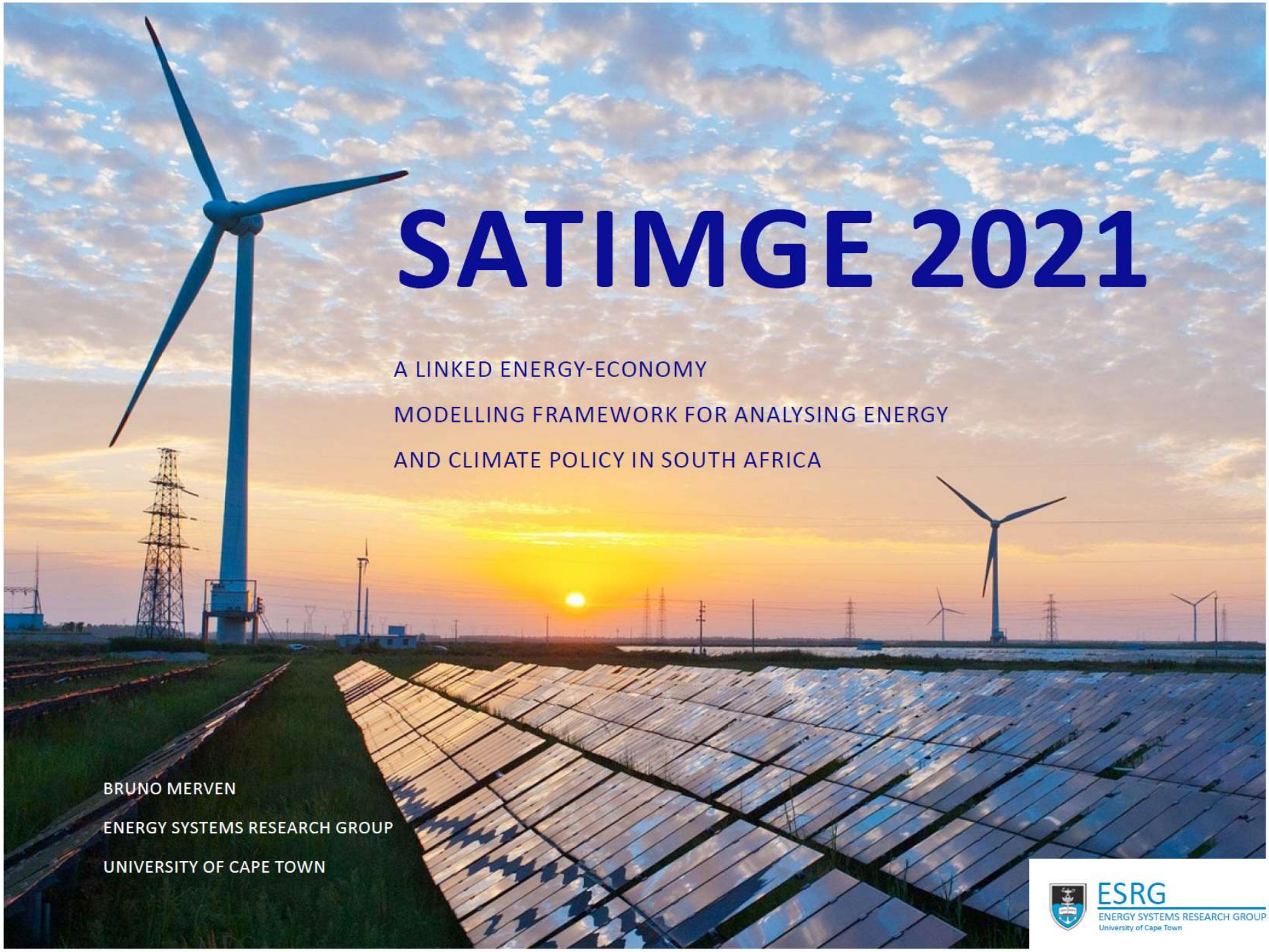

SATIMGE 2021

A LINKED ENERGY-ECONOMY MODELLING FRAMEWORK FOR ANALYSING ENERGY AND CLIMATE POLICY IN SOUTH AFRICA

BRUNO MERVEN

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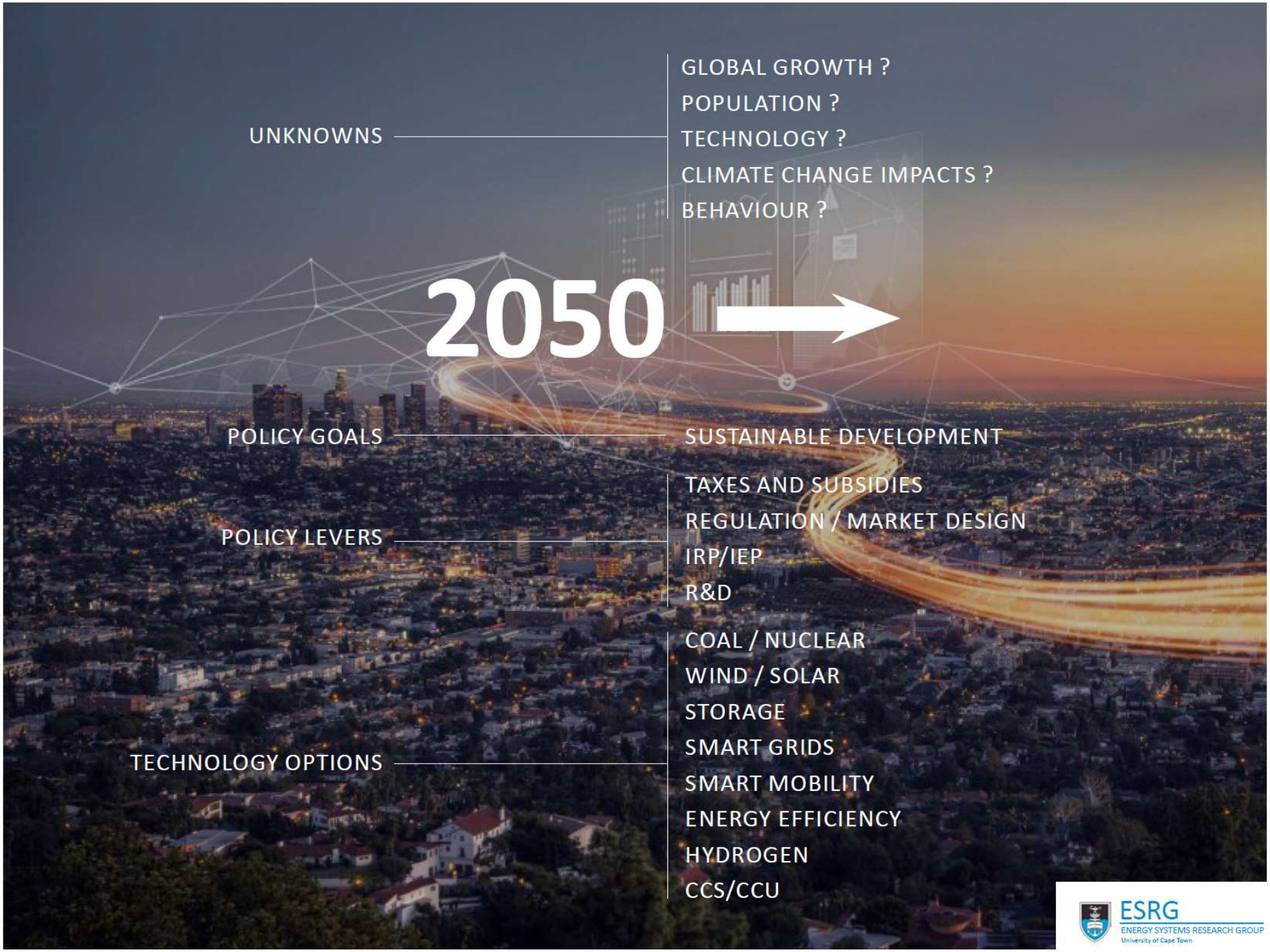
UNKNOWNS
GLOBAL GROWTH ?
POPULATION ?
TECHNOLOGY ?
CLIMATE CHANGE IMPACTS ?
BEHAVIOUR ?
2050
POLICY GOALS
SUSTAINABLE DEVELOPMENT
POLICY LEVERS
TAXES AND SUBSIDIES
REGULATION / MARKET DESIGN
IRP/IEP
R&D
TECHNOLOGY OPTIONS
COAL / NUCLEAR
WIND / SOLAR
STORAGE
SMART GRIDS
SMART MOBILITY
ENERGY EFFICIENCY
HYDROGEN
CCS/CCU
ESRG
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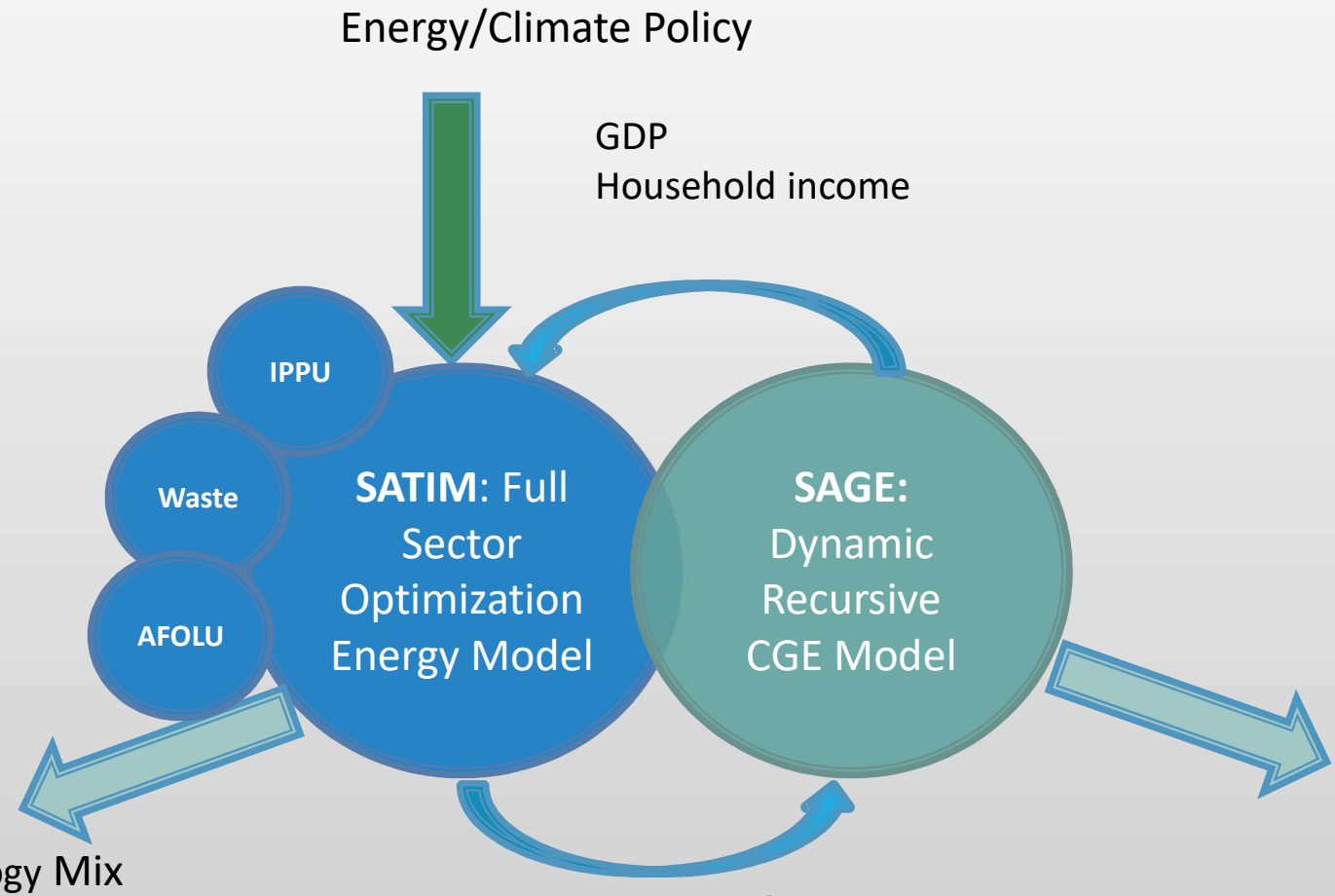
University of Cape Town

SATIMGE 2021



Power Sector Production function
Expenditure on Power Sector expansion plan
Production function of all activities (energy)
Consumption function of households (energy)
Capacity for Exogenous Sectors: Coal mining, Hydrogen, Power, Refineries

