1,69	1,79	2,17	2,39	8,49
Forestry (ERs)	$MtCO_2eq$	1,05	0,78	0,48	0,47	0,76	0,91	4,45
Kigali Amendment (ERs)	$MtCO_2eq$	0,30	0,20	0,92	0,77	1,50	1,46	5,15
Other environment (ERs)	$MtCO_2eq$	0,00	0,00	0,02	0,00	0,00	0,00	0,02
Transport								
Transport PAMs (ERs)	$MtCO_2eq$	0.21	0.87	2.57	4.62	5.24	4.51	18.03

An assessment of emissions reductions to be achieved from the PAMs informing the determination of SETs is presented in figure 3-1 below.

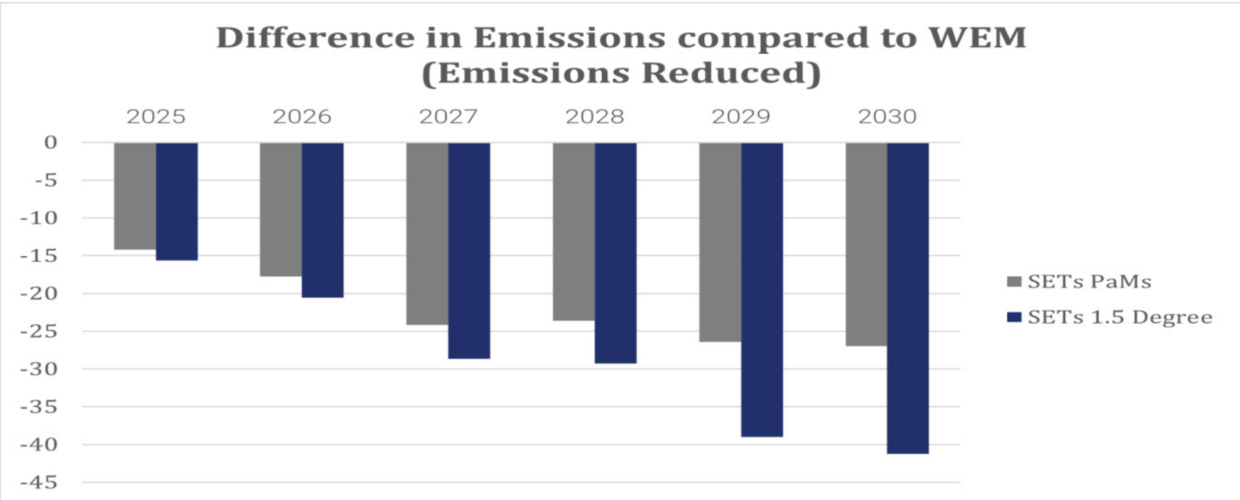


Figure 3-1: GHG Emission reductions results from PAMs to be used for SETs allocation (2025-2030).

[5] ERs are emissions reductions achieved relative to the WEM scenario.
[6] ELs are emission levels that must be achieved in a given year within the SETs commitment period. The SETs commitment period in this case is (2025-2030).

Table 3-2: Qualitative SETs Allocations

Sector	PAM	Target	Leading Department
Agriculture	Conservation of Agriculture Resources Act, Climate Smart Strategic Framework, Climate Change Sector Plan	Update the key policies to incorporate climate mitigation and carbon sequestration, including supporting measures (including the Conservation of Agriculture Resources Act, Climate Smart Strategic Framework and Climate Change Sector Plan) Update policies with the following activities, where relevant: Nitrogen inhibitors in crops Updating fertilizer schedules Increase availability of soil sampling, standardise nitrogen testing. Feed changes in livestock subsector. Conservation agriculture Sharing best practices across Provinces for climate mitigation	**Department of Rural Development, Agriculture and Land Reform**
	Conservation Agriculture Policy	Provide training and capacity to extension officers to support smallholder farmers on zero cost climate change mitigation options	
	Livestock emissions research programme	Identify emissions reduction technologies and opportunities in the livestock subsector	
	Agriculture Sector Implementation Plan	Develop a sector implementation plan to for applying climate mitigation activities	
Human Settlements	Sector Climate Response Strategy, National Housing Code	Develop a climate response strategy for the sector that outlines in an implementation the low carbon development pathway for the sector, including other departments, local and provincial governments.	**Department of Human Settlements**
		Develop a Red Book Implementation Strategy to mainstream the Red Book into implementation programmes	
		Include an assessment of climate smart settlements in the evaluations of housing programmes and policy.	
		Provide coordination and support to Provinces/Local governments, including bylaws, to ensure climate smart settlements are developed	
	Green Drop Report	Include auto generation of energy from onsite biodigesters as a criterion in the Green Drop Report.	**Department of Water and Sanitation**
Mining	Draft Mine Closure Strategy Derelict and Ownerless Mines Programme	Include revegetation/carbon sequestration in the mine closure process	**Department of Mineral**

Sector	PAM	Target	Leading Department
	The Exploration Strategy for the Mining Sector of South Africa and Critical Minerals Strategy (Draft in Progress)	Include the future low carbon economy in The Exploration Strategy for the Mining Sector of South Africa and Critical Minerals Strategy.	**Resources and Energy**
	Sustainable Development Reporting Guidelines (note developed)	Include climate change mitigation in the Sustainable Development Reporting Guidelines	
Energy	Energy Demand Side Management	Develop an updated demand side management programme	
Transport	National Land Transport Strategic Framework 2023 to 2028	Implement the Urban Objectives of the land transport strategy. Develop an implementation plan and pilot in two cities. Develop a pilot project to implement the stated goal of 5% of rural population with access to public transport within 1km. Implement a pilot project to increase transport by non-motorised/bicycle in 3 cities. Develop a strategy to roll out charging stations	**Department of Transport**
	White Paper of National Transport Policy	Develop implementation plan for increasing fuel efficiency, cleaner fuels and the adoption of fuel-efficient modes of transport, including the promotion of low-carbon modes of transport in existing and newly designed transport systems.	
	White Paper on National Rail Policy	Develop the National Rail Implementation Plan for priority corridors. Implement an enhanced PRASA Service Recovery Plan to have all 10 existing corridors operating and include additional corridors included in the plan. Develop an M+E System for tracking the modal shift for passenger and freight from road to rail.	
	Roadmap for the Freight Logistics System in South Africa 2023	Develop a monitoring as evaluation framework to track the modal shift of freight from road to rail	
	Draft Comprehensive Maritime Transport Policy, 2017	Develop an implementation strategy to deploy energy efficient technologies and other climate mitigation opportunities to reduce fuel related GHG emissions in port facilities and in ship operations	
	White Paper on National Civil Aviation Policy	Develop an implementation strategy to:	

Sector	PAM	Target	Leading Department
		Research, develop, demonstrate, diffuse and commercialise alternative fuels for use in aviation. uptake measures to limit or reduce aviation's emissions considering the roles of airport authorities, air traffic service providers and aircraft operators. participate in market-based measures, such as carbon pricing.	
	Draft Roads Policy	Develop the National Roads Master Plan, a National Road Investment Strategy and associated implementation plan ensuring GHG emissions mitigation measures are included	
Environment	Carbon Budgets	Mandatory carbon budgets	**Department of Forestry, Fisheries and Environment**
	National Waste Management Strategy	30% waste diverted from landfill sites	
	MTSF (DFFE) (Kigali Amendment)	Decrease consumption by HFC by 45%	
	MTSF (DFFE)	5400 ha of temporary unplanted areas (TUPs) planted. 15 000 ha approved for afforestation. 200 000 trees planted outside forests footprint	
	REDD+ Strategy	Development of a REDD+ Strategy for the country	
	Medium-Term Strategic Framework	90% of wildfires suppressed	
		Rehabilitation of 100 wetlands (9 603 ha)	
		Thicket restoration (30 637 ha)	
		2 500 ha of land for indigenous species cultivated. Wetlands of International significance designated. 17.7% in total land area under conservation (21 652 699 of 121 991 200 ha)	

4 Implications for the 2030 NDC

4.1 NDC Overview

The latest NDC for South Africa was submitted in September 2021. It presents updated targets for 2025 and 2030 considering the country's economic circumstances and a fair contribution to the global fight against climate change. The NDC targets includes relevant policies at the time when the NDC was derived including a very ambitious power sector investment plan as set out in the 2019 Integrated Resource Plan, the Green Transport Strategy, enhanced energy efficiency programmes and the carbon tax. It is assumed that substantial multilateral support is available to implement these measures, as provided for in the Paris Agreement.

4.1.1 Scope Considerations of the NDC

The NDC was developed based on an analysis of economy-wide emissions using the National Greenhouse Gas Inventory as a baseline (NIR). The latest available NIR was 2000-2017 submitted with the Fourth Biennial Update Report using the Global Warming Potentials (GWPs) of the IPCC Second Assessment Report. All gases were covered including five greenhouse gases, CO_2, CH_4, N_2O, HFCs and PFCs. SF_6 and NF_3 were not included due to the lack of data. A few subcategories are not estimated due to either activities not occurring in South Africa or lack of data at the time. The land sector is included in the NDC excluding the emissions from natural disturbances, most notably wildfires. All carbon pools are included except dead organic matter – litter is included but dead wood is not currently included.

4.1.2 Use of GWPs

The NDC targets were finalised considering the GWPs of the Fifth Assessment Report, which is estimated to have an impact of about +10 to 20 Mt CO_2eq in the target years compared to the analysis if the Second Assessment Report were used. The GWPs of the Fifth Assessment Report will be used for national GHG accounting from 2024 in accordance with the Annex to decision 18/CMA.1 of the Paris Agreement.

4.2 Aggregated impact of SETs vs NDC target points

The combination of SETs is assessed against the NDC in figure 4-1 below. This includes the three scenarios assessed. The first is the baseline scenario "With Existing Measures" which includes all PAMs that have been implemented before and up to 2022 that are projected to 2030. The SETs scenario includes the package of PAMs that form the SETs as described in table 3-1. The third scenario, named SETs 1.5, is the more ambitious scenario that would guide the country to achieving the low point of the NDC (350 Mt CO_2eq) by 2030 through higher investments.

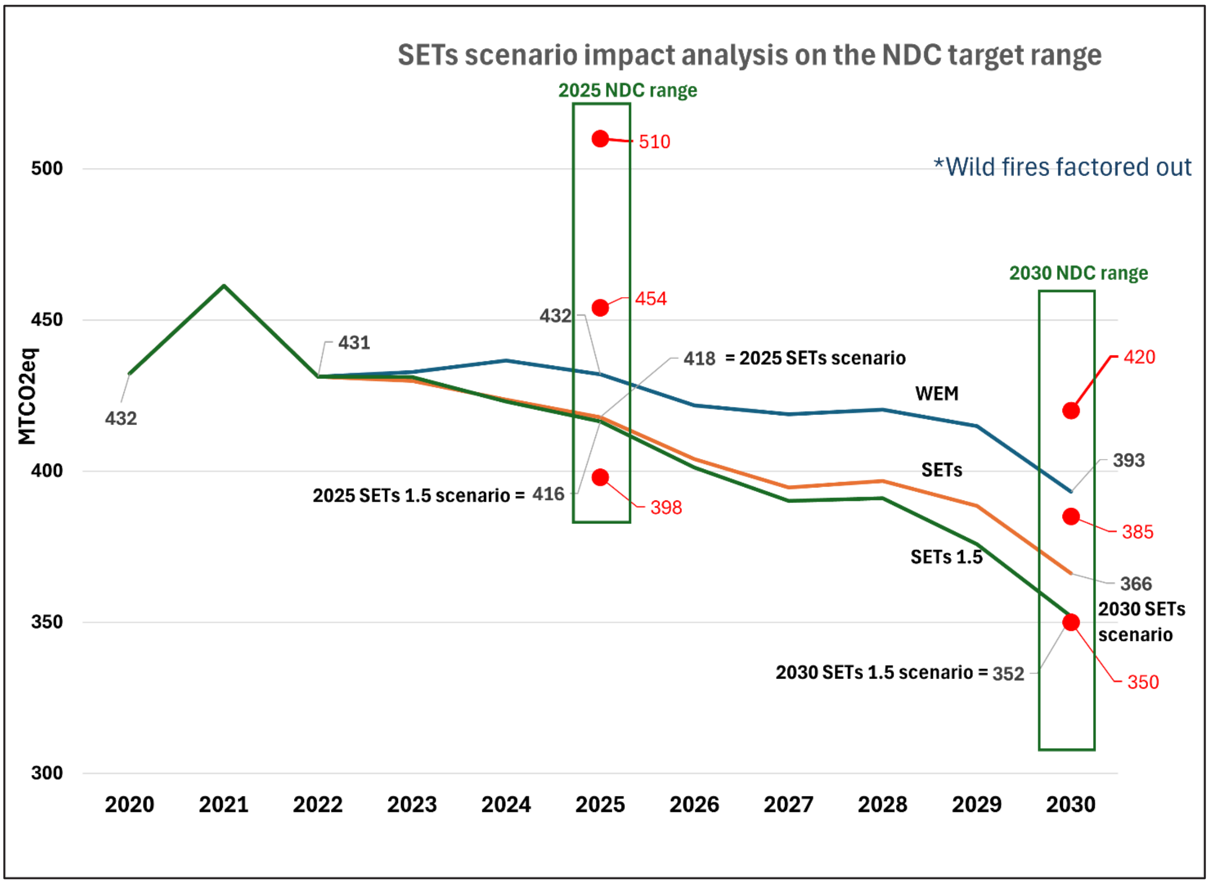


Figure 4-1: Assessing the aggregate impact of SETs allocation on the updated NDC target range.

In 2025, the country's current emissions trajectory is likely to fall within the NDC range, as represented by WEM in the above image. The SETs scenario, which includes all the PAMs targets to be allocated to sectors, will bring the emissions further down to about 19 Mt CO_2eq away from the low point of the NDC. With further ambition to set the country on a 1.5-degree scenario an additional 2 Mt CO_2eq can be shaved off the emissions to be 17 Mt CO_2eq away from the low point of the NDC.

In 2030, all scenarios including the WEM scenario is likely to meet the NDC. The WEM scenario is about 26 Mt CO_2eq below the high point of the NDC, 8 Mt CO_2eq from the mid-point of the NDC and 43 Mt CO_2e from the low point of the NDC. The SETs scenario, which achieves 366 Mt CO_2eq in 2030, is about 16 Mt CO_2eq from the low point of the NDC. The low point of the NDC can be achieved with an additional investment of 3% (an additional ~R28 trillion per year) across the energy, transport, waste, agriculture and environment sectors. The 1.5-degree scenario is estimated to be 352 Mt CO_2eq in 2030.

A key assumption of this assessment of WEM, SETs and 1.5-degree scenarios is that the policies are implemented as stated. If key policies such as the Integrated Resource Plan with its prescribed electricity build plan and decommissioning plan are not achieved the NDC may not be achieved.

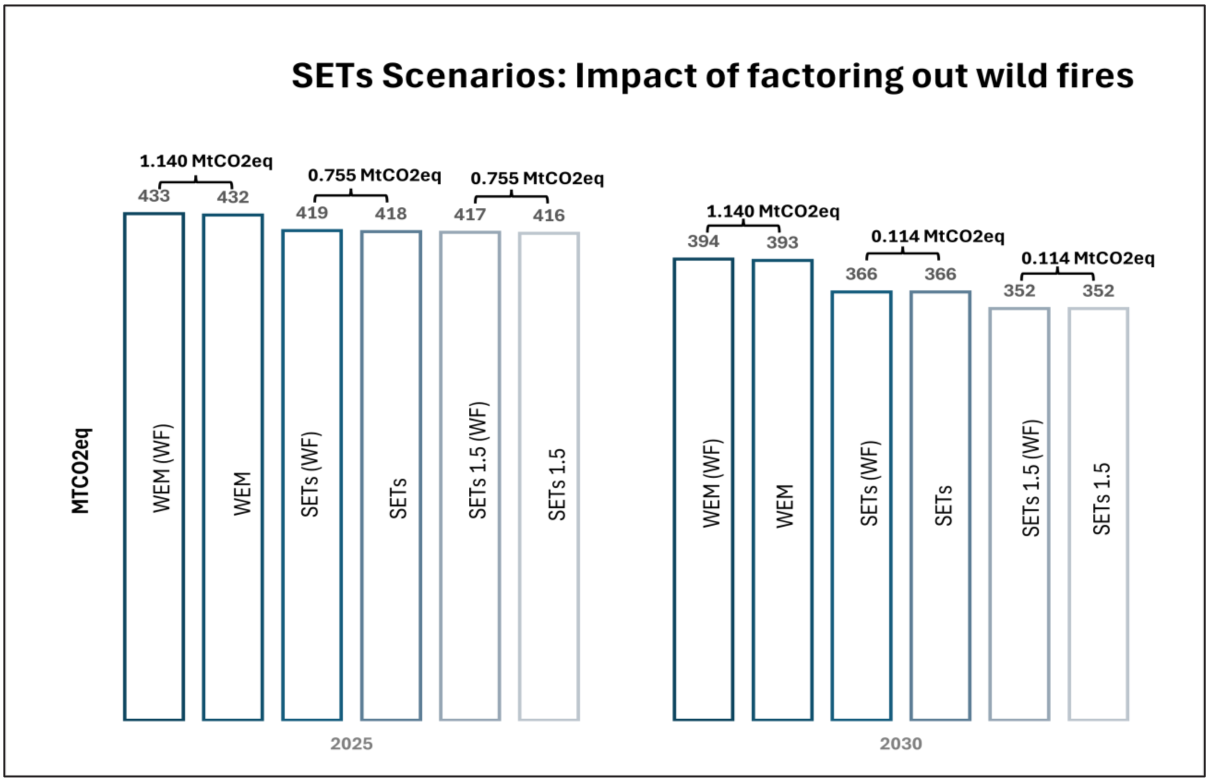


Figure 4-2: Assessing the impact of factoring wildfires on total emissions per scenario (2025, 2030).

4.3 Economic Impacts and Co-benefits of SETs

Economic Growth and Gross Value Added (GVA):

SETs will have an overall positive impact on economic growth. Growth would be similar to the historical years growth rate of 1.5%.

All scenarios assessed increase GVA of the country relative to the WEM. The annual average increase in GVA for the SETs scenario is 1.15%, for the Realistic SETs it is 1.11% and for the SETs 1.5-degree scenario it is 1.33%.

Figure 4-3: Growth per scenario

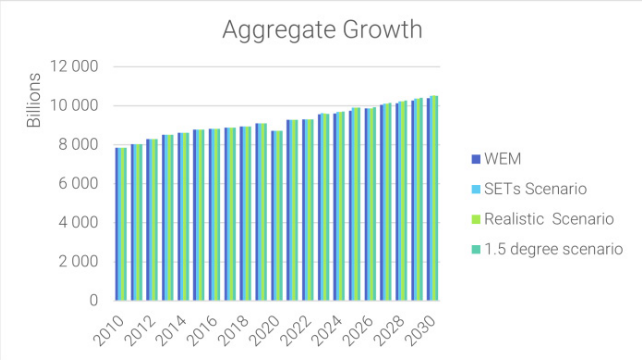
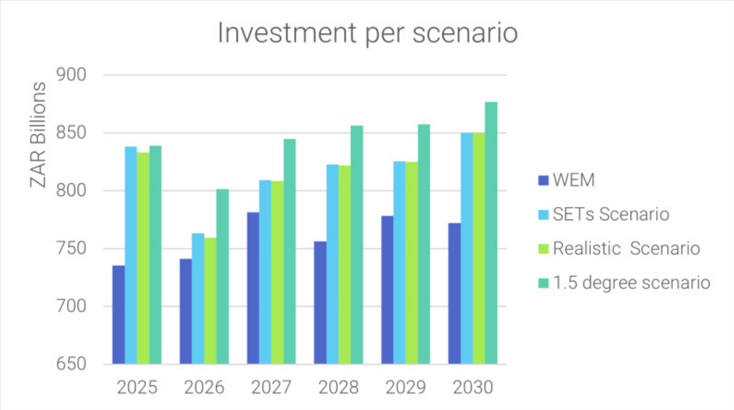


Table 4-1: Percent change of the scenarios against the WEM

Percent Increase of the SETs scenario compared to WEM					
2025	2026	2027	2028	2029	2030
0,67%	1,06%	1,76%	0,48%	1,31%	1,60%
Percent Increase of the Realistic SETs scenario compared to WEM					
0,50%	1,08%	1,75%	0,42%	1,32%	1,60%
Percent Increase of 1.5 Degree Scenario Compared to WEM					
0,54%	1,13%	1,72%	1,01%	1,70%	1,90%

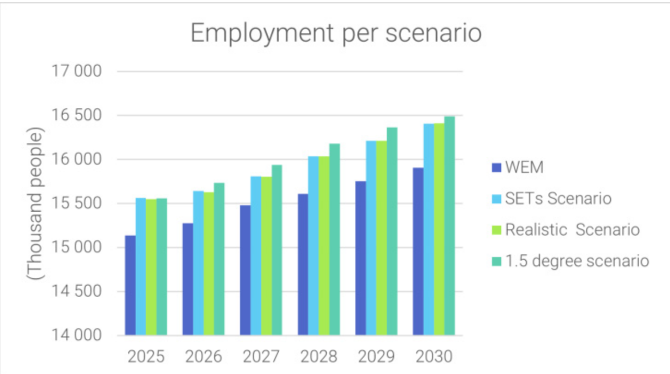
Investment:
Investment into the country economy will be highest with higher emissions reductions. Investments include the amount of flow into all sectors of the economy not only the sectors that are affected by SETs. The largest share of investment would go into the services sector due to the initial share of the sector within the whole economy.
The 1.5 Degree scenario is expected to result with the most investments averaging to about R829 trillion each year between 2025 and 2030. This is compared to the WEM scenario, which would result in an average R755 trillion of investment each year. The SETs scenario is estimated to achieve an average of R811 trillion each year and the Realistic scenario would achieve about R808 trillion each year. The investment deeds to achieve the 1.5 degree scenario compared to the SETs scenario is 3%, or R28 trillion annually.

Figure 4-4: Investment per scenario



Employment:
The SETs scenario has a net increase of employment of 2.7% compared to the WEM scenario, **or about 419 000 jobs added each year between 2025 to 2030. The SETs 1.5-degree scenario** increases implement by an additional 0.6% compared to the SETs scenario, or 517 000 jobs annually between 2025 to 2030. The SETs 1.5-degree scenario increases overall employment by 3.3%, or 517 000 jobs compared to the WEM annually. The highest growth sectors are electricity, manufacturing and construction.

Figure 4-5: Employment impacts per scenario



Key Co-benefits

SETs will have additional impacts specific to each sector in many ways. The below table lists the key co-benefits for the sector that will be tracked. These have been identified with sector line departments that are relevant to the specific PAMs of focus.

Table 4-2: Key Co-benefits of SETs per sector

Sector	Key Co-benefits
Energy	Water Air Quality Access to Affordable Electricity Economic Growth
Trade and Industry	Air quality

Sector	Key Co-benefits
	Employment Economic Growth
Transport	Air Quality Cost Savings For Users Cost Savings For Government Road Safety Reduced Traffic
Mining	Safety (reduced methane) Soil quality Biodiversity
Human Settlements	Air Quality Cost Savings Building Efficiency Reduced Traffic
Agriculture	Cost Savings Yield Climate Change Resilience
Environment	Biodiversity Climate Resilience Cleaner Environment

5 M+E Framework for SETs

5.1 M+E Approach

The SETs are to be aligned with the overall national planning system as implemented by DPME. The overall monitoring and evaluation (M+E) of the SETs will be part of the Medium-Term Development Plan (MTDP) monitoring and assessment process as it already exists. In this way, the Presidency will have the role of providing oversight of the performance of implementing the SETs. Sector departments are expected to report on progress of the assigned SET. Information to be provided includes evidence of achieving a qualitative SET (e.g. completed implementation strategy) and data collected to track a quantitative SET (e.g. energy efficiency achieved per end-use sector). DFFE will support where needed, including with translating sector activity data to greenhouse gas emissions equivalence and the overall analysis of the SETs performance against the NDC. Sector departments are not expected to report against SETs in terms of GHG emissions equivalent. A template for M+E of a SET will be developed with the sector department at the start of the SETs allocation period so that the information that is needed to be collected is clear from the beginning.

The overall performance of the SETs is conducted at the end of the 5-year MTDP period. The review of SETs will include the business-as-usual performance analysis by the DPME in terms of strategic reporting assessment. An additional step will include an overall assessment of performance of the SETs in relation to the NDC. This work will be supported by DFFE, who is equipped with the capacity and tools to track greenhouse gas emissions performance including the national greenhouse gas inventory system. It is noted that SETs will be assessed every 5 years, however since the SETs will be part of the APP, there will be an annual tracking component based on the existing APP review structures. Annual tracking will provide the necessary information for government to direct resources to ensure SETs are achieved that may be behind schedule.

The general process of the M+E is:

1. SETs are allocated by Government to line departments.
2. SETs are integrated into the MTSF and included in the Government budgetary planning process, the medium-term development plan (MTDP).
3. SETs are considered in the strategic outcomes that form part of the Performance Agreement with Ministers and subsequently integrated into the Delivery Agreements.
4. SETs are subsequently incorporated into the respective line department Annual Performance Plans
    a. Where necessary, Line Departments can ensure provincial and line department MTDP, strategic plans and annual performance plans incorporate aspects of the SETs that may be relevant.
5. Monitoring of performance of SETs is part of the monitoring tools and reports at the DPME.
    a. Electronic Quarterly Performance Report System: This provides the necessary information for Government to track performance against Annual Performance Plans.
    b. Annual Reports: This provides information on the institution's performance relative to the targets set in the Annual Performance Plan and the budget. It is submitted during the preceding financial year.
    c. End-term performance reviews:
    d. Auditor General of South Africa:
6. Evaluation of performance is conducted by the DPME quarterly and annually according to APP and annual report processes based on key indicators only.
7. Performance to achieve SETs is comprehensively reviewed at the end of the 5-year MTSF term. This includes an overall analysis of the performance of SETs in relation to the NDC and sector activities.

Table 5-1: Roles and Responsibilities

Institution/Minister	Roles and Responsibilities
Ministers	Integrate SETs within the relevant outcomes as part of the Delivery Agreement
Department of Monitoring and Evaluation under the Presidency	Oversight of the M+E system.
Department of Forestry, Fisheries and Environment	Conducting greenhouse gas emissions performance analysis at the sector and national level. Provide the assessment of GHG emissions relative to the NDC.
Line Department	Reporting into the national planning system, e.g. quarterly, annual reports. Providing additional detail of activity data (non-greenhouse gas emissions data) where requested
National Treasury	Provide budgetary analysis and performance tracking.

The purpose of the Strategic Plans is to set out an institution's policy priorities, programmes and project plans for a 5-year period. It focuses on the strategic outcome orientated goals for an institution as a whole and objectives for each of its main service delivery areas.

The Annual Performance Plan sets out the objectives and activities that institutions intend to do in the upcoming financial year that contributes to the achievement of the longer term MTSF. They are linked to the Strategic Plan and the budget.

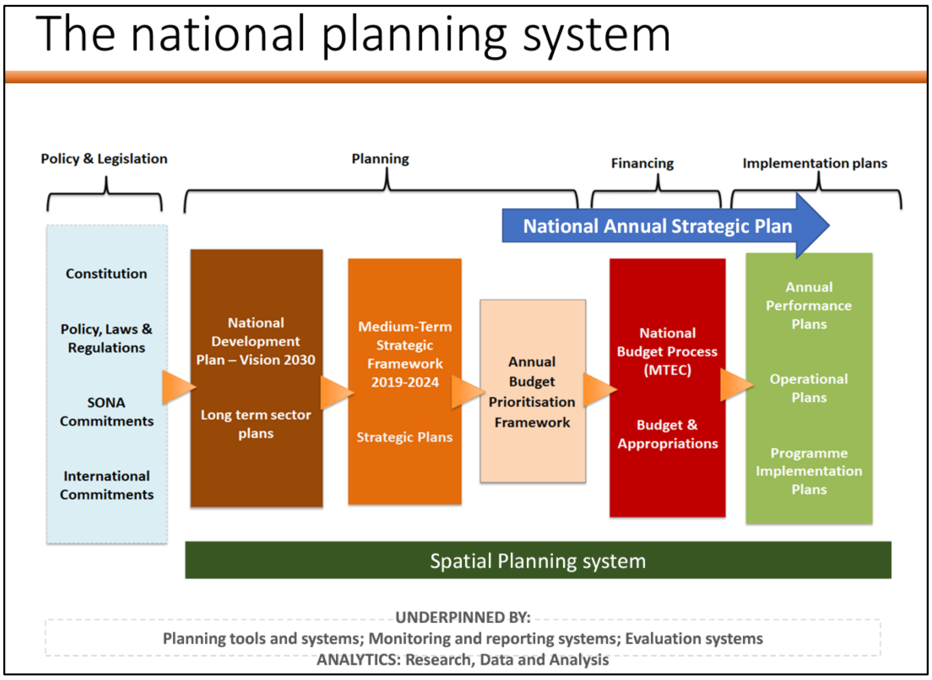


Figure 5-1: National Planning System

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forestry, fisheries & the environment

Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

SECTORAL EMISSION TARGETS

Technical Report

CONTENTS

1 INTRODUCTION

A core objective of this project is to present on the technical assessment conducted to inform the SETs. It describes the DFFE Integrated Climate Change Mitigation Model (referred as the Integrated model) used in the analysis. It includes the background and assumptions to the analysis conducted using the model.

