ENERGY SYSTEMS RESEARCH GROUP

Net zero pathways for South Africa

Summary of analysis and results

For the Presidential Climate Commission
Net Zero Working Group

Marquard, Cunliffe, Merven, McCall, Hughes, Tatham, Caetano, von Blottnitz

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UNIVERSITY OF CAPE TOWN
IYUNIVESITHI YASEKAPA • UNIVERSITEIT VAN KAAPSTAD

Overview

Introduction

This project has been undertaken by the CSIR and ESRG to provide research analysis and an evidence base to the **Presidential Climate Commission (PCC) of South Africa**, to support its objectives of facilitating conversations and building understanding of **South Africa's just energy transition**.

In this work, **ESRG examines potential energy and sectoral mitigation pathways** through which South Africa could reach net zero CO_2 emissions by mid-century, and identify opportunities and risks to ensuring the transition **just and equitable**.

CSIR's Climate and Air Quality Modelling team examine one of the foremost opportunities, namely the improved health and reduced mortality of communities and areas through reduction in **combustion-based air pollution**.

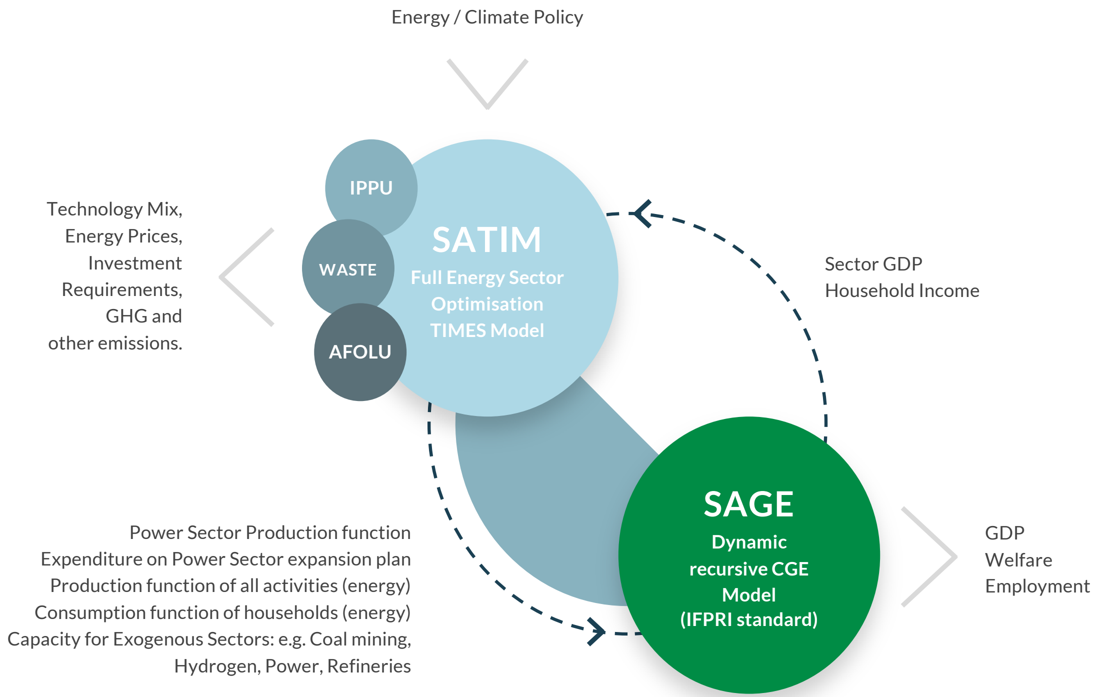
The research team have also identified many areas for further research.

This work has been supported by the **UK Partnering for Accelerated Climate Transitions (UKPACT)** program, funded by the UK Government's International Climate Finance portfolio.

Objective and methodology

- Examine features of potential pathways to net zero CO_2 for South Africa and develop **scenarios** that illustrate
    - Timing and characteristics of energy transitions
    - Costs (monetary and externalities) & benefits
    - Co-benefits and impacts
    - Risks
- That are **contextualised** by global uncertainties & risks, incl.
    - Future of the multilateral climate regime
    - Extent of pressure to mitigate
    - Climate change impacts
- **Model the scenarios** using ESRG's **SATIMGE** and CSIR's Air Quality Modelling framework **CSIRO ESM** and **CAMx**

Use of linked energy systems & computable general equilibrium models



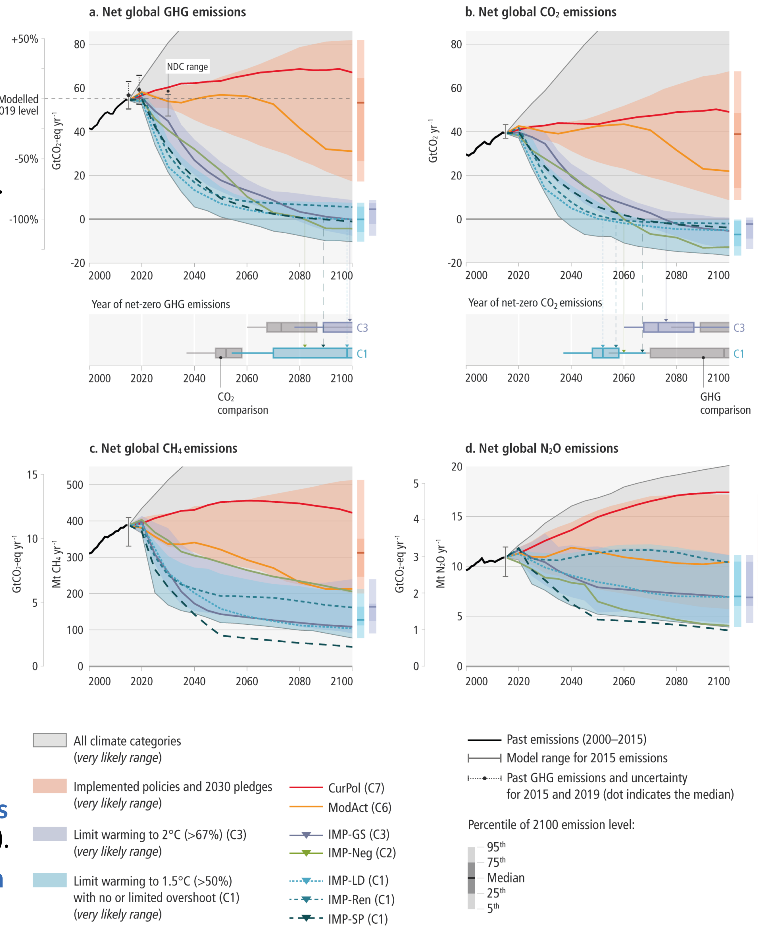
Framing the net zero challenge

Andrew Marquard

Defining and understanding net zero

- The current climate change we are experiencing **is caused by anthropogenic emissions of GHGs, and the atmosphere is global.** The global warming impact of a unit of any GHG is unrelated to WHERE it is emitted.
- The "net" in net zero CO_2 emissions means a balance of sources and sinks. In other words, in the relevant timeframe (usually a year, which takes into account seasonal fluctuations), **CO_2 emissions =** **absorbtion of CO_2**.
- Climate science has shown that **halting net emissions of CO_2 is needed to halt global warming**. Stopping global warming below a certain threshold (1.5 or 2 degrees) **also requires keeping within a global CO_2 budget** between now and global net zero.
- The **risks and climatic consequences of exceeding 1.5°C globally are likely to be severe**, particularly for the Global South where food and water insecurity is already acutely felt.
- The physical science basis for a global net zero CO_2 emissions target is based on an assessment of **which global GHG emissions pathways meet the Paris Agreement's policy goal of preventing more than 1.5 degrees of global warming (50% chance)** above pre-industrial levels.
- These pathways are **derived from 3131 scenarios from 95 model families** (with hundreds of sensitivity runs per scenario), for **GLOBAL anthropogenic emissions**, and share several characteristics:
    - **Net CO_2 emissions declining ~45% by 2030** (below 2010) and **reaching zero around 2050 – 55.**
    - **Deep declines in CH_4, N_2O and other non-CO_2 GHGs.**
- The science provides guidance on GLOBAL pathways / mitigation. **All other** **net zero CO_2 emissions targets are based on specific accounting approaches** (which emissions to count, and which emissions not to count).
- The institutional/legal context matters. **For countries, UNFCCC/Paris Agreement agreed GHG estimation methods define how to count GHG emissions, and what GHG emissions to count**. How to divide the remaining GHG budget between countries is a different and more complex question.

Modelled mitigation pathways that limit warming to 1.5°C, and 2°C, involve deep, rapid and sustained emissions reductions.



GLOBAL mitigation pathways - IPCC AR6 WG3 Summary For Policy Makers Fig. 5 (2022)

Background on the international climate legal / policy regime

International climate law is built on the United Nations Framework Agreement on Climate Change, which South Africa ratified in 1997, and its Paris Agreement, which South Africa ratified in 2016. South Africa has been a consistent supporter of a strong rules-based regime, which is very strongly in our interest (being a middle-income, middle-sized country).

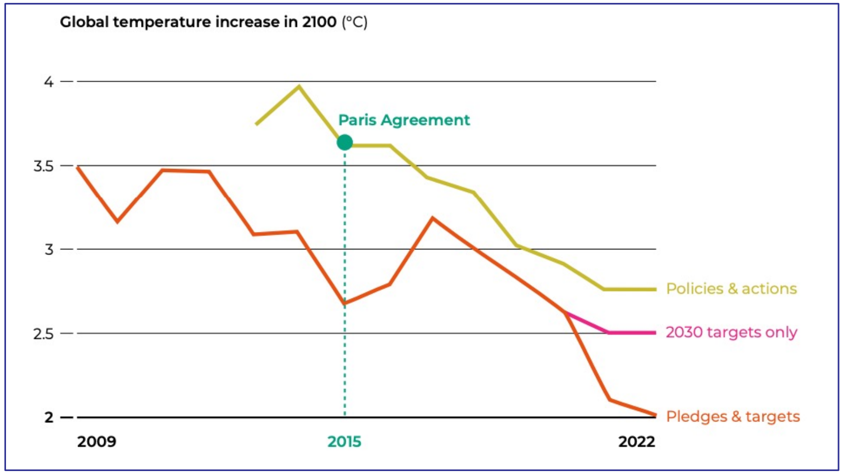
The Paris Agreement is built on strong global emissions targets and a nationally-determined process for countries setting their own emissions targets, according to the principle of common but differentiated responsibilities and respective capabilities, in the light of national circumstances, AND in the light of the long-term goals of the PA. In addition, support is to be provided to developing countries to achieve these goals. Every five years, a Global Stocktake is conducted to assess progress in meeting these long-term goals.

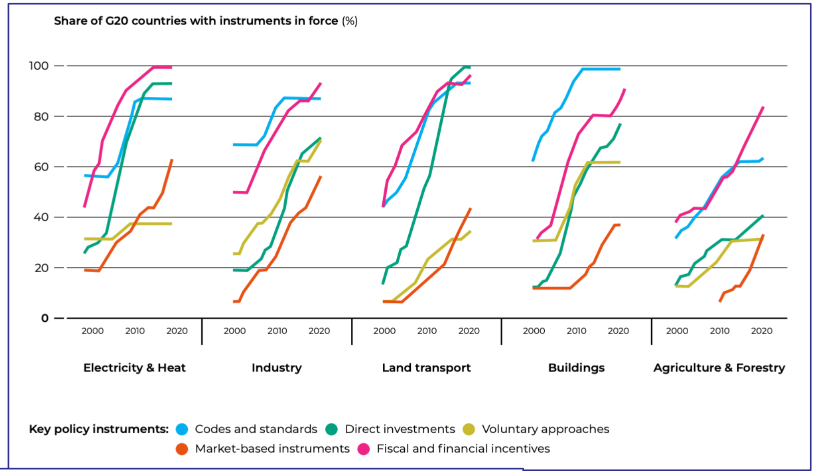
Countries have to explain how they consider their NDCs to be **fair and ambitious**, and how they've taken the outcome of the Global Stocktake into account. The first GST, which was completed at COP 28 in Dubai, concluded that a) there has been significant progress in countries' efforts, but that mitigation, adaptation and finance goals are far from being met.

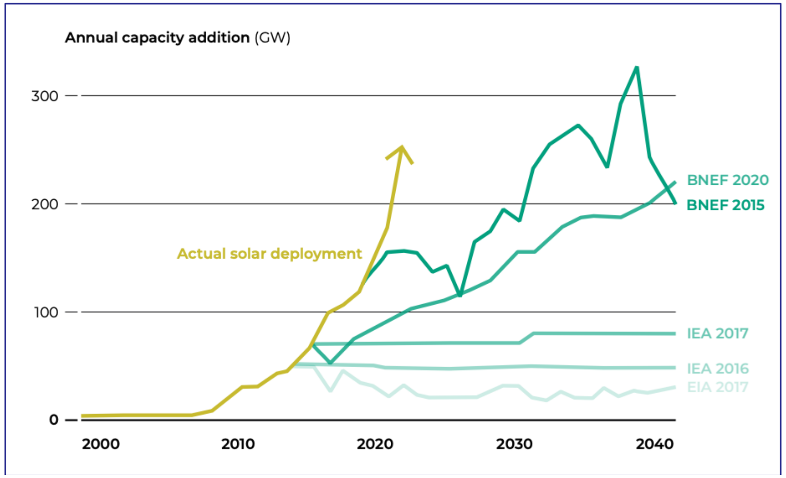
The PA and subsequent decisions do not provide quantitative guidance on how countries should set their NDC targets, but both the PA and subsequent decisions up to 2023 provide more and more qualifications for what will be considered "fair and ambitious". These include specific provisions to move away from coal and other fossil fuels, more specific provisions for the PA's long-term target, and specific provisions on the just transition.

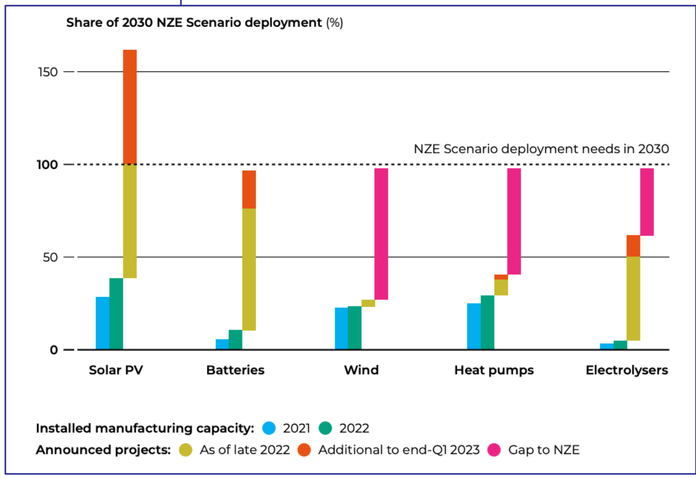
Is the multilateral regime working?

(all figures from FIVE MAJOR SHIFTS SINCE THE PARIS AGREEMENT THAT GIVE HOPE IN A JUST, PARIS-COMPATIBLE TRANSITION) (New Climate Institute 2023)









What does this mean for quantifying a net zero pathways for SA?

This matters in two key respects:

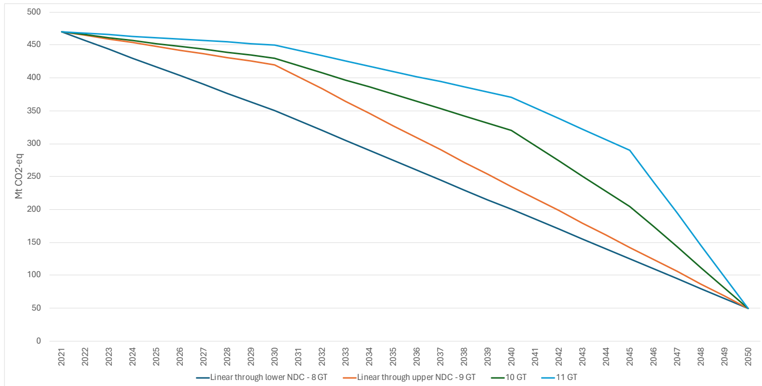
1. How and what to count for a net zero trajectory, i.e. conventions and accounting – based on the existing international institutional arrangements:
    - For net zero: the annual sum of CO_2 sources and sinks, as accounted for in SA's national GHG inventory, will equal or be lower than zero. This will EXCLUDE categories which are estimated, but are not included in the calculation of SA's total annual co2 emissions (CO_2 emissions from international flights and CO_2 from international shipping).
    - For the cumulative GHG budget (2021-2050): The sum of the annual sums of all GHGs, as accounted for in the SA GHG inventory for the years 2021-2050, excluding CO_2 emissions from international flights and CO_2 from international shipping, and accounted for by using GWPs required under the Paris Agreement.
2. What would constitute a "fair and ambitious" long-term GHG emissions pathway for South Africa?
    - Such a pathway should consist of a fair contribution by SA to the long-term goal of the PA of keeping global warming to within a 1.5 degree threshold, considering the legal framework of the UNFCCC/PA (this includes consideration of our status as a developing country, which in turn includes an expectation that we will receive international support).
    - For net zero – which year Should SA reach net zero in?
    - For the cumulative budget, how much GHG emissions space is SA entitled to between now and net zero?

South Africa's net zero challenge

South Africa has pledged to move towards net zero CO_2 economy-wide by 2050, and to ensure a just transition and maximise the economic advantages of the transition. SA has also set an NDC target for 2030 which sets the country on a downward emissions trajectory to 2050.

