technical SUMMARY

SOUTH AFRICA'S GREENHOUSE GAS MITIGATION POTENTIAL ANALYSIS

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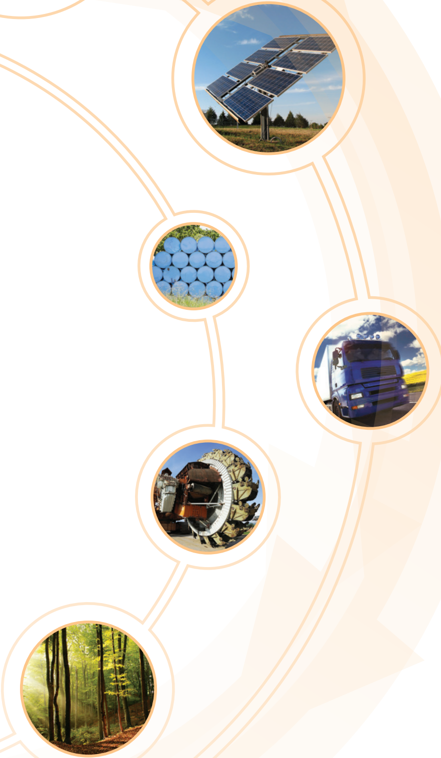

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The suite of reports that make up South Africa's Greenhouse Gas (GHG) Mitigation Potential Analysis include the following:

Technical Summary

Main Report

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List of Abbreviations

Abbreviation	Definition
AD	anaerobic digestion
AFOLU	agriculture, forestry and other land use
CGE	computable general equilibrium
CH_4	methane
CNG	compressed natural gas
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DEA	Department of Environmental Affairs
DERO	desired emission reduction outcome
DoE	Department of Energy
EMU	electric multiple unit (train set)
ERC	Energy Research Centre, University of Cape Town
EV	electric vehicle
FCEV	fuel cell electric vehicle
GDP	gross domestic product
GHG	greenhouse gas
GHGI	National Greenhouse Gas Inventory
GWP	global warming potential
HFC	hydrofluorocarbon
IEP	integrated energy plan
INFORUM	inter-industry forecasting model
IPCC	Intergovernmental Panel on Climate Change
IRP	integrated resource plan

Abbreviation	Definition
$ktCO_2e$	kilo tonnes of carbon dioxide equivalent
LFG	landfill gas
LTMS	Long-Term Mitigation Scenarios
MAC	marginal abatement cost
MACC	marginal abatement cost curve
MCA	multi-criteria analysis
Mt	million tonnes
$MtCO_2e$	million tonnes of carbon dioxide equivalent
MW	megawatt
N_2O	nitrous oxide
NCCRP	National Climate Change Response Policy
NGP	New Growth Path
NT	National Treasury
PHEV	plug-in hybrid electric vehicle
PPD	peak, plateau and decline trajectory
SATIM	South African TIMES model
SF_6	sulphur hexafluoride
TWG-M	Technical Working Group on Mitigation
UNFCCC	United Nations Framework Convention on Climate Change
WAM	'with additional measures' scenario
WEM	'with existing measures' scenario
WOM	'without measures' scenario
ZAR/R	South African Rand

Glossary

Term	Definition
Abatement	Actions taken to reduce GHG emissions (see Mitigation)
Abatement pathway	An abatement pathway defines a set of emission reduction trajectories (pathways), which are technologically achievable over time. The pathway merely identifies what is technically possible without providing a detailed scenario-based description of how that outcome would be achieved.
Carbon dioxide equivalent (CO_2e)	The universal unit of measurement used to indicate the global warming potential (GWP) of each of the six Kyoto greenhouse gases. It is used to evaluate the impacts of releasing (or avoiding the release of) different greenhouse gases.
Carbon intensity	The amount of emissions of CO_2 per unit of GDP. Carbon intensity can also be expressed on a per capita basis.
Climate change	A change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability over comparable time periods (Source: United Nations Framework Convention on Climate Change – UNFCCC).
DERO	Desired emission reduction outcomes (DEA, 2011a).
Direct emissions	Emissions that are produced by organisation-owned equipment or emissions from organisation-owned premises, such as carbon dioxide from electricity generators, gas boilers and vehicles, or methane from landfill sites.
Emission reduction scenario	Scenario describing plausible future emission trajectories to reflect the likely quantity and trend of greenhouse gas emissions released for a given period, including variances related to levels of economic growth, the structural makeup of an economy, demographic development and the effect of emission reduction policies.
Emissions sink	Any process, activity or mechanism that removes a greenhouse gas from the atmosphere.
Emissions source	Any process, activity or mechanism that releases a greenhouse gas, an aerosol or a precursor of a greenhouse or aerosol into the atmosphere. Only greenhouse gases are considered for the purposes of this study.
Emissions trajectory	Future greenhouse gas emissions are the product of complex dynamic systems, determined by driving forces such as demographic development, socio-economic development and technological change. Emission trajectories are alternative computations of the likely quantity and trend of greenhouse gas emissions released for a given period, including variances related to levels of economic growth, the structural makeup of an economy, demographic development and the effect of emission reduction policies.

Term	Definition
Greenhouse gas	Greenhouse gases (GHGs) are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Besides carbon dioxide, nitrous oxide and methane, the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and Perfluorocarbons (PFCs) (IPCC, 2007).
Greenhouse gas sink	A sink is defined as any process, activity or mechanism that removes a GHG from the atmosphere (IPCC, 2007).
Greenhouse gas source	A source is defined as any process, activity or mechanism that releases a GHG, an aerosol or a precursor of a GHG or aerosol into the atmosphere. In this study, only South African sources of GHG emissions have been considered (IPCC, 2007).
Indirect emissions	Emissions that are a consequence of the activities of the reporting company but occur from sources owned or controlled by another organisation or individual. They include all outsourced power generation (e.g. electricity, hot water), outsourced services (e.g. waste disposal, business travel, transport of company-owned goods) and outsourced manufacturing processes. Indirect emissions also cover the activities of franchised companies and the emissions associated with downstream and/or upstream manufacture, transport and disposal of products used by the organisation, referred to as product life-cycle emissions.
Integrated Energy Plan (IEP)	An energy planning document managed by the Department of Energy that provides overall national energy sector guidance and macro-planning. An IEP considers the appropriate balance between demand and supply options for providing the requisite energy services in South Africa, based on the inclusion and consideration of all fuel types and energy carriers. Normally it covers a twenty year planning period and has the overall objective of balancing energy supply and demand with resources, in concert with safety, health and environmental issues.
Integrated Resource Plan (IRP)	South Africa's Integrated Resource Plan for Electricity (DoE, 2011), published as a notice under the Electricity Regulation Act No. 4 of 2006) is a planning framework for managing electricity demand in South Africa for the period 2010 to 2030. The Integrated Resource Plan (IRP) 2010 assesses a range of potential scenarios to deliver the country's future electricity demand, based on an assumed average economic growth of 4.6% for the period. The IRP estimates that electricity demand by 2030 will require an increase in new generation capacity of 52 248MW. This substantial increase in capacity is required to address projected demand, the decommissioning of a number of existing power stations (commencing from 2022 onwards), and the need to provide for an adequate electricity reserve margin.

Term	Definition
Marginal abatement cost curve (MACC)	A marginal abatement cost curve (MACC) shows the costs and potential for emissions reduction from different measures or technologies, ranking these from the cheapest to the most expensive to represent the costs of achieving incremental levels of emissions reduction.
Mitigation measures	Typically, mitigation measures are technologies (i.e. a piece of equipment or a technique for performing a particular activity), processes, and practices, which, if employed, would reduce GHG emissions below anticipated future levels, when compared to the status quo or existing counterfactual technique normally employed.
Mitigation opportunity	An anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases.
Mitigation potential	The mitigation potential of a measure is the quantified amount of GHGs that can be reduced measured against a baseline (or reference). The baseline (or reference) is any datum against which change is measured. Mitigation potential is represented in tonnes of carbon dioxide equivalent (tCO_2e).
New Growth Path (NGP)	The New Growth Path (NGP), released in November 2010, represents government's new 'framework for economic policy and the driver of the country's jobs strategy'. The NGP prioritises job creation in all economic policies and outlines strategies to enable South Africa to develop in an equitable and inclusive manner. A particular focus is placed on investment in infrastructure and skills development. The NGP's priority sectors are manufacturing; mining and beneficiation; agriculture, rural development and agro-processing; infrastructure development; tourism; the creative industries; and certain high-level business services. The NGP targets 5 million new jobs by 2020.
Peak, Plateau and Decline (PPD) trajectory	South Africa's benchmark national GHG emissions trajectory range. According to the Peak, Plateau And Decline (PPD) emissions trajectory, South Africa's long-term mitigation strategy calls for the carbon emissions trajectory to peak between 2020 and 2025, plateau for approximately a decade and decline in absolute terms thereafter (DEA, 2011a).
Projection	In general usage, a projection can be regarded as any description of the future and the pathway leading to it.
Scenario	A scenario is a coherent, internally consistent and plausible description of a possible future state of the world. It is not a forecast; rather, each scenario is one alternative image of how the future may unfold. A projection may serve as the raw material for a scenario, but scenarios often require additional information (e.g., about baseline conditions).