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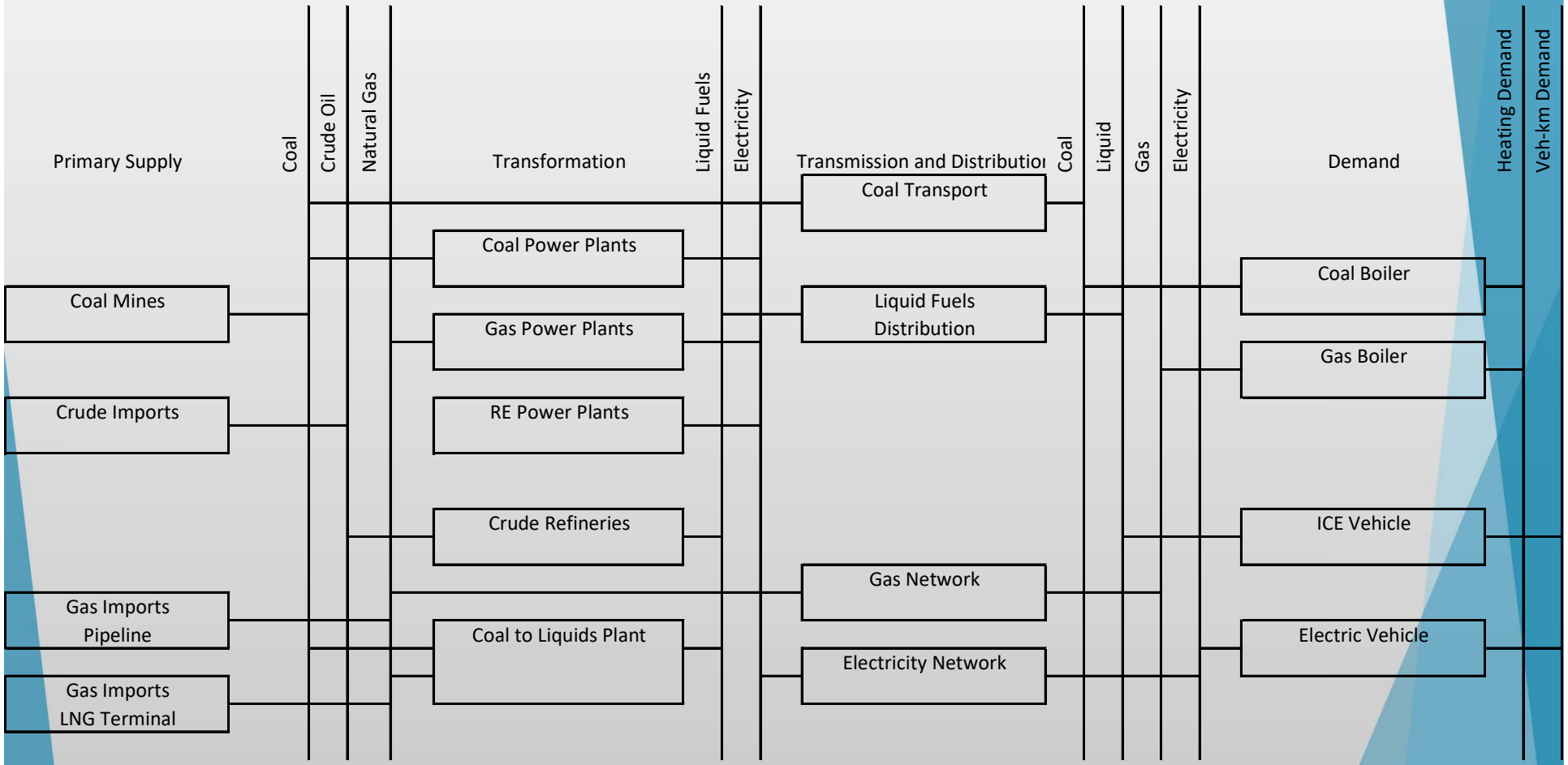
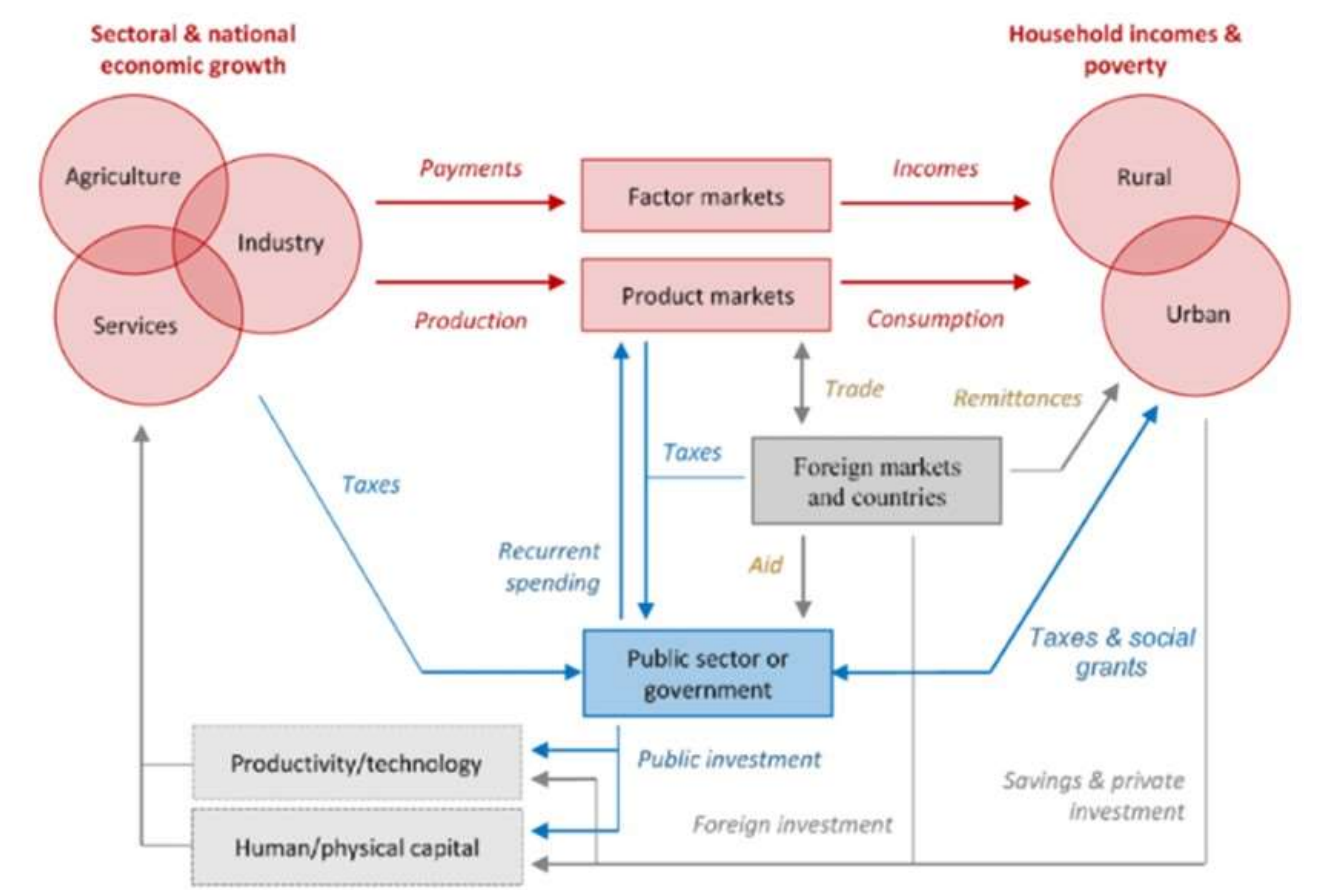
SATIM Full Sector Energy Systems Model (abstract/sketch)

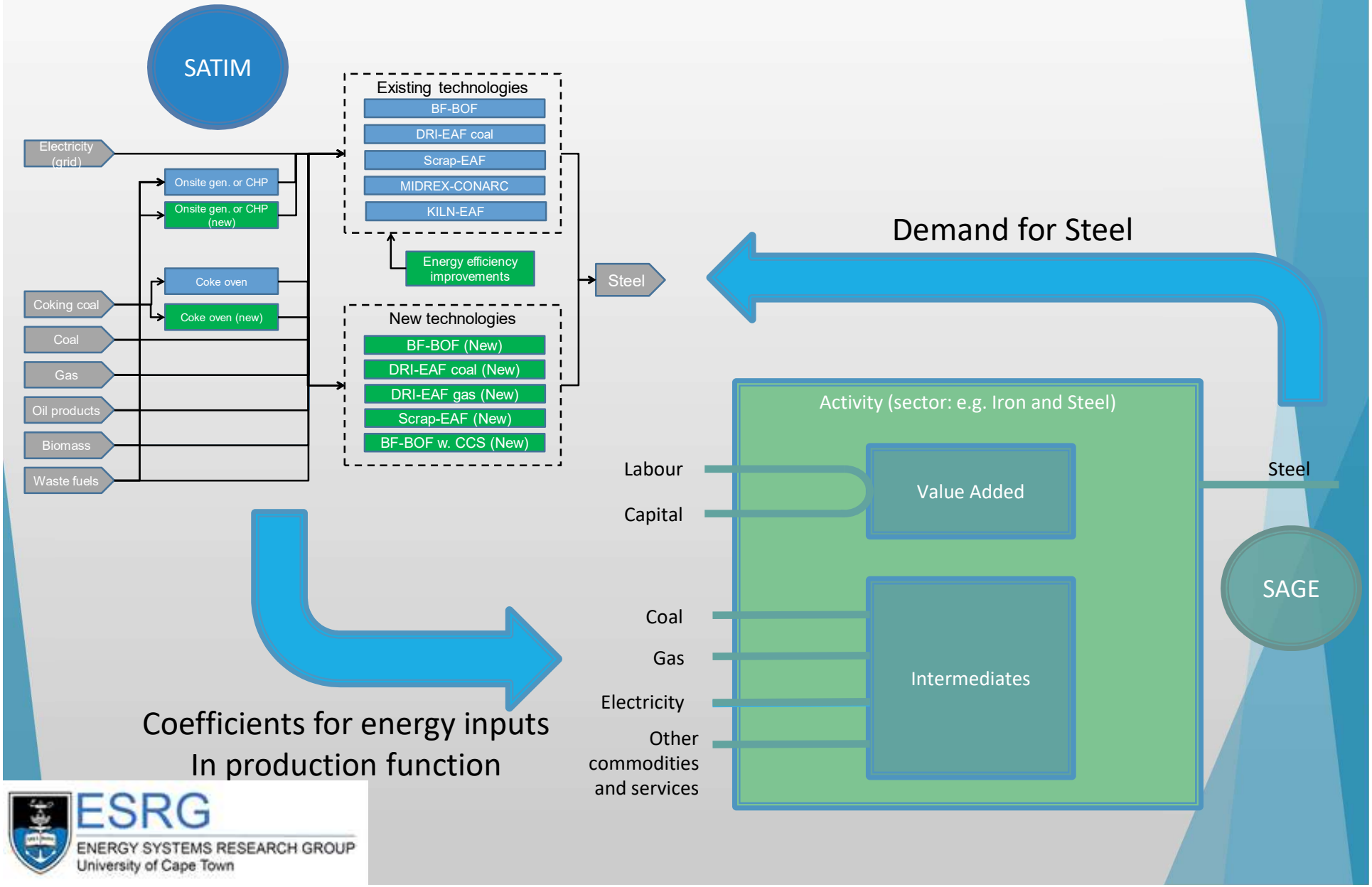


Energy detailed SA CGE model (SAGE)



- 56 economic activities, 59 commodities
- 10 Income deciles, 4 labour skill categories
- Upward sloping curve for labour
- Putty-Clay capital and endogenous capital accumulation
- Fixed Current Account with flexible exchange rate
- Fixed growth for foreign savings

Linked model: production of steel



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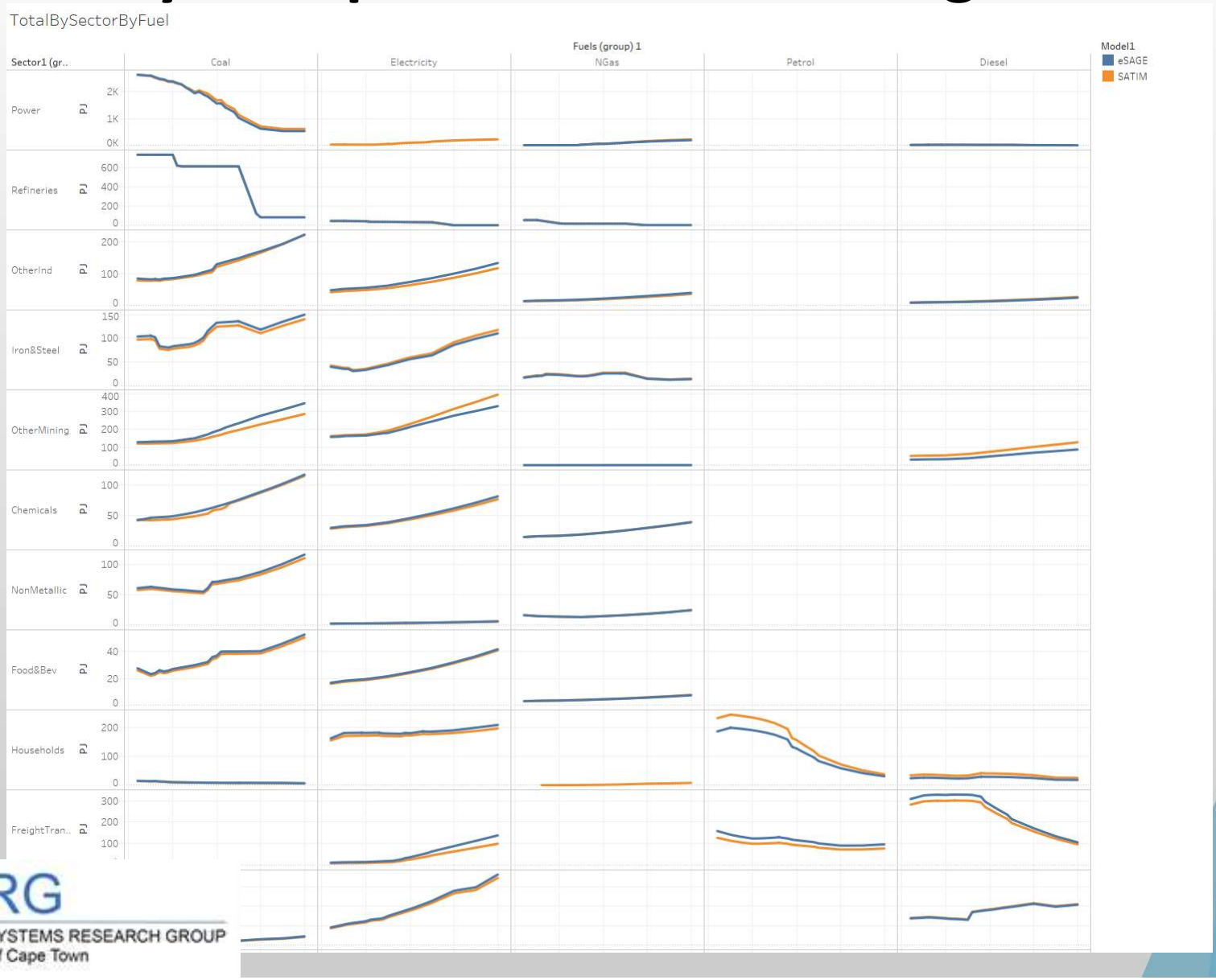
Linking CGE model to energy model necessary to capture technical change

SATIM SAGE



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2003	DME IEP-1	MARKAL+LEAP
2006	EPSD-SA - IAEA	MARKAL
2007	DEA LTMS	MARKAL
2008	WWF Costing 2020 RE Target	MARKAL
2010	DME Review of RE white paper	MARKAL
2011	GIZ/DEA Low Emission Pathways	SATIM-2011
2012	SANEDI-Transport	SATIM-2012
2013	NPC-Power Plan	SATIM-EL-2012
2014	UNU-WIDER SATIMGE-beta1	SATIMGE-beta1
2015	UNEP Uncertainty in Baseline CO2	SATIM-MC-2015
	DDPP SA Nuclear: Risk Analysis	SATIMGE-2015
2016	WB Thirsty Energy	SATIM-W-2016
	UNU-WIDER SATIMGE-beta2	SATIMGE-beta2
2017	FCO Gas Study	SATIM-MC-2017
	SANEDI-Transport 2	SATIM-2017
	DEFF PAMS	SATIMGE-2017
2018	SANEDI Flexible Demand	SATIM-FD-2018
	CER Coal-IPPs	SATIM-2018
	Alt-IRP	SATIMGE-2018
2019	CoBenefits Study	SATIMGE-2018
	SA-TIED	SATIMGE-2019
2020	2030 NDC Update	SATIMGE-2020
2021	Net-Zero	SATIMGE-2021
	DDP-BIICS	SATIMGE-2021
	UK Pact Hydrogen	SATIMGE-2021
2022	Imagine	SATIMGE-2022
	NDC Aspects	SATIMGE-2022
	Net-Zero V2	SATIMGE-2022

SATIMGE – 2021 Improvements:
Mainly focused on adding options for reaching Net-Zero

- Mining
  - EVs and Hydrogen fuel cell trucks
- Metals
  - Iron&Steel – Hydrogen
  - Ferrochrome & manganese – bio-carbon reductants + CCS/CCU
- Cement and lime: Clinker substitution + CCS/CCU
- Ammonia: Hydrogen based production
- Other Industries: Process heat supplied using electricity/hydrogen
- Transport: EVs and H2 trucks (these were already there)
- Power: hydrogen storage + fuel cells and CCS options, coal plants allowed to run at lower annual average capacity factors (20%), retirement endogenous
- Crude refinery retirement endogenous
- CTL retirement endogenous and part of Chemicals sector output linked to CTL output
- Residential Electricity (energy) recalibrated
- Waste: more mitigation achieved
- AFOLU: more mitigation options allowing for up to 45 Mton of CO2 sinks by 2050
- Green H2 based exports added to model

