DEEP DECARBONIZATION PATHWAYS

POLICY LESSONS ON DEEP DECARBONIZATION

in large emerging economies

SOUTH AFRICA

Hilton Trollip with the participation of Bryce McCall and Fadiel Ahjum

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Contact

Henri Waisman, henri.waisman@iddri.org
Hilton Trollip, hiltontrollip@gmail.com

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Editing: Marta Torres Gunfaus, Anna Pérez Català, Henri Waisman.
Layout: Ivan Pharabod.

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SOUTH AFRICA

Hilton Trollip, Honorary Research Associate,
Energy Systems Research Group, Department of Chemical Engineering, University of Cape Town.

Thanks to Bryce McCall and Fadiel Ahjum at the Energy Systems Research Group (ESRG) at the University of Cape Town as core team members of SA-DDP for providing quantitative analysis for this work. The first step of our analysis, to identify what is possible and important, is based on the ESRG modelling work.

Disclaimer

The results presented in this report are outputs of the academic research conducted under the DDP BIICS project as per the contractual agreement. The academic work does not in any way represent our considered opinion for climate negotiations and also does not reflect the official policy or position of the Government of South Africa.

WHY IS THIS REPORT SUBMITTED TO GST, AND WHAT TO EXPECT?

This report contains policy recommendations to realise national deep decarbonization pathways based on in-country scientific model-based analysis in four countries: Brazil, India, Indonesia and South Africa. This digest includes a description of deep decarbonization scenarios' main features, main synergies and trade-offs with country non-climate objectives, priority short-term policies and actions and key international enablers and accelerators of domestic transitions. Thus, it provides relevant information for the Mitigation, Finance flows and Means of Implementation & Cross-cutting thematic areas of the Global Stocktake (GST). Whereas the report does not provide a collective picture, bottom-up granular policy lessons from these four large emerging economies are essential input to assess the adequateness of the progress achieved and necessary action to keep the global long-term goals of the Paris Agreement within reach.

For each of these areas, we identify in the table below against which specific guiding questions, this report can provide relevant elements:

	In the DDP BIICS Policy Lessons Report you can find…
Mitigation	
2. What is the collective progress made towards achieving the long-term mitigation goal in Article 4.1 of the Paris Agreement, in the light of equity and the best available science?	Country assessments explored Current Policy Scenari-os (CPS) to understand the outcome of the current policy packages: main features and emission profiles can be found in Part I of each of the country chapters. Priority short-term policies and actions section in Part II discusses priorities based on a gap analysis be-tween CPS and Deep Decarbonisation scenarios (DDS).
3. What are the projected global GHG emissions and what actions are Parties undertaking to achieve a balance between anthropogenic emis-sions by sources and removals by sinks of GHGs, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty (Article 4.1 Paris Agree-ment, Decision 19/CMA.1, paragraph 36(b))?	The emission profiles of the DDS scenarios are in Part I of each of the country chapters. They represent a country-driven perspective of the national contribu-tion to the Paris Agree-ment global mitigation goal in the context of sustainable development. Projections explicit emissions by sources and removals by sinks.
Finance flows and Means of Implementation	
11. What are the barriers and challenges, including finance, technology development and transfer and capacity-building gaps, faced by developing coun-tries?	All country chapters put an emphasis on barriers and chal-lenges for realising the domestic transformations. This is namely covered in Part 2, including two specific sections on Investment patterns and Key international enablers and accel-erators of domestic transitions.
12. What is the collective progress made towards achieving the long-term vision on the importance of fully realizing technology development and transfer in order to improve resilience to climate change and to reduce greenhouse gas emissions referred in Article 10.1 of the Paris Agreement? What is the state of cooperative action on technology develop-ment and transfer?	This is best reflected under Key international enablers and accelerators of domestic transitions section in Part II for each of the country chapters. This digest focuses on the key enablers for the priority actions that have been identified to get onto the right path towards deep decarbonisation.
13. What progress been made on enhancing the ca-pacity of developing country Parties to imple-ment the Paris Agreement (Article 11.3 Paris Agreement)?	Progress on the enhancement of capacity is implicit in the assessment of the progress (as modelled in the CPS scenario) and the policy analysis of the gap that exists between current trends and the required level of action.

Cross-cutting	
16. To achieve the purpose and long-term goals of the Paris Agreement (mitigation, adaptation, and finance flows and means of implementation, as well as loss and damage, response measures), in the light of equi-ty and the best available science, taking into account the contextual matters in the preambular paragraphs of the Paris Agreement: a. What are the good practices, barriers and chal-lenges for enhanced action? b. What is needed to make finance flows consistent with a pathway towards low GHG emissions and cli-mate-resilient development? c. What are the needs of developing countries related to the ambitious implementation of the Paris Agree-ment?	The DDP approach underlying this report's research is funda-mentally a country-driven exploration, back casting from the mid-century emission and socio-economic objectives to inform the short-term deci-sions within and across systems. Sectoral deep dives allow for an in-depth investigation of all levers, which are traditionally represented poorly in existing long-term roadmaps. Country-level lessons derive critical informa-tion for international discussion on overall progress, thus the entire report brings relevant evi-dence to this cross-cutting question.
17. What is needed to enhance national level action and support, as well as to enhance international co-operation for climate action, including in the short term?	The analyses underpinning this report have been de-signed under the premisses that scientific assess-ments should be seen less as an instrument to illus-trate transition pathways in a normative manner than as a way to determine the inclu-sive whole-of-society conversation that would be required to make the transition effective and acceptable in specific contexts. The gap between existing evidence and concrete ac-tion highlights that the carbon neutral transition is not only a matter of techno-economic feasibility but es-sentially a question of political economy and policy implementation. The report intends to bring clarity for each of the countries about the choices to be made in the transition, about the concrete policies and ac-tions that can be envisaged, about those who can be winners and those who may lose, and the measures adopted to manage the socio-economic costs of the transition. As a high-level digest, this is captured in Part 2 of the country chapters.

FOREWORD

Henri Waisman, Marta Torres Gunfaus, Anna Perez Catala, IDDRI.

The world has agreed to prevent the irreversible damages to human and natural ecosystems caused by anthropogenic global warming by limiting the rise of global temperature to well below 2°C and to pursue efforts to limit it to 1.5°C. To this, the Paris Agreement grounds this goal in terms of global emission trajectories and the need to embed them in the in the context of sustainable development and efforts to eradicate poverty. Subsequently science (IPCC SR1.5) further specifies that global neutrality concerning carbon dioxide specifically should happen between 2050 (for 1.5°C) and 2075 (for 2°C). It also points out the necessity of minding non-CO_2 forcers to maintain the global objective. To reach this scale of emission reductions, the scientific assessment concludes that rapid and far-reaching transformations, far beyond what has been observed in the past, are required in all components of the economic system, ie in energy, urban and infrastructure, industry and land and ecosystems. Such drastic transitions in turn require profound changes in technologies but also in social, economic, institutional and policy conditions. Science finally shows that the changes required by climate objectives can be compatible with broader sustainable development objectives if action is implemented without delay, is guided by strategic visions of transformations informing the design of well-designed policy packages and the cooperation among actors and is enabled by effective international cooperation. With these framework conditions at hand, countries are set to explore national pathways to explain how the rapid and far-reaching transitions required globally can happen in each country context.

National deep decarbonisation of large emerging economies has been largely explored from a techno-economic perspective, resulting in viable sets of long-term pathways under a number of conditions. Existing analysis shows that the national transition can mostly been initiated using existing technologies and market instruments at low and often net negative financial cost and that, usually, these transformations can have associated large overall net economic benefits when external economic costs and benefits are factored in. However, similar to most parts of the world, most major necessary decarbonisation transformations are either not happening or happening at a slower pace. This gap between existing evidence and concrete action highlights that the carbon neutral transition is not only a matter of techno-economic feasibility but essentially a question of political economy. Actual implementation requires clarity about the choices to be made in the transition, about the concrete policies and actions that can be envisaged, about those who can winners and those who may loose and the measures adopted to manage the socio-economic costs of the transition. Scientific assessments should therefore be seen less as an instrument to decide transition pathways in a normative manner than as a way to inform the inclusive whole-of-society conversation that would be required to make the transition effective and acceptable.

The DDP community behind this report has committed to this vision of the role of scenario analysis in the public debate. The body of knowledge emerging from this community aims at ensuring that the features of the techno-economic deep decarbonisation transformations are contextualized in the diversity of country circumstances and described with sufficient details and granularity to inform decisions required to drive these transformations. Key challenges to date, which are critical to increase ambition and accelerate action, include: connecting the scenarios analysis and the diversity of policies and actions to implement in the real world; revealing the critical conditions that are outside the control of national authorities, where international cooperation must play a role; ensuring ownership of the insights emerging from the scenarios by a diversity of actors to empower them in the public debates.

The DDP approach underlying this report's research is established with these key challenges in mind.

It is fundamentally a country-driven exploration, back casting from the mid-century emission and socio-economic objectives to inform the short-term decisions across systems. Sectoral deep dives allow for an in-depth investigation of all levers, opportunities and challenges suited to inform domestic stakeholder debate in highly complicated sectors, such as transport, industry, or agriculture/land-use, which are traditionally represented poorly in existing long-term roadmaps. The stakeholder engagement approach to the development of the scenarios and emanating policy insights is an essential mean for these scientific assessments to serve an action agenda.

This report presents a synthesis of the results of the assessment conducted in India. Part I describes the main features of the economy-wide Deep Decarbonization Scenario(s) (DDS), including a description of key national-scale socio-economic aspects and an explicit characterisation of the emission objective and trajectory. To realise the necessary changes to get on track to this path, a description of the Current Policy Scenario (CPS) is also presented, including a description of the main policies and actions considered. Scenario results include an in-depth description at sector level for the deep dives selected by each country. Part II focuses on key policy lessons, which can serve as direct inputs into policy conversation at the country level. It includes a description of the main synergies and trade-offs with country non-climate objectives, priority short-term policies and actions, with a focus on where shifts from current paths are critically required, investments patterns and key international enablers and accelerators of domestic transitions.

SOUTH AFRICA

INTRODUCTION

The techno-economic features of emissions pathways have been modelled to show how a low carbon pathway might be approached by 2050 and to inform policy analysis to serve a short-term action agenda[1]
The pathways rely on highly detailed modelling to assess economic sectors, industries and activities relevant to CO_2[2] emissions and to highlight areas for priority mitigation action and policy attention.

To be meaningful, long-term techno-economically plausible ambition requires feasible short-term action
An inspiring and effective action agenda requires clarity about what is important, which then informs consequent prioritisation and pragmatic action. Techno-economic modelling shows what technical actions are necessary in an ideal simulated world, and what actions to avoid, and the timing of the actions, in order to move onto, and then stay on, the long-term pathways.

Structure of this report
Groups of key techno-economic features of long-term pathways are presented for time periods and sectors. On the basis of these, priority techno-economic measures are identified. Then, policy analysis incorporates political and institutional factors to come up with recommendations for feasible strategic short-term policy actions to implement the techno-economic measures within the real world of competing priorities and interests.

1 This is a stand-alone paper but has been produced in conjunction with three other papers: "Policy Lessons Decarbonization policy implementation in South Africa", "South Africa Climate Mitigation Policy Ambition" and "South Africa – DDP Sectoral Deep Dives: Green Iron.
2 It also covers quantitative analysis for all other significant GHG emissions to serve the processes of prioritization and an action agenda. All emissions quantities, unless otherwise specified, refer to CO_2.

PART 1: SCENARIO RESULTS

CONSTRUCTING THE SCENARIOS

Two scenarios were modelled using the SATIMGE[3] model: the current policy scenario (CPS) and the deep decarbonisation scenario (DDS)
The CPS and DDS use the same underlying assumptions about economic structure and growth. For mitigation policy, the CPS incorporates existing policies-and-measures (PAMS). For DDS, an 8GtCO_2eq cumulative emissions cap[4] is imposed with SATIMGE to identify least-cost options and associated energy system, economic and emissions pathways.

Optimistic[5] general economic policy scenarios are modelled as a context for mitigation
Optimistic scenarios rely on successes in policy reforms to address structural economic issues to reverse a decade-long increasingly severe poverty and unemployment crisis. They align with similar optimistic scenarios in a number of official definitive papers from the South African Reserve Bank and National Treasury, notably the National Treasury paper *"Economic transformation, inclusive growth, and competitiveness: Towards an economic strategy for South Africa"* (National Treasury, 2019). The Covid-19 pandemic introduced severe short-term negative impacts which are factored in[6].

Scenarios use mid-level UN population forecast of 75m in 2050, a 25% increase over 30 years. Urban/rural ratio goes from 66:34 to 80:20

Economic growth and the evolution of economic structure are endogenously modelled
Along with population growth, assumptions regarding three core drivers of economic growth, namely total factor productivity, foreign investment and labour supply growth are used in the SATIMGE model to endogenously simulate growth and evolution in economic structure.

GDP increases 221% and GDP/cap by 174%
GDP increases accelerate: 22%, 31% and 38% in 2020-2030, 2030-2040 and 2040-2050. Income inequity decreases and poverty is substantially reduced as the 'low income' household category decreases from 48% to 28% from 2020-2050.

Conservative assumptions[7] are rigorously adopted in modelling decarbonisation transitions in core parameters such as cost evolutions of low-emissions technologies.
The intention in choosing the conservative end in ranges of parameters, especially those projecting far into the future, is to avoid skewing the essential features of the decarbonisation transformations towards making them more plausible than the level of uncertainty suggests. Validating assumptions on core parameters and adjusting where appropriate has been a key focus of policy analysis and stakeholder engagements to inform modelling.

