mitigation REPORT

SOUTH AFRICA'S GREENHOUSE GAS MITIGATION POTENTIAL ANALYSIS

TECHNICAL APPENDIX B – MACROECONOMIC MODELLING

environmental affairs
Department:
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On behalf of:
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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

Technical Appendices:

Appendix A: Approach and Methodology

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Appendix C: Energy Sector

Appendix D: Industry Sector

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List of Abbreviations

Acronym	Definition
AFOLU	Agriculture, Forestry and Other Land Use
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DEA	Department of Environmental Affairs
DoE	Department of Energy
GDP	gross domestic product
Gg/yr	gigagrams per year
GHG	greenhouse gas
IEP	Integrated Energy Plan
INFORUM	Inter-Industry Forecasting Model
IPCC	Intergovernmental Panel on Climate Change
MACC	Marginal Abatement Cost Curve
MCA	multi-criteria (decision) analysis
OEI	other energy industries
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

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Appendix B

Macroeconomic Simulations

Macroeconomic simulations are used first of all to get a reference case projection of economic growth to inform projections of changes in GHG emissions. Secondly, the simulations allow the changes in economic growth and employment to be assessed 'with additional measures' to mitigate GHG emissions. In other words the modelling provides an estimate of the impact of the measures, based on the underlying assumptions used in the model.

1. Methodology for Impacts Assessment

The methodology applied for the macroeconomic modelling is described in Appendix A. In interpreting the results of the modelling of the impacts (after mitigation measures are applied), there are some key concepts which need to be noted here regarding the way the production structure in each sector is handled, the way the backward and forward linkages work and the impact of balance of payments adjustments.

1.1 Accommodating Changes to the Production Structure

The default is that the Inter-Industry Forecasting Model (INFORUM) model that is being used applies the current structure of production in the country. However, in some cases the large scale of change associated with the mitigation measures will change the structure of production. This study only incorporates the impact of changes in the energy sector on the economy's structure both because of its importance and because of the scale of the shift away from coal-based energy generation measures. These structural changes were made primarily to reduce the importance of coal mining in the South African economy, as the increased role of renewables and nuclear power in future will reduce the country's dependence on coal-based power and hence the need to mine coal.

It is also recognised that there are some changes in production structure in other sectors, waste most notably, but it was not possible to model these changes due the level of complexity involved in doing this analysis. Furthermore, sectors react differently to the various mitigation options because of their peculiar production structures, which make it very difficult to model with an appropriate level of confidence.

In the case of waste management, an adjustment to the final results for employment was made to take into consideration the very different nature of the waste mitigation measures in relation to what is provided for in the macroeconomic model. Therefore, direct employment figures for new waste management technologies associated with the individual mitigation measures were based on figures from the international literature (Cottica and Kaulard, 1995, Murray, 1998).

Finally, some adjustments have been made to employment figures for the AFOLU sector as the mitigation measures, although broadly aligned with the agriculture sector, have significantly different employment characteristics.

The scale of these measures does not, however, represent a change to the production structure in the agriculture and forestry sector as the measures are, in total, not large in relation to the scale of the sector as a whole.

1.2 Backward Linkages

The backward linkages refer to the economic impact on other sectors of the economy if a specific sector increases its production. This may be expected to translate into a rise in the demand for raw materials, other intermediate inputs and the remuneration of labour, and capital inputs. Please refer to Technical Appendix A: Approach and Methodology, Section 3 for a detailed discussion of the key assumptions of the modelling framework.

The backward linkages originate from two main sources, namely during the construction phase of a project and when the project becomes operational. The construction phase entails the establishment of capital assets. For example, in order to generate electricity, a power station (a very substantial capital asset) has to be constructed, which in itself creates economic activities through, for example, additional employment opportunities. The operational impact refers to the creation of economic activities driven by the production process. For instance, to generate electricity requires the buying of raw materials such as coal and the payment of salaries and wages on an ongoing basis.

Backward linkages can also change the production structure of the economy due to the implementation of a particular mitigation option, which can therefore be taken into account. For example, if renewable energy options are introduced in lieu of coal-fired power stations, the structure of the economy is altered. Such an event will reduce the need for new coal mines (or extending the lifespan of existing ones) which can have a significant negative effect on employment opportunities in that sector.

1.3 Forward Linkages

In this instance, the forward linkage effect refers mostly to the impact that a specific mitigation option has on the overall competitiveness of the economy. In some cases the mitigation option's effect can be counterproductive to what is currently in effect and in other cases it is the opposite. This effect is largely reflected in the prices of the goods and services produced by a sector, which could have an effect on the international competitiveness of the country. Depending on the price elasticities of the demand for local products, this in turn could have an effect on production and employment.

The model is activated by the net cost impact on a specific sector's unit production costs. It also rests on the assumptions that if a sector's product price increases or decreases because of an increase or decrease in production cost, this will decrease or increase the price competitiveness of the sector. To some extent the supply-side constraints introduced in the model also determine the price effects. This is discussed in Section 1.2 above as well as in Section 3 of Appendix A.

1.4 Balance of Payment Adjustment

A technical adjustment to the model was necessary to ensure that the empirically measured impact of a mitigation option can be compared to a counterfactual outcome. For these purposes, the deficit on the current account of the balance of payments, as a percentage of the country's overall economic activity or gross domestic product (GDP), was taken as a controlling measure demonstrating the ability of the economy to financially carry the burden of a particular mitigation option. For instance, the deficit on the current account of the balance of payments amounts to 6% of GDP in the base case scenario, namely with no changes to existing energy policies. Therefore for controlling purposes the deficit on the current account of the balance of payments was constrained to 6% for each of the GHG pathways.

In terms of national accounting theory, a deficit on the current account of the balance of payments (exports less imports) must be equal to the deficit on the capital account (savings less investment). Everything being equal this implies that given the limited pool of domestic savings, investment in some other projects would have to be adjusted downwards to make provision for the required investment and life cycle costs implied by the mitigation option(s). Simulating the workings of a market economy, the model will use an increase in the real interest rate to restore equilibrium in the capital markets in cases where domestic savings are insufficient to meet investment needs. The effect of this will be a decrease of overall domestic demand (therefore increasing savings and decreasing other investment (excluding investment in mitigation options in particular).

By constraining the current account to 6% of GDP for the various options, a comparative study of the economic effectiveness of one of the pathways with the counterfactual was simulated.

2. Implementation Pathways: Explanations and Data Sources

2.1 Implementation Pathways Explained

The structure of the GHG mitigation pathways and the level of penetration achieved are aligned with the structure described at the end of the methodology description in Appendix A:

	Percentage of total technically feasible mitigation potential			
	25%	50%	75%	100%
Balanced pathway				
Focus on costs and implementability pathway				
Focus on social and non-GHG environmental impacts pathway				

More specifically the pathways are defined as follows.

- A balanced weighting pathway, representing a broad consensus among all interest groups represented on the Technical Working Group on Mitigation.
- A pathway which emphasises costs and implementability of mitigation measures.
- A pathway which emphasises social and non-GHG environmental impacts of mitigation measures.

