



**SOUTH AFRICA'S ENERGY SECTOR
INVESTMENT REQUIREMENTS
TO ACHIEVE ENERGY SECURITY
AND NET ZERO GOALS BY 2050**

Socio-Economic Impact Study
2025

Preface

This publication contains two studies that form part of a four-part study of the investment requirements to achieve net zero and energy security. The four studies are as follows:

- the literature review entitled “South Africa’s Energy Sector Investment Requirements to Achieve Energy Security and Net Zero Goals by 2050: Literature Review;”
- the technical analysis based on energy modelling, qualitative policy assessment and market sounding entitled “South Africa’s Energy Sector Investment Requirements to Achieve Energy Security and Net Zero Goals by 2050;”
- the macro-level socio-economic implications of the ‘green industrialisation’ scenario based on the outputs of a Computable General Equilibrium (CGE) modelling simulation; and
- the micro-level socio-economic impacts of the energy transition with specific reference to Mpumalanga, and the possible welfare and industrial policy responses.

This publication contains the last two of the above four-part study, namely the macro- and micro-implications of the energy transition.

The second of the four-party study assessed three scenarios: ‘green industrialisation,’ ‘market forces,’ and ‘business-as-usual’, as well as a number of sensitivities around those scenarios. The preferred scenario was ‘green industrialisation’ because it is lowest cost, achieves the carbon targets of South Africa’s NDC, and ensures energy security. It will also attract the highest levels of investment at the lowest cost. Furthermore, the demand curve through to 2050 and rate of coal closure through to 2050 is based on the 2019 Integrated Resource Plan (adjusted for known deviations), which is, in turn, similar to the 2025 Integrated Resource Plan. Although many studies of South Africa’s energy future have been undertaken, this is the first to include estimates of both capital costs and operational costs through to 2050. It also includes the costs of expanding the transmission grid to cater for connections of approximately 5 GW of renewables per annum, installing 23 GW of gas, plus substantial battery backup. The final estimate of the total cost of the ‘green industrialisation’ was estimated to be R138 billion per annum, which is less than R141 billion per annum for the ‘market forces’ scenario, and R160 billion for the business-as-usual scenario. The market sounding confirmed that there is at least R100 billion available per annum for investment in the energy transition, which is confirmed by the Green Cape study that found that climate finance investments (mainly in energy) amounted to R130 billion (86% of which came from the private sector, and nearly all from domestic sources).

Given that the ‘green industrialisation’ scenario is the preferred scenario, the obvious question that follows is what the socio-economic impacts of this preferred scenario will be at two levels: the macro-

economy in general, and Mpumalanga's micro-economy, in particular people employed by the coal mines and coal-fired power stations.

To assess the macro-economic implications of the 'green industrialisation' scenario, a CGE modelling exercise was done by the University of Pretoria. Four significant general findings are reported in this study. Firstly, the 'green industrialisation' scenario generates a double dividend in the long run, that is, higher rates of GDP growth and improved environmental outcomes relative to the baseline. Second, not all provinces will benefit equally. Without the kinds of interventions proposed in the fourth part of the study by Professor Borhat (see below), Mpumalanga in particular will suffer relative losses and disruption beyond 2030. Third, the CGE modelling supports the view that the cost of inaction will be higher than the costs of acting sooner rather than later. If the energy transition is delayed because of inappropriate policies and regulations, this will have significant negative socio-economic implications in the medium to long run. These costs include pollution-related health costs, negative returns on environmental degradation, increased economic penalties in the form of CBAM-type policies, and rising maintenance costs associated with our aging coal fleet. Fourth, government welfare and industrial policy should anticipate the divergent trajectories across provinces, with Mpumalanga potentially shrinking, and Northern Cape booming. Given that the Northern Cape now exports more energy than it consumes, it is South Africa's first green province. This is an investment attractor. It is, however, going to warm far faster than Mpumalanga which means the latter might in the long run be a more appropriate region for generating solar power given that solar panels become less efficient the hotter they get. Furthermore, Mpumalanga does not need much investment in the transmission grid.

The report by Professor Borhat from UCT is a micro-economic study of the coal value chain which is, of course, overwhelmingly located within Mpumalanga. According to the study, the coal industry accounts for roughly 76 406 jobs nationally, 87% of which are in Mpumalanga. The coal-fired power stations employ 30 481 people, highlighting the large number of other direct and indirect jobs that exist across the coal value chain. The typical worker is young and male and mostly located in Mpumalanga. Borhat distinguishes between workers who are minimal just transition challenge, workers who are an intermediate just transition challenge, and workers who are the core just transition challenge. The total number in the first category comprises 17 203 workers (25.97%). They are a minimal challenge because they are higher skilled, mostly with tertiary education occupying managerial and professional positions. The second category comprises 44 142 workers (66.63%), comprising semi-skilled workers with lower levels of education and skill. Nevertheless, they have a reasonable chance of finding alternative employment. Finally, the third group comprises 4 754 workers (7.18% of Mpumalanga coal workforce). These are the lowest skilled workers and therefore least likely to find alternative employment without skills retraining programmes. Overall, only 10% of the entire workforce will be affected by the energy transition between 2025 and 2030. The real impacts start to materialise from the early 2030s onwards which means there is time to prepare for these impacts. The advantage of Borhat's study is that he then correlates a range of welfare policies to mitigate the impact of the energy transition on all three categories

of workers, in particular the *intermediate* and *core* categories. This, in turn, relates to the industrial policies that will also be needed to mitigate the impacts anticipated in the CGE modelling study by University of Pretoria.

In short, these two reports should be read together. Whilst the CGE study takes an economy-wide approach to understanding the overall effects of an unmitigated 'green industrialisation' scenario, highlighting key regional, industry, labour and household outcomes at a macro level, Bhorat's study takes a deep dive approach to investigating the coal sector and labour market in Mpumalanga, specifically. Importantly, potential mitigation strategies for vulnerable regions and workers are noted in both studies, with Bhorat's study further elaborating on how such support programmes could look like and be implemented. The overall conclusion is clear: the energy transition yields a positive outcome at a macro level across various metrics but will have differential impacts on provinces and jobs. However, the real impacts will only be felt from the early 2030s onwards. This provides policy space for crafting effective welfare and industrial strategies that will mitigate against the adjustment costs of the energy transition in Mpumalanga and take advantage of the positive economic impacts on some other provinces.

Disclaimers

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Abbreviations

Term	Definition
AfCFTA	African Continental Free Trade Agreement
BAU	Business-As-Usual
BESS	Battery Energy Storage Systems
CBAM	Carbon Border Adjustment Mechanism
CES	Constant Elasticity of Substitution
CGE	Computable General Equilibrium
CO ₂	Carbon Dioxide
CO ₂ tax	Carbon Emissions Tax
CoPS	Centre of Policy Studies
CPI	Consumer Price Index
DOE	Department of Energy
DBSA	Development Bank of Southern Africa
DMRE	Department of Mineral Resources and Energy
EAF	Energy Availability Factor
EVs	Electric Vehicles
GDP	Gross Domestic Product
GEMPACK	General Equilibrium Modelling Package
GHG	Greenhouse Gas
GI	Green Industrialisation
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IRP	Integrated Resource Plan
JET-IP	Just Energy Transition Investment Plan
IPCC	Intergovernmental Panel on Climate Change

MW	Megawatt
NDC	Nationally Determined Contributions
NDP	National Development Plan
NT	National Treasury
OSeMOSYS	Open-Source Energy Modelling System
PCC	Presidential Climate Commission
REIPPPP	Renewable Energy Independent Power Producer Procurement Programme
RRoR	Required Rate of Return
SARB	South African Reserve Bank
SAREM	South African Renewable Energy Masterplan
SA-TIED	Southern Africa – Towards Inclusive Economic Development
SATIMGE	South African Times Model General Equilibrium
SDG	Sustainable Development Goals
SETA	Sector Education and Training Authorities
SEZ	Special Economic Zone
SOE	State-Owned Enterprise
StatsSA	Statistics South Africa
STEPS	Stated Policies Scenario
TDP	Transmission Development Plan
TERM	The Enormous Regional Model
ToR	Terms of Reference
UNFCCC	United Nations Framework Convention on Climate Change
UPGEM	University of Pretoria General Equilibrium Model
WEO	World Energy Outlook
WHO	World Health Organisation



SOCIOECONOMIC STUDY 1:

Macro-level socio-economic implications of the ‘green industrialisation’ scenario based on the outputs of a Computable General Equilibrium (CGE) modelling exercise

Professor Heinrich Bohlmann

1 Introduction

This report serves as a supplement to the main Beyond the Gap (BtG) report titled “*South Africa’s Energy Sector Investment Requirements to Achieve Energy Security and Net-Zero by 2050*” in which various electricity generation-mix scenarios and pathways were developed based on different sets of assumptions, least-cost versus best-cost considerations, and other sensitivities from policy preferences to funding constraints. The main purpose of this report, following from the project’s terms of reference (ToR), is to add socio-economic analysis based on the reference case Green Industrialisation (GI) (Scenario A) pathway or scenario developed in the BtG report using a regional-dynamic computable general equilibrium (CGE) model of South Africa. In line with South Africa’s NDCs, the GI pathway represents an ambitious, yet achievable, departure from the current generation mix and is therefore an important scenario to interrogate further. The added CGE analysis aims to provide a more holistic understanding of the broader economic and socio-economic impacts at a national, provincial and industry level of the GI transition scenario relative to a baseline scenario in which the transition does not occur. In particular, the performance of the different provinces relative to each other is important to understand where mitigation efforts should be concentrated, where skills and labour migration concerns need to be addressed, and where infrastructure for booming regions should be developed.

The structure of the report is as follows: Section 2 reviews and contextualises some of the literature relevant to the socio-economic impacts of transitions not explicitly covered in the BtG report, as well as literature focused on the CGE methodology relevant to environmental and climate policy work. Following on from this literature, Section 3 describes the CGE methodology in general, with emphasis on the features of the University of Pretoria General Equilibrium Model (UPGEM) used in this study. Section 4 details the various simulations run using UPGEM, starting with the unperturbed baseline simulation, and then moving on to the various policy simulations. The main policy simulation replicates the new build programme in the Green Industrialisation (GI) scenario to analyse the broader general equilibrium effects of this transition pathway. Additional policy simulations related to some of the likely negative effects of a potential funding gap for new build investments are also run. Linked to prior literature, these simulations are intended to give, at least a partial view, of the cost of inaction as it relates to the proposed energy transition. Throughout Section 4, key results and outcomes from the policy simulations are reported and discussed. Section 5 discusses various other considerations important to the overall topic, combining aspects of the literature, discussions with stakeholders, and direct and indirect implications of the CGE modelling results for key socio-economic indicators. Section 6 concludes and provides several policy recommendations based on the evidence produced and referenced in this report. Tables and figures containing data and simulation results too detailed for the main text are included in various Annexures to the report in the last section.

2 Literature

This section does not intend to replace or repeat the extensive literature review on energy transitions, technologies, and investment requirements in the main BtG report, but to supplement it with literature relevant to the socio-economic implications of transitions and related policy interventions, in particular where CGE modelling or similar methods were utilised. We will therefore not cover the details of the Integrated Resource Plan (IRP), determination of the Green Industrialisation (GI) pathway, financing or funding gap aspects, or associated literature again in this report.

As South Africa's current planning to enable a just energy transition towards cleaner sources of energy and electricity generation gathers pace, economic modelling continues to play an important role across key areas of environmental policy analysis. Earlier work by Van Heerden et al (2006 & 2016) and Arndt et al (2014) on South Africa's carbon tax design and implementation produced both useful technical analysis and a solid foundation for CGE models to be developed further, especially with regards to electricity sector and regional dimension detail. In terms of simulation results, these papers all produced strong evidence of a long-run double dividend stemming from the implementation of a carbon tax with various suggestions on revenue recycling options also tested. CGE models have also more recently been used in the construction of South Africa's Integrated Resource Plan (IRP), measuring its socio-economic implications, achievement of associated Sustainable Development Goals (SDGs) and Nationally Determined Contributions (NDCs), and understanding of the investment and financing needs to complete the transition, amongst others. The combination of SATIM-GE hybrid models (UCT, 2024) and TERM-style CGE models (Bohlmann et al, 2019 & 2023) have enabled the analysis of transition pathways at a detailed regional and household level, on top of the usual macro-level analysis, making a significant contribution to the South African literature on this topic.

Changing the status quo of an economy through policy intervention inevitably produces a combination of 'winners' and 'losers'. Climate policy in South Africa is no exception. Evidence from CGE modelling studies on carbon taxes and the energy transition have shown that while there are various benefits to implementing climate policy in the form of environmental improvements, efficiency gains, and investment related to new industries, some incumbent industries stand to lose. Linked to the concept of Creative Destruction, disruption or cost in one place (e.g. coal value chain in the Mpumalanga province) is often met with opportunity and gains in another (renewable energy value chain in the Cape provinces). Dynamic CGE models are able to clearly unpack these structural shifts, highlight short-term adjustment costs or other unanticipated effects, and quantify the net impacts on the economy and its various actors over time. Furthermore, any mitigation strategies to counter the impacts in provinces such as Mpumalanga can first be tested and refined using CGE methods.

In the case of climate policy in South Africa, it is important to note that these planned long-term structural shifts are both necessary and by design (PCC, 2024). The need to decarbonise the economy is essential,

especially given South Africa's status as one of the highest CO₂ emitting countries on a per capita basis and all its associated negative environmental and health externalities. The literature is near unanimous on the likelihood of a long-term double dividend for South Africa as it relates to the implementation of its climate policy. However, as already noted, if these long-term gains are to be realised, various short-run adjustment costs must be taken into account and appropriate mitigation plans designed, especially in the case of workers and protecting livelihoods.

As a precursor to this impact study, Bohlmann et al (2019, 2023) looked at the energy transition in South Africa in two different phases. The first paper simply looked at the national and regional impacts should the energy-mix move away from coal in the long run using a comparative-static model. The paper lacked detail in what the non-coal energy mix would look like as well as the adjustment path but gave early evidence as to the diverging regional impacts of the proposed energy transition. The second paper added dynamic analysis and a more detailed timeline of the transition, including most-likely decommissioning and new build schedules based on the IRP2019. The message was essentially the same, highlighting that, in the absence of additional mitigation strategies, coal-rich regions like Mpumalanga will lag behind other regions post-transition. The good news is that this message has been noted and understood for many years now. Additional work on the transition, including this report, has now been able to focus on the details of updated and more credible energy-mix transition pathways as provided in the main BtG report, give additional clarity related to the likely timing of the impacts and possible mitigation strategies, explicitly include coal export pathway considerations based on adjusted International Energy Agency projections (IEA, 2024 & 2025), and more clearly articulate the impacts of the transition on other socio-economic variables, including key labour market indicators and linking those findings to recent literature on this topic.

One of the most prominent studies on the labour market related to the energy transition in South Africa has been Bhorat et al. (2024). The team conducted an in-depth study into South Africa's labour market, with a particular focus on Mpumalanga and the industries and workers exposed to the looming energy transition. The research showed that while the coal mining industry represents a relatively small proportion of the economy, regionally concentrated in both output and employment terms in Mpumalanga, the economic footprint is felt more acutely in its downstream linkages and also as a core export revenue generator. Supporting the base data in UPGEM, an upper-bound national estimate of the direct jobs in coal suggest about 75,000 jobs in the industry, with 80% of these in Mpumalanga. The majority are semi-skilled jobs, employing predominantly young African males with Matric+ educational levels. In moving to an early labour market assessment of the size and shape of the just transition, it is clear that the most extreme challenge lies with about 5,000 workers in elementary occupations who are unlikely to find alternative employment easily. Social protection measures, such as income support, will be essential for these workers. In addition, the bulk of the coal industry workforce – some 50,000 workers in semi-skilled positions – likely require a much more complex and creative set of solutions to derive a medium-term policy response ensuring continued employment and income support to these workers and

their households. The study, like many other on the topic, supports the view that while the transition away from coal is necessary for South Africa's environmental and economic future, it must be managed carefully to ensure that the livelihoods of those dependent on the coal industry are not unduly compromised. The World Bank (2024) study also supported these findings but added significant weight to the case for training and support for new skills related to green transitions. The details of these training programmes are still being finalised by the relevant authorities in South Africa, but work on this front is well underway.

Other sub-topics related to environmental policy currently being analysed in other studies on South Africa using CGE methods are the impact of large-scale adoption of electric motor vehicles in coming years and its implications for tax revenue collection given that petroleum is heavily taxed; the possible establishment and growth of a green hydrogen sector and other localisation strategies to boost manufacturing and industrialisation efforts; the impact on trade of the European Union's (EU) Carbon Border Adjustment Mechanism (CBAM); and the impact of climate change on the agricultural sector and broader economy, including food and water security investments. Repercussions

3 Methodology

The University of Pretoria General Equilibrium Model (UPGEM) used in this study is a TERM-style bottom-up regional dynamic CGE model for South Africa, developed in collaboration with the Centre of Policy Studies (CoPS) in Melbourne. UPGEM is a well-documented model that offers detailed insights into the various inter-linkages of the country's economy – at both a national and provincial level – and how shocks promulgate through and affect its various actors.¹ The current UPGEM model database reflects industry-level economic structures based on the 2019 Supply and Use Tables (SUTs) published by StatsSA (2023), updated to reflect 2022 figures for key macro aggregates. The base year data may therefore be considered as representative of the year 2022 as industry-level structures are generally fairly 'sticky' in the short run. The UPGEM database in this study was aggregated to 60 individual industries, down from over 100 industries in the master national databases. Following the TERM-style methodology described in Wittwer (ed) (2012, 2017) a bottom-up regional dimension was created to reflect the details of each of the nine provinces in South Africa. In order to capture key details relevant to this project, the electricity sector was disaggregated from a single industry in the original source data into four main generator industries (coal, gas, nuclear, renewables and other) and a separate electricity distribution industry from who all users purchase the final electricity commodity. The relative shares of these generator types reflect 2022 data from Eskom (2024). The model and database further recognises

¹ See Wittwer (ed) (2012, 2017) for a description and various applications of the underlying TERM CGE methodology developed at the Centre of Policy Studies. Also see Dixon & Rimmer (2002), Dixon et al. (2013), Adams & Parmenter (2013) and Madden et al (eds) (2020) for additional policy applications and details of the methodology.

multiple household income group and tax type detail, amongst other features, similar to that described in Roos et al (2020).

Computable general equilibrium (CGE) models such as UPGEM are primarily designed for practical policy analysis. As such, it has long been one of the preferred methods for policymakers and stakeholders to assess the direct and indirect economic impacts of various shocks and interventions, including those related to environmental regulation and energy transitions. CGE models are underpinned by large economy-wide datasets, such as supply-use tables and social accounting matrices, that provide a detailed snapshot of the economy and its various inter-linkages in the base year. These datasets, grounded in strict national accounting frameworks, are then combined with various other supplementary data sources and implemented on a robust theoretical specification that allows for credible economic behaviour such as price-induced substitution and resource constraints. These key characteristics set the CGE methodology apart from previous generation input-output (I-O) multiplier and system dynamics (SD) models. The theory of a CGE model, which describes the behaviour of all participants in the economy linked to its underlying database, is represented by a large system of equations that typically contain thousands of variables alongside a series of empirically estimated elasticities and parameters.

Standard CGE models all have equations describing the nature of markets; intermediate demands for inputs to be used in the production of commodities; household demands for goods and services; investor demands for inputs to capital creation; government demands for commodities; and foreign demands for exported goods². The demand and supply equations in UPGEM are derived from the solutions to the optimisation problems which are assumed to underlie the behaviour of private sector agents in conventional neo-classical microeconomics. Each industry minimises cost subject to given input prices and a constant returns to scale production function. Zero pure profits are assumed for all industries. Households maximise a Klein-Rubin utility function subject to their budget constraint. Units of new industry-specific capital are constructed as cost-minimising combinations of domestic and imported commodities. The export demand for any locally produced commodity is inversely related to its foreign-currency price. Government consumption and the details of direct and indirect taxation are also recognised in the model.