2 BACKGROUND TO THE MODEL

The integrated model was developed in the Analytica modelling platform by Lumina Decision Systems (www.lumina.com). Analytica is a powerful modelling platform that is more visual, transparent, and flexible compared to typical spreadsheet models. The integrated model was developed over a number of years and includes the Mitigation Potential Analysis (MPA), South Africa's Greenhouse Gas (GHG) Emission Pathways (referred to as GHG Pathways) model, the Policies and Measures (PAMs) model and Ex-post tools model:

- **Mitigation Potential Analysis (MPA) model:** The South African Mitigation Potential Analysis (MPA) conducted in 2014 identified and analysed mitigation options in key economic sectors (Energy, Transport, Waste, Industry and Agriculture) in the country. The process involved updating the projection of GHG and generating marginal abatement cost curves (MACCs) for key sectors and sub-sectors. In addition, a socio-economic and environmental assessment of the mitigation options was conducted in order to assess the wider macro-economic impacts of implementing the identified mitigation options. The MPA was modelled using Excel, however in order to facilitate future changes and additions to the model, there was a need to move the MPA into a user-friendly interface, Analytica. The MPA model in Analytica includes an economic model in the form of social accounting matrix (SAM) to evaluate the socio-economic implications of mitigation options individually, for sectors, and the economy as a whole. Additional socio-economic, environmental and implementability criteria for each mitigation option are included in the model as part of the MCA. The MPA contains two key scenarios: With Existing Measures (WEM), and With Additional Measures (WAM). The MPA has been updated since 2014, with the most recent update taking place in 2022.
- **GHG Pathways model**: The GHG Pathways model provides an analysis of projected national GHG emission pathways for South Africa under different scenarios. The scenarios range from those under which no mitigation action is taken, to those in which mitigation action is taken in an economy with a structure largely similar to that of today, to those under which there is greater transformation of the economy. The different emission pathways are informed by factors including the country's existing and potential

future (climate and non-climate) PAMs; future economic developments; new science, evidence and information; and technological advances.

- **PAMs model**: The PAMs study and model determines the potential mitigation impact of PAMs that are currently in place on South Africa's emissions trajectory to 2050. This understanding is required to assess whether the "current" PAMs are sufficient to meet the overall mitigation ambition for the country, as contained in the National Climate Change Response Policy (NCCRP) and South Africa's NDCs as part of the global mitigation effort in terms of the Paris Agreement, or whether government needs to implement additional PAMs. The model also provides an understanding of the socio-economic costs and benefits of a selection of planned PAMs by linking them to the SAM and the E3ME socio-economic model.
- **Ex-post tools**: The Ex-post tools model translates existing ex-post mitigation assessment models for tracking South Africa's transition to a lower carbon economy into Analytica and integrates them with existing ex-ante models. Four tools (Mitigation Quantification Tool, Mitigation Action Database, Biennial Update Report (BUR)/Monitoring and evaluation (M&E) Explorer and Tracking, and Evaluation Portal) are included. The model outputs are guided by both international and domestic reporting requirements such as the reporting requirements for the UNFCCC's National Communication (NC) and BUR.

The rationale for including all these models into an integrated framework is so that they can be updated simultaneously. The integrated model provides a single platform for updating common assumptions. The integrated model develops emission projections to 2050 based on historical activity data together with assumptions on emission drivers and mitigation activities. For the model to remain current, it is important that the historical data reflects the 2000 to 2022 national GHG inventory and that the assumptions that underpin the emission projections reflect the country's existing and potential (climate and non-climate) PAMs; future economic developments; new science, evidence and information; and technological advances. Updating and improving the integrated model is, therefore, a necessary first step to provide DFFE with current analysis to inform both the Development Pathways as well as support the development of Sectoral Emissions Targets (SETs).

The section that follows describes the improvements and updates to the integrated model, input and assumptions, sub-sectors as well as the model structure.

2.1 The model framework and structure

The Integrated model uses a bottom-up approach to estimating greenhouse gases taking into account the activity data and mitigation potential in key economic sectors (where possible). The Integrated models also includes two economic models. The first is in the form of a social accounting matrix (SAM) which is used to evaluate the socio- economic implications of the mitigation options individually. The SAM is located and modelled with the Integrated models Analytica framework. The second is a socio-economic model developed by Cambridge Econometrics, which is external but linked to the Integrated Model. This assesses the socio-economic implications of mitigations options for sections and the economy as a whole. Additional socio-economic, environmental and implementability criteria for each mitigation option are included in the model as part of a multi-criteria assessment (MCA).

The model is routinely updated to incorporate the latest information and to update with improved data sets. The most recent update took place in February 2024 as part of the SETs analysis. The general approach to updating the model is undertaken in four phases, namely:

- Collation of existing data and assumptions on emission drivers and mitigation measures in the model;
- Desktop review to identify updated information and data in the open literature;
- Stakeholder consultations and bilateral engagements on emission drivers; sector- and sub-sector specific activity data, mitigation measures and growth projections; updates to the MCA and SAM; and
- Update of the model in Analytica and generation of results.

Engagement and consultations with key stakeholders is key part of the approach to updating the model. For example, for the 2021 MPA Update the stakeholder engagement included sessions with the project's Technical Working Group; engagements with stakeholders grouped according to the thematic areas of Energy and Transport; Industry, Waste; and Agriculture, Forestry and Other Land Use (AFOLU); and bilateral meetings with specific industry sub-sectors. During the SETs project, stakeholder engagement included session with relevant line departments as well as the project steering committee (PSC).

Key assumptions underpinning the model are aligned with government policies and plans, with sector-specific information obtained through stakeholder engagement and literature research where required to fill the gaps. The model has been most recently updated in 2024 with the most current available data.

The following key sources of data were used for updating historical data across sectors include:

- **Statistics South Africa (StatsSA) sectoral growth data.** This data is used to project production data that is available forwards to 2022 and backwards to 2000 as required. Here again in some sectors the growth data is aggregated, requiring the assumption to be made that the aggregated growth data also represented sub-sector growth.
- The **National GHG inventory from 2000 to 2022.** This data provides an extension to the existing data and fills a number of the gaps. In some sectors the inventory only has emissions data, whilst in others it includes production data.
- The **Minerals Council** annual publication, which provides production data of individual commodities.
- **Annual reports of individual companies and sector specific reports.** In some cases, these were used to provide energy and emissions data, confirm intensities, and in others to cross-correlate production data.
- **Sector-specific data** supplied by individual sector representatives.
- The **South African Energy Balance to 2020.** The energy balance is recognised to have a number of inconsistencies, and in some sectors is too highly aggregated to be useful for the purposes of this current project. However, it was used as a fall-back where no other data is available.

2.2 Cross-cutting assumptions and input data

Key drivers of emissions found in the Integrated model include population projections, Gross Domestic Product (GDP) growth and sectoral growth rates. Updates were made to assumptions around these key assumptions, as well as a selection of other cross-cutting parameters.

2.2.1 Population

A desktop review of historic population for South Africa was conducted to provide the information required to update the model with the latest available population data. Historic population data was updated to reflect the most recent historical population dataset from 2002 to 2022 (Statistics South Africa, 2020a, 2021b, 2022). The population projections were revised during the 2021 MPA update, with the medium scenario updated in 2024 to align with the IRP 2023:

1. **High scenario:** In alignment with DFFE's position to use official government data as inputs where possible, the Statistics South Africa data inputs (historical and projected) are included in the model.
2. **Medium scenario (default):** This is aligned with the population projections used for the IRP 2023 and is assumed to follow the United Nations population projection from its Population Division (United Nations, 2022). This is used as the default scenario.

3. **Low scenario:** 'Low fertility variant' of the population projection found in UN (2019).

The number of households and households per province were also updated to reflect the latest available data (2000 to 2021) (Statistics South Africa, 2021a).

2.2.2 GDP

The Statistics South Africa Gross Domestic Product first quarterly release provided updated GDP figured to update historic GDP numbers in the model through to 2022.

The model was updated during the 2021 MPA update to include three GDP projections. For the WEM and PAMs projections, the GDP projections to 2030 will an output from the South Africa Socio-Economic model, which is linked to the integrated model.

3 SUB-SECTOR MODEL ASSUMPTIONS

Throughout the model, Energy Balance and GHG Inventory data used in the sub-sector modules has been updated to the most recent versions of these sources, namely the Energy Balance 2000 to 2020 and the latest GHG Inventory 2000 to 2022. The GHG Inventory is the main data source, with the Energy Balance from the Department of Energy and Mineral Resources (DMRE) used as a fall-back in the absence of any other reasonable data. The Energy Balance is recognised to have a number of inconsistencies, and in some sectors is too highly aggregated to be used.

3.1 Energy

3.1.1 1 A 1 a Electricity and heat production

Fuel combustion emissions category	**1.A.1.a.i Electricity generation**

The Integrated Model includes a least-cost optimization model for the electricity sector. This model is not intended to replicate more sophisticated PLEXOS® models used in electricity planning, but rather to derive an indicative build plan that is consistent with the demand projections of the Integrated model. In the model the electricity module includes an optimization sub-routine that draws the demand projections from other parts of the model to determine the build and generation plan (and associated emissions profile) for a number of projections. The model represents a simplification as it does not include time of use data or grid stability considerations.

The electricity sector has been updated since the 2021 MPA update. One of the key changes includes the disaggregation of existing coal-fired power stations into individual power stations.

Although the IRP 2019 build plan is still used as the baseline scenario (WEM), inputs and assumptions updated to reflect the latest data provided by Eskom (including publicly available data from Integrated Reports), DMRE, (Lazard, 2023) and (EPRI, 2021)

The electricity sector model generates build plans, based on a number of different projections:

- **With existing measures (WEM)**: IRP 2019 build plan is used to 2030, thereafter the build plan is optimized based on least cost.
- **PAMs projections**: This is based on the IRP 2023 build plan for Horizon 1 to 2030. From 2031 to 2050, the build plan is based on the IRP 2023 Horizon 2 build plans (see Section 4.2.1 for more details).

3.1.2 Petroleum refining

Fugitive emissions category	**1.B.2.a Oil**
Fuel combustion emissions category	1.A.1.b Petroleum refining

Activity data to 2022

Production data from the South African Petroleum Industry Association (SAPIA) is used to 2020. For energy and electricity, the following assumptions are made to update data to 2022:

- Electricity data is used from 2000 to 2009, from the MPA, and data provided by SAPIA is used from 2010 to 2022. Fuel data is used from the 2022 GHG Inventory. SAPIA provided electricity and fuel use data to 2028, accounting for the impact of Clean Fuels II.

Fugitive emissions for the petroleum sector use data from 2022 GHG Inventory from 2000 to 2022.

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in Table 3.1, along with the most important assumptions that determine their impact on emissions outcomes.

Table 3.1: Petroleum refining sector existing mitigation measures

Mitigation measures	Description
Energy efficiency[1]	

[1] Energy efficiency measures are applied using a maximum saving and an uptake, so the technical limit of the measure is never exceeded in the model.

Mitigation measures	Description
Improve steam generating boiler efficiency	Applies to fuel use: 1.9% saving
Improve process heater efficiency	Applies to fuel use: 0.9% saving
Waste heat recovery and utilisation	Applies to fuel use: 5% saving
Waste heat boiler and expander applied to flue gas from the FCC regenerator	Applies to fuel use: 3% saving
Energy management and monitoring system	Applies to electricity and fuel use: 2% saving
Improved process control	Applies to electricity and fuel use: 2% saving
Improved heat exchanger efficiencies	Applies to fuel use: 4% saving
Improved electric motor system controls and (variable speed drivers (VSDs)	Applies to electricity use: 6% saving
Energy efficient utility systems	Applies to electricity use: 4% saving
GHG emissions abatement	
Minimise flaring and utilise flare gas as fuel	Reduces GHG emissions by 75%
Electricity generation	
Efficient energy production (CCGT and CHP)	Applies to electricity use: 60% saving

Source: (DEA, 2014b)

Table 3.2: Maximum uptake of mitigation measures in petroleum refining

Mitigation measures	2020	2030	2040	2050
Energy efficiency				
Improve steam generating boiler efficiency	100%	100%	100%	100%
Improve process heater efficiency	20%	20%	20%	20%
Waste heat recovery and utilisation	50%	100%	100%	100%
Waste heat boiler and expander applied to flue gas from the FCC regenerator	50%	50%	50%	50%
Energy management and monitoring system	100%	100%	100%	100%
Improved process control	20%	20%	20%	20%
Improved heat exchanger efficiencies	50%	50%	50%	50%
Improved electric motor system controls and VSDs	50%	100%	100%	100%

Mitigation measures	2020	2030	2040	2050
Energy efficient utility systems	50%	100%	100%	100%
GHG emissions abatement				
Minimise flaring and utilise flare gas as fuel	100%	100%	100%	100%
Electricity generation				
Efficient energy production (CCGT and CHP)	0%	50%	50%	50%

Source: (DEA, 2014b)

3.1.3 Oil and gas

Fugitive emissions category	1.B.2.a Oil 1.B.2.b Natural gas
Fuel combustion emissions category	1 A 1 c ii Other energy industries

Activity data to 2022

Production data from the MPA (based on company questionnaires) was used to 2012 and is updated to 2019 using DMRE supplied data. A three-year rolling average is used to project production to 2022. In terms of energy use, the following assumptions are made to update data to 2022:

- It is assumed that diesel used in this sector for electricity generation is linked to oil production, while natural gas is linked to gas production. No autonomous improvement in energy intensity is assumed.
- Data from the MPA is used to 2012, and then a 3-year rolling average intensity is assumed to 2022. Mitigation uptake to 2022 is applied between 2013 and 2022.

For venting and flaring emissions, the data from the 2022 GHG Inventory is used.

Mitigation measures

The mitigation measures included in the model are listed in the table below along with the key assumptions that determine their impact on emissions outcomes. No updates were made to the existing mitigation measures.

Table 3.3: Oil and gas production sector existing mitigation measures

Mitigation measure	Description
Energy efficiency	
Energy monitoring and management system	Applies to fuel use : 2% savings
Improved electric motor system controls and VSDs	Applies to fuel use : 4% savings
Energy efficient utility systems	Applies to fuel use : 4% savings
Waste heat recovery and utilisation in process	Applies to fuel use : 20% savings
Fuel switch	
Eliminate gas venting by capturing and utilising waste natural gas	Reduces GHG emissions by 75%. Achieves 3% fuel savings
GHG emissions abatement	
Eliminate gas venting by destruction by flaring of vented natural gas	Reduces GHG emissions by 75%

Source: (DEA, 2014a)

Table 3.4: Maximum uptake of mitigation measures in the oil and gas sector

Mitigation measures	2020	2030	2040
Energy efficiency			
Energy monitoring and management system	100%	100%	100%
Improved electric motor system controls and VSDs	100%	100%	100%
Energy efficient utility systems	100%	100%	100%
Waste heat recovery and utilisation in process	100%	100%	100%
Fuel switch			
Eliminate gas venting by capturing and utilising waste natural gas	50%	50%	50%
GHG emissions abatement			
Eliminate gas venting by destruction by flaring of vented natural gas	50%	50%	50%

Source: (DEA, 2014a)

3.1.4 Other energy

Fugitive emissions category	1.B.3. Other
Fuel combustion emissions category	1.A.1.c Manufacture of Solid Fuels and Other Energy Industries

Activity data to 2022

The following approach is used for updating energy use data in this sector:

- Historical fuel use (bituminous coal, natural gas and RFO/HFO) and electricity use data from 2000 to 2020 from one company and from 2000 to 2012 from the initial MPA for the other company. The data is projected to 2022 following production, although a 0.1% per annum autonomous savings per year is applied, as is a proportion of the mitigation savings potential (DEA, 2014b)

Under fugitive emissions data is taken from the 2022 GHG inventory and company data to 2020.

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the tables below along with the most important assumptions that determine their impact on emissions outcomes. Based on publicly available stakeholder information, an additional mitigation measure has been added (renewable electricity generation) and the timing and uptake of some mitigation measures have been updated (shading indicates changes to mitigation measures such as a new measure, changes to uptake or timing of implementation).

Table 3.5: Other energy sector existing mitigation measures

Mitigation measure	Description	Type of change
Energy efficiency		
Energy monitoring and management systems	Applies to fuel use: 2.5% savings	-
Improved process control	Applies to fuel use: 0.7% savings	-
Improved electric motor system controls and VSDs	Applies to electricity use: 7% savings	-
Energy efficient utility systems	Applies to electricity use: 3% savings	-
Improved heat systems	Applies to electricity use: 14% savings	-
Additional mitigation measures	Applies to fuel use: 18% saving	-
Fuel switch		
Conversion of feedstock from coal to natural gas	Reduces GHG emissions by 11.6%	-
Electricity generation		

Mitigation measure	Description	Type of change
Increase onsite gas-fired power generation - using internal combustion engines	Applies to electricity demand: 27% savings. Comes with a 5% increase in fuel use.	-
Waste heat recovery power generation	Applies to electricity demand: 25.8% savings.	-
Waste gas recovery and utilisation	Applies to fuel demand: 50% savings. Reduced GHG emissions by 0.5%	-
Renewable electricity	Applied to electricity	Addition

Source: (DEA, 2014b)

Table 3.6: Maximum uptake of mitigation measures in the other energy sector

Mitigation measures	2020	2030	2040	2050	Type of change
Energy efficiency					
Energy monitoring and management systems	15%	20%	30%	50%	-
Improved process control	100%	100%	100%	100%	-
Improved electric motor system controls and VSDs	50%	100%	100%	100%	-
Energy efficient utility systems	50%	100%	100%	100%	-
Improved heat systems	50%	100%	100%	100%	-
Additional mitigation measures	0%	4%	40%	85%	Timing of uptake moved earlier
Fuel switch					
Conversion of feedstock from coal to natural gas*	0%	11%	11%	11%	Uptake updated
Electricity generation					
Increase onsite gas-fired power generation - using internal combustion engines	45%	45%	45%	45%	Uptake updated
Waste heat recovery power generation	8%	8%	8%	8%	Uptake updated
Waste gas recovery and utilisation	100%	100%	100%	100%	-
Renewable electricity generation**	500 MW by 2030				Addition

*Approximately 40 – 60 PJ/year
Source: (DEA, 2014a) and stakeholder input (February 2022)

3.1.5 Coal mining

Fugitive emissions category	1.B.1.a Coal mining and handling 1.B.1.b Uncontrolled combustion and burning coal dumps
Fuel combustion emissions category	1.A.1.cii Other energy industries

Activity data to 2022

For this sub-sector, saleable coal production from 2000 to 2022 is taken from the 2022 GHG Inventory. Saleable coal production includes both local and export saleable coal. For fugitive emissions, the 2022 GHG inventory approach applied between 2000 and 2022 is used. For fuel and electricity data the following approach is taken:

- The available fuel (diesel, petrol and residual fuel oil) and electricity data is extrapolated based on production data from 2013 to 2022. Except for biofuels-related mitigation measures, some uptake of mitigation is assumed between 2010 and 2022. Mitigation is applied from 2013 to 2022.

Projections to 2050

Future production in the coal mining sector is largely linked to local demand for electricity generation, CTL and demand in other industrial sectors. In this work, an attempt is made to link coal mining output to demand for coal under all the projections, to ensure internal consistency within the model. This means for scenarios where local demand is lower (WAM) less new coal mines are developed. However, for levels of export coal, the South African Coal Roadmap scenarios are consulted and aligned as follows: WEM/PAMs – At the Forefront; WAM – Low Carbon World (The Green House, 2013). Assumptions are required to extend the Roadmap scenarios to 2050 from 2040.

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the table below along with the most important assumptions that determine their impact on emissions outcomes. Based on stakeholder input, a new mitigation measure was added (electricity vehicles) and a measure related to biodiesel was removed (all changes are indicated by shading in the tables below).

Table 3.7: Coal mining and handling sector existing mitigation measures

Mitigation measures	Description	Type of changes
Energy efficiency		
Improve energy efficiency of mine haul and transport operations	Applies to fuel use: 15% savings	-
Process, demand and energy management system	Applies to electricity use: 5% savings	-
Energy efficient lighting	Applies to electricity use: 1% savings	-
Install energy efficient electric motor systems	Applies to electricity use: 20% savings	-
Optimise existing electric motor systems (controls and VSDs)	Applies to electricity use: 10% savings	-
Fuel switch		
Use of electric vehicles for transport and handling equipment	Assumed to replace diesel vehicles and are approximately 3 times more efficient per km (MJ/km) than their diesel counterparts.	Addition
Electricity generation		
Onsite clean power generation	Assumed to meet 10% of electricity requirements	-
GHG Emission Abatement		
Coal mine methane recovery and destruction by flaring	Can abate 30% of methane (revised down to reflect low concentrations of methane which are not high enough to sustain a flare)	-

Source: (DEA, 2014a)

Table 3.8: Maximum uptake of mitigation measures in coal mining and handling sector

Mitigation measures	2020	2030	2040	2050	Type of change
Energy efficiency					
Improve energy efficiency of mine haul and transport operations	25%	50%	50%	50%	-
Process, demand and energy management system	25%	50%	50%	50%	-
Energy efficient lighting	50%	50%	50%	50%	-
Install energy efficient electric motor systems	25%	50%	50%	50%	-
Optimise existing electric motor systems (controls and VSDs)	25%	50%	50%	50%	-
Fuel switch					

Use of electric vehicles for transport and handling equipment	0%	5%	80%	100%	Addition
Electricity generation					
Onsite clean power generation	20%	40%	80%	80%	-
GHG Emission Abatement					
Coal mine methane recovery and destruction by flaring	0%	2.5%	5%	5%	-

Source: (DEA, 2014a)

3.2 Industry

3.2.1 Iron and steel

IPPU emissions category	2.C.1. Iron and steel production
Fuel combustion emissions category	1.A.2.a Iron and steel

Activity data to 2020

Existing production data is from the 2022 National GHG inventory. In terms of energy use and emissions, the following assumptions are made to update data to 2022:

- **Fuel data:** The 2022 GHG Inventory is used for fuel data from 2000 to 2022. The data is not disaggregated by technology type. As such the fuel data is allocated to the technology types using the same allocation as in the MPA for solid and gaseous fuels.
- **Electricity data:** The electricity intensity for EAF, as used in the MPA, is retained and extrapolated forward to 22 and backwards to 2000 based on production and adjusting for autonomous energy efficiency.

The following autonomous improvements in energy efficiency are applied to the iron and steel sector until 2030, based on inputs from stakeholders. No autonomous improvements are applied thereafter.

Table 3.9: Assumed autonomous improvement in energy efficiency in the iron and steel sector (from 2021 to 2030).

Autonomous improvement in energy efficiency	% annual improvement
Annual improvement in fuel intensity (BOF and BOS)	0.51%
Annual improvement in electricity intensity (BOF and BOS)	0.51%
Annual improvement in electricity intensity (EAF)	0.50%

Annual improvement in fuel intensity (DRI)	0.44%
Annual improvement in electricity intensity (DRI)	0.44%
Annual improvement in process emission factor	0.00%

Mitigation measures

The mitigation measures included in the Integrated model are listed in the table below along with the most important assumptions that determine their impact on emissions outcomes. Updates to the mitigation measures were limited to updating the uptake as well as the timing of implementation, based on stakeholder input (shaded in the tables below).

Table 3.10: Iron and steel production sector existing mitigation measures

Mitigation measures	Description
Energy efficiency	
BOF waste heat and gas recovery	This measure results in a 2.1% savings in energy use
Top gas pressure recovery turbine	0.8% energy saving
Energy monitoring and management system	Applies to fuel and electricity: 0.5% savings
Improved process control	Applies to fuel and electricity: 2.5% savings
Improved electric motor system controls and variable speed drives	Applies to electricity use: 0.6% saving
Energy efficient boiler systems and furnaces	Applies to fuel use: 1% saving
Energy efficient utility systems	Applies to electricity use: 0.4% saving
Improved heat exchanger efficiencies	Applies to fuel use for heat exchanger: 1%
Production pathway shift	
Electric arc furnace (EAF) and secondary production route	EAF processes save 96% of process emissions over primary production, requiring 72% less energy.
Technology substitution	
DRI - Midrex	7% more energy efficient than BOF + BOS based on international benchmarks
DRI - HYL	4% more energy efficient than BOF + BOS based on international benchmarks
DRI - ULCORED	13% more energy efficient than BOF + BOS based on international benchmarks

Source: (DEA, 2014a)

Table 3.11: Maximum uptake of mitigation measures in iron and steel production sector

Mitigation measures	2020	2030	2040	2050	Type of change
Energy efficiency					
BOF waste heat and gas recovery	0%	30%	100%	100%	-
Top gas pressure recovery turbine	0%	100%	100%	100%	-
Energy monitoring and management system	0%	50%	100%	100%	Uptake applied from 2025 Uptake updated
Improved process control	0%	50%	100%	100%	
Improved electric motor system controls and variable speed drives	0%	50%	100%	100%	Uptake applied from 2022 Uptake updated
Energy efficient boiler systems	0%	50%	100%	100%	Uptake applied from 2025 Uptake updated
Energy efficient utility systems	0%	50%	100%	100%	
Improved heat exchanger efficiencies	0%	50%	100%	100%	
Production pathway shift					
Electric arc furnace (EAF) and secondary production route	30%	100%	100%	100%	-
Technology substitution					
DRI - Midrex	15%	15%	15%	15%	-
DRI - HYL	0%	15%	15%	15%	-
DRI - ULCORED	0%	15%	15%	15%	-

Source: (DEA, 2014a

3.2.2 Ferroalloys

IPPU emissions category	2.C.2. Ferroalloys production
Fuel combustion emissions category	1.A.2.a Iron and steel

Activity data to 2022

Production data from 2000 to 2022 is available from the 2022 National GHGI, split by ferroalloy product category, with additional ferroalloy categories included. Process emission factors used are as per the latest GHG inventory. In terms of energy and emissions, the following assumptions were made to update data to 2022:

- The Ferroalloy Producers Association (FAPA) provided electricity data for 2016 to 2019. The electricity data is extrapolated to 2022 and from 2011 to 2015 as above. In addition, mitigation measures are assumed to have been applied between 2010 and 2015. Fuel use data in 2020 was provided from SAGERs. Fuel data is extrapolated back to 2000 and forward to 2022 based on production and intensity. An autonomous improvement in fuel intensity of 0.45% is assumed.

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the tables below, along with the most important assumptions that determine their impact on emissions outcomes. Based on stakeholder input, new mitigation measures were added (and some mitigation measures removed) and the mitigation potential, applicability and uptake of mitigation measures were also updated (shaded in the tables below).

Table 3.12: Ferroalloy production sector existing mitigation measures

Mitigation measures	Description	Type of change
Energy efficiency		
Implementing best available techniques	Applies to electricity and fuel use: 5% saving. Applies to process emissions: 10% saving	Addition
Energy monitoring and management system	Applies to fuel and electricity use: 1% saving.	
Improved electric motor system controls and VSDs	Applies to electricity use for motors (approximately 3% of total electricity use): 5% savings	
Energy efficient utility systems and improved heat exchanger efficiencies	Applies to electricity use and fuel use (approximately 3% of total electricity use): 5% electricity savings and 0.5% fuel use saving	Mitigation measures combined
Electricity generation		
Waste gas recovery and power generation - CO from closed furnace	3.5% electricity savings	Savings revised down
Renewable electricity generation (solar PV, wind and hydrogen)	Applies to electricity use	Addition
Waste heat recovery and power generation - from semi-closed and open furnaces	Applies to electricity use: 2.75% saving	Addition
Fuel switch		

Mitigation measures	Description	Type of change
Use biocarbon reductants instead of coal/coke	Maximum share of biocarbon reductants is set at 1.5%	
Fuel switch from consumable gas to waste gas	Applies to fuel use: 12%	Addition

Source: (DEA, 2014a) and stakeholder input (October 2021)

Table 3.13: Maximum uptake of mitigation measures in ferroalloy production sector

Mitigation measures	2020	2030	2040	2050	Type of change
Energy efficiency					
Implementing best available techniques	80%	80%	80%	80%	Uptake previously 0%
Energy monitoring and management system	50%	80%	80%	80%	Uptake updated
Improved electric motor system controls and VSDs	10%	20%	30%	40%	
Energy efficient utility systems and improved heat exchange efficiencies	50%	100%	100%	100%	Mitigation measures combined (uptake remains the same)
Electricity generation					
Waste gas recovery and power generation - CO from closed furnace	5%	10%	20%	35%	Uptake updated
Renewable electricity generation (solar PV, wind and hydrogen)	0%	10%	30%	30%	Addition
Waste heat recovery and power generation - from semi-closed and open furnaces	5%	10%	20%	55%	
Fuel switch					
Use biocarbon reductants instead of coal/coke	0%	0.3%	0.7%	1.3%	Update updated
Fuel switch from consumable gas to waste gas	10%	15%	15%	20%	Addition

Source: (DEA, 2014a), adjusted for assumed uptake in 2020.