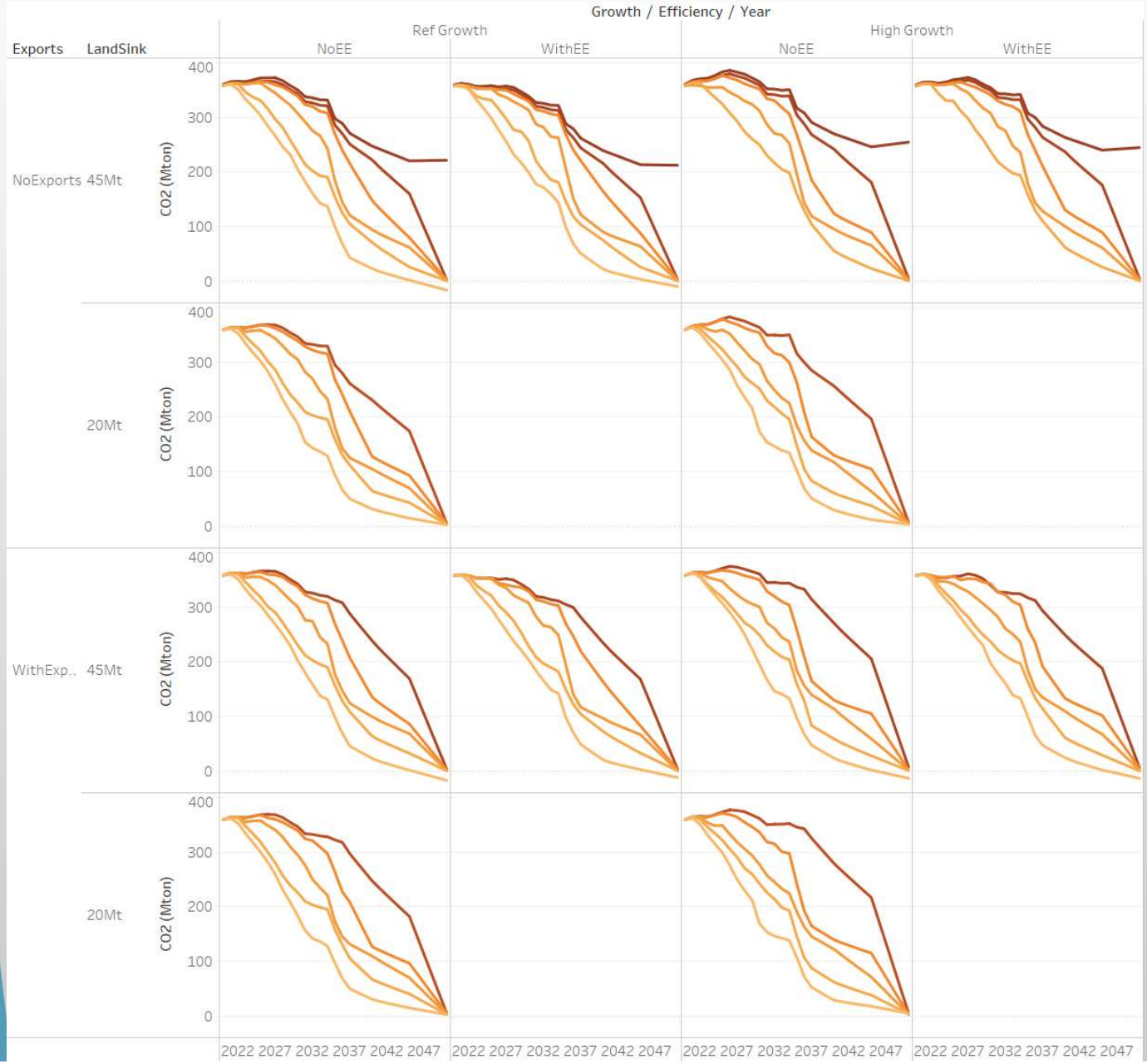
Net-Zero Scenarios run so far (64 runs)

- 2 different reference GDP growth projections (productivity gains)
- 2 different assumptions around Energy Efficiency (Tech in Industry, behaviour in transport/mode switching, commerce and residential – lower useful energy demand)
- 2 different levels for land sinks by 2050 (20 Mton and 45 Mton)
- Without and with Green H2 based products from growing from 2030 to 2050 (iron-14mton and ammonia 6.7mtons) exports
- Different levels of cumulative CO2eq ranging from no limits, down to 6Gton (2021-2050)
- Currently NOT exploring uncertainty space on fuel prices (assuming low IEA-WEO 2020 oil/gas prices throughout~50$/bbl), and Technology Costs (uncertainty on learning for solar, wind, storage, nuclear, hydrogen, CCS)

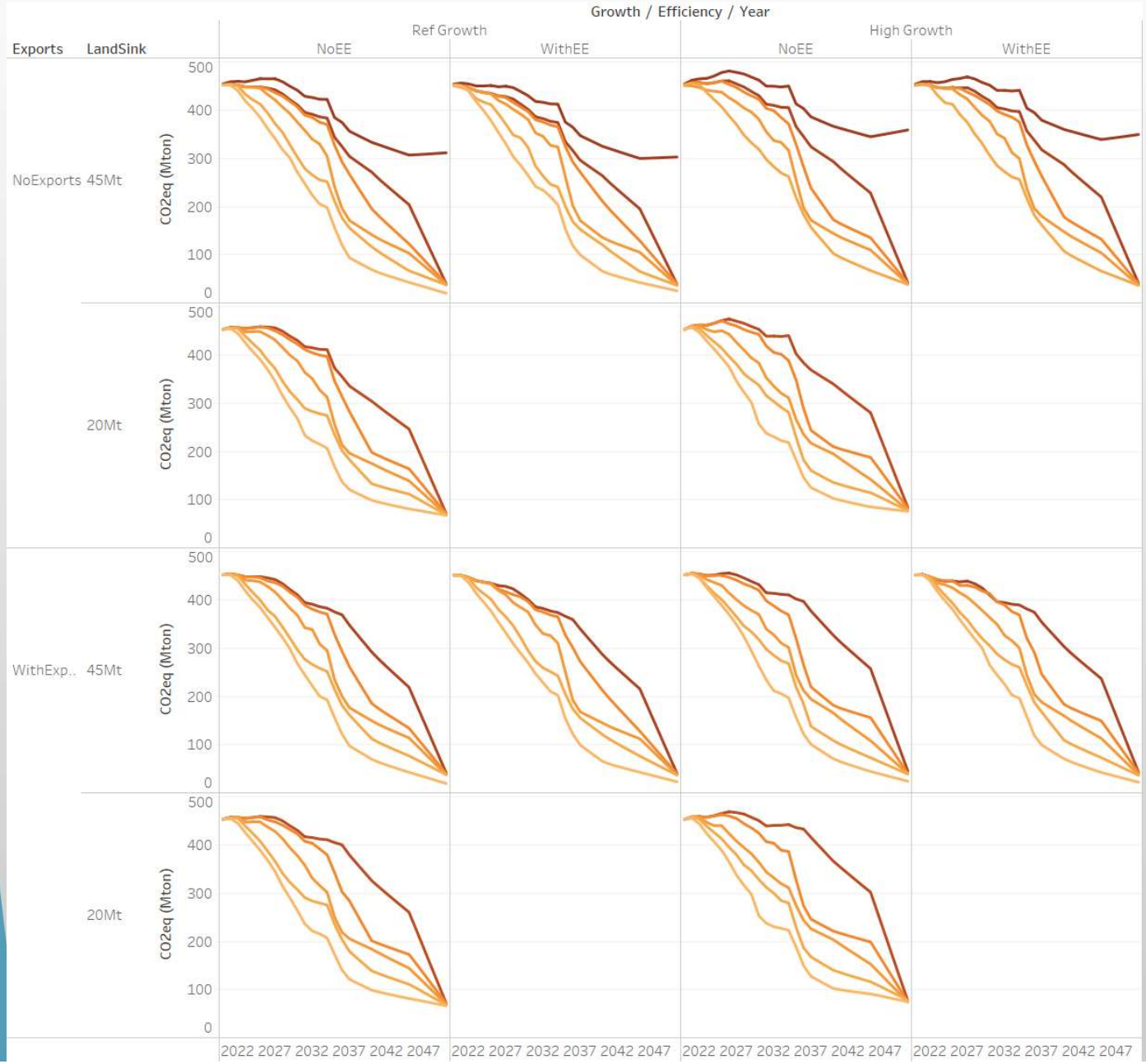
Cumulative emissions budgets, 2021-2050

- The net zero goal in 2050 in itself does not guarantee that South Africa will follow an emissions trajectory within its "fair share"
- A literature survey indicates a range from 7 Gt upwards (with an outlier below this) - we have modelled 6, 7, 8, 9 Gt cumulative emissions limits
- 6 Gt is an outlier, but was included to explore the implications of an extremely ambitious scenario
- The latest CAT "modelled pathways" are around 8.6 Gt
- A range of emissions outcomes defined by the updated NDC and a net zero target gives an emissions budget of 7-10 Gt.

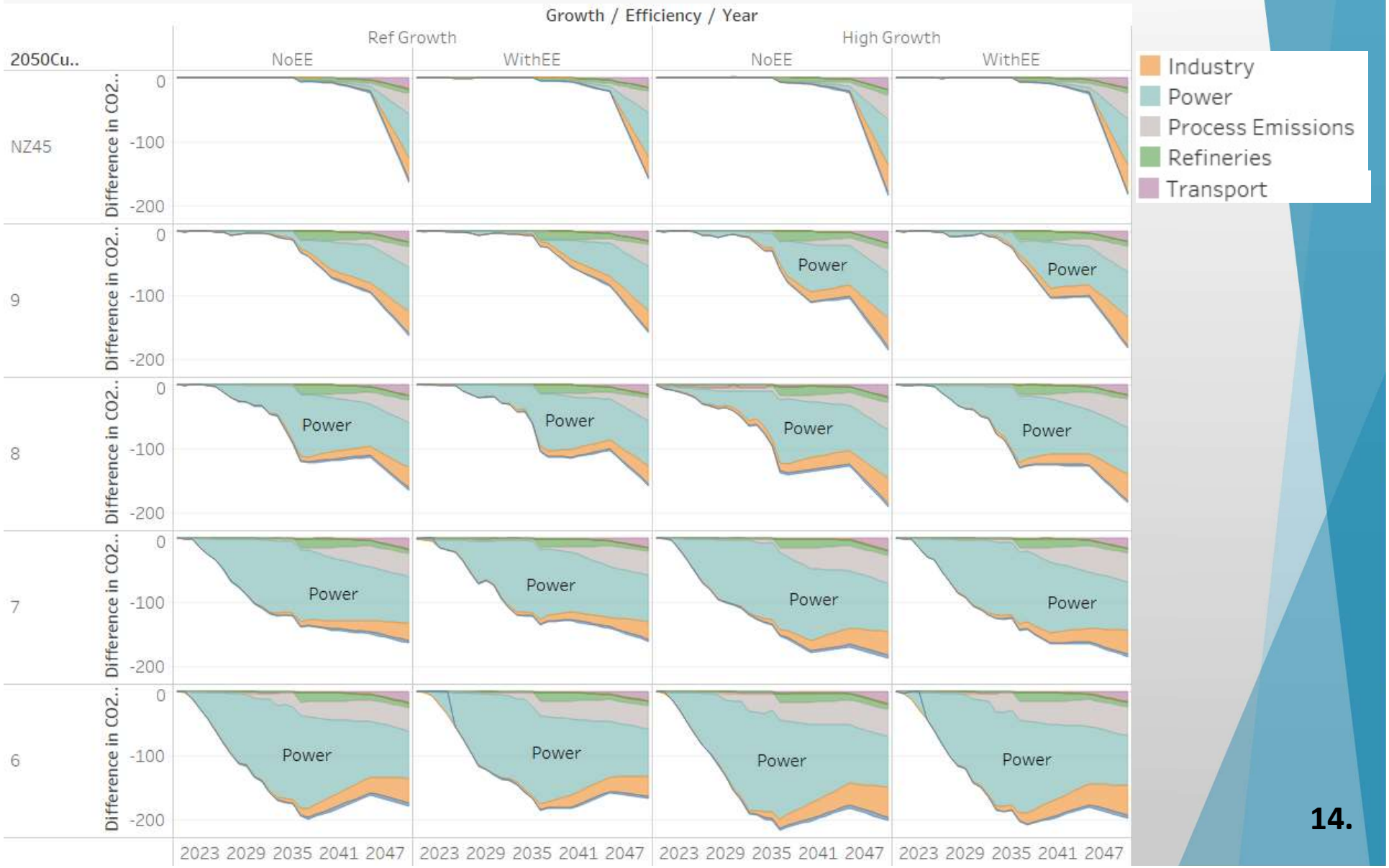
Preliminary Results: CO2



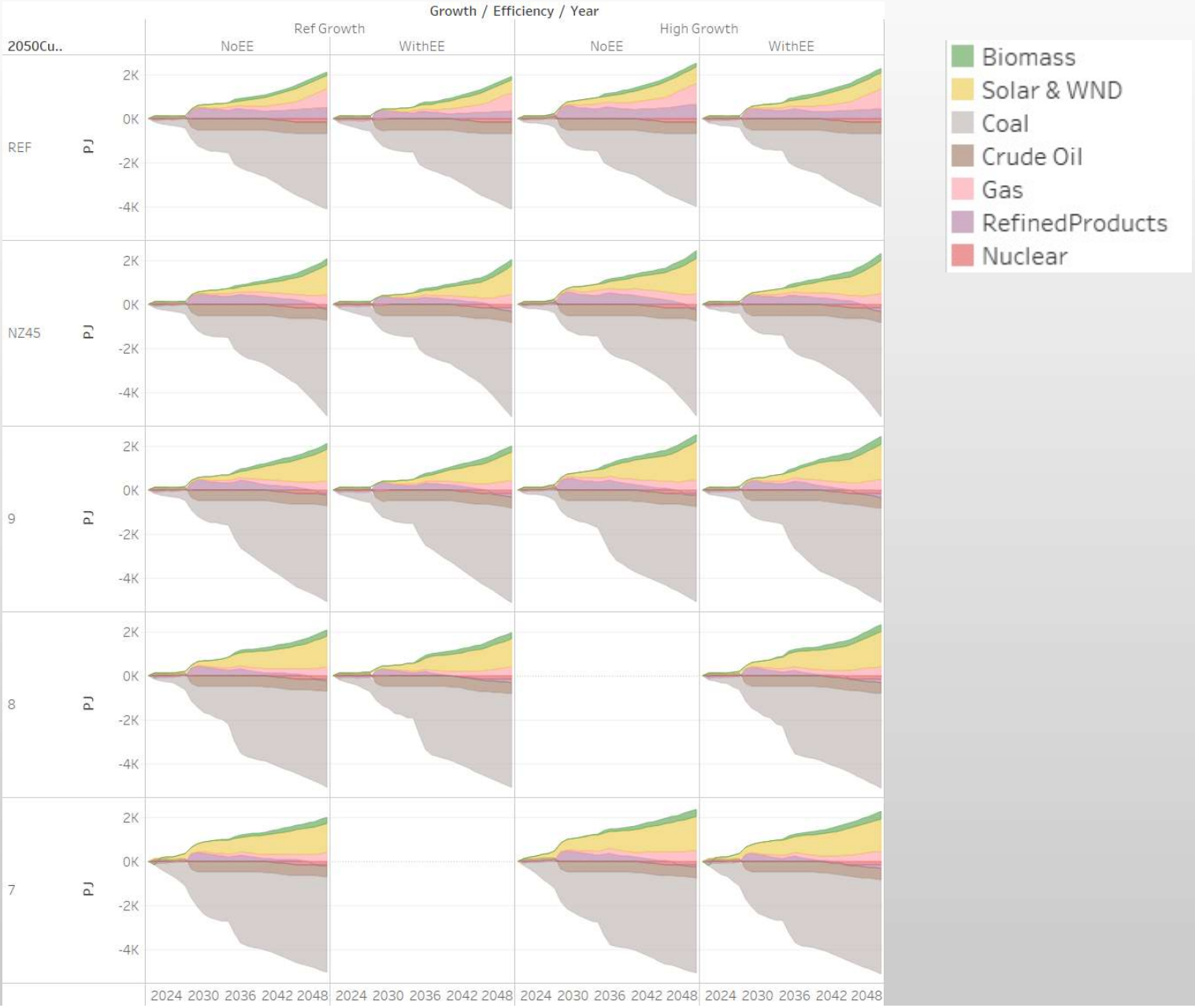
CO2 eq: down to ~20-80 Mton CO2eq by 2050



