SOUTH AFRICA'S NDC TARGETS FOR 2025 AND 2030

Technical analysis to support consideration of the emissions trajectory in South Africa's NDC

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This technical report presents the analytical underpinning of the Presidential Climate Commission's recommendations to the South African government on the mitigation component of the first updated nationally determined contribution (NDC). To read the full NDC recommendations from the Commission, visit https://www.climatecommission.org.za/.

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EXECUTIVE SUMMARY

South Africa's Department of Forestry, Fisheries and the Environment (DFFE) released an updated draft Nationally Determined Contribution (NDC) for public consultation in March 2021, as an update to South Africa's first NDC communicated under the Paris Agreement in 2016. The mitigation targets contained in the 2016 NDC consisted of a greenhouse gas (GHG) emissions target range in 2025 of 398 to 614 Mt CO_2-eq, and in 2030 a GHG emissions target range of 398to 614 Mt CO_2-eq, for all national GHG emissions, including those from land use. The draft update proposes revised target ranges of 398 to 510 Mt CO_2-eq for 2025, and 398 to 440 Mt CO_2-eq for 2030.

These targets were identified by the DFFE on the basis of:

- An assessment of South Africa's "fair share" of global emissions for 2025 and 2030, in light of the latest science and the Paris Agreement's long-term temperature goal of keeping global warming to "well below 2 degrees Celsius" and making efforts to keep warming within 1.5 degrees, and
- An assessment of the likely GHG emissions outcome of the implementation of current South African policies with a potentially significant mitigation impact, including the Integrated Resource Plan 2019 (IRP 2019), the draft post-2015 National Energy Efficiency Strategy, the Green Transport Strategy (GTS) and the carbon tax

Targets were set fairly conservatively to take into account uncertainties in the estimation of national GHG emissions, and uncertainties in policy implementation.

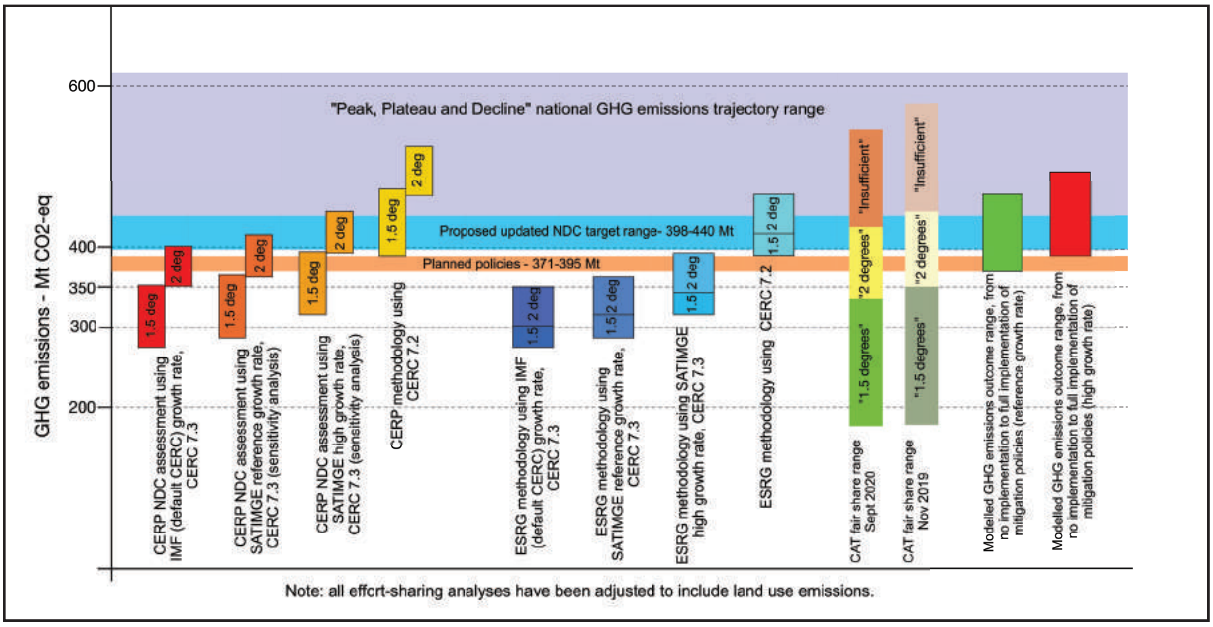
The Presidential Climate Commission (PCC) held public hearings on the proposed updated NDC on 7 May 2021, which led to the commissioning of additional technical work by the University of Cape Town's Energy Systems Research Group (ESRG) on the NDC targets, to:

- Assess South Africa's "fair share" contribution to global mitigation efforts in terms of the Paris Agreement, especially with respect to the 2030 target
- Model, using the SATIMGE economy-wide modelling framework, potential GHG emission target levels corresponding to this "fair share"
- Propose options for the NDC target range in response to the DFFE's proposed target ranges, in the light of key national policy priorities

The PCC also expressed a strong interest in understanding the relationship between the proposed 2030 NDC target and the aspirational net zero CO_2 emissions target for 2050 contained in South Africa's Low-Emission Development Strategy, submitted to the United Nations Framework Convention on Climate Change (UNFCCC) in 2020. South Africa's "fair share" for 2030 was assessed considering the Climate Action Tracker (CAT) analysis, an approach that considers more than 50 analyses of countries' "fair shares", using a wide range of interpretations of the key equity principles of the UNFCCC and its Paris Agreement; and the Climate Equity Reference Calculator (CERC), an approach to equity principles that best represents South Africa's interpretation of these principles.

These two approaches were also used by the DFFE in the NDC updating process. It is worth emphasising that both assessments have been updated recently (CAT in September 2020, and CERC currently). Both the original and updated assessments, using two different approaches to using the CERC calculator, are presented in Figure 1. A summary of this rather complex consideration is that **South Africa's GHG emissions would need to be at a level of 350 Mt CO_2-eq or below in 2030 to be consistent with a 1.5-degree global pathway, and 420 Mt CO_2-eq in 2030 to be consistent with a 2-degree pathway** based on the UPDATED assessments of CAT and CERC.

Figure 1 – CAT and CERC assessments of South Africa's "fair share" for 2030. For more details, see Figure 6 and accompanying text below.



The modelling analysis was undertaken using the SATIMGE modelling framework, an economy-wide linked energy-economy-environment model that combines a technology-rich energy modelling framework and an economy-wide CGE (computable general equilibrium) model, with AFOLU (agriculture, forestry and other land use) and waste modules. The analysis focused on GHG emissions outcomes in 2030, using two economic growth rates. The key conclusions from the modelling analysis were:

- **The GHG emissions outcome of current policies in 2030 is likely to be between 370 and 395 Mt CO_2-eq**, depending on the economic growth rate, which is below the proposed NDC target range of 398 to 440 Mt CO_2-eq

- **For the 2020s, the electricity sector is the source of most GHG mitigation in the economy**. After this, transport and other sectors play a larger role. A more ambitious NDC target in 2030 would mostly require additional mitigation in the electricity sector, which would include less utilisation of existing coal plants, and additional investments in renewable energy
- **Employment impacts in the coal and electricity sectors of more ambitious national mitigation targets are marginally positive**; however, a just transition is essential to ensure that no one is left behind in the transition
- For additional mitigation outcomes down to 350 Mt CO_2-eq in 2030, there is the potential for policy optimisation, which will probably include additional renewable energy capacity
- **Without international climate finance, economic modelling indicates that a significantly more ambitious mitigation target (below 360 Mt) will have a negative economic impact**, primarily due to the massive additional investment that would be required in the power sector. In general, for each 50 Mt of additional mitigation in 2030 (beyond the full implementation of current policies), an additional R200-billion of investment is required up to 2030. Energy efficiency has significant economy-wide benefits as a mitigation option
- **Current policies and measures are not necessarily the most cost-effective mitigation options to 2030. Policy optimisation will result in a more ambitious national mitigation outcome up to around 350 Mt in 2030**, through considering measures such as earlier retirement of some of Eskom's coal fleet, additional renewable energy capacity, and the avoidance of more expensive new capacity such as the proposed coal and hydroelectricity plants in the IRP 2019, with a positive economic outcome.

Currently, there is not a sufficient analytical basis to place the 2030 NDC target in the longer-term context of South Africa's in-principle commitment to reaching net zero CO_2 emissions by 2050 in its Low-Emission Development Strategy (LEDS) submitted to the UNFCCC in 2020. Such work is currently ongoing. Reaching this goal will require very rapid decarbonisation of the South African economy in the 2030s and 2040s. A net zero CO_2 goal is equivalent to around 60Mt of CO_2-eq in 2050 (comprising remaining non-CO_2 GHGs), which means decarbonising the economy at a rate of more than 150 Mt per decade in the 2030s and 2040s. A more ambitious mitigation target in 2030 will considerably lessen the risk of the necessity to undertake very costly and rapid mitigation in the two decades that follow.

1 BACKGROUND

Following the Presidential Climate Commission (PCC) hearings on the Department of Forestry, Fisheries and the Environment's (DFFE) updated draft Nationally Determined Contribution (NDC) on 7 May 2021, additional analysis was commissioned by the Energy Systems Research Group (ESRG) to inform the NDC mitigation target range recommendations of the PCC. The scope of work focused on:

- Fair share analysis: identifying GHG emissions levels for 2025 and 2030 for South Africa consistent with the long-term global temperature goals of "well below 2 degrees" and 1.5 degrees as contained in the Paris Agreement. The quantification of these levels was undertaken using the equity-based Climate Equity Reference Calculator (CERC) and the Climate Action Tracker (CAT), taking into account recent updates by CERC and CAT, to identify South Africa's "fair share" in relation to its NDC targets
- Modelling analysis: using the same modelling framework as used for the NDC analysis, a range of GHG emissions outcomes for 2030 were modelled, corresponding to the "fair share analysis" above, to identify the efforts required for South Africa to reach these levels in 2030
- Proposal and evaluation of specific NDC target options, in line with the Paris Agreement

2
SOUTH AFRICA'S 'FAIR SHARE' IN TERMS OF THE PARIS AGREEMENT

A BRIEF INTRODUCTION TO 'FAIR SHARES'

The overwhelming scientific consensus on climate change is that it is caused by emissions of greenhouse gases (GHGs) resulting from human activity. Because of the fact that GHGs are long-lived in the atmosphere, and over time mix evenly in the global atmosphere, ALL GHGs, from any source on the planet, contribute to climate change globally. The problem therefore needs to be addressed multilaterally, which is the focus of the United Nations Framework Convention on Climate Change (UNFCCC 1992) and its Paris Agreement (UNFCCC 2015).

The multilateral climate change regime has since its inception in the UNFCCC in 1992 strived to avoid "dangerous climate change". This has now been defined in the Paris Agreement as "well below 2 degrees", with efforts to keep climate change to below 1.5 degrees (UNFCCC 2015) above pre-industrial levels. Previous multilateral decisions on the temperature limit referenced 2 degrees (Cancun decision 1/CP.16), based on a combination of what scientists thought of as an acceptable temperature limit, as well as what was considered feasible in terms of mitigation. More recent science, as well as strong pressure from vulnerable countries (especially African, small island states and least developed countries (LDCs), some of which may disappear altogether at 1.5 degrees), has indicated that 2 degrees may not be a safe limit to global warming. Decision 2/CP.17 in Durban called for consideration of both 2°C and 1.5°C. In the aftermath of the Paris Agreement, the Intergovernmental Panel on Climate Change (IPCC) produced a special report on 1.5 degrees (IPCC 2018a), which confirmed that:1.5 degrees is a possible but challenging global temperature limit; and the difference in terms of climate impacts between 1.5 and 2 degrees of global warming is very significant, and for some ecosystems and countries, global warming of an additional 0.5°C is potentially catastrophic

Global climate models have for the past few decades produced assessments of which global GHG emissions pathways will meet these temperature goals, using integrated assessment models. Pathways for a 1.5-degree temperature goal are presented in Figure 2. The key problem is then how much GHG emissions limitation/reduction each country should be responsible for?

Countries have very diverse national circumstances – some countries have very high levels of development; some are LDCs; some have contributed a great deal to historical emissions (underpinning the current crisis) and some have not; and some have abundant fossil fuel resources that their economies may depend on, while others have abundant renewable energy resources. For the past three decades, international climate change negotiations have failed to agree on a process of allocating each country's share of this global effort multilaterally.

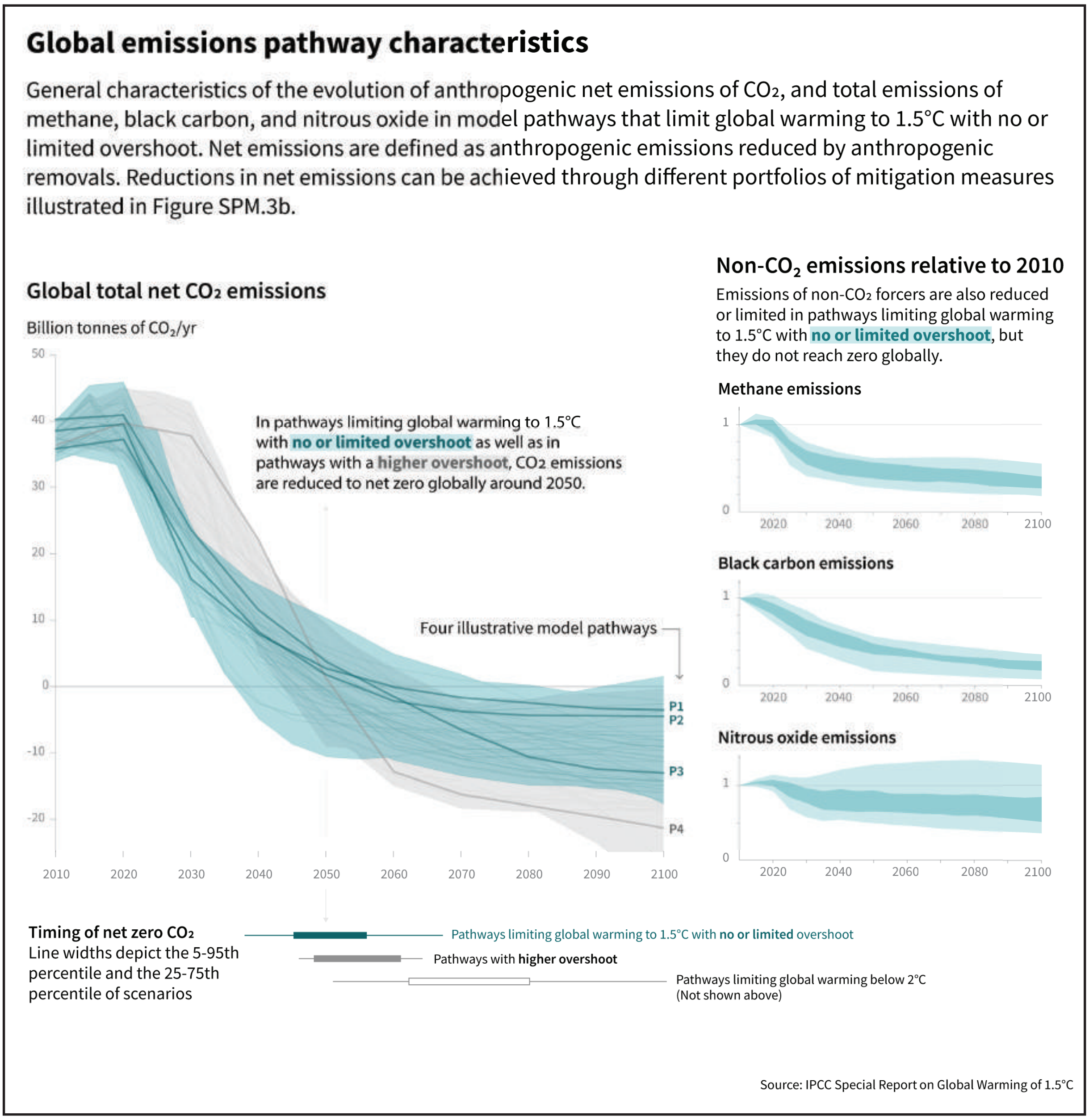
The innovative solution that lies at the heart of the Paris Agreement is the Nationally Determined Contribution (NDC), whereby every country defines its own mitigation target. The criteria each country should consider in doing so are set out in Article 4.3:

- Each NDC should represent a progression beyond the previous one
- Each NDC should represent a country's "highest possible ambition", and
- This level of ambition should reflect "common but differentiated responsibilities and respective capabilities, in the light of different national circumstances"

Each country is therefore required to put forward an NDC that is "fair and ambitious", taking these criteria into account, as its contribution to the global temperature goal of the Paris Agreement ("well below 2 degree" with efforts to remain below 1.5 degrees"); and to state in its NDC how its contribution is fair and ambitious, in the light of the criteria above.

A number of approaches have been proposed over the past two decades to operationalise these principles, and quantify what the "fair share" of each country should be. These approaches generally share between them the same overall global emissions trajectories (to achieve the global goal), but differ in how the overall mitigation task is divided between countries. The danger of this diversity of approaches is that countries may choose the approach that is favourable to them. If each country did this (chose the approach most favourable to them), then the overall outcome would not be sufficient to achieve the long-term temperature goal. "Fair shares" should therefore also take into account what other countries are likely to do.

Figure 2 – Global emission pathways to limit temperature increase to 1.5 °C (IPCC 2018b).