Term	Definition
Technical mitigation potential	Technical mitigation potential is the amount by which it is possible to reduce GHG emissions or improve energy efficiency by implementing a technology or practice that has already been demonstrated. In some cases implicit economic considerations are taken into account (IPCC 2007).
Technical Working Group on Mitigation (TWG-M)	In order to develop the mitigation approaches set out in the National Climate Change Response Policy, the Department of Environmental Affairs established a Technical Working Group on Mitigation. The purpose of the TWG-M was to provide technical inputs and support identification of mitigation options, as well as to assist the DEA to coordinate and align mitigation work at sectoral and national levels.

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1. Introduction

Under the United Nations Framework Convention on Climate Change (UNFCCC) and its Kyoto Protocol, South Africa is committed to contributing its fair share to global greenhouse gas (GHG) mitigation efforts in order to keep the temperature increase well below 2°C. Under the Copenhagen Accord, South Africa will implement mitigation actions that will collectively result in a 34% and a 42% deviation below its business as usual emissions growth trajectory by 2020 and 2025 respectively. In accordance with Article 4.7 of the UNFCCC, the extent to which this outcome can be achieved depends on the extent to which developed countries meet their commitment to provide financial, capacity-building, technology development and technology transfer support to developing countries (UN, 1992).

In order to meet this obligation and in developing a comprehensive policy framework for responding to climate change, Government has developed the National Climate Change Response Policy (NCCRP) (DEA, 2011a). It presents the vision for an effective climate change response and the long-term transition to a climate-resilient, equitable and internationally competitive lower-carbon economy and society – a vision premised on Government's commitment to sustainable development and a better life for all. The Response Policy outlines a strategic response to climate change within the context of South Africa's broader national development goals, which include economic growth, international economic competitiveness, sustainable development, job creation, improving public and environmental health and poverty alleviation.

The NCCRP defines it as a strategic priority to prioritise cost effective and beneficial mitigation policies, measures and interventions that lead to a reduction in emissions below the country's business as usual trajectory as measured against a benchmark Peak, Plateau and Decline (PPD) GHG emission trajectory. According to the PPD, South Africa's long-term mitigation strategy calls for the carbon emissions trajectory to peak in the period 2020 to 2025, then plateau for up to 10 years thereafter and decline in absolute terms by 2050.

One of the key elements in the overall approach to mitigation is identifying desired sectoral mitigation contributions. This involves defining desired emission reduction outcomes for each significant sector and subsector of the economy based on an in-depth assessment of the mitigation potential, best available mitigation options, science, evidence and a full assessment of the costs and benefits. In accordance with this requirement and as part of its mandate to implement the NCCRP, the Department of Environmental Affairs has commissioned this Greenhouse Gas Mitigation Potential Analysis for South Africa. Through a process of identifying and analysing mitigation options, the overall objective of this study is to present a set of viable options for reducing GHGs in key economic sectors. Options for reducing GHG emissions presented should be realistic, aligned with national development objectives and based on best available information. In accordance with this, the three required outcomes of the study were:

- Projection of national GHG emissions into the future
- Identification and analysis of mitigation opportunities in key sectors of the economy
- Socio-economic and environmental assessment of the identified mitigation options

In meeting these objectives, two projections of national GHG emissions have been developed. Both projections assume a targeted level of economic growth which is aligned with national development plans. The two GHG projections account for future emissions in the absence of any mitigation actions (since 2000) and on the basis of only those mitigation actions implemented prior to 2010, respectively. The sensitivity of GHG emissions projections to economic growth assumptions has also been assessed. Mitigation options have been identified and analysed and combined to construct marginal abatement cost curves (MACCs) for key sectors and subsectors. The key sectors are energy, industry, transport, waste, and agriculture, forestry and other land use (AFOLU). The potential socio-economic and environmental impacts of the identified options have been assessed and a multi-criteria analysis (MCA) framework for decision-making has been developed. Based on the MACCs and using the outputs from the MCA model, an estimate of technical mitigation potential (assuming all identified mitigation options are fully implemented) at the national scale has been developed. These inputs have also been combined to develop a set of illustrative national abatement pathways. A summary of each of these outputs is provided.

2. Projecting Economic Growth

GHG emissions projections developed under this study were based on a targeted level of future economic growth in accordance with the "moderate growth rate" defined by National Treasury. The projection of moderate growth assumes that the economy will grow steadily, with continued skills constraints and infrastructure bottlenecks in the short- to medium-term. The moderate growth scenario forecasts real growth in gross domestic product (GDP) of 4.2% per annum over the medium-term (defined in the Draft Integrated Energy Plan as 2015–2020 (DoE, 2013) and 4.3% per annum over the long-term (2021–2050), according to the 2012 Medium Term Budget Policy Statement (NT, 2012).

A detailed inter-industry forecasting model (INFORUM) was used as the basis for projecting economic growth in all sectors of the South African economy. The INFORUM modelling system is macroeconomic, dynamic and multi-sectoral in nature. It depicts the behaviour of the economy in its entirety, accommodating the workings of all the major markets in an interrelated, dynamic framework. It therefore lends itself to projecting aggregate GDP and all its components, as well as the demand categories that determine GDP, instantaneously and dynamically.

The multi-sectoral system includes an input-output (I-O) table and accounting which shows the magnitude and diversity of intermediate consumption within the context of the current economic structure. This allows the system to integrate intermediate input prices with sectoral price formation which ultimately determines overall price levels in the economy. This is done through the use of behavioural equations for final demand that depend on prices and output; and functions for income that depend on production, employment and other variables.

Another important feature of this macroeconomic multi-sectoral model is its bottom-up approach. In this approach, the model mimics the actual workings of the economy in that the macroeconomic aggregates are built up from detailed levels at the industry or product level, rather than first being estimated at the macroeconomic level and then simply distributed among sectors.

All econometric models, including the INFORUM model, have certain limitations, since they are built mainly on historic information and the structure of the economy changes slowly over time. As a consequence, they are only ideally suitable for impact analysis over a medium term horizon. Over the long term this model, like others, is unlikely to adequately capture structural changes that might occur in the economy; for example, as a result of a shift from coal-based electricity generation to gas-based electricity generation. To account for this, the intermediate production structure of the INFORUM model was adjusted in an attempt to take into account changes that will be brought about by the mitigation options, more specifically those affecting the energy sector.

A further limitation of the INFORUM model is that it does not automatically take certain constraints into account, as computable general equilibrium (CGE) models do when conducting impact analyses. However, this has been accounted for by adjusting monetary and fiscal policy interventions through changing the interest rate, government spending and tax rates, to restore certain requirements, such as a specific percentage GDP deficit on the current account of the balance of payments.

The final demand projections for South Africa for the medium growth scenario are set out in Table A below. These projections form the base for the production projections for the 46 sectors used in the INFORUM model. The forecasts by National Treasury are also included for comparison. The projection of growth in GDP per annum (at constant 2012 prices) from the INFORUM model for the full period is 4.0%, slightly lower than National Treasury's forecast for the Integrated Energy Plan model of 4.2%.

Table A: Final demand projections for the medium growth scenario based on the INFORUM model

GDP and final demand components (2012 constant prices)	Growth rate per annum over period (%)						
	2013-2052	2013	2014	2015-2022	2023-2032	2033-2042	2043-2052
Final consumption expenditure by households	3.9	2.2	3.8	3.6	3.8	4.2	4.3
Final consumption expenditure by government	3.9	4.4	5.1	3.7	3.8	4.0	4.0
Gross capital formation	5.0	1.6	3.7	4.8	5.0	5.3	5.3
Exports of goods and services	3.4	2.8	3.0	3.3	3.3	3.5	3.6
Imports of goods and services	4.1	2.4	3.5	4.1	4.1	4.2	4.3
Total GDP (2012 constant prices)	4.0	2.4	3.7	3.6	3.9	4.3	4.5
National Treasury forecast	4.2	3.0	3.8	4.2	4.3	4.3	4.3

As stated above, GDP growth in individual industry subsectors is aligned to targeted levels of national economic growth and projections of growth in individual sectors driven by the INFORUM model.

3. Projecting Reference Case Greenhouse Gas Emissions

Projections of GHG emissions to 2050 from all sectors included in the draft Greenhouse Gas Inventory for South Africa (GHGI) (DEA, 2013) have been provided. Two different projections have been produced:

A reference case projection: This is a projection of emissions from 2000 to 2050 which assumes that no climate change mitigation actions have taken place since 2000. Thus for the period from 2000 to 2010, it does not follow the actual observed path of emissions but the path that emissions would have taken if none of the climate change mitigation actions implemented in this period had taken place. The UNFCCC refers to this as a 'without measures' (WOM) projection (UNFCCC, 2000).

A 'with existing measures' (WEM) projection: This projection incorporates the impacts of climate change mitigation actions including climate change policies and measures implemented to date. For the period 2000 to 2010 the projections follow the actual path of observed emissions.