Dynamic behaviour is typically specified through equations describing physical capital accumulation; lagged adjustment processes in the labour market; and changes in current account and net foreign liability positions. Capital accumulation is specified separately for each industry and linked to industry-specific net investment in the preceding period. Investment in each industry is positively related to its expected rate of return on capital, reflecting the price of capital rentals relative to the price of capital

² Different types of equations or functional forms are used to describe the behaviour of different actors in the model. For example, in the case of industries, optimising equations determining the commodity composition of industry output may be derived subject to a CET function, whilst functions determining industry inputs may be determined by a series of CES nests. Intermediate commodity and primary factor composites are typically combined using a Leontief or fixed-proportions function, with each commodity composite a CES function of a domestic and imported equivalent, and each primary factor composite a CES aggregate of labour (itself a composite CGE aggregate of different labour types), capital, and land.

creation. For the government's fiscal accounts, a similar mechanism for financial asset/liability accumulation is specified. Changes in the public sector debt are related to the public sector debt incurred during a particular year and the interest payable on previous debt. Adjustments to the national net foreign liability position are related to the annual investment/savings imbalance, revaluations of assets and liabilities and remittance flows during the year. In policy simulations, the labour market follows a lagged adjustment path where wage rates respond over time to gaps between demand and supply for labour across each of the different occupation groups, based on the specific characteristics of each of these groups.

Dynamic CGE models such as UPGEM are designed to quantify the effects of a policy change, or exogenous shock, to the economy, over a period of time. A good way to examine the impacts of an exogenous shock, such as the imposition of a new electricity generation pathway, is to compute the differences between a scenario in which the shock has occurred – the policy simulation – and a counterfactual scenario in which the particular shock under examination did not occur – the business-as-usual baseline scenario. Results are then reported as percentage change deviations over time between the first 'baseline' simulation run and the second 'policy' simulation run.

The model's closure settings, that is, the choice of exogenous versus endogenous variables, can be considerably different between the two runs. In the baseline we exogenise those variables for which reliable forecast information exists, which typically includes macroeconomic variables, such as the components of GDP, population growth and various price indices forecast by various macroeconomic specialists. Industries, such as electricity, which have explicit build programmes and a regulated pricing structure, may also have its available forecast data included in the baseline run. In the policy run, all the naturally endogenous variables are indeed set as endogenous, because we are interested in the impact of the policy change on them. This setting represents a more natural model closure where the variable for which the equation was written is typically set as endogenous. Standard baseline forecast and policy closures appropriate for UPGEM are described in Dixon & Rimmer (2002: 262-274). UPGEM is implemented and solved using the GEMPACK suite of programs described in Horridge et al. (2013).

Ultimately, a good understanding of all these aspects and key tasks in CGE modelling – theoretical structure, database construction, and closure rules – are required in order to sensibly design credible baseline and policy simulations, interpret results, and validate their accuracy. Whilst this report leans toward a less technical description of the modelling, interested readers are encouraged to study the finer details of the methodology from the key references listed in this section, in particular, Dixon et al (2013).

4 Modelling Scenarios

Baseline Scenario

The baseline scenario in UPGEM is a hypothetical business-as-usual (BAU) projection of the economy, starting from the 2022 base year data, and looking ahead up to 2050. This scenario serves to provide

an unperturbed baseline against which the effects of policy simulations can be isolated and measured in dynamic CGE simulations. The baseline projection does not aim to capture any potential structural changes in the economy that may arise from policy proposals (e.g. SAREM), anticipated climate effects, or any other exogenous shock not already included in macroeconomic projection models and other sources from where baseline forecast data used in UPGEM is considered. As we will continue to emphasise throughout this report, the baseline projection methodology as applied in this study (and is common throughout the CGE literature) therefore serves more of a technical role and should not be viewed as viable long-term forecast of the South African economy in its own right. Interpreting levels outcomes must be carefully considered as a result. For example, South Africa is likely to experience significant economic, fiscal and environmental headwinds in the absence of an energy transition – that is, should the business-as-usual continue. This looming threat to the economy is not adequately captured in current macroeconomic based forecasts produced by traditional macro forecasting specialists such as the IMF, or locally, National Treasury. The climate conscious literature discusses a number of factors that will contribute to pulling down the economy under a status-quo energy-mix outlook (Swilling, 2023; PCC, 2024). Chief amongst those include the rapid deterioration of existing coal infrastructure that will raise maintenance costs far beyond business-as-usual, and the inability to replace the ageing fleet of coal-fired power stations due to financing constraints. Moreover, external policies like the CBAM threaten entire value chains in South Africa, especially those in the export sector, should our coal-heavy energy mix persist. In short, the business-as-usual baseline scenario painted here should not be held up as legitimate standalone scenario, but merely as a technical exercise in order to facilitate the intended analysis of this report.

Despite the known issues associated with the traditional baseline simulation approach, it remains a necessary technical exercise. For the sake of understanding levels results produced by policy simulations, we briefly describe the key assumptions on which the baseline scenario in this study was based. For the 2023-2030 baseline period, detailed historical data and medium-run projections from National Treasury are used for all main macroeconomic variables. Beyond 2030, a bland macroeconomic projection anchored to SARB's projected long-run steady-state GDP forecast of 2.5% is applied. Traditionally, such a long-term view of GDP growth would be considered rather conservative for a developing country like South Africa, but in the absence of meaningful institutional reforms to reverse the declining trend of the last 15 years, it is much more likely to be considered as ambitious.

Cumulatively up to 2050, real GDP is projected to grow by 86% at an annual average of 2.3% with employment growth slightly below GDP at 68% and 1.8%, respectively. Only modest total factor productivity growth of around 10% is projected over the baseline period. At a provincial level, Gauteng (GP), the Western Cape (WC), and KwaZulu-Natal (KZN) is projected to grow at a slightly faster pace, with the Northern Cape (NC), Limpopo (LP) and North West (NW) lagging slightly behind national GDP growth. Inflation is projected to average 4% per annum over the baseline period, and population growth

is expected to gradually decline from 1.1% to 0.8%. Details of the baseline simulation results are shown in Figure 1 and Figure 2.

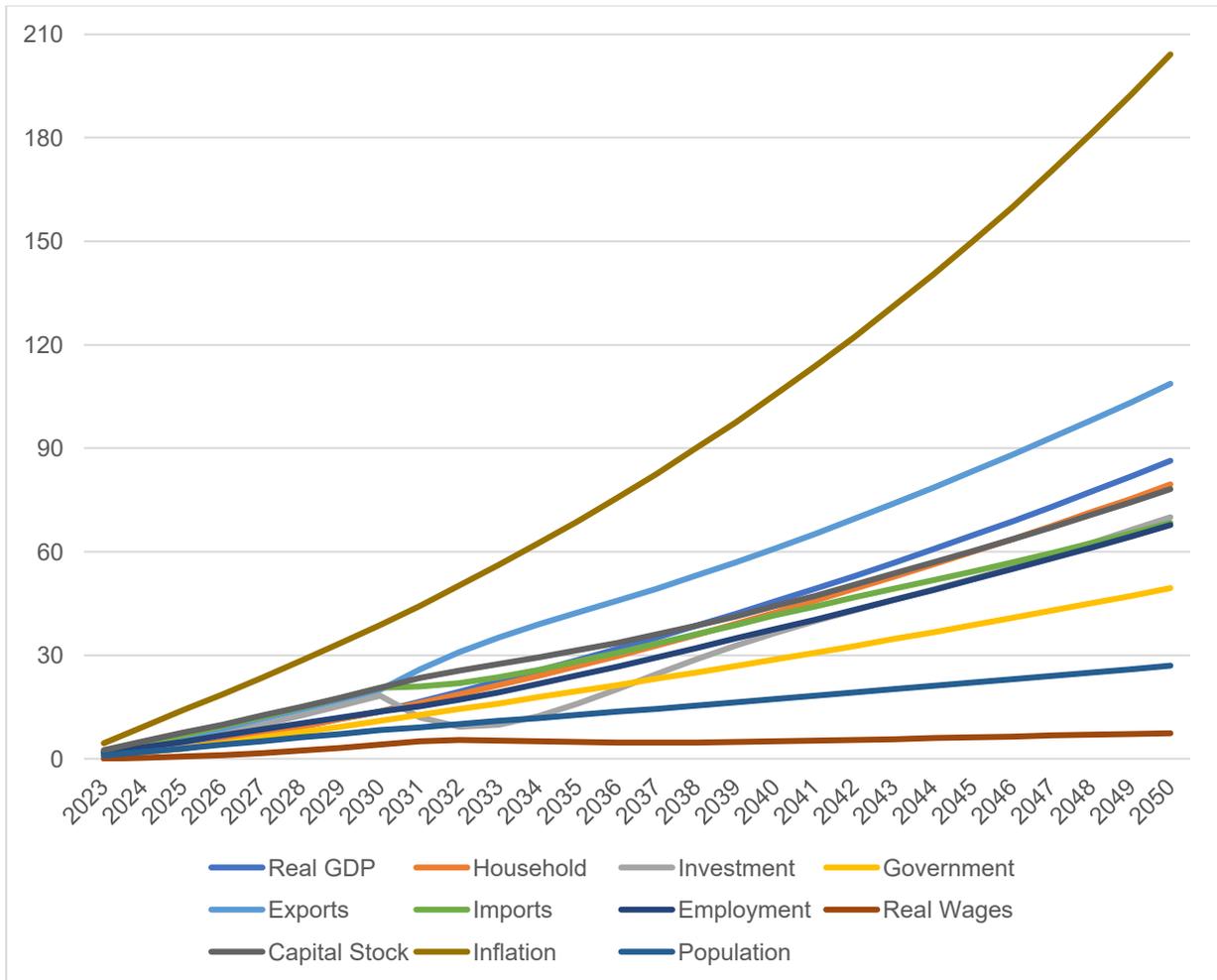


Figure 1: Baseline National Macro Projections (Cumulative %Δ 2023-50)

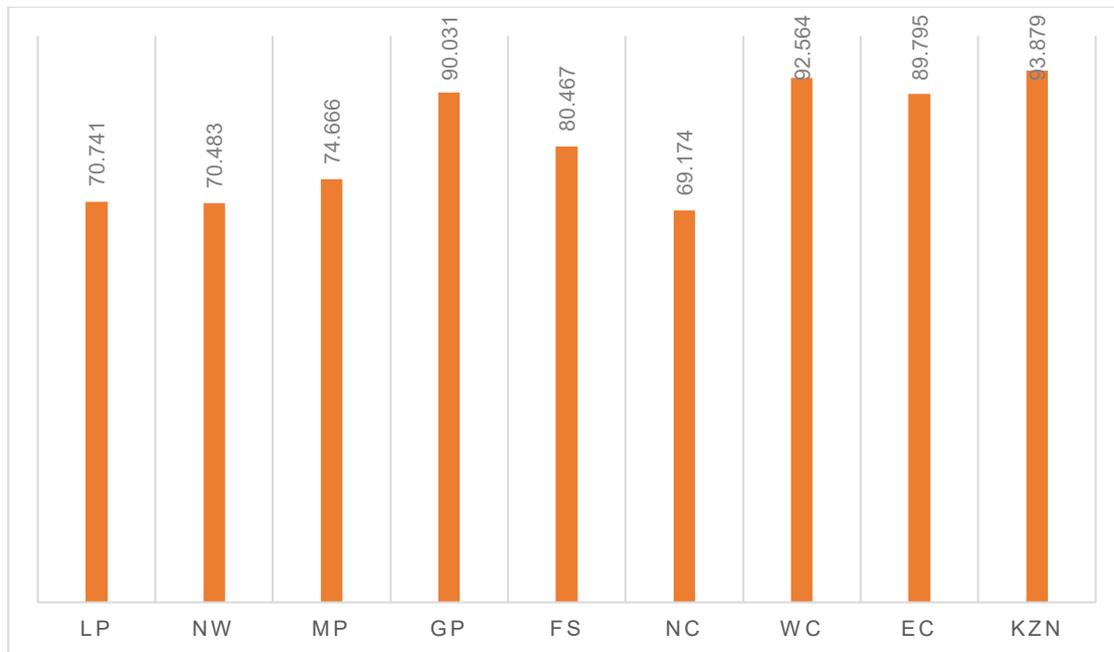


Figure 2: Baseline Provincial Real GDP Projections (Cumulative %Δ 2050)

With the baseline simulation in place, policy shocks can now be implemented on UPGEM. This methodology allows for the effects of each policy shock scenario (described in the next section) to be isolated and measured, allowing for a detailed understanding of the effects of each shock whilst keeping all other naturally exogenous variables (e.g. tax rates, population growth) on their baseline path. There are two ways of looking at the results of the baseline versus policy scenario runs. The first way is to compare cumulative percentage changes for the same variables in both the baseline and policy run simulation over time. The second way is to translate the level of the policy run results into percentage deviations relative to the baseline. Each method has merit, although many CGE modellers prefer the % deviation approach as it is more robust in its interpretation to changes in the underlying baseline projection values over time. In this report, both methods will be presented where appropriate.

Green Industrialisation Energy Pathway

The Green Industrialisation (GI) energy pathway developed using the OSeMOSYS optimisation model and detailed as Scenario A in the main BtG report titled *"South Africa's Energy Sector Investment Requirements to Achieve Energy Security and Net-Zero by 2050"*, is used as the benchmark or reference case energy-mix scenario in the policy run for this report to assess the socio-economic impacts of the energy transition. The main details of the GI pathway and its impact of the electricity generation-mix through 2050 are captured in Figure 3 (total installed capacity by main generator type), Figure 4 (coal generation capacity by province), and Figure 5 (renewable generation by province). In summary, the GI scenario produces strong growth in renewable energy (mainly solar and wind) across most provinces in South Africa, in particular the Northern Cape, whilst seeing all but two coal-fired power stations (Kusile and Medupi) decommissioned by 2050. No new nuclear is built, and limited gas capacity is added. As a

result, industry output for coal generation, and to a lesser extent, coal mining, falls significantly in Mpumalanga compared to the baseline which reflects a continuation of the current coal-dominant generation mix. As discussed in more detail in the results section, industry employment naturally follows a similar path as output.

For the GI scenario, we translated its energy-mix pathway outcomes detailed in the main BtG report into annual shocks for output and investment for each of the four main electricity generator types in UPGEM, namely i) coal, ii) gas, iii) nuclear, and iv) renewables and other. Changes to battery storage capacities are not exogenously specified in this application of UPGEM, but its expanded use is (at least partly) endogenously captured through the model’s mechanisms. Details of the percentage change shock values to output and investment for coal and renewables in each province are shown in Annexure B.

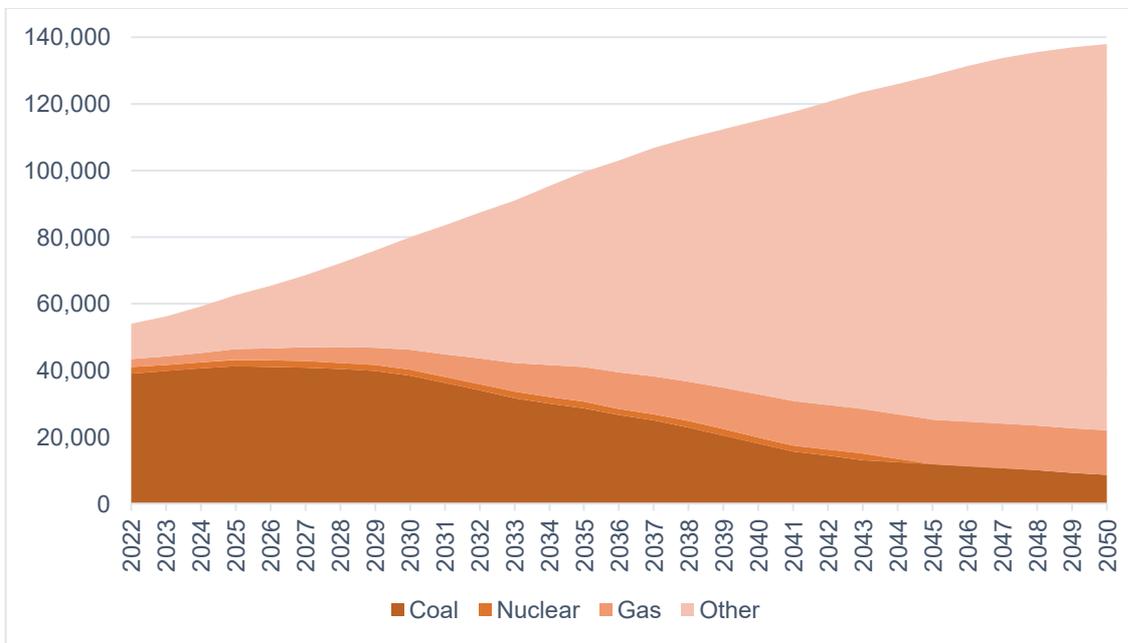


Figure 3: GI Pathway Generation Capacities by Type (MW) (2022-2050)

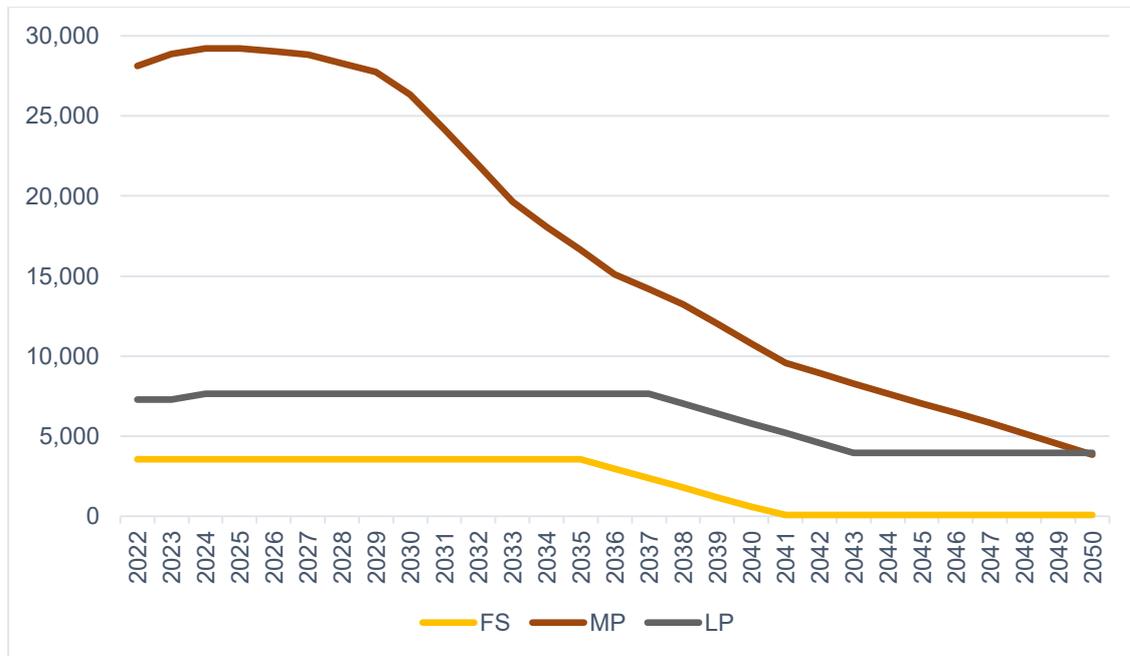


Figure 4: GI Pathway Coal Generation Capacities by Province (MW) (2022-2050)

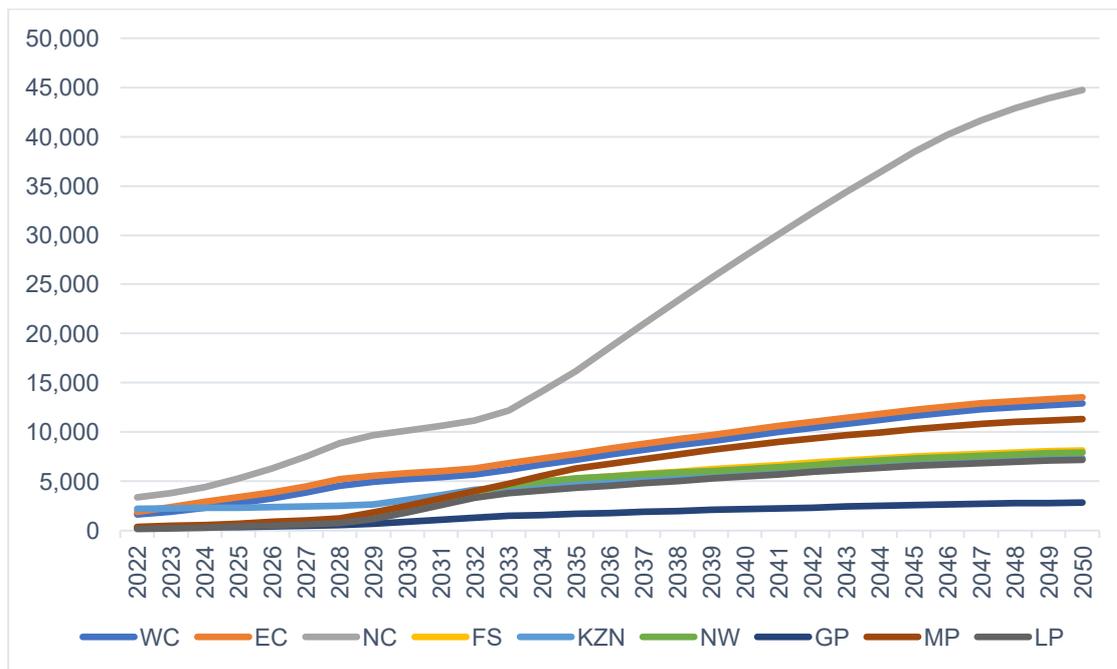


Figure 5: GI Pathway Renewable Generation Capacities by Province (MW) (2022-2050)

In addition to the output and investment shocks related to the GI scenario, we run this simulation under two different sets of assumptions related to coal trade. The first simply assumes national coal exports will remain on its baseline path (that is, the relevant variable is exogenous and unshocked in the policy run thereby maintaining its baseline values over time), whilst the second and more realistic variation, explicitly takes into account the anticipated decline in coal trade globally, and by implication coal exports from South Africa, beyond the medium term. Starting from the general STEPS scenario developed by the International Energy Agency (IEA 2024 & 2025), and adjusting for South Africa's cost competitiveness advantages, this scenario exogenously projects that coal exports will initially remain relatively stable up to 2030 before gradually falling by approximately 50% relative to 2022 levels by 2050 as global use of coal in electricity generation is expected to decline. Within the context of the global energy shift and international commitments, the drop in coal exports is expected to become especially severe beyond 2040, directly impacting the South African coal mining industry that already exports around 40% of its output to international markets. Despite this large drop in coal exports, this scenario represents a slower paced reduction compared to most other coal exporting countries and overall global trends through 2050 projected by the IEA. Unless otherwise stated, results for the GI scenario will be based on the second set of assumptions regarding coal trade.