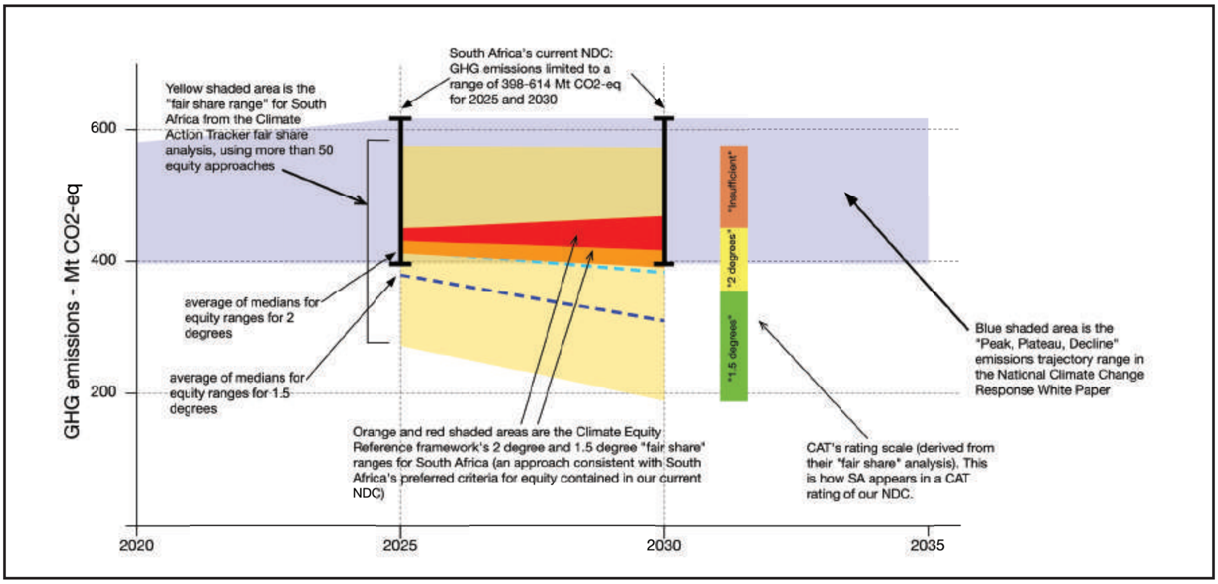
For this reason, the DFFE chose to use a combination of approaches (UCT 2021a). The first is the Climate Equity Reference Project (CERP)[1], which uses key principles (capability, responsibility and development) to allocate the global mitigation burden in a way that is consistent with the UNFCCC and Paris Agreement, as well as South Africa's own development-focused approach to addressing climate change. A very closely related approach was also used by South Africa in its first NDC in 2015/16. The CERP has developed an online tool, the Climate Equity Reference Calculator (CERC), which quantifies fair shares for countries for 2025 and 2030 in the context of global emissions pathways to limit temperature increase to 2 degrees and 1.5 degrees.

The second is the Climate Action Tracker[2], a project that assesses fair shares using more than 50 different approaches (to represent what is claimed to be the full diversity of approaches to fair shares), and then derives a "fair share" range for countries for 2025 and 2030 based on the full range of approaches, with an extra step that divides this range into "insufficient", "2 degrees" and "1.5 degrees".

SOUTH AFRICA'S 'FAIR SHARE' IN THE PROPOSED NDC

South Africa's fair share, using the "fair share lens" below, was one of the considerations taken into account when setting the proposed NDC target ranges. This is presented in Figure 3, which compares the fair share ranges from CERC and CAT with the previous NDC targets.

Figure 3 – CERC/CAT equity lens for South Africa's NDC update, 2025 and 2030.

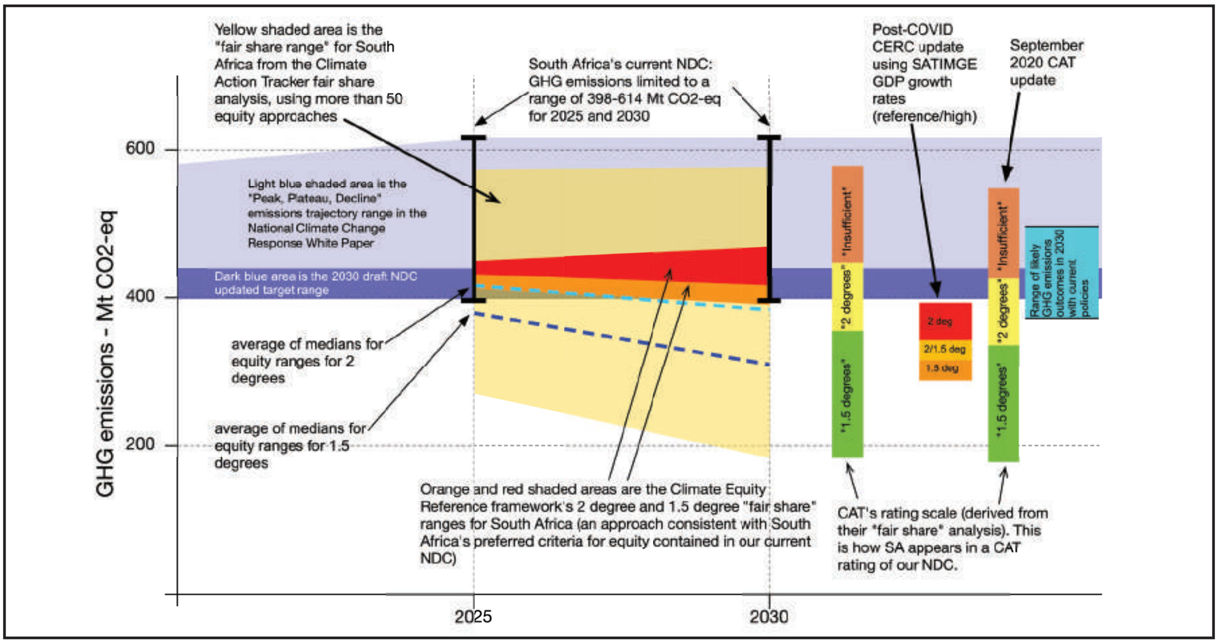


After the NDC target ranges were proposed and included in the updated draft NDC, both CERC and CAT updated their databases to take into account recent developments, including lower growth rate expectations as a result of the Covid-19 pandemic. The revised results are presented in Figure 4.

The two shifts of consequences are that the upper range of the proposed 2030 target range is no longer within the CAT "2 degrees" range; and that, because of the large shift downwards of the CERC "fair share range", the proposed NDC range does not overlap with the CERC range at all.

1 See https://climateequityreference.org/.
2 See www.climateactiontracker.org.

Figure 4 – CERC/CAT equity lens for South Africa's NDC update, 2025 and 2030, with added updated "fair share" ranges for CAT (post-September 2020) and CERC (May 2021). The CERC range here is derived from a sensitivity analysis using SATIMGE growth rates as described above. The single bar (with 2, 2/1.5 and 1.5 divisions) combines the reference and high growth rate sensitivity analyses presented in Figure 14 and described above. The 2/1.5 block is where the two ranges overlap. The bar on the right indicates likely GHG outcomes in 2030 with different growth rates and degrees of policy implementation, of the implementation of currently planned policies.



The CERC is also the basis of a proposal from the Centre for Environmental Rights (CER)[3] for a 2030 NDC range of 286 to 364 Mt CO2-eq (without land use), or 275 to 353 Mt CO2-eq (with land use, adjusted using the SATIMGE baseline land-use value for 2030)(Centre for Environmental Rights 2021). This in turn is based on an assessment of South Africa's updated draft NDC (Climate Equity Reference Project 2021) – carried out for the Centre for Environmental Rights and others by the Climate Equity Reference Project, which maintains the CERC – that used a slightly different methodology to that used to derive the ranges in Figure 4.

[3] *The version of the CERC on which this analysis is based (CERC 7.3) is not yet available publicly. The CERC website version, which is available currently, is still CERC 7.2, and so these values may still change with the finalisation of the new version*

Figure 5 – Comparison of South African GDP growth rates used in CERC versions 7.2 and 7.3, and SATIMGE growth projections (left), and the resulting size of the South African economy.

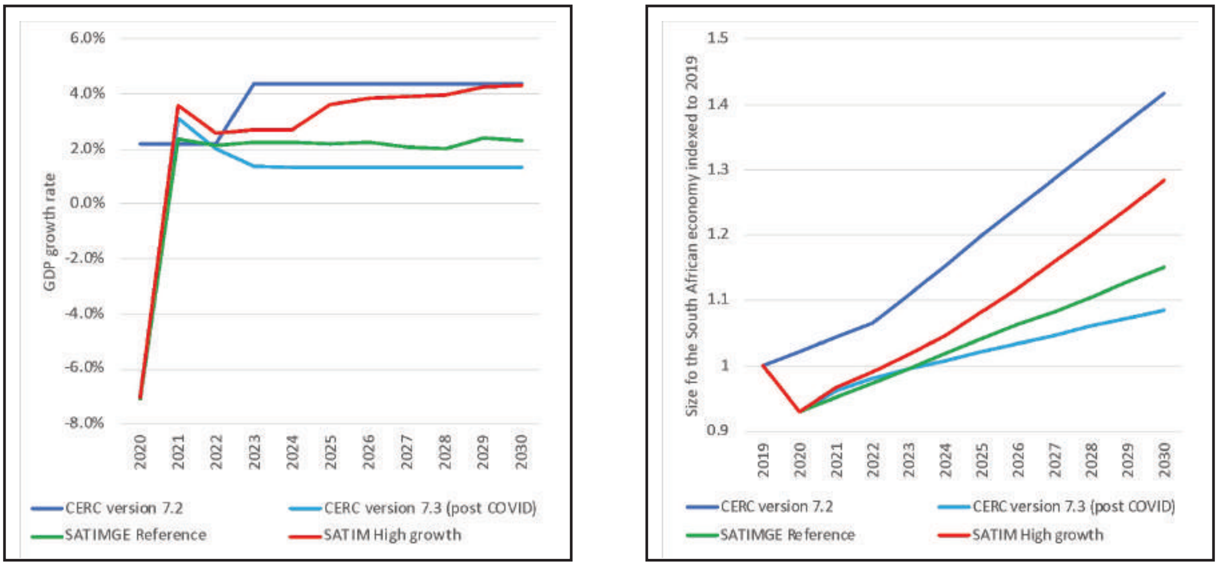
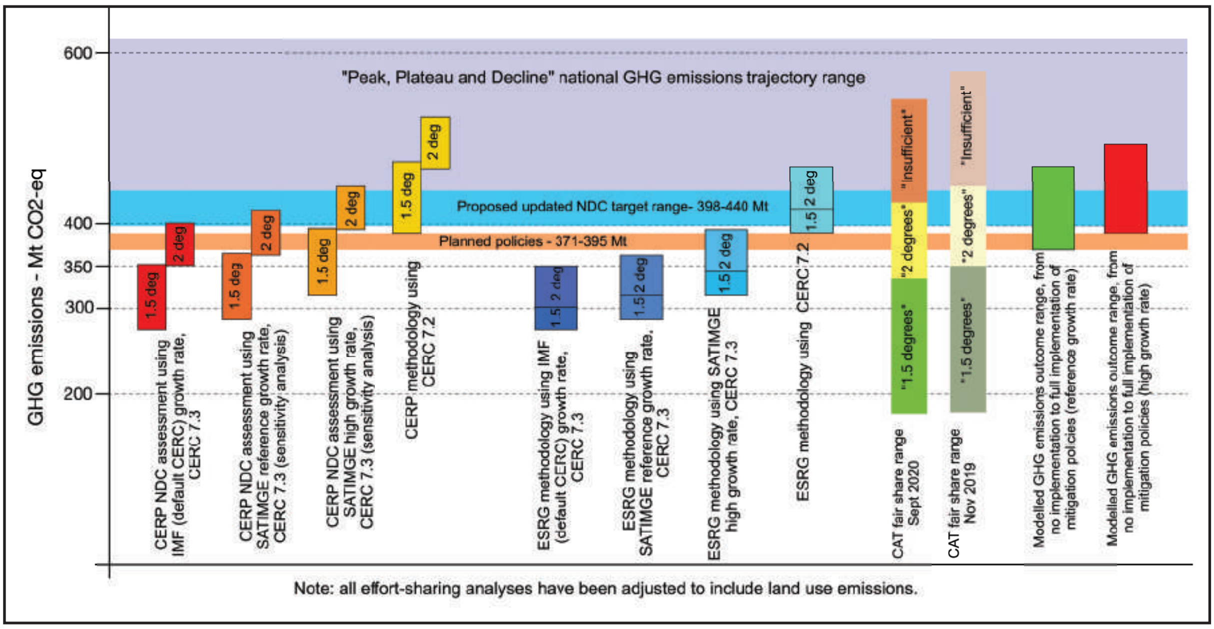


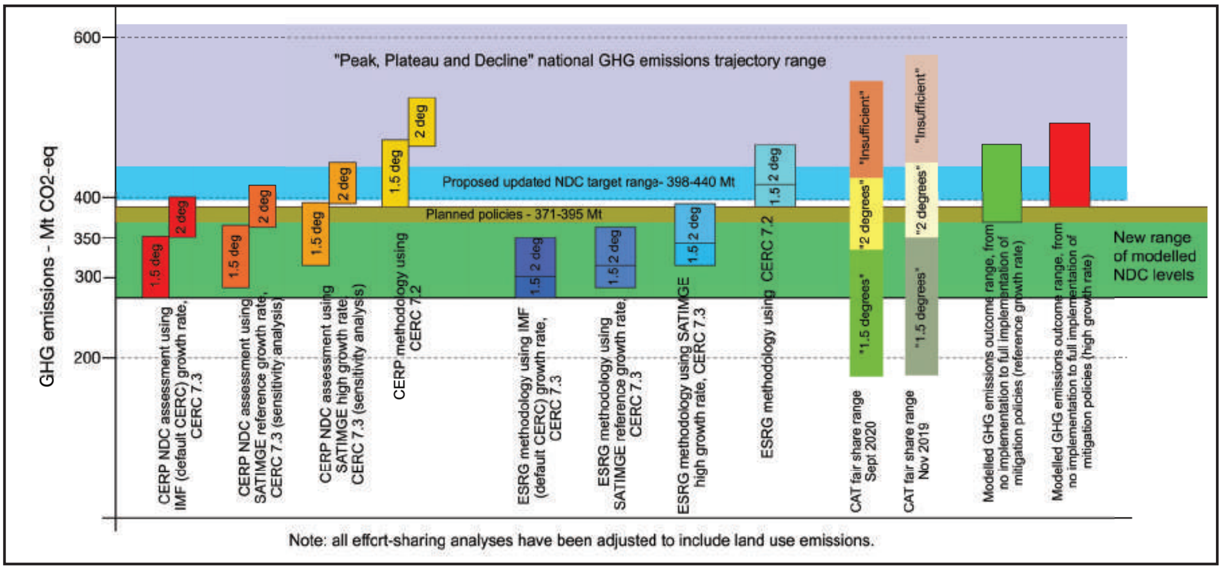
Figure 6 – Comparison of fair shares for 2030: on the left 1.5- and 2-degree ranges a) as contained in the CERP NDC assessment; b) and c) sensitivity analyses from the CERP NDC assessment using the SATIMGE growth projections; and d) the CER assessment methodology using CERC 7.2 (the previous version of CERC, which was used for the analysis here). And on the right, d), e) and f) – using the same set of growth rates and CERC 7.3, but using the ESRG methodology, and g) the current assessment using CERC 7.2 above. To the right of this is the CAT fair share range (updated – 22 September 2020 version), for comparison, which is slightly lower than the version used in this analysis below – see below). All results have been adjusted to include land-use emissions, to allow comparison with the proposed NDC target range. The two bars on the far right are the results of SATIMGE GHG emissions modelling (with reference and high growth rates). The top of each GHG emissions range represents GHG emissions outcomes with no policy implementation, and the bottom of each range represents emissions outcomes with full implementation of mitigation policies. The orange shaded band represents the range of outcomes for full implementation, which is below the proposed NDC range.



The other key change from the pre-Covid assessment is that the assumed economic growth rate for South Africa to 2030 is very low, at 1.3% per annum. Since CERC is particularly sensitive to a baseline which is calculated on the basis of projected GDP growth, this results in a much lower fair share for South Africa. The pre-Covid version of CERC assumed a growth rate for South Africa in the 2020s of over 4%, which is now considered too optimistic. The CERC analysis also usefully contains some sensitivity analyses for the economic growth rates, which were used in the technical analysis undertaken by UCT of South Africa's likely GHG emissions trajectories in the 2020s (UCT 2021b). The different growth rate assumptions are presented in Figure 5. The "fair share" results from all these analyses are presented in Figure 6.

In order to provide a range of options for the PCC to deliberate on possible adjusted target ranges for the NDC, a range of mitigation outcomes has been identified in relation to the above fair share results, which takes into account the range of the results, views that have been advanced by stakeholders, and the existing range of results (so as not to duplicate existing work). As observed above, the Centre for Environmental Rights proposed in its submission on the updated draft NDC an NDC target range for 2030 that is identical to the "fair share" range for 2030 (Centre for Environmental Rights 2021) for 1.5 degrees from the CERP assessment (Climate Equity Reference Project 2021).

Figure 7– Figure 6 with the proposed GHG emissions range for modelling analysis (275 to 390 Mt) superimposed on the various fair shares for South Africa in 2030.



The bottom of this range (275 Mt) has been used as the bottom of the modelling range, and the top of the range has been set at a value slightly below the GHG emissions outcome for the high growth rate (395 Mt). The proposed range is therefore from around 275 to 390, to encompass both 1.5- and 2-degree fair share ranges, below the current analysis.

The results for modelling the outcomes of this range will give a good indication of the required additional effort these target levels would require. In order to relate this rather complex diagram to potential NDC target levels, "threshold levels" for each assessment have been specified in Table 1 and Table 2, for both 1.5 and 2 degrees. The threshold level for each approach is the top of the value for the range of each approach. These have been condensed into ranges and then assessed against each approach ("yes" = below the upper end of the respective fair share range). The "ESRG old CERC" assessment has been included for information, but based on the information available, these results are no longer valid.

