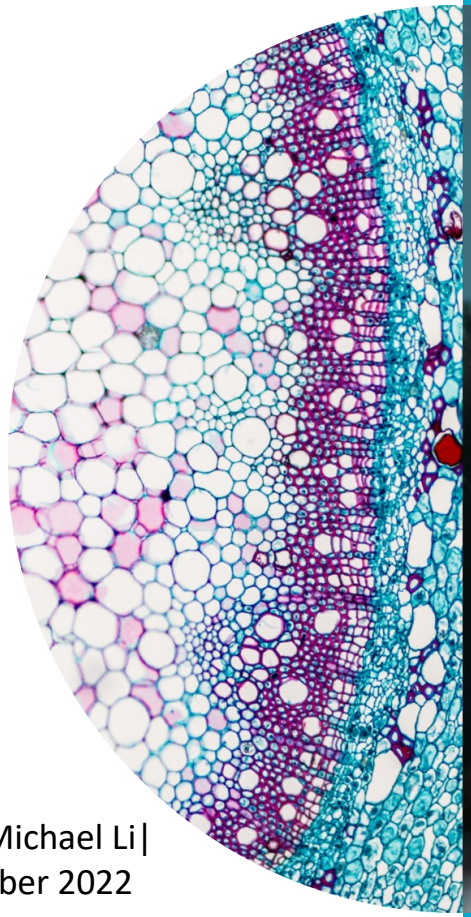
Multi-sector modelling: Approach and draft results



Luke Reedman, Jay Gordon, Michael Li|
FRG Presentation|21 September 2022

I would like to begin by acknowledging the Awabakal people as the Traditional Owners of the land that I'm meeting from today, and pay my respect to their Elders past and present.

Overview of modelling approach

What is TIMES?

- TIMES (The Integrated MARKAL-EFOM System) modelling framework is developed and maintained by the International Energy Agency (IEA) and has been used extensively in many countries
- Partial equilibrium model of the energy system
- Used in over 70 countries by ~200 teams
- CSIRO and Climateworks Centre have co-developed an Australian implementation - AusTIMES

AusTIMES overview

Typical scenario assumptions

Demand
- 8 demand regions (ACT,NSW,NT,QLD,SA ,TAS,VIC,WA)
- End uses specified by sector, including heating, cooling, vkt, industrial production.

Energy prices
- Import price oil products etc.
- Exogenous gas prices

Resources
- Detailed renewable resource availability

Policy
- Carbon budget
- Taxes
- Subsidies
- State and federal policies

REFERENCE ENERGY SYSTEM

Energy Carrier >30

Conversion
- Electricity generation
- Biomass processing
- Biofuel production
- Hydrogen production

Transmission / Distribution
- Multiple transmission zones
- Unit level existing thermal generator representation

Demand Sectors

Agriculture (AGR)
Agriculture, forestry and fishery

Commercial (COM)
Specified per Service type

Residential (RSD)
Specified per Building Type

Transport sector
Road, rail, shipping, aviation

Industry sectors
Specified per sector

Energy system optimization model formulated as a Linear Programming problem. Objective function is to minimize total discounted system cost over the projection period.

Techno-Economic Parameters (examples)

- Investment cost
- Fixed O&M costs
- Variable O&M costs

- Efficiency
- Availability factors

Environmental Parameters

Emission factors:
- CO_2, N_2O, CH_4

Model Outputs
(Technology, Zone, Year)

Energy use by energy carriers, presented by: Time/Sector/sub-sector

End-use technology:
- Number of vehicles per type
- Mix of heating equipment (electrification)
- Implementing of energy efficiency