3.2.3 Aluminium

IPPU emissions category	2.C.3. Aluminium production
Fuel combustion emissions category	1.A.2.b Non-ferrous metals

Activity data to 2022

Production data on aluminium is available from the 2022 National Greenhouse Gas Inventory (DFFE, 2022). Company level fuel and electricity use data was available from 2014 to 2020 (stakeholder input). MPA data is available from 2000 to 2012 for electricity and 2009 to 2012 for fuel. The following assumptions are thus made:

- The **electricity data** available was extrapolated based on production and a rolling three-year average intensity. An annual autonomous improvement in electricity intensity of 0.1%[2] is applied. No autonomous energy efficiency in fuel intensity is assumed.
- **Fuel data** for non-ferrous metal is used from 2022 GHG Inventory, minus the calculated fuel use from the lead and zinc sector (natural gas only)
-

Process emission factors used are as per the latest National GHG Inventory.

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the table below along with the most important assumptions that determine their impact on emissions outcomes. Changes to mitigation measures were limited to changing the uptake of one mitigation measure (see shading in tables below).

Table 3.14: Primary aluminium production existing mitigation measures

Mitigation measures	Description
Energy efficiency	
Improved process control	Applies to electricity use: 2% savings
Improved electric motor system controls and VSDs	Applies to electricity use for motors (approximately 8% of total electricity use): 10% savings
Energy efficient utility systems	Applies to electricity use for utility systems (approximately 3% of total electricity use): 5% savings
Production pathway shift	
Switch to secondary production and increase recycling	Assumes 15% of primary production could be shifted to secondary production (limited by scrap availability). 90% less emissions compared to primary production.

[2] Based on input from industry expert

Table 3.15: Maximum uptake of mitigation measures in Aluminium production sector

	2020	2030	2040	2050	Type of change
Energy efficiency					
Improved process control	50%	50%	50%	50%	-
Improved electric motor system controls and VSDs	5%	25%	50%	50%	Update updated
Energy efficient utility systems	50%	50%	50%	50%	-
Production pathway shift					
Switch to secondary production and increase recycling	0%	50%	100%	100%	-

Source: (DEA, 2014a, adjusted for assumed uptake in 2020

3.2.4 Lead production

IPPU emissions category	2.C.5. Lead production
Fuel combustion emissions category	1.A.2.b Non-ferrous metals

Activity data to 2022

Production data for 2000 to 2022 period is sourced from the 2022 National GHG Inventory. Process emissions are calculated using the International Panel on Climate Change (IPCC) emission factor. Based on input from stakeholders, lead production was changed from primary to secondary production. The following is assumed for fuel and electricity use:

- . Fuel and electricity use from 2000 to 2022 is calculated based on the energy requirements for a rotary furnace (secondary furnace). Fuel and electricity use is consistent across all projections.

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the tables below along with the most important assumptions that determine their impact on emissions outcomes. No stakeholder input was provided on the mitigation measures.

Table 3.16: Lead production sector existing mitigation measures assumptions

Mitigation measures	Description
Energy efficiency	

Energy monitoring and management	Applies to fuel: 1% saving
Improved electric motor system controls and VSDs	Applies to electricity: 0.2% saving
Energy efficient utility system	Applies to electricity: 0.2% saving
Improved heat exchanger efficiencies	Applies to fuel and electricity: 0.5% and 0.2% saving respectively

Table 3.17: Maximum uptake of mitigation measures in Lead production sector

Mitigation measures	2020	2030	2040	2050
Energy efficiency				
Energy monitoring and management	20%	20%	20%	20%
Improved electric motor system controls and VSDs	20%	20%	20%	20%
Energy efficient utility system	50%	100%	100%	100%
Improved heat exchanger efficiencies	50%	100%	100%	100%

3.2.5 Zinc production

IPPU emissions category	2.C.6. Zinc production
Fuel combustion emissions category	1.A.2.b Non-ferrous metals

Activity data to 2022

Production data for 2000 to 2022 period is sourced from the 2022 GHG Inventory. Production to 2022 is assumed to be consistent across all the projections. Process emissions are calculated using the IPCC emission factor. The following is assumed for fuel and electricity use:

- Fuel and electricity use from 2000 to 2022 is calculated based on the energy requirements of an imperial smelting furnace and production per production type. Fuel and electricity use is consistent across all projections. Coke and coal are used as reductants in the zinc sector.

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the table below along with the most important assumptions that determine their impact on emissions outcomes. No stakeholder inputs were provided on the mitigation measures.

Table 3.18: Zinc production sector existing mitigation measures assumptions

Mitigation measures	Description
Energy efficiency	
Energy monitoring and management	Applies to fuel: 1% saving
Improved electric motor system controls and VSDs	Applies to electricity: 0.2% saving
Energy efficient utility system	Applies to electricity: 0.2% saving
Improved heat exchanger efficiencies	Applies to fuel and electricity: 0.5% and 0.2% saving respectively

Table 3.19: Maximum uptake of mitigation measures in zinc production sector

Mitigation measures	2020	2030	2040	2050
Energy efficiency				
Energy monitoring and management	20%	20%	20%	20%
Improved electric motor system controls and VSDs	20%	20%	20%	20%
Energy efficient utility system	50%	100%	100%	100%
Improved heat exchanger efficiencies	50%	100%	100%	100%

3.2.6 Cement

IPPU emissions category	2.A.1. Cement production
Fuel combustion emissions category	1.A.2.f Non-metallic minerals

Activity data to 2022

The production data reported in the National 2022 GHG inventory is used to 2022 (assumed to represent clinker production). Cement production data is calculated based on clinker production and clinker content, as reported in the 2022 GHG Inventory. Process emissions factors are taken from the inventory and process emissions are calculated based on production data. The following assumptions are made to allocate electricity use data to cement production:

- **Electricity use** is in 2011, 2012 and 2013 is estimated by using an intensity of 106, 108 and 103 kWh/tonne of cement respectively (provided by stakeholders). Electricity in previous and subsequent years is adjusted according to production and autonomous improvements in electricity intensity (0.5%), Between 2013 and 2022 additionally by mitigation in the sector.

- **Fuel use data** was provided by SAGERS for 2020 and the Energy Balance[3] for 2000 to 2020. For the remaining year (and fuels not covered by the Energy Balance) fuel use was estimated using fuel intensity, production, and the improvement in energy intensity. Autonomous energy efficiency improvements for cement are 0.9% for fuel (only applied after 2020) and 0.5% for electricity (Kermeli, Graus and Worrel, 2014).

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the tables below along with the most important assumptions that determine their impact on emissions outcomes.

Table 3.20: Cement production sector existing mitigation measures

Mitigation measures	Description
Energy efficiency	
Improved process control	Applies to electricity and fuel use: 5% savings
Reduction of clinker content of cement products[4]	Minimum clinker content of cement assumed to be 68% (increased from 60% in response to TWG comment). Note that as clinker content is already approximately 70% this no longer represents a mitigation opportunity.
Energy monitoring and management system	Applies to electricity and fuel use: 1% savings
Improved electric motor system controls and VSDs	Applies to electricity use: 2.5% savings
Energy-efficient utility systems	Applies to electricity use: 5% savings
Electricity generation	
Waste heat recovery from kilns and coolers/cogeneration	Approximately 12% electricity savings

Source: (DEA, 2014a)

Table 3.21: Maximum uptake of mitigation measures in cement production sector

Mitigation measures	2020	2030	2040	2050
Energy efficiency				
Improved process control	100%	100%	100%	100%

[3] Proportion of coal use in the non-metallic minerals sector of the energy balance is taken as 70% for the cement sector

[4] Clinker content is controlled by a combination of customer product demand and by the SABS ENV 197 cement standard and the availability of extenders. Some customers want pure cement so that they can add extenders increasing the mitigation potential to far higher than the cement industry can offer. The industry will always reduce the clinker content to an absolute minimum that they can given the client base and circumstance. It is a simple business imperative. (Stakeholder comment, May 2022)

Mitigation measures	2020	2030	2040	2050
Reduction of clinker content of cement products	50%	75%	100%	100%
Energy monitoring and management system	100%	100%	100%	100%
Improved electric motor system controls and variable speed drives	50%	100%	100%	100%
Energy-efficient utility systems	50%	100%	100%	100%
Electricity generation				
Waste heat recovery from kilns and coolers/cogeneration	0%	50%	50%	50%
Fuel switch				
Utilise waste material as fuel[5]	5%	40%	63%	88%

Source: (DEA, 2014a)

3.2.7 Lime

IPPU emissions category	2.A.2. Lime production
Fuel combustion emissions category	1.A.2.f Non-metallic minerals

Activity data to 2022

Production data is taken from the 2022 GHG Inventory to 2022. For fuel use, a similar approach is taken as for cement. SAGERS data is provided for 2019 and 2020 and the Energy Balance data from used from 2000 to 2020 (where the percentage contribution of lime to the energy balance is assumed to be 15% for coal only and all-natural gas for the non-metallic minerals sector is allocated to glass manufacturing). This percentage remains consistent between 2000 and 2022. For fuel types that are not included in the energy balance, the data is extrapolated back to 2000 using a two-year rolling average intensity, production and improvement in fuel intensity.

For electricity use, the MPA obtained an electricity demand figure from respondents for 2010. The electricity intensity figure was used to project electricity demand backwards to 2000 and forwards to 2022, assuming an autonomous improvement in electricity intensity of 0.5%[6] per annum over this period. Further reductions in demand for 2010 to 2022 were added, calculated using the mitigation potential in the MPA.

Process emission factors are taken from the 2022 National GHG inventory.

[5] If enough waste fuels are "available" with consistent quality, and price then the cement industry will use waste fuel as a partial replacement. Swapping to waste fuels is more about effectively getting rid of waste than emission reduction. Waste generally comes from major centres and cement factories are normally far away from major centres in South Africa (Stakeholder comment, May 2022)

[6] Assumption

Mitigation measures

The mitigation measures included in the Integrated model are listed in the table below along with the most important assumptions that determine their impact on emissions outcomes. No stakeholder inputs were provided on the mitigation measures.

Table 3.22: Lime sector existing mitigation measures

Mitigation measures	Description
Energy efficiency	
Installation of shaft preheaters	Applies to fuel use: 20% savings
Energy monitoring and management system	Applies to fuel and electricity use: 1% savings for each
Improved process control	Applies to fuel use: 3% savings
Improved electric motor system controls and VSDs	Applies to electricity use: 5% savings
Energy-efficient utility systems	Applies to electricity use: 4% savings
Improved heat exchanger efficiencies	Applies to fuel use: 1% savings
Technology substitution	
Replace rotary kilns with vertical kilns or PFRK	Applies to fuel use: 53% savings
Fuel switch	
Use alternative fuels including waste and biomass	Reduces GHG emissions by 60%

Source: (DEA, 2014a)

Table 3.23: Maximum uptake of mitigation measures in lime sector

Mitigation measures	2020	2030	2040	2050
Energy efficiency				
Installation of shaft preheaters	20%	40%	40%	40%
Energy monitoring and management system	60%	60%	60%	60%
Improved process control	40%	40%	40%	40%
Improved electric motor system controls and VSDs	80%	80%	80%	80%
Energy-efficient utility systems	80%	80%	80%	80%
Improved heat exchanger efficiencies	80%	80%	80%	80%
Technology substitution				
Replace rotary kilns with vertical kilns or PFRK	5%	30%	55%	80%
Fuel switch				
Use alternative fuels including waste and biomass	0%	40%	65%	90%

Source: (DEA, 2014a)

3.2.8 Glass production

IPPU emissions category	2.A.3. Glass production
Fuel combustion emissions category	1.A.2.f Non-metallic minerals

Activity data to 2022

Production data for 2000 to 2022 period is sourced from the National 2022 GHG Inventory. Production to 2020 is assumed to be consistent across all scenarios. Process emissions are calculated using the IPCC emission factor. For fuel use, a similar approach is taken as for cement and lime. SAGERS data is provided for 2019 and 2020 and the Energy Balance data from used from 2000 to 2020 (where the percentage contribution of lime to the energy balance is assumed to be 15% for coal only. This percentage remains consistent between 2000 and 2022). For fuel types that are not included in the energy balance, the data is extrapolated back to 2000 using a two-year rolling average intensity and production. Historic electricity use is assumed to follow the Energy Balance electricity data for non-metallic minerals minus the electricity use in the cement and lime sector.

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the tables below along with the most important assumptions that determine their impact on emissions outcomes. Based on stakeholder input, changes to the mitigation measures were limited to updating the uptake and removing one mitigation measure (changes are shaded in the tables below).

Table 3.24: Glass production sector existing mitigation measures assumptions

Mitigation measures	Description
Energy efficiency	
Energy monitoring and management	Applies to fuel and electricity: 1% saving
Improved electric motor system controls and VSDs	Applies to electricity: 2.5% saving
Energy efficient utility system	Applies to electricity: 2% saving
Energy efficient lighting	Applies to electricity: 1% saving
Energy efficiency cooling	Applies to electricity: 2% saving
Increased use of cullet (only applied to container glass)	The use of cullet can increase to 40% in 2030, 50% in 2040 and 60% in 2050
Technology substitution	

Mitigation measures	Description
New state of the state furnace	Applies to fuel and electricity: 8% saving in 2030, 6% additional saving in 2040 and 4% additional saving in 2050
Switch to electric furnace	Applies to fuel: 70% saving and comes with an 124% increase in electricity use
Switch to oxyfuel furnace	Applies to fuel and electricity: 7% saving

Source: DEA, 2014 and Stakeholder input (October 2021)

Table 3.25: Maximum uptake of mitigation measures in glass production sector

Mitigation measures	2020	2030	2040	2050	Type of change
Energy efficiency					
Energy monitoring and management	**50%**	**75%**	**100%**	**100%**	**-**
Improved electric motor system controls and VSDs	50%	50%	50%	50%	-
Energy efficient utility system	50%	75%	100%	100%	-
Energy efficient lighting	75%	100%	100%	100%	Updated uptake
Energy efficiency cooling	5%	10%	10%	10%	-
Increased use of cullet	35%	35%	50%	70%	-
Technology substitution					
New state of the state furnace	10%	40%	27%	0%	-
Switch to electric furnace	0%	0%	20%	40%	-
Switch to oxyfuel furnace	0%	0%	20%	35%	-

Source: DEA, 2014 and stakeholder input (October 2021)

3.2.9 Chemicals

IPPU emissions category	2.B. Chemicals Industry 2.B.1. Ammonia production 2.B.2. Nitric Acid production 2.B.5. Carbide production 2.B.6. Titanium dioxide production 2.B.7. Soda ash production 2.B.8.f. Carbon Black 2.B.8.g. Hydrogen production
Fuel combustion emissions category	1.A.2.c Chemicals

Activity data to 2022

The following approach was undertaken to update data to 2022 in the integrated model:

Ammonia

Company-level data is available for ammonia production, process emissions and electricity from 2000 to 2020, extrapolated to 2022 based on company growth rates.

Nitric Acid

Nitric acid production is sourced from company-level and publicly available data from 2000 to 2020, extrapolated to 2022 based on growth in production. In terms of process emissions, the following approach is taken:

- The 2000 to 2022 process emissions are taken from the National GHG inventory data.

For electricity demand:

- For the specific company for which data is available, the electricity demand for 2000 to 2020 is used and extrapolated based on company growth rates. The other production plants are assumed to have the same electricity intensity as the company for which data is available in each year.

Carbide and carbon black

Production data is used from the National 2022 GHG inventory through to 2022. In terms of process emissions, it is assumed that there has been no mitigation since 2000. As such, process emissions for all projections follow the same trajectory and is taken from the 2022 GHG Inventory.

Titanium dioxide

Production data to 2022 is taken from the 2022 National GHG Inventory. In terms of process emissions, it is assumed that there has been no mitigation since 2000. As such, process emissions for all projections follow the same trajectory and is taken from the 2022 GHG Inventory.

Soda ash and hydrogen

Production data to 2022 is taken from the 2022 National GHG Inventory. In terms of process emissions, the data used is from the National 2022 GHG Inventory. The emissions are estimated by a Tier 3 approach and are only available for 2019 and 2022 for soda ash (CO_2 process emissions) and 2018 to 2022 for hydrogen (CO_2 process emissions).

Electricity demand for the remainder of the chemicals sector

The above commodities only cover a proportion of the chemicals sector in terms of electricity demand, and little further data is available to reconcile the data for this sector. In the absence of any substantive information, the following approach is taken to developing 2000 to 2022 projections for this sector:

- Energy balance data for electricity for 2000 to 2020 is used as a starting point.
- The energy balance data, however, aggregates chemicals and petrochemicals production, and so electricity demand for petrochemicals as per the calculation described elsewhere in this document is subtracted from the energy balance data. Data for 2000 and 2001 appeared incorrect in the energy balance so growth rates were used to calculate these from 2002 data.
- Electricity demand is extrapolated to 2022 using the sectoral growth rate. Electricity demand from ammonia and nitric acid production is subtracted from this number as it is captured separately.
- Mitigation is applied to 2019 and 2022

Fuel use in the chemicals sector

As indicated previously, no time series disaggregated data is available on fuel use for the above commodities or the remainder of the chemicals sector. The only data that is available is a single set of data for 2011 provided by the Chemical and Allied Industries' Association (CAIA) to the MPA study, on bituminous coal, residual fuel oil and natural gas in the sector as a whole and SAGERs data for 2019 and 2020. This data is projected forwards to 2022 and backwards to 2000 using the growth rates of "other chemicals sector" as provided by StatsSA (2021b). A proportion of the mitigation gains in the MPA for 2012 to 2018 and 2021 to 2022 is applied, as is an autonomous efficiency improvement of 0.92%[7] per annum.

Total chemicals production

Total chemicals production was available from CAIA for the MPA for 2007 to 2012. Before 2007 a rolling average production was used. After 2012 production was kept constant to 2022. This was done given the new nitric acid plant built in 2011.

[7] Based on UK data on improvements in chemicals sector(DEA, 2014b)

Mitigation measures

The mitigation measures included in the Integrated model are listed in the tables below along with the most important assumptions that determine their impact on emissions outcomes. Other energy sector mitigation measures are applied to ammonia production linked to CTL. Changes to the mitigation measures were limited to updating the mitigation potential of N_2O abatement for new production plants (see shading in tables below).

Table 3.26: Chemicals' production sector existing mitigation measures

Mitigation measures	Description	Type of change
Energy efficiency		
Revamp: increase capacity and energy efficiency	Applies to fuel use and electricity, saving 15% and 10% respectively.	-
Energy monitoring and management system	Applies to fuel and electricity use: 2% savings for each	-
Advanced process control	Applies to fuel use: 5% savings	-
Improved electric motor system controls and VSDs	Applies to electricity use for motors: 6% saving	-
Energy efficient utility systems	Applies to electricity use for utilities: 2%	-
Increase process integration and improved heat systems	Applies to fuel use: 10% savings	-
GHG Emissions abatement		
N2O abatement for new production plants	85% process emissions abatement	Emissions abatement reduced from 90%
Electricity generation		
Combined heat and power (CHP)	Can reduce grid electricity demand by 15%, but with a 46% increase in reference fuel demand.	-

Source: (DEA, 2014a) and stakeholder engagement (October 2021)

Table 3.27: Maximum uptake of mitigation measures in chemicals production sector

Mitigation measures	2020	2030	2040	2050
Energy efficiency				
Revamp: increase capacity and energy efficiency	20%	40%	40%	40%
Energy monitoring and management system	20%	40%	40%	40%
Advanced process control	20%	40%	40%	40%
Improved electric motor system controls and VSDs	20%	40%	40%	40%

Mitigation measures	2020	2030	2040	2050
Energy efficient utility systems	20%	40%	40%	40%
Increase process integration and improved heat systems	20%	40%	40%	40%
GHG emissions abatement				
N_2O abatement for new production plants	10%	10%	10%	10%
Electricity generation				
Combined heat and power (CHP)	25%	50%	50%	50%

Source: (DEA, 2014a)

3.2.10 Pulp and Paper

IPPU emissions category	2.H.1. Pulp and paper industry
Fuel combustion emissions category	1.A.2.d Pulp, paper and print

Activity data to 2022

Updated production data from The Paper Manufacturers Association of South Africa (PAMSA) is used to extend production data to 2022.

In terms of fuel and electricity use, the following assumptions are made for the integrated model:

- **Fuel data:** MPA fuel data, presumed to be from respondents and covering bituminous coal, gasworks gas, natural gas, diesel and biomass, is used from 2000 to 2009 (given that the data covers a greater number of energy carriers than the energy balance) and data provided from PAMSA (covering the same fuel types) is used from 2016 to 2021. For natural gas and gasworks gas, the fuel data from 2010 to 2015 is taken from the Energy Balance. For the remaining fuel types, the fuel intensity for 2010 to 2015 is assumed to follow a three-year rolling average ratio against total production, although the 0.32% annual reduction in fuel intensity for the sector is applied for these years. The same approach is applied to projecting fuel data to 2022.
- **Electricity data: Energy** balance data is used for electricity for the sector for 2000-2015 and electricity data provided by PAMSA is used from 2016 to 2021. Electricity data is projected to 2022 using a three-year rolling average electricity intensity, production and improvement in electricity intensity.

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the table below along with the most important assumptions that determine their impact on emissions outcomes.

Table 3.28: Pulp and paper production sector existing mitigation measures

Mitigation measures	Description
Energy efficiency	
Energy monitoring and management system	Applies to electricity and fuel use: 1% saving
Improved electric motor system controls and VSDs	Applies to electricity use for motors: 7% saving
Energy efficient utility systems	Applies to electricity use for utilities: 3% savings
Improved process control	Applies to fuel use: 5% savings
Energy efficient boiler systems and kilns and improved heat systems	Applies to fuel use: 10% saving
Energy Recovery System	Applies to fuel use: 10% saving
Fuel switch	
Convert fuel from coal to biomass/residual wood waste	Could abate 100% of fossil-fuel related emissions
Electricity generation	
Combined Heat and Power	Could off-set 84% of grid-based electricity, but with associated increases in fuel use of 26%

Source: (DEA, 2014)

Table 3.29: Maximum uptake of mitigation measures in pulp and paper production sector

Mitigation measures	2020	2030	2040	2050
Energy efficiency				
Energy monitoring and management system	30%	80%	80%	80%
Improved electric motor system controls and VSDs	30%	80%	80%	80%
Energy efficient utility systems	30%	80%	80%	80%
Improved process control	30%	80%	80%	80%
Energy efficient boiler systems and kilns and improved heat systems	50%	100%	100%	100%
Energy Recovery System	80%	80%	80%	80%
Fuel switch				

Mitigation measures	2020	2030	2040	2050
Convert fuel from coal to biomass/residual wood waste	5%	25%	25%	25%
Electricity generation				
Combined Heat and Power	30%	80%	80%	80%

Source: (DEA, 2014a)

3.2.11 Mining and quarrying

Fuel combustion emissions category	1.A.2.i Mining (excluding fuels) and Quarrying

Activity data to 2022

Production data for all named commodities to 2022 was obtained from the DMRE SAMI data and Minerals Council. The named commodities include gold, PGMs, diamonds, iron ore, manganese and chromite, among others.

Although some fuel and electricity use data was available in company reports, it was not possible to build up a comprehensive picture of fuel use for all commodities. Given the variability in the respondent data used in the MPA and the mismatch with the Energy Balance, the following fuel-specific approaches were taken.

- For diesel use, the respondent data for the specified commodities fell within the energy balance values and thus this data was extrapolated forward and backwards based on production. Natural gas in PGMs use was included from the respondent data and extrapolated similarly to diesel.
- For other minerals, the fuel data is based on the 2022 GHG Inventory manufacturing and construction fuel use and the estimated percentage energy demand of the mining sector from the South African Energy Sector report (published in 2021)
- Electricity use data for Gold and PGMs was related to the energy balance electricity data using the heuristic that approximately 47% and 33% of mining electricity can be attributed to gold and PGMs respectively (Eskom, 2010). This was applied between 2000 and 2022.
- For all scenarios mitigation is applied after 2012 for fuels.

The following autonomous improvements (or declines) in energy efficiency are applied to the sectors from 2020 (for all other commodities the energy efficiency improvements are assumed to be 0%):

Table 3.30: Assumed autonomous improvements in energy efficiency in mining

Commodity and energy carrier	Percentage annual autonomous improvement / decline
Chromite mining electricity efficiency	0.5%
Manganese mining electricity efficiency	0.5%

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the tables below along with the most important assumptions that determine their impact on emissions outcomes. Based on stakeholder inputs, a new mitigation measure was added (use of electric vehicles for transport and handling equipment, replacing biofuels mitigation measures) and the uptakes of mitigation measures were also updated (shown in shading in the tables below).

Table 3.31: Mining and quarrying sector existing mitigation measures

Mitigation measures	Description	Type of change
Energy efficiency		
Improve energy efficiency of mine haul and transport operations	Applies to fuel use: 5% savings (revised downwards in response to comment that mines are located further from beneficiation operations)	-
Process, demand & energy management system	Applies to electricity use: 5% savings	-
Energy efficient lighting	Applies to electricity use: 1% savings	-
Install energy efficient electric motor systems	Applies to electricity use: 5% savings	-
Fuel switch		
Use of electric vehicles for transport and handling equipment	Assumed to replace diesel vehicles and are approximately 3 times more efficient per km (MJ/km) than their diesel counterparts.	Addition
Electricity generation		
Onsite clean power generation	Can offset 10% of grid electricity requirements	-

Source: (DEA, 2014a) and stakeholder input (October 2021)

Table 3.32: Maximum uptake of mitigation measures in mining and quarrying sector

Mitigation measures	2020	2030	2040	2050	Type of change
Energy efficiency					
Improve energy efficiency of mine haul and transport operations	0%	50%	50%	50%	-

Mitigation measures	2020	2030	2040	2050	Type of change
Process, demand & energy management system	25%	50%	50%	50%	-
Energy efficient lighting	25%	50%	50%	50%	-
Install energy efficient electric motor systems	25%	50%	50%	50%	-
Fuel switch					
Use of electric vehicles for transport and handling equipment	0%	5%	80%	100%	Addition
Electricity generation					
Onsite clean power generation	20%	50%	60%	60%	Uptake updated

Source: (DEA, 2014a) ,stakeholder input (October 2021)

3.2.12 Non-specified industry

Fuel combustion emissions category	1.A.2.m. Non-specified industry

Activity data to 2022

This sector covers the fuel combustion emissions associated with the balance of manufacturing and construction industries not modelled explicitly. It includes food processing, beverages and tobacco, other process use of carbonates, wood and wood production among others. Production data and process emissions are not needed.

Fuel and electricity use is calculated using the fuel and electricity consumption from the explicitly modelled sectors and the total energy use for either the sector or nationally (depending on fuel type and data source). The difference is assumed to represent the balance of fuel and electricity use in the manufacturing and construction and is termed “other” manufacturing and construction. The following approach is taken to calculate fuel and electricity use.

- **Electricity**: Total historical electricity demand for South Africa is taken as total national local sales based on Eskom and non-Eskom sales (2000 to 2022). Historical electricity consumption in the modelled sub-sectors is aggregated and subtracted from total historical electricity demand to determine historical electricity consumption from “other manufacturing and construction”.
- **Fuels**: The 2022 GHG Inventory 2022 manufacturing and construction fuel use is taken as the fuel demand in industry in South Africa. The historical fuel consumption across

industry is aggregated and subtracted from the 2022 GHG Inventory to give fuel use associated with "other" manufacturing.

- An autonomous improvement in energy efficiency of 0.5% is applied in this sector (Kermeli, Graus and Worrell, 2014)

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the table below along with the most important assumptions that determine their impact on emissions outcomes. All the mitigation measures are energy efficiency measures. The applicability of each mitigation measures is based in the IEP, 2012 energy and electricity end-use (DoE, 2012).

Table 3.33: Non-specified industry sector existing mitigation measures

Mitigation measures	Description
Energy efficiency	
EMMS	Applies to fuel and electricity use: 1% savings each
Improved process control	Applies to fuel and electricity use: 0.4% and 1% saving each
VSDs	Applies to electricity use for motors: 2.5% saving
Energy efficient utility systems	Applies to electricity use for utilities: 2% saving
Energy efficient lighting	Applies to electricity use for lighting: 1% saving
Energy efficient boiler and kilns	Applies to fuel use and electricity use: 7.6% and 4% saving each

Source: (DoE, 2012)

Table 3.34: Maximum uptake of mitigation measures in non-specified industry construction sector

Mitigation measures	2020	2030	2040	2050
Energy efficiency				
EMMS	50%	75%	100%	100%
Improved process control	50%	75%	100%	100%
VSDs	50%	75%	100%	100%
Energy efficient utility systems	50%	75%	100%	100%
Energy efficient lighting	50%	75%	100%	100%
Energy efficient boiler and kilns	50%	75%	100%	100%

3.2.13 Other sectors

The table below summarises the inputs and assumptions for other sectors.