Table 1 – Threshold levels for 1.5 degrees fair shares for South Africa in 2030 (including land use)

NDC target level/GHG outcome (Mt CO2-eq)	336	337-343	344-352	353-406	407-417	+418
CERP assessment	yes	yes	yes	no	no	no
CERP assessment (sensitivity to SATIMGE growth)	yes	yes	yes	yes	no	no
ESRG updated CERC (using SATIMGE growth rates)	yes	yes	no	no	no	no
CAT (updated)	yes	no	no	no	no	no
ESRG old CERC	yes	yes	yes	yes	yes	no

Table 2 – Threshold levels for 2 degrees fair shares in 2030 (including land use)

NDC target level/GHG outcome (Mt CO2-eq)	363	364-401	402-426	427-444	445-466	+467
CERP assessment	yes	yes	no	no	no	no
CERP assessment (sensitivity to SATIMGE growth)	yes	yes	yes	yes	no	no
ESRG updated CERC (using SATIMGE growth rates)	yes	no	no	no	no	no
CAT (updated)	yes	yes	yes	no	no	no
ESRG old CERC	yes	yes	yes	yes	yes	no

A BRIEF NOTE ON THE NATURE OF SOUTH AFRICA'S NDC TARGET

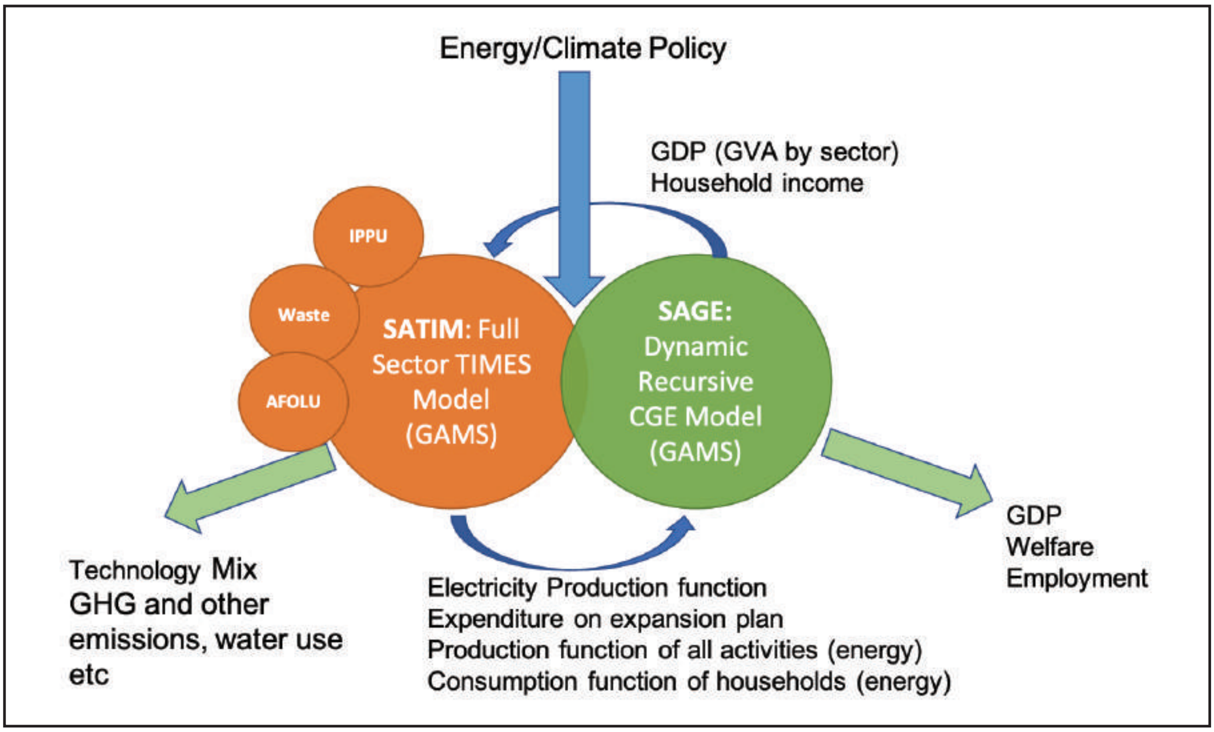
South Africa's NDC target is not unique in consisting of a range, but it is perhaps unique in that it is an economy-wide, fixed-level target range that does not reflect conditionality (even though it has been interpreted as such), and the range is considerable in the existing NDC. There is no explanation in the current (2016) NDC concerning the purpose of the range. On the one hand, the range, without any further explanation, represents a lack of transparency in that it creates uncertainty concerning the emissions outcome in 2030. This has led most observers to treat the South African NDC target as synonymous with the upper end of the range only. On the other hand, the range does offer the possibility of communicating the intention of higher mitigation ambition (than the upper end of the range) to potential investors/ providers of international climate finance.

3
MODELLING ANALYSIS OF NDC TARGET OPTIONS, FROM 275-390 MT IN 2030

A BRIEF DESCRIPTION OF THE MODELLING FRAMEWORK SATIMGE

GHG emissions, and other relevant indicators, were modelled using SATIMGE, which consists of the South African TIMES model (SATIM) hard-linked to ESAGE, a variant of the South African General Equilibrium CGE model with a more granular energy sector. Both models, as well as the linked modelling framework, are maintained by the Energy Systems Research Group at the University of Cape Town. SATIMGE now includes all sectors of the economy and all IPCC emissions categories contained in the South African GHG National Inventory Report (NIR), with the inclusion of waste and AFOLU emissions.

Figure 8 – SATIMGE integrated modelling framework.



All results discussed below were modelled using this integrated framework. SATIM contains a sophisticated representation of the electricity system, on the supply and demand sides, including detailed time resolution on both. Because TIMES is a linear optimisation model, SATIMGE can optimise in terms of the overall systems cost for specific GHG emissions objectives, including GHG emissions in a specific year, and/or cumulative GHG emissions constraints over a specific period. The SATIMGE modelling framework is presented in Figure 8.

It is important to note that SATIMGE starts from a base annual growth rate, and deviates from this in response to the GDP impact of modelled constraints (for instance, modelled policies and measures). It is also important to note that the electricity demand in SATIMGE is endogenous, i.e., that because the models are economy-wide, SATIM chooses both supply- and demand-side technologies to supply energy demands[4], and determines the electricity demand from this. By contrast, in the IRP 2019 electricity-only model, electricity demand is exogenous, i.e., provided to the model. SATIMGE is closely calibrated with the revised 2017 GHG NIR.

[4] *Energy demand in SATIM is "useful energy demand" – for instance, a certain amount of lighting in households. This demand for lighting can be satisfied by a menu of lighting technologies (for instance, incandescent, fluorescent or LED lightbulbs), which the model chooses according to overall costs and/or other imposed constraints.*

MODELLING METHODOLOGY FOR THIS PROJECT

The key goal for this analysis as stated above is to explore the implications of potential NDC targets in the range from 275 to 390 Mt CO2-eq. Rather than constrain GHG emissions in the economy to a series of levels for 2030, which usually leads to suboptimal outcomes (focused on achieving the emissions outcome in that year only), the approach used in this analysis sets a range of long-term cumulative GHG emissions outcomes (the sum of annual emissions from 2020 to 2050), to achieve a range GHG emissions outcomes in 2030, which then form part of cost-optimal long-term mitigation pathways.

Cumulative emissions outcomes were then varied to produce the required range of 2030 outcomes, with the required level of granularity. The result of this approach is that the model identifies a cost-optimal GHG emissions trajectory to 2050[5]. The great advantage of this approach is that it inherently considers the longer-term implications of choices made in the 2020s in terms of mitigation, and for the same set of assumptions, each point in 2030 corresponds to one cost-optimal trajectory for a specific long-term emissions constraint. The potential drawback of the technique is that it is sensitive to the cost and availability of post-2030 mitigation options.

This approach was used, via a range of 69 modelled cases, to achieve a sufficiently granular range of GHG levels for 2030, with and without the IRP 2019, with and without other policies and measures (specified below), and with two GDP growth rates (specified below). This range of results will then be assessed for what mitigation actions would be needed to achieve these outcomes; how these actions relate to current policies in terms of required investment; and the impact of each pathway on GDP and employment.

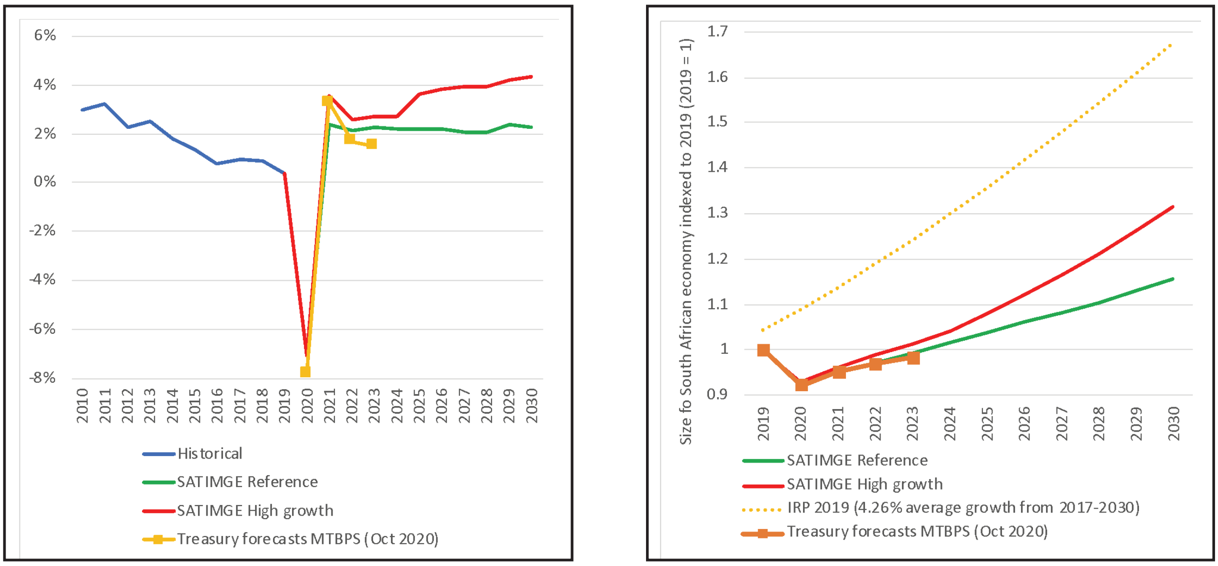
KEY ASSUMPTIONS AND POLICY OPTIONS

This section will describe the base economic growth rates used in the analysis, and then outline the policy variations modelled.

GDP growth rate

The economic growth rate is one of the key drivers for GHG emissions growth in the model. This analysis used two base growth rates from 2020 on – a “reference” growth rate, based on a range of growth projections from 2020 on, post-Covid; and a “high” growth rate, based on the potential impact of reforms proposed by the Treasury in (National Treasury 2019).

Figure 9 – Economic growth (historical, SATIMGE reference, SATIMGE high, and Treasury forecasts from October 2020) (left) and the resulting size of the economy relative to 2019 (right).



5 *In a linear optimisation model such as SATIM, and for two cumulative GHG emissions constraints (cumulative GHG emissions from 2020-2050), a and b, if a>b, then for each annual GHG emissions level in these trajectories, ayear >= byear for all years in the cumulative range.*

This results in a base[6] reference growth rate that reaches 2.3% and 4.3% respectively by 2030, which are presented in Figure 9. Both growth rates are lower than the growth rate underlying the IRP 2019 demand forecast.

Variations in modelled cases

Sixty-nine cases were modelled in total: 31 with the high growth rate, and 38 with the reference growth rate. Forty were modelled with a package of mitigation measures (excluding electricity) including the Green Transport Strategy (GTS) and the draft National Energy Efficiency Strategy, and 29 without additional policies and measures. Twelve were modelled with the IRP investment plan (specified below) with fixed retirement of Eskom's coal fleet; sixteen were modelled with the IRP investment plan, but with flexible retirement, and five with a version of the IRP without the non-renewable energy investments in the IRP.

The IRP's retirement schedule specifies the latest dates at which Eskom's existing coal plants will retire, while "flexible retirement" allows the option of these plants retiring early, if their annual utilisation drops below 40%[7]. A combination of these were modelled without GHG emissions constraints, to confirm the GHG outcomes for current policies; and combinations were then modelled with increasingly stringent cumulative GHG emissions constraints, to yield a variety of cost-optimal pathways to 2030, constrained and unconstrained by policy targets as specified below, which results in a range of GHG emissions levels in 2030 between 275 and 380 Mt Co2-eq.

Other measures common to all scenarios include the application of the carbon tax, which is modelled as being implemented at a nominal rate of R120/ton in 2019, rising as per the Carbon Tax Act to R127.30 (in 2019 rands) by 2022, and remaining at that level in real terms thereafter. The effective tax rate (after allowances) is R31.8/ton after 2022. It is assumed that existing gas-to-liquid capacity in Mossel Bay (PetroSA) retires in 2024, and that the coal-to-liquids complex maintains its current capacity until at least 2035, and meets Sasol's 10% GHG emissions reduction target by 2030, through substitution of on-site coal generation with renewables-generated electricity. In the waste sector, it is assumed that the modernisations introduced by the first and second National Waste Management Strategy are maintained.

Modelling the electricity sector

The electricity sector was modelled in the following variations:

- The IRP 2019 investment plan as described below to 2030, without flexible retirement of the existing coal fleet, with the addition of additional capacity as required
- The IRP 2019 investment plan as described below to 2030, with flexible retirement of the existing coal fleet, with the addition of additional capacity as required
- A variant of the IRP 2019 with renewable energy capacity only, with flexible retirement, with the addition of additional capacity as required
- No fixed investment plan, with flexible retirement – in these cases, the model identifies the least-cost investment plan to meet electricity demand, taking into account any GHG emissions constraint

Committed capacity as specified in the IRP 2019 is completed as specified in Table 3 below in all cases, with adjustments based on updates contained in Eskom's 2019 Medium-Term System Adequacy Outlook, while the timing of the REIPPPP (Renewable Energy Independent Committed capacity as specified in the IRP 2019 is completed as specified in Table 3 below in all cases, with adjustments based on updates

6 *The "base" growth rate is the growth rate of the modelled scenario with existing policies only (i.e., no implementation of current policy plans). The modelling framework meets demand by choosing an optimal pathway. The addition of policies/plans (for instance the IRP 2019) has GDP impacts, which would cause deviations from the base growth rates.*

7 *This is an aggregate figure derived from local and international estimates (for instance, see CSIR (2020)). A more accurate estimate would require more detailed data on individual plants, which is not in the public domain. The use of this value in the modelling analysis in no way suggests that this threshold would be used as the sole criterion for the actual retiring of these plants.*

contained in Eskom's 2019 Medium-Term System Adequacy Outlook, while the timing of the REIPPPP (Renewable Energy Independent Power Producer Procurement Programme) project's connection to the grid was reassessed using updated estimates from www.energy.org.za. For solar thermal, 400MW was assumed to have been connected by 2018 and 100MW only was added in 2019 (as opposed to 300MW being connected by 2018 and 300MW in 2019).

Table 3 – Committed capacity in the IRP 2019 and in SATIMGE for this analysis, contained in all scenarios; differences are highlighted in yellow

MW	2019	2020	2021	2022	2023
Coal IRP 2019	2 155	1 433	1 433	711	0
Coal SATIMGE	722	2 166	1 444	722	722
PV IRP 2019	0	114	300	400	0
PV SATIMGE	0	114	300	400	0
Wind IRP 2019	244	300	818	0	0
Wind SATIMGE	0	244	300	818	0
CSP IRP 2019	300	0	0	0	0
CSP SATIMGE	100	0	0	0	0

The new capacity investment plan for the IRP 2019 has been implemented as stated in Table 4 (DMRE 2019), with the following caveats, which have been highlighted in yellow in the table:

- The 750MW of planned coal capacity, which is scheduled in the IRP to begin operation in 2023, has been shifted to 2026, to allow sufficient lead time for auctioning, contracting, construction, etc.
- The new wind power capacity, which is due to begin coming online from 2022, had been shifted back to the latter half of 2023 to allow sufficient time for auctioning, contracting, construction, etc. This means that 800MW of wind capacity comes online in 2023, followed by 1 600MW per year as specified in the IRP, until 2030. The additional wind capacity is added after 2030
- 1 000MW of new natural gas capacity, which is scheduled to begin operation in 2024, has been shifted to 2026
- The "other" category is occupied in the unspecified years from 2019 to 2022 by 1 500MW of on-site PV, and the 500MW/year in this category is assumed to be taken up with on-site PV until 2030

Table 4 – New build in IRP 2019's Table 5 compared with the way it has been included in scenarios modelled with the inclusion of IRP 2019; differences are highlighted in yellow.

		2022	2023	2024	2025	2026	2027	2028	2029	2030
Coal	IRP 2019	0	750	0	0	0	750	0	0	0
	Planned policies scenario	0	0	0	0	750	750	0	0	0
Hydro	IRP 2019	0	0	0	0	0	0	0	0	2 500
	Planned policies scenario	0	0	0	0	0	0	0	0	2 500
Storage	IRP 2019	513	0	0	0	0	0	0	1 575	0
	Planned policies scenario	513	0	0	0	0	0	0	1 575	0
PV	IRP 2019	1 000	1 000	0	1 000	0	0	1 000	1 000	1 000
	Planned policies scenario	1 000	1 000	0	1 000	0	0	1 000	1000	1 000
Wind	IRP 2019	1 600	1 600	1 600	1 600	1 600	1 600	1 600	1 600	1 600
	Planned policies scenario	0	800	1 600	1 600	1 600	1 600	1 600	1 600	1 600
Gas/diesel	IRP 2019	0	0	1 000	0	0	2 000	0	0	0
	Planned policies scenario	0	0	0	0	1 000	2 000	0	0	0
Other	IRP 2019	-	500	500	500	500	500	500	500	500
	Planned policies scenario	450	500	500	500	500	500	500	500	500

Energy availability factors (EAFs) used in this modelling analysis were not those in the IRP 2019, which are considerably more optimistic than historical values, but have been sourced from (Wright and Calitz 2020), which are in turn based on historical projections. The use of lower EAFs has a notable impact on GHG emissions during the modelling period.