Each pathway can be considered over a range of mitigation levels, namely 100%, 75%, 50% and 25% of the total technically feasible potential of all options. The 100% level includes all 172 mitigation options, at some stage of the 40 year (2010–2050) programming period. The 75%, 50% and 25% levels include the mitigation options which account for these percentages[1] of the total technically feasible mitigation potential in terms of their score in the multi criteria analysis (MCA) taking all the measures into consideration. In other words, the ranking is done on all 172 measures together, not by sector.

For each of the three pathways the projection captures the effects of additional mitigation actions leading to a reduction in the carbon intensity of electricity supply, reductions in demand and direct fuel or process-related emission reductions in end-use sectors.

As indicated in Appendix A, the pathways have been developed in order to demonstrate how the analysis conducted and tools developed during this project can best be used. The criteria weightings from the MCA model are used to rank mitigation measures under all the pathways. This ranking would explicitly allow decision-making regarding the implementation of mitigation actions to be conducted on the basis of an assessment of a broad range of factors (including the potential broader socio-economic and environmental impacts of each measure), rather than basing a decision purely on the abatement and cost information provided in a MACC.

2.2 Data Sources

The data for the various assessments used in the INFORUM modelling system is based on estimates of the investment, operational and net cost impacts of the original 172 mitigation options. It stands to reason that assumptions that differ from those used in conducting this analysis will lead to different impact results. The classification of the mitigation options and their prioritisation using the MCA was completed prior to the running of the economic models and are not altered as part of this modelling.

The data is provided on an annual basis at constant 2011 prices for each of the mitigation options, classified per sector. As already indicated the data has been ordered in terms of investment, operational cost and the cost savings in terms of the counterfactual base case options. It is important to note that the effects are the net effects, i.e. the proposed option minus the counterfactual, where the counterfactual refers to the technology that will be followed if there is no intervention in future.

1 Note that the cut- offs at 75%, 50% and 25% are not exact as only full measures are included and typically a single measure will straddle the 25 percentile boundaries.

3. Results A: the Reference Case (Final Demand Projections for South Africa)

The final demand projections for South Africa for the low, medium and high growth scenarios are as set out in Table 1, Table 2 and Table 3 below. These projections form the basis for the production projections for the 46 sectors, as presented in the subsequent tables. The growth rate forecasts by National Treasury for the Integrated Energy Plan (IEP) (DoE, 2013) are also included for comparative reasons. The forecasts in this study are generally slightly lower than those of National Treasury.

Table 1: Final demand projections for the low growth scenario

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	3.4%	1.8%	3.3%	3.1%	3.3%	3.7%	3.8%
Final consumption expenditure by government	2.6%	2.6%	3.7%	2.4%	2.5%	2.7%	2.7%
Gross capital formation	3.5%	0.1%	2.0%	3.2%	3.5%	3.9%	4.0%
Exports of goods and services	2.4%	0.6%	1.6%	2.2%	2.3%	2.6%	2.9%
Imports of goods and services	2.6%	0.9%	2.0%	2.6%	2.5%	2.7%	2.7%
Total GDP (2012 constant prices)	3.4%	1.4%	3.0%	3.0%	3.3%	3.7%	3.9%
National Treasury forecast for the IEP model	3.7%	2.8%	3.0%	3.8%	3.8%	3.8%	3.8%

Table 2: Final demand projections for the medium growth scenario

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 for the IEP model	4.2%	3.0%	3.8%	4.2%	4.3%	4.3%	4.3%

Table 3: Final demand projections for the high growth scenario

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	4.5%	2.7%	4.3%	4.1%	4.4%	4.8%	5.0%
Final consumption expenditure by government	5.3%	6.2%	6.4%	5.1%	5.2%	5.3%	5.3%
Gross capital formation	6.6%	3.1%	5.3%	6.5%	6.6%	6.9%	6.9%
Exports of goods and services	4.4%	3.8%	3.9%	4.3%	4.3%	4.4%	4.6%
Imports of goods and services	5.8%	3.9%	5.1%	5.7%	5.7%	5.9%	6.1%
Total GDP (2012 constant prices)	4.7%	3.0%	4.4%	4.3%	4.5%	5.0%	5.2%
National Treasury forecast for the IEP model	5.2%	3.5%	4.0%	5.0%	5.4%	5.4%	5.4%

The growth in GDP for the period 2013–2052, where GDP is used to measure total economic growth, is 3.4%, 4.0% and 4.7% for the low, medium and high growth scenarios respectively.

3.1 Production Projections for the Main Economic Sectors under the Low, Medium and High Growth Scenarios

GDP growth projections developed under this study are based on a targeted level of future economic growth based on 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 GDP growth of 4.2% per annum over the medium-term (defined in the draft Integrated Energy Plan as 2015–2020) and 4.3% per annum over the long-term (2021–2050), according to the 2012 Medium Term Budget Policy Statement (National Treasury, 2012).

For the sensitivity analysis, growth assumptions were again based on the inputs provided by National Treasury. Following the 2012 Budget forecast (National Treasury, 2012), the low-growth scenario assumed real GDP growth of 3.8% per annum over the medium and long-term. The main drivers of the low growth over the period were the assumptions of continued skills constraints, infrastructure bottlenecks and low global growth. The high growth scenario assumed an improved domestic outlook and recovery from the financial crisis with stronger commodity prices, reduced infrastructure bottlenecks and higher global growth. Real growth was assumed to be 4.8% per annum over the medium-term and 5.4% per annum over the long-term.

The production projections for South Africa for the low, medium and high growth scenario are set out in Table 4, Table 5 and Table 6 below.

From the tables it is evident that the secondary and more specifically the tertiary sectors are growing faster than the primary sector.

Table 4: Production projections for the main economic sectors for the low growth scenario

No.	Sectors	2013-2052	2013	2014	2015-2022	2023-2032	2033-2042	2043-2052
1	Agriculture, forestry and fishing	2.2%	1.1%	2.5%	2.0%	2.0%	2.3%	2.5%
2	Mining and quarrying	2.6%	0.0%	1.1%	1.9%	2.2%	3.0%	3.5%
3	Manufacturing	3.5%	0.7%	2.9%	3.2%	3.3%	3.9%	4.0%
4	Electricity, gas and water	2.9%	1.4%	2.8%	2.7%	2.6%	3.2%	3.4%
5	Construction	2.9%	0.6%	2.5%	3.0%	2.7%	3.2%	3.2%
6	Wholesale and retail trade; hotels and restaurants	3.4%	1.6%	3.1%	3.2%	3.2%	3.7%	3.8%
7	Transport, storage and communication	3.6%	2.0%	3.4%	3.5%	3.2%	3.8%	3.9%
8	Finance, real estate and business services	3.7%	2.0%	3.3%	3.6%	3.5%	4.0%	4.1%
9	General government services	3.0%	2.6%	3.8%	2.9%	2.7%	3.2%	3.3%
10	Personal services	4.1%	2.6%	3.7%	4.0%	3.8%	4.3%	4.4%
	Total Production	**3.4%**	**1.5%**	**3.1%**	**3.2%**	**3.1%**	**3.7%**	**3.9%**

Table 5: Production projections for the main economic sectors for the medium growth scenario