The projections were produced using a bottom-up methodology; models were produced for each sector and are described fully in the technical appendices for each sector. Overall the projections are consistent with the moderate growth rate for the economy, based on the growth rates for particular economic sectors as defined in the macroeconomic modelling. The methodology used in the models is consistent with that used in the draft GHGI, and historic emissions for the period from 2000 to 2010 are taken from the latest (draft) version of the GHGI for the WEM projection, updated in some cases by more recent information from industry. The largest revision is to the power sector, where information from Eskom on the energy content of coal used for generation leads to an estimate of historic power sector emissions in this study which are on average 20% lower than those estimated in the draft GHGI.

Projections of all GHGs in the economy are shown for the reference case WOM projection in Figure A and Table B. It is projected that if no climate change mitigation measures had been implemented then emissions in 2010 would have been 28% higher (at 555,151 ktCO_2e) than in 2000 (432,467 ktCO_2e). Projected emissions continue to rise steadily, due largely to the assumed economic growth, reaching 903,700 ktCO_2e by 2030, and 1,692,471 ktCO_2e by

2050, almost four times more than emissions in 2000. The largest contributor to emissions is the power sector, where the carbon intensity is high as it is predominantly based on coal-fired generation. In 2010, together with other energy related sectors it accounted for 58% of emissions. If emissions from the power sector are allocated to end users of electricity, then the industry sector (which includes buildings) dominates emissions, accounting for 63% of emissions in 2010 (rising to 76% by 2050).

In the WEM projection (Figure B and Table C), where climate change mitigation measures which have already been implemented are considered, together with the impact of existing climate change policies and measures, total GHG emissions are forecast to be 25,479 ktCO_2e lower than in the WOM scenario in 2010 and 99,866 ktCO_2e lower in 2050. The reduction in 2010 is mainly due to measures already implemented by industry. The reduction in 2050 is predominantly due to some decarbonisation of the power sector as a result of commitments by the power sector under the Integrated Resource Plan (IRP) (DoE, 2011).

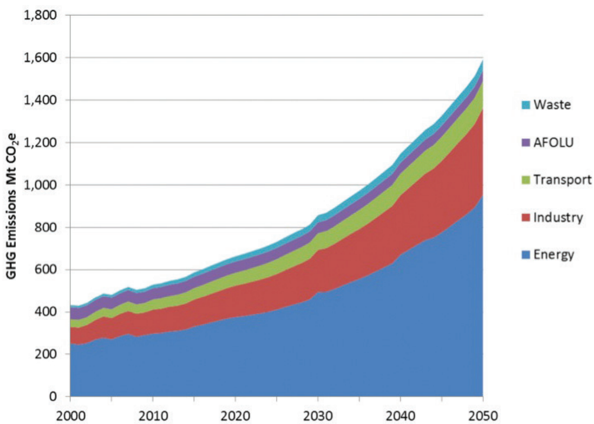


Figure A: National GHG emissions under the reference case 'without measures' (WOM) projection, showing a breakdown per sector (2000–2050)

Table B: National GHG emissions under the reference case WOM projection (2000–2050) (ktCO$_2$e)

	2000	2010	2020	2030	2040	2050
Energy	251,718	323,174	410,788	537,301	741,938	1,042,549
Industry	78,265	113,116	149,182	199,296	281,609	409,578
Transport	35,481	47,715	61,070	80,411	106,678	136,684
AFOLU	56,801	54,311	53,268	52,506	52,216	52,159
Waste	10,202	16,836	24,999	34,186	43,251	51,502
Total	**432,467**	**555,151**	**699,307**	**903,700**	**1,225,692**	**1,692,471**

Table C: National GHG emissions under the 'with existing measures' (WEM) projection (2000-2050) (ktCO$_2$e)

	2000	2010	2020	2030	2040	2050
Energy	251,718	298,109	375,994	494,066	670,107	953,956
Industry	78,265	113,116	149,182	199,296	281,609	409,578
Transport	35,481	47,715	60,242	78,106	101,066	125,825
AFOLU	56,801	54,311	53,268	52,506	52,216	52,159
Waste	10,202	16,421	24,584	33,771	42,836	51,087
Total	**432,467**	**529,672**	**663,270**	**857,745**	**1,147,834**	**1,592,605**

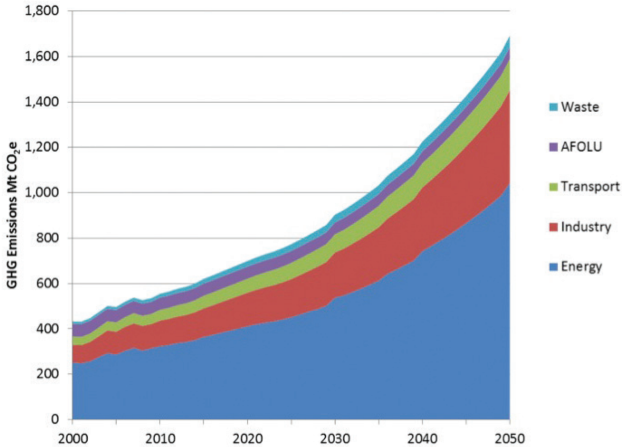


Figure B: National GHG emissions under the WEM projection, showing a breakdown per sector (2000–2050).

4. Sensitivity of Emissions Projections to Economic Growth

A sensitivity analysis was carried out based on a higher and lower rate of projected economic growth. These growth assumptions were based on the inputs provided by National Treasury. Following the 2012 Budget forecast (NT, 2012), the low-growth scenario assumed real GDP growth of 3.8% per annum over the medium and long-term. Under the high growth scenario, real growth was assumed to be 4.8% per annum over the medium-term and 5.4% per annum over the long-term (DoE, 2013).

The changes in growth were used to derive high and low growth emissions projections for the energy, industry and waste sectors. As projections for the transport and AFOLU sectors are based on forecasts of transport demand and agricultural production made by other studies, it was outside the scope of this study to update these projections.

Table D gives a sectoral breakdown of emissions under the low and high economic growth scenarios. Overall, with lower economic growth, emissions are projected to be 15% (232,079 ktCO_2e) lower than in the medium growth scenario by 2050 (refer to Table C), reducing the growth in emissions between 2010 and 2050 by 44%. This is driven by lower emissions in the industry and energy sectors. Emissions from industry are 23% (95,548 ktCO_2e) lower under the low growth scenario in 2050 and emissions from the energy sector 14% (135,509 ktCO_2e) lower. Emissions from the waste sector are only 2% lower in the high GDP per capita rates forecast for 2050, as waste generation per capita shows little increase with rises in GDP per capita.

If economic growth were to be higher than the moderate growth rate assumed for the WEM projection, then emissions are projected to be 18% (289,718 ktCO_2e) higher in 2050 than under a medium growth scenario, increasing the growth in emissions between 2010 and 2050 by 55% to 355%. Additional emissions come from the industry sector (133,306 ktCO_2e) which grows at a faster rate, and from the energy sector (155,983 ktCO_2e), where emissions from the power sector increase to meet additional electricity demand from the industry sector.

Table D: National GHG emissions under the WEM projection (2000–2050) for low and high economic growth ($ktCO_2e$)

	2020	2030	2040	2050
Low economic growth				
Energy	365,256	467,470	602,590	818,447
Industry	140,551	175,115	231,045	314,030
Transport	60,242	78,106	101,066	125,825
AFOLU	53,268	52,506	52,216	52,159
Waste	24,404	33,000	41,850	50,064
Total	**643,720**	**806,197**	**1,028,766**	**1,360,526**
High economic growth				
Energy	388,652	527,038	748,533	1,109,939
Industry	157,420	225,076	343,547	542,884
Transport	60,242	78,106	101,066	125,825
AFOLU	53,268	52,506	52,216	52,159
Waste	24,485	33,887	43,166	51,515
Total	**684,066**	**916,613**	**1,288,527**	**1,882,323**

5. Identification and Analysis of Mitigation Potential in Key Sectors

Mitigation options have been identified and analysed and then combined to construct MACCs for key sectors and subsectors. The mitigation potential of a measure was defined as the quantified amount of GHGs than can be reduced measured against a baseline (or reference). The use of the term potential is consistent with the IPCC's Fourth Assessment Report (IPCC, 2007), where it was used to report the quantity of GHG mitigation compared with a baseline or reference case that can be achieved by a mitigation option with a given cost (per tonne) of carbon avoided over a given period. Mitigation potential is represented in equivalent tonnes of carbon dioxide (tCO_2e).

Estimates of mitigation potential for key sectors have been calculated independently of changes in other sectors.

In all cases, the sectoral and subsectoral mitigation potential estimates have been developed in close consultation with a broad range of stakeholders, including industry, government and civil society – through a mechanism of sector specific task-teams established for this purpose. For the purposes of this study, the reference case projection of GHG emissions is defined as the 'with existing measures' (WEM) projection. The mitigation potential of all measures was calculated with reference to this projection.

Technical assumptions which govern the selection of measures and the construction of MACCs for all sub-sectors are discussed in detail in the technical appendices for each sector; and summarised in the Main Report.