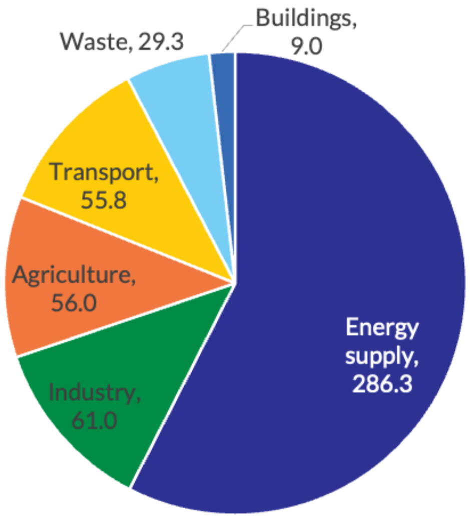
Multi-layered challenge:

- **Long-term emissions objective to be realised in ~2.5 decades time, during which uncertainties abound**, e.g.:
  - Geopolitics, trade policies, and the multi-lateral climate response
  - Technology developments and cost trajectories (look at the history of solar PV!)
  - Impacts of current and future warming
  - Land sink
- **Requires decisions to be taken in the short-term, which may result in "lock-in" to various outcomes**
- **Arises at a time when South Africa has to overcome multiple generational socio-economic challenges**, and immediate and acute crises such as load-shedding
- **What we can say for sure is SA <u>will</u> face long-term GHG emissions constraints, trending towards net zero emissions**, and faces known and unknown risks that will manifest in the global future and in the way we choose to respond

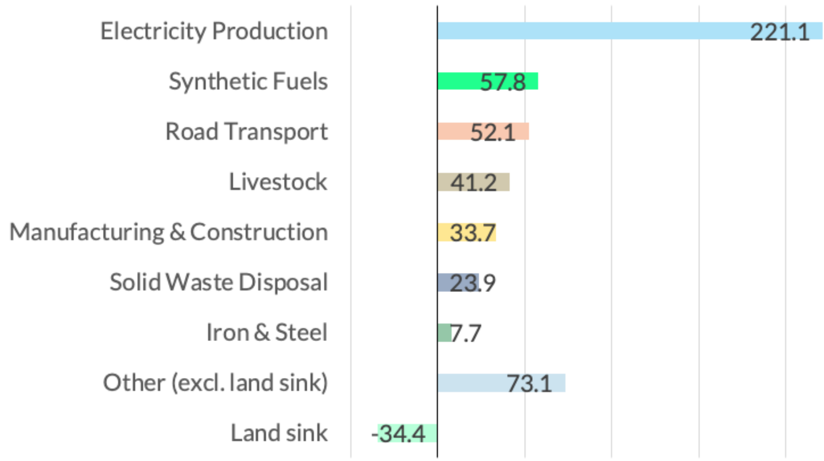


South Africa’s current emissions profile

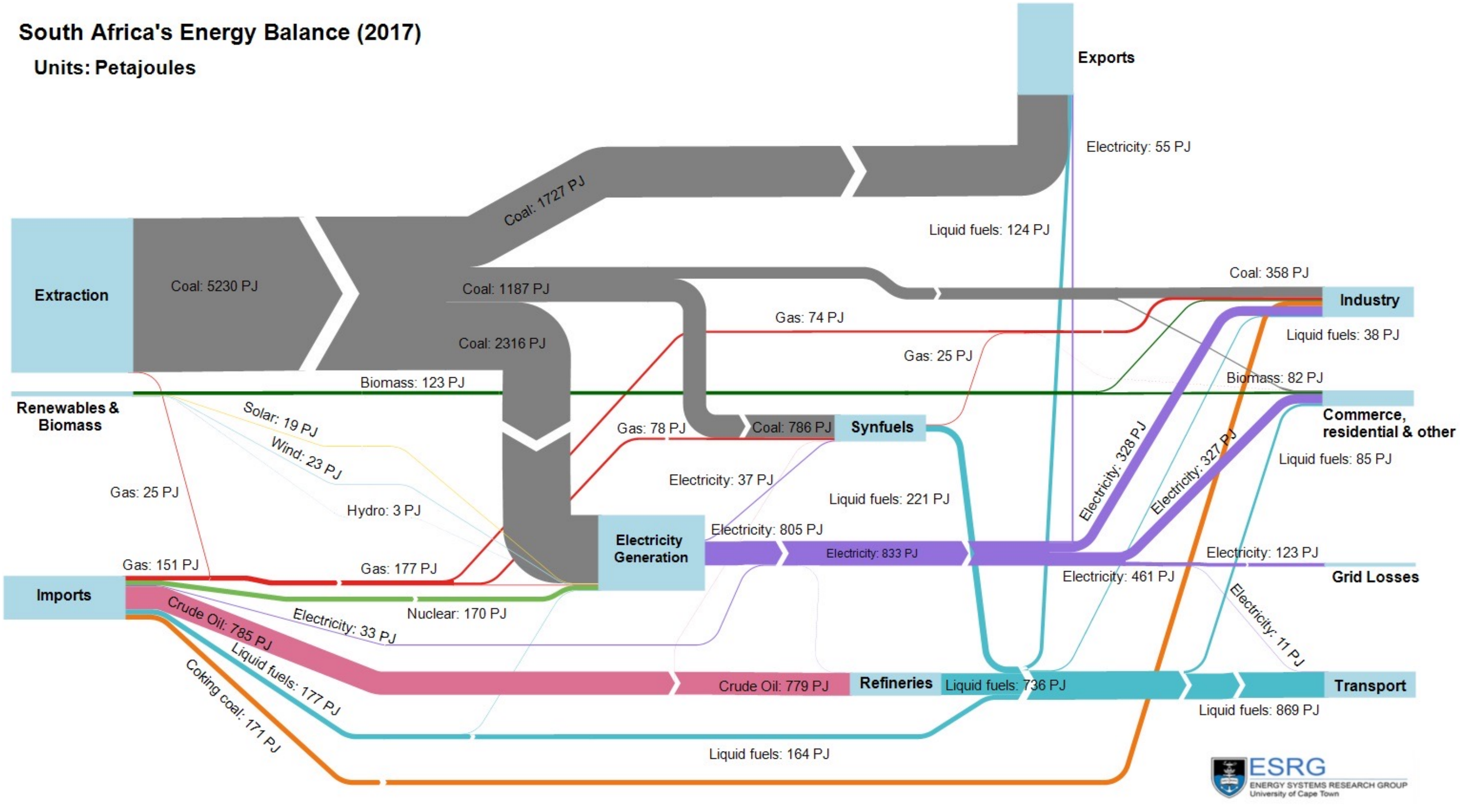
GHG emissions profile (2019)
[$MtCO_2$-eq] excl. LULUCF



GHG emissions by major sub-sector (2019)
[$MtCO_2$-eq]



South Africa's energy balance



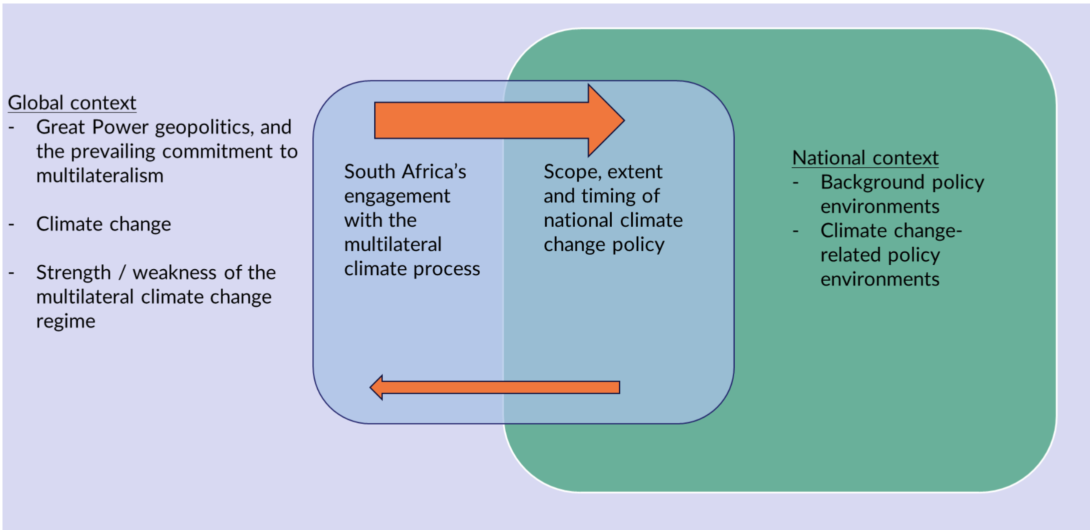
Methods & study design

Guy Cunliffe

International developments vs. national policy choices

In analysing long-term potential decarbonization pathways for South Africa, we adopt a two-tier approach, in order to unpack the complexities and uncertainties that exist at multiple levels:

1. **Global context** – developing a framework for navigating different possible pathways for the multilateral climate regime and the consequences;
2. **National context** – assessing how different national policy choices and market developments would position SA within the different global futures, and identifying opportunities and risks.



AM to check, Guy to edit

Global context - Worlds A and World B

International future ‘worlds’ were conceived to contextualise South Africa’s emission pathways and policy decisions within two different global mitigation pathways, to begin to identify and differentiate commonalities and risks inherent in the policy choices SA makes.

Worlds were differentiated as:

- **A**: a more ambitious climate world with a strong multilateral rules-based regime, with stricter policies on carbon-intensive trade, a more rapid transition to EVs, reduced demand for fossil fuels and a greater market for ‘green’ export trade, and greater climate support for developing countries
- **B**: a more divergent climate world, with a slower transition to clean fuels, products and technologies, and more limited or no support to developing countries. This world comes with high risks that SA and other developing countries will be subject to MORE pressure to mitigate than in world A.

Distinctions were made in terms of:

- Higher or lower fossil fuel price projections
- Higher or lower EV cost reduction projections
- Full or partial ramp up of CBAM prices on carbon-intensive commodities
- Availability or not of export market for “green” products, e.g. steel and ammonia from green H_2

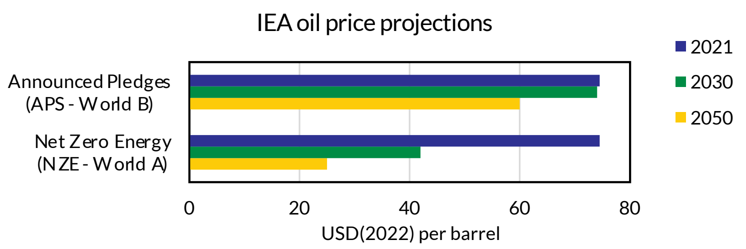
How we modelled worlds A and B

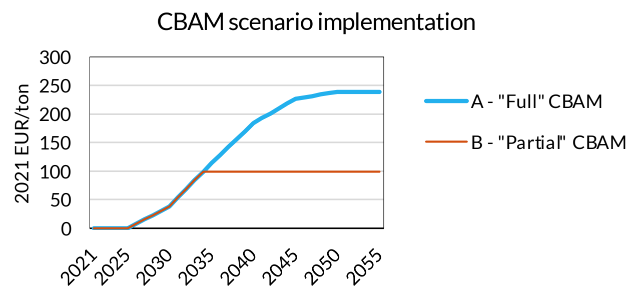
Distinctions between the two conceptual worlds were made in the CGE:

World	Fossil fuel projections	EV price projections	CBAM	Green exports
A	Lower demand – IEA NZE price	IEA NZE (faster learning)	Full price ramp-up (2021 – 2055)	Available (applied as a sensitivity in some cases)
B	Higher demand – IEA APS prices	IEA APS (slower learning)	Partial price ramp-up (2021 – 2034)	Not available

To be explored in further work:

- Green and concessional FDI (likely more available in World A)
- Externality and damage costs (likely higher in World B)
- Interaction between CBAM and domestic carbon tax





Notes
IEA APS – Adjusted Policies Scenario (NDC compliant)
IEA NZE – Net Zero Energy scenario (for global net zero CO_2 by 2050)
(IEA World Energy Outlook 2023)

Scenario elements

- World: {A, B}
- Year net zero CO_2 reached in: {2050, 2055, not reached}
- GHG limit ($GtCO_2e$, 2021-50): {8, 9, 10, 11, unlimited}
- Energy efficiency[1]: {NEES-Adjusted, None}
- CTL projection[2]: {Sasol plan, Endog Retire, Late Retire}
- Green exports available: {Yes[3], No}
- SA domestic carbon tax[4]: {Current levels, Higher levels}
- Localisation policy[5]: {Current levels, SAREM consistent}
- Coal power plants[6]: {Endog refurb/retire, Forced ref, No ref}
- CCS: {Available, Not available}

World	A	B			
Net zero CO2 year	2050	2055	No NZ		
GHG limit (2021-50) [GtCO2-eq]	8	9	10	11	No limit
Energy Efficiency	NEES*	None			
CTL	Sasol Plan	Early	Late		
Green exports	Yes	No			
SA carbon tax	High	Current			
Localisation	SAREM	Current			
Coal power plants	Endog	Forced fix	No fix		
CCS	Available	NA			

Full scenario run matrix in forthcoming report appendix

Notes

1 Cases with energy efficiency are based on partial achievement of draft 2015 NEES targets in industry and commerce, improvements in residential energy efficiency based on ESRG/SANEDI data (report under review), and partial mode switching (private-to-public and road-to-rail) in land transport (see Ahjum 2020)

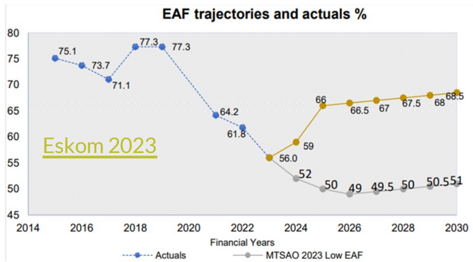
2 Most cases assume default projection for CTL activity based on the Sasol Climate Change Report 2023; variations include (1) allowing the model to endogenously retire CTL units on a least-cost basis from 2035 ("early") and (2) forcing CTL units and activity to remain online until 2045, followed by a linear ramp down to 2050 ("late")

3 Green export availability only modelled as a sensitivity in selected World A cases; it is assumed green exports would not be available in World B

4 South Africa's domestic carbon tax is modelled at the current levels, equivalent to R120 per tonne with existing allowances, and at higher levels ramped up to ~$120 per tonne by 2050, as per the tax proposal contained in the 2022 National Budget Review

5 Cases modelled with existing local content requirements and policies ("current levels") or adjusted to meet levels as per the draft South African Renewable Energy Masterplan 2022 ("SAREM consistent"); the latter are modelled with a localisation price premium of 5%, implemented on a gradual basis from 2020 – 2050

6 Projections for existing coal power capacity and performance are based on the model endogenously selecting to either refurbish and restore underperforming plant to higher EAF levels, and/or to retire plant early, or to allow plant to continue operating at current performance levels. Selections are made on the basis of least-cost and within the broader applicable GHG constraints, with costing for refurbishment to improve EAF based on the EPRI IRP 2019 data; where plants are refurbished, their availability improves to align with the weighted average higher projections shown in Eskom's 2024-2028 MTSAO report (see Figure 5)



Assumptions & limitations

NB assumptions:

- Perfect foresight modelling
- **Conservative land sink estimate (~10 $MtCO_2$pa)** for a prudent assessment of carbon space. With strong measures in the land and agricultural sectors, more GHG space could be freed up to offset the risks of a slower transition in the rest of the economy.
- Coal fleet refurbishment costs (and model endogenously selecting refurbishment or early retirement on a least-cost basis) to substantially improve the performance of the current coal fleet.

Not covered in detail in this analysis (i.e. further work):

- Optimisation and mitigation potential of Waste and AFOLU. This was modelled in more detail in previous work.
- Significant changes in consumer behaviour (for instance, moving to a plant-based diet).
- Interaction between domestic carbon tax and international CBAM (in theory, the effective imposition of a national carbon price at a level consistent with international carbon markets would provide protection from the CBAM).
- Large-scale concessional finance (access to the required investment at significantly below commercial rates, including the costed risks of exchange rate movements).
- Climate change damage impacts, costs .
- Further analysis of options for carbon capture/storage/removal in terms of technical feasibility, capacity (how much we can store), and cost.
- Carbon market mechanisms and internationally traded offsets
- GHG accounting of international shipping and aviation (not counted for SA's national NDC or net zero targets)
- The consequences of national and international bottlenecks of key infrastructure components
- Spatialisation – sub-national analysis of the energy system

Full scenario matrix

N = 40

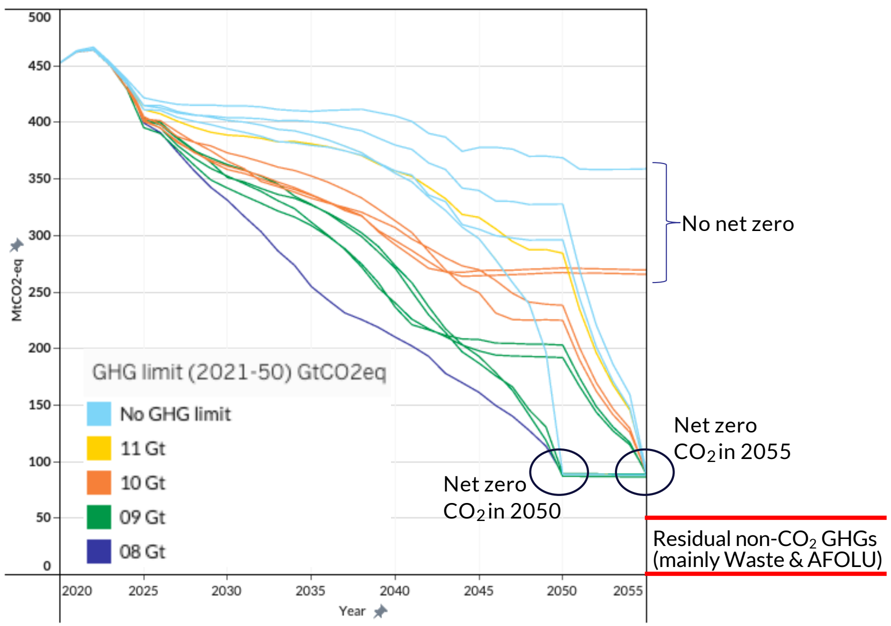
Scenario name	World	GHG limit (2021-50)	NZ CO_2 Year	Efficiency	CTL	Exports	CO2Tax	Localisation	ECoalRefurbish	CCS
A - 08Gt - NZ2050 - EE	A	08 Gt	NZ 2050	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	CurrentLevels	EndogenousRefurbish	WithCCS
A - 08Gt - NZ2050 - EE - SAREM Loc	A	08 Gt	NZ 2050	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - 09Gt - NZ2050 - EE - Early CTL - SAREM Loc	A	09 Gt	NZ 2050	EE	**EarlyRetirement**	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - 09Gt - NZ2050 - EE - Delay CTL - SAREM Loc	A	09 Gt	NZ 2050	EE	**DelayedPhaseOut**	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - 09Gt - NZ2050 - EE - GreenXpts - High C Tax - SAREM Loc	A	09 Gt	NZ 2050	EE	PlannedPhaseOut	**GreenExprts**	**High Carbon Tax**	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - 09Gt - NZ2050 - EE - GreenXpts - SAREM Loc	A	09 Gt	NZ 2050	EE	PlannedPhaseOut	**GreenExprts**	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - 09Gt - NZ2050 - EE	A	09 Gt	NZ 2050	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	CurrentLevels	EndogenousRefurbish	WithCCS
A - 09Gt - NZ2050 - EE - SAREM Loc	A	09 Gt	NZ 2050	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - 09Gt - NZ2050 - EE - SAREM Loc - No CCS	A	09 Gt	NZ 2050	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	**NoCCS**
A - 09Gt - NZ2050 - GreenXpts - High C Tax	A	09 Gt	NZ 2050	NoEE	PlannedPhaseOut	**GreenExprts**	**High Carbon Tax**	CurrentLevels	EndogenousRefurbish	WithCCS
A - 09Gt - NZ2050 - SAREM Loc	A	09 Gt	NZ 2050	NoEE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - 11Gt - NZ2050 - EE - SAREM Loc	A	11 Gt	NZ 2050	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - No limit - NZ2050 - EE - SAREM Loc	A	No limit	NZ 2050	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
B - 09Gt - NZ2050 - EE - Early CTL - SAREM Loc	B	09 Gt	NZ 2050	EE	**EarlyRetirement**	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
B - 09Gt - NZ2050 - EE - Delay CTL - SAREM Loc	B	09 Gt	NZ 2050	EE	**DelayedPhaseOut**	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
B - 09Gt - NZ2050 - EE - GreenXpts - High C Tax - SAREM Loc	B	09 Gt	NZ 2050	EE	PlannedPhaseOut	**GreenExprts**	**High Carbon Tax**	**SAREMConsistent**	EndogenousRefurbish	WithCCS
B - 09Gt - NZ2050 - High C Tax - SAREM Loc	B	09 Gt	NZ 2050	EE	PlannedPhaseOut	NoGreenExprts	**High Carbon Tax**	**SAREMConsistent**	EndogenousRefurbish	WithCCS
B - 09Gt - NZ2050 - EE - SAREM Loc	B	09 Gt	NZ 2050	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
B - 09Gt - NZ2050	B	09 Gt	NZ 2050	NoEE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	CurrentLevels	EndogenousRefurbish	WithCCS
B - 11Gt - NZ2050 - EE - High C Tax - SAREM Loc	B	11 Gt	NZ 2050	EE	PlannedPhaseOut	NoGreenExprts	**High Carbon Tax**	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - 09Gt - NZ2055 - EE - SAREM Loc	A	09 Gt	NZ 2055	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - 10Gt - NZ2055 - EE - GreenXpts - SAREM Loc	A	10 Gt	NZ 2055	EE	PlannedPhaseOut	**GreenExprts**	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - 10Gt - NZ 2055 - EE - SAREM Loc	A	10 Gt	NZ 2055	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - 11Gt - NZ2055 - EE - SAREM Loc	A	11 Gt	NZ 2055	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - No limit - NZ2055 - EE - SAREM Loc	A	No limit	NZ 2055	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
B - 09Gt - NZ2055 - EE - SAREM Loc	B	09 Gt	NZ 2055	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
B - 10Gt - NZ2055 - EE - SAREM Loc	B	10 Gt	NZ 2055	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
B - No limit - NZ2055 - EE - SAREM Loc	B	No limit	NZ 2055	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - 10Gt - No NZ - EE - GreenXpts - SAREM Loc	A	10 Gt	No NZ	EE	PlannedPhaseOut	**GreenExprts**	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - 10Gt - No NZ - EE - SAREM Loc	A	10 Gt	No NZ	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - No limit - No NZ - EE - High C Tax - SAREM Loc	A	No limit	No NZ	EE	PlannedPhaseOut	NoGreenExprts	**High Carbon Tax**	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - No limit - No NZ - EE	A	No limit	No NZ	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	CurrentLevels	EndogenousRefurbish	WithCCS
A - No limit - No NZ - EE - SAREM Loc	A	No limit	No NZ	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - No limit - No NZ - EE - SAREM Loc - Force Refurb	A	No limit	No NZ	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	**ForcedRefurbish**	WithCCS
A - No limit - No NZ - High C Tax - SAREM Loc	A	No limit	No NZ	NoEE	PlannedPhaseOut	NoGreenExprts	**High Carbon Tax**	**SAREMConsistent**	EndogenousRefurbish	WithCCS
A - No Limit - No NZ	A	No limit	No NZ	NoEE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	CurrentLevels	EndogenousRefurbish	WithCCS
B - 10Gt - No Nz - EE - SAREM Loc	B	10 Gt	No NZ	EE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	**SAREMConsistent**	EndogenousRefurbish	WithCCS
B - No limit - No NZ - EE - High C Tax - SAREM Loc	B	No limit	No NZ	EE	PlannedPhaseOut	NoGreenExprts	**High Carbon Tax**	**SAREMConsistent**	EndogenousRefurbish	WithCCS
B - No limit - No NZ	B	No limit	No NZ	NoEE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	CurrentLevels	EndogenousRefurbish	WithCCS
B - No limit - No NZ - No Refurb	B	No limit	No NZ	NoEE	PlannedPhaseOut	NoGreenExprts	Current Carbon Tax	CurrentLevels	**NoRefurbish**	WithCCS