No.	Sectors	2013-2052	2013	2014	2015-2022	2023-2032	2033-2042	2043-2052
1	Agriculture, forestry and fishing	2.5%	2.2%	2.9%	2.3%	2.2%	2.6%	2.8%
2	Mining and quarrying	3.7%	1.9%	3.0%	3.4%	3.3%	3.9%	4.3%
3	Manufacturing	4.1%	1.5%	3.5%	3.8%	3.8%	4.4%	4.6%
4	Electricity, gas and water	3.5%	2.2%	3.4%	3.3%	3.2%	3.7%	3.9%
5	Construction	4.6%	2.3%	4.2%	4.7%	4.4%	4.9%	4.9%
6	Wholesale and retail trade; hotels and restaurants	4.1%	2.3%	3.7%	3.9%	3.8%	4.3%	4.5%
7	Transport, storage and communication	4.1%	2.8%	4.1%	4.1%	3.8%	4.3%	4.4%
8	Finance, real estate and business services	4.3%	2.9%	4.0%	4.1%	4.0%	4.5%	4.6%
9	General government services	4.0%	4.0%	4.8%	4.0%	3.8%	4.1%	4.2%
10	Personal services	4.5%	3.3%	4.2%	4.4%	4.2%	4.7%	4.7%
	Total Production	**4.1%**	**2.5%**	**3.9%**	**3.9%**	**3.8%**	**4.4%**	**4.5%**

Table 6: Production projections for the main economic sectors for the high growth scenario

No.	Sectors	2013-2052	2013	2014	2015-2022	2023-2032	2033-2042	2043-2052
1	Agriculture, forestry and fishing	3.0%	2.6%	3.4%	2.8%	2.7%	3.1%	3.3%
2	Mining and quarrying	4.6%	2.6%	3.8%	4.2%	4.2%	4.9%	5.3%
3	Manufacturing	4.6%	1.7%	4.0%	4.2%	4.2%	4.9%	5.2%
4	Electricity, gas and water	4.1%	2.6%	4.0%	3.8%	3.8%	4.3%	4.5%
5	Construction	6.4%	4.0%	5.9%	6.4%	6.2%	6.6%	6.7%
6	Wholesale and retail trade; hotels and restaurants	4.8%	2.8%	4.4%	4.5%	4.5%	5.1%	5.3%
7	Transport, storage and communication	4.7%	3.3%	4.7%	4.6%	4.4%	4.9%	5.1%
8	Finance, real estate and business services	4.9%	3.4%	4.6%	4.7%	4.6%	5.1%	5.3%
9	General government services	5.1%	5.4%	5.9%	5.0%	4.8%	5.2%	5.2%
10	Personal services	4.8%	3.7%	4.6%	4.7%	4.6%	5.0%	5.1%
	Total Production	**4.9%**	**3.1%**	**4.6%**	**4.6%**	**4.5%**	**5.1%**	**5.3%**

3.2 Sensitivity of Emission Projections to Growth Assumptions

The level of GHG emissions for the reference scenario is determined by the detailed sectoral production projections over the programming period. The 46 detailed sectoral projections are available electronically on request.

3.3 Results

The results from the analysis for the baseline position (medium growth) are shown below:

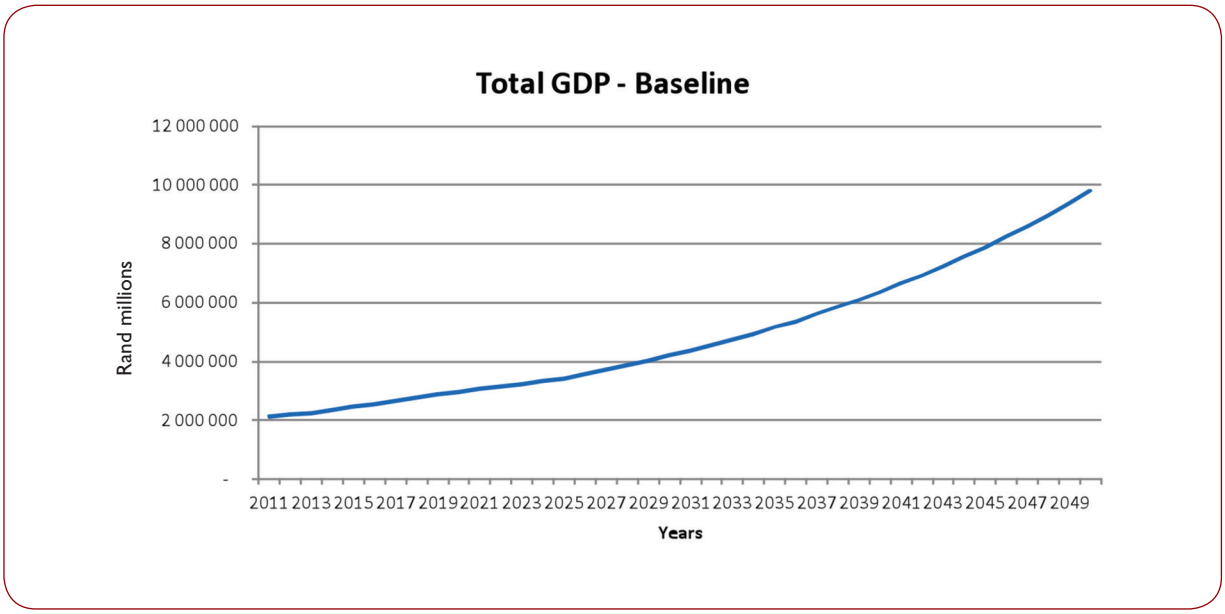

Figure 1: Graph showing trend in GDP over 40 years for medium (likely) growth scenario

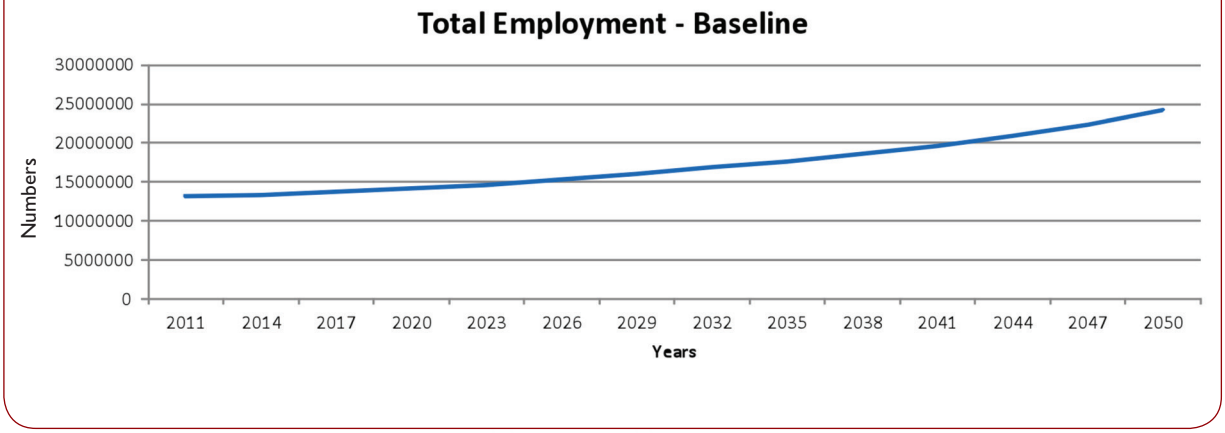

Figure 2: Graph showing trend in employment over 40 years for medium (likely) growth scenario

4. Results B: Impact Assessment

4.1 Distribution of Mitigation between Measures and across Levels of Implementation of Mitigation Potential

Before reporting on the results of the economic analysis it is important to recognise the way the actual mitigation potential within each sector is distributed as this strongly influences the trends for GDP and employment impact. The results for the balanced pathway are shown in Table 7 below.

