ENERGY SYSTEMS RESEARCH GROUP

Draft

Technical analysis to inform the development of the mitigation component of South Africa's second NDC

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Summary

1. South Africa has a legal obligation to submit an NDC every five years, show progression with a fair and ambitious contribution; should contribute to global goals, 1.5 °C and global net zero emissions by 2050, while ensuring socio-economic development proceeds sustainably.
2. A robust benchmark for South Africa's 2035 NDC mitigation target range – South Africa's "fair share" contribution to achieving the long-term goals of the Paris Agreement, and consistent with the equity principles of the Agreement, is a range from **261-345 Mt CO_2-eq**, including land use and natural disturbances.
3. Existing measures already in place, and the implementation of current policies and plans, notably energy efficiency measures, the second phase of the Carbon Tax, SAREM deployment, implementation of the draft IRP 2024, and implementation of the green transport strategy and just transition plan for the transport sector, will result in GHG emissions in 2035 in a range from **359 Mt CO_2-eq (limited or delayed implementation) to 289 Mt CO_2-eq** (full implementation) (incl. LULUCF, assuming a medium economic growth rate of around 2.5%).
4. The **electricity sector remains central to mitigation efforts** in 2035 and in the longer term.
5. The electricity sector model results were stress-tested using several industry-leading power-sector specific models including PLEXOS, PyPSA, and FlexTool3, with full 8760 hour chronology and detailed unit level operational constraints – benchmark results showed that the future systems in 2035 are reliable and generation technology utilization metrics track well.
6. The wide range of results demonstrate the critical importance of assumptions on GDP growth and policy implementation, and sector trends driving technology transitions, as well as the consideration of other sources of uncertainty in the underlying evidence base, including uncertainty in estimating GHG emissions from the land sector.
7. South Africa's 'highest possible ambition' can be achieved with economic diversification and faster economic growth, through fully implementing current policy and operationalizing existing policy goals in key sectors, alongside scaled-up finance and international support, and aligned with a fair share effort.
8. Assessing existing policies and measures demonstrates the considerable mitigation co-benefits of current plans in the electricity, industrial, transport, and other policy domains.

Acknowledgments

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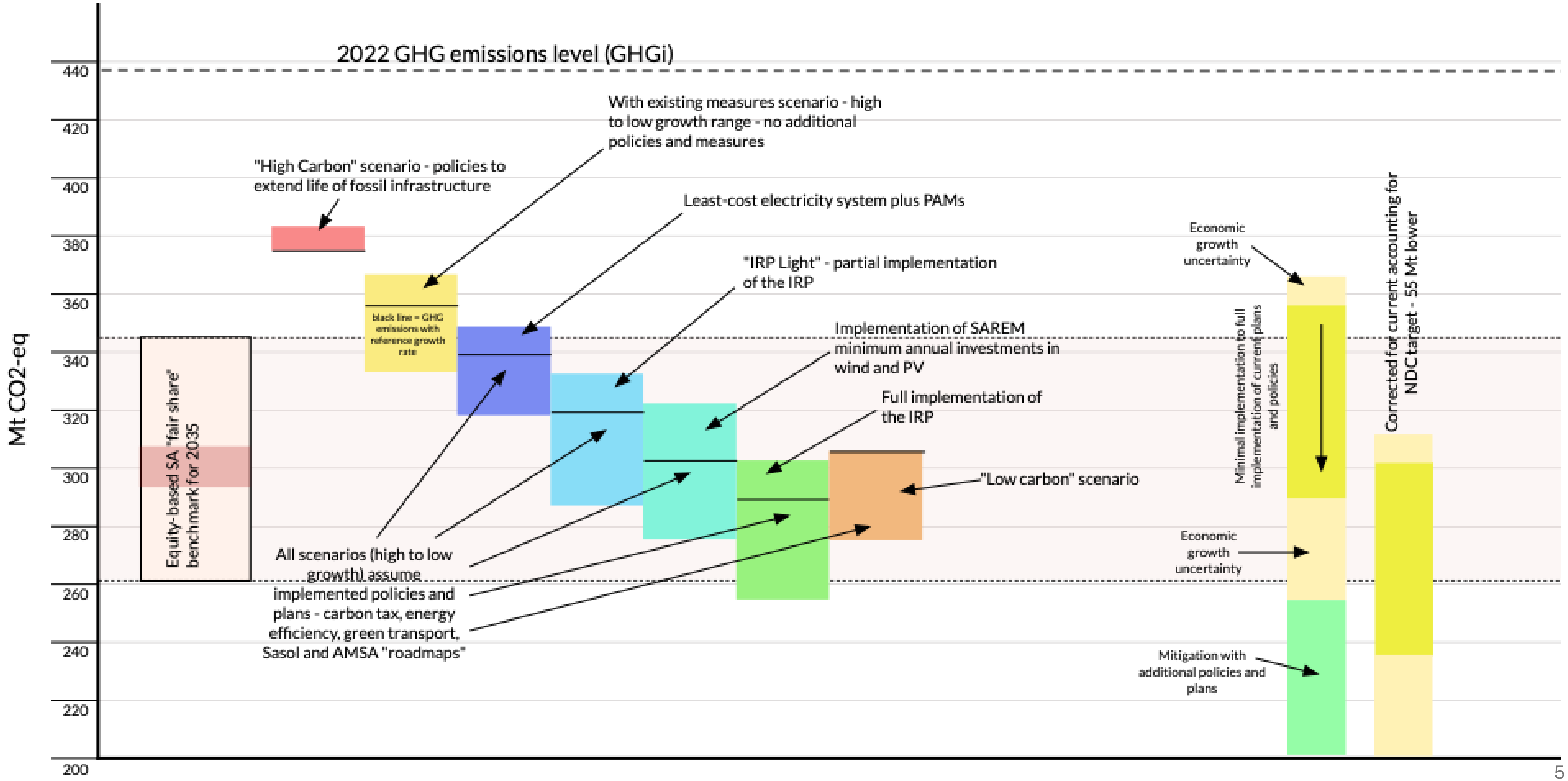
Thanks and disclaimer

We are very grateful for the very valuable advice and assistance provided by the DFFE during this analysis.

The assumptions and methodology, and the consequent results, represent the views of the Energy Systems Research Group at the University of Cape Town, and do not necessarily represent the views of the DFFE or the South African government.

Summary of GHG emissions outcomes in 2035, with different economic growth rates and adjustment for NDC accounting (natural disturbances), compared to “fair share” benchmark



Overview – context, key objectives and approach

This technical analysis has the primary objective of supporting the Department of Forestry, Fisheries and the Environment (DFFE) in its development of the mitigation component of South Africa's second NDC. The mitigation analysis is part of a broader set of analyses to support the NDC, including work on adaptation and loss and damage (undertaken by the African Climate and Development Initiative (ACDI)) at the University of Cape Town (UCT), and work on support requirements / provision by SouthSouthNorth (SSN).

The analysis has been primarily undertaken by the Energy Systems Research Group (ESRG) at UCT, with contributions from PRISM at UCT, the CSIR, and CRSES at the University of Stellenbosch.

The goal of the analysis is to assess the following:

- South Africa's international obligations with regard to the Paris Agreement;
- An assessment of what national mitigation contribution up to 2035 would constitute South Africa's "fair share";
- An assessment of the GHG emissions implications in 2035 of current mitigation and/or mitigation policies and plans;
- An assessment of what additional measures would be required to achieve additional mitigation outcomes in 2035;
- Additional analysis of the implementation requirements and just transition requirements for a representative GHG emissions outcome in 2035;
- Additional analysis on the impact of specific GHG emissions pathways on local air pollution; and
- Additional assessment of the reliability and GHG emissions outcome of electricity systems modelled in SATIMGE for specific GHG outcomes using other modelling frameworks;

These are DRAFT results – comments and feedback are welcome; the technical report will be finalized shortly.

Methodological approach

The study consists primarily of two components:

- An assessment of South Africa's international legal obligations, and benchmarks for South Africa's "fair share" mitigation contribution for 2035;
- An analysis of the impacts of current policies and plans on national mitigation outcomes for 2035.

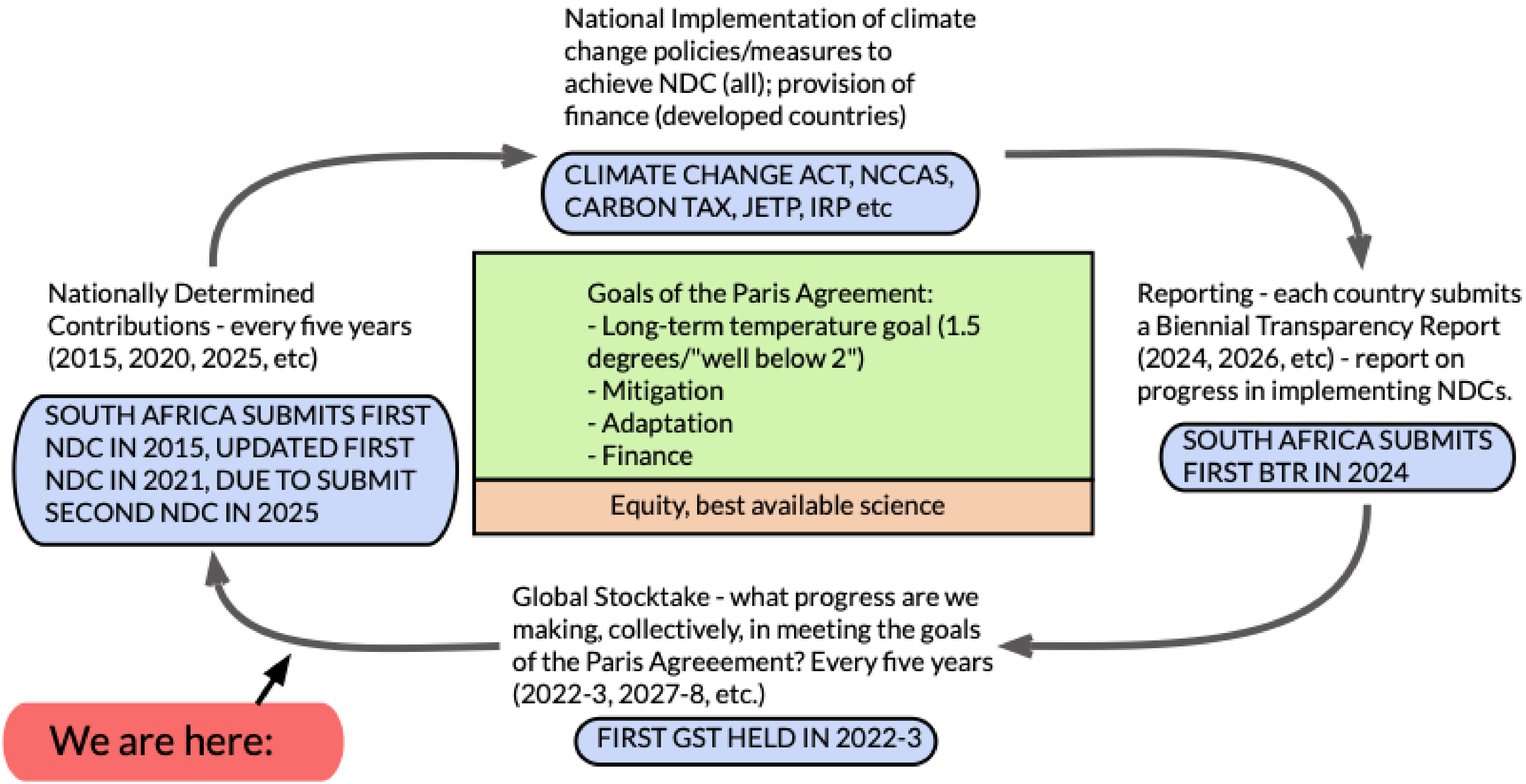
The first component was undertaken via an analysis of mitigation obligations and objectives of the Paris Agreement and subsequent decisions, with particular reference to the Paris Agreement's recently-concluded Global Stocktake (GST), and a quantitative analysis of international benchmarks for South Africa "fair share"; potential mitigation outcomes were then evaluated after the mitigation analysis against these benchmarks and any relevant international legal obligations arising from South Africa's ratification of the Paris Agreement.

The mitigation analysis was undertaken using a scenario-based approach to assess the GHG emissions impact of current policies and plans, using the SATIMGE modelling framework to evaluate these. Policies and plans were assessed individually against a "with existing policies" baseline, and then clustered into sets of policy options. SATIMGE consists of a suite of energy/emissions/economy models which are hard-linked (via key drivers and results parameters), which together model GHG emissions across the economy, and provides both bottom-up technical detail, and economy-wide analysis of the economic impacts of specific technology pathways. SATIMGE is calibrated to a 2017 energy balance (where applicable), a 2019 social accounting matrix (where applicable), and calibrated to any subsequent available data, including South Africa's national GHG inventory. This is followed by a post-model analysis of investment requirements and just transition requirements for a representative GHG emissions outcome in 2035. Results are assessed against the international benchmarks and other relevant criteria.

An assessment of key uncertainties, as well as NDC accounting issues, are assessed in an endnote.

International context:
South Africa’s legal obligations under the Paris Agreement, and benchmarks for South Africa’s fair contribution

The Paris Agreement "ambition cycle" – countries make national contributions, report, consider collectively what progress we have made, and make further contributions



NDCs under Article 4 of Paris Agreement

Each NDC will be a progression (in ambition, coverage, form etc.) on previous NDCs (4.3)

NDCs will reflect countries' "highest possible ambition", taking into account "common but differentiated responsibilities and respective capabilities, in the light of different national circumstances" (4.3)

It is explicit in the Paris Agreement that support will be provided to developing countries for implementation (4.5)

NDCs must be communicated every five years and take into account the outcomes of the global stocktake (4.9)

- 5-year periods of implementation (e.g. 2025 NDC implemented 2031-2035)

Parties must account for their NDCs (4.13) and must provide detailed information for clarity, transparency and understanding (ICTU)

Should strive to develop and communicate long-term low greenhouse gas emission development strategies (4.19)

Outcomes of first global stocktake (GST 1)

Global stocktakes (GST) assess collective progress in implementing Paris Agreement and achieving its long-term goals

Broad scope: global temperature goal, mitigation, adaptation, loss and damage, response measures, means of implementation (finance, technology and capacity-building)

Equity and ambition, based on science (cross-cutting in GST)

GST1 found that:

- The latest science confirms the importance of achieving the 1.5 degree long-term temperature goal – impacts are far more severe at 2 degrees;
- "..despite overall progress on mitigation, adaptation and means of implementation and support, **Parties are not yet collectively on track towards achieving the purpose of the Paris Agreement and its long-term goals**"
- More is needed in mitigation , adaptation and support, and especially in "this critical decade" (the 2020s) – at a national level and via enhanced international cooperation.

Detailed outcomes for each area of climate action and support.

Long-term global goals

Temperature goal: GST decision 1/CMA.5 confirmed shift in emphasis from "well below 2" to 1.5 °C

Mitigation: contribute to long-term goal mitigation in Article 4.1 ('net zero') in mitigation target range for 2035

- peaking a.s.a.p. and rapidly reducing thereafter
- Just transition to net zero CO2 emissions by 2050, informs (does not set) mitigation ambition in 2035; encouraged in three decisions- Glasgow, Sharm-el-Sheik and Dubai (GST)
- Energy package: contribute to global efforts to transition away from fossil fuels, 3xRE and 2xEE

Adaptation:

- 11 thematic targets under global goal for adaptation – SA will set own goals, and show how those contribute
- Information and institutions: Ways to track progress in adaptation, including institutional arrangements

Finance: financial obligations and flows – though NCQG agreed year after GST1

Equity and ambition: historical responsibility and responsibility for the future; equity in mitigation, adaptation and support. Transitioning away from fossil fuels "in a just, orderly and equitable manner" – essential part of reaching 1.5 °C

How SA's NDC2 draft has been informed by outcomes of GST1

Countries have a legal obligation under the Paris Agreement to:

- consider the outcomes of the GST in preparing their NDCs (Art 4.9)
- explain in their NDCs **how** the GST has been taken into account (decision 4/CMA.1)

How we take the GST into account is up to us ("nationally determined");

Draft NDC2 responds to the GST in several ways:

1. 1.5 °C - relevant to mitigation, adaptation and finance
2. Mitigation: just energy transition package, and contribute to long-term goal on mitigation (effectively global 'net zero')
3. Importance of economic diversification, including green industrialisation
4. Eight national adaptation goals, mapped against GST1 outcome and GGA decision
5. Institutional arrangement (including inventory) for better information for adaptation and L&D
6. Equity in adaptation
7. Finance: extent to which SA can achieve highest ambition depends on extent of support mobilised; SA has established funds and expects a fair share of international climate finance

Fair share analysis – CERC, CAT (and CEM)

The analysis here refers to three frameworks that analyse countries' fair shares in the context of the global mitigation burden associated with long-term Paris temperature goals (1.5°C and "well below" 2°C).

- Climate Equity Reference Calculator (CERC) - CERC operationalises CBDR-RC by combining data on historical emissions, income (including distribution), and a development threshold to calculate each country's "fair share" of mitigation effort—including domestic reductions and climate finance—through adjustable equity parameters on responsibility, capability, and development status.
- Climate Action Tracker (CAT) - CAT compiles a wide spectrum of effort-sharing studies (incorporating responsibility, capability, equality, as well as more contentious approaches such as grandfathering and least-cost allocation) into a "Fair Share" emissions reduction range for each country, then evaluates countries' NDCs and policies against this range—rating their ambition and equity contribution according to how they compare to that range (using normative terms for temperature outcomes, such as "1.5°C Paris Agreement compatible", although literature indicates such direct links are questionable)
- Climate Equity Monitor (CEM) - CEM applies a strict per-capita equality approach—allocating both historic emissions "debt/credit" and future carbon budget strictly in proportion to present-day national populations—without consideration of other equity criteria like capability or development needs.

The first two – CERC and CAT – were applied in analysis of the NDC1-Update; the third – CEM – is entirely new to this analysis, and is the first fully-global-south-developed equity framework available in literature.

Other benchmarks for SA’s contribution to global temperature and mitigation goals

Other benchmarking tools and frameworks exist in literature for comparing and evaluating NDC targets for 2035, which do not meet criteria for the operationalization of equity principles consistent with the principles of CBDR&RC-NC as embodied in PA Art 4.2. Challenges include:

- Inclusion of equity principles that are inconsistent with international law, e.g. ‘grandfathering’
- Limited or no analysis of who pays for mitigation
- Extensive use of global integrated assessment models (IAMs) “downscaled” to country level to allocate the global mitigation effort. While IAMs are essential as a basis for global climate policy, very effective in modelling global emissions pathways capable of limiting global warming to a specific temperature level and assessing the collective impact of countries’ contributions, country-level data on which mitigation outcomes are based in these models is frequently inaccurate; moreover, most IAMs allocate mitigation effort to countries on a global “least cost” basis without regard for national circumstances or any of the relevant principles of the Paris Agreement.

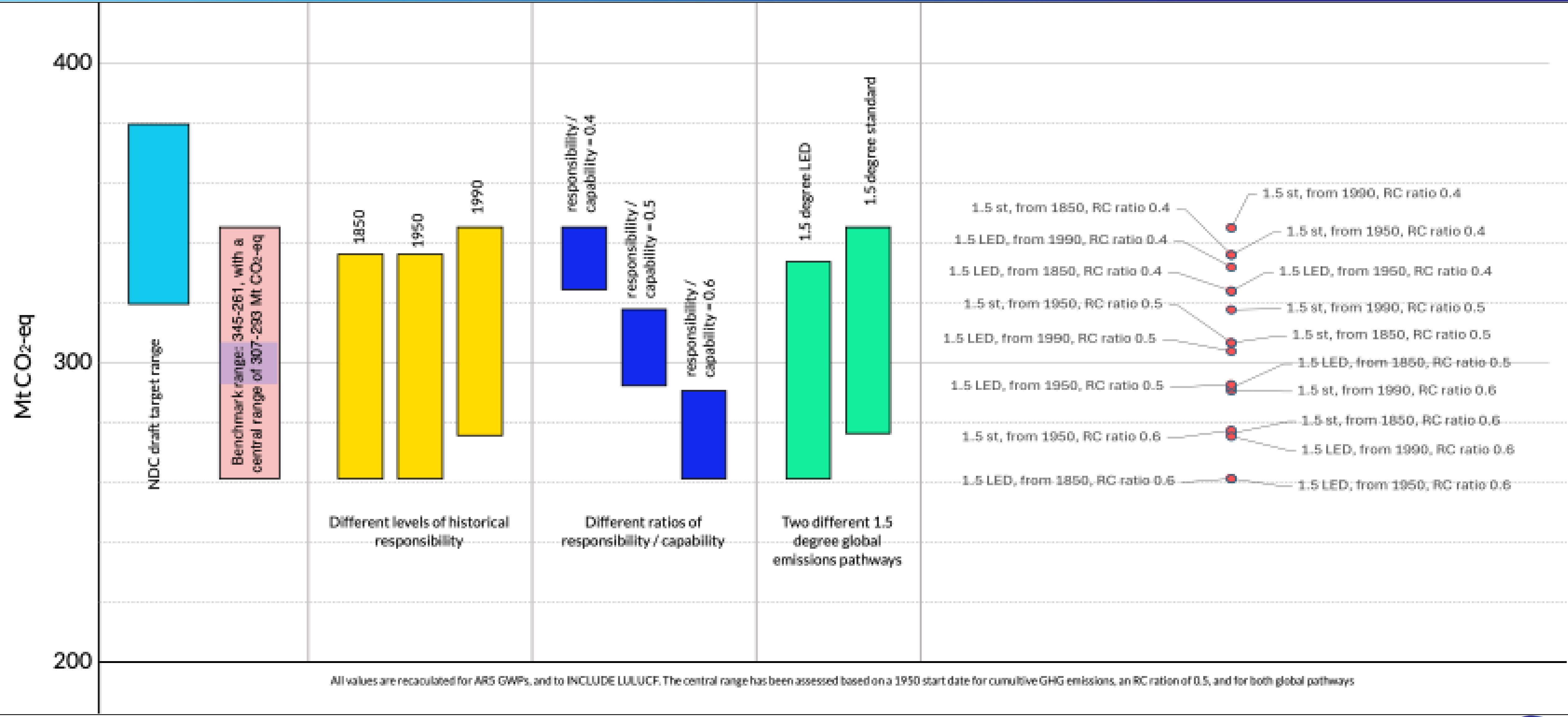
While therefore not credible for benchmarking the South African NDC, these will likely be referenced by other countries and actors as a basis for their assessment of South Africa’s NDC targets, and so these have also been reported here.

Range of fair share

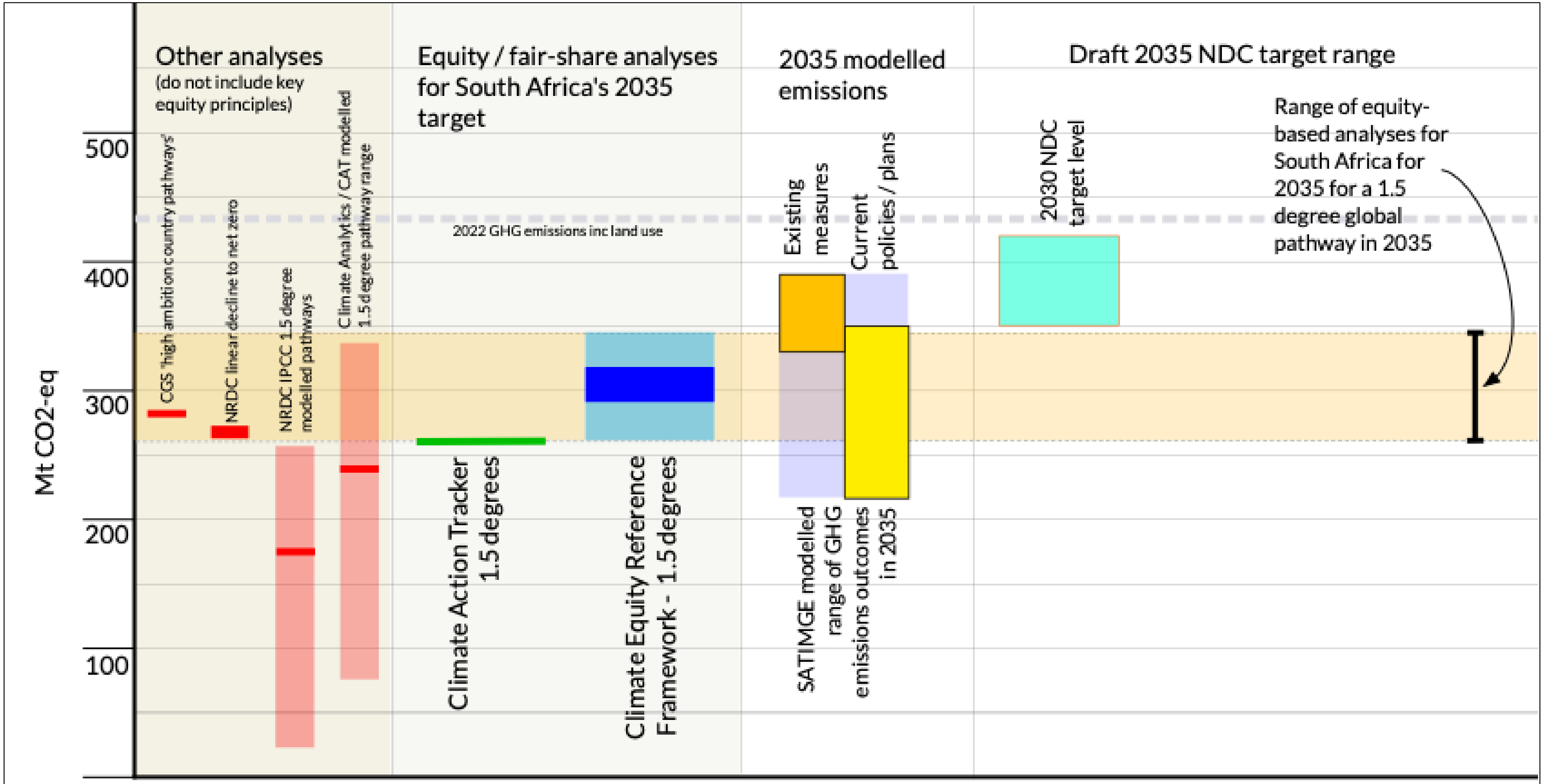
South Africa considered equity in mitigation, including fair shares, for which there is a wide range of analyses – given that global warming levels such as 1.5 °C and 2 °C (which is not the same as "well below 2 °C") are assessed to 2100; that limiting temperature increase depends on all countries; and that fair share assessments vary depending on the choice of indicators used to approximate equity. Estimations for South Africa's fair share (adjusted to include land use emissions and AR5 GWP values) for 2035, using a methodology consistent with equity principles contained in the UNFCCC and its Paris Agreement, range from **345 Mt CO2-eq to 261 Mt CO2-eq.** These results can be replicated using the Climate Equity Reference Framework calculator at https://calculator.climateequityreference.org/ and the parameters presented in the next slide. It should also be noted that the CAT benchmark for South Africa's 2035 NDC target is at the BOTTOM of this range. CERC is considered the approach to fair shares which is most consistent with South Africa's climate policy and national development priorities

GHG emissions outcomes in 2035 above the range are not consistent with the 1.5°C goal, based on this approach. The range depends on different weightings of capability and responsibility.; However, whether an outcome within the range is consistent with the 1.5°C goal depends on choices made by other countries –if all countries chose points at the top of their respective ranges, the global GHG emissions outcome would result in global warming of more than 1.5°C.

Assessment of a benchmark range for South Africa's 2035 mitigation target using the Climate Equity Reference Calculator (CERC)



Equity benchmarks



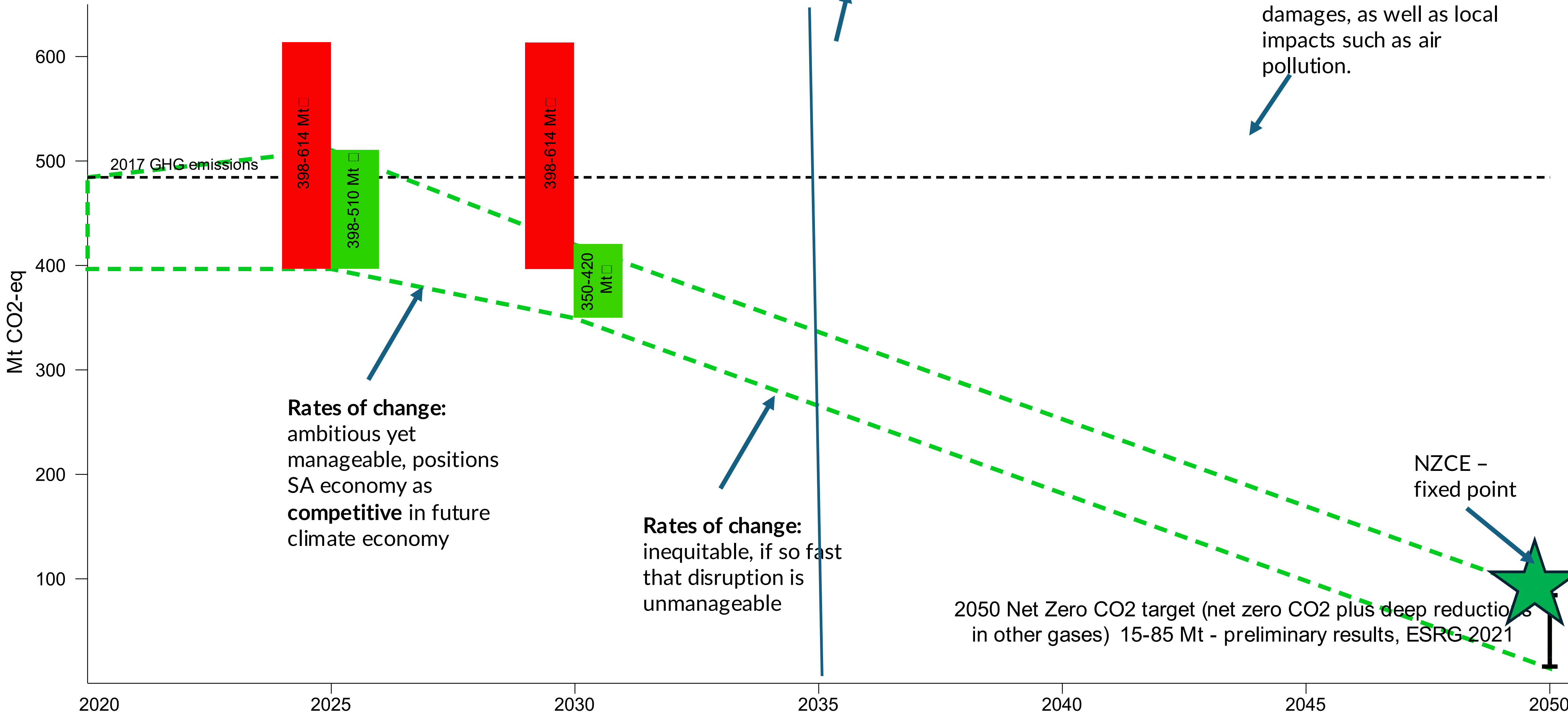
Note: All values have been adjusted to include land use emissions/sinks, and for GWP values - adjusted to values in IPCC's 5th Assessment Report. Sources: Climate Action Tracker - https://climateactiontracker.org/ for both equity and modelled pathways assessments for South Africa; Climate Analytics - https://1p5ndc-pathways.climateanalytics.org/ for modelled pathway; Centre for Global Sustainability - Assessment of high ambition country pathways - https://cgs.umd.edu/node/13872; Climate Equity Reference Framework and calculator - https://calculator.climateequityreference.org/ and https://climateequityreference.org/calculator-about/. "Other analyses" are either based on analysis and downscaling of IPCC IAM global scenarios (Sixth Assesment Report) or on bespoke IAM modelling, and do not include key equity principles. The CAT and CERC analyses apply equity principles contained in the UNFCCC and its Paris Agreement in their analyses.

Socio-economic implications of mitigation:
- Employment
- Poverty
- Energy prices for poor households,
- Etc

Inequity – impacts
SA emits too much, so do others, and poor communities suffer impacts and losses & damages, as well as local impacts such as air pollution.

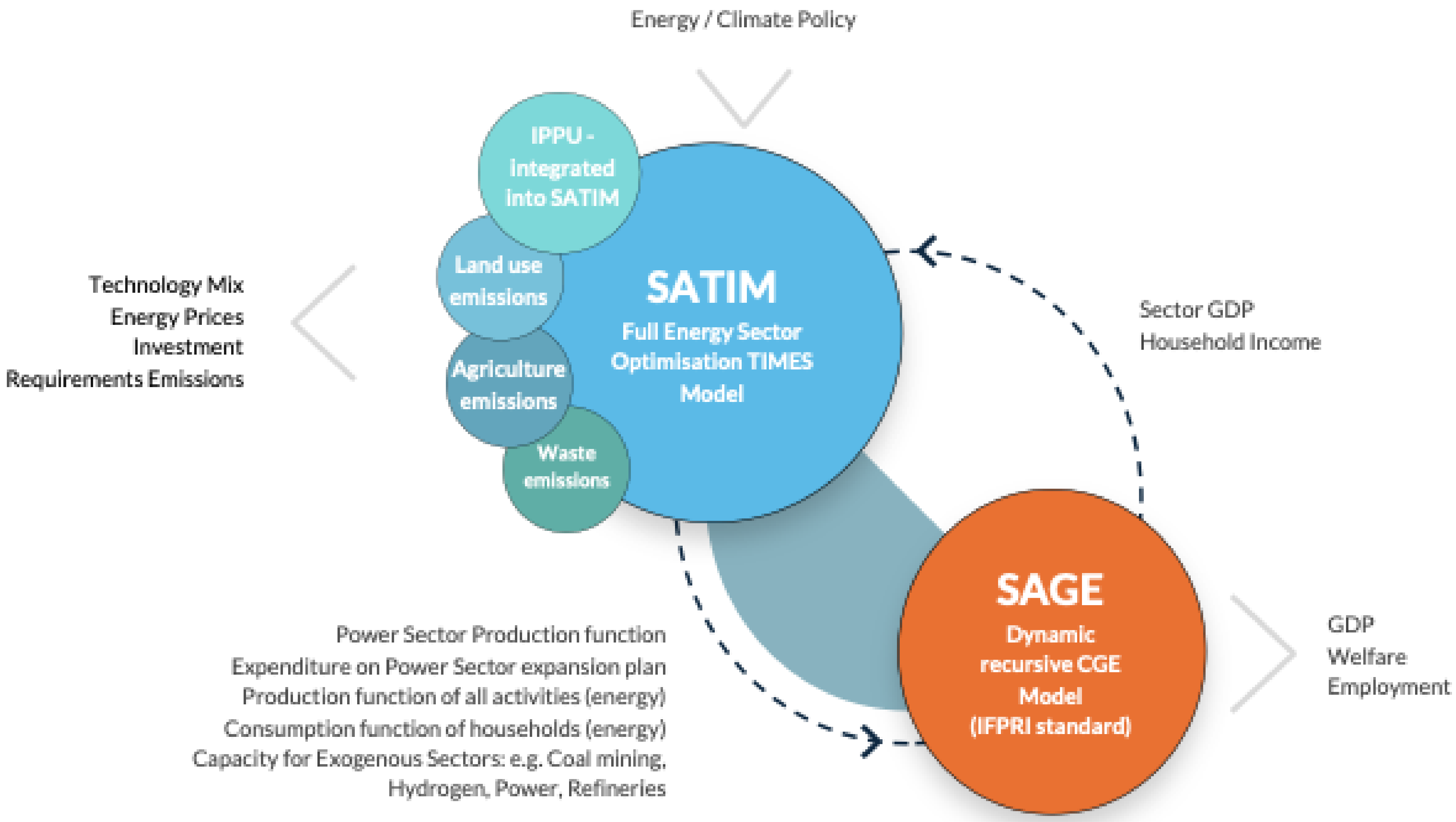
Peaked Emissions excluding LULUCF peaked at 529 Mt CO_2-eq in 2008

2008/9



The SATIMGE modelling framework
Methodology, structure and calibration

SATIMGE – a complex systems model of energy/economy/emissions



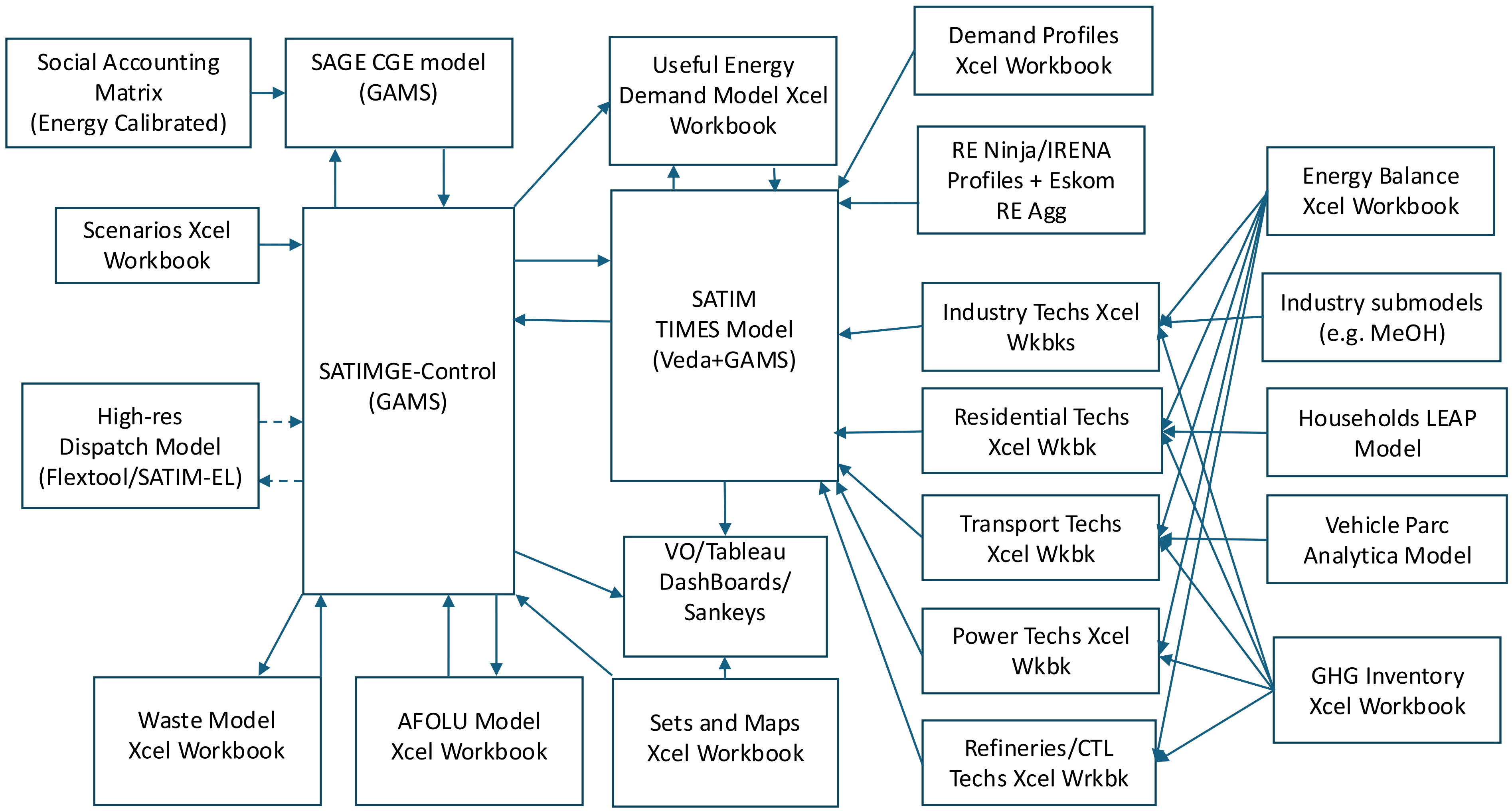
Description of SATIMGE modules

SATIMGE is a systems modelling framework which consists of five components:

- The South African TIMES model – a model built on the TIMES platform of the South African energy and industrial system. SATIM has been developed, maintained and enhanced for two decades by the Energy Systems Research Group at UCT, and is an inter-temporal bottom-up partial equilibrium optimization model of South Africa's energy sector, with elements of the industrial system relevant to material flows and GHG emissions. SATIM obeys principles of energy conversion and energy systems, and its objective function is to minimize the sum of all discounted costs (in the system) over the planning horizon subject to constraints and system parameters. It is a full-sector model, which includes all energy demands and supply and transformation options. SATIM is calibrated to the 2017 energy balance, and calibrated to the most recently-available technology, energy and emissions data. The TIMES model generator is supported by IEA ETSAP, and applied widely to the analysis of energy and climate policy problems;
- ESAGE – The "Energy" version of the South African General Equilibrium model, a dynamic recursive, country level, economy wide model that simulates the functioning of the South African economy. ESAGE is an extension of the core static CGE model used by the International Food Policy Research Institute (IFPRI) described in (Lofgren et al., 2002), calibrated on the South African social accounting matrix, and with added resolution in the energy sector to model shifts in energy technologies in detail;
- A spreadsheet-based GHG emissions model of non-energy emissions from the agriculture sector;
- A spreadsheet-based GHG emissions model of the land sector (GHG emissions arising from land use, land use change and forestry);
- A spreadsheet-based GHG emissions model of the waste sector.

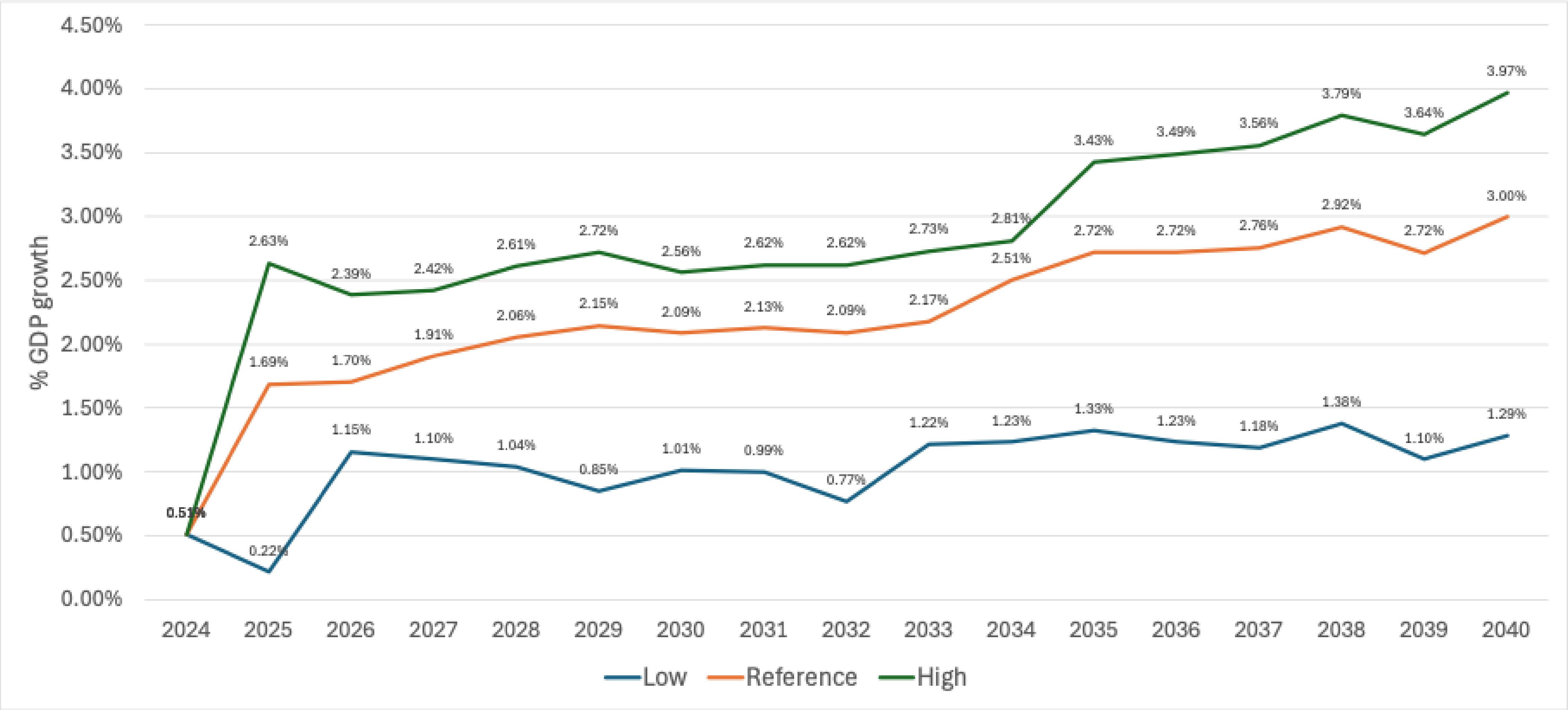
These five components are hard-linked, and exchange data on drivers (population, GDP) and activities (investment, fuel use). The integration serves three primary purposes: 1) SATIM provides technology-rich representation of physical systems (the energy and industrial systems); 2) ESAGE provides feedback to SATIM on the impact of investment and costs on the economy and households; and 3) integration of the land, agriculture and waste models ensures consistency of drivers such as GDP and population, and consistency where there are causal relationships between sectors in each model (for instance, extraction of firewood for domestic cooking is modelled in SATIM (as household energy use) and is also modelled in the land sector model (as vegetation removals)).