Other Policy Shock Scenarios

In addition to the new energy pathway scenario, we run three additional policy shock scenarios related to the potential effects of a funding gap and subsequent underinvestment in the energy sector emerging. Each simulation is run under typical policy run closure rules. The first scenario (A1) reduces the scale of energy investments by 50% relative to the GI scenario; the second (A2) simulates a permanent once-off 1% increase in borrowing costs reflecting an increase in economy-wide risk and required rates of return from investors; and the third scenario (A3) increases general tax rates on final users by 1% reflecting a scenario in which tax revenues need to rise to help finance aspects of the new build programme due to a funding gap.

Results for scenarios A2 and A3 in particular must be viewed in light of the shock implemented – a once-off implementation at a benchmark 1% magnitude only. History suggests that shocks related to the events modelled here, e.g. electricity supply shortages leading to loadshedding, tax revenue collection and budgetary shortfalls, etc. may lead to multiple shocks of this nature that would raise the overall magnitude of the shocks beyond these benchmark levels. Whilst these three additional simulations are designed to give some insight into the effects of a funding gap, they are by no means designed to be a comprehensive assessment of all possible spillover effects of such an event or series of events.

Policy Simulation Results

A number of variables have been identified as most relevant to judge the socio-economic impact of the various scenarios, in particular the GI pathway, within the context of the overall project. From a national

macroeconomic perspective, we will track the following variables: i) real GDP, ii) gross fixed capital formation (GFCF), iii) consumption, iv) exports, v) inflation, vi) employment, and vii) real wages. From a regional and more micro-perspective, we look at provincial-level industry output alongside real GDP, GFCF, consumption and employment variables for selected provinces. We also refer to these results in the role they will play in driving other socio-economic variables such as internal migration and infrastructure development needs.

4.1.1 GI Energy Pathway Simulation Results

At a national level, the GI scenario paints a relatively positive picture in terms of economic impacts, even in its unmitigated form. From the BtG report we can also confirm that the outcome of the GI scenario will be most favourable in terms of environmental outcomes as emissions are significantly reduced relative to the coal-generation dominated baseline. Figures 6 to 12 capture the results of key economic variables across various dimensions. Most macro variables perform slightly above baseline levels, largely driven by improved GFCF stemming from the new build programme. To give an understanding of the potential level against which the policy deviations occur, Figure 6 shows the cumulative % change projections for baseline real national GDP relative to real GDP of the GI scenario at both national and provincial levels. As previously noted, the baseline projection for national real GDP, which sees a cumulative increase of 86% between 2023 and 2050, serves as a technical anchor against which the GI scenario policy simulations deviate and allows for comparative regional analysis. Whilst in a traditional sense the average growth in the baseline can be viewed as conservative, it should not be mistaken for a business-as-usual forecast of the economy. As already discussed and the global climate conscious literature has made clear, more so given the facts of the South African economy and energy sector, long-term macroeconomic forecasts that does not explicitly consider the costs associated with mitigating against climate trends, fast-depreciating coal-fired power stations, and economic penalties associated with inaction such as CBAM, cannot legitimately be used to compare levels outcomes of policy simulations like the CI scenario against. The value and practical use of the baseline is therefore limited to a technical one that allows for the interpretation of policy simulation results as discussed.

Figure 7 show these same results for real GDP as % deviations relative to the baseline. For example, while Mpumalanga's (MP) real GDP may be expected to decline by up to 16% in 2050 relative to the baseline in the GI scenario as per Figure 7 (in an unmitigated scenario that only considers the change in electricity generation-mix and associated build schedules), Figure 6 highlights the fact that under our hypothetical baseline growth conditions, this implies that the MP economy would still grow by around 43% relative to 2022 levels. Despite the uncertainty associated with any baseline projection, this does underscore the importance of proper interpretation of simulation results. In short, despite the predicted decline in the MP economy relative to the baseline, it is still likely to emerge as a much larger economy in real terms in 2050 under the GI scenario than it is today, and even more so if planned mitigation strategies can be successfully implemented and likely positive spillover effects come to fruition. That is, the 16% decline should not be interpreted as a contraction in an absolute sense. In fact, given the factors

excluded from our business-as-usual baseline projection, Mpumalanga (and South African as a whole) may be considerably better off in the long run by avoiding the costs of inaction. What will be an unavoidable consequence of the energy transition to MP is that, in the absence of additional mitigation policies, it will grow slower than other provinces and the national average. It will therefore be a key task of policymakers and stakeholders to design, test, and implement good strategies that will reduce the growth deficit MP will otherwise face.

Figure 8 shows the % deviation in gross fixed capital formation (GFCF) or investment expenditure at a national and provincial level. The slightly erratic path, in terms of % deviation relative to the baseline, of GFCF in the Northern Cape (NC) is dictated by the projected slowdown in the renewable build programme in the province between 2028 and 2033 while new required transmission infrastructure is being built. Beyond 2033, investment in terms of generation capacity coming online and becoming productive capital stock picks up again. Conversely, for MP, beyond 2030 the net impact of large-scale decommission versus limited new build of renewables, sees GFCF gradually falling more and more below its baseline levels. This is exacerbated by the impact of declining coal exports on the coal mining industry, on top of the impact of reduced coal demand for coal-fired electricity generation. The large projected jump in GFCF or investment spend in the NC under the GI scenario highlights the need for supporting infrastructure and logistical services to be in place to ensure no bottlenecks are experienced. UPGEM projects strong growth in such construction and related services, but since there is a large degree of central planning often involved in these projects, it is worth noting in advance. A further note of caution as it relates to GFCF is crowding out effects at an industry level. In the Northern Cape especially, although this is general true at a national level too, UPGEM predicts that other industries outside of the booming electricity generation and transmission sector will face a tight market for goods and services in the short to medium term. Rising prices for construction goods and services will therefore dampen GFCF outside of the sectors directly driven by the transition and new build programme.

Figure 9 shows the % deviation in household consumption. These results, unsurprisingly given the theoretical structure of the model, closely follows the results for GNP and GDP. Once again, households in the MP are expected to lose in relative terms, with households in the NC, and to a lesser extent WC and EC, offsetting this loss. Overall, national household consumption is essentially expected to remain very close to baseline levels, similar to GNP and GDP. Readers are again reminded that these % deviation declines relative to the baseline are not expected to yield an absolute decline in consumption as low but steady growth is expected in the baseline.

Figure 10 shows the % deviation in exports and imports, as well as closely related price variables, the terms of trade and CPI inflation. After an initial increase above baseline levels of imports, imports gradually start decreasing as the real value of the Rand starts to depreciate slightly. Exports remain a touch below baseline levels up to 2040, after which it moves above baseline. The terms of trade is large driven by the export price since import prices are considered exogenous in the policy run. The export price in turn is governed by domestic output prices which can be captured by the CPI inflation. After an

initial bump above baseline while domestic supply conditions adjust, inflation gradually starts falling back to baseline and eventually just below. At an aggregate level, however, inflation effects are very minor.

Figure 11 shows the % deviation in aggregate employment on a wage bill weighted basis at a national and provincial level. As expected, employment outcomes closely follow output, although slightly more muted due to accommodating relative price changes. Occupation and industry specific employment results shown in the Annexures highlight the importance of this analysis beyond an aggregate level. Employment for most occupation groups in the coal sector in Mpumalanga drop significantly over time, although minor gains are seen in other sectors that are able to pick up and benefit from the slack labour market conditions. Figure 12 shows the % deviation in real wages and generally follows from the employment outcomes. When demand for labour rises relative to initial supply, real wage pressure emerges. Over time, this pressure is alleviated by the gradual movement of labour to where relatively higher wages and better earning opportunities exist. Our modelling assumptions imply lower real wage pressure for lower-skilled occupation groups given the high rates of unemployment in the country. Overall, the GI scenario yields higher than baseline wages, except for MP and LP who are hardest hit by the relative loss in activity related to coal-fired electricity generation and coal mining. How many workers will be able and willing to migrate in order to take up better paying jobs elsewhere over time, as predicted by the model, is subject to ongoing research.

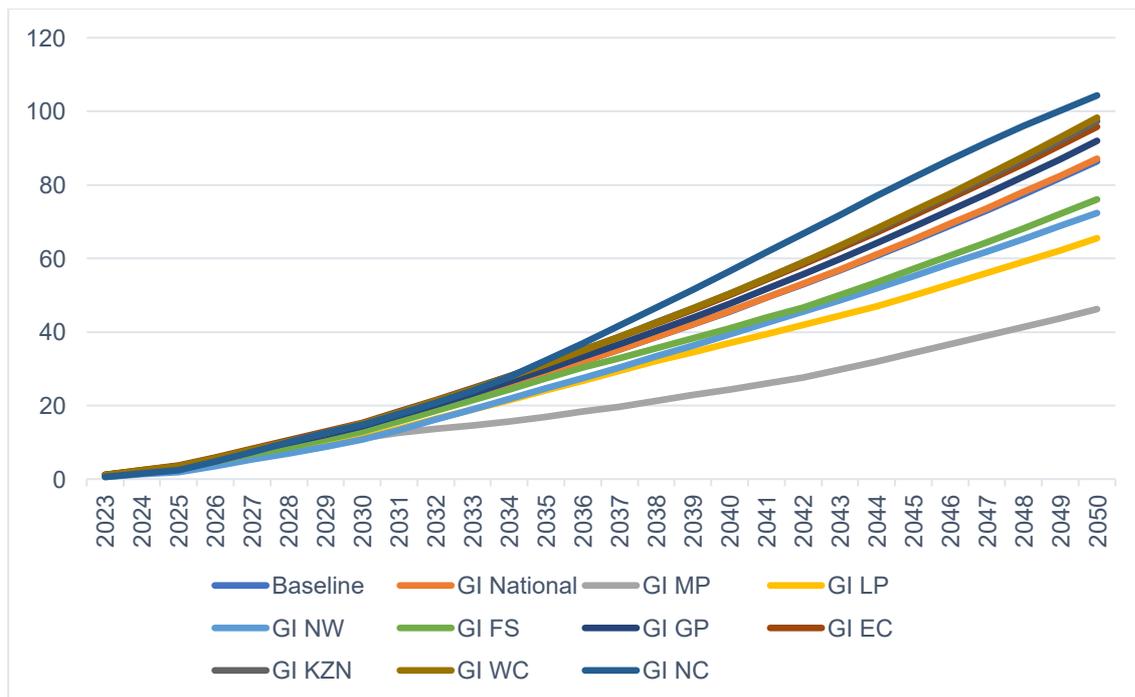


Figure 6: Real GDP Cumulative %Δ for Baseline and GI Scenario

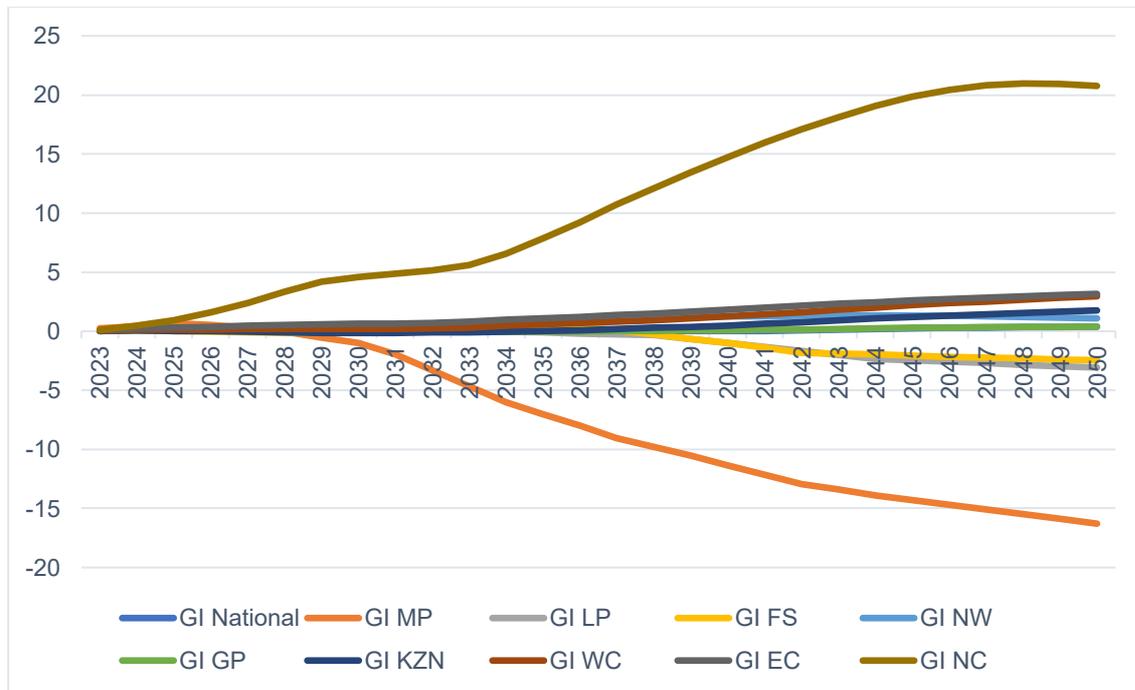


Figure 7: Real GDP Cumulative % Deviation from Baseline for GI Scenario

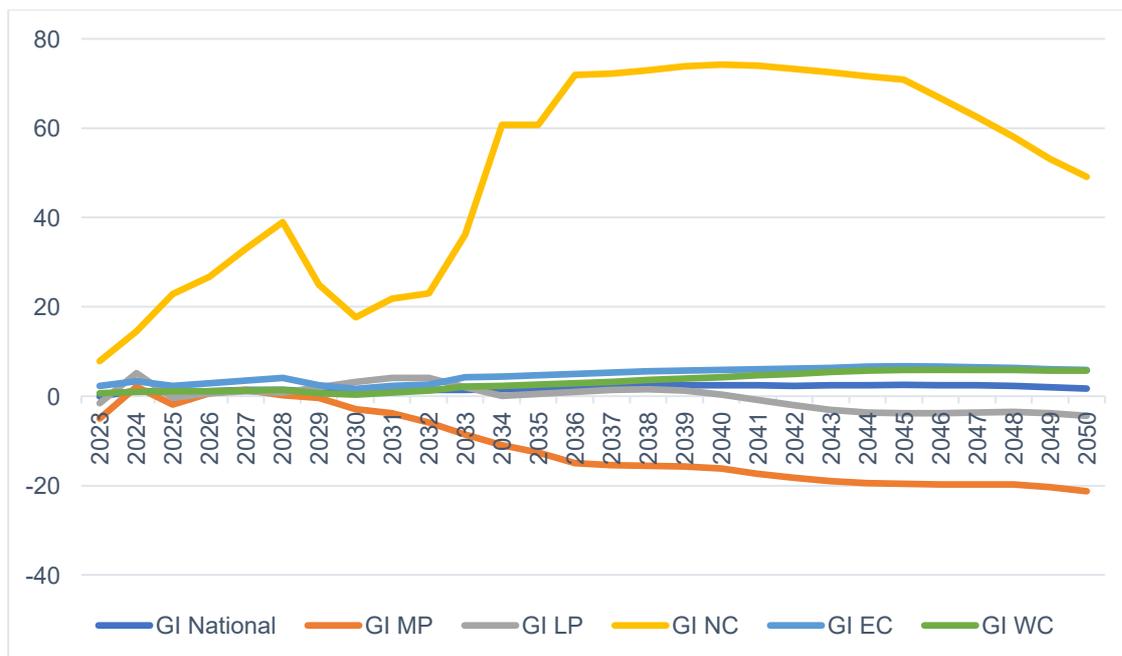


Figure 8: Gross Fixed Capital Formation Cumulative % Deviation from Baseline for GI Scenario

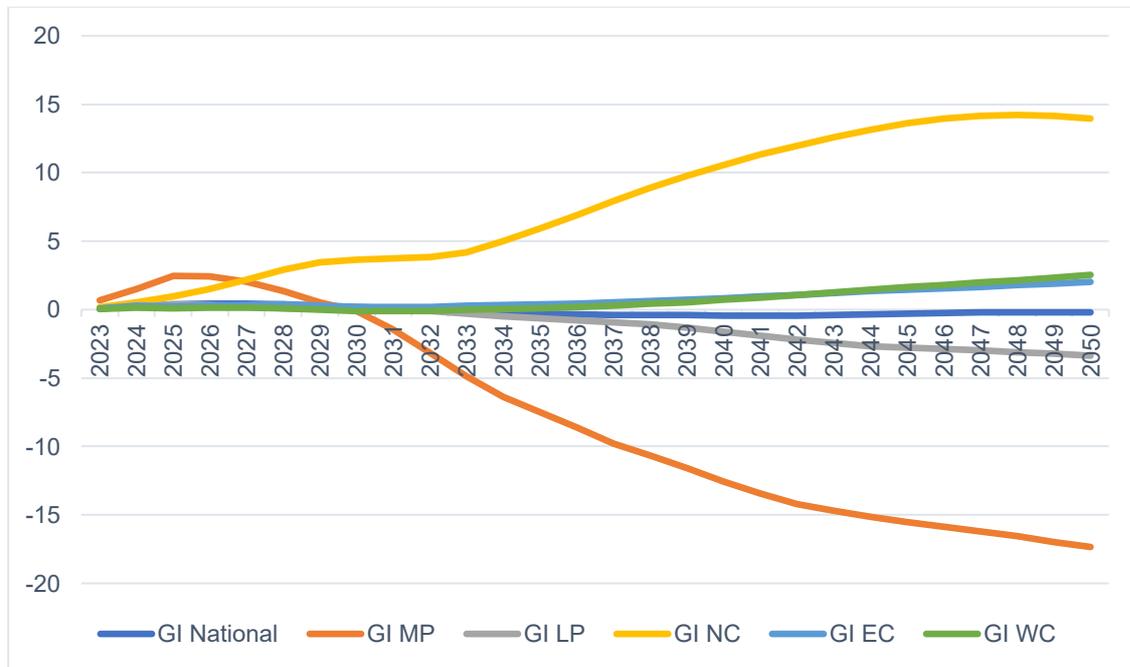


Figure 9: Household Consumption Cumulative % Deviation from Baseline for GI Scenario