Costs
- Total System Costs
- Sector Costs

Shadow prices
- Electricity
- Hydrogen production

Environmental
- GHG emissions

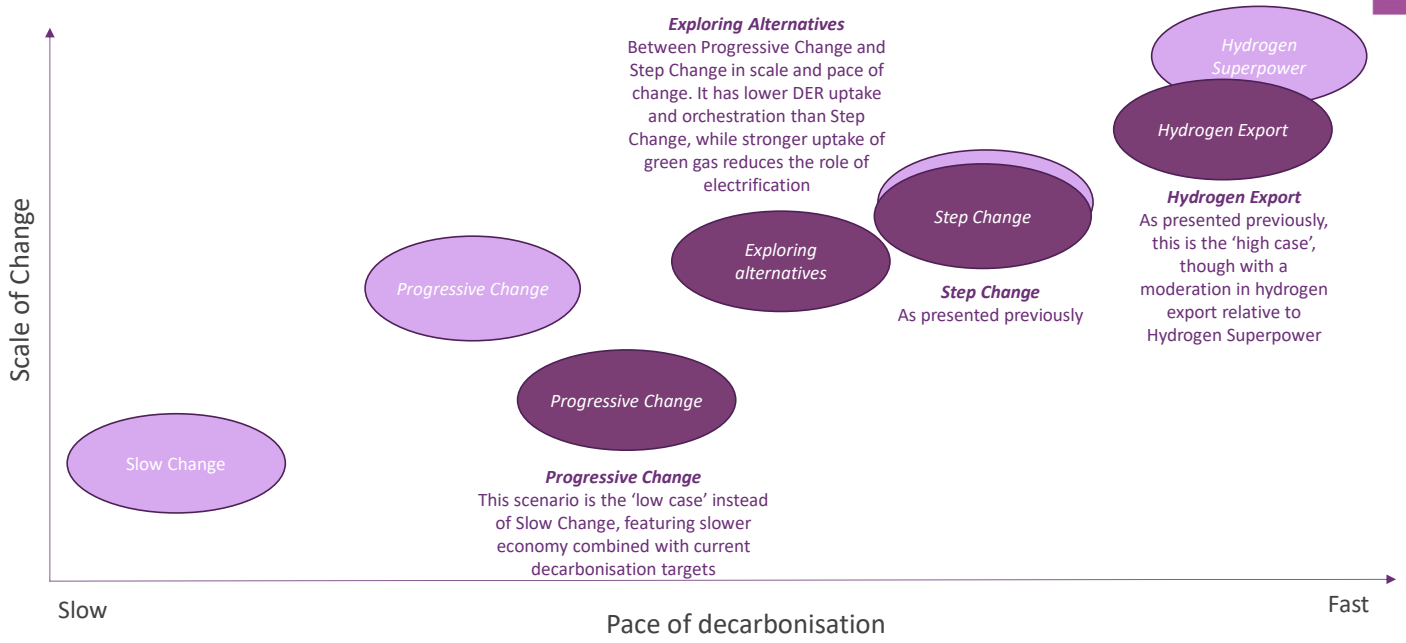
Link to other consultancies

Consultancy	Output	Input to AusTIMES
Macroeconomic projections (BIS Oxford)	Population growth Industry GVA growth	Activity driver for residential and industry
Fuel price projections (Lewis Gray Advisory for NEM/Rystad Energy for WA)	Wholesale gas prices	Input for fuel costs for end-use sectors
DER/EV projections (CSIRO)	Capacity of rooftop PV, behind-the-meter batteries, EVs and FCEVs	DER capacity Transport demand Shares of EVs and FCEVs in vehicle kilometres travelled

Scenario narratives

Updated draft scenarios

The Draft IASR will seek consult on:



Changes from MSM2021

- Carbon budget approach
- Direct Air Capture (DAC)
- Land sequestration approach
- Additional industry sub-sectors and technologies
- Hydrogen export and blend limits
- Inclusion of biomethane
- Electrification
- Energy Efficiency

Carbon budget approach

2021 Multi-sector modelling

- Carbon price trajectories were applied, and iterated until scenarios met their carbon budget/s
- Global carbon budgets were derived from the Intergovernmental Panel on Climate Change (IPCC)'s Special Report on 1.5°C (2018)
- National carbon budget calculations follow those used by the Climate Change Authority (2014)