SATIMGE-2024 components

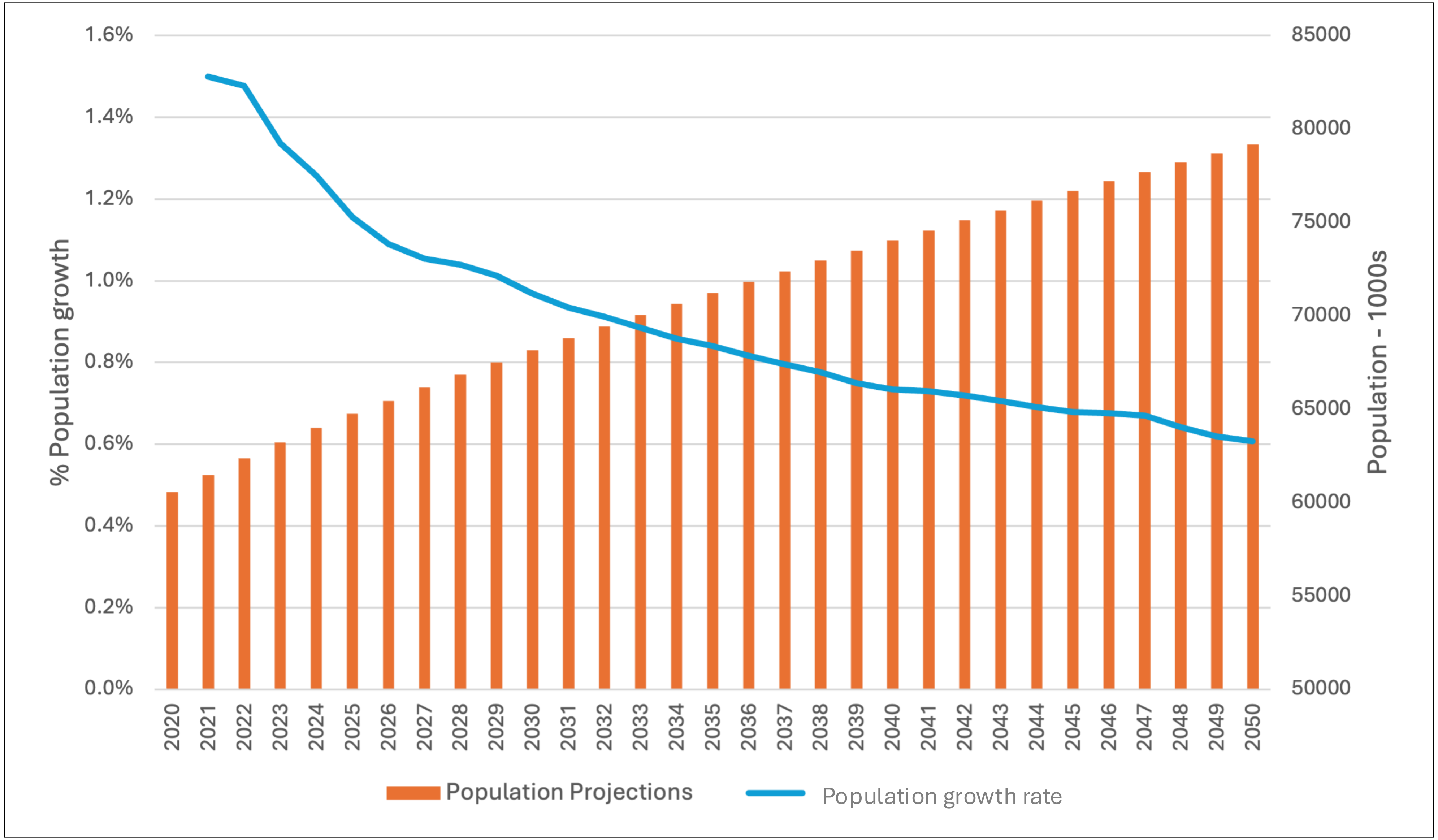


GDP growth assumptions used in the analysis

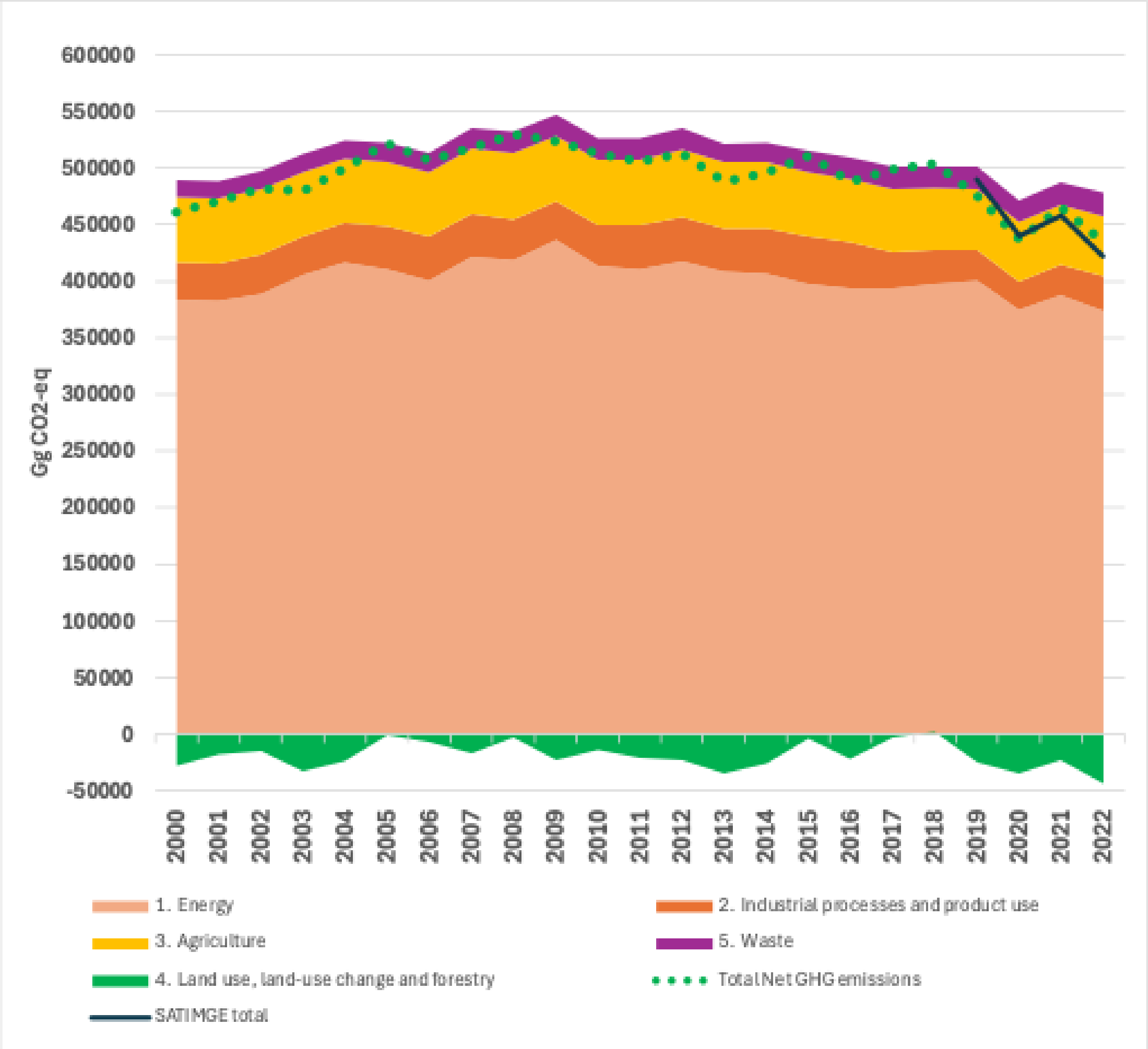
Three scenarios – High, Medium, Low – based on 2024 Treasury growth scenarios (to 2031) plus available long-term forecasts (OECD, others)



Population growth (UN projections)



GHG emissions now / historically from latest GHGi, and SATIMGE calibration



South Africa's GHG emissions are dominated by the energy sector, with much smaller contributions from Industrial Processes, Agriculture, Land Use and Waste.

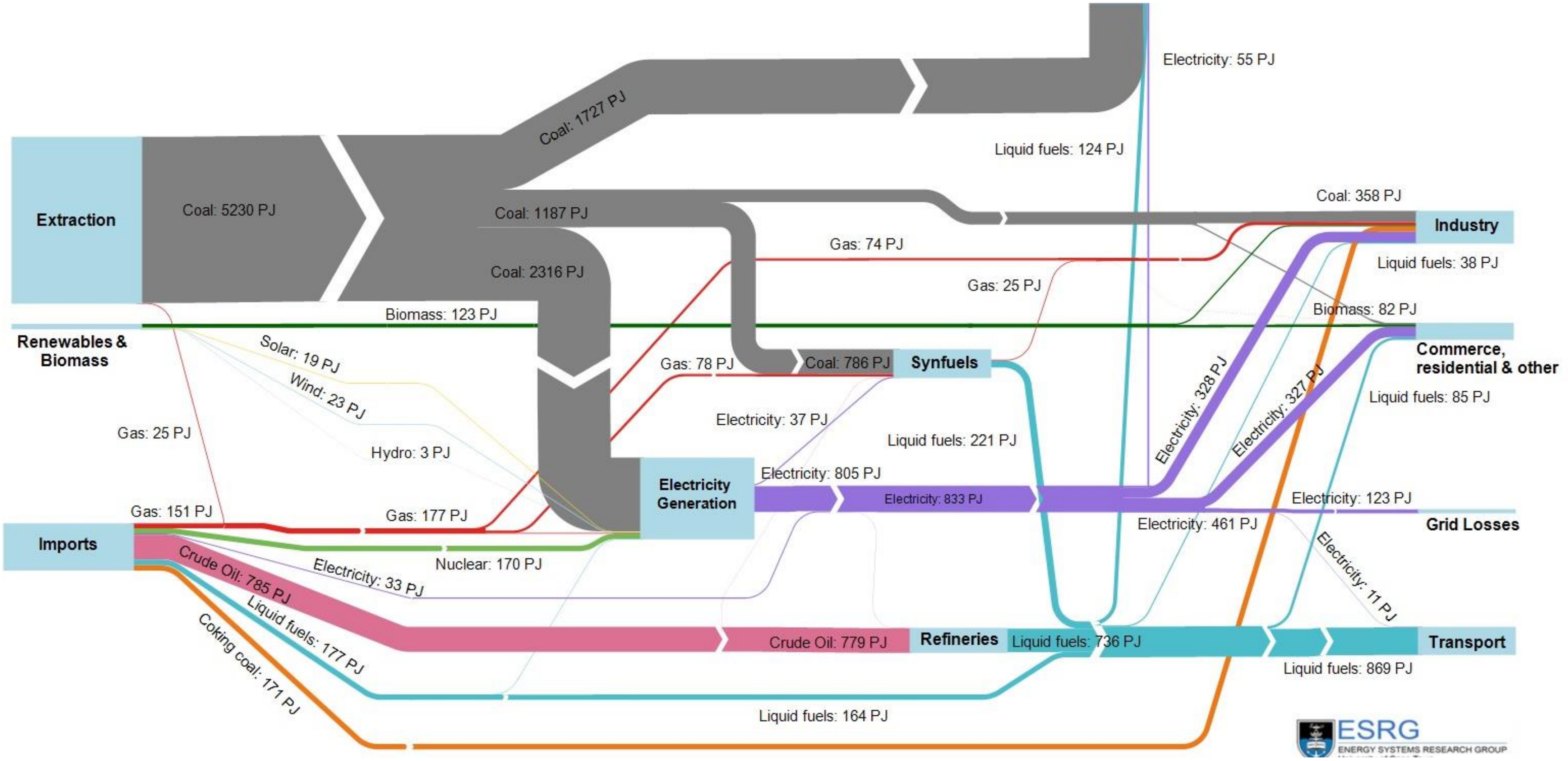
The most significant source of GHG emissions is the electricity sector.

GHG emissions peaked in 2008/9, and have declined gradually since.

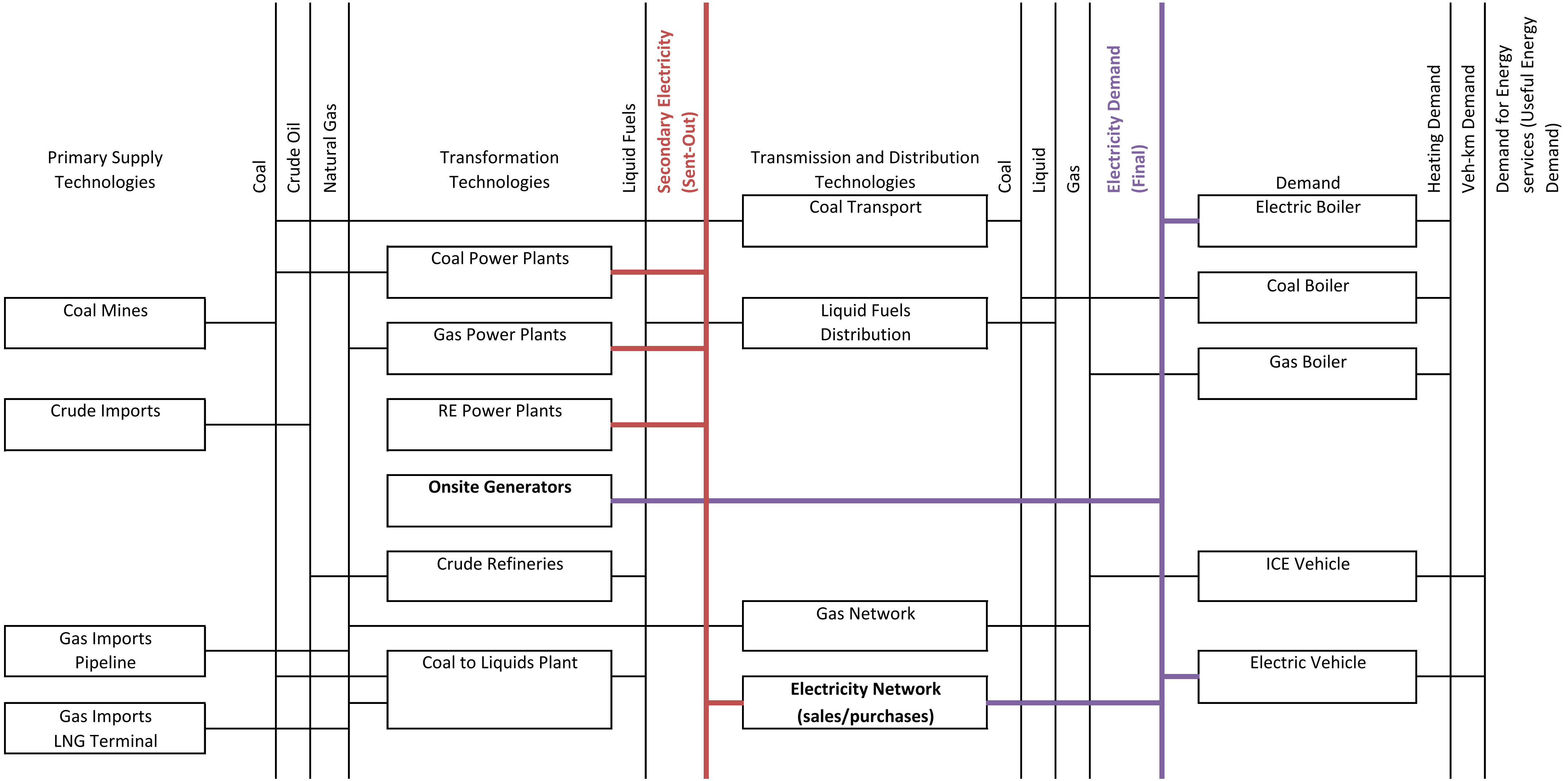
Drivers for this decline have been a decline in electricity demand, investment in low-carbon electricity generation, a move away from energy-intensive industry, with more recent contributions from load-shedding and COVID

SATIMGE model time series overlaps the GHGi for the period 2019-2022 – modelled GHG emissions have a 1-3% variance from the GHGi totals (3-13 Mt), on account of revised land sector estimates and uncertainties in the total supply of coal and liquid fuels.

SATIM's Reference Energy System is built on a 2017 energy balance and calibrated to subsequent historical data



SATIM is a bottom-up, technology-rich model – snapshot of part of the reference energy system



Demand - Industry characterisation in SATIM

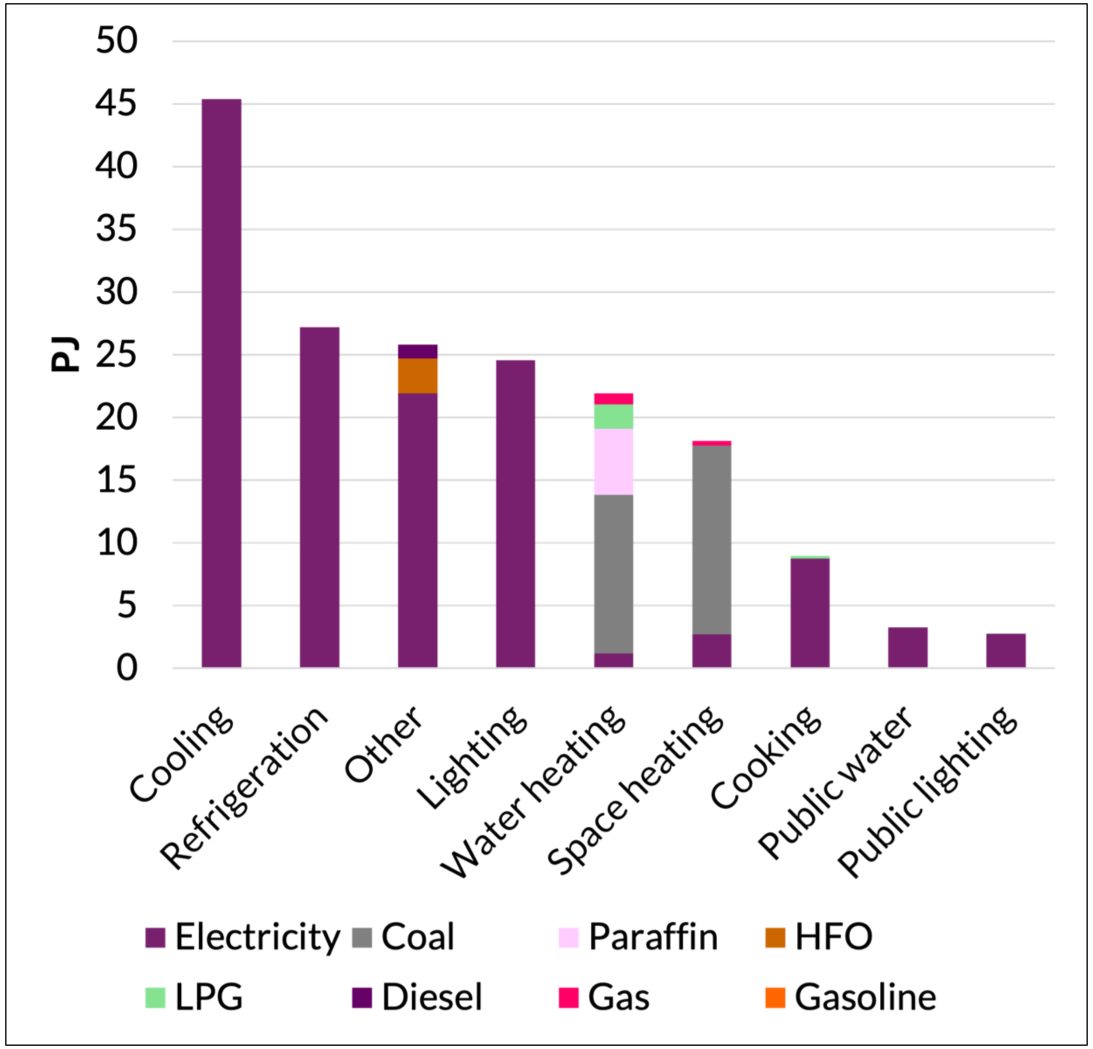
Approach to modelling	Industrial subsector	Production	Comment
Methodology One: large, energy intensive industries	Iron and Steel	Mt Crude steel	All primary, and secondary producers of crude steel, coke production included here (which is sold to chrome industry)
	Ferro Alloys	Mt FerroChrome, and FerroManganese	
	Aluminium	Mt Aluminium finished product	
	Pulp and paper	Mt Paper product, and dissolving pulp	
	Non-metallic minerals (NMM)	Mt Cement, bricks, and glass	Cement, bricks, lime, glass
	Platinum Group Metals (PGMs)	Tonnes of Platinum, and other PGMs	Includes mining of the ores
Methodology Two: More numerous, less concentrated industries.	General other manufacturing not covered elsewhere	**Useful energy services demand (PJ) for each sector:** Lighting, Compressed air, HVAC, cooling, pumping, Fans, Other motive, Electro-chemical, Process heat	Production of general other goods (textiles, clothing, pots and pans etc.)
	Mining		Includes coal mining, excludes: PGM ores.
	Chemicals		Chemicals production linked closely to basic chemicals produced at Secunda -
	PNFM: Other precious and non-ferrous metals		Gold, copper, nickel, zinc, and others.
	Food and beverages		Processing of agriculture products into food products, includes sugar industry

Demand – Commercial sector characterisation in SATIM

The commercial sector in SATIM consists of commercial buildings including offices, retail space, warehouses, schools, hospitals, and government buildings.

Energy service demand is estimated based on the energy intensity of energy services required as a **function of floor area (PJ/m²)** and is linked to growth in floor area and improvements in energy efficiency over time.

End-uses are reflected in terms of **fuel** and **technology** (e.g. electric LED lighting)

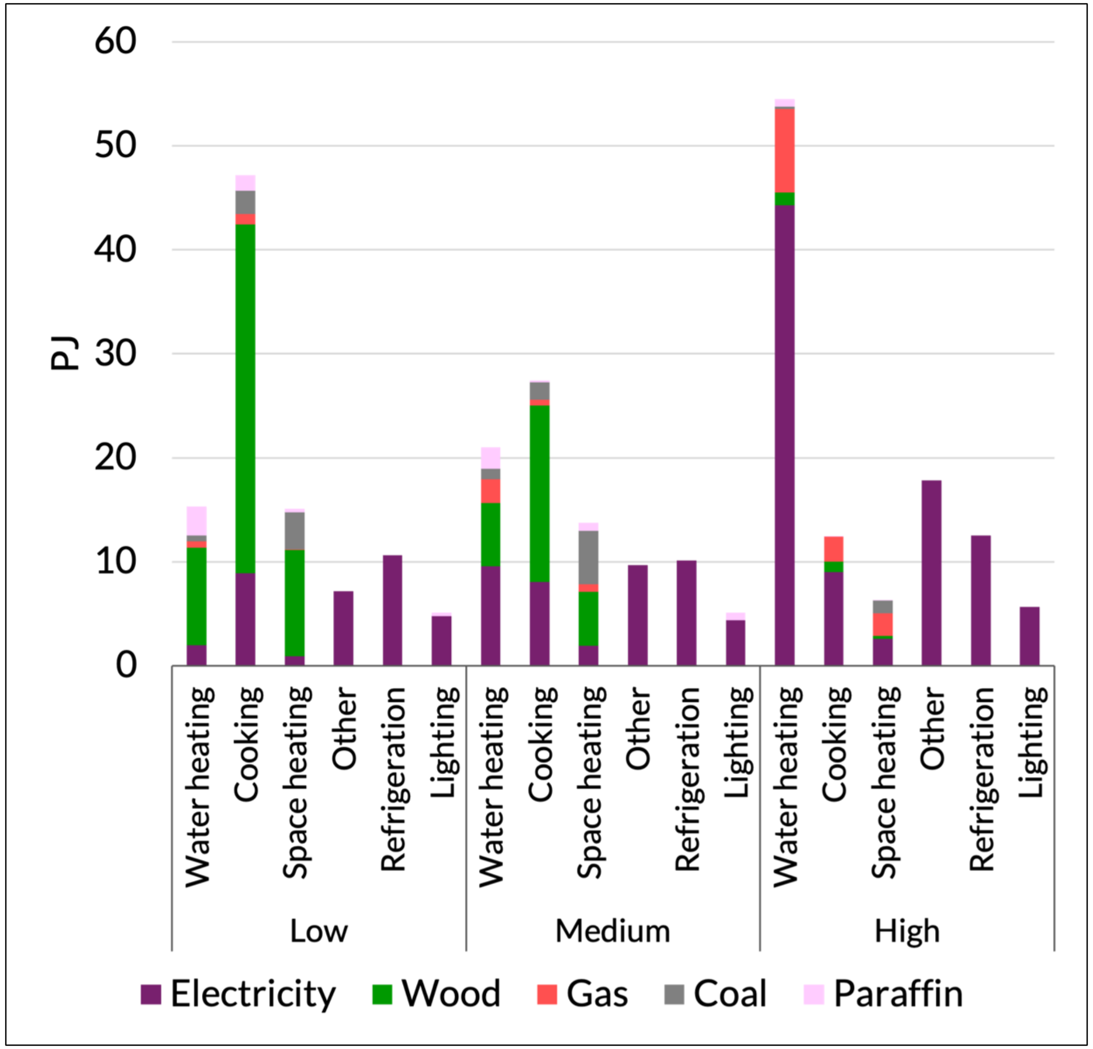


Base year (2017) final commercial energy demand by fuel and end use in SATIM

Demand – Residential sector characterisation in SATIM

Model structure and disaggregation

Disaggregation level	Drivers
Households: **Low, middle and high income groups**	Population, household size, GDP
Energy Service Demands: **Lighting, cooking, water heating, space heating and cooling, Refrigeration, Other**	Household income, electrification, Policies and regulations such as building standards Behaviour change
Fuels: **Wood, coal, paraffin, gas, electricity** **Appliances:** **(televisions, washing machines, dish washers, etc).**	Household income, electrification, Policies and regulations such as fuel subsidies, appliance standards



Base year (2017) final energy demand by fuel and income group in SATIM

Demand –Transport sector characterisation in SATIM

Demand projections are determined based on GDP and population growth, with 80% elasticity for freight and 50% for passenger. Split between modes of transport – e.g. road/rail and vehicle types – are specified exogenously:

- Historic mode shares determined from data (energy balances, fuel sales, StatSA transport surveys, eNaTIS and NAAMSA)
- Future splits estimated based on policy and scenario analysis

Passenger transport (measured in passenger-kilometers (pkms))

- Passengers classified by income level (low, medium and high) with assumptions on:
  - Private vehicle ownership
  - Occupancy
  - Mileage
  - Time budget for travel
  - Average speed
- Computed with GDP and population to determine future pkm demand by type of vehicle (private, MBT, BRT, rail, etc.)
- Matched with optimum fuel mix to model future vehicle stock and energy usage

Freight transport

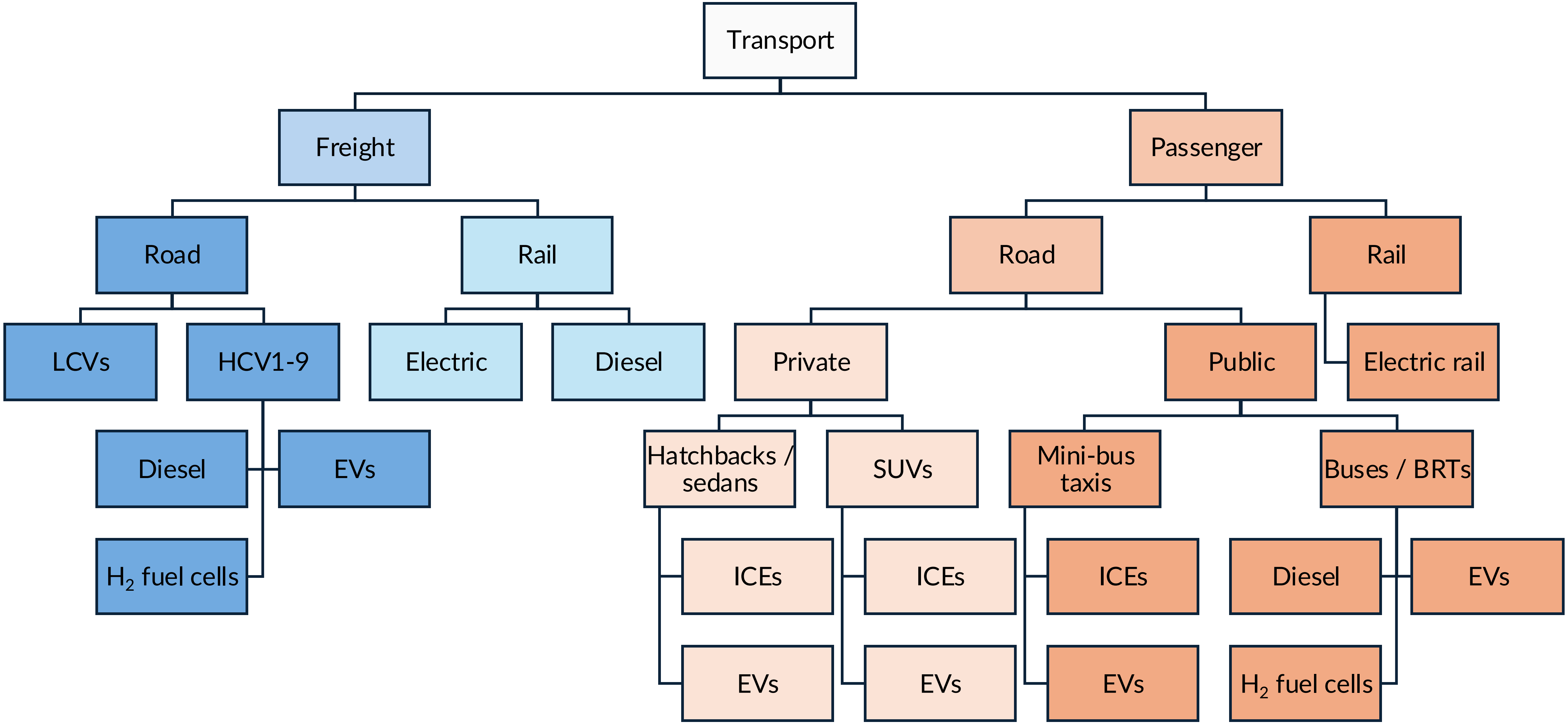
(measured in ton-kilometers (tkms))

- Road freight disaggregated by vehicle class (LCV and HCV 1 – 9)
- All new rail assumed to be electric
- tkm demand driven by tonnage per vehicle class, mileage; matched with optimum fuel mix to model future vehicle stock and energy use

Key factors influencing future transport demand and technology:

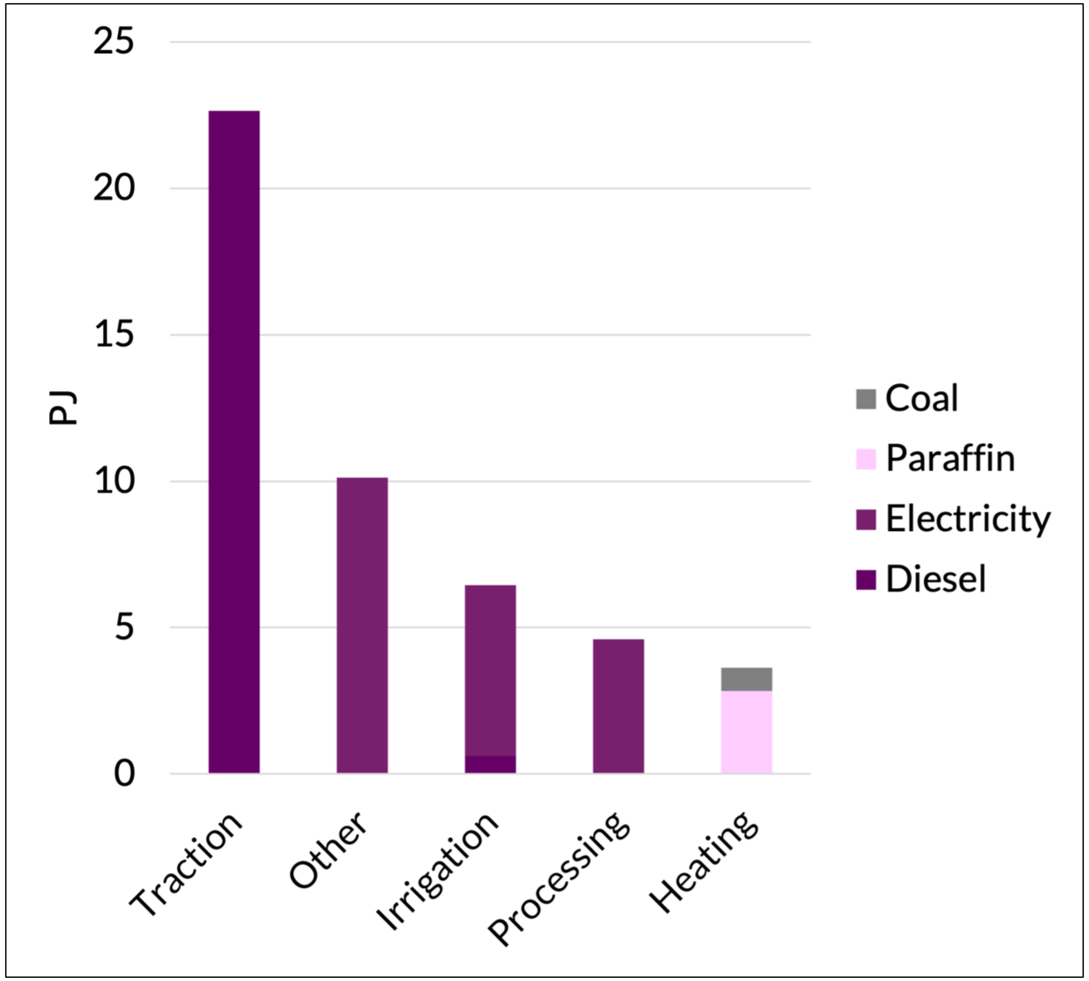
- Fuel prices
- Vehicle prices (EV cost parity; H_2 vehicles)
- Public transport and integration
- Consumer behaviour

Available transport modes / technologies in SATIM



Demand –Agriculture energy use characterisation in SATIM

- Limited representation in SATIM currently
- Energy services captured within agriculture are heating, processing, irrigation, traction and "other".
- Processing and other are supplied by electricity only
- Traction is supplied by diesel but can shift to electricity beyond 2025.
- Heating is supplied primarily by paraffin with a small amount coming from coal and can shift to electricity, gas or HFO beyond 2025.
- Irrigation is supplied primarily by electricity with a small amount supplied by diesel and can shift to 100% electricity by 2030.
- Non-energy GHG emissions from the agriculture sector are modelled separately



Base year (2017) agricultural final energy demand

Energy supply in SATIM – by carrier and technology

Sector	Existing capacity/supply	New supply options
Power	Coal OCGTs Nuclear Solar, Wind Pumped storage	As existing, with updated costs (learning) + Batteries, Distributed generation, With CCS (coal and gas options)
	Transmission and distribution	New infrastructure costs
Liquid fuels	Sasol synthetic fuels facility	
	Crude refineries (imported crude)	New refineries costed, refurbishment of Durban refineries available
	Imports of refined products	Can continue to import
Solid fuels	Coal (mining) Biomass	(As existing)
Gas	Natural gas (pipeline imports, Mossgas)	LNG terminals at coastal ports plus domestic pipelines

Oil and Gas prices

Oil and gas prices are assumed to remain constant over the entire modelling period.

Imports	Price in 2022 Rands
Crude oil	$75 /bbl = R203 /GJ
LNG – regional	R160 / GJ
LNG – international	R167 /GJ

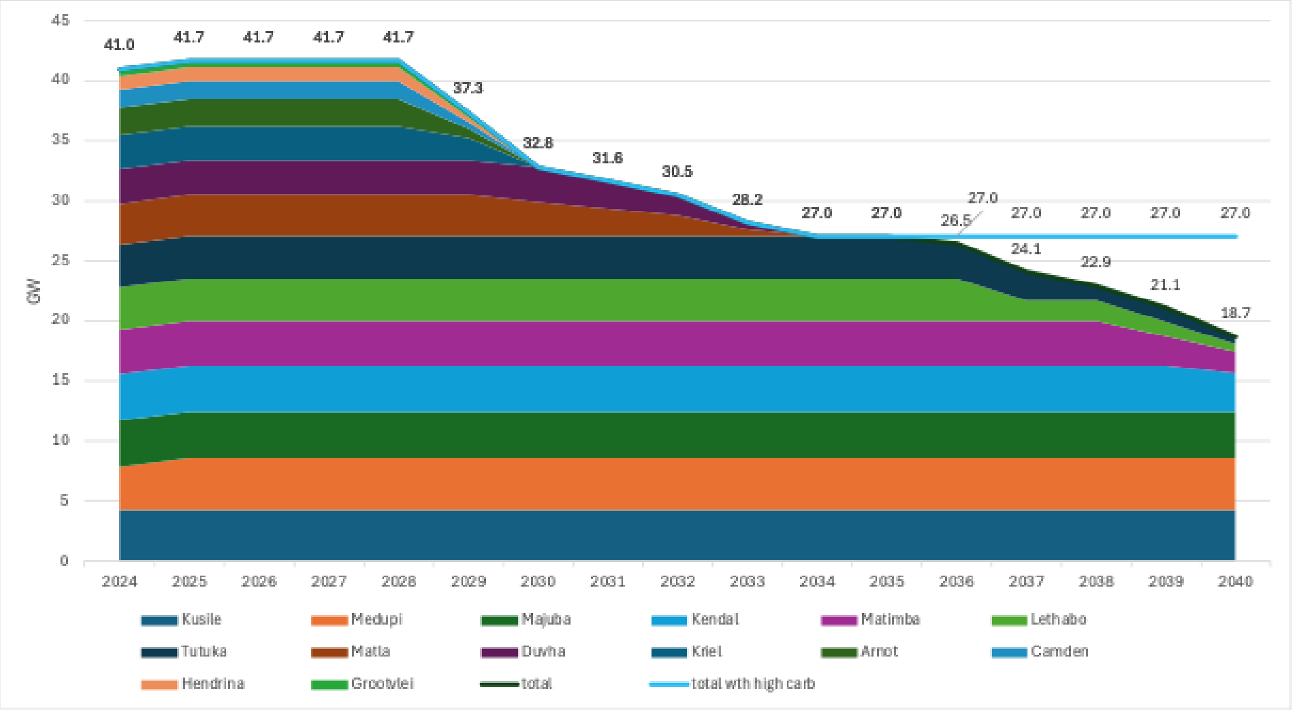
SATIMGE accounts for the investment costs of FSRU and terminals separately, raising the cost of gas supply for power (and other sectors) to ~R200/GJ.

Characterization of the South African electricity system in SATIM

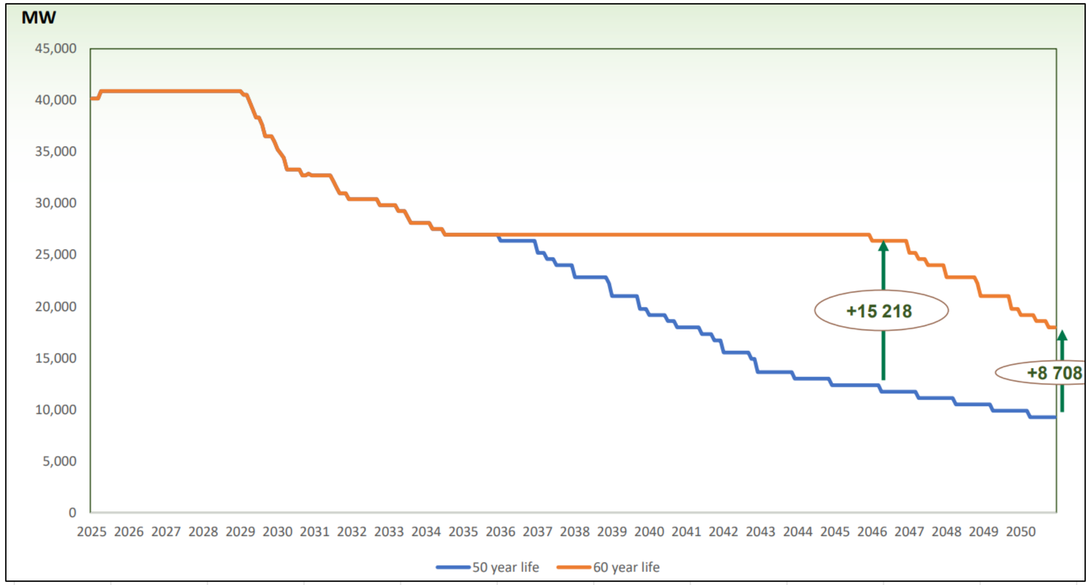
- Most significant source of GHG emissions in the SA economy, and also central to the decarbonization of other sectors (transport, "hard to abate" sectors)
- GHG emissions from the sector subject to three key parameters:
  - Electricity demand
  - The lifetime and utilization of the existing coal fleet
  - The GHG intensity of new generating capacity
- Demand is determined endogenously, and is dependent on economic growth and the extent to which other sectors electrify
- Existing coal fleet:
  - Retirement schedule – as per draft IRP 2024
  - Availability projections (EAF) – aggregate Eskom EAF from draft IRP 2024, downscaled to plant level via IRP 2019
- New capacity – constrained for first few years by availability of grid capacity (until 2031); thereafter assume that grid development can be achieved fast enough to accommodate new capacity.

Existing Coal Fleet Parameters: Expected Life of Plant / retirement schedule

- Retirement schedule for Eskom's coal fleet is an annualized version of the retirement schedule in the draft IRP 2024 (which is specified by month)
- Three variants in the model: 1) fixed retirement for whole period; 2) fixed retirement with the life extension of remaining stations in 2035; 3) 'endogenous retirement' - model is allowed to retire coal plants/units earlier than specified in the retirement schedule, based on cost.



Eskom coal fleet capacity in SATIMGE



Station	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9	Unit 10
Komati										N/A
Arnot	01-Apr-29	31-Aug-29	31-Jul-29	31-Mar-30	24-Nov-29	31-May-29	N/A	N/A	N/A	N/A
Camden	30-Aug-29	30-Apr-29	30-Nov-29	31-Jan-29	30-Dec-29	31-Jul-29	31-Mar-30	31-Aug-29	N/A	N/A
Grootvlei	16-Aug-29	31-Mar-30	04-Sep-29				N/A	N/A	N/A	N/A
Hendrina		10-Feb-29		31-Mar-29	31-Dec-29	13-Sep-29	19-Apr-29			21-May-29
Kriel	05-May-29	13-Jun-29	27-Jan-30	21-Feb-30	12-Mar-30	31-Mar-30	N/A	N/A	N/A	N/A
Duvha	17-Aug-31	30-Sep-31		30-Jun-33	30-Mar-33	21-Feb-34	N/A	N/A	N/A	N/A
Matla	22-Aug-30	29-Jun-31	11-Dec-31	15-Oct-32	23-Aug-33	20-Jul-34	N/A	N/A	N/A	N/A
Kendal	30-Sep-39	19-Jun-41	15-Dec-42	30-Nov-42	23-Dec-43	09-Dec-44	N/A	N/A	N/A	N/A
Kusile	29-Aug-68	30-Oct-70	30-Aug-71	30-Jun-72	31-Dec-72	30-Jun-73	N/A	N/A	N/A	N/A
Lethabo	21-Dec-36	10-Jul-37	26-Mar-37	02-Dec-38	30-Jun-40	27-Dec-41	N/A	N/A	N/A	N/A
Majuba	31-Mar-46	31-Mar-47	31-Mar-48	31-Mar-49	31-Mar-50	31-Mar-51	N/A	N/A	N/A	N/A
Matimba	03-Dec-38	03-Dec-38	28-Sep-39	29-Sep-40	30-Sep-41	30-Sep-42	N/A	N/A	N/A	N/A
Medupi	31-Jul-71	30-May-69	30-Oct-68	30-Nov-67	30-Apr-67	31-Aug-65	N/A	N/A	N/A	N/A
Tutuka	30-Dec-35	30-Dec-36	30-Dec-37	30-Dec-37	30-Dec-39	30-Dec-41	N/A	N/A	N/A	N/A

Draft IRP 2024 retirement schedule, with 60-year life option

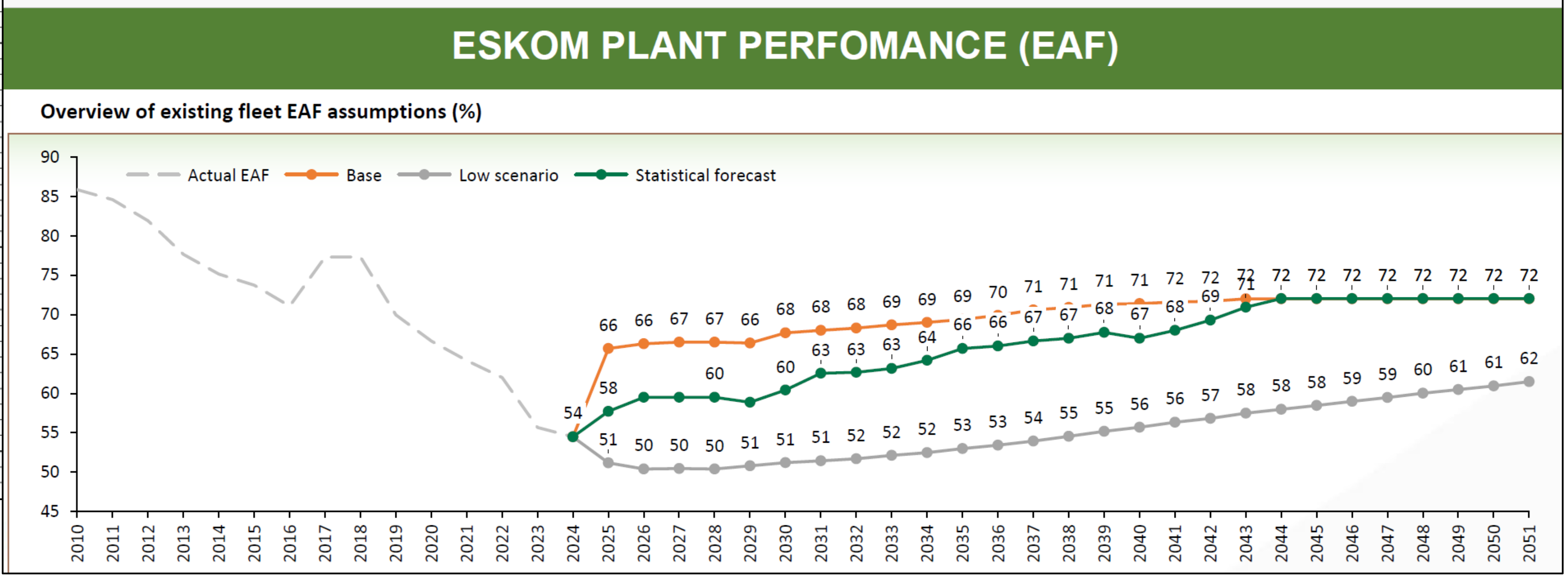
Existing Eskom Fleet Parameters: Availability Projections (EAF)

- **“Statistical Forecast” - Green Line** from IRP2024 (Fleet EAF reaches 66% in 2035), and using IRP2019 for per plant weighted EAF scaling of fleet average EAF in SATIMGE

Source: IRP 2024 (fleet EAF) and IRP 2019 (per plant weighted allocation assumption)

Table 6: Projected Eskom Plant Energy Availability Factor

	IRP 75.5% EAF FY2025 to FY2031 : EAF											
STATION	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
ACACIA	98.40	98.39	82.34	98.39	89.66	96.82	98.63					
ANKERLIG	98.12	94.20	98.13	96.81	97.81	95.16						
GOURIKWA	95.88	94.03	97.70	97.44	98.00	91.56						
PORT REX	97.71	93.07	92.46	92.62	98.14	96.16						
GARIEP	98.77	95.96	89.94	98.75	96.95	91.95						
VANDERKLOOF	94.73	98.87	88.95	84.44	98.85	97.61						
DRAKENSBERG	75.36	84.72	81.29	91.09	90.05	83.22						
INGULA	93.28	98.92	94.37	94.71	97.35	90.85						
PALMIET	86.05	98.83	94.45	87.89	98.80	88.92						
PEAKING	91.79	94.34	92.47	94.31	96.20	91.16						
KOEBERG	84.16	82.96	70.32	90.08	86.46	74.93						
NUCLEAR	84.16	82.96	70.32	90.08	86.46	74.93						
ARNOT	65.08	62.44	65.36	62.27	62.82	65.48						
DUVHA	54.48	49.67	60.16	56.92	62.82	61.12						
HENDRINA	60.93	55.96	69.35									
KENDAL	69.10	71.34	65.47	73.17	69.03	74.14						
KRIEL	54.10	63.42	54.63	51.39	65.20	64.44						
LETHABO	73.98	72.38	75.61	71.00	70.41	74.88						
MAJUBA	73.05	74.62	75.32	72.62	74.50	77.04						
MATIMBA	82.75	80.14	81.64	81.12	81.20	78.37						
MATLA	67.30	68.76	70.74	70.97	69.49	70.53						
TUTUKA	56.06	56.86	54.05	59.15	54.92	61.15						
BIG 10	66.78	67.18	67.69	67.53	68.44	70.41						
CAMDEN	60.00	55.81	61.24	64.67	63.05							
GROOTVLEI	89.15											
KOMATI	87.39											
TOTAL RTS	63.21	55.81	61.24	64.67	63.05							
Current Fleet Tota	71.00	71.53	71.40	72.71	73.63	73.85						
KUSILE	72.00	76.55	83.72	81.44	81.62	83.16						
MEDUPI	76.64	79.23	84.22	83.58	85.20	81.90						
NEW BUILD	75.31	78.29	84.00	82.54	83.42	82.53						
ESKOM TOTAL	71.5	72.5	73.5	74.5	75.5	75.5						



Note: The actual EAF for 2024 was 60% and not the forecast 54% in the draft IRP 2024. This resulted (provisional data) in higher electricity sector GHG emissions in 2024 (over 200 Mt instead of 185 Mt).