Table 3.35: Other sectors inputs and assumptions

IPCC Sector	Activity data	Mitigation measures
1 A 2 k Manufacturing and construction 1 A 2 k Construction	Fuel and electricity use data is from the GHG Inventory fuel study and Energy Balance from 2000 to 2020 respectively.	No mitigation measures identified for the sector
1 A 5 Non-specified 1 A 5 a Non-specified stationary	Fuel use data from 2000 – 2022 is from the 2022 National GHG Inventory	No mitigation measures identified for the sector
2 A 4 Other process uses of carbonates	Data from 2000 – 2022 is from the 2022 National GHG Inventory IPCC process emissions factor	No mitigation measures identified for the sector
2 D Non energy production and solvent use 2 D 1 Lubricant use 2 D 2 Paraffin wax use	Data from 2000 – 2022 is from the 2022 National GHG Inventory IPCC process emissions factors	No mitigation measures identified for the sector
2 F Substitutes for ODS 2.F.1.a. Refrigeration and stationary air conditioning 2.F.1.b. Mobile air conditioning 2.F.2. Foam blowing agents 2.F.3. Fire protection 2.F.4. Aerosols	Data from 2000 – 2022 is from the 2022 National GHG Inventory IPCC process emissions factors	No mitigation measures identified for the sector

3.3 Transport

3.3.1 Domestic aviation

Fuel combustion emissions category	1.A.3.a.ii. Domestic aviation

Activity data to 2022

The fuel and emissions data for the period up to 2022 are sourced from the 2022 National Greenhouse Gas Inventory.

- For fuel use, GHG inventory data was used for jet kerosene and aviation gas from 2000 to 2022.
- A 2.5% improvement in energy efficiency is applied from 2023.

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the table below along with the most important assumptions that determine their impact on emissions outcomes. Through stakeholder consultations, it was recommended to reduce the uptake rate of improved efficiency through retrofits since the industry is unlikely to retrofit existing aircraft incrementally. The uptake rate of biofuels was also reduced to reflect the lack of uptake in 2020. Shading indicates changes to mitigation measures.

Table 3.36: Domestic aviation sector existing mitigation measures

Mitigation measures	Description
Fuel saving	
Improved efficiency - retrofit	Retrofit of winglets and engine upgrade result in 2% emissions saving. The lifetime is 10 years.
Early retirement	30,000 tonnes abatement over 25 years (lifetime).
Fuel switch	
Biofuels	The replacement of jet kerosene and aviation gas with biofuels

Source: (DEA, 2014a)

Table 3.37: Maximum uptake of mitigation measures in domestic aviation sector

Mitigation measures	2020	2030	2040	2050	Type of change
Fuel saving					
Improved efficiency - retrofit	0	43*	0	0	Shifted to 2025 (from 2020) due to COVID
Early retirement	0	0	5	0	
Fuel switch					

Mitigation measures	2020	2030	2040	2050	Type of change
Biofuels	0	17%	32%	52%	Uptake updated

*Uptake in 2025
Source: (DEA, 2014a) and stakeholder inputs (2021)

3.3.2 Road Transport

Fuel combustion emissions category	1.A.3.b. Road transport

Activity data

The following approach is used to model the energy use and emissions in the road transport in the Integrated model:

- **Vehicle parc model**: A vehicle parc model models the vehicle fleet from 1981 to 2050. The model uses estimates of scrapping curves, annual vehicle mileage and mileage decay to determine what the existing vehicle fleet will look like in the future based on historic vehicle sales (1981 to 2022).
- **Demand model**: Two sub-models project demand for passenger and freight transportation (for both road and rail) to 2050:
    - Passenger demand model: A time budget model is used to calculate passenger travel demand for road and rail in vehicle.km and passenger.km for each vehicle type
- Freight demand for road and rail is determined using sector growth rates for road and rail and historic freight demand.
- Road transport mitigation measures are divided into modal shift mitigation measures and efficiency and alternative fuels mitigation measures (road mitigation measures). Modal shift measures are applied to the vehicle fleet prior to road mitigation measures to take into account the change in demand per vehicle type. These projections assume a 1% autonomous improvement in energy efficiency. Electricity use associated with mitigation measures is also considered.

Key data sources/assumptions underpinning the vehicle parc

Key assumptions and inputs used in the vehicle parc model are shown in Table 3.38. The value of the assumptions varies depending on the type of vehicle and fuel use (diesel or petrol). The assumptions will align with those used in the vehicle parc model used for the NDC update.

Table 3.38: Vehicle parc model assumptions and Inputs

Assumption/Input	Description	Units
Weibull K and Weibull L	Weibull constants are used to determine the vintage profile	-
Mileage decay	The rate of mileage decay over time	%
Fuel economy	The fuel economy per vehicle type and fuel type	l/100km
Fuel economy improvement	The improvement in fuel economy over time	%
Load factor	For freight and passenger vehicles	Tonnes/vehicle or passengers per vehicle
Historical sales	Per vehicle type from 1981 to 1999	Number of sales
New sales	Per vehicle type from 2000 – 2019	Number of sales
Vintage year	The year in which a particular vehicle was sold	Year
Mileage start	The mileage per vehicle type at the start of its lifetime	km
Mileage adjusted and mileage scale adjusted	Constants used to determine mileage over time	-

Key data sources underpinning the demand projections

The growth in freight and passenger demand is largely influenced by population growth and economic growth, although other factors do play an important role. The freight demand model is also influenced by GDP projections and sector growth rates, specifically transport sector and mining sector growth rates. Key inputs and assumptions for the demand model are summarised in Table 3.39.

Table 3.39: Transport demand assumptions and inputs

Assumption/Input	Description	Key values
Passenger transport demand		

Assumption/Input	Description	Key values
Number of people per income group	The population multiplied by the projected income level split	Million people
Private vehicle[8] ownership	The private vehicle ownership per income group	Low income: 7% Middle income: 22.7% High income: 78.4%
Private vehicle ownership	The private vehicle owned per person per income group	Low income: 0.25 vehicles/person Middle income: 0.31 vehicles/person High income: 0.41 vehicles/person
Private vehicle and other private vehicle[9] mileage	Mileage per vehicles for persons with private vehicles per income group	Low income: 8,150 km/year Middle income: 13,650 km/year High income: 17,7200 km/year Other private vehicle: 18,00 km/year
Average speed for private vehicles	The average speed for private vehicles	34 km/hour
Load factors	The vehicle occupancy	1.4 people/vehicle
Passenger elasticity	Sensitivity to change	Changes over time
Split between private vehicles[10]	Percentage split between cars, SUVs and motorcycles	Car: 84% SUV: 13% Motorcycle: 4%
Public transport wait time	The percentage of time walking/waiting time for public transport of total travel time by public	1%
Travel time per household	The amount of time spent travelling per household	330 Hours/year
Average speed for public transport	This is separated into road and rail public transport	BRT: 30 km/hour, Bus and MBT: 20 km/hour
Split between types of public transport	This is separate for road public transport and rail public transport and is applicable to MBT, bus and metro rail (in terms of p.km)	Time dependent

[8] Private vehicles include cars, SUVs and motorcycles
[9] Other private vehicles include government, rental and company vehicles
[10] Based on the actual 2014 split in the vehicle parc model – to be updated once the model has been updated.

Assumption/Input	Description	Key values
BRT/Gautrain percentage of travel time (with and without private vehicles)	The percentage travel time using BRT/Gautrain for people with and without private vehicles	Time dependent
Freight transport demand		
Freight elasticity	Sensitivity to change	0.8
Load factor	The freight load per vehicle	Varies depending on the vehicle type
Railways transport sector growth rate	The projected growth in rail transport	Calculated based on inputs from the SAM model, SACC 2050 and mining sector (including coal mining) growth rates.
Mining sector growth rate[11]	The projected growth in the mining sector (accounting for commodities that require bulk transport to reach export markets)	See the sections on coal mining and industry.
Common assumptions/inputs		
Road transport sector growth rate	The projected growth of road transport	Calculated based on inputs from the SAM model and economic growth across all sectors

Source: ERC demand model

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the sections that follow along with the most important assumptions that determine their impact on emissions outcomes. No new mitigation measures were identified. Note that the uptake in the WAM differs from that contained in the Green Transport Strategy, as this is modelled as a policy and measure (PAM) in the integrated model. The following mitigation measures are included:

- Improved efficiency – ICE
- Modal shift – freight and passenger transport
- Alternative fuels – HEV, PHEV, EV, FCEV and CNG
- Biofuels

[11] An average of the mining growth rates

Improved efficiency

There are two efficiency measures: Improved efficiency – Petrol internal combustion engine (ICE) and Improved efficiency – Diesel ICE, each with varying efficiencies and uptake depending on the vehicle type. Uptake decreases over time for conventional ICE as alternative vehicles powertrains (e.g. PHEV or HEV) uptake increases (Table 3.40).

Table 3.40: Maximum uptake of improved efficiency – ICE per vehicle type in 2050

Mitigation measures	WAM 2050
Improved efficiency – petrol ICE	
Car	5%
SUV	5%
Motorcycle	50%
MBT	25%
LCV	12%
Improved efficiency – diesel ICE	
Car	7.5%
SUV	7.5%
Bus/BRT	45%
MBT	20%
LCV	15%
HCV1	35%
HCV2 – HCV9	25%

Biofuels

Biofuels penetration for road transport is summarised in the table below. The Industrial Biofuels Strategy (2007) aims to achieve a 2% penetration level of biofuels, revised down from 4.5%. The proposed blending ratio for South Africa is 2% biodiesel or 8% bioethanol blend. Noting that not much has happened in terms of implementation the penetration rates have been moved out by a decade. Shading indicates changes to the mitigation measures.

Table 3.41: Penetration of biofuels in road transport sector by volume for WAM

Biofuels	2020	2030	2040	2050	Type of change
1G Biodiesel	0%	5%	9.5%	10%	Uptake delayed by 10 years

2G FT Biodiesel	0%	0	0%	0%	Uptake delayed by 10 years
1G Bioethanol	0%	5%	9.5%	10%	Uptake delayed by 10 years

Alternative fuels – HEV, PHEV and EV

Alternative fuels – HEV (hybrid electric vehicles) and PHEV (plug-in hybrid electric vehicles) apply to both petrol and diesel vehicles, with varying efficiencies and uptake depending on the vehicle type.

PHEV also use electricity, in addition to petrol and diesel as a fuel source. A utility factor (percentage of kilometres driven using electricity as a fuel source) of 59%, 36% and 54% is used for cars, SUVs and LCVs respectively to determine electricity use.

Alternative fuels – EV (electric vehicles), Alternative fuels – FCEV (fuel cell electric vehicles) and Alternative fuels – CNG (Compressed natural gas) have varying efficiencies and uptake depending on the vehicle type. EV use electricity as a fuel source. A utility factor of 100% is applied to all vehicles.

Table 3.42: Maximum uptake of alternative fuels in 2050 - per vehicle type

Mitigation measures	HEV petrol	HEV diesel	PHEV petrol	PHEV diesel	EV	FCEV	CNG
Car	12.5%	12.5%	10%	10%	38.6%	1%	3%
SUV	35%	15%	12.5%	7%	12.5%	0.5%	5%
MBT	15%	12%	12%	6%	10%	-	-
Bus/BRT	-	39%	-	-	10%	1%	5%
LCV	27.5%	15%	13.5%	7%	7.5%	0.5%	2%
HCV1	-	35%	-	15%	15%	-	-
HCV2-9	-	17.5%	-	15%	2.5%	-	40%
Motorcycle	-	-	-	-	48%	2%	-

Modal shift

There are two modal shift measures applied in the road transport model:

1 Shifting passengers from cars to public transport: The shift occurs between private vehicles (e.g. cars and SUVs) and public transport vehicles (e.g. buses, Metrorail)

2 Shifting freight from road to rail: The shift occurs between HVC1 and Rail Other and HCV2-HCV9 and Rail Corridor. The shift between LCV and Rail exports is 0%

For modal shift measures the SACC 2050 modal shift assumptions in 2050 were utilised for both freight and passenger transport. These are summarised in the table below. Historic modal split is used for 2000 to 2019, based on the vehicle parc model. Where these assumptions have changed in developing the NDC update, this work will align with updated assumption.

Table 3.43: WAM modal shift assumptions in 2050

Vehicle	WAM Vehicle type split
Passenger	
Car	36.5%
SUV	3.00%
Motorcycle	2.50%
Bus	8.00%
MBT	38.0%
BRT	4.00%
Metrorail	7.75%
Gautrain	0.25%
Freight Corridor	
Rail corridor	30.0%
Road corridor (HCV2 - 9)	70.0%
Freight Other	
Rail other	70.0%
HCV1	30.0%

Source: (DEA, 2014c)(DEA, 2014c)(DEA, 2014c)(DEA, 2014c)(DEA, 2014c)(DEA, 2014c)(DEA, 2014c)(DEA, 2014c)(DEA, 2014c)(DEA, 2014c)(DEA, 2014c)(DEA, 2014c)(DEA, 2014c)

3.3.3 1 A 3 c Railway transport

Fuel combustion emissions category	1.A.3.c. Rail transport

In terms of energy and emissions, the following updates were made to the sector:

- Because the influence of existing policies is limited, all projections are assumed to be the same. Freight historic fuel and electricity is sourced from the Transnet Integrated and Sustainability Reports (Transnet, 2018, 2021, 2022).
- For Passenger rail historic fuel and electricity use for 2010 is as per the MPA.
- For electricity, the electricity use is assumed to be the data from the Energy Balance (2000 to 2020) minus freight electricity demand. Fuel demand is assumed to grow at the same as rate as electricity demand.

Historically, the historic freight demand (in tonne.km) from 2000 to 2022 was determined using freight demand in 2006 and 2015. Additional data sourced from the Transport Starter Data Kit for South Africa and Logistic Barometer report provided more accurate and up-to-date data (Havenga et al., 2016; Tan et al., 2023). Assumptions and inputs related to projections and mitigation measures remain the unchanged.

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the table below along with the most important assumptions that determine their impact on emissions outcomes.

Table 3.44: Rail transport sector existing mitigation measures

Mitigation measures	Description
Energy efficiency	
Improved efficiency - EMUs	50% potential saving
Fuel saving	
Improved efficiency - Diesel	40% potential saving
Fuel switch	
Alternative fuels - Hybrid diesel	50% potential saving
Metrorail voltage upgrade	10% potential saving
Alternative fuels - CNG	
Biofuels	Displace rail diesel

Source: (DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)

The uptake of each mitigation measure within the fleet will vary depending on the scenario and the locomotive type. Scenario 2 is the same as Scenario 1 except Scenario 2 assumes a gradual uptake of diesel hybridisation. The uptake of Metrorail voltage upgrade, CNG and biofuels for the railways sector is provided in the table below.

Table 3.45: Maximum uptake of mitigation measures in railways sector

Mitigation measures	2010	2015	2020	2030	2040	2050
Fuel switch						
Metrorail voltage upgrade	0%	0%	0%	100%	100%	100%
Alternative fuels - CNG	0%	0%	0%	0%	0%	0%
Biofuels	0%	0%	0%	5%	9.5%	14.9%

Source: (DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)(DEA, 2014a)

3.3.1 Waterborne navigation

Fuel combustion emissions category	1.A.3.b Waterborne navigation

Activity data to 2022

Fuel use data for 2000 to 2022 period is sourced from the 2022 National GHG Inventory and is consistent across all scenarios.

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the table below along with the most important assumptions that determine their impact on emissions outcomes.

Table 3.46: Waterborne navigation production sector existing mitigation measures assumptions

Mitigation measures	Description
Fuel saving	
Propeller polishing	Applies to fuel use: 3.5% saving
Autopilot upgrade	Applies to fuel use: 1.8% saving
Water flow optimisation	Applies to fuel use: 2.5% saving
Water routing	Applies to fuel use: 2% saving
Propeller upgrade	Applies to fuel use: 7.8% saving
Hull cleaning	Applies to fuel use: 4% saving
Air lubrication	Applies to fuel use: 9.8% saving
Hull coating	Applies to fuel use: 2.8% saving
Wind power	Applies to fuel use: 9.4% saving
Water heat reduction	Applies to fuel use: 7% saving
Speed reduction – 10% speed reduction	Applies to fuel use: 12% saving

Mitigation measures	Description
Main engine retrofits	Applies to fuel use: 0.8% saving
Speed controlled pumps and fans	Applies to fuel use: 0.08% saving
High-efficiency lighting	Applies to fuel use: 0.5% saving
Solar panels	Applies to fuel use: 2% saving

Table 3.47: Maximum uptake of mitigation measures in waterborne navigation sector

Mitigation measures	2020 *	2030	2040	2050
Fuel saving				
Propeller polishing	0%	7%	15%	20%
Autopilot upgrade	0%	7%	15%	20%
Water flow optimisation	0%	7%	15%	20%
Water routing	0%	7%	15%	20%
Propeller upgrade	0%	2.6%	7.5%	10%
Hull cleaning	0%	7%	15%	20%
Air lubrication	0%	1%	5%	7.5%
Hull coating	0%	12%	20%	25%
Wind power	0%	2.6%	7.5%	10%
Water heat reduction	0%	2.6%	7.5%	10%
Speed reduction – 10% speed reduction	0%	12%	20%	25%
Main engine retrofits	0%	7%	15%	20%
Speed controlled pumps and fans	0%	7%	15%	20%
High-efficiency lighting	0%	2.6%	7.5%	10%
Solar panels	0%	2.6%	7.5%	10%

*Uptake starts in 2022

3.4 Other sectors

3.4.1 Commercial/institutional

Fuel combustion emissions category	1.A.4.a. Commercial/institutional

Key data sources and assumptions

The key parameters used in the estimates of emissions projections from commercial buildings have been updated to the most recent data available and includes the following:

Table 3.48: Key data and parameters used in projecting emissions from commercial buildings

Key data	Source of data
Total building stock	SACC 2050 (DFFE, 2014) and Building Statistics 2014 to 2020 (Statistics South Africa, 2020b)
Split of floor area	ERC, 2018 (technical appendices) (DEA, 2018)
Historic fuel use (per fuel type)	National GHG Inventory 2000 to 2022
Historic electricity use	Energy Balance 2000 to 2020

Stock of existing buildings to 2050 is projected and disaggregated into retired, new, and existing buildings based on the building stock growth rate and retirement rate.

Activity data to 2022

Historic energy and emissions data for the sector has been updated with data from the most recent GHG Inventory (2000 to 2022). Electricity use is based on the Energy Balance to 2020 and projected to 2022 based on total building stock growth.

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the table below along with the most important assumptions that determine their impact on emissions outcomes. No changes were made to the mitigation measures.

Table 3.49: Commercial/institutional sector existing mitigation measures

Mitigation measures	Description
Energy efficiency	
Solar water heating	Applies to fuel and electricity use: 2% and 0.2% saving each
Efficient lighting	Applies to electricity use: 18% saving
Heat pumps – existing buildings	Applies to electricity use: 5% saving
Heat pumps – new buildings	Applies to electricity use: 6% saving
HVAC: with heat recovery – New buildings	Applies to electricity and fuel use: 10% and 16% saving each

HVAC: Variable speed drives – Existing buildings	Applies to electricity use: 12% saving
HVAC: Variable speed drives - New buildings	Applies to electricity use: 15% saving
HVAC: Central air conditioners – New buildings	Applies to electricity use: 4% saving
Energy efficient appliances	Applies to electricity use: 4% saving
Passive building/improved thermal design – New buildings	Applies to electricity and fuel use: 29% and 45% saving each

Source: (DEA, 2014a)

Table 3.50: Maximum uptake of mitigation measures in commercial/institutional sector

Mitigation measures	2010	2015	2020	2030	2040	2050
Energy efficiency						
Solar water heating	0%	0%	0%	0%	0%	0%
Efficient lighting	0%	15%	25%	37.5%	50%	75%
Heat pumps – existing buildings	0%	15%	25%	37.5%	50%	75%
Heat pumps – new buildings	0%	15%	25%	37.5%	50%	75%
HVAC: with heat recovery – New buildings	0%	7.5%	15%	25%	37.5%	50%
HVAC: Variable speed drives – Existing buildings	0%	7.5%	15%	25%	37.5%	50%
HVAC: Variable speed drives - New buildings	0%	7.5%	15%	25%	37.5%	50%
HVAC: Central air conditioners – New buildings	0%	7.5%	15%	25%	37.5%	50%
Energy efficient appliances	0%	7.5%	15%	25%	37.5%	50%
Passive building/improved thermal design – New buildings	0%	7.5%	15%	25%	37.5%	50%

Source: (DEA, 2014a) and input from TWG in 2018

3.4.2 Residential sector

Fuel combustion emissions category	1.A.4.b. Residential

Key data sources and assumptions

The following key parameters and data sources underpin the residential sector model:

Table 3.51: Key data and parameters used in projecting emissions from households

Residential	Data Source
Household electrification to 2050	South Africa 2050 calculator (DEA, 2014c)
Useful energy demand	South Africa 2050 calculator (DEA, 2014c) and 2022 GHG Inventory
Efficiency per fuel type and end-use	SATIMES model UCT study (Hughes and Larmour, 2021)
Proportion of fuel use per household and end-use	SATIMES model UCT study (Hughes and Larmour, 2021)
Household elasticities	South Africa 2050 calculator (DEA, 2014c)
Average income growth	South Africa 2050 calculator (DEA, 2014c)
Proportion of electricity use per household and end-use	South Africa 2050 calculator (DEA, 2014c)
Electricity efficiency per end-use	South Africa 2050 calculator, SATIMES model
Fuel and electricity technology shares in 2015	General Household Survey (StatsSA, 2018)
End-use electricity and fuel use	South Africa 2050 calculator (DEA, 2014c) UCT study (Hughes and Larmour, 2021)
Base year technology shares	South Africa 2050 calculator (DEA, 2014c) UCT study (Hughes and Larmour, 2021)

The technology shares in 2022 for each energy-use were adjusted to align with the 2022 GHG Inventory fuel use for the residential sector.

Projections to 2050

Population, coupled with household size and income split, income growth and GDP growth are key assumptions used to project the number of households per income level. This is a key variable in determining fuel and electricity use in the sector. In 2050, 55% of households are projected to be low income, decreasing by only 5% from a 60% share in 2019.

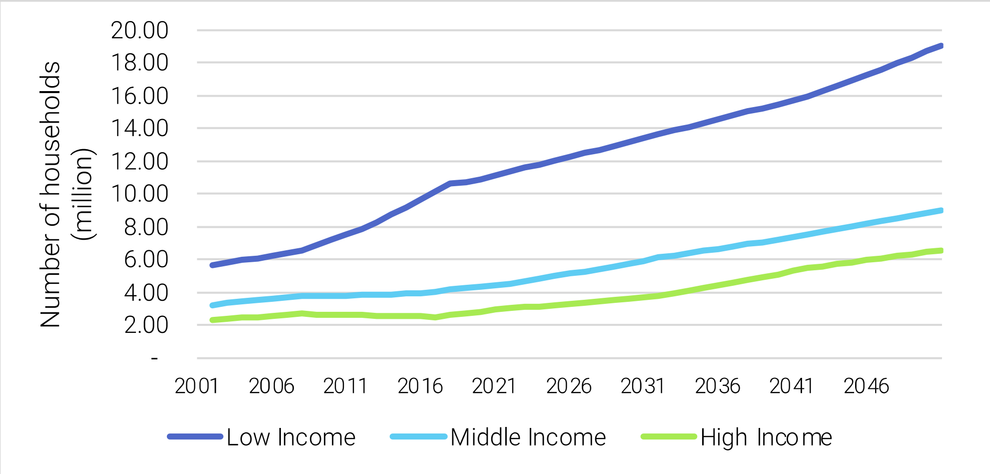


Figure 1: Number of households per income level (based on UNDP High population growth)

Household electrification is from the SACC 2050 and assumes 100% electrification in high income households. Over time, low income and middle-income households become increasingly electrified.

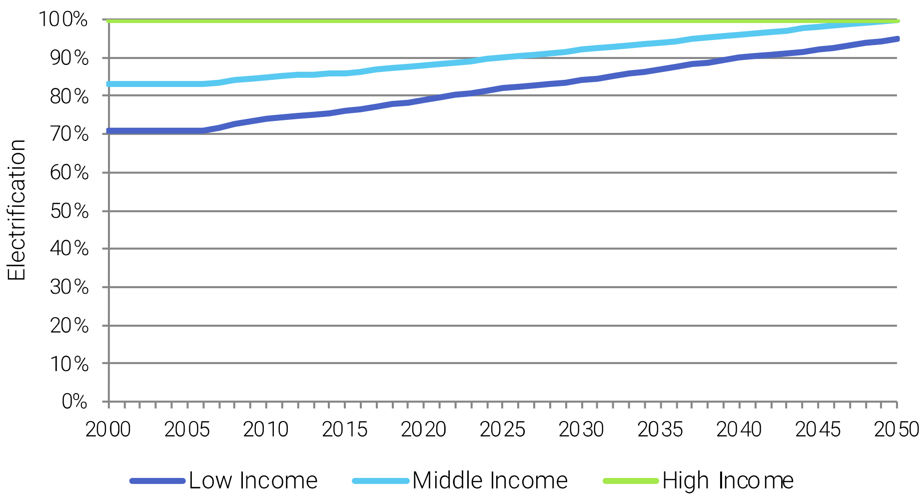


Figure 2: Electrification to 2050 per income level

Mitigation measures

The mitigation measures that are included in the Integrated Model are listed in the table below along with the most important assumptions that determine their impact on emissions outcomes. No new mitigation measures were identified.

Table 3.52: Residential sector existing mitigation measures

Mitigation measures	Description
Energy efficiency	

Energy efficient appliances	Applies to electricity use.
Energy efficient lighting (LED)	Applies to electricity use.
Solar water heating including low pressure solar water heating	Applies to electricity and fuel use.
Energy efficient refrigeration	Applies to electricity use.
Fuel switch	
LPG for cooking	Applies to electricity and fuel use.
LPG for space heating	Applies to electricity and fuel use.

Source: Based on data from (StatsSA, 2018) and (DEA, 2014c)

3.4.3 Agriculture, forestry, fishing and fish farms

Fuel combustion emissions category	1.A.4.c. Agriculture, forestry, fish and fish farm

Activity data to 2022

Historic fuel use for the sector from 2000 to 2022 is taken from the 2022 GHG Inventory. Electricity use data is from the Energy Balance for 2000 to 2020 and extrapolated to 2022 using the sectors growth rate. For electricity and fuel use is assumed to be the same for all projections.

Mitigation measures

The mitigation measures that are included in the Integrated model are listed in the table below along with the most important assumptions that determine their impact on emissions outcomes.

Table 3.53: Agriculture, forestry, fishing and fish farm sector existing mitigation measures

Mitigation measures	Description
Energy efficiency	
Energy monitoring and management system	Applies to fuel and electricity: 1% saving
Improved electric motor system controls and VSDs	Applies to electricity: 1.4% saving
Energy efficient lighting	Applies to electricity: 0.5% saving
Energy efficient irrigation system	Applies to fuel and electricity: 1% and 3% saving respectively
Energy efficient water heating	Applies to electricity: 2% saving
Energy efficient vehicles and tractors	Applies to fuel: 10% fuel saving

Source: (DEA, 2014a)

Table 3.54: Maximum uptake of mitigation measures in Agriculture, forestry, fishing and fish farm sector

Mitigation measures	2020	2030	2040	2050
Energy efficiency				
Energy monitoring and management system	40%	60%	80%	80%
Improved electric motor system controls and VSDs	40%	60%	80%	80%
Energy efficient lighting	40%	60%	80%	80%
Energy efficient irrigation system	40%	60%	80%	80%
Energy efficient water heating	40%	60%	80%	80%
Energy efficient vehicles and tractors	10%	30%	50%	70%

Source: (DEA, 2014a, adjusted for assumed uptake in 2020

3.1 Waste

3.1.1 Managed Waste Disposal

Emissions category	4.A.1. Managed waste disposal sites

Activity data to 2022

The activity data and calculations used to calculate the emissions in the Managed Waste Disposal sector are aligned with the 2022 GHG Inventory, with key assumptions and inputs used to determine the waste generation profile and associated methane emissions summarised in the table below.

Table 3.55: Waste assumptions and inputs

Description	Assumption	Source
Domestic waste generation per capita	398 kg/capita/annum	2022 National GHG Inventory
Percent of waste to solid waste disposal sites	76%	2022 National GHG Inventory
Waste Composition %	26% food waste, 17% garden waste, 18% paper, 2% wood, 36% plastics, other inert and 2% nappies	2022 National GHG Inventory
Fraction of population burning waste (Pfrac)	0.09	2022 GHG Inventory
Degradable organic carbon fraction of MSW	Food and garden waste: 0.15	2022 GHG Inventory

	Paper: 0.05 Wood: 0.43 Textiles and nappies: 0.24 Plastic, other inert: 0 Industrial: 0.1	
Methane recovery	10 kt (2000 to 2017), 18.04 kt from 2008 to 2050	MPA
Fraction of methane in gas	0.5	2022 GHG Inventory
Methane generation constant	Food waste: 0.06 Garden waste: 0.09 Paper and textiles: 0.04 Wood: 0.02 Nappies and industrial: 0.05 Plastics, other inert: 0	2022 GHG Inventory
Methane correction factor (managed)	1	2022 GHG Inventory
Waste generation rate for industry	0.4 (Gg/$mGDP/year)	2022 GHG Inventory

Projections to 2050

Based on the assumptions above, domestic and industrial waste projections will be directly proportional to population and GDP growth respectively.