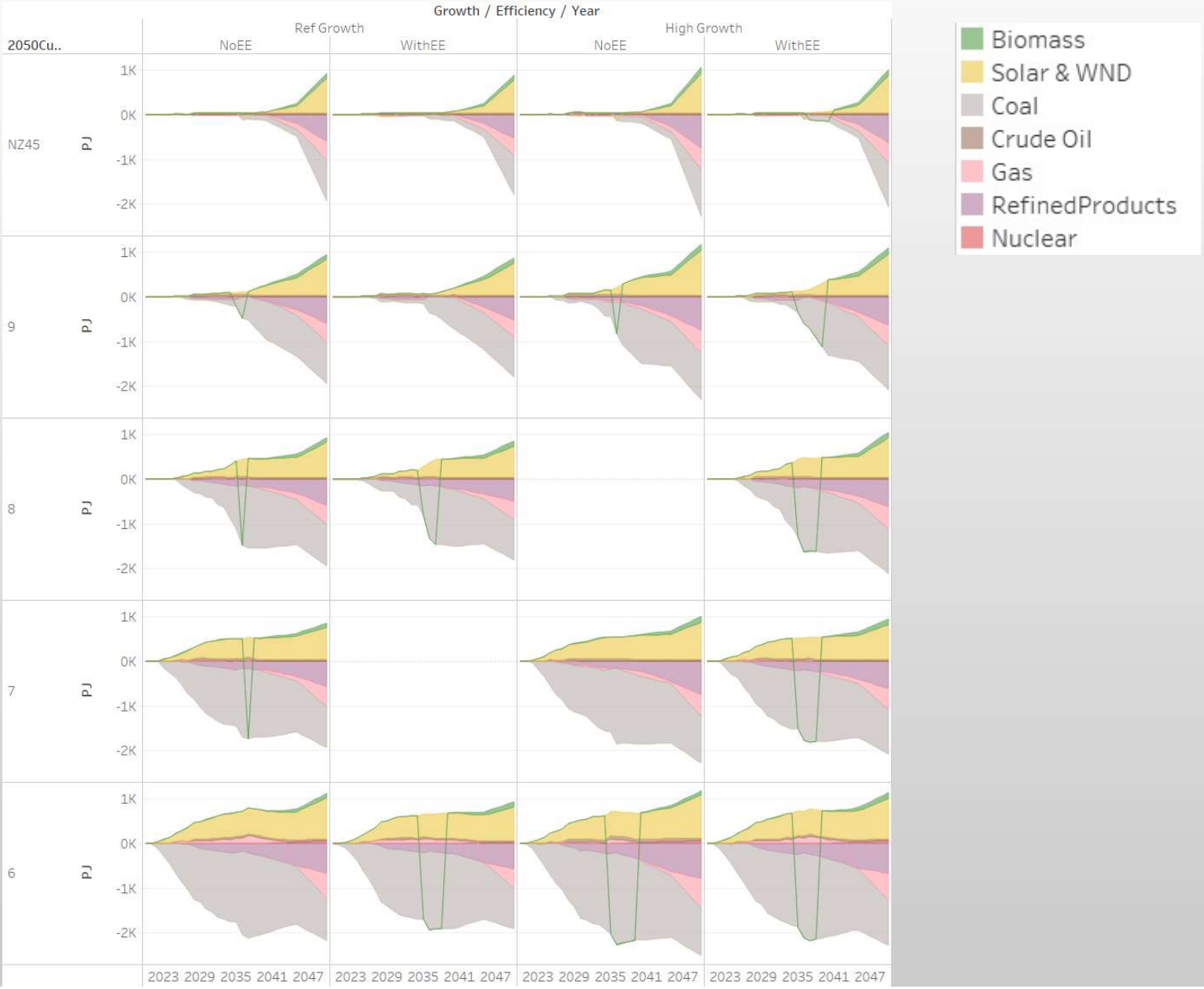
Where reductions are occurring?
Looking at the difference in CO2eq in Energy and IPPU relative to the reference cases (i.e. least cost)



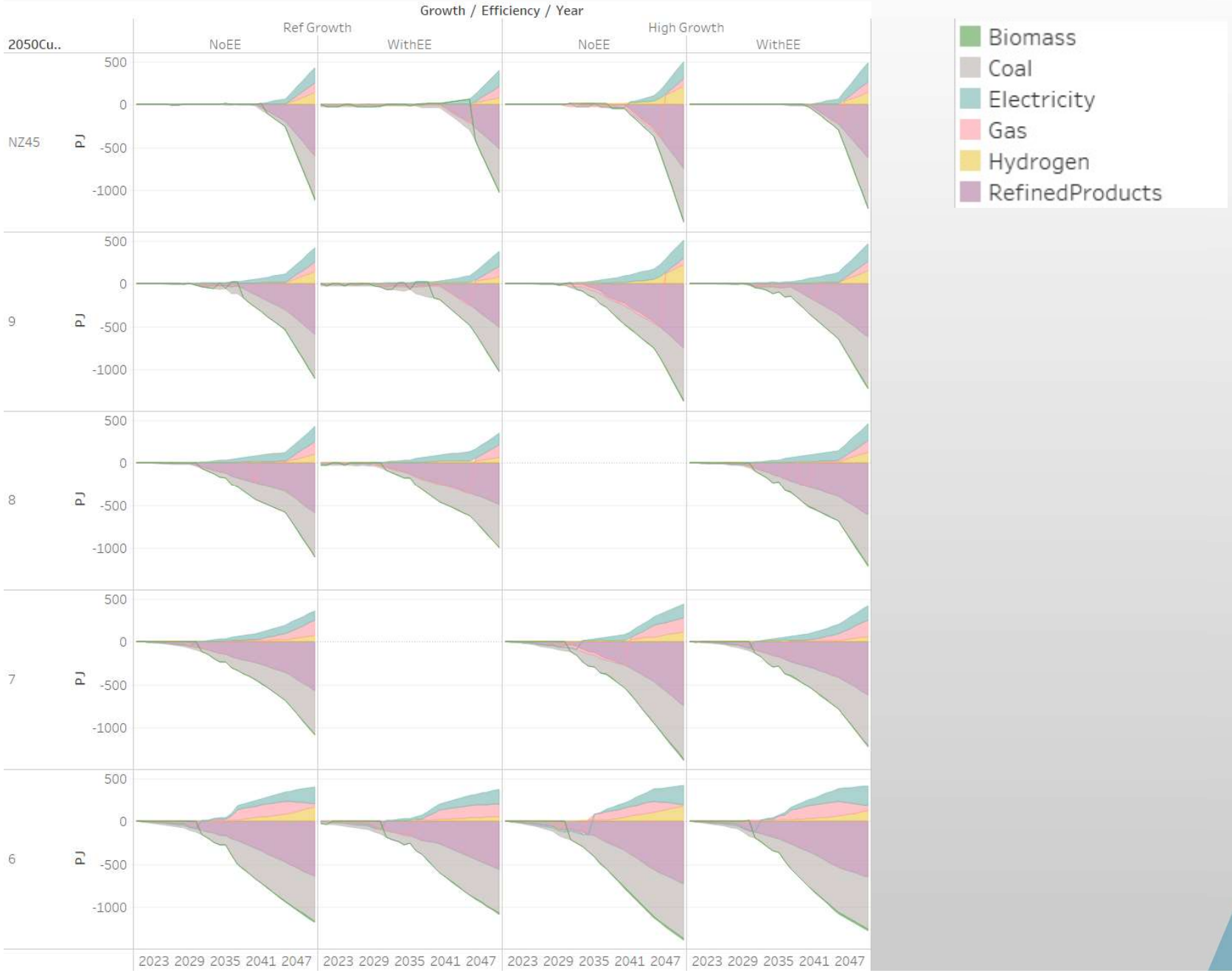
Difference in Primary Energy Supply: Relative to 2021



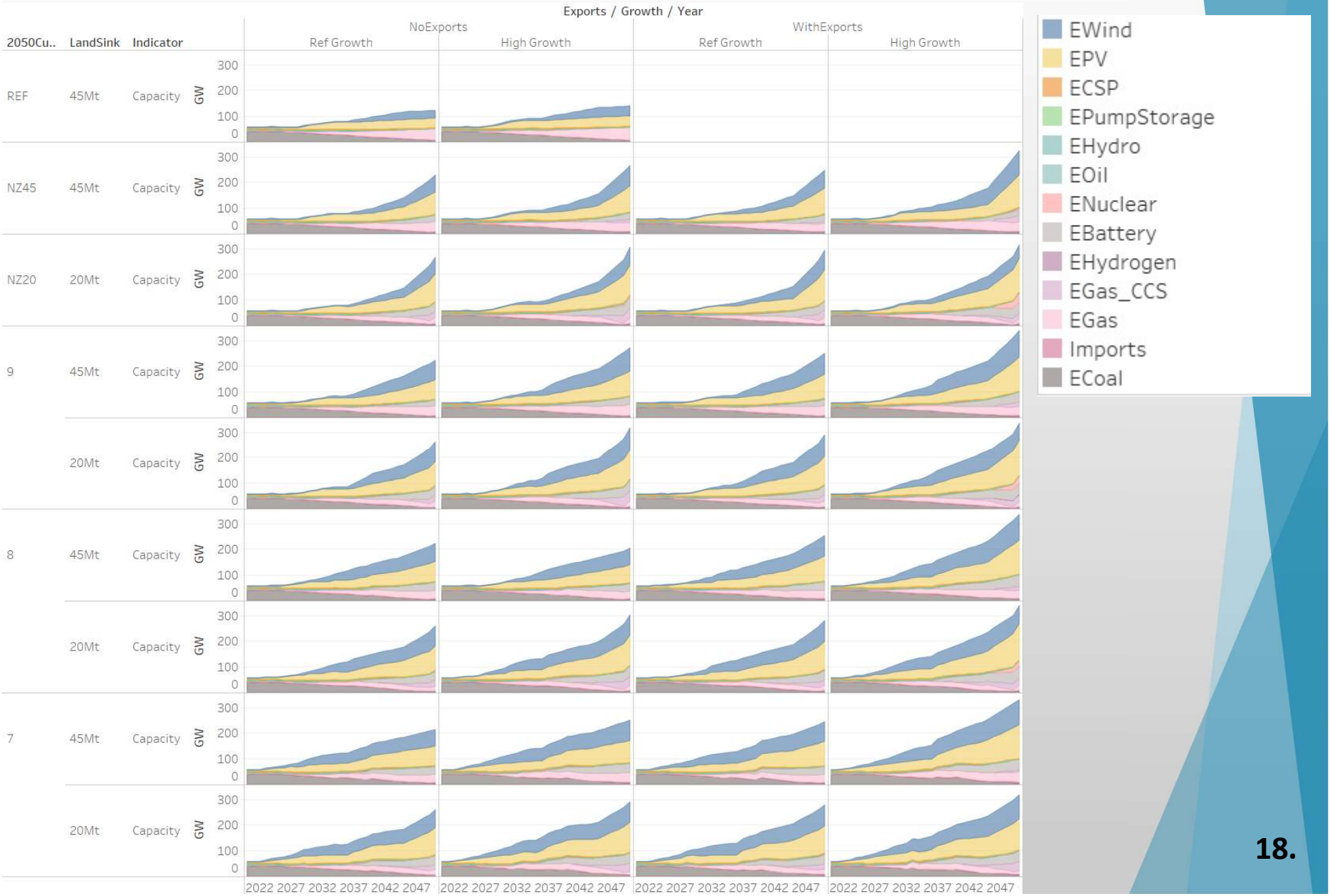
Difference in Primary Energy Supply: Relative to Reference



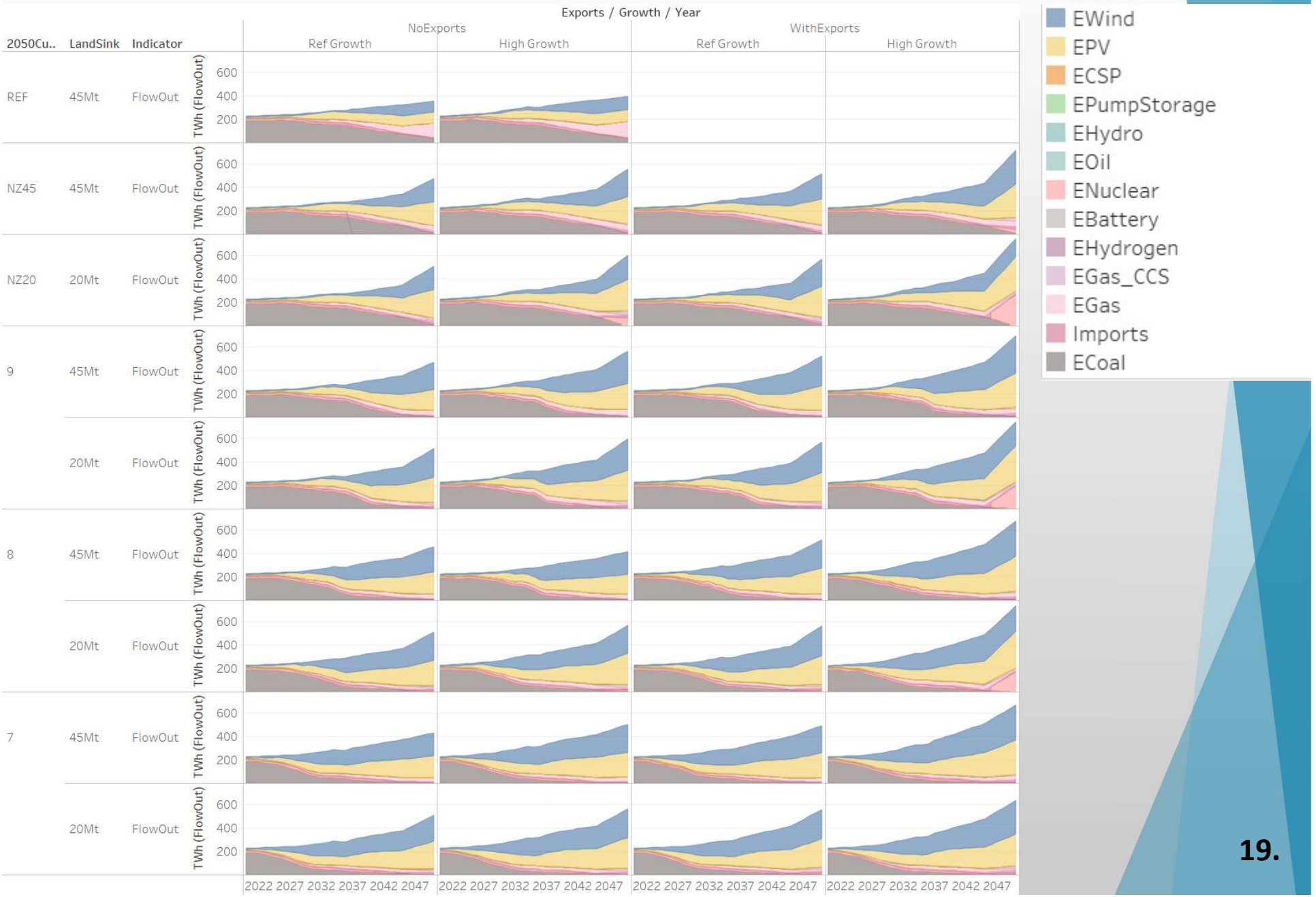
Difference in Final Energy Relative to Reference