The core global-scale exogenous parameters include costs of electricity generation technologies, energy storage; vehicle drive-train and basic material industry process technologies

3 SATIMGE: energy systems model linked to a detailed economic model developed at the Energy Systems Research Group, University of Cape Town. Detailed bottom-up modelling (SATIM) of the energy system (including all economic and consumption activities is done linked to an economy-wide computable general equilibrium (CGE)
4 An 8Gt cumulative emissions cap would imply significant progress on the South African 2015 NDC. Appropriate levels for the next iteration of the NDC are subject to official processes that this DDP analysis seeks to inform.
5 A full range of scenarios would include scenarios covering (not completely unlikely) exogenous general economic policy conditions causing ongoing economic stagnation etc.
6 As of end of 2020 – the pandemic has had further substantial negative impacts and continues to (22 September 2021)

7 The modelling requires assumptions to be made on key numbers such as the cost of a battery electric vehicle in 2040, or the cost of an industrial process not yet fully commercialized, such as hydrogen-reduced direct reduction iron. Much expert opinion and the best available science are employed. The modelling aims at being as open source as practicable and is backed up by numerous public domain reports.

RECENT ECONOMIC HISTORY AND CURRENT SITUATION

The economy is characterised by a decade of economic stagnation, falling investment and de-industrialisation, increasing unemployment, now at 34.4%, increased poverty and inequity and increasing social instability
The South African National Planning Commission[8], stated in December 2020 that: "*Over the past decade, there have been clear signs of danger that South Africa could veer towards a downward spiral. … We are in a vicious circle ensuing from a toxic confluence of factors, namely falling investment, further diminishing tax revenues, and debt service costs that crowd out all other spending and thus constrain resources for investment in development. The results are falling employment and rising poverty and inequality.*"

The worsening socio-economic situation, exacerbated by the Covid-19 pandemic, has recently been further complicated by the July 2021 insurrection.
Poverty and unemployment provide a fertile ground for social and political instability. The insurrection started in conjunction with the arrest of former president Zuma. Three-hundred and thirty-six (336) people were killed and there was widespread violence, destruction, and economic damage with key transport routes closed and infrastructure damage. This exacerbates the economic *'vicious cycle'*.

8 NPC (2020) Economic Progress towards the National Development Plan's Vision 2030. Executive Summary. South African National Planning Commission (NPC). December 2020. Available at: www.nationalplanningcommission.org.za/publications_reports.

An economically crippling electricity shortage has been one of the main causes of economic decline
This is detailed in the electricity section below. From an economy-wide perspective, international policy enablers are relevant to supporting emissions mitigation policy which is also the most effective measure to simultaneously address the electricity shortage.

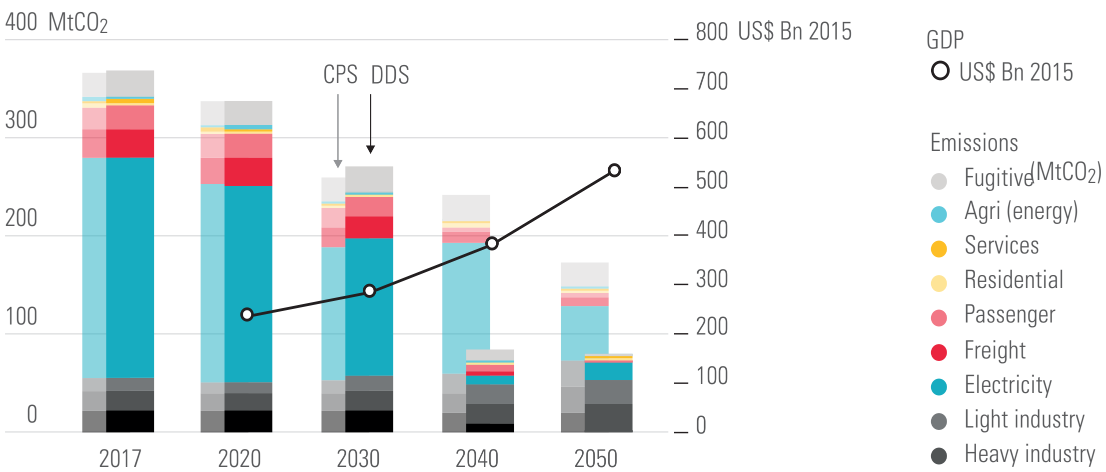
TECHNO-ECONOMIC KEY FEATURES OF THE SCENARIOS

2020-2050: Economy-wide scenario

Substantial economy-wide decarbonisation of the South African economy from 377 to 78Mt[9] CO_2 is techno-economically possible with little impact[10] on GDP
The most striking feature comparing the scenarios for overall emissions mitigation policy over the long term is that GDP is very similar for the CPS and DDS. This means that, to reach 78Mt of residual emissions in the aggregate, there is no aggregate GDP net loss to the economy compared with the CPS.

9 All emissions numbers stated in Mt refer to annual emissions (i.e. Mtpa) unless otherwise specified. This does not include non-CO_2 emissions – see section on industry for details on these. Unless specified, this report only considers decarbonisation. This includes CO_2 as a process emission.
10 Within the resolution** of input data and assumptions and the modeling the differences between CPS and DDS GDP results are very small: smaller than the resolution – in 2050 DDS GDP is 1% less than CPS. It is 2% higher in 2030 and 1% lower in 2040..

Figure 1. GDP growth and emissions from energy for CPS and DDS



GDP is dominated by services, but minerals based industry and coal-generated electricity remain tightly inter-linked with the economy and contribute most emissions. Industry accounts for more than 50% of electricity demand. Over the 2020-2050 period industrial GDP contribution decreases from 26%-22%. This could vary widely depending on economic and industrial policy – see later.

In the DDS, electricity generation (200 to 16Mt) and transport (51 to 3Mt) decarbonise almost completely. Industry CO_2 emissions increase (30 to 53Mt).

Residential and services emissions remain at a low ~5Mt.
Residential and commercial buildings account for 45% of electricity demand but because electricity decarbonises completely their induced emissions are close to zero by 2050.

The differences in emissions reduction between CPS and DDS are striking, between overall decadal rates and between sectors.
Emissions reduce about 20% for both scenarios over 2020-2030, but then reductions in CPS stall and DDS has a huge 70% reduction from 2030-2040. Then DDS stalls from 2040-2050.

These differences are stark pointers to where (in which sectors) and when policy action is necessary and also to the challenges that have to be addressed by effective decarbonisation policy.

Decarbonisation of electricity is important in its own right but also a central requirement for decarbonisation of all other sectors

It is crucial that the DDS is viewed not only as an emissions pathway but also as a socio-economic development opportunity
This is both from the perspective of social and economic justice but also from the perspective of the minimum progress in addressing poverty and under-employment being necessary to sustain the political stability consistent with South Africa's other transitions: the democratic transition and a transition from undue impacts of an extractive[11] economy which has historically been and still is a main cause of gross inequity and poverty. These transitions are intertwined.

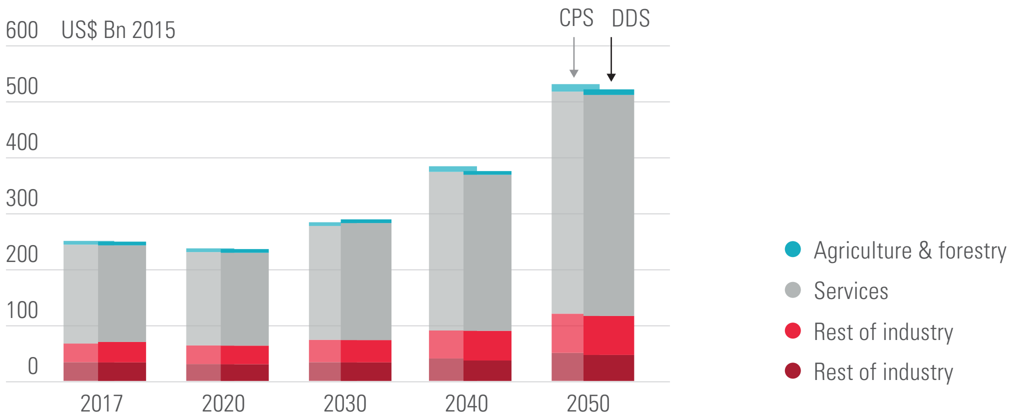
2020-2030 Decade

Both CPS and DDS emissions reductions of about 20% over 2020-2030 are very similar. Thus from 2020-2030, the DDS is basically a least-cost pathway. CPS requires an additional R170Bn capital investment costs compared to DDS

Costs of renewable energy electricity generation drive reductions in electricity emissions from 200-141Mt (59Mt) which is 90% of the total economy-wide emissions reductions of 67Mt over 2020-2030.

11 This is meant in the sense of an economy based on extractive institutions, not the physical extraction of minerals – see Acemoglu, D. and Robinson, J. A. (2012) Why Nations Fail: The Origins of Power, Prosperity and Poverty. 1st edn. New York: Crown. ;

Figure 2. Economic structure - GDP



For the CPS, electricity generation is specified by the officially mandated generation capacity expansion plan, the Integrated Resource Plan (IRP2019). Virtually the same electricity generation and emissions patterns result for the DDS.

Transport emissions also decrease 20%, from 51-41Mt (10Mt) but are a much smaller proportion of the total. Transport emissions reductions are driven by transport policy, mainly modal shift.

Possibly the most critical result in the techno-economic analysis is the urgent need to add wind and solar-PV generation as soon as is practicable to close a serious short-term supply gap and then to implement 20GW of renewable energy, at least, from 2021-2030 both as a least cost energy plan, regardless of emissions and to get onto the DDS. This result provides the focus on electricity for the main parts of this paper below.

2030-2040 Decade

The large difference (158Mt) of emissions reductions in the CPS and DDS pathways between 2030-2040 is one of the most notable features of South African decarbonisation.
CPS and DDS start at similar levels of ~265 but CPS hardly drops and DDS goes down to 83Mt, resulting in a huge difference of 158Mt by 2040. About 80% is due to electricity generation emissions reductions.

It is also notable that for DDS, significant additional mitigation costs are incurred over least-cost CPS. An additional capital investment of R400Bn is required for electricity over the period.

Most economy wide emissions reductions (130/158Mt) result from a shift to renewable energy electricity generation.
This requires substantial additional investments in renewable energy generation capacity. Existing coal power stations are run well below capacity, substituted by wind and solar-PV.

Transport decarbonization involves a shift to electric and hydrogen technologies which relies on decarbonization of electricity.

Passenger transport decarbonizes at the same rate in DDS as CPS mainly due to reductions in battery-electric vehicle costs.
Emissions reduce from 20 to 6Mt, a 75% reduction.

Freight transport emissions reduce from 20 to 9Mt in CPS vs. 20 to 9Mt in DDS, indicating no additional costs for mitigation in DDS.

The first successes in substantial industrial process emissions mitigation occur in this period, in zero-emissions iron production.

2040-2050 Decade

DDS emissions reductions stall in 2040, decreasing marginally from 83 to 78Mt in 2050. Mainly industrial emissions remain.

In 2040 there are 11Mt electricity, 21Mt heavy industry and 19Mt light industry emissions.
About half of this residual 83Mt could be affordably decarbonised with existing technologies, though at additional cost, leaving a residual of 40Mt, mainly in heavy industry processes.

Residential and services emissions.
These contribute less than 1% of total emissions in 2020 and 2050: a total of ~5Mt in 2050.

'Residual' emissions Policy – Not a current priority

There is high uncertainty over how the last 40Mt of heavy industry[12] emissions will be decarbonised.
But it is likely that solutions will be found in the coming thirty years and so the DDS can be viewed as approaching a net-zero 2050 target. While these 40Mt need attention, we don't allow that to divert our focus for this piece to serve a short-term action agenda.

12 This is with the current exception of iron and steel production which is decarbonised in the DDS

SOCIO-ECONOMIC FEATURES OF THE SCENARIOS

Distribution of costs and benefits

There has been considerable contestation around emissions mitigation policy and resistance to implementation.

Uneven distribution of costs and benefits would be associated with transition to renewable energy if not addressed by complimentary policy measures

While reaching 78Mt[13] has a neutral GDP effect on the overall economy there is a very uneven distribution of benefits and costs. Renewable energy generators and related equipment and services suppliers will benefit directly. Owners of coal-related assets including mineral rights, mines, and coal power stations will suffer very large (>ZAR trillions) direct losses. This creates large challenges. Some of these will be addressed in this chapter but problems such as the loss of coal-sales revenues to minerals rights holders, espcially when they have significant economic and political influence present difficult policy challenges.

There are also "indirect[14] " transition costs/impacts not captured in the model that pose policy challenges

Many workers will lose jobs in coal and related industries, and other industries such as motor vehicle manufacturing[15] and cannot simply take up the new jobs in (for example) renewable energy industries. This could be because of skills mismatches or because, for example, coal industries are concentrated in a few geographic areas and whole communities in these areas are dependent on coal workers and cannot simply move.

Dedicated policies could have an additional and substantial positive impact on aggregate GDP and employment. If these are implemented they could assist with distribution of benefits and alleviating negative impacts

As mentioned above, economic growth was modelled endogenously in SATIMGE. Factor productivity[16] drives incremental growth. However, substantially higher growth driven exogenously is possible. Global decarbonisation will create demand for decarbonised commodities (such as hydrogen as a fuel), intermediate goods (such as zero-embodied emissions steel) and zero/low-embodied emissions final products. South Africa has a comparative advantage in its renewable energy resources, especially high insolation and land for solar-PV farms which could make these low/zero-embodied emissions commodities and goods competitive in export markets where there could be shortages of zero-emissions electricity and hence higher prices.