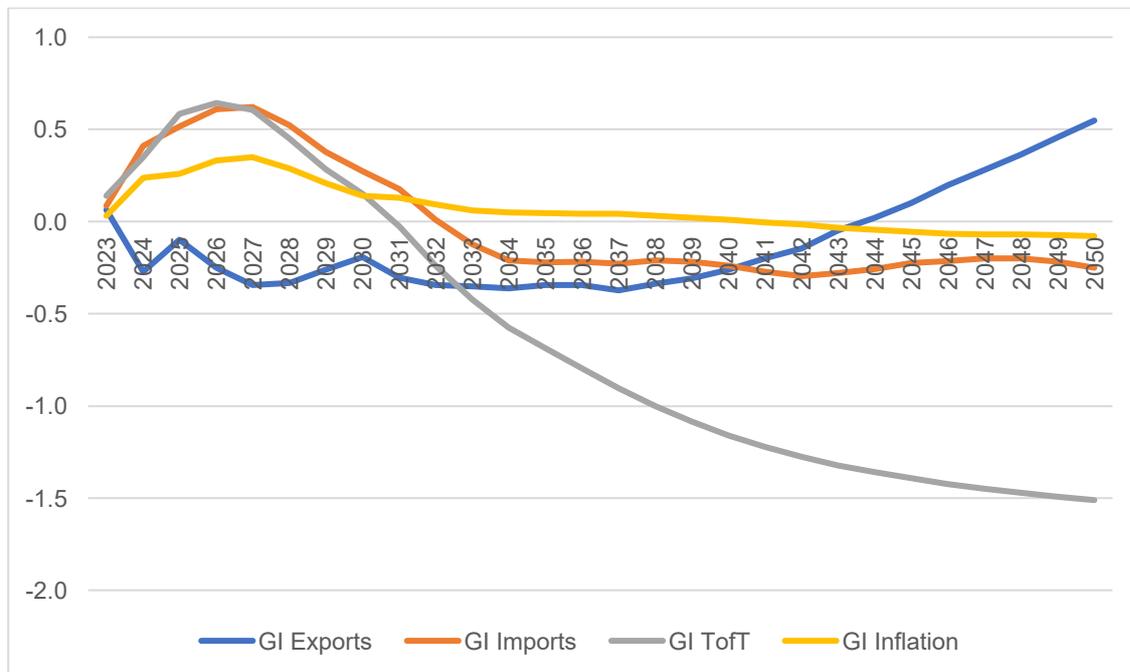


Figure 10: National Trade and Prices Cumulative % Deviation from Baseline for GI Scenario

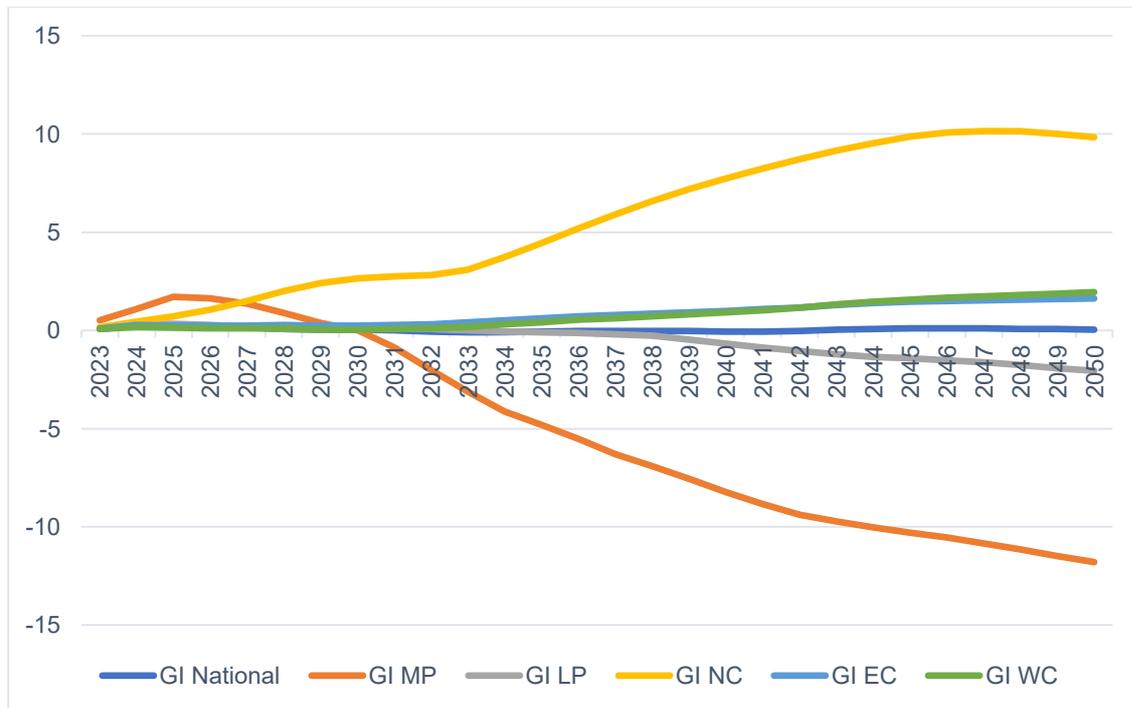


Figure 11: Employment Cumulative % Deviation from Baseline for GI Scenario

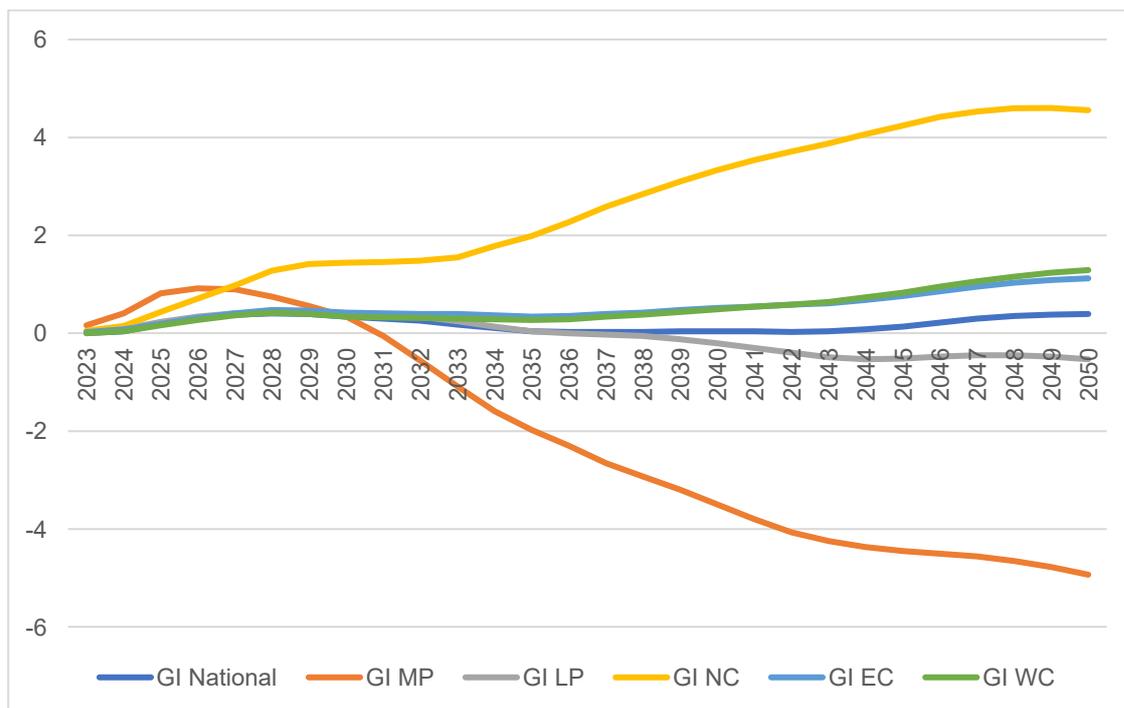


Figure 12: Real Wages Cumulative % Deviation from Baseline for GI Scenario

4.1.2 Reduction in Scale of New Build Programme

Lowering the scale of the GI scenario's renewable build programme by 50% will reduce electricity output by close to 40% in the LR and significantly curtail economic growth, placing additional pressure on economic activity and off-grid solutions for households and businesses. Our analysis and simulation results from UPGEM confirm what many have already experienced over the last two decades – in the absence of dependable grid-based electricity, economic activity suffers, investment stalls, and our unemployment and inequality crises deepen. Whilst some households and businesses are able to reallocate spending towards off-grid solutions (mainly rooftop solar PV and battery storage) and minimise the impact of loadshedding events and rising electricity costs, this is not an option everyone can afford. Moreover, this reallocation comes with significant opportunity costs in the short run as spending or investments that would otherwise have occurred are now substituted.

A pivot towards a more coal-dominant energy mix (resembling the energy-mix in the baseline) under this scenario, even if underinvested, will simply worsen our environmental outcomes, continue a costly coal fleet maintenance programme, and cause us to miss our own NDC and air quality targets on top of likely significant long-run economic repercussions from CBAM-type policies and their associated penalties on carbon-intensive economies. This scenario is certainly to be avoided, and stresses the need to secure dependable and affordable long-term funding for the transition. As noted in the main BtG report and elsewhere in this report, economy-wide derisking in order to lower required rates of return will be an important element to ensuring a full funded GI-type energy transition in South Africa.

4.1.3 Increase in Borrowing Costs

When events occur that risk the macroeconomic stability of a country, such as a poorly performing electricity sector, the effects ripple through the entire economy. A key channel through which such shocks quickly promulgate through the economy, is an increase in external borrowing costs as risk perceptions and associated metrics deteriorate. Higher risk, real or perceived, to investors equate to higher required rates of return (RRoR) to compensate. This lowers the amount of investment at any nominal rate of return offered in the economy.

Results from a simple benchmark simulation using UPGEM confirms this outcome. As shown in Figure 13, for every 1% rise in the RRoR on investment, GFCF falls by approximately 5% relative to the baseline and real GDP by just over 1%. The key message here is that higher borrowing costs significantly lowers investment and overall economic activity. Moreover, should our energy transition be underfunded or otherwise poorly executed, signaling deeper institutional problems, risk premiums associated with both general macroeconomic issues and specific energy sector issues will likely rise even further than the benchmark 1% modelled here. This results of this scenario is indicative of South Africa's current investment climate as higher risk premiums and subsequent borrowing costs have significantly constrained investment into South Africa over the past decade, seeing GFCF as a share of GDP fall to around 15%.

4.1.4 Increase in General Consumption Taxes

Another scenario that is likely to play out should the transition be underfunded or a general funding gap arise is an increase in taxes designed to raise government revenue and limit any budget deficit. Increasing general taxation on consumption, through for example an increase in VAT, to fund any investment gap associated with the energy transition will directly lower disposable income and harm macro outcomes closely linked to household spending.

Results from a simple benchmark simulation using UPGEM confirms this outcome. As shown in Figure 13, for every 1% increase in consumption taxes, GFCF immediately falls by approximately 0.7%, household consumption by 0.45% and real GDP by 0.25%, relative to the baseline, before slowly recovering towards baseline levels. The key message here is that higher taxes significantly lowers disposable income, investment and overall economic activity, and will likely worsen inequality further. Without getting anything additional in return in comparison to a fully funded transition scenario, an underfunded transition that will require the raising of taxes to accomplish delivers far worse outcomes to the economy, and should be avoided.

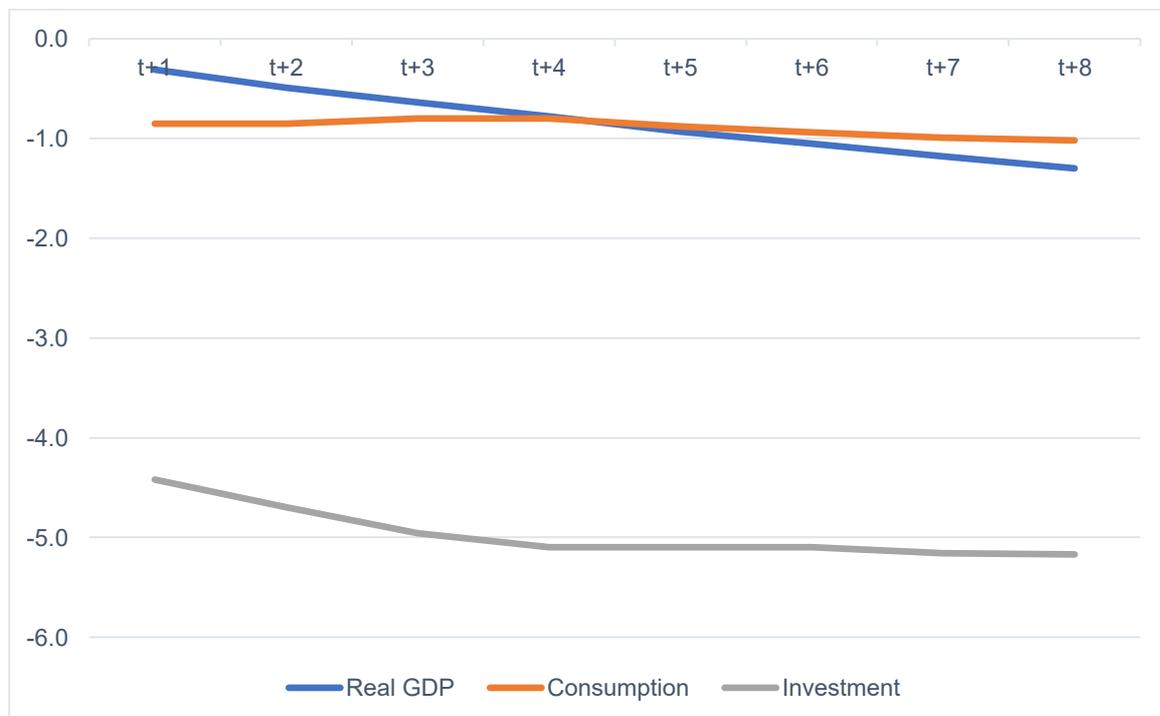


Figure 13: Main Macros % Deviation from Baseline for a 1% Increase in Borrowing Costs

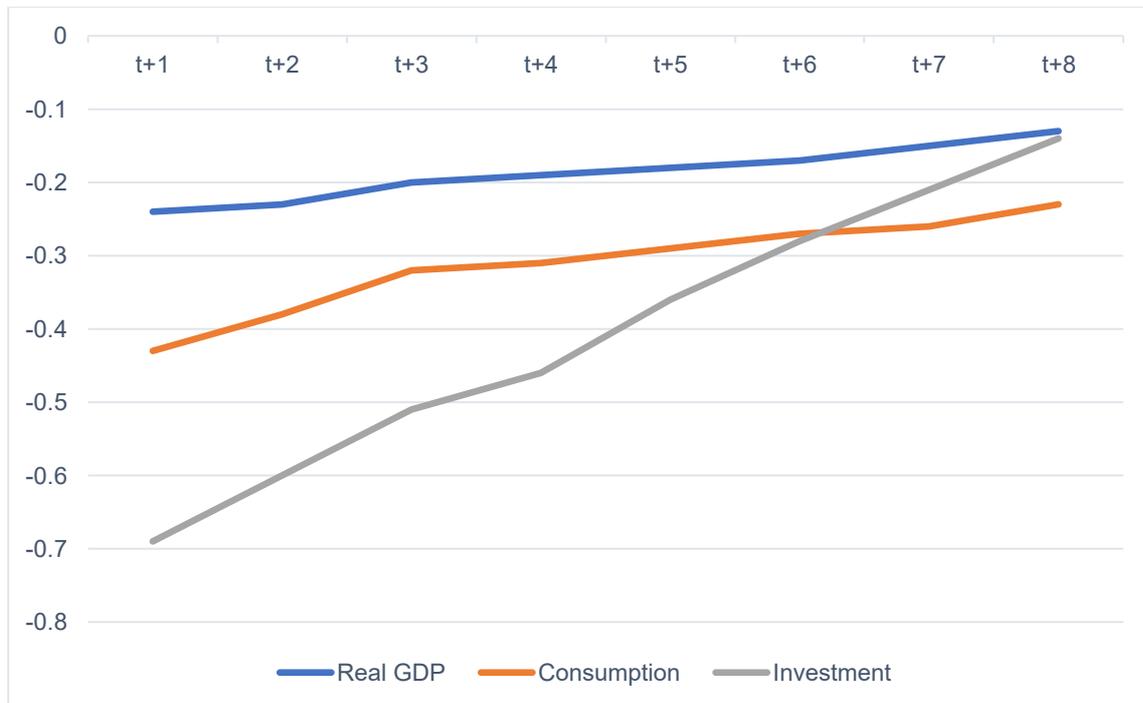


Figure 14: Main Macros % Deviation from Baseline for a 1% Increase in Consumption Taxes

5 Other Considerations

The modelling of the Green Industrialisation (GI) transition scenario produces a clear and coherent set of results as far as it pertains to the variables in the University of Pretoria General Equilibrium Model (UPGEM). Furthermore, our other policy shock scenarios, especially when considered alongside the supporting literature, highlights the urgency with which funding for the transition must be secured and economy-wide derisking strategies to accompany the overall transition implemented. Despite the double dividend outcome of the GI scenario at a national level, the attention for many has always been on those who lose in the transition, regardless if such relative losses are only temporary. As has been well documented, Mpumalanga, and to a lesser extent, Limpopo, certainly falls into that category. Additional work to facilitate new ideas, smart investments, and a renewed sense of urgency to lift total factor productivity and raise private sector investor interest will be required to counteract the loss of economic activity associated with the coal value chain.

In this section we consider various other aspects of South Africa's proposed energy transition that does not necessary stem directly from the modelling results described in this report but is either indirectly implied or must otherwise be considered to allow for a broader contextual understanding of the likely socio-economic impacts and mitigation strategies. Key topics to be discussed as other considerations to the unmitigated simulation results for the GI scenario as well as the other policy simulations include the

integration of the energy transition with the South African Renewable Energy Masterplan (SAREM), the need for improved coordination between SAREM and other sector-specific masterplans and how it pertains to the overarching goal of localisation and reindustrialisation in South Africa, labour market considerations including internal migration and skills development, various positive and negative spillover effects not directly accounted in UPGEM including health, climate, urbanisation, life expectancy, etc. as well as the impact of the European Union's (EU) Carbon Border Adjustment Mechanism (CBAM) and other regulatory issues.

The SAREM is an ambitious plan designed to support the local renewable energy industry and associated value chains in the interest of affordable and secure production (DMRE, 2025). There are several core industrialisation pillars on which SAREM is built that also ties into potential socio-economic mitigation strategies. Most notable is the plan's aim to build significant local value chains in the domestic production of solar PV, wind turbines, inverters, and battery storage systems. To help facilitate this, public and private sector investment will be actively encouraged and supported through procurement policy and other incentives. In addition, skills development and job creation programmes are expected to run parallel to this effort and will include coordination with SETAs and universities to build curricula around renewable energy technologies. SAREM also highlights the need for enabling infrastructure and market demand, grounded in the strengthening of grid infrastructure and system readiness to absorb new renewable capacity, coordination between Eskom and IPPs, and alignment with the IRP and REIPPPP to improve policy certainty and ensure demand signals for local industry. Finally, SAREM also looks at policy and trade alignment. The plan calls for the possible use of industrial policy tools like tariffs, incentives, and SEZs to protect and grow local manufacturing; leveraging regional trade frameworks like AfCFTA to expand export opportunities; and ensuring coherence between energy, trade, and industrial strategies across departments and sectors.

In light of these goals tied to the SAREM, there exists ample opportunity for numerous mitigation strategies to be developed in regions like Mpumalanga (MP) that do not economically benefit from the transition alone in a direct way. In addition to the generation of renewable power itself to take advantage of the extensive transmission network and grid capacity available in Mpumalanga (reflected to some extent in the GI scenario's new build programme that allocates over 10GW of grid-tied renewable generation capacity to MP), building a local renewable energy value chain in an area bordering the Gauteng City Region – the largest economic hub in Africa – that is rich in required labour and infrastructure will be of great support to the SAREM. Policymakers and stakeholders are therefore advised to carefully consider such opportunities to help boost the region and fortunes of communities and value chains adversely impacted by the necessary transition away from a coal-based energy sector. The final point on the SAREM and its mitigation role is the need to better coordinate the implementation and regulatory details with masterplans from other sectors. Priority must be given to enacting an

environment conducive to new and rapid industry growth, investment, industrialisation and ultimately, employment, in support of the overarching climate goals and commitments of South Africa.