This report covers the five key sectors. Within each of these key sectors, mitigation potential has been analysed for a number of sectors and subsectors. These are shown in Table E.

Table E: List of key sectors, sectors and subsectors covered in the mitigation potential analysis.

Key Sector	Sector	Subsector
Energy	Power	Electricity and heating
	Non-power	Petroleum refining
		Other energy industries
		Coal mining
		Oil and gas
Industry	Metals	Aluminium production
		Ferroalloys production
		Iron and steel production
	Minerals	Cement production
		Lime production
	Chemicals	Chemicals production
	Mining	Surface and underground mining
	Buildings	Residential
		Commercial/institutional
	Other	Pulp and paper production
Transport	Road	Road
	Rail	Rail
	Aviation	Aviation
Waste	Waste	Municipal waste
Agriculture, forestry and other land-use (AFOLU)	AFOLU	AFOLU

The processes and procedures for identifying and quantifying mitigation options are outlined in the Main Report. In summary, the final list of measures and the estimates of mitigation potential are derived initially from international GHG mitigation best practice technologies and best available techniques, and verified and confirmed in consultation with South African sector experts and stakeholders.

MACCs were developed at national, key sector and subsector levels. MACCs show the costs and potential (in tonnes of CO_2e abated) for emission reductions from different measures or technologies, ranking these from the cheapest to the most expensive to represent the marginal costs (in rand (R) per tonne of CO_2e abated) of achieving incremental levels of emissions reduction. The information in a MACC represents a static snapshot at a given point in time. The MACCs in this study provide snapshots for 2020, 2030 and 2050, presenting the annual technical mitigation potential relative to the reference WEM emissions projection. MACCs for all subsectors and sectors are shown in the Main Report.

A more detailed explanation of how the MACCs were developed and the assumptions which underpin them is provided in the Main Report, and in the individual sector appendices. It is noted that the MACCs shown in the report are based on sectoral estimates of mitigation potential and marginal abatement costs. All decisions to implement mitigation measures will be site specific and so the actual estimates of mitigation potential and marginal abatement costs may differ from those shown in the report.

It is also noted that other key inputs to the sectoral MACCs may differ in commercial applications. For example, a discount rate is applied to costs and benefits arising in the future, in order to report them in present-day value terms. The project team adopted a capital discount rate of 11.3% when generating the MACCs, in accordance with guidelines provide by National Treasury.

Similarly, while a specific set of energy prices were assumed for the study, it is recognised that when developing sector specific feasible mitigation options, prices applicable to the specific activity will need to be applied.

All of the mitigation measures and associated estimates of abatement potential and marginal abatement costs are presented in Table 32 of the Main Report for each of the three snapshots in time considered in this study: 2020, 2030 and 2050. The identifier associated with each measure is used in the legend of the MACC summaries per sector shown below. These identifiers are used consistently throughout the reports and can be used to look up measures and associated values in Table 32.

5.1 Mitigation Potential for the Energy Sector

Mitigation opportunities for energy sector emissions have focused on four separate sources of emissions, described below:

- Combustion emissions from the use of fuels in stationary combustion. Fuel combustion may be defined as the intentional oxidation of materials within an apparatus that is designed to provide heat or mechanical work to a process, or for use away from the apparatus.
- Fugitive emissions, which escape without combustion (e.g. leakage of natural gas and the emissions of methane during coal mining and flaring during oil/gas extraction and refining).
- Process emissions, from production processes, from the use of greenhouse gases in products, and from non-energy uses of fossil fuel.
- Indirect emissions from the consumption of electricity.

A summary of technical mitigation potential in 2020, 2030 and 2050 for all sectors and sub-sectors covered in the assessment of the energy sector is shown in Table F below. In calculating total technical mitigation potential for the energy sector, abatement estimates for the other energy industries and petroleum refining sectors show only the impact of measures which can be implemented in the sector. The estimates do not show savings which might occur due to a reduced need for new capacity in the sector if demand for liquid fuel is reduced as a result of successful implementation of mitigation options in the transport sector. If all transport mitigation options were to be successfully implemented then emissions in the energy sector could be reduced by a further 20.3 Mt CO_2 in 2050.

In summary, abatement options from the power sector dominate abatement potential for the energy sector, accounting for between 79% and 89% of total mitigation potential. The second largest contributor is the other energy industries sector, representing 3,529, 31,181 and 43,630 ktCO_2e in 2020, 2030 and 2050, respectively.

Table F: Summary of technical mitigation potential for the energy sector, including a breakdown by sector and subsector and showing results for 2020, 2030 and 2050 ($ktCO_2e$)

Sector	Subsector	2020	2030	2050
Power		28,585	137,149	416,555
	% Total	86.47%	79.48%	89.16%
Non-Power	Coal mining	385	1,284	3,112
	Oil and gas*	0	0	0
	Other energy industries	3,529	31,181	43,630
	Petroleum refining	558	2,951	3,891
	Subtotal	4,472	35,415	50,632
	% Total	13.53%	20.52%	10.84%
Total		**33,057**	**172,565**	**467,186**

** Mitigation potential for measures in the oil and gas sector has been excluded as outliers from this portion of the analysis. Please refer to Technical Appendix C: Energy Sector for details of abatement and marginal abatement costs.*

Mitigation potential expressed relative to the reference WEM projection is shown for each sector and subsector in Table G. Results indicate an 8.8%, 34.9% and 49% reduction relative to the WEM projection in 2020, 2030 and 2050, respectively.

Table G: Percentage reduction in reference WEM emissions for the energy sector, assuming all technical mitigation potential is implemented (%)

Sector	2020	2030	2050
Power	7.6	27.8	43.7
Non-Power	1.2	7.2	5.3
Energy sector total	8.8	34.9	49.0

A similar analysis conducted for the subsectors which comprise the non-power energy sector is shown in Table H. Results indicate a total mitigation potential of 7%, 43% and 42% relative to the reference case WEM projection. The vast majority of these potential savings originates from the other energy industries subsector.

Table H: Percentage reduction in reference WEM emissions for the non-power energy sector, assuming all technical mitigation potential is implemented (%)

Sector	2020	2030	2050
Coal Mining	0.6	1.5	2.6
Oil and Gas	0.0	0.0	0.0
Other Energy Industries	5.5	37.6	36.1
Petroleum Refining	0.9	3.6	3.2
Non-power energy sector total	7.0	42.7	41.9

5.2 Mitigation Potential for the Industry Sector

GHG mitigation opportunities are presented that cover emissions from three separate sources, described below.

- Emissions from industrial processes, from the use of greenhouse gases in products, and from non-energy uses of fossil fuel.
- Emissions from the use of fuels in stationary combustion. These emissions result from the combustion of fuels in order to provide heat or mechanical work.
- Indirect emissions from the consumption of electricity, where fossil fuels are consumed in order to generate the electricity.

A summary of technical mitigation potential in 2020, 2030 and 2050 for all sectors and subsectors covered in the assessment of the industry key sector is shown in Table I below.

In 2020, the metals sector accounts for just over one quarter of mitigation potential for the industry sector (12,249 ktCO_2e, 26%). This rises to 86,502 ktCO_2e (33%) in 2050. The proportion of total mitigation potential accounted for by the minerals sector rises from 3.5% in 2020 (1,553 ktCO_2e) to 8.5% (22,072 ktCO_2e) in 2050. By comparison, the buildings sector contribution to total mitigation potential drops from 49% (22,066 ktCO_2e) in 2020 to 30% (85,668 ktCO_2e) in 2050. The mining sector contribution to total mitigation potential is relatively stable, rising slightly from 12.5% (5,613 ktCO_2e) in 2020 to 17.7% (45,847 ktCO_2e) in 2050.

Mitigation potential expressed as a percentage of the reference WEM projection is shown for each sector and subsector in Table J.

Table I: Summary of technical mitigation potential for the industry sector, including a breakdown by sector and subsector and showing results for 2020, 2030 and 2050 (ktCO_2e)

Sector	Subsector	2020	2030	2050
Metals	Aluminium production	844	3,045	11,445
	Ferroalloys	5,579	13,407	30,392
	Iron and steel	5,825	19,507	44,665
	Subtotal	**12,249**	**35,959**	**86,502**
	% Total	**27.32%**	**34.63%**	**33.47%**
Minerals	Cement	1,258	3,666	15,059
	Lime	295	820	7,014
	Subtotal	**1,553**	**4,486**	**22,072**
	% Total	**3.46%**	**4.32%**	**8.54%**
Chemicals	Chemicals production	938	2,582	6,226
	% Total	**2.09%**	**2.49%**	**2.41%**
Pulp and paper	Pulp and paper	2,423	5,618	12,137
	% Total	**5.40%**	**5.41%**	**4.70%**
Other mining	Surface and underground mining	5,613	16,807	45,847
	% Total	**12.52%**	**16.18%**	**17.74%**
Buildings	Residential	14,551	23,375	42,303
	Commercial	7,515	15,023	43,365
	Subtotal	**22,066**	**38,398**	**85,668**
	% Total	**49.21%**	**34.70%**	**30.30%**
Total		**44,842**	**103,850**	**258,453**

Table J: Percentage reduction in reference WEM emissions for the industry sector, assuming all technical mitigation potential is implemented (%)

Sector	2020	2030	2050
Metals	8	18	21
Minerals	1	2	5
Chemicals	1	1	2
Mining	4	8	11
Buildings	15	19	21
Other: pulp & paper	2	3	3
Total	**30**	**52**	**63**

5.3 Mitigation Potential for the Transport Sector

The assessment of mitigation potential in the transport sector covers road and rail transport as well as civil aviation. For maritime transport, insufficient information was available on the emissions associated with inland navigation and coastal and short sea shipping was estimated to represent less than 1% of total freight transport. The sector was excluded as a consequence. Transportation of certain products (e.g. primary fuels) can also be made using pipelines. Within the GHGI, the emissions associated with energy used in pipeline transportation and fugitive releases are allocated to other sectors, and are thus not discussed in this sector.