Thus, a central and foremost economy-wide policy challenge is to identify, acknowledge and assess the imbalances of distributional impacts across industries, sectors and stakeholders, to identify social costs, and then to find policy solutions to address these

This is necessary both from a social justice perspective and to facilitate necessary support to implement these policies. South Africa is a rights-based constitutional democracy and transitions of the magnitude involved in decarbonisation need to be designed and implemented according to principles of procedural justice involving those affected by the transitions in planning the transition and justice in outcomes, ensuring negative impacts are addressed and ensuring positive benefits are equitably distributed.

Income poverty

SATIMGE simulates income poverty via income distribution among three household income levels at national level: high, medium and low, with low-income indicating a poverty[17] category. SATIMGE has additional descriptions of detailed household energy

13 With pro-active policy intervention it could be positive

14 These costs are no less important for not having direct calculable impacts in quantified financial terms. The number of jobs lost can be calculated but the social costs of either transferring to a different industry or being unemployed, especially when whole communities are regions have large impacts are not easily quantifiable. However they are real and have social welfare, economic and political ramifications that need to be addressed in policies that implement the transition.

15 Some industries such as internal combustion engine (ICE) motor vehicle (MV) manufacturers may not be able to transition because of large capital costs and international competition and demand is expected to drop rapidly for their products.

16 This is a core economic modeling parameter in the CGE model of SATIMCGE

17 Below certain household income thresholds a number of other household poverty indicators are highly likely although poverty measures are complex.

services which can also indicate poverty. Cooking and heating with coal, wood and paraffin are strong indicators. Most South African households are connected to electricity but affordability linked to low income leads to energy shortages and use of fuels with severe health and safety impacts.

There will be a substantial shift from 55% to 85% of households with affordable electrified energy services from the current situation of widespread energy poverty.

Given the core goals of decarbonisation and poverty eradication, this is an important indicator mainly because it shows that, at the aggregate level, decarbonisation can take place at the same time as reduction of income poverty. On their own, such aggregates are just an indicator and need to be integrated with other poverty reduction considerations. With the much lower proportion of low-income households (15%) by 2050, dedicated measures to alleviate income-effects on poverty become much more politically and economically feasible, such as dedicated energy assistance packages with the potential to eradicate energy poverty.

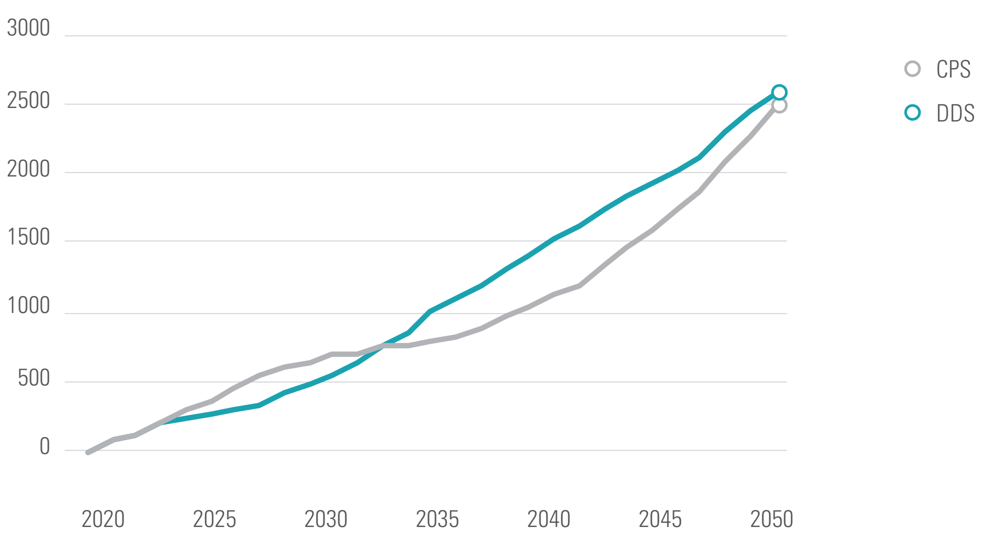
SECTOR-LEVEL RESULTS

Electricity

Overall electricity production, GDP and links to industry

In DDS scenario, electricity production increases from 217 to 380TWh (175%) in the 2020-2050 period, substantially less than the 221% GDP increase. This aligns with the services-dominated GDP increase and low level of industry decarbonisation via electrification; electricity only increases from 40 to 50% of energy usage and there is little improvement in energy intensity. Energy-intensive industry is by far the biggest user at about half of electricity demand, but its sectoral GDP only increases about 150%. The increase in total electricity production in the DDS is similar to CPS until 2030 and then only about 15% higher over the subsequent two decades. Industry remains largely un-decarbonised and if decarbonisation of these sectors is ultimately is via electrification (such as in Green Iron (GI) see industry section below), this will likely require substantial additional electricity to the current DDS. To achieve 8Gt the current DDS does not yet decarbonise most energy intensive industry either because it is too costly for thermal uses (swapping coal in boilers with electricity), or will rely on innovative industrial processes that have yet to be developed.

Figure 3. Cumulative electricity capital investment post 2021 in CPS and DDS [ZARm]



Physical transformations of electricity supply

The model-based analysis delivers an optimal least-cost pathway that involves a penetration of 20GW of renewable energy over 2020-30 for both CPS and DDS, but for both CPS and DDS this path is currently being disrupted and could be far from optimal in terms of broader economic considerations. The disruptions that have been underway for six years are the result of paralysis in electricity policy implementation and investment in new generation (see policy analysis section below). This will take at least a few years to 'correct' from when action begins. The disruptions are evidenced by an electricity shortage crisis, not mitigation policy. Because renewable energy is the largest part of a least cost and fastest solution this could likely speed-up emissions reductions through earlier substitution of coal generation because of poor coal plant performance. This could result in substantially more than 20GW of wind and PV being built. The reduction in electricity emissions in the DDS from 2020-2030 results from a generation system pathway which aligns with the current official IRP2019 generation expansion plan. This plan is based on least cost: emissions reduction was not an objective in formulating the plan. At the core of this plan is the addition of more than 20GW of PV and wind generation which will substitute coal-generation. Achieving the DDS mitigation pathway for electricity by 2030 therefore only requires existing policy to be implemented. In practice, however, the last decade has evidenced severe problems with implementing officially mandated policy.

It is imperative that at least 20GW of renewable energy generation are added by 2030. Its deployment should start as soon as possible and be done as fast as possible until the supply gap is filled. The core of a least-cost solution to an existing critical capacity shortage of between 4,000-8,000MW would be immediate rapid acceleration of wind and solar-PV additions to the grid. This is a no-regret techno-economic option. Neither the shortage nor this acceleration are modelled in the simulations underpinning CPS and DDS scenarios. While the most damaging effects of the shortage are managed black-outs, 'voluntary' curtailments of electricity-intensive industrial production, and running diesel-turbines, the record of the contribution of existing ~6GW of renewable energy generation shows that, despite this being variable and non-dispatchable, it has contributed substantially to reducing the intensity and periods of shortages on the national grid.

About 4,400MW of new coal generation is 'forced' into the DDS and CPS because it is in the current official IRP2019 generation expansion plan. From a purely techno-economic perspective, the IRP2019 report states that new coal generation is not part of a least-system-cost solution, even with no emissions constraint in the 2020-2030 period. Detailed studies[18] confirm this. From a broader economic perspective, two recent attempts to establish new coal power stations in South Africa, even with very favourable government support, failed to find financial backing[19]. Eskom's existing fleet of largely old coal-fired power stations is operating at very low and declining energy availability factors (EAFs). It is highly plausible that the power shortage could worsen. The situation has been deteriorating and EAFs are far lower than the SATIMCGE assumptions use in CPS and DDS scenarios. Altogether, it is becoming increasingly likely that the new coal capacity will not materialise. If so, on a least-cost pathway, a substantial increase in wind and solar-PV will be required.

Least-cost electricity generation from 2030-2040 without an emissions constraint (CPS), results in electricity emissions levelling out – coal electricity production stays constant and the increase in demand is met mainly by solar-PV[20]. However, with the economy-wide 8Gt emissions constraint (DDS), there is a profound shift with coal generation phasing out completely. Previous coal generation of some 125TWh (in CPS) is substituted, plus an increase in demand is provided by 209TWh of wind generation out of a total of 274TWh. This is made possible by an addition of 41GW of wind from 2030-2040 and requires an

18 McCall, B. et al. (2019) Least-cost integrated resource planning and cost optimal climate change mitigation policy: Alternatives for the South African electricity system. Available at: https://sa-tied.wider.unu.edu/sites/default/files/pdf/SATIED_WP29_February_2019_McCall_Burton_Marquard_Hartley_Ireland_Merven.pdf.; Wright, J. G. et al. (2019) 'Long-term electricity sector expansion planning: A unique opportunity for a least cost energy transition in South Africa', Renewable Energy Focus. Elsevier Ltd, 30, pp. 21–45. doi: 10.1016/j.ref.2019.02.005.

19 Government energy policy and regulatory agencies approved the power stations and offered sovereign guaranteed power purchase agreements. Even if government attempted to directly finance these through state ownership, substantial barriers would be experienced owing to Eskom's financial crisis and its aims to receive assistance for this via international climate finance.

20 Wind plays a role and gas (or other 'firm' power to cover variability) too but we focus on the main features of the transition in energy supply.

additional investment of R400Bn over CPS to accelerate phase out of coal to renewable energy electricity generation.

It is important to note that recent changes to regulations to allow private generators of less than 100MW onto the grid without requiring a license and empowering municipalities to procure power from independent power producers were not taken into account in the model-based scenarios. Both DDS and CPS use assumptions about the timetables in planning, procurement and regulatory processes which these latest regulations change substantially. Beforehand it was assumed that most generation additions would be the result of complicated government procurement and subject to complicated regulatory processes. The recent policy change could see 5,000MW of mainly solar-PV coming onto the grid in the next few years. Most of this would not have come onto the grid or would have been added much more slowly. Municipalities, and municipality customers could also add substantial amounts quickly. In the context of the economically crippling 'voluntary' curtailment of demand and controlled blackouts, this could significantly change the 2020-2030 pathway in terms of substantial additional renewable energy generation coming onto the grid much earlier than previously assumed. However, this won't substantially reduce emissions until the power shortage is over because it will be meeting suppressed demand.

Upstream renewable energy equipment industry links and economic benefits[21]

Additional economic considerations in relation to the power sector transformation, not explicitly included in the modelling, reveal further important techno-economic factors relevant to short-term policy. The largest is that the upstream renewable energy equipment manufacturing industry could be a substantial contributor to economic development and employment[22]. Most of the equipment installed in the 6GW, R200Bn renewable energy independent power producer procurement programme (REI4P) was imported. South Africa has the potential to manufacture most of this. The upstream equipment supply sector is included in the CGE part of SATIMGE, but SATIMGE currently optimises least electricity generation system costs, not including the upstream equipment manufacturing industry. This needs to be considered in broader economic and industrial policy analysis.

In DDS, 12GW of wind-generation capacity is added in 2020-2030; then 41GW in 2030-2040; and then 19GW in 2040-2050. If this equipment were to be supplied from local manufacture, this erratic demand would not facilitate easy linkages between the renewable energy construction programme and growing local renewable energy equipment manufacturing. From a national economic development perspective, upstream linkages should be factored into new renewable energy generation build rates.

Electricity demand and downstream energy intensive industry links

South Africa has a potential international advantage in the costs and amount of available renewable energy.Thus export markets become highly relevant. The recently accelerating commitments by countries and companies to zero-emissions targets are stimulating international demand for zero-embodied emissions commodities and goods. This demand could stimulate exports from South Africa that could create a demand for electricity many times that of the addition in the domestic demand-driven transition[23]. In essence, this involves exporting embodied renewable energy electricity. As SATIMGE models electricity demand endogenously[24], differing from other approaches that provide other feasible, plausible and relevant futures with a wide range of

21 The aim is to attempt to limit the analysis in this paper to techno-economic issues modeled in SATIMCGE but there are some important additional areas that need to be mentioned if not quantified

22 Definitive analysis of potential employment in upstream renewable energy equipment manufacturing is outstanding but there are indications that this could be among the most substantial and significant benefits of the transition to renewable energy. This is in addition to the incontrovertible analysis that shows that, even with imported equipment, the 2020-2030 period transition provides a least-cost electricity system while also playing a core role in addressing the electricity shortage.

23 See: Roos, T. and Wright, J. (2021) Powerfuels and Green Hydrogen (public version). https://www.researchgate.net/publication/349140439_Powerfuels_and_Green_Hydrogen_public_version ; Patel, M. " (2020) Green hydrogen: a potential export commodity in a new global marketplace. ww.tips.org.za/images/TIPS_Green_hydrogen_A_potential_export_commodity_in_a_new_global_marketplace.pdf ; Bischof-niemz, T. (2021) Green Hydrogen Export Opportunity for South Africa. Available at: www.ee.co.za/wp-content/uploads/2021/02/Tobias-Bischof-Niemz-presentation.pdf

24 As mentioned in the introductory section on *"CONSTRUCTING THE SCENARIOS"*, this method uses domestic demand drivers to derive growth.

electricity demand, the detailed exploration of export markets becomes central to energy policy planning. Under DDS, the production of "Green Iron" for export deep dive was explored and revealed the strong links with electricity demand projections (see Industry section below for details).

Dispatchable and firm power system assets and network services

DDS power sector transformation relies on the transition from one main energy source for electricity generation, namely coal, to renewable energy sources: wind and solar-PV. The latter are variable and non-dispatchable. To supply reliable power at every time of the day and night and every season, when "the wind might not be blowing and the sun not shining", sources of firm power are needed. Also, the transmission and control networks have to transition to handle very different power flows and new geographic distribution of generators. SATIMGE modelling includes the necessary firm power and estimates of network costs associated with the transitions to renewable energy generation in both CPS and DDS.