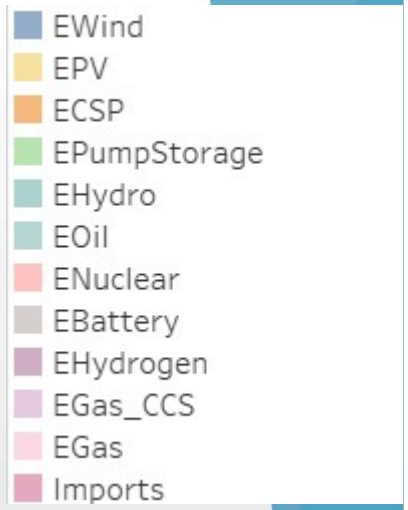
Power Installed Capacity



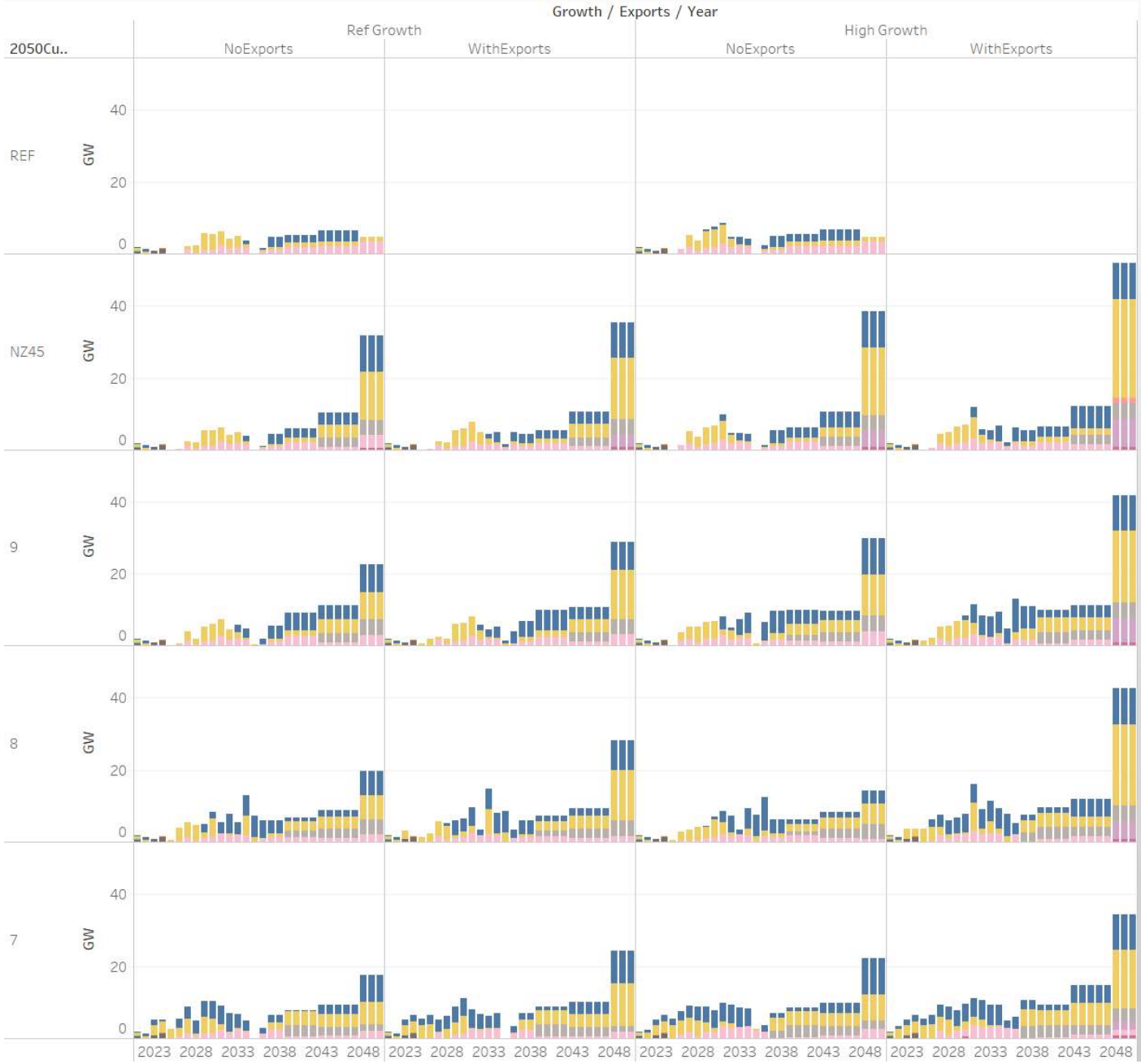
Power Production Mix

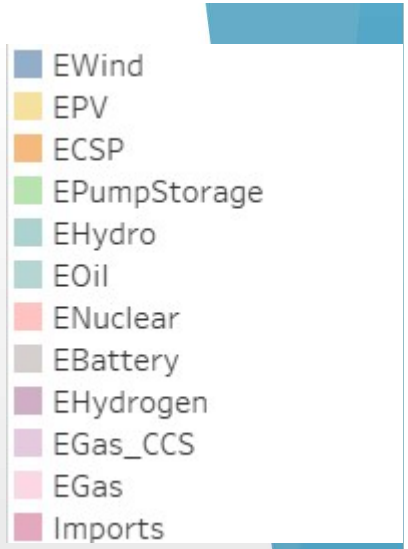


Power: New Capacity (to 2040)

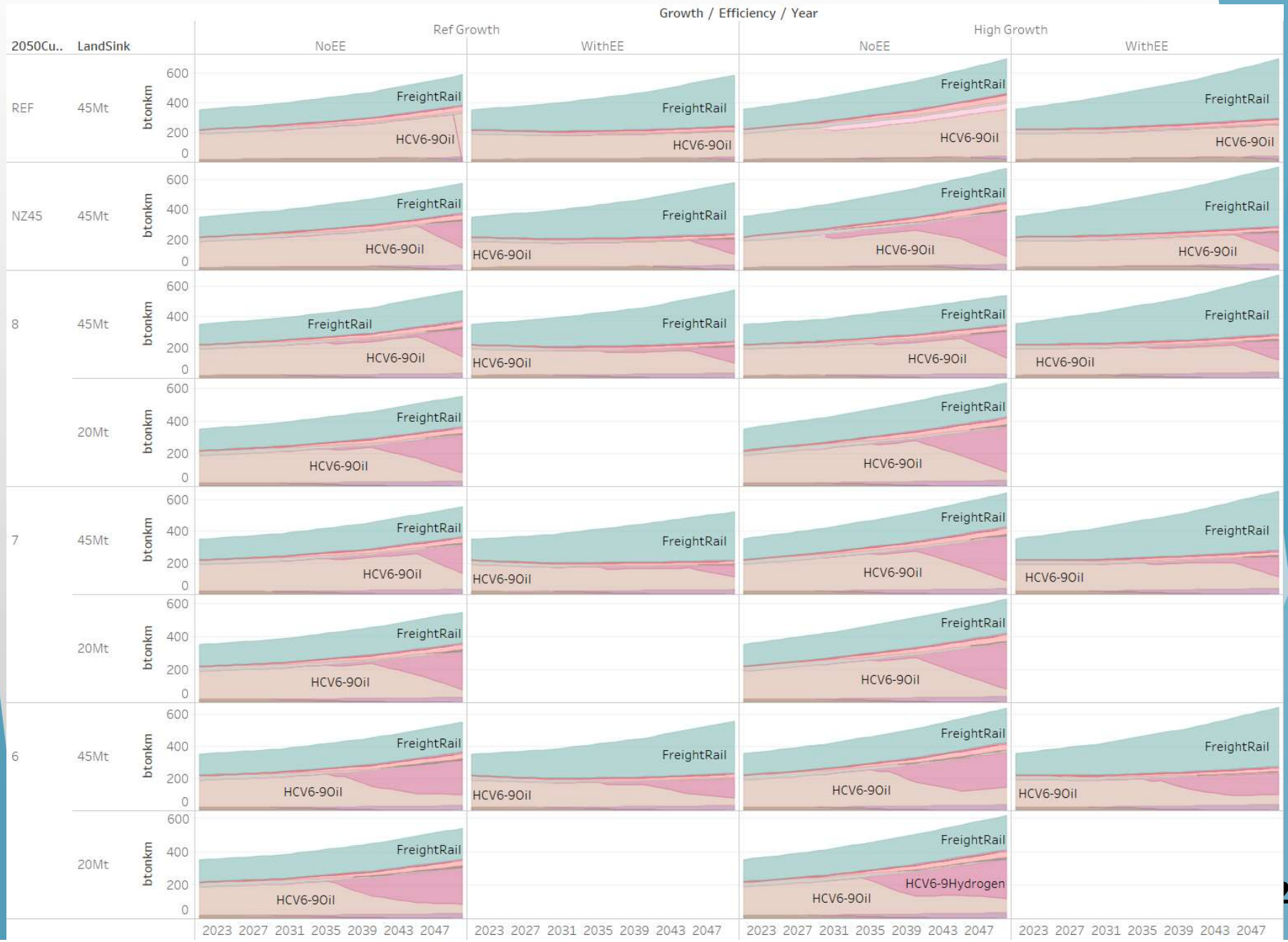


Power: New Capacity (to 2050)



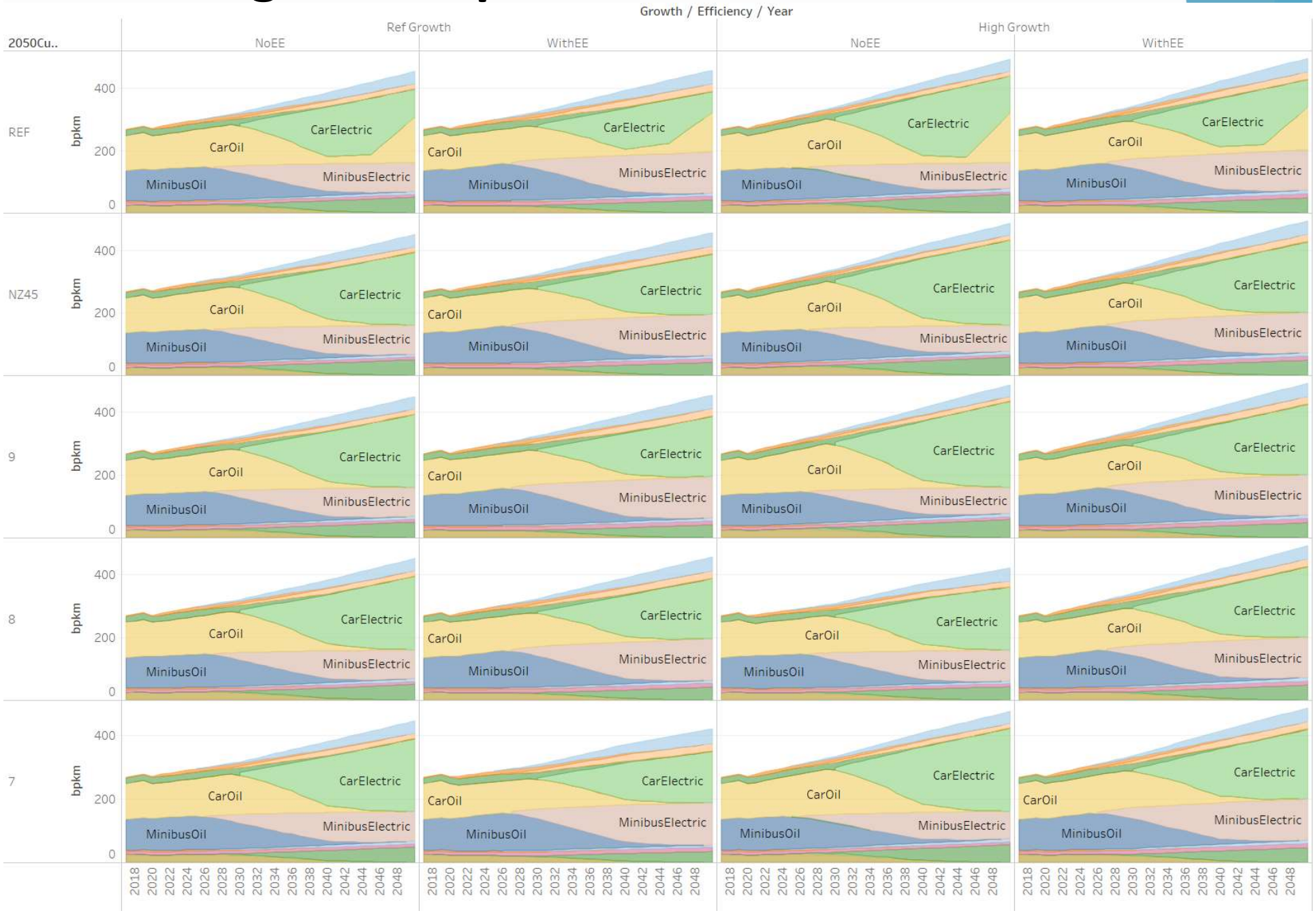


Freight Transport

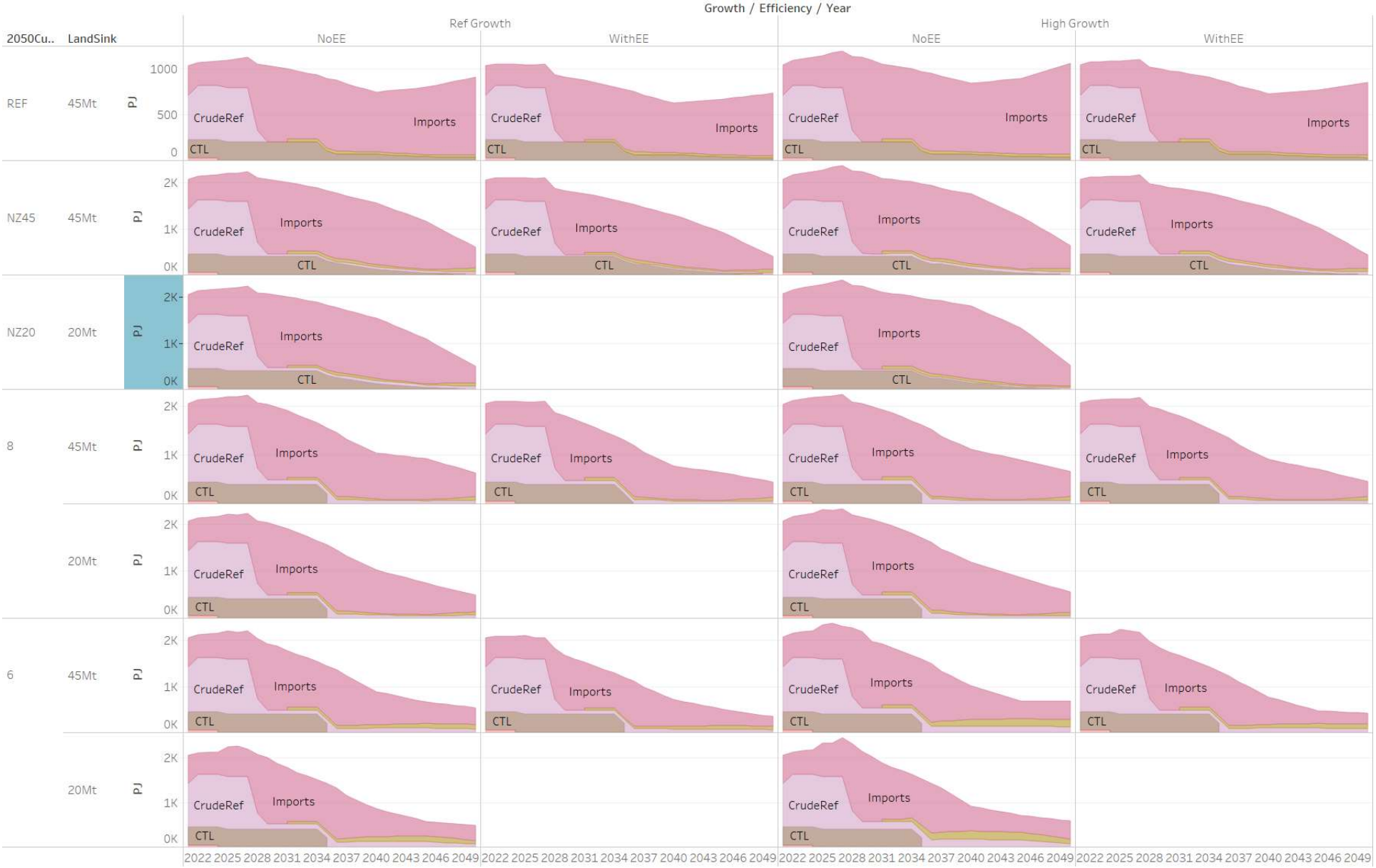


22.

