PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

Modelling an Inclusive Green Economy COVID-19 Recovery Programme for South Africa

cambridge econometrics
clarity from complexity

Environment, Forestry and Fisheries
Trade, Industry and Competition
Science and Innovation

UN environment United Nations Environment Programme

ILO

UNDP

UNIDO

unitar United Nations Institute for Training and Research

Final report

February 2021

Cambridge Econometrics
Cambridge, UK

info@camecon.com
www.camecon.com

Contact person: Stijn Van Hummelen (info@camecon.com)

Authors: Bence Kiss-Dobronyi, Luca Barbieri, Stijn Van Hummelen, Richard Lewney (Cambridge Econometrics)

Chapter 5: Mike Harfoot and Calum Maney (UN Environment Programme World Conservation Monitoring Centre)

Contributing author: Prof Margaret Chitiga-Mabugu (University of Pretoria)

Contributors: Advice and support from Marek Harsdorff (ILO), Adebiyi Odegbile (UNEP) and Jose Pineda (UBC Sauder School of Business) and representatives of PAGE agencies in South Africa and the South African government are gratefully acknowledged. Responsibility for the content remains with the authors.

Project director: Richard Lewney

PAGE PARTNERSHIP FOR ACTION ON GREEN ECONOMY

Policy Brief

Modelling a Green Economy Recovery for South Africa

This policy brief reports estimates of the potential economic, social and environmental impacts of key policies in the Economic Reconstruction and Recovery Plan (ERRP)[1] published by the South African Government in October 2020. It draws on a case study prepared within the wider project *Inclusive Green Economy response scenario modelling of COVID-19 recovery plans* by Cambridge Econometrics, in collaboration with Prof Margaret Chitiga-Mabugu of the University of Pretoria for the Partnership for Action on Green Economy.

South Africa faces the challenge of promoting short-term economic recovery from the impact of COVID-19 whilst ensuring long-term, environmentally-sustainable prosperity. The analysis reported here explores the tensions and opportunities presented by this challenge, by using the energy-economy-environment macro-econometric model E3ME.

The analysis modelled the impacts of key policies in the Economic Reconstruction and Recovery Plan (ERRP) which have been categorised as:

1. Conventional Policies
2. Public Works
3. Green Policies

Given the worldwide interest in the scope for Green Recovery policies, the analysis also included a 'Green Push' scenario, in which South Africa moves more quickly towards decarbonising its power generation system than is currently planned.

Key findings

- Green policies can promote economic growth, job creation and environmental sustainability and bring back GDP to what it would have been in the absence of COVID-19.
- A recovery without strong green policies would see greenhouse gas emissions return quickly to the levels seen before the COVID-19 pandemic and would continue to rise.
- If green policies are pursued, additional employment and economic activity can be achieved, while also cutting greenhouse gas emissions.
- Moving to a low-carbon economy involves job gains in new sectors and job losses in coal mining. Although there is a positive net effect, policies to support coal miners and their communities will be needed to promote a just transition.

cambridge econometrics
clarity from complexity

Context

South Africa's road to green recovery from COVID-19.

By October 2020, approximately 1.1m deaths have been recorded worldwide as a result of COVID-19. The global pandemic has also caused the largest global recession at least since the 1930s Great Depression. The latest global economic estimates predict a global contraction in GDP of more than 4% in 2020. Simultaneously, around the world, there has been a surge of national and corporate Net Zero commitments and green recovery policy developments in 2020.

Background of COVID-19 in South Africa

In common with the rest of the world, South Africa has been severely impacted by the COVID-19 pandemic. Compared with other G20 countries, the GDP impact in South Africa lies in the middle of the range. Recent estimates indicate that due to global developments and the lockdown restrictions imposed on the economy during the pandemic, GDP is likely to have contracted by 8% in 2020.

South Africa had been experiencing continued slow economic growth, persistently high unemployment and weak investment levels over the last two decades, even before the current crisis. The challenge is how to promote both short-term economic recovery and long-term, environmentally-sustainable prosperity. The analysis reported here integrates economic, social and environmental indicators in a single integrated model to review ways to stimulate the economy whilst complying with South Africa's global commitment to mitigate green-house gas emissions.

South African Government Policy Response to the Pandemic

The South African government has introduced several policy measures to mitigate the short-term impact of the pandemic. In October 2020 it announced a set of policies to promote long-term economic recovery: the Economic Reconstruction and Recovery Plan (ERRP).

Already in April 2020, a R500 billion stimulus package, equivalent to almost 10% of the country's GDP, was announced in April 2020 as a short-term response, designed to minimise the impacts on unemployment and incomes and also boost the health response to the pandemic. In the long run, the ERRP is designed to include an employment stimulus that aims at building back better whilst transforming the economy and the society and supporting the development of decent work opportunities. The first phase of the ERRP aims at creating over 800 000 job opportunities in 2020/21 and has an allocated budget of R19.6 billion for 2020/21.
The stimulus aims at creating jobs in key departments:

- basic education
- social development
- agriculture
- land reform and rural development
- environment, forestry and fisheries.

Objectives

The objective of the study was to carry out a reliable analysis of measures introduced by the South African Government through the ERRP to mitigate the short- and long-term impact of the COVID-19 pandemic. This was done using a structural macro-econometric model that allows simulation analysis of three key scenarios for recovery policies.

Environment-economy-energy modelling

The study used Cambridge Econometrics' global macro-sectoral economy-energy-environment model E3ME.

E3ME (www.e3me.com) is a model of the world's economic and energy systems and the environment which can be used to quantitatively evaluate the impacts of an input shock at national, regional or global through scenario-based analysis. The results reported here focus on three key indicators of economic, social and environmental outcomes: GDP, unemployment and CO_2 emissions.

Economic recovery scenarios for South Africa

The economic recovery scenarios build on key policies announced in the ERRP.

We distinguish three kinds of policies: conventional policies, public works and green policies. In the modelling, these policy sets are accumulated successively.

A	Conventional policies	R 835 bn over 10 years which includes interventions such as infrastructure investment, localisation of production, subsidies for the tourism sector and food vouchers.
B	Public works	R 68 bn over 5 years in the form of public employment programmes in various sectors.
C	Green policies	R 190 bn over 10 years including subsidies for renewables, grid investment, energy efficiency measures and restriction on new investment in coal-fired power stations.

We also test the impact of a stronger push towards decarbonising the power generation system than is envisaged in the ERRP.

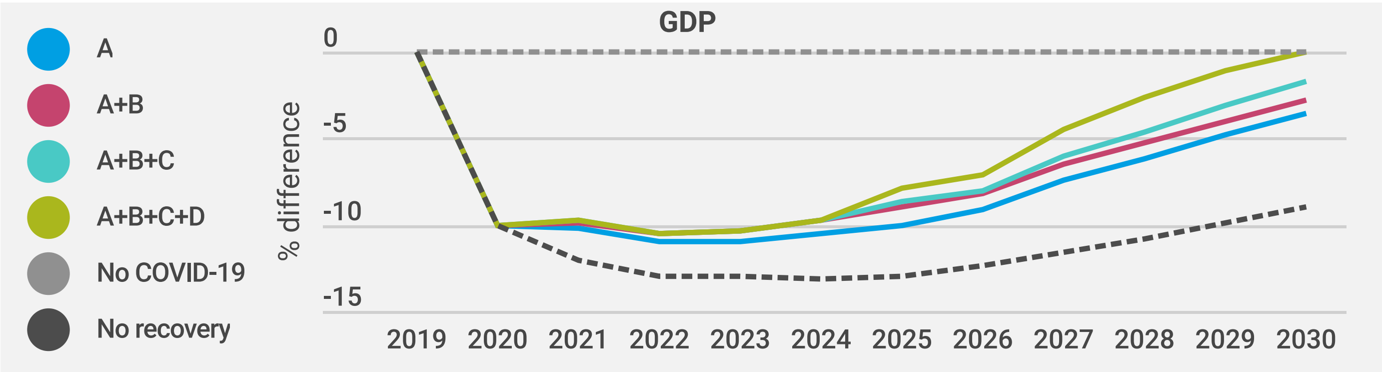
D	Green push	A stronger push towards renewables than is envisaged in the ERRP: early decommissioning of coal-based power generation and an additional R 300 bn of private financing to the power sector

A key assumption is that the funding required for the investments in all scenarios, both private and public, will be secured. Our modelling shows that policy incentives for renewable electricity will indeed leverage private investment in power generation. We have assumed, rather than simulated, the additional private sector investment expected to be leveraged by the conventional policies package in line with the estimates provided in the ERRP.

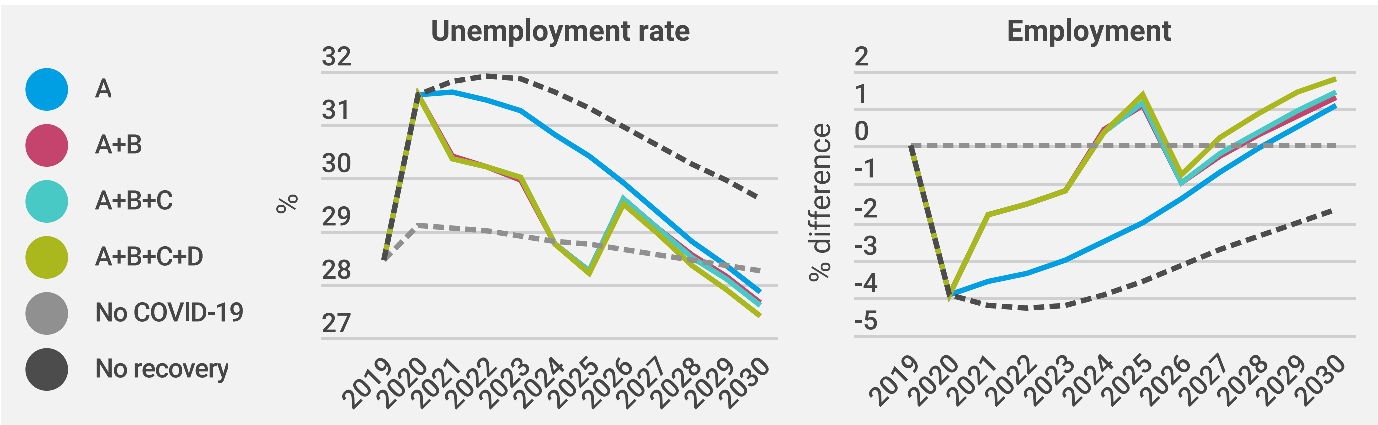
Findings

Green policies can promote both economic growth and environmental sustainability.

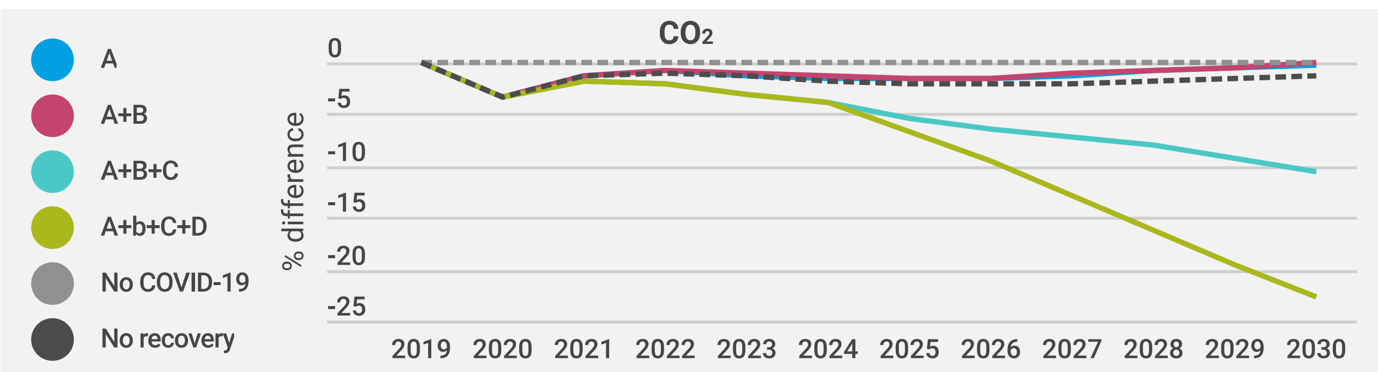
Overall, GDP can be boosted to regain the 2030 level projected before the pandemic. After the large decline in GDP in 2020, the policies in the scenarios promote an accelerated growth path over the rest of the decade, with growth exceeding 6% per annum from 2027.



The policies categorised as 'conventional' receive the largest level of spending (investment) in the ERRP, giving a large boost to GDP. These conventional policies boost employment, but a larger boost comes from the (temporary) public works programmes.



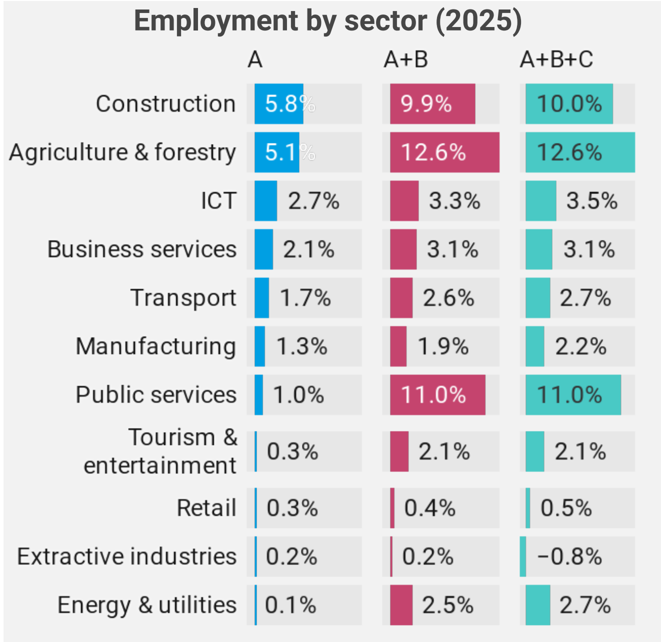
While the impact of the COVID-19 pandemic on economic activity and travel has reduced CO_2 emissions in 2020[2], scenarios without a 'green element' result in a rapid return to growth in CO_2 emissions and continuing increases in the long term.



When green policies are included, there is a substantial reduction in CO2 emissions by 2030.

Employment by sector results show that (compared to a baseline with COVID-19 impacts but no recovery):

- 'conventional' measures boost employment in the construction sector due to large-scale infrastructure investments.
- public works, substantially yet temporarily, increase employment in public services, agriculture and forestry.
- decarbonisation could lead to job losses in the production of fossil fuels, while jobs will be gained in production of renewable energy.



Additional analysis, performed by the UNEP World Conservation Monitoring Centre, using the ENCORE model, shows that circular economy measures and nature-based solutions should be included alongside decarbonisation policies to mitigate the impact on natural capital assets.

Conclusion

Without strong green policies, economic recovery will bring a rapid return to the CO_2 emissions levels seen before the crisis, and continuing increases thereafter. Green policies can promote higher economic activity and employment at the same time as significant cuts in CO_2 emissions. To achieve South Africa's greenhouse gas emissions target it will be necessary to avoid the lock-in to higher carbon emissions associated with building new coal-fired power stations. The transition to a low-carbon economy inevitably involves more activity in the low-carbon supply chain and less activity in coal mining. Like other countries with a significant fossil fuel extraction industry, South Africa will need 'just transition' policies to support those individuals and communities dependent on jobs that do not have a sustainable long-term future. Mitigation measures will also be needed to protect other natural capital assets.

[1] *The Presidency (2020). Building a society that works: Public investment in a mass employment strategy to build a new economy. The Presidency, South Africa, Pretoria. https://www.gov.za/sites/default/files/gcis_document/202010/south-african-economic-reconstruction-and-recovery-plan.pdf*

[2] *Evans, S., 2020. Analysis: Coronavirus set to cause largest ever annual fall in CO_2 emissions [WWW Document]. Carbon Brief. URL https://www.carbonbrief.org/analysis-coronavirus-set-to-cause-largest-ever-annual-fall-in-co2-emissions.*

PAGE gratefully acknowledges support from the following funding partners:

European Commission

Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety

Ministry for Foreign Affairs of Finland

Norwegian Ministry of Climate and Environment

Ministry of Environment Republic of Korea

Government Offices of Sweden Ministry of the Environment and Energy

Schweizerische Eidgenossenschaft Confédération suisse Confederazione Svizzera Confederaziun svizra Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER State Secretariat for Economic Affairs SECO

Contents

Tables

Figures

1 Introduction

1.1 Context for the project

This report has been prepared as a case study within the wider project *Inclusive Green Economy response scenario modelling of COVID-19 recovery plans*, undertaken by Cambridge Econometrics for ILO and UNEP. The project's aim was to undertake a credible, quantified analysis of the impact of alternative (non-green and green) COVID-19 recovery plans on key economic, social and environmental indicators globally and in selected PAGE[1] countries. The current report presents the analysis carried out for South Africa.

The analysis has been carried out using the energy-economy-environment model E3ME which covers the entire global economy in considerable geographical and sectoral detail. As a structural, macroeconometric model, E3ME is well suited to the analysis of the impact of COVID-19 and of stimulus policies to mitigate that impact. E3ME's sectoral and product detail supports an analysis of links between economic growth and environmental pressures, including many applications in the field of climate change mitigation. A short description of E3ME is included in Appendix A and further details can be found at www.e3me.com.

The projections and simulation results presented here are not predictions, but rather a quantified estimate of the scale of the difference that various alternative COVID-19 recovery packages could make to economic, social and environmental indicators.

1.2 The COVID-19 pandemic

The 2020 COVID-19 pandemic has plunged the world's economies and societies into the deepest crisis at least since the 1930s Great Depression, with a reduction in economic activity and employment that dwarfs the 2008 crisis and with a heavy toll in terms of lives lost.

By October 2020, the global number of cases surpassed 40 million, while deaths attributed to COVID-19 have surpassed 1.1 million (Our World in Data, 2020). The pandemic has shown the limitations of our health systems. A survey conducted by World Health Organization (WHO) from March to June 2020 of a sample of 105 countries found that 90% of the countries examined experienced disruptions to their health service, with low- and middle-income countries reporting the greatest difficulties (WHO, 2020).

Governments around the world responded to the rapid spread of the virus by introducing lockdown regimes in the period March-June 2020. These entailed (to varying degrees depending on the country): restrictions to domestic and international travel, restrictions on public gatherings, closure of schools, and closure of 'non-essential' activities such as restaurants, bars and hotels. The measures helped to contain the pandemic but at a huge cost in terms of lost production and employment.

[1] www.un-page.org.

The October 2020 International Monetary Fund (IMF) *World Economic Outlook* forecast a 4.4% contraction in global Gross Domestic Product (GDP) for 2020 (IMF, 2020a), while June's OECD *Economic Outlook* forecast a 7.6% contraction in 2020 in the case of a second wave of the pandemic (OECD, 2020a). In September 2020, the ILO estimated a 17% loss in hours worked in 2020 Q2 compared to 2019 Q2, equivalent to 495 million full-time equivalents (FTEs), with lower and middle-income countries being especially hit (ILO, 2020). The impact has been particularly severe on those whose work depends on social consumption and interaction, notably in the hospitality and leisure economy, where jobs are low-skilled, low-paid and are often occupied by young people. The loss of incomes and restrictions on social interaction have had major impacts on well-being, including mental and physical health conditions. Informal employment can act as an 'employer of last resort', particularly in countries where unemployment benefit support is limited or not available. To the extent that this is captured in the labour market data, it may appear in some countries as an increase in jobs in sectors where such employment is important. Despite the increase, this is another sign of labour market weakness.

To mitigate the impact on production, employment and incomes, governments have implemented sizeable stimulus packages, often on a scale amounting to several percentage points of their country's GDP (Bruegel, 2020; IMF, 2020b). Measures adopted widely include: furlough schemes to keep people in employment, income support, credit guarantees and liquidity support, tax deferrals, strengthening of health systems and support for SMEs (IMF, 2020b; OECD, 2020b). These measures put a major strain on public finances. For example, in October 2020 the IMF forecast public deficits in 2020 would reach 10% of GDP in the European Union, 16% in the G7 and 10% in emerging markets and developing economies (IMF, 2020a).

A positive side-effect of the collapse in output and travel has been a reduction in the pressures placed by economic activity on the environment. For example, greenhouse gas emissions are estimated to have declined by almost 9% in the first half of the year (Evans, 2020; Liu et al., 2020). While it is possible that the changes to behaviour brought about by the adjustment to life under lockdown may persist in a way that curbs emissions in the long term (e.g. more working from home / telecommuting), for the most part there is no reason to be confident that the reduction in emissions experienced in 2020 will be sustained when the pandemic crisis is over. Furthermore, spending on measures aimed at decoupling economic growth from environmental degradation has been cut. Investment has fallen sharply during the crisis, deferring the kinds of improvements in energy efficiency, electrification of final demand and expansion of renewable electricity capacity that are needed to permanently reduce emissions. When output recovers, there is every reason to expect energy demand and the associated emissions to rebound, and a similar effect is likely to be experienced across a range of environmental pressures.

1.3 Global recovery scenarios

In the months following the onset of the COVID-19 pandemic, modelling with E3ME (see Appendix A for further details on the modelling framework) was carried out to estimate the macroeconomic consequences of the crisis at the global level (Pollitt, 2020; Pollitt et al., 2020b) and in particular regions (Economic Commission for Latin America and the Caribbean, 2020; Pollitt et al., 2020a). These exercises also considered different cases of ‘green’ stimulus to the economy to induce a ‘green’ recovery. The modelling of a global recovery for this report is similar in design to those cases, but works with updated assumptions on the impacts of the COVID-19 pandemic as well as more recent data and an updated version of the E3ME model.