Results

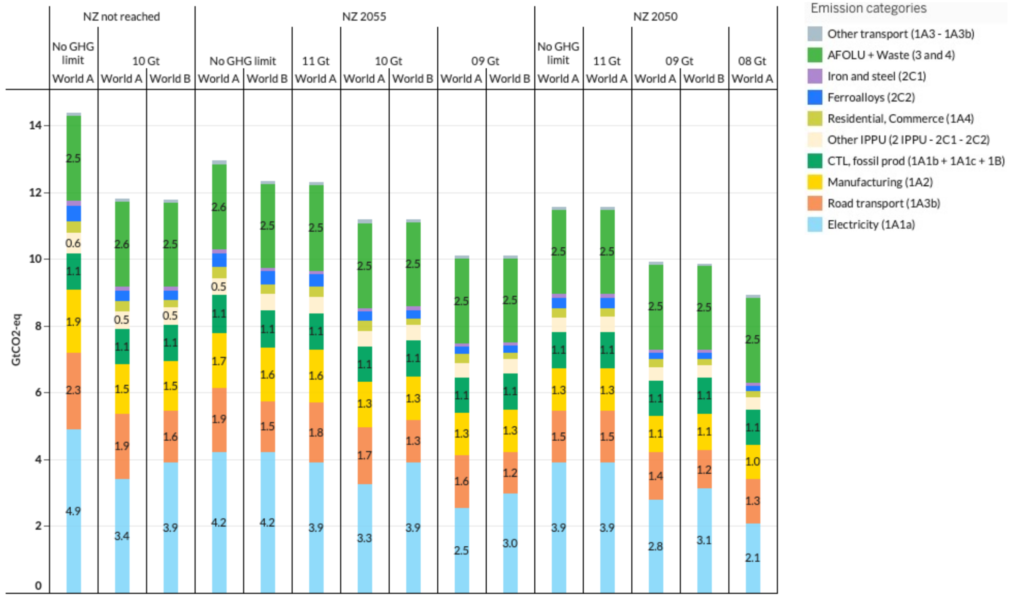
Guy Cunliffe, Bryce McCall,
Julia Tatham

GHG emission pathways

Emission pathways for varying cumulative GHG limits (8, 9, 10, 11 and unconstrained) reaching net zero CO_2 in 2050, 2055 or not at all.



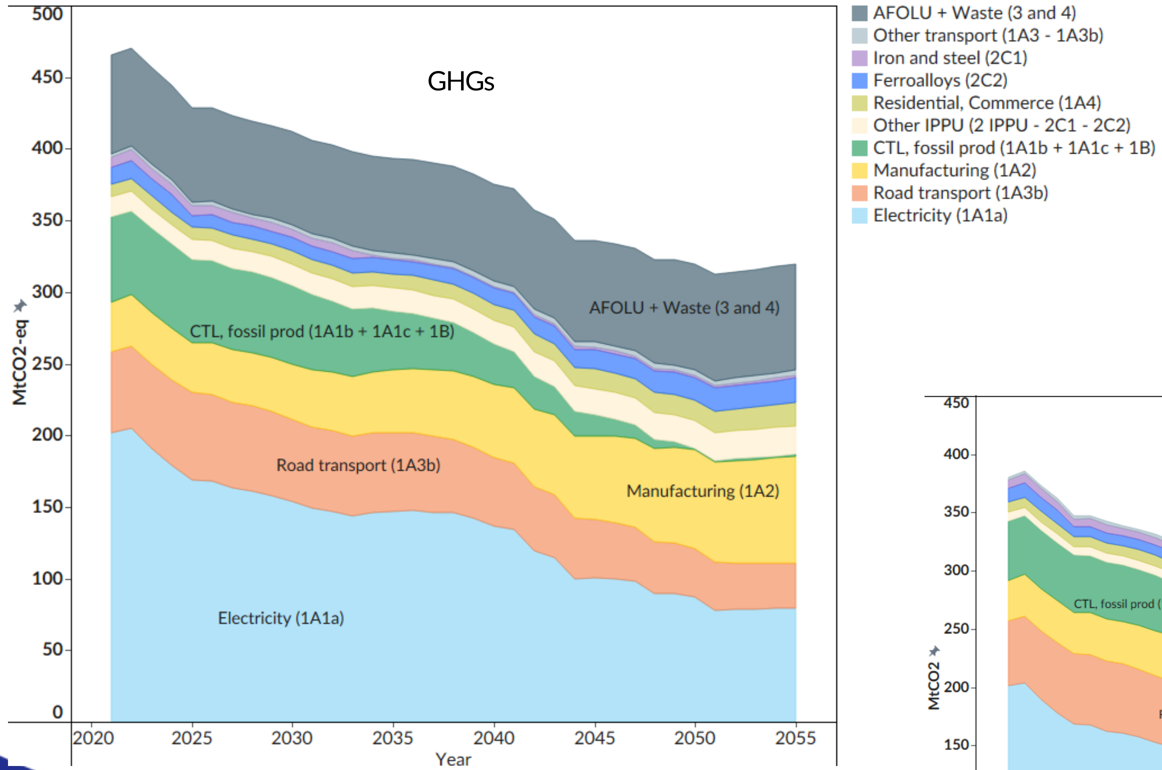
Corresponding cumulative GHGs over the 2021 – 2055 period for the same scenarios (see note below), disaggregated by sector.

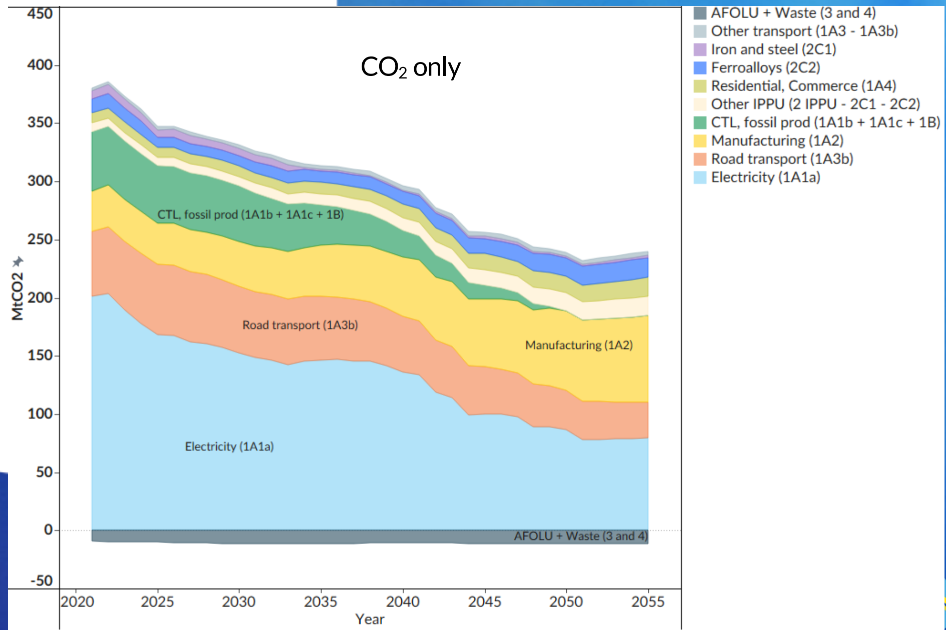


Note: Scenarios shown above all assume current (lower) domestic carbon tax levels, achievement of adjusted NEES energy efficiency targets, no green exports, SAREM consistent localisation, endogenous refurbish/retirement of coal plants and availability of CCS.

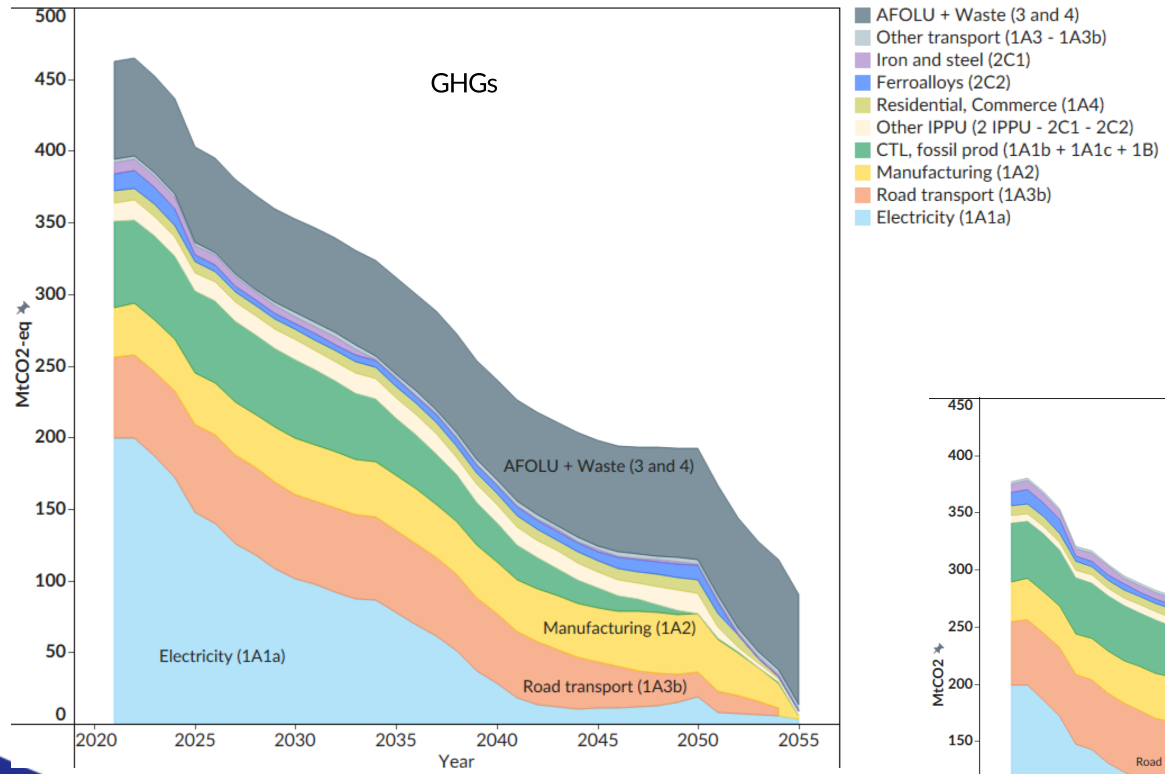
Fluctuations occur mainly in electricity, road transport and industry

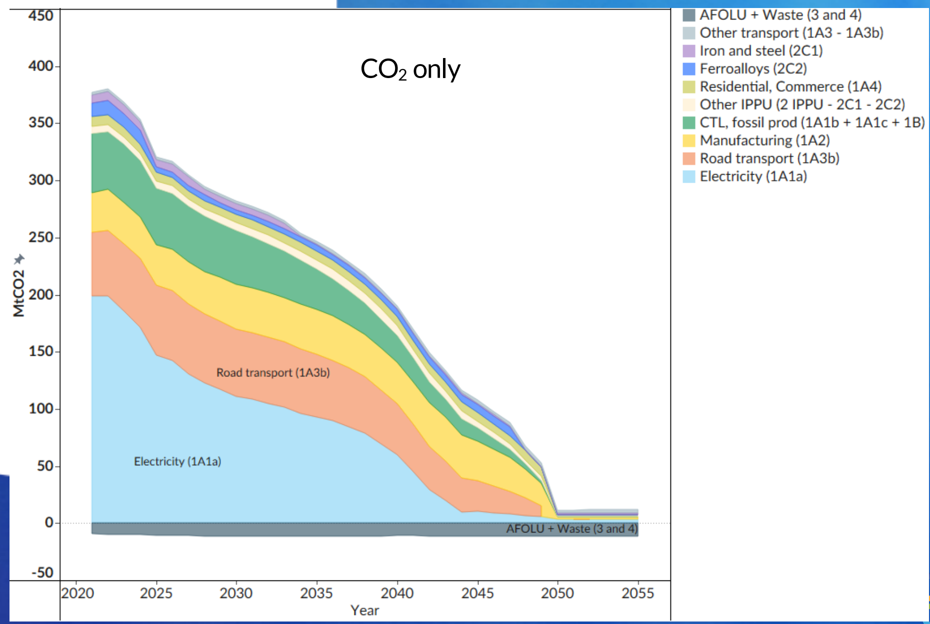
Reference case emissions: World B, unconstrained



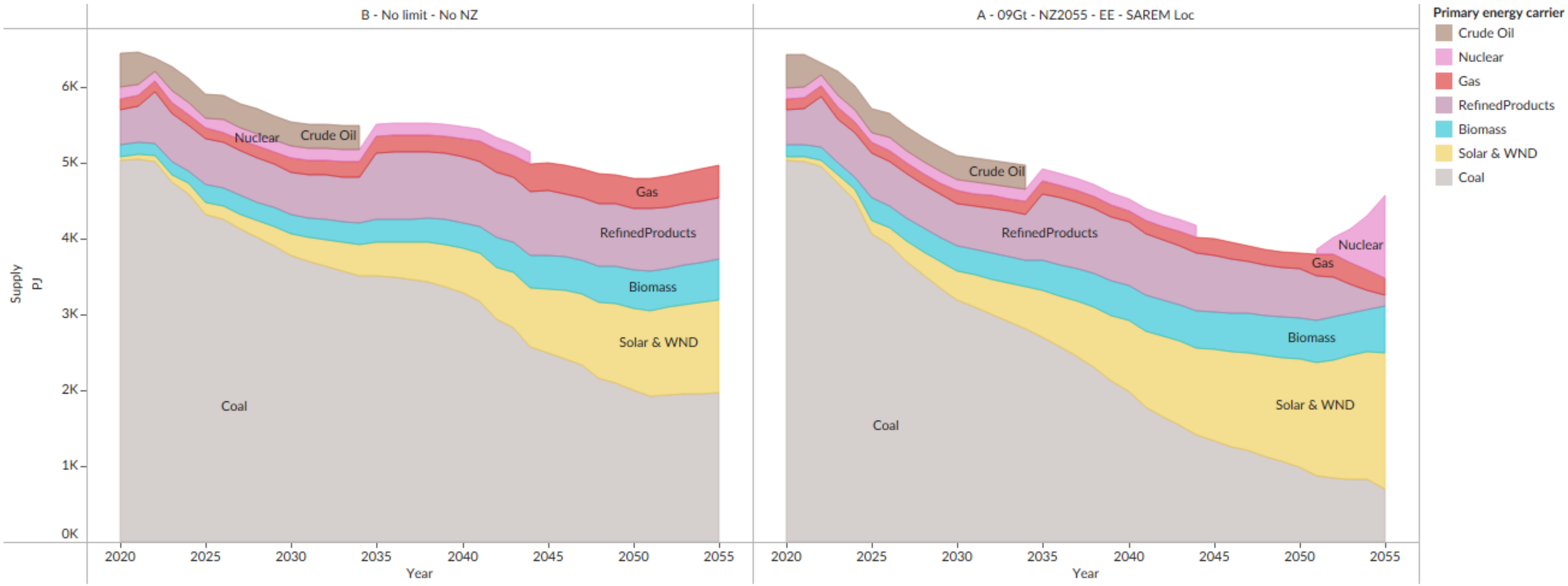


Typical Net zero case emissions: World A, 9 Gt, Net zero in 2055

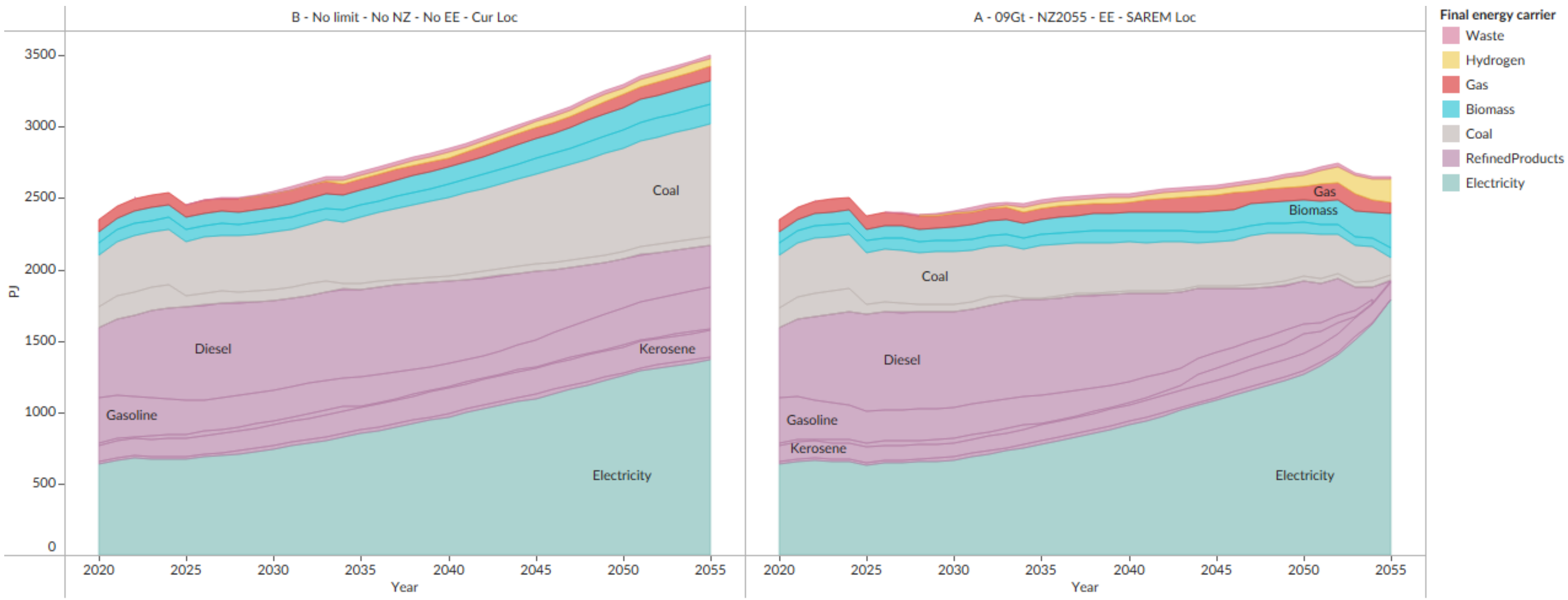




Total primary energy supply:
Reference (World B) and typical net zero (09 Gt 2055) cases