A range of potential mitigation measures were identified that could potentially be applied to the transport sector to deliver emissions reductions by 2050. These were discussed and agreed with the transport task team. The list of mitigation opportunities was categorised into the following types:

- Modal shift
- Demand reduction measures
- More efficient vehicle technologies
- More efficient operations
- Alternative lower-carbon fuels

The analysis shows that if all technically available mitigation potential in the transport sector was implemented, the GHG emissions could be reduced by 11,869 ktCO_2e in 2020, 39,525 ktCO_2e by 2030 and 117,151 ktCO_2e by 2050 (Table K).

Table K: Total mitigation potential for the transport sector, assuming all measures are implemented (in ktCO_2e)

Subsector	Measure	2020	2030	2050
Aviation	Aviation – improved efficiency - retrofit	1	-	-
	Aviation – early retirement	-	-	6
	Aviation – biofuels	212	571	969
Subsector total		**213**	**571**	**975**
Rail	Rail – improved efficiency – electrical multiple unit (EMU) train sets	N/A	102	112
	Rail – improved efficiency – diesel	47	147	372
	Rail – alternative fuels –hybrid diesel	N/A	39	128
	Rail – Metrorail voltage upgrade	N/A	48	48
	Rail – alternative fuels – compressed natural gas (CNG)	N/A	N/A	66
	Rail - biofuels	33	74	380
Subsector total		**80**	**410**	**1,107**

Subsector	Measure	2020	2030	2050
Road	Road – alternative fuels - CNG	20	246	1,579
	Road – alternative fuels – diesel plug-in hybrid electric vehicle (PHEV)	22	202	1,152
	Road – improved efficiency – petrol internal combustion engine (ICE)	4,349	12,538	25,241
	Road – alternative fuels – petrol hybrid electric vehicle (HEV)	450	1,872	7,522
	Road – improved efficiency – diesel ICE	1,875	8,122	28,448
	Road – alternative fuels – petrol PHEV	64	467	1,951
	Road – alternative fuels – fuel cell vehicle (FCEV)	-	4	616
	Road – alternative fuels – diesel HEV	176	933	5,041
	Road – alternative fuels – electric vehicle (EV)	-	57	750
	Road – shifting passengers from cars to public transport	820	3,087	9,396
	Road – shifting freight from road to rail	1,840	2,729	2,997
	Road – biofuels	1,959	8,286	30,374
Subsector total		**11,575**	**38,545**	**115,068**
TOTAL		**11,869**	**39,525**	**117,151**
TOTAL % reduction (relative to WEM with indirect emissions included)		**12%**	**30%**	**54%**

Mitigation potential expressed relative to the reference WEM projection is shown for each sector and subsector in Table L.

Table L: Percentage reduction in reference WEM emissions for the transport sector, assuming all technical mitigation potential is implemented (%)

Sector	2020	2030	2050
Road	13	32	59
Rail	2	6	11
Aviation	4	8	11
Total	**12**	**30**	**54**

5.4 Mitigation Potential for the Waste Sector

This section provides an overview of mitigation opportunities for the waste sector. The assessment of mitigation opportunities focused on the municipal waste sector (due to a lack of data on industrial waste disposal) and considered emissions from the following IPCC emission sources:

- 4A1 Managed waste disposal sites
- 4D Wastewater treatment and discharge

Mitigation opportunities from managed waste disposal sites arise from reductions of methane (CH_4) emissions contained in landfill gas which is generated as a result of the anaerobic decomposition of organic waste deposited in the landfill. Wastewater treatment options result from emissions of both CH_4 and N_2O depending on the treatment method.

Options identified for managed waste disposal fall into two categories. Firstly, better management of landfill sites, with recovery and flaring or use of landfill gas and secondly, alternative waste disposal options which would allow diversion of organic waste from the conventional landfill activities. While landfilling of waste is the primary means of managed waste disposal currently, there is interest in South Africa in exploring other waste management options. For example the Government is currently drafting a strategy on composting. While the options considered are focused on municipal solid waste, there may be other opportunities for using waste as a fuel.

The final list of measures considered for the waste sector includes:

- Managed waste disposal measures:
  - landfill gas collection to electricity
  - landfill gas collection and flaring
  - anaerobic digestion
  - energy from waste
  - windrow composting
  - home composting
- In vessel composting
- Paper recycling

Wherever possible, the assessment of mitigation options and potential has been aligned to the National Waste Management Strategy (DEA, 2011b), which promotes waste minimisation, re-use, recycling and recovery of waste while ensuring the effective and efficient delivery of waste services. Despite this, a mitigation option for waste minimisation was not evaluated for the purposes of the MACC due to a lack of information to evaluate how this might be achieved in practice, and data on the costs and reductions which might be achieved. Waste-water treatment options were not considered for the purposes of the MACC analysis due to a lack of data to assess mitigation potential and due to the small size of the emissions source in South Africa.

If all technically available mitigation potential in the waste sector was implemented, then the current analysis shows that GHG emissions could be reduced by 9,977 ktCO_2e in 2020, 22,122 ktCO_2e by 2030 and 39,658 ktCO_2e by 2050. This represents a total potential reduction of 41%, 66% and 78% (respectively) of reference emissions under the WEM projection (Table M).

Table M: Total mitigation potential for the waste sector, assuming all measures are implemented (in $ktCO_2e$)

Subsector	Measure	2020	2030	2050
Managed waste disposal	Land fill gas (LFG) recovery and generation	4,843	11,325	28,020
	Paper recycling	1,506	2,802	3,223
	LFG recovery and flaring	2,076	2,912	3,002
	Energy from waste	869	2,935	2,913
	AD	234	1,198	1,354
	In-vessel composting	83	112	197
	Home-composting programme	189	682	771
	Windrow composting	176	155	176
TOTAL		**9,977**	**22,122**	**39,658**
TOTAL % reduction (relative to WEM)		**41%**	**66%**	**78%**

5.5 Mitigation Potential for the AFOLU Sector

The final list of mitigation options presented for the AFOLU sector was agreed after correspondence and collaboration with the AFOLU task team and other experts and specialists in the field. The list of measures is as follows:

- Treatment of livestock waste
- Expanding plantations
- Urban tree planting
- Rural tree planting (thickets)
- Restoration of mesic grasslands
- Biochar addition to cropland

If all technically available mitigation potential in the AFOLU sector was implemented, then these results indicate that GHG emissions could be reduced by 5,315 $ktCO_2e$ in 2020, 10,206 $ktCO_2e$ by 2030 and 4,775 $ktCO_2e$ by 2050. This represents a total potential reduction of 10%, 19% and 9% (respectively) of emissions relative to the reference WEM projection (Table N).

Table N: Technical mitigation potential for the AFOLU sector, assuming all measures are implemented (in $ktCO_2e$)

Measure	2020	2030	2050
Urban tree planting	539	1,016	1,671
Treatment of livestock waste	155	1,485	1,485
Biochar addition to cropland	619	473	939
Restoration of mesic grasslands	192	461	499
Rural tree planting (thickets)	1,392	1,532	181
Expanding plantations	2,418	5,240	0
TOTAL	**5,315**	**10,206**	**4,775**
TOTAL % Reduction (relative to WEM)	**10.0%**	**19.4%**	**9.2%**

6. National Mitigation Potential

6.1 Marginal Abatement Cost Curves

National-scale MACCs are presented for each of the three snapshots considered (2020, 2030, 2050) in Figures C, D and E, respectively. Detailed inputs to the MACCs for each measure are provided in Table 32 of the Main Report. Note that the MACCs presented here are not adjusted for direct and indirect savings in the transport sector (as discussed above).

The individual measures which comprise the national MACCs are not identified in the figures below as this section focuses on a national summary of results. Abatement estimates and marginal abatement costs are summarised for each of the three snapshots in Table O. Results are presented per quartile of the total national mitigation estimate.

As illustrated in Figure C and summarised in Table O, the total amount of abatement estimated in 2020 is 105,059 ktCO_2e. This estimate assumes that all mitigation measures are implemented under a 'with additional measures' (WAM) projection and that the full estimate of technical mitigation potential identified in this study is realised for all measures. The mitigation potential estimate represents a reduction of 15.8% relative to the reference 'with existing measures' (WEM projection. The MACC illustrates that 37.8% of the total mitigation estimate for 2020 (39,716 ktCO_2e) can be achieved through implementing mitigation measures with a negative marginal abatement cost.