Table 5 – Average annual EAFs for Eskom's coal fleet

	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
IRP 2019	68%	69%	71%	71%	72%	73%	72%	72%	72%	73%	72%
Wright and Calitz 2020	61%	61%	62%	61%	60%	61%	60%	60%	60%	60%	59%

It should be emphasised that the electricity demand in the IRP 2019 is NOT the same as the resulting electricity demand contained in the results below. Because SATIMGE is an economy-wide modelling framework, the electricity demand is endogenous. The resulting electricity demand is compared to that of the IRP in the results section below. Generally, it is significantly lower than the assumed electricity demand in the IRP due to lower economic growth rates than those underlying the demand projections used in the IRP (these are presented above in the discussion of economic growth rates).

Modelling other sectors

For other sectors, two variations were modelled:

- Existing policies and measures only – policies and measures currently being implemented, including the carbon tax
- Planned policies and measures, which consist of:
    - o IRP 2019 in the electricity sector
    - o The Green Transport Strategy
    - o The draft post-2015 National Energy Efficiency Strategy
    - o The carbon tax
    - o Measures described below for the land sector

The GTS (DoT 2018) consists of a number of long-term qualitative goals, and a number of very ambitious quantified short-term goals. These have been implemented conservatively in the current analysis as follows:

- A shift from road to rail for corridor freight transport: by 2030, the rail share of corridor freight transport will be 30%, and by 2050, 50%
- A shift from private to passenger transport: a 20% relative shift to public transport by 2030
- Alternative vehicles: a minimum of 10% of the vehicle population will comprise EVs and hybrid vehicles by 2030, reaching 40% by 2050
- Minibus conversion to bi-fuel (CNG/ petrol) vehicles: 10% of the minibus taxi fleet will be converted to be bi-fuelled by 2030, reaching 40% by 2050
- Metrobus to gas: 10% of the municipal bus fleet will be converted to gas by 2030, reaching 30% by 2050

The GTS also contains references to biofuels – 2% blending with petrol and 5% blending with diesel by 2030 have also been included in the planned policies scenario.

Energy efficiency measures modelled in the planned policies scenario are, in the absence of a finalised energy efficiency policy and/ or strategy, based on the draft post-2015 National Energy Efficiency Strategy (NEES) (DoE 2016), which proposes sectoral targets for 2030. These are included as follows:

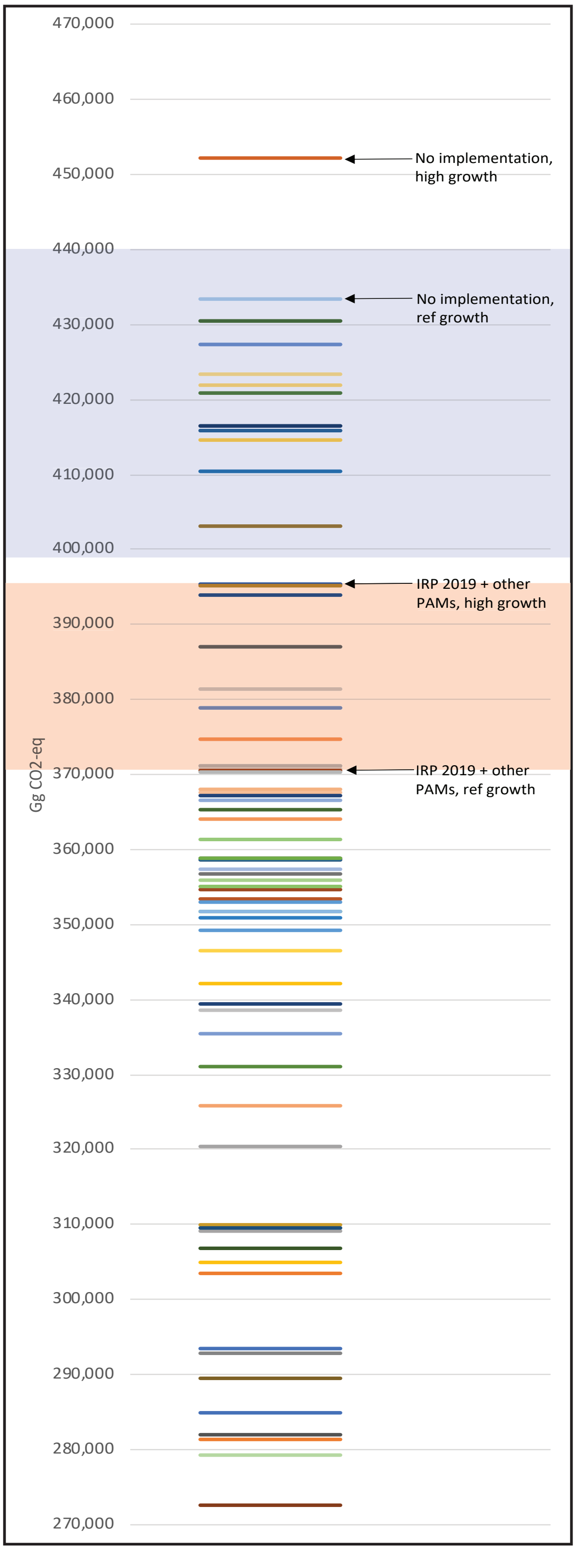
- Residential: a 30% improvement in the efficiency of household energy appliances by 2030, and a 20% improvement in the energy efficiency of residential buildings by 2030
- Commercial: a 37% reduction in energy intensity in commercial buildings, including government buildings, by 2030
- Mining: the 40 PJ savings identified by the NEES translates into a 4% energy saving by 2030.
- Manufacturing: 35% improvement in energy efficiency in all applications other than furnaces and kilns, which improve by 5%, by 2030

No planned policies for mitigation were found in the agriculture sector for non-energy emissions, and so there is no mitigation modelled in this sector. In the land sector, a number of measures were modelled as follows:

- Forest, woodland and grassland rehabilitation, and thicket restoration as contained in the Department of Agriculture, Forestry and Fisheries' (DAFF) 2015/16 to 2018/19 Strategic Plan (DAFF, 2015a), the Land Degradation Neutrality Targets, and the DAFF's draft Climate Change Sector Plan
- Replanting of temporarily unplanted plantations as contained in the DAFF 2015/16 to 2018/19 Strategic Plan
- Restoration of agricultural land as contained in the DAFF 2015/16 to 2018/19 Strategic Plan
- Conservation agriculture measures contained in the draft Conservation Agriculture Policy for the DAFF
- Afforestation measures contained in the DAFF's draft Climate Change Sector Plan

In the waste sector, it is assumed that the targets in the third National Waste Management Strategy are achieved for waste minimisation, further increases in recycling targets, and diversion of organic waste from landfill.

Figure 10 – National GHG emissions levels of 69 modelled cases for 2030. The blue band is the current proposed NDC target, and the yellow band is the range of GHG outcomes as a result of the implementation of current policies, with different GDP growth rates.



RESULTS

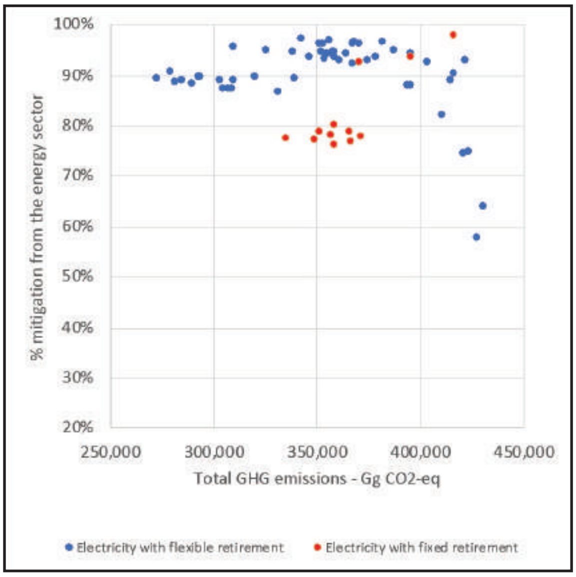
Sixty-nine cases were modelled with differing GHG emissions constraints and policy variations as above, with the resulting GHG emissions outcomes for 2030 as presented in Figure 10, with the proposed NDC target range for 2030. The cases with no implementation of mitigation policies (with reference and high economic growth), and full implementation – including the IRP 2019 – without any GHG emissions constraint, are highlighted. The lower end of the proposed NDC target range is higher than the likely emissions outcome of current mitigation policies, for both growth rates.

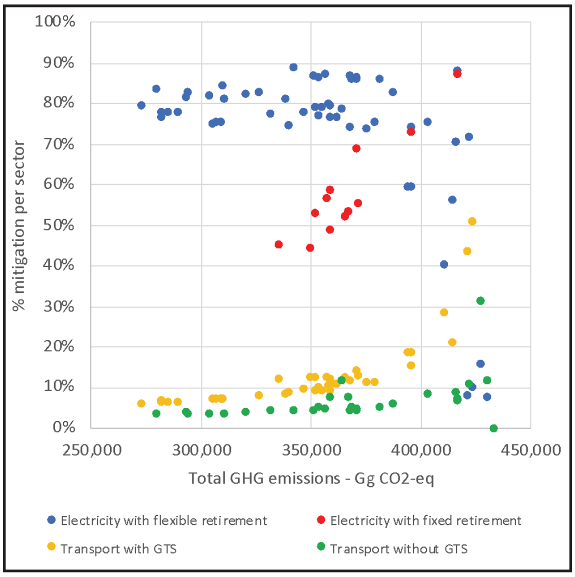
Characteristics and variations of these cases are described below, but an initial observation is that the currently proposed target range is set quite conservatively in relation to the expected outcomes of current policies, specifically the lower end of the target range.

Increasingly stringent GHG emissions constraints result in the modelling framework identifying more costly mitigation options. Additional mitigation options are assumed not to be available up to 2030 in the waste, land and agriculture sectors (these have not been identified and quantified, other than the measures described above); additional low-cost mitigation options in these sectors may, with further development, therefore be able to contribute more to reaching an ambitious mitigation target for 2030.

As a result, the options available to the modelling framework up to 2030 are in the electricity sector, the transport sector, and the industrial and buildings sector, including the abatement of some process emissions. Modal shifting in the transport sector is specified outside the modelling framework, but within the modal profile of the sector the modelling framework is able to shift to a wide range of alternative transport technologies. Figure 11 shows the percentage share of mitigation from the energy sector, and more specifically from the electricity and transport sectors.

Figure 11 – Shares of overall mitigation in 2030 for energy emissions (IPCC category 1)(left), and electricity and transport (IPCC categories 1A1a and 1A3 respectively); (mitigation = total GHG emissions in 2030 without emissions constraints or implementation of current policy plans minus total GHG emissions for each case)

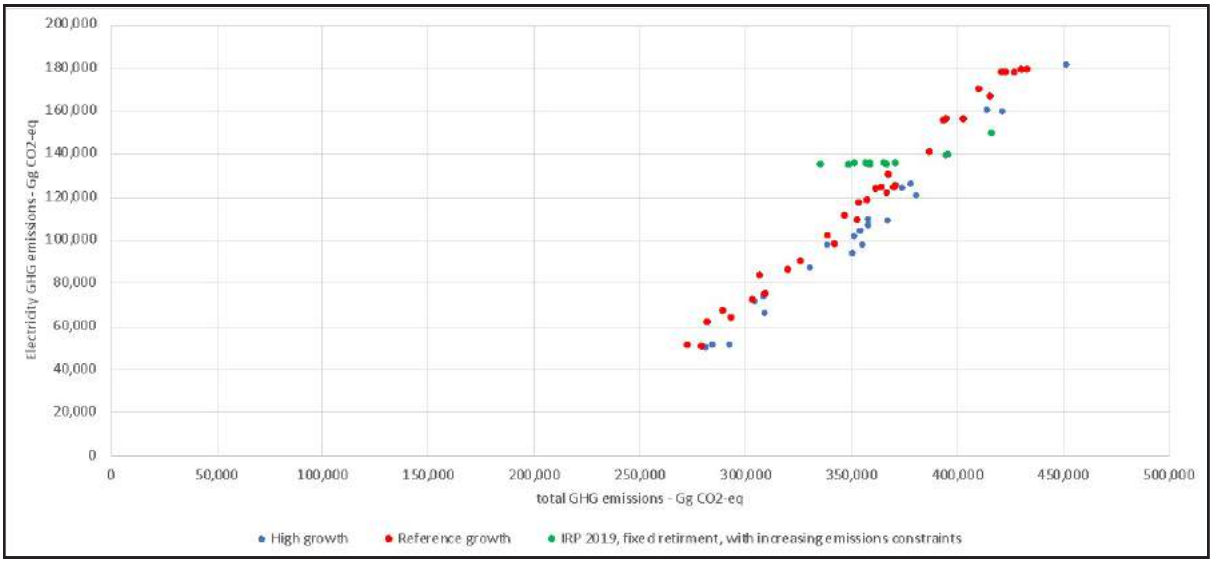




More than 90% of mitigation in 2030 results from decarbonisation of energy use, primarily from electricity and transport. The overwhelming share of this is from decarbonisation of the electricity sector, with a much smaller contribution from the transport sector. The cases in which retirement of coal plants is fixed (with a minimum utilisation rate of 40%) are highlighted in red. The minimum utilisation rate and the fixed retirement schedule imply that coal-plant emissions have a minimum level for each year, and as a result the electricity sector has a much lower contribution to mitigation in cases with higher GHG emissions constraints. This in turn results in the selection (pre-2030) of much more expensive mitigation options in the "hard to mitigate" sectors such as the iron and steel sector.

However, without these constraints, the share of mitigation from the electricity sector remains consistently high as the GHG emissions level in 2030 drops. The electricity sector is therefore the primary source, from a cost point of view, of additional mitigation potential by 2030, unless constrained as above. The relationship between the national GHG emissions level in 2030 and GHG emissions from the electricity sector is presented in Figure 12. The relationship is almost linear, which means that far more ambitious target levels in 2030 would mean very steep GHG emissions reductions in the 2020s in the electricity sector, consisting primarily of lower utilisation of coal power/ earlier retirement of the existing coal fleet, combined with investment in additional renewable energy capacity.

Figure 12 – Electricity sector emissions vs total GHG emissions for various levels of economy-wide mitigation in 2030.



For the same national GHG emissions level, electricity sector emissions are typically lower in the high growth case, since GHG emissions elsewhere in the economy are higher and more costly to mitigate (thus leading to more mitigation in the electricity sector).

In the transport sector, there is an underlying technology shift taking place both with and without additional policy, on account of global developments, as presented in Figure 13. In addition to this, in the presence of an overall GHG emissions constraint, there is a faster shift to electric vehicles, and with the addition of the Green Transport Strategy, a modal shift in both the freight and passenger sectors, which results in a higher contribution to mitigation, illustrated in Figure 11 (right). However, these shifts are far more pronounced after 2030, with and without policy, in terms of GHG emissions, meaning that the transport sector will make a significant but relatively small contribution to mitigation in the timeframe up to 2030. The mitigation impact of a shift to electric vehicles is also dependent on the marginal GHG emissions impact of additional electricity demand. With more investment in renewable energy, the marginal emissions impact of EVs is close to zero, whereas with higher utilisation of the coal fleet, the marginal emissions impact is very high.

The key source of additional mitigation up to 2030 will therefore be the electricity sector. What this will actually require in terms of additional generation capacity by 2030, and additional retirement of existing coal capacity, is presented in Figure 14, with reference and high growth rates, and with and without additional policies and measures. The addition of energy efficiency policies makes a significant difference to the scale of additional capacity required for each emissions level, as does the economic growth rate.

Figure 13 – Annual passenger kilometres travelled in South Africa by transport technology.