Mitigation measures

The mitigation measures that are included for the waste sector are listed in the tables below along with the most important assumptions that determine their impact on emissions outcomes. No new mitigation measures were identified.

Table 3.56: Managed waste disposal sites existing mitigation measures

Mitigation measures	Description
Electricity generation	
LFG recovery and generation	Applicability of LFG recovery is 30% in 2020, 50% in 2030 and 80% in 2050. Reduction in methane is 70%. Efficiency is 30%. NCV of waste is 9 GJ/tonne.
GHG abatement	
LFG recovery and flaring	Applicability of LFG recovery is 30% in 2020, 30% in 2030 and 20% in 2050. Reduction in methane is 30%. Capacity: 4 million tonnes/annum
Recycling	
Paper recycling	Plant capacity: 170,000 tonnes/annum

Mitigation measures	Description
Compost	
Home composting	Homes with gardens: 50%, Composting rates are 0.5 kg and 0.75 kg of waste for food and garden waste respectively.
Windrow composting	Capacity: 20,000 tonnes/annum. 50% of garden waste goes to windrow composting
In-vessel composting	Capacity: 30,000 tonnes/annum

Source: (DEA, 2014a)

Table 3.57: Maximum uptake of mitigation measures for managed waste disposal site

Mitigation measures	2020	2030	2040	2050
Electricity generation				
LFG recovery and generation	Not modelled as uptake			
GHG abatement				
LFG recovery and flaring	Not modelled as uptake			
Recycling				
Paper recycling – paper recycling rate	20%	50%	50%	50%
Compost				
Home composting – number of hh composting	10%	15%	20%	25%
Windrow composting	Not modelled as uptake			
In-vessel composting	Not modelled as uptake			

3.1.2 Biological Treatment of Solid waste

Emissions category	4.B Biological Treatment of Solid Waste

Activity data to 2022

Activity data from 2000 to 2022 for the biological treatment of solid waste by composting and anaerobic digestion at biogas facilities is sourced from the 2022 National GHG Inventory. The emissions are calculated using the 2006 IPCC default methane and nitrous oxide emission factors, the mass of waste estimated to be treated by composting or anaerobic digestions.

Projections to 2050

The projections to 2050 grow at the same rate as the projected GDP growth rate.

Mitigation measures

No mitigation measures are currently included in this sector.

3.1.3 Open Burning of Waste

Emissions category	4.C.2 Incineration and Open Burning of Waste

Activity data to 2022

The activity data for 2000 to 2022 are aligned with the 2022 National GHG Inventory. The fraction of the population assumed to be carrying out open burning of waste is 9%. The emissions are calculated using the IPCC default factors.

Projections to 2050

The projections to 2050 are currently assumed to grow with population.

Mitigation measures

No mitigation measures are currently included in this sector.

3.1.4 Domestic Wastewater

Emissions category	4.D.1. Domestic wastewater

Activity data to 2022

Population, disaggregated into rural and urban, income level split and a variety of waste assumptions to determine the methane and nitrous oxide emissions from domestic wastewater.

Table 3.58: Domestic wastewater assumptions and inputs

Description	Assumption	Source
Protein consumption	27.96 kg/person/year	IPCC default value
Biodegradable organic component (BOD)	13.505 kg BOD / cap/ year	2022 National GHG Inventory
Fraction of nitrogen in protein	0.16 Kg N/kg protein	FAO
Emission factor per disposal method	Varies based on type of disposal method and split between rural and urban and income levels	2022 National GHG Inventory

Degree of utilisation	Varies based on type of disposal method and split between rural and urban and income levels	2022 National GHG Inventory
Sewage disposal method	Varies based on time, type of disposal method and split between rural and urban and income levels	2022 National GHG Inventory

Projections to 2050

Domestic wastewater projections are influenced by population projections, income split and the split between rural and urban populations. Although the income split and rural/urban split are assumed to change over, for the waste sector these remain constant to align with the 2022 National GHG Inventory.

Mitigation measures

One mitigation measure has been included, being methane capture at wastewater treatment plants, based on a CSIR study commissioned by DFFE in 2014 (CSIR, 2014).

Information on the potential for methane capture at wastewater treatment plants is available for six metros: Johannesburg, Cape Town, eThekwini, Ekurhuleni, Tshwane and Nelson Mandela Metropolitan. Based on the analysis, a total of about 97,951 tonnes CH_4 per year can be captured with the existing infrastructure (CSIR, 2014.

3.1.5 Industrial Wastewater

Emissions category	4.D.2 Industrial Wastewater Treatment and Discharge

Activity data to 2022

The emissions data from 2000 to 2022 is from the 2022 National Greenhouse Gas Inventory. Emissions are estimated by taking into consideration the chemical oxygen demand of each activity, the maximum methane producing capacity per activity, the methane correction factor of each treatment system used and methane emission factors.

Projections to 2050

Industrial wastewater projections are influenced by GDP growth.

Mitigation measures

No mitigation measures were identified for this sector.

3.2 AFOLU

3 A Livestock	3 A 1 Enteric fermentation 3 A 3 Manure management
3 B Land	3 B 1 Forest land *3* B 2 Cropland 3 B 3 Grassland 3 B 4 Wetlands 3 B 5 Settlements 3 B 6 Other land
3 C Aggregated sources and non-CO_2 emission sources on land	3 C 1 Emissions burning 3 C 2 Liming 3 C 3 Urea application 3 C 4 Direct N_2O emissions from managed soils 3 C 5 Indirect N_2O emission s from managed soils 3 C 6 Indirect N_2O emissions from manure management

Projections to 2050

The agriculture, forestry and other land use sector (AFOLU) involves the production of livestock, cultivation of crops, forestry and other land use. The AFOLU sector differs from other sectors as it acts as both a source and sink of GHG emissions.

The 2022 National Greenhouse Gas Inventory is used to determine production of livestock and emissions. Land emissions and emissions from other sources are calculated using spatial extent of each land use type per province and a number of assumptions and emissions factors. Spatial extent (in hectares) of each land use type and the change over time are calculated using the land cover matrix and the fraction of land converted to other land (e.g. forest land convert to cropland or cropland remaining cropland). Livestock and manure management emissions are calculated using livestock population per livestock type (disaggregated by herd composition) and the relevant emission factors and assumptions e.g. fraction of nitrogen excretion. Emission factors and other assumptions used are predominantly from the GHG Inventory or other South African sources

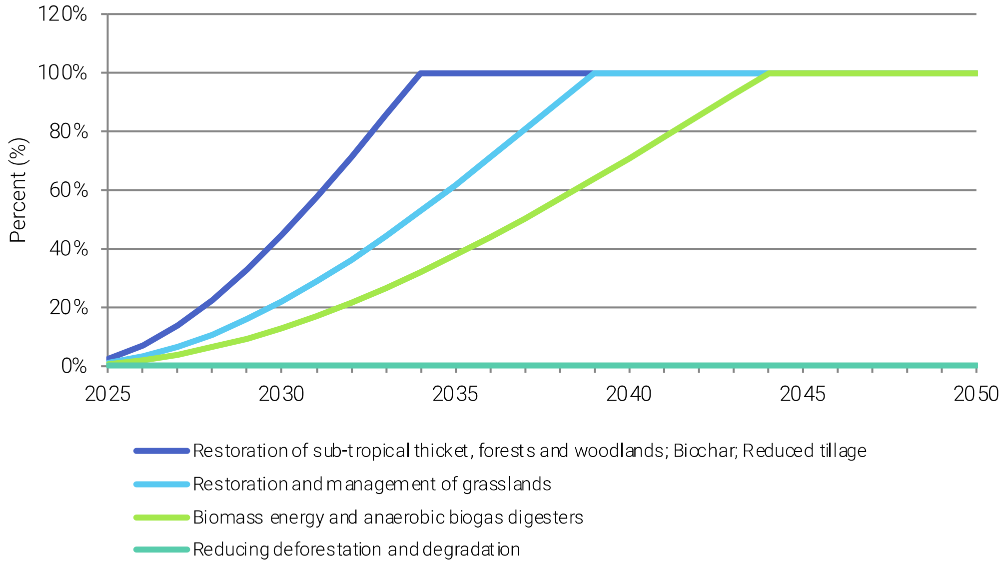
Mitigation measures

The mitigation measures and assumptions are based on the Carbon Sinks Assessment and Barriers and Opportunities Study. An additional measure is included from the literature: Utilizing activated carbon in livestock feed to reduce GHG emissions associated with enteric fermentation (shaded in the table below).

Table 3.59: AFOLU sector mitigation measures

Mitigation measure	Description
Restoration of: Sub-tropical thickets Coastal and scarp forests Broadleaf woodland	 Reduction: 1.2 tC/h, Spatial extent: 500,000 ha, Penetration:10% Reduction: 1.8 tC/ha, Spatial extent: 8750 ha Reduction: 1.1 tC/ha, Spatial extent: 300,000 ha
Restoration: Erosion Mesic Erosion Dry Grassland Mesic Avoided degradation mesic	 Reduction: 0.7 tC/ha, Spatial extent: 270,000 ha Reduction: 0.5 tC/ha, Spatial extent: 320,000 ha Reduction: 0.5 tC/ha, Spatial extent: 600,000 ha Reduction: 1.0 tC/ha, Spatial extent: 15,000 ha
Commercial small-growers afforestation: Eastern Cape KwaZulu Natal	Reduction: 1.5 tC/ha Area suitable: 60,000 ha Area suitable: 40,000 ha
Biomass energy (IAPs and bush encroachment)	Capacity: 360 MW, load factor: 75%
Biomass energy (biogasse)	Capacity: 52.5 MW, load factor: 85%
Anaerobic biogas digesters	Capacity: 800 MW, load factor: 75% Manure production (t/head) by feedlots (5.5), in-field (1.8), dairy (12.78) and subsistence cattle (1.8) Biogas production: cows (40 Nm3/tonnes), piggeries (45.6 Nm3/head) and poultry (2.6 Nm3/head).
Biochar	Reduction: 0.25 tC/ha, Spatial extent: 700,000 ha Penetration: 5% Mitigation potential: 5%
Reduced tillage	Reduction: 0.1 tC/ha, Spatial extent: 2, 878, 960 ha Penetration: 20% Mitigation potential: 25%
Reducing deforestation and degradation	This is achieved through planning and regulation. Spatial extent is currently unknown
Restoration of agricultural land	Reduction: 1 tC/ha
Commercial forestation	Reduction: 1.5 tC/ha
Livestock feed additive	30% reduction in emissions is assumed with application of activated char at 0.5% of dry matter

It will take a number of years before the mitigation measures reach full scale implementation. To account for this, the scale of implementation is gradually increased over a 'ramp-up' or 'roll-out' period until full potential is reached. The commercial small grower plantations are likely to be pulp wood Eucalyptus that would be harvested at Year 8. This mitigation measure is modelled as an 8-year cycle - growth for 8 years (ramp up period is 5 years), back to zero and the cycle is repeated. Commercial small-growers afforestation is affected by the Draft Climate Change Sector Plan and restoration of agricultural land and commercial forestation are affected by the DAFF Strategic Plan. Commercial small-growers afforestation in the WAM is shown in Figure 3. The restoration of agricultural land has the same ramp up as the restoration and management of grasslands (Figure 3).



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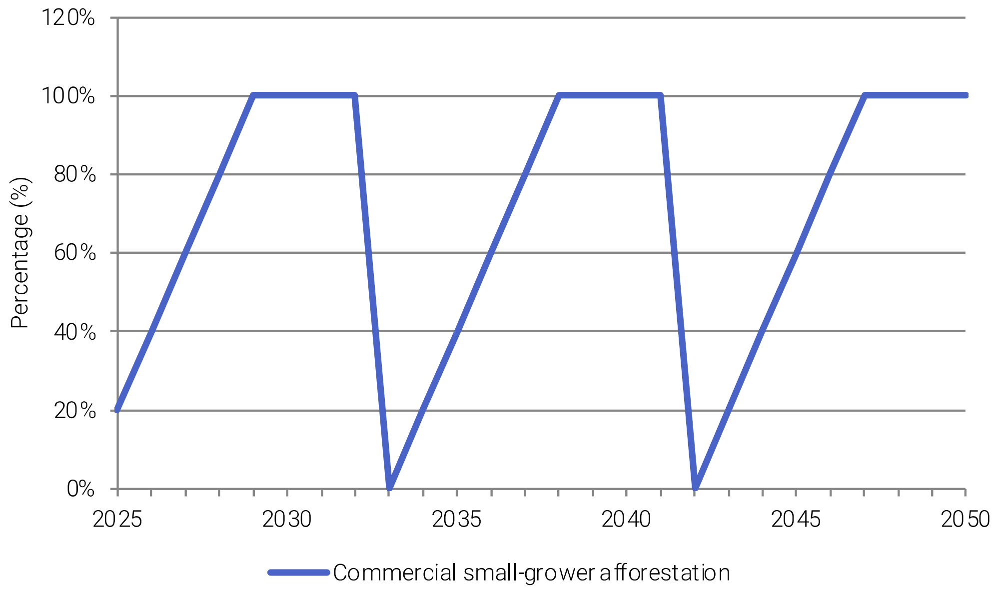

Figure 3: WAM ramp up of AFOLU mitigation measures over time

4 POLICIES AND MEASURES

The section that follows provides details on how the policies and measures (PAMs) are modelled in the Integrated Model.

4.1 Overarching PAMs

There is only one overarching PAM: the carbon tax. It applies to several sectors, across line departments, and potentially impacts fuel, fugitive and process emissions as well as electricity demand.

4.1.1 Carbon tax

The Carbon Tax is included in the Integrated model as it is described in the Carbon Tax Act of 2019. The following elements of the carbon tax are included in the model.

Table 4.1: Carbon Tax elements included in the integrated model

Carbon tax element	Description
Carbon tax rate (2023)	The carbon tax rate is R 159 per tonne of CO_2eq. The carbon tax rate will have larger annual increases to reach at least $30 by 2030 (as stated in the 2022 Budget Speech). Under the Implementation not achieved and Ambitious implementation scenario the carbon tax rate in 2023 is R 79,50 and R 190,80 per tonne of CO_2eq.
Increase in the carbon tax rate	The carbon tax rate will have larger annual increases to reach at least $30 by 2030 (as stated in the 2022 Budget Speech)
Allowances	The calculation of carbon tax includes a number of allowances: • Basic tax-free allowance • Fugitive emissions allowance • Trade allowance • Performance allowance • Carbon budget allowance • Offsets allowance These allowances differ per sector/activity. In addition, the performance, carbon budget and offsets allowance may differ for companies within sectors. For each sector these allowances are estimated for each carbon tax phase. In the case of the performance and offsets allowance, experts were asked to provide estimates of these for each sector and each phase. For example, in the initial carbon tax phases offsets are likely to be in short supply as there will be demand from all sectors and so the allowance was ramped up over time to show this. Similarly, the carbon

Carbon tax element	Description
	budget allowance was only allocated to those sectors who participated in the voluntary stage of carbon budgets. This allowance was the only one to fall away after 2022. The Carbon Tax Bill does not specify if or how these allowances will decrease in subsequent phases and therefore they are assumed to remain in place for the entire modelling period. This assumption is conservative as it is likely that these allowances will fall away. However, as the timing and rate of removal is not known it cannot be modelled at this stage.
Thresholds	The carbon tax only applies to companies that exceed thresholds for reporting. It was necessary to assume the proportion of emissions in each sector/activity that would arise from companies that are above the threshold and therefore liable for the carbon tax.
Carbon tax fuel levy	A carbon tax on fuel of 10c/l on petrol and 11c/l on diesel was introduced on 5 April 2023
Carbon tax electricity levy	The carbon tax will impact on electricity prices post 2022. The carbon tax electricity levy has been included as 1c/kWh after 2022.

The impact of the carbon tax on the uptake on mitigation in the integrated greenhouse gas model is determined as follows:

- For each emissions category, the fraction of emissions that will be above the reporting threshold is assumed. For IPPU emissions, the threshold is 100%, but for energy-related emissions the threshold is such that not all companies will need to report.
- For each sector, the contribution of each emission type (fuel, fugitive, process) to overall emissions is calculated for each year for the WEM projection. This is done to provide an estimate of the overall emissions per sector that will be above threshold remembering that the integrated model currently models the sector as a whole rather than modelling at the facility/company level. It is also used to calculate the allowances per sector by weighting the allowances according to the emissions in each activity. This provides an effective carbon tax rate for each sector.
- The effective carbon tax rate for each sector is then compared to the marginal abatement cost for mitigation measures in the sector. Only mitigation measures that reduce fuel use or direct emissions are included. Electricity efficiency measures are excluded as indirect emissions are not taxed and even though mitigation might save costs, the carbon tax liability would be unchanged.
- If the carbon tax rate is greater than the marginal abatement cost it is assumed that the companies who are above threshold, will implement the mitigation measure. The uptake of mitigation measures of the remaining companies in the sector will remain as per the

WEM. To account for the fact that there is not an instantaneous or perfect response to price signals an implementation threshold is introduced and set at 15%. This means that the effective carbon tax rate must be 15% higher than the marginal abatement cost, before uptake is triggered in the model.

- As mitigation is modelled differently in the electricity sector, the impact of the carbon tax is included by adding it onto the cost of fossil fuel. Here the effective carbon tax rate is converted into a Rands per tonne of fuel using the appropriate emission factor.

4.2 DMRE

Policies and measures included under the DMRE are the IRP 2023, Post-2015 NEES, Solar Water Heater (SWH) programme and the Electrification programme.

4.2.1 Electricity sector PAMs (updated IRP 2023)

The IRP 2023 build plan to 2030 (Horizon 1) is included in the Integrated model (Table 4.2), with costs and technology parameters and the retirement plan updated where relevant (DMRE, 2023). From 2030 to 2050 (Horizon 2), there are six potential scenarios provided in the IRP 2023:

- Reference
- Renewable energy
- Renewable energy and nuclear
- Delayed shutdown
- Delayed shutdown and repowering
- Renewable energy and clean coal

The user is able to select which scenario to apply for Horizon 2.

Table 4.2: IRP 2023 build plan to 2030 [MW]

Year	Coal	Gas[12]	Dispatchable capacity	CSP	Solar PV	Wind	Hybrid[13]	Distributed generation	BESS[14]
2024	Medupi and Kusile			100	1018		150	900	199
2025		1,220			4133	1738	476	900	654
2026					1045	275		900	
2027		1,000				684		900	2,615
2028		4,000			500			900	615

[12] IPP Programme and Eskom
[13] IPP Programme
[14] IPP Programme and Eskom

2029					500	1,500		900	
2030		1,000	1,376		500	1,500		900	

The following assumptions have been made to include the IRP 2023 Horizon 1 build plan in the integrated model:

- Coal: This refers to the commissioning of the final units of Medupi and Kusile. In the integrated model this is based on the latest schedule provided by Eskom, with Kusile Units 4 and 5 reaching commercial operation in 2024 and 2025 and Unit 4 of Medupi returning to operation in 2024 (Eskom, 2023)
- Gas is assumed to be a split between Gas CCGT and Gas OCGT.
- Dispatchable capacity can be coal FBC, gas CCGT or imports. It is assumed to be gas CCGT, due to the lead times associated with new coal builds.
- Hybrid IPP Programme is assumed to be split between solar PV, wind and BESS.
- Distributed generation is assumed to be rooftop PV in the residential and commercial sector.

Since the build plan to 2050 is determined by the IRP 2023 only the generation is optimized, based on least-cost.

4.2.2 Draft Post-2015 NEES

The approach to modelling the NEES is to adjust the uptake of mitigation measures to reflect the particular outcome expressed in the NEES (targets shown in Table 4.3).

The first step was to separate out the energy efficiency mitigation measures as the NEES targets would be achieved through the increased uptake of these measures. The next step was to see if the Maximum uptake achieved the NEES target or not. If the Maximum uptake achieves or exceeds the NEES target, then the Maximum uptake is assumed for the sector for the PAMs scenario. However, if the Maximum uptake does not achieve the NEES target, then the uptake of the energy efficiency mitigation measures is adjusted to ensure that the Post-2015 NEES target is met. This is done by increasing the rate of uptake (e.g. the rate of uptake in 2040 is moved up to 2030). For manufacturing sectors, the targets are only achieved if that uptake is set at 100% for all applicable measures. For residential, the uptake of mitigation measures had to be accelerated relative to the WAM. For commercial buildings even with 100% uptake of energy efficiency mitigation measures the target is not achieved. The uptakes are decreased and increased for the implementation not achieved and ambitious implementation scenarios respectively.

In the Integrated Model the targets related to transport, electricity (co-generation) and municipal services and fleet are excluded[15]. In the case of transport, it is assumed that the Transport PAMs takes preference (Section 4.3.1). Targets related to municipal services are not included to a lack of available data. The cogeneration target for the electricity sector is excluded because the build plan is determined by the 2023 IRP.

Table 4.3: Draft post-2015 NEES targets

Sector	Target (relative to 2015 baseline)
Manufacturing	16% reduction in the weighted mean specific energy consumption of manufacturing by 2030
Mining	Total energy saving of 40 PJ by 2030 (includes mining and quarrying as well as coal mining)
Agriculture	Total electricity saving of 1 PJ
Commercial	37% reduction in specific energy consumption (GJ/m^2) by 2030 50% reduction in specific energy consumption (GJ/m^2) by 2030 for public buildings
Residential	33% reduction in the average specific energy consumption of new household appliances by 2030 20% improvement in average energy performance of the residential building stock by 2030
Electricity sector	Less than 8% distribution losses by 2030 Less than 0.5% non-technical losses by 2030 10 PJ of electricity derived from grid-connected cogeneration plant by 2030
Municipal services	20% reduction in the energy intensity (measured as energy consumption per capita of population served) of municipal service provision, by 2030. The specific services included are street lighting, traffic lights, water supply and wastewater treatment. 30% reduction in the fossil fuel intensity of municipality vehicle fleets (measured as total fossil fuel consumption by municipal vehicles per capita of population served), by 2030.
Transport	20% reduction target in the average vehicle energy intensity (measured in MJ/km) of the South African road vehicle fleet, by 2030

4.2.3 SWH Programme

Solar water heaters (SWH) are already included in the residential sector as a technology option. The first step is to check the WAM scenario to see if the WAM achieved the target (Table 4.4). If the target is achieved under the WAM then the uptake for the PAMs scenario is set at the Maximum

[15] This was agreed by DFFE during the PAMs study in 2018/2019

uptake. Alternatively, if the Maximum uptake does not achieve the 2030 target, the PAMs uptake will be adjusted in order to achieve the target.

Table 4.4: Number of households with SWHs by 2030 per implementation scenario[16]

	Implemented as is	Implementation not achieved	Implementation with increased ambition
No. of households with SWH	3 500 000	3 000 000	5 000 000

4.2.4 *Electrification programme*

The residential sector includes modelling for household electrification for all projections. In order to meet the targets outlined in Table 4.5, additional electrification scenarios are included for the Electrification programme. It is assumed that non-grid connections are as a result of the installation of solar PV. The residential sector includes solar PV as a mitigation measure and for the PAMs, the percentage of households with solar PV is adjusted in order to meet the targets.

Table 4.5: Electrification programme targets per implementation scenario[17]

	Implemented as is	Implementation not achieved	Implementation with increased ambition
Grid	90%	90%	90%
Non-grid Solar PV	5%	3%	6%
Total	95%	93%	96%

4.3 DoT

4.3.1 *Transport PAMs*

The mitigation measures applicable to the Transport PAMs are already modelled in the Integrated model. The targets outlined in the Transport PAMs were modelled similarly to the NEES targets. Firstly, the PAM uptake was set to the Maximum uptake, and the results compared to the targets. Given the 2030 timeframe of the Transport PAMs targets in most cases the Maximum uptake was insufficient to meet the target. In these cases, the uptake was adjusted upwards to meet the target.

[16] Note: The NDP aims for 5 million SWH by 2030, however the target for the Implemented as is scenario was adjusted lower based on input from DFFE in November 2023.
[17] Based on input from DFFE non-grid is lowered from 7% to 5%.

The targets are summarized in the table below.

Table 4.6: Transport PAMs targets by 2030

Type	Measure	Implemented as is	Implementation no achieved	Ambitious implementation
Modal shift	Freight transport: Shift from road to rail Passenger transport: Shift from road to rail	10% 2%	5% 1%	20% 3%
Alternative fuels[18]	No. of EV No. of HEV No. of PHEV	5% 5% 8%	4% 4% 6%	6% 6% 10%
Non-motorised transport	% of non-motorised transport (for the 3 largest metros)	2%	1.5%	2.5%

4.4 DTIC

The Hydrogen Commercialisation Strategy and the Kigali Amendment fall under the Department of Trade, Industry and Competition.

4.4.1 Hydrogen Commercialisation Strategy

The Hydrogen Commercialisation Strategy consists of a hydrogen production target (Table 4.7) and fuel switch targets for the mining (I-MQ: Use of hydrogen power vehicles for transport and handling equipment) and transport sector (T-R: Alternative fuels – FCEV) (Table 4.8).

Hydrogen production falls under the Chemicals sector and for the Hydrogen Commercialisation Strategy PAM the growth rate is adjusted to ensure the production targets, shown in Table 4.7, are met. In addition, it is assumed that production shifts from grey hydrogen to green hydrogen over the modelling period, with green hydrogen accounting for 75% of hydrogen production by 2050.

Table 4.7: Hydrogen production per implementation scenario

	2027	2040	2050
Hydrogen production [mtpa]			
Implemented as is	2.70	3.7	7.0

[18] Of total vehicle parc

Implementation not achieved	1.35	1.90	3.5
Ambitious implementation	2.97	4.18	7.7

In the mining and quarrying sector and road transport sector, the uptakes for I-MQ: Use of hydrogen power vehicles for transport and handling equipment and T-R: Alternative fuels – FCEV are adjusted to meet hydrogen demand outlined in Table 4.8.

Table 4.8: Fuel switch targets – Hydrogen demand (ktonne)[19]

Sectors	Implemented as is	Implementation not achieved	Ambitious implementation
Mining	16	12	20
Transport	50	23	60

4.4.2 Kigali Amendment

The Kigali Amendment to the Montreal Protocol is an international, legally binding agreement to gradually reduce the consumption and production of hydrofluorocarbons (HFCs). South Africa ratified the Kigali Amendment in 2019 and as a Group II party it is committed to peak HFC consumption by 2024 with a phase schedule shown in Table 4.9 (Implemented as is). In the Integrated Model, the implementation of the Kigali Amendment will reduce emissions from HFCs in the 2 F Substitutes for ODS sub-sector.

Table 4.9: HFC phase down per implementation scenario

	Implemented as is	Implementation not achieved	Implementation with increased ambition
2024 - 2028	100%	100%	100%
2029 - 2034	90%	95%	86%
2035 - 2039	70%	74%	67%
2040 - 2044	50%	53%	48%
2045 onwards	20%	21%	19%

[19] Mining: 15 – 17 kt and Transport 39 – 70 kt

4.5 DALRRD

4.5.1 Agriculture PAMs

There are four mitigation measures that fall under Agriculture PAMs:

- Conservation agriculture;
- Feed changes;
- Inorganic fertilizer application;
- N inhibitors – livestock.

Conservation agriculture is already included in the Integrated model as a mitigation measure in the MPA and GHG Pathways sub-models. Conservation agriculture includes 1) zero tillage 2) maintenance of cover crops 3) diversity of crops 4) conservation. If one implements all four maximum potential is applicable. However, 25% is considered more realistic. For this measure the ramp up for PAMs is assumed to be the same as the WAM.

Table 4.10: Conservation agriculture assumptions

Assumption	Unit		Reference
Penetration/uptake rate	%	Implemented as is: 20% Implementation not achieved: 15% Implementation with increased ambition: 25%	SA Carbon Sinks Assessment
Cropland	Million hectares	2020: 13.87 2050: 13.47	Agriculture Baseline Study (used in the 2010 GHG Inventory)
Reduction C per unit area	Tonne C	0.1	Sector expert
Mitigation potential	%	25%	Sector expert
Ramp up	%	100% by 2037	Sector expert

The **feed changes** mitigation measure is applicable to the 3 A 1 Enteric fermentation sub-sector, with the assumptions per implementation scenario shown in the table below. The Implemented as is scenario is assumed to be the same as the WAM, with more and less ambitious abatement scenarios also modelled.

Table 4.11: Emissions abated [ktCO2eq] per implementation scenario

	2030	2050
Implemented as is	31.68	137.3
Implementation not achieved	23.76	103
Ambitious implementation	39.61	171.6

Inorganic fertilizer application falls under 3 C 4 Direct N_2O emissions from managed soils, with the application of inorganic fertilizer leading to N emissions from managed soils. This PAM is not modelled as a specific mitigation measure, rather it is reflected as a decrease in fertilizer application over time relative to the WEM.