Industry

Overall sector production, GDP and emissions

Overall industry production growth of 184% is lower than overall GDP growth of 221% but is still substantial. Light industry remains at 13% of GDP while heavy industry decreases from 13% to 9% of GDP. However, this still involves growth of 154% and 214% respectively for light and heavy industry.

Average emissions intensity for all sectors remains relatively constant except for iron and steel. In general, the 8GT cumulative emissions cap did not lead to decarbonisation of industry except for iron production, which is a special case – see below. SATIMGE became unstable when lower emissions caps were attempted and thus, for this analysis, these sectors remain in the "difficult to abate" category in overall terms. Basically, for most of the heavy industries technologies do not exist to model abating emissions economically and South Africa does not have carbon capture and storage (CCS) resources. For light industry the differential between coal and gas prices for heating and electricity for heating which could technically be used for decarbonisation are simply too large for credible decarbonisation at this stage. Other technologies such as concentrated solar power or more stringent mitigation policy could theoretically achieve full decarbonisation under more stringent emissions reduction policy.

Figure 4. Overall sector production (Mt)

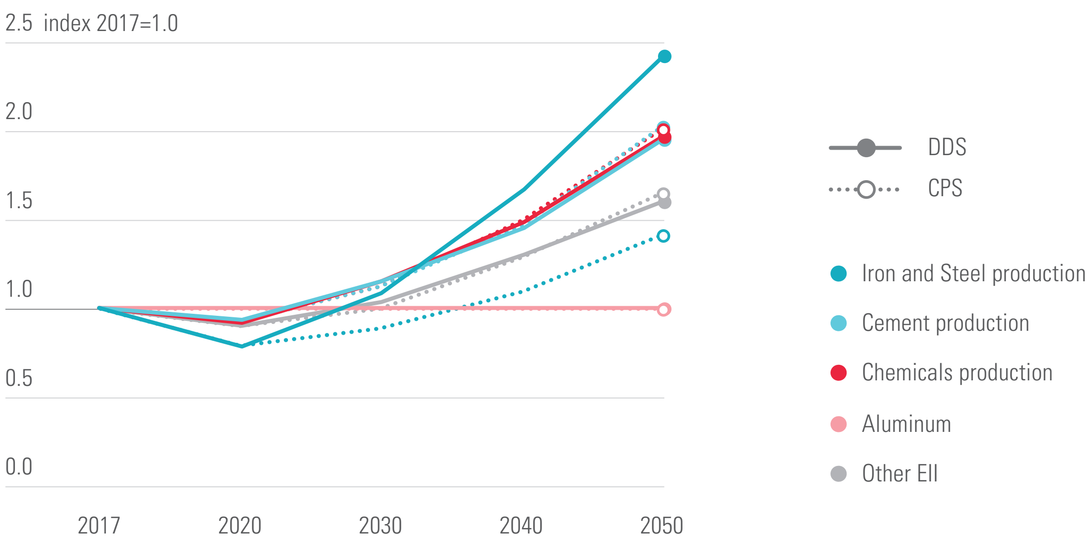
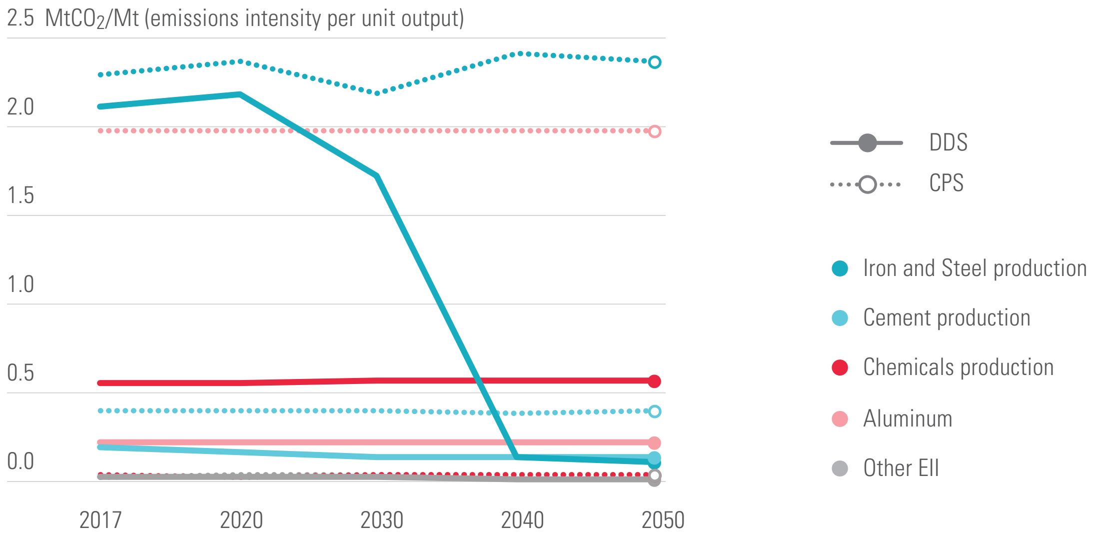


Figure 5. Sector combustion emission intensity



For the present exercise we assume firstly that heavy industry excepting steel production is not decarbonised but most importantly this is done with the caveat that it is likely that there will be technology developments and more stringent emissions mitigation policies in the ten-twenty year future term that will allow for economic decarbonization.

Passenger travel[25]

Passenger land travel is completely decarbonised through technology cost drivers mainly before 2040. There are no significant differences between the CPS and DDS for relevant indicators shown in the figure. From 2020-2050 for CPS and DDS Passenger mobility [p/cap/yr] increases by around 20%26. Public transport as a share of motorised passenger travel, increases from 50% to 56%[27].

From a decarbonisation perspective, in the DDS full decarbonisation of land travel is due to the evolving costs between conventional internal combustion engines (ICE), electric-drive technologies and energy costs such as hydrogen, electricity and oil product.[28] This is associated with an increase in mobility of roughly 20% [pkm/cap].

Other factors are relevant to the finer details of the pathways. One important example is around modal shift: the presumed decarbonisation from 2020-2030 results mainly from a modal shift to public transport. Passenger trip numbers plateau in 2030, with a proportional shift until 2050 towards private mobility. However, the extent of such a modal shift is largely dependent on stemming the markedly deteriorating quality and availability of public transport. The complexity of transport and in this case specifically the complexity of modal shifts in South Africa, limit the contribution that the aggregate national measures at the level of the basic DDP pathways can make to strategic short-term mitigation policy.

One centrally useful feature of the pathways is that for emissions mitigation policy, the modelling indicates that regardless of land transport policy, decarbonisation will be driven by technology costs and the sector will

25 We prefer passenger 'travel' to passenger 'transport' because in South Africa most trips are by foot and so no transport is involved. Also many ideal passenger mobility and access outcomes do not involve much transport.

26 These are rounded numbers according to the assessed resolution of the simulations over the time-periods

27 There is an increase from 1 to 1.5 from 2020 to 2030 for CPS and DDS and then a decrease back to 1 for CPS. These evolutions are dependent on highly uncertain policy implementation and ultimately do not affect decarbonisation and do not add much useful detail – see main text.

28 The non-zero residuals in the figure are all owing to air travel growing rapidly and remaining un-decarbonised. See below. This also masks the 70% reduction in surface transport emissions from 2030-2040.

fully electrify and decarbonise by 2050. Based on this, dedicated mitigation policy is not required to decarbonise passenger surface transport. Electricity demand for passenger transport will be about 5% of total electricity demand in 2050. For this exercise air travel was not considered for decarbonisation and emissions are 3Mt in 2050, although it is quite conceivable that in some ten-twenty years liquid fuels for aviation will be produced economically via an electrification route.

There are non-vehicle/fuel technology passenger mobility and access issues that are crucial to basic social welfare among very large poor populations who suffer much hardship owing to spatial planning and sub-standard basic infrastructure that require attention. Most relevant solutions can have positive emissions mitigation impacts. For example, "non-motorised transport" policy driven initiatives especially regarding pedestrian safety. Safety could be substantially improved with better pedestrian safety measures next to roads including walkways and lights, enforcement of Minibus taxi vehicle-standards and traffic regulations, and security on busses and trains.

Figure 6. DDS and CPS passenger transport drivers

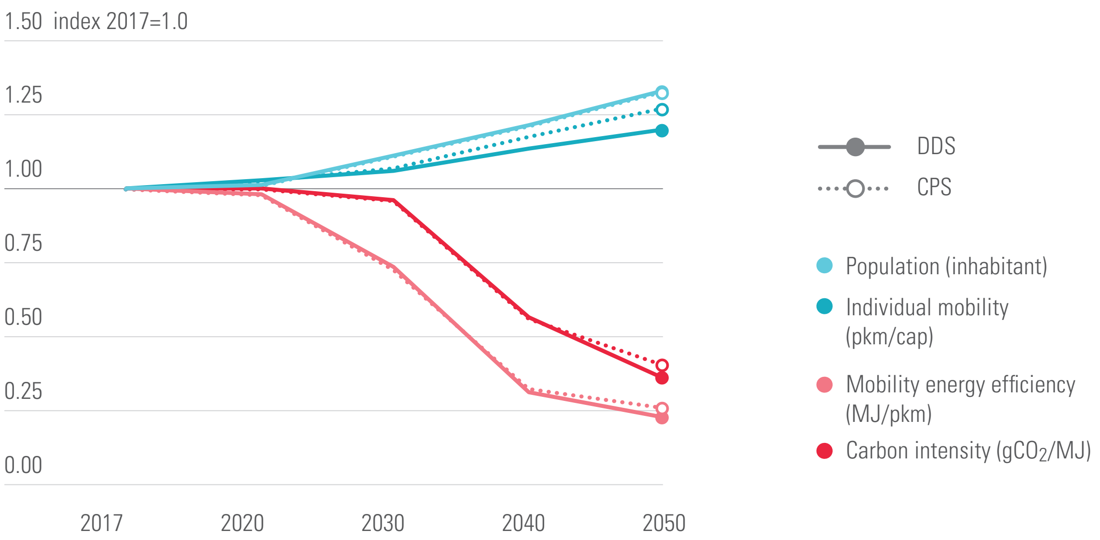
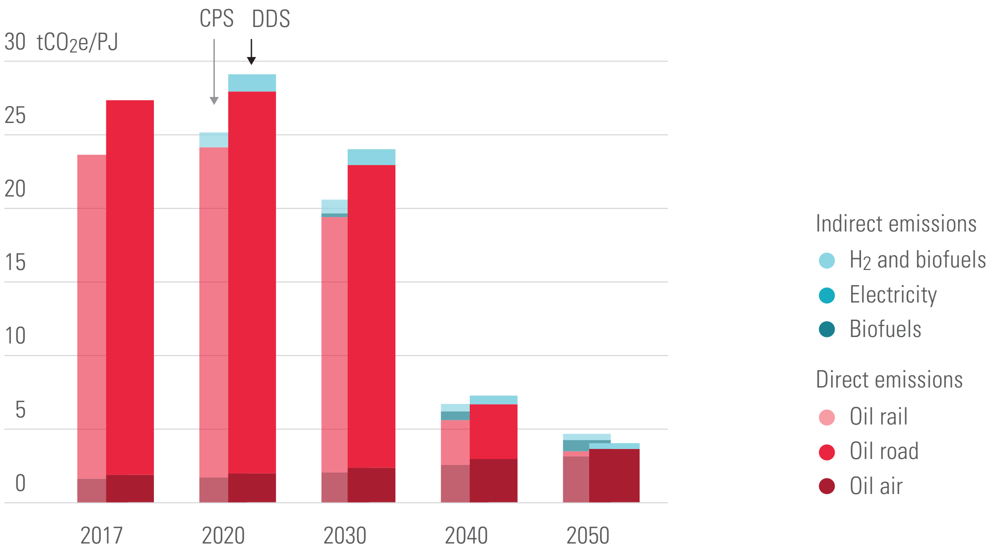


Figure 7. DDS and CPS passenger transport energy carbon intensity



Freight transport

Activity and modal split

From 2020-2050 total land freight transported for both CPS and DDS scenarios increases by around 70%, tracking growth projected for GDP.

Decarbonisation is driven by evolving costs between conventional internal combustion engines, electric-drive technologies and energy costs such as hydrogen, electricity and oil product, with full decarbonisation achieved in DDS

From 2020-2050 for a road-to-rail shift, there is a dramatic shift in rail corridor freight from less than 20% to approximate 70% for the DDS, whereas a less dramatic shift to 50% occurs for the CPS[29].

This may affect the rate of decarbonisation, depending on the rate of electrification of diesel-powered rail, but neither of these affect ultimate decarbonisation.

29 These are highly uncertain and depend on policy implementation and the relative quantities of bulk minerals exports, for example coal and iron ore compared with other goods.