The modelling requires a careful analysis of the different channels through which the pandemic affects the economy. The main assumptions include:

- a loss of economic capacity across sectors due to self-isolation, quarantine and other measures to reduce the spread of the virus
- a demand shock to relevant sectors, implemented as a reduction in consumer expenditure
- a shock to investment spending as a result of the large impact on uncertainty and hence on consumer and business confidence
- government responses, especially in the form of higher health-sector expenditure and transfers to residents
- a short-term shock to global oil prices as transport demand for petroleum products slumped.

The assumptions were developed by consulting a range of data sources on the observed impacts of the COVID-19 pandemic. For example demand shocks were estimated based on national level data from Google’s Community Mobility Reports (Google, 2020), TomTom Traffic Index (TomTom, 2020) and industry estimates.

Three different scenarios are modelled to show possible paths that the economy could take following the crisis. In the *COVID-19 baseline scenario*, future developments are driven by already announced measures[2] and no further interventions are implemented. In the *VAT Recovery scenario*, a 5 pp cut to VAT (or sales tax) is applied in 2021 and gradually phased out after 2024 (returning to the baseline by 2028). This scenario is meant to simulate the path of a recovery based on stimulating consumption spending through tax cuts, without any structural change or reform. In the *Green Recovery scenario,* a fiscal stimulus of the same size as in the VAT Recovery is implemented, but part of the spending is used to implement measures targeted at reducing CO_2 emissions. Necessarily, the scenarios are somewhat stylised (i.e. consistent across countries in terms of composition, with levels of intervention customised to the extent that relative changes lead to different changes in absolute terms across countries) in order to maintain a comparable treatment across countries.

In line with Pollitt et al. (2020b) these measures include:

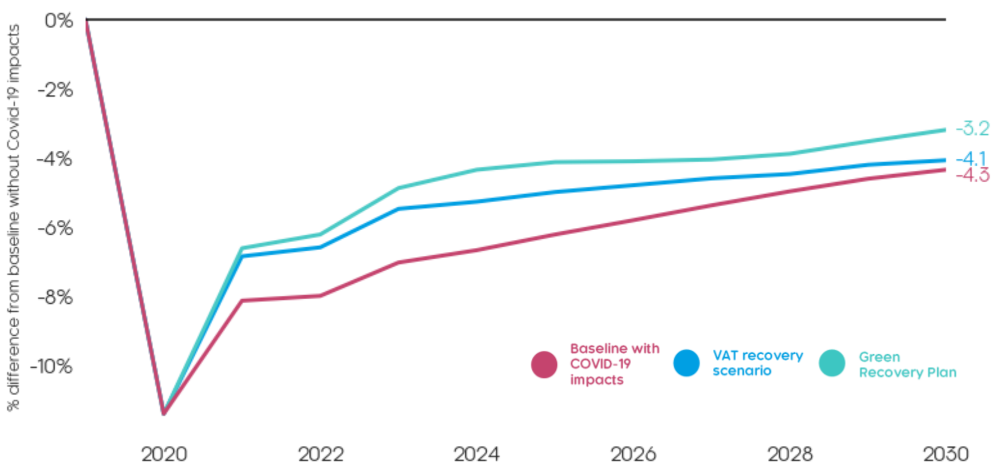
- a 67% capital subsidy for new wind and solar installations
- increased government spending to fund investment in the electricity grid to accommodate the new renewable energy capacity

[2] We include fiscal policy responses announced by July 2020 as collected by IMF (2020b) and Bruegel (2020).

- a car scrappage scheme to incentivise the purchase of electric vehicles, under which governments pay 20% of the purchase price of new vehicles
- an increase in energy efficiency in buildings (financed through government support), sufficient to reduce household energy consumption by 6% over 2021-2023
- a global tree-planting programme funded by governments amounting to 10 billion additional trees planted globally over 2021-2023.

Figure 1.1 shows the global GDP pathway in the three scenarios compared to a no-COVID-19 baseline (which projects how the global economy would have developed without the pandemic outbreak). In 2020, global GDP is 11% lower than the no-COVID-19 baseline, which translates into a -8% year-on-year decline in 2020, similar to the outcome projected in OECD's Double-hit scenario (OECD, 2020c). Thereafter, the trend is broadly similar in all scenarios: a relatively strong rebound in 2021 followed by a gradual recovery. However, GDP remains below the no-COVID-19 baseline in all scenarios even by 2030. Both the VAT and the Green Recovery scenarios show a stronger GDP recovery in 2021 than the COVID-19 baseline and the level of GDP remains higher thereafter. The Green Recovery scenario shows a somewhat stronger outturn for GDP than the VAT Recovery scenario.

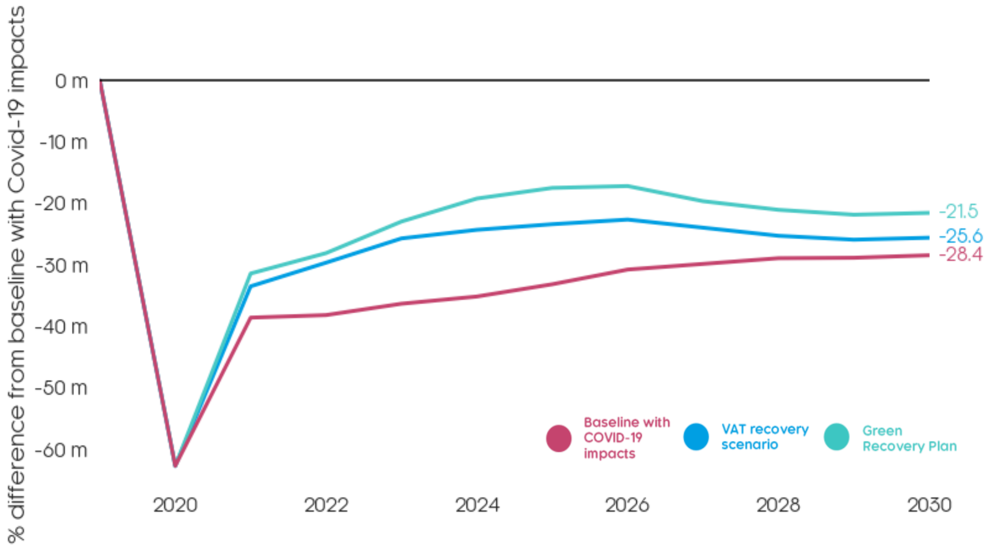
Figure 1.1: Impacts on global GDP, % difference from no-COVID-19 baseline



Source: E3ME modelling.

The results for employment are shown in Figure 1.2. In 2020, approximately 63 million jobs are lost globally compared to the baseline. In 2021, a 'natural' recovery restores approximately 25 million jobs, the VAT Recovery scenario has the potential to add another 2 million jobs, while the Green Recovery scenario could increase employment by 7 million jobs. By 2030 the difference between the scenarios largely diminishes, but employment remains lower in the COVID-19 baseline and the VAT scenario than the Green Recovery through the coming decade.

Figure 1.2: Impacts on global employment, level difference compared to no-COVID-19 baseline



Source: E3ME modelling.

The sectoral results in Table 1.1: show the structural shift in the Green Recovery Plan away from extractive industries (particularly fossil fuels) towards electricity generation and utilities in employment, and more generally the outcome in other sectors is better (the reduction in employment compared with the no-COVID-19 baseline is less).

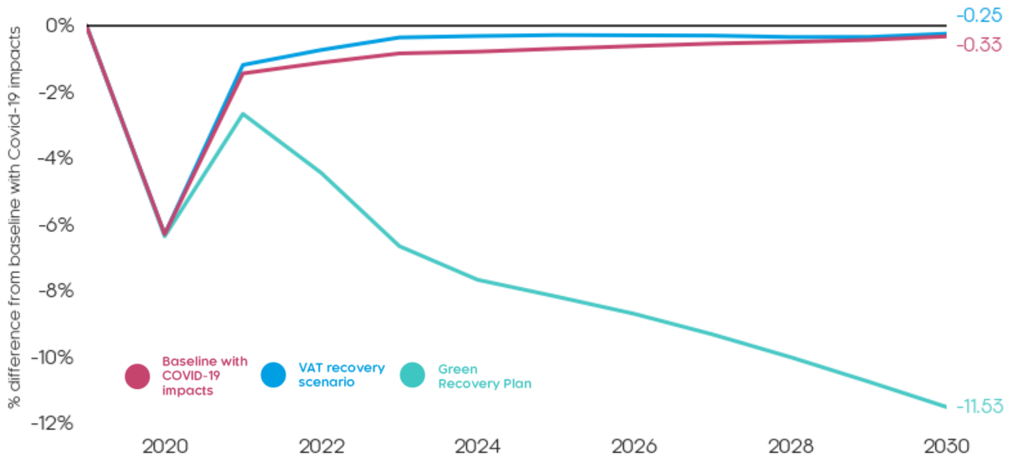
Table 1.1: Global sectoral employment impact in 2025, % difference from COVID-19 baseline

Sectoral employment % difference from baseline by 2025	**COVID-19 impacts** compared to no-Covid-19 baseline	**VAT recovery**	**Green recovery**
		compared to baseline with COVID-19 impacts	
Agriculture & forestry	-0.2%	0.1%	0.1%
Extractive industries	-0.6%	0.2%	-2.4%
Manufacturing	-0.7%	0.6%	0.8%
Energy & utilities	-1.2%	0.1%	0.9%
Construction	-0.8%	0.4%	1.1%
Retail	-1.0%	0.2%	0.3%
Tourism & entertainment	-1.1%	0.2%	0.3%
Transport	-1.3%	0.8%	1.0%
ICT	-0.6%	0.6%	0.7%
Business services	-2.7%	0.5%	0.6%
Public services	-0.9%	-0.1%	0.3%

Source: E3ME modelling.

Figure 1.3 shows the impact on CO_2 emissions. The reduction in economic activity caused by the pandemic leaves emissions more than 6% lower than the no-COVID-19 baseline in 2020. However, in both the COVID-19 baseline and the VAT Recovery scenario, CO_2 emissions pick up again as GDP recovers, returning almost to the level projected in the no-COVID-19 baseline by 2030. In contrast, emissions in the Green Recovery scenario decline further to over 11% below the no-COVID-19 baseline by 2030.

Figure 1.3: CO_2 emissions, % difference from no-COVID-19 baseline



Source: E3ME modelling.

The modelling supports the following conclusions:

- even with a recovery beginning in 2021, the pandemic is projected to have a sustained, long-term impact on employment and GDP in the absence of any recovery programme
- the VAT and Green Recovery programmes are expected to boost GDP by similar amounts, but the Green Recovery programme gives a stronger boost to employment, albeit with a stronger structural shift away from jobs in extractive sectors
- CO_2 emissions are much lower in the Green Recovery scenario.

A recovery supported by the policies included in the Green Recovery scenario is therefore expected to be:

- at least as good in terms of GDP
- better in terms of employment
- substantially better in terms of CO_2 emissions

compared with a recovery based on more conventional fiscal stimulus policies.

2 The COVID-19 pandemic: economic and social impacts in South Africa and the government's policy response

2.1 Introduction

This chapter presents an overview of the impact the pandemic has had so far on the economic conditions, employment and trade in South Africa. The chapter also provides a summary of the South African government's policy response to the pandemic, covering short-term and long-term measures.

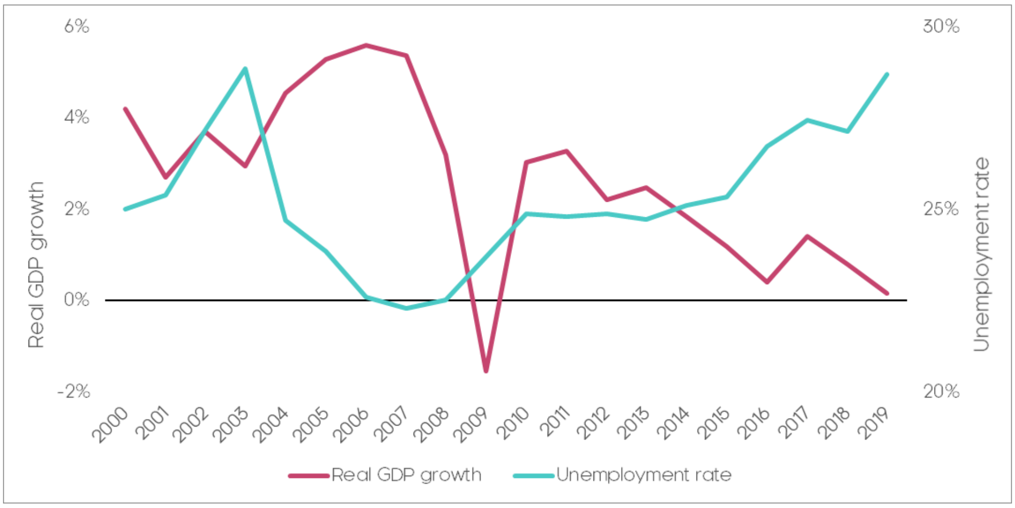
2.2 The impact of the pandemic

The first COVID-19 case in South Africa was reported in early March (Our World in Data, 2020). Towards the end of March, South Africa entered a lockdown regime which included the prohibition of public gatherings, the closure of restaurants, bars and all stores not selling essential goods, the closure of schools, strict travel restrictions and the closure of borders. Only essential activities and workers were allowed to keep operating. From the beginning of May, these lockdown restrictions were gradually lifted (South African Government, 2020a). With almost 700,000 cases detected by early October 2020, South Africa occupied the 10th place worldwide in terms of number of cases detected, and the number of deaths due to COVID-19 by that time amounted to 17,400 (Worldometer, 2020).

Economic impact

Economic conditions were already fragile when the pandemic struck. GDP growth had been slowing down for the past decade, while the official unemployment rate[3] rose to reach 28.7% in 2019 (Stats SA, 2020a).

Figure 2.1: GDP growth and unemployment before the pandemic



Source: CE based on Stats SA (2020b) and South African Reserve Bank (2020)

[3] The Labour Force Survey shows two definitions of unemployment rate. The unemployment rate according to the official definition (henceforth official unemployment rate) refers to persons aged 15-64, who were not employed, were available to work and actively looked for a job. The unemployment rate according to the expanded definition (henceforth expanded unemployment rate) refers to persons aged 15-64, who were not employed, were available to work but did not look for a job because of discouragement or other reasons (Stats SA, 2020a).

In 2020 Q2, GDP fell by 16% compared to 2020 Q1, the deepest quarterly decline on record in data going back to 1960 (Stats SA, 2020c). Economic activity declined sharply in April during the period of strict lockdown, and gradually started to recover after the restrictions were lifted by May 2020. However, figures on private transactions indicate that economic activity was still lagging below pre-pandemic levels in September (TIPS, 2020). As shown in Table 2.1, output in sectors such as mining and quarrying, manufacturing, construction, trade and accommodation, and transport and storage fell by more than a quarter in 2020 Q2 compared both to 2020 Q1 and 2019 Q2.

Manufacturing sales declined by 50% in April month-on-month and in June had recovered only to 85% of the March level. Among the major industries, automotive was particularly hit, only reaching 73% of March's sales figures in June.

All components of GDP except government spending fell in 2020 Q2. Private investment fell by a fifth, investment by State Owned Enterprises fell by a third, while general government investment remained mostly unchanged (TIPS, 2020).

Table 2.1: GDP growth by sector, seasonally adjusted

	2020Q2 - 2020Q1	2020Q2 - 2019Q2
Agriculture, forestry and fishing	4%	7%
Mining and quarrying	-28%	-33%
Manufacturing	-29%	-32%
Electricity, gas and water	-11%	-14%
Construction	-30%	-33%
Trade, catering and accommodation	-25%	-25%
Transport, storage and communication	-25%	-27%
Finance, real estate and business services	-8%	-6%
General government services	0%	1%
Personal services	-9%	-9%
Total	-16%	-17%

Source: CE, based on Stats SA (2020b)

Impact on trade

The pandemic was already leading to lower imports of goods at the beginning of the year due to supply chain disruption caused by the initial outbreak in China (TIPS, 2020). The lockdown brought a 50% fall in exports in April 2020, as mining and automotive production were stopped. Exports recovered in the months following the end of the lockdown, but imports continued to fall and were still below pre-pandemic levels in July 2020. Mining and manufacturing exports dropped by more than 50% in April but returned to pre-pandemic levels in June. Within manufacturing, exports of transport equipment and machinery (South Africa's two largest non-commodity export industries) declined by more than 80% from March to April but returned to pre-pandemic levels by July. A similar pattern was seen for other major exporting sectors such as chemicals and metal products (TIPS, 2020). Despite the recovery, exports in manufacturing and mining were still 26% and 14% respectively lower in 2020 Q2 compared to 2020 Q1, while agricultural exports increased by 32%.

Impact on employment

The pandemic struck a labour market characterised by a high share of low-skilled workers in low-skill occupations. In 2019, the community and social services sector employed 22% of workers, followed by the trade sector with 21% and finance and business services with 15%. Elementary occupations accounted for the largest share, employing 23% of workers, followed by sales and services (17%) and craft and related trades (12%) (Stats SA, 2020a). In the same year, 18% of workers were employed in the informal sector (Stats SA, 2020a). Almost half of the labour force is low-skilled (i.e. has not completed secondary education), while 18% have a tertiary degree (Stats SA, 2020a). The official unemployment rate is consistently above 20% and has been increasing through the past decade.

In 2020 Q2, employment fell by more than 13% both on a quarterly and annual basis. Construction was the most affected sector with a decline of more than 21% in 2020 Q2 compared to 2020 Q1, but every sector experienced a fall as shown in Table 2.2:. The official unemployment rate peaked at 30% in 2020 Q1 and then declined to 23.3% in 2020 Q2. The simultaneous decline in employment and the reported unemployment rate reflects an increase in inactivity: the labour participation rate fell by 13 percentage points (pp) between 2020 Q1 and 2020 Q2 (from 60% to 47%). The expanded unemployment rate reached 42% in 2020 Q2, a 2.3 pp increase compared to 2020 Q1. Although women's unemployment rates are generally lower than men's, both genders saw a 2 pp increase in the expanded unemployment rate in 2020 Q2 compared to 2020 Q1. All age classes experienced an increase in the expanded unemployment rate, but the largest decline in labour force participation was among those aged 15-34 with a 9 pp fall. Of the 2,2 million jobs lost between 2020 Q2 and 2020 Q1, 28% were lost in elementary occupations[4], 20% in sales and services and 19% in craft and related trade, the three occupations that employ the majority of the labour force.

Table 2.2: Employment growth by sector

	2020Q2 - 2020Q1	2020Q2 - 2019Q2
Agriculture	-8%	-5%
Mining	-14%	-2%
Manufacturing	-15%	-19%
Utilities	-2%	-25%
Construction	-21%	-22%
Trade	-11%	-14%
Transport	-11%	-10%
Finance and business services	-11%	-10%
Community and social services	-14%	-10%
Private households	-24%	-20%
Total	-14%	-13%

Source: Stats SA (2020a)

Outlook

In June the South African government expected low business confidence to persist through 2020, with investment and employment below 2019 levels.

[4] ILO ISCO classification: "*Elementary occupations involve the performance of simple and routine tasks which may require the use of hand-held tools and considerable physical effort.*" (ILO, 2012, p. 337)

Lower job growth and incomes will in turn reduce household consumption. The revised budget expected a 7.2% contraction in GDP during 2020 and a 2.6% growth in 2021 (National Treasury, 2020a). Similarly, in October 2020, the IMF forecast an 8% fall in GDP for 2020 followed by just 3% growth in 2021, with GDP not returning to the 2019 level until 2024 (IMF, 2020a). The IMF's projections took account of evidence of increased global economic activity in the second and third quarter of 2020, but noted that significant downside risks remain, especially regarding the evolution of the pandemic. June's OECD *World Economic Outlook* projected a GDP decline in the range -7.4% to -8.2% for 2020, depending on whether a second wave of the pandemic emerged (OECD, 2020a).

2.3 Short-term policy response

In order to mitigate the economic consequences of the pandemic, in April 2020 the South African government announced a R 500 billion stimulus package, an amount close to 10% of GDP. The stimulus package was targeted at addressing the immediate consequences of the pandemic (higher unemployment and lost incomes) and on enhancing the health response. It included measures to support households and businesses, for example through tax deferrals and credit guarantees, as shown in Table 2.3.

The combination of lower tax revenues due to reduced economic activity and higher public spending to stimulate the economy is expected to increase the budget deficit to 14.6% of GDP in 2020, and the debt to GDP ratio is expected to reach 81.7% in 2020, compared with a pre-pandemic projection of 65.6% (National Treasury, 2020a).

Table 2.3: Measures included in the stimulus package

Measures	Budget (R million)
Credit Guarantee Scheme	200,000
Job creation and support for SME and informal business	100,000
Measures for income support (Further tax deferrals, SDL holiday and ETI extension)	70,000
Support to vulnerable households for 6 months	50,000
Wage protection (UIF)	40,000
Health and other frontline services	20,000
Support to municipalities	20,000
Total	**500,000**

Source: (National Treasury, 2020b)

2.4 Long-term policy response

In October, President Ramaphosa announced the Economic Reconstruction and Recovery Plan (ERRP) (South African Government, 2020b). The Plan[5] aims at stimulating inclusive and equitable growth to "forge a new economy in a new global reality" (South African Government, 2020c). The policies detailed in the Plan encompass different domains and can be grouped into eight intervention areas:

- infrastructure investment
- energy security

[5] When we mention 'the Plan' in this report, this is a reference to the Economic Reconstruction and Recovery Plan (ERRP)

- employment stimulus
- strategic localisation, industrialisation, and export promotion
- tourism recovery and growth
- green economy
- food security
- gender equality and economic inclusion.

The interventions are to be accompanied by various “key enablers”: a macroeconomic framework for fiscal sustainability, regulatory changes to enable growth and increase the ease of doing business, building a capable state, skills development and economic diplomacy (South African Government, 2020c, 2020d).