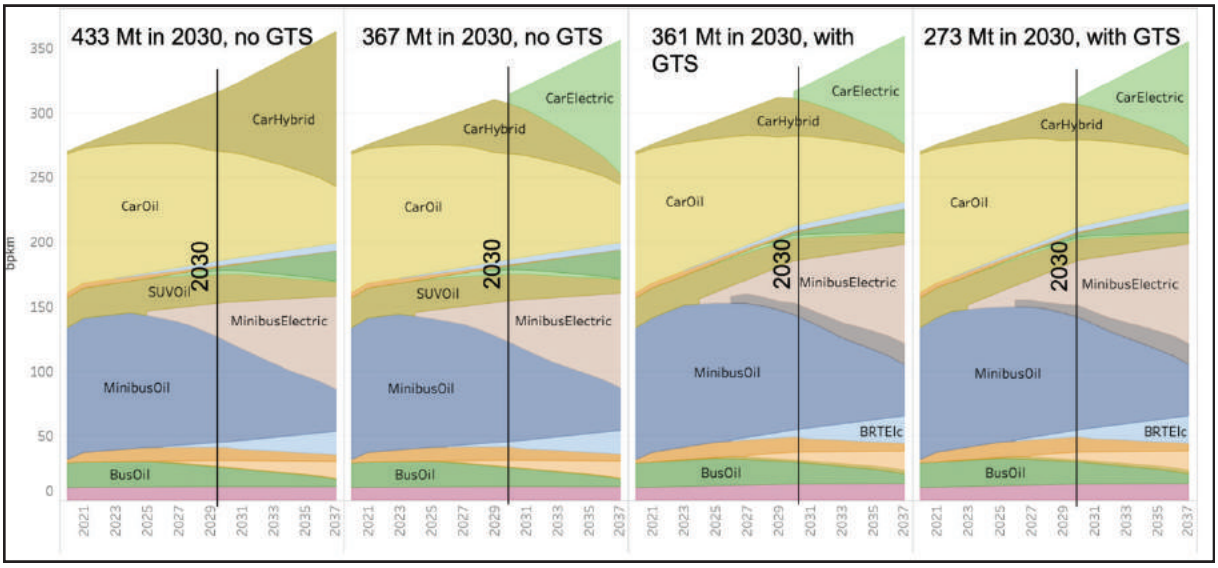
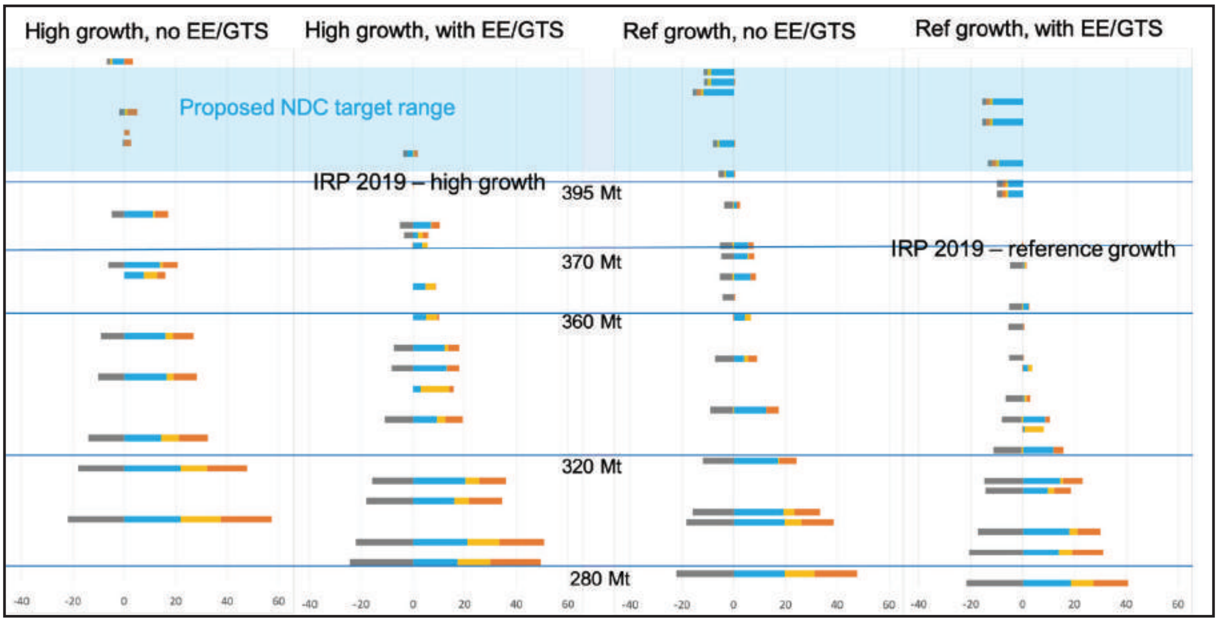
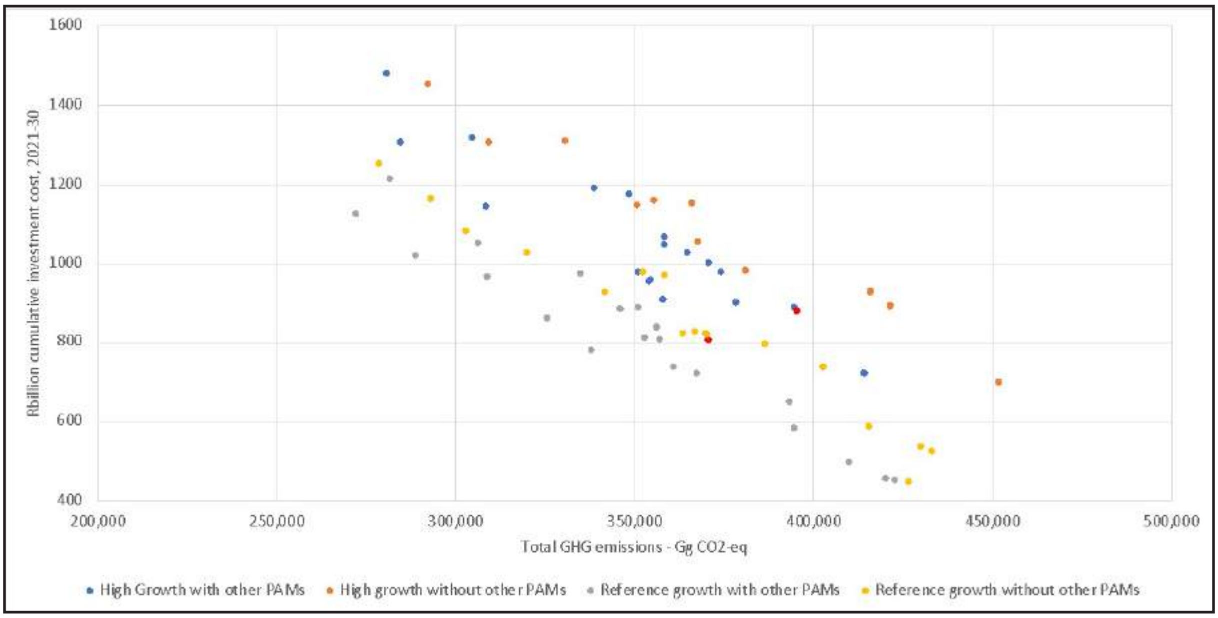


Figure 14 – Differences between coal, wind, solar and battery/OCGT capacity in the IRP 2019 case (with other policies and measures) and more GHG emissions-constrained cases, with different economic growth levels, and with and without other policies and measures. The scale at the bottom of the graphs is in GW of capacity, which is indicated for each modelled case in relation to the IRP 2019 cases (which have almost identical capacity for reference and high growth rates) for specific GHG emissions outcomes for the economy in 2030. Negative numbers indicate less capacity, and in the case of coal plants, earlier retirement than in the IRP 2019 schedule, AND avoiding building the new coal capacity specified in the IRP 2019. Positive numbers indicate additional capacity required.



Relatively small adjustments in the retirement schedule of existing coal plants and new renewable energy capacity are required to reduce national GHG emissions to around 350 Mt in 2030, and further reductions would require far greater additions. National NDC target levels of 280 Mt would require the retirement of much of Eskom's coal fleet, and the addition of more than 40GW of renewable energy capacity.

Figure 15 – Cumulative investment requirements in the electricity sector (2021-2030) with reference and high growth rates, and with and without additional policies and measures, plotted against national GHG emissions levels in 2030. The red dots indicate the IRP 2019 plus other PAMs (policies and measures) cases (reference growth rate on the left, high growth rate on the right).

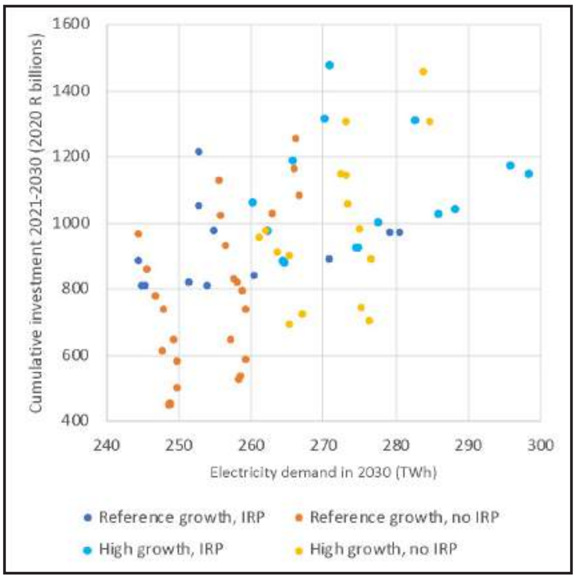


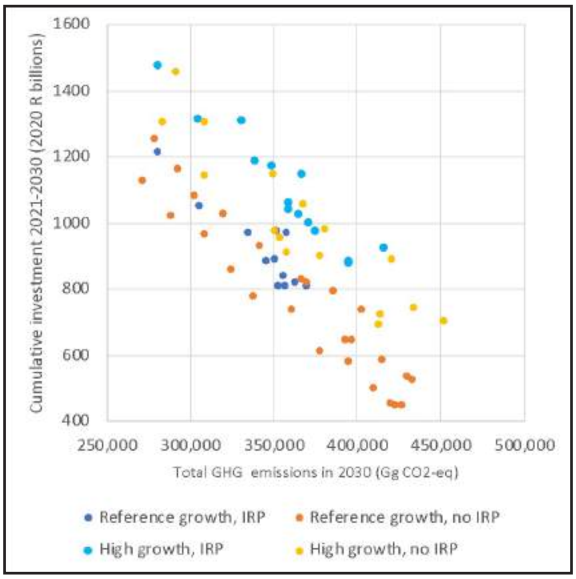
The corresponding investment requirements in the electricity sector from 2021 to 2030 are presented in Figure 15. These INCLUDE the investment costs incurred for the remaining units of Medupi and Kusile (as applicable), and the additional coal plants and hydro capacity (in the DRC) in the IRP in the cases in which these occur. With due consideration for other factors, the investment cost rises around R200-billion per additional 50 Mt mitigated in 2030 beyond the IRP levels for either growth rate.

This is true on aggregate for similar cases with different levels of GHG emissions constraint, but there is also a range of cumulative investment requirements for each national emissions outcome, which correspond to differences in electricity demand, resulting from either different economic growth rates (higher or lower electricity demand); different degrees to which energy efficiency policies have been implemented (higher or lower electricity demand); and the additional cost impact of the IRP (since some of the policy adjustments in the IRP 2019 – specifically the new coal plants and the imported hydro option – are more expensive than other options (renewable energy)).

There are two characteristics worth noting as presented in Figure 16 – the non-IRP cases (with different GHG emissions constraints) have similar demands for the policy and non-policy cases (with and without energy efficiency) (the orange and yellow bars), with slightly declining electricity demand for more ambitious mitigation cases due to slightly lower economic growth as described below.

Figure 16 – Cumulative investment in the power sector (2021-2030) vs electricity demand in 2030 (left) and total GHG emissions (right), separated into IRP and non-IRP cases.





The nature of the fixed IRP 2019 build plan and the minimum utilisation of coal plants (set at 40%) results in far more expensive mitigation elsewhere in cases in which a more stringent GHG emissions outcome is required by 2030, which significantly increases electricity demand (mainly in the iron and steel sector, replacing coal with hydrogen in the late 2020s). This is because the combination of a minimum annual utilisation of the coal fleet, plus a fixed retirement schedule, renders further reduction in emissions from the electricity sector below around 135 Mt impossible (see the green dots in Figure 12, representing cases in which both these constraints exist). The right-hand graph (the same data as presented in Figure 15 but with cases separated into IRP and non-IRP cases) demonstrates that for any specific level of national GHG emissions in 2030, the IRP cases have higher investment requirements, for the reasons cited above.

The economic impact of different mitigation outcomes is presented in Figure 17, in terms of the impact on the size of the economy in 2030, relative to the case in which the IRP 2019 plus other current policies are fully implemented, for the reference growth rate (left) and high growth rate (right). Generally, there is a slightly negative impact on economic growth, which is proportional to the overall mitigation outcome. The driver for this is mainly the increase in the capital requirements of the power sector with more mitigation, which have the effect of crowding out investment elsewhere in the economy (i.e., from more productive sectors).

There are a couple of elements that may change this overall outcome:

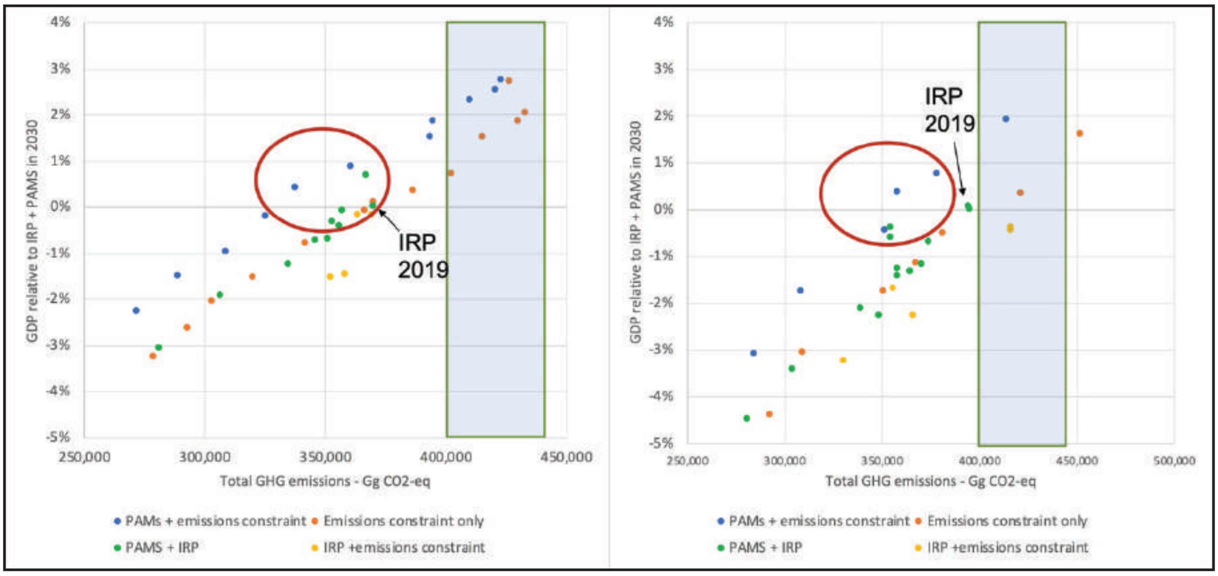
- The first is that this result is driven by the underlying assumption that the South African economy has a relatively closed capital supply. This has been disputed by some economists
- The second is that the social and economic costs of additional water consumption and externalities related to air pollution and coal mining are probably not fully captured in the modelling framework. Although the model does account for externalities at the same rate as the IRP 2019, it does NOT account for the significant costs of compliance of the existing coal fleet with current air pollution legislation

- The model also does not contain a social cost of carbon, and does not account for the potential employment benefits of demand-side programmes such as energy efficiency

Aside from these caveats, there are two notable conclusions to be drawn from these results:

- In comparison to the IRP 2019 case, there are other options that have lower national GHG emissions, but have a positive or negligible negative impact on economic growth – i.e. it is possible to explore more optimal mitigation policies that will result in greater mitigation with economic benefits, and
- Enhanced access to international climate finance could partially or completely offset any GDP loss as a result of increased ambition

Figure 17 – GDP impact – relative size of the economy in 2030 in relation to the IRP 2019 (plus additional PAMs) cases, plotted against the national GHG emissions level in 2030 for each case. The red circle highlights cases with similar GDP impact but significantly different levels of mitigation.



Employment impacts, presented for the electricity and coal sectors in Figure 18, are relatively neutral, with a slight net increase with increased ambition, with losses in the coal sector as a result of less coal being used for electricity generation being offset by gains in the electricity sector. It is also important to note that these new employment opportunities in the electricity sector would not necessarily be created in the same areas of the country, and would not necessarily require the same skills. This is based on the assumption that coal exports remain constant at around 75 Mt, which may not be the case in an increasingly carbon-constrained world. The employment losses that result from a fall in exports would occur regardless of mitigation in South Africa.

Figure 18 – Total employment in the electricity sector (red) and coal sector (yellow) in 2030, for each case, plotted against total GHG emissions in 2030. The combined figure for both sectors is in green.

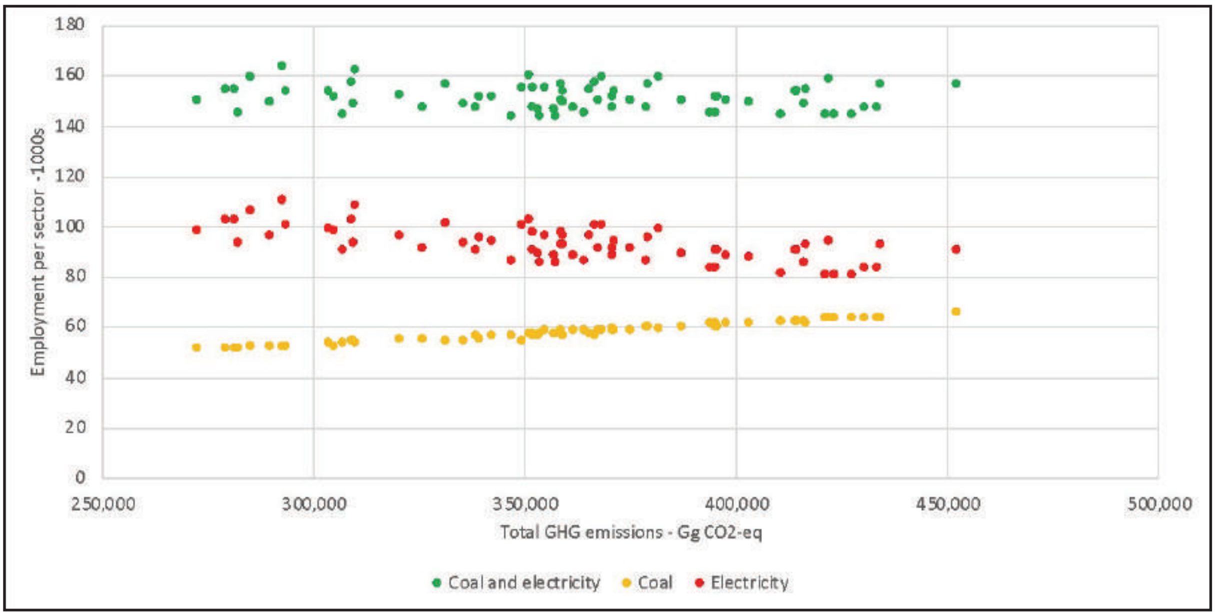
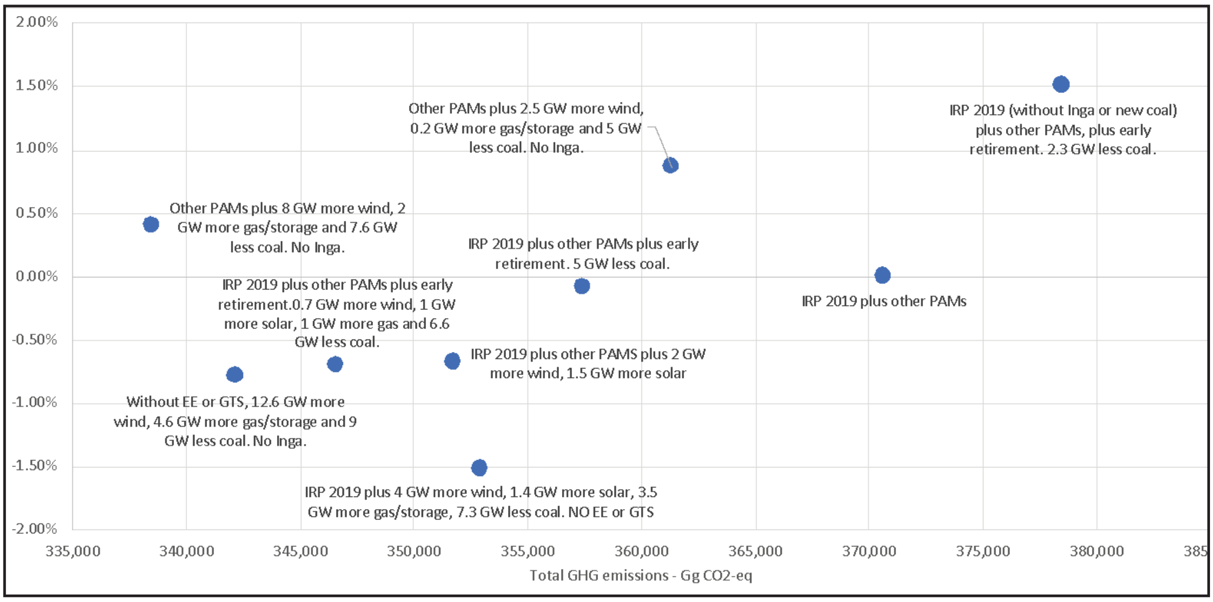


Figure 19 – A range of modelled cases with GHG emissions outcomes between 335 Mt and 385 Mt, with contrasting economic impact. The Y axis is the % difference in the size of the economy in 2030 in relation to the "IRP 2019 plus other PAMs" case, i.e., a case in which the IRP 2019 and other current policies are implemented (all cases assume the reference growth rate). Figures for capacity addition/subtraction are relative to the IRP, and coal capacity differences INCLUDE the 1.5GW of new coal capacity specified in the IRP, if investment in this capacity has been avoided in the respective case.