Table 4.12: Amount of inorganic fertilizer applied [tonnes N per year] per implementation scenario

	2030	2050
Implemented as is	331,908	383,879
Implementation not achieved	442,544	511,838
Ambitious implementation	221,272	255,919

Nitrogen inhibitors for livestock reduces the nitrous oxide emissions from excreta (urine patches) in the pastoral system. Nitrogen inhibitors are applicable to beef and dairy cattle, sheep and goats, with the uptake per implementation scenario shown in Table 4.13.

Table 4.13: Uptake of N inhibitors for livestock [%] per implementation scenario

	2030	2050
Implemented as is	10%	20%
Implementation not achieved	7.5%	15%
Ambitious implementation	12.5%	25%

4.6 DFFE

4.6.1 Carbon budgets

The impact of Carbon Budgets on the uptake on mitigation in the Integrated model is determined as follows:

- For each emissions category, the fraction of coverage is applied. For some sectors the coverage may be 100%, but for some categories not all companies will need to report.
- For the percentage of the emissions category that the carbon budget is applied, it is assumed that the companies will implement the mitigation measure. The uptake of mitigation measures of the remaining companies in the sector will remain as per the WEM.
- The Maximum uptake is used to determine whether the carbon budget benchmark intensity targets are met. If the targets are met or exceed the Maximum uptake is used. If the target is not met, the Maximum uptake is adjusted until the target is met.
- For the Implemented not achieved and Ambitious Implementation scenarios the uptake is decreased or increased respectively.

Sector	Type	Unit	Process	Combustion	Fugitive	Sector coverage [%]
Iron and steel	EAF	tCO2eq/t crude steel	0,09	0,16	-	50%
Electricity	Coal	tCO2eq/MWh sent out	0,00	1,22	-	100%
Electricity	Gas	tCO2eq/MWh sent out	0,00	0,84	-	100%
Cement	Clinker	tCO2eq/clinker	0,52	0,33	-	50%
Petroleum refining		tCO2eq/CWT	0,000	0,05	0,0002	26%
Glass	Flat and container	tCO2eq/t glass melt	0,12	0,32	-	80%
Pulp and paper		Mill-based tCO2eq/ADT /tCO2eq/t - product/paper		1,21	-	100%
Ferroalloys	Process	tCO2eq/t	1,53		0,00	99%

Ferroalloys	Combustion	tCO2eq/t		0,0011	-	80%

4.6.2 NWMS 2020

The National Waste Management Strategy (NWMS) 2020 key target Is waste diverted from landfill (Table 4.14). There are number mitigation measures in the waste sector that can be used to achieve this target, including household composting, windrow composting and recycling.

Waste is modelled differently to the other sectors in the integrated model and so to achieve the targets above, the relevant model variables are changed in the PAMs scenarios until the targets are achieved. These is including the recycling rate, percentage of composting households and percentage of waste treated by windrow composting, among others. It is noted that the WAM is used for the relevant variables in order to achieve the targets within the 2030 timeframe.

Table 4.14: Waste targets per implementation scenario

Target	Implemented as is	Implementation not achieved	Implementation with increased ambition
Waste diverted from landfill	30%	24%	40%

4.6.3 Forestry PAMs

There are four forestry-related targets that fall under the Forestry PAMs:

- 30 000 ha Thicket restoration;
- 400 ha of temporary unplanted areas (TUPs) planted;
- 15 000 ha approved for afforestation;
- 200 000 Number of trees planted outside forests footprint.

To include these targets in the integrated model, the targets are mapped to relevant mitigation measures (Table 4.15) and the area per mitigation measure updated accordingly. The ramp up is based on sector expert opinion[20]. The small growers' plantations are likely to be pulp wood Eucalyptus that would be harvested at Year 8. This mitigation measure is modelled as an 8-year cycle - growth for 8 years (ramp up 5 years), back to zero, growth for 8 years, up until 2050.

[20] Personal communication: Tony Knowles

Commercial afforestation is assumed to have the same ramp up as commercial small-grower afforestation.

Table 4.15: Forestry targets per implementation scenario

Targets	Mitigation measure	Implemented as is	Implementation not achieved	Implementation with increased ambition
30 000 ha Thicket restoration	Restoration of sub-tropical thicket, forests and woodlands	30,000	22,500	37,500
5400 ha of temporary unplanted areas (TUPs) planted	Commercial small-grower afforestation	5,400	4,050	6,750
15 000 ha approved for afforestation	Commercial small-grower afforestation	15,000	11,250	18,750
200 000 Number of trees planted outside forests footprint	Commercial afforestation	200,000	175,000	250,000

4.6.4 Other environmental PAMs

The Other environmental PAMs are solely focused on the suppression of wildfires. This PAM is not mapped to a specific mitigation measure in the Integrated model, rather the projected area burnt, which is used in the 3 C 1 Emissions from Biomass Burning sub-sector, is adjusted to reflect the target (Table 4.16).

Table 4.16: Wildfires suppressed per implementation scenario.

Target	Implemented as is	Implementation not achieved	Implementation with increased ambition
Wildfires suppressed	90%	50%	95%

4.7 DWS

4.7.1 Methane capture

Based on input from DFFE the uptake of methane capture, the uptake of methane capture at wastewater treatment plants is assumed be 15%. This is applied to Domestic wastewater sub-sector (4 D 1 Domestic wastewater).

Table 4.17: Uptake per implementation scenario

	Implemented as is	Implementation not achieved	Ambitious implementation
Uptake	15%	11%	19%

5 SECTOR BY SECTOR ANALYSIS FOR SETS

5.1.1 Mining

The mining sector includes the primary extraction of a variety of minerals ranging from coal to platinum group metals, ferroalloys, manganese, iron ore, chrome, titanium to industrial minerals like clay, limestone and silica. The sources of greenhouse gas emissions is largely CO2, CH4 and N2O from fuel use to conduct operations, the fugitive emissions of CH4 from underground coal mines and the impact on land sector GHG emissions.

The Department of Mineral Resources and Energy primarily govern the mining sector under the National Mineral and Petroleum Resources Act (Act No. 28 of 2002) although additional Departments are responsible for policies that impact the sector. The only existing policy with an effect on GHG emissions is the DMRE **Post-2015 National Energy Efficiency Strategy (NEES)**, which has a target to increase efficiency of energy use. The Department of Forestry, Fisheries and Environment regulates the environmental impact of mining under the National Environmental Management Act (NEMA)(Act No. 107 of 1998). The **Financial Provisioning Regulations** (2015) under NEMA require mines to provide for and execute rehabilitation of the environmental impacts from mining activities.

Emissions reductions in the mining sector would be from reducing fuel use or changing technology to use non GHG emitting energy sources, reducing fugitive emissions from coal mines, reducing the disturbance of carbon sinks during mine operations and enhancing the carbon sinks during and after mine rehabilitation. Currently the only policy driving emissions reductions is the Post-2015 NEES. There are no PaMs existing to reduce fugitive emissions from coal mines, reducing the disturbance of carbon sinks and enhancing carbon sinks during and after mine rehabilitation.

Transitioning this sector to being low carbon will require implementation of the national energy efficiency strategy, policy to manage fugitive emissions from coal mines and improved management of carbon sinks during and after mining operations. Additional policy is needed for the monitoring and management of fugitive emissions from coal mines and to improve the management of carbon sinks during and after mining operations. In the near term to 2030, this requires energy efficiency to be increased in terms of energy unit per mine unit output, the development of a monitoring system of fugitive emissions from underground coal mines and amending the Financial Provisioning Regulations to include the management of carbon sinks during and after mine rehabilitation.

The Mining sector also has a role to play in the broader low carbon transition since. Key minerals are needed across the value chains of new technologies, of which will be important to reduce GHG emissions in the other sectors. The Critical Minerals Strategy (in development) by the DMRE will contribute to this development.

5.1.1 Agriculture

The agriculture sector includes the production crops and livestock that feeds into our food system. The sources of GHG emissions in agriculture are CO2, CH4 and N2O from fuel consumption, N2O and CH4 from soils, N2O and CH4 from livestock and CO2 from land disturbances. The agriculture land has the potential to sequester carbon. In 2022 the Livestock sector, specifically enteric fermentation accounted for most of the emissions (40,637 ktCO2eq) and the Cropland sector contributed 3,509 ktCO2 to national emissions.

The Department of Agriculture, Land Reform and Rural Development primarily governs this sector and the Provincial government plays a significant role in agriculture policy as well. There are key existing policies that are relevant with potential to drive emissions reductions if amended to include elements of climate change mitigation and finalised, such as the Conservation of Agriculture Resources Act (Act no. 43 of 2983), the Draft Conservation Agriculture Policy (2017), Draft Climate Smart Agriculture Strategic Framework (2018), Draft Climate Change Sector Plan (2015), National Policy on Organic Production (under reform), Policy on Agriculture in Sustainable Development (no date). The DMRE Post-2015 National Energy Efficiency Strategy, which has a target to increase efficiency of energy use, is an additional policy with importance to GHG emissions reductions.

The emissions reductions of the agriculture sector would be from reducing CH4 and N2O emissions from livestock, N2O and CH4 emissions from agriculture soils, increasing carbon sequestration in soils, CO2 from land disturbances and CH4, N2O and CO2 from reducing fuel use or changing technology to use non GHG emitting energy sources. Conservation has the potential to sequestrate CO2, at an estimated rate of 0.02 to 0.07 tCO2/hectare. Currently the only policy driving emissions reductions is the Post-2015 NEES. The Draft Conservation Agriculture Policy and the Conservation Agriculture Resources Act have the potential to guide widespread adoption of conservation agriculture, there are no specific targets or mechanisms to set targets.

Transitioning this sector to being low carbon will require implementation of the national energy efficiency strategy, policy to manage GHG emissions from livestock, agricultural soils and land disturbances. The existing policy needs to be streamlined and amended to prioritise feasible mitigation options that does not threaten food security. In the near term to 2030, this requires energy efficiency to be increased in terms of energy unit per unit food production, the update of the Conservation of Agriculture Resources Act and the Draft Conservation Agriculture Policy to drive carbon sequestration in soils. New technologies to reduce emissions from livestock need to be reviewed and assessed in what can be implemented, such as nitrogen inhibitors and changes in feed for livestock.

5.1.1 Human Settlements

Human settlements can refer to how we as communities interact with the built environment. It includes residential and commercial buildings, utilities like water and sanitation and overlaps with other key GHG emitting activities such as mobility, waste, energy use and land use. GHG Emissions include CO_2, N_2O and CH_4 from fuel consumption and CH_4 from wastewater. The Commercial and residential sectors accounted for approximately 3.7% of national emissions in 2022.

The Department of Human Settlements (DHS), the Department of Water and Sanitation and the Department of Mineral Resources and Energy govern this sector. Impacts of human settlement activities also result from Department of Forestry, Fisheries and the Environment, Department of Transport and the Department of Agriculture, Rural Development and Land Reform. The DHS, which is responsible for the National Housing Act (Act no. 107 of 1997) plays a major role in providing housing guided by the National Housing Code (2009). DWS drives policy for water and sanitation services, including incentivising good governance of water and sanitation at the local government level through the Green Drop Report and supporting infrastructure activities. DMRE is the custodian of the Post-2015 National Energy Efficiency Strategy which includes energy efficiency of residential and commercial buildings. DFFE governs the waste related policy, DARDLR is responsible for spatial planning and Department of Transport governs the transport systems.

Emissions reductions in the human settlements would result from reducing the energy use in residential and commercial buildings, reducing the release of CH_4 from wastewater treatment facilities and designing human settlements in a way that reduces the need to travel long distances for work, leisure or other social needs, which in turn will reduce fuel use, and a reduction on the impact settlements have on land use. Key policies that impact emissions reductions in human settlements include the National Housing Code, the Greed Drop Report, Post-2015 NEES and SPLUMA.

Transitioning the human settlements sector to being low carbon will require amendments to policy and the reprioritisation of policy components. The mainstay of the Department of Human Settlements is to roll out housing programmes. Integrating the development of climate-smart communities that consider housing design, spatial planning to reduce distances travelled, and improved utilities like wastewater treatment facilities that capture CH_4 into the housing programmes will make an impact on GHG emissions reductions. In the near term (2030), it is recommended to mainstream the Red Book: The Neighbourhood Planning and Design Guide (CSIR, 2019) in housing programmes, to assess the extent to which climate smart communities can be developed by conducting a baseline assessment and to estimate the potential for improving settlements to be climate smart, to include in the Green Drop Report a criterion that drives local governments to capture CH_4 and utilise it as an energy source and to update the Climate Smart Sector Plan at DWS to include management of methane.

5.1.1 Trade & Industry

The industry sector includes all manufacturing and production in the country. The GHG emissions from this sector include CO_2, CH_4 and N_2O from fuel consumption, CH_4 from fugitive emissions, CO_2 from process emissions, CO_2, CH_4 and N_2O from waste. The industry sector accounted for

13% of national emissions (including FOLU) in 2022 (not including energy industries: include CTL/GTL). More than half of these emissions are a result of process emissions and the remaining 47% are due to energy emissions.

The industry sector is influenced by multiple Departments including the Department of Trade, Industry and Competition (DTIC), DMRE, National Treasury and DFFE. The DTIC is responsible for enabling a sustainable and competitive industrial sector, the DMRE is responsible for managing the energy use, DFFE manages the air quality, waste and biodiversity impacts of industry and the National Treasury governs the financial aspects of industry. The relevant policy from these departments include the Post-2015 NEES at DMRE, the tax regulations like the carbon tax and the financial incentives, such as the 12L Tax Deduction of Energy Efficiency Savings and the Automotive Incentive Scheme from National Treasury and the waste, air quality, climate and biodiversity policies under NEMA at DFFE. The policies at the DTIC that are relevant are the Green Hydrogen Commercialisation Strategy, the various Master Plans that have been developed for furniture, sugar, R-CTFL, poultry, steel, automotive and forestry, Strategy for Green Trade Barriers, National Building Regulations and Building Standards Act, the National Cleaner Production Centre and Industrial Energy Efficiency Project and the South African Road to Production of Electric Vehicles (The Roadmap). All of these policies will have a contribution to transitioning the industry sector to being low carbon.

Emissions reductions in the industry sector come from a reduction of fuel consumption through, for example, improved efficiency, the switch to non-renewable fuels, alternative production processes that can substitute for production processes that result in process emissions, improved management of fugitive emissions and a reduction of waste.

Transitioning industry to being low carbon requires support and incentives to allow industry to make the technological and behavioural shift. There are many aspects of the value chain of low carbon industry that is needed to be considered to enable the transition. New technologies and fuels (e.g. hydrogen) need to be developed and commercialised, investors need the correct policy signals, industry needs enabling environment to make the shift, including gaining access to resources to allow them to act at the facility level. Specific PaMs that will/would contribute to the near term transition in 2030 include the Green Hydrogen Strategy for South Africa, Master Plans, incentive schemes such as the Manufacturing Competitiveness Enhancement Programme, 12 L Tax Deduction of Energy Efficiency Savings, Automotive Incentive Scheme, Strategy for Green Trade Barriers, National Building Regulations and Building Standards Act, National Cleaner Production Centre and Industrial Energy Efficiency Project, South African Road to Production of Electric Vehicles (The Roadmap).

Industry also has a key role to provide for the necessary inputs for other sectors to transition being low carbon. This refers to the scaling up of production of technologies and materials that are needed in other sectors to make the transition. A Green Industrial Strategy would be instrumental to coordinate the needed effort.

5.1.1 Transport

In 2022, the transport sector, consisting of domestic aviation, maritime and road subsectors, accounted for 12% of national GHG emissions (including FOLU), of which 11.75% can be attributed to the road transport sector. It is the second largest contributor to emissions after the electricity sector and is largely a result of the emissions of CO_2, CH_4 and N_2O from the combustion of hydrocarbons.

Emissions reductions in the transport sector include retrofitting existing aircraft for improved efficiency, early retirement of aircraft (replaced with newer efficient aircraft) and biofuels in the aviation sector, improved efficiency of internal combustion engines, shifting freight and passenger transport from road to rail and mass transit (passenger), technology swich from internal combustion engines to hybrid electric vehicles, plug-in hybrid electric vehicles, electric vehicles, fuel cell electric vehicles and compressed natural gas and substituting fossil fuel use with biofuels in the road sector, improved efficiency of train locomotives and fuel switching to hybrid diesel, CNG, biofuels and metro rail voltage upgrade in the rail sector, and a set of fuel saving measures in the maritime sector such as propeller upgrade, speed reduction, propeller polishing and wind power applications.

Within the Transport sector, there are several overarching policies and regulations that support and manage the relevant sub-sector PAMs. Both the Department of Transport and the Department of Mineral Resources and Energy have roles in governing the transport sector. The key policies are summarized below:

White Paper on National Transport Policy: The White Paper on National Transport Policy (2021) aims to provide "safe, reliable, effective, efficiency, environmentally benign and fully integrated transport operations and infrastructure" to both freight and passenger customers. The policy does consider environmental impacts with regards to transport with strategic objectives to 1) Promote fuel efficiency, cleaner fuels and the adoption of fuel-efficient transport modes; 2) Promote compact urban form and eco-mobility in land use and transport planning; and 3) Reduce the climate change impact of transport by promoting low-carbon modes.

Comprehensive Maritime Transport Policy (CMTP), 2017: The CMTP focuses on proper government and management and the development of the maritime transport sector in South Africa. In terms of climate change mitigation, the CMTP highlights environmental and energy issues with a focus on alleviating current and future impacts of the maritime industry and port system by introducing measures to encourage the implementation of energy efficiency technologies (DoT, 2017a) .

White Paper on National Civil Aviation Policy, 2017: aims to provide "safe, secure, reliable, effective, efficient and fully integrated civil aviation operations and infrastructure…whilst being environmentally and economically sustainable.". With regards to climate change and mitigation, the White Paper covers aircraft operations and the environment, specifically aircraft emissions and measures to reduce emissions, reducing fuel consumption and the use of alternative fuels.

Draft Roads Policy for South Africa, 2017: aims to "to allow the development and management of a road network that is safe for all its users, well-maintained and serves as a catalyst for social and economic development." With respect to climate change and mitigation, a clear outcome of the Policy is the integration of non-motorised transport (NMT) and eco-mobility modal options into the transport system, with broad objectives to reduce carbon emissions (DoT, 2017b) .

National Land Transport Strategic Framework (NLTSF) 2023 – 2028: The NLTSF is a legal requirement of the National Land Transport Act, 2009. It NLTSF is a national 5-year land transport strategy which aims to give guidance on transport planning and land transport delivery. Overarching goals of the NLTSF include reducing the impact of transport on the environment, promote sustainable transport modes and promote the introduction of green energies in transport, among others (DoT, 2023a).

Rail White Paper:

Emissions reductions in the transport sector come from a reduction of fuel consumption and the switch from hydro-carbon fuels. Emissions reductions can result from technology changes and from behavioural changes in transport.

The transition to a low carbon sector requires systematic changes in the existing transport systems. This requires technology changes, such as a shift to electric vehicles, and behavioural changes, such as increased use of freight transport. This in turn requires key infrastructure developments and operational improvements in existing transport systems. It also requires how we think of mobility and land use planning so that mobility can be efficient and easier. Though significant change are needed, incremental changes are recommended to be implemented in the near-term (2030) to initiate the momentum in the road transport, rail and aviation sectors. For the road transport sector, this includes meeting the urban objectives of the Land Transport Strategic Framework and meeting the medium-term objectives for the Rail White Paper. It also requires implementing already identified (but not yet implemented) transport efficiency measures that are considered low hanging fruit and including known efficiency measures in the aviation and maritime policies.

5.1.1 Energy

The energy sector is defined by the supply and demand of fuel use for energy use. Fuels may be GHG emitting (non-renewable fuels) or non-GHG emitting. The energy sector is by far the most significant contributor, accounting for 86% of national emissions in 2022 (including FOLU). The GHG emissions from the supply side of energy, which is comprised of electricity and heat production, petroleum refining and the manufacture of solid fuels and other energy industries (including coal mining, oil and gas, CTL and GTL) accounted for 52% of national emissions, largely made up of the electricity sector's share (87%) in 2022. The GHG emissions include CO2, CH4 and N2O from fuel consumption and CO2 and CH4 from fugitive emissions.

The energy sector is cross-cutting across most all sectors and it is largely governed by the DMRE whom manages a policy framework to plan for energy supply for solid fuels and electricity, demand side management and energy efficiency. The Department of Public Enterprises plays a role in the governance of Eskom, the majority role player in the electricity subsector. The key energy policies are summarised below:

Emissions reductions in the energy sector would result from a reduction of fuel consumption, a fuel switch to non-renewable fuels and improved management of fugitive emissions. Given the significant volume of GHG emissions emitted from electricity generation, which is currently fuelled by coal, the electricity subsector is a key focus to reduce national GHG emissions. Key efforts to reduce electricity sector emissions include the decommissioning of existing coal power plants and building new power generation that is fuelled by non-renewable fuels.

Transitioning to a low carbon sector requires effort both on the supply side, by making the necessary fuels (e.g. hydrogen) and technologies available while removing (and decommissioning) existing GHG emitting technologies, and the demand side by improving energy efficiency, production and consumption of goods. With a focus on the electricity sector, shifting the power generation infrastructure from coal based to non-GHG emitting technologies requires a variety of efforts: policy e.g. NERSA regs, long term planning (IRP), appropriate transmission infrastructure, within the framing of a Just Transition.

5.1.1 Environment & Forestry

The environment sector is classified by the greenhouse gas emitting and carbon sequestration activities that fall under policy framework of the Department of Forestry, Fisheries and the Environment (DFFE). It includes the management of carbon stocks and carbon sequestration in non-agricultural lands, company carbon budgets, solid waste management and the management of hydrofluorocarbons (HFCs).

Emissions reductions in the environment sector would come from enhancing carbon sequestration in disturbed ecosystems such as grasslands and indigenous forests, managing fires, reducing the emissions of solid waste into the atmosphere and reducing the emissions of HFCs into the atmosphere.

The policy framework in the environment sector includes the policies and measures that stem out of the National Environmental Management Act (NEMA) (No 107 of 1998). This includes the national waste strategy, the phase down of HFCs as linked to the Kigali Amendment to the Montreal Protocol, and various programme and projects as part of the DFFE strategic operational plan (Annual Performance Plan).

Transitioning to a low carbon sector requires implementation of the Waste Act, the phase down of HFCs and the prioritisation of enhancing carbon stocks in disturbed ecosystems while also ensuring existing carbon stocks remain undisturbed.

6 THE SOCIO-ECONOMIC MODEL

The purpose of this section is to describe the socio-economic model developed for the integrated model of the DFFE. The socio-economic model aims to complement the Analytica integrated energy model by providing feedback on the socio-economic impacts of the energy system. The model adds a layer of complexity to the integrated model by estimating the economic impacts of the pathways at the national, industry and household levels. The model is tailored to the integrated model and accurately represents the South African economy.

The socio-economic model captures every relevant aspect of a single-country macroeconomic model and has been developed and designed to be used for scenario analysis. There are two competing approaches to macroeconomic modelling. Neither approach is better than the other, but the two methods are used to answer different questions:

- Optimisation models, such as Markal and TIMES, are designed to identify ways of minimising cost in the energy system, subject to a set of constraints (including policy) and (micro-)behavioural assumptions.
- Simulation models are used to project outcomes in response to policy changes, based on econometrically estimated relationships between variables.

The simulation approach is appropriate for Analytica's needs. The socio-economic model is calibrated with data parameters that reflect real-world observations and in a way that socioeconomic impacts are simulated from changes agreed within the Analytica environment. The key principles of the socio-economic model are the following:

- Agents make decisions under conditions of fundamental uncertainty; at any time, they do not know the full range of options available to them.
- Markets are subject to frictions in both the short- and long-runs; prices do not automatically balance supply and demand.
- There is usually spare capacity in the economy, including, for example, unemployed workers.

The model is demand-driven, with the assumption that supply adjusts to meet demand (subject to constraints), but at a level that is likely to be below maximum capacity.

The model structure is based on a Social Accounting Matrix (SAM) of South-Africa. A SAM table is similar to the logic of Input-Output (IO) tables as its main purpose is to determine the relationship between economic sectors and actors. The SAM table is divided between industries, products, households, and labour types. Industrial production is represented at the level of products consumed by other sectors as intermediate demand, and by consumers as final consumption. Final consumption is broken down by household income decile, and the labour account of the industries is broken down by occupation.

6.1 Model linkages

The model has been developed and integrated into the Analytica framework without the need to iterate the results. This allows us to intuitively imagine the integration as an extended version of the Analytica model's initial GDP and sectoral growth calculation, with the purpose of reflecting the wider socio-economic effects of growth assumptions projected by the Analytica model.

Therefore, the connection between the models is based on two API linkages. One to import Analytica's results into the socio-economic model, and the other one to export the extended outputs of the socio-economic model back to Analytica, which are used for further steps in the modelling framework.

The model starts with a series of exogenous inputs (assumptions). These inputs represent features that lie outside the scope of the modelling tool, for factors that the model itself cannot cover or data prior to the model's period of execution. The main exogenous inputs of the model are sourced from the integrated Analytica model, such as the sector growth rates.

6.2 Econometric estimations

The model uses two types of econometric equations: fixed-effects panel, long-run and short-run parameters. The estimation process happens independently of model runs and must be initiated separately in case the underlying modelling assumptions change.

The **fixed-effects regression model** is used to estimate the effect of intrinsic characteristics of individuals in a panel data set. The fixed-effect panel estimates are used to estimate the coefficients that determine the changes of four main macroeconomic variables of the model: employment, average wages, investment, and price. The four variables are estimated with four equations that are connected to each other. Employment is explained by output and average wage. Average wages are explained by output and unemployment, while investment is explained by output only. Finally, price is explained by wages.

The model is also capable of estimating the long-run and short-run parameters of an **error correction model** (ECM). The ECM is a time series model most commonly used for data where the underlying variables have a long-run common stochastic trend, also known as cointegration. ECMs are a theoretically based approach useful for estimating both short-run and long-run effects of one time series on another.

All specified models use the econometric estimation method of Ordinary Least Squares (OLS). The algorithm developed is designed to test for cointegration in the time series variables and includes several statistical and economic tests to decide whether the estimated parameters are realistic.

6.3 Economic structure

A flowchart representation of the model structure is shown in Figure 4. The model logic is best explained starting from Analytica growth rates. Analytica's growth rates are expressed in tons, which are first converted into growth in monetary terms using corresponding sub-sectoral output shares as weights and then applied to the latest available sectoral monetary potential output figures. The sectoral growth rates obtained from Analytica are taken as potential output growth rates. Potential output is assumed to be the maximum output of a given industry in a given year. In other words, the model assumes that production capacity increases by the growth rates taken from the integrated model.

At first, output is assumed to equal potential output as outlined in Figure 4. However, the demand-driven nature of the model assumes that the economy is demand-driven; consequently, it is supply that adjusts to meet demand. So, output will eventually be given by total demand. As the flowchart shows, overall sectoral demand is made up of four components: consumer demand, intermediate demand, investment demand, and residual demand. The first three components and how they are modelled are described below, starting with the consumer demand channel, as that is the most complex one. A fourth component to final overall demand is residual demand, which includes government spending and international trade. It is given based on the historical proportion of residual demand which is the difference between actual output and consumer, intermediate and investment demand.

Once the four components of demand have been calculated, output is set equal to their aggregated value at the level of the first so-called iteration of the model run. This level of output is already likely to be below maximum capacity. Therefore, at the end of the first iteration of the model run, the total sectoral demand at the right-hand side of the flowchart is taken as output and the model is run again until the difference between sectoral demand and the initial sectoral output levels at the beginning of an iteration is below the threshold (0.1% difference).

The core of the model calculation is based on the historical economic indicators (output, employment etc.) and the social accounting matrix (SAM), which contains an initial representation of the economy, showing the structure of industries, products and income groups within it, with flows between them. While the input-output tables define the interrelationships between industries, the SAMs provide insights at the product level. In addition, the SAM, combined with appropriate labour force and household expenditure data, is a useful tool for assessing the impact of changes in sectoral composition on income distribution. In the South African SAM integrated into the socio-economic model, labour and household accounts are disaggregated by occupation and income deciles. This type of disaggregation helps to assess the labour force and distributional impact of sectoral changes.

Sectoral employment is given by the estimated econometric relationship between employment and output and the previous period's wage average. GVA is assumed to grow at the same rate as output, while average sectoral wages are given by the estimated econometric relationship between average wage and output and unemployment. Unemployment is calculated as labour force minus employment, where employment is given as described above. Labour force is derived using Analytica's population growth assumption under the pathway used, the previous year's working age population share, and the labour force participation rate as assumed in the input data.

Disposable income is calculated from wages using the SAM, defining total consumption for each income decile by deducing savings. Then, the consumer demand of each income decile for each product category is computed using the SAM. Prices are given by the estimated econometric relationship between prices and wages which then affect the consumption demand structure as described below under the price effects. Having channelled in these effects, we get sectoral consumption demand.