In 2030 (Figure D), the national estimate for mitigation potential rises to 348,220 ktCO_2e. This represents a 40.6% reduction of emissions, assuming all identified mitigation measures are implemented relative to the reference WEM projection. A smaller proportion (25% or 87,945 ktCO_2e) of mitigation potential can be achieved through implementing mitigation measures with a negative marginal abatement cost.

In 2050 (Figure E), the estimate of national mitigation potential rises further to 887,169 ktCO_2e (55.7% of the reference WEM projection). Only 25.5% (226,661 ktCO2e) of mitigation potential can be achieved through implementing mitigation measures with a negative marginal abatement cost.

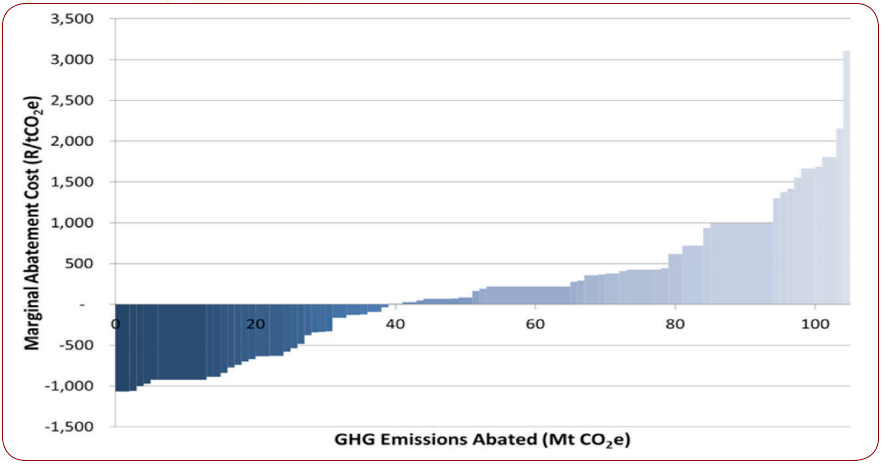


Figure C: National marginal abatement cost curve for 2020

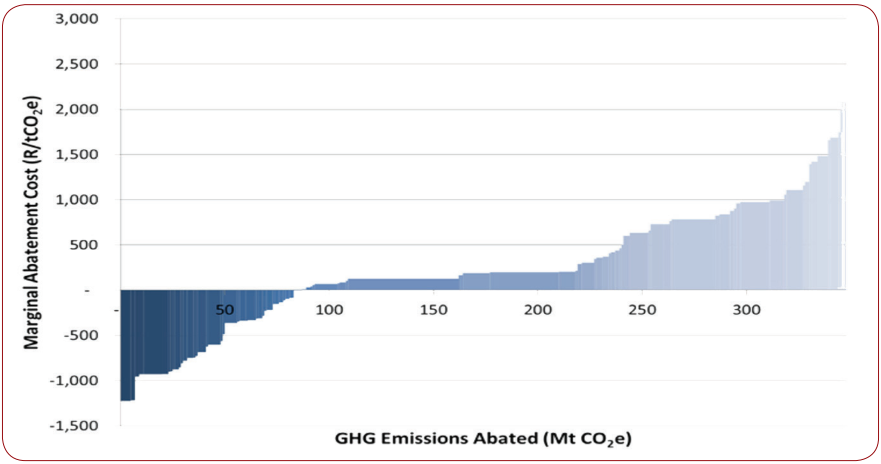


Figure D: National marginal abatement cost curve for 2030

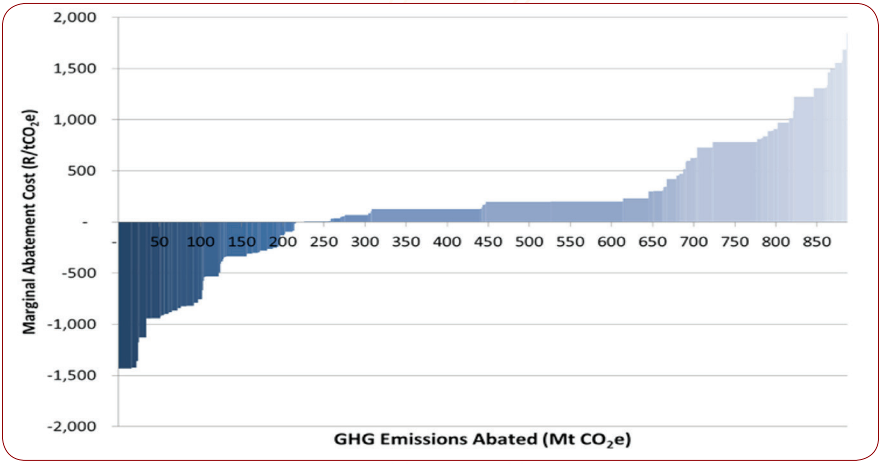


Figure E: National marginal abatement cost curve for 2050

Table O: Total national mitigation potential, assuming full implementation of all measures under the WAM projection. Results show abatement ($ktCO_2e$) as well as upper and lower bounds for marginal abatement cost (R/tCO_2e) per quartile of total abatement, for 2020, 2030 and 2050

	2020			2030			2050		
	Total abatement	MAC lower bound	MAC upper bound	Total abatement	MAC lower bound	MAC upper bound	Total abatement	MAC lower bound	MAC upper bound
First quartile	27,306	-1,068	-402	60,137	-1,226	-337	124,954	-1,432	-408
Second quartile	11,417	-402	-83	29,501	-337	29	133,124	-406	8
Third quartile	29,056	-72	346	148,140	30	420	409,519	13	401
Fourth quartile	37,281	359	3,105	110,442	434	2,445	219,571	420	4,340
Overall	105,059			348,220			887,169		
Reduction compared to WEM	15.84%			40.59%			55.69%		

6.2 Technical Mitigation Potential

A breakdown of national mitigation potential per key sector is presented in Table P and graphically in Figure F. When considering the total mitigation which might be achieved across all sectors, it is important to account for the interaction between sectors. For example, implementation of mitigation measures in the power sector will reduce the carbon intensity of electricity supplied, hence reducing the savings achieved by demand side electricity saving measures, and mitigation measures in the transport sector will reduce demand for liquid fuels, reducing the amount of new capacity and hence emissions in the refining and other energy industries sector. The national estimates of mitigation potential presented in this section account for these interactions.

The analysis of mitigation potential has included estimates for emission savings related to energy efficiency and reduced electricity consumption. The study has also explicitly considered options for reducing emissions in the power sector, by reducing the carbon content of South Africa's electricity supply through a combination of measures, including a switch to renewables and the implementation of further nuclear power. As the dependence on coal-based fossil fuels in the electricity supply diminishes over time, the carbon intensity of electricity reduces over time. This effect impacts on estimated savings related to the reduced consumption of electricity in end use sectors of the economy. To accommodate this, emissions from the power sector have been reallocated to end use sectors and electricity-related emissions savings have been adjusted for the progressive reduction of carbon intensity of the electricity supply over time.

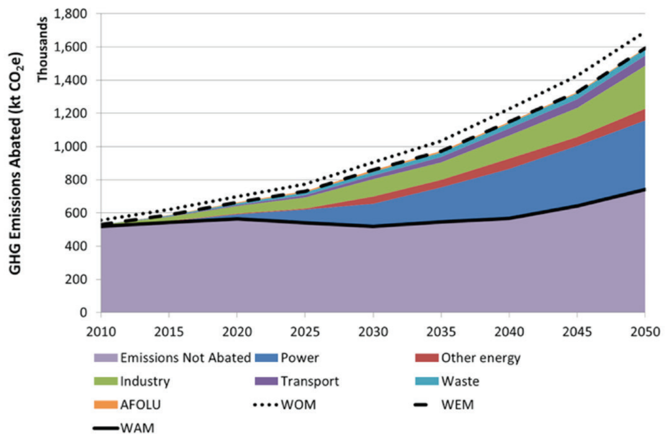
In calculating total technical mitigation potential for the energy sector, abatement estimates for the other energy industries and petroleum refining sectors have been adjusted to account for reductions in the demand for liquid fuels as a result of the implementation of abatement measures identified in the transport sector. In effect, reductions in direct emissions (i.e. from fuel combustion) are allocated to the transport sector, and the indirect effects on fuel production are reflected in the other energy industries and petroleum refining sectors. Therefore, emissions (and hence abatement estimates) are adjusted in the other energy industries and petroleum refining sectors to reflect the reduced demand for liquid fuels associated with the implementation of abatement in the transport sector.[1]

1. This adjustment implicitly assumes that the abatement measures identified for the transport sector will be fully implemented. In practice, the level of implementation may be lower than this, or other factors may influence growth in fuel demand from transport, which will in-turn influence the level of liquid fuel demand and the emissions from the other energy industries and petroleum refining sectors.