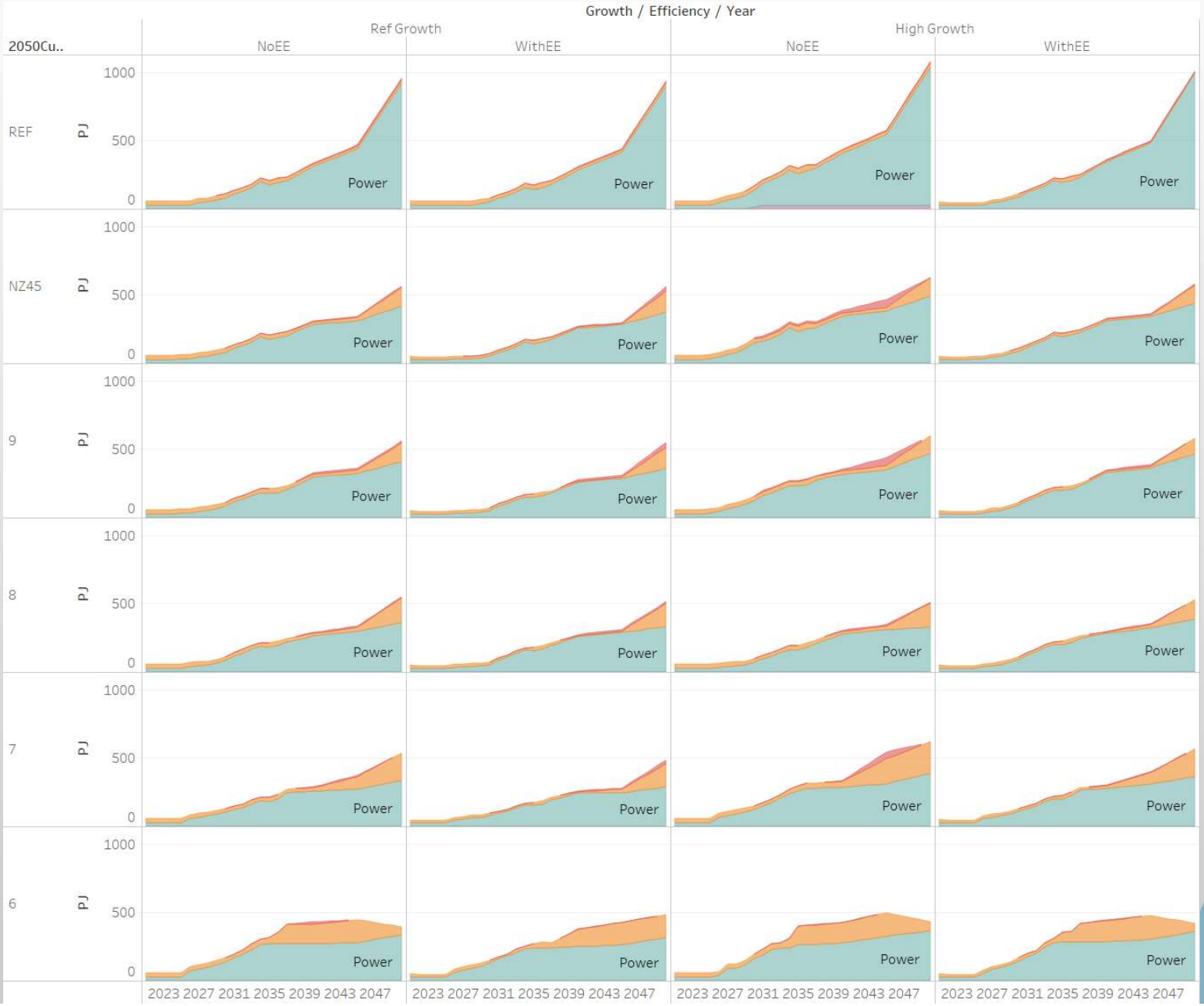
Passenger Transport



Liquid Fuel Supply



Natural Gas

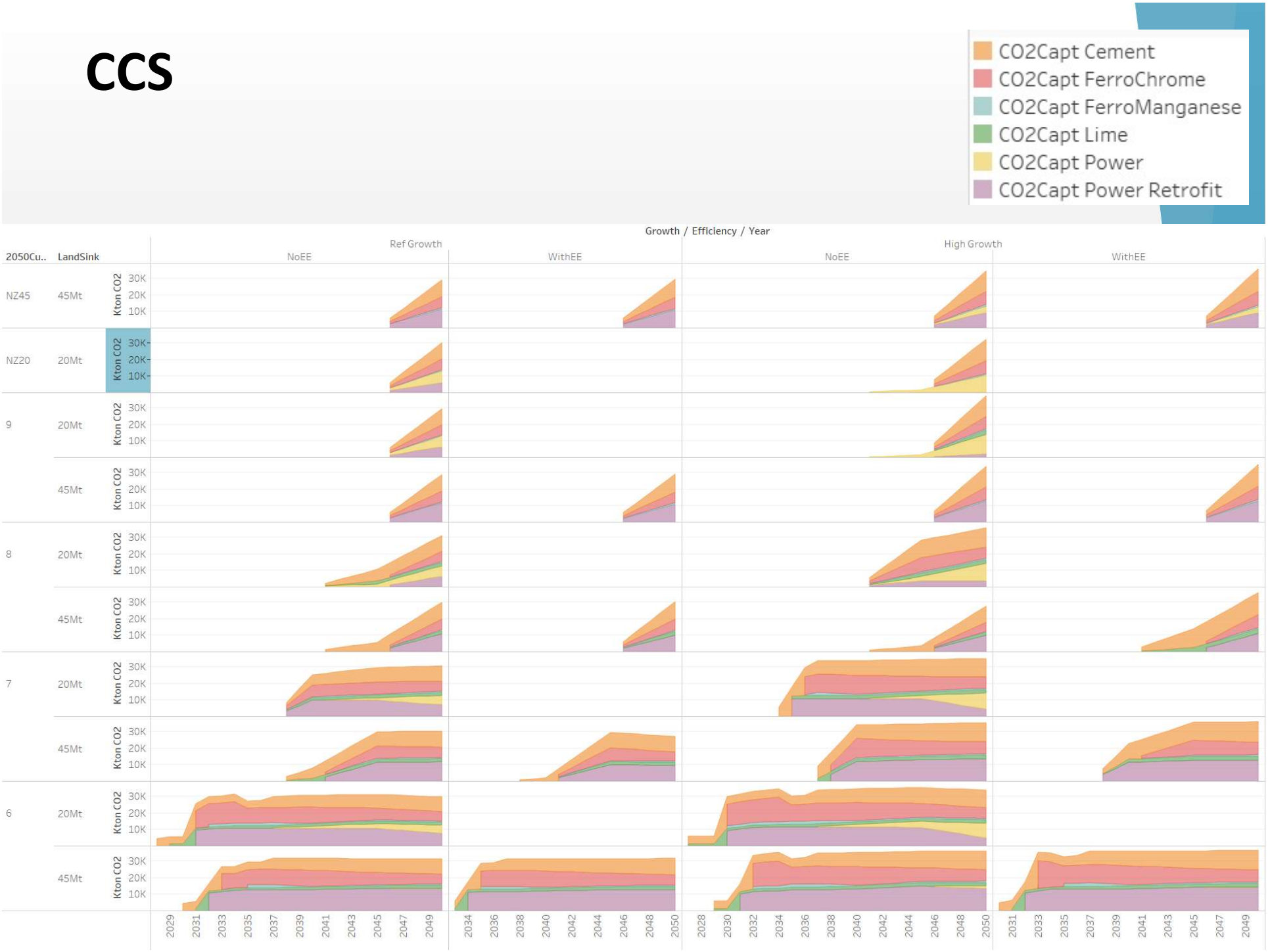

Growth / Efficiency / Year
Ref Growth
High Growth
2050Cu..
NoEE
WithEE
NoEE
WithEE
REF
NZ45
9
8
7
6
PJ
1000
500
0
Power
2023 2027 2031 2035 2039 2043 2047

Hydrogen


Growth / Exports / Year
Ref Growth
High Growth
2050Cu..
NoExports
WithExports
NoExports
WithExports
REF
NZ45
9
8
7
PJ
0
100
200
300
400
2029 2033 2037 2041 2045
2029 2033 2037 2041 2045
2031 2035 2039 2043 2047
2032 2036 2040 2044 2048


ChemicalS33 Ammonia
EHydrogen Power
FreightRoad
IndOther
Iron_Steel351
Mining2

CCS


CO2Capt Cement
CO2Capt FerroChrome
CO2Capt FerroManganese
CO2Capt Lime
CO2Capt Power
CO2Capt Power Retrofit
Growth / Efficiency / Year
Ref Growth
High Growth
NoEE
WithEE
2050Cu..
LandSink
NZ45
NZ20
9
8
7
6
45Mt
20Mt
Kton CO2
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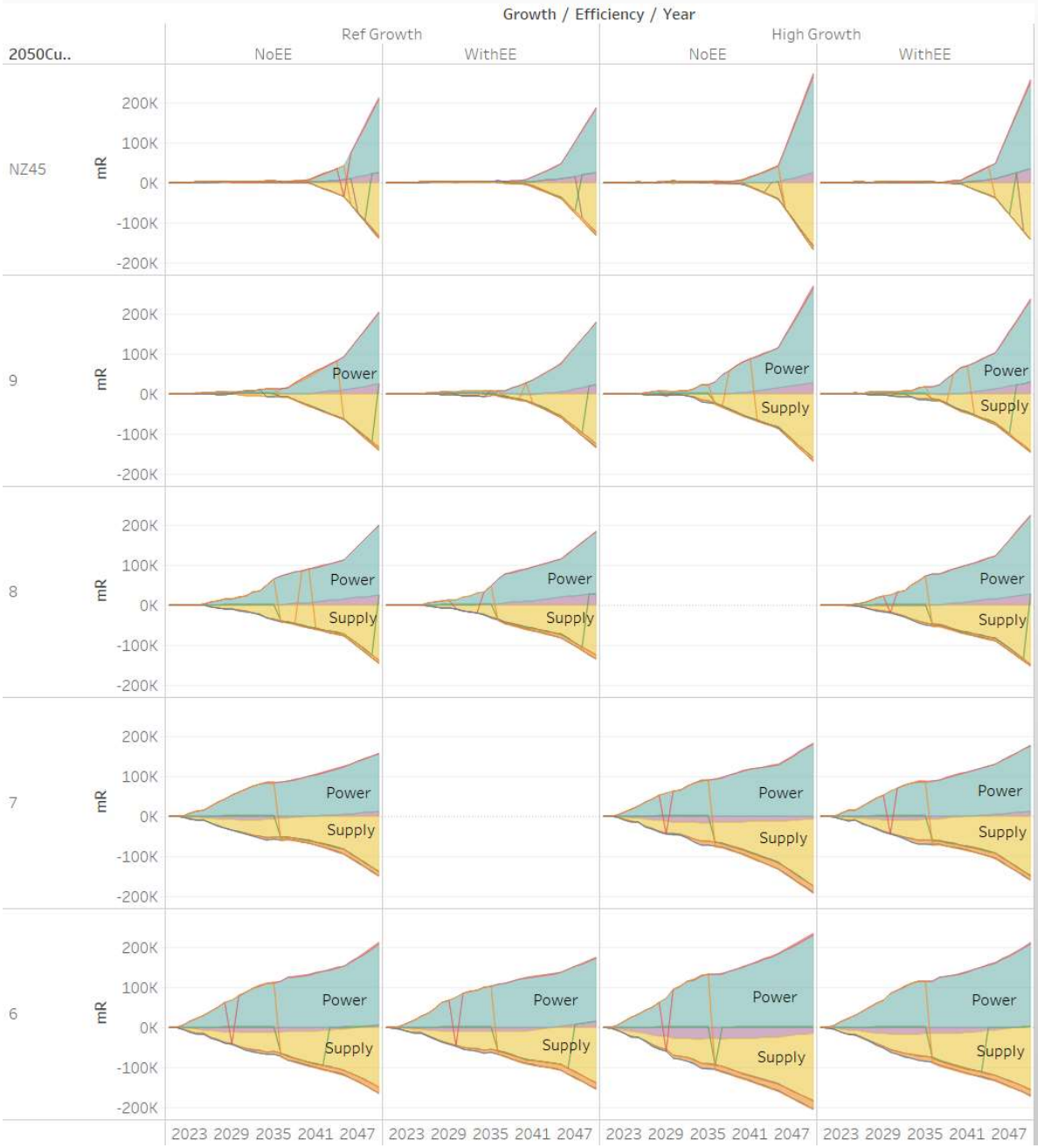
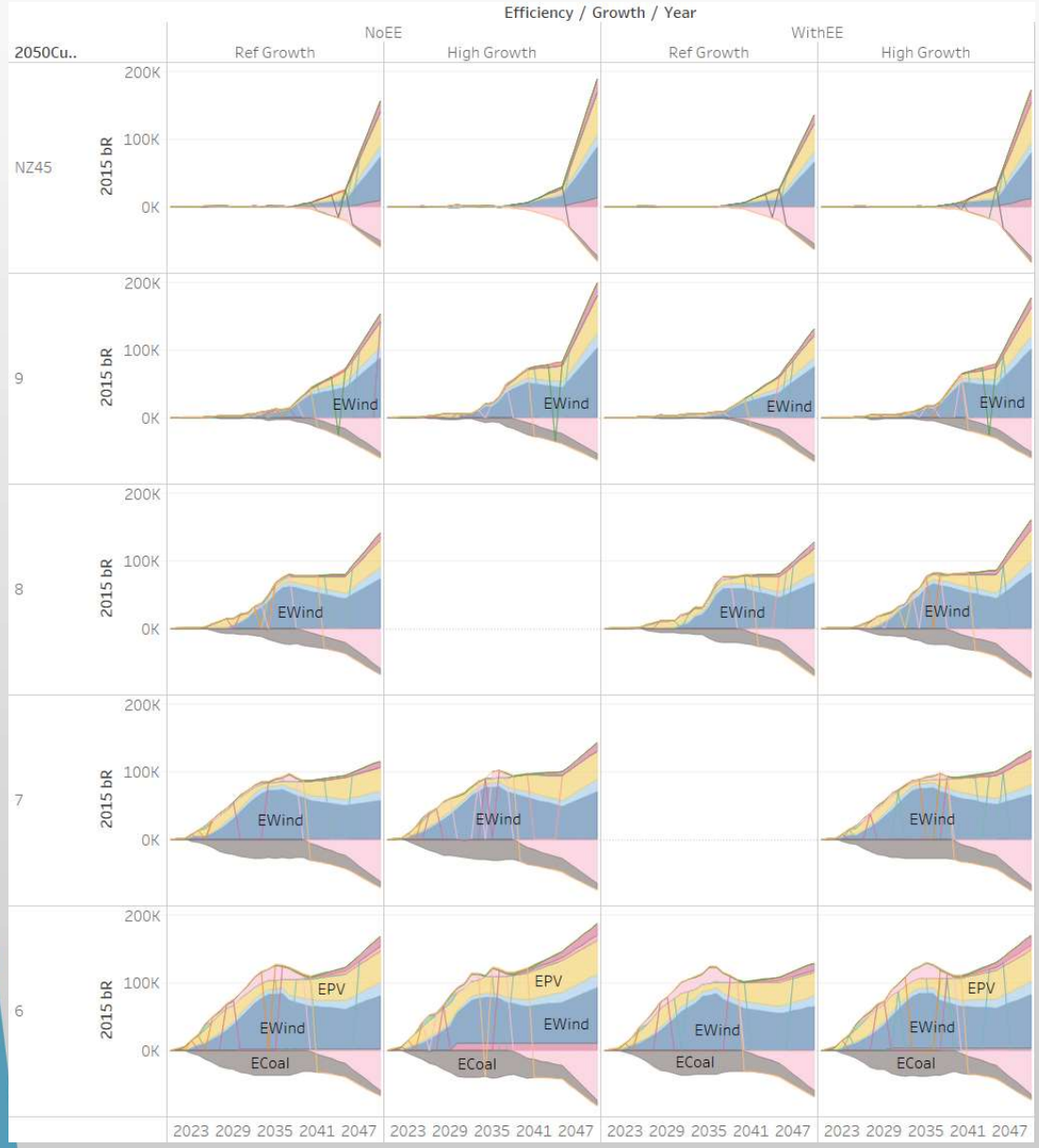
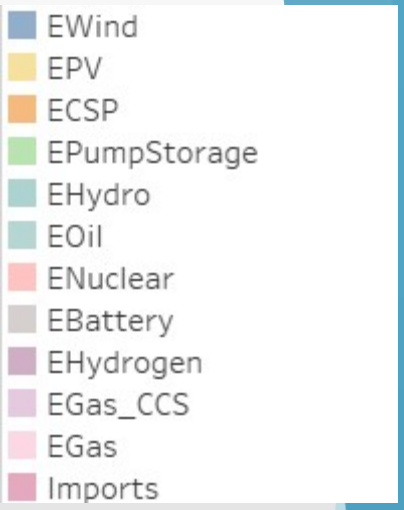
Difference in System Costs