Intermediate demand is calculated from simply applying South Africa's input-output table, which is derived from the SAM. Investment is given by the estimated econometric relationship between investment and output, plus abatement investment figures received from Analytica. Then, to calculate the demand impact of investment, an investment converter is applied. The investment converter determines the industries in which investment in a particular sector generates demand, for example, building a new power plant generates demand in the construction sector.

All variables are measured in real terms (2015 Rand in most cases), but price level increases and relative changes in product group prices are included in the model. First, each year the price changes generated by consumers are calculated using an econometric estimation where the dependent variable is the price explained by wages. These price changes are then passed back to production in the form of input price increases. Producer price increases are calculated by applying the input-output coefficients to the price changes calculated by the econometric equation. These two effects determine the total price changes in the model.

Once prices have been calculated in each year of the modelling period, they are incorporated into the final demand of households by affecting the consumption basket. The methodology is based on the use of product price elasticity coefficients. For each product, price changes are calculated on the basis of sectoral price increases in each year, and the price differences are combined with exogenous price elasticity coefficients to calculate the consumption levels. In addition, similar to price elasticities, the model includes income elasticity effects to dynamically estimate household consumption at the decile level, following the same logic as for price elasticities.

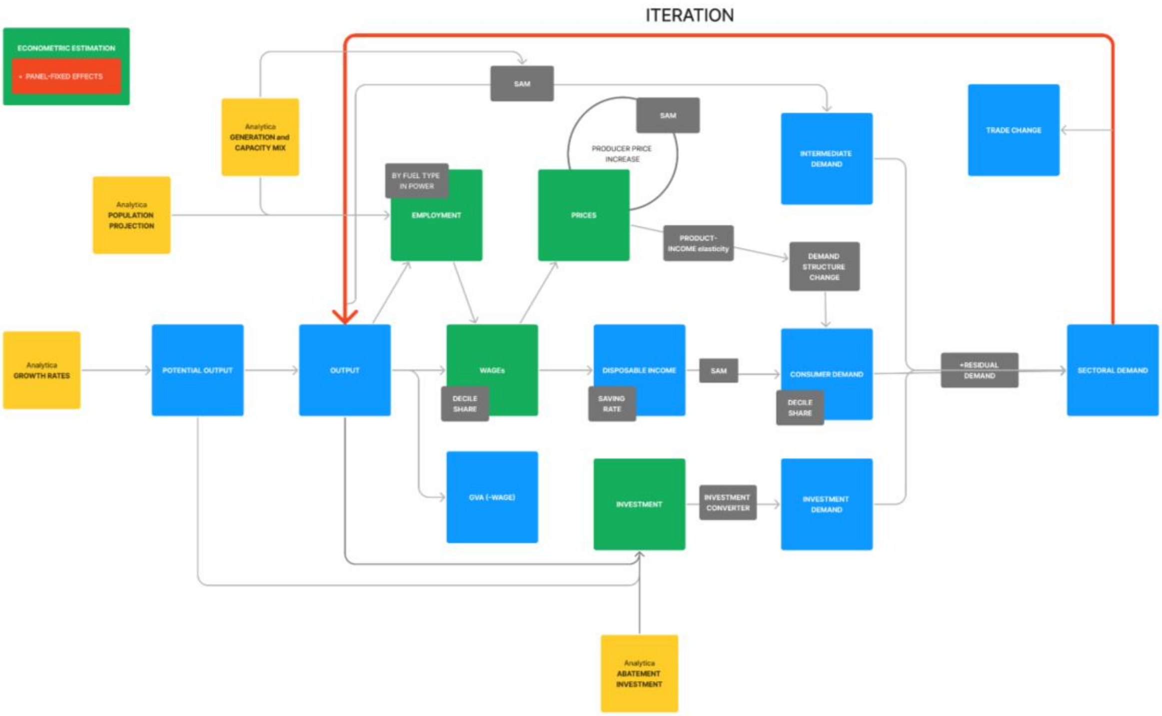

Figure 4: Schematic overview of the socio-economic model

6.4 Results

The socio-economic model calculates various economic indicators that shed more light on the potential impacts of the decarbonisation pathways. In the following we present the most important economic outcomes of the model.

6.4.1 Sectoral output

The primary results of the socio-economic module are the endogenously modelled sectoral output values derived from the exogenous growth assumptions in the integrated model. The endogenous sectoral growth rates reflect the interlinkages between the economic sectors and between the sectors and consumers.

The model uses the sectoral growth rate from the integrated model as the potential output for each sector, representing a maximum that is feasible to produce. This potential is taken through the logic of the economic structure to calculate actual estimates of the output values.

6.4.2 Employment

Sectoral, total employment and unemployment figures are also available. Unemployment is calculated as the difference between total employment and the labour force projection. In addition, employment in the electricity sector is broken down by fuel type, depending on the electricity generation split of the given path, as the results of the optimisation module of the integrated model are also fed in.

6.4.3 Consumption

Household consumption is calculated at decile and product level. Household decile disposable income is derived from the wage results and then the decile and product level results are calculated using the SAM. Incorporating decile level results into the model allows the inequality effects of different decarbonisation pathways to be captured at a detailed level.

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ANNEXURE: FULL SET OF PAMS CONSIDERED

Table 0.1: Categories of Policies and Measures

Category	Sub-category	Explanation	Example
Regulatory measures	Legislation, Regulation, Strategies and Standards	These measures have a direct impact on emissions by setting legally enforceable limits or standards. Strategies can also serve as overarching guidance frameworks for Government.	IRP, IEP, NEES, LEDs
Economic measures	Tax, Allowances, subsidies and off-sets	These measures provide economic incentives or disincentives on emissions by imposing taxes, allowing tax rebates or providing subsidies	12L tax rebates, electricity generation levy
Direct Government Actions	Government procurement, infrastructure and investment	Government takes direct action to effect abatement through procurement and investments in infrastructure and technology which gives rise to lower greenhouse gas emissions	Procurement and investment in the transport sector (e.g freight modal shift and mass public transit), Waste Phakhisa, etc.

Support Measures	Voluntary actions, support for research and development	Refers to a wide range of actions related to education, capacity, research development and deployment or government support for voluntary actions	Support research development and innovation, funding related to capacity building and energy/emissions audit, primary education which has a long-term indirect effect
Information programmes	Awareness raising	Refers to a programme that raises awareness on, for example, energy conservation	Labelling programmes, energy advice programmes

Table 0.2: Overarching PAMs Contributing to the Country's Low Emissions Development Path

PAM Name	Category	Type	Reference
South Africa's first Nationally Determined Contribution	Regulatory measure	International commitment	(DFFE, 2021b)
South Africa's Low Emissions Development Strategy (SA-LEDS) 2050	Regulatory Measure	Strategy	(RSA, 2020)
Climate Change Bill	Regulatory Measure	Bill	(RSA, 2022a)
Act No. 15 of 2019: Carbon Tax Act, 2019	Economic Measure	Act	(RSA, 2019)
Carbon Budget	Regulatory/Economic Measure	Measure	(RSA, 2022a)

Department of Mineral Resources and Energy: Energy and Mining PAMs

The following table presents a list of PAMs relevant to the Energy sector.

Table 0.3: Energy Sector PAMS

PAM Name	Category	Type	Quant/Qual 2030 SET	Hard SET Activity and Indicator	Reference
Draft Integrated Energy Plan	Regulatory Measure	Report			(DoE, 2016b)

Integrated Resource Plan (IRP2019)	Regulatory Measure	Plan	Quantified included in WEM	Grid Emissions Factor GWh zero CO_2e (nuclear, hydro, solar, wind)	(DMRE, 2019)
Draft Integrated Resource Plan (IRP2023)	Regulatory Measure	Plan	Quantitative	Scenario specific	
Confronting the Energy Crisis: An Action Plan to end Load Shedding	Regulatory Measure	Plan			(RSA, 2022b)
Energy Action Plan: Update December 2022	Regulatory Measure	Plan			(RSA, 2022c)
Renewable Energy Independent Power Producers Procurement Programme (REIPPPP)	Direct Government Action	Programme	Quantitative		(RSA, no date)
South African Renewable Energy Masterplan (SAREM) Draft 2022	Regulatory Measure	Plan			(DMRE, DTIC and DSI, 2022)
A Framework for a Just Transition in South Africa	Regulatory Measure	Framework			(PCC, 2022)
Just Energy Transition Investment Plan	Regulatory Measure	Plan			(RSA, 2022d)
DMRE Strategic Plan 2020-2025	Regulatory Measure	Plan			(DMRE, 2020c)
DMRE Annual Performance Plan 2022/2023	Regulatory Measure	Plan			(DMRE, 2022a)
Draft Post-2015 National Energy Efficiency Strategy	Regulatory Measure	Strategy	Quantitative	Sector specific	(DoE, 2016a)
Department of Public Enterprises Strategic Plan 2020/2021 – 2024/2025	Regulatory Measure	Plan			(DPE, 2020)

Electricity Regulations Act 4 of 2006	Regulatory Measure	Act			(RSA, 2006)
Electricity Regulations Act 4 of 2006, amended Schedule 2, 2022	Regulatory Measure	Act			(DMRE, 2021a)
Free Basic Alternative Energy Policy (Household Energy Support)	Regulatory Measure	Policy			(DME, 2007b)
Electricity Pricing Policy	Regulatory Measure	Policy			(DMRE, 2022c)
Integrated National Electrification Programme	Direct Government Action	Programme			(DoE, no date a)
Act No. 34 of 2008: National Energy Act, 2008	Regulatory Measure	Act			(RSA, 2008)
Gas Utilisation Master Plan (GUMP)	Regulatory Measure	Plan			(DMRE, 2021c)
The Green Hydrogen Commercialisation Strategy for South Africa	Regulatory Measure	Strategy			(DTIC, 2022)
Hydrogen Society Roadmap for South Africa 2021	Regulatory Measure	Framework			(DSI, 2021)
HySA Hydrogen South Africa	Regulatory Measure	Programme			(HySA Systems, no date)
Environmental Levy on Electricity Generated in South Africa	Economic Measure	Levy			(SARS, 2020)
Amendment of Regulations regarding Petroleum Products Specifications and Standards	Regulatory Measure	Regulation			(DoE, 2017)
Regulations for the Mandatory Display and Submission of Energy Performance Certificates for Buildings	Information Programme	Regulation			(DMRE, 2020a)

Upstream Petroleum Resources Development Bill	Regulatory Measure	Bill			(RSA, 2021b)
Act No. 28 of 2004: Petroleum Pipelines Levies Act, 2004	Economic Measure	Levy			(RSA, 2004b)
Regulations Regarding Petroleum Products Specifications and Standards for Implementation	Regulatory Measure	Standards			(DMRE, 2021b)
Clean Fuels II	Regulatory Measure	Regulation			(SAPIA, no date)
Roadmap towards Cleaner Fossil Fuels in South Africa	Support Measure	Roadmap			(SANEDI, 2022, 2023)
Integrated Bioenergy Programme		Programme			

The following table presents a list of PAMs relevant to the Mining sector.

Table 0.4: Mining PAMS

PAM Name	Category	Type	Quant/Qual 2030 SET	Hard SET Activity and Indicator	Reference
Derelict and ownerless mines	Programmes	Programme	Qualitative	Long Term SET: Hectares revegetated, CO_2e sequestered	(DMR, 2019)
Artisanal and Small-Scale Mining Policy	Regulatory Measure	Policy			(DMRE, 2022b)
Act No. 28 of 2002: Mineral and Petroleum Resources Development Act, 2002	Regulatory Measure	Act			(RSA, 2002)
Proposed regulations pertaining to financial provisioning for the mitigation and rehabilitation of environmental damage caused by	Regulatory Measure	Regulations	Qualitative	Long Term SET: Planned Hectares	(DFFE, 2022)

reconnaissance, prospecting, exploration, mining or production operations				revegetated, Planned CO_2e sequestered	

Department of Transport PAMs

The following table presents a list of PAMs relevant to the Transport sector.

Table 0.5: Transport PAMs

PAM Name	Category	Type	Quant/Qual 2030 SET	Hard SET Activity and Indicator	Reference
Green Transport Strategy (2018–2050)	Regulatory Measure	Strategy			(DoT, 2018)
National Land Transport Strategic Framework 2023–2028	Regulatory Measure	Framework			(DoT, 2023a)
White Paper on National Transport Policy	Regulatory Measure	White Paper			(DoT, 2022d)
White Paper on National Rail Policy	Regulatory Measure	White Paper	Quantitative included under Transport PAMs	Freight rail kms achieved. Number of passenger rail corridors in full operation	(DoT, 2022c)
Draft National Non-Motorised Transport Policy	Regulatory Measure	Policy			(DoT, 2008)
National Transport Master Plan (NATMAP) 2050	Regulatory Measure	Plan			(DoT, 2016)
Department of Public Enterprises Strategic Plan 2020/2021 – 2024/2025	Regulatory Measure	Plan			(DPE, 2020)
Draft Post-2015 National Energy Efficiency Strategy	Regulatory Measure	Strategy			(DoE, 2016a)

DoT Revised Strategic Plan for the fiscal years 2020/21 - 2024/25	Regulatory Measure	Plan			(DoT, 2022b)
DoT Annual Performance Plan for the financial year 2022/23	Regulatory Measure	Plan			(DoT, 2022a)
Regulations regarding the Mandatory Blending of Biofuels with Petrol and Diesel	Regulatory Measure	Regulation			(RSA, 2012)
Rural Transport Strategy for South Africa	Regulatory Measure	Strategy			(DoT, 2007)
Auto Green Paper on the Advancement of New Energy Vehicles in South Africa	Regulatory Measure	Green Paper			(DTIC, 2021a)
Biofuels Industrial Strategy of the Republic of South Africa	Regulatory Measure	Strategy			(DME, 2007a)
South African Biofuels Regulatory Framework	Regulatory Measure	Framewor k			(DMRE,2020b)
Bus Rapid Transit System	Direct Government Action	Project			(DoT, no date)
Fuel Levy on the Sale of Aviation Fuels	Economic Measure	Levy			(DoT, 2023b)
Phasing out of Inefficient Fossil Fuel Subsidies	Economic Measure	Subsidies			(The World Bank, 2014)
New Vehicle Tax	Economic Measure	Tax			(NT, 2022)
Draft Comprehensive Maritime Transport Policy	Regulatory Measure	Policy			(DoT, 2017a)
National Freight Logistics Strategy	Regulatory Measure	Strategy			(DoT, 2005)
National Freight Strategy	Regulatory Measure	Strategy			(DoT, 2017b)
Act No. 12 of 2005: National Ports Act, 2005	Regulatory Measure	Act			(RSA, 2005)
Act No. 5 of 2009: National Land Transport Act, 2009	Regulatory Measure	Act			(RSA, 2009a)

Vehicle Labelling Scheme	Information Programme	Labelling			

Department of Human Settlements including buildings

The following table presents a list of PAMs relevant to Human Settlements including buildings.

Table 0.6: Human Settlement PAMs including buildings

PAM Name	Category	Type	Quant /Qual 2030 SET	Hard SET Activity and Indicator	Reference
DHS Annual Performance Plan 2023-24	Regulatory Measure	Plan			(DHS, 2023a)
DHS Revised Strategic Plan 2020-2025	Regulatory Measure	Plan			(DHS, 2020)
DHS Sector Climate Response Strategy	Regulatory Measure	Strategy			
DHS Environmental Implementation Plan 2020/2021 – 2024/2025	Regulatory Measure	Plan			(DHS, 2023b)
Integrated Urban Development Framework	Regulatory Measure	Framework			(COGTA, 2016)
DPW Green Building Policy	Regulatory Measure	Policy			(DPW, 2018)
SANS 10400-XA: Energy Usage in Buildings Regulations	Regulatory Measure	Regulation			(RSA, 2011b)
SANS 204: Energy efficiency in Buildings	Regulatory Measure	Regulation			(RSA, 2011a)
Draft Post-2015 National Energy Efficiency Strategy	Regulatory Measure	Strategy			(DoE, 2016a)
Energy Efficiency and Demand Side Management (EEDSM) Programme	Direct Government Action	Programme			(DMRE, no date)
Solar Water Heaters	Support Measure	Programme			(RSA, no date a)
Compulsory Specification for Energy Efficiency and Labelling of Electrical and Electronic Apparatus	Information Programme	Labelling			(DTI, 2014)

Integrated National Electrification Programme (including New Household Electrification Strategy)	Direct Government Action	Programme			(DoE, no date a)
Liquefied Petroleum Gas (LPG) Rollout Strategy	Regulatory Measure	Strategy			(DMRE, 2022d)
Product Standards and Labelling	Regulatory Measure	Regulation			(DME, 2005)
Green Drop Report	Regulatory Measure	Report			(DWS, 2023b)
DWS Annual Performance Plan 2023/2024 to 2025/2026	Regulatory Measure	Plan			(DWS, 2023a)
DWS Revised Strategic Plan 2020/2021 to 2024/2025	Regulatory Measure	Plan			(DWS, 2023c)

Department of Trade, Industry and Competition PAMs

The following table presents a list of PAMs relevant to the Industry sector.

Table 0.7: Industry Sector PAMs

PAM Name	Category	Type	Quant/ Qual 2030 SET	Hard SET Activity and Indicator	Reference
Climate Change Bill	Regulatory Measure	Bill			(RSA, 2022a)
Act No. 15 of 2019: Carbon Tax Act, 2019	Economic Measure	Act			(RSA, 2019)
Carbon Budget	Economic Measure	Measure			(RSA, 2022a)
Draft Post-2015 National Energy Efficiency Strategy	Regulatory Measure	Strategy			(DoE, 2016a)
DTIC Environmental Implementation Plan 2020/2021 – 2024/2025	Regulatory Measure	Plan			(DTIC, no date a)
DTIC Annual Performance Plan 2023-24	Regulatory Measure	Plan			(DTIC, 2023)
DTIC Strategic Plan 2020-25	Regulatory Measure	Plan			(DTIC, 2020d)

National Industrial Policy Framework	Regulatory Measure	Framework			(DTI, no date)
Industrial Policy Action Plan 2018/19–2020/21	Regulatory Measure	Plan			(DTI, 2018)
South Africa's Just Energy Transition Investment Plan (JET IP)	Regulatory Measure	Plan			(RSA, 2022d)
Green Hydrogen Commercialisation Strategy for South Africa	Regulatory Measure	Strategy			(DTIC, 2022)
Hydrogen Society Roadmap for South Africa	Regulatory Measure	Framework			(DSI, 2021)
Hydrogen South Africa Programme	Regulatory Measure	Programme			(HySA Systems, no date)
Masterplan for the South African Furniture Industry	Regulatory Measure	Plan			(DTIC, 2021b)
South African Sugar Value Chain Master Plan 2030	Regulatory Measure	Plan			(DTIC, 2020c)
South African R-CTFL Value Chain Master Plan to 2030	Regulatory Measure	Plan			(DTIC, 2020b)
The South African Poultry Sector Master Plan	Regulatory Measure	Plan			(DTIC, 2019)
South African Steel and Metal Fabrication Master Plan	Regulatory Measure	Plan			(DTIC, 2020e)
South Africa's Automotive Industry Master Plan to 2035	Regulatory Measure	Plan			(DTIC, 2018)
Auto Green Paper on the Advancement of New Energy Vehicles in South Africa	Regulatory Measure	Green Paper			(DTIC, 2021a)
Master Plan for the Commercial Forestry Sector in South Africa 2020–2025	Regulatory Measure	Plan			(DTIC, 2020a)
Automotive Incentive Scheme	Economic Measure	Incentive			(DTIC, no date a)
Manufacturing Competitiveness Enhancement Programme	Economic Measure	Industrial financing and loan facilities			(DTIC, no date c)

Act No. 58 of 1962: Section 12L Deduction for Energy Efficiency Savings	Economic Measure	Income Tax deduction			(SARS, 2019)
National Cleaner Production Centre and Industrial Energy Efficiency Project	Support Measure	Programme			(NCPC, no date; NCPC-SA, 2020)
Kigali Amendment on HFCs South Africa	Regulatory Measure	Regulation			(DFFE, 2019)
Strategy for Green Trade Barriers (forthcoming)	Regulatory Measure	Strategy			
Companies Act					

Department of Agriculture, Land Reform and Rural Development - Land PAMs

The following table presents a list of PAMs relevant to Land.

Table 0.8: Land PAMs

PAM Name	Category	Type	Quant /Qual 2030 SET	Hard SET Activity and Indicator	Reference
Act No. 16 of 2013: Spatial Planning and Land Use Management Act, 2013	Regulatory Measure	Act			(RSA, 2013)
Act No. 70 of 1970: Subdivision of Agricultural Land Act, 1970	Regulatory Measure	Act			(RSA, 1970)
Act No. 43 of 1983: Conservation of Agricultural Resources Act, 1983	Regulatory Measure	Act			(RSA, 1983)
Draft Conservation Agriculture Policy	Regulatory Measure	Policy			(DAFF, 2017b)
Act No. 10 of 2004: National Environmental Management: Biodiversity Act, 2004	Regulatory Measure	Act			(RSA, 2004a)
Preservation and Development of Agricultural Land Bill	Regulatory Measure	Bill			(RSA, 2021a)
Act No. 84 of 1998: National Forests Act, 1998	Regulatory Measure	Act			(RSA, 1998a)

Act No. 101 of 1998: National Veld and Forest Fire Act, 1998	Regulatory Measure	Act			(RSA, 1998b)
Act No. 57 of 2003: National Environmental Management: Protected Areas Act, 2003	Regulatory Measure	Act			(RSA, 2004c)
Draft National Spatial Development Framework	Regulatory Measure	Framework			(DPME and DALRRD, 2018)
DALRRD Strategic Plan 2020-2025	Regulatory Measure	Plan			(DALRRD, 2020)
DALRRD Annual Performance Plan 2023/2024	Regulatory Measures	Plan			(DALRRD, 2023)
Draft Climate Change Sector Plan for Agriculture, Forestry and Fisheries	Regulatory Measure	Plan			(DAFF, 2015)
Draft Climate Smart Agriculture Strategic Framework	Regulatory Measure	Framework			(DAFF, 2018)
Agroforestry Strategy Framework for South Africa	Regulatory Measure	Framework			(DAFF, 2017a)
National Biodiversity Economy Strategy (NBES)	Regulatory Measure	Strategy			(DEA, 2016a)
Forestry 2030 Roadmap (Forestry Strategy 2009-2030)	Regulatory Measure	Strategy			(DAFF, no date)
National Reduction of Emissions from Deforestation and Forest Degradation (REDD+) programme	Support Measure	Programme			(DEFF, 2020b, 2020a)
Working for Programme	Support Measure	Programme			(DFFE, no date d, no date c, no date a, no date b)
Comprehensive Agricultural Support Programme (CASP)	Information Programme	Programme			(DALRRD, no date)
National Extension Reform					
National Policy on Organic Production (under reform)	Regulatory Measure	Policy			
National Protected Area Expansion Strategy for South Africa	Regulatory Measure	Strategy			(DEA, 2016b)
Policy on Agriculture in Sustainable Development	Regulatory Measure	Policy			

Sector GHG Reduction Plan (yet to be developed)		Plan			

Department of Agriculture, Land Reform and Rural Development - Agriculture PAMs

The following table presents a list of PAMs relevant to Agriculture.

Table 0.9: Agriculture PAMs

PAM Name	Category	Type	Quant/ Qual 2030 SET	Hard SET Activity and Indicator	Reference
Act No. 43 of 1983: Conservation of Agricultural Resources Act, 1983	Regulatory Measure	Act			(RSA, 1983)
Draft Conservation Agriculture Policy	Regulatory Measure	Policy			(DAFF, 2017b)
Draft Climate Smart Agriculture Strategic Framework	Regulatory Measure	Framework			(DAFF, 2018)
Act No. 10 of 2004: National Environmental Management: Biodiversity Act, 2004	Regulatory Measure	Act			(RSA, 2004a)
Draft Climate Change Sector Plan for Agriculture, Forestry and Fisheries	Regulatory Measure	Plan			(DAFF, 2015)
DALRRD Strategic Plan 2020-2025	Regulatory Measure	Plan			(DALRRD, 2020)
DALRRD Annual Performance Plan 2023-2024	Regulatory Measures	Plan			(DALRRD, 2023)
National Policy on Organic Production (under reform)	Regulatory Measure	Policy			
South African Sugar Value Chain Master Plan 2030	Regulatory Measure	Plan			(DTIC, 2020c)
South African R-CTFL Value Chain Master Plan to 2030	Regulatory Measure	Plan			(DTIC, 2020b)

The South African Poultry Sector Master Plan	Regulatory Measure	Plan			(DTIC, 2019)
Preservation and Development of Agricultural Land Bill	Regulatory Measure	Bill			(RSA, 2021a)
Comprehensive Agricultural Support Programme (CASP)	Information Programme	Programm e			(DALRRD, no date)
Policy on Agriculture in Sustainable Development	Regulatory Measure	Policy			

Department of Forestry, Fisheries and the Environment PAMs

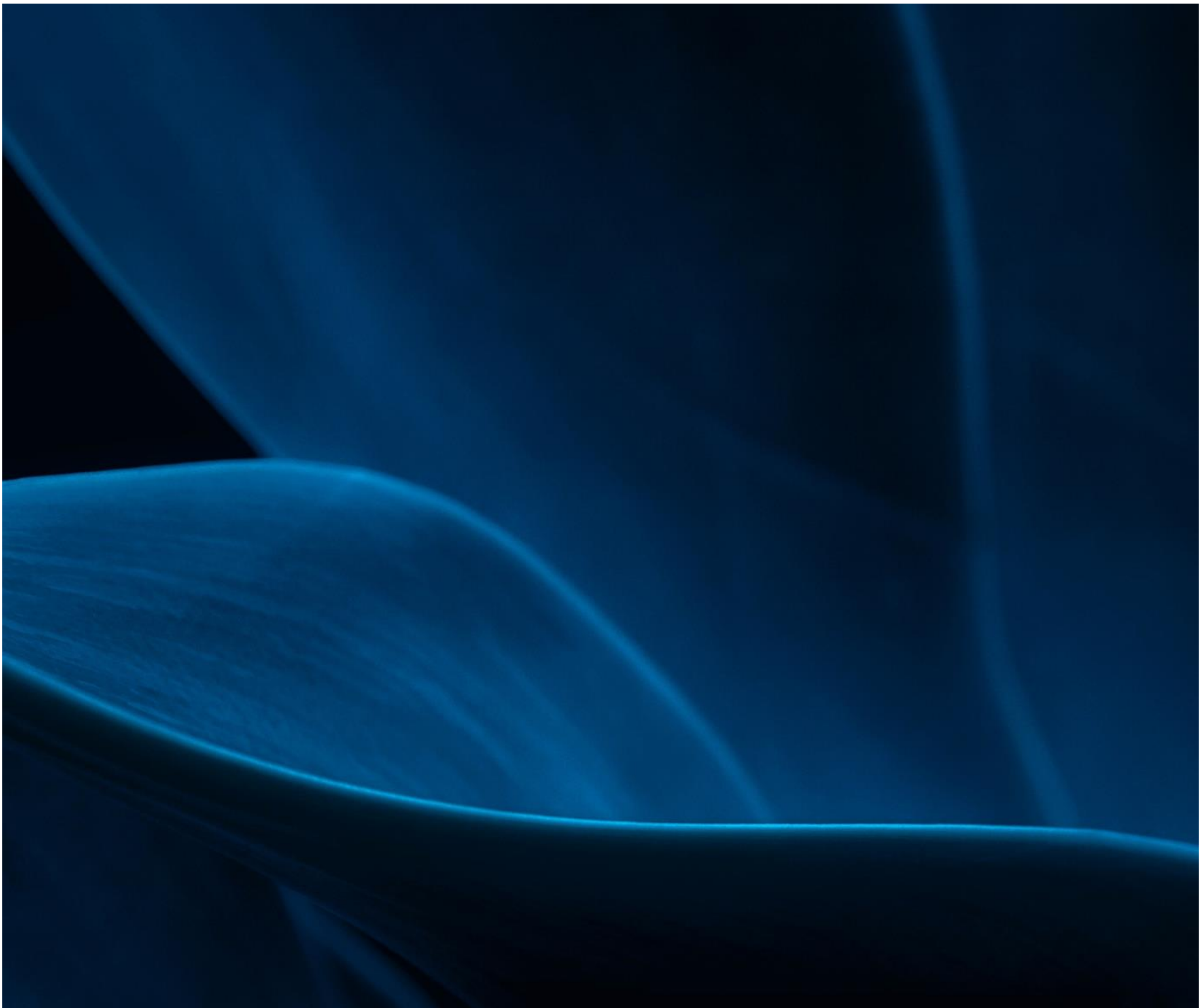
The following table presents a list of Environmental PAMs.