Figure 8. Freight transport - Emission drivers

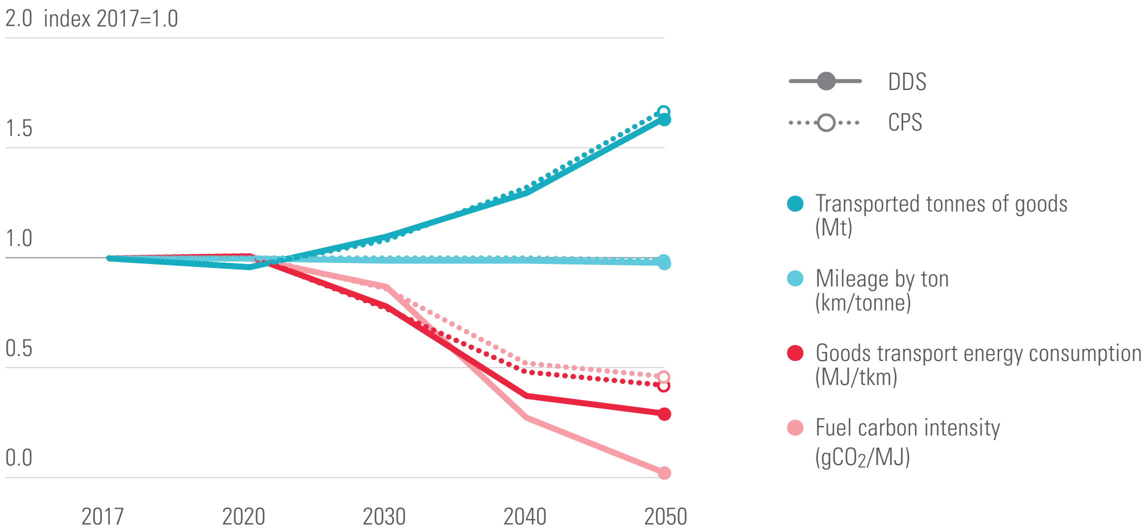
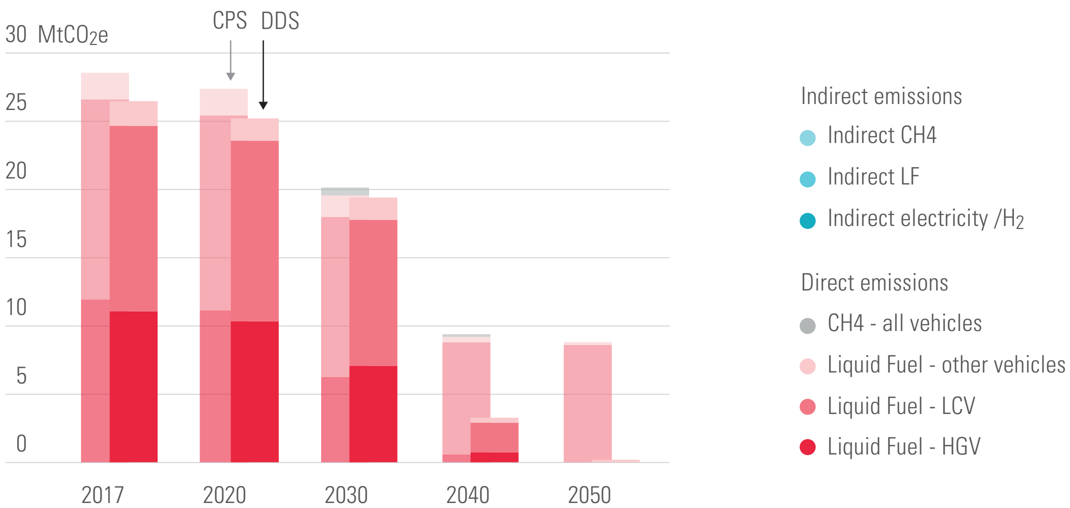


Figure 9. Emissions from fuel combustion



Emissions profile

Freight transport in the DDS is fully decarbonised from 29Mt, on a cost optimal basis, irrespective of the uncertain rate of modal shift.

Electrification in freight transport is primarily driven by uptake in the light commercial vehicle (LCV) segment in both scenarios. Declining costs of battery electric options, in line with international projections, is the main reason. For CPS the (highly uncertain) cost trajectory of battery electric light commercial vehicles (LCVs) is the main reason for the very big difference between CPS and DDS.

This leads to a similar stock (about 1.5m each) of ICE, hybrid-ICE EVs and battery-EVs in 2050. This leads to 9Mt of emissions in 2050 for CPS vs zero for DDS where there are only BEVs by 2050. A full switch to BEV LCVs requires an economy wide emissions constraint (carbon budget) in place.

LCV vehicle traffic almost doubles from 2020-2050. Given that much of this is in urban areas, especially already highly congested metros, there are notable implications for road infrastructure.

Heavy goods vehicles decline in population by about a third due to a modal shift to rail, with total transport energy consumption consequently decreasing by two-thirds.

Freight transport electricity demand will account for about 10% of total electricity demand in 2050. Infrastructure for electricity and hydrogen supply will require new investment to support some 200,000 BEVs and 100,000 fuel-cell EVs (FCEVs) by 2050.

Freight transport policy

Similarly, to passenger transport for emissions mitigation policy the SATIMCGE modelling has conclusive results that regardless of surface transport policy, decarbonisation will be driven by technology costs and the sector will fully decarbonise by 2050.

PART 2: KEY POLICY LESSONS

SHORT-TERM PRIORITES STIMULATED BY TECHNO-ECONOMIC ANALYSIS

ECONOMY-WIDE PERSPECTIVE ON PRIORITIES

From an economy-wide perspective, by far the highest priority short-term policy to get onto a Paris-compatible pathway, from combined economic and emissions perspectives is to add substantial renewable energy generation to the power system as quickly as reasonably possible. Apart from incremental improvements in energy use and other efficiencies, the potential substantial reductions in transport and industrial emissions only occur post 2030. While some preparations are necessary to facilitate the substantial post 2030 reductions these are not short-term policy priorities. The electricity sector also offers the greatest positive opportunities for direly needed short-term economic and socio-economic benefits (see details of electricity shortages and economic performance earlier and "renewable energy equipment industry links" above) and poses the most challenging negative socio-economic effects (see section 2.3.5 "Distribution of costs and benefits" above). These also indicate high priority for urgent short-term strategic policy attention even from a non-emissions reduction perspective.

In 2030-2040, electricity continues to be by far the most crucial area for policy attention. This is due to the huge emission reduction potential between CPS and DDS during this decade combined with the fact that DDS requires additional investments of R400Bn in renewable energy generation over 2030-2040 to prevent the stall in CPS emissions reductions in 2030. Nevertheless, over 2030-2040, several transformations, particularly within industrial sectors, may become crucial to macro-economic aspects of just transition (JT) pathways. The zero-emissions iron production is an important example of the potential contribution zero-emissions commodity exports can make to the national economy and to the South African participation in least-cost global sectoral decarbonisation. For South Africa to participate early in global sector decarbonisation requires more than technology transitions. Dedicated policies involving innovations in new business models and co-operation along value chains are required to achieve significant cost reductions in global decarbonisation. These are detailed in the section below on the "Green Iron Deep Dive". The emission abatements are small in relation to those achieved by greening electricity but important as an example of how kick-starting decarbonisation of a major industry can be achieved in what has been regarded as a hard-to-abate sector and of implications for future attention to abating 'residual' emissions in this sector.

SECTORAL DEEP DIVES

Electricity

There has been much in-depth analysis[30] that provides a solid resource for policy lessons to inform mitigation policy going forward. The progress of national electricity planning processes and associated implementation measures has been recorded and analysed in depth. These analyses have covered the legal and techno-economic features within broader contexts of emissions mitigation policy and national economic, political and security crises. The policy analysis below builds on them.

30 Baker, L. (2017) 'Post-Apartheid Electricity Policy and the Emergence of South Africa's Renewable Energy Sector', The Political Economy of Clean Energy Transitions. doi: 10.1093/oso/9780198802242.001.0001.; Wright, J. G. and Calitz, J. R. (2020) 'Systems analysis to support increasingly ambitious CO_2 emissions scenarios in the South African electricity system'. Available at: http://hdl.handle.net/10204/11483.; Wright, J. G. et al. (2019) 'Long-term electricity sector expansion planning: A unique opportunity for a least cost energy transition in South Africa', Renewable Energy Focus. Elsevier Ltd, 30, pp. 21–45. doi: 10.1016/j.ref.2019.02.005.; McCall, B. et al. (2019) Least-cost integrated resource planning and cost optimal climate change mitigation policy: Alternatives for the South African electricity system. Available at: https://sa-tied.wider.unu.edu/sites/default/files/pdf/SATIED_WP29_February_2019_McCall_Burton_Marquard_Hartley_Ireland_Merven.pdf.; Lawrence, A. (2020) South Africa's Energy Transition. Palgrave Macmillan. Palgrave MacMillan.; Baker Lucy and Jesse Burton Hilton Trollip (2020) 'The Energy Politics of South Africa', in Hancock, K. J. and Allison, J. E. (eds) §The Oxford Handbook of Energy Politics. Oxford University Press. doi: 9780190861360.001.0001.

Policy context

The South African electricity system is almost[31] entirely state-owned and state operated. Electricity prices are administratively set at all levels. Apart from a small amount of on-site own supply[32] and some municipal generation and storage facilities, 100% state-owned Eskom either owns all electricity generation assets or controls these assets through long-term PPAs. Eskom also controls the national transmission grid. More than 85% of energy is generated by coal power stations. These Eskom power stations consume 120Mt of coal a year, procured for some R70Bn from privately-owned coal mines.

One of the significant successes of democratising South African governance has been the Electricity Regulation Act (ERA) passed in 2006, requiring the Energy Ministry to regularly publish generation capacity expansion plans, called integrated resource plans (IRPs) according to strict regulatory rules including that they be based on least-cost planning and that departures from least cost would need to be sufficiently[33] motivated. Before the ERA, these plans had been formulated behind closed doors, and only sometimes made public.

National government controls[34] all additions of generation capacity to the grid. New generation is allowed onto the grid via a two-step process tightly specified by the Electricity Regulation Act (ERA). Firstly, government (the Department of Energy, DOE) publishes a generation capacity expansion plan, called the Integrated Resource Plan (IRP) which specifies how much of each technology will be connected to the grid in each year over the medium to long term. Secondly, the energy minister issues a "determination as to whether the new generation capacity shall be established by Eskom, another organ of state or an IPP".

31 There are small, but important exceptions, most of which will be addressed below, because these largely represent (so far) how renewable energy has been able to gain a toe-hold in the national electricity generation mix.

32 And a small amount of municipally owned or controlled assets.

33 In general, South African law requires administrative action to be demonstrably rational

34 There has been a recent relaxation of this control – see details regarding the *"Recent policy changes to allow private generators of less than 100MW onto the grid"*. Concessions have also been made to municipalities to allow them to source power from independent power producers.

An exemplary, and exceptional, successful mitigation policy implementation from 2008-2014

A very recent comprehensive paper[35] on mitigation policy states that "After a promising start, South Africa's climate institutions have been largely still-borne, neither managing to develop nor exercise any influence over the country's overwhelmingly dominant and highly concentrated emitting sector: coal-based energy. From an international view, this state of affairs is not immediately obvious". The only substantial effective direct impact in terms of emission reductions of mitigation policy implemented to date has been in the electricity generation industry. Even in this most successful policy implementation, the results have been small and mixed.

This sole substantial mitigation success involved a sequence of mandates at the highest government level and much cross-departmental co-operation, as follows: the Long-Term Mitigation Scenarios (LTMS) (Cabinet mandated 2005-2007), Copenhagen Peak Plateau Decline (PPD) commitment (President of South Africa 2009), incorporation of PPD in 2011 South African Climate Policy White Paper's Department of Environmental Affairs (DEA)), IRP2010-2030 (Department of Minerals and Energy (DME) 2011), and REI4P (National Treasury (NT), DME 2011-2014). The implementation of the REI4P on the ground required a joint effort by DME and NT in a special for-purpose office established outside normal DMRE lines of management, namely the IPP office[36].

The IRP/determination-governed system in the ERA only came into effect in 2011. Until then Eskom had effectively decided what generation would be added to its system even though the DOE had unsuccessfully tried to take control in the 2000s. In a radical departure from previous policy, the first detailed[37] IRP under the system imposed an emissions constraint on a least-cost plan to implement South African emissions mitigation policy in line with its Copenhagen pledge. This commitment in 2011 by a developing country to incur substantial additional costs to mitigate emissions demonstrated climate leadership

35 Tyler, E. and Hochstetler, K. (2021) 'Institutionalising decarbonisation in South Africa: navigating climate mitigation and socio-economic transformation', Environmental Politics. Routledge, pp. 1–22. doi: 10.1080/09644016.2021.1947635. page 15.

36 https://www.ipp-renewables.co.za/

37 Two 1-page 'token' IRPs were published in 2010 and 2011 to retrospectively legalize the Medupi and Kusile power stations

and was remarkable at the time. Despite a system where renewable energy generation additions were significantly above least cost at the time, 30 GW of renewable energy generation was incorporated into the IRP2010-2030.

In another radical development, the renewable energy generation was implemented via the renewable energy independent power producer procurement programme (REI4P). A government auction programme with periodic bid windows invited privately owned independent power producers (IPPs) to submit bids. Despite being privately owned, the IPPs are the result of state procurement as Eskom was required in terms of the ERA to sign power purchase agreements (PPAs) with award winners, and thus, their electricity production is state-owned backed by sovereign-guarantees.

From 2011-2014, four bid windows were run resulting in 6GW of new PV[38] and wind generation and fixed investments of some R200Bn. This was from a very low base of renewable energy electricity generation. The projects have been completed and now contribute some 4% of electricity to national generation. The REI4P auctions ceased in 2015. This is viewed as a success because it managed to muster cooperation and support across government and connect foreign policy to mitigation policy and then to electricity policy resulting in substantial investments directly aimed at reducing emissions, it is viewed as small because 4% of electricity is just a start and "mixed" because after only 4 years it stalled owing to a combination of ineffective government by DME and Eskom refusal to sign the PPAs already legally awarded.

A significant unexpected result of the REI4P was the rate of decline in average procurement prices from ZAR 2.79 to ZAR 0.92 from 2012-2014. The crucial, revolutionary impact of this was that by 2015 cost-optimisation modelling showed that renewable energy generation had evolved to providing lower costs for South African system expansion than new coal generation. Emissions mitigation no longer involved a cost trade-off but actually delivered net direct financial benefits.