Infrastructure investment

The infrastructure investment programme of the Plan aims at increasing the stock of public infrastructure, which in turn will support jobs in the construction industry. A combination of public (10%) and private (90%) finance is expected to unlock R1 trillion in investment for strategic infrastructure projects (South African Government, 2020d). This investment will be allocated mainly in the transport sector (e.g. reducing costs of movement by freight, developing affordable public transport), in construction (e.g. maintaining public buildings), digital technology (e.g. rollout of broadband), water (e.g. bulk water infrastructure) and energy (to allow the implementation of the 2019 Integrated Resource Plan) (Department of Energy, 2020a).

Table 2.4: Details of the employment stimulus programme

Department	Programme	Employment Opportunities	Budget (R'000)
Presidency; Trade, Industry and Competition: IDC	Social Employment Fund	35,000	210,000
Basic Education	Teaching assistants and support for schools	344,933	7,000,000
Social Development	Income relief, job retention and registration support	111,142	588,728
Agriculture, Land Reform and Rural Development	Subsistence Producer Relief Fund	74,626	1,000,000
Environment, Forestry and Fisheries	Investing in the environment	50,311	1,983,000
Sports, Arts and Culture	Support for the creative, cultural and sport sectors	34,070	665,000
Health	Expanding community health workers, outreach team leaders and nurses	5,531	393,571
Transport	Provincial Roads Maintenance	37,079	630,000
Cooperative Governance	Municipal infrastructure	25,000	50,000
Trade, Industry and Competition	Services sector development incentives	8,000	120,000
Science and Innovation	Graduate programmes	1,900	44,999
Department of Women, Youth and Persons with Disabilities	Support to youth owned enterprises	5,000	119,000
Public Works and Infrastructure	Professional services programme	1,560	158,880
Provinces	Provincial PEPs programmes	50,000	TBD
Cities	Metro PEPs programmes	32,663	841,217
Total		**816,815**	**13,804,395**

Source: South African Government (2020e)

Employment stimulus

The employment stimulus programme will build on existing employment programmes such as the Expanded Public Works Programme (EPWP) (South African Government, 2020d). Special emphasis is placed on social employment to support forms of work for the common good in themes such as greening and the environment, health and care, community safety, education support, food security and nutrition, creative arts and sports, among others (South African Government, 2020e), as shown in Table 2.4. The stimulus is expected to create some 800,000 new job opportunities by 2021 at a cost almost R14 billion, with a cost per opportunity of almost R17,000.

Strategic localisation, industrialisation and export promotion

The Plan aims at increasing the competitiveness of the South African economy, emphasising the local dimension of production. The key objectives are (South African Government, 2020d):

- reducing the proportion of imported intermediate goods
- improving the efficiency of local producers
- developing export competitive sectors.

Current local content targets are shown in Table 2.5. The government intends to intensify localisation on this base. Increased local sourcing by both the private and public sector, "buy local" campaigns, sectoral master plans and revised trade agreements are planned for this purpose (South African Government, 2020d).

Table 2.5: Local content targets by product

Key economic sector	Local production % (2014)	DTI minimum local component threshold within sector	
Communication, Medical and other Electronic Equipment	29%	Set Top Boxes	30%
		Portable Radio	60%
		Mobile Radio	60%
		Repeater	60%
		Rail Signalling System and associated components	65%
		Prepaid Electricity Meters	70%
		Post Paid Electricity Meters	70%
		SMART Meters	50%
Other Fabricated Metal Products	52%	Electrical and telecom cables	90%
Manufacturing of Transport Equipment	59%	Buses (Bus body)	80%
		Rail Rolling Stock	65%
		Working Vessels/Boats (All types)	60%
Structural Metal Products	60%	Steel Power Pylons, Monopole Pylons, Substation Structures, Powerline Hardware, Street Light Poles, Lattice Towers	100%
Electrical Machinery & Apparatus	61%	Transformers and Shunt Reactors (depending on class)	10-90%
		Inverter	40%
Textiles, Clothing, Leather Products and Footwear	63%	Textiles, Clothing, Leather Products and Footwear	100%
Publishing and Printing	67%		
Machinery & Equipment	70%	Valves products and actuators	70%
Other Manufacturing & Recycling	71%		
Chemicals & Chemical Products (incl. Plastic Products)	75%	Wheely Bins	100%
		OSD Tender	70%
		Family Planning Tender	50%
Petroleum	76%		

Wood and Wood Products	81%		
Transport	82%		
Basic Metal Products	85%	Conveyance Pipes	80-100%
Business Services	87%		
Non-Metallic Mineral Products	88%		
Paper and Paper Products	88%		
Communication	96%		
Meat, Fish, Fruit, Vegetables, Oils and Fat Products	100%	Canned/Processed Vegetables	80%
Furniture	100%	Office Furniture	85%
		School Furniture	100%
		Base and Mattress	90%

Source: South African Government, (2020c)

Energy security

The Plan recognises a reliable supply of energy as a pre-requisite for the economic recovery and growth; Eskom's challenges in assuring adequate electricity capacity have been an obstacle to growth (Department of Energy, 2020b; Presidential Economic Advisory Council, 2020). To ensure a stronger and more diversified energy capacity, the 2019 Integrated Resource Plan (IRP) anticipates the addition of 14 GW of wind energy and 6 GW of solar energy to existing capacity by 2030 (Department of Energy, 2020a). In the short term, 2 GW of additional capacity under existing projects and projects under bid window 4 of the Renewable Energy Independent Power Producer Procurement Programme are to be connected by June 2021, and a further 2 GW are to be added within 12 months under the Risk Mitigation Power Procurement Programme. Other policies in the energy security domain include:

- continuing the nuclear programme at the appropriate pace
- supporting generation for own use
- implementing market and regulatory change to increase the use of LPG
- restructuring Eskom.

Despite the additional renewable capacity envisaged in the IRP, coal and fossil fuels are going to keep playing a significant role in the energy mix and further non-green investment is envisaged, as confirmed by President Ramaphosa's speech[6] (South African Government, 2020b) and the approval given for construction of a new coal-fired power station in the South African Energy and Metallurgical Special Economic Zone in Limpopo.

Green Economy intervention

The Plan recognises the potential of the green economy in addressing the challenges of inequality, poverty and unemployment while providing a sustainable solution to climate vulnerability and driving economic competitiveness (South African Government, 2020c). The green economy intervention comprises the retrofitting of public and private buildings in order to improve energy and water efficiency, as well as the retrofitting of the ageing Mpumalanga power station with solar power. Other interventions include the support of small farmers through Private Public Partnerships and improved

[6] The speech claims, for example, that "the current timeframes for mining, prospecting, water and environmental licenses will be reduced by at least 50% to facilitate new investment" and that "The Petroleum Resources Development Bill will be finalised to unlock our country's enormous untapped potential in upstream oil and gas reserves" (South African Government, 2020b).

waste management through the diversion of waste from landfill and a gradual shift toward the circular economy.

Other interventions: food security, tourism, gender equality

The Plan acknowledges the problem of food security, which will be further exacerbated by the COVID-19 pandemic. The Plan aims at implementing a set of measures to ensure food security for 230,000 households, which are expected to create 317,000 new jobs in agriculture and to increase agricultural production by R80 billion (South African Government, 2020c).

The tourism sector has been severely hit by the COVID-19 pandemic. The Plan introduces measures such as campaigns to increase domestic tourism, improving health and safety protocols and introducing e-visa programmes and visa waivers (South African Government, 2020d).

All the interventions outlined in the Plan are intended to increase the participation of disadvantaged groups, such as black people, women, youth and persons with disabilities. Therefore, the Plan envisages interventions such as quotas for women in public procurement, legal remedies to close the gender pay gap and encouraging the formation of cooperatives, ease the access to funding and provide training opportunities for the above-mentioned groups (South African Government, 2020c).

3 Key environmental issues and policy objectives in South Africa

3.1 Introduction

Despite progress in the implementation of green policies in some countries, current global efforts are not sufficient to meet the energy-related Sustainable Development Goals and the temperature targets set by the Paris Agreement (IEA, 2020a). Global warming is expected to have severe consequences for South Africa. Water scarcity will be further exacerbated by reduced rainfall and higher evaporation rates, requiring difficult trade-offs in water resource allocation between urban-industrial use, agriculture and sanitation. Higher temperatures and more variable rainfall will reduce crop yields, while increasing sea levels, coastal storms and acidification of estuaries will diminish fish stock and erode coastal lands (Department of Environmental Affairs, 2018). The dangers of climate change have long been acknowledged by South African policy-makers (Averchenkova et al., 2019; Department of Environmental Affairs, 2018; Montmasson-Clair and Chigumira, 2020).

This chapter presents an overview of the key environmental issues in South Africa, with the aim to inform priorities for the modelling of the relationship between economic recovery and environmental objectives. It notes the main policies and targets, with a particular focus on climate policy.

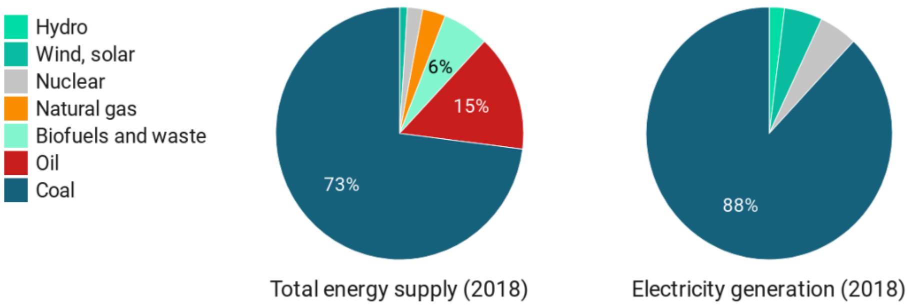
3.2 Environmental challenges

Reliance on coal

South Africa's economy depends heavily on fossil fuels, especially its own coal. South Africa was the eight biggest coal producer in 2018 (OECD, 2020d) and in 2017 exported one third of its coal production, making it the fifth largest coal exporter in the world (IISD, 2019). In 2018 coal, natural gas and oil accounted for 91% of total energy supply as shown in Figure 3.1.

Figure 3.1 also shows that in 2019, 88% of electricity was generated from coal and just 7% was generated from renewable sources (hydro, wind and solar). In 2018, the electricity and heat sector, fuelled mostly by coal, was responsible for 52% of CO_2 emissions in South Africa (IEA, 2020b). Clearly, reducing the reliance of the energy sector on coal is a key challenge for South Africa to curb emissions as part of its contribution to mitigating climate change.

Figure 3.1: Energy supply and electricity generation by source, 2018



Source: CE, based on IEA (2020b).

Water scarcity

South Africa is a water-scarce country, with an estimated 49% of its population living in water-scarce areas (World Data Lab, 2020), and it is characterised by high spatial and temporal variability of rainfalls (SANBI, 2019). Agriculture accounts for 62% of all water use, followed by municipalities which account for 27%. Despite being a water-scarce country, water consumption per capita in South Africa is higher than international benchmarks, and water demand is forecast to increase further, especially in the municipalities sector (Donnenfeld et al., 2018). Climate change will reduce precipitation on average and increase its variability, making droughts more frequent and severe (GreenCape, 2020).

The issue of water scarcity is compounded by the lack of adequate water sanitation bulk infrastructure. It is estimated that 40% of South African wastewater is untreated and that approximately 50% of wastewater treatment is inadequately performed. The resulting water pollution presents environmental and health risks for the communities that access water directly from rivers (GreenCape, 2020).

Threats to ecosystems

South Africa is among the richest countries in the world in terms of biodiversity, ranking as one of the top ten nations in terms of plant richness and third for marine species endemism. An estimated 418,000 jobs are directly related to biodiversity (e.g. biodiversity conservation, tourism, fisheries), a level of employment comparable with that of the mining sector, while the biodiversity-based tourism industry is worth over R30 billion per year. Moreover, healthy ecosystems are essential for water security and help in climate change adaptation by offering better protection from extreme weather events. However, it is estimated that about half of South Africa’s ecosystems are threatened by overutilisation of resources, invasion of alien species, mining activities and climate change. Rivers, wetlands and coastal areas are the most endangered ecosystems (SANBI, 2019).

3.3 Environmental policies

A wide variety of environmental strategies, policies and programmes are in place in South Africa, which has implemented one of the most elaborate and consultative climate governance systems among developing and emerging economies (Averchenkova et al., 2019). This section summarises the main strategies and targets.

Nationally Determined Contribution to tackling climate change and long-term goals

South Africa has pledged to keep its CO_2 emissions in the period 2025-2030 within the range of 398-614 mtCO_2 (UNFCCC, 2016), which represents a 17%-78% increase compared to 1990 levels and a 26% decrease or 12% increase compared to 2010 levels (Climate Action Tracker, 2020). By 2050, the South African government projects an emissions range of 212-428 mtCO_2 (South African Government, 2011). It was estimated before the pandemic that, under policies currently implemented, South Africa would reach a level of emissions 33% to 39% above the 1990 level by 2030. If the COVID-19 crisis reduces emissions in the long term, there could be scope to revise the target down (Climate Action Tracker, 2020).

National Climate Change Response White Paper

The main document detailing the environmental policy of South Africa is the National Climate Change Response White Paper (South African Government, 2011). The document sets out the guiding principles of climate policies, together with priorities for adaptation (e.g. water and biodiversity conservation) and mitigation (e.g. establishment of the “peak, plateau and decline” trajectory of greenhouse gases). Moreover, the White Paper establishes a series of Near-Term Flagship Programmes in areas such as water conservation, renewable energy, energy efficiency, transport, waste and others. A number of key adaptation and mitigation mechanisms have been developed starting from the flagship programmes, such as the Renewable Energy Independent Power Producer Purchase Programme, acknowledged as one of the most successful cases of competitive tenders for grid-connected renewable energy by independent power producers (Averchenkova et al., 2019).

National Development Plan

The National Development Plan published (NDP) in 2012 establishes several areas of interventions to eliminate poverty and reduce inequality in South Africa, with a time horizon that goes up to 2030. In terms of environmental challenges, the NDP presents the following vision (National Planning Commission, 2012):

- providing South Africans with secure housing, clean water, decent sanitation and affordable and clean energy
- investing in more sustainable technologies and programmes to conserve and rehabilitate ecosystems and biodiversity assets
- investing in recycling infrastructure and waste-to-energy projects
- growing the renewable energy sector
- reducing carbon emissions while maintaining competitiveness
- implementing policy and regulatory frameworks for land use, in order to ensure the conservation and restoration of protected areas
- investing in new agricultural technologies.

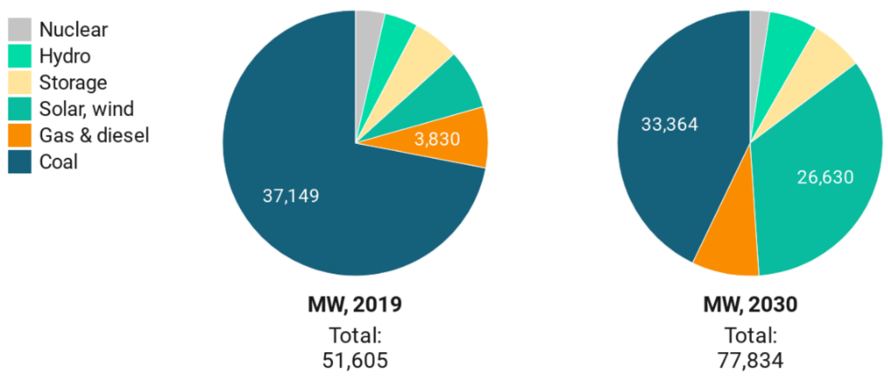
The NDP also establishes several targets for 2030 to address the most pressing socio-economic issues such as unemployment, inequality and education:

- reaching a 6% unemployment rate by 2030, with total employment increasing to 24 million
- increasing the labour force participation rate to 65% by 2030
- increasing GDP per capita to R110,000 by 2030 (in 2010 prices) from 50,000 in 2010
- increasing the proportion of national income earned by the bottom 40% to 10% by 2030
- employing 2 million people with public employment programmes
- having 80%-90% of learners completing 12 years of schooling
- increasing enrolment at universities, reaching 1.62 million by 2030
- making early-childhood education a top priority.

Integrated Resource Plan

The Integrated Resource Plan (IRP) establishes key targets for the electricity sector (Department of Energy, 2020a). Historically, most of the installed capacity has been based on coal. Despite the envisaged decommissioning of some coal plants, coal is still expected to play a substantial role in the energy mix, therefore creating the need for further investment in more efficient and clean coal technologies such as Carbon Capture Use and Storage, and High-Efficiency Low-Emissions technologies. However, the IRP also envisages an increased importance of renewable energy (such as solar and wind) for the production of electricity. The IRP expects coal to account for 43% of installed capacity in 2030, from 72% in 2019, while renewable sources like wind and solar are expected to account for 34% of installed capacity in 2030, from only 7% in 2019, as shown in Figure 3.2.

Figure 3.2: Installed capacity by source, IRP



Source: CE, based on IRP (2020a)

Sustainable Development Goals

The Sustainable Development Goals (SDGs) provide key metrics to assess environmental progress and guide policymaking. National strategies such as the NDP speak directly to several SDGs (Stats SA, 2019) and South Africa still faces significant challenges to meet the SDGs related to environment. For example, while the provision of safely managed drinking water services and sanitation services has increased, only 58% of South Africa's bodies of water comply with water quality objectives, and only 52% of water containing waste is safely treated (SDG 6). In terms of energy security (SDG 7), South Africa has made progress in large-scale renewables, although the single-seller model within the electricity market remains an issue. In terms of sustainable cities and communities (SDG 11), South Africa has seen an unwelcome increase in the percentage of population living in informal dwellings and a deterioration in services provided for those individuals, while air quality and the proportion of municipal waste recycled have increased. In terms of protection of marine and land ecosystems (SDGs 14 and 15), indicators show that South Africa is engaged in activities aimed at protecting ecosystems, although the indicator showing the aggregate survival probability of species has worsened (Stats SA, 2019).

Evaluation of green economy initiatives and programmes in South Africa

PAGE carried out a comprehensive analysis of green economy initiatives implemented between 2010 and 2016 within eight sectors[7] (PAGE, 2017). The analysis identified 32 green economy-related policies and strategies and more than 1,000 green initiatives across all provinces and sectors, highlighting the need for policy alignment and coherence to achieve the intended outcomes. One key conclusion of the study is that green economy initiatives created jobs and contributed to the reduction in greenhouse gas (GHG) emissions. Since most initiatives were publicly funded, the study recommended scaling up access to private and international capital to enable investment in the economy-wide transition. Energy, transport and agriculture were found to be the most active sectors with initiatives in solar and bioenergy, non-motorised transport and farming. Agriculture was identified as the sector with the highest job creation potential, followed by sustainable waste management and resource and conservation management. The latter sector has been supported by the Expanded Public Works Programmes (EPWP) which created jobs and significantly improved land and water quantity and quality.

[7] Energy, transport and infrastructure, agriculture, resource conservation and management, buildings and the built environment, sustainable consumption and production, sustainable waste management, water management.

4 Recovery scenarios for South Africa

4.1 Introduction

As noted in previous chapters, the COVID-19 crisis has had a profound impact on South Africa, exacerbating long-standing economic and social issues. In response, the South African government has introduced measures to mitigate the short-term impact of the pandemic, and recently announced a long-term recovery plan called the Economic Reconstruction and Recovery Plan (ERRP) (South African Government, 2020c, 2020d).

An earlier approach to integrate economic, social and environmental indicators in a model capable of simulating alternative development paths, including a green economy path, was carried out in UNEP (2013) using the SAGEM systems dynamics model. That study showed that investments in the green economy generate economic benefits comparable to business-as-usual investments but significantly higher environmental benefits. The present study, using the E3ME macroeconometric model, places green economy analysis in the context of the present economic crisis. It differs from the earlier study by using a model with:

- global coverage, in which South Africa is represented as one of more than 60 countries/regions
- substantial sectoral detail for the South African economy, to capture the important structural changes between sectors
- a Keynesian analysis of how output depends on expenditure, well suited to analysis of conditions in which incomes have been sharply reduced and the economy is operating well below full capacity.

This chapter presents the results of a modelling exercise designed to assess the contribution to improved economic, social and environmental outcomes of different recovery measures. While detailed modelling of the Plan[8] is beyond the scope of this study, the scenarios reported below have nevertheless been informed by the Plan's policy measures and objectives (the Plan is described in Section 2.4) so as to provide an indication of the direction and magnitude of impact of the Plan's different elements. An additional sensitivity scenario ('Green push') is included to assess the impact of a faster transition away from coal-power generation than the one currently envisaged by the South African government.

4.2 Scenario design

The starting point for the scenarios is a COVID-19 baseline projection, similar in concept to the global COVID-19 baseline projection described in Section 1.3. This projection estimates a -9.1% annual GDP shrinkage in 2020 due to the effects of the pandemic. This is similar to IMF's projections of a -8% recession in 2020 (IMF, 2020c). In this projection GDP growth stays negative in 2021 (about 1% decrease) but increases from 2022.

[8] When we mention 'the Plan' in this report, this is a reference to the Economic Reconstruction and Recovery Plan (ERRP)

Key policies announced in the Plan are grouped into three sets for the purpose of this modelling exercise:

- **conventional policies**, including interventions such as infrastructure investment, localisation of production, subsidies for the tourism sector and food vouchers
- **public works**, in the form of public employment programmes in various sectors
- **green policies**, including subsidies for renewables, grid investment, energy efficiency measures and restriction on new investment in coal-fired power stations.

In our analysis, these policy sets are accumulated successively: first only the impacts of the ‘conventional policies’ are modelled; then the effects of the ‘public works’ package is added; finally, the ‘green policies’ are added to give the combined effect of all three sets of the Plan.

The distinction between ‘green’ and other policies is a crude one, and some policies that we have classified as ‘conventional’ or ‘public works’ likely include, in the detail, activities with a positive environmental impact. For example, infrastructure investment might be directed at climate change adaptation. Localisation policies might be seen as strengthening South Africa’s capacity to produce green technologies and hence an accompanying measure to policies that cut demand for fossil fuels. Support for wildlife tourism may well have important benefits for ecological management. Public works programmes may include labour-intensive projects to improve environmental conditions, such as clearing invasive plant species that exacerbate water scarcity. It has not been possible to determine the scale of such ‘green’ elements within the Plan and so reclassify them to a third policy set, and so in the modelling outcomes their economic impacts remain within the conventional and public works scenarios.