2022 Multi-sector modelling

- A carbon budget is directly enforced in the model, as a cumulative emissions constraint
- Global carbon budgets are derived from the Intergovernmental Panel on Climate Change (IPCC)'s Sixth Assessment Report (2021)
- National carbon budget calculations follow approach used by the CCA (2014) but updated to reflect most recent IPCC science (2022)

Emissions sequestration

2021 Multi-sector modelling

- Land-based sequestration was an exogenous input, based on previous Climateworks Centre/CSIRO modelling
- Technical sequestration was limited to a few specific applications of CCS
- No purchase of international offsets is assumed

2022 Multi-sector modelling

- Land-based sequestration is based on a cost curve approach (DISER 2021)
- Technical sequestration considers DAC and several new industrial applications of CCS
- No purchase of international offsets is assumed

Table 15. Australian land sequestration by source in 2050 as a function of payment level

Supply price (A$/tCO2-e)		0	10	20	30	40	50	60	70	85	100	150	200	250	300
Conservative, high threshold															
Total LUC supply	$MtCO_2$-e	8.1	10.0	11.9	16.4	21.1	25.9	30.7	35.4	54.0	77.7	167.2	245.0	306.3	367.5
Soil carbon	$MtCO_2$-e	3.0	3.3	3.7	4.1	4.4	4.8	5.2	5.6	6.3	7.2	10.3	13.5	16.8	20.2
On-farm plantings	$MtCO_2$-e	1.4	2.1	2.8	5.3	8.0	10.7	13.4	16.1	32.3	54.6	139.1	209.8	262.2	314.7
Other supply	$MtCO_2$-e	3.7	4.5	5.4	7.0	8.7	10.4	12.0	13.7	15.4	15.9	17.9	21.7	27.2	32.6
Area of on-farm plantings	Mha	0.1	0.2	0.2	0.4	0.6	0.8	1.0	1.2	2.2	3.5	6.6	10.9	13.6	16.3
Area removed from production	Mha	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	6.9	8.6	10.3

https://www.industry.gov.au/sites/default/files/November%202021/document/australias-long-term-emissions-reduction-plan-modelling.pdf

Updates to industry modelling

- Climateworks Centre is a delivery partner in the Australian Energy Transitions Initiative (Australian Industry ETI)
- Australian Industry ETI is developing decarbonisation pathways with heavy industry, with findings to be released later this year
- Some early research from that work have informed the modelling used in this work
- Includes 9 new industry subsectors (e.g. disaggregation of mining, chemicals)
- Range of improvements to technology representation in industry

Hydrogen

- **Hydrogen export assumptions**
  - Includes electrolysers connected to NEM/SWIS/NWIS, and excludes electrolysers connected to non-regulated (or privately owned) networks
  - *Hydrogen Export* scenario based on maintaining LNG share of global trade in hydrogen based on the mapped IEA scenario
- **Hydrogen in gas networks**
  - Currently, all scenarios are consistent with up to 10% hydrogen blending share by 2030 (buildings and industry).
  - *Hydrogen Export* scenario assumes up to 100% by 2050, other scenarios capped at up to 10% by 2050.
- **Green steel**
  - Same assumption as MSM2021: 50Mtpa by 2050 in *Hydrogen Export* scenario

Hydrogen export assumptions (Mt)

Scenario	2030	2040	2050
Exploring Alternatives and Step Change	NEM: 0.07 SWIS: 0.0025 NWIS: 0.0050	NEM: 0.14 SWIS: 0.125 NWIS: 0.25	NEM: 0.21 SWIS: 0.19 NWIS: 0.4
Hydrogen Export	NEM: 2.75 SWIS: 1.06 NWIS: 2.12	NEM: 5.1 SWIS: 2.06 NWIS: 4.13	NEM: 8 SWIS: 3.28 NWIS: 6.56

Hydrogen in gas networks

Scenario	2030	2050
Progressive Change, Exploring Alternatives and Step Change	Max 10% by volume for buildings and industry	Max 10% by volume for buildings and industry
Hydrogen Export	Max 10% by volume for buildings and industry	Max 100% by volume for buildings and industry