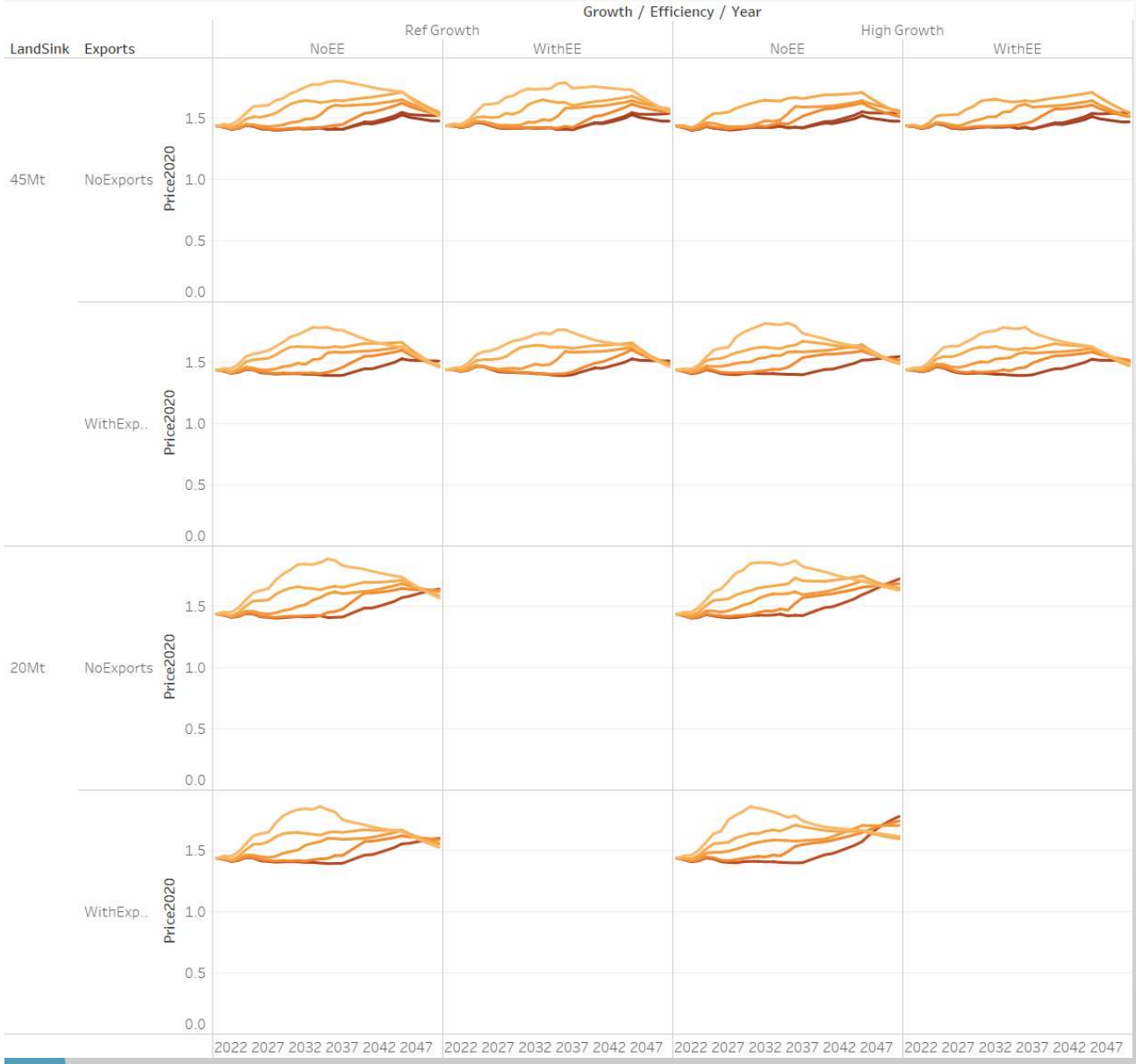


Difference in System Cost: Power Sector



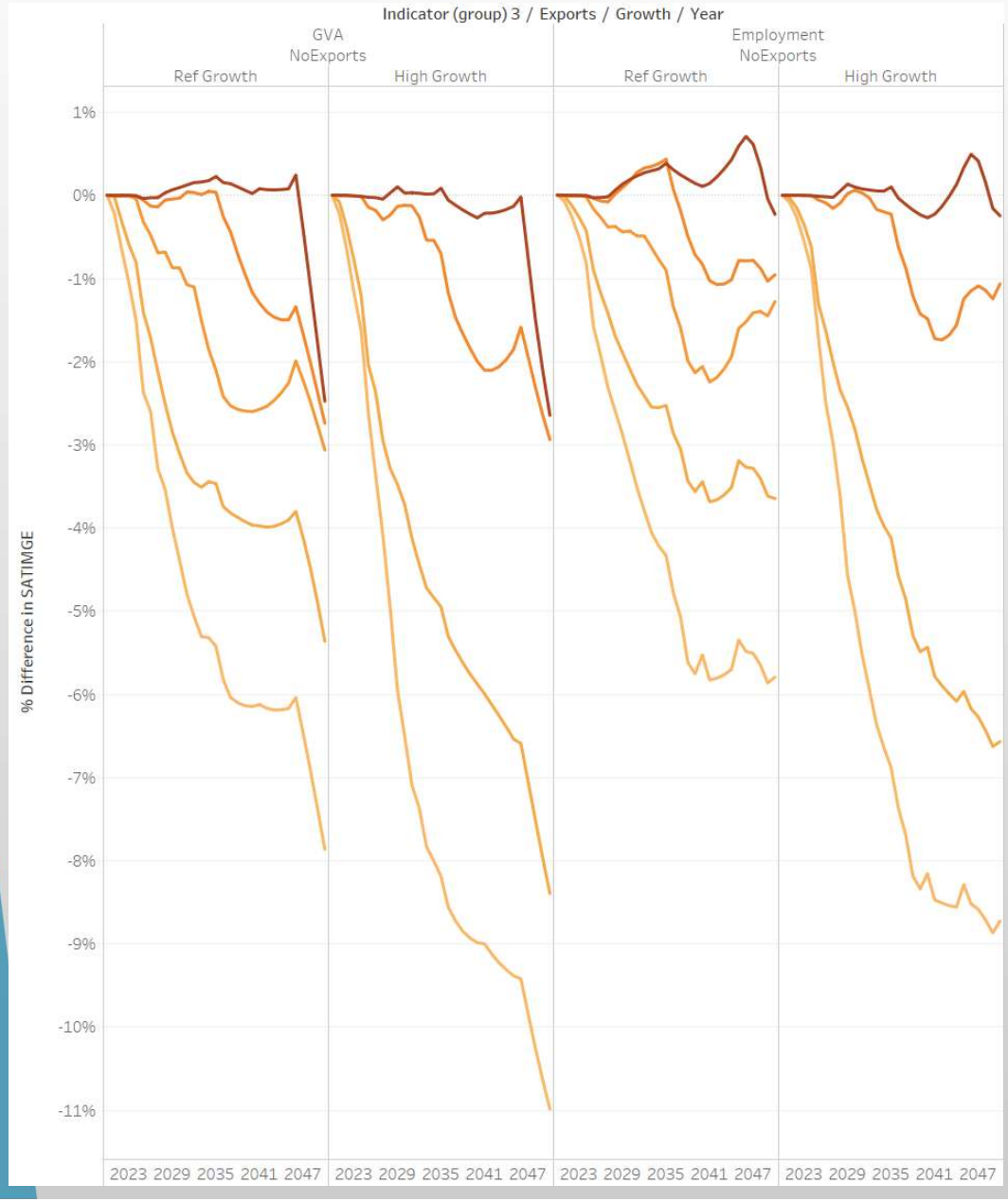


Unit Cost Electricity



- Despite increase in system cost, higher demand for electricity results in converging unit costs across scenarios.

GVA and Employment Impact



- Savings rate of domestic agents is constant share of GDP.
- Foreign savings has same constant growth across all scenarios.

Initial Conclusions

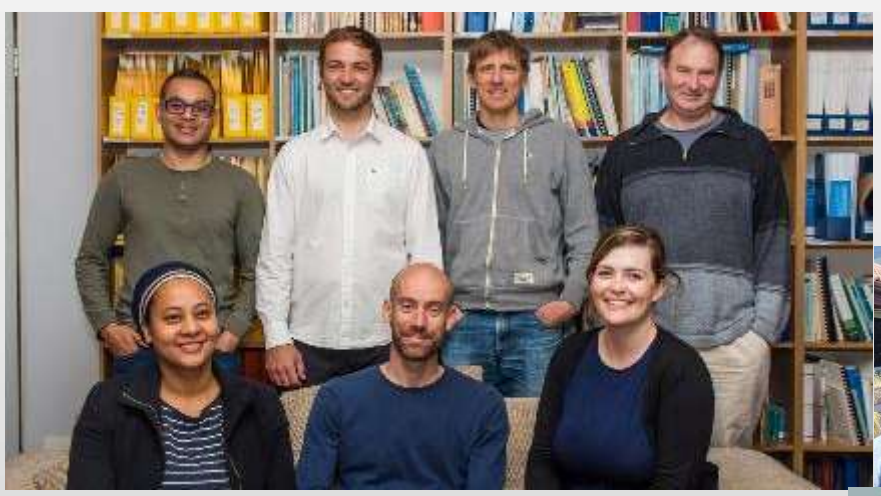
1. After updating SATIMGE in 2020 to do the 2030 NDC update, it was further updated in 2021 for a netzero carbon analysis. More detailed work will still need to be done on the modelling framework.
2. 64 scenarios have been modelled to 2050, based on different carbon sink values, different cumulative emissions budgets and other factors.
3. Decarbonization of sectors in which technology options are known and costs are competitive is not (technically) challenging, and comprise most of South Africa's GHG emissions.
4. The last mile decarbonization from 2040 to 2050 is complex, with significantly higher costs and technology uncertainties, and requires a lot of further work.
5. The cumulative carbon space available to the system is sensitive to the assumptions around the carbon sink that is available.

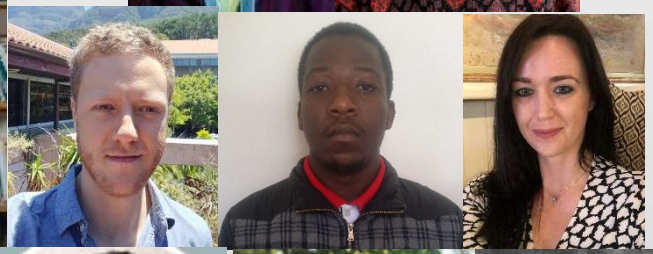
SATIMGE-2022

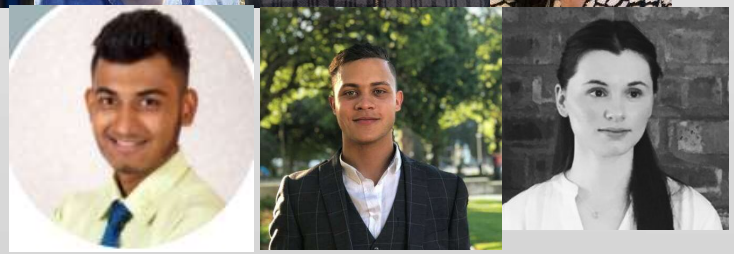
- Further unpacking of Pathways to Net-Zero for South Africa by 2050-2060 in collaboration with CSIR and NBI
- Link to Global models under Imagine and NDC-Aspects in collaboration with international partners, to get projected global commodity and CO2 prices, and carbon space available for South Africa.

Thank you!

We are open for collaboration and contributions for future work…







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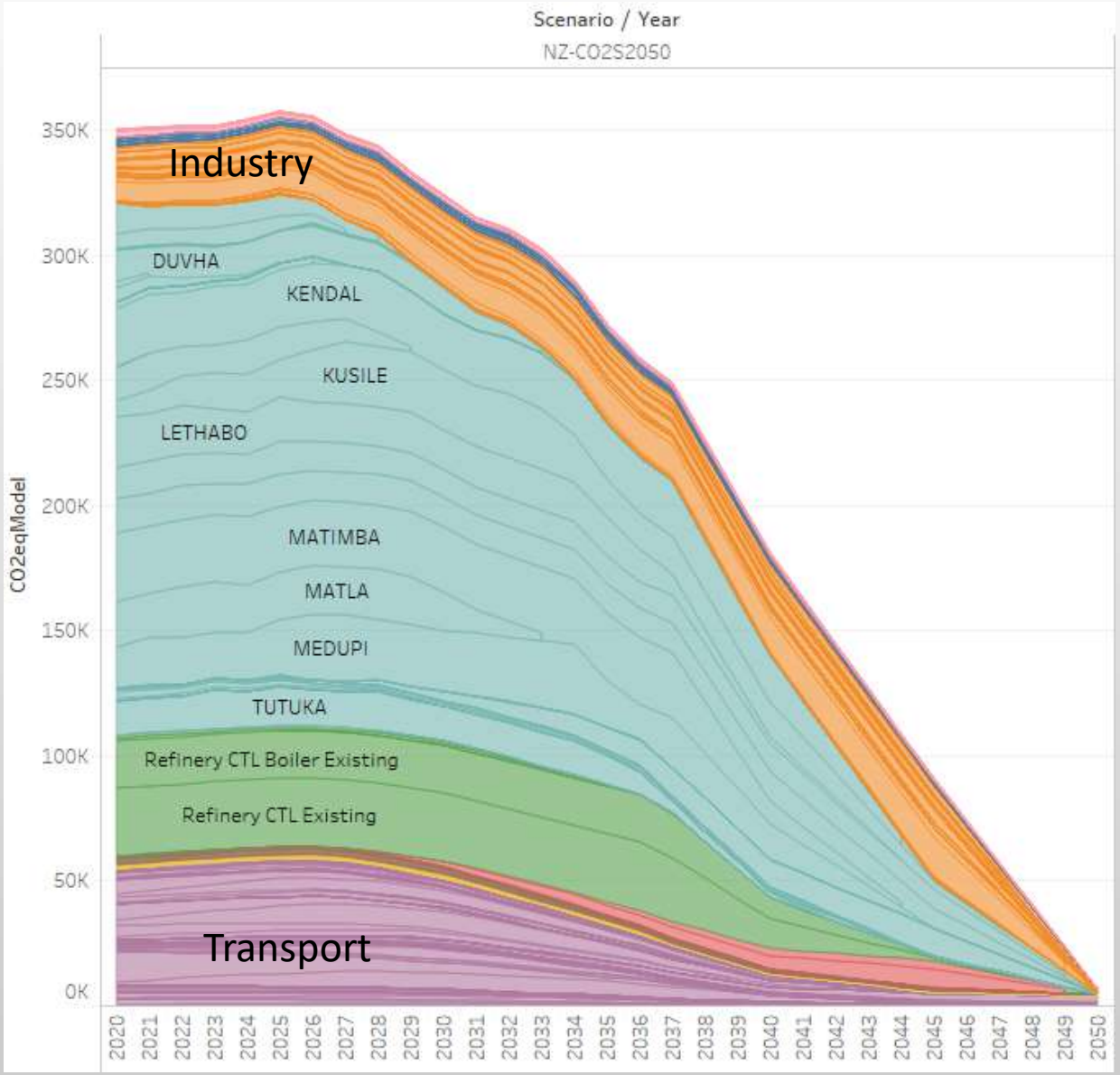
University of Cape Town