Final energy consumption:
Reference (World B) and typical net zero (09 Gt 2055) cases



Sectoral analysis

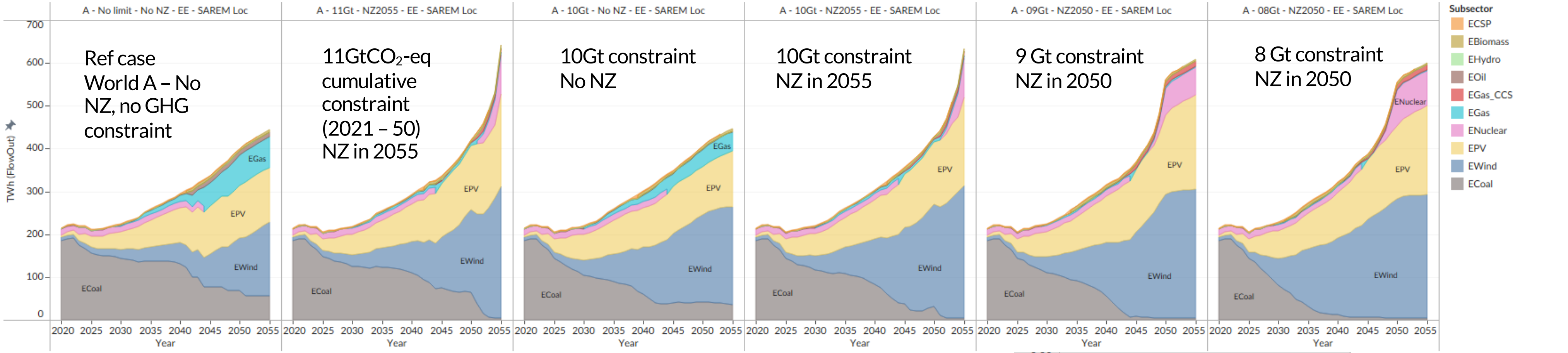
Guy Cunliffe, Bryce McCall,
Julia Tatham

Power

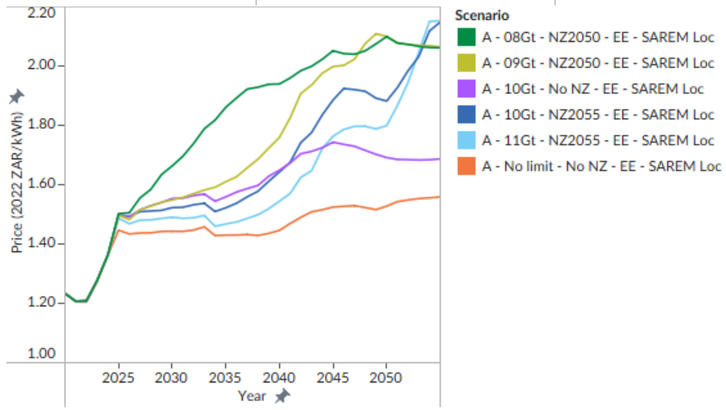
Electricity sent out by scenario and cost per kWh

With and without net zero and GHG constraints

All scenarios shown here include EE and SAREM consistent localisation



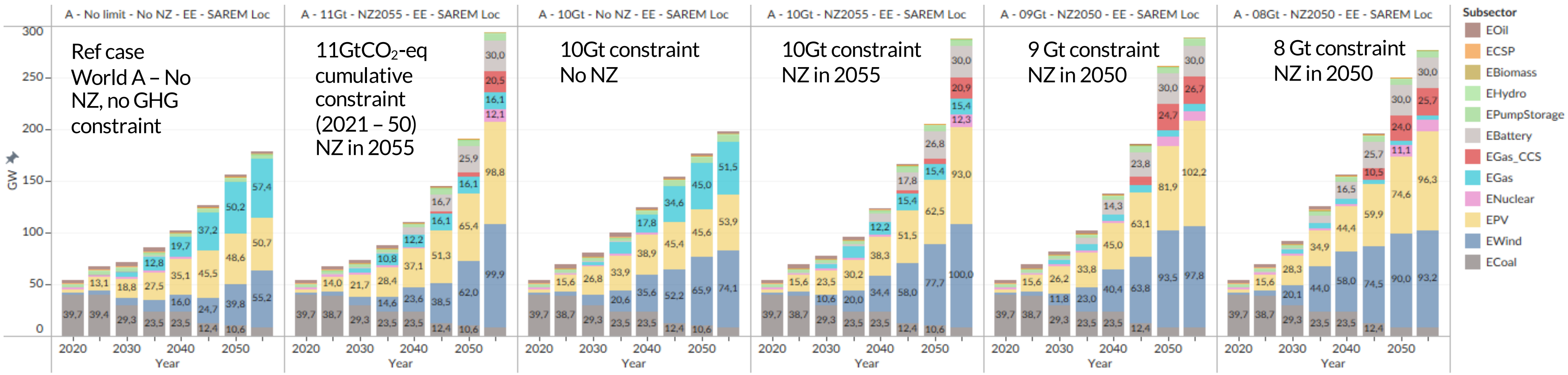
- Electricity generation by scenario with increasing GHG ambition (note that production from storage is not shown on these graphs)
- Increasing GHG constraints lead to more rapid coal phase-down
- Nuclear build in the last few years due to discounted costs and last-mile net zero effects
- Where GHGs are constrained in 2021 – 2050, but net zero is not reached, there is less of a last-mile effect (and, absent constraints after 2050, the model builds no gas)
- These effects (net zero and non-net zero) are reflected in the cost of electricity



Total capacity by technology

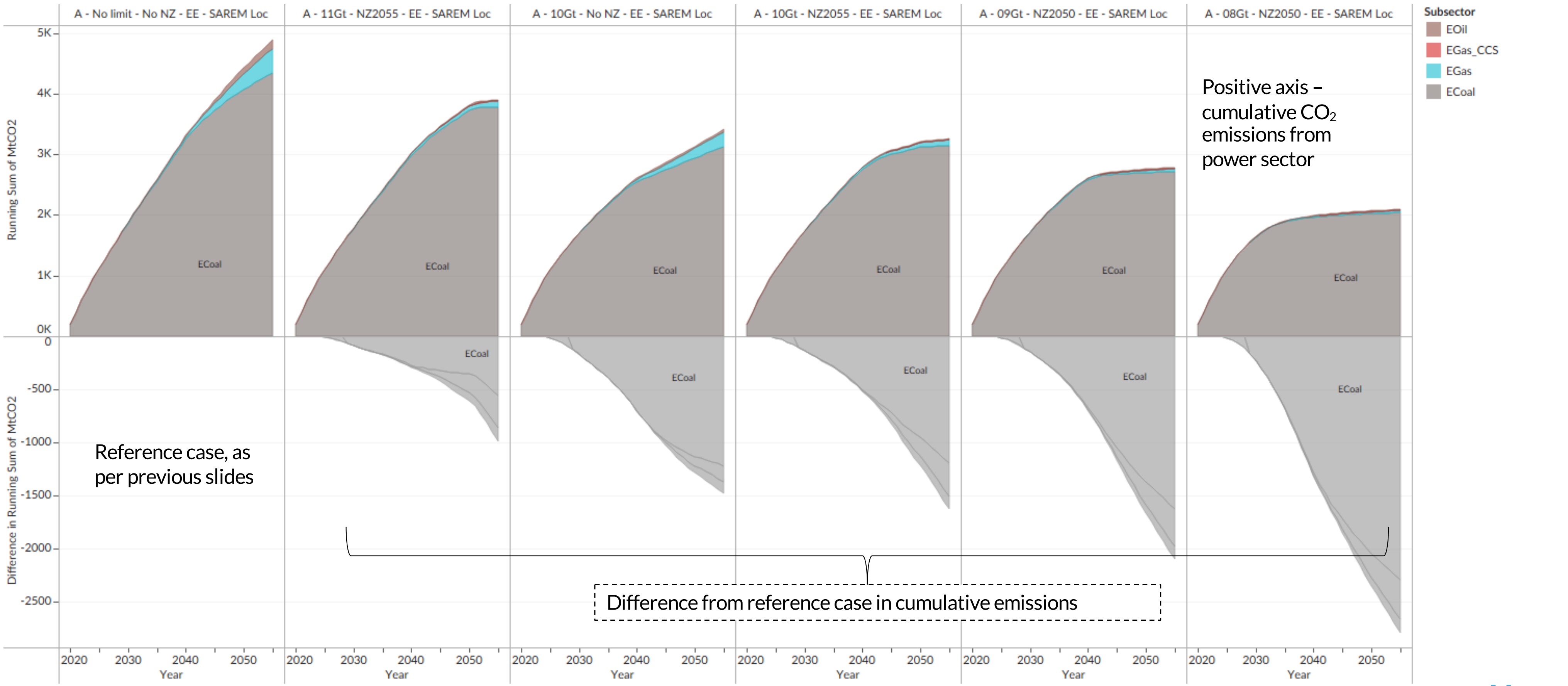
With and without net zero and GHG constraints

All scenarios shown here include EE and SAREM consistent localisation



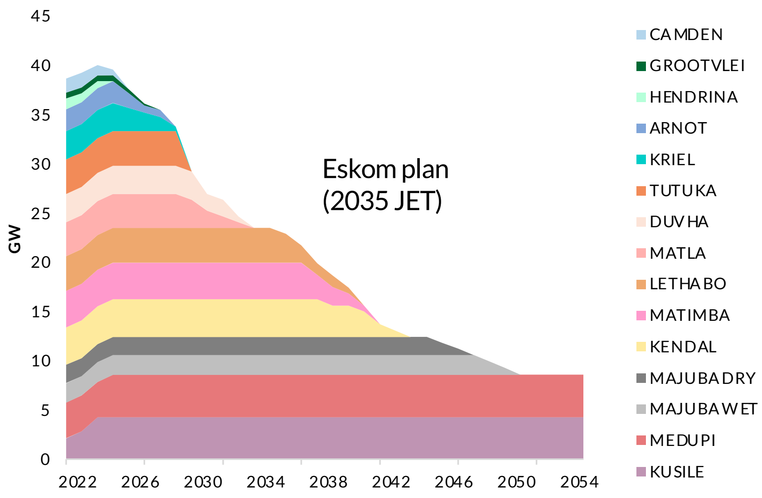
- Last mile building of new zero-carbon capacity to meet net zero targets (including gas CCS, with low utilisation) and ramp-up of battery storage

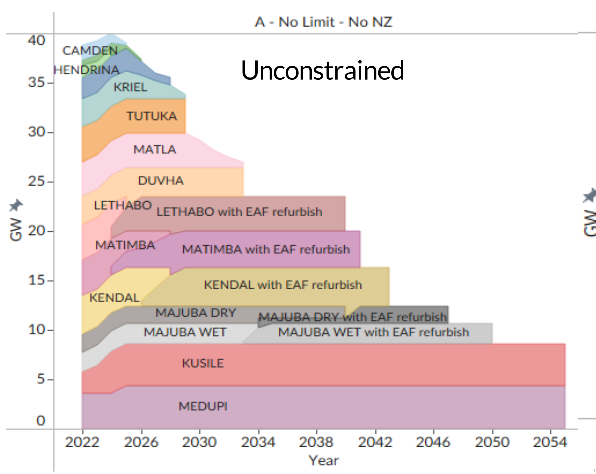
Power sector CO_2 emissions
Cumulative by scenario and relative to reference case

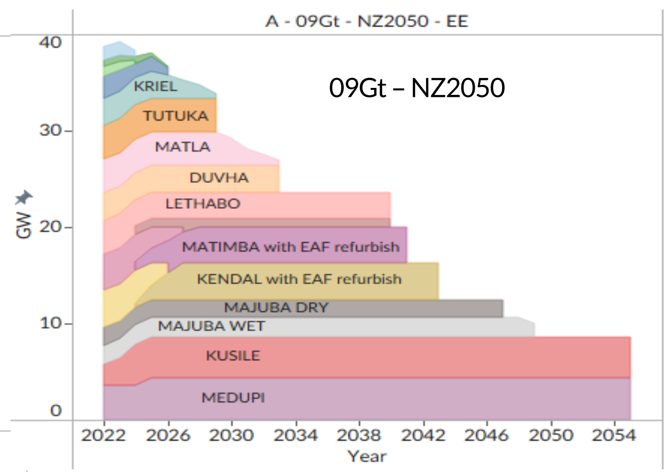


Coal fleet optimisation

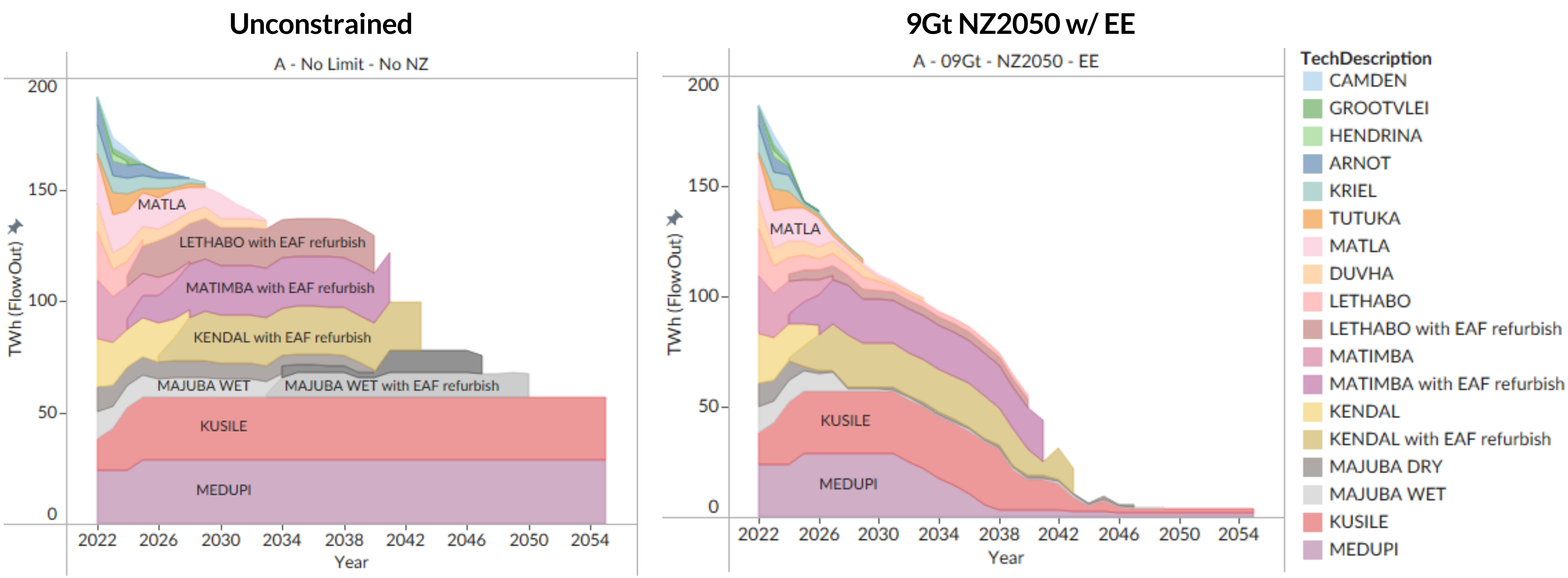
Eskom plan compared with SATIMGE endogenous refurbish/retire - GW







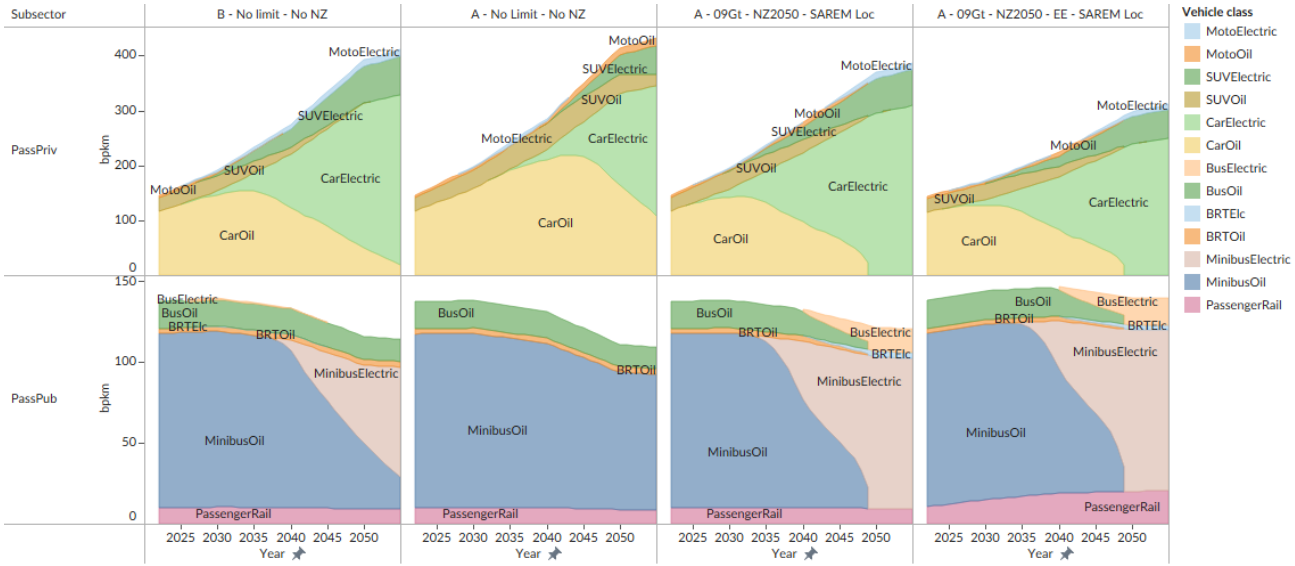
Coal fleet optimisation
SATIMGE endogenous sent-out