Whilst being cognizant of opportunity costs and comparative advantages, urgently pursuing these opportunities as part of a suite of mitigation strategies regions like Mpumalanga will need to ensure a both a green and just transition is very important. It should also be emphasised that general macroeconomic improvements and policy reforms that lower the cost of doing business and raises investor confidence in Mpumalanga, as well as any other province that falls below its baseline projection, will serve as a significant boost to mitigation efforts in the country. Such improvements typically yield numerous positive spillover effects, including productivity and competitiveness gains, attracting talented entrepreneurs and new business, etc. that has the overall potential to more than offset the relative losses of the transition shock on the region. Alongside the health and air quality benefits of a GI scenario for communities living in and around heavy polluting coal-fired power plants and mines, these potential economic and socio-economic benefits should be strategically used as a catalyst for the renewal of economic regions deeply dependent on coal. A further positive spillover of such actions will be that the social protection needs of vulnerable workers in the coal value chain identified in this study will be made more affordable and likely be required for a shorter period of time.

A key long-term prediction from UPGEM on the GI scenario, regardless of the success of mitigation efforts in Mpumalanga, will be the need for a shift in labour and capital primary production factors to the Northern Cape where most new build activity will take place. This will place pressure on local infrastructure and other scarce resources, including essentials such as water, housing and schooling. As the transition is expected to ramp up beyond 2030, the NC region needs to ready itself in order to take advantage of the rapid period of growth anticipated. For many, climate is already a concern in the NC where temperatures can reach extreme highs (and lows). In combination with the arid and water-scarce landscape, both mitigation and adaptation efforts needs to be included in this next planning phase for the province to ease looming labour migration and urbanization frictions.

The EU's Carbon Border Adjustment Mechanism (CBAM) is of particular importance when considering the economic costs of climate inaction. The policy is essentially designed to impose a carbon price on the embedded emissions of certain imports into the EU. On top of existing reporting requirements, the policy is expected to carry financial implications from 2026. Should South Africa and its export-oriented industries that are also carbon-intensive such as iron and steel, aluminium, cement, etc. continue down its current path, it would significantly impact their business and ability to compete. Besides industry-specific losses, the overall macroeconomic impact of the CBAM on South Africa is expected to be negative across the board, with around 10% of total exports to the EU, or 2.5% of total export value, at direct risk. Decarbonisation of the local economy, supported by its own carbon-pricing and other incentive and regulatory structures, is the only sustainable solution to the impending impacts from CBAM. South Africa may be able to negotiate a temporary extension to some of the most impactful aspects of the

CBAM, but EU's policymakers will not look favourably upon such a request unless more certainty on the country's transition to a low-carbon energy pathway is provided. The GI pathway therefore presents an opportunity to not only serve as a catalyst for new investment and energy security, but crucially, also to avoid the negative impacts of CBAM on key industries in South Africa.

There are a number of other issues that warrant consideration when assessing the proposed energy transition in South Africa and its associated socio-economic impacts, particularly when viewed through the lens of the GI pathway developed in the main BtG report. It is no secret that economic growth and investment has largely stagnated in the last 15 years or so. As we near the end of 2025, real GDP per capita and real investment levels currently sit below 2007 levels. The lack of investor confidence resulting from years of poorly performing institutions, declining state capacity, failing infrastructure including electricity supply, and a high cost of doing business, has cost South Africa billions in lost economic activity compared to baseline forecasts from that period. If funding can be secured as discussed in the main BtG report, the GI scenario will generate significant GFCF and investment opportunities, and by implication help to reverse the negative trend in the closely associated construction and related services sectors, as well as macroeconomy in general.

The GI scenario represents a no-regret option across many dimensions of the economy. High-probability positive spillover effects, many of which have already been discussed, will add to the already positive outlook across most regions and the country as a whole. From the lower cost of capital associated with a world where there is strong climate commitments, a more flexible, responsive and modern energy sector, to avoiding the negative effects of inaction such as poor environmental outcomes in coal regions, and CBAM-type economic implications, it is clear that there is no time to waste in fully embracing the proposed energy transition whilst designing appropriate mitigation plans where needed.

Moreover, whilst the current UPGEM methodology suggests that Mpumalanga's economy will decline under the GI scenario relative to the baseline scenario – which is correct in a technical sense – it is important to emphasise again and recognise that aspects of the status quo baseline as it pertains to Mpumalanga will not be realistically attainable without incurring significant additional long-term costs not adequately accounted for in macroeconomic forecasting models. Specifically, maintenance costs (typically reflected through depreciation rates in economic models) of the province's aging coal-fleet is expected to increase significantly in the longer term, with some of the oldest power stations already exhibiting such cost implications. Combined with the reality that external funding for new coal stations is getting harder and more expensive, maintaining a coal-intensive energy mix and one of the pillars of the Mpumalanga economy will not be possible. In essence, the GI scenario may therefore reflect a scenario that is realistically as good as MP residents can hope for. With added benefits stemming from well planned and implemented mitigation plans including targeted social protection, and associated spillover effects such as a cleaner environmental footprint, the MP may well be wondering in the years to come why a GI pathway was not introduced earlier.

With over R100bn per annum readily available for energy-sector investments in the medium term but unable to be fully unlocked for various reasons discussed in the main BtG report, the GI scenario also presents an opportunity to build a credible pipeline of RE projects and limit the outflow of funds from institutional investors who are allowed to export up to 45% of their investments. The implications for GFCF, spillover investment growth, and upstream industrialisation could be a catalyst for transformative economic growth in South Africa for decades to come. Transformation efforts are likely to benefit from the GI scenario too as REIPPPP continues to create better opportunities for new and black-owned businesses compared to mature economic sectors. Finally, the concept of socially owned renewables, for which RE projects lends itself well as emphasised in the JET-IP, is worth exploring as it would create opportunities for communities to not just enjoy the benefits of greater energy security, but also become equity holders in its provision.

6 Conclusion and Recommendations

Energy transitions away from fossil fuels towards low-carbon alternatives in countries like South Africa are complex in terms of design, implementation and their economy-wide effects. This report, alongside the main BtG report, aims to provide a clear and concise reference for what the socio-economic effects of a transition scenario such as the Green Industrialisation (GI) pathway will look like under a realistic set of assumptions. Whilst the environmental benefits of the proposed energy transition have been well documented and includes limiting global warming and extreme weather events, improved air and water quality, and preservation of ecosystems, amongst others, the economic and socio-economic effects have generally faced more scrutiny. In this report we used outputs from the University of Pretoria General Equilibrium Model (UPGEM) to give evidence on the economic impacts as well as additional insights into socio-economic impacts of the GI transition scenario.

The first key finding in this report was that the GI scenario generates a double dividend, that is, positive GDP growth and environmental outcomes relative to the baseline. Other indirect and positive spillover benefits not modelled, but known from the literature, will boost these gains even further. This is an important finding as it confirms that, at least at a national level, there will be space to deal with any adjustment costs the transition will bring. Second, some provincial-level outcomes are expected to diverge significantly from the baseline beyond 2030, necessitating the immediate design and implementation of mitigation strategies and social protection programmes in regions such as Mpumalanga where relative losses and disruption will be experienced. This will be important to ensure, both from a socio-economic and political perspective, that both a green and just transition is achieved. In understanding the simulation results, readers are again reminded that negative deviations in variables

such as regional GDP in Mpumalanga generated under the GI scenario should not be interpreted as an economic contraction. The value of the modelling exercise is to quantify expected regional differences in socio-economic impact, and how broader economic structures are expected to change, thereby highlighting the need for various other interventions to help manage the transition. Third, our modelling supports the view that the cost of inaction as it relates to the energy transition and supporting policy will have significant negative socio-economic implications in the medium to long run. Besides health and environmental concerns, increased economic penalties in the form of CBAM-type policies and rising maintenance costs associated with our aging coal fleet will heap further pressure on the baseline view of the economy, in particular that of Mpumalanga. Fourth, government should note the anticipated shift, and associated challenges, in regional labour, infrastructure other resource needs associated with the GI scenario. For example, the expected boom in the Northern Cape economy in coming years will require action on the part of officials today to ensure the province can take full advantage of not only activity related to the transition, but maximising its potential to generate and capture the benefits of potential spillover effects.

In developing and analysing the GI scenario across both the main BtG report and this supplemental socio-economic impact report, great care was taken to avoid the threat of making large-scale investment decisions with long-term impacts without a supporting evidence base that could result in the proliferation of regret options. A key benefit of renewable energy (RE) investments is their modular, demand-driven nature. This leads to more flexible and affordable projects with a much lower probability of regret. In contrast, single, large and expensive infrastructures like coal-fired power plants, oil refineries or nuclear plants, that are consequently also more subject to technical delays (as highlighted by South Africa's recent experience with building Kusile and Medupi or returning Koeberg to service), are extremely risky when viewed in terms of potential regret options. This contrast has major implications for risks associated with capital allocation decisions.

Ultimately, the key conclusion from this socio-economic study is that, with good mitigation plans in place to protect vulnerable communities and workers, South Africa can achieve a green, just and profitable energy transition. Besides an already encouraging double dividend at national level in the long run, a number of important positive spillover effects will likely emerge on a much faster timescale. The Green Industrialisation scenario represents a historic opportunity for South Africa to reverse its decades long decline in gross fixed capital formation, growth and inequality, and the ability to deliver dependable and affordable electricity to its people. Business-as-usual has no viable long-term future in South Africa. As noted in various other parts of the literature, the case for transitioning faster, as reflected in the GI scenario, is now as strong from an economic perspective as it is from an environmental perspective. Based on the evidence of these reports, we recommend that policymakers and stakeholders continue to work together to make this transition a reality in the shortest possible timeframe.

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Annexure A: Decommissioning Schedules

Table 1: GI Scenario Coal and Nuclear Power Plant Decommissioning Schedules used in UPGEM (2023-2035) (MW)

DECOMMISSION (MW)	Prov	Start	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
1 I4_arnot	M	2,100	delayed							175	17	17	17	17	17
2 I4_camden	M	1,481	delayed				20	400	400	400	48				
3 I4_duvha	M	2,875								delayed		57	57	57	57
4 I4_grootvlei	M	570	delayed			190	19	19							
5 I4_hendrina	M	1,098	delayed				15	160	160	160	16	16	16	14	8
6 I4_kendal	M	3,840													
7 I4_komati	M	0	decommissioned in 2022												
8 I4_kriel	M	2,640				delayed				660	66	66	66		
9 I4_kusile	M	2,880	built	built											
10 I4_lethabo	F	3,558													
11 I4_majuba	M	3,807													
12 I4_matimba	LP	3,690													
13 I4_matla	M	3,450							delayed		69	69	69	69	69
14 I4_medupi	LP	3,600		built											
15 I4_tutuka	M	3,510													
16 I4_koeberg	W	1,854													
Total		40,953	0	0	0	190	19	54	560	1,395	2,166	2,260	2,260	1,588	1,440

Table 2 (continued from 1): GI Scenario Coal and Nuclear Power Plant Decommissioning Schedules used in UPGEM (2036-2050) (MW)

DECOMMISSION (MW)	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045	2046	2047	2048	2049	2050	End
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1 I4_arnot	350	350	350															0
2 I4_camden																		0
3 I4_duvha	575																	0
4 I4_grootvlei																		0
5 I4_hendrina																		0
6 I4_kendal			640	640	640	640	640	640	640									0
7 I4_komati																		0
8 I4_kriel																		0
9 I4_kusile																		4,32
10 I4_lethabo	593	593	593	593	593	593												0
11 I4_majuba										609	609	609	660	660	660			0
12 I4_matimba			615	615	615	615	615	615										0
13 I4_matla																		0
14 I4_medupi																		4,32
15 I4_tutuka	585	585	585	585	585	585												0
16 I4_koeberg									927	927								0
Total	2,10	1,52	2,14	2,43	2,43	2,43	2,43	1,25	1,25	1,56	1,53							8,64
	3	8	3	3	3	3	3	5	5	7	6	609	609	660	660	660		0

Annexure B: GI Scenario Exogenous Shocks
Table 3: GI Scenario Shocks to Coal Generation Industry Investment and Output (%)

CoalGen GFCF	LP	MP	FS	CoalGen Output	LP	MP	FS
1 Y2023	-31.67	-30.88	-31.67	1 Y2023	2.50	2.50	2.50
2 Y2024	47.60	23.60	0.00	2 Y2024	0.00	0.06	0.00
3 Y2025	-30.64	-18.97	0.00	3 Y2025	2.38	1.25	0.00
4 Y2026	0.00	0.00	0.00	4 Y2026	0.00	0.00	0.00
5 Y2027	0.00	-0.65	0.00	5 Y2027	0.00	-0.65	0.00
6 Y2028	0.00	-0.65	0.00	6 Y2028	0.00	-0.65	0.00
7 Y2029	0.00	-1.87	0.00	7 Y2029	0.00	-1.87	0.00
8 Y2030	0.00	-1.98	0.00	8 Y2030	0.00	-1.98	0.00
9 Y2031	0.00	-5.03	0.00	9 Y2031	0.00	-5.03	0.00
10 Y2032	0.00	-8.22	0.00	10 Y2032	0.00	-8.22	0.00
11 Y2033	0.00	-9.35	0.00	11 Y2033	0.00	-9.35	0.00
12 Y2034	0.00	-10.31	0.00	12 Y2034	0.00	-10.31	0.00
13 Y2035	0.00	-8.08	0.00	13 Y2035	0.00	-8.08	0.00
14 Y2036	0.00	-7.97	-2.44	14 Y2036	0.00	-7.97	-2.44
15 Y2037	0.00	-9.08	-16.67	15 Y2037	0.00	-9.08	-16.67
16 Y2038	0.00	-6.19	-20.00	16 Y2038	0.00	-6.19	-20.00
17 Y2039	-8.04	-6.59	-25.00	17 Y2039	-8.04	-6.59	-25.00
18 Y2040	-8.74	-9.25	-33.33	18 Y2040	-8.74	-9.25	-33.33
19 Y2041	-9.58	-10.19	-50.00	19 Y2041	-9.58	-10.19	-50.00
20 Y2042	-10.60	-11.35	-86.85	20 Y2042	-10.60	-11.35	-86.85
21 Y2043	-11.85	-6.69	0.00	21 Y2043	-11.85	-6.69	0.00
22 Y2044	-13.45	-7.17	0.00	22 Y2044	-13.45	-7.17	0.00
23 Y2045	0.00	-7.72	0.00	23 Y2045	0.00	-7.72	0.00
24 Y2046	0.00	-7.96	0.00	24 Y2046	0.00	-7.96	0.00
25 Y2047	0.00	-8.65	0.00	25 Y2047	0.00	-8.65	0.00
26 Y2048	0.00	-9.47	0.00	26 Y2048	0.00	-9.47	0.00
27 Y2049	0.00	-11.33	0.00	27 Y2049	0.00	-11.33	0.00
28 Y2050	0.00	-12.78	0.00	28 Y2050	0.00	-12.78	0.00

Table 4: GI Scenario Shocks to Renewable Generation Industry Investment (%)

OthGen GFCF	LP	NW	MP	GP	FS	NC	WC	EC	KZN
1 Y2023	441.20	188.10	260.41	86.86	61.55	112.96	179.94	251.38	-46.92
2 Y2024	41.71	44.67	43.40	48.10	49.63	46.90	44.85	43.53	72.72
3 Y2025	13.20	12.15	12.59	10.97	10.47	39.19	12.08	-18.12	3.94
4 Y2026	15.94	14.80	15.29	13.52	12.95	14.89	14.73	13.96	5.19
5 Y2027	20.96	19.65	20.21	18.15	17.48	19.76	19.57	18.68	7.52
6 Y2028	18.02	17.08	17.49	15.98	15.48	17.16	17.02	16.37	7.27
7 Y2029	156.78	194.72	152.84	99.08	549.98	-29.86	-29.65	-28.67	48.74
8 Y2030	67.46	67.40	15.85	14.90	38.06	-24.90	-24.66	-23.51	104.44
9 Y2031	14.85	14.84	14.17	13.43	14.99	7.75	7.65	7.19	12.43
10 Y2032	4.46	4.46	4.28	4.08	4.50	2.48	2.45	2.31	3.81
11 Y2033	-24.19	-24.18	4.10	3.92	-10.04	50.84	50.25	47.46	-40.39
12 Y2034	-33.78	-27.51	3.94	-33.98	-38.52	67.41	3.19	3.07	2.46
13 Y2035	2.83	3.02	3.79	2.86	3.03	3.83	3.09	2.97	2.40
14 Y2036	1.65	-22.86	-21.68	1.67	-14.68	20.31	1.80	1.73	1.41
15 Y2037	1.57	1.26	1.80	1.59	1.43	2.23	1.71	1.65	1.34
16 Y2038	1.49	1.20	1.71	1.51	1.36	2.10	1.62	1.56	1.28
17 Y2039	1.42	1.14	1.62	1.43	1.29	1.99	1.54	1.49	1.22
18 Y2040	1.35	1.09	1.54	1.36	1.23	1.87	1.46	1.41	1.16
19 Y2041	1.28	10.15	-8.79	1.29	1.17	1.77	1.38	1.34	10.80
20 Y2042	1.21	1.13	1.23	1.22	1.11	1.67	1.31	1.27	1.19
21 Y2043	1.15	1.07	1.16	1.16	1.05	1.57	1.24	1.20	1.13
22 Y2044	1.09	1.01	1.10	1.09	0.99	1.48	1.17	1.13	1.07
23 Y2045	1.03	0.96	1.04	1.03	0.94	1.39	1.10	1.07	1.01
24 Y2046	-2.90	-2.71	-2.93	-2.92	-2.66	-3.93	-3.12	-3.02	-2.86
25 Y2047	-3.24	-3.01	-3.27	-3.26	-2.96	-4.43	-3.49	-3.37	-3.18
26 Y2048	-3.60	-3.35	-3.64	-3.63	-3.28	-4.99	-3.89	-3.76	-3.54
27 Y2049	-4.00	-3.71	-4.05	-4.04	-3.63	-5.63	-4.34	-4.19	-3.93
28 Y2050	-2.61	-2.41	-2.64	-2.63	-2.36	-3.74	-2.84	-2.74	-2.57

Table 5: GI Scenario Shocks to Renewable Generation Industry Output (%)

OthGen Output	LP	NW	MP	GP	FS	NC	WC	EC	KZN
1 Y2023	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50	2.50
2 Y2024	34.60	16.08	21.37	8.67	6.82	10.58	15.48	20.71	-1.12
3 Y2025	36.69	21.27	26.16	13.63	11.56	15.70	20.69	25.57	1.78
4 Y2026	29.53	19.29	22.81	13.20	11.40	19.90	18.86	14.93	1.93
5 Y2027	25.90	18.38	21.10	13.25	11.63	18.86	18.03	14.76	2.15
6 Y2028	24.69	18.63	20.91	14.04	12.50	19.04	18.33	15.44	2.52
7 Y2029	23.10	18.32	20.18	14.36	12.96	18.66	18.07	15.60	2.87
8 Y2030	53.62	53.09	47.97	28.70	98.35	8.99	8.75	7.71	6.38
9 Y2031	58.90	58.52	36.47	25.09	66.94	4.64	4.52	4.03	16.88
10 Y2032	41.19	41.02	29.69	22.29	44.55	4.93	4.81	4.30	16.04
11 Y2033	29.17	29.09	22.90	18.22	30.82	4.69	4.59	4.12	13.83
12 Y2034	15.06	15.02	18.63	15.42	19.63	8.97	8.77	7.92	4.86
13 Y2035	6.54	7.62	15.70	6.68	7.66	16.46	8.07	7.34	4.63
14 Y2036	6.14	7.08	13.57	6.26	7.11	14.13	7.46	6.84	4.43
15 Y2037	5.67	3.70	7.81	5.77	4.65	15.17	6.81	6.27	4.16
16 Y2038	5.26	3.50	7.09	5.35	4.35	12.90	6.24	5.78	3.91
17 Y2039	4.89	3.31	6.49	4.97	4.08	11.19	5.75	5.35	3.68
18 Y2040	4.56	3.13	5.96	4.63	3.84	9.85	5.33	4.97	3.48
19 Y2041	4.27	2.97	5.50	4.33	3.62	8.77	4.95	4.63	3.29
20 Y2042	4.00	3.53	4.08	4.06	3.41	7.88	4.61	4.33	3.89
21 Y2043	3.76	3.33	3.83	3.81	3.23	7.14	4.31	4.06	3.66
22 Y2044	3.54	3.15	3.60	3.59	3.05	6.51	4.03	3.81	3.45
23 Y2045	3.34	2.98	3.40	3.38	2.89	5.97	3.78	3.58	3.25
24 Y2046	3.15	2.82	3.20	3.19	2.74	5.49	3.56	3.37	3.07
25 Y2047	2.67	2.40	2.72	2.71	2.33	4.56	3.00	2.85	2.61
26 Y2048	2.23	2.01	2.27	2.26	1.96	3.74	2.50	2.38	2.18
27 Y2049	1.82	1.64	1.85	1.84	1.60	3.00	2.03	1.94	1.78
28 Y2050	1.43	1.29	1.45	1.45	1.26	2.33	1.59	1.52	1.40