Finally, Figure 19 takes a much closer look at the data presented in Figure 17. The nine cases presented contain details on additional capacity/retired capacity in relation to the total capacity in 2030 resulting from the IRP 2019 investment plan. The existence of a number of options with emissions below 370 Mt in 2030, and economic impacts within a small band (+/2%), suggest that from a mitigation point of view, and in terms of economic impacts, there is considerable potential to achieve more ambitious mitigation in 2030 by updating the IRP, and considering: the value of the additional coal and hydro capacity; the possibility of retiring some of the existing coal fleet earlier than planned; or running these plants at a much lower utilisation rate.

Energy efficiency programmes clearly have a significant economic benefit the should not be underestimated. This analysis does not consider the potential economic benefits of a large-scale green hydrogen/green ammonia export industry, which would in turn be based on a far more rapid expansion of renewable energy capacity.

4
TARGET CHOICE OPTIONS

Based on discussions of the proposed NDC mitigation target range during the PCC hearings on 4 May 2021, three options are proposed for the 2030 target range, as presented in Figure 20:

1. The first option proposes accepting the target range as proposed in the NDC
2. The second option proposes moving the entire NDC range downwards
3. The third option proposes moving only the bottom of the range downwards

Options 2 and 3 each have two sub-options, and these have been assessed using a number of criteria, in Table 9. The ranges in the options have been compared to the fair shares analysis in Figure 6, presented graphically in Figure 21, Figure 22, Figure 23 and Figure 24. These have also been assessed in relation to the relevant fair share approaches (as in Table 1 and Table 2) in Table 6 and Table 7.

In Table 8, a range of characteristics are presented for modelled cases within GHG emissions ranges corresponding to the target options above. These include a range of cases with different economic growth rates, and with and without energy efficiency and the GTS. There are a number of notable differences between target levels which emerge from this.

The first is that the uncertainties around economic growth and implementation are greater than the impacts of moving from a target level of 440 Mt to 420 Mt, although this does bear more careful analysis, since only a few cases were modelled in the upper range. The impact of a move from the 370-390 Mt range to the 340-360 Mt range is not very significant in terms of the possible ranges of required capacity, although the investment requirements could be double those in the higher range. There is quite a high sensitivity to the implementation of energy efficiency policies, and the higher cost of the non-renewable capacity in the IRP also has a large impact on costs. Significantly, higher amounts of additional investment and capacity are required to meet an NDC target in the lower range, and probably, and most significantly, this would require the early retirement of a large proportion of Eskom's coal fleet.

What these results unequivocally suggest is that in seeking an optimal mitigation outcome in 2030 there is considerable room to rethink current mitigation policies, including the IRP 2019.

Figure 20 – Three options for consideration regarding the proposed NDC target range for 2030.

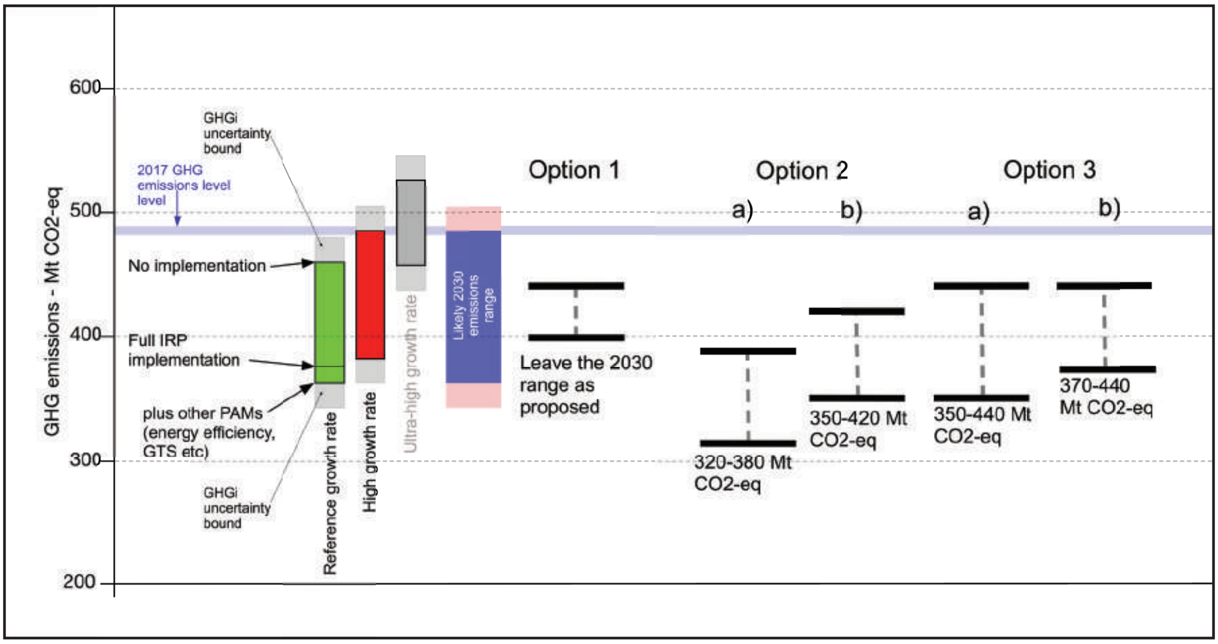


Figure 21 – Fair share analysis with option 2(a).

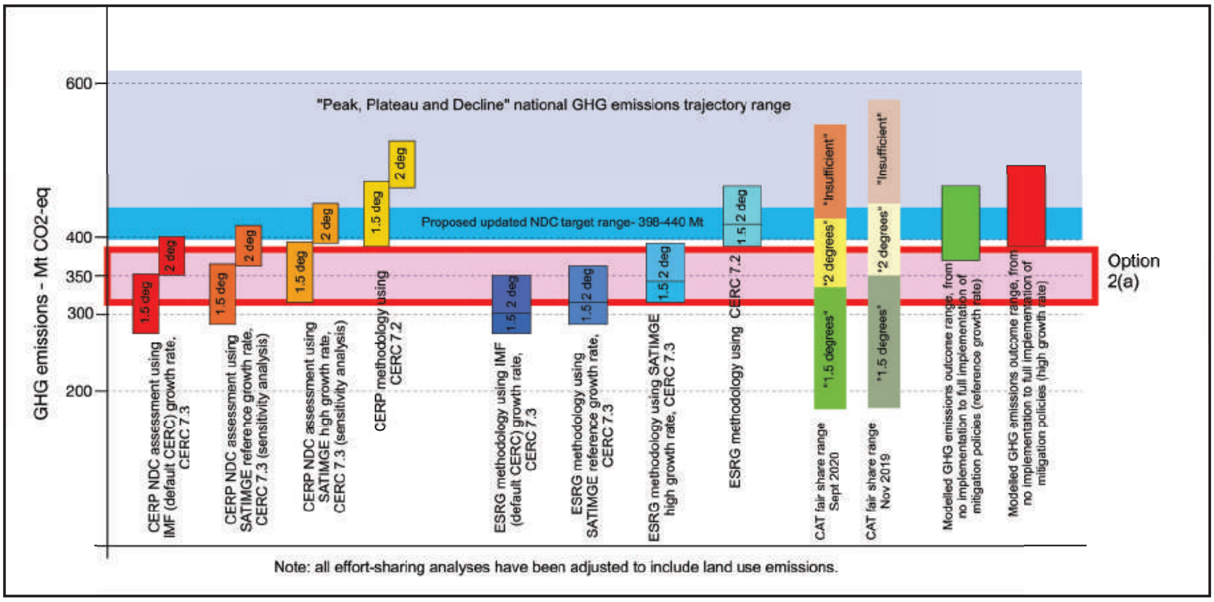


Figure 22 – Fair share analysis with option 2(b).

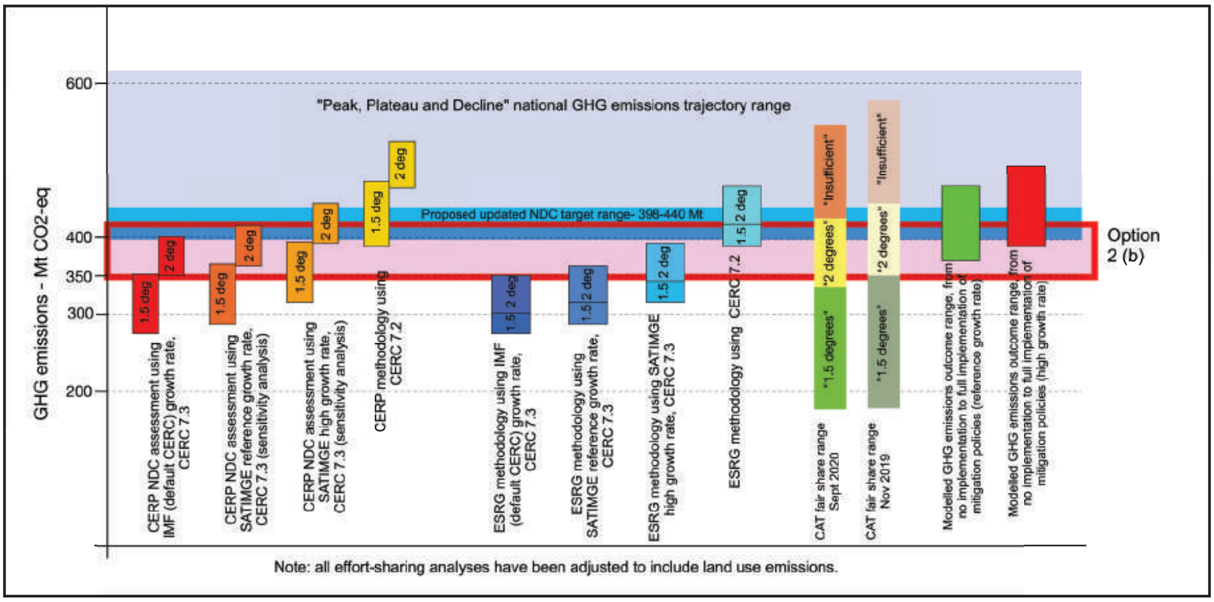


Figure 23 – Fair share analysis with option 3(a).

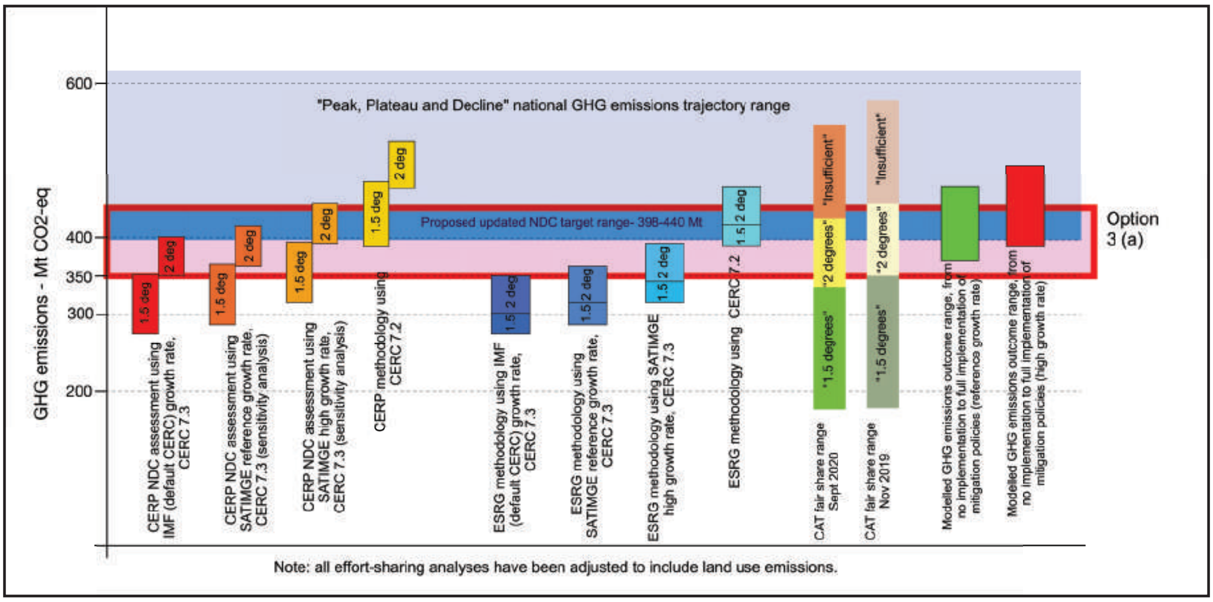


Figure 24 – Fair share analysis with option 3(b).

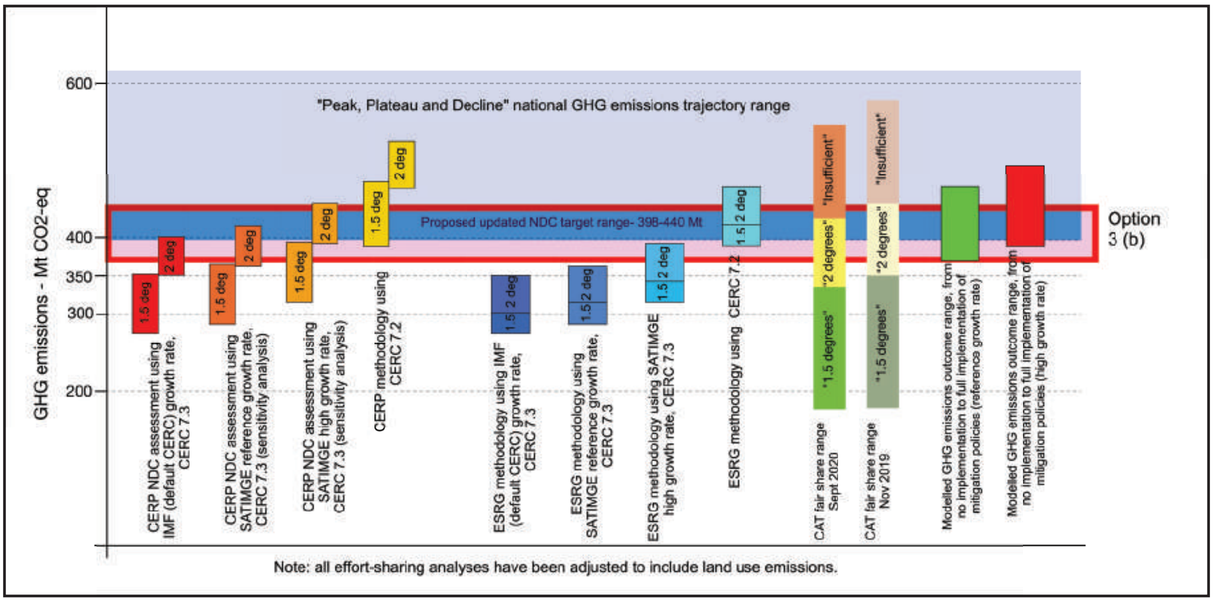


Table 6 – NDC target options evaluated against fair share ranges for 1.5 degrees

NDC target level/GHG outcome	320 Mt	350 Mt	370 Mt	380 Mt	398 Mt	420 Mt	440 Mt
CERP assessment	yes	yes	no	no	no	no	no
CERP assessment (sensitivity to SATIMGE growth)	yes	yes	yes	yes	yes	no	no
ESRG updated CERC (using SATIMGE growth rates)	yes	no	no	no	no	no	no
CAT (updated)	yes	no	no	no	no	no	no
ESRG old CERC	yes	yes	yes	yes	yes	no	no

Table 7 – NDC target options evaluated against fair share ranges for 2 degrees

NDC target level/GHG outcome	320 Mt	350 Mt	370 Mt	380 Mt	398 Mt	420 Mt	440 Mt
CERP assessment	yes	yes	yes	yes	yes	no	no
CERP assessment (sensitivity to SATIMGE growth)	yes	yes	yes	yes	yes	yes	yes
ESRG updated CERC (using SATIMGE growth rates)	yes	yes	no	no	no	no	no
CAT (updated)	yes	yes	yes	yes	yes	yes	no
ESRG old CERC	yes	yes	yes	yes	yes	yes	yes

Table 8 – Range of requirements in 2030 of modelled cases within the specified GHG emissions ranges (in terms of electricity-generating capacity ADDITIONAL to the IRP 2019 case); the additional investment requirement; % mitigation coming from the electricity sector; and economic impact expressed in terms of % GVA difference from the IRP 2019/other PAMs case (corrected for differences in economic growth). Cases with the IRP build plan, no endogenous retirement of coal plants AND an emissions constraint have been excluded

NDC target range		Additional wind power	Additional solar power	Additional OCGT/ batteries	Addition coal retirement/ avoidance *	Additional investment requirement (relative to the IRP)	% mitigation from the electricity sector	% increase/ decrease in the size of the economy in 2030
		GW	GW	GW	GW	R billions	%	%
310-330	Minimum	11.8	-0.5	3.9	-18.0	51	75%	-3.3%
	Maximum	21.8	10.4	15.4	-10.7	429	84%	-0.2%
340-360	Minimum	0.0	-0.4	0.2	-10.7	-73	74%	-2.1%
	Maximum	16.6	3.1	9.0	-5.0	308	89%	0.9%
370-390	Minimum	0.0	-0.5	-0.2	-6.3	-88	69%	-1.2%
	Maximum	13.8	2.2	5.7	0.0	174	86%	0.8%
410-430	Minimum	-11.6	-1.1	-1.6	-1.8	-361	8%	-0.5%
	Maximum	0.3	0.8	3.9	0.0	49	88%	2.8%
435-450	Minimum	-8.94	-1.29	0.385	-1.5	-284	0%	2.0%
	Maximum	-4.72	-0.67	3.415	-1.5	-180	0%	1.6%

* This INCLUDES avoidance of the 1.5GW of new coal in the IRP (which is not in any cases except those with the IRP build plan).