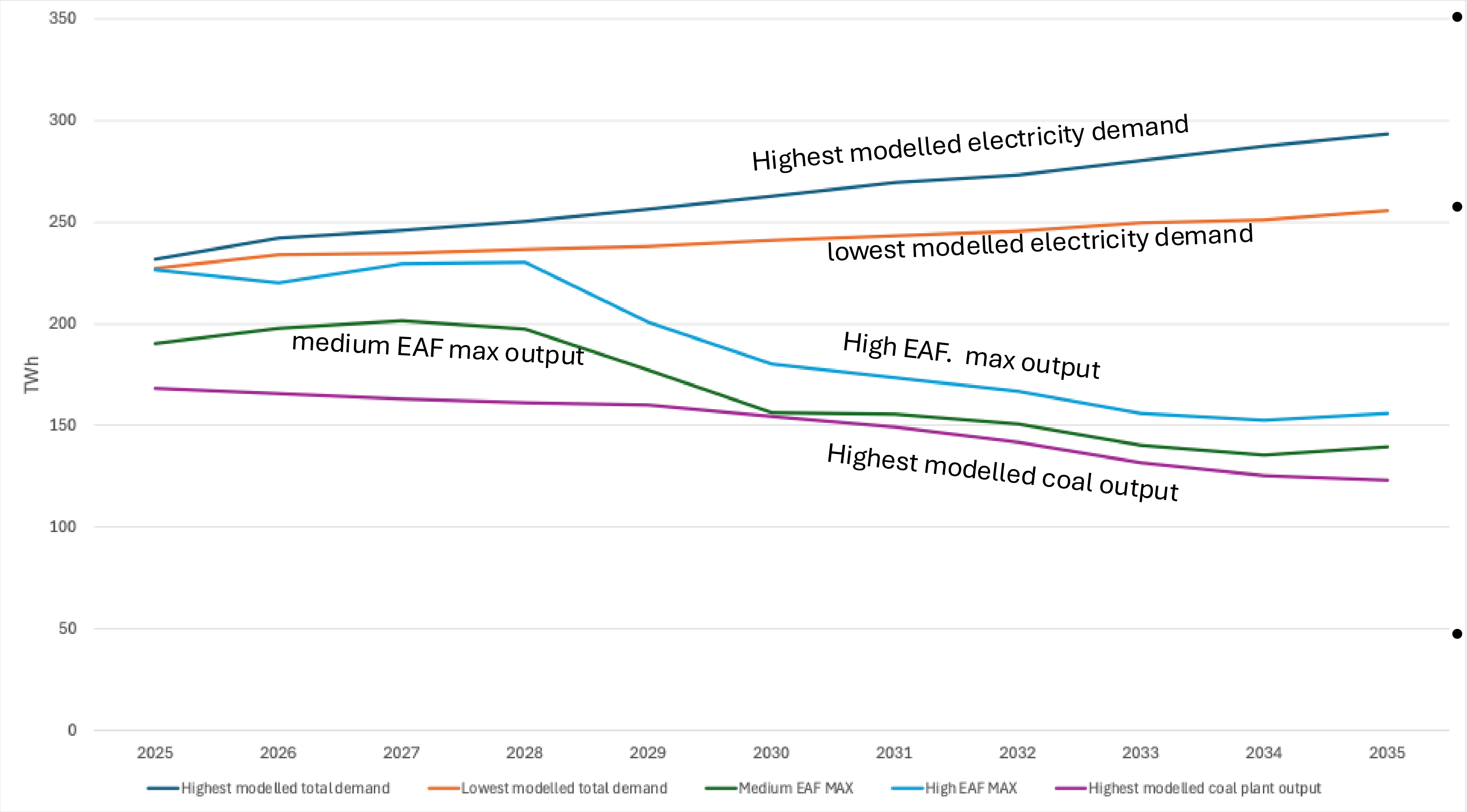
Eskom Coal Plant Efficiency Assumptions

- In SATIMGE each existing coal power plant has an individually assigned total average thermal efficiency value for converting the energy content in the coal to electrical energy. All units at each plant type listed are assumed to have the same efficiency (other than Majuba Wet/Dry).

- Multiple sources are used, and values are selected depending on data availability and quality using a specific model *assumption* from (IRP/EPRI, CSIR, Meridian PyPSA-RSA/CSIR) or a thermal efficiency *calculation* from data scraped from historical fuel use and electricity production data (Eskom AEL & CDM)

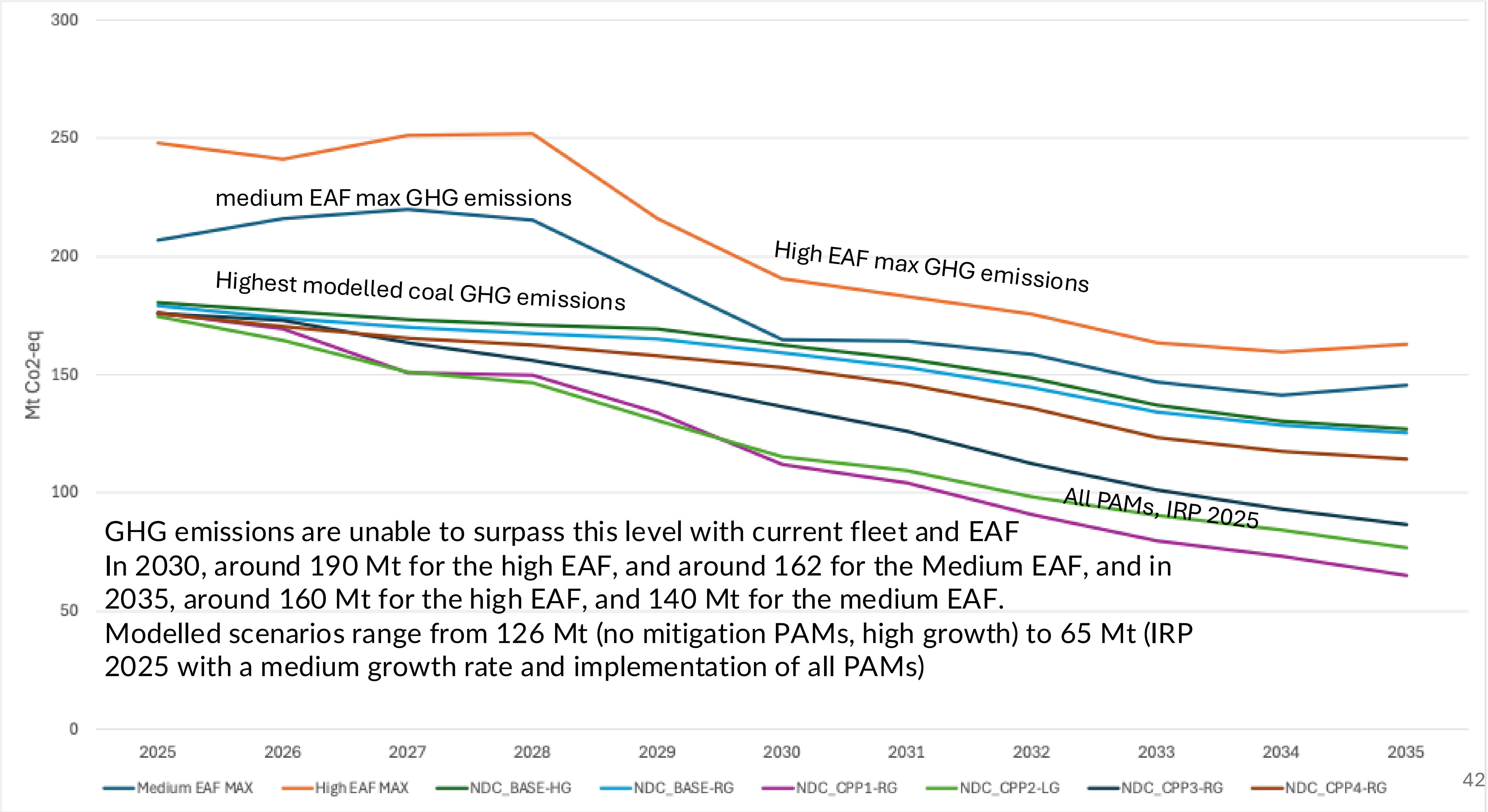
Eskom Coal Plant	Average Efficiency (%) in SATIMGE	Source
Arnot	28.0%	Meridian/CSIR (PyPSA-RSA/ZA)
Camden	27.3%	New AEL/CDM Based Calculation (2021-2022 data)
Duvha	29.8%	Meridian/CSIR (PyPSA-RSA/ZA)
Grootvlei	27.2%	Meridian/CSIR (PyPSA-RSA/ZA)
Hendrina	26.9%	Previous AEL/CDM Based Calculation (2009-2017 data)
Kendal	30.6%	Meridian/CSIR (PyPSA-RSA/ZA)
Komati	24.2%	Previous AEL/CDM Based Calculation (2009-2017 data)
Kriel	27.7%	Meridian/CSIR (PyPSA-RSA/ZA)
Kusile	36.7%	IRP Assumed Value
Lethabo	34.0%	Previous AEL/CDM Based Calculation (2009-2017 data)
Majuba Wet	31.0%	Assumption from World Bank water study
Majuba Dry	30.0%	Assumption from World Bank water study
Matimba	32.7%	New AEL/CDM Based Calculation (2021-2022 data)
Matla	32.1%	New AEL/CDM Based Calculation (2021-2022 data)
Medupi	37.1%	IRP Assumed Value
Tutuka	31.1%	Previous AEL/CDM Based Calculation (2009-2017 data)

Implications of the energy availability factor (EAF) on coal fleet output



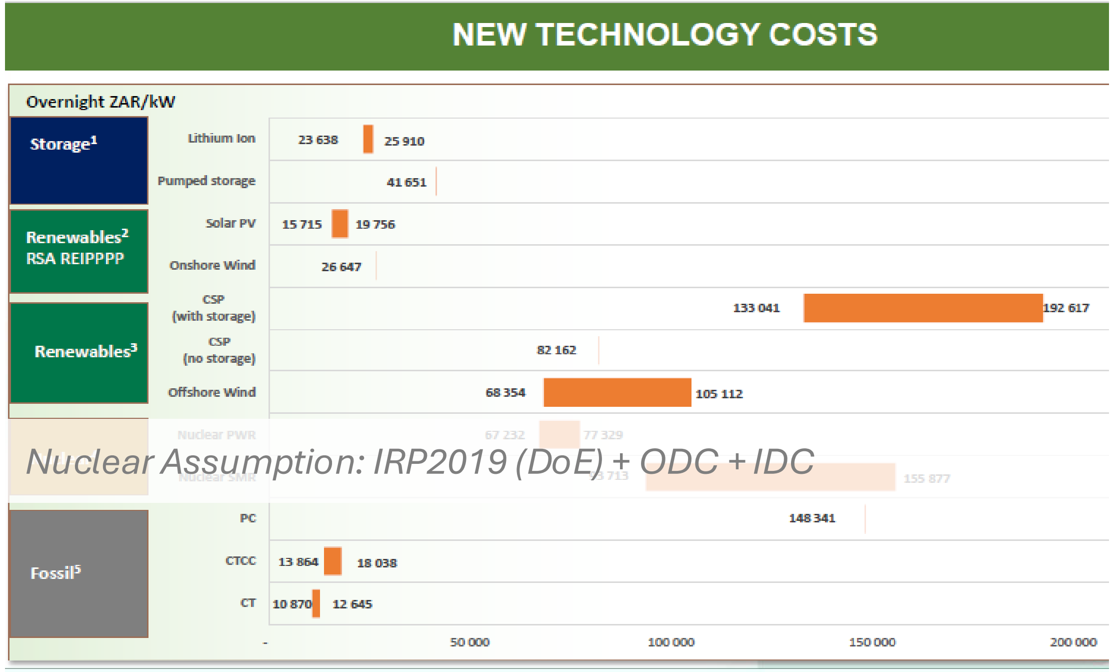
- The coal fleet output depends on plant availability (EAF)
- Even with the (very optimistic) high EAF scenario in the draft IRP 2024, the coal fleet can produce a maximum of ~180 TWh in 2030, and 150 TWh in 2035
- The medium EAF implies a maximum of 156 TWh in 2030, and 139 TWh in 2035.

Implications of the energy availability factor (EAF) on coal fleet GHG emissions



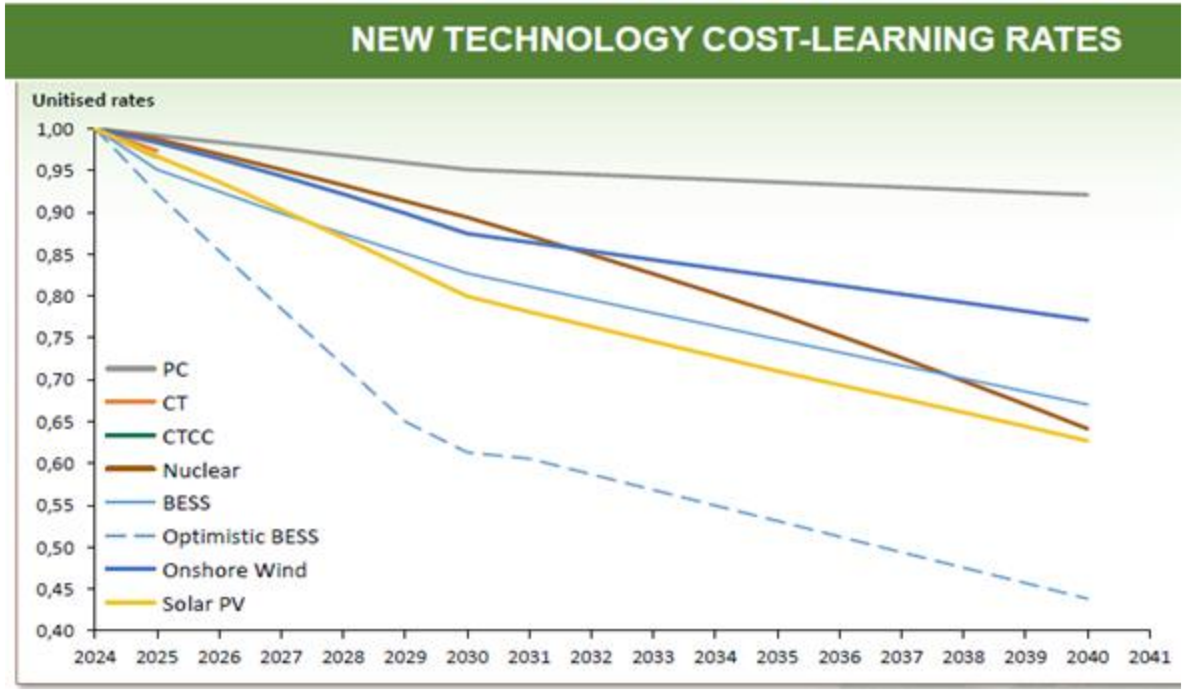
New Gx Technology Investment Costs:

- Costs in SATIMGE as in draft IRP 2024 for new Conventional, Renewables, Storage and learning curves for all technologies, with the exceptions of adjustments for nuclear, LNG, existing coal, RE profiles, and IDC+ODC (described in following slide). Nuclear uses IRP2019 investment costs (DoE) with added ODC & IDC. SATIMGE is adjusted to 2022 ZAR. Low end of solar PV and BESS range chosen for starting cost.
- Learning rates identical to draft IRP 2024 projections, default (not optimistic) BESS learning used.



Sources:
1. Lithium ion – EPRI, Pumped storage – Eskom Gx
2. Independent Power Producer Office
3. EPRI
4. DMRE Nuclear Branch
5. EPRI

Acronyms:
a. CSP-Concentrated Solar Power
b. PC- Pulverised coal with CCUS
c. CTCC-Gas CCGT
d. CT-Gas OCGT

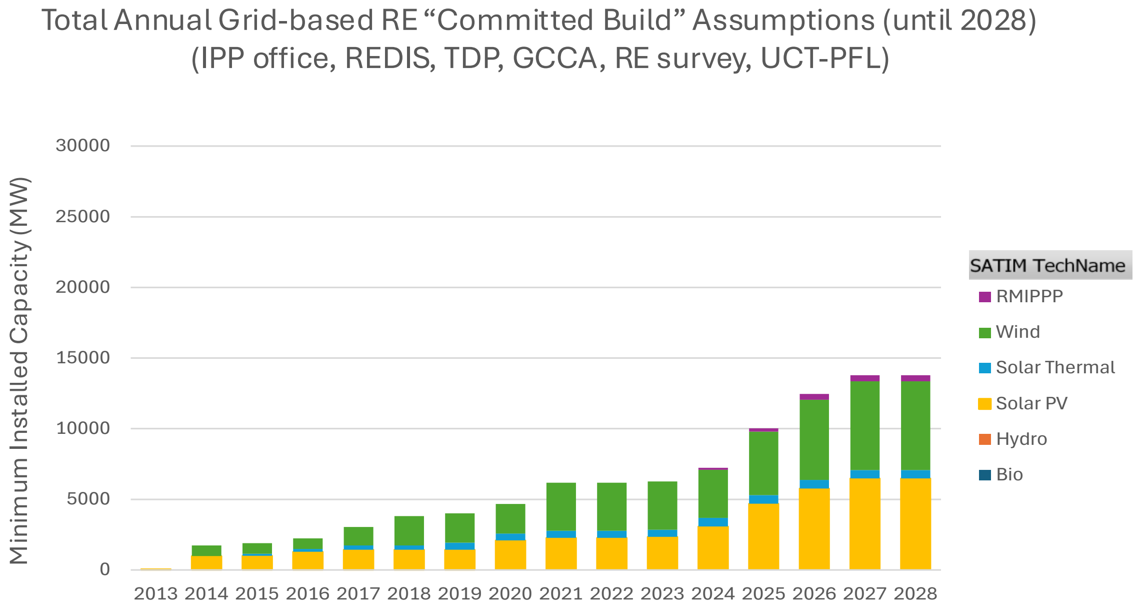


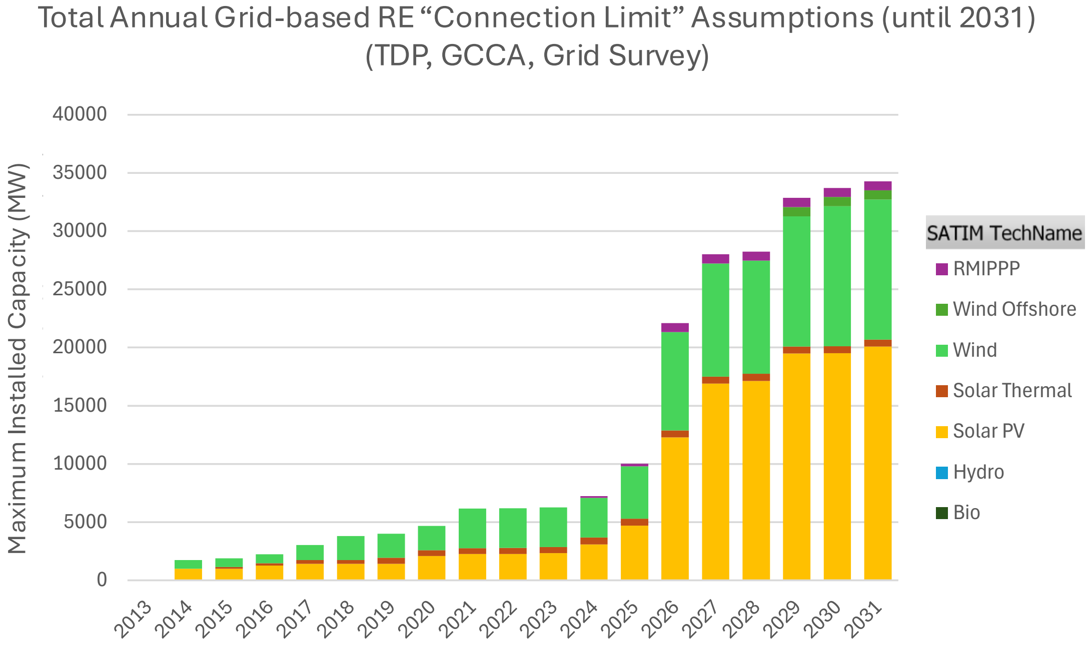
New Power Technology Costs & Performance Parameters

- New Electricity Generation Technologies – Cost & Performance:
  - In line with Draft IRP 2024 for new Conventional, Renewables, Storage and learning curves for all but nuclear, LNG, and existing coal which have adjustments per below
  - SATIMGE includes interest during construction and owner and developer costs (IDC & ODC)
  - RE production profiles - Spatiotemporal modelling for 10 "Eskom Supply Areas" bias-corrected to existing RSA RE historical production data (REDIS, ERA5, Eskom RE Survey, RE.ninja API)
- Nuclear: IRP 2019 (DoE costs+10% ODC) + 8 years of IDC
- Eskom coal fleet: Costs for O&M and per plant coal supply costs (MYPD5+RCA Application)
- Gas-to-Power - LNG
  - Gas price: constant or projected as per IEA scenarios (WEO 2024)
  - LNG terminal, storage, regasification costs - FSRU and land-based terminal as options (Hunt 2023).
  - Load Factor base assumptions: Open-Cycle (10% min LF), Combined-Cycle (20% min LF), 50% min LF for Combined-Cycle in selected scenarios with IRP build-plan

Centralized RE Characterisation: Installation and Grid Capacity Limits

- Grid capacity data sources to 2031: IPP Database (IPP projects), REDIS, TDP 2024 (capacity limits), GCCA 2025 (BQ projects), RE-Survey 2024 (limits beyond TDP), UCT-PFL IPP Dashboard (wheeling projects)
- Post-2031: New capacity growth capped at 20%/yr for PV & batteries, 10%/yr for wind (from 2032 onward)
- Scope: Modelled separately for 10 Eskom Supply Areas (9 provinces + Hydra Cluster); aggregated national totals shown below





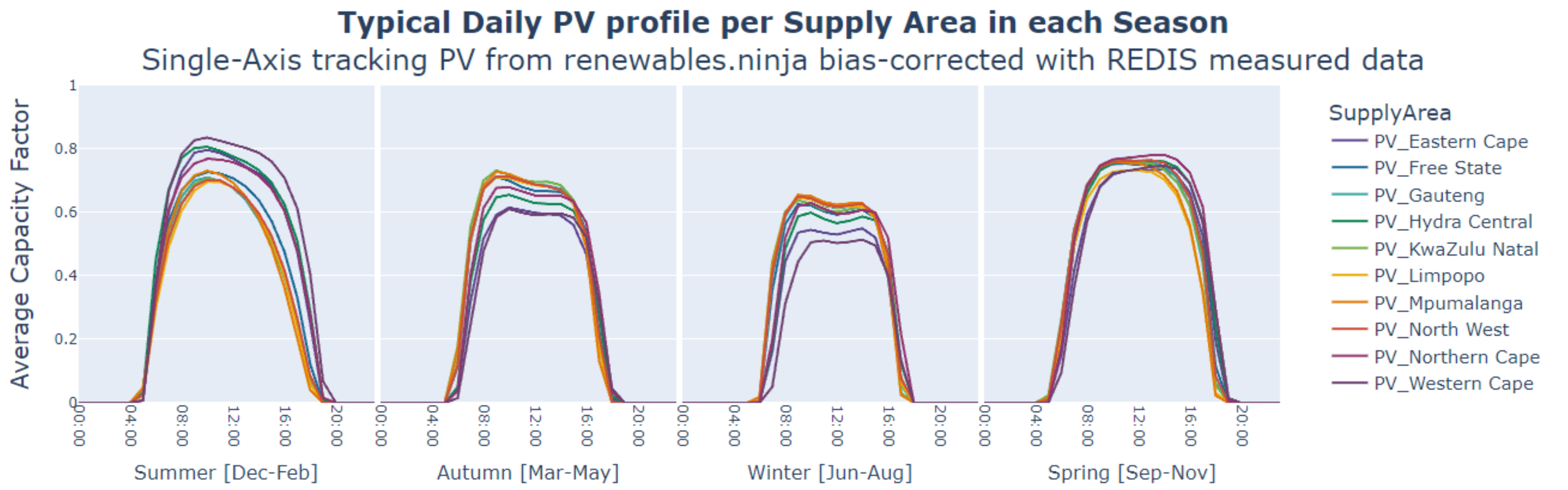
Grid Characterization and Reserve Margin

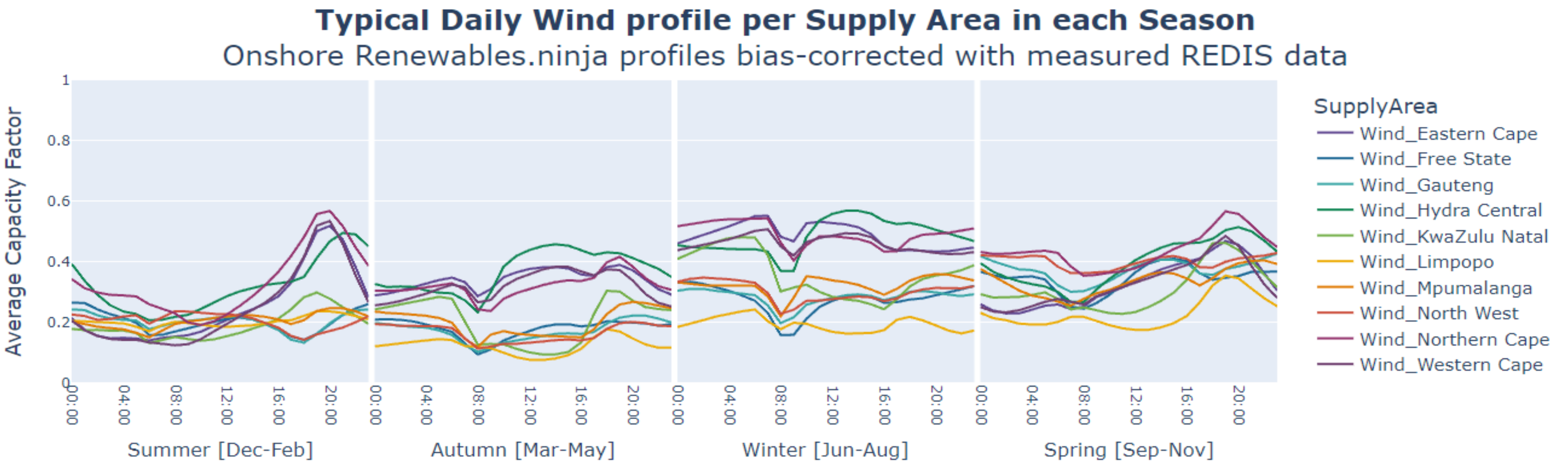
- Tx & Gx connection constraints limited by annual capacity limits per Province up to 2031 based on latest TDP+GCCA (NTCSA, 2024).
- Tx costed at 2 different levels:
  - 1st - Tracks peak Tx demand (Tx_1 = Peak Demand on Tx): 13,500 R/kW (TDP adjusted to 2022 ZAR)
  - 2nd - Tracks total installed Gx capacity (Tx_2 = Total Installed Gx Capacity): 2,800 R/kW (IRP 2019)
- Tx average system losses: ~3.9% (NERSA)
- Dx costs: Based on MYPD, unit cost differs based on sector (e.g. Residential is more expensive per MW than for connection to Large industry)
- Dx Losses: Based on Calibration of Sales vs production (specified per sector, e.g. Residential has higher losses than Large Industry)
- "15% Firm Planning Reserve Margin" included in SATIMGE.
  - Requirement of 15% margin of total installed dispatchable capacity above peak grid demand included in SATIMGE.
  - "Capacity Credits" assigned per tech – VRE and imports cannot contribute (0% credit), older coal plants contribute less than newer plants (per plant credit based on EAF, reflecting reduced reliability reality). Battery storage has a reduced contribution (75% credit). Other new and existing dispatchable techs (inc gas, diesel, coal and nuclear etc.) and domestic hydro as well as Pumped Storage have 100% capacity credit. CSP and RMIPPP have 50% and 75% credits respectively.

RE Generation Profiles: Hourly spatial profiles for 10 Eskom "Supply Areas" for utility-scale wind and solar PV power plants

- Hourly wind and solar profiles are modelled with the Renewables.ninja API for each of the 10 Eskom Supply Areas with locations and capacities weighted by existing RE plants and Eskom RE survey with highest likelihood of development
- Profiles are "bias-corrected" using measured historical generation performance data timeseries from REDIS for "ground truth" calibration

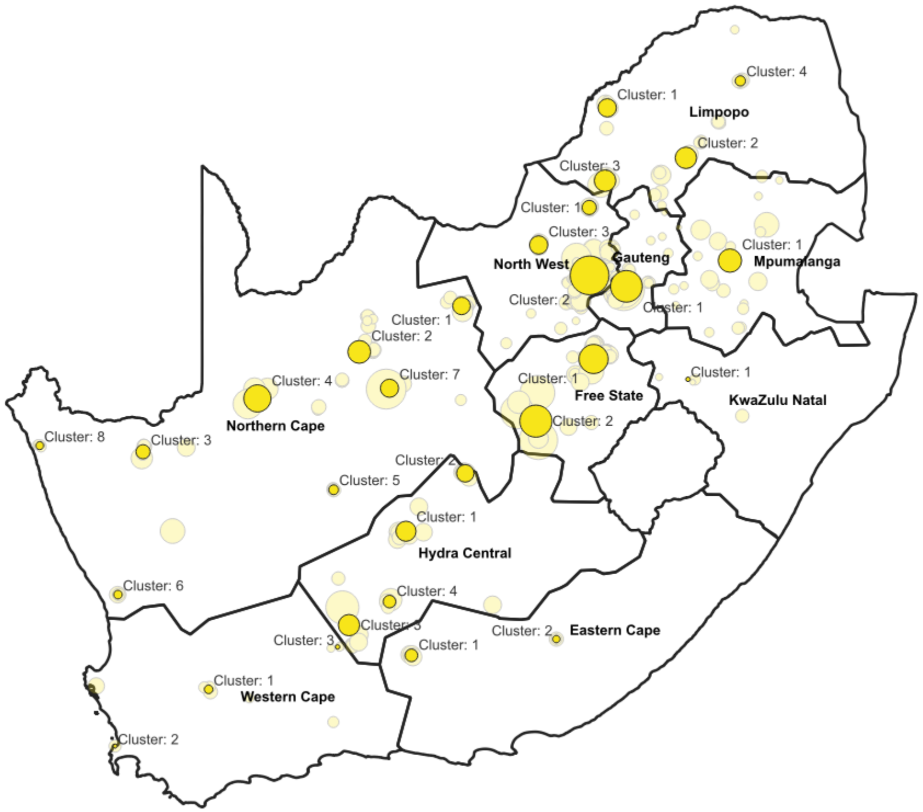
	Single-Axis PV (Average CF%)	Onshore Wind (Average CF%)
Eastern Cape	27.6%	35.3%
Free State	28.9%	25.2%
Gauteng	28.5%	25.9%
"Hydra Central"	29.6%	39.4%
KwaZulu Natal	28.6%	26.7%
Limpopo	27.6%	18.8%
Mpumalanga	28.1%	26.7%
North West	28.7%	26.9%
Northern Cape	30.2%	39.7%
Western Cape	28.2%	33.9%

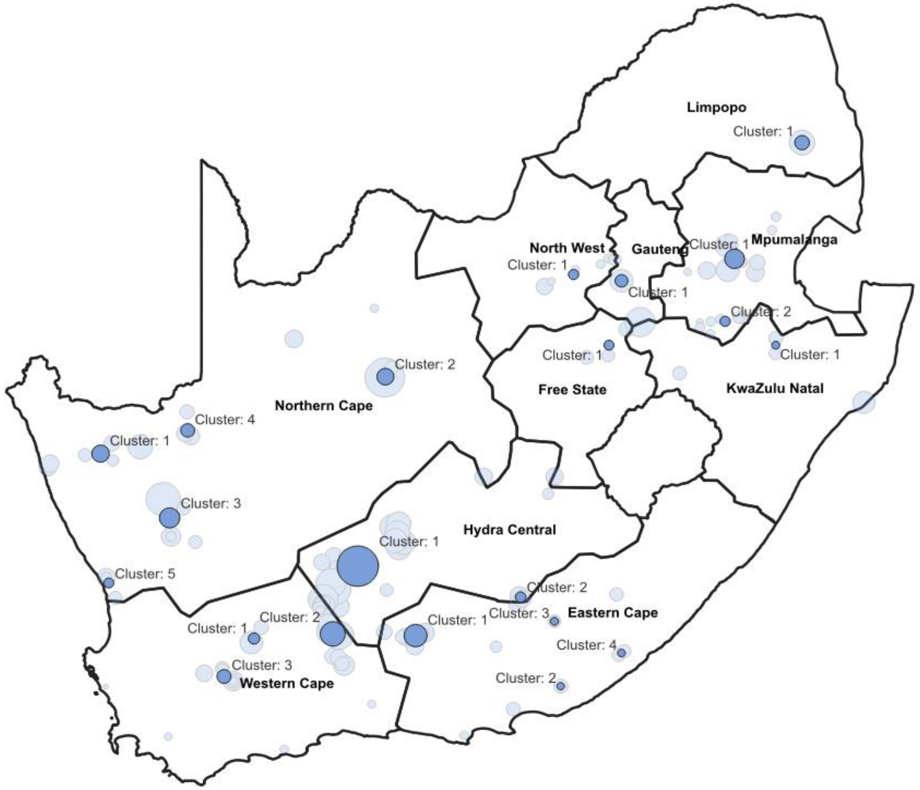




Renewable Energy Power Generation Supply Profiles – Clustering & Modeling

1. Eskom Survey Location Data -> “Weighted DBSCAN” spatial clustering in 10 “Eskom Supply-Areas”.
2. Resulting in 21 Wind Locations and 29 PV locations profiles extracted from renewables.ninja API
3. Hourly Profiles (21+29) are aggregated into the 10 Supply Areas and weighted by survey data MW capacity
4. Aggregated profiles (10) are “bias-corrected” using historical “ground-truth” data from existing RE plants





Characterization of liquid fuels supply – crude refineries

- Crude refineries operational as of 2024:

		Cape Town (Astron)	Inland (NATREF)
Imported crude oil consumption (PJ)		151.8	211.0
Annual Production (PJ)	Diesel	51.0	78.4
	Gasoline	43.4	65.9
	HFO	29.2	7.5
	Kerosene	18.1	43.5
	LPG	1.8	0.5
	Other liquid fuels	2.9	7.6
CO2 emisssions (kt)		591.5	913.8

- Both refineries assumed operational at full capacity, earliest retirement in 2038
- Option to refurbish the Durban refineries or build a new (world-scale refinery) if cost-optimal

Characterization of liquid fuels supply - Synfuels

Assume PetroSA GTL plant in Mossel Bay shut down in early 2020s and is not restarted

Secunda coal-to-liquids plant is a very significant GHG emissions source, and also integrated into liquid fuels and chemicals

The modeling focuses on the following three primary categories to assess energy and emissions pathways at Secunda:

Baseline (No transition)

- Assumes business-as-usual operation of CTL without any interventions. Secunda plant is ageing, facing high maintenance and risk of decommissioning. Emits >53 Mt CO_2 annually; regulatory and water stresses constrain operations.
- No renewable energy integration, no process modifications.
- Existing equipment performance (e.g., turbines, boilers) is maintained with minimal efficiency improvements.
- Represents the continued use of a fossil-fuel-dominant configuration with fixed emissions intensity.

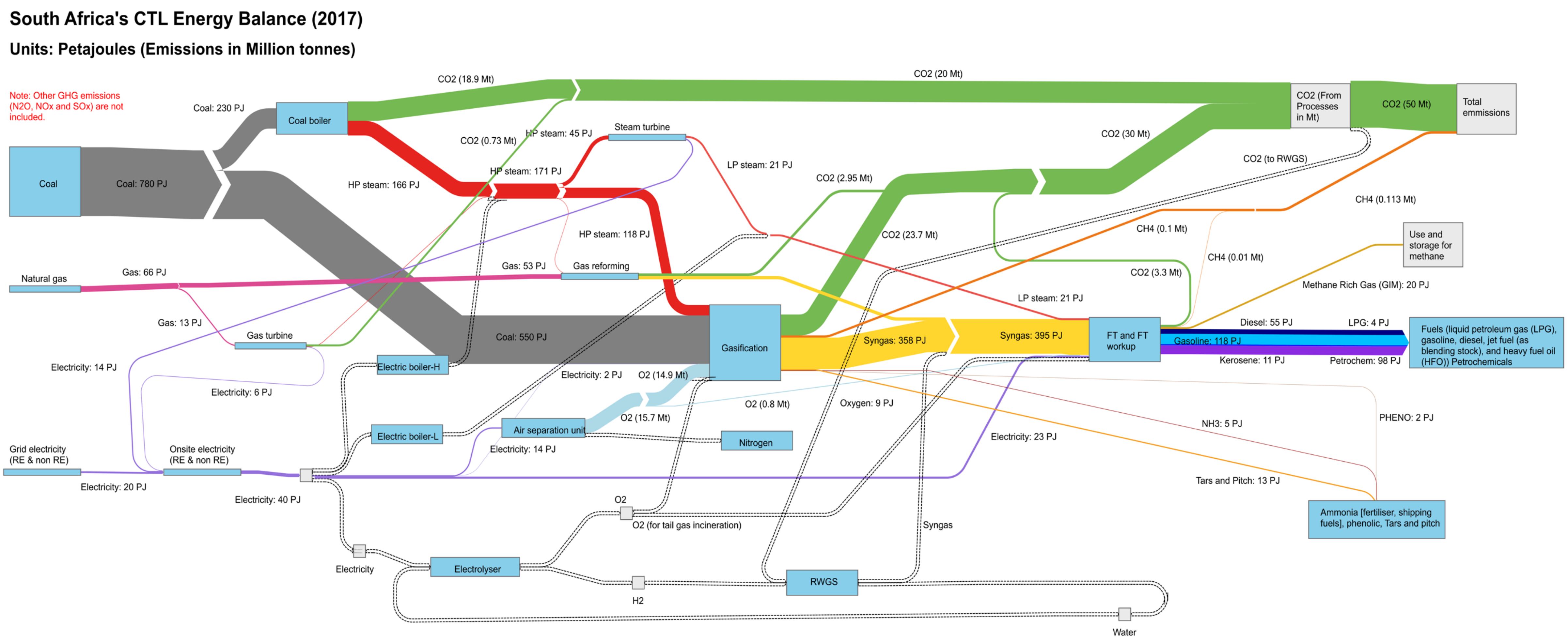
Roadmap-Aligned (No structural shift)

- Represents Sasol's 2030 roadmap targeting 30% reduction in Scope 1 & 2 emissions vs. 2017 – implemented ONLY for Secunda
- Includes integration of renewable electricity (target of ~2 GW by 2030), incremental efficiency improvements (boilers, gasification, FT synthesis), and limited use of carbon credits.
- The CTL process structure remains unchanged; no alternative feedstocks or new conversion technologies are introduced.

Structural Decarbonization

- Introducing new technologies and structural transitions.
- Technologies include:
  - Electric boilers for high- and low-pressure steam.
  - PEM electrolysis for green hydrogen production.
  - RWGS reactors converting $CO_2 + H_2$ into synthetic syngas.
- Enhances electrification of thermal systems and recycles CO_2 to close the carbon loop.

Sankey diagram of Sasol sub-model in SATIM



Additional technologies represented (e.g., Electrolysis, RWGS)

Modelled Secunda and coal to liquids technologies in SATIM

Existing process / Optional new processes	Technology	Description
Existing processes at CTL facility at Secunda, modelled in SATIM	Coal Boilers	Produces high-pressure steam from coal, with progressive efficiency improvements from 72% to 80% as part of the 2030 roadmap plan.
	Steam Turbines	Consumes high-pressure steam and produces low-pressure steam and electricity; modeled with a flexible CHPR (heat-to-power ratio), with the expectation that its use will be minimized under the 2030 roadmap plan and replaced by renewable electricity.
	Gas Turbines	Operates on gas and off-gas, with an electrical efficiency (EFF) of 0.44 and an overall efficiency of 80%; availability declines due to the planned phase-out of gas imports by 2034.
	Fischer-Tropsch	Converts syngas into synthetic fuels (gasoline, diesel, kerosene, LPG, and petrochemicals); efficiency improves from 69% to 75% under the 2030 roadmap aimed at reducing CO_2 emissions.
	Gasification	Converts coal, steam, and O_2 into syngas, ammonia, phenolics, and tar; efficiency increases from 65%→75% under the 2030 roadmap plan aimed at reducing CO_2 emissions.
	Air Separation Units	Produces oxygen and nitrogen using approximately 250 kWh per ton of O_2; 17 units are modeled, with a total production capacity of 47,000 tonnes of oxygen per day.
	Gas reformer	Produces syngas from methane-rich or Mozambican natural gas; phased out by 2034 following the end of gas imports from Mozambique, 70% efficiency.
	Grid Electricity Transfer	It represents electricity imports from Eskom and renewable energy sources, which are supplied to the onsite electricity system alongside power generated internally. The assumed efficiency is 100%.
New technology options in SATIM for Secunda	Electric Boilers (HP & LP)	Produce steam from electricity at 95% efficiency; deployed from 2031 onward.
	Electrolyzers	PEM-based hydrogen production; consumes water and electricity; modeled from 2031, 70% efficiency.
	RWGS	Converts H_2 and captured CO_2 into syngas; capital and O&M costs modelled.

On the economy: South African General Equilibrium (SAGE)

Dynamic recursive CGE model

Uses a 2019 Social Accounting Matrix

- SAM adjusted for energy balance, CGE includes actual energy volumes
  - Energy is an intermediate input
  - Heterogeneity in tariffs
- Potential for new energy technologies
  - E.g., Hydrogen economy
- Separation of investment and capital: energy and non-energy
  - Different investment demands and return payouts
- Key inputs for energy separated (e.g. machinery for energy versus non-energy) to better capture localisation opportunities

Sectors/commodities in SAGE

Agriculture	Crops (11)
	Livestock
	Forestry
	Fishing
Mining (6)	Coal (high vs low), Gas, PGMs
Manufacturing	Food (14)
	Non-food (31)
	Refineries and different products
	Hydrogen and new linked VCs
	Specific energy machinery
Other industry (4)	Differentiate between energy and non-energy construction
Services (13)	Transport differentiation by mode (road/rail/other) and market (passenger/freight)

Additional work – comparative modeling of electricity options, and air quality analysis

Electricity system:

- Electricity systems with high rates of VRE have additional modelling challenges
- SATIMGE has some required simplifications in the electricity sector - key simplifications include:
  - Lower level of spatial detail
  - Reduced time resolution using typical days
  - Simplified transmission grid representation
- All these could lead to SATIMGE results being overoptimistic on what we are able to achieve by 2035 (i.e. a version of the system which is less reliable, more costly, less efficient)
- These are partially addressed by benchmarking and stress-testing with other detailed power-sector specific models to conduct comparative analysis, measure potential deviations, conduct reliability/flexibility/operability testing, and feed back results into SATIMGE's constraints and assumptions

Air quality:

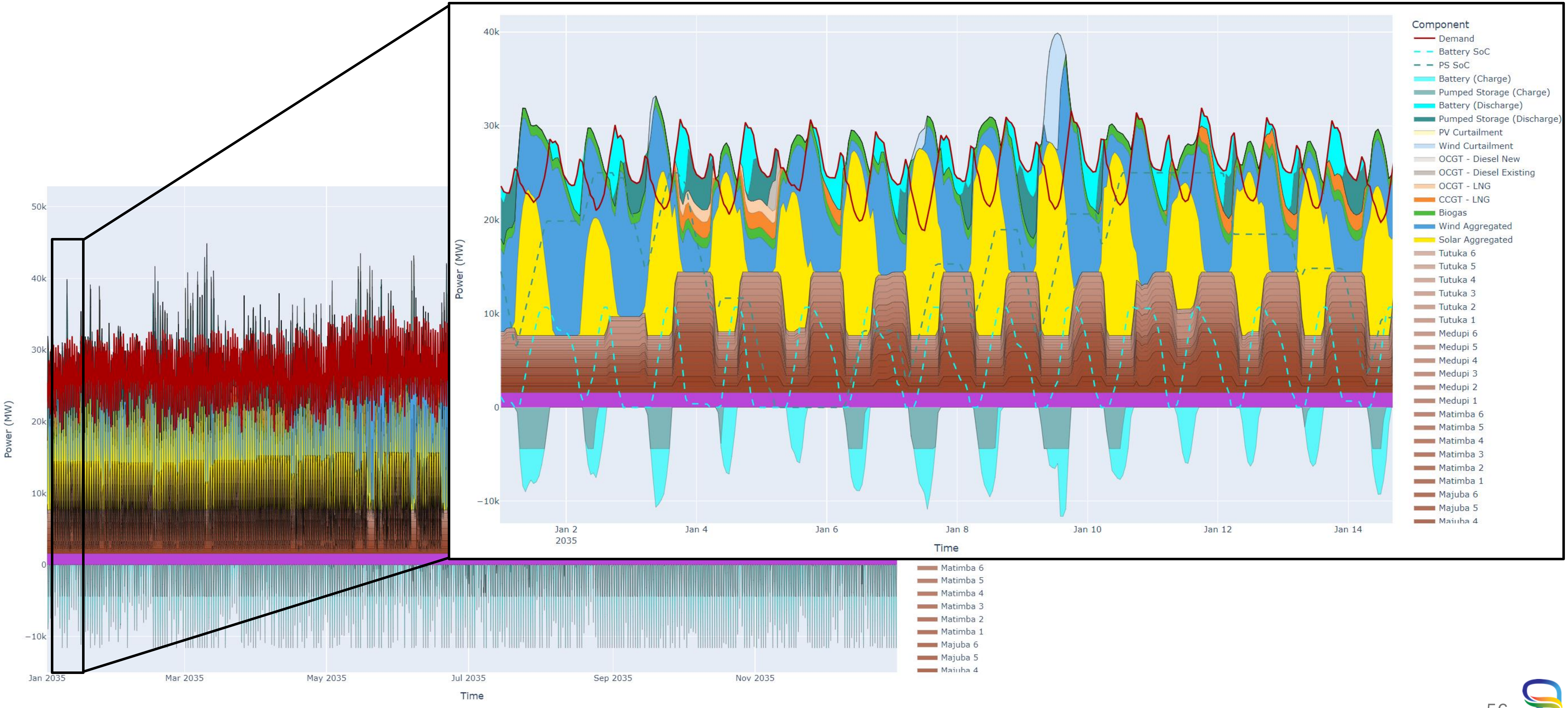
- In SA, air pollution is in most cases inextricably linked to fossil fuel use – hence, any mitigation strategy would also reduce air pollution / increase air quality, and will also result in many saved lives, which is key addition to the mitigation evidence base
- SATIMGE can tell us how much air pollution is produced for a given mitigation scenario, but not what the impact on ambient air quality would be, and what the impact of air quality would be on human health – this requires further analysis using additional analytical tools
- Hence we supplement the energy-economy modelling with tools that can assess these effects, notably the CSIR's Air Quality Systems model…

Power Sector Benchmarking & Validation: High-resolution multi-model testing

- Objective: **Validate, benchmark, and stress-test power sector results of SATIMGE with multiple high-resolution detailed power sector focused models using an iterative soft-linked modelling approach**
- Key Focus Areas:
  - SATIMGE power sector results stress tested with full 8760 hourly chronology and detailed power system operational constraints with several industry leading complementary models validating and benchmarking system operation, reliability, flexibility, and cost, feeding back results to SATIMGE for model convergence.
  - Unit level representation of the 2035 RSA power system configuration scenarios with per-tech operational constraints (operational/fuel/investment costs, ramp rates, minimum stable generation, part-load efficiencies, start-up costs, etc., spatial RE production and demand profiles, transmission system, curtailment, etc.)
- Models Included in Validation Efforts:
  - **PLEXOS** (SUN) – Single-node, full PLEXOS details, 8760 hours, Monte Carlo for statistical outage profiles and unserved energy, detailed dispatch only, no capacity expansion (closed proprietary software)
  - **FlexTool3** (IRENA) – Spatial 10-node Eskom Supply Areas and Single-node, Tx system for spatial, unit commitment, representative weeks for spatial, dispatch test and spatial RE/Storage allocation (open-source code)
  - **PyPSA (UCT-ESRG)** – Single-node, 8760 hours, all coal units individually modelled, system dispatch mode *and* single step capacity expansion mode (open-source code)

PyPSA – Hourly Dispatch Validation Visualization

8760-hour least-cost dispatch timeseries – coal fleet dispatched at unit level



Power Sector Benchmarking & Validation: PLEXOS Results by SUN

- The electricity system results of the **SATIMGE NDC modelling were stress-tested by SUN in a scenario-matched PLEXOS unit commitment model** for 3 key representative scenarios for 2035. Additionally, 2 variations were modelled per scenario to investigate the impact of relaxing GHG/carbon emission constraints.