A paralysing electricity policy impasse from 2014-2021

There has been a seven-year electricity policy implementation impasse in awarding new contracts for constructing or procuring any new utility-scale electricity generation. The electricity shortage has been a central factor in decline of economic growth and de-industrialisation and increases in unemployment and poverty. Several factors explain this impasse.

Firstly, in 2015, in actions of questionable legality, Eskom refused to sign PPAs with IPPs that had been awarded by national government in the REI4P. These were subsequently signed shortly after the removal of President Zuma in 2018.

Secondly, coal IPP projects have been proving to be un-financeable despite strong government support. The DME issued a Determination for 2,500MW of coal and announced a coal IPP programme at the end of 2014. After two awards amounting to 1,500MW in 2016, the selected bidders did not manage to secure financing. These projects are basically unviable owing to their economics, environmental permitting problems and related withdrawal of financiers. It is now becoming unlikely that investments in new coal-fired electricity will be financeable in future without very special state aid.

Thirdly, the gas IPP programme has not managed to get off the ground owing to credibility problems related to the stalling of the REI4P. In 2015, the DME issued a Determination for 3,126MW of gas generation. In 2018, the DOE stated[39] that "Eskom signing of the REIPPPP is a precondition for international investor confidence in the IPPPP and the Gas Programme" and that the bid process would start when the IRP had been updated. However, the IRP2019 shifted new gas to 2024. If it had been implemented as initially envisaged, much of the supply shortage could have been avoided and space would not have been created for the RMIPPP and the current attempts at contracting emergency gas-fired generation mounted on Karpower ships.

Last, Eskom coal procurement contracts have been at the centre of structures and processes-labelled State Capture[40]. President Zuma, cabinet ministers, previous Eskom CEOs, senior Eskom executives and coal mine owners have been implicated. Some of the same people were involved in the stalled REI4P (Eskom refused to sign contracts of awarded bids). These people were also openly part of a high visibility misin-

38 Some CSP plants were also 'procured'.

39 Department of Energy. Presentation on the independent power producer procurement programme (REI4P) to the Portfolio Committee on Energy parliament. Cape Town 06 March 2018.

40 We capitalize it as it has a specific meaning for South Africa – Chipkin, I. *et al.* (2018) *Shadow State: The Politics of State Capture*. doi: 10.18772/22018062125.

formation campaign to discredit renewable energy in general and the REI4P in particular. In December 2016 the South African Public Protector published the "State of Capture" report that provided evidence of coal contracts (allegedly) illegally awarded by Eskom. The evidence implicated individuals, including the then Eskom CEO. Subsequently this evidence has been corroborated in a parliamentary enquiry and judicial commission. These processes also revealed information about the state procurement regulatory capacity at National Treasury (NT) and Finance Ministry National Prosecuting Authority (NPA) being disabled to facilitate such (allegedly) illegal contracts. Evidence leaves little doubt that irregular coal contracts were (and possibly still are) at the centre of a large network called State Capture.

In brief, the REI4P has been limited to existing awards from its first 2011-2014 bid windows. Going forward, Eskom coal procurement contracts are of significant relevance to implementing renewable energy generation policy because a transition to renewable energy will strand coal assets involving trillions of Rands.

The REI4P and the history of distribution of costs and benefits within the broader South African policy context

While the renewable energy independent power producer procurement programme (REI4P) was a success in economic efficiency terms, it has been viewed by crucial stakeholders as highly skewed against economic transformation and a replication of legacy extractive economic arrangements. Serious and deep issues around distribution of costs and benefits and protection of vulnerable communities need to be addressed. This is a central feature of the mission that is developing in the Presidential Climate Commission.

The apartheid-era electricity system was an important component in the social and economic system of gross inequality, exclusion and oppression. South Africa enjoyed 14 years of democratic transition, post-apartheid growth and substantial improvements in socio-economic conditions from the end of the apartheid government in 1994 until 2008. Since the 2007-2008 Great Recession, South Africa has been experiencing an escalating economic, socio-economic and human development crisis. The electricity system has become a central site of policy conflict which is still largely unresolved.

Until 2006, a mass household electricity programme extended electricity access to most urban households but then stalled. Adequate electricity is now too expensive for some 40% of South African households who suffer energy poverty. Transformation and reform of the upstream electricity generation and coal supply sides has been problematic. Conflict in the ANC which has ruled since 1994, between proponents of Washington Consensus-style reforms and anti-privatisation has caused serious policy conflict, uncertainty, and instability. Organised labour, which was a major player in over-throwing apartheid, is the most powerful anti-privatisation proponent in terms both of economic power (industrial action) and in rallying political support inside the ANC and at elections.

The transition to renewable energy generation involves investments in renewable energy generation of a substantial scale in national terms – electricity spending is more than 5% of GDP and the transition involves shifting this quantum of spending from coal to renewable energy. Investments of at least R30Bn per annum in wind and PV will be required each year until 2030 and trillions of Rands over the 2020-2050 transition.

At an aggregated level, the national electricity system, national economy and local and global natural environments are direct beneficiaries. This provides the system-wide motivation for the transition. However, at a disaggregated level, benefits and costs of the REI4P have been unevenly distributed. Benefits flow to renewable energy project developers, equipment suppliers, land and renewable energy generation facility owners and operators, and financiers (especially if privately-owned and being rewarded at market rates) and employees of all of these.

This inequitable distribution of benefits has supported resistance to the transition. South Africa has a history of gross inequity of the distribution of costs and benefits involving natural resource exploitation and in energy and electricity production in particular. Therefore, addressing distribution of costs and benefits is crucial for social justice. It is also necessary to garner and maintain political support for the transition.

Addressing the distributional inequality is also techno-economically and politically feasible. Organised labour has consistently stated that it views the contracting of IPPs as privatisation of Eskom through the back door and that they oppose this. Important civil society organisations and NGOs also oppose it or at least demand that the energy transition does not replicate existing severe inequities in the electricity system. There has been a struggle for more than twenty years over regulation and reform of the 100% state-owned vertically integrated electricity monopoly which owns and operates a generation fleet dominated (85%) by coal generation. Government was well on the path to privatising part of the Eskom coal fleet in 2002. However, national strike action put an end to privatisation plans. The first major power shortage in 2008 was the direct result of the policy impasse of combined failed privatisation of coal generation and of government preventing Eskom from building coal power stations as it always had. No plants were built from 1998-2006 despite a known looming supply shortage[41]. Eskom had contracted BEE miners without ensuring performance capabilities and the South African electricity system entered a period of generation capacity shortages and multiple problems in Eskom coal supply contracts that has steadily worsened. Linked to anti-privatisation and coal contracts aimed at BEE transformation, but re-directed and a central driver of State Capture, important constituencies in the ANC have been effective in (intentionally or not) being a major factor in the policy impasse. The REI4P was presented as privatisation and effectively halted. Eskom coal contracts were a mainstay of State Capture and Eskom showed negative interest in contracting utility-scale renewable energy.

In 2018, after the removal of President Zuma, moves were immediately made to sign the REI4P awards. The National Union of Mineworkers South Africa (NUMSA) and Transform RSA (an organisation associated with supporting key state capture figures) mounted a court challenge in March which failed, and contracts worth R57Bn were signed for 27 projects that had been stalled since 2015. The Coal Transporters Forum then launched a court process to nullify the contracts which also failed.

The direct economic and financial beneficiaries were mainly local project developers, foreign renewable energy equipment suppliers and local and foreign financiers. Most of the finance was supplied on commercial terms and was underwritten by state (sovereign) guaranteed PPAs.

Civil society groups mobilised along social justice lines, organised labour with an anti-capitalist stance and state capture cronies, funded by proceeds of coal contract rent-seeking, were allied in their resistance to utility-scale RE-IPPs. The facts that the allies in the anti-IPP cause used were correct: the REI4P did provide rich rewards to project developers and owners and their financiers and mostly foreign renewable energy technology companies. Also, renewable energy would lead to the phase-out of coal, although with the generation shortage all extra generation for some time (still) provides relief for an over-stressed coal fleet and reduces the need to run very expensive diesel peakers and also reduces economically damaging load shedding.

Mobilisation against renewable energy also raised the issue of the impact of a coal phase-out on the coal industry and employment. To garner necessary support for the transition there is a need to distribute benefits from the huge growth in the renewable energy sector fairly and to protect vulnerable coal workers and their communities as coal is phased out. Localising renewable energy equipment manufacture will significantly increase economic benefits and, if well managed, can assist with both distribution of economic benefits and protection of the vulnerable by locating renewable energy manufacturing in coal areas which in many cases are already industrial areas with industrial infrastructure. If effectively integrated with industrial policy, a stable and credible steady demand for renewable energy equipment could drive substantial re-industrialisation through local manufacture of renewable energy equipment which will increase national employment substantially, although jobs will be lost in the coal mining and coal power stations.

Short-term strategic policy recommendations

Policy analysis

The DDS achieves the same emissions reductions as the CPS in the 2020-2030 period. The CPS requires more capital investment because of deviations in the official IRP2019 plan which forces new coal power stations into the plan despite them costing more. Thus, over the 2020-2030 period, if current electricity policy is implemented the resulting emissions will still put South Africa onto a DDS pathway.

41 Froestad, J. Nøkleberg, M. Shearing, C. Trollip, H (2018) 'South Africa's Minerals-Energy-Complex: Flows, regulation, governance and policing', in Omorogbe, Y. and Ordor, A. (eds) Ending Africa's Energy Deficit and the Law Achieving Sustainable Energy for All in Africa Oxford University Press, p. 327.

However, as explained above, implementation of electricity policy has for some time been paralysed by entangled factional politics in the ruling party with fossil-industry rents and corruption centred on coal-based electricity playing a large role. Government has not managed to break the log-jam in energy policy implementation in the electricity policy context. Recently there been signs of policy implementation starting to become un-stuck but to achieve necessary scale policy commitment across government needs to be clearer and much more stable. There are risks that coal and gas interests could force economically irrational amounts of new coal and gas generation into the mix, undermining both short- and long-term emissions reductions as well as the economy.

Therefore, the core and immediate major South African real world decarbonisation challenge is breaking this log-jam and to initiate new investments in renewable energy. Secondly, the grossly economically and financially irrational coal power stations and gas Karpowerships that have been forced into official plans need to be independently reviewed. This will involve implementing existing legal requirements in decision-making to ensure that clear and transparent reasons are made public, particularly when they depart from least cost solutions. Further on, with views to the 2030-2040 period, specific mitigation policy is required to drive reductions in electricity emissions. This will need to be implemented via electricity policy mechanisms.

Intra-government institutional arrangements

Solutions to the policy implementation impasse need to navigate a fragmented state where "…numerous government agencies, generally with poorly defined mandates and inadequate resourcing" and when they disagree "there was often no way to expedite dispute resolution. These factors led to long-running inconsistencies in policies, regulations and implementation." "…only Cabinet, the Presidency and the courts have the power to arbitrate disputes between government agencies." [42] As detailed below, the Presidency has recently demonstrated leadership to break one long running impasse in connecting renewable energy generation to the grid. This might be a model for a practical solution for accelerating renewable energy roll-out until the intra-governmental challenges with contradictory policies and plans are addressed.

In June 2021 President Ramaphosa over-rode[43] his Minerals and Energy Minister via Operation Vulindlela (OV), and directly intervened in electricity policy implementation and lifted the threshold for licensing connections to the grid from 1MW to 100MW. The reasons have been given by OV as the need to get generation onto the grid as fast as possible and that existing DMRE initiatives, even if successful, would not close the power supply gap and continue to cause substantial economic damage. Via OV the Presidency, Finance Ministry and National Treasury have accepted the findings of techno-economic analyses and have been explicit about the damage caused by the protracted and worsening electricity shortage. They have also explicitly stated[44] that even if the current DMRE RMIPPP and REI4P Bid Window 5 go smoothly, "these current interventions will not be sufficient to meet the electricity supply shortfall until at least late 2023 or early 2024". They cite 2020 Eskom and CSIR estimates of the power shortage of 4,000MW and 8,000MW respectively. OV estimates that by 2024 the renewable energy that will be connected to the grid will reduce GDP loss by 1.75% from the "severe electricity shortage" and add 0.5% of GDP through investments in renewable energy by the private sector, yielding a very significant economic benefit of 2.25%. This is through simply lifting a restriction.

This recent policy intervention by the Presidency is a stark example of what has become necessary to break (some of) the policy implementation impasse and the damage and unrealised benefits that would have resulted from not intervening in delays and resistance in DMRE policy implementation. However, there has not been a positive acknowledgement of this by the DMRE. The Energy Minister stated that his "arm had been twisted"[45]. Then, pushed by the president to implement the measure, the DMRE delayed the publication of the regulations lifting this restriction until past the deadline. Then, the first version of the

42 Magetla, N. (2021) *Draft Policy Brief for the Presidential Climate Commission Governance and the Just Transition - October 2021.*

43 https://www.news24.com/news24/southafrica/news/twisting-mantashes-arm-operation-vulindlela-drove-raising-embedded-energy-threshold-to-100mw-20210611

44 South African Presidency Operation Vulindlela (2021). Supporting the implementation of priority structural reforms. Presentation to the Presidential Climate Commission (PCC). 30 July 2021.

45 https://www.businesslive.co.za/bd/national/2021-06-10-ramaphosa-twists-mantashes-arm-to-free-up-new-power-generation/

regulations created much uncertainty and had to be updated. Today there is still uncertainty in poorly drafted regulations that continue to hinder implementation.