Table 9 – Options 1 to 3, briefly evaluated in terms of a number of policy-relevant criteria

Target options for 2030	Option 1 – as is	Option 2 – move entire range down		Option 3 – move bottom of range down	
	398-440	**a) 320-380**	**b) 350-420**	**a) 370-440**	**b) 350-440**
Climate change policy implementation requirements	Current policies will very likely achieve a GHG level within the range without additional measures.	Upper end – current policies, with additional measures with higher growth; lower end – far more ambitious electricity sector mitigation, measures required in other sectors.	Upper end – current policies; lower end – augmented IRP 2019, with some earlier retirement (relative to the IRP 2019) and more RE.	Current policies. With higher economic growth, achieving the lower end would require augmenting the IRP.	Upper end – current policies; lower end – augmented IRP 2019, with some earlier retirement (relative to the IRP 2019) and more RE.
Equity, fair share (relative to revised assessment)	Upper end is above fair share ranges; lower end is 2 degrees compatible in some assessments.	Lower end is 1.5 degrees compatible in all analyses; upper end is 2 degrees compatible.	Lower end is 1.5 degrees compatible in some analyses; upper end is 2 degrees compatible only in CAT.	Upper end is above fair share ranges; lower end is 2 degrees compatible.	Upper end is above fair share ranges; lower end is 1.5 degrees compatible in some assessments.
International positioning	Does represent progression. Difficult to argue that the range constitutes South Africa's "highest possible ambition" in relation to current policies.	Ambitious target range, Larger range is less credible, and the lower part of the range is not supported by current policy.	Larger range is less credible. Lowering of upper bound sends a clear signal of ambition and commitment to current policies.	Much larger range is less credible and less transparent without reframing, but more aligned with current policies.	Much larger range is less credible and less transparent without reframing, but signals South Africa's willingness to incrementally increase ambition.
Risk of not achieving the target	Limited to no risk. Will require at least limited implementation of existing policies.	High risk, without implementation of existing policies plus further measures.	Medium-low risk of not landing within the range.	Limited to no risk. Will require at least limited implementation of existing plans.	Limited to no risk. Will require at least limited implementation of existing plans.

Table 9 – Options 1 to 3, briefly evaluated in terms of a number of policy-relevant criteria (Continued)

Target options for 2030	Option 1 – as is	Option 2 – move entire range down		Option 3 – move bottom of range down	
	398-440	**a) 320-380**	**b) 350-420**	**a) 370-440**	**b) 350-440**
Social, developmental case	Current policies will result in co-benefits such as pollution reduction, potential green industrialisation, etc.	Enhanced ambition would enhance these benefits significantly, but requires negative impacts of faster transition to be addressed via additional policies.	Current policies will result in co-benefits such as pollution reduction, potential green industrialisation, etc. More commitment would enhance job creation.	Current policies will result in co-benefits such as pollution reduction, potential green industrialisation, etc.	Current policies will result in co-benefits such as pollution reduction, potential green industrialisation, etc.
Trade and competitiveness	Limited threat of border tax adjustments (BTAs).	No risk of countermeasures. Will create opportunities for faster entry into green export markets.	Smaller risk of BTAs.	Smaller risk of BTAs.	Smaller risk of BTAs.
Support requirements/ ability to mobilise international climate finance (ICF)	Weaker alignment with current policies may undermine the NDC's usefulness to attract ICF.	High potential to attract ICF. Implementation further down the range will require extensive support.	Clear signal of more ambition, if framed; will require additional support to go beyond the IRP 2019.	Better alignment with current policies at the bottom of the range.	Leaves the door open for a more ambitious programme at the bottom end of the range.

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ADDENDUM: CARBON PRICING

Some additional exploratory modelling was done to test the sensitivity of the model to different carbon prices, with the future research goal of quantifying the impact that various carbon pricing levels will have on the South African economy. For this analysis, only SATIM was used, and a carbon price was imposed on the economic sectors the carbon tax is currently imposed on.

A note of caution – the policy relevance of this initial piece of analysis is that the Treasury will in the next year or so decide on an approach to set the carbon tax level from 2023 on (phase 2). It is therefore very useful to understand how GHG emissions will likely change in response to a specific carbon price. It may also be useful to consider the introduction of a social cost of carbon in planning processes (as in, notably, the United States). However, the following should be borne in mind:

- Bottom-up optimisation models usually underestimate the potential impact of carbon pricing, since indirect impacts of carbon pricing on demand are not captured, as these would be in the full linked model SATIMGE
- Demand-side responses by firms such as investments in efficiency improvements, and any other mitigation options which are not captured in SATIM, would not be captured in this analysis
- SATIM and similar technology-rich models are very good at capturing the direct economic impact of carbon pricing on technology choice on the supply and demand sides
- In reality, a carbon price in its current form in South Africa of a carbon tax would be one mitigation instrument among several, and the complex effect of multiple instruments, some of which would also have an impact on prices, is not captured here

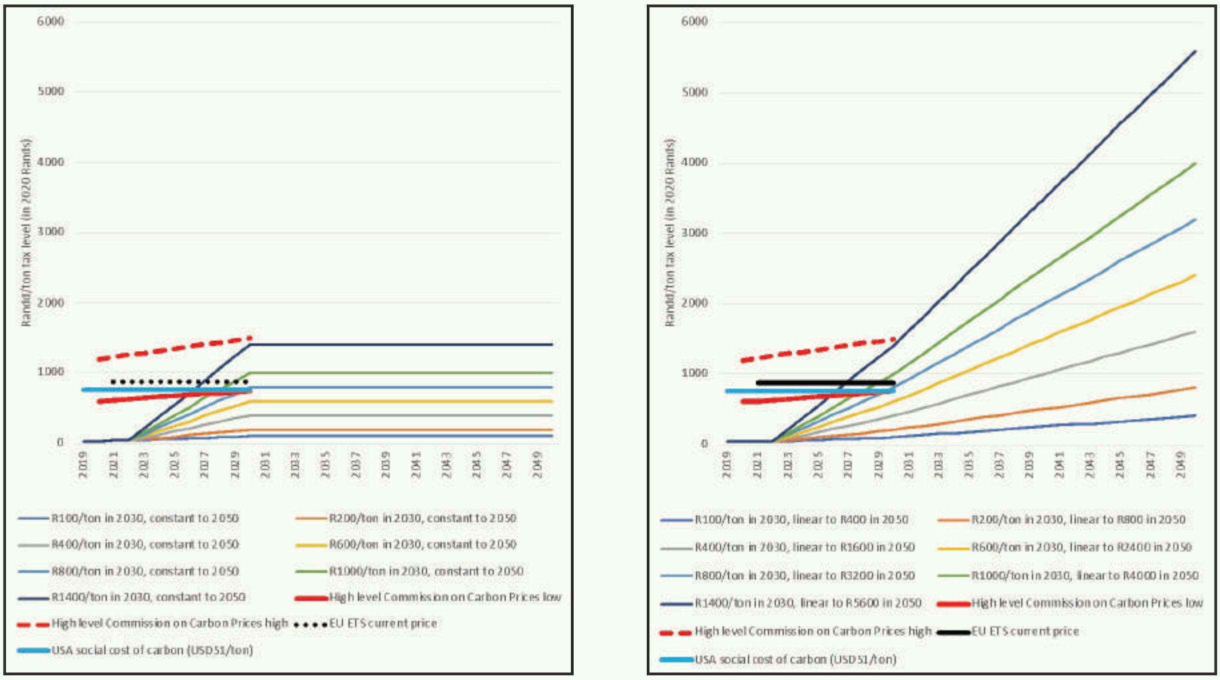
The usefulness of this analysis, which is a preliminary piece of analysis to a more detailed consideration of carbon pricing, is then to provide an envelope for the response of the energy/industrial system to carbon pricing.

The carbon price range imposed on SATIM was derived from the marginal cost of GHG mitigation in the series of cases modelled above using the full linked version of SATIMGE. Marginal carbon prices for the work above rise to R3 300/ton by 2050, for a total CO2-eq cumulative emissions budget of around 7 Gt[8]. Optimised mitigation pathways based on cumulative emissions tend to produce marginal carbon price trajectories that are highly sensitive to the discount rate, which should be borne in mind.

The tax levels modelled over time are presented in Figure 25. Two sets of carbon price trajectories have been modelled: both sets feature a carbon price which increases from the current effective tax rate of R31/ton, assuming an average tax-free allowance of 80% on the basic rate of R120, corrected for inflation, to a range of values for 2030, from R100 to R1 400/ton.

[8] *It should also be borne in mind that the marginal carbon price in results from optimisation models, when modelling cumulative GHG emissions constraints, is highly sensitive to the discount rate. Lower discount rates lead to higher initial prices and lower prices later in the time period.*

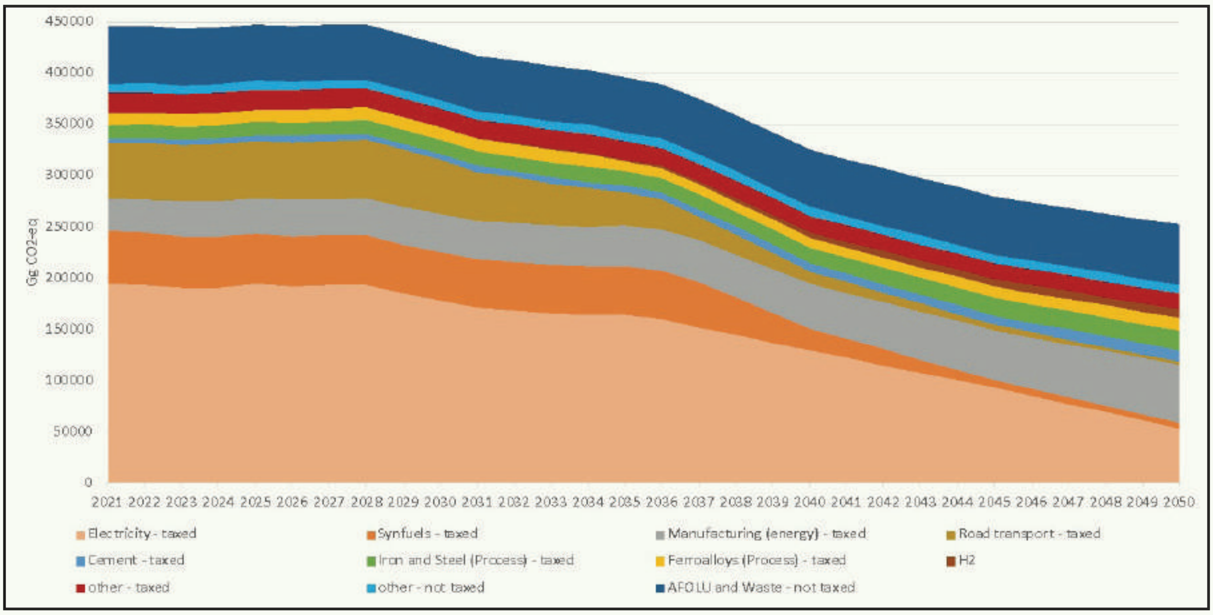
Figure 25 – Modelled carbon price levels, constant from 2030 (left) and linearly increasing (right).



In half the cases, the carbon price stays at this level, and in the other half the tax rises linearly to significantly higher levels by 2050 of between R400 and R5 600/ton. For comparison, the lower and upper limits of the global carbon price of between US$40 and US$80 by 2020, and US$50 and US$100 by 2030, recommended by the High-Level Commission on Carbon Prices, and the current carbon price on the EU Emissions Trading Scheme (which will presumably set a benchmark for the EU's proposed carbon price-related border tax adjustment), and the US social cost of carbon, are included. The base carbon price in the model remains constant at the current price, which is too low to have any significant mitigation impact in the model[9]. The emissions profile of the unconstrained case with only the existing tax (kept constant at its 2022 level in real terms until 2050) is presented in Figure 26.

[10] The carbon price, as in the existing tax regime, is applied to all GHG emissions except agriculture, waste and the land sector, and small-scale combustion in the residential and commercial sectors. The carbon price will therefore have little direct impact on these sectors. There is a gradual energy transition occurring during this period in the electricity and transport sectors, which also affects the liquid fuels sector. The application of a carbon price serves to accelerate this process, and to incentivise shifts in other "hard to mitigate" sectors, in which there is no current economic incentive to shift to lower-carbon options. The mitigation impact of the carbon price trajectories indicated in Figure 25 is presented in Figure 27 and Figure 28.

Figure 26 – GHG emissions to 2050 with the base carbon price only (R31/ton in 2020 rands).



The carbon price, as in the existing tax regime, is applied to all GHG emissions except agriculture, waste and the land sector, and small-scale combustion in the residential and commercial sectors. The carbon price will therefore have little direct impact on these sectors. There is a gradual energy transition occurring during this period in the electricity and transport sectors, which also affects the liquid fuels sector. The application of a carbon price serves to accelerate this process, and to incentivise shifts in other "hard to mitigate" sectors, in which there is no current economic incentive to shift to lower-carbon options. The mitigation impact of the carbon price trajectories indicated in Figure 25 is presented in Figure 27 and Figure 28.

The overall mitigation impact is a complex combination of timing and the price level, which reflects the composition of the underlying economic and technical characteristics of South African GHG emissions. Initial observations are that significant mitigation only begins to take place from R200/ton on, and that there is very little further mitigation with a carbon price of R2 000 and above, by 2050. The difference between a constant carbon price of R1 400 from 2030, and a price which increases from this level to R5 600, is slight.

Figure 27 – Economy-wide response to different carbon price levels: constant from 2030 (left) and increasing from 2030 (right).