Table P: Total technical mitigation potential for the WAM projection (ktCO2e). Estimates for the other energy industries and petroleum refining sectors have been adjusted to account for reductions in the demand for liquid fuels as a result of the implementation of abatement measures identified in the transport sector. Results are shown per key sector, and also as a percentage reduction of the reference case WEM projection. Total remaining emissions under the WAM projection are also shown.

Sector/projection	2020		2030		2050	
	Abatement / reference emissions	% WEM	Abatement / reference emissions	% WEM	Abatement / reference emissions	% WEM
WOM (reference)	699,307		903,700		1,692,471	
WEM (reference)	663,270		857,745		1,592,605	
Power	28,585	4.31%	137,149	15.99%	416,555	26.15%
Other energy	4,472	0.67%	44,154	5.15%	71,002	4.46%
Industry	44,842	6.76%	103,850	12.11%	258,453	16.23%
Transport	6,952	1.05%	22,530	2.63%	62,101	3.90%
Waste	9,977	1.50%	22,122	2.58%	39,658	2.49%
AFOLU	5,315	0.80%	10,206	1.19%	4,775	0.30%
Emissions abated (relative to WEM)	**100,143**	**15.10%**	**340,012**	**39.64%**	**852,544**	**53.52%**
Remaining emissions (WAM)	**563,127**		**517,733**		**740,061**	

Figure F: National abatement potential assuming all measures are implemented under the WAM projection. Results are shown for each of the key sectors, and reference projections for the WOM and WEM are also shown. The total for all remaining emissions is indicated using purple shading.



The largest contributor to abatement in 2050 is the power sector, (at 416,555 ktCO_2e). This is a 26% reduction of emissions relative to the reference WEM projection. This estimate ramps up significantly after 2030, once a new nuclear power plant is commissioned. Overall, the energy sector accounts for technical mitigation potential of 5% (33,057 ktCO_2e), 21% (181,304 ktCO_2e) and 31% (487,557 ktCO_2e) compared to the reference case WEM projection in 2020, 2030 and 2050, respectively.

The second most significant contributor to national mitigation potential is the industry sector, accounting for 258,453 ktCO_2e in 2050 (a 16.2% reduction relative to WEM). Technical mitigation from the remaining three sectors (transport, waste, AFOLU) reaches 106,534 ktCO_2e in 2050 (a 6.7% reduction of reference WEM emissions).

The national estimates of mitigation potential for 2020, 2030 and 2050 represent a reduction of 15.1%, 39.6% and 53.5%, respectively, relative to the WEM projection. If the same estimates of technical mitigation potential are expressed relative to the 'without measures' (WOM) reference case projection, they are 14.3%, 37.6% and 50.4%.

7. Development of National Abatement Pathways

Having defined national mitigation potential in the previous section, focus now shifts from assessing individual measures to assessing pathways which are essentially groupings of mitigation measures. It is the intention in the remaining section of the report to demonstrate how these pathways can be constructed and what the broader macroeconomic impact of those choices would be, if implemented.

7.1 Level of Implementation of Mitigation Potential

A straightforward way to illustrate a range of different mitigation outcomes for South Africa is simply to implement varying amounts of the total mitigation potential identified in this study. This is shown in Figure G which plots four different 'with additional measures' (WAM) pathways. The pathways assume varying proportions of implementation of the total mitigation potential over time – 100%, 75%, 50% and 25%. Also plotted on the same figure are the reference case emission projections developed in this study (WOM and WEM) as well as the Growth Without Constraint (GWC) curve and the Peak, Plateau and Decline (PPD) emission reduction trajectory range (developed under the Long-Term Mitigation Scenarios (LTMS) study and under the NCCRP, respectively). The comparison indicates firstly that emission reductions achieved by 2050 (with respect to the WEM reference case) are 213,136, 426,272 and 639,408 ktCO_2e for the 25%, 50% and 75% levels of implementation of mitigation potential, respectively.

The WAM pathway, which assumes all mitigation potential is implemented, achieves emission reductions which fall within the PPD range, between 2010 and 2040. The 75% implementation pathway follows the upper limit of the PPD range between 2010 and 2030. Maintaining emissions reductions which fall within the PPD range after 2040 will require more mitigation potential to be identified and implemented in future than has been estimated in this study.

Lastly, absolute levels of emissions in South Africa do not reduce over the long term. Assuming all identified mitigation potential is implemented, emissions decrease in absolute terms in both 2020 and 2030. But in 2050, and for all other levels of implementation of abatement potential, no absolute emission reductions relative to 2010 are achieved. This result is driven largely by the assumptions driving the decarbonisation of South Africa's electricity supply (given this sector's dominance of both projected emissions and estimated mitigation potential). These assumptions tie the reduction of dependence on coal-based power and diversification towards other energy sources (such as renewables, biofuels and nuclear power) to modelling that was conducted under the Integrated Resource Plan (DoE, 2013). By definition, the IRP planning horizon was limited to 2030. Beyond this horizon, the share of coal and non-coal-based power in South Africa is effectively held constant – with growth in supply driven by demand from end-use sectors.

This effectively places a limitation on the level of diversification of South Africa's power supply which will have to be reconsidered in future. A more aggressive decarbonisation of South Africa's electricity supply will have to targeted as part of the process of updating the Integrated Resource Plan if an absolute reduction in emissions relative to current levels, or a more ambitious emission reduction target (such as PPD) is to be achieved.

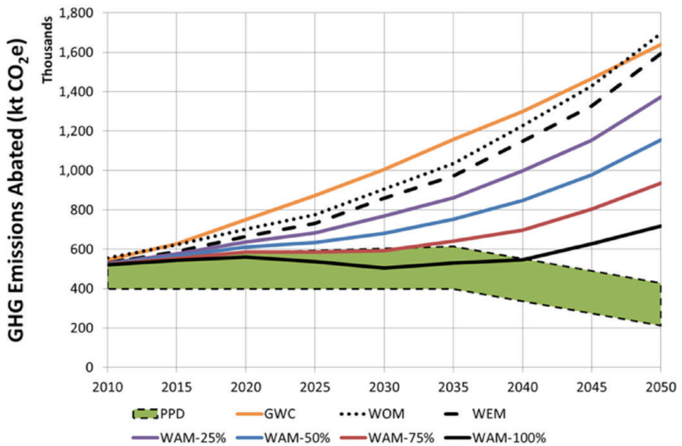


Figure G: National abatement pathways based on the 'with additional measures' (WAM) projection. Pathways indicated assume different levels of implementation of the national mitigation potential (100%, 75%, 50%, 25%). Also shown for reference are the reference case WOM and WEM projections as well as the Growth Without Constraint (GWC) and Peak, Plateau and Decline (PPD) scenarios developed under the LTMS study (ERC, 2007) and NCCRP (DEA, 2011a), respectively.

Figure H shows how the sector breakdown in mitigation potential changes with different levels of implementation of mitigation potential. This occurs because of the distribution of measures in each sector across the full spectrum of measures. For example, it is evident from the graph that energy measures are not well represented in the top 50th percentile of total mitigation. In contrast, transport has strong representation in the top 50th percentile. This pattern of mitigation by sector is important when applying the economic analysis and implies that the only way to compare impact across pathways and level of implementation of mitigation potential is to normalise the impacts (GDP and employment) by dividing by the amount of mitigation potential for the sector.

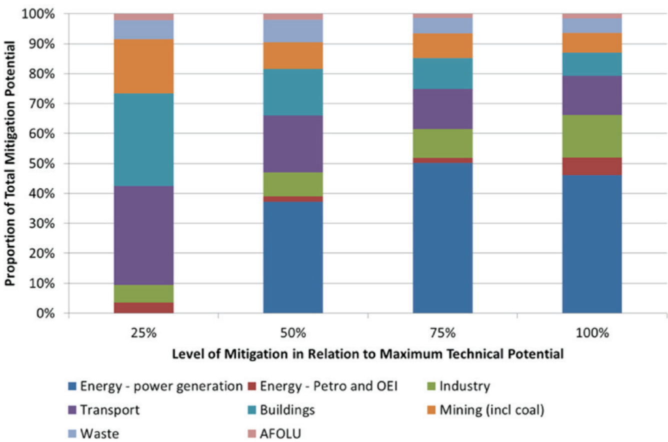


Figure H: Split in technical mitigation potential between sectors as the level of implementation of identified mitigation potential is increased (note: cut-offs are not at exact 25 percentiles).

7.2 Marginal Net Benefit

Three mitigation pathways have already been determined, based on different weightings of the main criteria in the multi-criteria analysis (MCA) framework approved by the TWG-M. By definition, the MCA framework is developed to allow decision-making regarding the ranking of measures which considers more than merely abatement potential and marginal abatement cost. The selected pathways are:

- A balanced weighting pathway, which allows for relatively equal consideration of all key factors in the MCA model;
- A pathway which emphasises the cost and implementability of mitigation measures , effectively assigning a larger weight to those measures which have lower marginal abatement costs and are easier to implement; and
- A pathway which emphasises social and environmental factors, effectively prioritising measures with lower impacts in these areas

The concept of marginal net benefit and the use of marginal abatement net benefit curves (MANBCs) allow a ranked list of mitigation options to be established which, as they are applied incrementally, create increasing levels of mitigation with decreasing net benefit, taking all criteria into consideration. The curves for each of the three abatement pathways are shown in Figures I, J and K below. Using these curves, it is possible to read from the horizontal axis how much total mitigation can be achieved, with 25%, 50%, 75% and 100% of total mitigation potential used for illustration purposes. Scores for each measure are also expressed relative to the full range of scores for each pathway, to indicate the relative net benefit associated with implementing any one measure.