The ‘green policies’ element focuses on climate mitigation and is designed to be in line with the prescriptions of the IRP and to contribute to decarbonisation. We also include a high ambition sensitivity (‘Green push’), which adds further green measures to the recovery package aiming beyond the IRP goals. This involves stricter regulations on new coal investments and a faster transformation of the energy system towards renewable energy sources. South Africa’s reliance on coal has been identified in Section 3.2 as one of the key environmental challenges the country is facing.

As the Plan provides only high-level indications on the funding of the measures, the modelling makes certain assumptions about both the extent and the funding of these policies. We follow the assumptions of the Plan regarding the large role attributed to private investment, which the much smaller government spending element is intended to unlock. Unless it is clear that the intention is to repurpose currently planned spending, an increase in government borrowing is assumed to fund the public spending element[9].

[9] PAGE (2017) finds that most green economy initiatives in South Africa are publicly funded.

4.3 Scenario assumptions

In this section we present in more detail the assumptions for each of the scenarios that have been modelled.

Scenario A: conventional policies

The first scenario focuses on key ‘conventional’ (i.e. without specifically green content) policies included in the Plan.

Its main element is a large-scale public infrastructure investment programme, which is expected to unlock R1 trillion in investment over the next ten years for strategic infrastructure projects (South African Government, 2020d). In the scenario this program is composed of two parts: 10% is considered to be public investment, while 90% is expected to be private investment, unlocked by the public investments. In the scenario, it is assumed that the Plan is successful in leveraging the private investment.

The time profile and the allocation of the investment among sectors are calculated based on the number and value of Sustainable Infrastructure Development Symposium South Africa (SIDSSA) projects already gazetted (Ramokgopa, 2020) and on communications about planned SIDSSA projects (Investment and Infrastructure Office, The Presidency, 2020). Energy-related investments are excluded from this scenario as we classify these as ‘green policies’. Hence, additional investment amounting to R 759 billion over ten years is included in the scenario. Seven focus areas are targeted: agriculture, road and water transport, water supply, public administration and municipal works, housing and telecommunications.

The second measure included in the scenario focuses on increasing the local content of products in line with the ideas of the Plan (South African Government, 2020d). Building on policies such as local content requirements (LCR), which are already introduced for several products and industries in South Africa (Kaziboni and Stern, 2020), the scenario envisages a substantial reduction of imports in certain areas. We assume that the Plan is successful in raising local content.

Imports are assumed to be reduced by 10% by 2030 for the following products: mining, textiles, pharmaceuticals, rubber & plastics, metal goods, electronics, vehicles and other transport equipment. This can be understood as an extension of existing LCR policies, therefore not only increasing the amount of local production, but building local supply chains and possibly encouraging inflows of FDI (foreign direct investment) (Silva and UNCTAD, 2014). While it remains to be seen whether LCR policies can attract FDI in all cases (Silva and UNCTAD, 2014), there is some evidence that additional FDI through these policies is at least possible (Kaziboni and Stern, 2020). Therefore, in the modelling, a moderate level of additional investment (totalling to R 11 billion over 10 years) is also assumed.

As a third measure, loosely based on the Tourism Recovery Plan (Department of Tourism, 2020), a R 15 billion subsidy package over three years is provided to certain sectors particularly exposed to the negative economic impact of the pandemic. These include tourism, transport and services. The subsidies are expected to help the sectors recover as well as to introduce new local measures that can increase demand such as improved health and safety protocols. Some initiatives will have a ‘green’ element (a positive impact on ecological management). As the Plan states that these measures are intended to be budget neutral (Department of Tourism, 2020), that is how we have represent them in the scenario.

Finally, the Plan earmarks substantial spending for food vouchers for vulnerable groups (South African Government, 2020c). In the scenario additional food consumption by households amounting to R 50 billion is modelled as a result of this. In E3ME the main impact is to boost consumption in real terms and thus agricultural production: it is not assumed that, under present conditions, the increased spending would significantly raise prices due to a rising marginal cost of production.[10]

Scenario A+B: conventional policies + public works

The second scenario includes all elements of Scenario A and adds public works measures.

The public works measures are structured as follows. We assume that about 2.3 million job opportunities will be created by 2023 followed by a further 2.3 million over 2024-2025 (broadly in line with our interpretation of the Plan). We assume that the job opportunities are short-term in nature. Mkhatshwa-Ngwenya (2016) found that, in the 2004-2014 period, EPWP measures resulted in a ratio of one full-time equivalent (FTE) job per 3-4 work opportunities (WO); in the period 2014-2019 the ratio was calculated to be one FTE job per 2.6-3.2 WO (Department of Public Works and Infrastructure, 2020). The implication is that contracts last about three months on average, and so the annual FTE number of workers employed is one quarter of the headline job opportunities figure. This amounts to an addition of some 255,000 FTE jobs each year over 2021-2023 and 380,000 over 2024-2025. The average cost per FTE job is assumed to be R 44,000 (Department of Public Works and Infrastructure, 2020). In all cases job creation is financed publicly and we assume that the expenditure adds to public borrowing. The public works programmes are concentrated to the following sectors (South African Government, 2020e): agriculture, transport, water supply, construction (including infrastructure and road maintenance), public administration, education, healthcare, forestry and services. Again, some initiatives will have a ‘green’ element (labour-intensive projects to improve the environment).

Scenario A+B+C: conventional policies + public works + green policies

The third scenario includes all elements of ‘Scenario A+B’ and adds in green policy elements[11].

The green policies are designed to reach the power generation capacity targets set out in the IRP (Department of Energy, 2020a). First, a 20% capital subsidy to wind and solar power investments is introduced over 2021-2025, triggering net R 152 billion energy investment over ten years[12]. Apart from the 20% subsidy (which amounts to R 10 billion[13]) this energy investment is assumed to be covered by private finance; E3ME’s submodule for power generation simulates investment in power generation and the model’s outcome broadly supports this assumption. All-in-all, this means that about

[10] To the extent that ‘fire-sale’ prices have been accepted by farmers in response to the crisis, some of the demand stimulus might support farm incomes through price support rather than increased production.
[11] The green policies included in the modelling are just a small set of the green policies potentially available (see section 4) and therefore they don’t represent a full green policies package.
[12] Gross investment into renewables through the same period is R 169 bn, but there is R 56 bn disinvestment from coal, as energy efficiency drives down energy demand in the scenario.
[13] Note that this is not 20% of the net investment amount cited above, but 20% of the renewable investments made between 2021 and 2025 as subsidies are only granted through this period.

6.6% of the overall investment in this case is assumed to be coming from government sources.

To accommodate the new renewable energy capacity and to facilitate energy security, grid investments are necessary. In the scenario R 42 billion is earmarked for this with government financing, over six years (2021-2025).

Third, the scenario assumes energy efficiency investments, substituting capital (e.g. insulation) for energy inputs to buildings. The investments amount to R 12 billion over five years, which results in a 10% reduction of household energy consumption. This, again, is financed through public investment.

Finally, the scenario assumes restrictions on new coal investments so that the total capacity of coal-based power generation remains within the 33 GW ceiling set as the 2030 goal of the IRP (Department of Energy, 2020a).

Scenario A+B+C+D: Green push

As a fourth case, we consider a scenario in which the decarbonisation agenda is pursued at a faster pace, with a lower ceiling for coal-fired power generation capacity and correspondingly higher investment into renewables than the plans laid out in the IRP. In this sensitivity all elements of the 'A+B+C scenario' are still included, but the 'green policies' part is strengthened.

With regard to coal-fired power generation, we assume that annual investment in coal-fired plants is limited to current levels (less than R 40 billion per year), which reduces total coal-fired capacity to approximately 25 GW by 2030. An additional R 343 billion investment in renewable power generation is triggered in the scenario (due to the coal replacement). Compared to the A+B+C scenario, an additional R 9 billion through subsidies and R 13 billion in grid investment is added in the scenario.

These green policies focus on the energy sector because this is an area with large greenhouse gas abatement potential, and because high reliance on coal has been identified as one of the key environmental challenges in South Africa. But, as Meyiwa et al. (2014, p. 423) notes, while focussing on energy policy "*is undoubtedly a step in the right direction, as it also has the potential of improving the livelihood of the urban poor, if this is done at the expense of investments in natural capital sectors, the outcome might have a negative impact on the poor and marginalised who depend on the environment*". Therefore, additional green policies to those modelled here, with potentially less impact on the GHG emissions and the overall economy, but with significant environmental benefits and improvements to natural capital, can and should be considered.

Private financing assumptions

The private financing assumptions made in the scenarios are informed by existing plans and expectations expressed in the Plan; i.e. the magnitude of the expected private investments is taken as given from the announced plans and used as an assumption in the modelling.

Table 4.1: Indicative ratio of private investment and public spending assumed

	A	A+B	A+B+C
Including reallocated spending			
Private investment	82%	76%	75%
Public spending	18%	24%	25%
Counting only "new" spending			
Private investment	92%	85%	82%
Public spending	8%	15%	18%

Note: public spending on the large-scale public infrastructure programme is assumed to be covered by already planned government expenditures or to be reallocated from existing spending, however it is counted towards public spending here.

The magnitude of the 'conventional policies' package, taking account of both public and private spending, is quite large, amounting to about 3% of South Africa's annual GDP in any given year. The other policy elements add to this amount. This level of funding is assumed to be available; no assessment is made of any financing barriers to this magnitude of investment that may exist, nor on the source or feasibility of the financing. It is assumed that the South African government is successful in attracting and leveraging the level of financing envisaged in the Plan. This is important to understand, as most of the economic impact is driven by the assumed magnitude of the stimulus.

The treatment of finance in the E3ME model is consistent with the theory of 'endogenous money' (Pollitt and Mercure, 2018), with the understanding that the primary limit on borrowing is banks' assessment of the commercial viability of investment opportunities. The investments determined within the model are assumed to be profitable commercial opportunities and so capable of attracting finance.

Public financing assumptions

Consistent with the announced plans, part of the additional spending is assumed to be publicly financed. Public spending can generally be financed in three ways: (1) with increased government borrowing, (2) by balancing or reallocating existing funds from other government expenditures (3) by increased taxation. In the scenarios, the public finance is assumed to be financed by a combination of reallocating budgets and increased government borrowing. Where relevant, these assumptions have been highlighted in the scenario descriptions above.

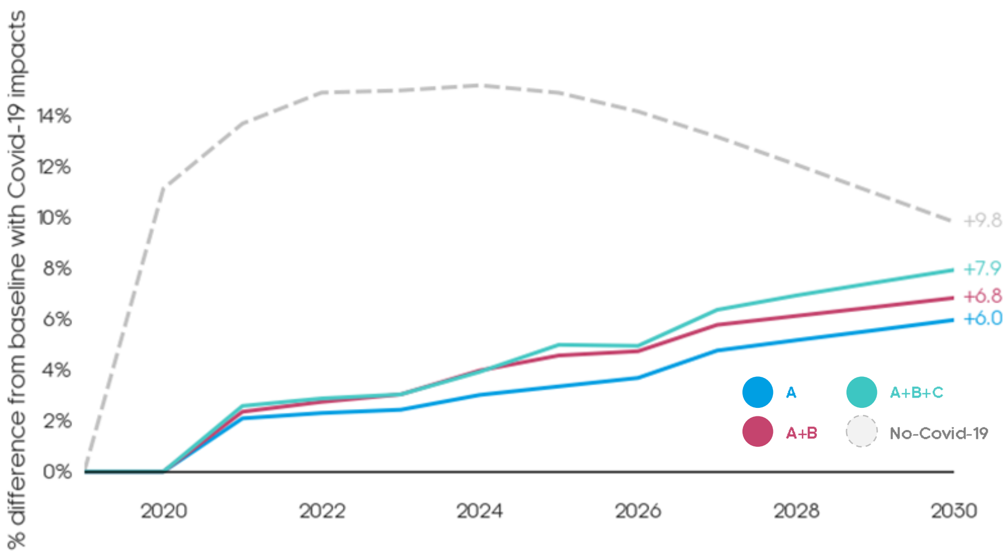
4.4 Scenario results

This section presents the results from the model simulations, focussing on three key indicators of economic, social and environmental outcomes: GDP, unemployment and CO_2 emissions. We include a comparison with a projection of what would have happened in a counterfactual case (no-COVID-19 baseline), which assumes GDP growth of about 1.3% per annum from 2019 to 2030 with a slightly increasing trend, jobs growth of about 0.8% per annum and an annual decrease of 0.1 pp in the rate of unemployment.

Based on the assumptions made, and notably that the South African government will be successful in attracting substantial private sector investment, the package of measures boosts GDP sufficiently to regain the 2030 level as projected before the pandemic. But the respective scenarios vary in their impacts on unemployment and, especially, CO_2 emissions. In the absence of the green policies, the economic recovery results in higher emissions in 2030 than projected in the no-COVID-19 baseline).

Conventional policies receive the largest level of spending (investment) in the Plan. Consequently, Scenario A, the scenario simulating conventional policies, produces the largest boost to GDP. This can be seen in Figure 4.1, which compares scenario outcomes with the COVID-19 baseline (the horizontal axis in the chart). The smaller public works and green policies receive less spending, but boost GDP further when implemented alongside the conventional policies.

Figure 4.1: Impacts of the scenarios on GDP (difference from COVID-19 baseline)

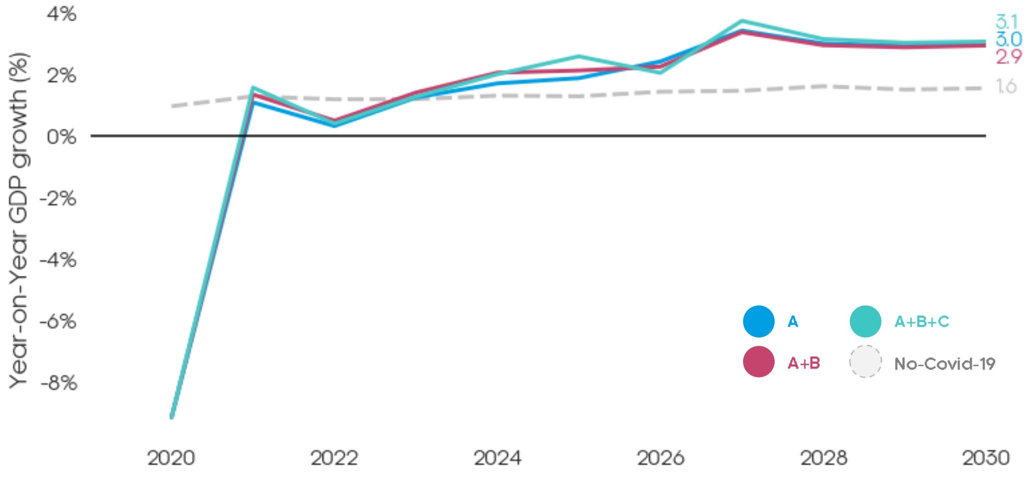


Source: E3ME modelling.

Because the green policies package focuses on decarbonising power generation, it involves substitution of investment in renewables for investment in coal-fired power stations. Renewables require more up-front investment than coal in return for the elimination of ongoing fossil fuel inputs during operation; hence there is a net increase in investment in the years when the subsidy is in operation. The boost to GDP from the combined package raises demand for electricity, giving a further stimulus to investment in renewables power generation in subsequent years.

Figure 4.2 shows the projected rate of GDP growth under each of the three scenarios, together with the GDP growth rate projected before the pandemic occurred. After a strong decline in GDP in 2020, the policy packages are estimated to deliver an accelerated growth path for the rest of the decade, with growth exceeding 3% per annum from 2027. Again, it should be noted that the bulk of this higher growth rate is driven by the assumption that private investment to finance the conventional policies will be levered in successfully by the South African government (scenario A).

Figure 4.2: Impacts of the scenarios on economic growth

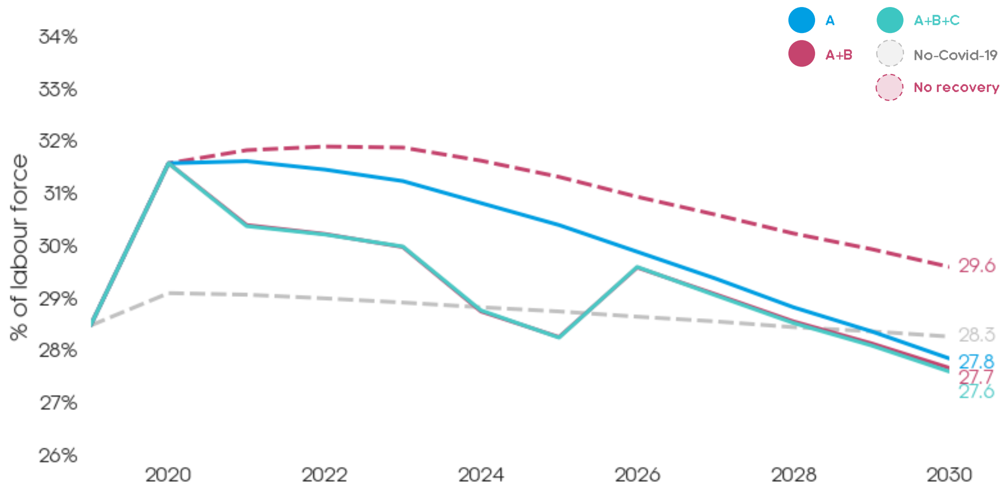


Source: E3ME modelling.

Employment outcomes

Figure 4.3 shows the effect of the scenarios on the official unemployment rate. In the COVID-19 scenario with no recovery measures, unemployment remains high, above pre-COVID-19 levels and the level the model would have projected in the absence of COVID-19 (i.e. the no-COVID-19 baseline). The stimulus given by the recovery measures, however, creates new jobs and brings unemployment levels below the no-COVID-19 baseline, contributing towards the goal of addressing the structural issue of unemployment in South Africa.

Figure 4.3: Unemployment in the scenarios



Note: The chart shows the official rate of unemployment.
Source: E3ME modelling

Because scenario A involves the largest level of public and private investment it has by itself the largest impact on jobs. The public works programme in scenario B drives unemployment down further, but by its nature this impact is temporary and largely disappears when the programme comes to an end.

In scenario C, the focus is on measures to decarbonise the economy, resulting in job losses in coal mining. Nevertheless, these job losses are offset by new jobs created in other areas, notably the renewables supply chain, resulting in a small positive impact on economy-wide unemployment.

Table 4.2 shows the sectoral impacts of the scenarios. Results are presented for the year 2025, when the impact of the policies (including public works measures) is highest.

Table 4.2: South Africa sectoral employment impact in 2025, % difference from COVID-19 baseline

Sectoral employment % by 2025	'A' scenario	'A+B' scenario	'A+B+C' scenario
	compared to baseline with COVID-19 impacts		
Agriculture & forestry	5.1%	12.6%	12.6%
Extractive industries	0.2%	0.2%	-0.8%
Manufacturing	1.3%	1.9%	2.1%
Energy & utilities	0.0%	2.5%	2.7%
Construction	5.8%	9.9%	10.0%
Retail	0.3%	0.4%	0.5%
Tourism & entertainment	0.3%	2.1%	2.1%
Transport	1.7%	2.6%	2.7%
ICT	2.7%	3.3%	3.5%
Business services	2.1%	3.1%	3.1%
Public services	1.0%	11.0%	11.0%

Source: E3ME modelling.

As can be observed, compared to a baseline with COVID-19 impacts, most sectors gain in all scenarios. Some sectoral differences can also be noticed: Scenario A boosts employment in the construction sector above all, a result driven by large-scale infrastructure investments in the scenario. Scenario A+B, however, also substantially increases employment in public services and agriculture & forestry. A direct effect of the public works program in these fields. While nearly all sectors gain employment in the scenarios there is a noticeable exception: extractive industries in the combined scenario A+B+C.

Economic transformation inevitably involves some jobs being lost and other jobs being gained, and this applies equally when the transformation is the decarbonisation of the economy: decarbonisation will lead to job losses in the production of fossil fuels while jobs will be gained in production of renewable energy. This is the mechanism that can be observed in scenario A+B+C. Extractive industries lose about 1.0% employment (compared to A+B), while manufacturing, energy & utilities and construction gain 0.2%, 0.2% and 0.1% respectively. The net effect is positive in total employment, due to the relative size of these sectors.

Economies that have a heavier dependence on that sector, including South Africa, face the challenge of managing this transition so that all workers share in its benefits, economically as well as environmentally. Localisation is important here: the greater the South African content in the renewables supply chain, the more the incomes generated by higher investment in renewables will be captured and spent within the country, while helping to mitigate climate change.