Findings:

- Electricity production per technology type **corresponds well** with SATIMGE for the CPP4-HG (348.7 Mt CO2eq) and CPP3-HG (322.2 Mt CO2eq) scenarios, indicating that operational constraints are being reasonably accounted for. The designed systems are also shown to be **very reliable**, with annual unserved energy below 1.5 GWh for both scenarios (well below the 20 GWh threshold at which the system would be considered reliable).
- The CPP4-8-NZ-RG (263.7 Mt CO2eq) scenario performs less well, both in terms of matching capacity factors and system reliability, with an average annual unserved energy of 72.69 GWh. It should be noted that in the CPP4-8-NZ-RG scenario, the designed system **is capable of operating reliably if emission constraints are relaxed**. Allowing for a 5% increase in carbon output results in the annual unserved energy decreasing to 5.99 GWh.

– Stellenbosch University, PLEXOS Model, 2025.

Policies and plans

Selection of and quantification of policies and plans

A total of 64 mitigation and/or mitigation-relevant policies and plans were assessed as part of this analysis. Some of these would, if implemented, have a direct impact on GHG emissions in 2035 (for instance the draft IRP 2024), and others play an enabling role (for instance, reform of the electricity sector). This includes Sasol's and AMSA's mitigation "roadmaps".

Many key mitigation policies and/or policies with significant implications for GHG emissions in 2035 are currently being revised or awaiting implementation; these include the draft IRP 2024 as presented to NEDLAC in January 2025 which awaits finalisation, the South Africa Renewable Energy Masterplan (SAREM) which has been approved by the Cabinet but currently awaits implementation; measures to implement market mechanisms contained in the Electricity Regulation Amendment Act – uncertainties in the institutional structure of the electricity sector, and the related restructuring of Eskom; the Green Transport Strategy (GTS), which the Department of Transport is currently planning to revise; the draft post-2015 National Energy Efficiency Strategy (NEES), which has not yet been approved by Cabinet, and is now being updated by the Department of Energy and Electricity; amendment of the Carbon Tax rate, which is still being finalised by the Treasury, and related industrial policies to localise supply chains of renewable energy (in SAREM) and electric vehicles.

In addition, the DFFE is in the process of implementing the Climate Change Act, which requires the Minister to establish regulations for Sectoral Emissions Targets and Carbon Budgets, to set these for a series of five-year periods, and also to establish/revise a long-term GHG emissions trajectory for the country; the DFFE is also in the process of revising South Africa's Long-term Low Emissions Development Strategy (LT-LEDS)

In this context, the modelling of mitigation options per sector have been limited to sectors in which policies and plans exist (in final or in draft form); where there is significant uncertainty in quantifiable policy goals applicable to 2035, key policy objectives have been extrapolated where feasible. This analysis is therefore NOT a mitigation potential analysis (a comprehensive assessment of mitigation options across the economy). There may therefore be further options for mitigation up to 2035 which has not been considered here. In particular, measures specific to the agriculture, land-use and waste sectors could be significant contributors to additional emissions reduction, but reductions in these sectors were not analysed.

Key quantified policies and plans implemented in SATIMGE

Key policies and plans which were quantified and implemented in SATIMGE are listed below by sector. These are described in more detail in the slides below. Information on how these were included in scenarios is contained in the next section.

Electricity:

- Draft IRP 2024 (NEDLAC version) – includes harmonization of base model assumptions (costs, retirement schedule for the coal fleet), and implementation of the investment plan, as well as an additional variant (IRP “light”) with less added capacity;
- SAREM – Minimum thresholds of RE capacity installed each year – 1 GW PV minimum, 1 GW wind minimum, total of 3 GW, until 2029; 1.5 GW PV minimum, 1.5 GW wind minimum, total of 5 GW, and additional costs;

Transport:

- Passenger/freight modal shift – extrapolated from the Green Transport Strategy, other sources
- Shifts to EVs – fast, medium and slow shift parameterized in terms of when EVs in different classes reach capital cost parity with ICEs – consistent with different levels and timing of the localisation of EV manufacture

Synthetic fuels – Sasol “roadmap” for GHG emissions to 2030

Iron and Steel sector – AMSA roadmap

Carbon tax – current proposals implemented as per 2025 budget for post-2025 period

Energy efficiency – demand-side measures informed by the Post-2015 NEES and the draft SETs technical work, own assessment of more recent market information

Electricity supply – Draft IRP 2024 model implementation

The analysis makes use of the NEDLAC version of the draft IRP 2024; where there is a lack of sufficient detail, assumptions have been made as described below. Technology costs and EAF assumptions are aligned with IRP values, and applied across scenarios as described above. Electricity demand is slightly lower than in the draft IRP 2024. In SATIMGE, demand is endogenous (a model result rather than an input), reflecting lower economic growth and more conservative EV uptake.

The schedule for new capacity additions and retirement of the coal fleet are fixed until 2042; thereafter, SATIMGE chooses least-cost options to meet electricity demand. Because the build plan is fixed over this period, lower demand translates into reduced coal utilization (given that RE and nuclear are dispatched first), resulting in lower GHG emissions.

	Coal	Gas - IPP Programme	Gas - Eskom	Nuclear	Hydro	Pumped Storage	CSP	Solar PV	Wind	Hybrid IPP Programme	Distributed Generation	BESS - IPP Programme	BESS - Eskom	Other private projects (inc
rent Base (	39520	1005	2825	1860	1600	2732	500	2287	3443		6165		219	104
2024	720							0	0	150	900			
2025	720						100	960	1738	476	900	712		
2026								3553	964		900		144	35
2027								2886	2847		900		150	332
2028								0	770		900	615		
2029			3000					24	760		900	2615		
2030		3000						800	2000		900	200		
2031								1000	2500		900	200		
2032		1250						1200	2600		900	200		
2033		1250						1400	2600		900	200		
2034		1250						1600	3000		900	200		
2035		1000						2000	3000		900	200		
2036		1250		1250				1600	2000			500		
2037		1500		1250		1332		1600	3000			500		
2038		1250		1350				1600	3000			500		
2039		1250		1350				1600	3500			500		
2040		1250						1600	3500			500		
2041		500						1600	3500			500		
2042		500						1600	3500			500		

The following assumptions have been made regarding new capacity specified in the IRP:

- Distributed generation is assumed to consist entirely of distributed/onsite PV.
- “Gas Eskom” and the “Gas IPP Programme” comprise:
  - Existing diesel OCGTs.
  - 6 GW gas as CCGTs (minimum 50% annual utilisation).
  - Additional gas capacity as OCGTs or CCGTs, chosen through optimisation.

Electricity supply – "Light" version of Draft IRP 2024 model implementation

- The "light" version of draft IRP 2024 was modelled to reflect lower electricity demand, and the investment plan has been scaled down until 2035; thereafter, least-cost optimization applies.
- Implemented as two thirds (67%) of the IRP build for new capacity (model can add more if required).
- Distributed generation: 600 MW per year (scaled back from 900 MW per year).
- Gas capacity assumptions:
  - 4 GW CCGT with at least 50% annual utilization to 2035.
  - Remaining gas capacity (OCGT vs CCGT) determined through optimization.

	Coal	Gas - IPP Programme	Gas - Eskom	Nuclear	Hydro	Pumped Storage	CSP	Solar PV	Wind	Hybrid IPP Programme	Distributed Generation	BESS - IPP	BESS - Eskom	Other private projects (inc. Diesel, Bioenergy, etc.)
2027								1 924	1 898		600		100	221
2028								-	513		600	410		
2029			2 000					16	507		600	1 743		
2030		2 000						533	1 333		600	133		
2031								667	1 667		600	133		
2032		833						800	1 733		600	133		
2033		833						933	1 733		600	133		
2034		833						1 067	2 000		600	133		
2035		667						1 333	2 000		500	133		

Electricity supply / industrial policy – South African Renewable Energy Masterplan (SAREM) model implementation

The SAREM is quantified in two ways in the model:

1. A minimum annual threshold for investment in wind and solar PV (utility and distributed) is set from 2027 until 2040:
   - 2027 to 2029: 3 GW minimum of wind and PV – 1 GW minimum wind, 1 GW minimum PV, and the remaining 1 GW is allocated by the model between these two technologies;
   - 2030-2040: 5 GW minimum of wind and PV - 1.5 GW minimum wind, 1.5 GW minimum PV, and the remaining 2 GW is allocated by the model between these two technologies;
   - No minimum investment after 2040.
2. A moderate cost increase for wind and PV components has been included, to account for cost premia arising from local manufacture: 0.6% aggregate increase on all components by 2030, ramping up to 1.2% increase by 2050, assuming an increasing share of the value chain is localised.

Synthetic fuels - Sasol “roadmap” model implementation

The Sasol “roadmap” to meet a GHG reduction target will, if implemented, have a significant impact on South Africa’s GHG emissions, in 2030 and afterwards. The target has been implemented for Secunda only (this is Sasol’s key emissions source).

Key targets and implementation mechanisms as presented

- Target: –30% Scope 1+2 emissions by 2030 vs 2017 baseline (modelled GHG emissions in 2017 (calendar year), covering combustion and process / fugitive emissions from Secunda only).
- Mechanisms: ~2 GW renewable PPAs, efficiency gains, declining gas, selective carbon credits; capex refocused (R4–7 bn for operations, R2–4 bn for RE).

Implementation in model

- Roadmap interventions (e.g. renewable energy integration, efficiency gains) are modelled as time-series parameter shifts through 2030 to increase efficiency and reduce onsite coal- and gas-fired generation, assumed to be replaced by contracted renewable energy (wheeled over the Eskom grid)
- Structural decarbonisation options are available post-2030

Scenarios Notes

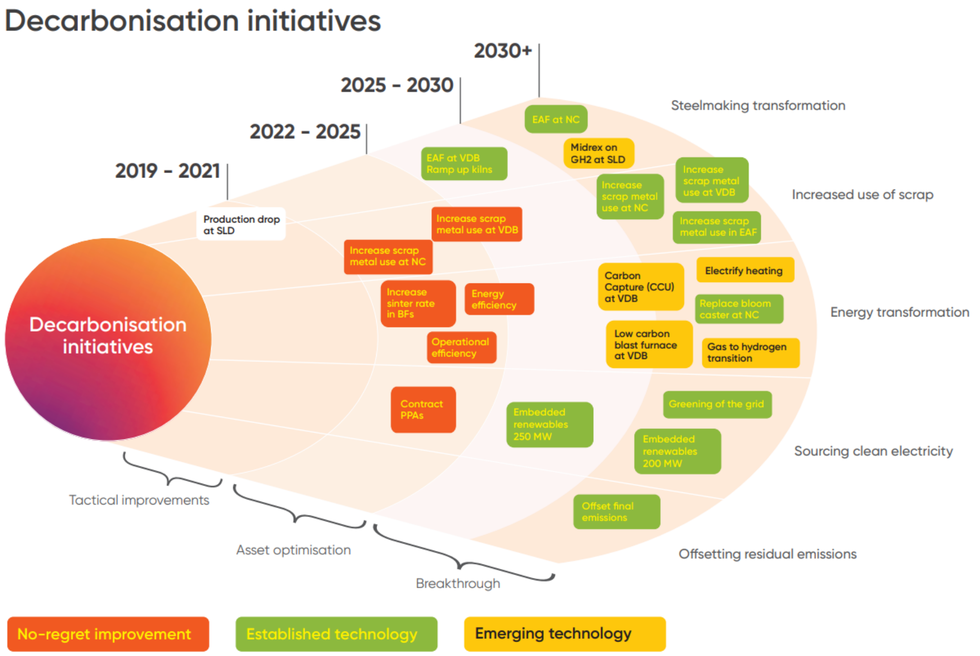
- Scenarios either include or exclude 2030 roadmap measures; as below, the “with existing measures” INCLUDES implementation of the roadmap.
- Roadmap-aligned runs: production capped till 2030.
- CTL unit retirement: endogenous (least-cost) or fixed (policy-driven).

Iron and Steel – AMSA decarbonization roadmap model implementation

The roadmap includes operational efficiencies, increased use of scrap, contracting renewable electricity supply, and building one (potentially two) large electric arc furnaces (EAFs), with hydrogen technologies potentially deployed later on in the 2030s.

Modelling the plan in SATIM

- efficiency and optimisation measures applied at operations
- Construction of EAF ~1.7Mt pa at Vanderbijl Park by 2029. Fed by Coal-DRI.
- Renewable power use is accounted for under power sector committed build plan to 2027
- Hydrogen as input to Saldanha, or new DRI kilns are not forced but left to be optimised by model



Legend

BFs	Blast furnaces
EAF	Electric arc furnace
NC	Newcastle Works
PPAs	Power purchase agreements
SLD	Saldanha Works
VDB	Vanderbijlpark Works
DRI	Direct reduced iron

Industry energy efficiency measures model implementation

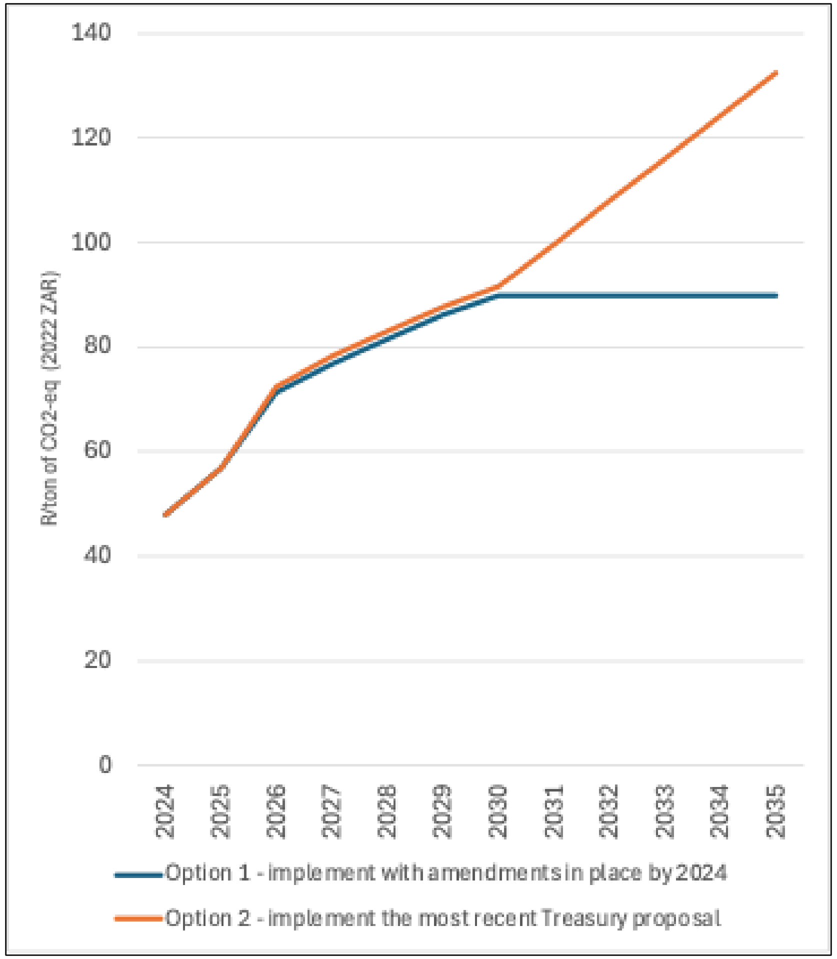
Energy efficiency in industry is based on a collection of sector and end-use measures, derived from limited available national data and international literature, using a bottom-up approach (including the draft SETs analysis).

End use	Target	Comment
Lighting	All LED by 2030 with minimum 105 lm/W requirement	Baseline assumption ~10% are still Fluorescents in 2030. Based on General Service Lamps min energy efficiency.
Motors	Faster phase out of IE0,1,2 motors, faster phase in of IE3 and above from 2030. National average motor efficiency rises from baseline estimate for 2030 of 92.9% to 93.7%, and from 93.7% to 94.6% for 2040.	A faster phase out of existing stock of motors. Based on proposed MEPs strategy. Affects other systems
Cooling	5% EE gain by 2030, 13% by 2040	System improvements plus motor EE gain.
Compressed air	CA systems improve from 5% to 5.25% by 2030, and from 5.1% to 5.6% by 2040	System wide improvements for CA. Includes Motors efficiency gain
Pumping	Assume same efficiency gain as motors EE measure	
Fans	Assume same efficiency gain as motors EE measure	
HVAC	Assume same efficiency gain as motors EE measure	
Other motive	Assume same efficiency gain as motors EE measure	
Boilers and steam	Fuel boiler + steam systems: 6% by 2030, 20% by 2040. Electric boiler + steam systems: 2% by 2030, and 7% by 2040	Based on assumptions about uptake of various boiler systems efficiency measures like installing economisers, burner upgrades, insulation, and others

Carbon tax model implementation

Two options for the carbon price:

1. **Option 1**: Carbon tax regime stays as it is in 2024, i.e. headline rate increases as specified in the 2022 Taxation Laws Amendment Act, to 2030, remains at the 2030 level thereafter; allowances remain the same as in 2024, electricity sector only pays the environmental levy.
2. **Option 2:** Carbon tax is revised as per the National Treasury's discussion document and most recent Budget Review: headline rate increases as specified in the 2022 Taxation Laws Amendment Act, remains at 2030 level thereafter; basic allowance declines by 2.5% per year after 2030; trade exposure allowance remains the same; performance allowance stays at 5%; carbon budget allowance drops to zero from 2026; electricity sector revenue "neutrality" to 2030, full tax regime thereafter; carbon offset allowance – 15% for combustion, 10% for process emissions; allowance for process/fugitive emissions drops to zero from 2036.



Weighted average effective carbon tax rate in ZAR 2022

Transport – mode shifting model implementation (extrapolated from the GTS)

1) Freight transport mode shift options

	No modal shift	With mode shifting
Split between Urban Rail and HCV1 (light commercial vehicle) share	Current split for urban freight between rail and road maintained throughout modelling horizon	Modest growth in urban rail relative to light commercial vehicles between 2025 and 2050
Split between Rail and Road Corridor freight transport	Rail corridor share shifts from 13% in 2017 to 8% in 2024, then recovers to 11% by 2030 and stays constant thereafter	Rail corridor share follows same trajectory as 'No modal shift' to 2024, then grows 8% p.a. from 2025 – 2050, offsetting growth in road transport

2) Passenger transport modal shift options

	No modal shift	With mode shifting
Annual average private vehicle mileage	Constant throughout modelling horizon	Reduces to 95% of 'no modal shift' level by 2050
Average speeds of private vehicles groups	Private vehicle average speed reduces 1% per annum from 2025 due to congestion	Private vehicle average speed reduces 0.5% per annum from 2025 (reduced congestion)
Bus Rapid Transit usage	BRT use grows 2.5% p.a. from 2025	BRT use grows 6% p.a. from 2025
Shifts in public transport split between rail and road	Share of public transport by rail (passenger-kilometres) recovers to pre-Covid levels by 2030 (~10.7 billion pkm), remains constant thereafter	Same as 'no modal shift' to 2030; then rail share grows 3% p.a. thereafter up to 2050

Transport – electrification model implementation (extrapolated from the GTS)

Assumed capital cost (CAPEX) parity point of EVs relative to ICEs:

	Slow uptake	Medium uptake	Fast uptake
Description	Conservative	"Medium" optimism, between slow and rapid	Optimistic
Source	Current market + global trends (IEA, NREL)	Mid point parity between slow and rapid	Current market + accelerated trends

	Year of parity	Year of parity	Year of parity
Cars	2035	2030	2030
SUVs	2035	2030	2030
Motorcycles	2035	2030	2030
MBTs	2040	2035	2030
Buses	2045	2040	2030
BRTs	2045	2040	2030
Light commercial vehicles	2035	2030	2030
Heavy commercial vehicles	2045	2040	2030

Mitigation scenarios

Developing policy scenarios to explore GHG emissions outcomes in 2035

A set of core scenarios were developed to explore the impact of policies, measures and plans on GHG emissions and other policy goals in 2035. On the basis of initial results (which confirmed previous results), the most significant determinant of GHG emissions outcomes in 2035 is what happens in the electricity sector – measures in other sectors have a much less significant impact.

The basis for the scenario analysis is the “with existing measures” (WEM) scenario, which assumes no further development and implementation of mitigation or mitigation-relevant policies and measures, but DOES incorporate existing plans. The GHG emissions pathway to 2035 is modelled on a “least cost” basis (i.e. the model chooses the pathway with the lowest total discounted system cost). This scenario is then used to explore the impact of the policies, measures and plans identified above, individually.

Following this, a set of policy scenarios are used to explore the impact of combinations of electricity sector policies and plans and those in other sectors – “current policies and plans” (CPP). Two additional scenarios are added to assess the impact of a delayed transition (a ’high carbon’ scenario), and an accelerated transition (a ‘low carbon’ scenario).

In addition to these scenarios, a number of additional variations were modelled using more stringent long-term GHG emissions constraints, to assess what additional measures would be needed to achieve a more ambitious GHG target in 2035. These are modelled for the WEM scenario and for the CPP scenario with SAREM investment minimums, and the CPP scenario with other policies and plans, but no specific policies/plans in the electricity sector.

A detailed account of the content of each scenario is provided in the tables below.

A note on what has and has not been included, sensitivity analyses, “least cost” pathways and long-term GHG emissions constraints

- “Least cost” pathways are optimized by SATIM using total discounted systems cost over the modeling period as its objective function, subject to constraints. This optimization process excludes sectors not modelled in SATIM, i.e. non-energy agriculture and land use and waste, and also has no impact on parameters in the model which are specified exogenously – for instance the modal shares in the transport sector. The term “least cost” does NOT imply that these pathways can be implemented without considerable effort;
- The **WEM scenario** INCLUDES the Sasol and AMSA “roadmaps”, as these are currently in place and presumably being implemented. The impact of these is evident when comparing WEM with the high carbon scenario;
- All scenarios have been modelled with **all three growth rates**;
- In addition to growth rates, **several sensitivity analyses** have been modelled using the WEM scenario for different crude oil price levels, with and without the application of the minimum emissions standards and with high and low coal plant energy availability factors (EAFs);
- Further aggregate **GHG emissions constraints** (to map the impacts of more ambitious mitigation targets) are applied to the whole modelling period (2021-50) to identify optimal mitigation pathways with more ambitious outcomes in 2035; this results in additional mitigation in sectors of the model which are able to respond to this constraint, which includes electricity supply, liquid fuels supply, and demand-side technologies in the industry, transport, commerce and residential sectors; exogenously specified characteristics of the energy system (for instance the modal splits in the transport sector) will not respond to more stringent GHG constraints; sectors modelled outside of SATIM will also not respond to GHG emissions constraints; hence constraints have been modelled with and without key policies and plans.
- In total we have modelled 7 scenarios and 92 variants, assessing the impact of growth rates, policies and plans, GHG budgets, and sensitivities to key parameters.

Scenario	Description	Electricity - coal retirement	Electricity - new build	Liquid fuels supply	Iron and Steel	Transport	Energy efficiency measures	Carbon tax
With Existing Measures (WEM) (BASE in figures)	Policies and plans in place by 2024; no additional policies, plans, measures.	Draft IRP 2024 retirement schedule sets the maximum retirement year for each coal plant; plants will be retired if least-cost.	Minimum level of committed build to 2027; soft constraint to 2031; least-cost pathway after this.	Synthetic fuels - Implementation of Sasol "roadmap"; Secunda retires in the model by the late 2040s. The model will be able to retire Secunda from 1 January 2031 on if part of a least-cost pathway, given constraints (for instance, a stringent GHG emissions budget). Crude refineries - Astron and Natref are assumed to continue to produce liquid fuels at current volumes until end 2038, thereafter the model will be able to retire them if least-cost.	least-cost	No modal shift, medium EV uptake	No additional measures	Current carbon tax
Current Plans and Policies (CPP) (CPP4 in figures)	All policies and plans currently being contemplate are implemented, except the IRP and SAREM	Draft IRP 2024 retirement schedule sets the maximum retirement year for each coal plant; plants will be retired if least-cost.	Minimum level of committed build to 2027; soft constraint to 2031; least-cost pathway after this.	Synthetic fuels - Implementation of Sasol "roadmap"; Secunda retires in the model by the late 2040s. The model will be able to retire Secunda from 1 January 2038 on if part of a least-cost pathway, given constraints (for instance, a stringent GHG emissions budget). Crude refineries - Astron and Natref are assumed to continue to produce liquid fuels at current volumes until end 2038, thereafter the model will be able to retire them if least-cost.	AMSA roadmap followed: predominantly the deployment of a large new Arc Furnace in 2029	Modal shift, medium EV uptake	Additional measures applied	Proposed phase 2 carbon tax
Current Plans and Policies with draft IRP 2024 (CPP-IRP) (CPP1 in figures)	All policies and plans currently being contemplate are implemented, and implementation of the draft IRP 2024.	Draft IRP 2024 retirement schedule is fixed for the modelling period (to 2055).	New build identical to draft IRP 2024 until end 2042; thereafter least cost.	Synthetic fuels - Implementation of Sasol "roadmap"; Secunda retires in the model by the late 2040s (no earlier retirement). Crude refineries - Astron and Natref are assumed to continue to produce liquid fuels at current volumes until end 203,l thereafter the model will be able to retire them if least-cost.	AMSA roadmap	Modal shift, medium EV uptake	Additional measures applied	Proposed phase 2 carbon tax
Current Plans and Policies with draft IRP 2024 light (CPP-IRP light) (CPP2 in figures)	All policies and plans currently being contemplate are implemented, and implementation of 2/3rds of the draft 2024 IRP plan.	Draft IRP 2024 retirement schedule sets the maximum retirement year for each coal plant; plants will be retired if least-cost.	New build is 2/3rds of the capacity specified in draft IRP 2024 until 2035; thereafter least cost.	Synthetic fuels - Implementation of Sasol "roadmap"; Secunda retires in the model by the late 2040s (no earlier retirement). Crude refineries - Astron and Natref are assumed to continue to produce liquid fuels at current volumes until end 2038, thereafter the model will be able to retire them if least-cost.	AMSA roadmap	Modal shift, medium EV uptake	Additional measures applied	Proposed phase 2 carbon tax

Scenario	Description	Electricity - coal fleet retirement schedule	Electricity - new build	Liquid fuels supply	Iron and Steel	Transport	Energy efficiency measures	Carbon tax
Current Plans and Policies with SAREM (CPP-SAREM) (CPP3 in figures)	All policies and plans currently being contemplate are implemented, and implementation of SAREM.	Draft IRP 2024 retirement schedule sets the maximum retirement year for each coal plant; plants will be retired if least-cost.	Annual investment in wind and PV capacity (utility and distributed) consistent with SAREM thresholds for localisation: 2027-2029 - 3 GW in total of wind and solar; 2030-2040 - 5 GW in total of wind and solar; until 2040. Moderate cost increase: 0.6% aggregate all components by 2030, ramping up to 1.2% by 2050 (increasing localisation).	Synthetic fuels - Implementation of Sasol "roadmap"; Secunda retires in the model by the late 2040s (no earlier retirement). Crude refineries - Astron and Natref are assumed to continue to produce liquid fuels at current volumes until end 2038, thereafter the model will be able to retire them if least-cost.	AMSA roadmap	Modal shift, medium EV uptake	Additional measures applied	Proposed phase 2 carbon tax
High Carbon (HCARB in figures)	Delayed transition - longer life for the coal fleet, high utilization of coal plants (min 50%), refurbished refineries and minimum level n gas utilization of 120PJ.	Draft IRP 2024 retirement schedule is fixed for the modelling period (to 2055), WITH the ADDITIONAL life-extensions proposed as an option in the IRP.	Minimum level of committed build to 2027; soft constraint to 2031; least-cost pathway after this.	Synthetic fuels - Sasol "roadmap" NOT implemented; Secunda retires late-2040s; Crude refineries - Astron and Natref are assumed to continue to produce liquid fuels at current volumes until end 2038, thereafter the model will be able to retire them if least-cost. Durban refineries are refurbished and begin operations again in 2030.	Roadmap not followed. Imports of steel decline, and drop to ~750kt by 2030, and 600kt pa in 2035. Secondary steel production is reduced to just 15% of national production.	No modal shift, slow EV uptake	No additional measures	Current carbon tax
Low Carbon (LCARB in figures)	All policies and plans currently being contemplate are implemented, minimum RE investment, accellerated EV uptake, coal plants and refineries can be retired from 2027 on.	Draft IRP 2024 retirement schedule sets the maximum retirement year for each coal plant; plants will be retired if least-cost.	Annual investment in wind and PV capacity (utility and distributed) consistent with SAREM thresholds for localisation: 2027-2029 - 3 GW in total of wind and solar; 2030-2040 - 5 GW in total of wind and solar; until 2040. Moderate cost increase: 0.6% aggregate all components by 2030, ramping up to 1.2% by 2050 (increasing localisation).	Synthetic fuels - Implementation of Sasol "roadmap"; Secunda retires in the model by the late 2040s. The model will be able to retire Secunda from 1 January 2027 on if part of a least-cost pathway, given constraints (for instance, a stringent GHG emissions budget). Crude refineries - Astron and Natref are assumed to continue to produce liquid fuels at current volumes until end 2038, thereafter the model will be able to retire them if least-cost	AMSA roadmap	Modal shift, fast EV uptake	Additional measures applied	Proposed phase 2 carbon tax

Results

GHG emissions pathways to 2035

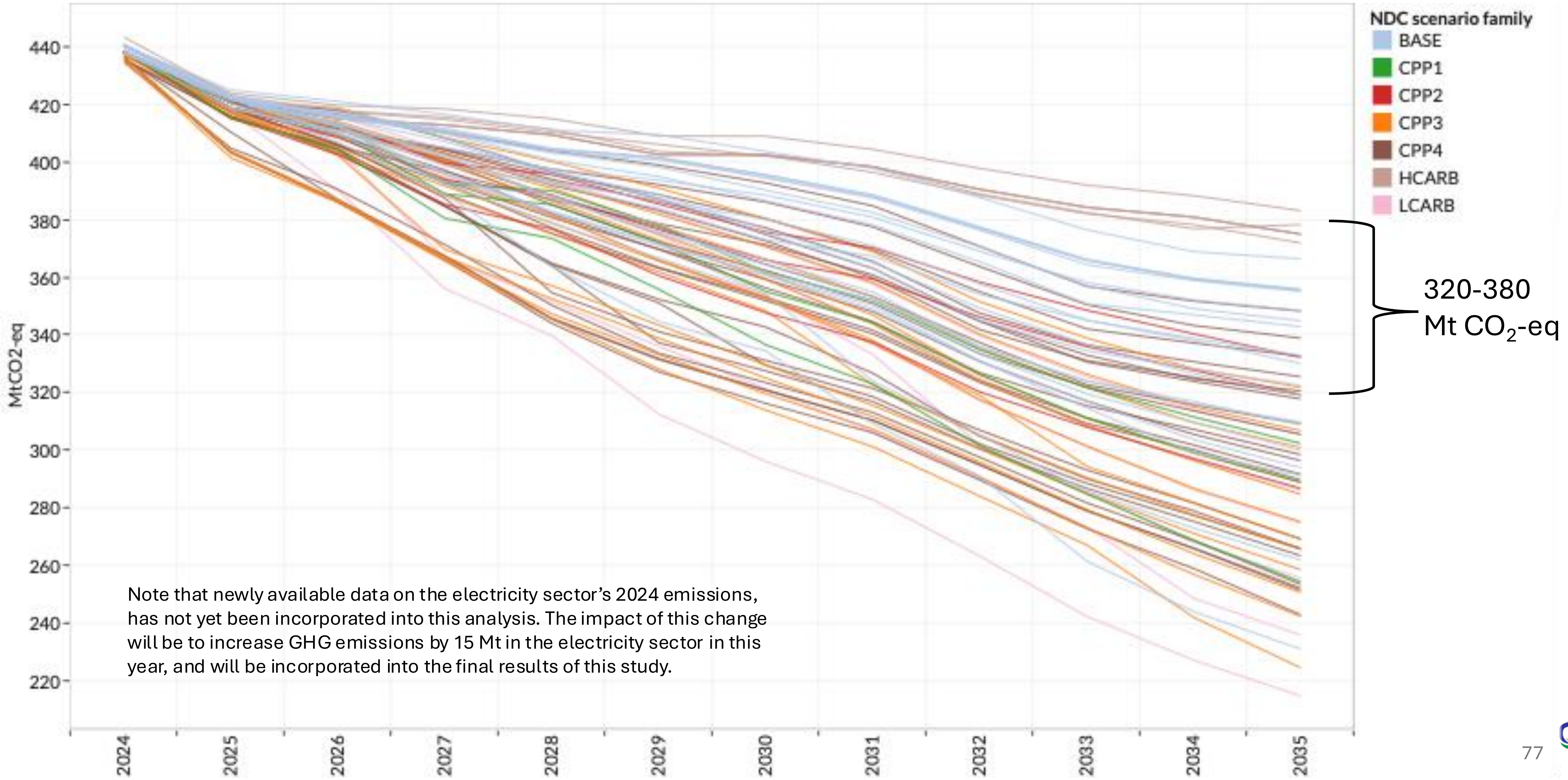
Seven core scenarios were modelled, as described above, with 92 variations in total for different economic growth rates and other sensitivities; for some core scenarios, additional GHG constraints were modelled to map more ambitious outcomes in 2035.

All modelled GHG pathways are presented in the next three slides – which cover a range of technically feasible emission outcomes ranging from 383 Mt CO_2-eq to 215 Mt CO_2-eq in 2035 (discounting many other practical constraints).

These are disaggregated into cases with and without additional GHG constraints, and thereafter by major GHG emitting sectors in the two slides which follow. Following this overview, scenario results are analysed in more detail on a sectoral level to understand the outcomes for each scenario.

The results disaggregated by emitting sector illustrates responsiveness to GHG constraints and/or associated mitigation policies. The waste and agriculture respond to changes in GDP, whereas the land sector only responds minimally, which is partly accounted for because no mitigation policies or plans were modelled for these sectors; of the sectors which do respond, the electricity sector has the widest variation; the details of each sector's response will be further elaborated below.

GHG emissions pathways for all scenarios and variants

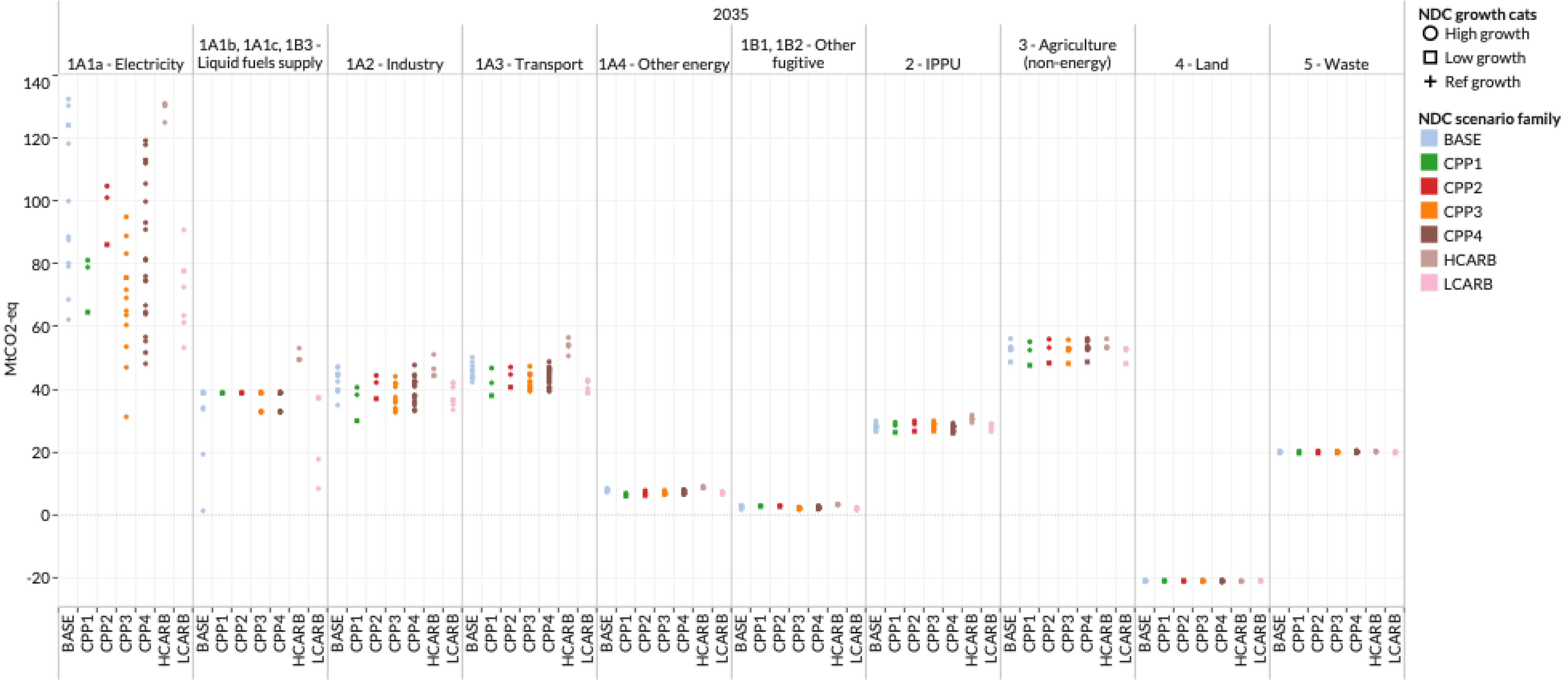


Note that newly available data on the electricity sector's 2024 emissions, has not yet been incorporated into this analysis. The impact of this change will be to increase GHG emissions by 15 Mt in the electricity sector in this year, and will be incorporated into the final results of this study.

2035 net national GHG emissions outcomes for all variants

2035 GHG emissions outcomes disaggregated by sector

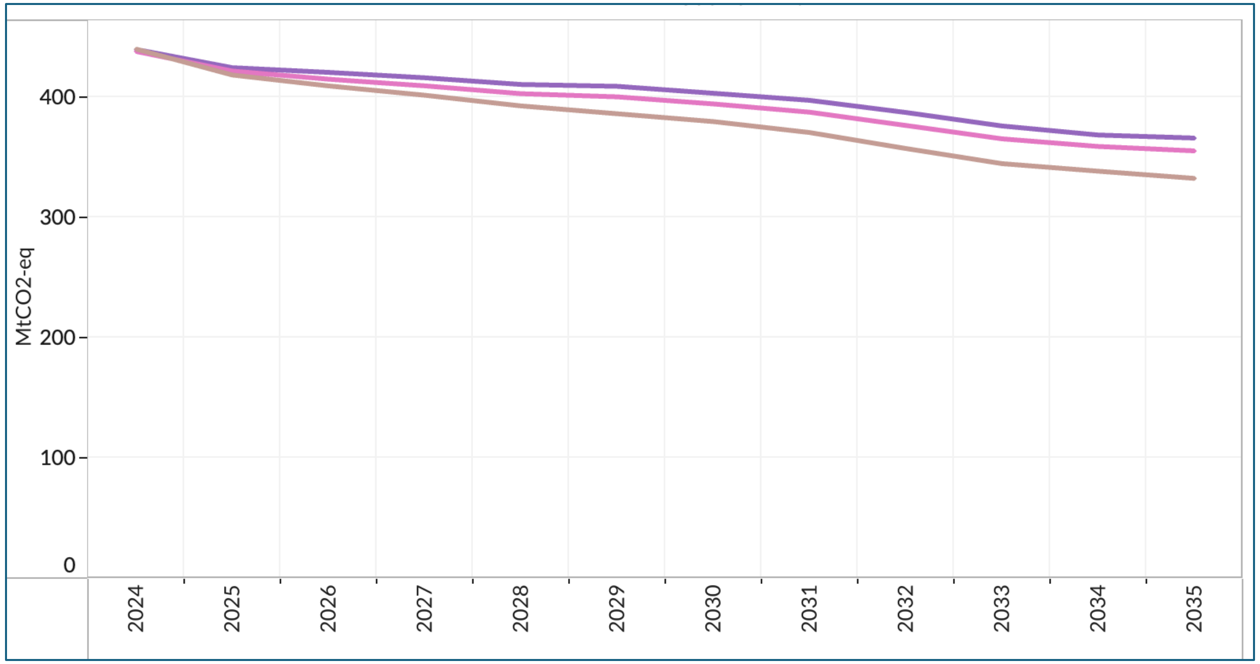
The range of outcomes in each sector highlights the determinate role of the electricity sector, with contributions from liquid fuels supply, industry and transport, and far smaller variations in the rest of the economy

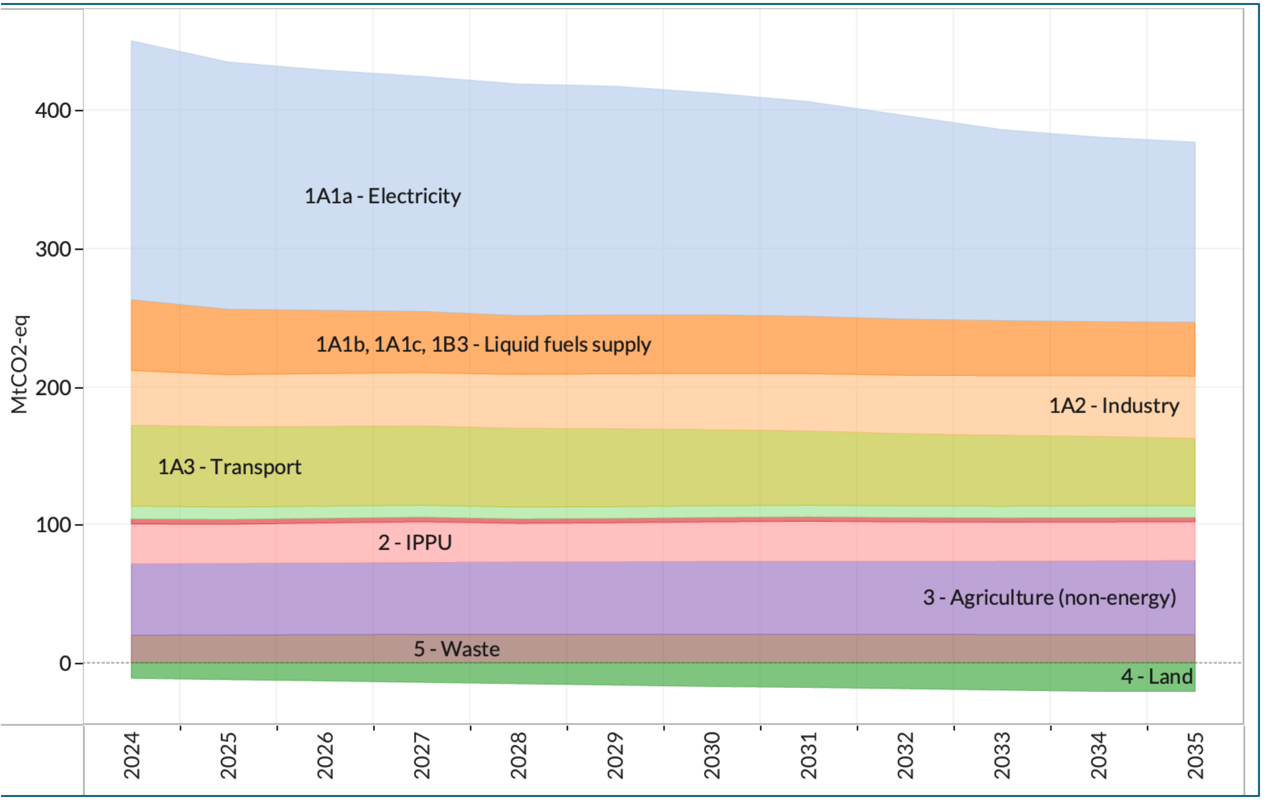


GHG emissions outcomes in 2035 for the "with existing measures" scenario

With **no additional measures** put in place from 2024, GHG emissions in 2035 range from **333-366 Mt CO2-eq** (range based on low to high growth assumptions);

Most GHG emissions still arise from energy supply/transformation/use, and most of the change from 2024 takes place in the electricity sector.

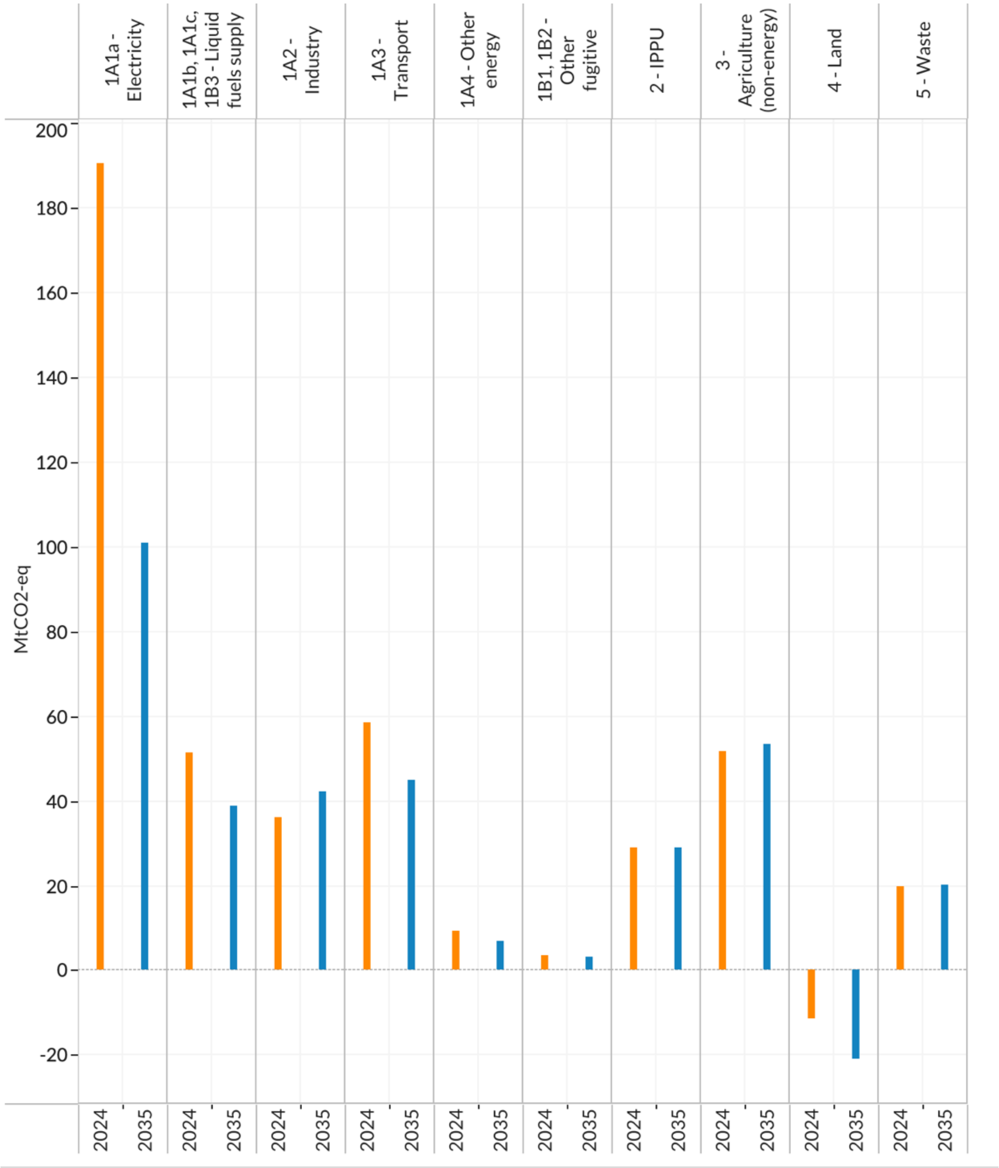




GHG emissions to 2035 for high, medium and low economic growth rates (above); and disaggregated by main GHG sources for the medium growth case (left)

Changes between 2024 and 2035 GHG emissions in the WEM scenario (medium growth rate)

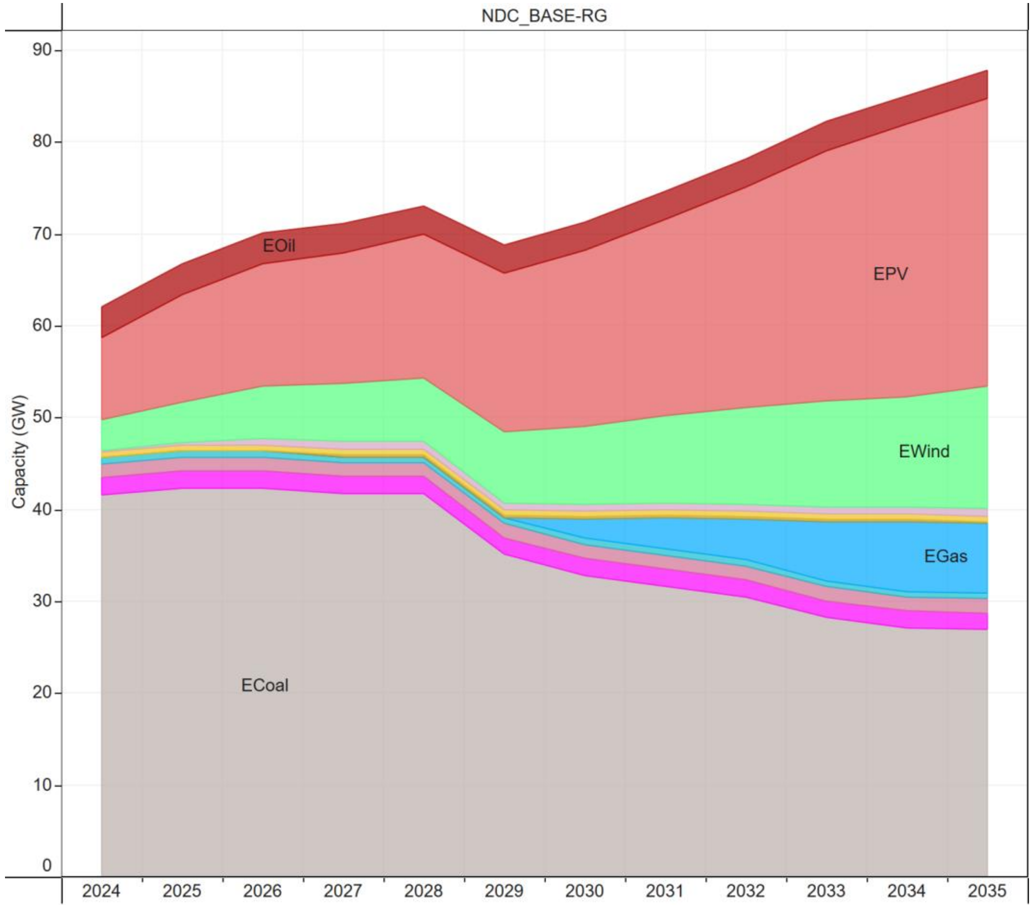
- Electricity – largest source of emissions reductions, driven by planned coal retirements and new low-/zero-emissions capacity additions.
- Liquid fuels supply – reduction reflects Sasol's CTL roadmap
- Transport – reductions due to market-driven increase in private and public EV uptake; limited increase in passenger rail
- Industry – growth in GHG emissions with the economy; no significant technology changes.
- Agriculture – emissions rise with economic growth (more livestock).
- Land – land sink projected to grow by ~10 Mt.