Transport

Road transport by vehicle type
ICE to EV transition across World A, B and 09Gt scenarios

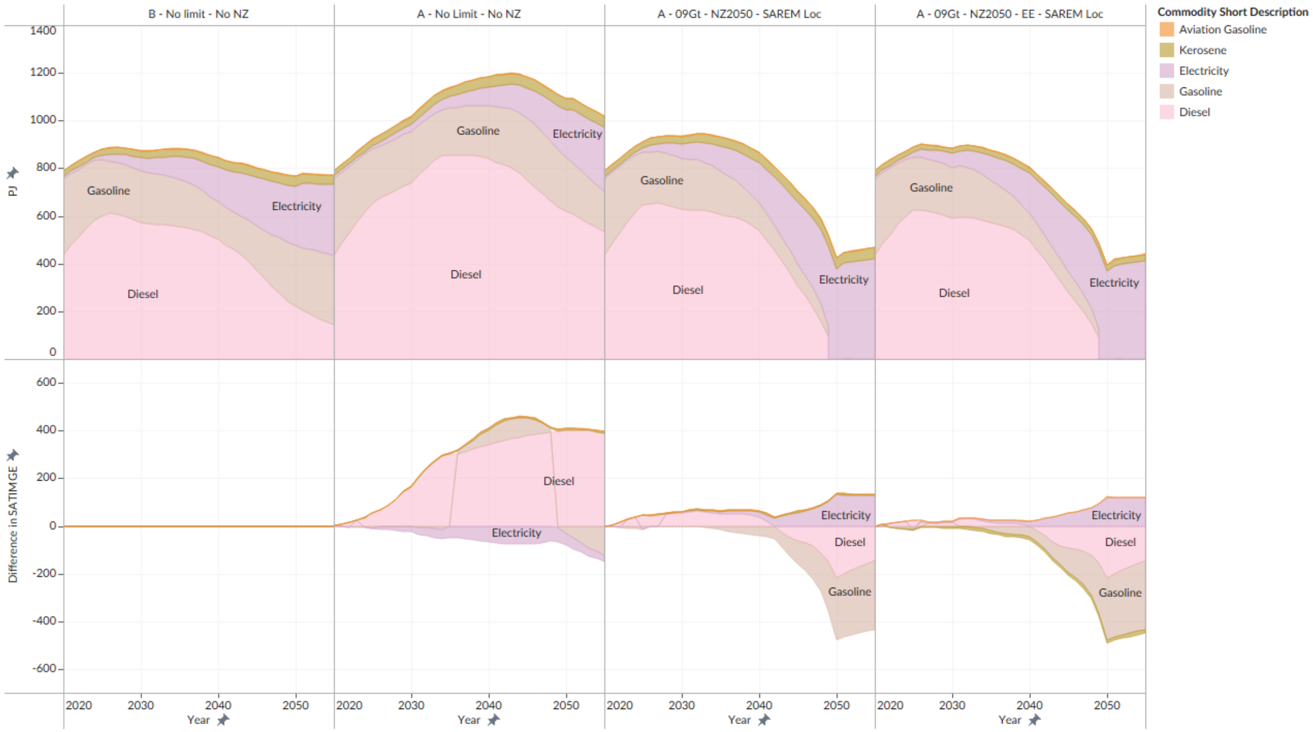
World B reference, World A reference and World A 09Gt with and without EE



- Transition to electric vehicles more rapid in World B than A due to IEA fuel price projections (NB risk of uncertainty with fuel prices); GHG constraints accelerate this shift, even in World A
- Energy efficiency scenario reflects a shift from road to rail transport
- Model results highly sensitive to fuel price and electric vehicle learning – further sensitivities need to be explored here

Transport fuels by scenario

World B reference, World A reference and World A 09Gt with and without EE



Difference in fuel use show, relative to a World B reference case, for World A unconstrained and 09Gt with and without energy efficiency (mode switching)

Fuel use shown here excludes international aviation and pipeline leakages

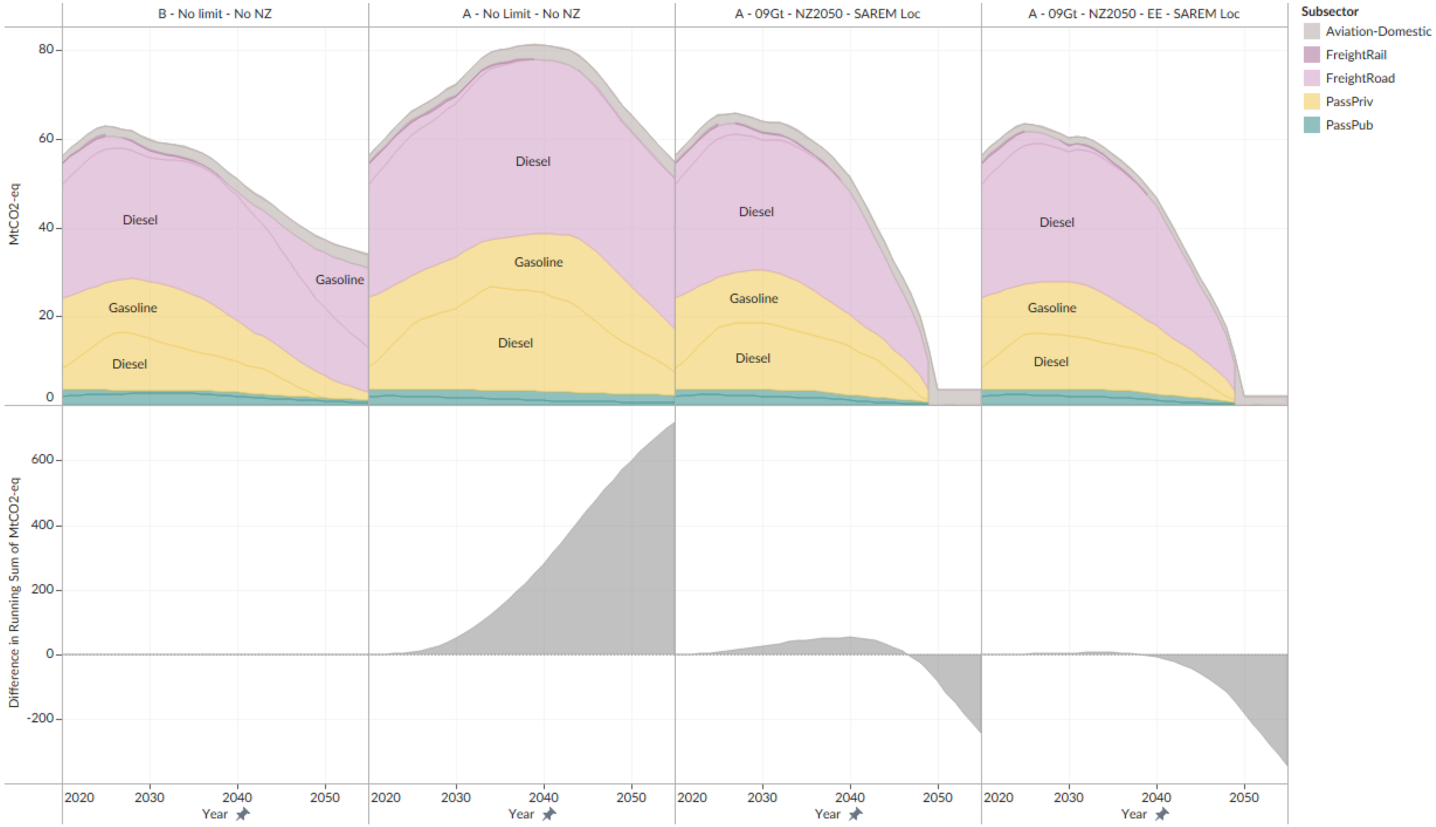
Overall reduction in energy demand in the 09Gt scenarios is due to the greater efficiency of EVs relative to ICEs, and in the case of the EE scenario also to a moderate shift in road-to-rail

Transport GHG emissions

World B reference, World A reference and World A 09Gt with and without EE

Annual GHG emissions

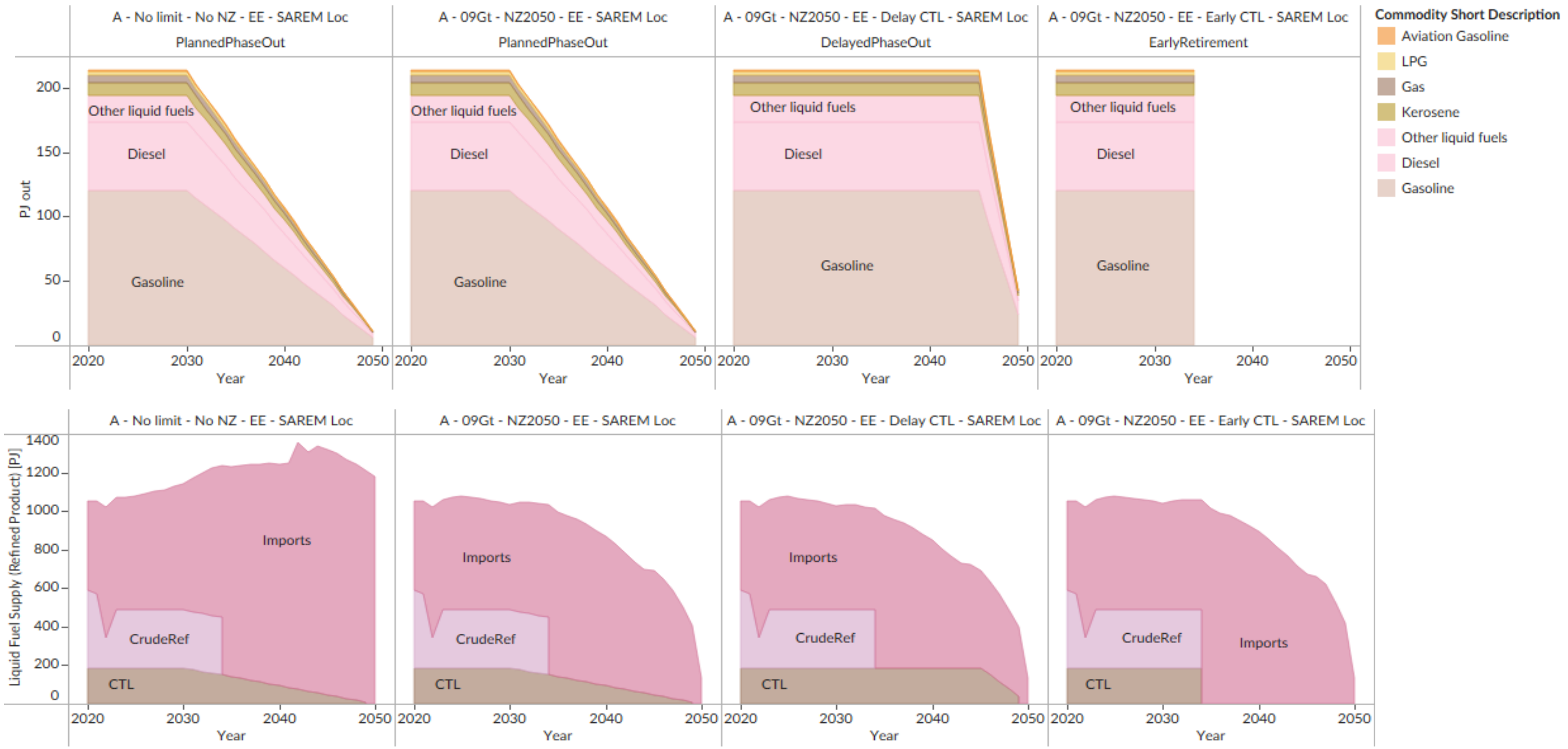
Difference in Cumulative GHG emissions relative to World B ref



Industry

Coal-to-liquids

Impact on liquid fuels and imports

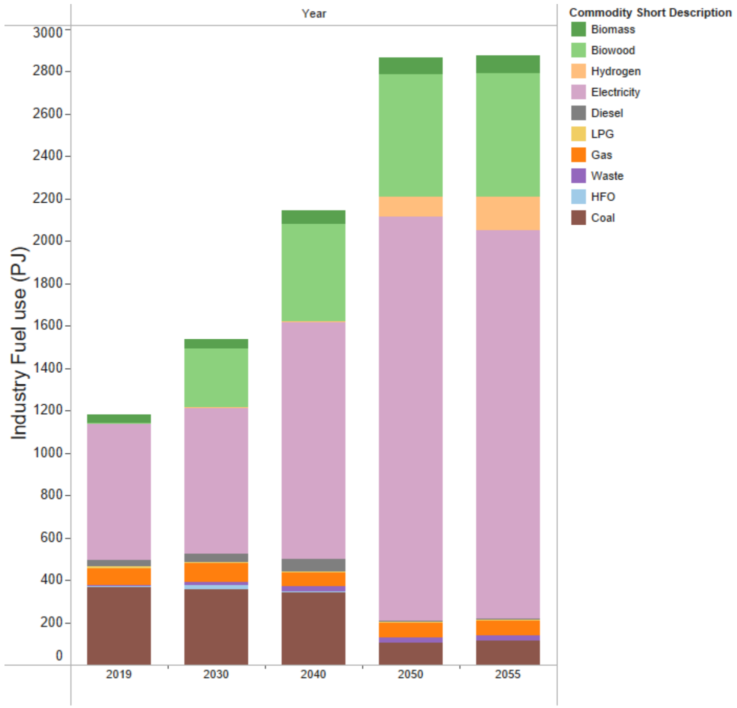


Impact of different CTL futures on GHG emissions

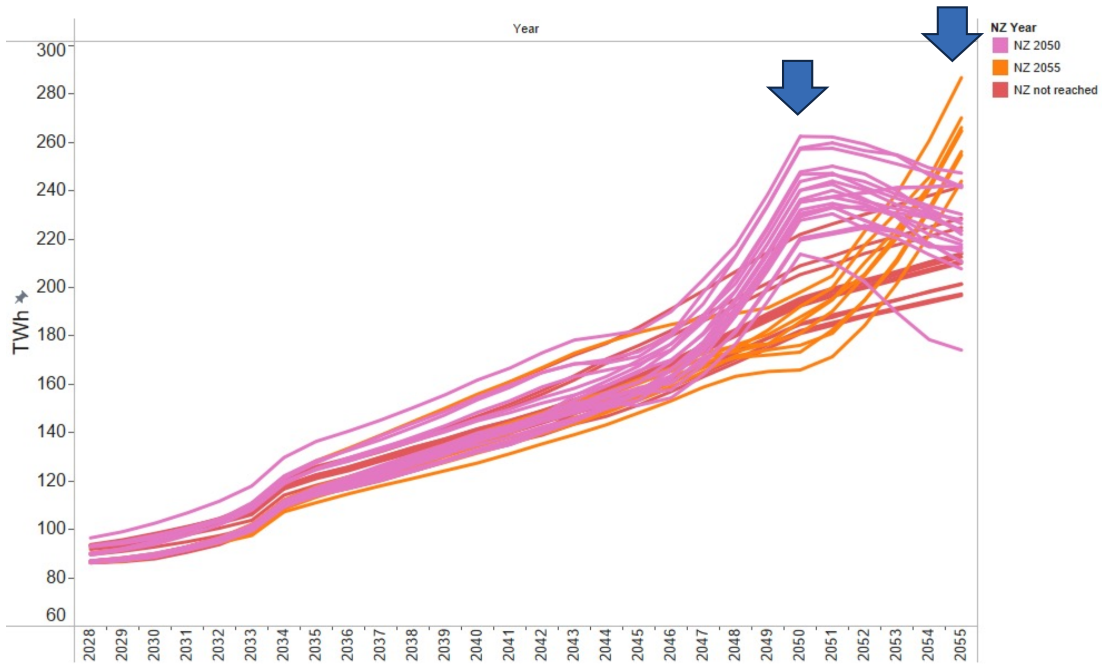
Delayed ramp-down of CTL reduces emissions space for electricity (under a constrained GHG scenario), whilst earlier closure has the opposite effect.

Industry overall
(excl. CTL)

Generally: electrify, but with heat requirements this is done very late.
CCS is required.
Biomass has a role.



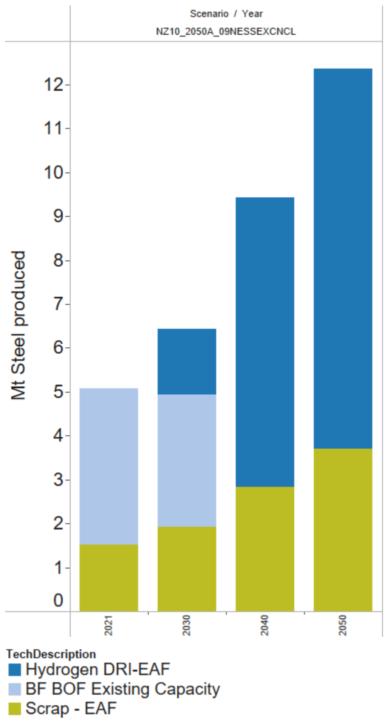
South African industrial energy consumption



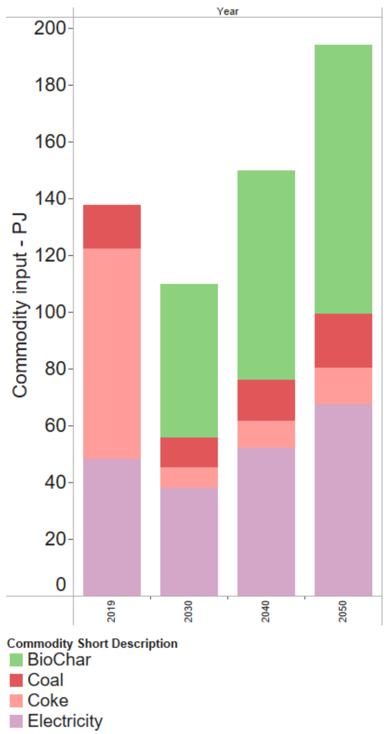
South African industrial electricity consumption