Table 7: Pattern of mitigation potential by sector and level of implementation of mitigation

Main sector	Quartile			
	First	Second	Third	Fourth
Energy - power generation	0.0%	39.8%	41.8%	18.4%
Energy - petro and OEI	14.5%	0.2%	6.0%	79.3%
Industry	10.1%	17.6%	22.9%	49.5%
Transport	61.3%	10.6%	5.1%	23.0%
Buildings	97.2%	2.8%	0.0%	0.0%
Mining (including coal)	65.1%	0.0%	27.7%	7.2%
Waste	32.4%	47.3%	1.7%	18.6%
AFOLU	32.6%	27.0%	6.2%	34.2%

The above pattern is shown graphically below (Figure 3), in this case showing the total amount of mitigation and how it is distributed by quartile, assuming all measures are included.

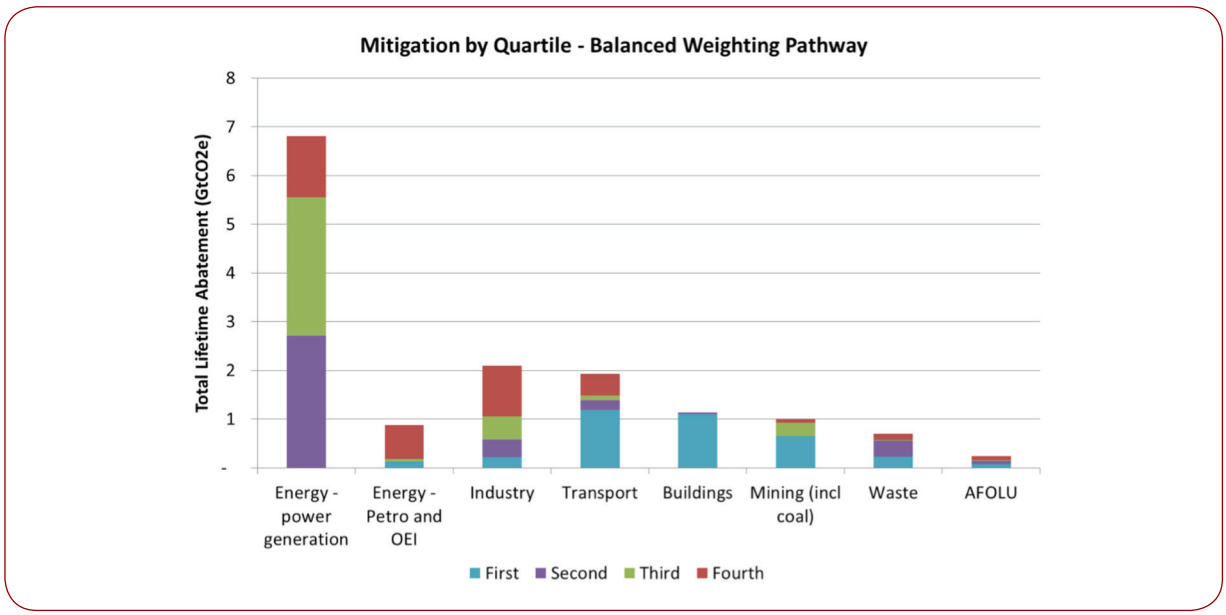

Figure 3: Graph showing the distribution of mitigation by sector and by quartile of total mitigation potential for the Balanced Weighting pathway

The important observation from the table and graph is that the distribution of mitigation potential between sectors varies as the penetration towards maximum mitigation progresses. So, for example, for buildings, mining and transport the mitigation measures are concentrated in the top 25 percentile while for energy (petroleum and other energy industries (OEI)) and industry a large proportion of mitigation falls into the lowest 25 percentile. The power generation sector dominates the second and third quartiles.

The pattern shown above is an indication of how mitigation measures are prioritised under the Balanced Weighting pathway. Those in the first quartile have the highest net benefit. A more detailed assessment of the distribution of these measures is shown in Figure 4 below.

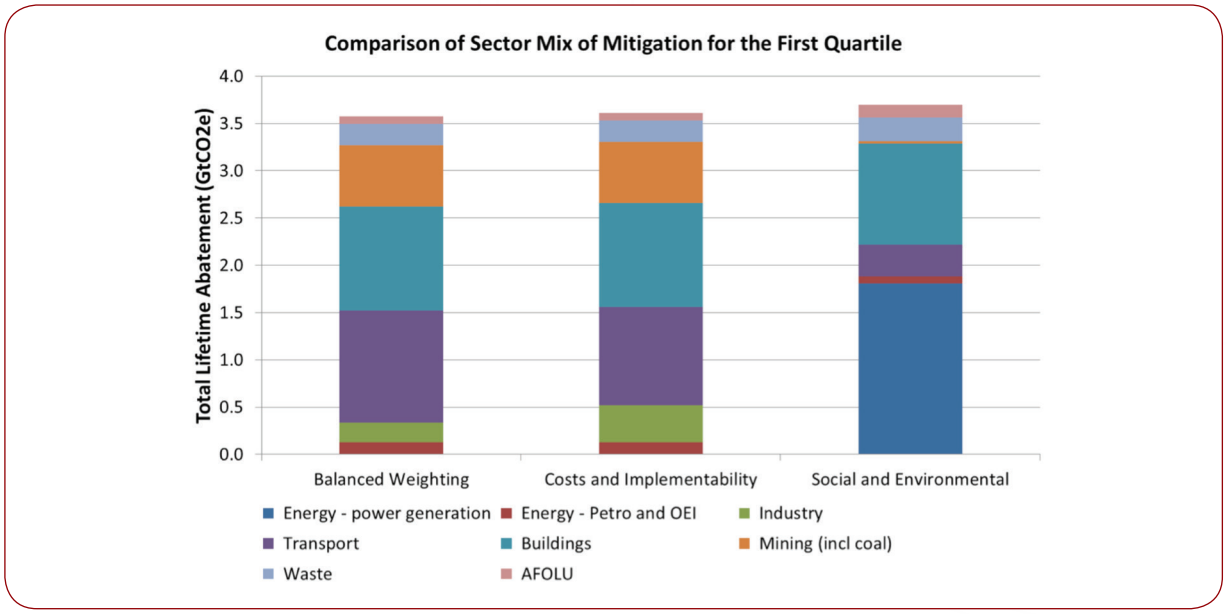

Figure 4: Pattern of mitigation potential for first quartile of mitigation

Secondly, it is notable that for some measures (buildings and waste, for example) there is little change which means the shifting of criteria weights does not shift the measures in or out of the 25% level of implementation of identified technical mitigation potential by much. On the other hand the inclusion of power generation measures only occurs if the social and environmental focus pathway is chosen.