Operation Vulindlela (OV) has demonstrated a successful institutional solution to the challenges that the DMRE faces while it continues to carry out both minerals promotion and electricity planning and licensing authorities. This double function exposes it to politically and economically powerful incumbent coal and fossil interests, which have been embroiled in state capture while at the same time the DMRE has to manage the imperatives of a transition that will involve substantial economic losses for these interests. While OV has proven its potential and provided partial compensatory benefits, the intervention does not go to the root cause of the problem. A more permanent institutional solution to the DMRE policy impasse is needed. A starting point would seem to be separating out the energy portfolio from minerals in the Department of Mineral Resources and Energy (DMRE) back into a Department of Energy as structured when the REI4P was launched. This would reverse the decision made in June 2019 to merge the Department of Energy (DOE) and the Department of Mineral Resources, to go back to 2010 when the Department of Minerals and Energy had been divided into two Departments to precisely balance the interests of the coal industry and nascent gas industry[46] vs interests of rational electricity planning which had proved problematic.

In parallel, the president could establish an executive structure in the presidency to extend the advisory structures and processes that have emerged in the Presidential Climate Commission (PCC) and Operation Vulindlela (OV) and empower and hold accountable this executive structure to address inter-agency contradictions and competition that have been delaying implementation and urgently attend to the acceleration of renewable energy deployment to address the power-supply shortage.

Electricity policy implementation also depends on DMRE and Eskom cooperation which has a poor record. This cooperation remains to be far from assured with a current combative relationship evident between the Eskom CEO and energy minister[47] over the issues of the role of renewable energy in national electricity supply and expectations that Eskom will sign PPAs with the Karpower ships. The Presidency-extended structures could enhance the coordination between DMRE and Eskom.

Integrated policy actions

The just transition (JT) can stabilise and re-build the electricity generation sector, which is central and contingent to national security, the success of the democratic transition and addressing poverty and unemployment, as well as achieving net zero by 2050. Coal electricity generation is in inexorable decline. Without effective management this will lead to the rapid collapse of regional economies already in severe distress. A managed electricity system transition in the form of the JT managed by the PCC could turn this around and facilitate decarbonisation of other sectors. Government has to be convincing that plans for the coal phase-out will include measures to address welfare in coal regions to regain/maintain security and social stability as a basis for sufficient support for the constitutionalists to enable investments in the renewable energy roll-out.

A number of academic and technical studies have described the potential requirements and elements of a Just Transition Transaction (JTT) specifically for the power sector[48]. The need for procedural justice is a central feature and a number of proposals have been made. These include social plans for coal regions, retraining of coal sector workers, re-purposing of coal power stations. This involves siting renewable energy generation in coal regions (economically viable despite not being optimal renewable energy resource areas), assistance with economic diversification and establishing renewable energy equipment manufacturers in coal regions within an energy/industrial policy that provides sufficient

46 As well as coal promotion, DMRE is also responsible for upstream oil and gas policy and regulation. There has been a recent condensate discovery categorised by TotalEnergies as *"a new world-class gas and oil play"* (Announced in July 2019, https://totalenergies.com/media/news/press-releases/total-makes-significant-discovery-and-opens-new-petroleum-province-offshore-south-africa).

47 This is not only reported in the press but evident in comments made by these office holders on recorded videos on social media.

48 Burton, J., Marquard, A. and McCall, B. (2019) Socio-Economic Considerations for a Paris Agreement-Compatible Coal Transition in South Africa.; Climate Investment Funds. 2020. Supporting Just Transitions in South Africa: Just Transition Case Study. Washington, DC. www.climateinvestmentfunds.org/sites/cif_enc/files/knowledge-documents/supporting_just_transitions_in_south_africa.pdf; https://www.wri.org/just-transitions/south-africa - World Resources Institute (2021) South Africa: Strong Foundations for a Just Transition.

demand certainty from the renewable energy generation roll-out for local equipment manufacturers. So overall governance and outline proposals for the JTT exist but this needs to be developed now through to implementation using the Presidential Climate Commission (PCC) JTT process.

Localisation of production of renewable energy equipment – A secure state-backed, stable demand for renewable energy can create a 'pipeline of utility scale projects' over the medium term, which in turn, creates a stable demand for renewable energy equipment. This demand can serve as a basis for establishing an industrial policy to establish a large domestic renewable energy equipment manufacturing industry. Policy has been unpredictable and policy implementation stop-go. However, investment in utility scale generation has either been directly through 100% state-owned Eskom, or backed by sovereign guaranteed power purchase agreements (PPAs). It is most likely that even if future PPAs aren't backed by formal sovereign guarantee the counter party will either be state-owned Eskom or a state-owned (transmission) system operator. This will effectively put the state into a guaranteeing situation anyway as has been made clear with the current Eskom debt crisis. Failure of Eskom to honour debt is tantamount to a sovereign default. Thus, whether government creates more certainty by, for example, providing credible commitments to implementing the IRP2019 renewable energy programme or not, it will in effect be committing state resources to backing the programme. A formal credible commitment would create certainty demand for upstream renewable energy equipment that would form the basis for industrial policy integration and investments by renewable energy equipment manufacturers. This will enable investment both in electricity generation and upstream renewable energy equipment manufacturing.

Enable state-owned and independent power producer utility scale investments and household, community, business and municipal participation in investments in electricity generation.

To address major economic and political constituencies, programmes that involve state and community ownership need to be added to the existing REI4P, which has been limited to large private corporate ownership of generation assets. It is unlikely that the struggle between proponents and opponents of state/public/private ownership will be resolved soon. This struggle has been de-stabilising energy policy since initial attempts at sector reform in the early 2000s. In the context of a damaging electricity supply crisis and the need for rapid transition to make a fair contribution to GHG emissions mitigation, progress should not remain hostage to this struggle. A necessary compromise could involve a policy commitment to implement both private and public/community-ownership programmes in parallel. Detailed plans for this for this can be developed in the JT structures being set up in the PCC.

Regarding ownership of generation, decarbonisation pathways offer a range of possibilities. Conflict, since the early 2000's, over resolving one ownership model has been a central cause of the energy shortage. Techno-economic analysis within existing institutions indicates that a number of ownership options have a role to play and these do not have to be exclusive. Possibly all are required to achieve the rate and scale required. REI4P, state-owned utility-scale and household, community, business and municipal ownership of electricity generation can play an effective role to meet energy needs and mitigate emissions and at the same time distribute considerable benefits of the huge roll-out of renewable energy generation across society. For example, state-owned Eskom has recently announced its willing intention to embark on a state-owned utility scale renewable energy generation investment programme. Local government initiatives to implement innovative public/private mixes in own-supply and embedded generation are another example.

Utility-scale, medium-scale distributed and embedded small-scale, public and privately-owned are all elements in an optimally functional system: all need implementation as rapidly as possible, Regardless of the various pathways to ultimate decarbonisation of electricity, and regardless of externalities such as emissions, accelerating a rapid roll-out of renewable energy electricity generation: at utility-scale and small-scale, centralised, distributed, embedded, own-supply, public and privately-owned over the next 5-10 years is techno-economically rational and an imperative to address the electricity supply shortage of between 4,000-8,000MW to arrest and turn around economic stagnation. GHG emissions mitigation and local environmental protection in this case are co-benefits. Localisation through stable policy and commitments to state-backed procurement programmes and integrated industrial policy have huge potential to add substantial economic development, industrial development and employment.

Short-term action agenda

Investments in generation

See graph *"Cumulative electricity capital investment post 2021 in CPS and DDS" at the beginning of the electricity section.*

The following specific policy actions are required to achieve the rapid acceleration and increased scale:

Accelerate REI4P Bid Window 5 implementation: Technocratic policy and implementation institutional capacity and mechanisms for the renewable energy rollout exist but implementation needs to be re-vitalised and accelerated.

Prepare and run an expanded REI4P Bid Window 6 that will be based on an independently reviewed maximum rate of utility-scale renewable energy construction to fill the electricity supply gap as soon as possible.

Both the REI4P and the Bid Windows utilise an existing programme to address an emergency – a utility-scale central-buyer-driven renewable energy rollout. While the well-established REI4P implementation mechanisms are probably best suited to accelerate utility-scale renewable energy generation investments in the short term to most effectively begin to fill the critical supply shortage, they do not necessarily have to be the only or biggest contributor to the renewable energy programme in the medium to longer term. Parallel central buyer programmes can be run and the REI4P-style programme can undergo substantial adjustments to ensure support of costs and benefits distribution consistent with the kind of just transition of which details are beginning to emerge in Presidential Climate Commission processes. Much of the economic benefits would involve equipment for REI4P projects being sourced from local manufacturers. This is dealt with in more detail below, but in the short term it makes sense for the REI4P to continue in its current form to fill the large power supply gap.

To address issues of the REI4P being biased towards privatisation, a similar programme to the REI4P can be established where state-owned Eskom can run auctions to achieve efficiencies and competitive prices but Eskom takes public ownership on a build, operate, transfer system once operation is proven at contracted levels. A renewable energy publicly owned power producer procurement programme: REPOPPP can be run in parallel with the REI4P. This could be a hybrid of the auction and conventional tender systems. Government commitment to this could avoid the conflict and stalemate between supporters of the two approaches delaying action. It must be noted that despite its 100% ownership stake, Eskom is governed at arms' length as a profit making company and government has often been challenged in getting Eskom to implement official policy. The unbundling of Eskom and extraction of the national transmission grid from the Eskom vertically integrated monopoly is an example. This been attempted for twenty years without success so far despite well-resourced reform programmes and a number of official statements over the years including a number of announcements in the annual Presidential State of the Nation Address that it would happen "this year" or soon. The ability of government to 'order' Eskom to implement a policy of replacing its coal stations with renewable energy has not yet been demonstrated. Given the urgency of getting PV and wind onto the grid it would make sense to continue with the REI4P while the success of an Eskom driven programme is investigated.

Last but not least, partially releasing additional demand and supply from the existing command and control approach can be unleashed through mobilising opportunities similar to, for example, the recent amendment to regulations to increase to 100MW the threshold for licensing of own–generation and generation to wheel over the grid. This element will exploit the space opened up by government allowing access to the national grid solely regulated by technical requirements. The potential revolutionary impact needs heavy emphasis. Until this development, in essence, all substantial additions of generation capacity were tightly controlled by the Minister of Energy. In general, electricity generation was either owned by Eskom or procured by Eskom as the 'single buyer' for re-sale, creating an effective monopsony and monopoly. Eskom is saddled with crippling debt and most of the coal-fired generation fleet that supplies >85% of electricity reaching the end of its economic life with serious performance problems (fleet EAF at 63% and steadily declining).

This development, forced by the presidency over the head of the DMRE, is a departure from policy trajectories implemented up until now. However, if and when a potential suppressed supply of some 5,000MW of projects starts connecting with a 4,000MW-8,000MW supply-demand gap, the results could be profound. The amendment to the regulation is very recent and much uncertainty surrounds it not least because of the apparent lack of alignment between presidency interventions in energy policy and established DMRE practices as demonstrated over the past five years even after the Zuma presidency had been terminated and substantial efforts started against state-capture. The main mode of implementation which would substantially alter the electricity generation landscape enabled by the sub-100MW dispensation would be for large investments in generation based on private contracts with one or more customers (who could probably be traders) to wheel power over the grid to these customers. If the regulatory authority NERSA enforced fair and open access this could result in a large parallel market freed from the single buyer constraint and tariff control.

Generation planning

The IRP2019 needs to be updated in at least three important respects. The update should contemplate a publicly review process by a panel of independent analysts. These aspects are:

- Incorporating least-cost pathway modelling analysis reflecting latest relevant technology cost assumptions and removing the irrational coal and nuclear power previously forced in without appropriate backing rationale and analysis;
- Extending it to 2050, and;
- Including scenarios that factor in a successful JTT/JET which mobilises finance to accelerate the phase-out of coal and to address social costs of coal phase out. The REI4P and additional renewable energy investment programmes need to be accelerated to implement the updated IRP.

Rescind the risk mitigation independent power producer programme (RMIPPP) and institute a tender procedure that rationally addresses the short-term power shortage. Currently an emergency IPP programme, launched to address a power supply shortage estimated to be between 4,000MW-8,000MW (of typical maximum demand of ~30,000MW) has been delayed twice, is mired in controversy and could likely flounder. A major problem is the attempt by the DMRE to force into the programme a seemingly irrational 20-year contract for base-load gas-fired power, the Karpower[49] ships, despite this being far from least cost after the initial period when it contributes to filling the 'short supply gap'. Owing to the fundamental irrationality of one attempt after the next, detailed above, by DMRE to forcefully implement projects which are techno-economically not viable into what is turning out to be a fairly robust legislative and regulatory system a huge power shortage is wreaking havoc with the electricity system and economy. Twenty year contracts to cover a short-term power shortage offering take-or-pay 50% baseload contracts to using 'emergency' style reasoning is another of the same and is more likely to exacerbate the shortage by failing.

Industry

From an economy wide perspective, a specific economy-wide mitigation political and policy challenge is to separate out the 78Mt of 'residual' emissions, mainly in industry, so that the current absence of economic/technology solutions to decarbonise these emissions does not compromise policy progress for the large proportion (299 out of 377Mt) of emissions that can be economically decarbonised, with little GDP impact. Industry does have economy-wide interlinkages, especially with the electricity sector, but it has its own particular challenges, especially technological, but also economic and political. Historically, anti emissions mitigation policy initiatives have often mobilised an alliance of coal, electricity and energy intensive industry interests. These particular challenges need to be understood and addressed by policy in a way that does not hinder decarbonisation of sectors which have existing decarbonisation technological and politically and economically feasible policy solutions. Importantly, industrial decarbonisation needs to be addressed in a way that does not compromise the rate and scale of electricity sector decarbonisation.