Heavy Industry

Steel



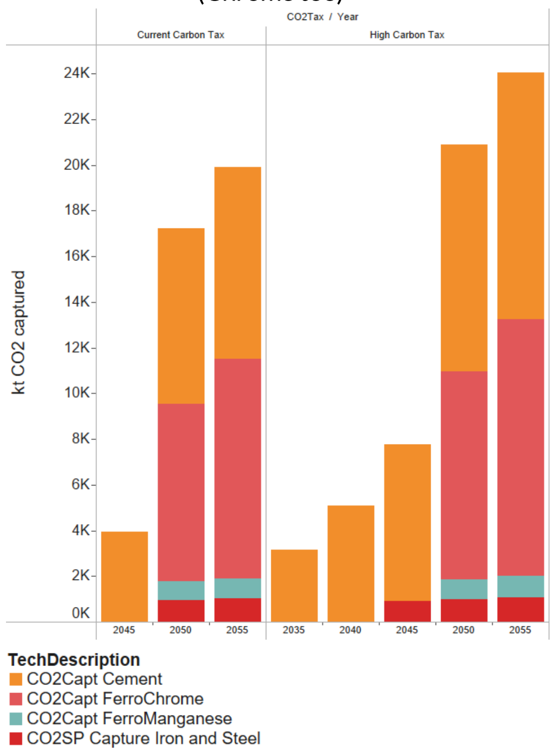
Ferro-Alloys*



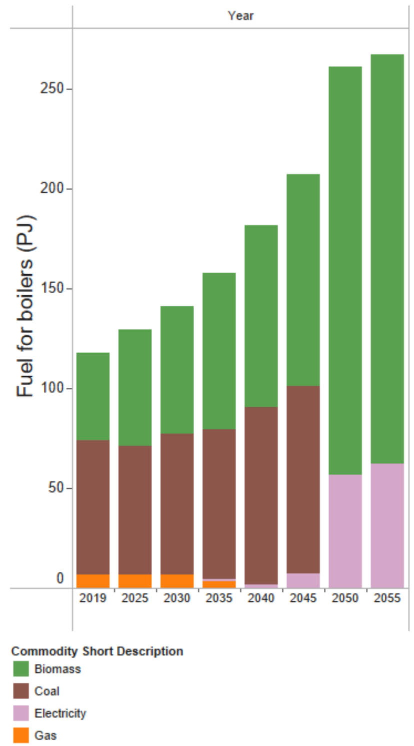
*More work needs to address chrome industry options better

Cement: CCS

(Chrome too)



Pulp and Paper



Rest of industry

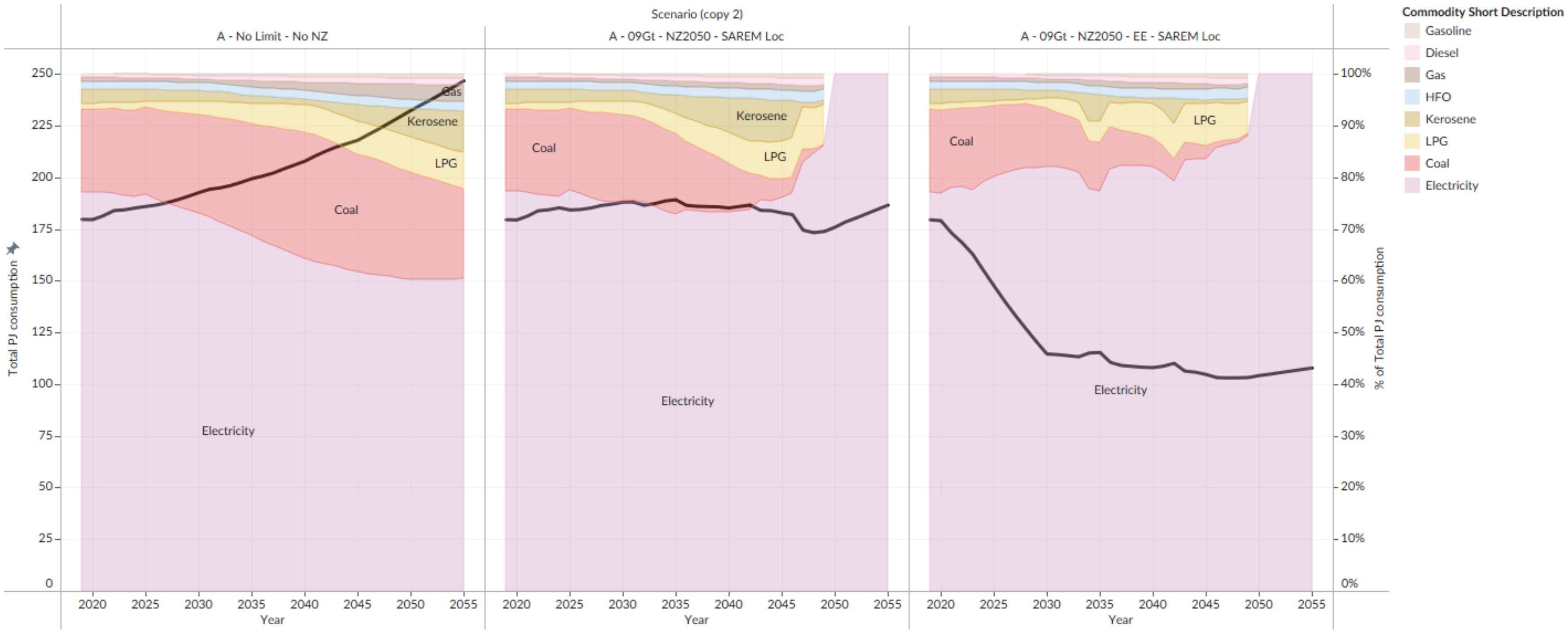
Heat, and electricity for processes

the main energy requirement

To meet Net-Zero:

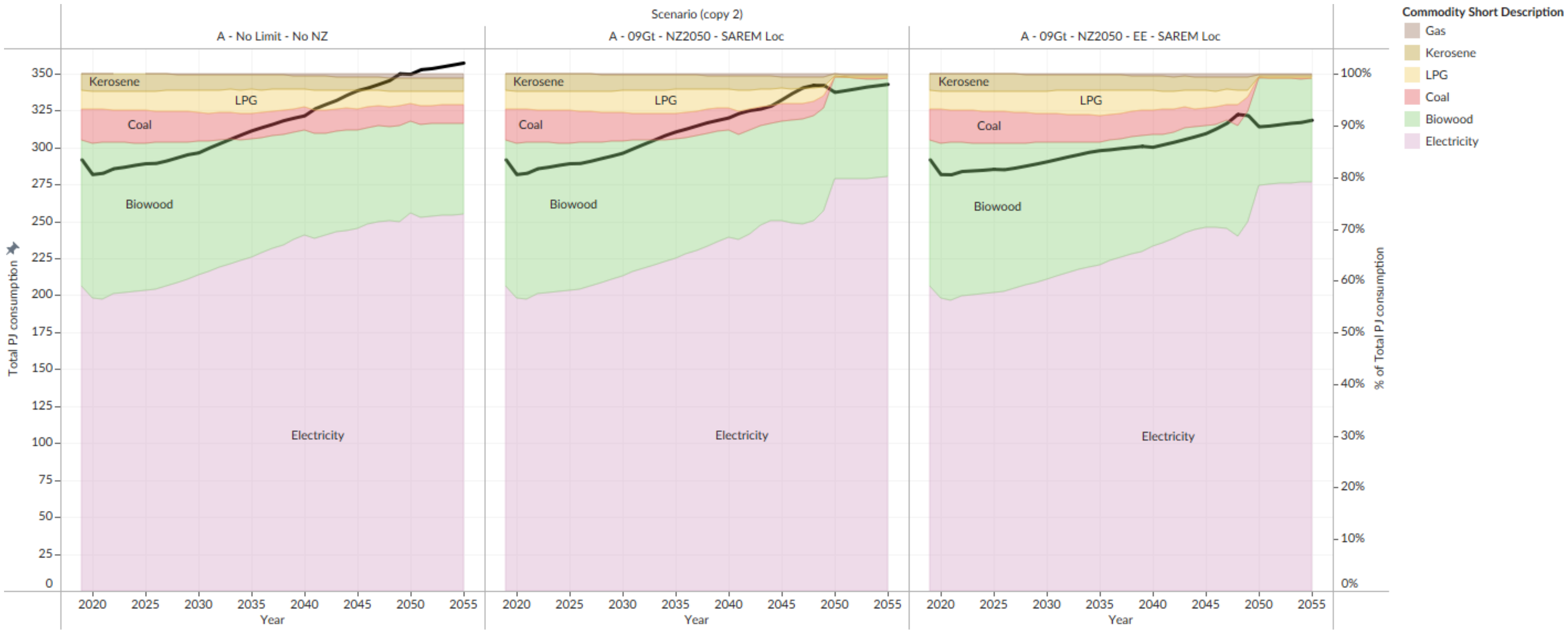
- Coal phase out, but slowly
- Switching to electricity
- Some Hydrogen for high temp requirement
- Biomass in relevant industries: generally at its max

Commerce

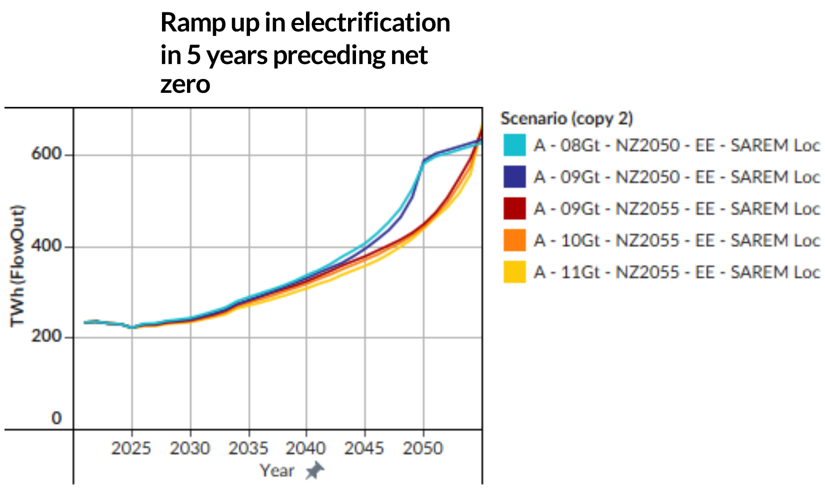


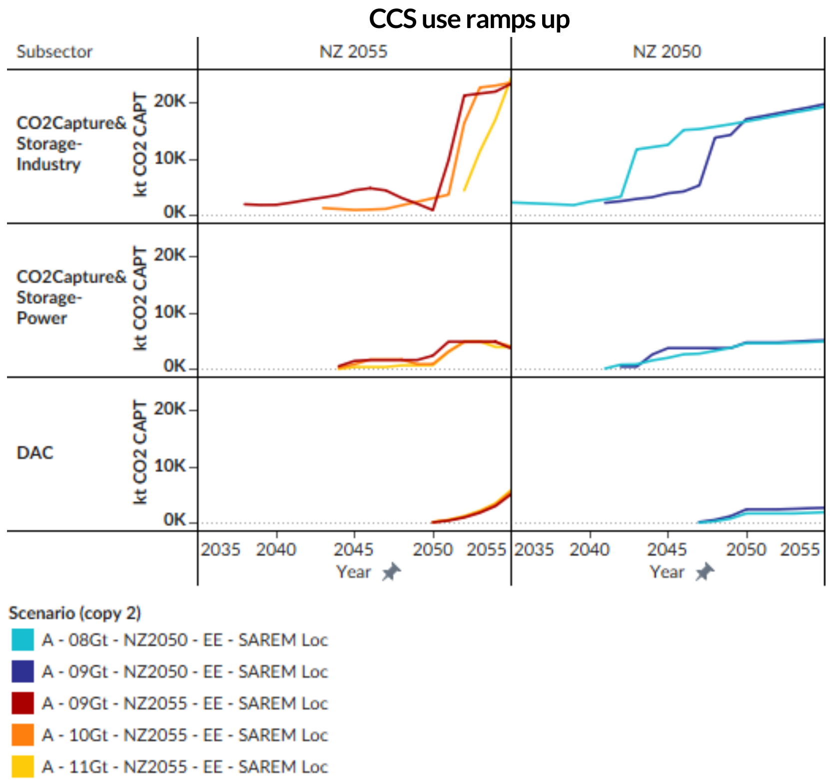
Scenario (copy 2)
A - No Limit - No NZ
A - 09Gt - NZ2050 - SAREM Loc
A - 09Gt - NZ2050 - EE - SAREM Loc
Total PJ consumption
% of Total PJ consumption
Year
Gas
Kerosene
LPG
Coal
Electricity
Commodity Short Description
Gasoline
Diesel
Gas
HFO
Kerosene
LPG
Coal
Electricity