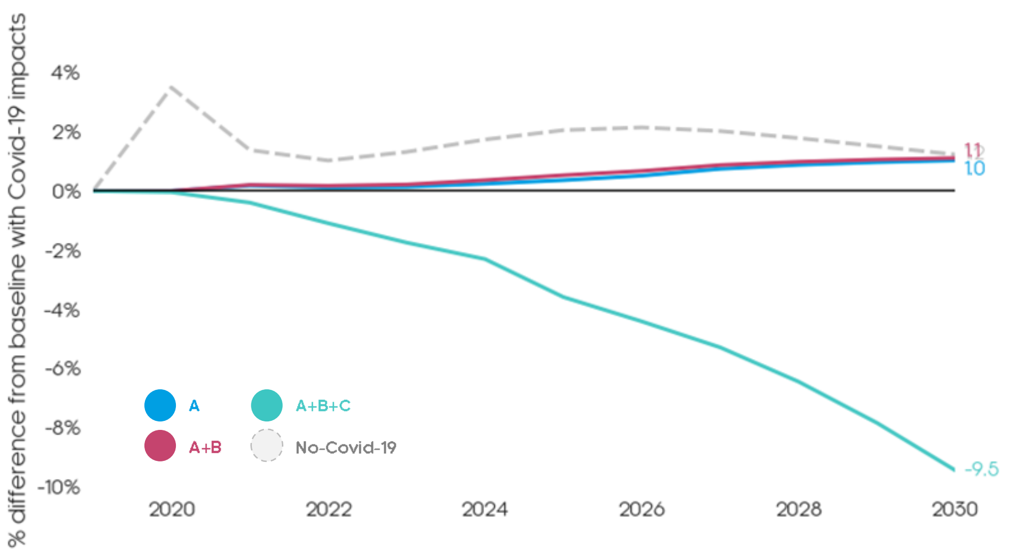
CO_2 emissions

Despite the country's high reliance on coal, South Africa aims to reach its NDC (nationally determined contributions) goals. This is reflected in the strategies laid out in the Integrated Resource Plan (Department of Energy, 2020a) and the National Development Plan (National Planning Commission, 2012). While the impact of the COVID-19 pandemic on economic activity and travel has reduced CO_2 emissions (Evans, 2020; Liu et al., 2020), the challenge is to combine economic recovery with sustained reductions in CO_2 emissions over time.

The scenario results are shown in Figure 4.4. It suggests that a recovery without strong green policies can lead to a quick return to the emissions levels seen before the crisis, in line with others' findings (Evans and Gabbatiss, 2020; Peters et al., 2012). The higher economic activity in scenario A and scenario A+B result in an increase in CO_2 emissions, matching the pre-pandemic projection in 2030. Without green policies to foster the transition, the need for expanded and reliable power generation is likely to be met through additional investment in coal-fired power generation, which will not be consistent with meeting targets to reduce carbon emissions.

The results for scenario A+B+C indicate that higher economic activity can lead to significant CO_2 emission reductions if policies to green the economy are implemented: a reduction over 9% compared to the baseline is achieved by 2030, equivalent to a reduction of more than 7% from 2010 levels, compared with an increase of 4% from 2010 levels in scenario A+B. Both cases are within South Africa's broad target range for emissions of -26% to +12% of 2010 levels by 2030 (Climate Action Tracker, 2020), but clearly a recovery with green policies secures a much better environmental outcome.

Figure 4.4: Impact of the scenarios on CO_2 emissions (difference from COVID-19 baseline)



Source: E3ME modelling.

4.5 A green(er) recovery

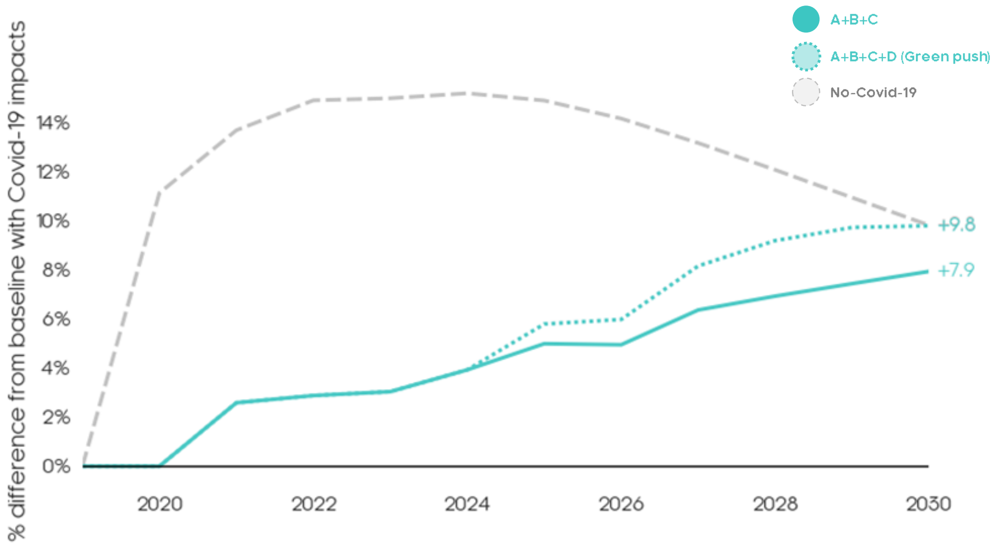
The A+B+C+D, or 'Green push' scenario simulates a future in which South Africa goes beyond its current plans in terms of transitioning to a low-carbon economy[14]. Again, the focus is on the goal of cutting carbon emissions rather than broader green objectives which may have quite different economic

[14] Possibly challenging the limits that the IRP currently imposes on annual build on renewables (Department of Energy, 2020a),

impacts still. The scenario assumes the same rate of capital subsidy for renewables as is included in the green policies of scenario A+B+C, but the assumption of a lower limit for coal-fired generation capacity in this scenario results in higher investment in renewables, increasing investment needs by an additional R 300 billion over 10 years[15].

Figure 4.5 shows the impact on GDP. The greater scale of investment in this scenario gives a substantial further boost to GDP compared with the combined Scenario A+B+C.

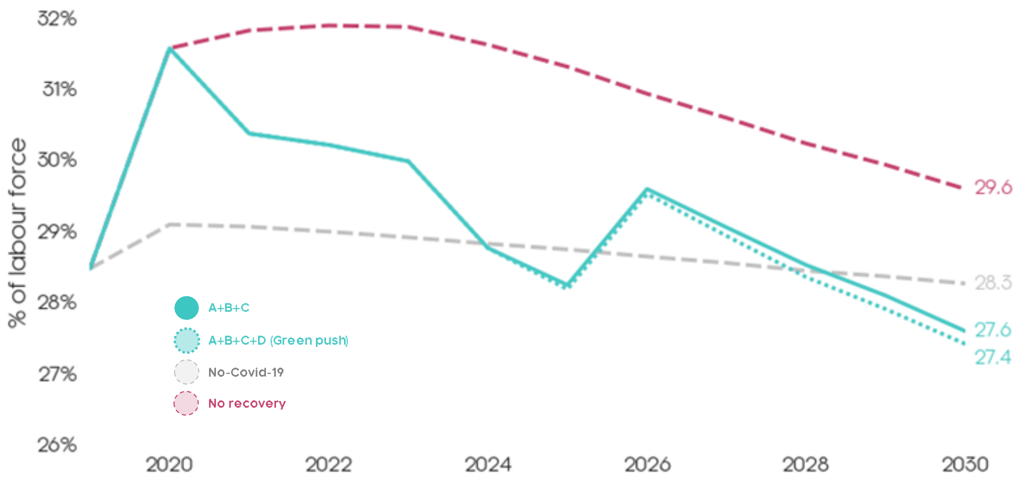
Figure 4.5: Economic activity (GDP), 'Green push' results



Source: E3ME modelling.

Figure 4.6 shows the scenario's impact on unemployment. As in the case of the A+B+C scenario, the 'Green push' scenario results in job losses in the coal sector but unlocks new jobs in the renewables sector.

Figure 4.6: Unemployment, 'Green push' results



Source: E3ME modelling.

[15] By the structure of the E3ME model, it is assumed that this additional investment will be met by private financing. However, as capital subsidies are included in this scenario as well, some of the additional capital is subsidized (therefore increasing government spending as well).

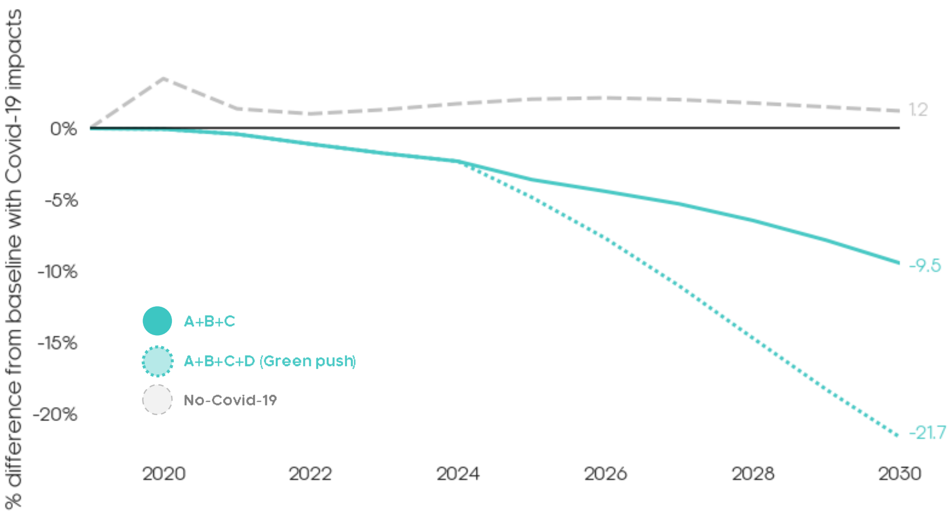
The net effect of the 'Green push' scenario on employment compared to A+B+C is slightly positive, but the difference between the two scenario outcomes for the rate of unemployment is less than 0.2 percentage points.

This result is not unexpected given that studies on the employment effects of green policies have generally found a positive net job creation for the aggregate economy but employment losses in specific sectors and regions. For example, the ILO estimates that switching to renewable sources for energy generation and improving energy efficiency could create 18 million jobs net globally by 2030 compared to a business-as-usual scenario (ILO, 2018). Employment increases (24 million) are concentrated in the renewable energy and construction sectors, although the manufacturing, waste, services and agricultural sectors also benefit thanks to supply chain linkages.

Employment losses (6 million) are concentrated in fossil fuel-based electricity generation and in the mining sectors. At the regional level, the ILO expects a net loss of 350,000 jobs in Africa and of 300,000 jobs in the Middle East by 2030, compared to a business-as-usual scenario. Similar conclusions are reached by a study also based on the E3ME model (Eurofound, 2019), which projects a 0.5% increase in global employment by 2030 thanks to the implementation of policies consistent with the 2 degree target, compared to a baseline scenario without such policies. Within the European Union, the study shows that employment increases in all sectors except for energy and mining, and that the only Member State that experiences a minor net loss of employment is Poland, whose economy is highly dependent on coal. Therefore, it is possible to conclude that the employment benefits of the green economy might be lower in countries, such as South Africa, where energy generation, economic activity and employment rely heavily on coal.

Figure 4.7 shows the impact on CO_2 emissions. By 2030, projected CO_2 emissions are 22% lower than in the COVID-19 baseline, or 20% lower than 2010 levels. This puts South Africa much closer to the more ambitious end of its NDC reduction target (26% reduction). The 'Green push' scenario thus highlights that a higher ambition / faster-paced green transition recovery can lead to positive economic effects while rapidly reducing carbon emissions.

Figure 4.7: CO_2 emissions, 'Green push' results



Source: E3ME modelling.

Nevertheless, there are two implications of the results that should be noted. Firstly, the ‘Green push’ scenario results in early decommissioning of coal-based power generation. E3ME treats this as a sunk cost, but it reduces the investment return to that earlier investment. Secondly, the scenario implies the need for more than R 300 billion of additional private financing to the power sector on top of the investments already included in scenario A+B+C.

5 Environmental impact

This chapter presents results from the analysis undertaken by the United Nations Environment Programme World Conservation Monitoring Centre (UNEP-WCMC) on the wider impacts of the scenarios on natural capital and ecosystem services.

5.1 Introduction

To estimate the broad environmental impacts of the scenarios, we combined data on the growth of economic sectors from the E3ME model, and knowledge about how the economy and environment interact from the ENCORE tool to make fuzzy cognitive maps, which we then perturbed under four economic scenarios.

ENCORE was developed as a tool to understand the impacts and dependencies of environmental change on the economy (NCFA and UNEP-WCMC, 2018). It describes the sign and relative strength of the impacts different phenomena have on one another, and contains information on:

- economic sectors
- production processes that they drive
- natural resources used as input to- and the non-product outputs from- these processes
- drivers of environmental change resulting from anthropogenic and natural processes
- natural capital assets
- ecosystem services

and the inter-linkages between these nodes. These linkages together represent the causal chain of economic growth in one sector's impacts, and feedbacks, on the environment.

Cognitive maps are network diagrams which, fundamentally, describe how systems work in a qualitative way (Özesmi and Özesmi, 2004). They do this by representing features of a system as nodes, where connections between nodes represent causal relationships. They have a wide range of uses, especially in modelling the outcomes of policy options, and have many benefits: they can model systems using simple knowledge when detailed information is unknown, they can simultaneously incorporate knowledge from many sources, they can interpret variables which are abstract or unmeasurable, and can incorporate feedbacks in a system (Kosko, 1986). These network models can account for complex interactions, for example in this use-case, production processes fed by economic sectors, but which are also dependent on ecosystem services provided by natural capital assets which they themselves can harm.

Fuzzy cognitive maps replace the linear positive/negative relationship with an activation function where interactions strengths are mapped to numbers between -1 and 1, incorporating fuzzy logic in the models (Özesmi and Özesmi, 2004). This function is useful because it represents nonlinear relationships between phenomena with tipping points, which are common in nature and earth systems.

We began by mapping E3ME sectors to production processes in the ENCORE tool, guided by a mapping of E3ME sectors to subindustries relevant to each process. We then constructed an interaction matrix using ENCORE's interaction strength (the per capita effect of one node on another) ratings, which ranged from very high to very low for most connections between production processes, drivers, assets and services, as well as representing the dependency of production processes on ecosystem services using a traffic light system.

Cognitive maps can also take uncertainties into account by simulating a spread of plausible interaction strengths, given qualitative information about them (Baker et al., 2018). We used the qualitative interaction strength information from ENCORE to guide simulations of fuzzy cognitive maps which fulfilled the criteria set by ENCORE, without explicitly defining any interaction strengths. Specifying the sets of interaction strengths from ENCORE alongside some scenario-specific knowledge, we employed these methods to generate a suite of plausible networks.

Finally, we perturbed the model in different ways for each timestep of the scenarios we were interested in projecting the outcomes of, plotting the consequences of each scenario on downstream changes in drivers, natural capital assets, and ecosystem services.

5.2 Drivers of impact

Overall node size

Below are listed the five nodes in each ENCORE class with the largest or most impacted equilibrium node values projected for 2030.

Largest production process nodes in 2030:

- Construction materials production
- Infrastructure holdings
- Iron extraction
- Iron metal production
- Steel production

Largest anthropogenic impact driver nodes in 2030:

- Disturbances (sensory disruptions to ecosystems)
- Marine ecosystem use
- Freshwater ecosystem use
- Other resource use
- Solid waste

Largest drivers of environmental change in 2030:

- Habitat modification
- Population changes
- Pollution
- Weather conditions
- Invasive species

Most depleted assets in 2030:

- Water
- Species
- Habitats
- Soils and sediments
- Atmosphere

Most impacted ecosystem services (largest deficits) in 2030:

- Surface water
- Ground water
- Water quality
- Flood and storm protection
- Ventilation

The above nodes are a natural consequence of the relative size of the E3ME sectors, as they are all downstream of the largest sectors of the economy in the case study.

Present-day economic activity puts considerable pressure on natural capital, and results show that pressures on natural capital assets (and commensurate decrease in these natural capital assets) continue to mount over 2020-30 in the no recovery, baseline scenario as well as every recovery scenario examined. Changes to nodes distant from economic sectors, such as those representing natural capital assets, were relatively small, likely because the growth in economic sectors was small relative to their total size. In our simulations, no asset, service, nor driver of environmental change overtakes another in scale in the 2020-30 period in any scenario, and the only 2020-30 shift in impact drivers is that ‘solid waste’ overtook ‘terrestrial ecosystem use’ as the larger impact driver in all scenarios. There are numerous small shifts in the scale of production processes, and these differ by scenario. Overall, patterns common to all our fuzzy cognitive mapping scenarios are such that economic sectors have a large effect on natural capital, and though the degree of this change differs between scenarios, this leads to further decreases in natural capital assets and mounting ecosystem service deficits.

The downstream consequences of the spread of GDP across economic sectors are concentrated on pathways which negatively impact the “water” natural capital aspect, and therefore ecosystem provisioning services such as stocks of surface water, groundwater and high-quality water, as well as regulatory services such as flood and storm protection. Though, as below, the size of the water node does not change much in the scenarios, it remains highly impacted due to historic and current economic activity.

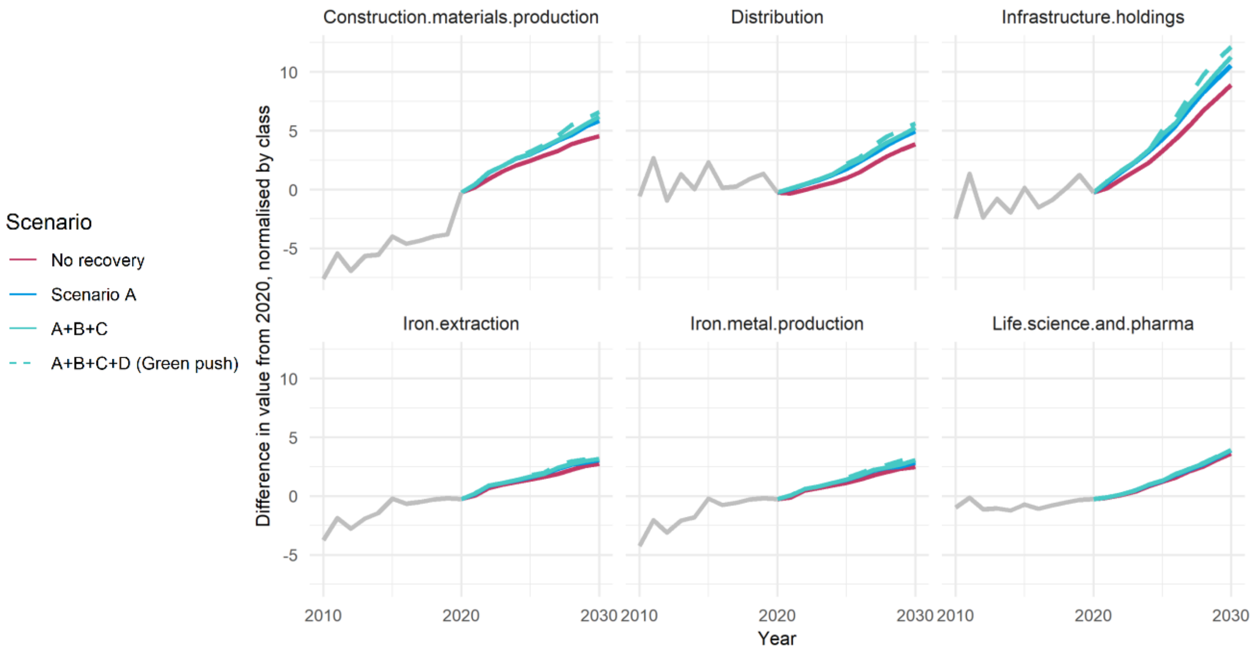
These results differ from those generated by other scenario modelling exercises, such as those performed for a technical report by the South African Department for Environmental Affairs (Bassi et al., 2019) which found that water was not necessarily impacted heavily in each of the fuzzy cognitive mapping scenarios. This specific difference in our results likely arises due to a lack of inclusion of mitigation outcomes in terms of water use (in Bassi et al. (2019), 20% of the impacts of agriculture were modelled as shifting to low impact, and municipalities and industry were modelled as being 20% more efficient with water use – this is not the case in our models, which only accounts for raw change in economic sector sizes). This key difference, amidst other similarities (such as invasive species posing a major threat to biodiversity, an element common to both models), highlights the need for mitigation activities to accompany economic shifts from one sector to another, and may highlight the need to include more knowledge in the fuzzy cognitive maps in order to capture the fact that a green push may also involve a shift towards choosing less impactful pathways to achieving economic growth.

Change in node size 2020-2030

In this section, we will consider which nodes in each class have experienced the most change from 2020 – 2030, rather than simply the raw sizes of the nodes in order to highlight differences in ecological outcomes between the scenarios, and changes that are projected over the 2020 – 2030 period.

Figure 5.1 shows the six production processes with the largest change from 2020 to 2030[16]. All six of the production process nodes with the largest changes experienced growth (but with different amounts of growth between the scenarios) over time, and only a very small number of processes contracted in size in any scenario.

Figure 5.1: Production processes

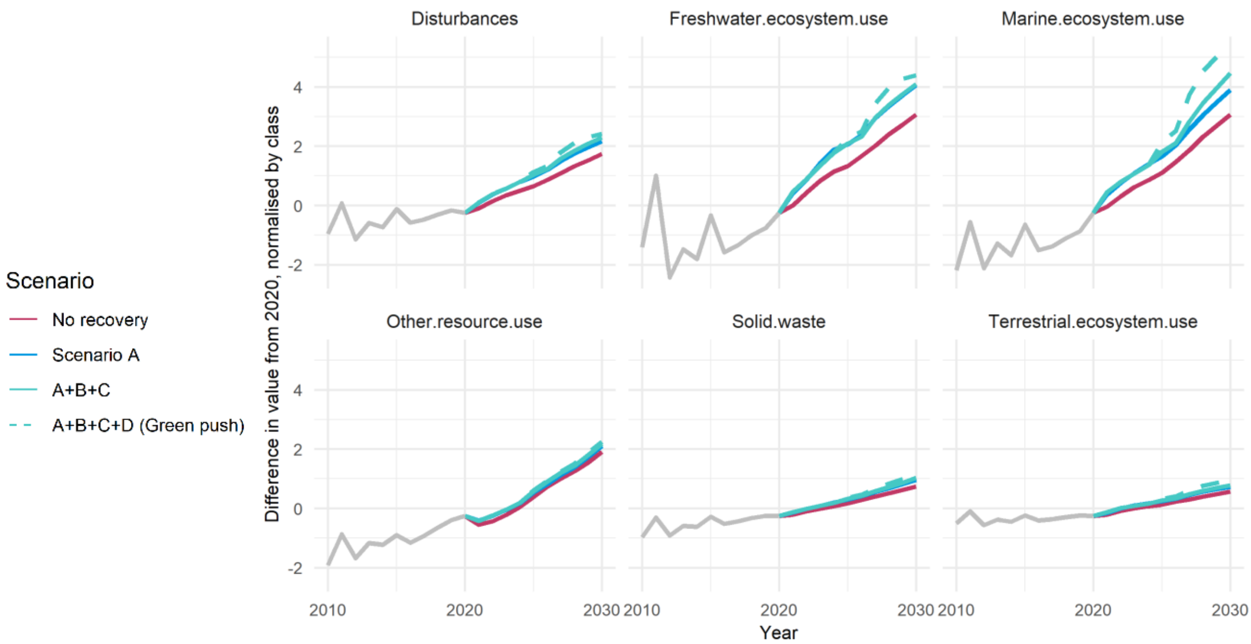


Source: ENCORE/E3ME fuzzy cognitive mapping

Figure 5.2 shows the relative change in anthropogenic impact drivers which had the largest change from 2020 – 2030. Notable changes are the increases in impact drivers linked to the direct utilisation of nature, as well as general diffuse impacts like pollution and disturbances.