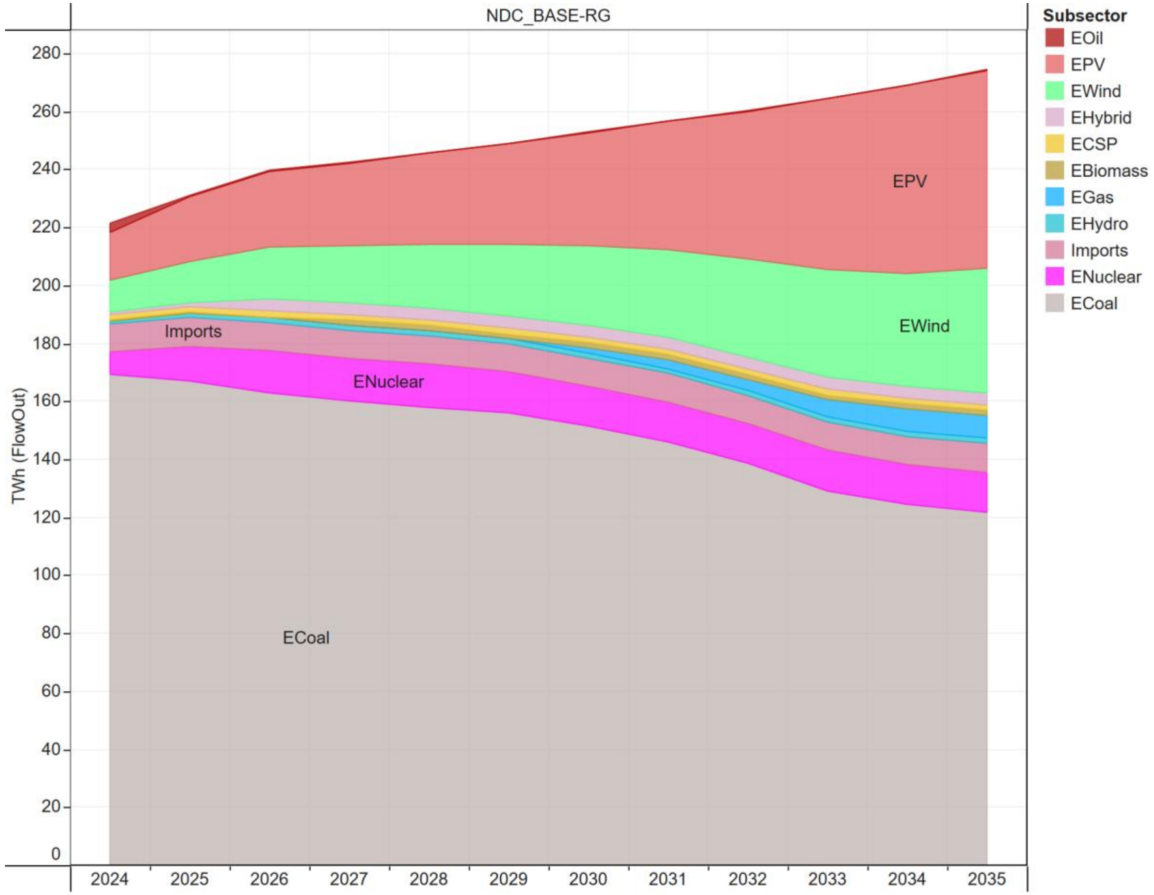
Projected change in GHG emissions (2024–2035) by major emitting sector

Electricity capacity and production in the WEM scenario

Capacity

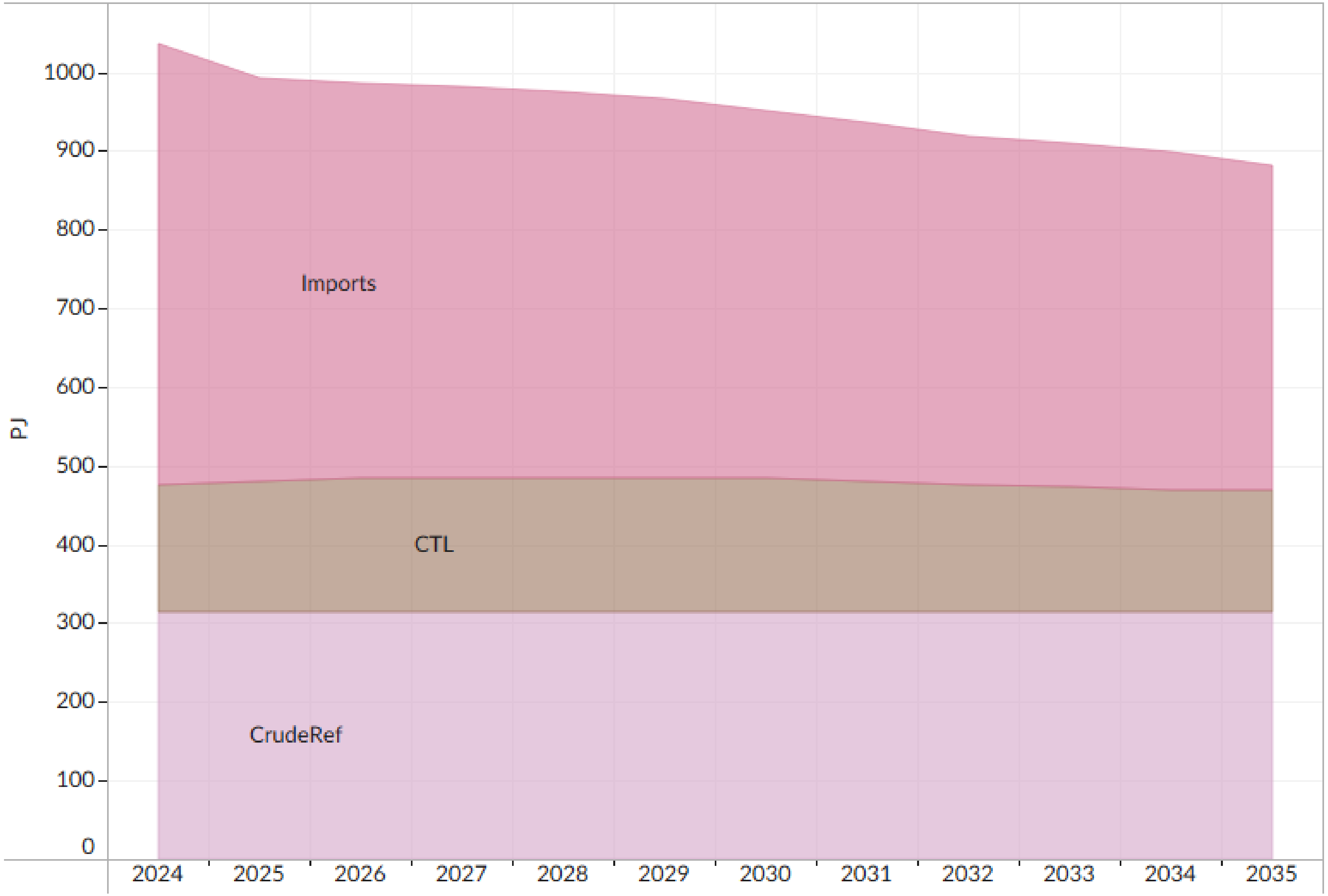


TWh sent out



Retirement of coal plants reduces total coal capacity from 42 GW in 2024 to 27 GW in 2035; the load factor of the fleet rises in 2030 from 43% in 2028 to 53% in 2031; the remaining capacity gap is filled by wind and solar PV (utility and distributed); gas capacity rises to 7.5 GW, of which 1.5 GW is CCGT and the remainder OCGT plants. New capacity is added by the model on a least-cost basis, after the addition of committed capacity in 2025-7.

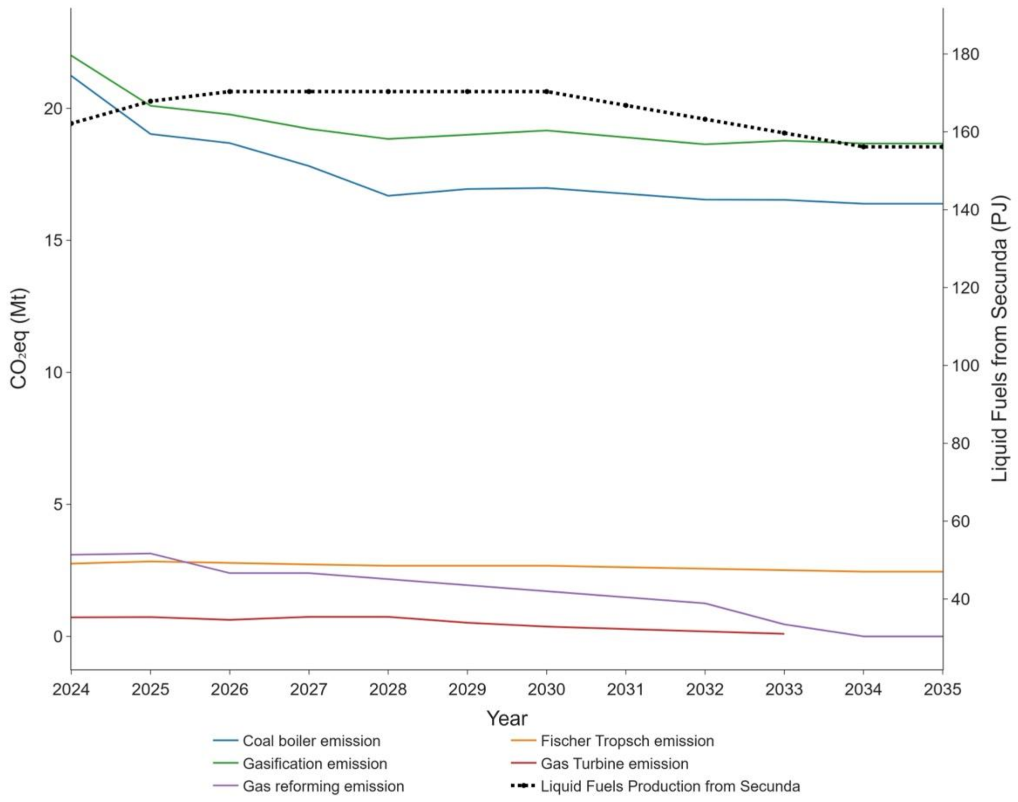
Liquid fuel supply in the WEM scenario



The figure to the left presents total liquid fuels supply in South Africa by source, with imports of refined product remaining dominant through 2035 in the wake of the shutdown of the two coastal crude refineries – crude refinery output from the Astron and NATREF refineries is assumed to be constant. Liquid fuels demand declines slowly towards 2035 as a result of a shift from ICEs to EVs.

Secunda synthetic fuels production: CO_2 Emissions and Fuel Output in WEM: impact of the roadmap

The roadmap as implemented in SATIM (downscaled from Sasol group to Secunda: 30% CO_2-eq reduction of Scope 1&2 GHG emissions from Secunda from 2017 levels) achieves roughly 25% emissions reduction relative to 2017 levels (Secunda only) by 2030 through efficiency measures and switching from onsite coal-based electricity generation to renewable electricity procurement (via the grid).

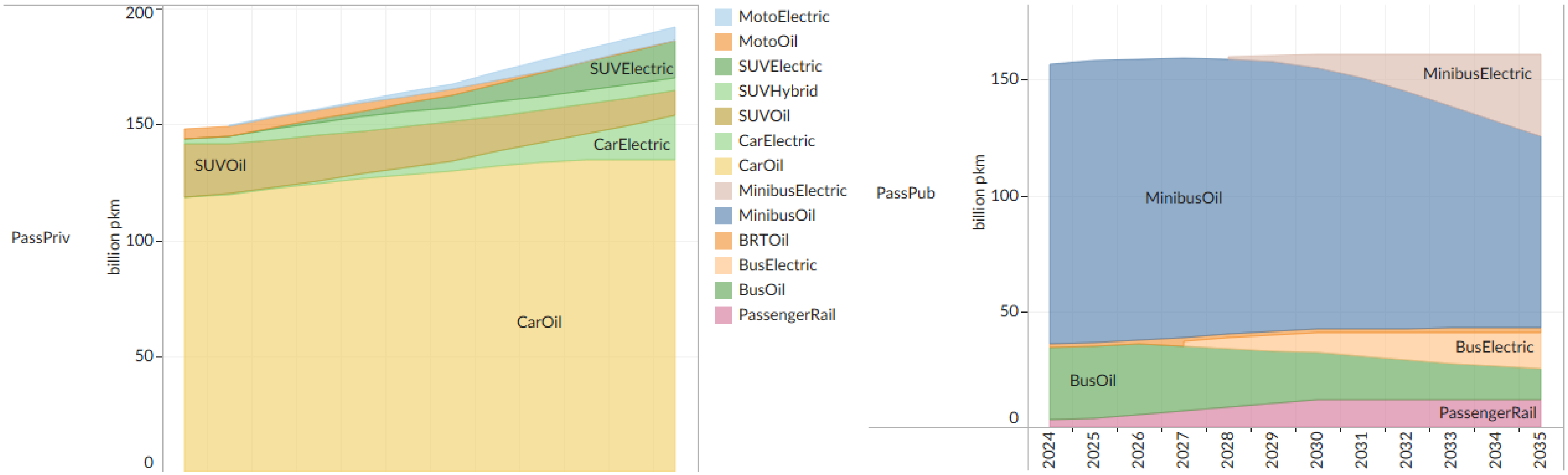


Year	Scope 1 emissions (Mt CO2-eq)	Scope 2 emissions (Mt CO2-eq)	Total emissions (Mt CO2-eq)	% Reduction compared to 2017 levels	All production from CtL including petrochemicals (PJ)	Liquid fuels production from CtL (PJ)
2024	50.02	3.25	53.27	8.9%	263.71	162.21
2025	46.04	4.46	50.50	13.6%	272.98	167.88
2026	44.46	4.29	48.75	16.6%	277.02	170.36
2027	43.10	3.66	46.77	20.0%	277.02	170.36
2028	41.31	2.26	43.58	25.5%	277.02	170.36
2029	41.28	2.77	44.06	24.7%	277.02	170.36
2030	41.11	2.78	43.89	24.9%	277.02	170.36
2031	40.25	2.82	43.07	26.3%	271.25	164.96
2032	39.39	2.85	42.24	27.8%	265.47	163.26
2033	38.57	2.97	41.54	29.0%	259.7	159.66
2034	37.72	3.04	40.76	30.3%	253.93	156.17
2035	37.72	3.04	40.76	30.3%	253.93	156.17

Passenger transport in the WEM scenario

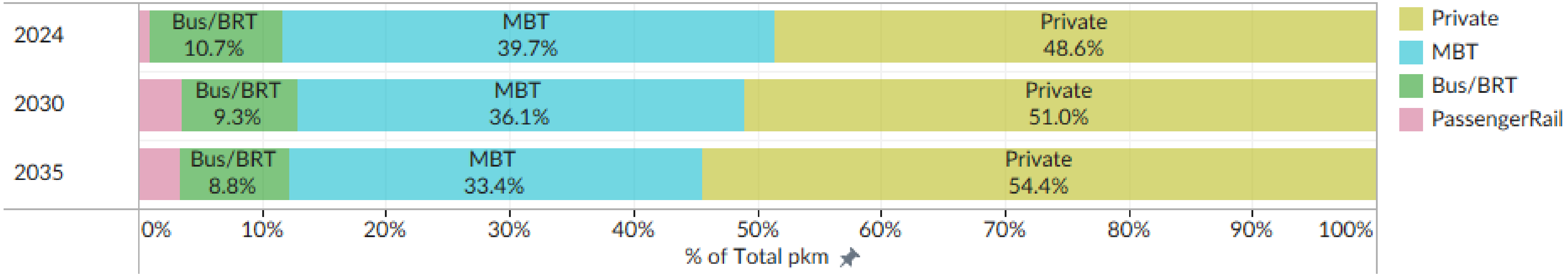
The WEM scenario shows sustained growth in EV passenger transport, with private cars dominating the provision of passenger kilometres (pkms).

In public transport the use of the internal combustion engine (ICE) declines.

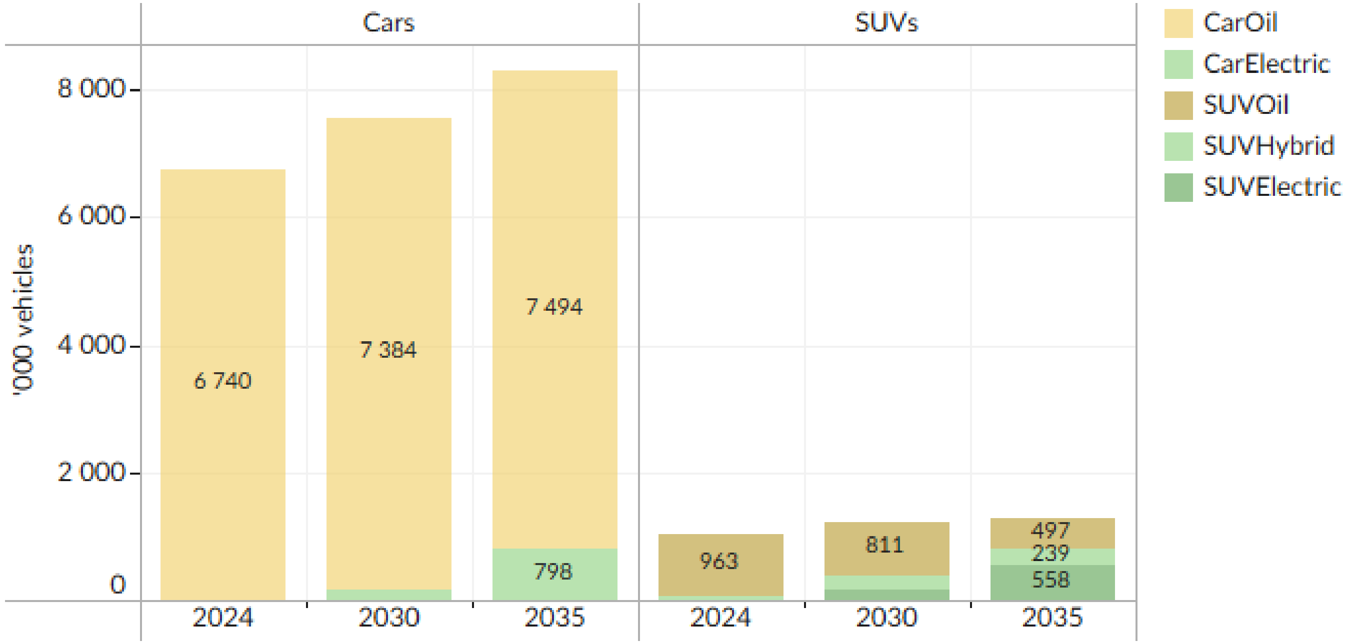


Passenger transport – WEM Scenario

Without further policy intervention, it is assumed that as car ownership rates increase, the proportion of passenger transport provided by private vehicles will slowly rise.

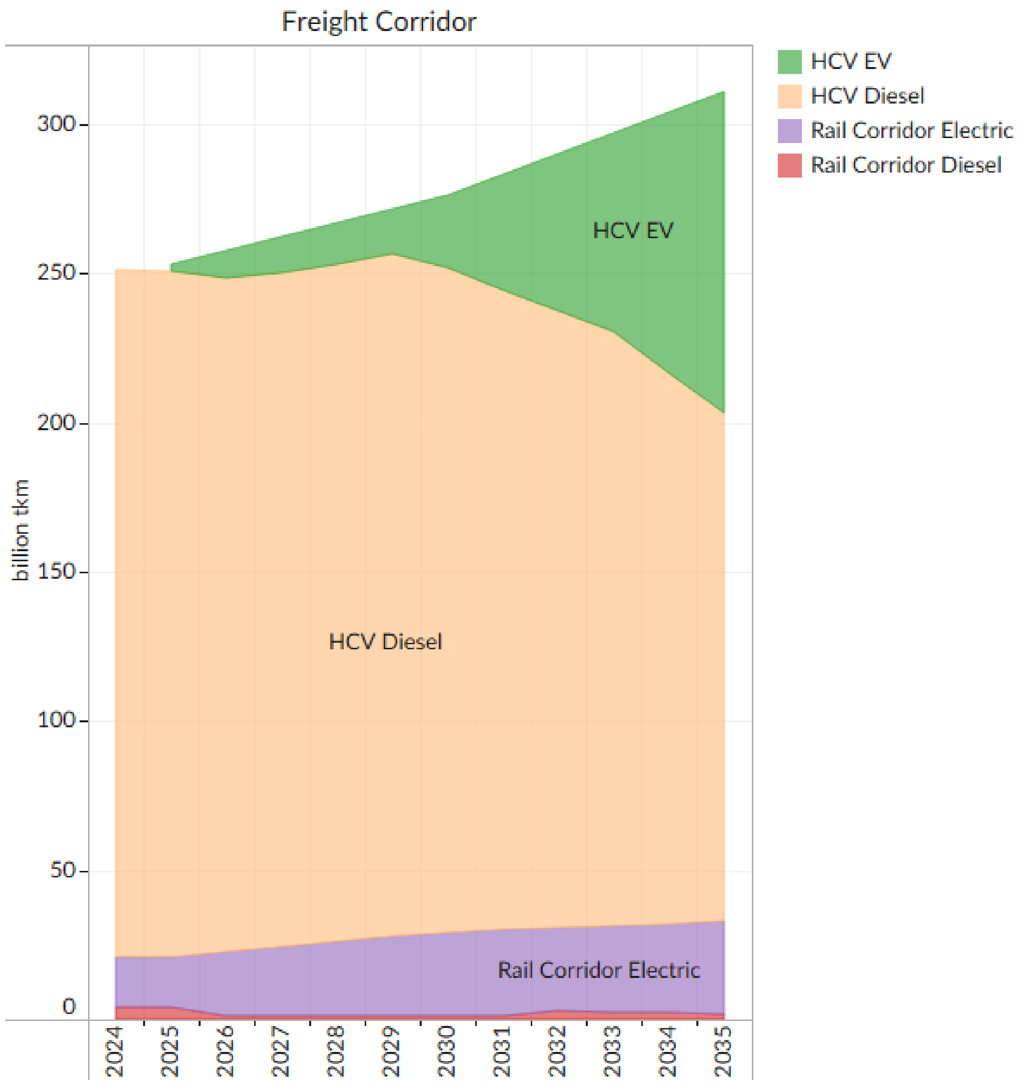


Growth in the passenger EV market is driven mainly by market forces (figure shows total fleet)

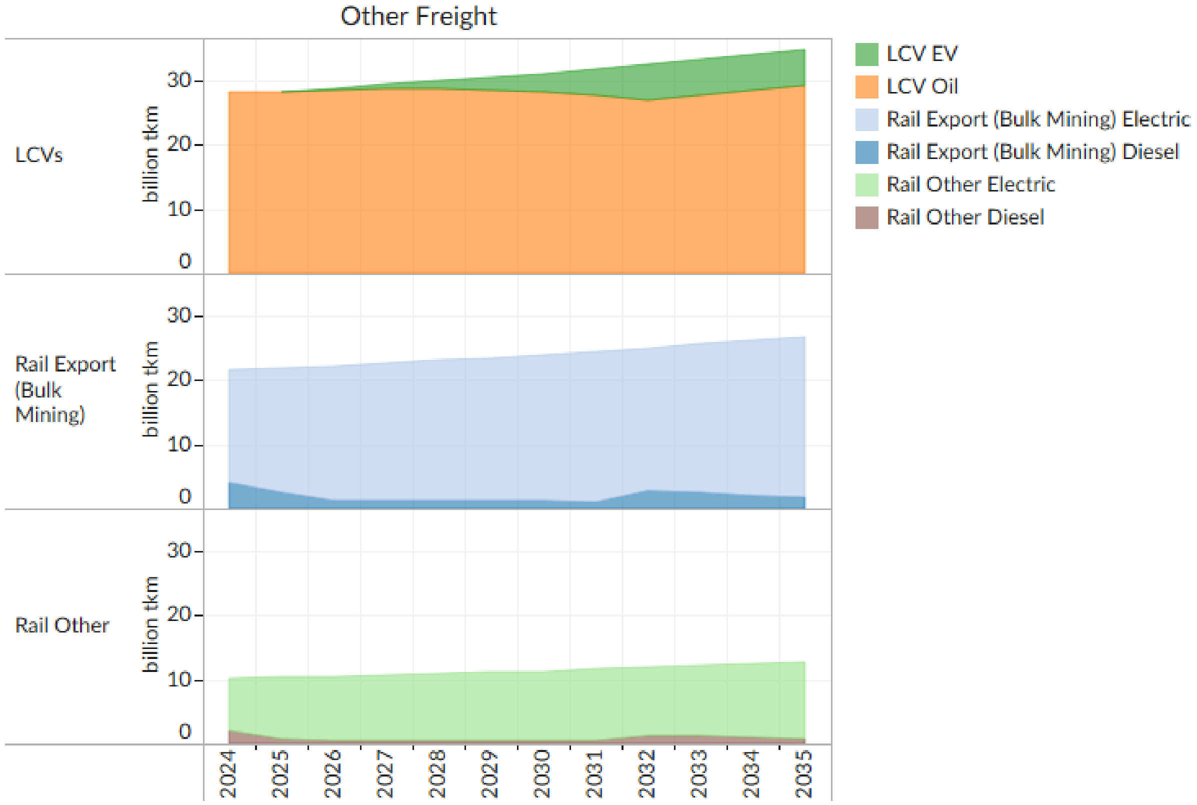


Freight Transport - WEM scenario

Freight Corridor

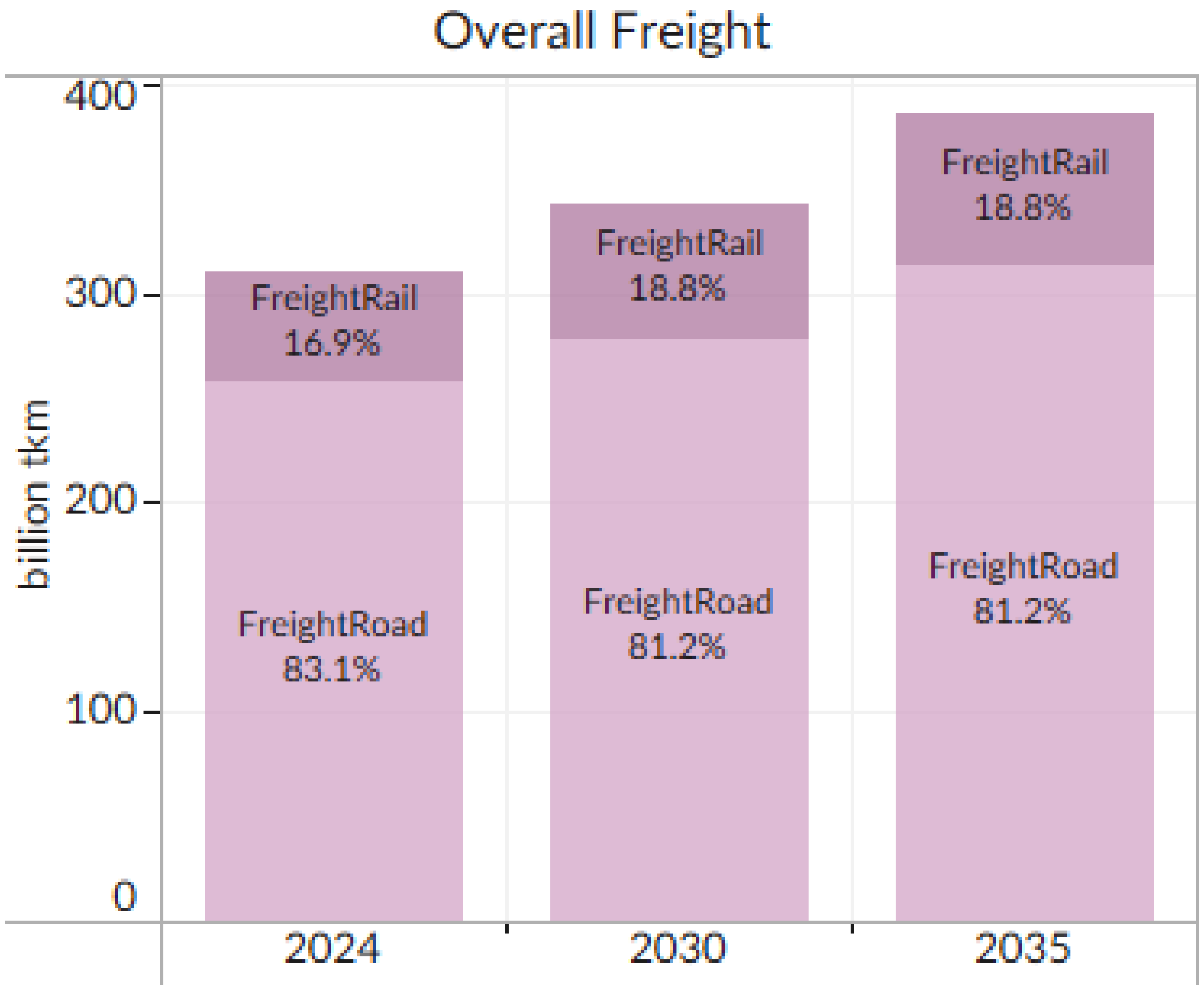


Road freight transition from ICEs to EVs begins, especially in the early 2030s, driven by assumed HCV and LCV learning rates, which lower EV costs relative to ICEs (subject to high uncertainty) .



Freight demand grows and road remains dominant – WEM scenario

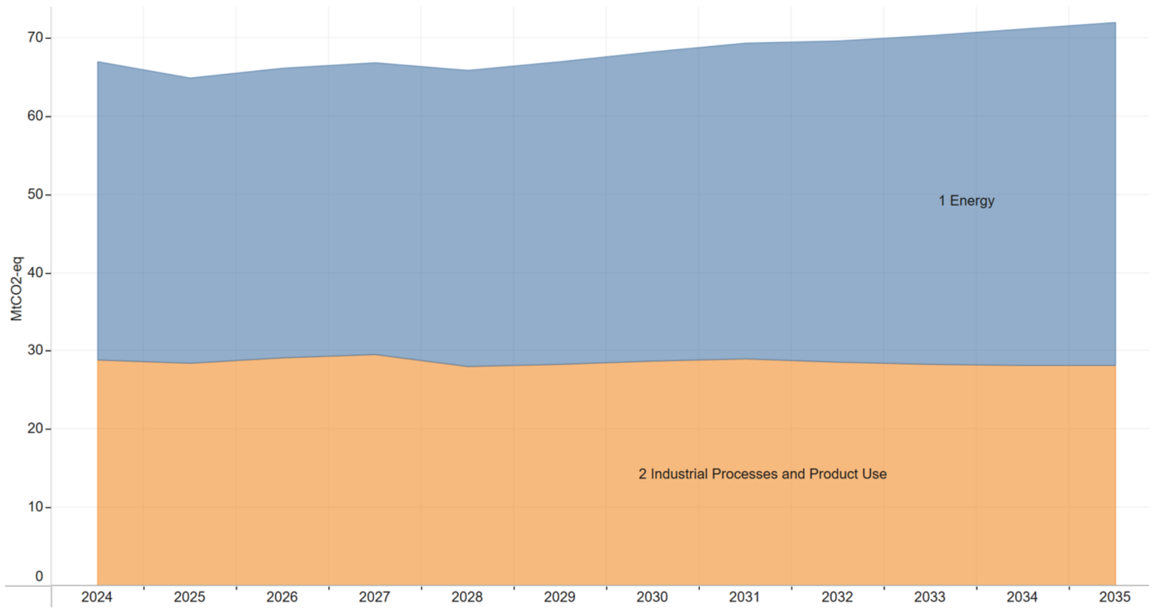
- Total freight demand grows steadily from 2024 to 2035.
- Road freight remains dominant, accounting for ~81% of tonne-kilometres.
- Rail freight increases slightly, from ~17% in 2024 to ~19% in 2030 and 2035, through assumed recovery in existing rail capacity, without extension for new capacity
- No major shift from road to rail is projected without additional policies.



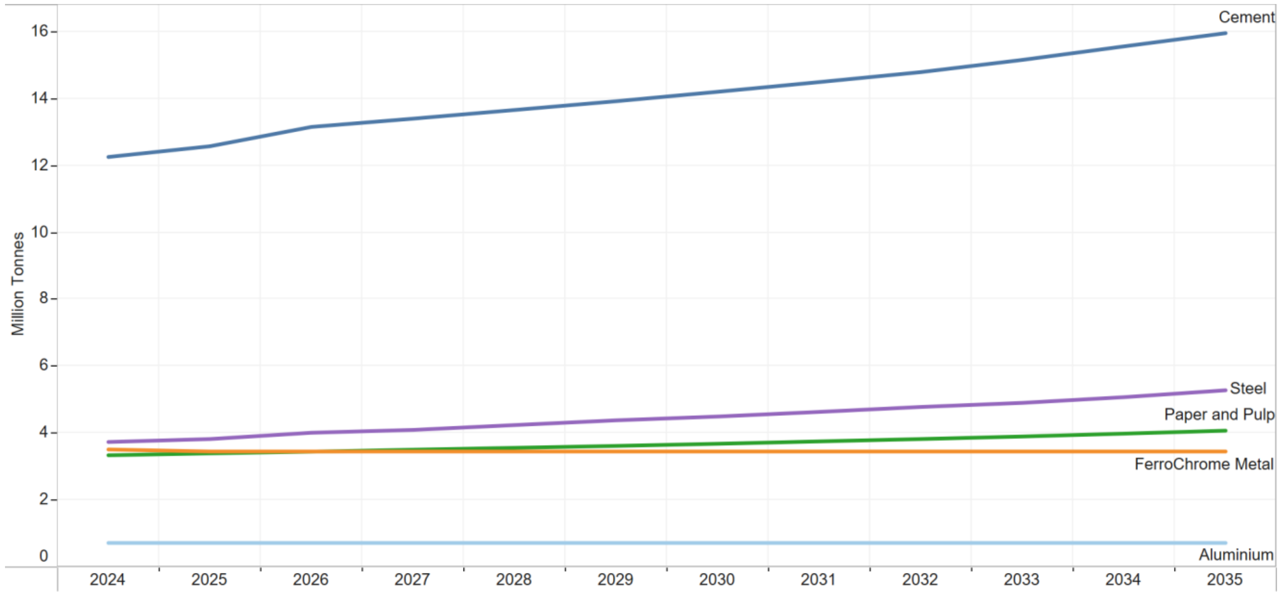
Industry in the WEM scenario

Emissions rise slightly to 2035 from increased economic activity and fuel required for general manufacturing.

Output for the metals industries grows slightly, combined with some technology shifts (e.g. arc furnaces), clinker substitution, and some biomass usage, emissions from heavy industry remains flat or declines slightly.



Emissions from all industries

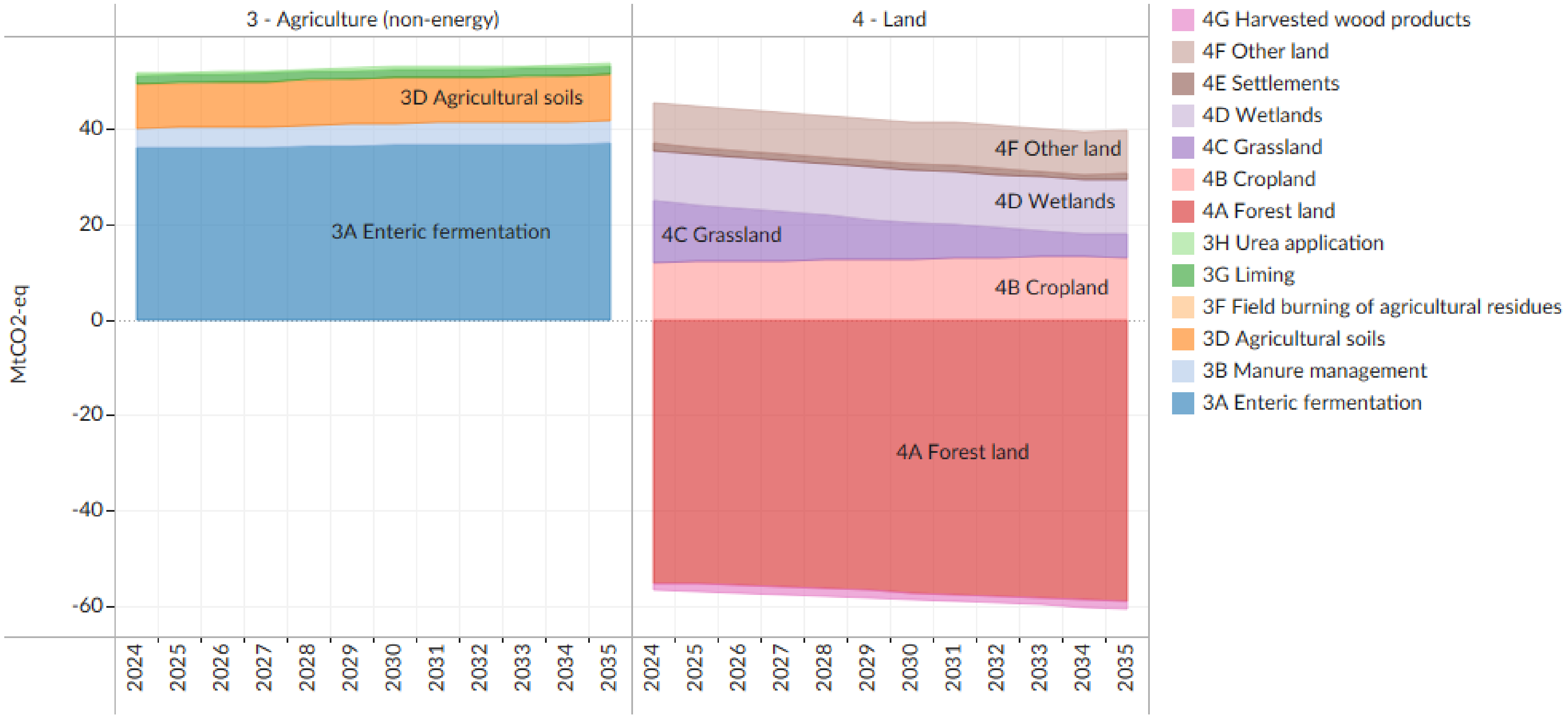


Heavy industry production

Agriculture and land sector emissions - WEM scenario

Agriculture (non-energy) emissions are dominated by enteric fermentation (livestock methane). Agricultural soils and manure management are secondary contributors, and field burning, liming, and urea application make minor contributions.

In the land sector, forest land is the major carbon sink, which increases slowly towards 2035.

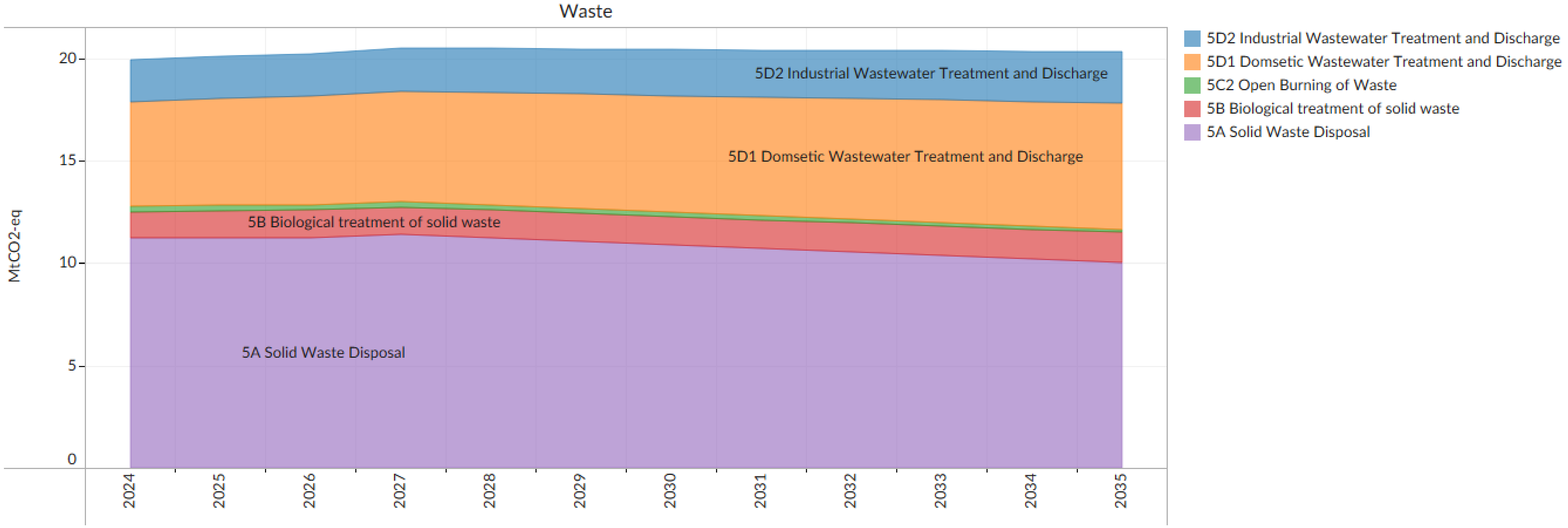


Waste

Solid waste disposal (landfills) is the dominant waste emission source, and wastewater treatment (domestic and industrial) contributes significantly.

5A: driven by waste per capita, % to solid waste disposal, composition, and industrial waste. Changes made to industrial ash calculations.

5D2: driven by industrial sectors, changes made to pulp and paper calculations.



Impact of individual policies and plans

These were modelled individually for comparison against the WEM scenario:

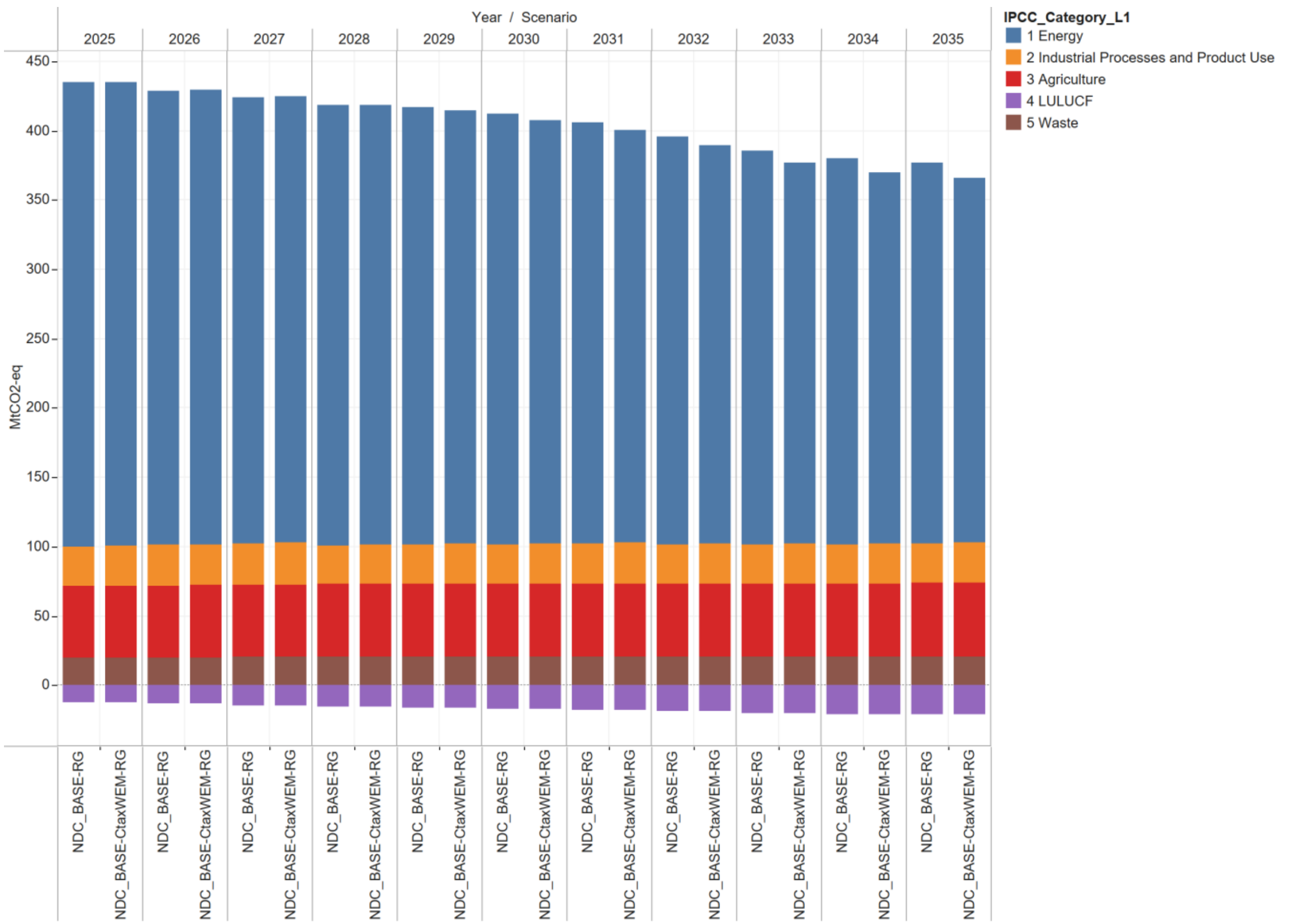
	1A1a - Electricity	1A1b, 1A1c, 1B3 - Liquid fuels supply	1A2 and 2 - Industry (including IPPU)	1A3 - Transport	Other	TOTAL
WEM	130	39	73	49	65	356
Freight modal shift	130	39	74	48	65	356
Passenger modal shift	130	39	74	48	65	356
EV fast uptake	131	39	74	47	65	355
Energy efficiency measures	125	39	72	48	64	349
Carbon tax	120	39	74	47	64	345
draft IRP 2024 "light"	108	39	73	46	64	330
SAREM	98	39	73	46	64	319
draft IRP 2024	85	39	69	45	62	300

GHG emissions reductions resulting from the implementation of the Sasol and AMSA roadmaps will be discussed in the following section (sectoral comparisons against the "high carbon" scenario), since these are included in the WEM.