49 https://www.dailymaverick.co.za/article/2021-10-01-smelly-midnight-lifeline-karpowership-gets-another-extension-for-emergency-power-deal/; https://www.businesslive.co.za/bd/opinion/2021-03-23-nod-to-high-proportion-of-gas-to-powerships-is-fishy/

Government and industry policy developments

It has been problematic for government as a whole to impose on industry its policy of top-down sector and company emissions budgets. One reason is explained by Meckling et al[50]. Firstly, idealized economic agents in models are often modelled to respond, marginally, to marginal changes. While that might apply to a large number of consumers responding to price signals among a large number of products (if you put taxes on whisky up, they shift to wine…) that's not how investments in lumpy, long economic life major capital investments work. In this case, the effect of a slowly increasing cost, as Meckling *et al indicate:* "…*imposes costs on the powerful few—well-organized energy and energy-intensive manufacturing firms—and provides dispersed benefits to the weak many—the broader public. The few regulatory losers have greater incentives and capacity to organize politically and prevent policy implementation. Therefore, polluters shape the political game more than potential winners.*" This is a decades old story in South Africa, especially with a weak state, which in the State Capture[51] era has become so weak the rule based constitutional democracy has been at risk. Basically, (with some exceptions,) the big corporate incumbents have called the tune[52]. Another cause of the challenge for government to formulate and implement effective mitigation policy for heavy industry is the contradiction of state-owned electricity monopoly and the DMRE persisting with pro-coal and anti-renewable energy actions for electricity generation when mitigation options for electricity are far less costly than for heavy industry. Addressing this policy contradiction will garner support from industry for mitigation policy. Also, international trade and technology developments have over the past three years very quickly changed fundamentals in the business context for many of South African businesses. South African business is now acknowledging that future survival, never mind success, lies in decarbonisation.

Decarbonisation of emissions intensive trade exposed industries (EITEIs) with complex transnational value chains such as chemicals and steel will require global sector decarbonisation to enable early participation of small economies such as South Africa. Specific example of this cooperation would be a combination of access to technology, participation in lead markets that have been created in some large industrialised countries to drive decarbonisation of these industries and open and fair markets for zero/low embodied emissions commodities and goods.

South African Green Iron (GI) concept

The so-called Green Iron concept is the opportunity for South Africa to export renewable energy embedded in beneficiated domestic iron ore, hugely increasing the value of this iron ore and so generating export revenues while facilitating accelerating sector decarbonisation. Such revenues could emerge as a significant foreign exchange earner for the South African economy to become essential to creating the macro-economic conditions needed to support a just transition, including replacing unsustainable coal export revenues and taxes. In addition, green HDRI investments would help enlarge the base for the entire renewable energy value chain in South Africa driving jobs creation. Ultimately, GI could be a foundational stepping stone on the path to accelerating primary steel decarbonisation and a sustainable and profitable revitalization of South African industry.

Primary iron/steel production is the biggest global industrial emitter of greenhouse gasses (GHGs). Most emissions come from the production of primary iron from iron-ore. Many countries and steelmakers have announced net-zero commitments. Technologies to produce zero-emissions "green iron" (GI) exist. Much progress has been made on hydrogen direct-reduced iron (HDRI). It is not yet proven at commercial scale but there are strong indications it will be in the next 5-10 years. Though it will cost more than conventional/current technologies at first, demand is anticipated in some markets and end-uses such as voluntary supply chain decarbonisation, markets regulated by end-use standards, government procurement or

50 Meckling, J. et al. (2015) 'Winning Coalitions for Climate Policy How Industrial Policy Builds Support for Carbon Regulation', Science. doi: 10.1126.

51 Baker, Lucy. Burton, Jesse. Trollip, Hilton. (2020) 'The Energy Politics of South Africa', in Hancock, K. J. and Allison, J. E. (eds) §The Oxford Handbook of Energy Politics. Oxford University Press. doi: 9780190861360.001.0001.

52 Tyler, E. and Hochstetler, K. (2021) 'Institutionalising decarbonisation in South Africa: navigating climate mitigation and socio-economic transformation', Environmental Politics. Routledge, pp. 1–22. ; Trollip, H. et al. (2020) Linking the international climate regime to the political economy barriers of raising ambition. H2020 COP21 Ripples. Available at: www.cop21ripples.eu/wp-content/uploads/2020/02/RIPPLES_D4.4a_Main-Report.pdf.

car-buyers prepared to pay 1-2% more for vehicles with zero embodied emissions steel.

Commercial-scale GI plants have been announced to begin operating in the EU from 2024-2030. Policy-created "Lead Markets" with decarbonisation targets, R&D support, market protection, and (public and private sector) policy-driven "market-pulls" are driving competitive innovation. These include voluntary commitments (e.g. Orsted & Volvo) and government actions such as regulations for environmental footprints of buildings and direct government green procurement mentioned in formal policy documents such as the EU New Industrial Policy. Lead Markets are a core element of EU Industrial Policy.

As decarbonisation accelerates, it is likely that it will be less costly to produce GI in South Africa than in the EU. This is mainly because of the abundant, very low-cost renewable energy potential in South Africa and the predicted high demand for low-carbon electricity and hence higher electricity price in the EU, which has more limited renewable energy resources. A commercially competitive South African GI plant would have a dedicated solar PV supply, electrolysers and hydrogen storage for a continuous feed of hydrogen.

South African GI plants could feed into the 'second phase' of the establishment of HDRI, namely global diffusion, from around 2027-~2030, when the technology has been proven at scale in the initial EU lead market. GI could become a certified commodity feedstock for steelmaking.

Overall, the result of this research was that considerations of the potential for decarbonisation of iron and steel production underwent a fundamental shift from being viewed as 'impossible to abate' to developing a transition as detailed below, using innovations in technology and global value chain configurations. The final modelling result was that by 2035 green iron production is 'chosen' in the model under a 8Gt emissions cap as the preferred technology.

Production of GI at a South African location, for export to the EU, could have substantial financial and economic benefits for both South Africa and Europe. Such an arrangement could reduce the overall costs of EU decarbonisation while making its steel industry more competitive. To facilitate timely green HDRI investments, cooperation is required between South Africa, the EU and steelmakers in terms of technology accessibility and market access. This is possible within current policy frameworks but will require specific policy implementation mechanisms and efforts. It will need to navigate WTO, international trade, EU-single market, state-aid, level playing field etc. policies and rules within the context of the SA-EU Free Trade Agreement and Strategic Partnership. South African GI export plants will be feasible on purely commercial terms. The investment will be on basis of exports but product will be available for local markets. South Africa is not in the same position as the EU when it comes to creating a domestic market to warrant the large lumpy investment involved in a GI plant. However, GI will become more competitive with conventional iron across markets over time, as economies of scale and technology learning reduces costs and climate policy induces carbon pricing worldwide. Southern African markets will then be in a position to consider it for local use.

INTERNATIONAL ENABLERS

One primary enabler of South African emissions mitigation policy will be ongoing credible commitments and progress in other countries, and rich countries in particular, in implementing the Paris Agreement.

The second primary enabler flows from the first and regards means of support to South Africa for implementing a Just Transition (JT[53]). The history of South Africa's extractive economy and current socio-economic conditions make it especially critical to attend to uneven distribution of costs and benefits, social costs and the potential for renewable energy to make a substantial contribution to economic development. The Presidential Climate Commission (PCC) has adopted the JT as a core organising principle for climate policy. A South African version of the just transition concept was mentioned in the Climate Change Response White Paper (DEA 2011). This was integrated by the National Planning Commission (NPC) with procedural and distributive justice elements within the just transition (JT) concept. The NPC has handed over the results of its engagement

53 For more detail on the JT and the PCC see Trollip, H. (2021) *"Climate emission mitigation policy ambition"* at pp139-144 of *"Climate ambition beyond emission numbers - Taking stock of progress by looking inside countries and sectors"* https://www.iddri.org/en/publications-and-events/report/climate-ambition-beyond-emission-numbers-taking-stock-progress

process (Vision and Pathways for a Just Transition to a low carbon, climate resilient economy and society[54]) to the Presidential Climate Commission (PCC). Integrated policy is only beginning to develop solutions to the institutional and governance processes involved in the rise of renewable energy technologies and demise of coal.

The Presidential Climate Commission has begun formulating the details for a Just Transition (JT) with a first set of concrete results in a report scheduled for completion in December 2021. Developing politically feasible solutions to structural issues in the economy that have resulted from centuries of extractive economic development is a complex challenge. The PCC has stated that: "…and one of the first tasks of the PCC is to understand the impacts of climate change on jobs, both positive and negative."

Thirdly, support to break through the electricity policy implementation impasse is critical, as a core national political challenge to getting onto a deep decarbonized emissions pathway. The urgent next steps involve construction and connection of as much new renewable energy electricity generation as is practicably possible firstly to fill the economically crippling electricity generation supply gap and then to implement (at least) some 20GW of new wind and PV generation specified in the IRP2019. In turn, addressing the very uneven distribution of costs and benefits linked to substantial expansion of renewable energy generation capacity, and phasing out of coal generation is one core requirement of addressing social justice issues and the associated legitimate[55] political challenge. Key stakeholders have made it clear that expansion of the renewable energy capacity, mainly through the REI4P mechanism, will not adequately distribute financial and economic benefits. At the same time, this expansion involves costs and losses among a separate group of stakeholders mainly related to coal electricity generation.

The benefits of the transition to renewable energy electricity generation can be substantially increased through integrating electricity policy with upstream renewable energy equipment manufacturing and downstream industrial utilisation of South Africa's comparative advantage in renewable energy generation costs. Although DDS does not require additional capex over CPS in the 2020-2030 decade, commitment to addressing social costs is a central aspect of the JT. In terms of international enablement, it would be necessary for South Africa to be convinced that there was credible international support for South Africa to commit to addressing these costs. Also, in line with Paris Agreement principles, it would be reasonable for SA to seek international support to address these costs. Last, in the 2030-2040 period although DDS is also GDP-neutral compared with CPS, in addition to social costs, very substantial additional investment costs will be required in electricity capital plant in DDS (R1518Bn) above those in CPS (R1118Bn), a difference of R400Bn. Also, over this period, in DDS existing coal power stations will be retired early and/or operated below the levels of CPS, yielding substantially lower revenues for these assets. International policy enablement will be necessary in terms of credible international commitments to Paris Agreement principles, both commitments to emissions reductions and international support to address these social costs, for finance for additional investments and to address substantial revenue losses. To assist with costs outlined above JT Plans involving international climate finance are being formulated within a Just Transition Transaction (JTT) [56]

The Just Transition Transaction (JTT)

President Ramaphosa communicated an initial sum of US$11Bn to the UNFCCC. Eskom, at the centre of the national JT is the monopoly, state-owned coal-based state-owned electricity utility at the centre of the 'creative destruction' and 'utility death spiral' that can't cover interest on its debt which has been major factor in downgrade of sovereign debt to junk and has announced its own Just Energy Transition (JET) which it has announced that it plans to present at COP26[57].

54 https://www.nationalplanningcommission.org.za/assets/Documents/Vision_and_Pathways_for_a_Just_Transition_to_a_low_carbon_climate.pdf

55 Legitimate in terms of core principles of South Africa's constitutional democracy

56 Winkler, H. et al. (2021) 'Just transition transaction in South Africa: an innovative way to finance accelerated phase out of coal and fund social justice', Journal of Sustainable Finance & Investment. Taylor & Francis, pp. 1–24. doi: 10.1080/20430795.2021.1972678.

57 https://www.news24.com/fin24/economy/eskom-in-talks-with-lenders-foreign-governments-to-fund-clean-energy-projects-20210806

Open and fair international trade in low-embodied emissions commodities and goods

A third priority area is energy-intensive trade-exposed industries (EITEIs). There is growing acknowledgement that global sector decarbonisation cooperation and associated policies could be more effective than purely national decarbonisation policies. This would require short-term action informed by long-term perspectives and trade policy cooperation to enable participation of countries with small markets for these industries. This is further detailed in the Industry section above.

DDP

The DDP is an initiative of the Institute for Sustainable Development and International Relations (IDDRI). It aims to demonstrate how countries can transform their economies by 2050 to achieve global net zero emissions and national development priorities, consistently with the Paris Agreement.. The DDP initiative is a collaboration of leading research teams currently covering 36 countries. It originated as the Deep Decarbonization Pathways Project (DDPP), which analysed the deep decarbonization of energy systems in 16 countries prior to COP21 (deepdecarbonization.org). Analyses are carried out at the national scale, by national research teams. These analyses adopt a long-term time horizon to 2050 to reveal the necessary short-term conditions and actions to reach carbon neutrality in national contexts. They help governments and non-state actors make choices and contribute to in-country expertise and international scientific knowledge. The aim is to help governments and non-state actors make choices that put economies and societies on track to reach a carbon neutral world by the second half of the century. Finally, national research teams openly share their methods, modelling tools, data and the results of their analyses to share knowledge between partners in a very collaborative manner and to facilitate engagement with sectoral experts and decision-makers.
www.ddpinitiative.org

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The University of Cape Town (UCT) is a public research university located in Cape Town in the Western Cape province of South Africa. UCT was founded in 1829 as the South African College making it the oldest higher education institute in South Africa.[4] In terms of full university status, it is the oldest university in South Africa and the oldest extant university in Sub-Saharan Africa together with Stellenbosch University which received full university status on the same day in 1918.

http://www.uct.ac.za

IDDRI

The Institute for Sustainable Development and International Relations (IDDRI) is an independent, not-for-profit policy research institute based in Paris. Its objective is to identify the conditions and propose tools to put sustainable development at the heart of international relations and public and private policies. IDDRI is also a multi-stakeholder dialogue platform and supports stakeholders in global governance debates on the major issues of common interest, such as actions to mitigate climate change, protect biodiversity, strengthen food security, and to manage urbanisation. The institute also participates in work to build development trajectories that are compatible with national priorities and the sustainable development goals.

www.iddri.org