[16] The Y-axis represents the difference between the size of each node in a given year/scenario pair with the value of the same node in 2020, relative to the mean change experienced by all nodes of the same class, across all scenarios. This transformation allows for comparison of temporal changes between nodes of different connectivity and size within the same class.

Figure 5.2: Anthropogenic impact drivers



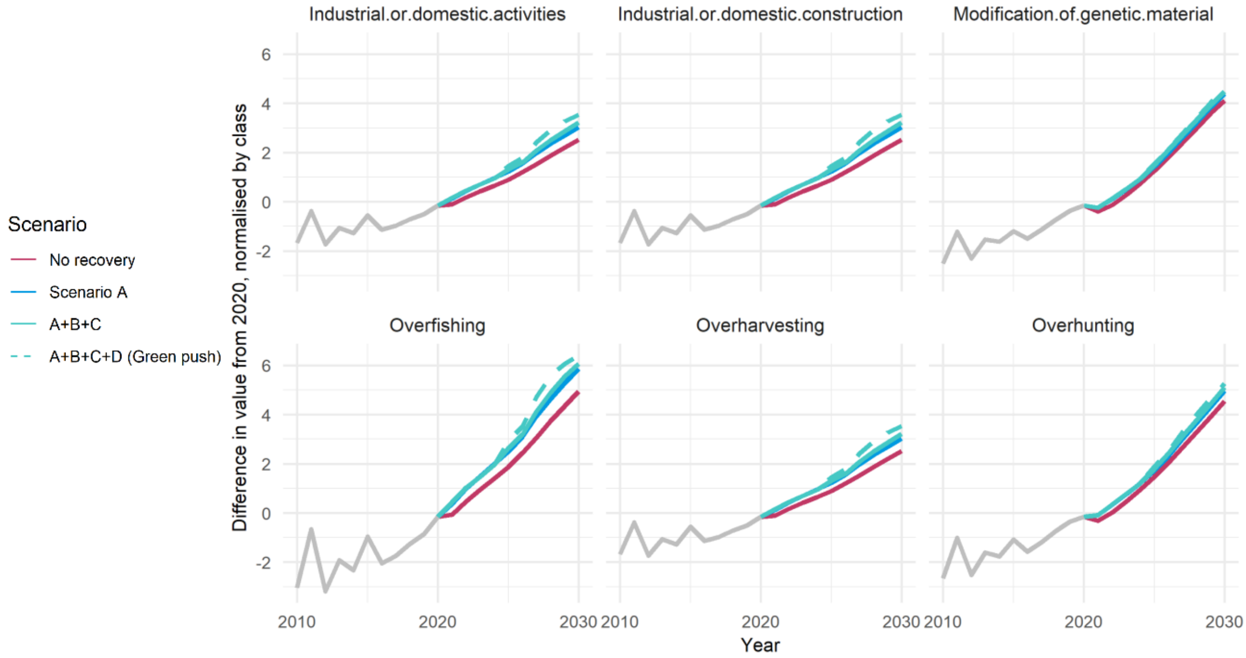
Source: ENCORE/E3ME fuzzy cognitive mapping

We may interpret these results as showing that the most significant "emerging threats" largely concern the direct use of ecosystems, and disturbance of ecosystems through sensory disturbances or pollution. As with the production processes, the general trend for impact drivers is an increase proportional to the overall growth in the economy. The main determinants of which impact driver nodes experience the biggest growth are the size of the economic sectors upstream of each node, and the combined interaction strengths between the upstream sectors, the relevant production processes, and the impact driver nodes. The node sizes are also sensitive to how many production processes contribute to them.

Figure 5.3 shows the relative change from 2020-2030 in drivers of environmental change, with a spotlight on those six which experienced the most change.

The node "human modification of genetic material", though growing rapidly relative to other drivers of change, is not (as represented in the network) a particularly large node, showing that though it is an emerging issue, it is not likely to have drastic impacts on downstream nodes in its present state

Figure 5.3: Drivers of environmental change

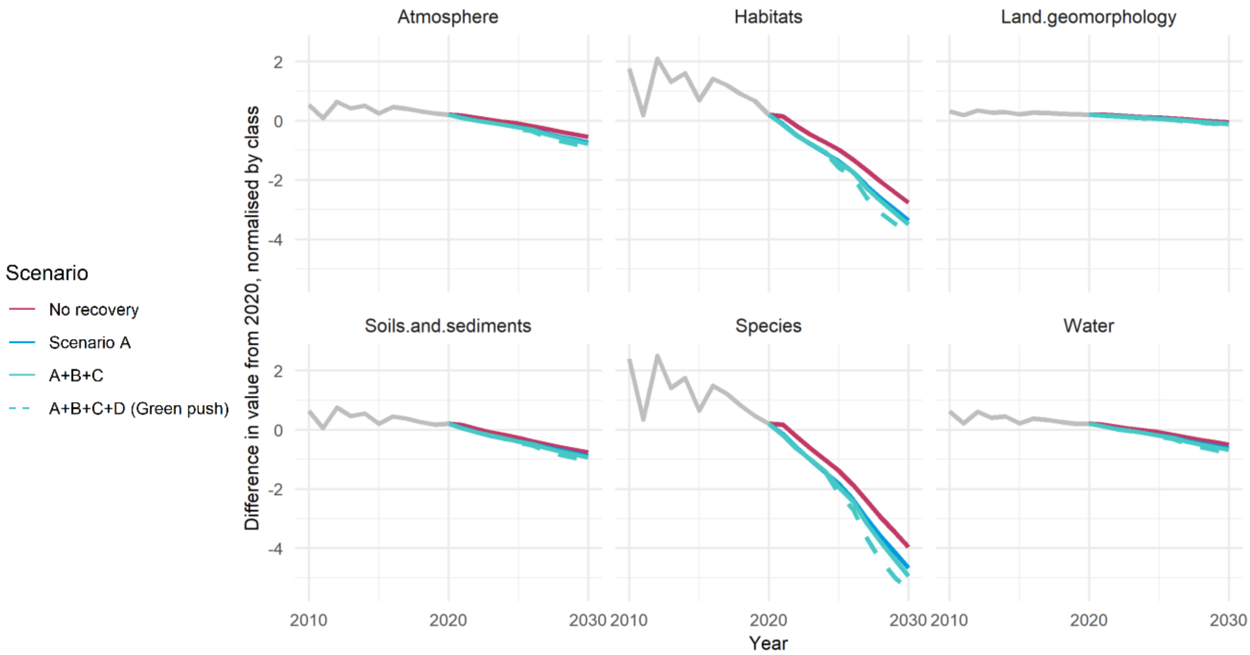


Source: ENCORE/E3ME fuzzy cognitive mapping

5.3 Impact on natural capital

Figure 5.4 shows the relative change in the size of the natural capital asset nodes from 2020 – 2030 across the scenarios.

Figure 5.4: Natural capital assets



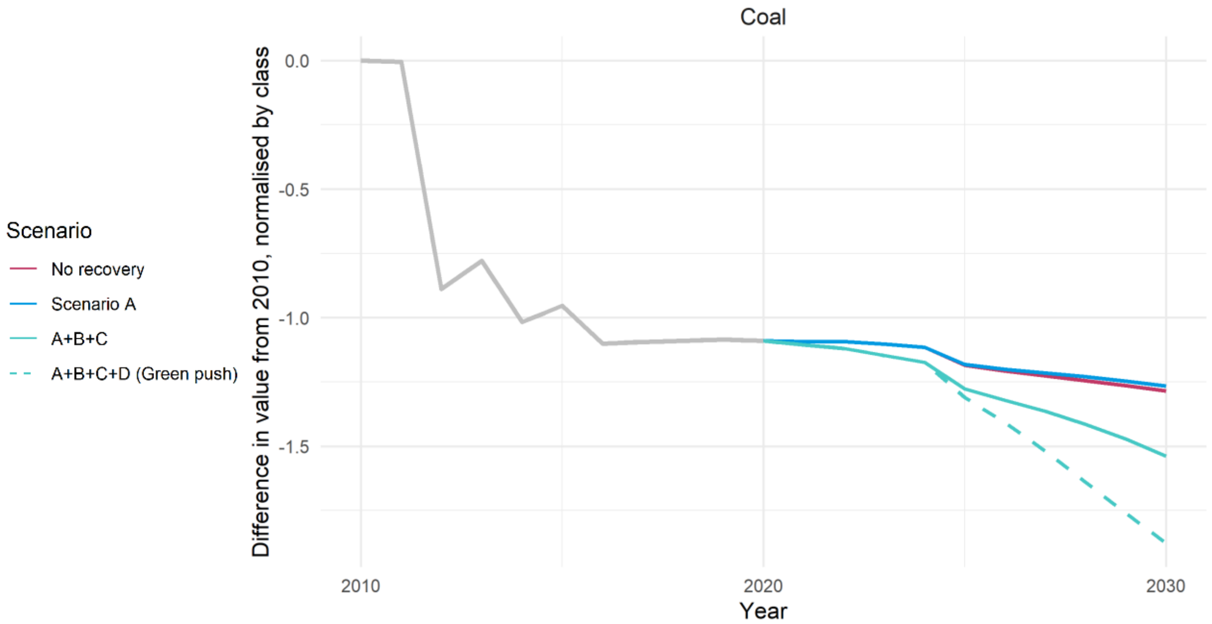
Source: ENCORE/E3ME fuzzy cognitive mapping

The most at-risk elements of natural capital over the 2020-2030 period are species and habitats: the values of these nodes experienced a greater relative loss than others. This means the model predicts that, in reality, declines in habitat quality and species populations may be under increasing pressure due to the activity of economic sectors. While the differences between scenarios are relatively small and in line with historical trends, the pressure is apparently greatest in the 'Green push' scenario, most likely due to its overall greater economic increase. It is also important to recognise that, though the "water" node has a less drastic continued decline than other nodes here, it was already highly impacted before the 2020-2030 period and so has less potential to accommodate further loss. This contrasts with nodes such as "land geomorphology", which follows a similar trajectory to "water" but has a much higher equilibrium node state, showing that it is truly less at-risk. Also, the way that energy sector GHG emissions are modelled by these methods is independent of that used in earlier chapters of this report, so the projected impact on the "atmosphere" is not comparable between the two approaches.

5.4 Case study: coal and mining

Figure 5.5 shows that, in the 'Green push' scenario, the "Coal" sector is diminished relative to other scenarios, and over time.

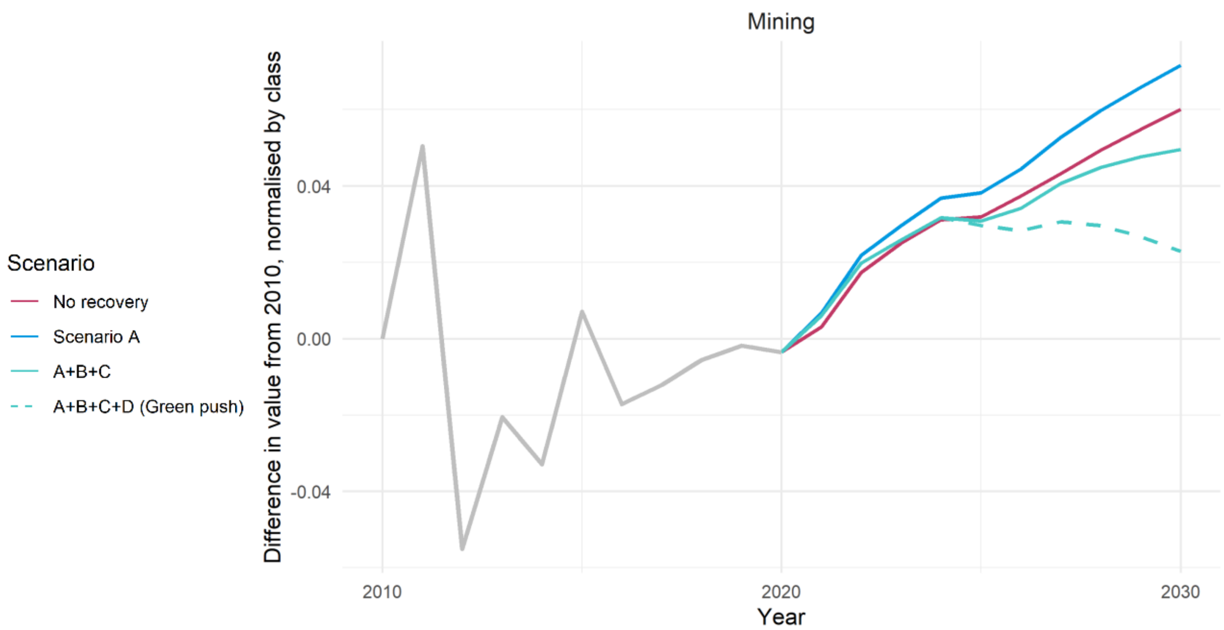
Figure 5.5: Coal node relative change from 2010-2030



Source: ENCORE/E3ME fuzzy cognitive mapping

Figure 5.6 demonstrates that, in the 'Green push' scenario, this leads to a diminished "mining" production process node in the latter half of the 2020-2030 period relative to the other scenarios we simulated.

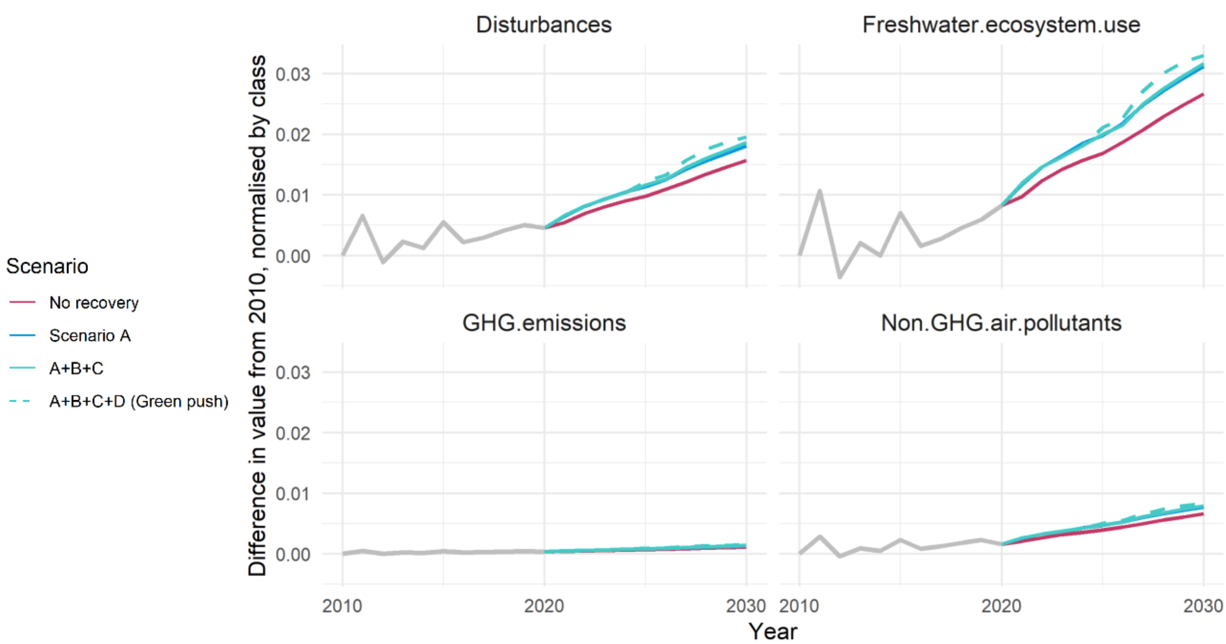
Figure 5.6: Mining node relative change from 2010-2030



Source: ENCORE/E3ME fuzzy cognitive mapping

This represents diminished mining activity in a scenario where a reliance on mining coal for energy production is removed. However, this does not translate to a decrease in the children nodes of the "mining" production process node: this is shown in Figure 5.7 below.

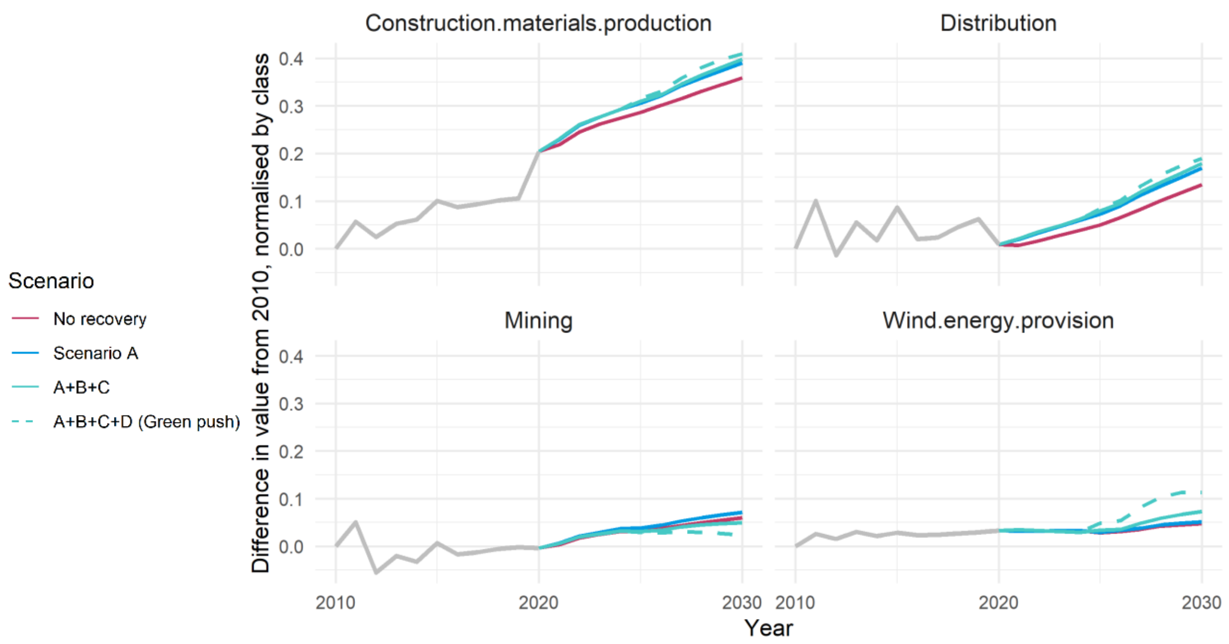
Figure 5.7: Impact driver child nodes of mining



Source: ENCORE/E3ME fuzzy cognitive mapping

This illustrates well the risks of a policy that focuses on mitigating one environmental impact without including measures to mitigate other kinds of impact. In the ‘Green push’ scenario, the nodes representing coal, and therefore mining as an extension, shrink, but the additional investment to put renewable capacity in place requires more construction materials. If these are extracted as virgin raw materials, the net effect on mining may be to increase its activity, resulting in more damage to natural capital. Figure 5.8 illustrates this for a selection of the parent nodes of disturbances.

Figure 5.8: Production process parent nodes



Source: ENCORE/E3ME fuzzy cognitive mapping

This result is also, in part, due to the relative naivety of the network. In the simulations above, all interactions between the coal sector and greenhouse gas emissions (for example) are mediated by the mining node. The network makes no assumptions as to whether coal-based mining is any more impactful on the range of impact drivers than other types of mining, such as those which would be necessary to replace coal-power infrastructure with renewable alternatives, or any of those production processes which share child nodes with mining. This is why scenarios A, A + B + C, and the ‘Green push’ all see an increase in “disturbances” relative to the “no intervention” baseline; they all involve major increases in construction works not seen in the baseline. The ‘Green push’ leads to further, smaller, increases in many production processes (and so impact drivers) because it necessitates an expansion in production processes such as wind energy provision (which contributes to construction processes), to facilitate the phasing-out of coal.

Overall, patterns emerge due to the interpretation method of the network alongside the large growth of other sectors to accommodate the reduction in coal. Although the ‘Green push’ sees reduction in coal/mining, and oil/gas, growth of other sectors overwhelms these effects. Cutting coal in the ‘Green push’ leads to an overall decrease in the “Mining” process, but mining is one of many processes feeding into each of the impact drivers it contributes to, so its decrease is lost amongst the wave of increases elsewhere. Another feature of the network that may contribute to this is how highly-connected the impact drivers are: the impact drivers mining contributes to have many origins. ENCORE includes 86 distinct production processes in its network, and the impact drivers linked to mining have, on average, 44 parent nodes. In short, because these two layers of the network are so interconnected, any change upstream is likely to have similar effects downstream, leading to an overall rule of more growth leading to more impact.

5.5 Impact per unit economic growth

However, though overall impact is higher under the ‘Green push’, impact from economic sectors in this scenario is potentially flowing through process nodes with a lower per capita impact than mining (due to having a lower interaction strength with impact drivers). We should therefore expect that the ‘Green push’ may achieve more economic growth per unit decrease in natural capital assets than other scenarios. The “efficiency” of scenarios in terms of economic return per unit damage to natural capital was calculated by measuring the ratio of overall economic growth across all sectors to the decrease in natural capital asset node values for each scenario and timestep. For each simulation, we noted the scenario which gave the highest efficiency. Nonlinearities in the relationship between economic growth and environmental damage led to scenario A, with low overall extra growth, being selected often. However, the ‘Green push’ scenario led to the highest economic return per unit environmental damage more often than scenario A + B + C, despite providing greater economic growth.