Residential



“Last mile” challenges and uncertainties



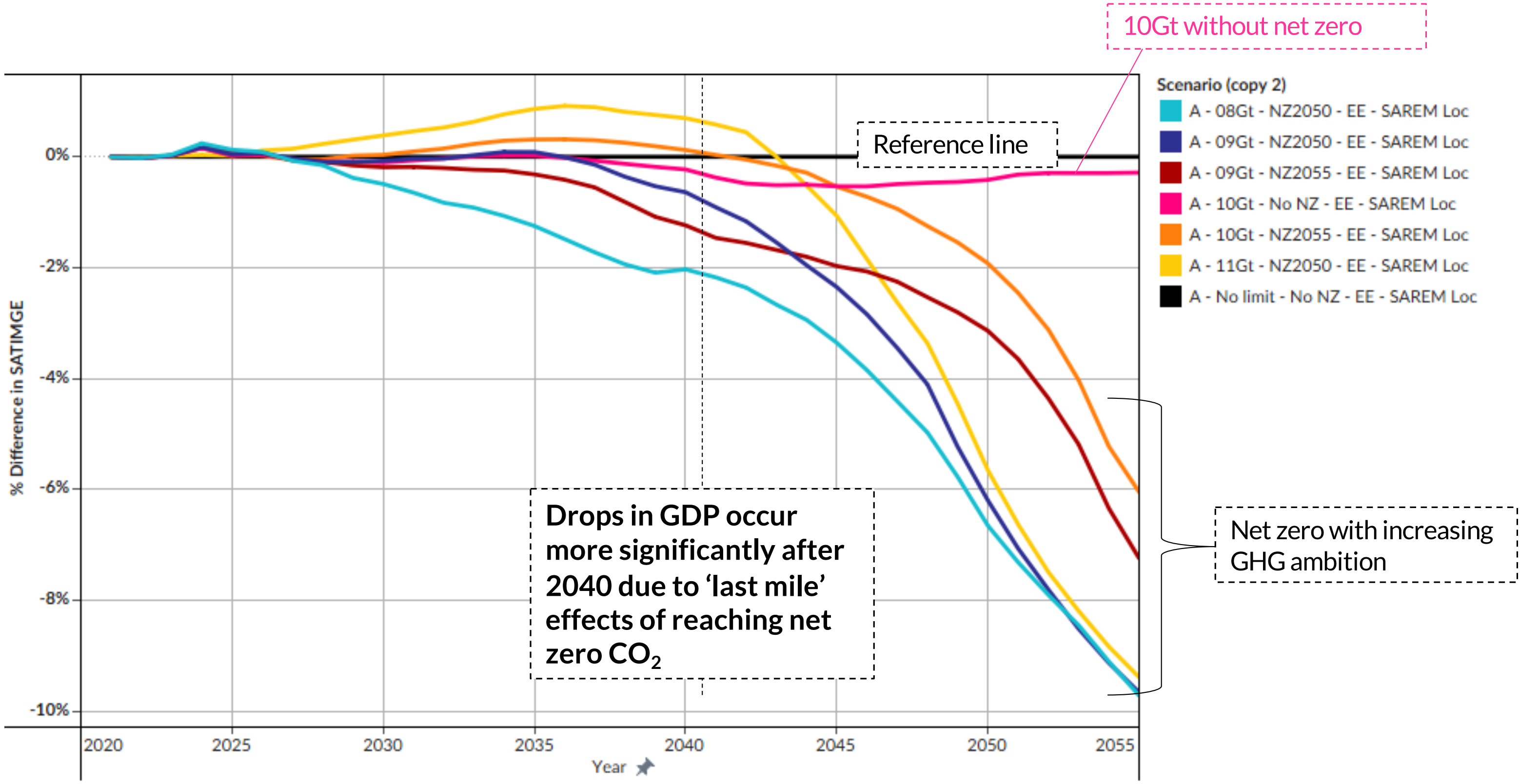


Economic performance

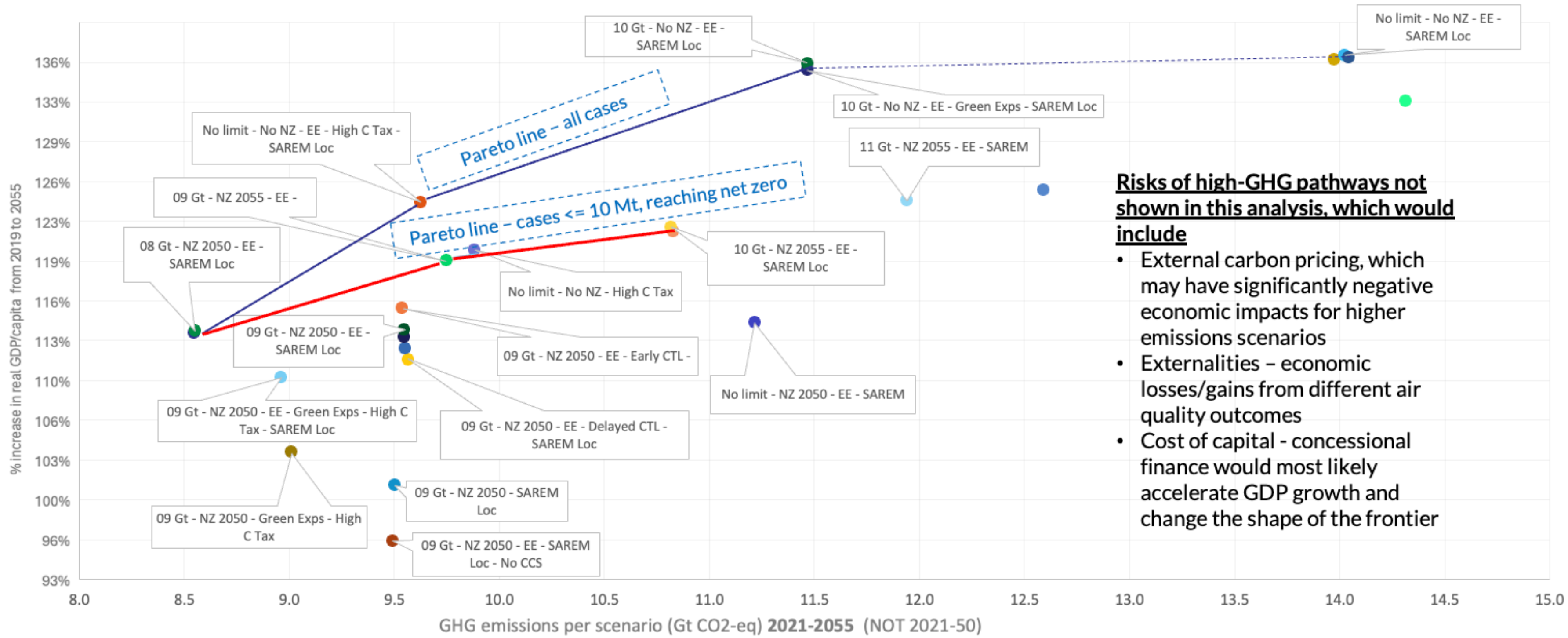
Julia Tatham, Guy Cunliffe

“Last mile” GDP effects

% Difference in GDP per capita below reference (unconstrained run) by year



Pareto analysis for World A:
Economic performance vs. cumulative emissions

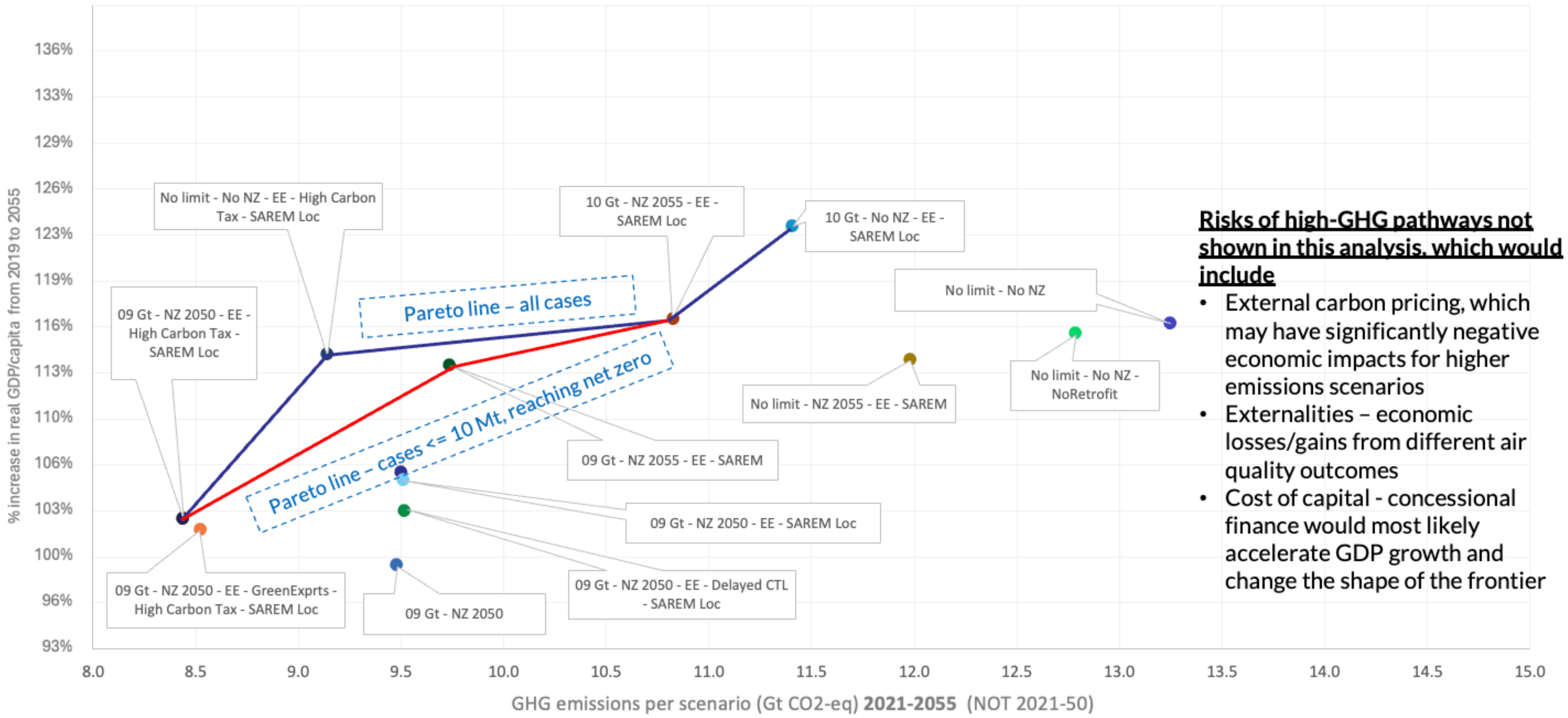


Risks of high-GHG pathways not shown in this analysis, which would include

- External carbon pricing, which may have significantly negative economic impacts for higher emissions scenarios
- Externalities – economic losses/gains from different air quality outcomes
- Cost of capital - concessional finance would most likely accelerate GDP growth and change the shape of the frontier

The key takeaway from this analysis is that many scenarios with similar GHG emissions outcomes have significantly different development outcomes, and that a 10 Gt budget is a no-regrets option. Further work will be necessary to explore this further, and specifically the impact of concessional finance, the economic impact of air quality differences between scenarios, and the impact of individual measures. This analysis assumes NO concessional finance, and does not include externalities for air pollution.

Pareto analysis for World B:
Best performing scenarios in terms of total emissions and wealth gain



Risks of high-GHG pathways not shown in this analysis, which would include

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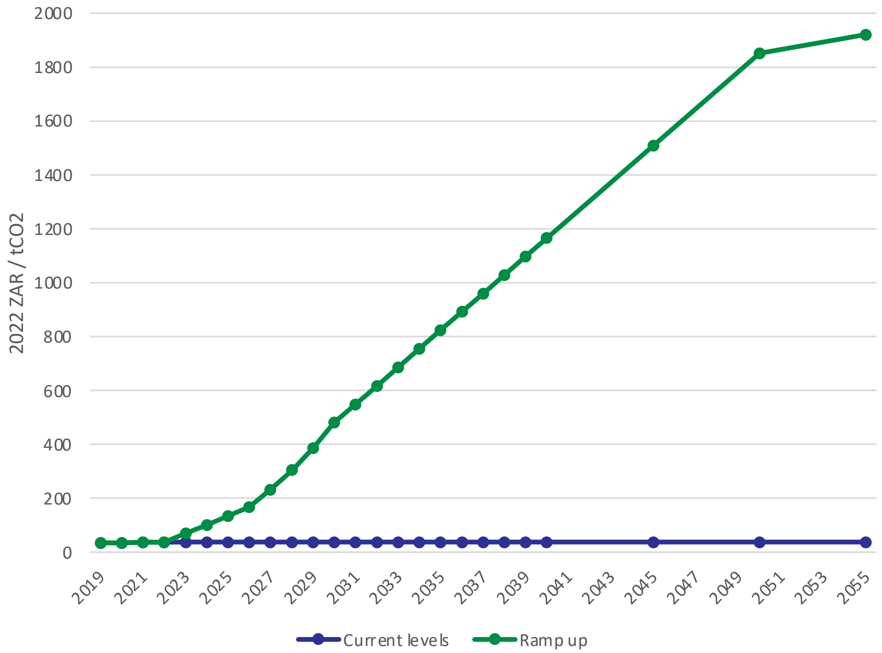
Key policies and measures

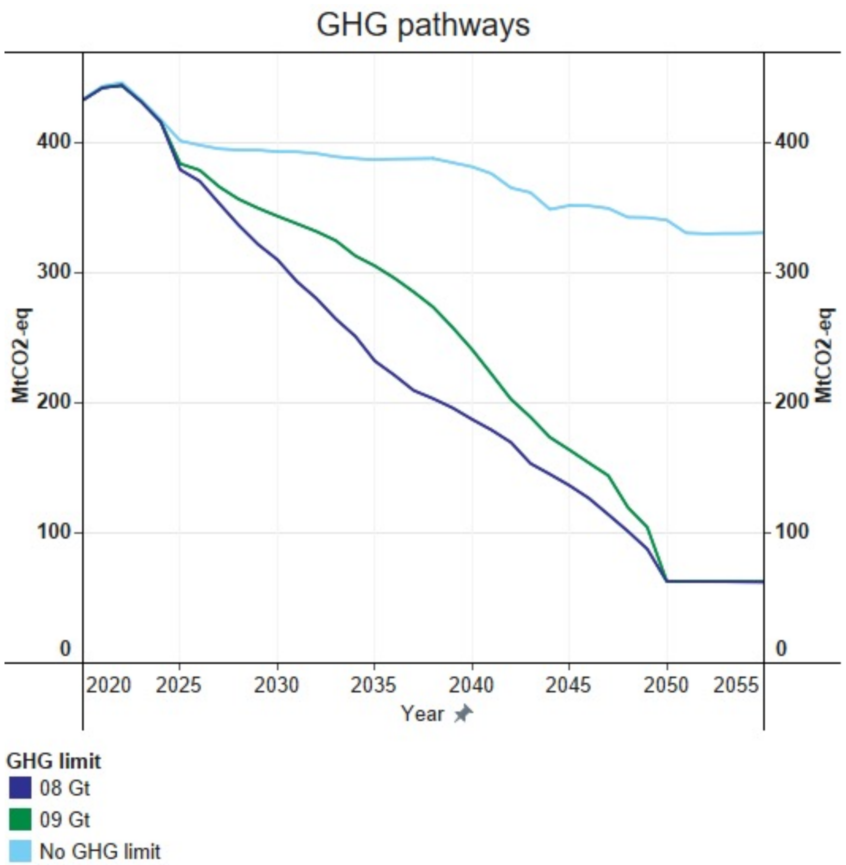
Julia Tatham, Bryce McCall,
Guy Cunliffe

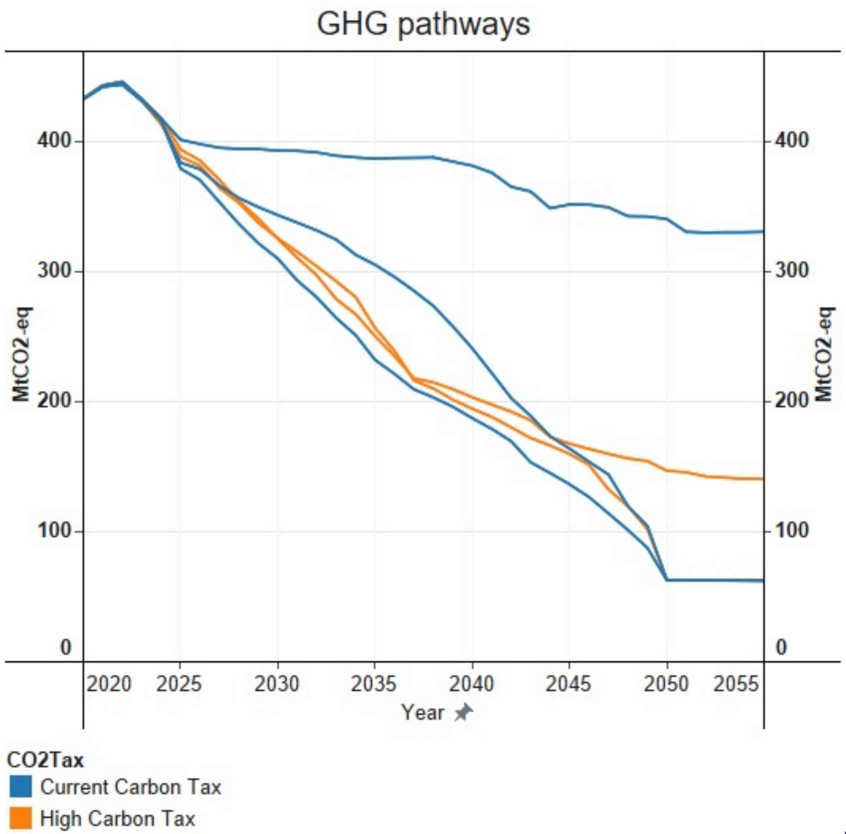


Carbon tax:
'Current levels' assumes a constant level at current levels of around R30 per ton (after allowances) ($1.5)
'Ramp up' – ramp to an effective rate of $30 by 2030 and $120 by 2050, phasing out allowances as proposed in the 2022 budget speech.

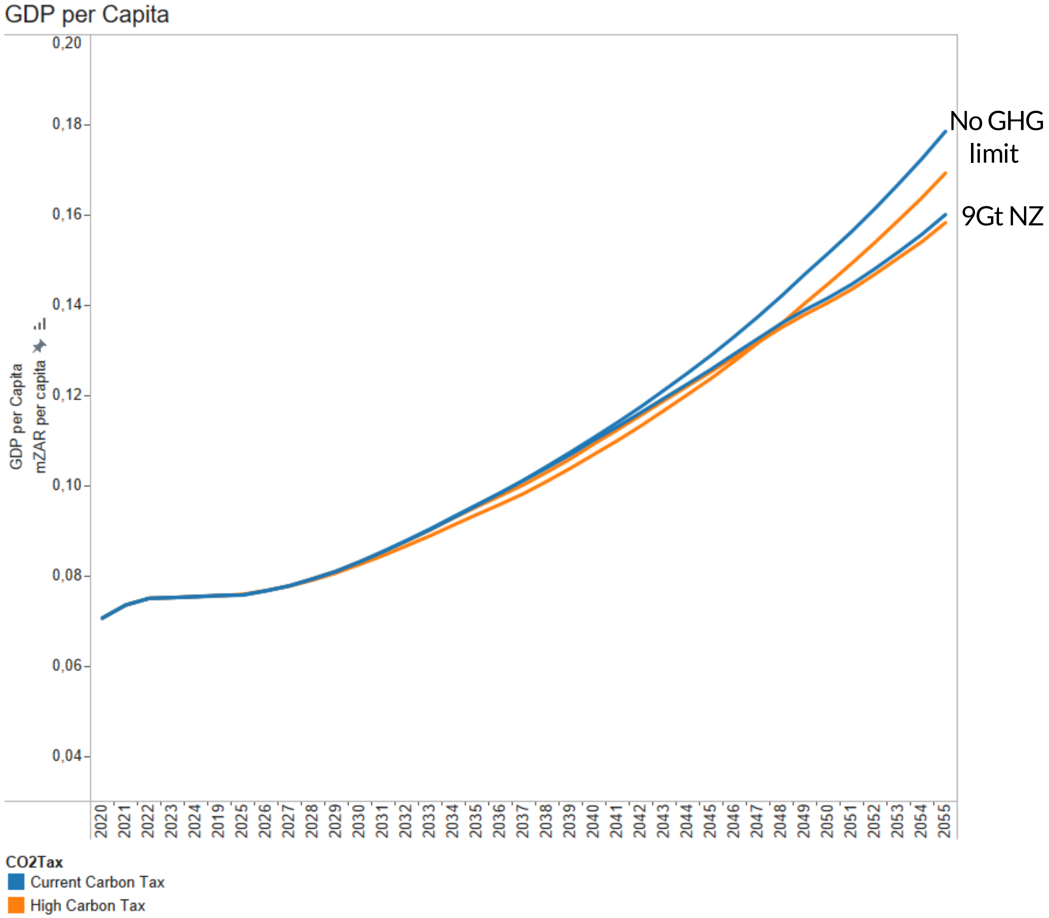
Carbon Tax

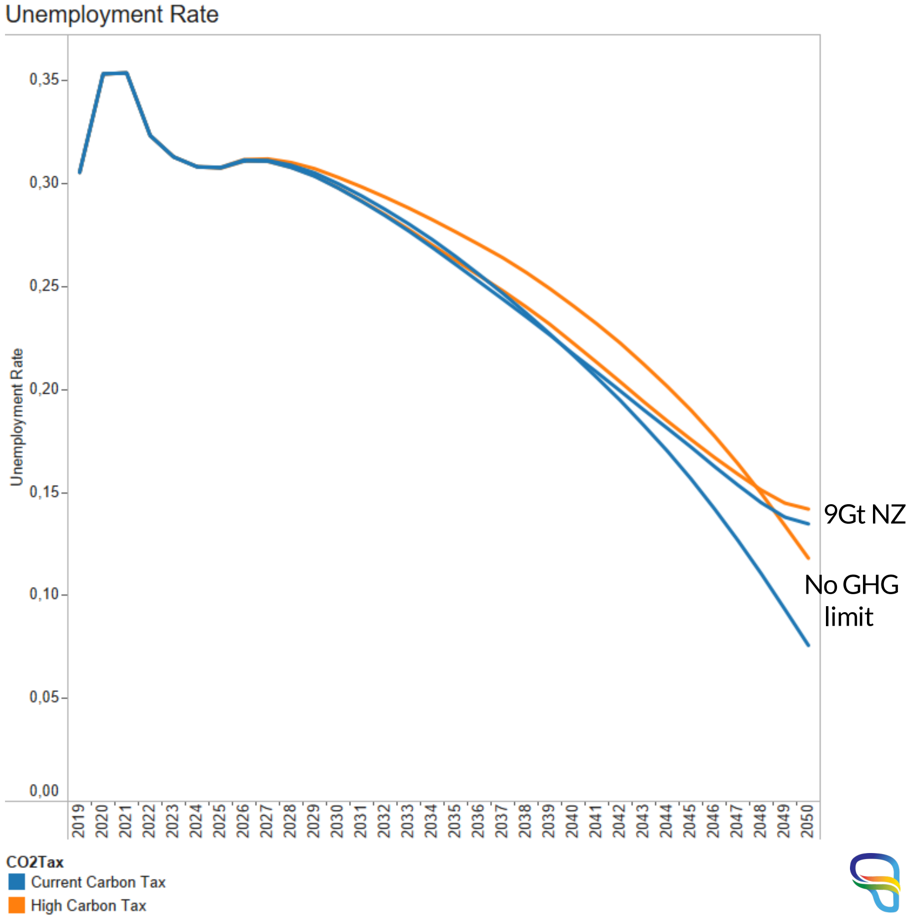
Carbon pricing





Carbon pricing



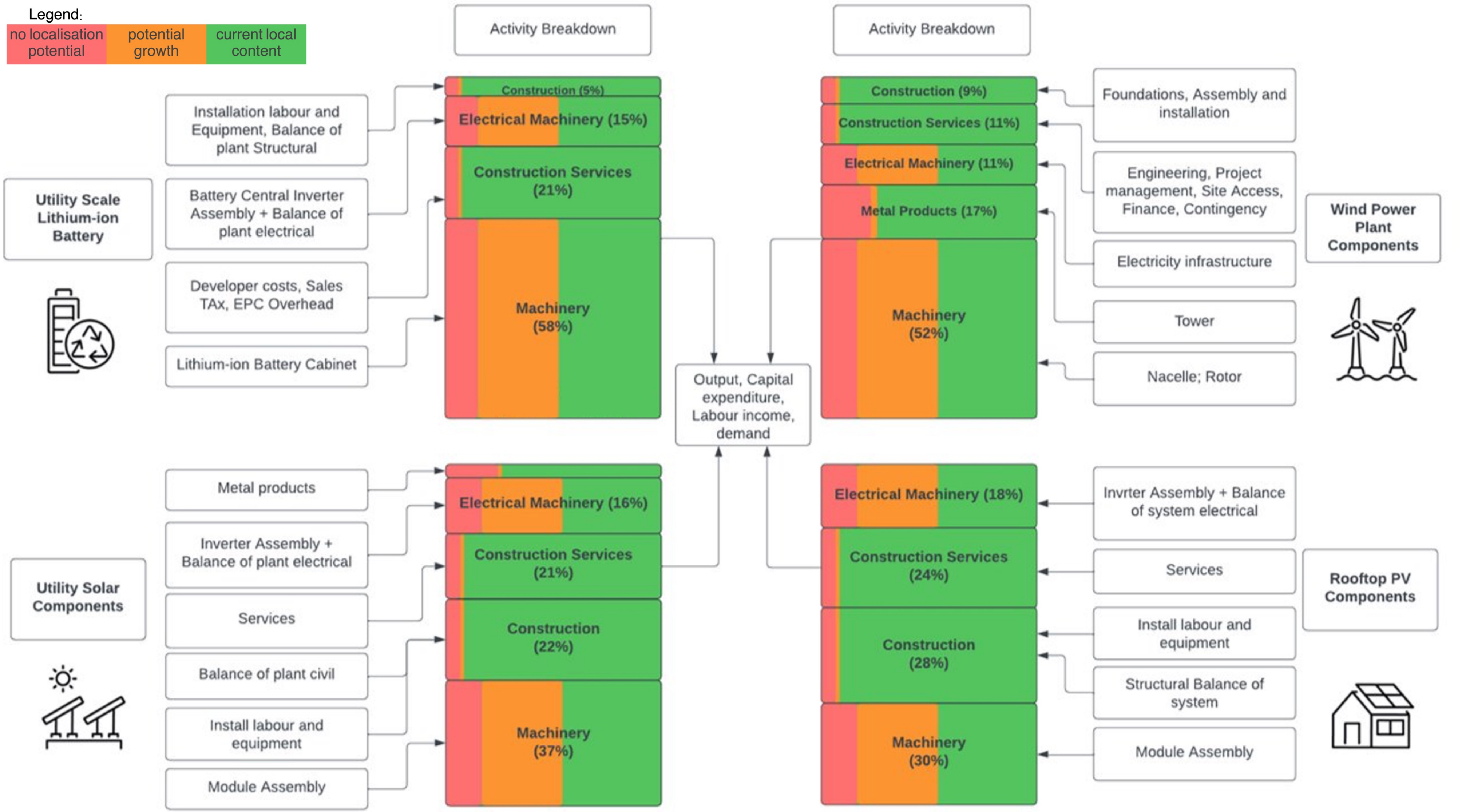


Local content in power sector (SAREM Levels)						
	2017	**2021**	**2025**	**2030**	**2040**	**2050**
Machinery	47%	47%	**55%**	**70%**	**75%**	**85%**
Electrical Machinery	48%	48%	**55%**	**70%**	**75%**	**85%**
Metal Products	76%	76%	**76%**	**78%**	**78%**	**78%**
Construction Services	94%	94%	**94%**	**95%**	**95%**	**95%**

- SAREM (2022) estimates that by 2030 South African manufacturing can achieve 70% localization of renewable energy components
- A 5% premium on the total investment cost of renewable energy is used.