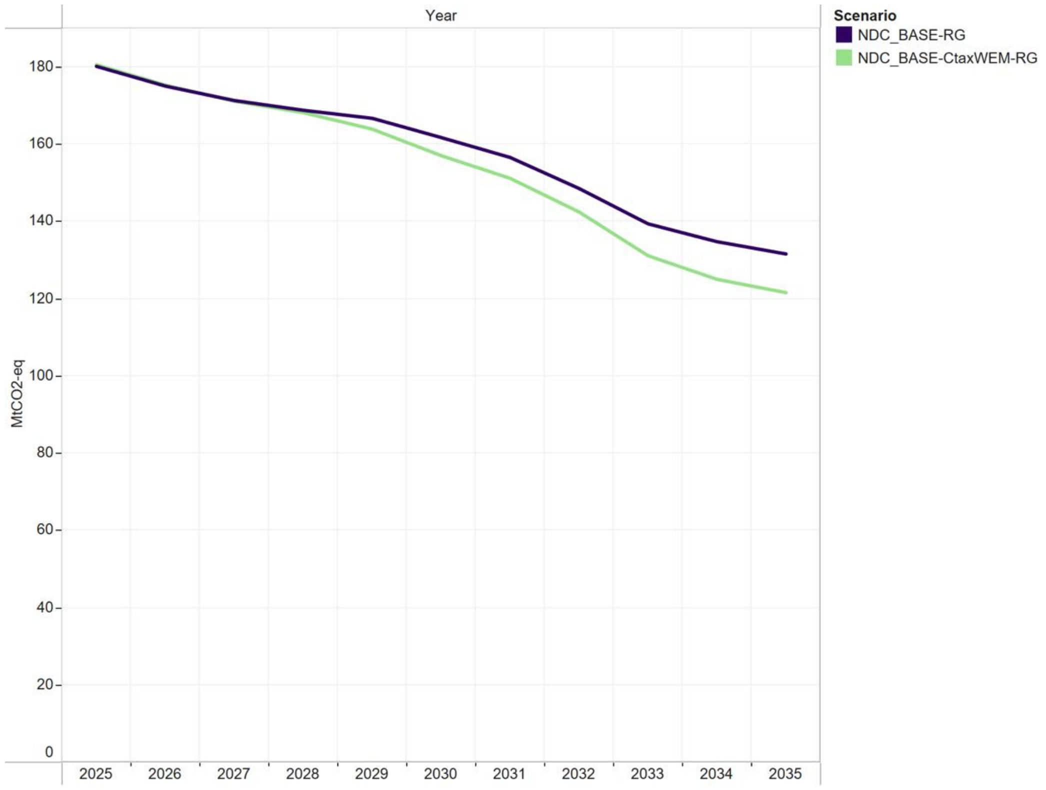
Carbon Tax

The proposed CO_2 tax rates, when applied in the SATIMGE framework reduce overall emissions from 356 to 345 MtCO2-eq, and almost all reductions (>95%) occur in the power sector.

Emissions by category

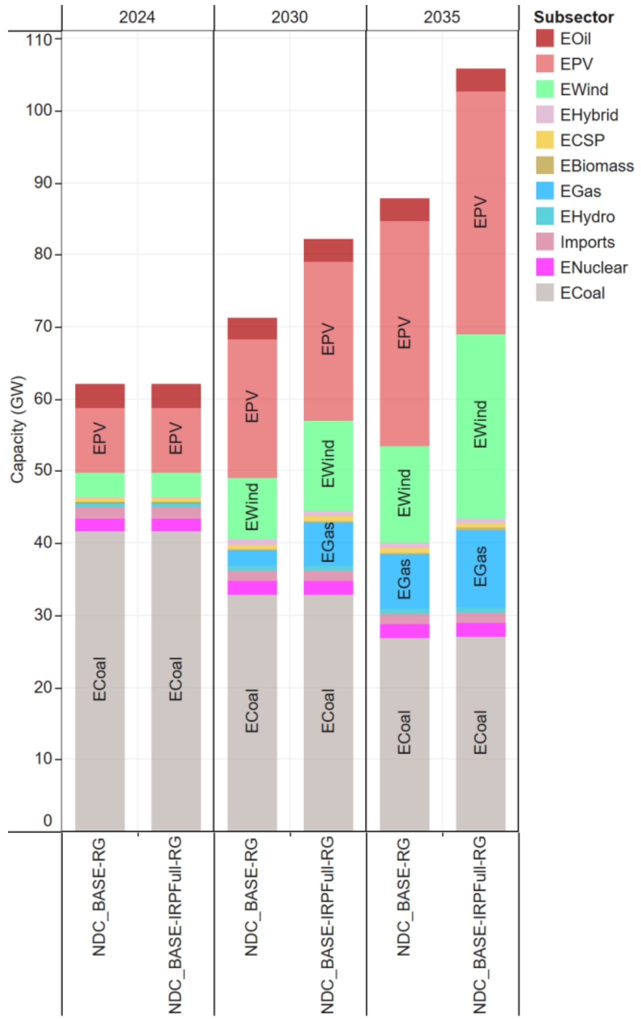


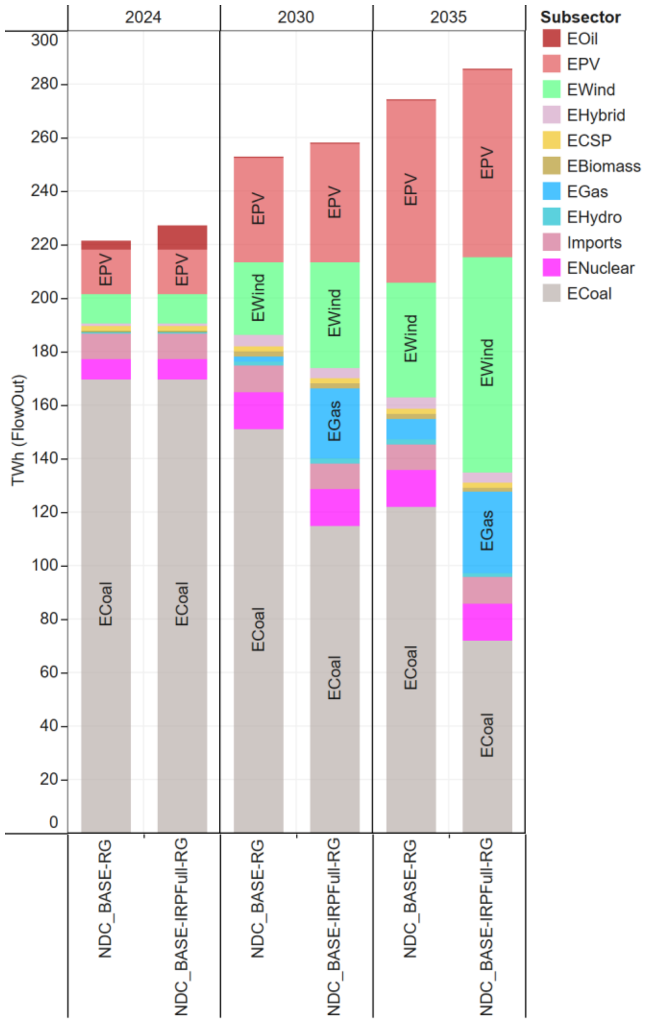
Power sector emissions



Draft Integrated Resource Plan 2025 - power capacity and generation

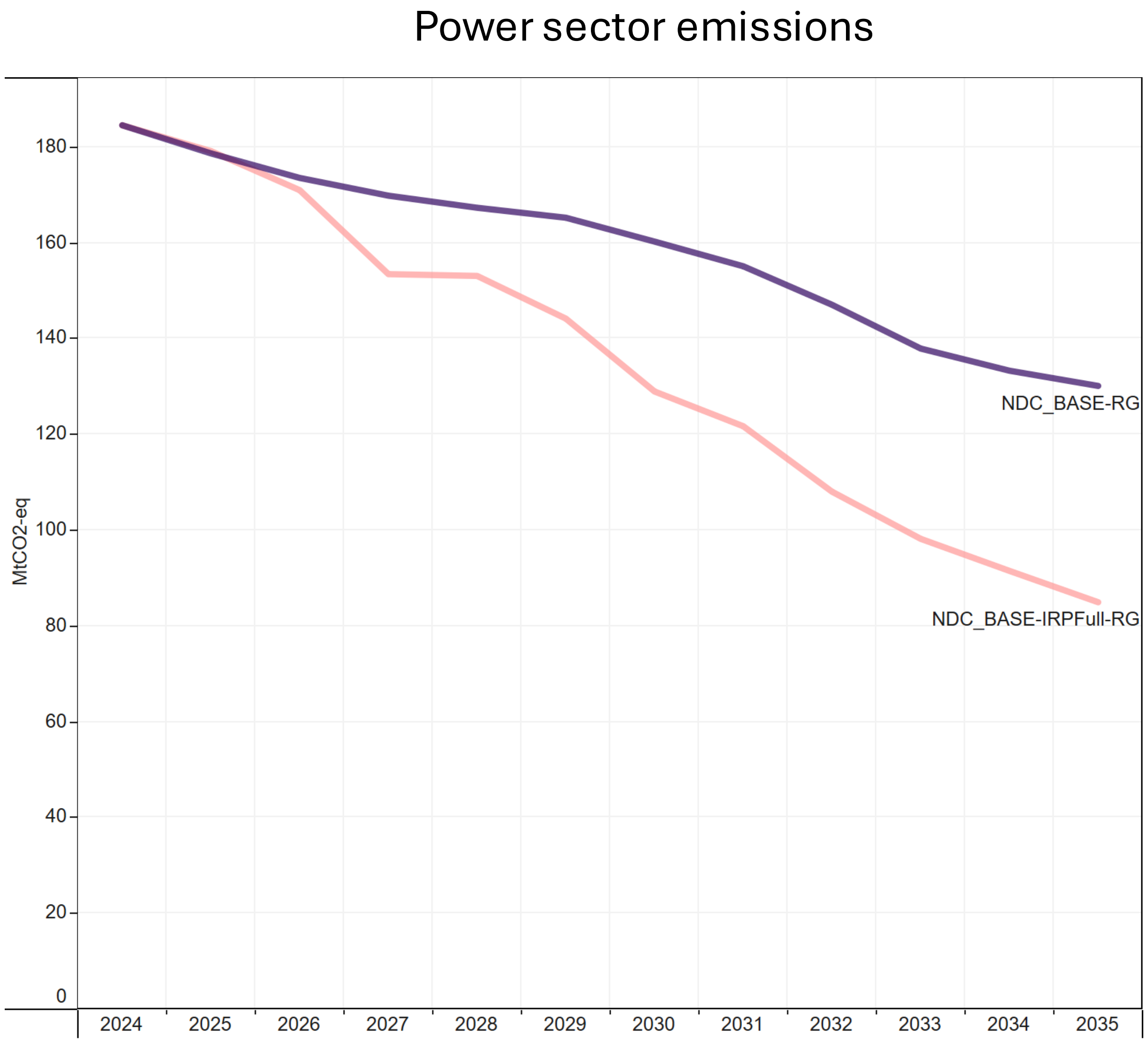
- The draft Integrated Resource Plan 2024 (IRP) results in major emissions reductions compared to the WEM power sector build
- The draft IRP contemplates major renewable capacity expansion (~60% increase by 2035)
- Installed capacity increases from 63 GW to 105 GW in 2035
- Wind emerges as the dominant renewable electricity source
- Coal's share of generation declines alongside the draft IRP planned retirement schedule





Draft Integrated Resource Plan 2025 – power sector emissions

Implementing the draft IRP brings emission reductions ~45 MtCO2-eq by 2035, 35% lower emissions compared to the WEM scenario.



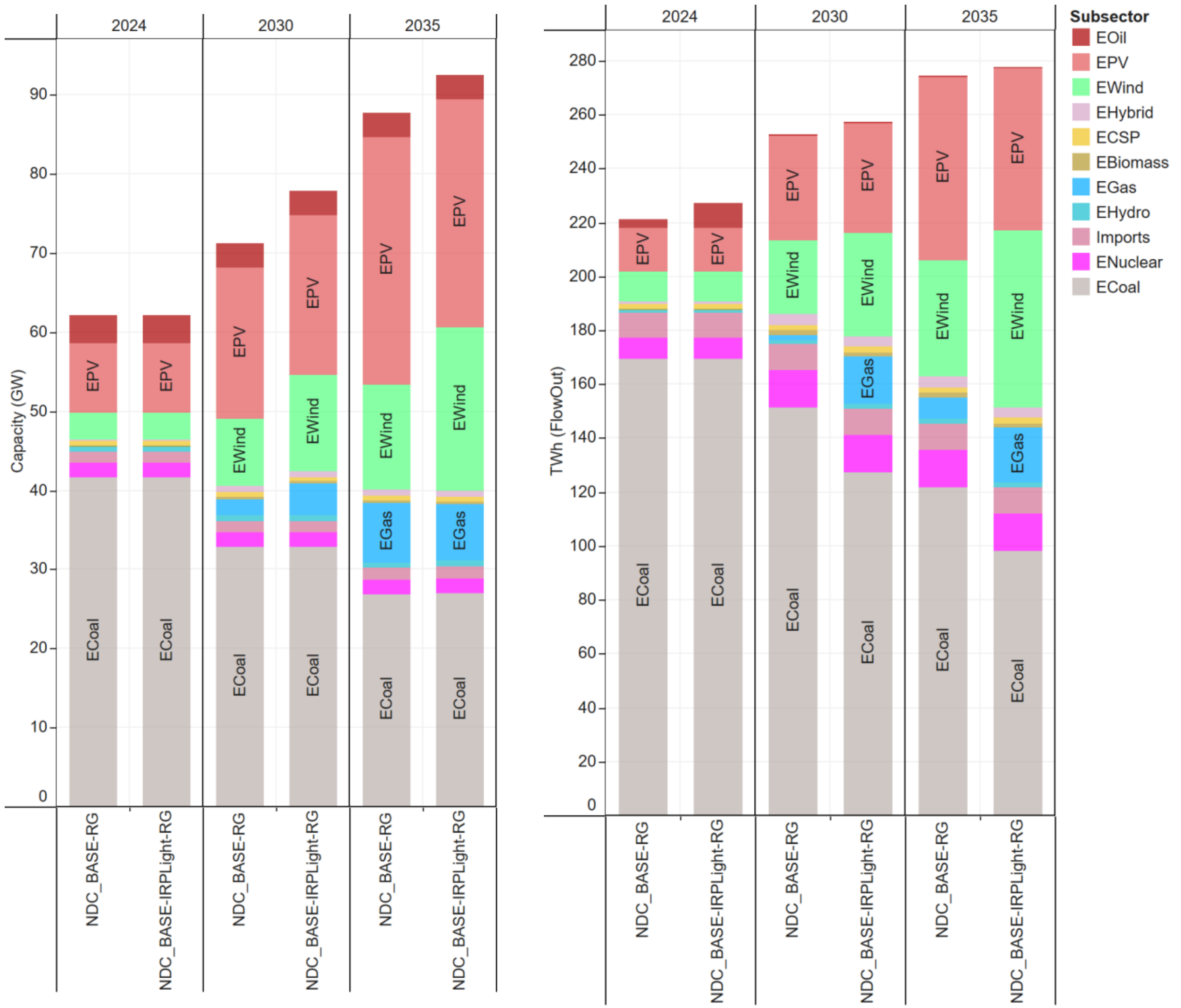
IRP Light Scenario – power capacity and generation

IRP Light scenario results in a more gradual renewable transition compared to full implementation of the draft IRP 2024, as well as extended coal generation in the medium term.

More conservative approach to power system transformation, with similar capacity outcomes but different deployment timeline.

Capacity

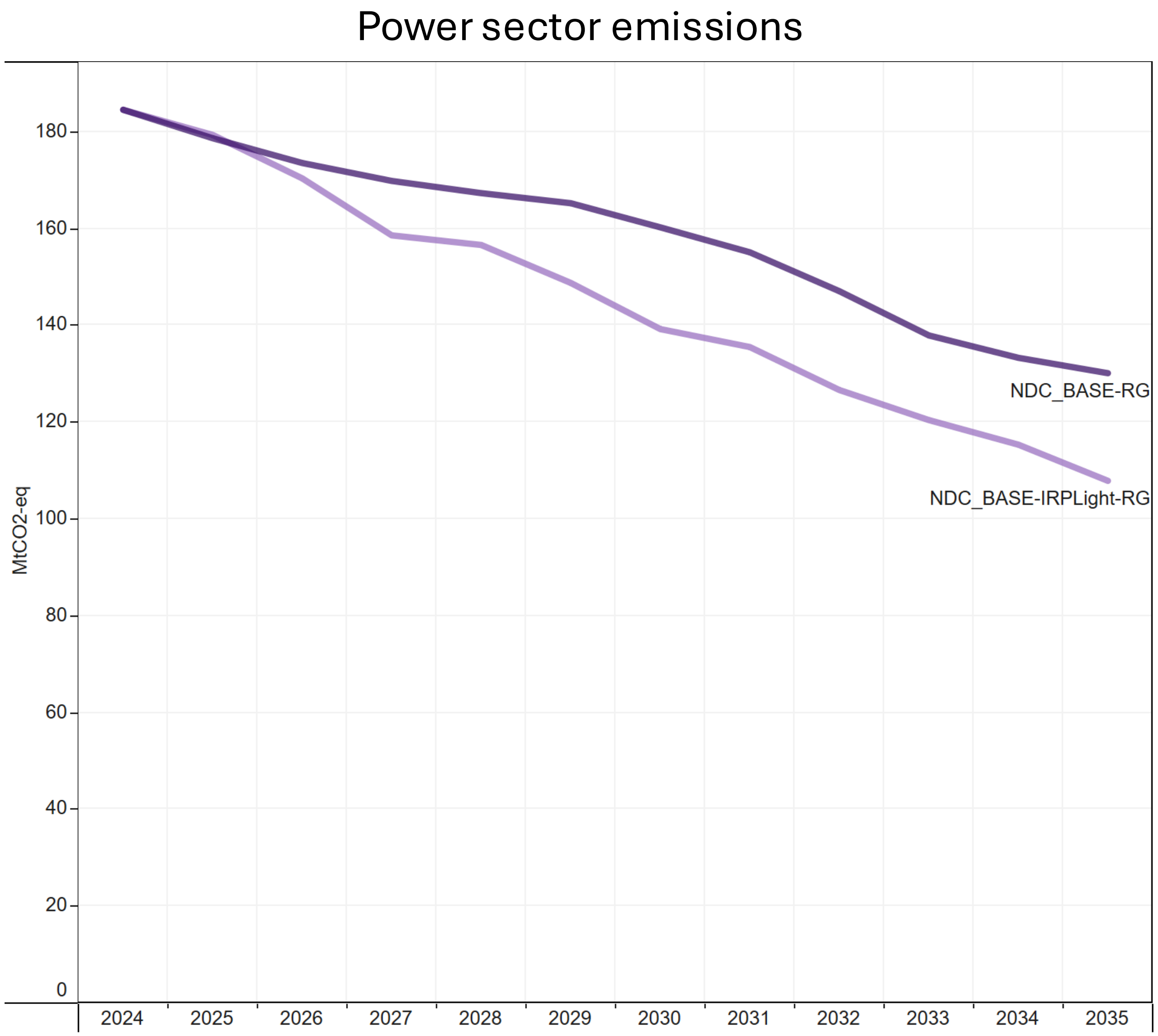
TWh output



IRP Light Scenario – power sector emissions

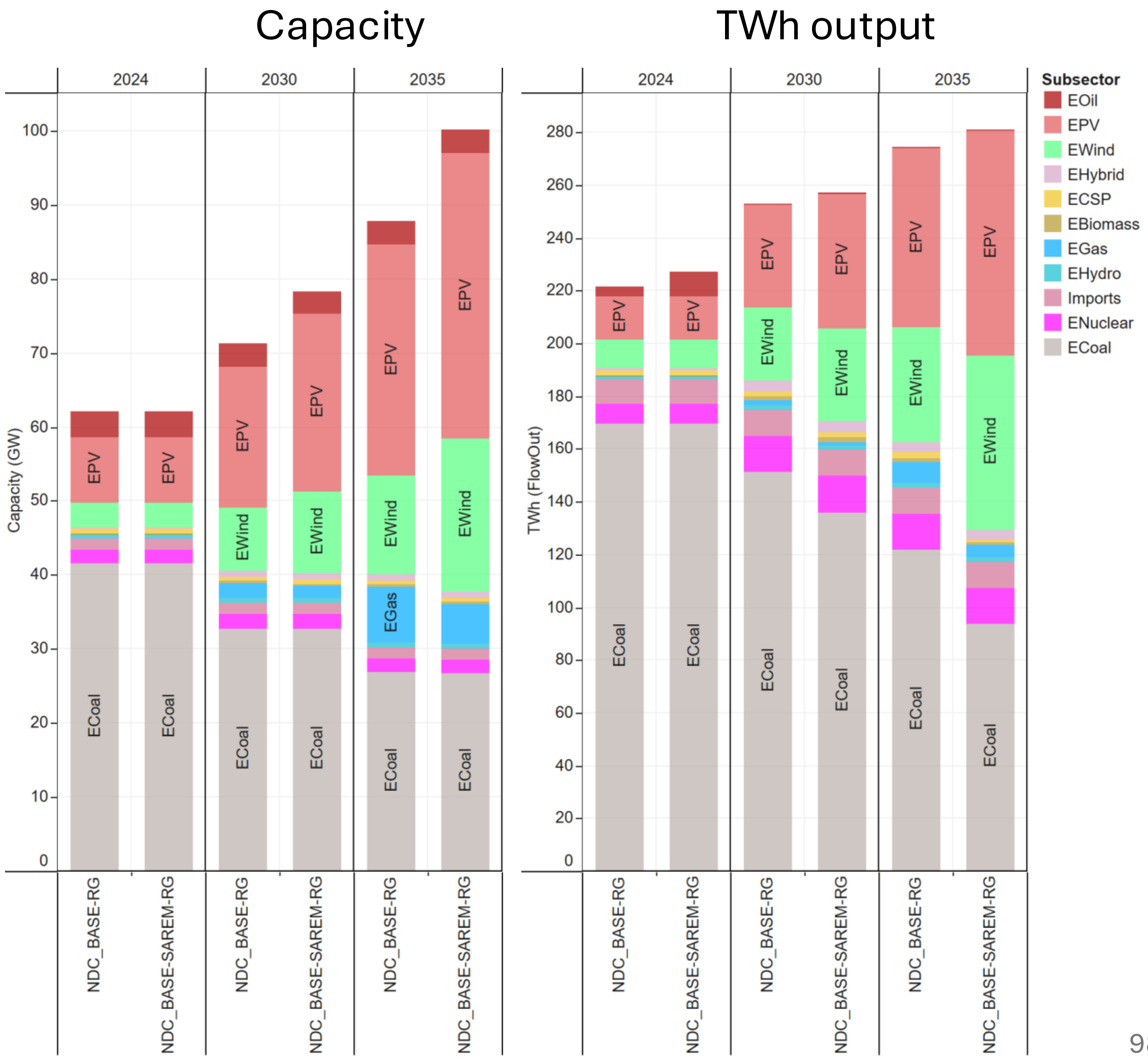
IRP light delivers moderate emission reductions (~15 MtCO2-eq by 2035), a 12% improvement over WEM scenario, with a slower decarbonisation pathway.

Trade-off between implementation pace and emission benefits between IRP and IRP light scenarios.



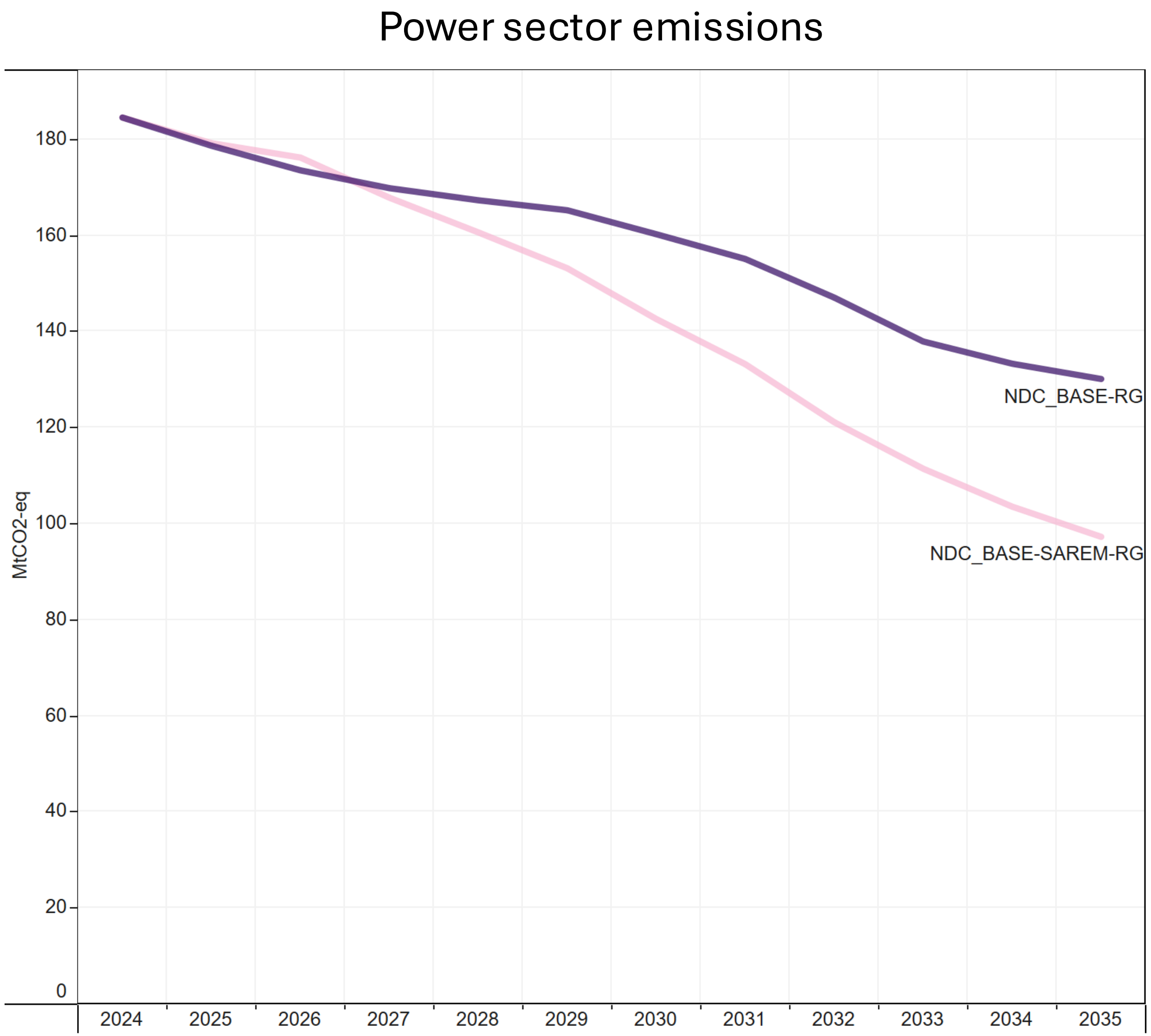
SAREM Scenario – power capacity and generation

- In the South Africa Renewable Masterplan (SAREM) scenario, total installed generation capacity expands from ~63 GW to ~100 GW by 2035.
- Total installed capacity is similar/different to full IRP
- Coal generation drops from ~170 TWh to 100 TWh over the period



SAREM Scenario – power sector emissions

The SAREM scenario delivers approximately 25 MtCO2-eq additional reduction by 2035, compared to the WEM scenario

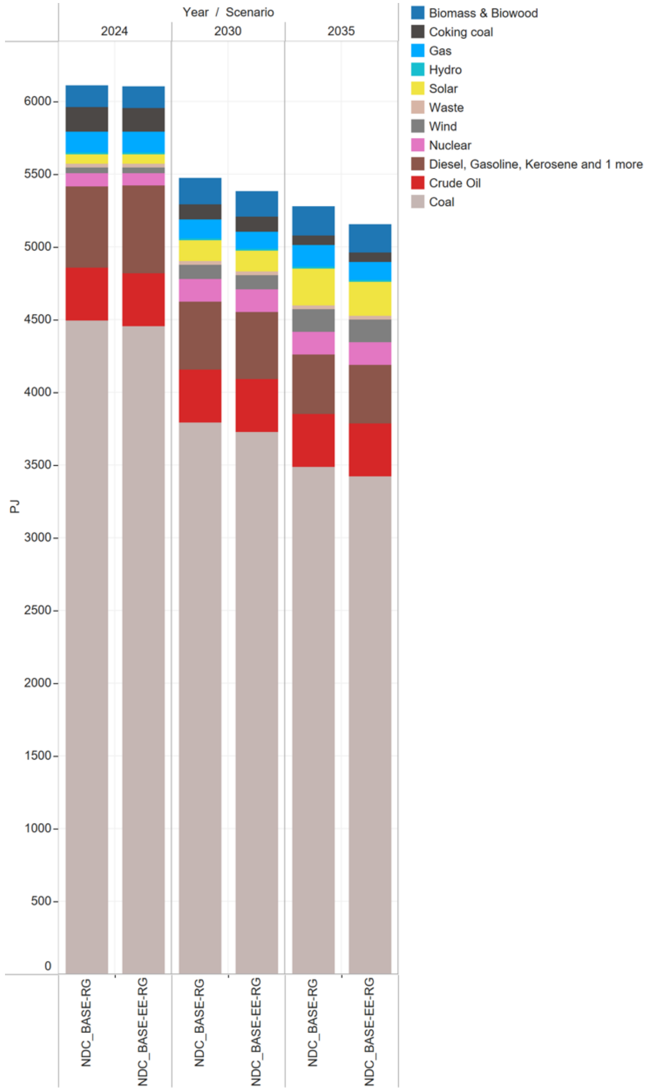


Energy efficiency gains in the system

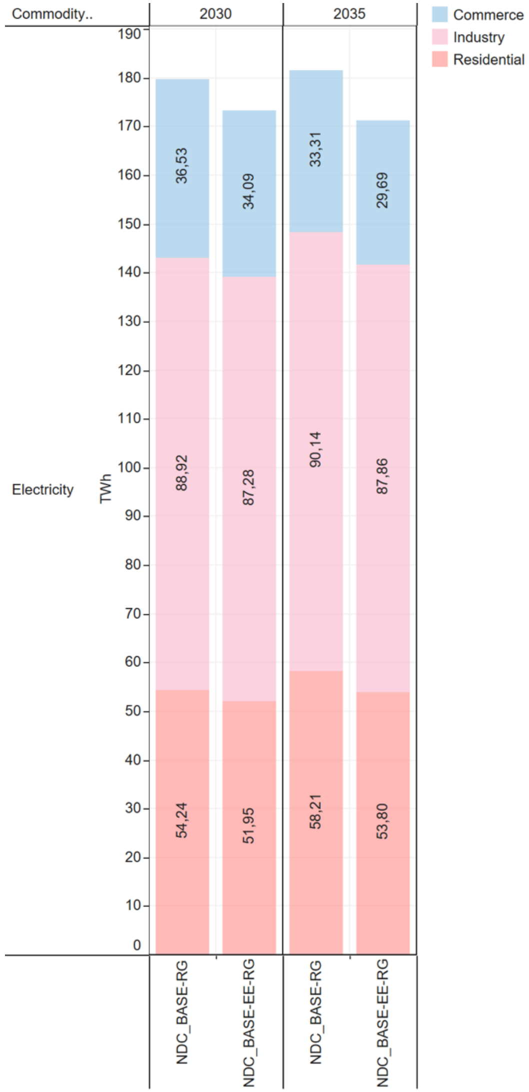
The various EE measures captured in the modelling framework result in a combined effect of roughly 6 TWh of electricity saved in 2030, increasing to about 10TWh by 2035.

This translates to a reduction of approximately 75PJ of coal, and 25PJ of gas consumption of primary energy (including industrial fuel savings of about 28PJ of coal for process heat and steam)

Primary energy use



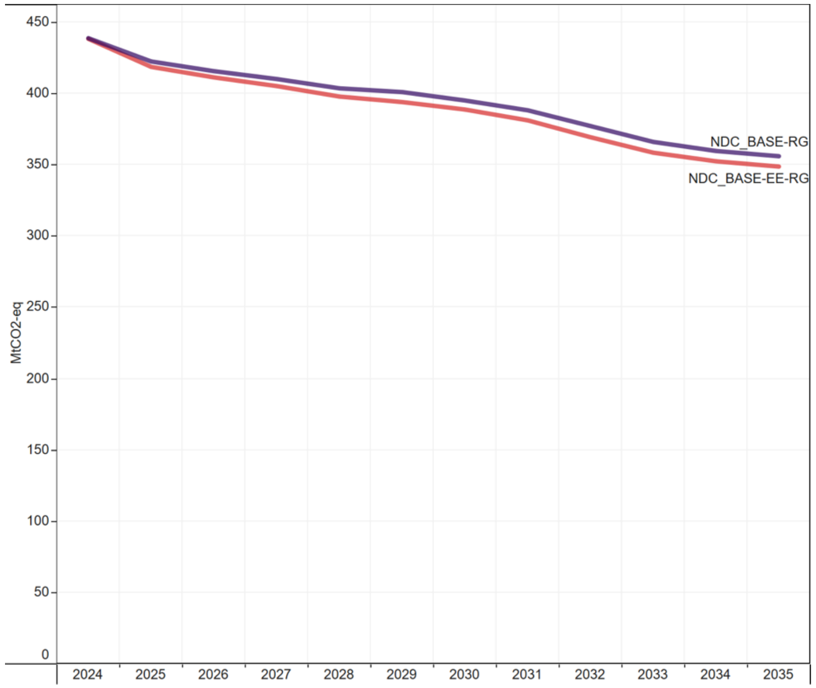
Electricity usage



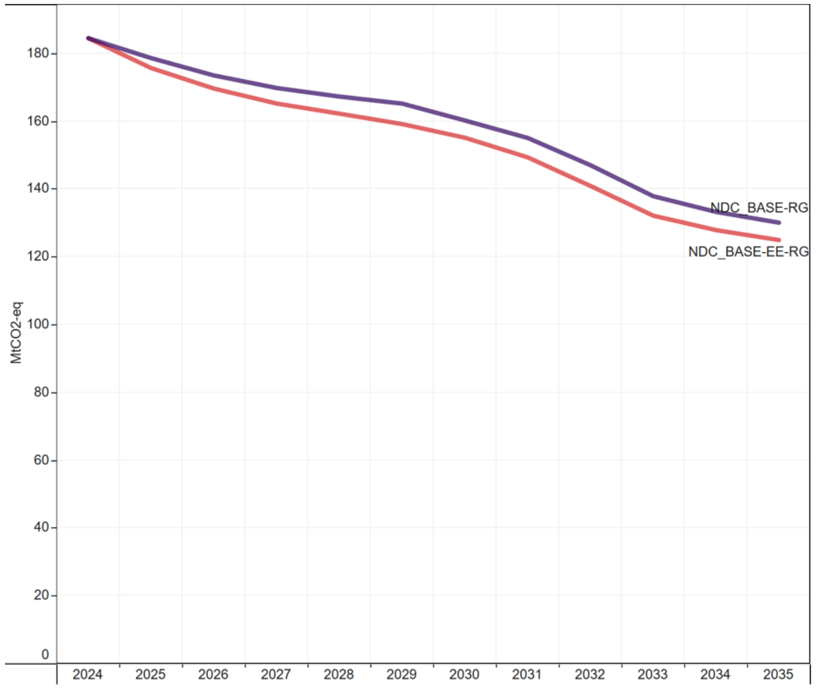
Energy efficiency impact on economy-wide and power sector emissions

Energy efficiency delivers consistent but modest reductions compared to WEM scenario, with a steady ~5-10 MtCO2-eq annual improvement (reduction) through lower electricity demand.

Total system emissions

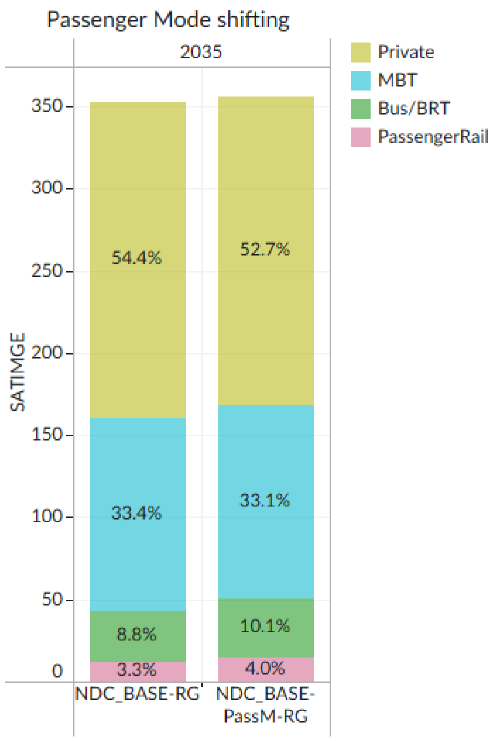


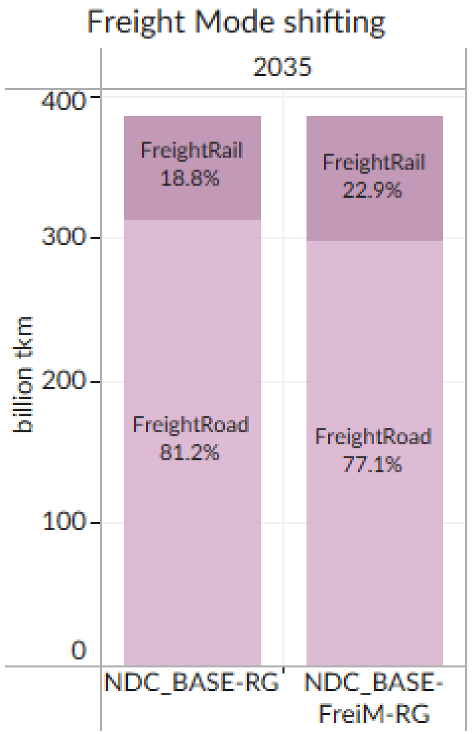
Power sector emissions

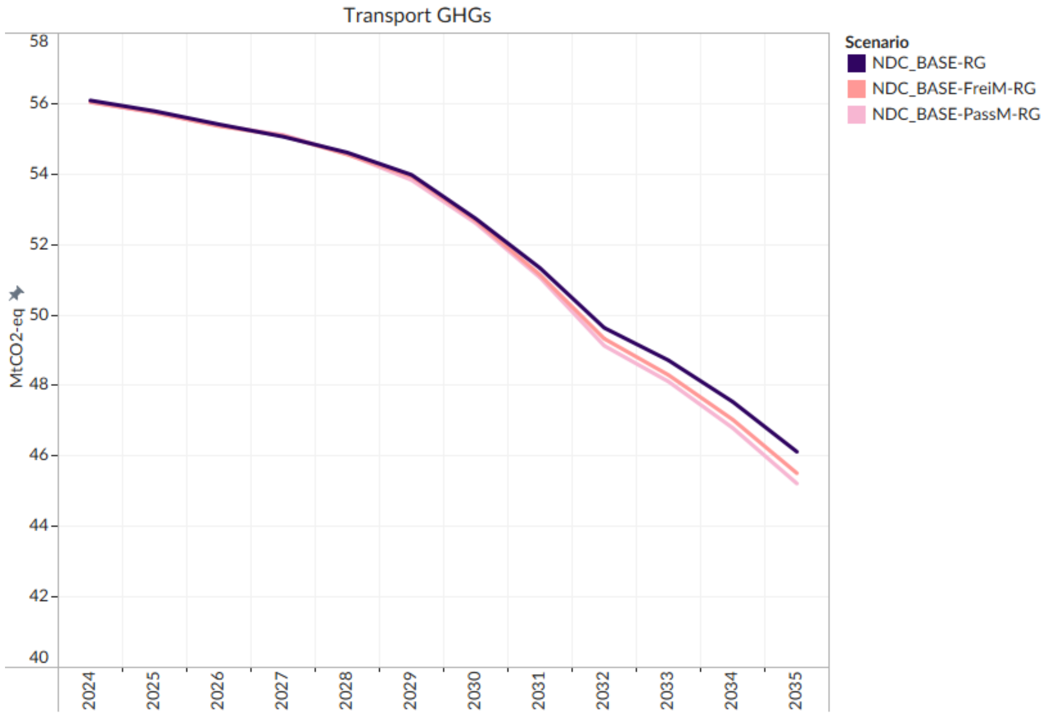


Transport – mode shifting

More ambitious mode shifting (beyond GTS 2018) would be needed to have a greater impact on emissions







GHG emissions outcomes for core scenarios

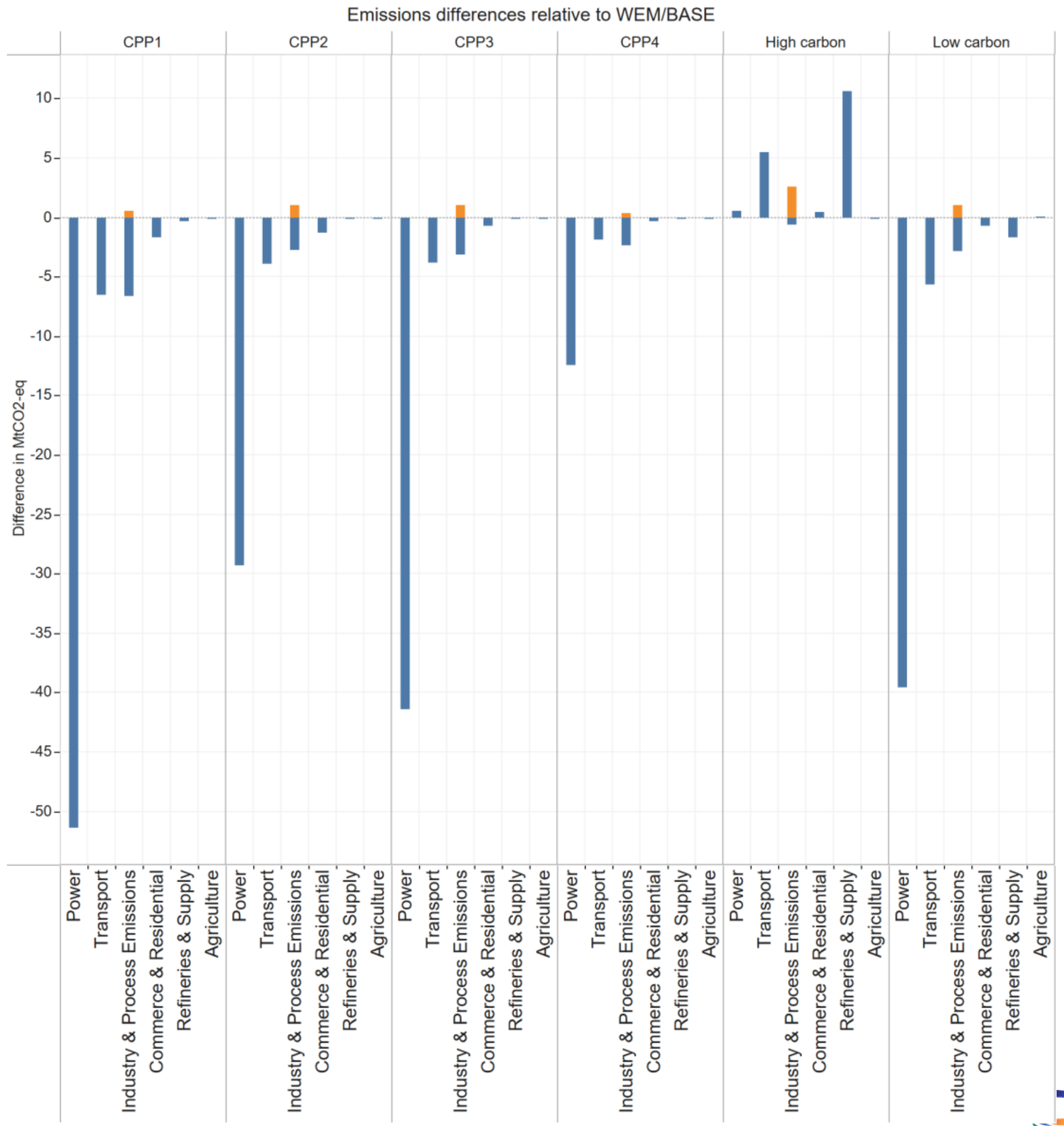
2035 GHG emissions outcomes for the policy scenarios using the the medium economic growth rate):

	1A1a - Electricity	1A1b, 1A1c, 1B3 - Liquid fuels supply	1A2 and 2 - Industry (including IPPU)	1A3 - Transport	Other	TOTAL
High carbon	131	50	75	54	65	375
WEM	130	39	73	49	65	356
Current plans and policies (non electricity)	118	39	71	47	64	339
CPP IRP light	101	39	71	45	63	319
CPP SAREM	89	39	71	45	63	307
CPP IRP	79	39	67	42	62	289
Low Carbon	91	37	71	43	63	306

"Current plans and policies" includes all non-electricity and cross-cutting plans and policies – the cumulative mitigation effect is slightly less than the sum of individual mitigation outcomes due to system interactions; the other CPP scenarios includes these and one of the three options for the electricity sector; "High carbon" excludes the AMSA and Sasol roadmaps. The impact of these, and also of the electricity variants, will be discussed in more detail below.