Green steel

Scenario	2050
Hydrogen Export	50 Mtpa (approximately 10x current steel production)

Biomethane

- Not a fuel option in 2021 MSM. Model has been updated based on FRG feedback
- Biomethane production is endogenous
- There are caps based on different feedstocks to produce biogas (the precursor to biomethane)
- The national quantum of available feedstocks from municipal solid waste, animal wastes, and lignocellulosic sources (Native Forest, Crop/stubble/grasses, and Plantation and short rotation trees) are based on the AusIndustry ETI project
- State/territory shares of the national quantum are proxied from the state/territory quantities of forestry, agriculture, and organic wastes and residue feedstocks sourced from ENEA Consulting and Deloitte (2021)
- Production of biogas from anaerobic digestion is a mature technology and no future cost reductions are expected
- Capital cost reductions in gasification and methanation are in the model, with a lower cost trajectory applied and a 7.5% biomethane target in 2030 in the *Exploring Alternatives* scenario

Updates to energy efficiency and electrification approach

2021 Multi-sector modelling

- Energy efficiency and electrification uptake varied by scenario based on hurdle rates
- This is a way to proxy various non-cost barriers to technology uptake
- However, setting specific hurdle rates can be subjective, with limited literature to refer to

2022 Multi-sector modelling

- We are freeing the model to make decisions not inhibited by hurdle rates
- However, limits on maximum uptake rates are varied by scenario
- These limits are varied with reference to IEA scenarios

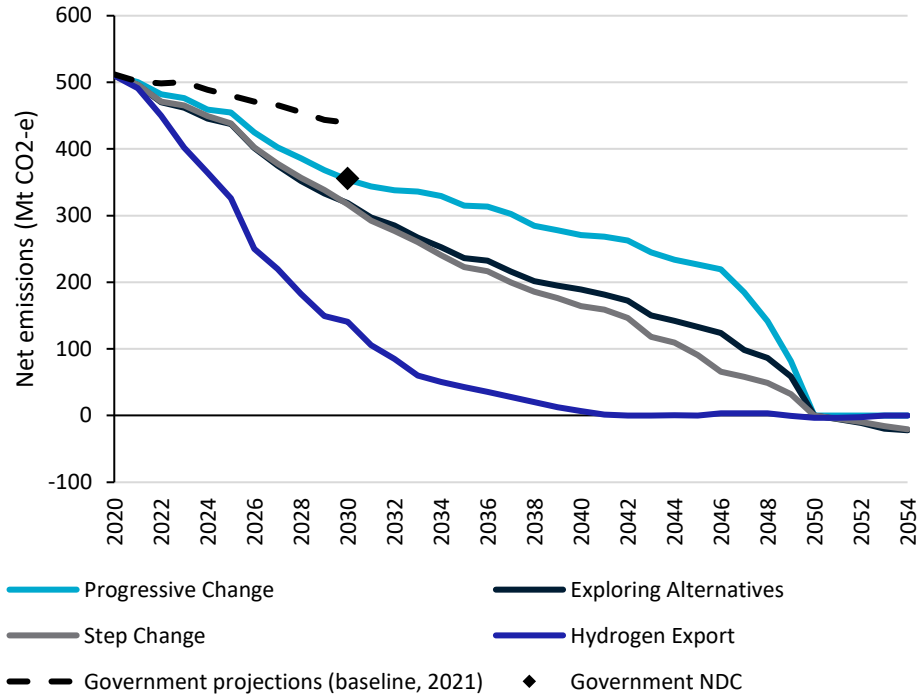
Updates to energy efficiency and electrification approach