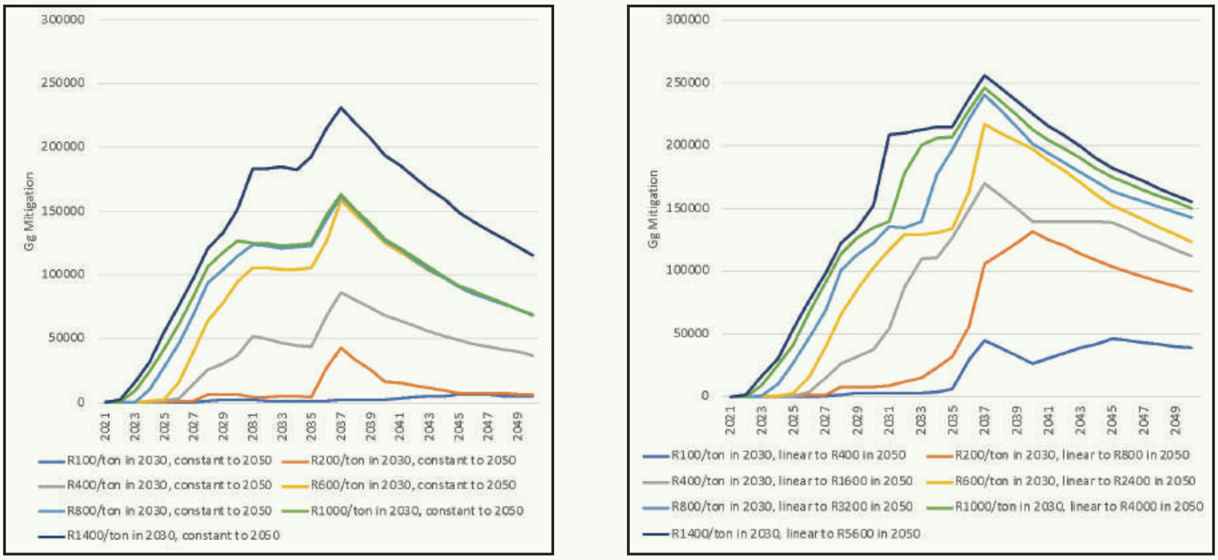
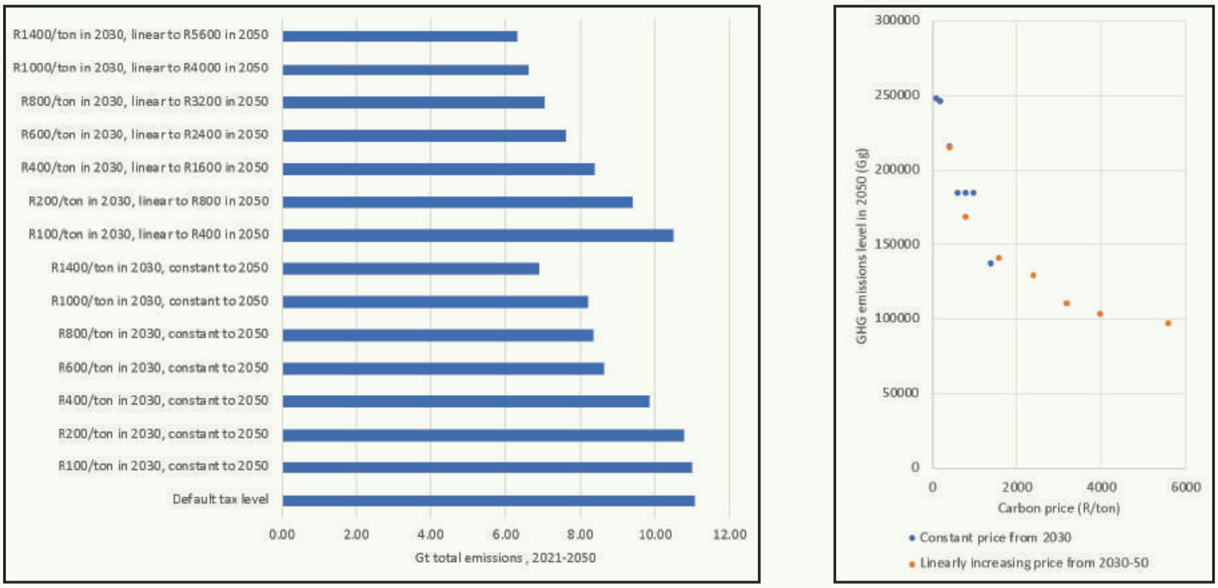
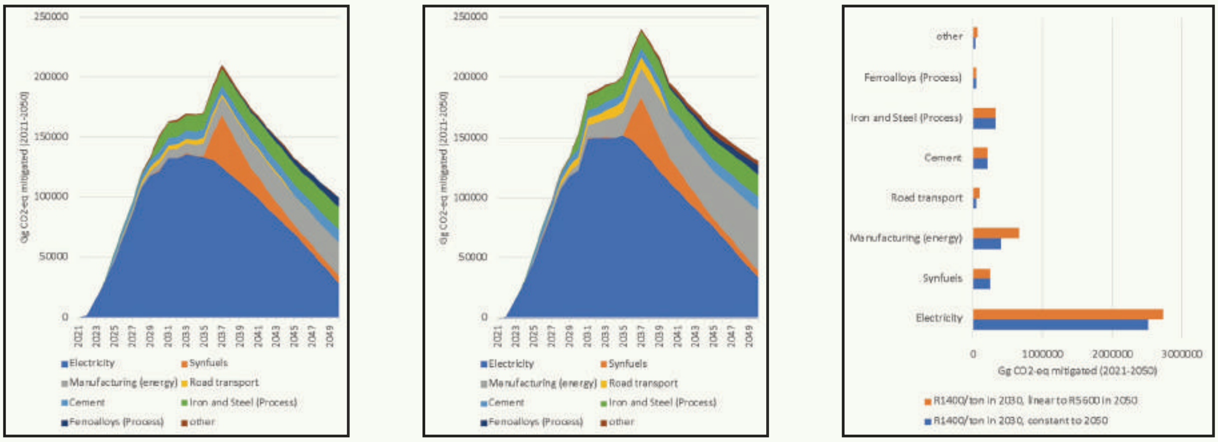


Figure 28 – Cumulative GHG emissions, 2021-50, with different carbon price paths (left), and the relationship between the GHG emissions level in 2050 and the carbon price in 2050 (right).



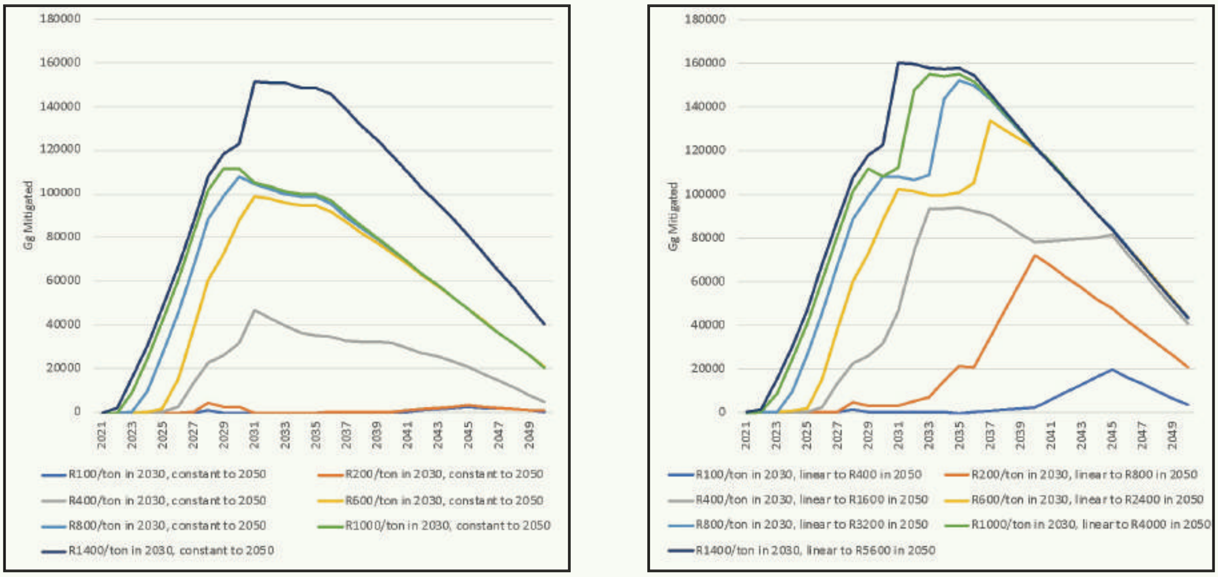
The sectoral impacts will be explored in more detail below. The timing of the impact of the carbon price is presented in Figure 29 for the highest two tax levels for the constant and increasing cases, as well as the cumulative mitigation impact. The largest mitigation impact is unsurprisingly in the electricity sector. The impact of the increasing tax is not that significant (resulting in an additional 13% of cumulative mitigation by 2050), from the constant level of R1400 to the higher level of R5 600.

Figure 29 – Mitigation impact of R1 400/ton in 2030, constant to 2050 (left), compared with the default tax case and R1 400/ton in 2030, linear to R5 600 in 2050 (middle), compared with the default tax case, and cumulative mitigation for the two cases (right).



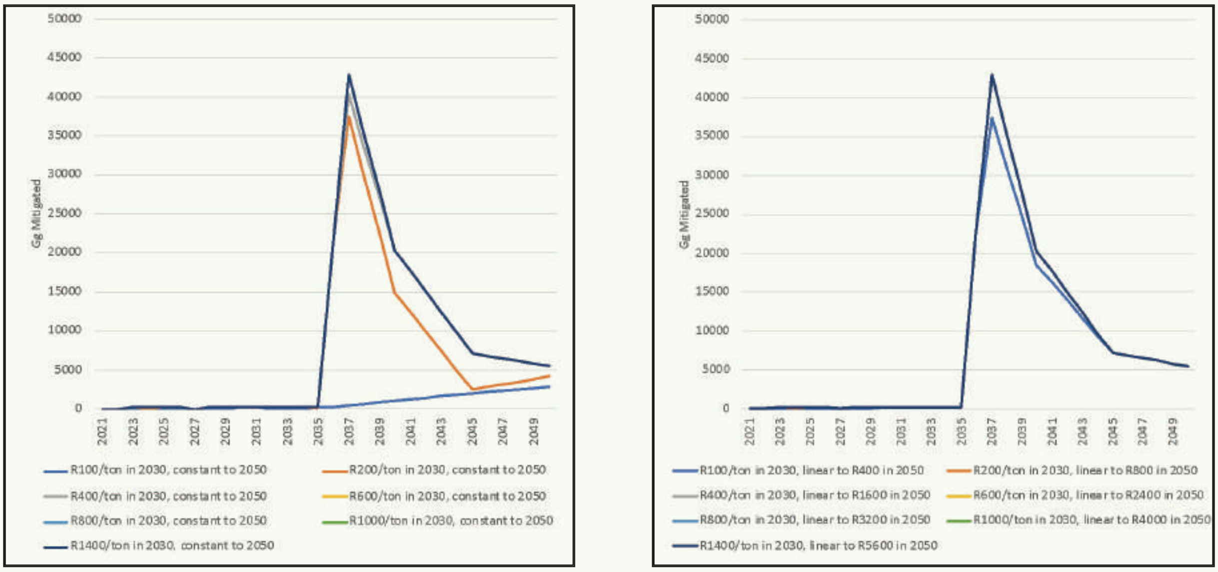
The application of the tax to the electricity sector results in an acceleration of the phasing out of coal power.

Figure 30 – Electricity sector mitigation as a result of the imposition of a carbon price.



A carbon price does not have a significant impact in accelerating the transition in the electricity sector below a price of R200 in 2030. A price consistent with the emissions outcome resulting from the IRP 2019 is around R500-600/ton in 2030. There is very little difference in the mitigation outcome between a price of R600 and R1 000 by 2030, but a much faster retirement of coal power after this, to a price of R1 400 in 2030. Higher carbon prices after this do not result in any significant additional mitigation impact overall. Around 20 Mt of GHG emissions remain in the electricity sector as a result of the use of natural gas.

Figure 31 – Synthetic fuels mitigation as a result of the imposition of a carbon price.



Synfuels production, being very carbon-intensive, is very sensitive to the carbon price. The current configuration of the model specifies continuation of synfuels production until 2035. At this point, from a carbon price slightly greater than R100/ton (the lowest price modelled), the sector ceases production, resulting in a sharp mitigation spike in 2035 as presented in Figure 31. By contrast, the transport sector is relatively unresponsive to carbon pricing, as presented in Figure 34. The tax, even at relatively high levels, accelerates the transition in the transport sector only slightly. The tax on synfuels is effectively passed through in the model to the cost of fuel. The inflexibility of synfuels production in the model until 2035 effectively inhibits an earlier response on the demand side.

Figure 32 – Carbon price impact on energy-related emissions in the manufacturing sector.

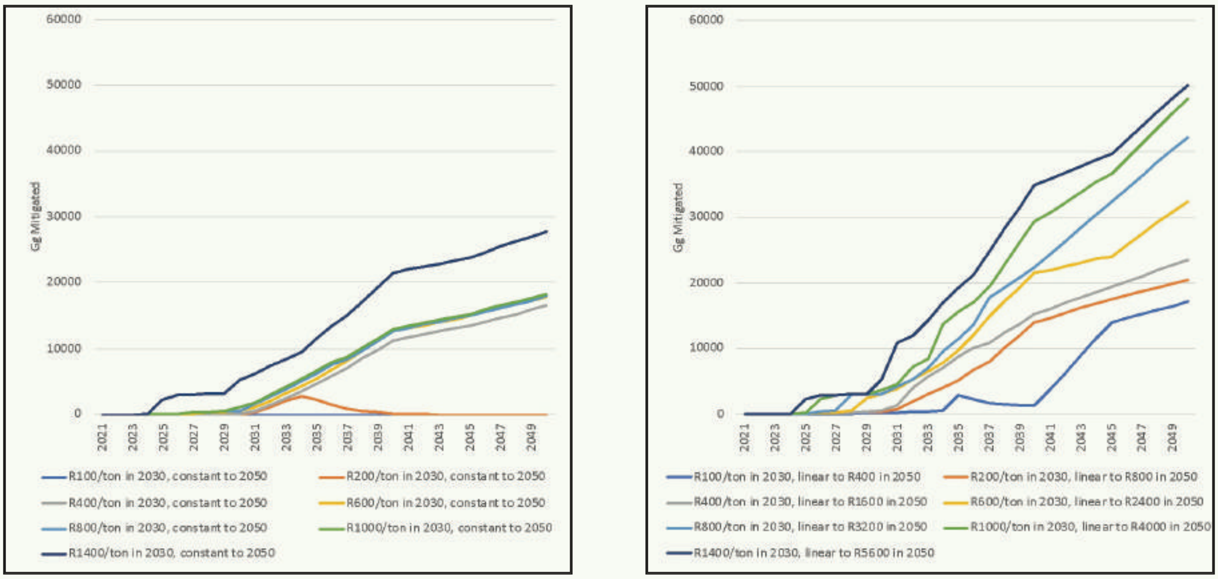


Figure 33 – Carbon price impact on industrial process emissions.

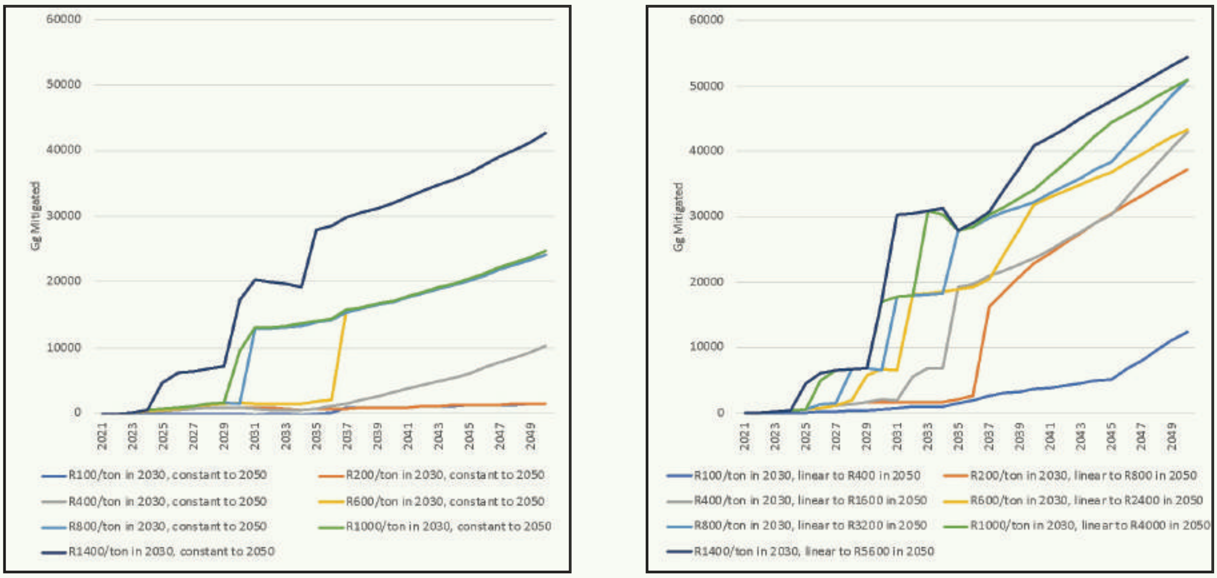
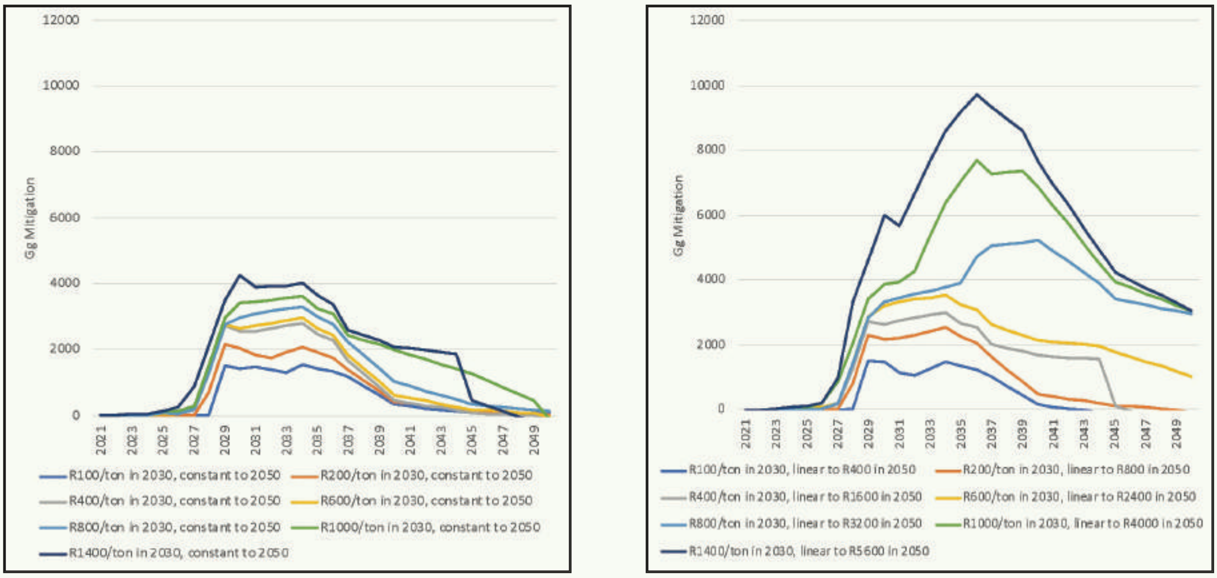


Figure 34 – Carbon price impact on the road transport sector.



The response of the manufacturing sector, in both energy-related emissions and also industrial process emissions, is more evenly distributed, and occurs at higher carbon prices. Specific measures that respond to the carbon price correspond to large-scale process interventions in industry such as shifting iron reduction from carbon to hydrogen and the use of CCS (carbon capture and storage), and the shift from the use of coal for combustion for heat to other energy sources such as gas (lower carbon, but not zero) or electricity. The marginal costs of the latter are high.

From a technical point of view, further work is required on carbon pricing which captures indirect/demand side responses to these carbon price levels, as well as the economic impact of a corresponding carbon tax. From a policy point of view, the key question is how the carbon tax will be approached after 2022 and, given the different timing and levels of response across sectors, how a carbon price will contribute to the outcome of other mitigation measures. Another related consideration is the use of a social cost of carbon in policy-related cost-benefit analyses and planning processes, and setting an appropriate carbon cost for this. While the economic rationale is different (the social cost is designed to internalise the cost of the impact of GHG emissions), it is interesting to note the impact that a specific social cost would have.

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