At the other end of the spectrum, the comparison by pathway with 100% mitigation is shown in Figure 5 below.

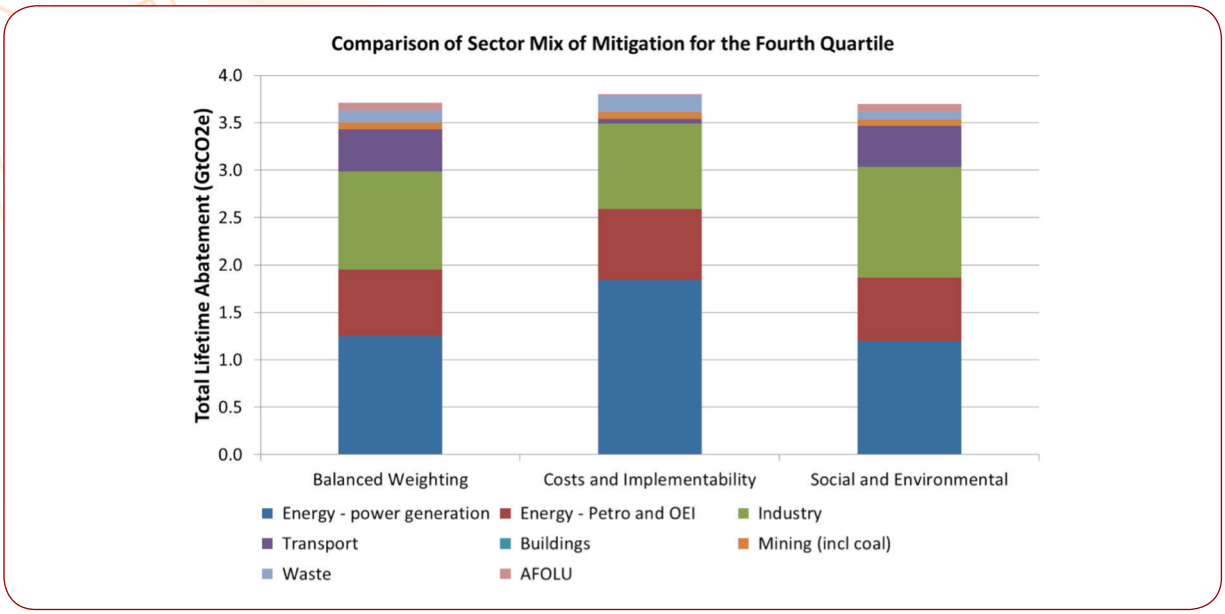

Figure 5: Pattern of mitigation potential for last quartile of mitigation

The last quartile of mitigation potential is dominated by energy and industry measures with the change between pathways not being very strong. The building sector is absent from this quartile for all pathways.

4.2 Total Impact: All Sectors

In this section the macroeconomic impact in total is reviewed. As already indicated only two macro-economic variables have been modelled. They are the impact on GDP and the impact on employment. Furthermore, only the dynamic impact is discussed, after taking into account the manual adjustment on the balance of payments in order to keep the economy's debt ratio at the same equilibrium point, prior to the initiation of the mitigation option.

4.2.1 Impact on GDP

The net impact on GDP, assuming 100% mitigation is achieved (i.e. the impact of the assessment, minus the impact of the counterfactual), is given in Table 8 below.

Table 8: GDP impact analysis by sector

Average Impact over the period (2010–2050), R million constant 2005 prices

Sector	Incremental impact						Dynamic impact		Proportion of total dynamic impact after balance of payment adjustment
	Backward linkage impact				Forward linkage impact	Net incremental impact	Dynamic impact providing for balance of payment adjustment		
	Additional (net) investment impact	Additional (net) operational cost	Impact due to change in production structure	Total backward linkages	Impact due to price change		Before balance of payments adjustment	After balance of payments adjustment	
	A	B	C	D = A+B+C	E	F = D+E	G	H	I
Energy	23,488	21,461	-5,493	39,456	-8,173	31,283	31,748	21,745	45%
Industry	4,397	787		5,184	160	5,343	5,403	2,371	5%
Buildings	1,067	1		1,068	4,350	5,419	5,401	5,401	11%
Other Mining	2,248	2,545		4,793	2,813	7,607	7,404	7,404	15%
Transport	13,658	-4,345		9,313	-807	8,506	8,533	8,533	18%
Waste	861	1,807		2,668	-888	1,780	1,793	1,793	4%
AFOLU	155	896		1,052	-89	963	964	964	2%
Total	45,874	23,154	-5,493	63,535	-2,634	60,901	61,246	48,211	100%

4.2.1.1 *Discussion of GDP results – 100% mitigation level*

Based on the analysis using the INFORUM model and applying all mitigation measures over the period 2010–2050, GDP increases on average (over the period) by approximately R48 billion. This constitutes approximately 1.5% of GDP in 2010.

In considering this 1.5% figure, the factors which influence positive and negative change in GDP need to be considered.

While backward-linked impacts are mostly positive (driven by capital expenditure and increased operating expenditure associated with the mitigation measures) the forward linkages often give negative GDP changes, driven by increases in prices.

The contribution of all the mitigation measures applied in each of the respective sectors to change in GDP is illustrated in Figure 6 below.

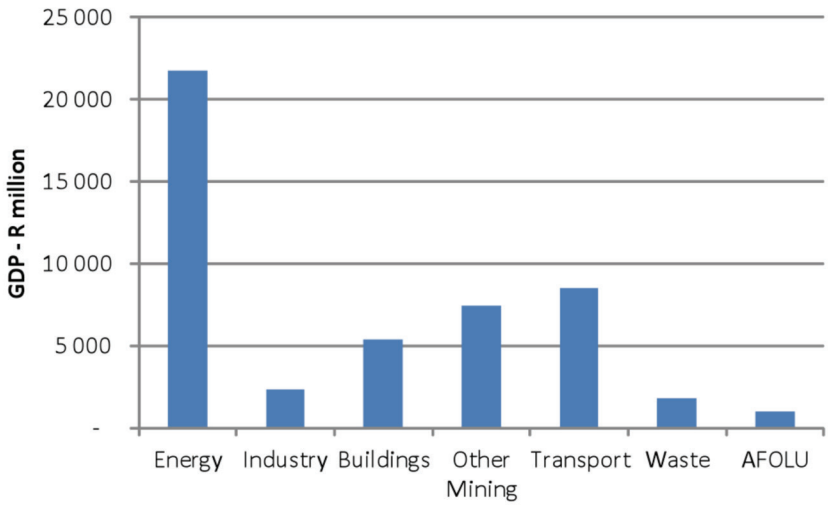

Figure 6: Contribution to change in GDP of all measures by sector

The energy sector makes the greatest contribution of 45% to the overall change in GDP. The mitigation options for buildings, mining and transport also make significant contributions towards GDP.

4.2.2 *Impact on employment*

The net impact (the impact of the assessment, less the impact of the counterfactual) on employment of the various measures is given in Table 9 below.