Annexure C: Simulation Results

Table 6: Main Industry Output, Cumulative % Change in Baseline Scenario (2035)

Output (2035)	LP	NW	MP	GP	FS	NC	WC	EC	KZN	National
Agriculture	35.8	26.4	28.0	25.8	25.8	30.5	29.9	29.3	28.3	28.9
Mining	10.9	9.1	10.5	30.0	9.8	11.2	23.1	21.2	13.9	10.6
Manufacturing	44.1	43.6	34.4	34.0	34.4	42.0	38.0	39.2	42.2	37.3
Construction	15.9	15.7	15.9	16.8	15.6	17.5	17.2	17.3	17.6	17.0
Utilities	29.4	27.3	28.9	26.7	28.0	34.1	23.2	28.4	27.4	28.0
Trade	27.0	25.8	27.8	30.6	26.7	24.4	34.1	34.4	37.9	31.4
Transport	34.7	34.5	33.4	36.2	35.0	33.4	37.3	37.0	37.1	36.4
Business	33.0	33.0	32.4	32.0	32.0	32.7	31.8	31.7	31.0	32.0
Public Admin	25.8	26.2	25.3	24.3	25.6	26.5	25.0	24.0	23.0	24.7

Table 7: Main Industry Output, Cumulative % Change in Baseline Scenario (2050)

Output (2050)	LP	NW	MP	GP	FS	NC	WC	EC	KZN	National
Agriculture	84.4	79.7	80.0	75.7	77.7	80.4	76.6	79.1	86.3	79.4
Mining	35.8	32.1	31.1	78.4	33.0	35.8	103.1	94.6	45.8	34.9
Manufacturing	135.5	144.1	103.4	112.7	109.3	173.8	117.5	122.7	129.8	118.4
Construction	61.5	63.0	61.1	67.3	64.4	70.6	69.6	68.3	67.6	66.9
Utilities	84.7	82.1	80.0	79.1	78.9	124.5	81.1	98.2	85.3	83.9
Trade	76.4	76.0	79.2	91.2	77.0	71.2	96.8	94.1	104.3	89.8
Transport	102.2	102.5	97.4	113.9	105.4	101.8	113.1	111.0	108.9	109.2
Business	106.1	105.4	104.2	100.8	101.8	105.7	101.9	103.6	101.1	101.6
Public Admin	71.6	74.2	71.6	67.9	75.1	75.8	72.2	68.0	64.9	69.9

Table 8: Main Industry Output, Cumulative % Deviation for GI Scenario (2035)

Output (2035)	LP	NW	MP	GP	FS	NC	WC	EC	KZN	National
Agriculture	0.4	-0.4	1.9	-0.9	0.1	-0.9	-1.1	-0.7	-1.2	-0.4
Mining	1.0	0.7	-5.9	-0.4	0.6	-1.5	-2.4	-0.6	-6.1	-0.7
Manufacturing	0.0	-0.6	1.9	-0.2	0.6	0.1	-0.7	-0.6	-0.7	-0.2
Construction	2.6	5.1	-2.7	0.1	4.4	40.4	4.3	6.0	1.9	2.8
Utilities	13.7	79.2	-31.2	7.9	37.1	143.8	32.8	60.0	9.0	9.7
Trade	0.8	1.2	-2.9	0.1	0.7	5.2	0.1	0.6	-0.4	0.1
Transport	0.2	-0.2	1.0	-0.4	-0.2	0.6	-0.3	-0.2	-0.4	-0.2
Business	0.2	0.1	-0.1	-0.1	0.1	0.9	0.2	0.6	0.1	0.1
Public Admin	-0.1	-0.4	2.0	-0.2	-0.4	-1.4	-0.2	-0.3	-0.1	-0.1

Table 9: Main Industry Output, Cumulative % Deviation for GI Scenario (2050)

Output (2050)	LP	NW	MP	GP	FS	NC	WC	EC	KZN	National
Agriculture	4.4	2.1	4.0	-3.3	2.1	0.8	-3.2	-2.2	-3.8	-0.4
Mining	5.1	3.7	-23.5	-4.7	3.4	-2.1	-10.2	-5.4	-17.9	-0.9
Manufacturing	2.2	1.6	2.5	0.6	1.9	3.0	0.1	0.2	0.3	0.8
Construction	-1.4	2.6	-10.8	-1.8	0.0	48.8	5.2	5.4	2.4	1.9
Utilities	-12.8	94.5	-63.8	-4.2	1.8	321.6	33.3	67.3	-2.9	0.0
Trade	0.3	2.7	-9.0	-0.3	-0.2	14.8	0.8	1.2	-0.6	-0.1
Transport	0.7	0.6	-3.4	-1.4	-0.3	7.0	0.8	0.9	-0.6	-0.3
Business	1.1	1.3	-2.3	-1.0	0.7	8.5	1.3	1.8	0.2	0.2
Public Admin	1.0	-0.2	4.2	-1.0	-0.5	-1.3	0.2	-0.3	-0.3	-0.1

Table 10: Main Industry Employment, Cumulative % Deviation for GI Scenario (2035)

Labour (2035)	LP	NW	MP	GP	FS	NC	WC	EC	KZN	National
Agriculture	-1.5	-1.4	-0.7	-0.9	-1.8	-0.2	-0.8	-1.3	-0.8	-1.1
Mining	-1.8	-0.3	-21.0	-0.5	-2.2	-1.8	-1.0	-2.5	-15.3	-4.3
Manufacturing	-1.4	-1.1	1.1	-0.2	-0.3	0.4	-0.7	-0.9	-0.4	-0.3
Construction	1.8	5.0	-3.9	-0.4	4.1	47.9	4.7	6.2	2.0	2.7
Utilities	13.7	69.2	-27.7	5.5	35.7	132.7	25.0	53.3	5.6	9.9
Trade	0.1	1.0	-5.1	0.2	0.2	5.9	0.5	0.6	0.0	0.0
Transport	-0.4	-0.5	0.2	-0.4	-0.8	0.9	-0.1	-0.3	-0.2	-0.3
Business	0.3	0.4	-0.4	0.0	0.2	2.1	0.6	1.1	0.4	0.3
Public Admin	-0.4	-0.6	2.0	-0.2	-0.7	-1.7	-0.1	-0.5	0.0	-0.2

Table 11: Main Industry Employment, Cumulative % Deviation for GI Scenario (2050)

Output (2050)	LP	NW	MP	GP	FS	NC	WC	EC	KZN	National
Agriculture	-3.9	-2.6	-3.1	1.8	-4.5	1.1	1.5	1.3	2.0	-0.6
Mining	-3.7	0.1	-53.1	-0.6	-4.3	-3.1	8.7	3.7	-30.7	-9.3
Manufacturing	-4.4	-1.7	0.6	2.4	-0.7	1.7	1.8	1.0	3.2	2.0
Construction	-2.6	1.7	-11.2	-1.7	-1.0	43.1	5.3	5.1	2.7	1.6
Utilities	-14.3	68.5	-59.0	-11.4	1.1	234.3	2.5	36.5	-16.7	-7.1
Trade	-2.8	0.5	-11.0	1.5	-2.8	13.5	3.1	2.4	1.7	0.7
Transport	-1.9	-1.1	-5.2	-0.3	-2.2	6.0	2.5	2.0	1.8	0.6
Business	0.4	1.0	-3.5	-0.9	0.3	10.3	1.6	2.2	0.3	0.2
Public Admin	-0.3	-1.1	4.0	0.0	-1.7	-2.4	1.3	0.1	1.0	0.3

Table 12: National Employment by Industry, Cumulative % Deviation for GI Scenario (2023-2050)

Employment	2030	2035	2040	2045	2050
1 I1_fieldcrop	-1.39	-1.29	-1.52	-1.29	-1.66
2 I1_fruitveg	-1.41	-0.9	-0.36	0.02	0.29
3 I1_othagric	-1.6	-1.25	-1.07	-0.73	-0.8
4 I1_forestry	-0.51	-0.09	0.57	1.16	1.48
5 I1_fishing	-0.54	-0.62	-0.72	-0.74	-0.76
6 I2_coal	2.37	-27.12	-51.66	-64.52	-69.95
7 I2_crudegas	-4.69	-1.22	5.35	10.06	12.39
8 I2_gold	-1.18	-0.25	0.33	0.76	0.94
9 I2_metalore	-1.11	-0.51	-0.27	-0.12	-0.13
10 I2_othmining	-1.21	-0.78	-1.16	-1.56	-2.57
11 I3_meat	-0.71	-0.72	-0.14	0.6	1.44
12 I3_fish	-0.72	-0.89	-0.83	-0.67	-0.24
13 I3_fruitveg	-0.61	-0.68	-0.17	0.31	1.11
14 I3_oilsfats	-0.63	-0.55	-0.06	0.53	1.14
15 I3_dairy	-0.78	-0.79	-0.42	0.22	0.87
16 I3_grain	-0.75	-0.44	0.75	1.28	2.57
17 I3_bakery	-0.88	-0.67	-0.16	0.4	0.94
18 I3_othfood	-0.78	-0.61	-0.04	0.48	1.11
19 I3_beverage	-0.41	-0.53	-0.38	-0.26	-0.14
20 I3_tobacco	-0.71	-0.39	-0.2	-0.09	-0.13
21 I3_textfoot	-1.09	-1.12	-0.88	-0.64	-0.45
22 I3_woodpap	-0.72	0.07	1.21	2.27	2.94
23 I3_petroref	0.75	2.56	4.18	4.98	5.18
24 I3_baschem	-1.85	-0.96	0.87	2.57	4.14
25 I3_othchem	-0.87	-0.59	-0.15	0.11	0.31
26 I3_rubber	-1.59	-0.49	0.9	2.01	3.09
27 I3_plastic	-1.27	-0.57	0.6	1.74	2.64
28 I3_glass	-2.17	-0.69	1.58	3.66	5.6
29 I3_nonmetal	0.76	1.73	2.75	2.99	2.65
30 I3_ironsteel	-1.23	-0.65	0.57	1.86	2.74
31 I3_elecmach	-0.73	1.64	4.23	5.35	5.91
32 I3_radtvins	-0.84	-0.69	0.3	1.11	1.48
33 I3_vehicles	-0.6	-0.55	-0.21	-0.32	0.03
34 I3_othtrans	-1.14	-1.04	-0.73	-0.52	-0.35
35 I3_othmanuf	-0.99	-0.68	-0.04	0.45	0.91
36 I4_coalgen	-2.12	-42.17	-69.07	-85.29	-91.4
37 I4_nucgen	-0.91	-1.07	-0.95	-0.78	-0.47
38 I4_gasgen	0.12	0.02	-0.02	-0.01	0
39 I4_othgen	170.28	288.07	337.67	328.24	267.72
40 I4_elecdist	8.46	5.01	-2.73	-5.02	-14.39

41 I4_water	-0.75	0.42	1.58	2.43	3.74
42 I5_construc	1.89	2.71	3.45	3.19	1.64
43 I6_wholesale	0.02	0.2	0.13	0.55	0.07
44 I6_retail	-0.27	0.1	0.41	0.93	1.04
45 I6_accom	-0.65	-0.65	-0.57	-0.3	-0.06
46 I6_restau	-2.77	-1.58	-0.12	1.6	3.15
47 I7_trnspass	-0.37	-0.25	0.06	0.52	0.68
48 I7_railfreig	-0.88	-0.82	-0.36	0.5	1.47
49 I7_roadfreig	0.07	-0.09	-0.42	-0.58	-0.68
50 I7_othfreig	0.08	-0.29	-0.77	-0.96	-1.07
51 I7_trnsaux	-0.38	0.14	0.56	1.09	1.73
52 I7_postcomm	-0.32	-0.36	-0.15	0.11	0.26
53 I8_finance	-0.15	-0.14	0.13	0.53	0.66
54 I8_realest	-0.49	-0.42	-0.05	0.43	0.81
55 I8_rentmach	0.15	0.17	0	-0.09	-0.35
56 I8_othbus	0.56	0.72	0.5	0.27	-0.18
57 I9_gengov	-0.35	-0.09	0.18	0.44	0.73
58 I9_educat	-0.13	-0.2	-0.25	-0.19	-0.22
59 I9_healthsoc	-0.36	-0.37	-0.34	-0.12	0.09
60 I9_othsrv	-0.21	-0.12	0.1	0.38	0.59



SOCIOECONOMIC STUDY 2:

Micro-level socio-economic impacts of the energy transition with specific reference to Mpumalanga, and the possible welfare and industrial policy responses

Haroon Borat and Francois Steenkamp

1 Introduction: Coal and Just Transition Policy Choices: The Case of South Africa

South Africa's planned phase-down of coal-fired electricity generation implies concentrated labour-market shocks in Mpumalanga and along the coal value chain. This paper integrates two Development Policy Research Unit (DPRU), University of Cape Town working papers in order to provide firstly - an empirical profile of the coal labour market and, second, an applied policy-matrix with costing and funding options for a just transition⁴. This summary then should ideally be read in conjunction with the two full papers.

The rationale for the paper lies in attempting to provide a more detailed labour market extension to the ongoing general equilibrium analysis of the impact of coal closure on Mpumalanga. This work⁵ uses the World Bank's Beyond the Gap methodology to, in essence, model the least cost routes available to South Africa to ensure its current and future energy security within the constraints of remaining in accordance with South Africa's Nationally Determined Contributions (NDC) energy and carbon targets. This is a piece of dynamic modelling which in addition considers in a sub-report, the consequences of one such route namely the Green Industrialisation (GI) pathway for Mpumalanga. Using the University of Pretoria General Equilibrium Model (UPGEM), this second report attests to the macroeconomic impacts at the national and provincial levels of a GI pathway – thus converging on coalescing around projected impacts on GDP, investment and consumption over time. Whilst these are useful additions to the policy debate, this work does not – nor is it intended to - delve into the very specific question of calibrating a Just Transition plan for those most likely to be affected by our search for energy security and adherence to the NDC targets – namely the workers in the coal industry in Mpumalanga. This paper attempts to fill this gap.

The core approach taken here is to firstly provide a stylised empirical overview of the coal labour market in South Africa, whilst noting that the coal industry and its attendant value chain dynamics is well known. Secondly the paper will utilise some of the key descriptors of the coal labour market – in particular its

⁴ The two papers of relevance here are: Borat.H, F.Steenkamp et al (2024) *Just Transition and the Labour Market in South Africa Measuring Individual and Household Coal Economy Dependence*. DPRU Working Paper WP 202402 Development Policy Research Unit, University of Cape Town: Cape Town.

https://commerce.uct.ac.za/sites/default/files/media/documents/commerce_uct_ac_za/1093/dpru-wp202402.pdf and Borat.H, F.Steenkamp et al (2025) *Ameliorating the Consequences of Coal Job Destruction: A Just Transition Policy Matrix Approach*. Development Policy Research Unit, University of Cape Town: Cape Town.

⁵ PwC (2025) *South Africa's Energy Sector Investment Requirements to Achieve Energy Security and Net Zero Goals by 2050*. Core Report and Socio-Economic Impact Report Unpublished mimeo.

occupation and age characteristics – to anchor a policy matrix approach to funding the just transition. In particular the paper proposes 4 core policy instruments (social assistance, mobility support, education & training and early retirement) applied to workers in 3 age bands and 3 skills categories. These 4 policy instruments then are combined in 5 different ways which we propose here as five possible policy packages. The paper concludes by costing each of the packages and generates estimates of funding gaps.

2 The Coal Labour Market in South Africa: Stylised Facts

The coal industry accounts for roughly 76 406 jobs nationally, with the bulk—66 252 jobs or about 87% — located in Mpumalanga. Coal-linked electrical utility employment adds a further 30 481 jobs in the province, taking the combined coal value-chain aggregate in coal to around 106 887 direct and indirect jobs. The typical worker is young and male, and the spatial concentration of employment underscores why labour-market adjustment costs will be geographically uneven.

Two central empirical devices required for thinking through a just transition away from coal dependence are the occupation–education and occupation-age matrices for coal workers. These ultimately provide both the mental framework and then also the empirical model and basis for calibrating a just transition policy solutions matrix for South Africa. In Table 13 below then, we show the level and share of coal mining workers in the occupation-education level space. The cells are shaded according to the size of each of these occupation-education level combinations. Increasing shares and levels of employment are represented by cells being shaded from light to increasingly darker shades of green. One is able to get a sense of where the bulk share of coal mining workers reside within the occupation-education level space. This is useful because different occupation-education combinations require policy interventions that vary in nature and scope. Thus, using this occupation-education level space, we put together a first attempt at breaking up the just transition challenge, by dividing the coal industry workforce into three analytical groupings.

The first grouping – defined as *Minimal Just Transition Challenge* – comprises workers with post-secondary education qualifications (i.e. diploma or degree), who work in high-skilled (i.e. manager, professional, technician) or semi-skilled (i.e. clerk, sales/services, craft and related trades, plant and machine operator) occupations. This grouping of workers, being **both** well-educated and working in high-skilled or semi-skilled occupations, can be characterised as relatively high-skilled, and as a result, more likely to find alternative employment opportunities as the transition unfolds. Quantifying this group – summing the cells lying in columns 5 to 6 and rows 2 to 8 – *results in 17 203 workers or a quarter of the Mpumalanga coal industry workforce (25.97%)*. Given their high skill level and relatively higher likelihood of finding alternative employment, we do not consider this grouping to be a just transition challenge.

From a policy standpoint, this grouping may require some marginal degree of employment matching intervention

Table 13: Coal Employment By Occupation and Education Level, 2019: Mpumalanga

	Primary	Incomplete secondary	Complete secondary	Diploma	Degree	Total
Manager			199 0.30%	223 0.34%	282 0.43%	704 1.06%
Professional		187 0.28%	117 0.18%	1 149 1.74%		1454 2.19%
Technician		888 1.34%	2 340 3.53%	1 654 2.50%	874 1.32%	5756 8.69%
Clerk			1 403 2.12%	2 050 3.10%		3453 5.21%
Sales/services			513 0.77%			513 0.77%
Craft & related traded	187 0.28%	6 948 10.49%	10 095 15.24%	8 105 12.23%	1 189 1.79%	26 522 40.03%
Plant & machine operator	596 0.90%	7 888 11.91%	12 781 19.29%	1 677 2.53%		23 097 34.86%
Elementary	144 0.22%	3 160 4.77%	1 229 1.86%	221 0.33%		4 754 7.18%
Total	927 1.40%	19 071 28.79%	28 677 43.28%	15 080 22.76%	2 344 3.54%	66 252 100.00%

Source: Borat et al. (2024)

Notes: Levels (top figure) and shares (bottom figure) are reported for each occupation-education level combination (each cell). Summation of all occupation-education level combinations equals total coal industry employment in Mpumalanga. Increasing shares and levels of employment are represented by cells being shaded from lighter to darker shades of green.

The second grouping – defined as an *Intermediate Just Transition Challenge* – comprises those with at most a complete secondary education (i.e. primary, incomplete secondary, complete secondary), who work in high- or semi-skilled occupations. Given the combination of relatively lower levels of education and high- or semi-skilled occupations, this grouping of workers can be described, for the most part, as

semi-skilled. Quantifying this grouping of workers – summing the cells lying in columns 2 to 4 and rows 2 to 8 – results in a total of approximately 44 142 workers (66.63%), and thus the bulk of the Mpumalanga coal industry workforce. Given the semi-skilled nature of this grouping, there is a degree of uncertainty regarding the appropriate policy intervention, as some have a reasonable likelihood of finding alternative employment opportunities. As such, this grouping may require a mix between employment matching mechanisms, skills top-up, income support interventions, or other forms of policy intervention.