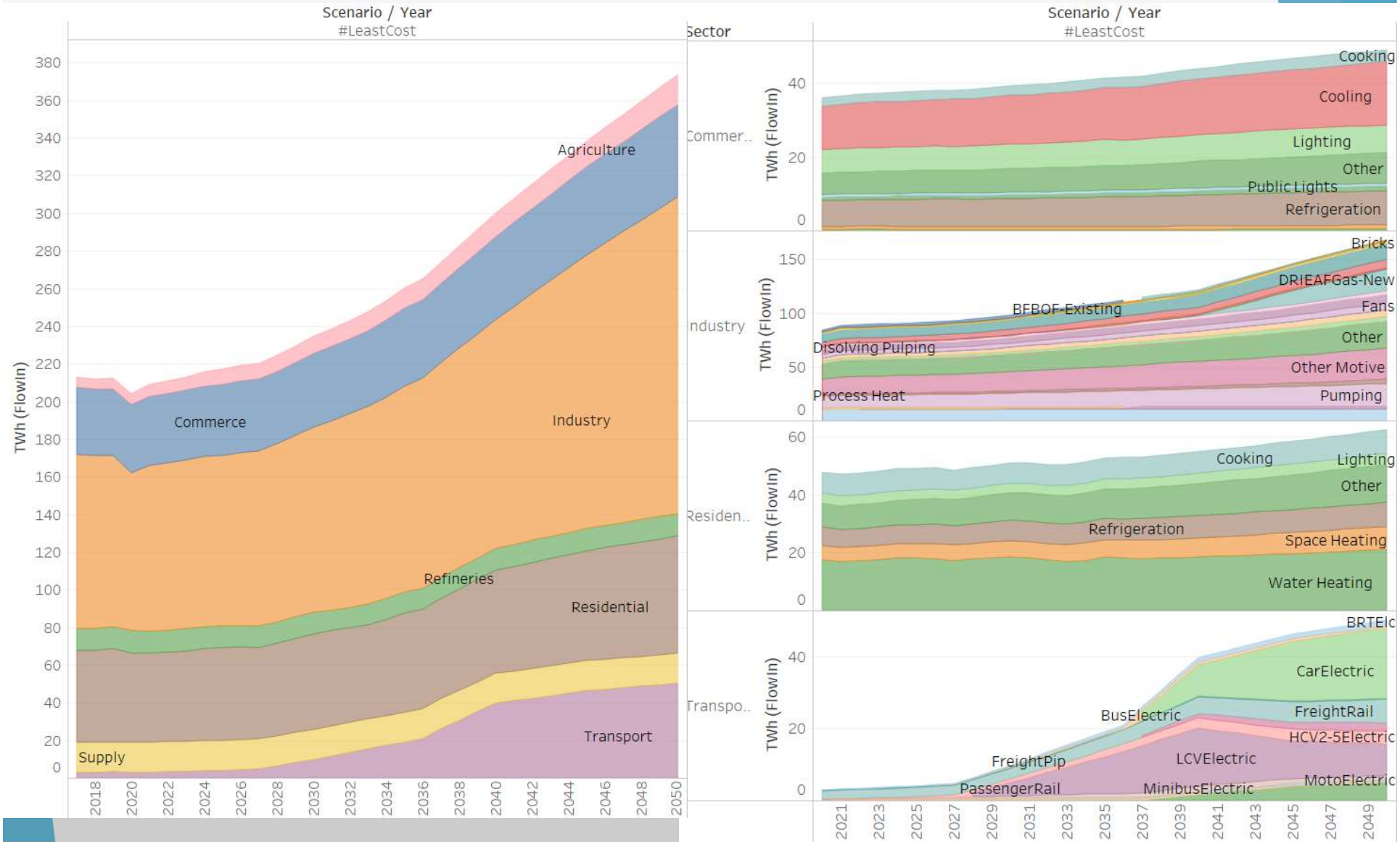
References: Past SATIM and SATIMGE projects

Year	Project	Link
2003	IEP-1	
2006	EPSD-SA - IAEA	http://www.erc.uct.ac.za/sites/default/files/image_tool/images/119/Papers-2006/Papers-2005/05Winkler-Alfstad-Howells-Energy_Policies_Phase2.pdf
2007	LTMS	http://www.erc.uct.ac.za/sites/default/files/image_tool/images/119/Papers-2007/07Scenario_team-LTMS_Scenarios.pdf
2008	Costing 2020 RE Target	http://www.erc.uct.ac.za/sites/default/files/image_tool/images/119/Papers-2008/08-Marquardetal-costing_a_2020_target.pdf
2010	Review of RE white paper	report not published
2011	Low Emission Pathways	report not published
2012	SANEDI-Transport	https://open.uct.ac.za/handle/11427/16905
2013	NPC-Power Plan	http://www.erc.uct.ac.za/sites/default/files/image_tool/images/119/Papers-2013/13ERC-Towards_new_power_plan.pdf
2014	UNU-WIDER SATIMGE beta 1	https://www.wider.unu.edu/sites/default/files/wp2014-135.pdf
2015	UNEP Uncertainty in Baselines	http://www.erc.uct.ac.za/sites/default/files/image_tool/images/119/Papers-2016/16-Merven-etal-Longterm_GHG_forecasts.pdf
	SDSN DDPP	http://www.erc.uct.ac.za/sites/default/files/image_tool/images/119/Papers-2015/15-Altieri-etal-Pathways_to_deep_carbonisation.pdf
	SA Nuclear: Risk Analysis	http://www.erc.uct.ac.za/sites/default/files/image_tool/images/119/Papers-2015/15-ERC-Nuclear_build_plan_Technical_report.pdf
2016	WB Thirsty Energy	https://openknowledge.worldbank.org/bitstream/handle/10986/26255/113464-WP-P144930-PUBLIC-W16014-eBook.pdf?sequence=5&isAllowed=y
	UNU-WIDER SATIMGE beta 2	https://www.wider.unu.edu/publication/development-linked-modelling-framework-analysing-socioeconomic-impacts-energy-and
2017	Gas Study	http://www.erc.uct.ac.za/sites/default/files/image_tool/images/119/Papers-2017/17-Merven-etal-Uptake_natural_gas_SA.pdf
	SANEDI-Transport 2	https://journals.assaf.org.za/index.php/jesa/article/view/4176
	PAMS	Final report not published - need to put draft released to stakeholders on our website
2018	SANEDI Flexible Demand	https://www.ee.co.za/wp-content/uploads/2018/10/Gregory-Ireland-University-of-Cape-Town-presentation.pdf (need to put report on our website)
	CER Coal-IPPs	https://cer.org.za/wp-content/uploads/2018/05/ERC-Coal-IPP-Study-Report-Finalv2-290518.pdf
	SA-TIED Alt-IRP	http://www.erc.uct.ac.za/sites/default/files/image_tool/images/119/Papers-2019/Alt%20IRP%20final%2007022019_2.pdf
2019	CoBenefits Study	https://www.cobenefits.info/wp-content/uploads/2019/03/COBENEFITS-Study-South-Africa-Employment.pdf
	SA-TIED	https://sa-tied.wider.unu.edu/climate
2020	DEFF-SSN 2030 NDC Update	Report Due early 2021
2021	DEFF-SSN Net-Zero	2021
	GCRF STITICA	
	IKI DDP-BIICS	2021

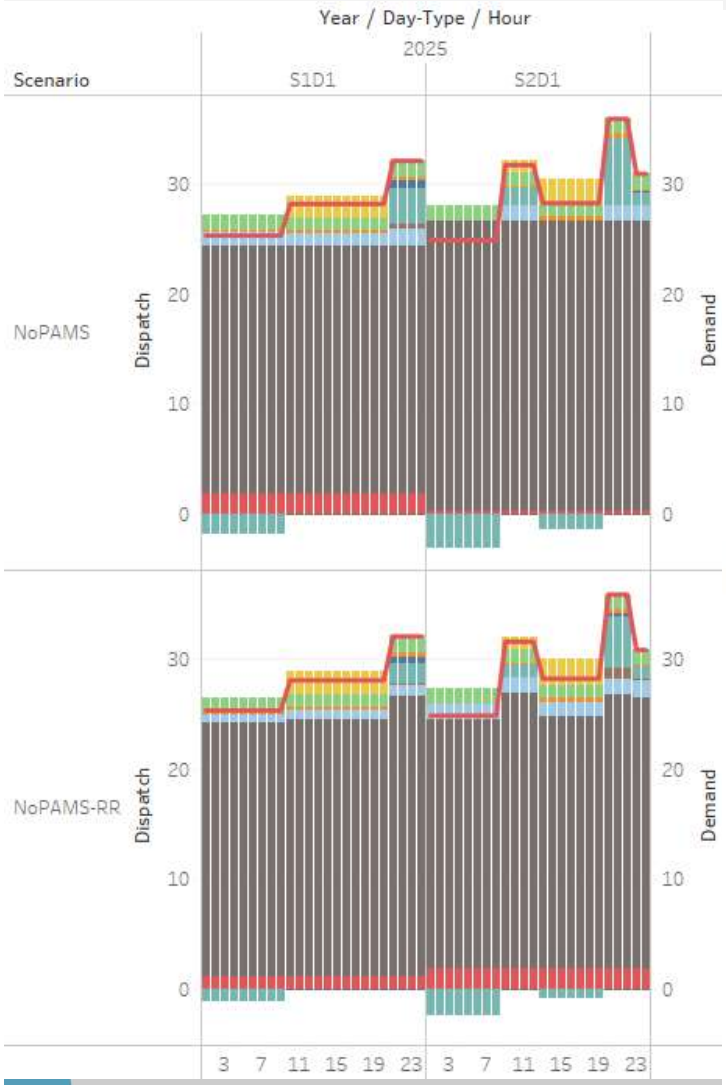
Reaching Net-Zero CO2 by 2050?



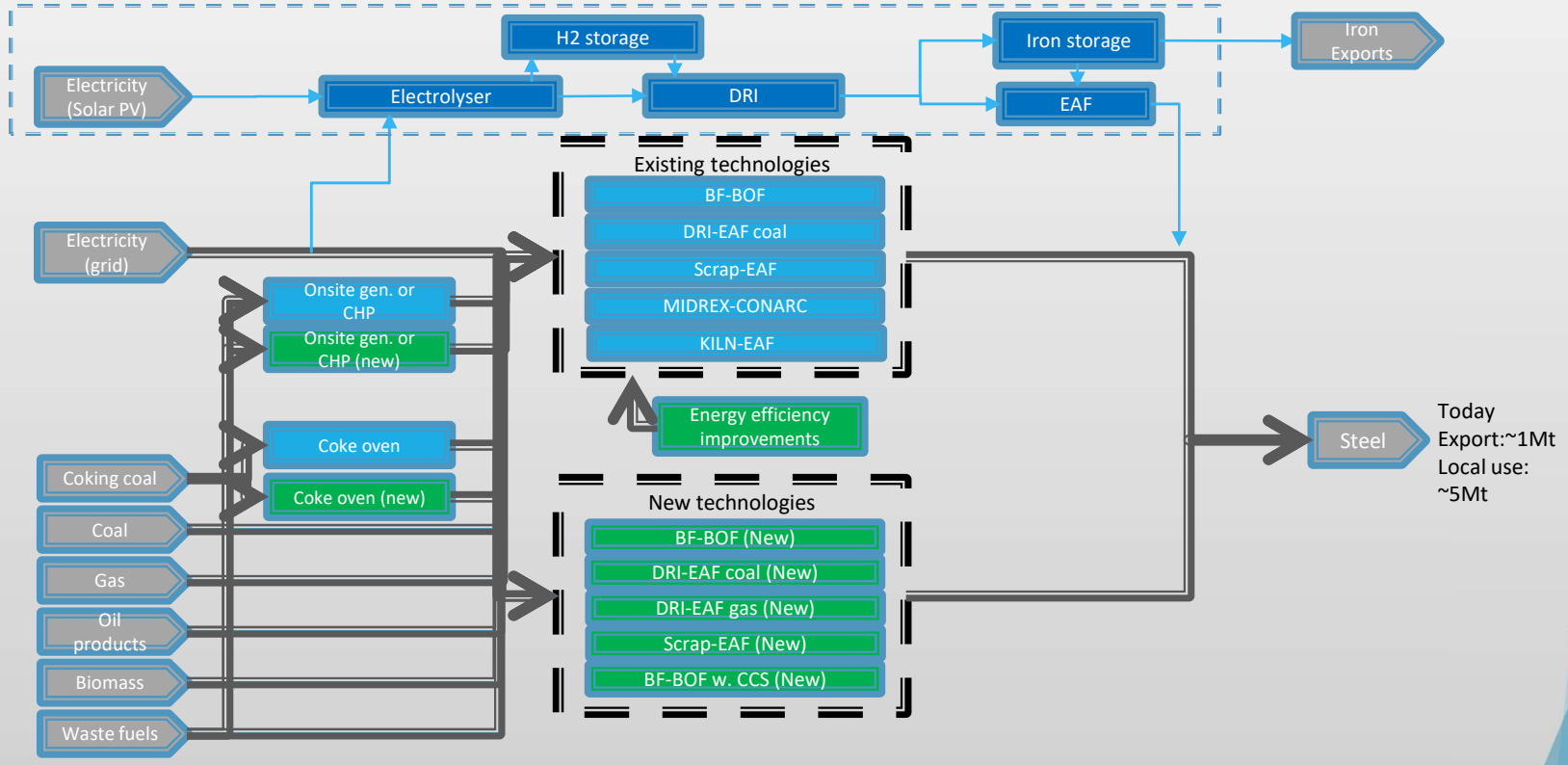
Demand Detail (Electricity)



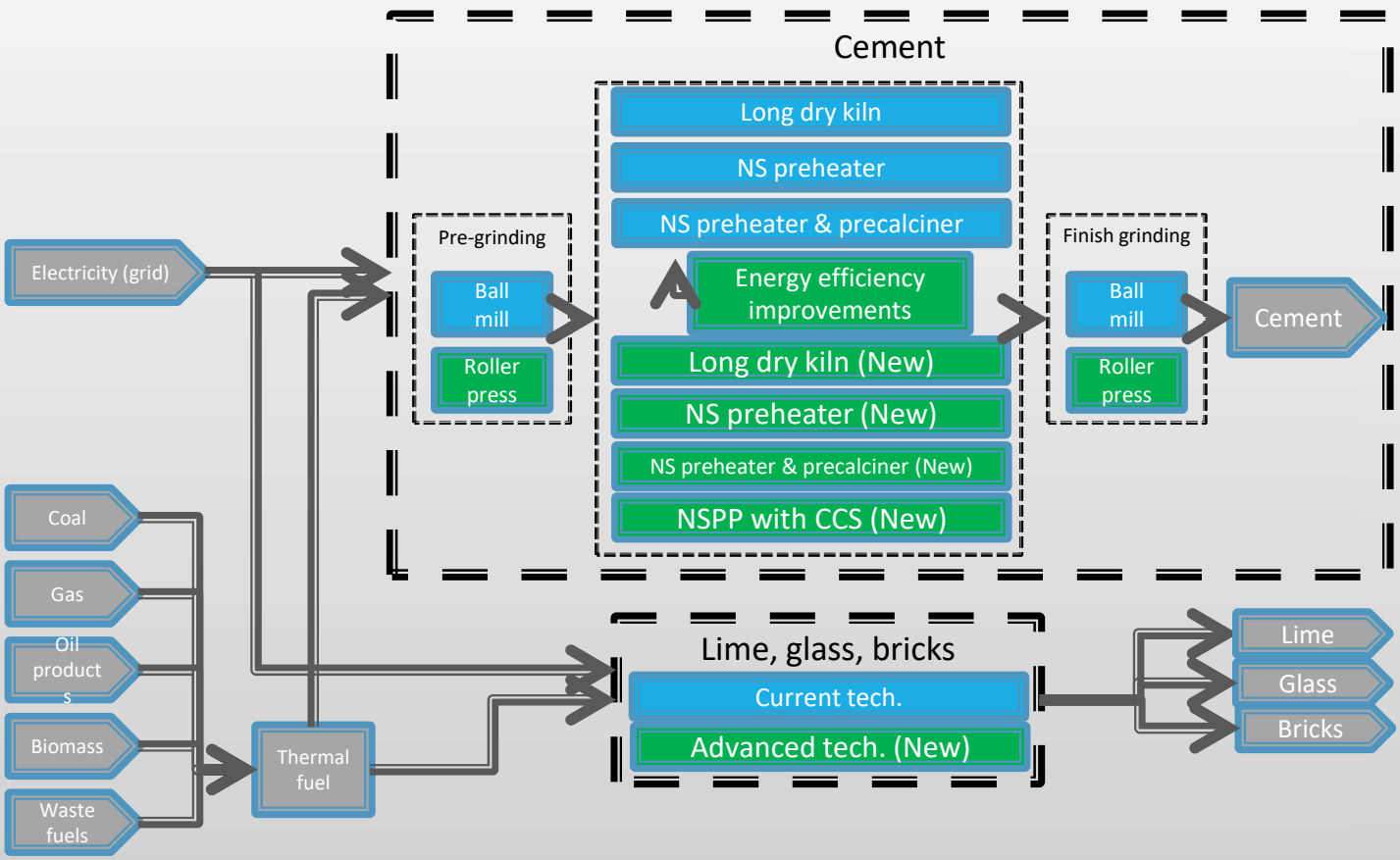
Dispatch in SATIM, coarse on temporal resolution but detailed on sectoral resolution



Hydrogen for iron & steel



Cement


Cement
Long dry kiln
NS preheater
NS preheater & precalciner
Energy efficiency improvements
Long dry kiln (New)
NS preheater (New)
NS preheater & precalciner (New)
NSPP with CCS (New)
Pre-grinding
Ball mill
Roller press
Finish grinding
Ball mill
Roller press
Cement
Electricity (grid)
Coal
Gas
Oil products
Biomass
Waste fuels
Thermal fuel
Lime, glass, bricks
Current tech.
Advanced tech. (New)
Lime
Glass
Bricks