Table 0.10: Environmental PAMs

PAM Name	Category	Type	Quant/ Qual 2030 SET	Hard SET Activity and Indicator	Reference
Water and Sanitation Sector Policy on Climate Change	Regulatory Measure	Policy			(DWS, 2017)
National Sanitation Policy 2016	Regulatory Measure	Policy			(DWS, 2016)
National Policy on Thermal Treatment of General and Hazardous Waste	Regulatory Measure	Policy			(DEA, 2009)
White Paper on Integrated Pollution and Waste Management for South Africa	Regulatory Measure	White Paper			(DEAT, 2000)
National Waste Information Regulations	Regulatory Measure	Regulation			(DEA, 2012b)
National Water and Sanitation Master Plan	Regulatory Measure	Plan			(DWS, 2018)
Municipal Waste Sector Plan	Regulatory Measure	Plan			(DEA, 2012a)

National Waste Management Strategy	Regulatory Measure	Strategy			(DEFF, 2020)
Operation Phakisa Chemicals and Waste Economy (CWE) initiative					
Waste Research, Development and Innovation Roadmap for South Africa (2015–2025)	Regulatory Measure				(DSI, 2015)
The National Organic Waste Composting Strategy	Regulatory Measure	Strategy			(DEA, 2013b)
National Water Resource Strategy 3	Regulatory Measure	Strategy			(DWS, 2021)
National Environmental Management Waste Act: List of Activities which have or are likely to have a detrimental effect on the environment	Regulatory Measure	Act			(DEA, 2017)
Act No. 59 of 2008: National Environmental Management: Waste Act, 2008	Regulatory Measure	Act			(RSA, 2009b)
National Norms and Standards for Disposal of Waste to Landfill	Regulatory Measure	Policy			(DEA, 2013a)
National Policy for the Provision of Basic Refuse Removal Services to Indigent Households	Regulatory Measure	Policy			(DEA, 2011)
National Water and Sanitation Master Plan	Regulatory Measure	Plan			(DWS, 2018)
Norms and Standards for Extraction, Flaring or Recovery of Landfill Gas	Regulatory Measure	Standards			
Act No. 84 of 1998: National Forests Act, 1998	Regulatory Measure	Act			(RSA, 1998a)
Act No. 101 of 1998: National Veld and Forest Fire Act, 1998	Regulatory Measure	Act			(RSA, 1998b)
Act No. 57 of 2003: National Environmental Management: Protected Areas Act, 2003	Regulatory Measure	Act			(RSA, 2004c)
Draft National Spatial Development Framework	Regulatory Measure	Framework			(DPME and DALRRD, 2018)

Agroforestry Strategy Framework for South Africa	Regulatory Measure	Framewor k			(DAFF, 2017a)
National Biodiversity Economy Strategy (NBES)	Regulatory Measure	Strategy			(DEA, 2016a)
Forestry 2030 Roadmap (Forestry Strategy 2009-2030)	Regulatory Measure	Strategy			(DAFF, no date)
Integrated Urban Development Framework	Regulatory Measure	Framewor k			(COGTA, 2016)
National Reduction of Emissions from Deforestation and Forest Degradation (REDD+) programme	Support Measure	Programm e			(DEFF, 2020b, 2020a)
Working for Programme	Support Measure	Programm e			(DFFE, no date d, no date c, no date b, no date a)



Socio-economic modelling of Sectoral Emissions Target allocations in South Africa

Final report – April 2024

forestry, fisheries & the environment
Department:
Forestry, Fisheries and the Environment
REPUBLIC OF SOUTH AFRICA

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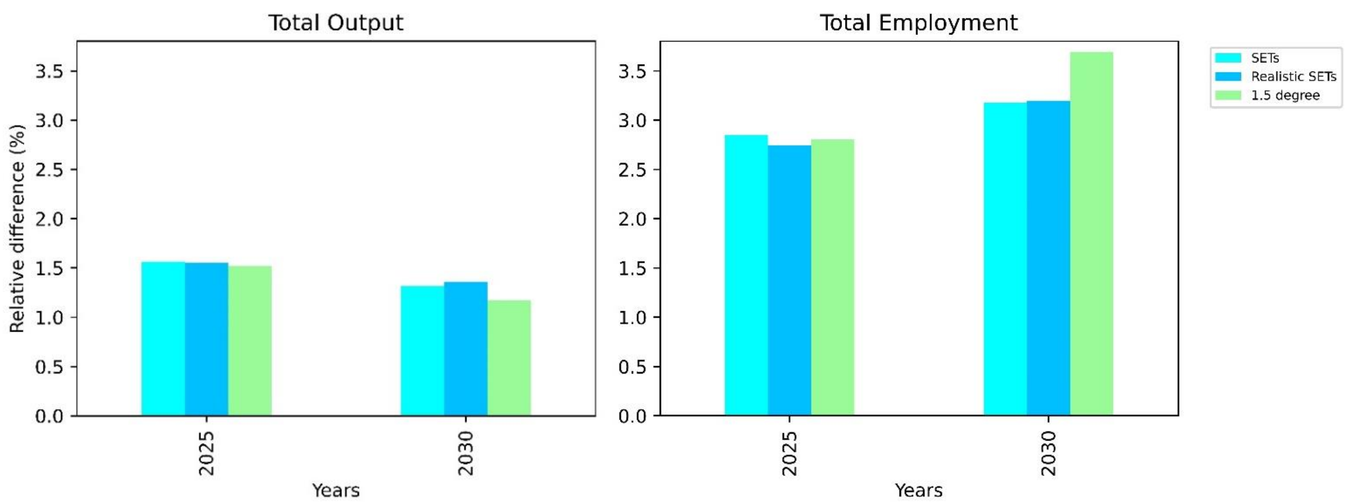
Executive Summary

This report gives a short overview of the socio-economic outcomes of a baseline scenario and three decarbonisation scenarios until 2030 in South Africa. The results are calculated using the new socio-economic model created for the Department of Forestry, Fisheries and the Environment of South Africa. The four scenarios analysed in this report are: (1) Baseline; (2) Sectoral Emission Targets (SETs); (3) Realistic SETs; and (4) 1.5 degree.

The results show that decarbonisation has a positive net effect on the economy. Decarbonisation triggers investment that boosts output across the economy through intersectoral links. While some sectors see a drop in output during the transition period, the overall effect on output and employment is positive in all scenarios. However, household consumption grows at a slightly slower pace in the decarbonisation scenarios than in the baseline as these scenarios need more investment.

Figure 1 Total output and employment by scenario, relative difference from baseline



Note(s): Charts show relative differences compared to the Baseline scenario.
Source(s): Based on own modelling.

+1.5%
Higher output in all decarbonisation scenarios in 2025

+R137B
Higher output by 2030 in the SETs scenarios

+3%
More jobs in the decarbonisation scenarios by 2030

+0.5m
Higher employment in all decarbonisation scenarios in 2030

Economic results

The new socio-economic model

The model seeks to enhance the integrated model of the Department of Forestry, Fisheries and the Environment of South Africa (DFFE) by giving economic feedback on the effects of the investments in the energy system. The model increases the complexity of the integrated model by measuring the economic impacts of the pathways at the national, industry and household levels. The model is customized to the integrated model and faithfully reflects the South African economy.

The main connections between the integrated model and the new socio-economic model are sectoral output and low-carbon investments. The socio-economic model takes low-carbon investment as exogenous inputs, while the sectoral output growth rates are used as possible output growth rates. The total demand for each sector consists of four parts: consumer demand, intermediate demand, investment demand, and leftover demand.

- The consumer demand calculation is based on the econometric estimation of sectoral estimation, which then translates into disposable income of households and then finally into consumption, incorporating price effects.
- Intermediate demand is calculated from applying South Africa's input-output table, which is derived from a Social Accounting Matrix (SAM).
- Investment demand is given by the estimated econometric relationship between investment and output, plus abatement investment figures received from the Energy model and applying an investment converter between investment and demand.
- Residual demand, which accounts for government spending and international trade.

Once the four components of demand have been calculated, sectoral output is set equal to their aggregated value, ensuring that supply equals demand in an iterative process.

Low-carbon investments

Low-carbon investment defines the level of decarbonisation ambition across the scenarios, representing the capital requirements of taking necessary steps and action needed to implement mitigation targets. Low-carbon investments represent a key primary exogenous input of the socio-economic model, and these investments affect the economy through supply chain links, leading to indirect investments in other sectors.

The analysis consists of four scenarios with different ambitions and investment levels. The baseline scenario reflects the policies and measures that are already in place and gives a projection based on them for the time period until 2030. This results in total investment levels of 750 billion Rand in 2023, which remains relatively stable over the years and reaches approximately 760 billion in 2030.

The three additional scenarios have higher total investment levels, already from 2023 onwards, as shown in Figure 2. The SETs and Realistic SETs scenarios follow almost identical investment patterns. Since investment influences other macroeconomic indicators, the two scenarios are also related in the other variables. By 2025, the SETs and 1.5 degree scenarios have a similar trend with a total annual investment of about 830 billion Rand in 2025. Several policies are estimated to end in 2026, which results in a significant drop in total investment of the SETs scenarios, being slightly higher than the baseline with 750 billion Rand and the 1.5 degree scenario at 800 billion Rand. Afterwards, investment consistently increases in all scenarios, reaching approximately 840 billion Rand in the SETs and 860 billion Rand in the 1.5 degree scenario.

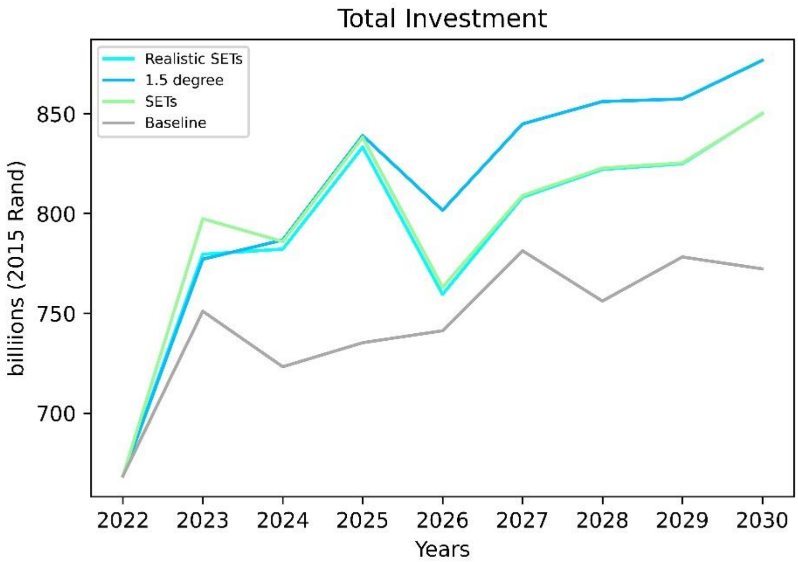


Figure 2 Total investment by scenario, billions, 2015 Rand

The baseline scenario envisages high investment spending in the electricity sector, while in decarbonisation scenarios investments in the electricity sector are lower but investments in other sectors such as agriculture, services and transport are higher. This allocation of investments represents how more ambitious climate policy needs to consider not only the development of the electricity sector as the primary source of clean energy, but also focus heavily on other large emitters to reduce their overall emissions.

Sectoral output

The results show that decarbonisation has a positive net effect on the economy. The key factor behind the expected economic growth is low-carbon investment, as it boosts demand and creates new possibilities for local suppliers through intersectoral links. Consequently, output is 1.17% above baseline in the 1.5 degree scenario in 2030, and by 1.32% (R137 billion in absolute terms) in the SETs scenarios (see Figure 3). The overall benefits are greater than the costs, while the economy undergoes structural changes. In addition, decarbonisation has an even more positive effect on gross value added (GVA), as sectors with higher value-added, like services, grow more rapidly. In 2025, GVA in all decarbonisation scenarios is 1.7% higher than in the baseline, while in 2030 it is 2% and 1.8% higher in the SETs and 1.5 degree scenarios, respectively.

The SETs scenarios show a significant decline in output in 2026, which is caused by a fall in low-carbon investment. This creates a disturbance in the economy, as some sectors face lower demand and have to adapt their production and employment levels. Output of these sectors improves in the following years, as low-carbon investments starts again, but it stays lower than in the 1.5 degree scenario.

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Increase in total output by 2030

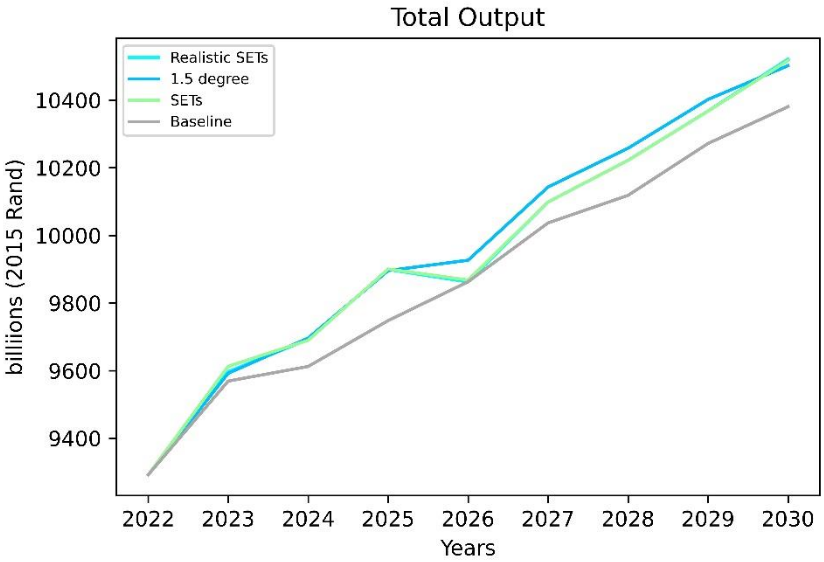

Figure 3 Total output by scenario, billions, 2015 Rand

Figure 4 shows how the output of different sectors changes under the decarbonisation scenarios. In the baseline scenario, the average output growth until 2030 is 1.4%, mainly driven by the services and metals sectors. Construction, mining and non-metallic minerals also benefit from the low-carbon investment, since they supply some of the goods and services needed for the energy transition. The sectors that rely on fossil fuels, such as petroleum, transport and other manufacturing face a drop in output due to the lower demand and higher costs of their products. Electricity also has a lower output, as it undergoes a green transition and produces less energy than in the baseline scenario.

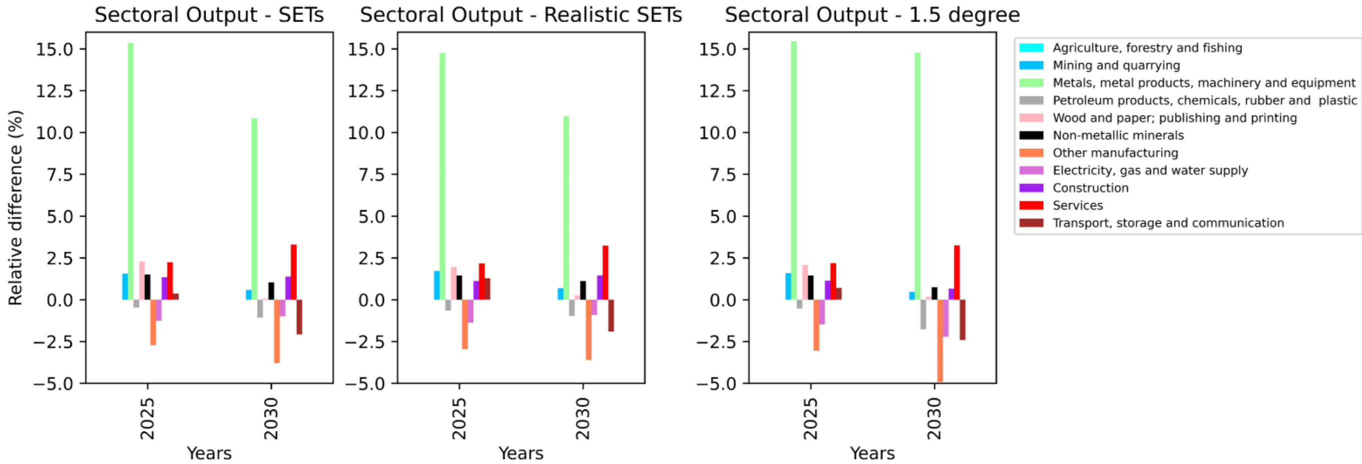

Figure 4 Sectoral output impacts by scenario, relative difference from baseline

Metals production and the services sector are the main beneficiaries of the low-carbon investment, both in absolute and relative terms compared to the baseline. The services sector grows faster than in the baseline scenario because it gains from the higher economic activity and income. By 2030, the sector reaches a 2.5-3% relative increase in its output compared to the baseline. In addition to metals, other mining and construction are also growth sectors in the decarbonisation scenarios, as they supply the goods and services required for the energy transition. The metals sector increases 10% more than the baseline, while construction has a more modest increase at 1-1.5% relative difference.

The low-carbon investment does not affect all sectors in the same way. The sectors that rely on fossil fuels, such as manufacturing, petroleum, and transport, see a drop in output because of the lower demand and higher costs of their product due to the emissions-intensive production processes. The output of the manufacturing sector is 2.5% lower than the baseline projections in 2030, while the output of the transport sector is only 1% lower in the same year. The transport sector suffers less than other sectors because it can adopt electric vehicles and their related technologies, which is why the sector grows faster than the baseline expectations in 2025. However, this also shows that using only technological solutions to meet emissions targets is not sufficient in the long run.

Employment

Moving to renewable energy sources is expected to generate new jobs in different parts of the economy. The extra job creation is expected to happen because of the multiplier effects of higher investment levels, which are assumed to help achieve more ambitious mitigation goals. The services sector is the main source of employment growth in all scenarios, as it benefits from the increased demand for low-carbon and energy-efficient services, such as public transport, recycling, education, health care, and tourism.

The changes in employment by sector for each scenario in 2030, compared to the baseline scenario, are shown in Figure 5. All scenarios have significant and positive employment impacts, especially in the services sector, which is the biggest economic sector in South Africa, accounting for nearly half of the total national output. Moreover, the services sector is labour intensive, so the rise in the output of the services sector has a larger effect on employment. In 2025, the total expected employment gains are about 400 thousand more jobs than the baseline in all other scenarios. Of this, 300 thousand are within the services sector and 100 thousand in other sectors.

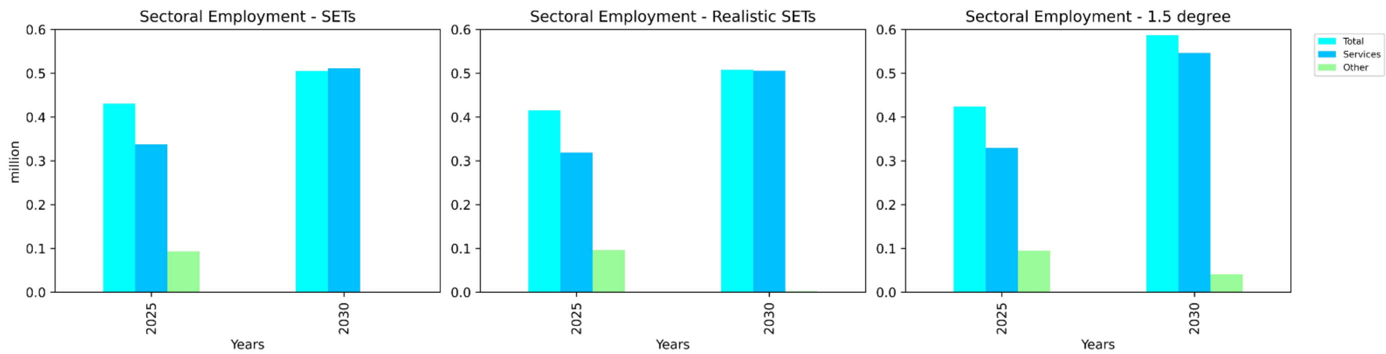

Figure 5 Employment impacts by scenario, absolute difference from baseline

Almost all the new jobs by 2030 will come from the services sector, which will add more than 500 thousand jobs above the current level in the two SETs scenarios. The other sectors will have little change in employment, in the SETs scenarios it is close to zero by 2030, which means either a decrease in demand for that sector, or an increase in productivity if total output is higher. Likewise, in the 1.5 degree scenario, the new jobs are even more than in the SETs scenarios, reaching almost 600 thousand, with 550 thousand of them in the services sector. In all scenarios, the services sector is expected to grow relatively by around 3-

3.5% in 2025 and 5-5.5% compared to the baseline.

The non-services sectors include agriculture, industry, and construction. The non-services sectors include both losing and gaining sub-sectors, but the net impact is still slightly positive in all scenarios, as the gains outweigh the losses. The non-services sectors that benefit the most from the low-carbon transition are the metals, metal products and machinery sector, which create around 75-115 thousand more jobs in all scenarios. The sector is essential for making green technologies that lower carbon emissions, and this increases the demand for it. The two SETs scenarios result in about 75 thousand new jobs each year in 2025 and 2030, while the 1.5 degree scenario raises the 75 thousand estimate to 115 thousand by 2030. Apart from the metals sector, the construction sector, as well as mining and quarrying, are sectors that grow significantly with an extra 15-25 thousand jobs. The metals sector would experience a 20-30% increase in its total employment from the extra jobs, while the other growing sectors would have a 3-7% increase.

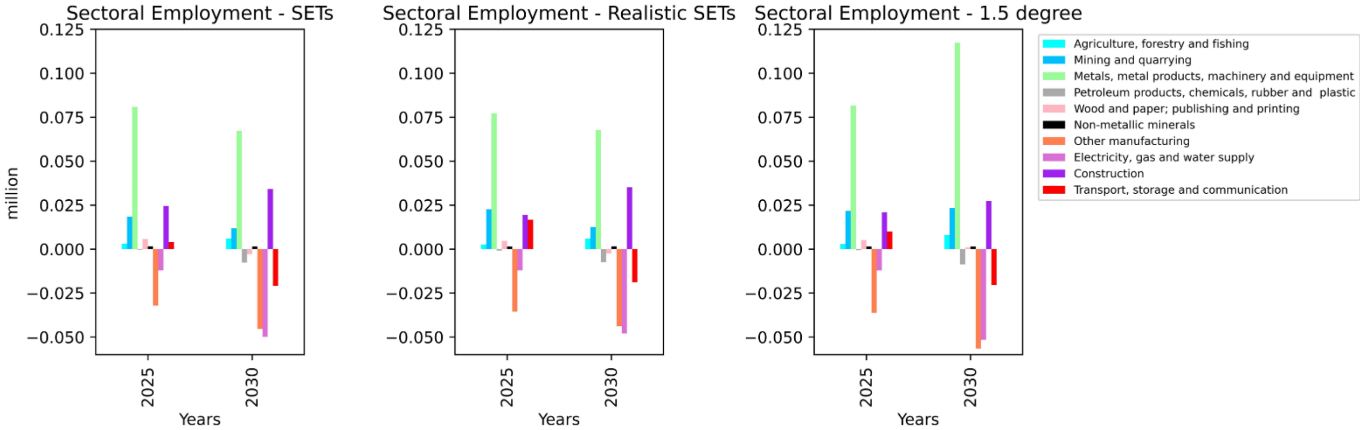

Figure 6 Employment impacts in the non-services sectors by scenario, absolute difference from baseline

The biggest declines are in the sectors of manufacturing and electricity and the sector of transport, storage and communications. Electricity and manufacturing each drop by about 40-50 thousand jobs by 2030, while transport loses around 25 thousand jobs. However, in all decarbonisation scenarios there are more jobs in the transport sector in 2025, due to the higher short-term investment in green technologies.

A key challenge for the shift to a low-carbon economy is to make sure that workers who are displaced from shrinking sectors can access new opportunities in expanding sectors. This requires a high level of labour mobility, both across regions and across occupations. Labour mobility relies on several factors, such as the access to training and education programs, the recognition of skills and qualifications, the provision of social protection and income support, and the elimination of barriers to mobility. Improving labour mobility can help lower the social costs of decarbonisation and increase its benefits, as well as promote innovation and productivity growth.

Distributional impacts

The shift to a low-carbon economy also poses a challenge of making sure that low-income households are not worse off because of the net zero policies. Low-income households usually use more of their income on goods and services that need a lot of energy, such as heating, electricity, and transport. Besides, low-income households may have less opportunity to use low-carbon technologies, such as renewable energy sources or electric vehicles, and may face more difficulties to adjust to the changing labour market conditions. Therefore, it is important to plan policy actions that consider the distributional effects of the shift and provide enough help and compensation to low-income households. This could involve direct transfers, subsidies, tax credits, or specific social programs that aim to lower energy poverty and increase energy efficiency. By reducing the harmful effects of the shift on low-income households, policy makers can improve the social support and possibility of the net zero policies and ensure a just and inclusive shift.

In the SETs, Realistic SETs, and 1.5 degree scenarios, more investment stimulates the economy, but it also slightly reduces households' disposable income and hence consumption compared to the baseline. Household consumption falls by over 5% in all the decarbonisation scenarios in 2025; however, in the SETs scenarios the difference narrows to around 4% by 2030. Household consumption is the lowest in the 1.5 degree scenario because this scenario has the most investments. Even though household consumption is smaller in the decarbonisation scenarios than in the baseline, it is important to note that consumption levels rise in all four scenarios. In the baseline, consumption grows by an average of 2% per year, while in the SET and 1.5°C scenarios, the rates are 1.6% and 1.3%, respectively. Hence, household consumption only rises at a slower pace in these scenarios than in the baseline.

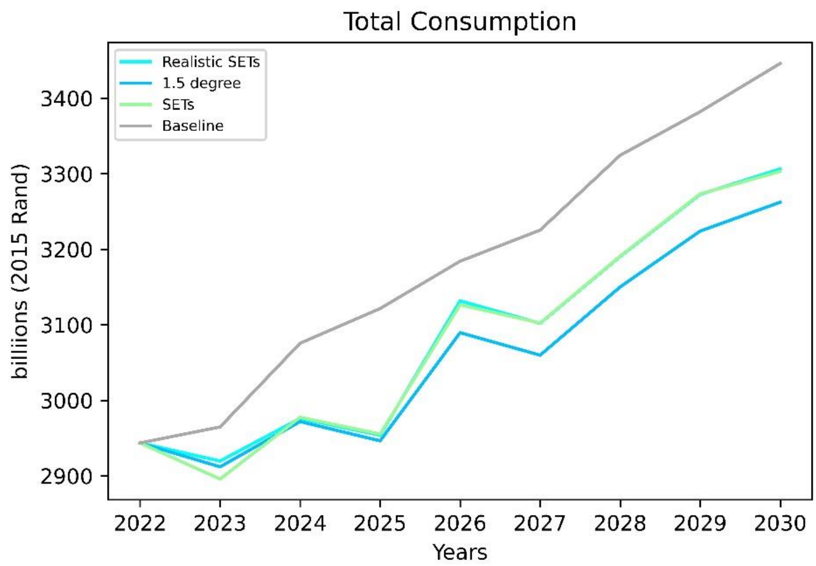

Figure 7 Total household consumption by scenario, relative difference from baseline

The low-carbon investments affect the household deciles in a similar way, but there are minor differences. In 2030, in the SETs and Realistic SETs scenarios the poorest income deciles see the biggest drop in consumption, while in the 1.5 degree it is the richest decile both in 2025 and 2030. This shows that the slightly different distribution of investments across the scenarios can result in different impacts on inequality.

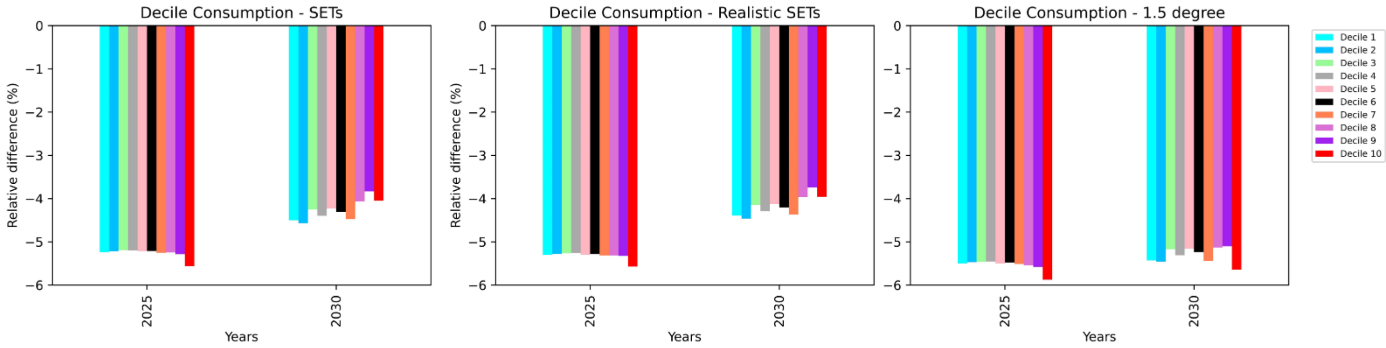

Figure 8 Distributional impacts by scenario, relative difference from baseline

The consumption drop is comparable in percentage terms across the income deciles, but there are big gaps in the absolute amounts. Because the high-income households spend a lot more than the low-income ones, most of the reduction occurs in the top deciles, which implies that the required investment to reach the mitigation targets is mainly paid by the top deciles.