Drivers of emissions changes in the scenarios

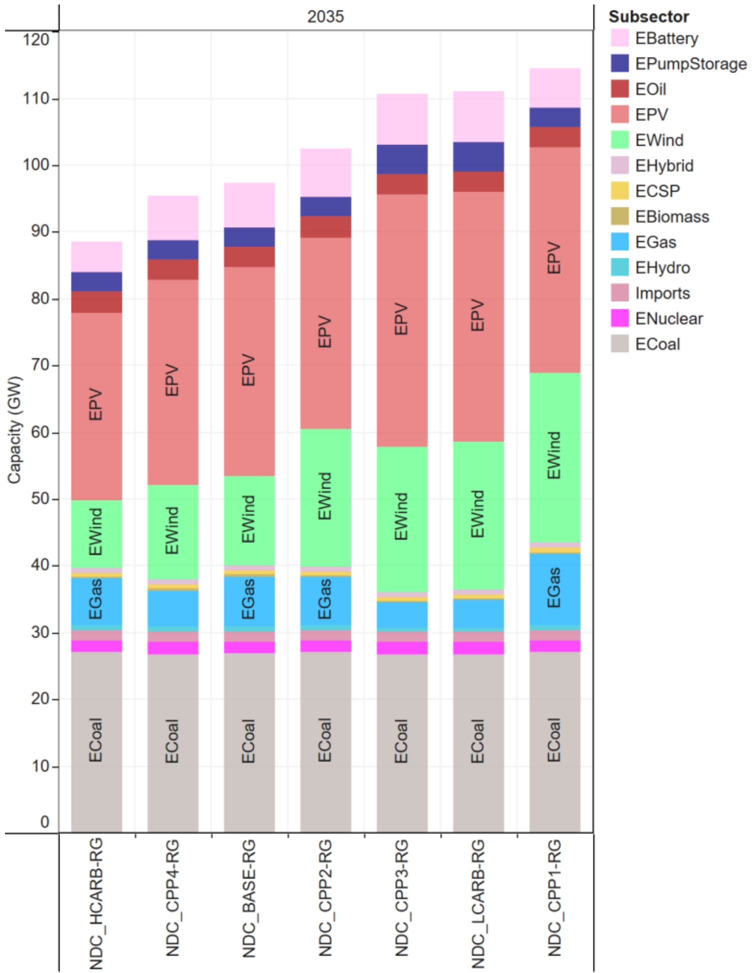
- Relative to the WEM scenario, the electricity sector plans result in the largest variation in emissions compared to other measures.
- The high carbon scenario sees a notable increase in emissions from liquid fuel production where Sasol does not implement efficiency measures nor curtail onsite coal-based power generation, and produces fuels and chemicals at a constant maximum of 7.2Mt of product a year.
- Transport sees a slower uptake of EV's (using less electricity), but with more direct emissions from fuel.
- The power sector sees little change, as the coal fleet ramps up to about 50% operating factor by 2030 in the WEM to accommodate the retiring capacity, and the life extension plan (as per draft IRP2024) only affects the fleet from 2035 and onwards, thus making little difference to the operations to 2030 and 2035.
- The low carbon scenario (with a SAREM build plan) sees a comparable power sector emissions decline to the CPP3 (SAREM), but with additional emissions reductions from the rollout of EV's and increased public transport.
- The Sasol and AMSA roadmaps, which are not implemented in the high carbon scenario, result in a reduction in 2035 (from the high carbon to the WEM scenario) of 8.9 and 2.1 Mt CO_2-eq respectively (scope 1 emissions only).



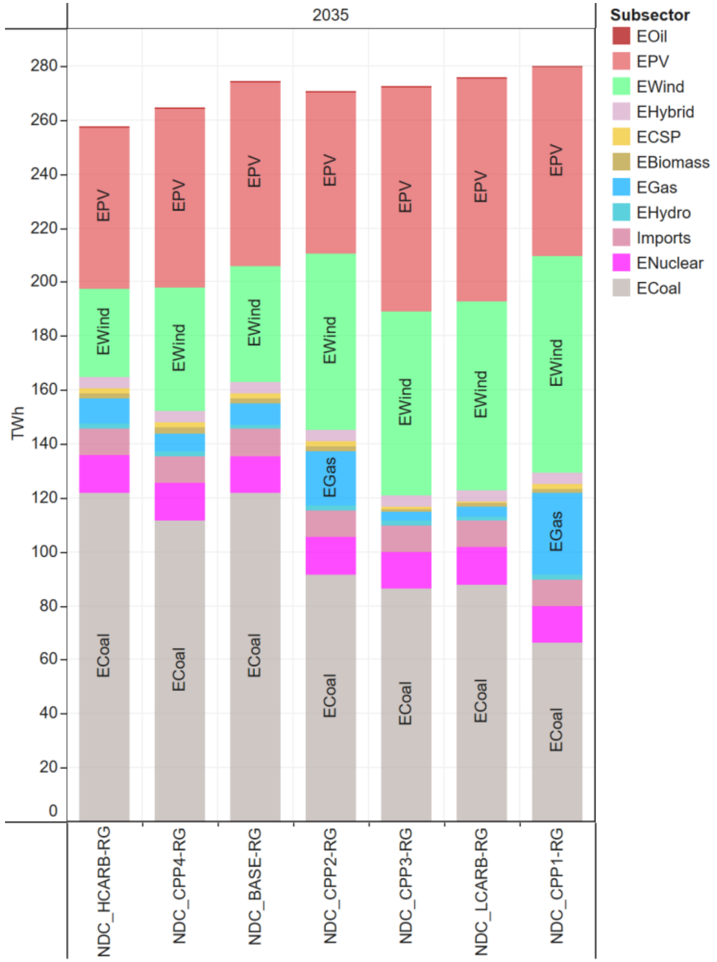
Scenario outcomes for the electricity sector

Capacity additions are fixed for the IRP scenario, and are lower bounds for the IRP light and SAREM cases; the lower carbon scenario has the same constraints as the SAREM scenario; the high carbon scenario has a minimum utilization rate for the coal fleet, and in the remaining scenarios, the model optimizes capacity (least-cost). The mitigation impact of the IRP scenario (with other policies and plans) is the largest, since excess capacity results in lower use of the coal fleet in 2035; the composition also varies from the least-cost cases in the amount of CCGT capacity and use, and in the wind/PV ratio. In the IRP plan, new nuclear plants come online in 2036, but do not affect GHG emissions in 2035.

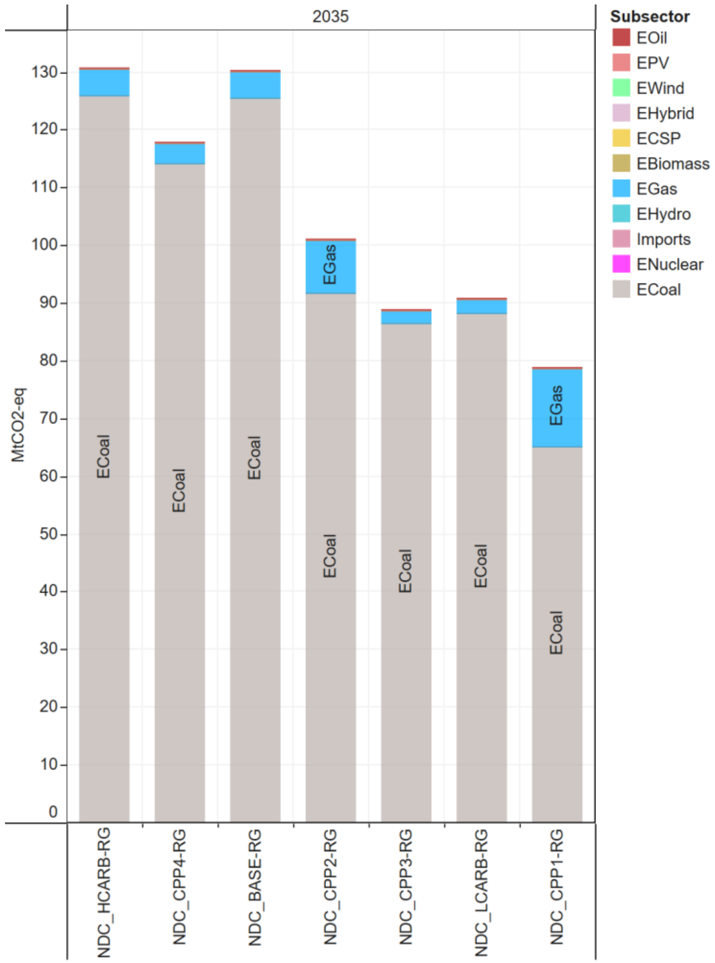
Capacity



TWh output



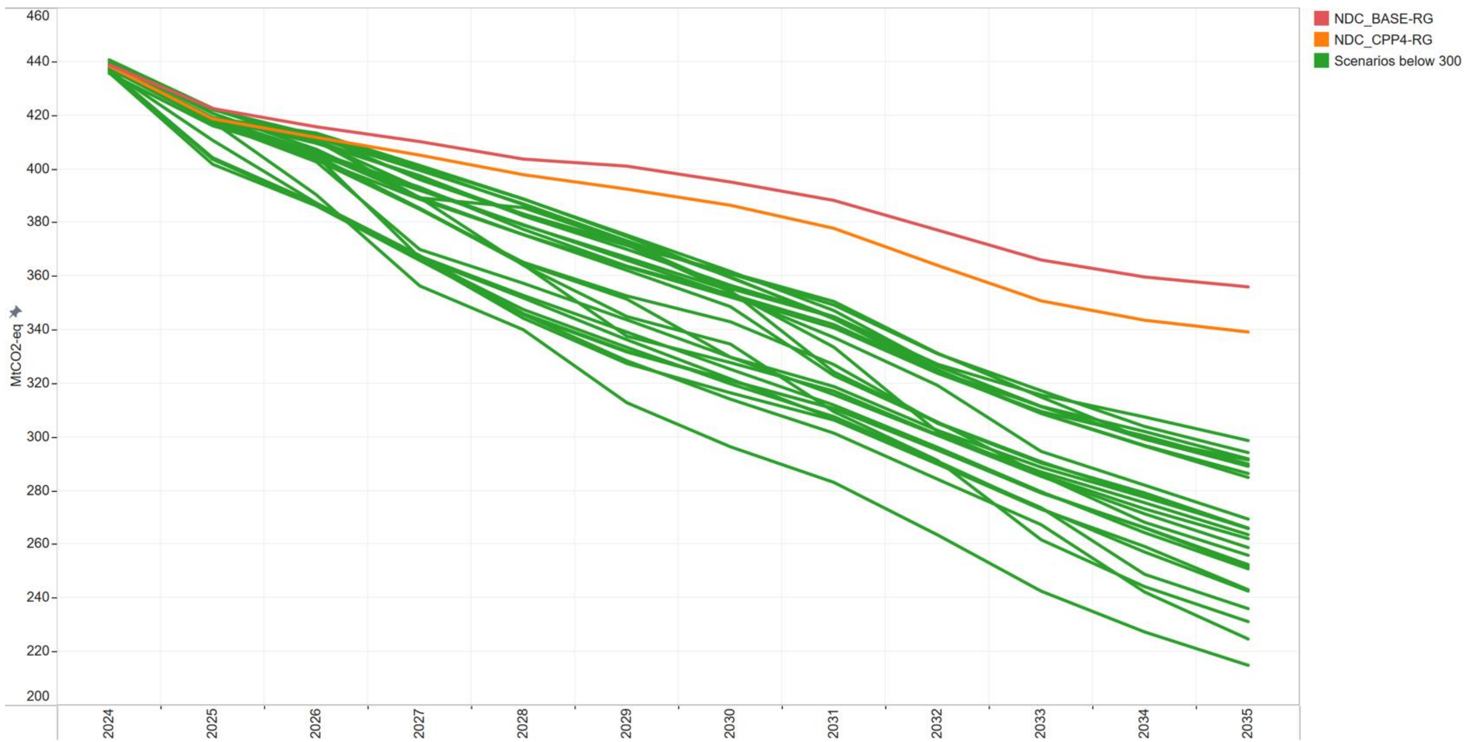
Electricity sector emissions



Additional mitigation: GHG-constrained cases

The implications of more ambitious mitigation outcomes can best be modelled by applying a long-term cumulative GHG emissions constraint, which generates a range of long-term optimal pathways, with a range of outcomes in 2035. The additional measures needed to arrive at these outcomes in 2035 can then be inferred from the system characteristics of each case, by comparing key indicators (for instance required low-carbon generation capacity) for more ambitious cases with existing policy.

Given the previous scenario results, a range of additional outcomes was modelled from 300 Mt to 200 Mt CO_2-eq. At these levels, tradeoffs occur between major emitting sectors, and in particular between reductions in electricity sector emissions and emissions from synfuels production.



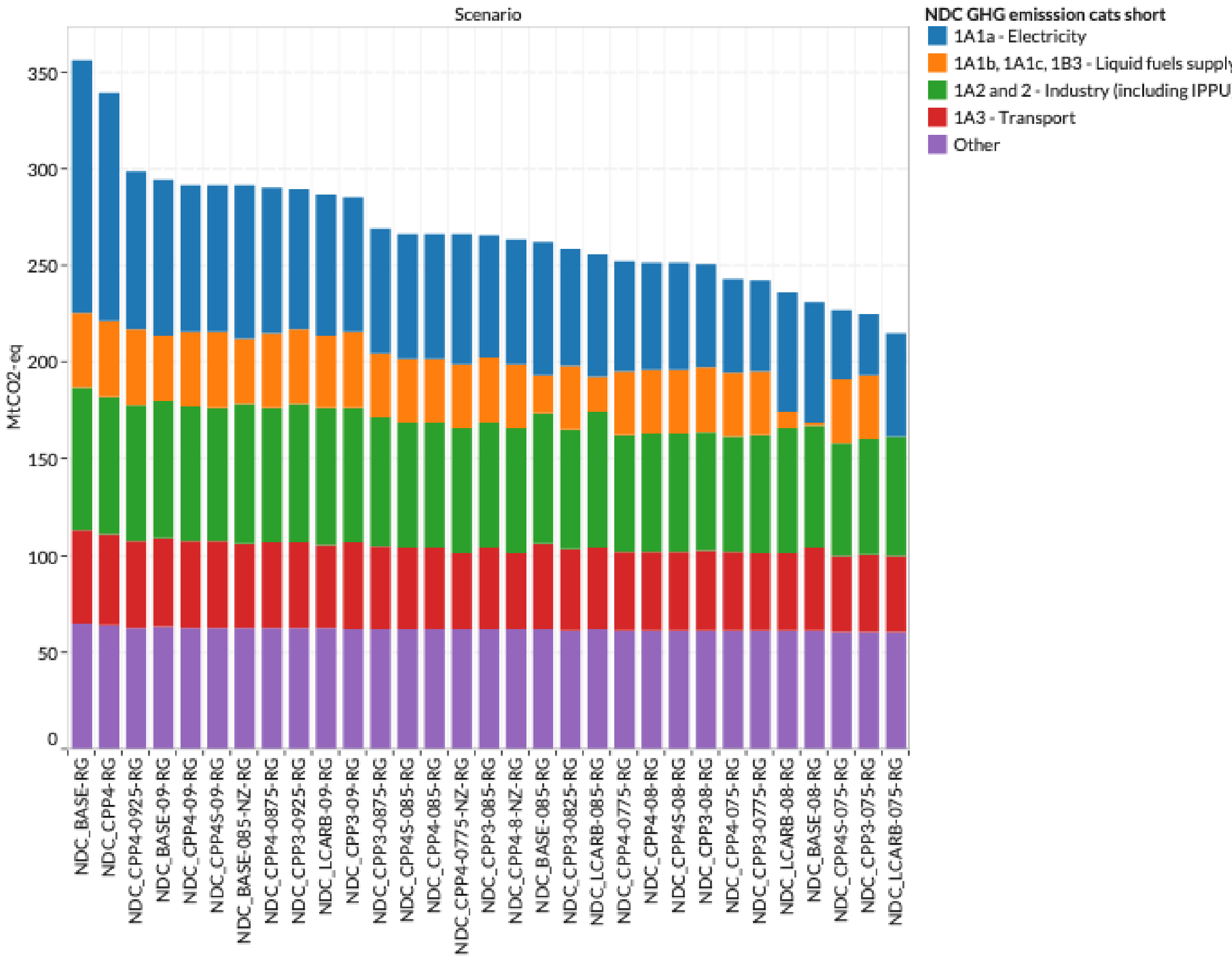
Scenarios below 300Mt CO2eq

For all additional mitigation cases, as for the policy scenarios, the electricity sector is the key source of mitigation.

Synthetic fuels production at Secunda reduces to the minimum allowed (70%), and in scenario families which allow for early retirement – drops below this level leading to lower mitigation effort in power and industry.

Industry emissions reduce from a combination of lower economic activity requiring lower levels of manufacturing, and from some technology shifts: in steel a shift to coal DRI kilns with EAF's, and some hydrogen usage.

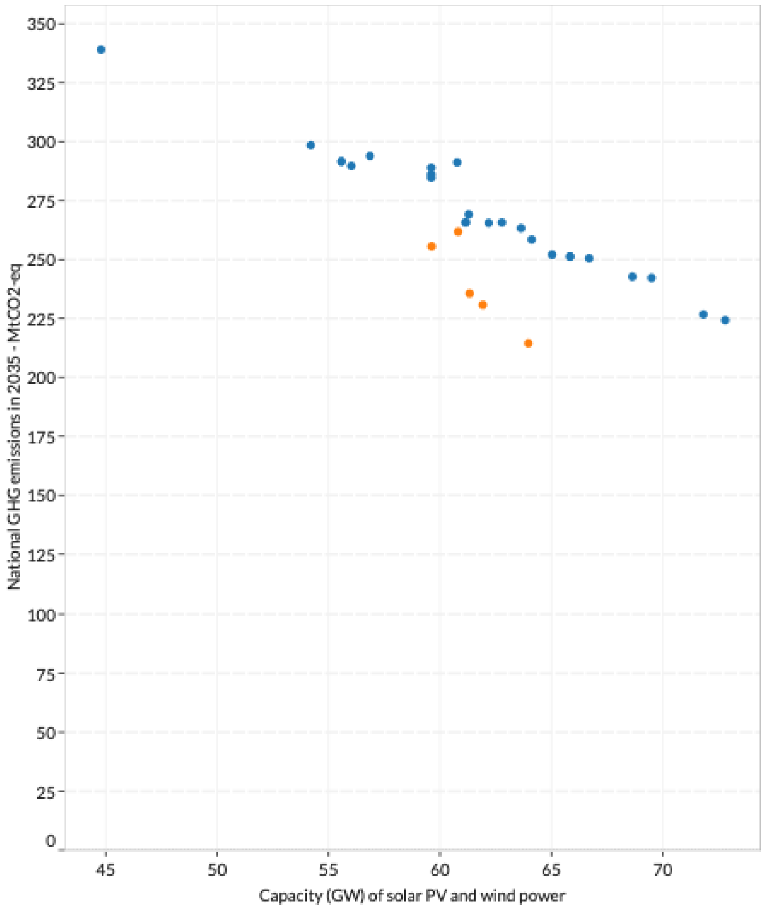
Mitigation in transport occurs with more rapid shift from gasoline/diesel to electricity, as well as road to rail, particularly in freight transport, the extent to which depends on the fuel price and EV price trajectory assumptions



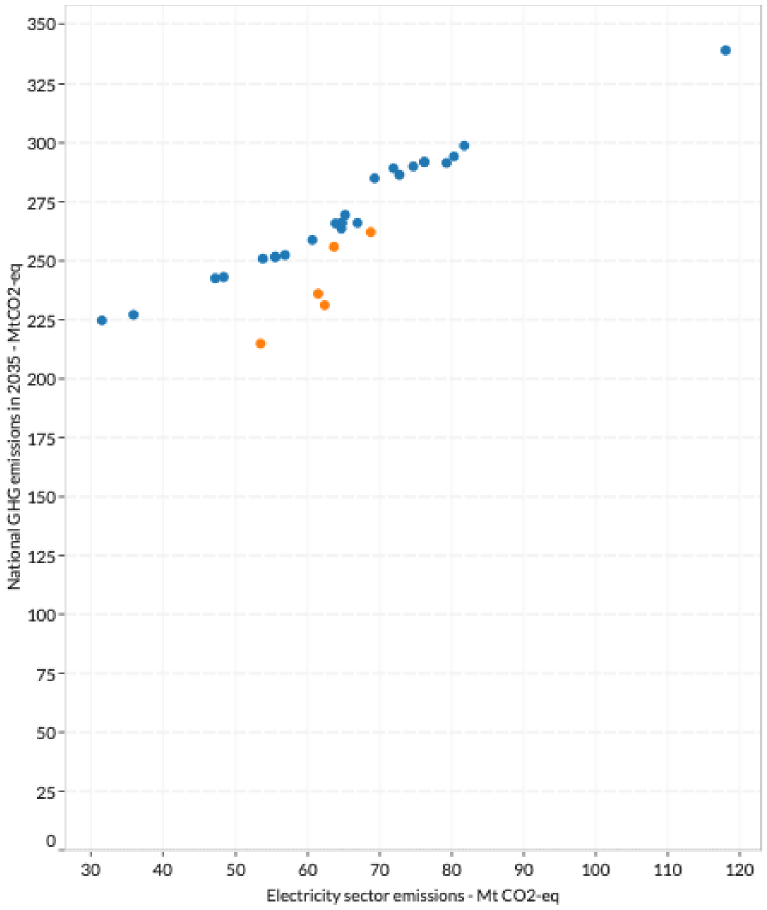
Electricity sector and liquid fuels production emissions

Additional mitigation effort requires additional low- or-zero carbon generating capacity. In most modelled cases in this analysis, the model chooses solar PV and wind power, with other necessary system elements, on the basis of total system cost. The figures to the right present the relationship between PV+wind capacity and total national GHG emissions in 2035 (left) and electricity sector emissions and total national GHG emissions (right). There is a near-linear relationship between both RE capacity and national emissions, and electricity sector emissions and national emissions.

The orange points denote cases in which production from Secunda is curtailed as an alternative to adding additional RE capacity , and these cases diverge from the overall trend (since emissions reductions are being sourced elsewhere). The cases in which this occurs have the flexibility to curtail synfuels production (in other words, the model considers this a less costly option for additional mitigation for national GHG emissions of 275 Mt or less).



Solar PV and wind capacity vs national GHG emissions for additional mitigation cases

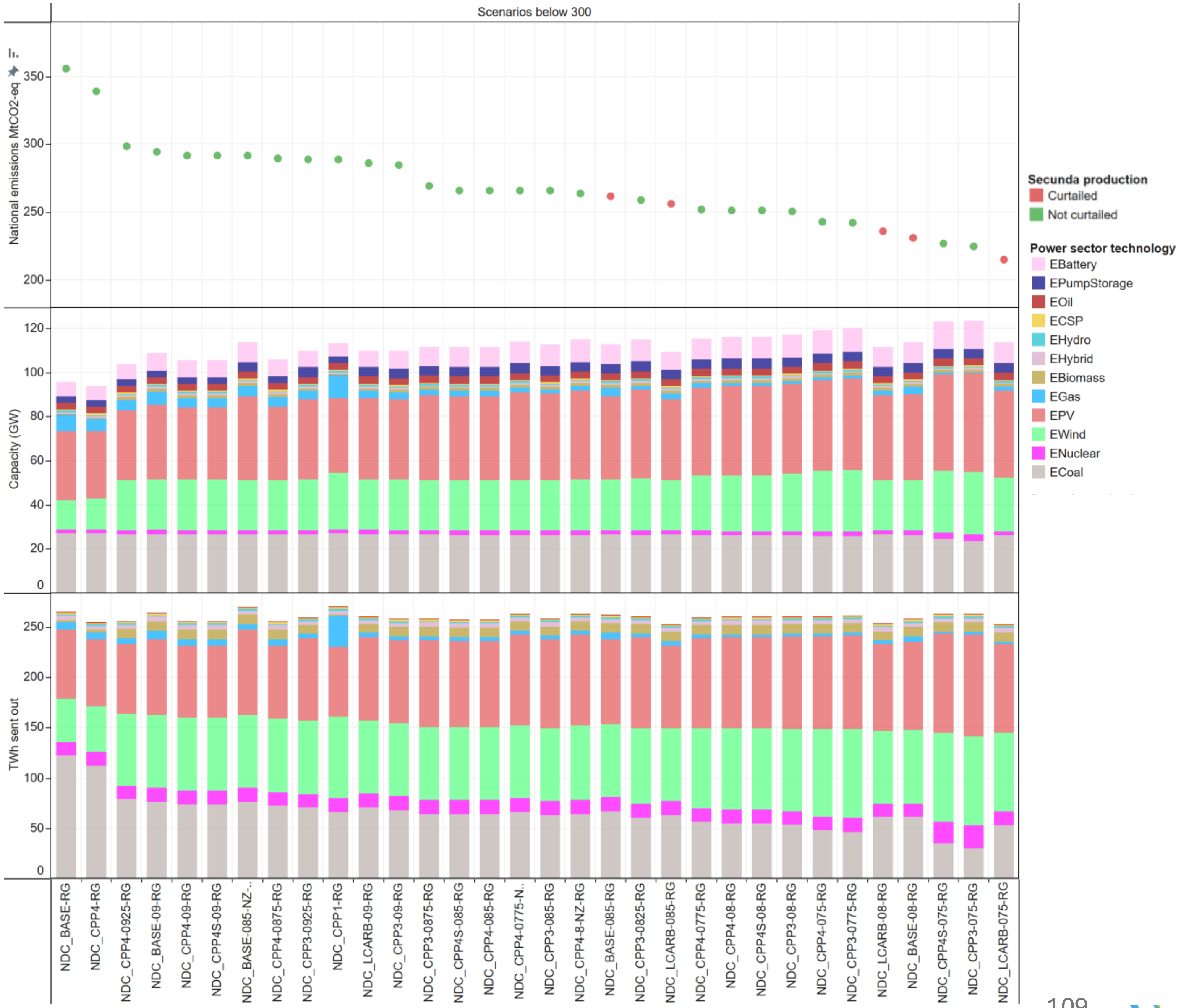


Power sector emissions vs national GHG emissions for additional mitigation cases

Power sector capacity and output for GHG emissions outcomes of <300 Mt in 2035

Additional mitigation below 300 Mt CO_2-eq in 2035 requires additional capacity in the electricity system to displace additional coal-fired power; the amount of additional capacity is determined by the amount of additional mitigation sourced elsewhere in the economy. The figure to the right correlates national GHG emissions in 2035 with capacity and output of the electricity system.

As in the previous slide, the orange points denote cases in which Secunda output is curtailed, which results in a lower requirement for additional capacity.

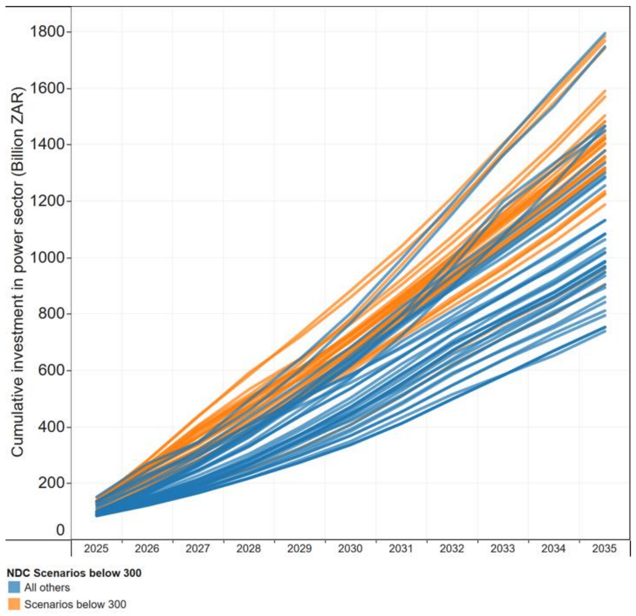


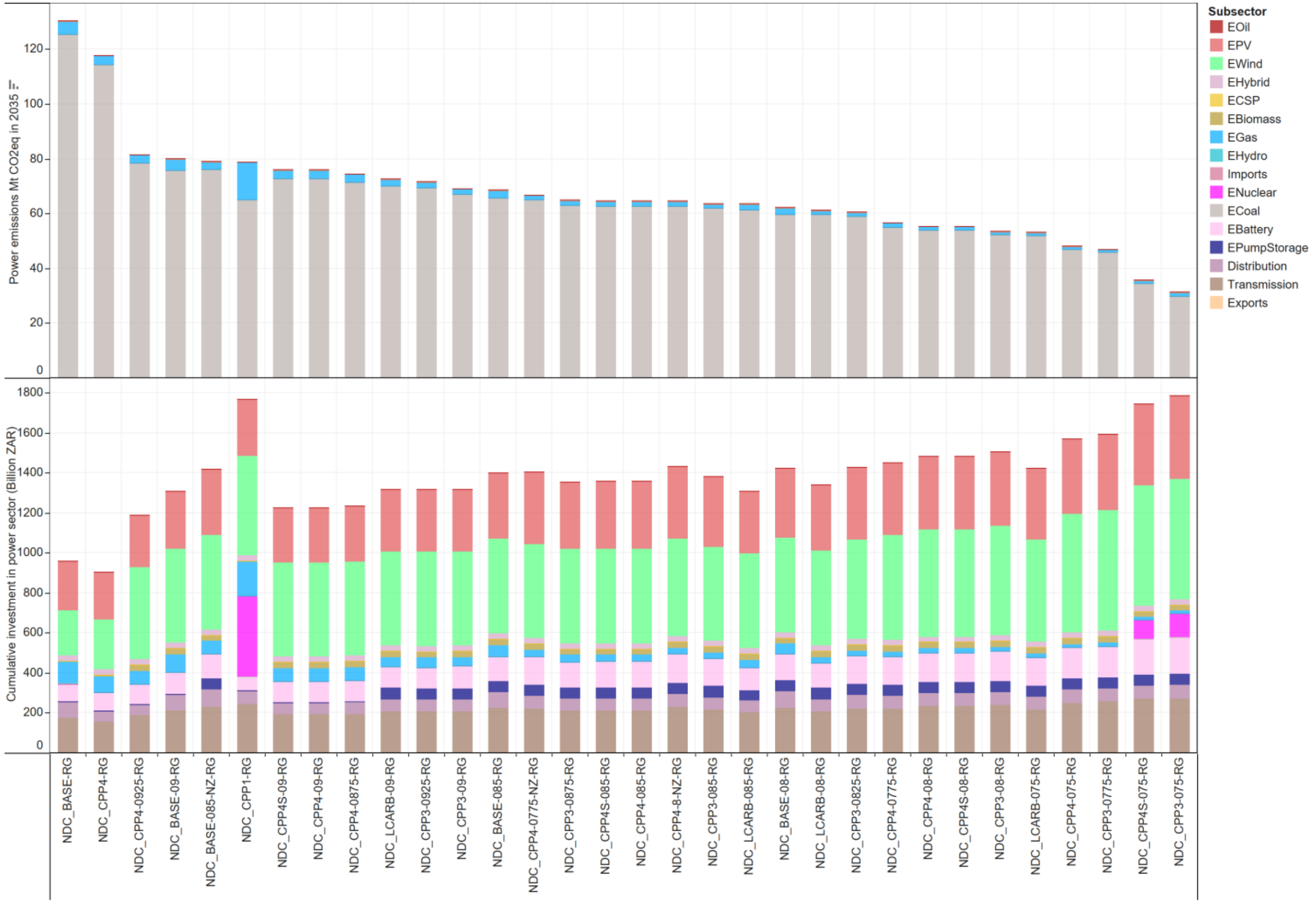
Power sector investment requirements

The power sector requires at least 960 Billion Rands (ZAR 2022) cumulative investment between 2025 and 2035 for the WEM scenario, and less for the CPP4 scenario, which contains more energy efficiency measures.

Additional mitigation effort increases the investment requirement to a minimum of 1200 Billion ZAR by 2035. Most of the investment is in renewable electricity generation capacity.

Nuclear investment occurs in the IRP build plan, and in the most extreme mitigation cases; although the nuclear capacity only comes online in 2036, the lead time requires investment in the period up to 2035.





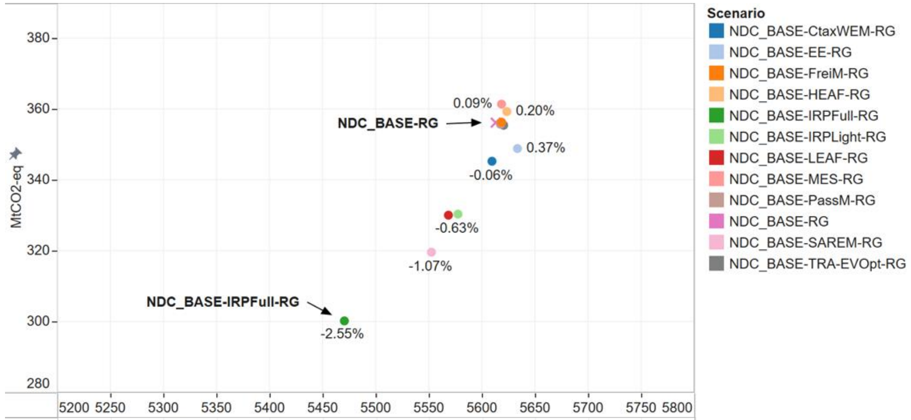
Power sector cumulative investments (2025 to 2035) for additional mitigation cases (<300Mt CO2eq) per technology

Impact on economy

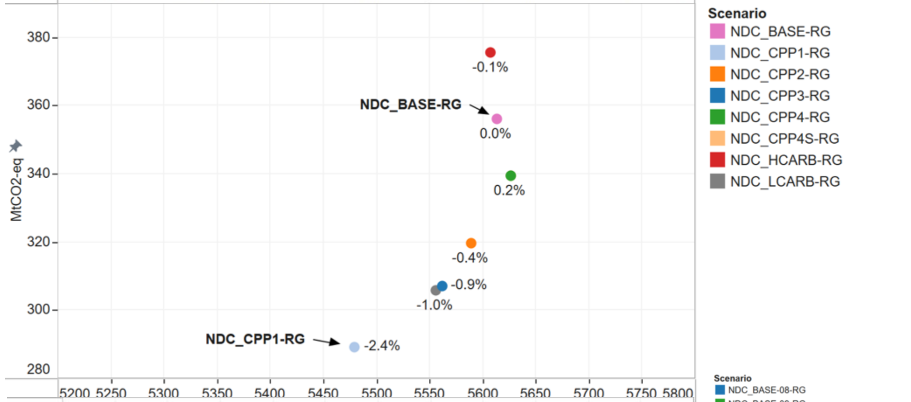
Generally it is observed in the SATIMGE framework that measures reducing emissions come with an impact on the economy through additional costs and investments.

In scenarios for the reference growth rates, the economy in 2035 is less than 3% smaller across all scenarios compared to the WEM scenario in 2035. This is true for the additional mitigation levels that achieve below 300Mt CO2eq in 2035.

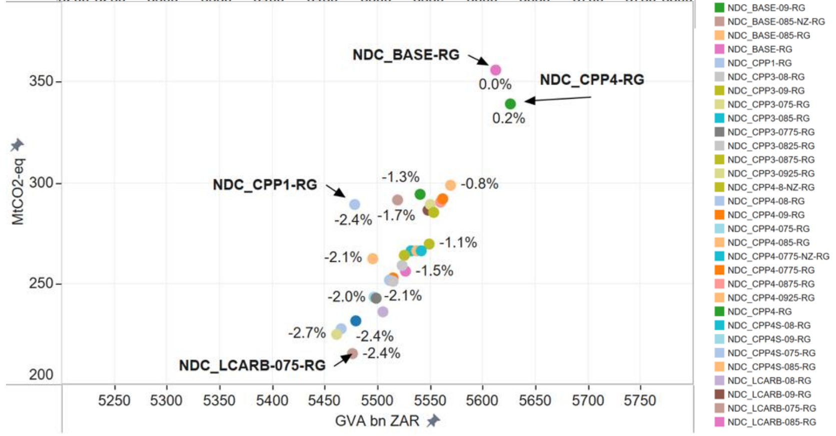
PAMS applied to WEM



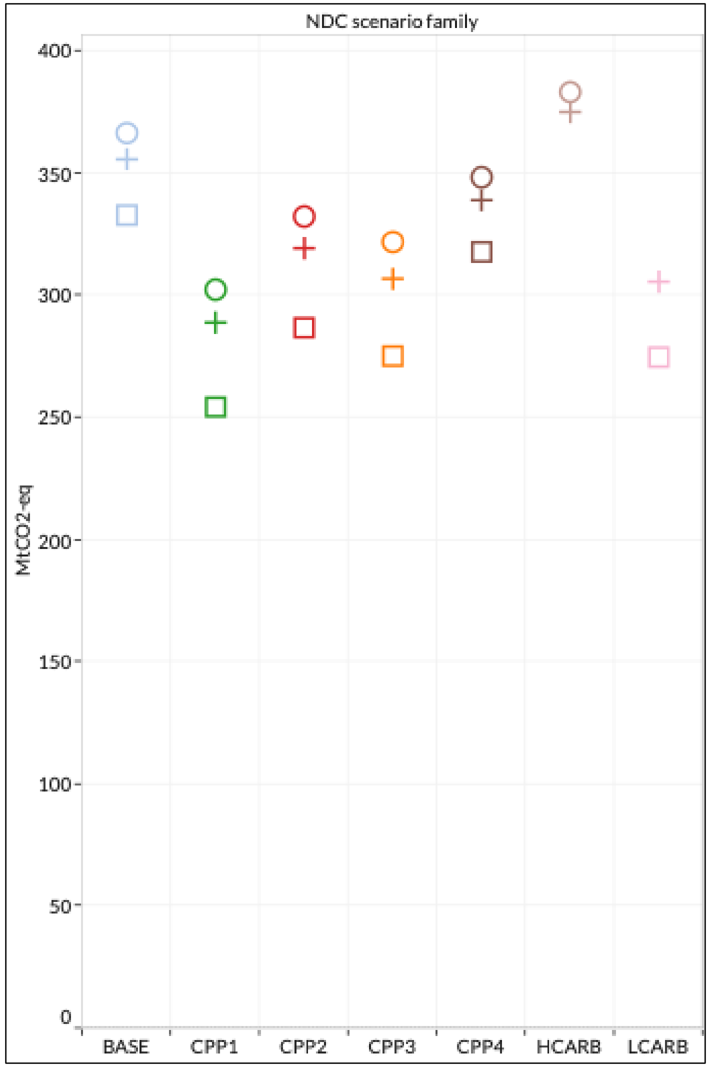
Family scenarios

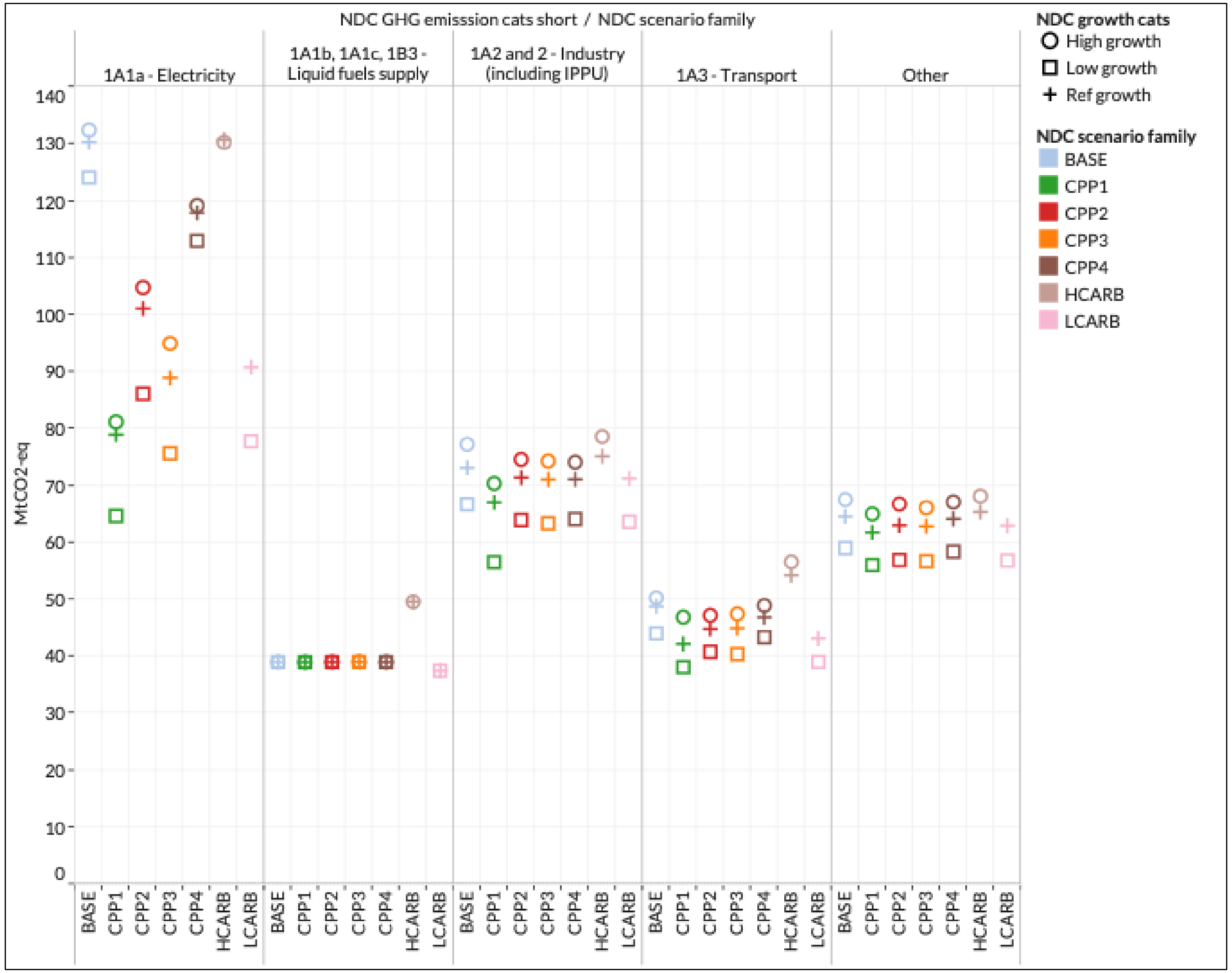


Additional mitigation



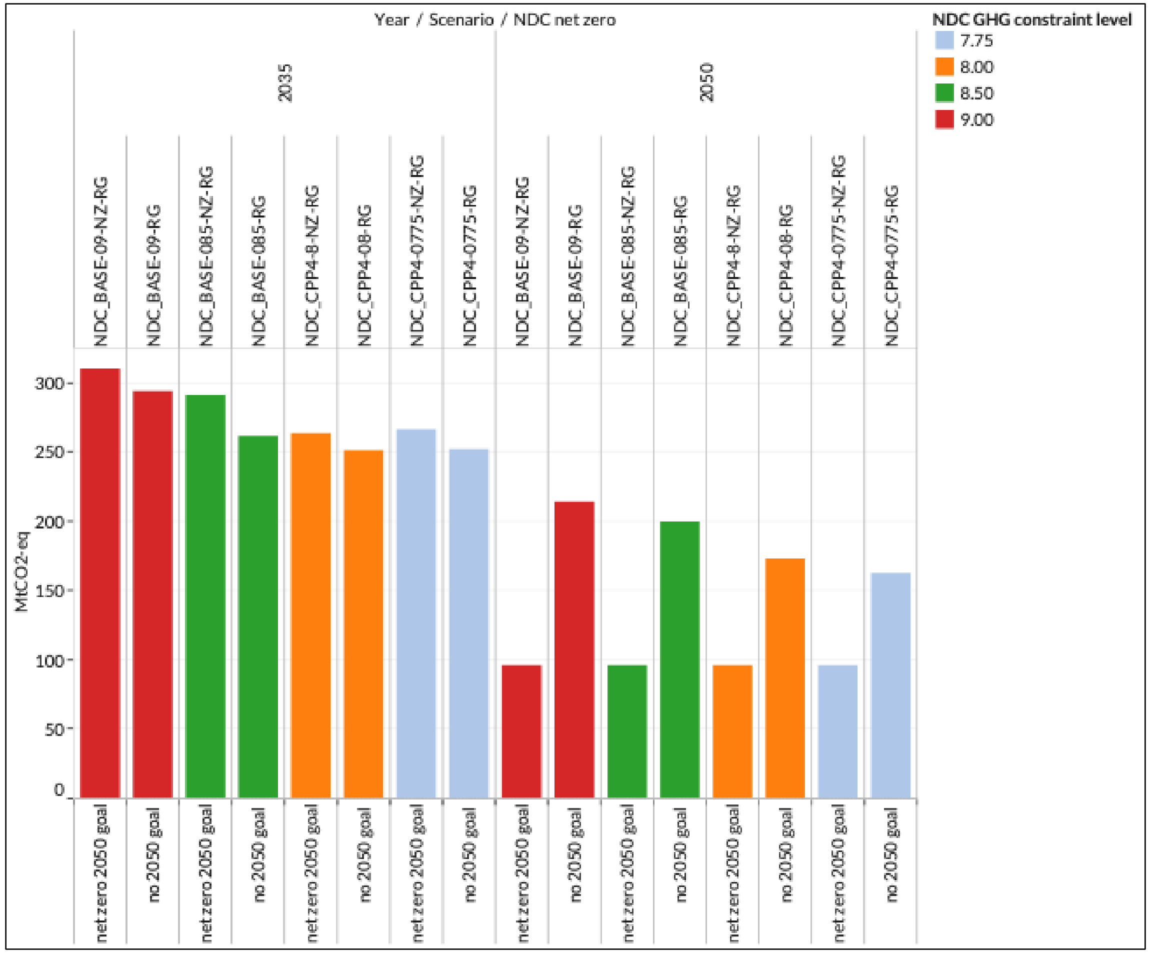
Sensitivity analyses – economic growth

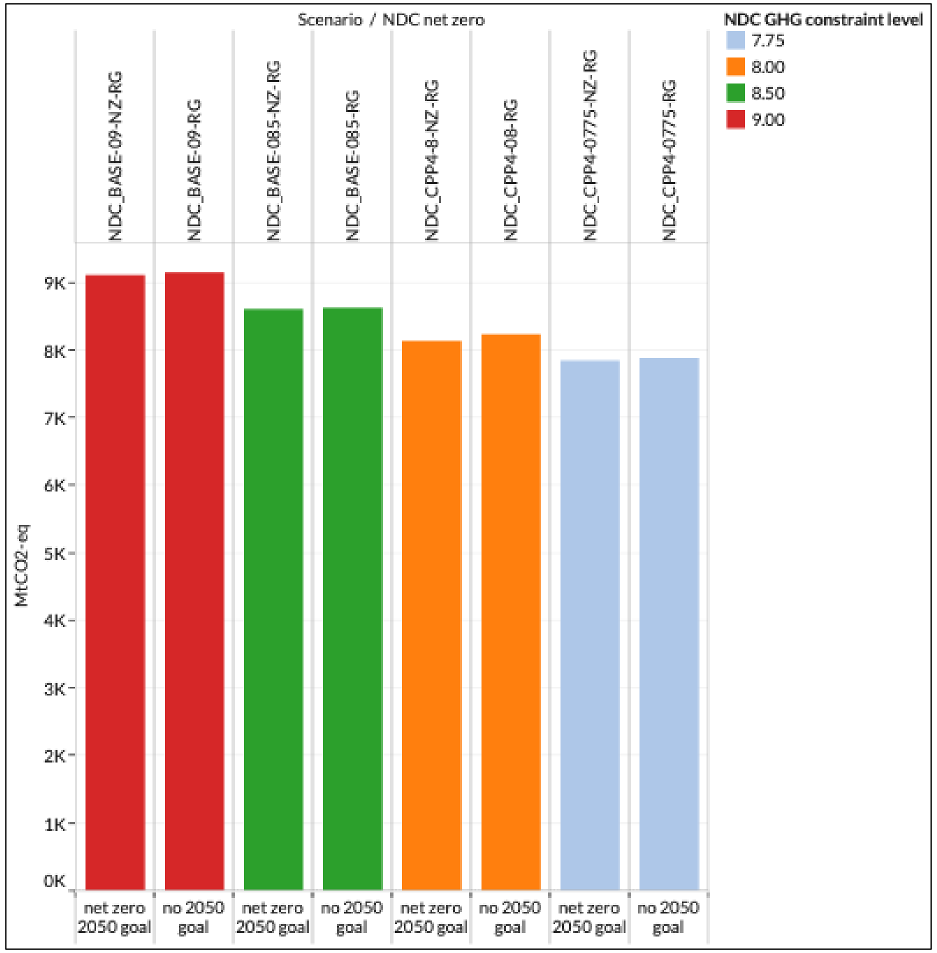




The figures on the left present the impact of different economic growth rates on GHG emissions outcomes in 2035, in total (left) and by major emissions source (right). The impact rates is significant –**high growth rates increase GHG emissions by between 33 to 48 Mt in 2035**. Much of this is in the difference between the reference growth rate and the low growth rate. Some of this change is driven simply by increased economic activity, whereas the impact on energy emissions is more complex and depends on available high-carbon infrastructure in each sector. Where capacity is optimized, the coal fleet will reach capacity before additional capacity is added, whereas in the cases where this is constrained, higher growth will lead to increased use of the coal fleet.