Table 9: Employment impact analysis results by sector

Average impact over the period (2010–2050), change in number of jobs

Sector	Incremental impact						Dynamic impact		Proportion of total dynamic impact after balance of payment, waste and AFOLU sector adjustments
	Backward linkage impact				Forward linkage impact	Net incremental impact	Dynamic impact providing for balance of payment adjustment		
	Additional (net) investment impact	Additional (net) operational cost	Impact due to change in production structure	Total backward linkages	Impact due to price change		Impact Before balance of payments adjustment	After balance of payments adjustment	
	A	B	C	D = A+B+C	E	F = D+E	G	H	I
Energy	67,243	40,106	-26,299	81,051	-46,741	34,310	40,510	-12,468	-6%
Industry	20,271	5,525	-	25,797	639	26,435	26,760	10,890	6%
Buildings	5,914	7	-	5,922	23,863	29,785	29,687	29,687	15%
Other Mining	7,067	3,828	-	10,895	14,756	25,651	24,605	24,605	13%
Transport	46,709	-12,211	-	34,497	-4,179	30,318	30,455	30,455	16%
Waste	3,719	4,075	-	7,795	-4,878	2,916	2,983	2,983	2%
AFOLU	1,371	10,000	-	11,371	-501	10,870	10,869	10,869	6%
Total	152,294	51,332	-26,299	177,327	-17,041	160,286	165,868	97,020	
							Adjust waste sector employment	65,000	33%
							Adjust AFOLU sector employment	33,000	17%
							Adjusted total	195,020	100%
							New total for waste	67,983	35%
							New total for AFOLU	43,869	22%

The total impact on employment, taken directly from the INFORUM model, is 97,000 jobs based on the standard figures in the model which uses the current structure of the economy in terms of labour intensity.

4.2.2.2 *Adjustments*

As noted in Section 1.1, there are changes to the structure of the economy in the case of waste which are not taken into consideration in the INFORUM modelling. In the case of the AFOLU sector, the scale of the measures is small in relation to the agriculture and forestry sector as a whole, but the nature of the additional measures is quite different to those for standard agriculture practice. Therefore adjustments have been made to the results for these two sectors. These adjustments are made only to ***direct employment*** as the backward and forward indirect employment effects are provided for through the impact of cost changes.

In the case of direct employment reliance is made on figures from the literature for the waste and AFOLU measures, with more detail provided in later sections of this appendix. Making these adjustments, as shown in the table above, gives total employment of 195,000 jobs.

4.2.2.2 *Interpretation of results with 100% level of mitigation potential implemented*

The distribution of employment gains (or losses) by sector, is shown in Figure 7 below.

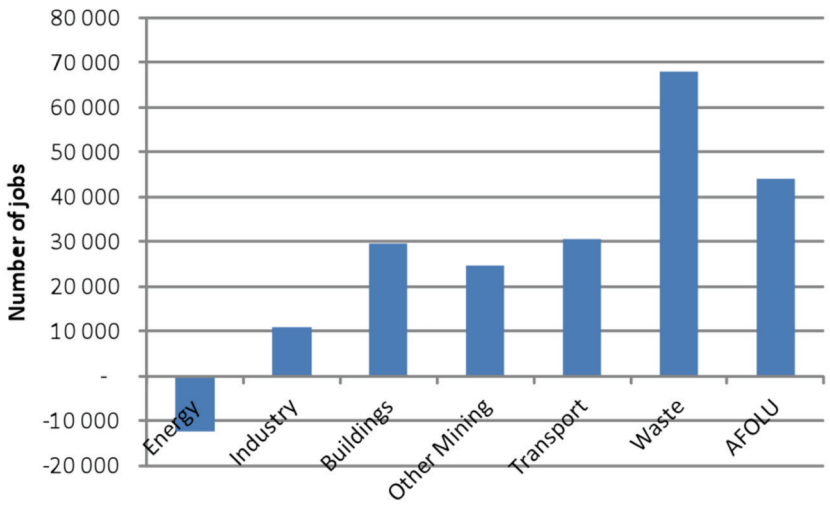

Figure 7: Employment impact (jobs created) by sector with all mitigation potential implemented

When all mitigation potential is implemented, the impact differs in terms of that for GDP, in that some of the sectors have a negative employment outcome, with the employment impact within the energy sector at 12,000 jobs lost. This job loss is primarily due to the fact that the proposed measures displace coal mining, which is a labour-intensive activity. Taking the results after adjustment into consideration, the biggest employment sectors are buildings, waste, mining, transport and AFOLU.

The final total of 195,000 jobs represents 1.2% of the average projected number of jobs in the South African economy over the period 2010 to 2050. The employment gains are, therefore, modest.

Further discussion on the employment figures for each sector is included in following sections of this appendix.

4.3 Energy

Definition

The energy sector comprises exploration and exploitation of primary energy sources, conversion of primary energy sources into more useable energy forms in refineries and power plants and the transmission and distribution of fuels. The energy subsectors examined and sources of emissions (as classified by the IPCC categories) are listed in Table 10 below.

Table 10: Energy subsectors (with IPCC emissions source classification) included in the mitigation analysis

Subsector	IPCC emissions category	
	Fuel combustion (1A)	Fugitive emissions (1B)
Electricity and heat production	1A1a	
Petroleum refining	1A1b	
Other energy industries	1A1c	
Other emissions from energy production		1B3
Coal mining and handling		1B1a
Oil and natural gas		1B2

GHG emissions projections and mitigation opportunities for the energy sector emissions focus on three 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).
- Indirect emissions from the consumption of electricity. The conversion of primary energy sources into more useable energy forms in power plants.

Impact on GDP

Looking at the GDP analysis results in Table 8 suggests that:

The backward linkages are positive throughout, whereas the forward linkages are negative. However, the total impact is positive.

- The backward linkages are positive due to the fact that in most cases the mitigation options require additional investment (more than the counterfactual) which has a positive effect on the economy. This new investment may be at the expense of other investment which might otherwise have taken place since capital (savings) is a scarce resource. This effect has been accounted for by ensuring that the impact on the balance of payments as a percentage of GDP, before and after the interventions, remains the same. This is done by making changes to the prime interest rate.
- In terms of the forward linkage, the cost of providing electricity is more expensive in the mitigation option than the counterfactual. For instance, electricity provided by wind turbines is more expensive than coal power stations in the current analysis. The additional electricity cost that the users of electricity must pay leads to increases in their output prices. This in turn leads to a less competitive international trade position, with negative effects on the domestic economy. Since the modelling framework is not integrated into a global system, the results presented here may not fully account for these trade effects.
- An important aspect for the energy sector is that there is a marked difference when the dynamic impact is adjusted for purposes of bringing the balance of payments back to the initial equilibrium point. The surplus/shortage on the current account of the balance of payments as a percentage of GDP is about a third of the dynamic impact before the adjustment. This is due to the fact that the interest rate was adjusted, with negative or positive effects on various sectors that are linked to the impact on the interest rate, through demand and supply.