The third grouping – defined as the *Core Just Transition Challenge* – comprises those engaged in low-skilled elementary occupations. This grouping of low-skilled workers – summing cells lying in row 9 – number 4 754 workers, or 7.18% of the Mpumalanga coal industry workforce. Given that these workers have low levels of education and work in low-skilled occupations, their likelihood of finding alternative employment is low. As such, it is likely that the appropriate policy response for this grouping is social protection in the form of income support.

Ultimately then, as a first approximation, we propose three analytical groupings to size the just-transition challenge. A *Minimal Just Transition Challenge* group comprising workers with post-secondary education in high- or semi-skilled occupations—around a quarter of Mpumalanga's coal workforce—who can likely re-match with modest policy support. An *Intermediate Just Transition Challenge* group, mostly semi-skilled with at most complete secondary schooling, accounting for roughly two-thirds of coal employment and will require a mix of skills top-ups, matching, and targeted support. Finally, a *Core Just Transition Challenge* cohort of workers in low-skill elementary occupations—about 8 percent of the workforce—facing the highest risk of long-term displacement and will need income support.

It is possible then to extend this approach to the just transition, and provide a similarly unique analytical and policy anchor for the just transition by estimating the above table in an occupation and age matrix. We provide this in Table 14 below. As with the above table, darker shades of green are associated with higher share of workers in that occupation-age cell. Hence the largest number of workers in coal in Mpumalanga in Table 14 below are in craft & related trades between the ages of 25 and 34. Furthermore, it is possible to extract categories of workers across another overlapping set of Just Transition cohorts.

Table 14: Coal Employment By Occupation and Age Level, 2019: Mpumalanga

Occup/Age	15-24	25-34	35-44	45-54	55-65	Total
Manager		282 0.43%	199 0.30%	223 0.34%		704 1.06%
Professional	187 0.28%	450 0.68%	117 0.18%	699 1.06%		1 454 2.19%

Technician	642 0.97%	2 664 4.02%	1300 1.96%	460 0.69%	691 1.04%	5 756 8.69%
Clerk	623 0.94%	2 569 3.88%	260 0.39%			3 453 5.21%
Sales/services				513 0.77%		513 0.77%
Craft & related traded	2 068 3.12%	10 687 16.13%	4 835 7.30%	7 602 11.47%	1 331 2.01%	26 522 40.03%
Plant & machine operator	1 560 2.36%	9 155 13.82%	6 926 10.45%	3 776 5.70%	1 679 2.53%	23 097 34.86%
Elementary	204 0.31%	2 490 3.76%	768 1.16%	1 292 1.95%		4 754 7.18%
Total	5 284 7.98%	28 297 42.71%	14 407 21.74%	14 565 21.98%	3 700 5.59%	66 252 100.00%

Source: Bhorat et al. (2024)

Notes: Levels (top figure) and shares (bottom figure) are reported for each occupation-age level combination (each cell). Summation of all occupation-age level combinations equals total coal industry employment in Mpumalanga. Increasing shares and levels of employment are represented by cells being shaded from lighter to darker shades of green.

For example then, the category of workers numbering 3700 who are between the ages of 55 and 65 across all occupations, could be considered an 'early retiree' cohort – in a just transition policy discussion where retirement funding options are key to the policy focus. In turn, workers aged 15-44 who are in the top 3 occupational categories and thus highly skilled as well as still in the heart of the working age life, may be considered to be a minimal just transition policy focus or challenge. Workers semi-skilled however in this age cohort numbering over 38 000 employees, could constitute the rump of the Just Transition Challenge where retraining in alternative employment may be required. Finally elementary workers for whom alternative employment or indeed retraining may be too large a transition – would be the focus of social assistance type support.

For completeness, we also quantify coal-headed household dependence and vulnerability, showing substantial shares of households with dependants and limited alternative earners—a further reason why

displacement shocks can translate into welfare losses without targeted support. The quantitative portrait therefore motivates a policy architecture that is cohort-specific, time-bound, and fiscally credible. The data below utilises the Census 2011 which at the time of writing was the latest available information linking coal workers to the households they reside in.

Table 15: Overall Household Composition of Coal households, Census 2011

		No. Dependents (age-related, unemployed and not econ. active)				
		0	1	2	>2	Total
No. Other Employed (incl. utils)	0	12.8 27.8%	4.7 10.3%	4.1 8.8%	7.9 17.2%	29.5 64.1%
	1	3.7 8.1%	2.3 5.0%	2.7 5.8%	3.7 8.1%	12.4 27.0%
	2	0.7 1.6%	0.4 0.8%	0.5 1.1%	1.1 2.3%	2.7 5.9%
	>2	0.3 0.7%	0.3 0.5%	0.2 0.4%	0.6 1.3%	1.4 3.0%
	TOTAL	17.6 38.3%	7.7 16.6%	7.4 16.1%	13.3 28.9%	46.1 100.0%

Source: Borat et al. (2024)

Note: 1. In each cell reporting numerical estimates, the first value reports the weighted number of households (in 000s), and the second value reports the share of coal households. 2. According to the individual-level dataset, there are 3 960 unique household IDs with a coal related employee, prior to weighting. When matching between the individual-level and household-level data in the 2011 Census data, 136 coal workers in the individual-level data do not match up to a household. These individuals are lost when using the household specific weights, as they do not have a household weight attached. Thus, the total number of coal households used for the weighted values is 3 824. 3. Due to rounding, the shares of coal households may not sum up to exactly 100 %. 4. Colour-coding in order of vulnerability: Green households have 1 or more individuals employed outside of coal and zero dependents; yellow households have zero dependents, but also have zero individuals employed outside of coal employment; orange households have one or more age-related, unemployed or not economically active dependent(s) and one or more individuals employed outside of coal employment; red households have zero individuals employed outside of coal employment and have one or more dependents.

The data shows that in terms of shaded cells above, green- and yellow-shaded households account for 38.3% of coal households (17 600 households) and can be considered less vulnerable, in terms of additional income streams, and less exposed, in terms of responsibilities to dependents. These households thus have zero dependents and at least one employed person in the household. Orange and red households are the most exposed, because these households have additional dependents to consider when thinking of mine closures. These households account for 61.6% of households, meaning that the majority of coal households (28 400 households) fall within the higher vulnerability categories.

It is important to note however that Tables 13 and 14 remain the critical empirical bridge, to derive the guidelines for the policy matrix approach developed below. The age-skill and education-skill layout is

precisely the bridge to policy design because it makes explicit for example how early-retirement, retraining or social assistance policy options can be targeted towards specific cohorts of workers. This analytical approach thus forms the heart of the approach to designing a just transition policy programme – which we turn to next.

3 A Just-Transition Policy Matrix: Funding Portals

In order to begin any discussion of the policy instrument available for a just transition policy approach – it is key to outline the various levers available to the government for such a policy programme.

The standard social assistance and social insurance pillars available for the JT include social grants, public works programmes, the Unemployment Insurance Fund (UIF) and its Labour Activation Programme/TERS, compensation funds, and voluntary retirement funds. The grant system is of limited direct use for displaced coal workers: eligibility is narrow, most coal workers contribute to UIF, and grant values are a small fraction of median coal wages. By contrast, the social-insurance pillar, especially UIF/TERS, and high pension coverage, can be leveraged for temporary income support, training subsidies via SETAs, and early-retirement packages; but gaps remain where existing instruments do not apply. Figure 15 provides an empirical assessment of the typical income support per capita as a share of the median coal wage. Hence, the data shows for example, that the value of the SRD grant is approximately one percent of the median coal wage, while the EPWP and the CWP wages are only 7 percent. It is critical to note that these payments are insufficient to sustain the livelihood of the average coal mining industry worker. However, there is potential to access funding from the education and training component of the EPWP, which may supplement an education and training intervention for displaced workers.

However, given available funding and existing administrative infrastructure, the social insurance pillar of South Africa's social protection system, with some additional fiscal support, is best placed to assist displaced coal mining industry workers. The UIF is designed to provide short-term relief to workers, such as those retrenched from their jobs. Given UIF coverage and job tenure levels among coal workers, it is likely that displaced coal workers will be eligible for the maximum UIF monthly payout for the period of a year. However, given the relatively high average wage for these workers, these benefits are likely to be insufficient.

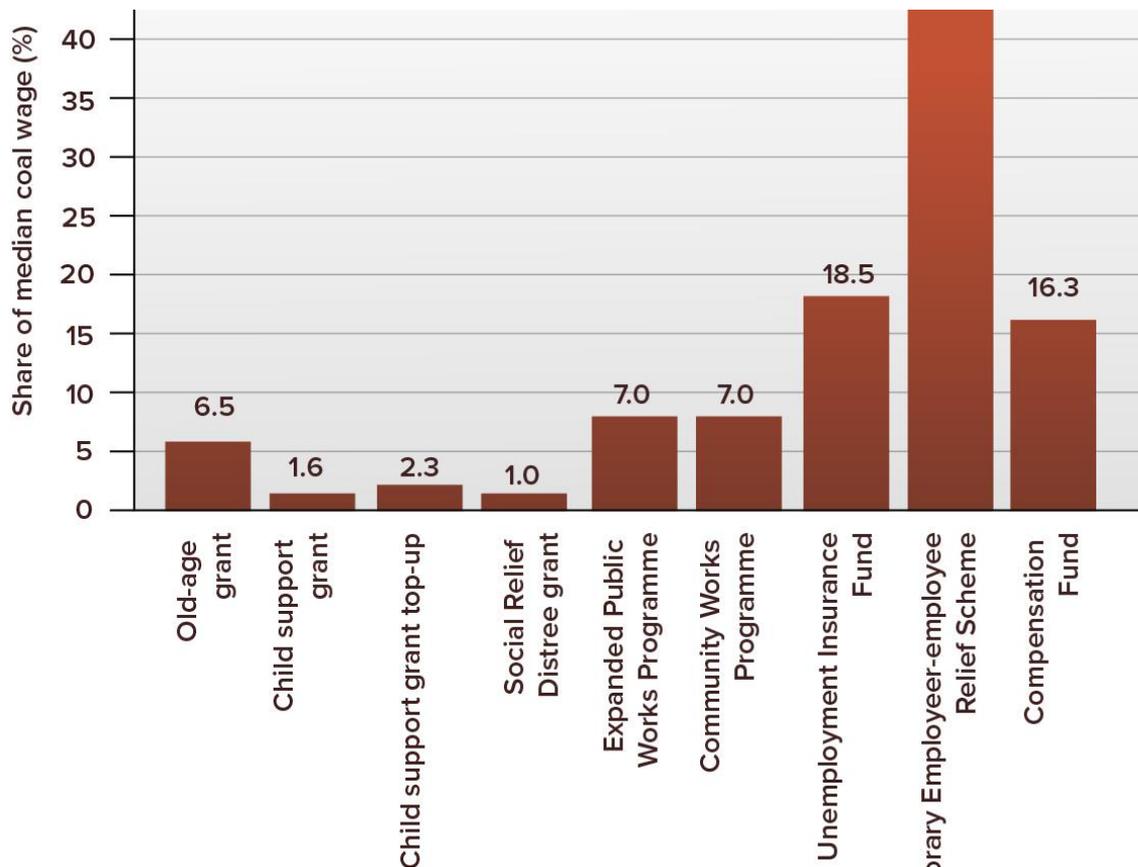


Figure 15: Grant/Programme Support As A Share Of Median Coal Wage

Source: Borat et al. (2025)

For example, our estimates suggest that the maximum UIF payout translates to 18.5 percent of the median coal mining industry wage. This suggests that a just transition social protection policy approach could leverage the existing UIF administrative infrastructure managed by the Department of Employment and Labour. However, such an approach would require additional funding to provide a social insurance payout that would help maintain the livelihoods of the displaced coal mining industry workers. Similarly, there is potential to leverage the existing administrative infrastructure associated with the Labour Activation Programme, such as the Temporary Employer-Employee Relief Scheme. This policy becomes important when considering efforts to provide education and training support to displaced coal workers. In the case of the just energy transition, the policy would need to operate outside its initial design since it may be the case that the coal mining firm is closing down (rather than seeking financial reprieve), in which case there is no job for the worker to return to. Nevertheless, the upskilling objective of the policy, in its original form, could be achieved by providing education and training to displaced workers to equip them to transition to an alternative job opportunity elsewhere in the economy. From a funding perspective, if the original design of the policy is applied, then, given that the median coal mining wage is well above the wage threshold for the policy, displaced workers would receive around R16 359 per

month, which equates to approximately 45 percent of the median wage for the industry. The latter alludes to the fact that a just energy transition policy that leverages off the Temporary Employer-Employee Relief Scheme, for example, would need to be adapted and receive supplementary financing to cover the income support gap, be it in full or part.

Finally, as shown in Borat et al. (2024a), pension coverage among coal mining industry workers is high, which means that there is an existing source of funding to support the older cohort of displaced workers. In previous energy transition episodes in other countries, early retirement packages remain a key policy tool used to assist displaced coal workers (Krawchenko & Gordon, 2021). Given pension coverage in the South Africa coal mining industry, it is well positioned to adopt such a policy. However, the use of early retirement packages would require additional funding to cover the gap in contributions incurred by workers who retire before their due retirement age.

4 Job Losses, The Age-Skills Matrix and JT Policy Instruments

The policy matrix approach taken in Borat et al (2025) assumes the job loss projections as contained in South Africa's Just Energy Transition Implementation Plan (JET IP). The JET IP predicts job losses to commence as the demand for coal declines over the period 2020 to 2030, with most of the job losses occurring from 2025 onward (The Presidency, 2022:49). Taking the current employment levels within coal at ???, we then assume employment losses at 5, 10 and 15% of these current employment levels. For our purposes here, we assume an employment loss between 2025 to 2030 of 10% of the total current coal labour force, which as the diagram below shows – accumulates to 7847 jobs.

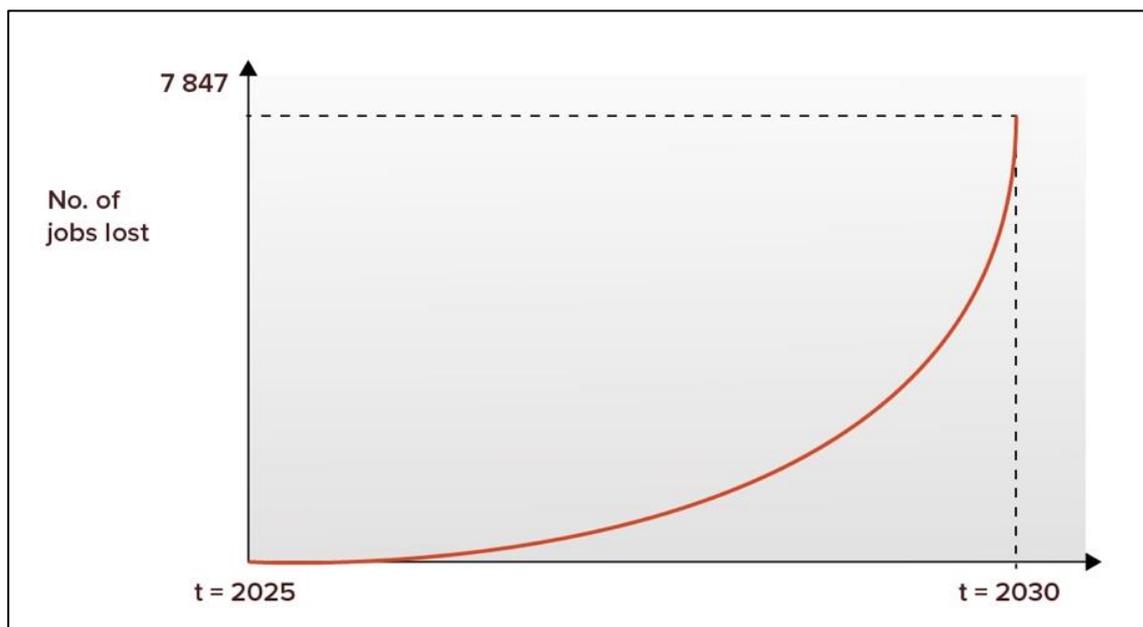


Figure 16: JET IP Job Loss Projections, 2025 - 2030

Source: *Bhorat et al. (2025)*

These total jobs lost in turn will be across all skills and age levels. We assume in turn that job losses retain the weighted employment shares of age and skill within the total retrenchment quantum of 7847 jobs. The table below outlines the exact number of jobs predicted to be lost within each age-skill cell for coal workers. Specifically, we divide coal workers into nine cohorts defined by three age groups (15–34, 35–54, 55+) and three skill groups (skilled, semi-skilled, unskilled). Skill proxies a worker's ability to re-match without support, while age proxies horizon in the labour market. Together, they determine appropriate instruments and parameterisation for a Just Transition policy package and its instruments.

Table 16: Coal Industry Age-Skills Distribution on the 10% Employment Loss

Occupation profile	Age Profile			Total
	Youth 15-34	Middle Age 35-54	Near Retirement 55+	
Skilled	509 6.5%	549 7.0%	111 1.4%	1 169 14.9%
Semi-skilled	2 145 27.3%	2 736 34.9%	554 7.1%	5 435 69.3%
Unskilled	563 7.2%	639 8.1%	39 0.5%	1 242 15.8%
Total	3 218 41.0%	3 925 50.0%	704 9.0%	7 847 100%

Source: *Bhorat et al. (2025)*

With the onset of mine closure then, we provide for four core alternative Just Transition policy instruments which are described in Table 17 below. These are a temporary income support grant (which could be long- or short-term), and education and training support scheme; an early retirement package and finally a mobility assistance scheme to facilitate job matching and uptake for retrenched workers. *Mobility assistance* refers to a once-off job-relocation grant to help retrenched workers move to where jobs exist by covering a short period of temporary housing (pegged to typical housing spend) plus a fixed moving/removal cost. It's targeted mainly at younger and mid-career skilled workers—the most mobile—so they can exit shrinking coal localities quickly, easing pressure on stagnant regional labour markets.

Table 17: Four JT Policy Instruments

Policy Instrument No.	JT Policy Instrument	Duration (from 2030)
1 (a)	Temp. income support grant (big)	5 years
1(b)	Temp. income support grant (small)	1 year
2	Education and training support	3 years
3	Early retirement package	65 less age at retirement
4	Mobility assistance	1/12 year

Source: Borat et al. (2025)

Temporary income support is a time-bound stipend, set as a share of a worker's previous wage, sustains livelihoods while keeping people attached to the labour market. The share and duration are varied by age: lighter, shorter support for younger workers to encourage rapid job search; larger, longer support for older workers who face tougher re-employment prospects. Scenarios range from fuller income replacement – which is purely for illustrative purposes – to the leaner more affordable “livelihood protection.” The *Early retirement* policy option is there to manage older workers' difficult transitions. Eligible workers are incentivised to retire earlier, with the package covering the employer retirement contributions they would have accrued until normal retirement age (differentiated for above-ground vs underground roles). Finally, *Education and training support* is crucial to prevent longer-run structural unemployment among displaced coal workers. In this option, the state funds re-skilling aligned to realistic destination jobs—e.g., a one-year post-grad engineering diploma for skilled workers; three-year millwright apprenticeships for semi-skilled; and three-year bricklayer/carpenter apprenticeships for unskilled—paired with temporary income support during training so households can cope while skills are rebuilt.⁶

In the above then, we have the building blocks to provide a costing of the just transition, through alternative combinations of these policy instruments. We thus have the job loss assumption - here we

⁶ The specific formulae and cost assumptions for each policy option are contained in detail in Borat et al (2025)

work with a 10% employment reduction - as well as an application of these losses by age and skills bands for coal workers. Based on the assumed age and skills band related quantum of losses, we then apply four policy options (assuming the income support as one instrument with two variations) within each of these age and skills cells. How to apply these policies within each of the age and skills band cells, is thus the next step, which we provide below in the form of five possible JT policy scenarios.