Figures I, J and K effectively illustrate the marginal net benefit (for the same level of abatement) that can be achieved following different implementation pathways. There are several ways to interpret these graphics. For example, implementing all measures in the top 50th percentile of measures (based on their marginal net benefit score) will yield only approximately 25% of total mitigation under the balanced weighting pathway as well as the pathway which seeks to implement first those measures which have relatively lower costs and are easier to implement

(Figure I and Figure J). By comparison, implementing the top 50th percentile of measures according to the pathway which emphasises social and environmental factors will achieve approximately 50% of the available lifetime technical mitigation potential (Figure K).

Key power sector measures (identified in the figures below) achieve relatively large amounts of abatement (nuclear power and renewables, for example) but generally have marginal net benefit scores which lie in the lower 50th percentile of scores for all measures. As a consequence, once implemented, the proportion of total abatement achieved reaches approximately 75% for all pathways.

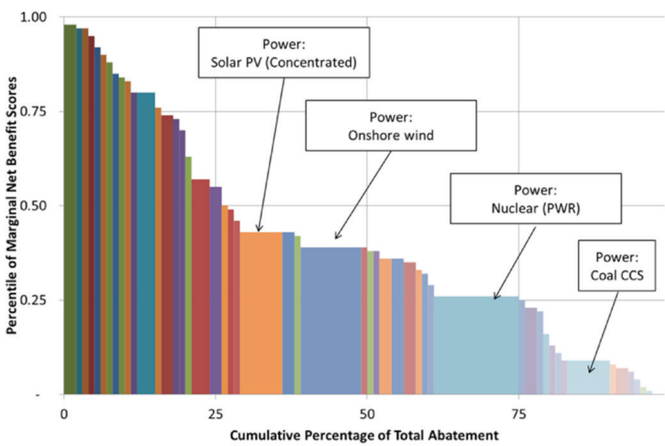


Figure I: Proportion of total abatement potential nationally plotted against marginal abatement net benefit scores (also shown as percentiles of all scores) for the balanced weighting abatement pathway.

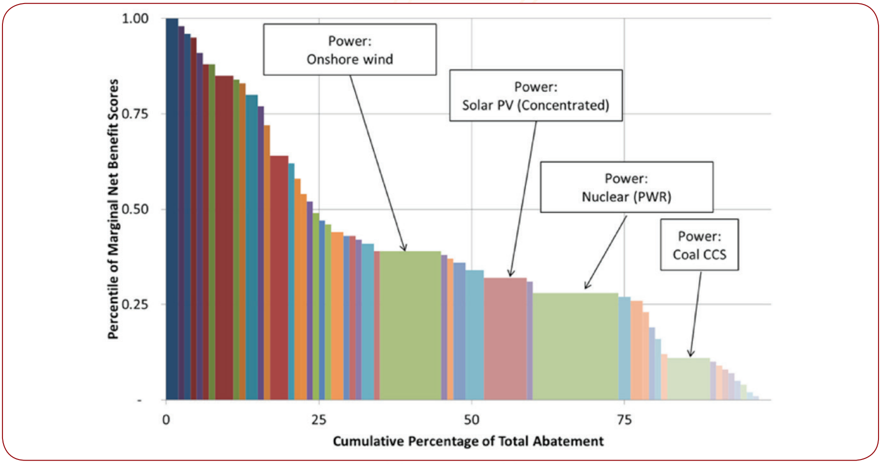


Figure J: Proportion of total abatement potential nationally plotted against marginal abatement net benefit scores (also shown as percentiles of all scores) for the abatement pathway which emphasises the cost and implementability of mitigation measures.

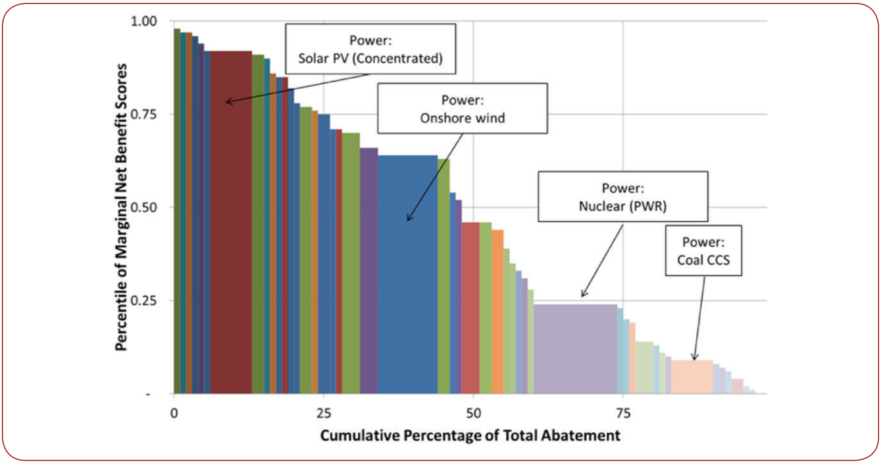


Figure K: Proportion of total abatement potential nationally plotted against marginal abatement net benefit scores (also shown as percentiles of all scores) for the abatement pathway which emphasises social and environmental factors.

Implementing the final quartile of mitigation potential in all three pathways will become harder, as measures become increasingly costly, with more substantially negative social and environmental impacts and also as the limits of technological possibilities are reached.

The scope of this analysis does not extend to a recommendation on the very difficult choices that will need to be made in selecting a level of ambition for abatement – both nationally and for specific sectors – nor how the implementation of mitigation measures to achieve that target level of mitigation will be achieved. Those decisions will be based on further technical analysis and modelling and implementation decisions will be made on the abatement potential and commercial feasibility of site-specific options.

Nonetheless, the framework developed in this study to combine the concept of the marginal net benefit of a range of mitigation options with an assessment of different implementation targets for the available mitigation potential is useful in the context of future decision-making regarding desired emission reduction outcomes.

8. Wider Macroeconomic Impacts of Implementing Mitigation Options

The INFORUM model has been used to assess the wider macroeconomic impacts of implementing the mitigation options identified in this study.

With regard to GDP impact, the modelling shows a positive outcome in terms of backward linkages for all sectors. With regard to forward linked impact the results are negative for energy, transport, waste and AFOLU sectors, associated with increases in net costs and hence the need for price increases on products and services associated with these sectors which reduces economic efficiency. In the case of the mining and buildings sectors, the forward impacts are positive, with industry being neutral. In total, if all mitigation measures are implemented, the marginal impact on GDP is approximately a 1.5% increase. This is a modest impact but is, nevertheless, significant in being positive.

Turning to the impact on employment, with the full implementation of mitigation potential the impact on employment is an increase of about 1.2%, also a modest increase but also significant in that it is positive. The net impact is negative in the case of the energy sector (largely because of the loss of low-skilled jobs in the coal mining sector as the proportion of renewables and nuclear power in South Africa's energy mix grows and hence demand for coal decreases). The impact on employment is positive for all other sectors with the waste sector as the biggest contributor, followed by AFOLU, buildings, transport and mining.

At average levels of impact on GDP of the order of 1.5% and on employment of 1.2%, with all mitigation measures included, the mitigation measures considered in this analysis will not have a major impact on the economy. What gains there are from direct employment and backward linkages are counteracted by losses due to forward linked effects: prices typically increase with increasing costs associated with implementing most measures without a related gain in revenue.

In conclusion, the economic assessment conducted in this analysis aims to illustrate the possible economic impacts from implementation of the range of mitigation measures identified in this study. It is accepted that no economic model is perfect and that the complexity of the economy combined with the complex set of mitigation measures applied to many sectors of the economy means that the results are useful mainly to show the broad scale and trends with respect to economic impacts. Further, while the economic analysis has been important for comparing the relative merits of individual mitigation measures, the overall economic impact results are of secondary importance to this particular study. Their presentation aims to stimulate debate rather than inform policy. Further work will be required to identify the economic costs of climate change and compare them to various adaptation and mitigation options. As part of this further work, there is a need to better understand the drivers and barriers of investment into greener technology.

9. Summary

A GHG mitigation potential analysis has been conducted for South Africa. The analysis has identified and analysed mitigation options in key economic sectors. In the process, an updated projection of national greenhouse gas (GHG) emissions into the future has been developed, along with marginal abatement cost curves (MACCs) for key sectors and subsectors. The MACCs provided estimates of mitigation potential and marginal abatement costs for a broad range of mitigation measures. Estimates of national mitigation potential have been derived from the sectoral MACCs. A socio-economic and environmental assessment of the identified mitigation options has also been conducted, leading to the development of national abatement pathways and an assessment of the wider macroeconomic impacts of implementing a broad set of mitigation options.

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