These results largely arise from the fact that though there can be “no growth for free” in the network model used, selecting pathways of economic change that follow less impactful downstream routes may allow for similar amounts of environmental damage to lead to greater return in terms of economic growth. Through basic inspection of the simulations where scenario A was selected, and the ‘Green push’ scenario was selected, it is apparent that where the interactions strengths are more extreme, the ‘Green push’ emerges more commonly as the preferable scenario. Further refinement of the network interaction strengths could enable us to determine which scenario would provide the greatest return across a more realistic spread of interaction matrices.

5.6 Implications for policy and mitigation

These results show that some natural capital assets, such as water, are already under extreme pressure from production processes in the case study. Where possible, growth strategies should take note of ways to reduce pressure on such nodes, noting, for example, that water suffers disproportionately from the effects of invasive species in this network, and that taking action to mitigate their impacts may allow for some recovery.

In our simulations, the baseline scenario with no COVID recovery led to the lowest impacts on all the natural capital assets, showing that generally, as total economic recovery increases from a point of lower economic activity due to the COVID-19 pandemic across the scenarios, so does total impact. This is reflected in Figures 5.1 – 5.4, which show that the biggest determinant of impact is the overall scale of regrowth.

It is interesting to consider relative impact, as this is what will highlight where "greener" options have been taken for growth. Sustainable options for growth may be linked to a smaller overall amount of pressure generated on natural capital assets. Economic growth in sectors with weaker impact interactions is less likely to lead to declines in ecosystem services that the production processes it relies upon depend on. Facing forward, prioritising growth and seeking opportunities in sectors and production processes which have weaker links to impact drivers may enable large growth relative to impacts. That said, much inevitable growth will still be linked strongly to degradation of natural capital. Further downstream mitigation strategies will therefore be necessary to limit the degradation of natural capital and maintenance of ecosystem services. In the selection exercise, although the majority of simulations led to scenario A giving the highest return-on-impact, in situations where this was not true the most likely scenario to be selected was the 'Green push'. It is also worth mentioning that in extreme scenarios (the high tail of the distributions, a feasible worst-case scenario), the values of the natural capital assets were least impacted in the 'Green push' scenario.

Another use of the model outputs is to examine which sectors may be particularly at-risk following the projections of the models. Examining the sum of service deficit nodes feeding back into each production process, it is clear that agricultural processes, and therefore the agriculture sectors, are most at-risk under the scenarios assessed. Irrigated arable crops emerged as more at-risk than rain-fed crops, and the forestry, livestock, and aquaculture processes also emerged as highly impacted by a reduction in ecosystem services. Other production processes (and linked sectors) such as telecommunications, financial services, and managed health care, were almost without detriment from ecosystem service deficits, as they are much less reliant on ecosystem services than other processes. This result emphasises how an economy can afford to grow to an extent through sectors which are not reliant on natural capital but must limit the impacts that sectors have on natural capital in order to preserve the productivity of those sectors which do rely on nature.

Conversely, we can use the network to identify the most beneficial opportunities for mitigating the impacts of recovery efforts. For example: in the 'Green push' scenario, one impact driver with a large relative growth is "Disturbances". Should disturbances be recognised as an impact driver in South Africa (the relationships defined by ENCORE are not specific to South Africa), this can be interpreted as sensory disturbances being an emerging driver of change over the 2020-2030 period. We can use the 2030 state of the node and look at its connections to production processes, identifying the biggest contributor to this across simulations of the 'Green push' scenario as "construction materials production", which is listed as having a "high" per capita impact on disturbances and is also the largest node in the parent nodes of disturbances. We can take the analysis a step further by listing the economic sectors responsible for the growth in construction materials production: Basic metals, forestry, metal goods, other mining, and wood and paper. Interventions to mitigate economic impacts on disturbances could therefore focus on the relationship between these sectors and the intermediate production processes relevant to disturbances, reducing the per capita impacts of the above sectors on construction materials production or mitigating the per capita effects of construction materials production on disturbances. These mitigation actions are likely to be scenario-specific but could (as a first example) involve activities such as recycling construction materials or developing and adopting lower-impact technologies for producing construction materials.

More broadly, in 2030, the most substantial production processes are anticipated to include infrastructure holdings, iron extraction, and iron metal and steel production. It is likely that mitigation will need to target the impacts from these processes as well; alongside decarbonisation, ‘Green push’ initiatives should consider ways to reduce the extraction of virgin materials and waste produced by production processes by reincorporating used products and materials, in doing so moving towards a circular economy.

For some of these processes, there are mitigation possibilities, for example by reducing infrastructure impacts through environmentally sensitive planning (e.g. Laurance et al. (2015)). For others, considering alternative options including substituting high impact materials with lower-impact alternatives will be valuable. From the perspective of species and habitats, the two assets most impacted in the scenarios considered here, our results point towards adoption of the mitigation hierarchy for mitigating and compensating the biodiversity impacts of developments (1, avoid; 2, minimise; 3, restore; and 4, offset, toward a target such as "no net loss" of biodiversity) (e.g. Milner-Gulland et al. (2021)).

When considering pathways towards a sustainable future, the IPBES Global Assessment (Brondizio et al., 2019), a global-scale assessment of the state and trends of biodiversity, identified eight leverage points for influencing systems to bring about transformation. We highlight a selection of these. Sustainable technology and innovations play a key role in transformations and responsible investment in sectors that have the greatest impact, combined with assessment of progress that goes beyond short-term economic profitability. Other strategic incentives to mitigate impacts from the largest sectors will be important. But perhaps most importantly, our analysis highlights the need for integrated management to realise co-benefits around stimulus measures and avoid trade-offs.

6 References

Averchenkova, A., Gannon, K.E., Curran, P., 2019. Governance of climate change policy: A case study of South Africa.

Baker, C.M., Holden, M.H., Plein, M., McCarthy, M.A., Possingham, H.P., 2018. Informing network management using fuzzy cognitive maps. Biological Conservation 224, 122–128. https://doi.org/10.1016/j.biocon.2018.05.031

Bassi, A.M., Musango, J.K., Pallaske, G., Batinge, B., 2019. Modelling the water-biodiversity nexus in four South African provinces - Eastern Cape, Limpopo, Northern Cape and Western Cape. Department for Environmental Affairs, South Africa.

Brondizio, E.S., Settele, J., Díaz, S., Ngo, H.T., 2019. Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES secretariat, Bonn.

Bruegel, 2020. The fiscal response to the economic fallout from the coronavirus. URL https://www.bruegel.org/publications/datasets/covid-national-dataset/ (accessed 7.9.20).

Climate Action Tracker, 2020. South Africa [WWW Document]. Climate Action Tracker. URL https://climateactiontracker.org/countries/south-africa/ (accessed 10.14.20).

Department of Energy, 2020a. Integrated Resource Plan 2019. South African Government.

Department of Energy, 2020b. Strategic Plan 2020-2025. South African Government.

Department of Environmental Affairs, 2018. South Africa's third climate change report 2017. South African Government.

Department of Public Works and Infrastructure, 2020. EPWP Response to Questions by Prof Chitiga.

Department of Tourism, 2020. Tourism Sector Recovery Plan COVID-19 response.

Donnenfeld, Z., Crookes, C., Hedden, S., 2018. A delicate balance - Water scarcity in South Africa. Institute for Security Studies.

Economic Commission for Latin America and the Caribbean, 2020. Building a New Future: Transformative Recovery with Equality and Sustainability. Summary. CEPAL.

Eurofound, 2019. Energy scenario: Employment implications of the Paris Climate Agreement. Publications Office of the European Union, Luxembourg.

Evans, S., 2020. Analysis: Coronavirus set to cause largest ever annual fall in CO2 emissions [WWW Document]. Carbon Brief. URL https://www.carbonbrief.org/analysis-coronavirus-set-to-cause-largest-ever-annual-fall-in-co2-emissions (accessed 10.12.20).

Evans, S., Gabbatiss, J., 2020. Coronavirus: Tracking how the world's 'green recovery' plans aim to cut emissions [WWW Document]. Carbon Brief. URL https://www.carbonbrief.org/coronavirus-tracking-how-the-worlds-green-recovery-plans-aim-to-cut-emissions (accessed 10.19.20).

Google, 2020. COVID-19 Community Mobility Report [WWW Document]. COVID-19 Community Mobility Report. URL https://www.google.com/covid19/mobility?hl=en (accessed 7.9.20).

GreenCape, 2020. Water, 2020 Market Intelligence Report.

IEA, 2020a. World Energy Outlook 2020. IEA, Paris.

IEA, 2020b. South Africa.

IISD, 2019. Beyond fossil fuels: Fiscal transition in BRICS.

ILO, 2020. ILO Monitor: COVID-19 and the world of work. Sixth edition.
ILO, 2018. World Employment and Social Outlook: Trends 2018. ILO, Geneva.
ILO, 2012. International Standard Classification of Occupations. ILO, Geneva.
IMF, 2020a. World Economic Outlook, Octobr 2020: A Long and Difficult Ascent.
IMF, 2020b. Policy Responses to COVID19 [WWW Document]. IMF. URL https://www.imf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19 (accessed 7.9.20).
IMF, 2020c. World Economic Outlook, Octobr 2020: A Long and Difficult Ascent.
Investment and Infrastructure Office, The Presidency, 2020. Sustainable Infrastructure Development Symposium South Africa.
Kaziboni, L., Stern, M., 2020. The impact of local content policies on EU exports and investment, and economic transformation in South Africa.
Kosko, B., 1986. Fuzzy cognitive maps. International Journal of Man-Machine Studies 24, 65–75. https://doi.org/10.1016/S0020-7373(86)80040-2
Laurance, W.F., Peletier-Jellema, A., Geenen, B., Koster, H., Verweij, P., Van Dijck, P., Lovejoy, T.E., Schleicher, J., Van Kuijk, M., 2015. Reducing the global environmental impacts of rapid infrastructure expansion. Current Biology 25, R259–R262. https://doi.org/10.1016/j.cub.2015.02.050
Liu, Z., Ciais, P., Deng, Z., Lei, R., Davis, S.J., Feng, S., Zheng, B., Cui, D., Dou, X., Zhu, B., Guo, Rui, Ke, P., Sun, T., Lu, C., He, P., Wang, Yuan, Yue, X., Wang, Yilong, Lei, Y., Zhou, H., Cai, Z., Wu, Y., Guo, Runtao, Han, T., Xue, J., Boucher, O., Boucher, E., Chevallier, F., Tanaka, K., Wei, Y., Zhong, H., Kang, C., Zhang, N., Chen, B., Xi, F., Liu, M., Bréon, F.-M., Lu, Y., Zhang, Q., Guan, D., Gong, P., Kammen, D.M., He, K., Schellnhuber, H.J., 2020. Near-real-time monitoring of global CO2 emissions reveals the effects of the COVID-19 pandemic. Nature Communications 11, 5172. https://doi.org/10.1038/s41467-020-18922-7
Meyiwa, T., Nkondo, M., Chitiga-Mabugu, M., Sithole, M., Nyamnjoh, F.B., 2014. State of the Nation: South Africa, 1994-2014 : a Twenty-year Review of Freedom and Democracy. HSRC Press.
Milner-Gulland, E.J., Addison, P., Arlidge, W.N.S., Baker, J., Booth, H., Brooks, T., Bull, J.W., Burgass, M.J., Ekstrom, J., zu Ermgassen, S.O.S.E., Fleming, L.V., Grub, H.M.J., von Hase, A., Hoffmann, M., Hutton, J., Juffe-Bignoli, D., ten Kate, K., Kiesecker, J., Kümpel, N.F., Maron, M., Newing, H.S., Ole-Moiyoi, K., Sinclair, C., Sinclair, S., Starkey, M., Stuart, S.N., Tayleur, C., Watson, J.E.M., 2021. Four steps for the Earth: mainstreaming the post-2020 global biodiversity framework. One Earth 4, 75–87. https://doi.org/10.1016/j.oneear.2020.12.011
Mkhatshwa-Ngwenya, E.N.M., 2016. Implementation of the Expanded Public Works Programme (EPWP) in South Africa (2004-2014). University of South Africa Pretoria.
Montmasson-Clair, G., Chigumira, G., 2020. Green economy policy review of South Africa's industrial policy framework. United Nations Environment Programme.
National Planning Commission, 2012. National Development Plan 2030. South African Government.
National Treasury, 2020a. Supplementary Budget Review 2020. South African Government.
National Treasury, 2020b. Economic measures for Covid-19. South African Government.
NCFA, UNEP-WCMC, 2018. Exploring Natural Capital Opportunities, Risks and Exposure: A practical guide for financial institutions. Natural

Capital Finance Alliance, UN Environment World Conservation Monitoring Centre, Geneva, Oxford and Cambridge.
OECD, 2020a. OECD Economic Outlook, June 2020 [WWW Document]. URL http://www.oecd.org/economic-outlook/june-2020/#Report
OECD, 2020b. OECD Country Policy Tracker.
OECD, 2020c. OECD Economic Outlook No 107 - Double-hit scenario – (Edition 2020/1) [WWW Document]. URL https://www.oecd-ilibrary.org/content/data/82024563-en
OECD, 2020d. Fossil fuel support country note - South Africa. OECD.
Our World in Data, 2020. Coronavirus (COVID-19) Cases - Statistics and Research [WWW Document]. Our World in Data. URL https://ourworldindata.org/covid-cases (accessed 7.9.20).
Özesmi, U., Özesmi, S.L., 2004. Ecological models based on people's knowledge: a multi-step fuzzy cognitive mapping approach. Ecological Modelling 176, 43–64. https://doi.org/10.1016/j.ecolmodel.2003.10.027
PAGE, 2017. Green Economy Inventory for South Africa: An Overview. Pretoria, South Africa.
Peters, G.P., Marland, G., Le Quéré, C., Boden, T., Canadell, J.G., Raupach, M.R., 2012. Rapid growth in CO 2 emissions after the 2008–2009 global financial crisis. Nature Climate Change 2, 2–4. https://doi.org/10.1038/nclimate1332
Pollitt, H., 2020. Assessment of Green Recovery Plans after Covid-19. We Mean Business Coalition.
Pollitt, H., Kiss-Dobronyi, B., Fazekas, D., 2020a. Green Recovery scenarios in Visegrad countries. Cambridge Econometrics, Cambridge - Brussels - Budapest.
Pollitt, H., Lewney, R., Kiss-Dobronyi, B., Lin, X., 2020b. A Post-Keynesian approach to modelling the economic effects of Covid-19 and possible recovery plans, C-EENRG Working Papers. University of Cambridge, Cambridge, UK.
Pollitt, H., Mercure, J.-F., 2018. The role of money and the financial sector in energy-economy models used for assessing climate and energy policy. Climate Policy 18, 184–197. https://doi.org/10.1080/14693062.2016.1277685
Presidential Economic Advisory Council, 2020. Briefing notes on key questions for SA's economic recovery.
Ramokgopa, K., 2020. Post by Kgosientsho Ramokgopa [WWW Document]. Facebook. URL https://www.facebook.com/599912910110968/posts/today-the-minister-for-public-works-and-infrastructure-patricia-de-lille-and-mys/2741473689288202/ (accessed 11.20.20).
SANBI, 2019. National Biodiversity Assessment Report 2018 Synthesis Report. South African National Biodiversity Institute.
Silva, S., UNCTAD, 2014. Local content requirements and the green economy. UN, New York; Geneva.
South African Government, 2020a. COVID-19 / Novel Coronavirus [WWW Document]. URL https://www.gov.za/Coronavirus (accessed 10.29.20).
South African Government, 2020b. President Cyril Ramaphosa: South Africa's Economic Reconstruction and Recovery Plan [WWW Document]. URL https://www.gov.za/speeches/president-cyril-ramaphosa-south-africa's-economic-reconstruction-and-recovery-plan-15-oct (accessed 10.23.20).
South African Government, 2020c. The South African Economic Reconstruction and Recovery Plan.
South African Government, 2020d. Building a new economy - Highlights of the reconstruction and recovery plan.

South African Government, 2020e. Building a society that works - Public investment in a mass employment strategy to build a new economy. South African Government.

South African Government, 2011. National Climate Change Response White Paper.

South African Reserve Bank, 2020. Economic and Financial Data for South Africa.

Stats SA, 2020a. P0211 - Quarterly Labour Force Survey (QLFS), 2nd Quarter 2020.

Stats SA, 2020b. P0441 - Gross Domestic Product (GDP), 2nd Quarter 2020.

Stats SA, 2020c. Steep slump in GDP as COVID-19 takes its toll on the economy [WWW Document]. URL http://www.statssa.gov.za/?p=13601 (accessed 10.9.20).

Stats SA, 2019. Sustainable Development Goals Country Report - South Africa.

TIPS, 2020. The Real Economy Bulletin - Second quarter 2020.

TomTom, 2020. Traffic congestion ranking | TomTom Traffic Index [WWW Document]. URL https://www.tomtom.com/en_gb/traffic-index/ranking/ (accessed 7.9.20).

UNEP, 2013. Green Economy Scoping Study: South African Green Economy Modelling Report (SAGEM) – Focus on Natural Resource Management, Agriculture, Transport and Energy Sectors.

UNFCCC, 2016. South Africa’s Intended Nationally Determined Contribution (INDC).

WHO, 2020. Pulse survey on continuity of essential health servicesduring the COVID-19 pandemic.

World Data Lab, 2020. Water scarcity clock [WWW Document]. URL https://worldwater.io/ (accessed 10.27.20).

Worldometer, 2020. Worldometer [WWW Document]. URL https://www.worldometers.info/coronavirus/ (accessed 10.23.20).

Appendix A E3ME

E3ME is a global macroeconometric model of the world's economic, energy systems and the environment, developed and maintained by Cambridge Econometrics. It was originally developed through the European Commission's research framework programmes and is now widely used in Europe and beyond for policy assessment, for forecasting and for research purposes.

E3ME is one of the most advanced models of its type today. Its main strengths are:

- A high level of disaggregation, enabling detailed analysis of sectoral and country level effects from a wide range of scenarios.
- An econometric specification that addresses concerns about conventional macroeconomic models and provides a strong empirical basis for analysis.
- Integrated treatment of the world's economies, energy systems, emissions and material demand. This enables E3ME to capture two-way linkages and feedbacks between each of these components.
- Economic activity is demand-driven, within supply constraints.

Dimensions and classifications

The current version of the model has the following dimensions:

- 61 regions – all major world economies (i.e. G20), the EU28 Member States and candidate countries plus other countries' economies grouped
- 70 industry sectors (43 for non-EU), based on standard international classifications
- 43 categories (28 for non-EU) of household expenditure
- 22 different users of 12 different fuel types
- 14 different users of 7 different raw materials
- 14 types of airborne emissions (where data are available) including the six greenhouse gases monitored under the Kyoto protocol[17]

E3ME's historical database covers the period 1970-2016 and the model projects forward annually to 2050. The main data sources are Eurostat, the OECD (both the National Accounts section and STAN), World Bank, UN, International Monetary Fund (IMF) and International Labour Organization (ILO), supplemented by data from national sources. Energy and emissions data are sourced from the International Energy Agency (IEA) and EDGAR global emissions database. Gaps in the data are estimated using customised software algorithms.

Econometric specification

E3ME's behavioural relationships (i.e. interaction between variables) are validated by historical relationships, expressed by econometrically estimated parameters derived from real-world time series data. In total there are 33 sets of econometrically estimated equations, including the components of GDP

[17] They are: carbon dioxide (CO_2), methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), and, sulphur hexafluoride (SF6).

(consumption, investment, international trade), prices, energy demand and materials demand. Each equation set is disaggregated by country and by sector.

Annual results are generated for the energy, environmental and economic variables using econometric techniques of cointegration and error correction to analyse these variables' short-run fluctuations around their long-run relationship. The system of error correction allows short-term dynamic (or transition) outcomes, moving towards a long-term trend. The dynamic specification is important when considering short and medium-term analysis (e.g. up to 2030) and rebound effects, which are included as standard in the model's results.

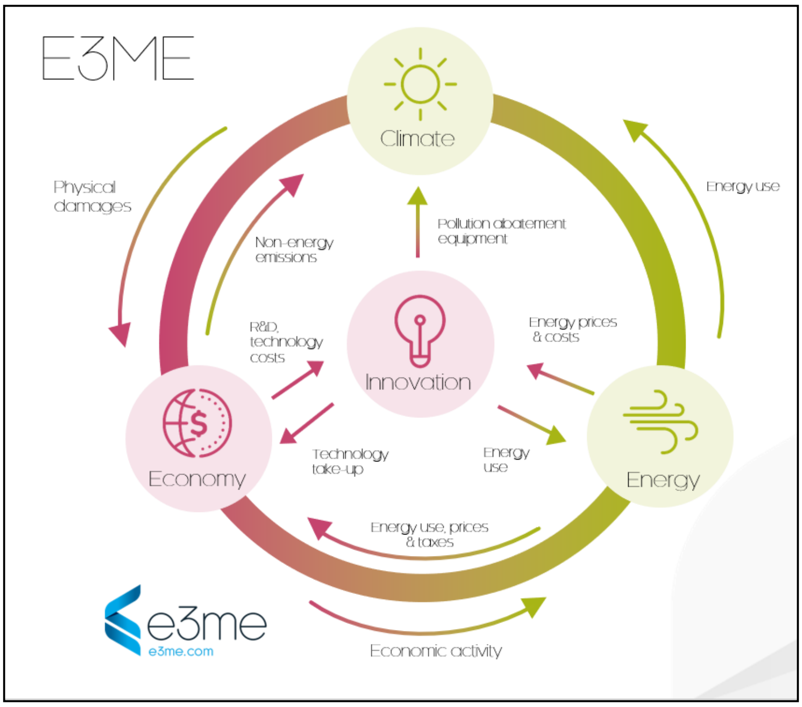
The econometric specification of E3ME gives the model a strong empirical grounding, by simulating responses to policy changes based on historically observed relations between variables, without imposing assumptions about household and firm behaviour (e.g. that agents have perfect knowledge and behave in an optimal manner). Thus, instead of trying to find least-cost pathways, the model simulates the responses to shocks (including changes in drivers such as economic, demographic or technological development, or both regulation and market-based policies).