Impact on employment

The employment figures are shown in Table 9. That table gives the total impact and the various components of the impact on employment of implementing all mitigation measures in the balanced weighting pathway. The simulations suggest that:

- The total impact on employment in the energy sector due to mitigation options differs considerably from that of the corresponding impact on GDP. This is driven by the substantially different fixed GDP to employment ratios for each mitigation measure.

- The additional operational cost effect (including the change in production structure) is now negative in contrast to the positive impact for GDP.The change in economic structure of the proposed GHG mitigation options relative to the energy counterfactual is less labour-intensive. An example of this is that the counterfactual includes coal mining, a very labour-intensive exercise, which might be replaced by one or more mitigation option.

4.4 Industry

Definition

The subsectors examined and sources of emissions for the industry sector, (as classified by the IPCC categories) are listed in Table 11 below.

Table 11: Industry subsectors (with IPCC emissions source classifications) included in the mitigation analysis

Industry sectors (and buildings)	Subsector	IPCC Emissions Category	
		Fuel combustion (1A)	Process Emissions (2)
Metals production	Iron and steel production	1A2a	2C1
	Ferroalloy production	1A2a	2C2
	Primary aluminium production	1A2b	2C3
Minerals production	Cement production	1A2f	2A1
	Lime production	1A2f	2A2
Chemicals production	Chemicals production (including ammonia, nitric acid, carbide, titanium dioxide, petrochemical and carbon black production)	1A2c	2B (including 2B1, 2B2, 2B5, 2B6 2B8)
Mining	Underground and surface mining (non-coal products)	1A2i	
Buildings	Commercial/institutional	1A4a	
	Residential	1A4b	
Other	Pulp and paper production	1A2d	

GHG emissions projections and mitigation opportunities are presented that cover GHG 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. Emissions result from the combustion of fuels in order to provide heat or mechanical work.
- Indirect emissions from the consumption of electricity.

Impact on GDP

The GDP figures are shown in Table 8, giving total impact and the various sources of the impact.

As far as the impact on GDP is concerned, the simulation suggests that:

The backward linkages are positive for all the implementation measures, whereas the forward linkages are negative for some and positive for other implementation measures. However, the total impact is positive across all the implemented measures.

The backward linkage is in most instances positive since most mitigation options require additional investment (more than the counterfactual) which has a positive effect on the economy.

In terms of the forward linkage, the cost of beneficiating minerals such as aluminium and ferroalloy is more expensive in the mitigation option than the counterfactual. This in turn leads to a less competitive international trade position, with negative effects on the domestic economy.

In terms of the adjustment on the dynamic impact for purposes of bringing the balance of payments to the initial equilibrium point, the surplus/shortage on the balance of payments as a percentage of GDP is far less than the dynamic impact before the adjustment.

Impact on employment

The figures in Table 9 show the composition of employment and final numbers of potential new jobs, assuming all measures are implemented according to the balanced weighting pathway.

As far as the impact on employment is concerned the modelling suggests that:

- The impact on employment of the industry mitigation option does not differ much to that of the impact on GDP, as the impacts are also all positive.
- The additional operational cost effect (including change in production structure) is positive and the industry sector measures have the potential to create new jobs but not on a large scale.

4.5 Mining

Definition

The mining sector includes all mining activities, including 'coal handling and mining' under the energy sector and 'surface and underground mining' under the industry sector.

Impact on GDP

Table 8 provides results of the impact on GDP based on the mitigation options for the mining sector.

As far as the impact on GDP is concerned the model results show that both the backward and forward linkages in this instance are positive.

Impact on employment

The employment figures in Table 9 indicate a substantial impact on employment, more or less in proportion to the contribution of the sector to GDP

4.6 Buildings

Definition

The building sector forms part of the industry sector and includes the subsectors residential buildings and non-residential buildings.

Impact on GDP

The figures in Table 8 indicate that in the case of the building sector, the backward and forward linkages plus the dynamic impact are positive across all the implemented measures. One of the main reasons for this is that the mitigation options included under this sector generally lead to energy saving which for this sector has a substantially positive effect on the economy's growth performance.

Impact on employment

The building sector is relatively labour-intensive and hence the combined mitigation measures have a substantially positive impact on employment. This is driven partly by replacement of current high energy-consuming equipment with more energy-efficient equipment.

4.7 Transport

Definition

Emissions for the transport sector are restricted to those arising within the national borders of South Africa, in accordance with IPCC reporting standards. Therefore, emissions associated with international aviation and international maritime transportation are excluded from the analysis.

In assessing the abatement opportunities, emission reductions have been assessed on a life-cycle basis. This means, for example, that abatement measures associated with changes in electricity consumption take into account any impacts on emissions in the electricity generation sector (1A1). Likewise emission factors associated with the use of biofuel take into account upstream emissions from biofuel production.

Impact on GDP

Figures in Table 8 show that the backward linkages are positive, whereas the forward linkages are negative. However, the total impact is positive.

The backward linkages are, in most instances, positive because the mitigation options require additional investment (exceeding the counterfactual), which has a positive effect on the economy.[2] The operational impacts are however negative, due to the fact that the operating costs of the mitigation options are cheaper than the counterfactual in almost all cases and therefore generate negative backward linked economic impact.

Impact on employment

As far as the impact on employment is concerned, the modelling suggests that the pattern of impacts on employment of the transport mitigation options does not differ much from that of the impacts on GDP. While there will be direct job losses associated with some measures (modal shift to mass transit, for example) these are outweighed by many other positive influences on employment.

2 Note that the modelling assumes that the investments will be made. However, the factors which will cause these investments to happen are complex. This is discussed in the main body of the report.

4.8 Waste

Definition

The assessment of mitigation potential for the waste sector is limited to the municipal waste sector.

Impact on GDP

As far as the impact on GDP is concerned the modelling suggests that the backward linkages are positive, whereas the forward linkages are negative. However, overall the outcome is positive. The backward linkage is in most instances positive since the mitigation options require additional investment and operational costs (more than the counterfactual) which has a positive effect on the economy.

Impact on employment

As noted above, the employment numbers for the waste sector have been adjusted taking into consideration that the structure of the sector and particularly the ratio of jobs to GDP will be substantially different after the mitigation measures are implemented. The adjustment has been made based on an assessment of direct employment for each individual measure, taking the following into consideration.

- International data on employment for the mitigation measures being proposed.
- Current levels of employment in the waste recycling industry.
- Current levels of employment in the solid waste sector in municipalities which will be influenced substantially by the shift from landfill disposal to new waste treatment and recycling measures.

As far as the impact on employment is concerned, taking the adjusted numbers into consideration, estimates suggest that the waste sector is a large employer in relation to other sectors. Backward linkages are positive and more highly positive than shown in the table with the additional direct employment provided for. Forward linkages are generally negative due to the negative net costs of the measures due to higher levels of spending on the additional measures in relation to landfilling.

4.9 Agriculture, Forestry and Other Land Use (AFOLU)

Structural issues

In the case of the AFOLU sector there is assumed to be no change to the current situation. This is related to the assessment that production is de-linked from economic growth and dependent on supply side factors; an assumption which holds true for the AFOLU sector for three primary reasons:

No change is assumed to natural biomes and, therefore, there are no sinks of CO_2 and no sources of CO_2 due to degradation of natural biomes.