Scenario	Max annual uptake of industry energy efficiency (indexed; 1 = Hydrogen Export)	Max final savings from energy efficiency in residential and commercial buildings (indexed; 1 = Hydrogen Export)	Source Based on electrification outcomes form mapped IEA WEO scenarios
Progressive Change	0.71	0.73	Stated Policies (STEPS)
Exploring Alternatives	0.78	0.75	Announced Pledges (APS)
Step Change	0.89	0.88	Sustainable Development (SDS)
Hydrogen Export	1.00	1.00	Net Zero 2050 (NZE2050)
Scenario	**Max annual uptake of industry electrification (indexed; 1 = Hydrogen Export)**	**Max final penetration of electrification in residential and commercial buildings (indexed; 1 = Hydrogen Export)**	**Source Based on electrification outcomes form mapped IEA WEO scenarios**
Progressive Change	0.33	0.72	Stated Policies (STEPS)
Exploring Alternatives	0.59	0.75	Announced Pledges (APS)
Step Change	0.78	0.94	Sustainable Development (SDS)
Hydrogen Export	1.00	1.00	Net Zero 2050 (NZE2050)

Draft results

PRELIMINARY

National emissions



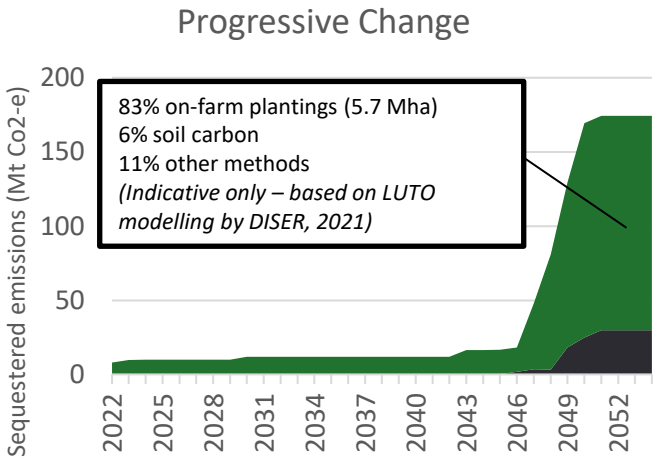
Scenario	Carbon budget (2021-2050, Mt CO2-e)	2030 constraint (Mt CO2-e)	2050 constraint (Mt CO2-e)
Progressive Change	N/A*	= 354	<= 0
Exploring Alternatives	7.124	<= 354	<= 0
Step Change	7.124	<= 354	<= 0
Hydrogen Export	3.423	<= 354	<= 0

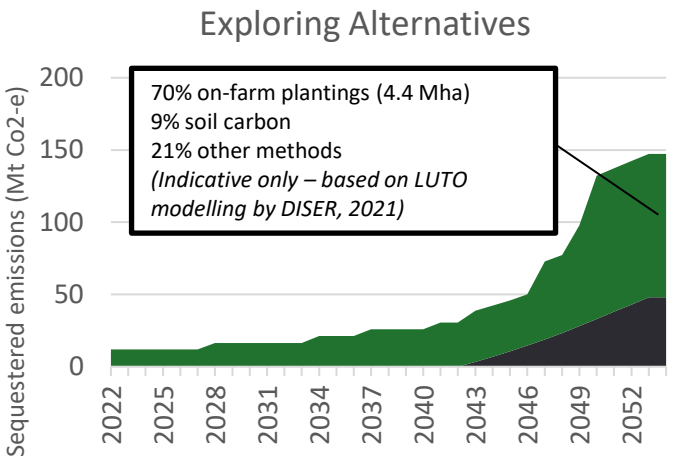
Note: 354 Mt CO2-e is Australia's 2030 NDC under the Paris Agreement; a 43% reduction on 2005 emissions.