E3 linkages

E3ME's structure is based on a standard National Accounts framework, with two-way links to energy consumption, emissions and material consumption. Economic activity undertaken by persons, households, firms and other groups in society has effects on other groups spread over time, and the effects persist into future generations, although many of the effects soon become so small as to be negligible. But there are many actors and the effects, both beneficial and damaging, accumulate in economic and physical stocks. The effects are transmitted through the environment (with externalities such as greenhouse gas emissions contributing to global warming), through the economy and the price and money system (via the markets for labour, capital and commodities), and through the global transport and information networks. The markets transmit effects in three main ways: through the level of activity creating demand for inputs of materials, fuels and labour; through wages and prices affecting incomes; and through incomes leading in turn to further demands for goods and services. These interdependencies suggest that a model should be comprehensive and include many linkages between different parts of the economic, environment, and energy systems.

The figure below shows how the three components (modules) of the model - energy, environment (represented as climate in the figure) and economy - fit together. The linkages between the components of the model are shown explicitly by the arrows that indicate which values are transmitted between components. For example, the economy module provides measures of economic activity and general price levels to the energy module and the energy module provides detailed price levels for energy carriers distinguished in the economy module and the overall price of energy as well as energy use in the economy. The E3ME environmental module covers 14 different air pollutants generated from end-use of different fuels and from primary use of fuels in the energy industries. There is also a separate module[18] which calculates physical demand for seven raw materials with feedbacks to the economy module in E3ME.

E3ME linkages



Demand-driven

E3ME is a hybrid model with top-down and bottom-up components in which output is driven by demand but subject to supply constraints. The category of demand-driven macroeconometric models to which E3ME belongs is often compared to the category of Computable General Equilibrium (CGE) models. In many ways, the modelling approaches are similar in scope and application. They are used to answer similar questions and use similar inputs and outputs, and they are based on the same statistical economic framework of the National Accounts. However, there are important differences between the modelling approaches, due to a different theoretical orientation (i.e. views on how the macro-economy works, what the most important mechanisms are at macro level and how they function). In a typical CGE framework, behaviour is determined through an optimising framework on markets, with constraints and often including an expectations formation mechanism (micro-foundations). Because of the assumption that prices clear markets, output is ultimately determined by supply factors (such the amount of labour and capital available) and prices adjust fully so that all the available capacity is used. In E3ME, supply adjusts to demand subject to constraints but not necessarily at maximum capacity. The model does not assume that prices always adjust to

[18] The module distinguishes 15 material user categories. However, not all these categories will use a particular material. The feedback to the economy is through Input-Output relationships of these user categories with the extraction sector: agriculture, forestry and other mining. The following link below provides information on previous applications using material submodule in E3ME: https://ec.europa.eu/environment/enveco/resource_efficiency/pdf/RMC.pdf

market clearing levels nor that all resources are fully utilised. As a result, regulation and other policy can lead to increases in investment, output and employment if the regulation or policy is able to draw upon spare economic capacity (i.e. unused capital and labour resources).

Appendix B EPWP

public works
& infrastructure
Department:
Public Works and Infrastructure
REPUBLIC OF SOUTH AFRICA

EXPANDED PUBLIC WORKS PROGRAMME

EPWP Response to Questions by Prof Chitiga

12 November 2020

1. **Per year, the expenditure:**

The table below shows the **reported** budget and expenditure for the Environment and Culture sector across all spheres of government.

YEARID	SECTOR	Reported BUDGET	Reported Expend.
14-15	Environment And Culture Sector	35 742 862 236,66	3 007 945 421,90
15-16	Environment and Culture Sector	8 017 150 559,67	2 614 007 614,30
16-17	Environment and Culture Sector	12 995 739 599,46	2 961 947 159,75
17-18	Environment and Culture Sector	9 409 568 399,42	2 926 691 723,13
18-19	Environment and Culture Sector	14 790 882 708,59	3 192 528 848,64
Total		**80 956 203 503,80**	**14 703 120 767,72**

2. **Per year, the number of employment opportunities created; (expressed, ideally, as the annual expenditure required to create a person-year of employment),**

Below is a summary of performance against targets for the Environment and Culture sector per sphere of government per year. Overall, the sector achieved 80% against the set targets for Phase 3 creating a total of 969 678 work opportunities.

Financial Year	Sector	Target	WO	% Achiev	Annual Target	Annual WO
2014-2015	Municipal	81 007	82 214	101%	227 650	221 090
	National	113 995	96 948	85%		
	Provincial	32 648	41 928	128%		
2015-2016	Municipal	81 562	43 929	54%	229 208	147 785
	National	114 804	81 130	71%		
	Provincial	32 842	22 726	69%		
2016-2017	Municipal	81 372	63 071	78%	230 550	200 281
	National	116 473	105 666	91%		
	Provincial	32 705	31 544	96%		
2017-2018	Municipal	81 239	76 723	94%	231 173	195 193
	National	116 997	81 199	69%		
	Provincial	32 937	37 271	113%		
2018-2019	Municipal	80 148	86 974	109%	232 923	205 329
	National	119 922	77 563	65%		
	Provincial	32 853	40 792	124%		
Total	Municipal	405 328	352 911	87%	1 151 504	969 678
	National	582 191	442 506	76%		
	Provincial	163 985	174 261	106%		
Total		1 151 504	969 678	84%		

Targets for Full Time Equivalents were also set in Phase 3. The target for the sector was to create 447 884 FTEs in Phase 3. The sector managed to create 334 486 FTEs in Phase 3 which is 78% of the set targets.

Financial Year	Sector	5 Year Target	FTE	% Achievement	Annual Target	Annual WO
2014-2015	Municipal	24 654	25 293	103%	84 514	77 169
	National	47 085	38 391	82%		
	Provincial	12 775	13 485	106%		
2015-2016	Municipal	25 887	16 224	63%	87 441	56 105
	National	48 417	32 117	66%		
	Provincial	13 137	7 764	59%		
2016-2017	Municipal	26 534	19 738	74%	89 671	62 878
	National	49 628	31 847	64%		
	Provincial	13 509	11 294	84%		
2017-2018	Municipal	27 198	25 163	93%	91 957	70 722
	National	50 868	33 059	65%		
	Provincial	13 891	12 500	90%		
2018-2019	Municipal	27 877	23 011	83%	94 301	67 613
	National	52 140	31 389	60%		
	Provincial	14 284	13 213	93%		
Total	Municipal	132 150	109 428	83%	447 884	334 486
	National	248 138	166 802	67%		
	Provincial	67 596	58 256	86%		
Total		447 884	334 486	75%		

The table below depicts the programmes implemented and reported by the Environment and Culture sector programme and its performance.

Programme [1]	Work Opp	FTE	Avg Wage [2]	Avg Duration	LI	WO Trained	Cost per FTE
Coastal Management	24 988	11 249	R 2 226,18	104	44%	8 349	R54 159,62
Municipal Infrastructure	1 108	115	R 2 239,49	24	91%		R27 503,97
Parks and Beautification	150 655	55 015	R 2 154,58	84	58%	16 359	R45 492,54
Sustainable Energy	1 267	340	R 2 649,94	62	74%	386	R46 008,40
Sustainable Land Based Livelihoods	477 699	151 056	R 2 080,48	73	58%	106 683	R44 637,94
Tourism and Creative Industries	44 097	19 926	R 2 300,60	104	44%	24 618	R57 327,58
Waste Management	269 864	96 785	R 1 961,54	82	64%	15 681	R38 096,44
Total	969 678	334 486	R 2 074,49	79	58%	172 076	R43 957,32

3. **How much of the spend was the wage (versus purchase of materials);**

Financial Year	Environment & Culture
2014-2015	R 1 562 995 811,59
2015-2016	R 1 386 542 155,20
2016-2017	R 1 644 333 817,83
2017-2018	R 1 934 780 752,31
2018-2019	R 1 966 355 039,90
Overall	R 8 495 007 576,82

A total of R8 billion was spent on wages in the sector during Phase 3.

4. **If the programme involved jobs in different kinds of activity, that would be useful to know (and if the cost per job varies across those)**

The Environment and Culture sector implements programmes across all provinces and spheres of government. Below are the key programmes implemented by the sector and their descriptions:

FOCUS AREA	DESCRIPTION OF PROGRAMMES	SECTOR PROGRAMMES
Sustainable land-based livelihoods	The creation of sustainable land-based livelihoods through activities that support land rehabilitation, clearing of invasive alien plants, the re-vegetation of landscapes, improving the productive potential of land, advocating and assisting communities, landowners and farmers with the implementation of appropriate agricultural and land-management strategies.	Comprehensive Agricultural Support and Land Care
		Working for Water
		Working on Fire
		Working for Wetlands
		Working for the Forest
		Other (Greening and gardening, fresh water farming, etc.)
Coastal management	This programme provides work and training for unemployed people in coastal communities to create and maintain a cleaner and safer coastal environment.	Working for the Coast
	Supporting the development of a sustainable fishing industry by promoting the conservation and sustainable use of marine resources, establishing certain water farming projects and facilities, and supporting the appropriate management of the fishing industry.	Working for Fisheries
Tourism and creative industries	This cluster of programmes provides work in the Tourism Sector and involves projects and programmes that contribute to the goals and	Working for Tourism
		Creative Industries
		Museum Services

	objectives of the government's tourism and heritage policies, with a focus on: • Tourism infrastructure development. • The development of tourist products. • Skills development and capacity building in the tourism industry and creative industries. • Supporting grassroots enterprises and practitioners in the cultural and creative industries. • Supporting initiatives which support the conservation of heritage and culture.	Cultural Services Language Services Heritage Services
Waste management	The Programme focuses on domestic waste management and the cleaning of public open spaces.	Working on Waste Urban Renewal Cleaning of Public Open Spaces Recycling
Parks and beautification	This cluster of programmes mainly involves: • Cleaning, clearing and the beautification of public open spaces such as municipal streets, parks, illegal dump sites, cemeteries, etc. • Supporting communities improve their local surroundings. • Developing infrastructure within protected areas.	People and parks Community parks
Sustainable energy	This area focuses on the provision of energy through renewable energy technologies and facilitating energy management through using LI methodologies to stimulate sustainable job creation, local economic development, technology skills transfer and capacity development within a South African context.	Working for Energy Other

5. What the impact has been so far?

The Environment and Culture sector conducted an Impact Evaluation for programmes implemented mostly by the Department of Environmental Forestry and Fisheries for Phase 3. Below are the summary findings on the impact of the programmes:

1. Environment and Culture sector has brought into focus on the national agenda the importance of investments in environmental protection and its relationship to the promotion of economic development.
2. E&C EPWP serves as an effective social protection mechanism for many participating households. The interventions mitigate the harsh impacts of poverty and unemployment but does not eradicate poverty or vulnerability completely.
3. The EPWP wage transfer has definitely provided an important source of income to a large numbers of households. It has contributed to enhancing consumption spending of households.

4. It has contributed to addressing hunger reduction and hence food security needs partially but not to nutritional security. This is confirmed with respect to the finding that most of the household income was spent on food. This is a well-known pattern for poor households who spend disproportionally on food.
5. Participants with longer duration of exposure to EPWP perceive their standard of living to be higher than those households exposed to shorter durations.
6. Participation in EPWP has allowed a substantial number of households with young children to invest in access to ECD provisioning and schooling. This is significant in the context of a substantial body of evidence which points to the positive role ECD access plays in breaking inter-generational poverty.
7. The income transfer has contributed to reducing debt and preventing participants from becoming indebted.
8. EPWP work experience has provided large numbers of young people with their first work experience, which is central to labour market access.
9. The programme has contributed to gender empowerment, with women who are earning reporting a new sense of agency and control over their lives.
10. The environmental assets created are reportedly contributing to growing the local economy. However, very little empirical evidence of the extent and nature of that impact is available.
11. Support to SMMEs through state procurement of services from SMMEs is a positive contribution to the sustainability of SMMEs.

Appendix C The ENCORE database and its application

C.1 FCM methods

1. Guided by a mapping of economic sectors from the E3ME model to similar sub-sectors used by ENCORE, we mapped a list of production processes to dimensions of the E3ME model. We then used data from ENCORE to create an interaction network describing positive and negative interactions between nodes, including three levels of intra-group materiality, high, medium, and low.

ENCORE not only includes the effects of production processes on ecosystem services, but their dependency upon them too. This means that as production processes put higher and higher demands on natural capital assets via impact drivers and drivers of environmental change, the "deficit" in ecosystem service provisions will begin to have a greater detrimental effect on those production processes dependent on them.

2. When using knowledge to tailor a FCM to a specific scenario, two types of connection strength can be specified. Most commonly known from real-world scenarios is an "effect strength", which describes the overall impact one node has on another. The other kind is an "interaction strength", which represents the intrinsic connection between two nodes and is the per capita influence one has on another.

We specify that interaction strengths vary by materiality strength as described in ENCORE The information in ENCORE describes conceptual "per capita" effects of one node on another, describing how intrinsically linked nodes are with a scientific evidence base, rather than quoting data from real-world scenarios. ENCORE contains hundreds of descriptions and knowledge bases linked to interaction strengths. For example, all production processes with a "high" impact on an impact driver will have a higher per capita interaction strength than those with a "medium" or "low" impact in the network. However, if a "medium" or "low" production process has an extremely high state value it can still have a larger overall effect.

We also specify some "effect strengths" using scenario-specific knowledge – the ability to do this easily is a key strength of FCM modelling. Dependencies of production processes on ecosystem services modelled as a disinhibition circuit, where a negative effect applied to a node that would otherwise cause its own negative effect leads to an overall positive change downstream in the network. In our first run of an experimental network model across four scenarios in South Africa, we specify two additional constraints:

- Water use: agriculture has the largest water use in our study scenario
- Mining: mining has a large per capita impact on impact drivers

3. We also had to account for uncertainty in our effect strengths. Causal loop diagrams traditionally ascribe positive/negative relationships between nodes without further indication of how that translates. FCMs use numbers between 0 and 1, alongside an activation function, to describe how nodes interact. We don't know our interaction strengths as they are difficult to measure (Baker et al, 2018), but we have lots of knowledge about the relative strengths of

interactions from ENCORE. We follow Baker et al (2018) in drawing interaction strengths from a random uniform distribution, accepting only sets of parameters that fit our constraints. The most common choice of activation function is a logistic function, which includes a shape parameter lambda, which represents how steep the “fuzzy” curve is and so how directly value flows from one node to another it is connected to. We randomly selected a lambda in each simulation that is suited to the network structure, constraining it to limit how large node sizes can grow to.

C.2 Mapping of E3ME sector to ENCORE production processes

E3ME economic sector	Linked production process
Agriculture etc	Alcoholic fermentation and distilling
Agriculture etc	Aquaculture
Agriculture etc	Freshwater wild caught fish
Agriculture etc	Large scale irrigated arable crops
Agriculture etc	Large scale livestock beef and dairy
Agriculture etc	Large scale rainfed arable crops
Agriculture etc	Saltwater wild caught fish
Agriculture etc	Small scale irrigated arable crops
Agriculture etc	Small scale livestock beef and dairy
Agriculture etc	Small scale rainfed arable crops
Air transport	Airport services
Air transport	Distribution
Air transport	Manufacture of machinery parts and equipment
Banking and finance	Financial services
Basic metals	Construction materials production
Basic metals	Iron extraction
Basic metals	Iron metal production
Basic metals	Metal processing
Basic metals	Mining
Basic metals	Steel production
Chemicals	Catalytic cracking fractional distillation and crystallisation
Chemicals	Cryogenic air separation
Chemicals	Gas adsorption
Chemicals	Incomplete combustion
Chemicals	Membrane technology
Chemicals	Natural gas combustion
Chemicals	Polymerisation
Chemicals	Recovery and separation of carbon dioxide
Chemicals	Solids processing
Chemicals	Synthetic fertiliser production
Chemicals	Vulcanisation
Coal	Mining
Communications	Cable and satellite installations on land
Communications	Fibre optic cable installation marine
Communications	Telecommunication and wireless services

Computing services	Infrastructure holdings
Construction sector	Construction
Construction sector	Glass making
Construction sector	Infrastructure builds
Construction sector	Infrastructure maintenance contracts
Construction sector	Manufacture of machinery, parts and equipment
Distribution sector	Distribution
Distribution sector	Distribution
Distribution sector	Distribution
Distribution sector	Distribution
Distribution sector	Distribution
Education	Infrastructure holdings
Electrical engineering and instruments	Cable and satellite installations on land
Electrical engineering and instruments	Electronics and hardware production
Electrical engineering and instruments	Infrastructure builds
Electrical engineering and instruments	Infrastructure maintenance contracts
Electrical engineering and instruments	Manufacture of machinery parts and equipment
Electrical engineering and instruments	Manufacture of machinery parts and equipment
Electrical engineering and instruments	Railway transportation
Electricity	Biomass energy production
Electricity	Electric nuclear power transmission and distribution
Electricity	Gas distribution
Electricity	Gas retail
Electricity	Geothermal energy production
Electricity	Hydropower production
Electricity	Infrastructure holdings
Electricity	Nuclear and thermal power stations
Electricity	Solar energy provision
Electricity	Wind energy provision
Electronics	Electronics and hardware production
Electronics	Electronics and hardware production
Electronics	Infrastructure holdings
Electronics	Manufacture of machinery parts and equipment
Electronics	Manufacture of semiconductor equipment
Food drink and tobacco	Alcoholic fermentation and distilling
Food drink and tobacco	Processed food and drink production
Food drink and tobacco	Production of leisure or personal products
Food drink and tobacco	Tobacco production
Forestry	Construction materials production

Forestry	Large scale forestry
Forestry	Production of forest and wood-based products
Forestry	Small scale forestry
Gas supply	Gas distribution
Gas supply	Gas retail
Gas supply	Infrastructure holdings
Health and social work	Infrastructure holdings
Health and social work	Life science pharma and biotech tools and services
Health and social work	Managed health care
Health and social work	Provision of health care
Hotels and catering	Cruise line provision
Hotels and catering	Hotels and resorts provision
Hotels and catering	Infrastructure holdings
Hotels and catering	Leisure facility provision
Hotels and catering	Restaurant provision
Hydrogen supply	Infrastructure holdings
Insurance	Financial services
Land transport etc	Construction
Land transport etc	Distribution
Land transport etc	Manufacture of machinery parts and equipment
Land transport etc	Railway transportation
Manufactured fuels	Manufacture of machinery parts and equipment
Mechanical engineering	Infrastructure builds
Mechanical engineering	Infrastructure maintenance contracts
Mechanical engineering	Manufacture of machinery parts and equipment
Mechanical engineering	Railway transportation
Metal goods	Alumina refining
Metal goods	Construction materials production
Metal goods	Iron extraction
Metal goods	Iron metal production
Metal goods	Metal processing
Misc. services	Infrastructure holdings
Misc. services	Leisure facility provision
Motor vehicles	Infrastructure holdings
Motor vehicles	Manufacture of machinery parts and equipment
Motor vehicles	Tyre and rubber production
Non-metal mining products	Mining
Oil and gas	Integrated oil and gas
Oil and gas	Manufacture of machinery parts and equipment
Oil and gas	Oil and gas drilling
Oil and gas	Oil and gas exploration surveys
Oil and gas	Oil and gas refining

Oil and gas	Oil and gas services
Oil and gas	Oil and gas storage
Oil and gas	Oil and gas transportation
Other business services	Distribution
Other business services	Infrastructure holdings
Other business services	Marine ports and services
Other manufacturing	Cable and satellite installations on land
Other manufacturing	Construction
Other manufacturing	Construction
Other manufacturing	Glass making
Other manufacturing	Houseware and specialities production
Other manufacturing	Infrastructure maintenance contracts
Other manufacturing	Jewellery production
Other manufacturing	Production of leisure or personal products
Other manufacturing	Tyre and rubber production
Other mining	Construction materials production
Other transport equipment	Distribution
Pharmaceuticals	Infrastructure holdings
Pharmaceuticals	Life science pharma and biotech manufacture
Pharmaceuticals	Life science pharma and biotech tools and services
Printing and publishing	Telecommunication and wireless services
Professional services	Distribution
Professional services	Distribution
Professional services	Environmental and facilities services
Professional services	Infrastructure holdings
Professional services	Infrastructure holdings
Professional services	Real estate activities
Professional services	Telecommunication and wireless services
Retailing	Infrastructure holdings
Rubber and Plastics	Vulcanisation
Textiles clothing and leather	Footwear production
Textiles clothing and leather	Manufacture of machinery parts and equipment
Textiles clothing and leather	Natural fibre production
Textiles clothing and leather	Production of leisure or personal products
Textiles clothing and leather	Synthetic fibre production
Water supply	Hydropower production
Water supply	Infrastructure holdings
Water supply	Water services e g wastewater treatment and distribution
Water transport	Distribution
Water transport	Marine ports and services
Water transport	Marine transportation
Wood and paper	Construction materials production
Wood and paper	Large scale forestry
Wood and paper	Paper packaging production

Wood and paper	Production of forest and wood-based products
Wood and paper	Production of paper products

cambridge econometrics

clarity from complexity

European Commission

Federal Ministry for the Environment, Nature Conservation, and Nuclear Safety

FORMIN.FINLAND.FI

MINISTRY FOR FOREIGN AFFAIRS OF FINLAND

NORWEGIAN MINISTRY OF CLIMATE AND ENVIRONMENT

Ministry of Environment Republic of Korea

Government Offices of Sweden
Ministry of the Environment and Energy

Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
State Secretariat for Economic Affairs SECO