Agricultural production, and associated emissions, is assumed to be constrained by supply side factors with the land area under agriculture, specifically, not expanding.

The area under commercial forestry is stable.

With production under the 'without measures' projection being constant, and with unchanged natural biomes, emissions are held constant. This is a rather artificial construct but is appropriate in that it allows a contrast with the reference case.

Definition

In the case of the AFOLU sector, the following mitigation options were included in the analysis:

- treatment of livestock waste
- biochar addition to cropland
- expanding plantations
- urban tree planting
- rural tree planting (thickets)
- restoration of mesic grasslands.

Impact on GDP

In analysing the impact on GDP, the simulation shows that the backward linkages are positive, whereas the forward linkages are negative. However, the total impact on the economy is positive. The backward linkage is, in most instances, positive owing to the mitigation options requiring additional investment and operational cost (more than the counterfactual) which has a positive effect on the economy.

Impact on employment

As noted above, the employment numbers for the AFOLU sector have been adjusted taking into consideration the fact that the mitigation measures have substantially different employment characteristics in comparison with the agriculture sector overall. The adjustment has been made based on an assessment of direct employment for each individual measure using figures from South African and international literature referenced in Appendix G. The figures have been adjusted to take into consideration that in many cases employment will not be permanent.

As far as the impact on employment is concerned, taking the adjusted numbers into consideration, it is evident that the AFOLU sector is a large employer in relation to the extent of its contribution to GDP. Backward linkages are positive and more highly positive than shown in the table with the additional direct employment provided for. Forward linkages are generally negative due to the negative net costs of the measures resulting from higher levels of spending on the additional measures.

5. Final impact on Projection over Time

The graph below (Figure 8) plots the trend over time showing the projected marginal change in GDP in relation to the baseline figures given in Section 3.

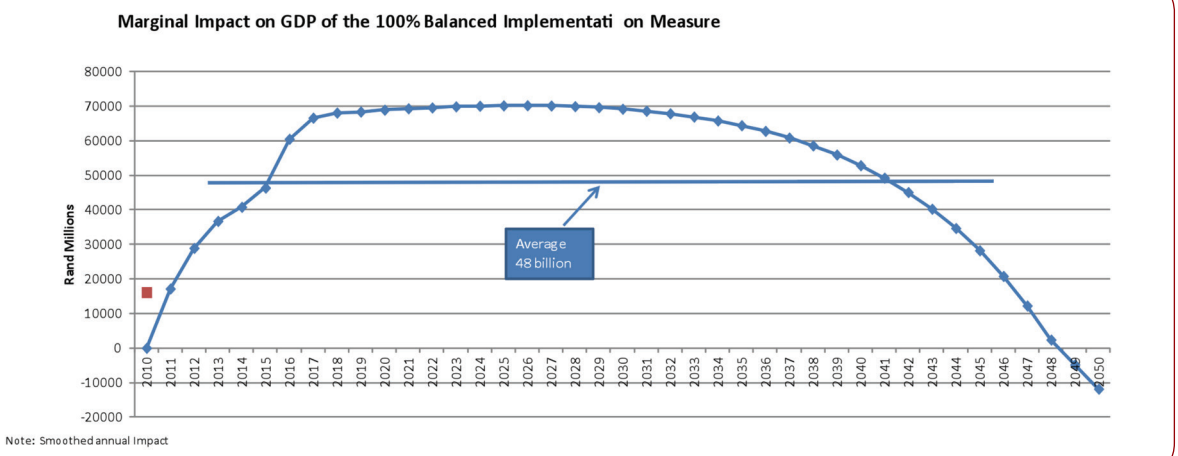

Figure 8: Marginal impact on GDP of 100% implementation of mitigation potential

The average marginal impact on GDP is R48 million, with a peak of R70 million in 2025. The marginal impact in 2010 is zero because no additional mitigation has been implemented yet at the beginning of the projection.

Considering the shape of the curve, the initial incline over approximately 10 years is caused largely by the investments which are progressively implemented over this period. The decline after 2030 is related to two factors. Firstly, most of the major investments have been made and the negative impacts of price increases are felt. Secondly, the measures implemented in the latter years tend to be those which are economically least favourable.

Turning to employment the marginal increase in employment in relation to the reference case is shown below (Figure 9).

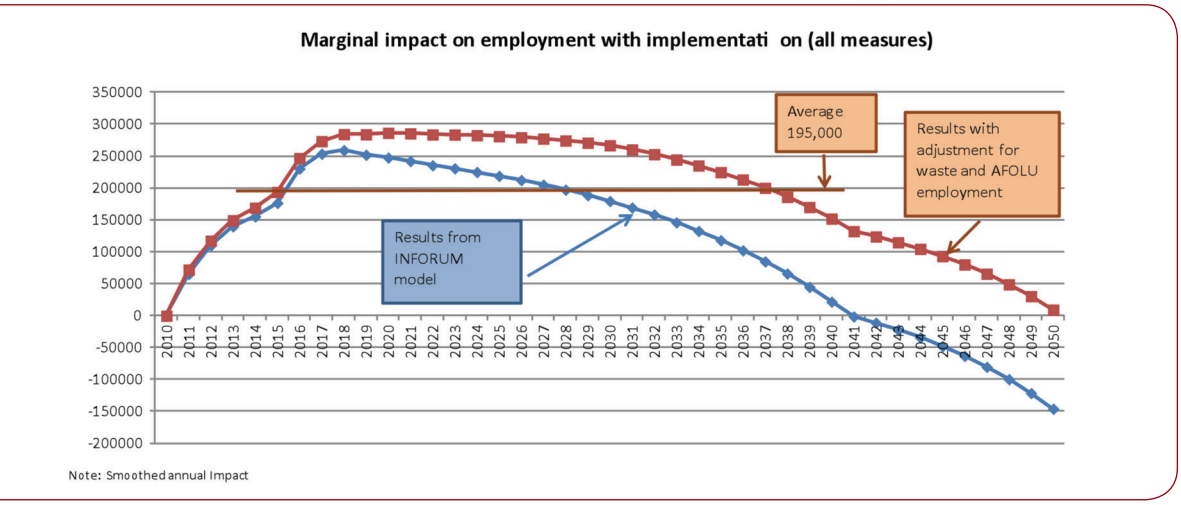

Figure 9: Marginal impact on employment, assuming 100% level of implementation of mitigation potential with balanced pathway

The overall impact on employment remains positive over the 40 year period, with an average of 195,000 jobs created between 2010 and 2050, assuming all technically feasible mitigation is implemented. As with GDP, the increase in the early years is largely driven by new investments. The declining trend in the marginal impact is related to the fact that over time for several sectors measures with lower employment benefits are included. But, on balance over the period, employment impacts are positive; largely because of the labour intensive measures in the waste and AFOLU sectors.

6. Summary and Conclusions

At average levels of impact on GDP of the order of 1.5% and 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. 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 in economic impacts. Further, it needs to be emphasised that this analysis proceeds on the assumption that the required investments will indeed be made. As explained in the main body of the report, there are many factors beyond the scope of economic modelling which will influence whether this will happen.

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