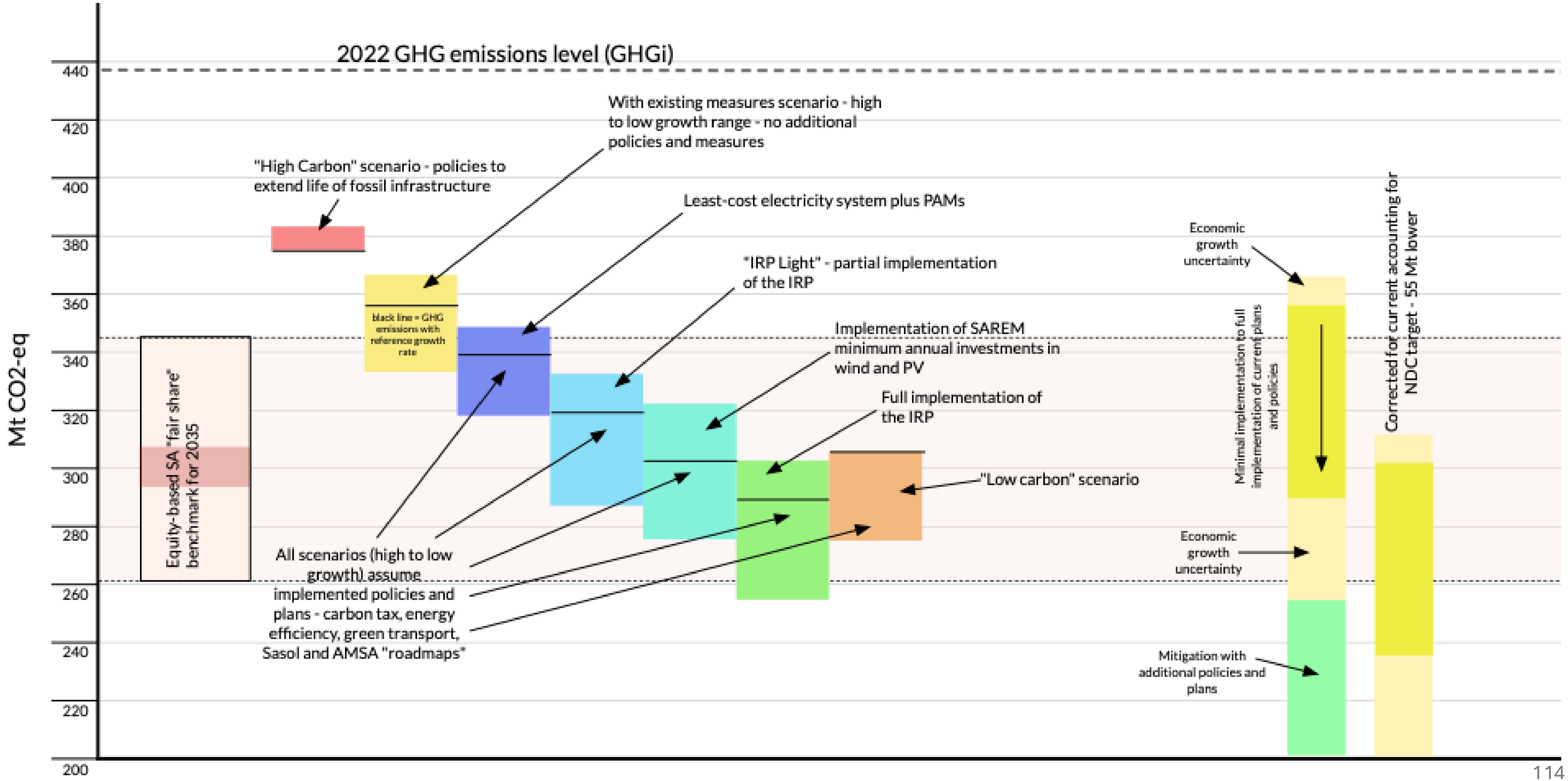
Impact of a long-term net zero goal, and observations on the long-term emissions budget





The figures above present pairs of modelled cases with identical long-term GHG emissions budgets / constraints (for total GHGs, 2021-50), but with different GHG goals for 2050 – GHG emissions levels in 2035 and 2050 (left – all gases) and aggregate emissions (2021-50) (right – all gases). The "net zero 2050 goal" cases have an emissions goal of net zero CO_2 in 2050 as well as an aggregate emissions budget from 2021-50, whereas the "no 2050 goal" cases only have an aggregate emissions budget (21-50). The aggregate budget is allocated by the model on a least-cost basis. Because the net zero goal requires rapid reductions in the 2040s to reach the goal, a greater part of the budget is available in the first two decades – hence the 2035 GHG emissions level in the net zero cases is higher than the 2035 level in the non-net zero cases with the same budget.

Summary of GHG emissions outcomes in 2035, with different economic growth rates and adjustment for NDC accounting (natural disturbances)



Sources of uncertainties in mitigation outcomes

GHG base data – Mitigation analyses are calibrated using available historical GHG information, which is compiled by the DFFE's GHG inventory (GHGi) team for both national policymaking and to fulfil international reporting obligations under the Paris Agreement. The South African GHGi is highly regarded internationally, The GHGi includes an assessment of uncertainty, which is estimated to be "11.9%-12.3%, with a trend uncertainty of 8.8%.. .. Excluding LULUCF reduces the overall uncertainty to 5.7%-6.4%, which is a reduction of the uncertainty from the last inventory." (DFFE 2024(a)). This assessment confirms the assessment undertaken for this analysis of different data sources for energy production and consumption, which indicate uncertainties in total annual fossil fuel use of around 5%. This uncertainty in the base data does not translate linearly into uncertainties in model results.

Land use emissions, including natural disturbances – there are two forms of uncertainty in modelling future land use emissions: 1) uncertainties regarding historical GHG time series; and 2) future projections of LULUCF emissions make use of long-term aggregate trends, and do not model large annual fluctuations which the historical data demonstrates. While the long-term trend in LULUCF emissions in South Africa is a slowly increasing GHG emissions sink of 35 000 Mt, emissions have fluctuated annually by as much as this amount. This poses a very significant challenge to a GHG emissions target in a specific year; there are approaches to accounting for the target which could address this uncertainty, which are discussed below.

GDP growth rate – this has been discussed above;

Technology capabilities and costs – especially in the energy sector, the rate of current technological innovation, the speed at which the costs of key technologies have been changing, and the speed of adoption of new technologies poses a significant source of uncertainty.

Developments in 2024 – Recently-available data for 2024 indicates that GHG emissions from the electricity sector are higher than anticipated (200 instead of 185) due to the actual EAF being higher than the estimate for 2024 in draft IRP 2024 (which was used in SATIM). This would mean that total GHG emissions in 2024 would be 15 Mt higher if SATIM EAF assumptions are updated.

Accounting for SA’s 2035 mitigation target

Accounting approach for the SA mitigation target for 2035

Under the Paris Agreement, countries are required to account for the implementation and achievement of their NDC targets. This is then reported in countries' Biennial Transparency Reports (BTRs). The way in which countries choose to do this has a potentially large impact on the actual GHG emissions level needed to reach their target. The Updated 2021 NDC contains NDC targets for the years 2025 and 2030. The targets consist of a GHG emissions range (in absolute terms, i.e. not defined in relation to a reference point) in each year, covers all gases, sectors and sources, but will be accounted for by EXCLUDING GHG emissions from natural disturbances (see subsequent slide); the same FORM of target will be contained in NDC2, for the year 2035.

In order to understand the potential impact of the accounting process, it is useful to draw on South Africa's first BTR, submitted in 2024. The BTR defines the indicator which South Africa will use to account for its NDC as total net annual GHG emissions, excluding natural disturbances. As in the table below, the difference in 2021 and 2022 was 40-50 Mt. The magnitude is partly an outcome of the DFFE's GHG inventory team having access to far more accurate land use data.

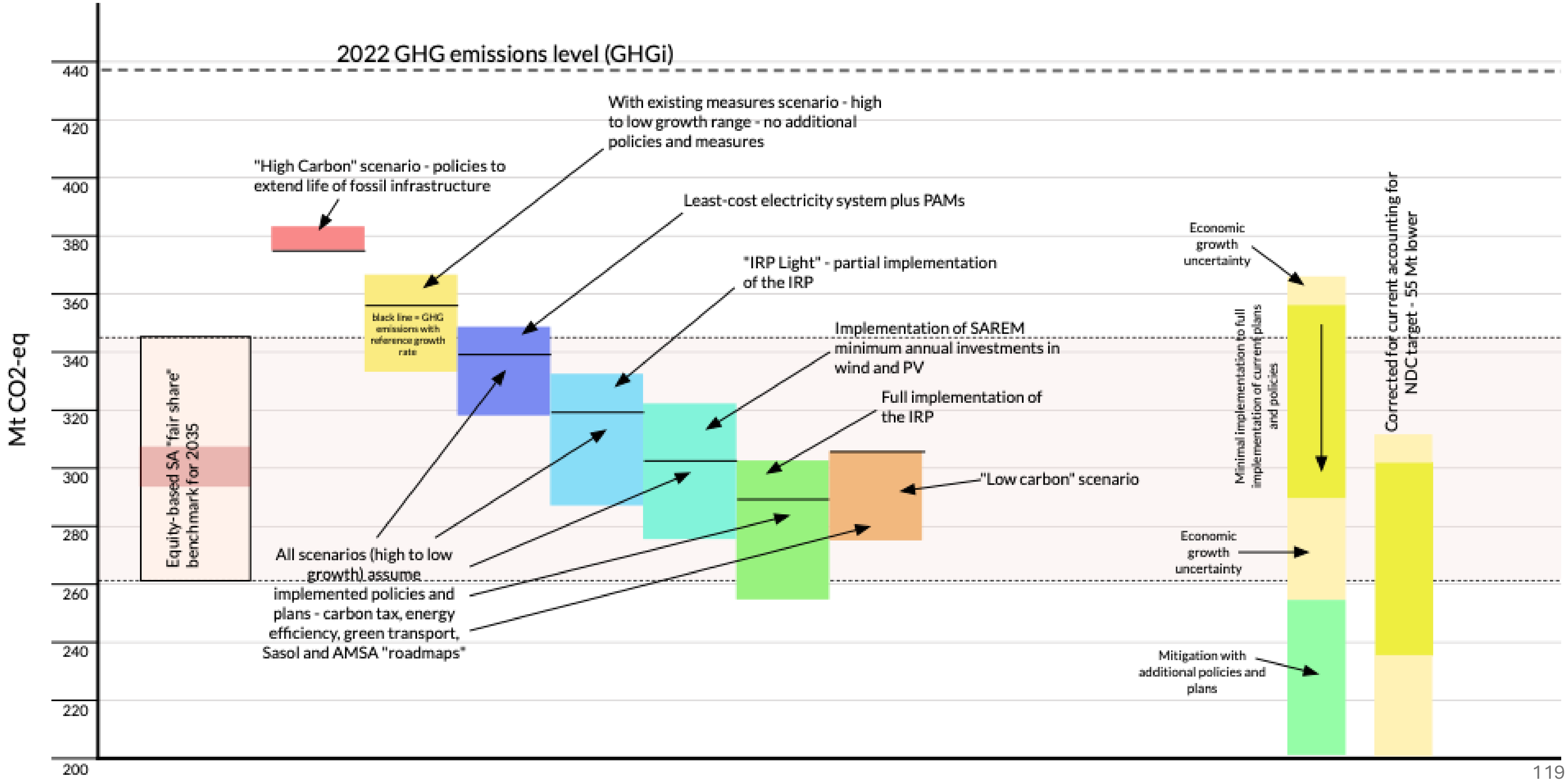
	Total annual GHG emissions including natural disturbances (Mt CO_2-eq)	Total annual GHG emissions excluding natural disturbances (Mt CO_2-eq)	Difference (Mt CO_2-eq)
2021	465	413	52
2022	435	394	41

The rationale for exclusion of natural disturbances is that since these are subject to very large annual fluctuations, which will mask the mitigation signal in the rest of the economy. The current NDC draft proposes to continue to exclude these emissions sources from accounting for our target, for the same reasons. There are two issues which would need to be addressed by policymakers in this regard: 1) the exclusion of natural disturbances, without the exclusion of the absorption of CO_2 following the disturbances, is a form of double counting – not supported under the Paris Agreement; and 2) if the mitigation target is set without excluding natural disturbances from GHG emissions estimates for the target year, then the target will be 55 Mt LESS ambitious than a target with an identical GHG emissions level which includes natural disturbances (55 Mt is the projected value for natural disturbances in 2035 used in SATIMGE).

An alternative would be to account using an average value for the 5-year implementation period of the NDC for either natural disturbances, or for the whole land sector. The latter is particularly effective at addressing the annual fluctuation problem, and also ensuring complete coverage of South Africa's mitigation target and enhancing transparency, which would also be a form of progression. Historical data indicates that over the period 2000-2022, the maximum annual fluctuation of land use emissions including natural disturbances was 27 Mt CO_2-eq; excluding natural disturbances decreases the average annual variability from 10 Mt to 3 Mt, but the maximum annual fluctuation is still 27 Mt; using a running average for land sector emissions in total reduces the maximum annual fluctuation to 6.2 Mt, and the average to 2.5 Mt.

Evaluating potential target ranges against benchmarks

Summary of GHG emissions outcomes in 2035, with different economic growth rates and adjustment for NDC accounting (natural disturbances), compared to “fair share” banckmark



Criteria for assessing mitigation ambition - summary

1. Equity: Compare GHG outcome in 2035 with fair share ranges of 1.5 °C; other, lower benchmark studies; consider longer-term context; delay means disruptive change later

2. Highest possible ambition: consider modelled outcomes of implementing current policies and plans; contribution to long-term global goal on mitigation ('net zero' globally), significant progression towards net zero CO_2 emissions by 2050

3. Socio-economic, "just" part of transition: consider speed, impact of transition, and what additional measures would be required to address these; balance long-term gains and short-term needs

4. Risk of not achieving the target: compare proposed target level with modelled outcomes of policies/plans; note that GHG emissions peaked in 2008/9 and were 439 Mt CO_2-eq in 2022

5. GST outcome taken into account seriously; how SA responds is nationally determined

6. Competitiveness: to what degree do policies and plans implemented position SA to be competitive in decarbonizing global economy?

7. Consistency with policy goals: assess against modelled outcomes; assume implementation of current plans

8. Green industrialization / economic diversification: Does implementation of policies and plans diversify economy and advance green industrialization?

In order to consider which mitigation target range South Africa should adopt for NDC2, GHG emissions outcomes between 240 and 380 Mt CO_2-eq by 2035 are assessed in 20 Mt increments, against several criteria, summarized below.

Range	Assessment against multiple criteria
360-380	Existing policies and plans not implemented; Not consistent with international “fair share” (as assessed with CERC). Risk of not achieving the target (keeping GHG emissions below the upper end of the range) very small; claim of ‘highest possible ambition’ very difficult to support. Not taking GST1 into account strongly; not competitive in future global economy; misses opportunities to diversify economy and low emission sustainable development; High risk of border tax adjustment from some trade partners. Cautious and risk-averse.
340-360	Existing policies and plans not fully implemented; Mostly not consistent with international “fair share”. Risk of not achieving the target low; claim of ‘highest possible ambition’ not credible. Not taking GST1 into account strongly; not very competitive in future global economy; misses opportunities to diversify economy and low emission sustainable development; Significant risk of carbon border adjustment measures (CBAMs). Tentative
320-340	Implements existing policies, incl. IRP in part. Consistent with top of fair share ranges. Some further ambition, and progression from 2030. Risk of missing target still low, only if not even partly implemented. Takes account of GST1. Starts to position SA for future global economy, and diversify SA economy. Some benefits for socio-economic development. Lesser impacts of CBAMs. Prudent.
300-320	Implements existing policies, incl. full IRP – to get to 300 Mt. Consistent with fair share ranges. Further ambition, and progression from 2030. Risk of missing target moderate, if not fully implementing policies. Takes account of GST1. Better position SA for future global economy, and helps economic diversification and green industrial policy in SA. Long-term benefits for socio-economic development. Lower impacts of CBAMs. Ambitious-but-realistic.
280-300	Implements existing policies, incl. IRP and SAREM. Well in fair share ranges. Moderate risk of missing target, additional mitigation measures will possibly be required, depending on economic growth rate . Demonstrates progression in mitigation ambition. Takes account of GST1. Long-term thinking in diversifying SA economy and positioning in future global economy. Investing and paying some costs now, to benefits to socio-economic development later. Increased ambition.
260-280	Rapid implementation of IRP, SAREM and other mitigation measures, incl. in industry, transport and other sector and end uses. At low end of fair share range. Consistent with green industrialisation, diversifies SA economy and positions well in future carbon-constrained global economy. Meeting target would require a more ambitious just transition programme to be implemented. Lower end sends clear signal to international community. Challenges for current socio-economic development Impact of CBAM negligible. Priority mitigation ambition.
240-260	Very rapid implementation of IRP, SAREM and would require additional mitigation measures. Below low end of fair share range (though not some benchmark studies that do not apply equity). High risk of missing target. Very rapid change likely disruptive., impacting socio-economic development and even green industrialisation. Good positioning for global economy but possibly at risk of domestic economy. Very challenging for current socio-economic development No risk of CBAM. Mitigation ambition is only focus.

Investment needs for mitigation and just transition for South Africa’s 2035 NDC

Assessing mitigation and Just Transition investment requirements

- South Africa has a long and rich body of work on just transitions, developed both inside and outside of government. In national policy, this includes in the National Climate Change Response White Paper (2011), the first I-NDC, the updated first NDC (2021), the work of the National Planning Commission (2010-2019) and the Presidential Climate Commission (2019 – present), culminating in the National Just Transition Framework, approved by Cabinet in 2022 and the Climate Change Act of 2024.
- The Climate Change Act is intended to "enable the development of an effective climate change response and a long-term, just transition to a low-carbon and climate-resilient economy and society for South Africa in the context of sustainable development" and defines a just transition as a shift towards a low-carbon, climate-resilient and ecologically sustainable economy and society which contributes toward the creation of decent work for all, social inclusion and the eradication of poverty (RSA, 2024).
- Similarly, policy developments across national sector departments include the DFFE's NEVA and SJRPs, the DMRE's JET Framework, and the DoT's draft Transport Just Transition plan), in provinces (for example, Mpumalanga's Phase I JT plan), municipalities (eg STLM's IDP), and in the work of Eskom's JET Office, overseeing Eskom's coal plant decommissioning and repurposing pathway.
- Alignment with JET-IP programmes and implementation in JETP sectors but also addressing impacts in sectors that were not contemplated in the IP due to timing or mitigation actions outside of JETP scope (eg DFFE SETs investments, EEDSM investments)
- The national Just Transition Framework focuses on four critical value chains, two of which are substantial emitters of greenhouse gases whose future is key to mitigation ambition, and which have significant socio-economic transition risks, namely the coal and automotive value chains.
- Policy approaches that improve outcomes towards justice (distributive, restorative and procedural) should include human resource development and skills; economic diversification, industrial development and innovation, and social protection measures.
- We have prioritized our analytic efforts in the sectors with highest mitigation (electricity, coal, and transport sectors) and socially just investment needs within those. Each intervention is categorised as to whether it is a mitigation or just transition intervention (or both), and which aspect of just transition the intervention contributes to, eg industrial development, etc.

Approach to building a comprehensive assessment of financing needs

- Organised by major emitting sector – electricity, coal , transport and automotive value chains; industry, end uses/EEDSM
- Risks and impacts identified from existing policy documents and literature (international and local)
- Methodology developed to assess investment needs: for modelled investments, eg infrastructure, this is an outcome of the bottom-up modelling and selected target range, or existing investment plans and needs in sub-sectors (eg transport, grid strengthening)
- Other investments must be calculated exogenously, for example workforce transition support (based on JET-IP methodology) or EV charging infrastructure (based on the number of EVs over time)
- We have aligned as much as possible with JET-IP and draft SETs-IP but some comparative limitations remain (especially extending those estimates further into the future)
- Social elements require stakeholder input to capture most recent trends, needs and forecasted requirements (SAREM, Transmission and Distribution supply chain/localisation investments)
- Many indirect investments need further work to cost or lack data for costing currently, notably supply chain investments in transport and electricity (rail, transmission, renewables, battery)
- Many JT interventions remain uncosted in the literature and require more data and analysis to assess the costs and financing options to address impacts
- Nascent investments (eg under the JET-IP) provide some data and as the ecosystem matures and these approaches advance, more information on concrete financing needs for projects will become available (for example through the Funding Platform)

Interventions for investment in mitigation and just transition: Transport

- Passenger modal shift: increase in public transport (buses and BRTs)
- Passenger modal shift: road-to-rail
- Freight modal shift: road-to-rail
- Increase in electric mobility: private passenger vehicles
- NEV charging infrastructure
- Increase in electric mobility: public passenger vehicles (minibus taxis and buses/BRTs)
- NEV Automotive manufacturing
- Worker transition support - employment impacts: petrol attendants, mechanics, dealerships
- Supply chain/ manufacturing of rail infrastructure (rolling stock, locomotives, rails, etc)
- Decommissioning/ site rehabilitation/ remediation of forecourts/garages

*not costed but TA/research programmes are proposed to develop estimates for financing needs and modalities

Interventions for investment in mitigation and just transition: electricity

- Utility-scale generation capacity: solar photovoltaic
- Utility-scale generation capacity: wind
- Utility/ large scale Battery energy storage system
- Pumped hydro storage system
- Embedded/ distributed generation capacity: solar photovoltaic
- Biogas (municipal waste water-to-energy)
- Transmission network (extension and strengthening)
- Distribution network (extension and strengthening)
- Social ownership of renewable energy and process
- 100% electrification of households
- Energy access provision improvements: efficient refrigeration
- Power market design and training and capacity building for social partners, market participants, munics etc

- Transmission: manufacturing and supply chain
- Distribution: manufacturing and supply chain
- Advanced metering infrastructure and digitalisation
- Energy access provision improvements for low-income households: energy service package
- Coal plant flexibility programme
- South African Renewable Energy Masterplan (SAREM) - localising generation and storage
- *not costed but TA included where possible to advance knowledge base

Interventions for investment in mitigation and just transition: end use sectors

- Commercial building EE
- Residential EE
- Agriculture and forestry EE
- Industrial EE
- DFFE SETs
- DWS SET
- Sustainable Manufacturing Support
- EEDSM roadmap, strategy development, planning

Interventions for investment in mitigation and just transition: coal and Mpumalanga

Decommissioning, repurposing, and repowering coal plants (Arnot, Kriel, Matla, Duvha)

Coal mine closure, rehabilitation, and land repurposing including rehabilitation shortfalls

Infrastructure improvements and service delivery (aligned with infrastructure for development programme under JET-IP)

Programme to assess service delivery costs to be transferred to municipalities from mines and Eskom e.g. waste water treatment, waste collection, transport services etc and funding options

JETP Funding Platform project pipeline, project preparation facility, business development support, and investment; (Aligned with Diversifying local economies programme under the JET-IP)

Coal workforce transition and youth and skills support (aligned with JET-IP programmes)

Core support for critical institutional strengthening and capabilities (eg on-budget support to government, secondments, MP Green cluster, etc) incl planning and institutional support for coal closures 2035 onwards

Supporting transition-impacted communities with governance and finance and implementation for grassroots projects for economic diversification opportunities

- Impacts on coal transport (e.g truckers) or other value chain impacts including suppliers and informal economy
- Steve Tshwete economic diversification projects
- Unlocking investments to enhance short-term employment growth in sectors identified by PCC analysis (aligned with JET-IP programmes on workforce, youth, and diversification)
- Support for Nkangala D-Lab identified investments and actions
- Public Employment Schemes in transition affected areas
- Not costed but included for completeness

Data for historical climate finance flows

- Climate finance flows have been estimated in the First Biennial Transparency Report (BTR1) (public, international, bilateral and multilateral using grants, technical assistance, equity, concessional loans) for 2021 and 2022 totalling USD 816.9m from bilateral and USD10.7m from multilateral sources (for mitigation, adaptation, and cross-cutting actions).
- CPI estimates including domestic, private, commercial sources and instruments, as well as international public support totals R131bnpa covering 2019-2021.
- The JET PMU tracks grants, concessional and policy loans, equity and debt instruments, and audits from bilateral and multilateral partners for JET-IP sectors/programmes
- Tracking is improving over time and data under JET-IP suggests growth over time
- Overall, a consistent data set should be developed and maintained, aligned with international reporting requirements and enabling tracking against proposed interventions and programmes, thus enabling NDC implementation monitoring

Investment cost assessment summary and by sector

Choosing a pathway for investment costing

For South Africa to achieve the proposed NDC target range in 2035 of 380-320Mt CO2eq will require the mobilisation of substantial investment, both international and domestic, public and private, commercial and non-commercial.

For some critical mitigation and enabling investments, the policy and regulatory regime, alongside mature technologies already in place, support commercial investments, including international debt and equity.

These remain critical for climate action but can be pursued largely by the private sector, shaped by government through existing or emerging policy, regulations and programmes (REIPPPP, SAWEM, ITPs, Masterplans)

Meeting the NDC target range, or a point within it, is achievable through multiple pathways or combinations of market and policy interventions. While the electricity sector is key in all pathways, a given target can be achieved with varying emphases/mechanisms. It is therefore difficult to create an investment costing for the entire range, given that various approaches and sectoral efforts can be consistent with the same target (but with different costs), and different investment combinations could result in a single point within the range. Similarly, different emissions pathways (themselves an outcome of given policy choices, technology pathways, retirement schedules, and GDP growth drivers) will be accompanied by differing impacts and outcomes, eg on sectoral workforces etc.

Investment and just transition costing thus dives into a single pathway (amongst several possible pathways) that is consistent with ambitious GDP growth assumptions (to account for emissions growth from economic recovery), existing policies, and is within the most ambitious (lower) end of the range for 2035.

Mobilising these investments is thus a critical enabling lever for the achievement of the ambitious (lower) range of the mitigation target and international support will be critical in meeting the lower range and existing policy goals

Scenario and target level for just transition and mitigation investment costing

The representative pathway for which investment and just transition requirements has been assessed, results in emissions of 322 Mt CO_2-eq in 2035 and assumes the implementation of the SAREM, the other policies and plans assessed above, and the high economic growth rate specified above.

The pathway captures the existing policy direction in South Africa in that it includes consistency with and implementation of existing policy and plans in South Africa including in electricity and industry (SAREM, CTL roadmap, DTIC White Paper EVs), existing NEES implementation trends, grid expansion (NTCSA's Transmission Development Plan and DEE's ITPPPP), modal shift investments (Transnet and PRASA investment plans), DoT's Transport JT Plan, DEE's energy access goals, the JET-IP and National Treasury's carbon tax.

This target level is therefore achievable **with the existing policy toolbox available** to government.

Estimations for South Africa's fair share (adjusted to include land use emissions) for 2035, using a methodology consistent with equity principles contained in the UNFCCC and its Paris Agreement, range from **345-261 Mt CO_2-eq**, depending on how the key principles of capability and responsibility are weighted.

The investment pathway target level is ***above*** **the CAT fair share upper limit** for South Africa for 1.5^{o}C in 2035 of 261 Mt, and **within the CAT 'almost sufficient' upper limit of 344 Mt** for 2035; it is **within the CERC fair share range** for 2035 for 1.5^{o}C of 261-345 Mt assessed here (dependent on chosen global pathways and weightings).

The target level is above the BUSA/NBI/BCG modelled target for South Africa in 2035 of 310 Mt.

The investment pathway and resulting target level for 2035 of 322 Mt CO_2-eq thus responds to both domestic just transition goals and international equity considerations.

Mitigation and just transition investment needs

Sector	Investment quantum 2026-2035 Million ZAR (2022 ZAR)
Electricity	1 701 449
Coal and Mpumalanga	88 592
Transport and automotives	1 642 259
EEDSM and end uses, incl SETs	40 937
Total investment 2035 NDC	**3 473 237**

- Costed investments total R3.5 trillion from 2026-2035 or R350bn/year on average
- These are not incremental/additional to BAU but total costs
- Many investments are common to many pathways and are aligned with existing policy/plans
- Notably, common investments are required for Mpumalanga's Just Transition investments for closing assets
- Green hydrogen investments still to be included

Transport and Automotives

Mitigation/ supporting or enabling infrastructure/ Just Transition-	Sector, intervention/ transformation	Cumulative investments Million ZAR 2026-2035	Cumulative infrastructure	methodology for estimating investmen need	methodology notes
Mitigation and just transition (service delivery)	Passenger modal shift: increase in public transport (buses and BRTs)	57 000	19,600 electric buses; 400 electric BRTs; 2,200 ICE BRTs	Number of electric buses deployed x capital cost of bus (including capital cost declines)	share of pkms translated to vehicle numbers and capex for vehicles
Mitigation and just transition (service delivery)	Passenger modal shift: road-to-rail	70 000	~1200 trainsets (~7200 coaches)	Drawn from PRASA annual reporting (see 2023/24) calibrated with rail pkm rise in inv scenario from 3 billion pkm (2024) to 14 billion pkm (2035)	modelled result, SATIMGE and Transport Just Transition Plan (passenger transport will still be road-dominant in 2035)
Mitigation	Freight modal shift: road-to-rail	430 000	~100 Mt additional rail capacity (incl. locomotives and rail network expansions and increased utilisation of existing infrastructure)		modelled result coupled with estimate analysis of Transnet current capex performance (2023/2024) and stated target of 250 Mt rail transported (Transnet only excl. private) in 2035 (from 151 Mt in 2024)
Mitigation	Increase in electric mobility: private passenger vehicles	860 000	2.5 million passenger NEVs	Cost per EV x uptake (R344 000 x 2 500 000)	modelled result, SATIMGE, TJTP
Supporting/enabling infrastructure	NEV charging infrastructure	26 250	250 000 AC chargers (incl. home) + 25 000 DC chargers excl. elec costs	estimated using model results but charger costs and split between AC and DC analysed outside of the model Assume 1 AC charger per 10 Evs, 25k ZAR per charger, and 1 DC charger per 100 Evs, 800k ZAR per charger	R8,5m / fast charger (AUDI/Rubicon 2024, TIPS FDI tracker Q4 2024); 2x charging points per charger (BD live). With grid cars
Mitigation and just transition (forward looking)	Increase in electric mobility: public passenger vehicles (minibus taxis)	66 000	90 000 electric MBTs		capex costs and finance package? Manufacturing vs retrofit
Just Transition (forward looking): economic diversification and enabling investments	NEV Automotive manufacturing	133 000	Automotive production capacity of ~665000 EVs pa by 2035	Drawing on estimate for domestic EV market growth plus market intelligence report on export market for target EV production value, plus global and domestic benchmarks for EV line capex and opex costs lower than TJTP estimate of R342 bn for OEMs (but this incl. battery value chain) and R68bn in tax support	modelled result, SATIMGE and White Paper; GreenCape MIR
Just Transition (impact mitigation) - technical assistance	Worker transition support - employment impacts: petrol attendants, mechanics, dealerships	2	Assess impacts over time and design and cost support packages		
Just Transition – industrial innovation forward looking; enabling infrastructure	Supply chain/ manufacturing of rail infrastructure (rolling stock, locomotives, rails, etc)	5	leverage existing industrial capabilities for domestic and export scale up - assess potential for localisation and design policy and investment packages		
Just Transition (restorative) - technical assistance	Decommissioning/ site rehabilitation/ remediation of forecourts/garages	2	phase I: TA to assess spatially disaggregated pathways and closure phase II: assess funding gaps for remediation of closing sites		
Total	**Transport, automotives and mobility**	**1 642 259**			

Electricity 1

Mitigation/ supporting or enabling infrastructure/ Just Transition - forward looking or impact mitigation; decent work, social inclusion, industrial development, skills	Sector, intervention/ transformation	Cumulative investments millions ZARs 2026-2035	Cumulative infrastructure	methodology for estimating investment need	methodology notes
Mitigation, just transition forward-looking (industrial development)	Utility-scale generation capacity: solar photovoltaic	241 000	24.322 GW	These include some committed projects entering commissioning in 2025-2027	modelled result, SATIMGE, tested with PLEXOS, PYPSA and Flextool
Mitigation, just transition forward-looking (industrial development)	Utility-scale generation capacity: wind	404 000	18.6 GW	These include some committed projects entering commissioning in 2025-2027	modelled result, SATIMGE, tested with PLEXOS, PYPSA and Flextool
Mitigation, just transition forward-looking (industrial development)	Utility/ large scale Battery energy storage system	109 000	7.485 GW	These include some committed projects entering commissioning in 2025-2027	modelled result, SATIMGE, tested with PLEXOS, PYPSA and Flextool
Mitigation	Pumped hydro storage system	56 000	Tubatse PHS 1 500 MW	Based on IRP 2024 and converted for currency years to 2022	ISA SIP estimate of R35 900 is lower than Eskom Generation number from IRP 2024 used in SATIMGE (R41 651/kW in assumed 2024 ZAR)
Mitigation	Embedded/ distributed generation capacity: solar photovoltaic	66 000	5000 MW over period (500 MW/year)	based on IRP 2024 with a lower bound to account for slower uptake and relative costs vs utility scale solar and current uptake trends	Policy assumption, IRP 2025
Mitigation	Biogas (municipal waste water-to-energy)	2 000	235 MW	Costs for capacity assessed in Nagel, 2019 and Capacity based on Stafford et al (2013) assessment of potential for municipal waste to energy	Scenarios with similar emissions outcomes often include the build out of the maximum biogas capacity of 1.26 GW and up to R27 bn total investment.
Supporting/ enabling infrastructure, Just Transition forward-looking (industrial development)	Transmission network (extension and strengthening)	395 189	A least 14 494km of powerlines, 132 650 MVA transformers, 2692 MVar capacitors, 16260 MVar reactors, 8 syncons to 2034 and additional expansion for 2035 capacity	NTCSA Capex plan of 112 534 and 2031-2035 expansion capex of R331bn, converted to 2022 ZAR.	Based on Transmission Development Plan (TDP 2025-2034 NTCSA) investment estimates (5yr capex plan/project level) supplemented with modelled results, SATIMGE to 2035 (via demand-linked premium). ITP projects assumed to be included in TDP estimates. SATIM capital expansion estimates account for 75% of NTCSA capital plan for the TDP, so we apply an increase to account for refurbishment, telecomms, real estate etc to ensure comparability with the NTCSA capex plan to 2030. Cross-checked against TDP and GCCA line deployment and then increased to account for line types. Converted from 2024 to 2022 ZAR at 0,891. Similar to announced TDP investment value of R440bn in 2024/25 financial year

Electricity 2

Supporting/ enabling infrastructure, Just Transition forward-looking (industrial development)	Transmission: manufacturing and supply chain	TBD		methodology for estimating investmen need	methodology notes
Supporting/ enabling infrastructure, Just Transition forward-looking (industrial development), energy access	Distribution network (extension and strengthening)	319100	5000km of new high voltage lines and 400 new high and medium voltage transformers with 53 000 MVA (LSF, 2023)		Aligned with JET-IP needs assessment. Modellig framework does not account for spatial detail of Distribution and thus underestimate investments needed at R65bn foor peak demand matching and R13.8bn for supply side). JET-IP estimates account for more dtetailed investment requirements and are therefore used.
Just transition, forward looking: industrial development	South African Renewable Energy Masterplan (SAREM) - localising generation and storage	1600		use JETP factory cost estimates to match localised production - need annual local outputs to calc factory capacity needs. Currently aligned with JET-IP investment requirements but underestimate	Need to align with new JET-IP portfolio
Supporting/ enabling infrastructure, Just Transition forward-looking (industrial development)	Distribution: manufacturing and supply chain	TBD			
Supporting/ enabling infrastructure	Advanced metering infrastructure and digitalisation	TBD			Scale up of pilot deployment from 2030-2035
Just transition, forward looking	Social ownership of renewable energy and process	250		At least 50 projects and R5m in project related support per project (lower than international peer countries such as Colombia)	Technology costs are accounted for in the new gen capacity line, but community/social ownership may require innovative or novel financing structures and resources to realise the justice ambition for various stakeholders across different socially-owned models
Just transition (service delivery and social protection) and mitigation; social inclusion	Energy access provision improvements: all low-income households have access to 350kWh energy/hh/month for a package of energy services	TBD			Based on ESRG social provision scenario: 1. 350 based on energy service needs for households
Just transition (service delivery and social protection) and mitigation; social inclusion	100% electrification of households through grid/off-grid/ mini-grid as needed DoEE goal for 2030 on electrification	74800		74800000000	JET-IP assumed R22 000/hh connected; 3.4million unelectrified households in 2025, assume no growth
Just transition (service delivery and social protection) and mitigation; social inclusion	Energy access provision improvements: efficient refrigeration rolled out to all low-income households by 2030	32500	6.5 million new energy efficient fridges deployed	Low end capital cost (R5000) for mid-range fridge-freezer combo, deployed for all low income households (6 500 000)	6,5 million households provided energy efficient fridges through swap programme (JT and HFCs).
Mitigation	Coal plant flexibility programme	TBD			
Technical assistance and capacity building	Power market design and training and capacity building for social partners, market participants, munics etc	10			20 training sessions for market participants, municipalities and social partners
Technical assistance and capacity building					
Total	**Electricity sector**	**1 701 449**			

Energy Efficiency, DSM and end uses, including SETs

Mitigation/ supporting or enabling infrastructure/ Just Transition - forward looking or impact mitigation; decent work, social inclusion, industrial development, skills	Sector, intervention/ transformation	Investment value: 2026-2035	methodology for estimating investmen need	methodology for estimating investment need	methodology notes
	Commercial building EE	12868			From SETs-IP and inflated to 2022 ZAR (2019*1,152)
	Residential EE	13363			From SETs-IP and inflated to 2022 ZAR (2019*1,152)
	Agriculture and forestry EE	3802			From SETs-IP and inflated to 2022 ZAR (2019*1,152)
	industry sectors	2880			From SETs-IP and inflated to 2022 ZAR (2019*1,152)
	DFFE SETs	6705			From SETs-IP and inflated to 2022 ZAR (2019*1,152)
	DWS SET	0			biogas/wastewater reflected in electricity gen investments
	Sustainable Manufacturing Support	1300			based on existing SEZ/green industry investments in pipeline
	EEDSM roadmap, strategy development, planning	20		ensure continuity in EEDSM implementation and planning and institutional arrangements	Estimate for TA
Total	**End uses and SETs**	**40937**			

Coal and Mpumalanga

Mitigation/ supporting or enabling infrastructure/ Just Transition - forward looking or impact mitigation; decent work, social inclusion, industrial development, skills	Sector, intervention/ transformation	Investment value: 2025-2030 2030- 2035 ZAR millions	methodology for estimating investment need	methodology for estimating investment need
Mitigation, just transition forward-looking (industrial development and economic diversification) and impact mitigation	Decommissioning, repurposing, and repowering coal plants (Arnot, Kriel, Matla, Duvha)	31987	Based on ACT IP and Komati estimates; investment plant cost/GW x closing GW. 11,2 GW x 168m USD = 1885 m USD	Power plants reaching the end of their lives in the NDC period (excluding Komati) Camden, Grootvlei, Hendrina, Arnot, Kriel, Matla, and Duvha. Based on CIF ACT Investment Plan 3GW @ 505m USD = 168m USD/GW (higher than Komati EJETP)
Just transition forward-looking (economic diversification and social protection) (restorative)	Coal mine closure, rehabilitation, and land repurposing including rehabilitation shortfalls	13942	Based on bottom assessment of gaps in rehabilitation funding for mines reaching LOM to 2035 as well as JET-IP estimates for abandoned mining land repurposing needs	based on JET-IP overall estimate supplemented by a mine by mine assessment of rehabilitation financial provisions and estimated shortfall for mines expected to reach LOM
Just transition (industrial development and social protection)	Infrastructure improvements and service delivery (aligned with infrastructure for development programme under JET-IP)	12300		Aligned with JET-IP as limited disbursement against programme. Proposed projects are within the envelope. Likely underestimate of need
Just Transition (social protection)	Programme to assess service delivery costs to be transferred to municipalities from mines and Eskom e.g. waste water treatment, waste collection, transport services etc and funding options	5		services currently delivered by Eskom plants/ coal mines that municipalities will need to absorb
Just Transition: economic diversification Mpumalanga	JETP Funding Platform project pipeline, project preparation facility, business development support, and investment; (Aligned with Diversifying local economies programme under the JET-IP)	24000		Aligned with JET-IP as limited disbursement against programme. Proposed projects under FP are within the envelope. Likely underestimate of need. Use FP applications to concretise over time and update
Just Transition: economic diversification and worker transition Mpumalanga	Unlocking investments to enhance short-term employment growth in sectors identified by PCC analysis (aligned with JET-IP programmes on workforce, youth, and diversification)	TBD		Assess if available
Just Transition: economic diversification	Support for Nkangala D-Lab identified investments and actions	TBD		Assess if available
Just transition – impact mitigation	Impacts on coal transport (e.g truckers) or other value chain impacts incl suppliers and informal economy	10		Need to identify impacts and design support packages and funding modalities

Coal and Mpumalanga 2

Mitigation/ supporting or enabling infrastructure/ Just Transition - forward looking or impact mitigation; decent work, social inclusion, industrial development, skills	Sector, intervention/ transformation	Investment value: 2025-2030 2030- 2035 ZAR millions	methodology for estimating investment need	methodology for estimating investment need
Just transition: worker transition and forward looking	Coal workforce transition and youth and skills support (aligned with JET-IP programmes)	4848	Support package (relocation, reskilling, severance and temporary income support) x number of impacted workers (forced job losses plus workers with age/skills profiles that make them unlikely to easily find new employment) as well retraining and redeployment for plant workers. Support package (skilling, job placement, etc) x Number of youth not entering coal mining due to reduced output vs a constant employment case	Aligned with JET-IP methodology for calculating worker support in coal workforce including Eskom and mining and extended to 2035; additional support for young workers not entering the sector. Due to life extension of Eskom plants and shifting out of plant closures, smaller number of impacted workers than in the JET-IP.
Just transition forward-looking	Steve Tshwete economic diversification projects	TBD		Just Transition identified projects in STLM IDP 2024
Technical assistance and capacity building and planning	Core support for critical institutional strengthening and capabilities (eg on-budget support to government, secondments, MP Green cluster, etc); Planning and institutional support for coal closures 2035 onwards	1350		Aligned with JET-IP.
Just transition – impact mitigation	Public Employment Schemes in transition affected areas			Assess need for updated PES estimates in support of JT efforts
Community Just Transition Fund	Supporting transition-impacted communities with governance and finance and implementation for grassroots projects for economic diversification opportunities	150		Based on CJTF estimates of small scale grant disbursement to community-led projects from 2026-2035
Total		**88592**		

Methodological considerations

- **Limited availability or poor quality of data**

The most critical challenge in identifying the quantum of investment needed for mitigation and just transition to 2035 is a lack of granular data. Data remains a challenge for several investment estimates, especially for areas with limited research (EEDSM) or where underlying data is a challenge (coal employment etc).

Many crucial just transition interventions and pillars remain uncosted or unknown even in the immediate term, let alone a decade into the future (for example, economic diversification investment at a sub-national level is not clearly costed in the medium to long-term).

Significant uncertainty persists and investment planning should concretise these estimates over time and especially on a short-term, rolling basis.

- **Financing considerations**

Financing design and finance sector dynamics and limits are excluded from the techno-economic and CGE modelling, except for foreign direct investment and its relationship to currency changes.

Financing gap analysis for sectoral/intervention investments should in future be mapped to funding sources and instruments and funding strategies developed for all interventions to achieve the target range and associated just transition needs.

Methodological considerations

- **Investment needs common across many modelled pathways**

Many investments needed are necessary but not sufficient for climate ambition, and are required across many/all modelled future pathways for South Africa. There are some incremental investment needs and costs associated with higher ambition but across many pathways there is a baseline need for just transition or infrastructure investments (for example, coal plant decommissioning, repurposing, and workforce interventions are required for a just transition for all plants closing in the period, whether or not an ambitious pathway is chosen; coal mine closure and EV investment etc).

These ‘common investments’ are ‘no-regret’ options for the country and planning and financial mobilisation should be pursued as a matter of urgency.

- **Timing of transition is critical**

While the numbers of workers, towns, communities and firms dependent on emitting sectors is large in aggregate, in many cases the transition will not necessarily have net negative impacts on jobs in a given sector (for example in electricity generation). Similarly, assessing the socio-economic impacts on the workforce, or concentrated regional risks due to dependence on particular sectors etc, is not as straightforward as assuming all workers will lose their jobs or all economic activity in a given region will cease. The spatial and temporal aspects of transition are critical, and including the age and skills profile of the workforce and timing of assets closures/transition provides a more accurate assessment of impacts and hence investments needed to support vulnerable actors in the transition. This is because workers ‘retire out’ of sectors over time, and hence some job losses are mitigated, depending on sector strategies to attract new workers before closure, as well as the success or not of economic development planning that crowds in new investments and attracts youth or younger workers. Similarly, spatial aspects of the liquid fuels transition require further analysis to assess where and when impacts on the downstream forecourt sector will occur.

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Acronyms

AD	anaerobic digestion
AMSA	ArcelorMittal South Africa
Bbl	barrel (oil)
BEV	battery electric vehicle
BESS	battery energy storage system
BTR	Biennial Transparency Report
CCS	carbon capture and storage
CCUS	carbon capture, utilisation and storage
CH_4	methane
CO_2	carbon dioxide
CPP	carbon pricing policy / carbon pricing pathway (check your use)
CTL	coal-to-liquids
CCGT	combined cycle gas turbine
CBDR&RC-NC	common but differentiated responsibilities & respective capabilities, in the light of national circumstances
CGE	computable general equilibrium
CPP	Current Policies and Plans Scenario
CSP	concentrated solar power
CARA	Conservation of Agricultural Resources Act
DBSCAN	density-based spatial clustering of applications with noise
DRI	direct reduced iron
Dx	distribution (electricity)
EV	electric vehicle
EF	emission factor
EAF	energy availability factor

ESRG	Energy Systems Research Group, University of Cape Town
EPR	extended producer responsibility
FSRU	Floating Storage Regasification Unit
FT	Fischer-Tropsch
FGD	flue gas desulphurization
GTS	Green Transport Strategy 2018
Gx	generation (electricity)
GW	gigawatt
GCCA	Global Cement and Concrete Association
GHG	greenhouse gas
GHGi	National Greenhouse Gas Inventory
HDV	heavy duty vehicle
HVC	high value chemicals
H_2	hydrogen
ICE	internal combustion engine
IDC	Industrial Development Corporation
IEP	Integrated Energy Plan
IEA	International Energy Agency
IPP	independent power producer
IRENA	International Renewable Energy Agency
Kt	kilotonne
kW	kilowatt
kWh	kilowatt-hour
LCOE	levelised cost of electricity
LDV	light duty vehicle
LNG	liquefied natural gas
Lm/W	lumens per watt

MES	Minimum Emissions Standards regulations under the National Environmental Management Act
Mt	megaton
Mt CO_2-eq	megaton carbon dioxide equivalent
MYPD	Multi-Year Price Determination
NEDLAC	National Economic Development and Labour Council
NECOM	National Energy Crisis Committee
NEES	National Energy Efficiency Strategy
NLTSF	National Land Transport Strategic Framework
NLTSP	National Land Transport Strategic Plan
NDC	nationally determined contribution
NO_2	nitrogen dioxide
NMT	non-motorised transport
OCHT	open-cycle high-temperature turbine (please confirm context)
ODC	ozone-depleting chemical
PassPriv	passenger private (cars)
PassPub	passenger public (transport)
PJ	petajoule
PV	photovoltaic
PGM	platinum group metals
PAMs	policies and measures
PEM	proton exchange membrane
REDD	reducing emissions from deforestation and forest degradation, plus conservation, sustainable management of forests, and enhancement of forest carbon stock
RWP	reference water pathway
RE	renewable energy

REDIS	Renewable Energy Data and Information System
RWGS	reverse water-gas shift
RMIPP	Risk Mitigation Independent Power Producer (Programme)
SAM	social accounting matrix
SATIMGE	South Africa TIMES model –South African General Equilibrium model framework
SHW	solar hot water
SAGE	South African General Equilibrium model
SANS	South African National Standards
SUN	Stellenbosch University
SO_2	sulphur dioxide
Tx	transmission (electricity)
TDP	transmission development plan
VRE +	variable renewable energy