5 A Just Transition Policy Matrix: Six Possible Policy Packages

As noted above, the policy instruments basket comprises: temporary income support; mobility (relocation and job-search) assistance; education and training; and early-retirement packages. In order to cost these possible JT options, we provide for five possible policy packages in which the use of each of the 4 policy options within the basket – is varied. It is important to note that in each of the five policy packages, each policy instrument is switched on or off for specific cohorts and parameterised along three margins—targeting, intensity (share of prior wage), and duration—so that the same total package can be re-oriented across scenarios without changing the underlying cohorts. Hence we have the following 5 possible policy scenarios:

- *JT Package 1: Universal Transition Payment.* A once-off severance equal to one year's wage for every cohort (temporary income support intensity = 100 percent; duration = 1 year), valued at the cohort's mean wage. The design is simple, offers cost certainty, but risks insufficiency for vulnerable workers beyond the first year.
- *JT Package 2: Big Grant Approach.* Extensive temporary income support for semi- and unskilled youth and middle-age cohorts (100 percent of wage for five years) plus early retirement for older workers; its generosity in intensity and duration drives the highest total cost. This package is purely for illustrative purposes, and should not be taken as a feasible fiscal option.
- *JT Package 3: Tailored Policy Approach.* Instruments are aligned to cohort needs: early retirement for 55+, mobility assistance for skilled youth/middle-age, training for semi- and unskilled youth/middle-age, and time-limited income support that is progressive by vulnerability (e.g., 50–60 percent for semi-skilled youth/middle-age; 70–80 percent for unskilled youth/middle-age), with durations aligned to training spells.
- *JT Package 4: Progressive/Efficient Labour-Market Orientation.* Similar targeting to JT Package 3 but with more moderate magnitudes/durations, emphasising faster re-entry and lower average benefit intensity; costs accordingly compress relative to Scenario 3.
- *JT Package 5: Cost-Saving Orientation.* Tighter targeting and shorter durations, including exclusions for some middle-age unskilled training slots, further reduce costs; this is the most frugal design after Package 1.
- *JT Package 6:* The policy package is biased towards concerns around re-attachment for older workers. It is identical to JT Policy Package 3, except retirement age lowered from 55 to 45.

The total package costs are computed by multiplying per-worker policy costs by cohort headcounts under each scenario, then summing across instruments and cohorts. For example, in the tailored approach – as the table below shows – policies from retirement through to temporary income support are switched on (1) or off (0) for each skills-age cohort of coal workers.

Table 18: The JT Package 3 Tailored Policy Approach: Detailed ‘Switches’

Policy matrix groupings		Social protection policies					
Skill category	Age cohort	Early retirement	Mobility assistance	Education and training	Temporary income support		
		on/off	on/off	on/off	on/off	Share of income (γ^g)	Duration (Years)
Skilled	Youth	0	1	0	0		
	Middle age	0	1	0	0		
	Near retirement	1	0	0	0		
Semi-skilled	Youth	0	0	1	1	0.5	3
	Middle age	0	0	1	1	0.6	3
	Near retirement	1	0	0	0		
Unskilled	Youth	0	0	1	1	0.7	5
	Middle age	0	0	1	1	0.8	5
	Near retirement	1	0	0	0		

Source: Bhorat et al. (2025)

Table 18 thus shows that in this policy package, we model a policy response where firstly all workers aged 55+ across skilled, semi-skilled and unskilled groups receive early retirement. Secondly, among younger and mid-career workers, only the skilled receive mobility assistance (and no other support) because they are likeliest to find jobs elsewhere. Thirdly, semi-skilled and unskilled youth and middle-aged workers receive funded education & training (assumed to be for three years) plus temporary income support whose generosity rises with vulnerability and age—semi-skilled youth at 50% of prior income and middle-aged at 60%, unskilled youth at 70% and middle-aged at 80%—with income support lasting at least as long as training (three years for semi-skilled and five years for unskilled, reflecting two extra years for the most vulnerable). This specific JT Policy Package 3 design concentrates fiscal resources on workers facing the steepest re-employment barriers while limiting support to less vulnerable groups to contain costs.

6 The JT Policy Package Costing: Results

If we take the 6 Policy Packages noted above (and included the early retirement only as a 6th for interest as well) – the results provided in Figure 17 below are instructive. They show clearly - assuming a 10% employment loss - that the purely illustrative big grant approach (JT Package 2) is the cost outlier: At a 100% wage coverage for 5 years, the Big Grant JT Package totals about R 10.34 billion—more than double the next most costly scenario.

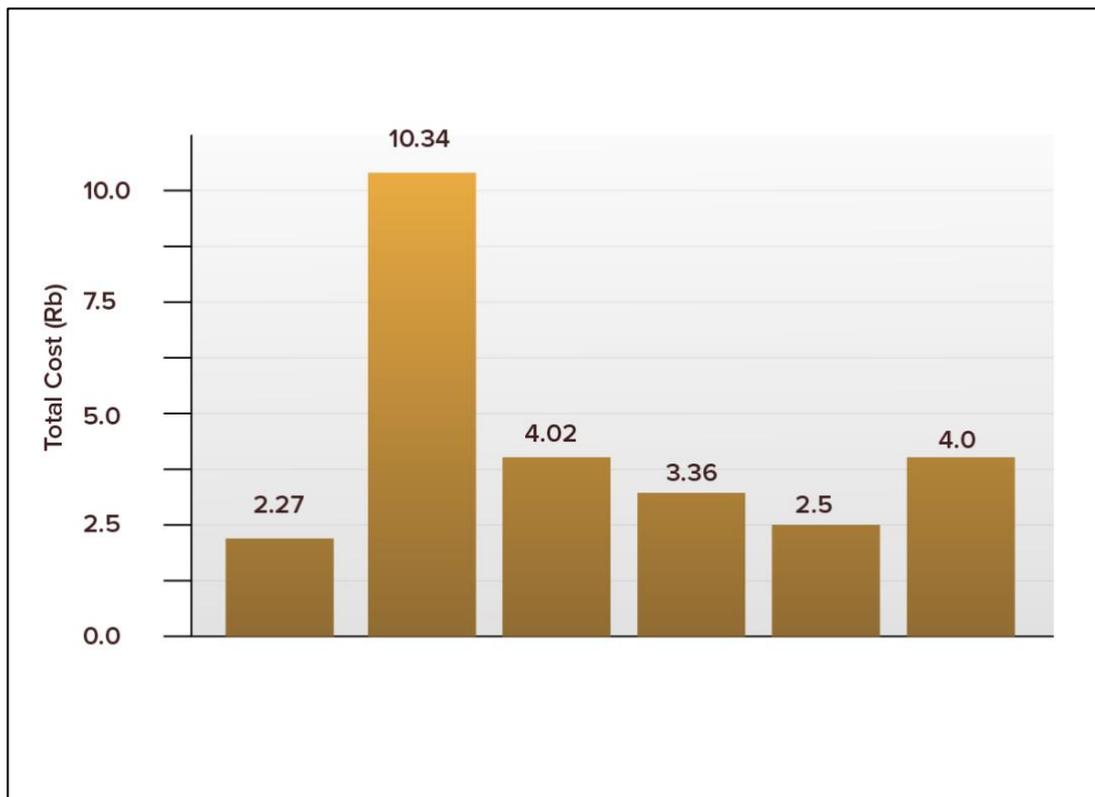


Figure 17: JT Policy Packages: Total Cost Estimates (R' bn.), at 10% Employment Loss Assumption

Source: Bhorat et al. (2025)

The tailored, efficient labour market and early-retirement-oriented packages cluster around R 4 billion, whilst the universal and cost-saving JT packages hover just over R2bn. in total cost.

It is important however to present the above in relative figures, as a proportion of a budgetary outlay – as well as these figures across different employment scenarios. The figure below provides this sensitivity and relative valuation. It is clear that the JT expenditure commitments are relatively modest – at least when compared against government's total social protection budget.

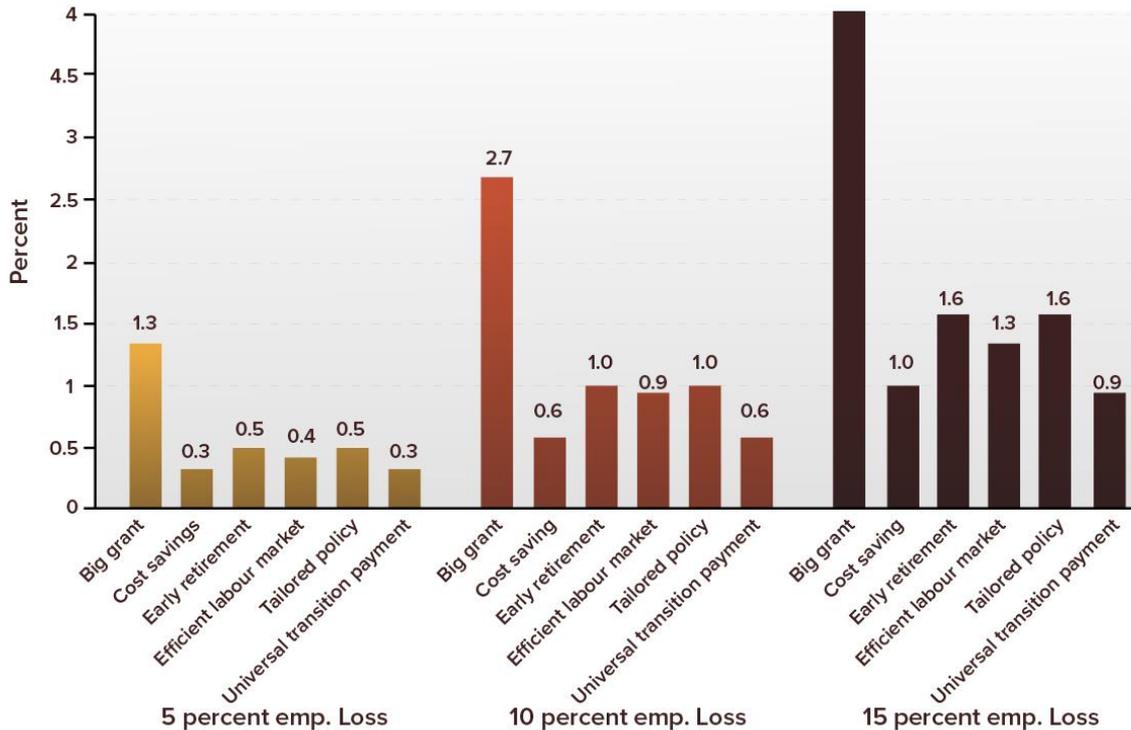


Figure 18: JT Policy Packages: Total Cost Estimates (Rbn.) as Share of Social Protection Budget, By Employment Loss Assumption

Source: *Bhorat et al. (2025)*

Figure 18 shows that the Big grant policy package constitutes 2.7% of total social protection expenditure and rising to 4.01% of the social-protection budget on a 15% employment loss assumption. In turn almost all other policy packages account for at most 1.6% of the Social protection budget. Whilst there cannot be an assumption that the fiscus alone will fund the JT Policy Packages, these relative estimates do provide a sense of the scale of the commitment that may be required. What should be clear also though is that policy choice in terms of a JT policy mixture will guide and direct cost.

One final nuance about costing: It is evident as the shares of expenditure show below that income support is the largest contributor to overall spending on the JT. Whilst it is of course dominant in the Universal Transition Payment and Big Grant Policy Packages, it constitutes over two-thirds of total spending in both the tailored policy and the efficient labour market package. Even in the cost saving package social assistance will be close to 60% of total spending. In our scenario here then, social grant spending will dominate the JT policy response in terms of cost.

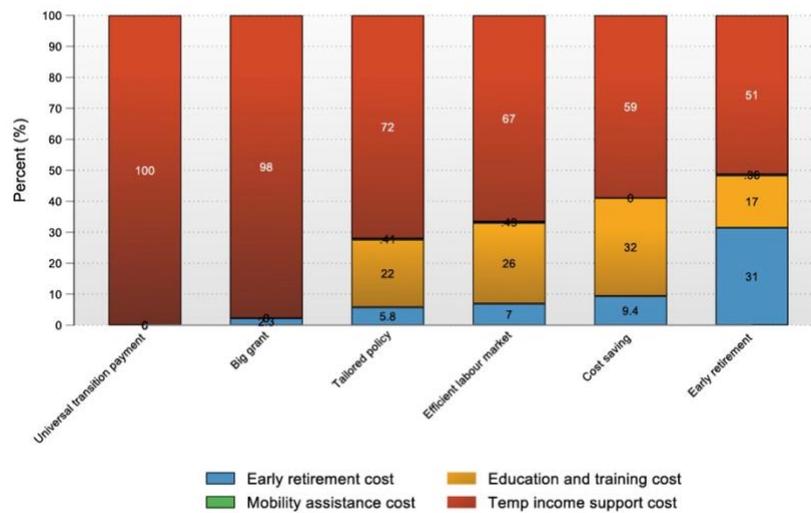


Figure 19: Policy Instrument Spending by Policy Package, % Share

Note also though that in the tailored policy, efficient labour market and cost savings policy packages – education and training remains a fairly substantive outlay. Mobility assistance, as to be expected is a very minor cost consideration. Retirement costs though do retain some presence in almost all policy packages except of course for the universal grant option.

7 Funding Gaps

Funding options for the above policy packages though remains unclear. We attempt here a very brief first take on the institutions in South Africa, where funding may be feasible from existing instruments. Specifically, we estimate how much of the above five just-transition policy packages for displaced coal workers can be financed from existing systems—UIF for unemployment insurance, the Labour Activation Programme’s TERS window for income support tied to training, and SETA (MQA) discretionary grants for education and training—and quantifies the residual “funding gaps”.

Methodologically, each policy component is matched to a feasible funding channel, accessible funding is calculated per policy-matrix group, and the gap is the difference between required cost and accessible funding (totals are not annualised). For the two grant-oriented packages, UIF is applied to temporary income support; the universal transition payment can access R625m of UIF against R2.3bn required (gap R1.7bn), while the big-grant model—five years of high replacement rates—has a far larger gap of R9.5bn because UIF only covers one year of the proposed package.

Table 19: Funding Gaps By Policy For Each Social Protection Policy Package Scenario, 10% Employment Loss

Instrument - Policy Package	Funding (Rm)	Temporary income support (Rm)	Education and training support (Rm)	Mobility assistance (Rm)	Early retirement package (Rm)	Total funding gap (Rm)
Universal transition payment	Required (A)	2 275				1 650
	Accessible (B)	625				
	Gap (A - B)	1 650				
Big Grant	Required (A)	10 109			234	9 774
	Accessible (B)	569				
	Gap (A - B)	9 540			234	
Tailored Policy	Required (A)	2 974	876	16	234	2 614
	Accessible (B)	1 194	292			
	Gap (A - B)	1 780	584	16	234	
Progressive	Required (A)	1 542	474		188	1 389
	Accessible (B)	657	158			
	Gap (A - B)	885	316		188	
Early Retirement	Required (A)	2 132	676	14	1 261	2 664
	Accessible (B)	1 194	225			
	Gap (A - B)	938	451	14	1 261	

Source: Borat et al. (2025)

In the three mixed policy packages (tailored, progressive, early-retirement-oriented), income support is aligned to TERS for one year, producing gaps of about R1.8bn (tailored), R885m (progressive), and R938m (early-retirement-oriented) on a 10% employment loss assumption. Education and training can leverage SETA funding for one of the three support years; the remaining two years are unfunded, yielding gaps of R584m (tailored), R316m (progressive), and R451m (early-retirement-oriented). Mobility assistance and early-retirement packages have no natural funding source in current programs, so their full costs are gaps. Overall, the pattern mirrors total package costs: TIS design and duration drive the gaps, with the big-grant scenario the clear outlier, and the others materially smaller.

A fiscal “stress test” links these gaps to institutional baselines. Our estimates shows that adding the universal transition and big-grant scenarios would barely move UIF claim counts (+0.9% and +0.82%) but would lift annual UIF spend by between 16-18% across either the big grant or universal transition

policy packages. In addition, using the TERS or for example the budget of the MQA SETA to fund the Just Transition, would require very specific and not modest increases in funding allocations to retrenched coal workers. Hence, our results show that reliance on the TERS-linked institutional funding covering income support for the three mixed policy packages - would require 3,348–6,084 additional beneficiaries (a 40%–72% rise) and an extra R445m to R883m per year - large in percentage terms (52%–103%) but still within the LAP's R3.1bn budget envelope (actual spend: R854m), with higher per-beneficiary costs and a three-to-five-year duration depending on scenario. For training, using funds from the MQA SETA would raise annual beneficiaries by 20%–37% and spending by R158m–R292m for three years. The policy takeaway is that existing institutions can shoulder a meaningful share—especially for one-year tranches—but multi-year, high-replacement temporary income support remains the dominant unfunded pressure, and any deployment will concentrate sizeable resources on a relatively small cohort of displaced workers.

A Note on Industrialisation for Mpumalanga

It must be noted that the above JT plans are specifically calibrated and presented as a social protection or income generation plan for coal workers. At its heart, the focus is on supporting coal workers in the transition. It is possible however, that parallel to such efforts there will be a series of interventions designed to revitalise the local economy of Mpumalanga as it enters a post-coal environment.

It is worth reflecting on the relationship between these interventions and what has been proposed here: Firstly, we would argue that independent of a successful industrialisation plan for Mpumalanga workers who are in our near retirement and low skilled categories above - are most likely going to remain a social protection *cum* income support target group. It is difficult to envisage a growth plan for Mpumalanga that is capable to absorbing all these categories of workers in the time required to kick-start a growth plan for the province – and indeed to provide the jobs matching all the skills of these workers. Secondly, in this respect, the cohort of workers who are targeted for education and training support may very well lie at the heart of how this proposed JT plan could be directly aligned to an industrialisation strategy for Mpumalanga or indeed for new jobs in the renewables industry not in Mpumalanga. The key here is to ensure that the skills upgrading which does get offered through the JT plan is very closely matched to available jobs and vacancies in other industries. These may or may not be jobs in Mpumalanga or in the renewables sector.

Finally, a word on an industrialisation plan: Work currently underway for the Presidential Climate Commission proposes the use of economic complexity analysis in order to appropriately and more nuanced manner – generate a possible post-coal growth plan for the province. The economic complexity approach very briefly - is predicated on the notion that the development of products not only requires the standard factors of production, but also the tacit productive knowhow on how to put all these inputs

together in a firm. This productive knowhow – or capabilities – is typically a key constraint to diversifying economic activities because, given its tacit nature, is not easily transferable, and tends to be spread across many individuals across society who need to coordinate across teams and organisations. Building economic complexity is a process of accumulating productive capabilities and thereby diversifying into more complex products. Simply put, an economy will move from growing apples to producing apple juice much more easily than moving from apples to jet engines. This notion of moving into ‘nearby products’ given existing knowledge, capabilities and other assets – lies at the heart of proposing any feasible industrialisation strategy for Mpumalanga. This work is ongoing, but should be viewed as a complement to this paper.

8 Conclusion

The coal labour market is large, spatially concentrated, and dominated by semi-skilled jobs with complete secondary education—traits that simultaneously raise displacement risks and create scope for skills-top-up interventions that enable re-matching. The labour market lens of deriving occupation–education and skills-age descriptors ultimately provide the empirical backbone for defining the contours of a just transition policy package.

Using 4 possible policy instrument, namely income support; mobility assistance; early retirement and education & training – we suggest five possible policy packages to the assumed employment loss of 10% of the current coal labour force. These policy instruments and packages are delivered then to workers in each of 3 age bands and 3 skills categories. Put differently then, our policy packages supports an approach that targets early-retirement offers to older cohorts; combines training and time-bound income support for semi- and unskilled youth and middle-aged workers; and finally uses mobility assistance selectively for skilled cohorts. These options are varied in intensity and length across the five policy packages. Importantly, in our generic model, such assumptions can be varied to arrive at different and alternative just transition packages and costs.

Whilst, on headline magnitudes, even the most generous scenario absorbs a modest share of the national social-protection budget – this figure is misleading. Most of the costs for the JT will likely be borne by a disparate set of institutions such as the UIF, the TERS and the relevant SETA. Whilst such funding can be partially mobilised out estimates above confirm that significant funding gaps will persist – in particular for multi-year income support and retirement top-ups. It must be emphasised however that the framework and policy interventions provided above are suggestive of a possible policy architecture. It is critical that such a design is benchmarked appropriately against other programmes which have managed the transition of workers and households out of coal. The experience for example in Poland and China are particularly noteworthy – as is the broader guidance provided by multilateral

institutions that have deep cross-country experience in this domain. In this respect, the work of the World Bank's Coal Transitions team is important as is their ongoing policy work (World Bank, 2018)⁷.

Ultimately this piece suggests that whilst an analytical and policy framework for setting up a just transition for coal workers is eminently feasible – the project packages and their funding details are amenable to change and alteration given the specific policy choices made and the availability of funding.

⁷ See the work of the World Bank on Transitioning from coal at: <https://www.worldbank.org/en/topic/extractiveindustries/brief/supporting-coal-regions-in-transition>

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