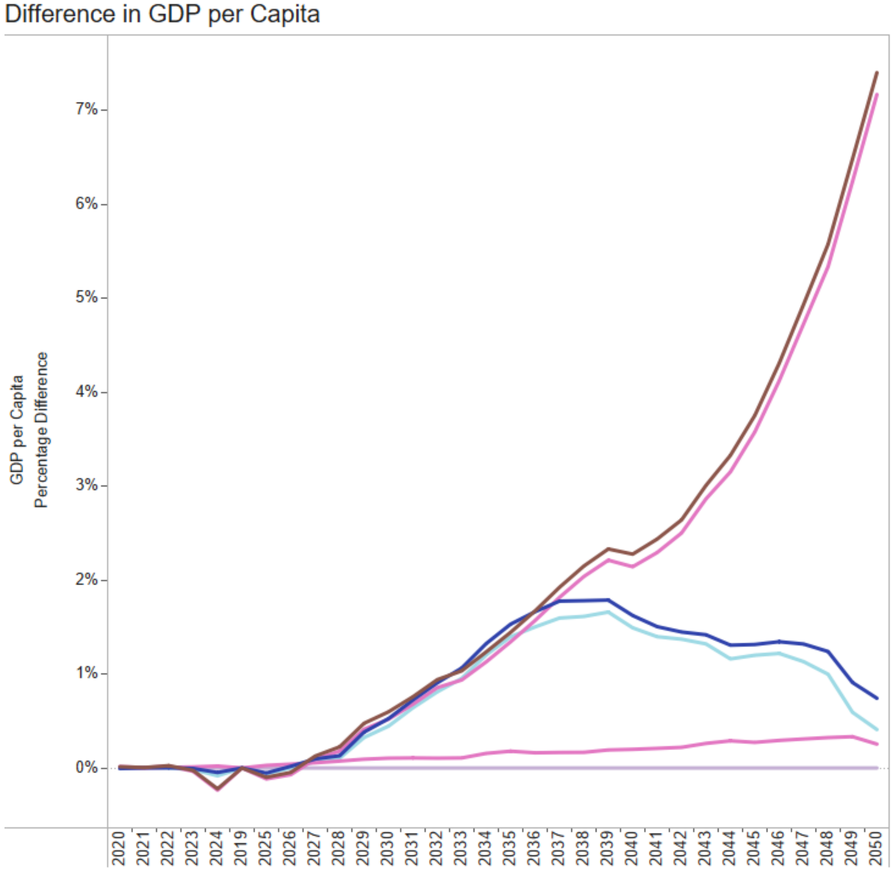
Localisation

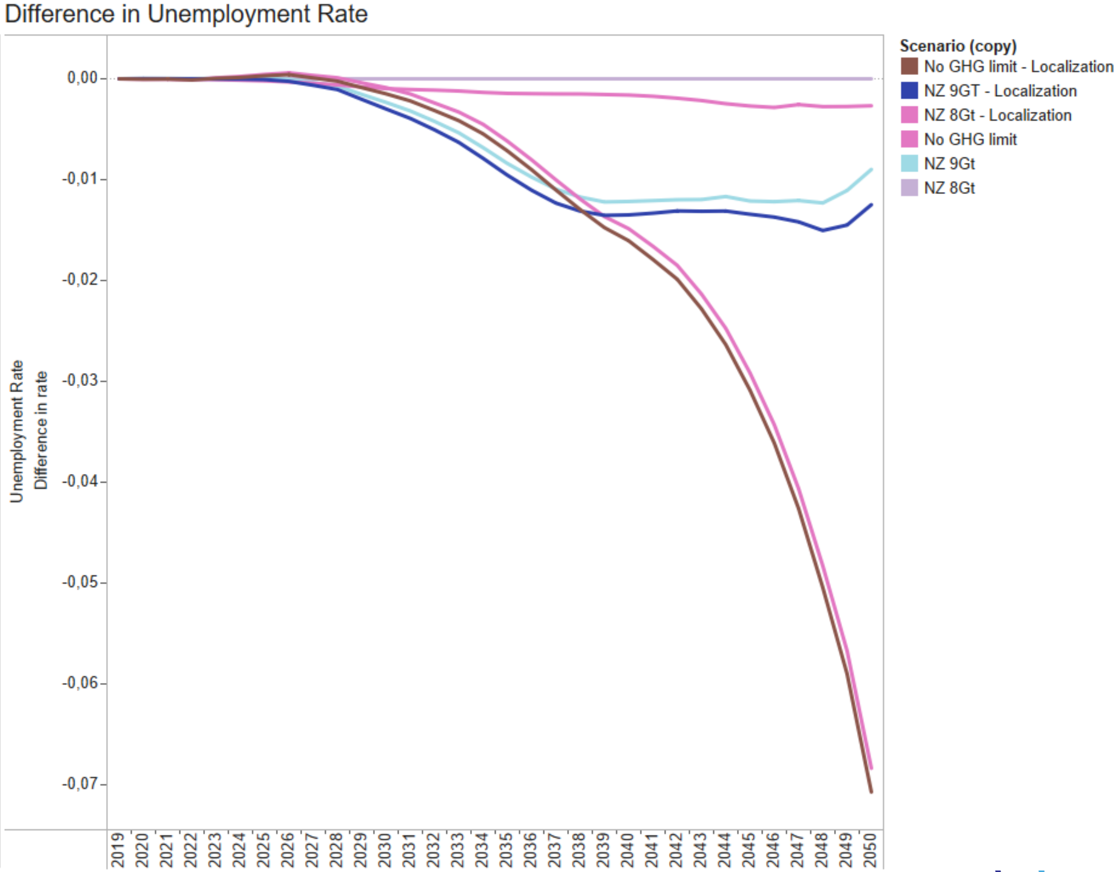
Localisation development in SATIMGE supported by the European Commission, and part of the DDP network coordinated by IDDRI



Legend:
no localisation potential
potential growth
current local content
Activity Breakdown
Activity Breakdown
Construction (5%)
Electrical Machinery (15%)
Construction Services (21%)
Machinery (58%)
Installation labour and Equipment, Balance of plant Structural
Battery Central Inverter Assembly + Balance of plant electrical
Developer costs, Sales TAx, EPC Overhead
Lithium-ion Battery Cabinet
Utility Scale Lithium-ion Battery
Construction (9%)
Construction Services (11%)
Electrical Machinery (11%)
Metal Products (17%)
Machinery (52%)
Foundations, Assembly and installation
Engineering, Project management, Site Access, Finance, Contingency
Electricity infrastructure
Tower
Nacelle; Rotor
Wind Power Plant Components
Output, Capital expenditure, Labour income, demand
Metal products
Inverter Assembly + Balance of plant electrical
Services
Balance of plant civil
Install labour and equipment
Module Assembly
Utility Solar Components
Electrical Machinery (16%)
Construction Services (21%)
Construction (22%)
Machinery (37%)
Electrical Machinery (18%)
Construction Services (24%)
Construction (28%)
Machinery (30%)
Invrter Assembly + Balance of system electrical
Services
Install labour and equipment
Structural Balance of system
Module Assembly
Rooftop PV Components

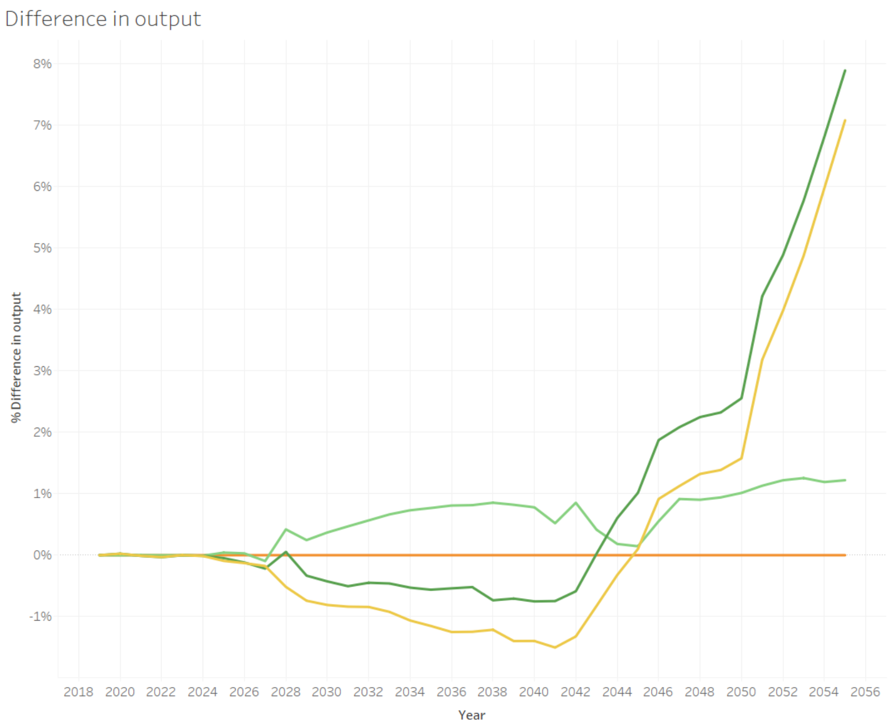
Localisation Impact

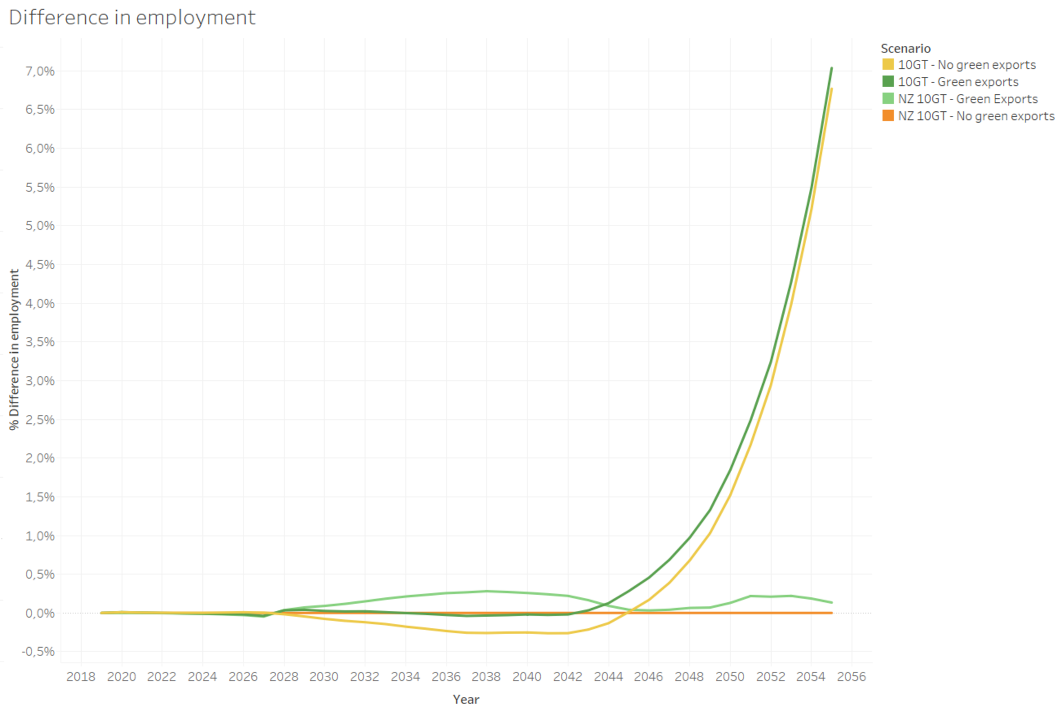




Percentage difference from NZ 8GT no localization scenario

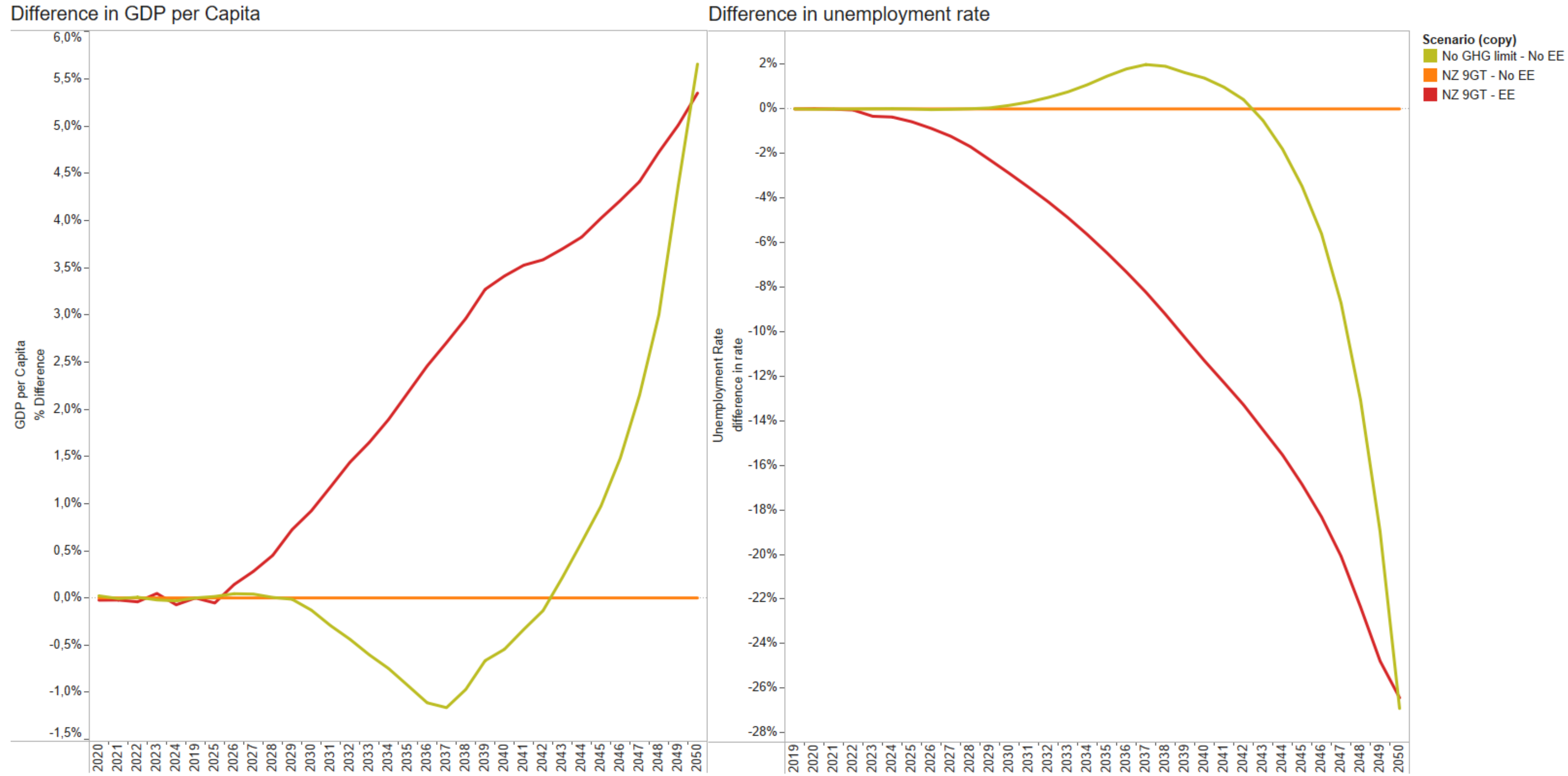
Green Exports





Percentage difference from no NZ 10GT no green exports scenario

Energy efficiency



Difference from NZ 9GT no energy efficiency scenario

Conclusions

Andrew Marquard

Major Conclusions

1. An ambitious and coherent mitigation pathway within the current "fair share" envelope of 9-10 Gt is achievable across worlds A and B, including reaching net zero CO_2 emissions in 2050/55, subject to the caveats below.
2. Key sectors for long-term decarbonization are electricity, road transport, liquid fuel supply and industry – these sectors require deep transformation; other sectors will play a significant role and cannot be disregarded. The core of South Africa's decarbonization remains the electricity sector throughout the timeframe.
3. All modelled cases which reach net zero CO_2 emissions in this study make use of a 10 Mt CO_2 annual CO_2 sink in the land sector, and up to 40 Mt of annual carbon capture and storage. If either of these options are not available in the 2040s and 2050 at the required scale, then reaching net zero would require other measures – technologies not yet available to mitigate emissions in the relevant sectors, and/or substitution of goods and services associated with these residual CO_2 emissions.
4. All scenarios which reach net zero require dramatically accelerated investment in the electricity sector within the 5-7 years before net zero is reached, which will require considerable national effort. Despite this, even a scenario with a very stringent GHG emissions budget (8 Gt to 2050) reaches net zero in 2050 AND doubles the GDP/capita by 2055.
5. Specific measures have a significant impact on GDP, and finding the optimal package is important to a just transition. Currently proposed carbon price levels are effective for mitigation but without international support, will have negative GDP impacts; localisation has a discernibly positive impact, but does not offset negative impacts of the "last mile" without climate finance; energy efficiency has mitigation and economic benefits across all scenarios and in all time horizons.

Further work

- The role of international climate finance / concessional finance is apparently very significant in determining GDP outcome, but requires further work and assessment using different modelling methodologies.
- The land sector requires more detailed work, both on its sink potential and on the risk of the sector becoming a net source.
- Developing a regional version for SATIMGE would provide more insights into the decarbonization trajectories and constraints of major emitting sectors.
- A more detailed analysis of current carbon pricing proposals and their relationship with other measures is necessary.
- More work on "last mile" technology options and alternatives (reducing / avoiding goods and services) is necessary, and technology options and costs will develop over time.
- The potential of CCS and CDR (which relies on CCS) need to be more thoroughly assessed for South Africa.
- Potential risks from bottlenecks and other short-term constraints need to be further explored.
- Work on air quality and the costs of air pollution need to be further integrated into economic analyses of GHG emissions pathways.
- Synergies and tradeoffs between changes in liquid fuels supply, chemicals, transport technologies, air quality and the overall GHG budget.
- The costs and benefits of later net zero targets (2060).
- Scenario analysis and backcasting.