**Progressive Change is not driven by a carbon budget. However a loose cumulative constraint operates in the model to drive emission reductions between constrained years.*

Negative emissions (national)

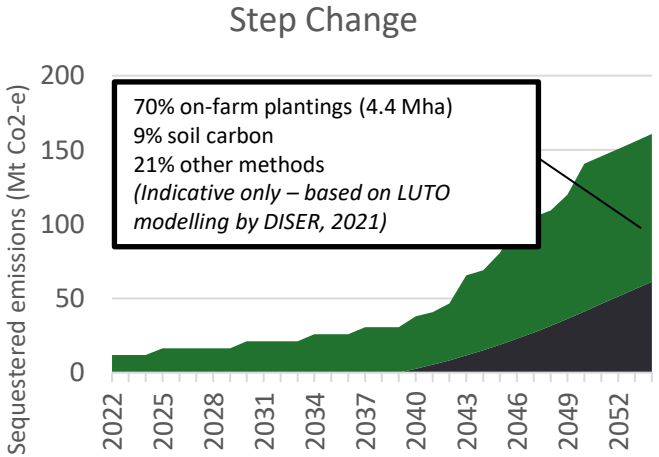
PRELIMINARY

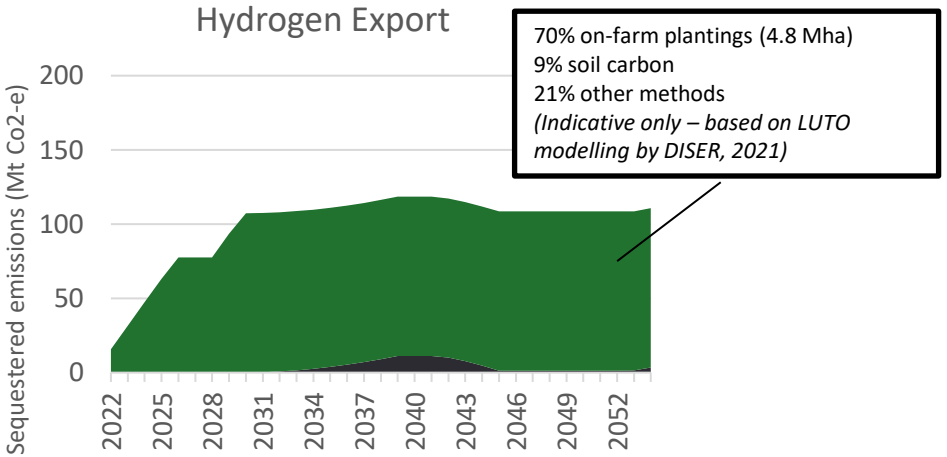




Land-based sequestration

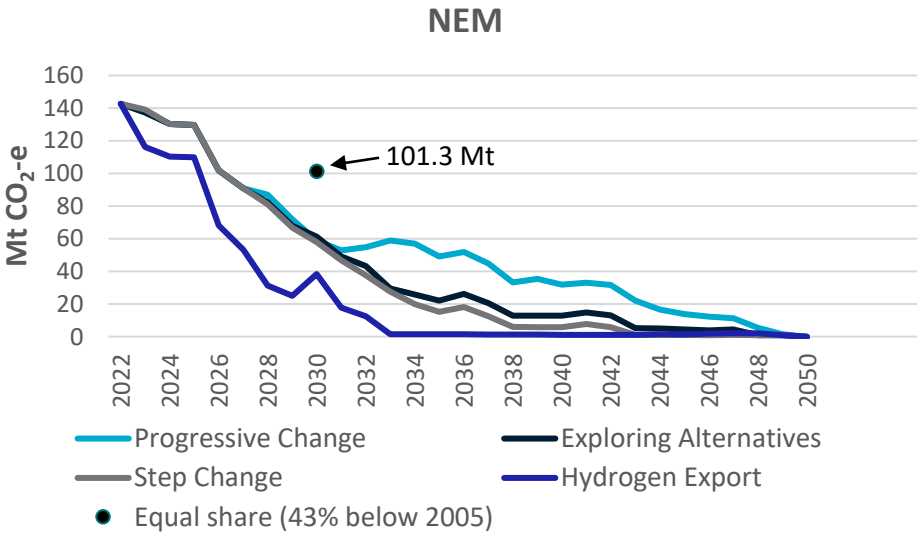
Direct air capture (DAC)

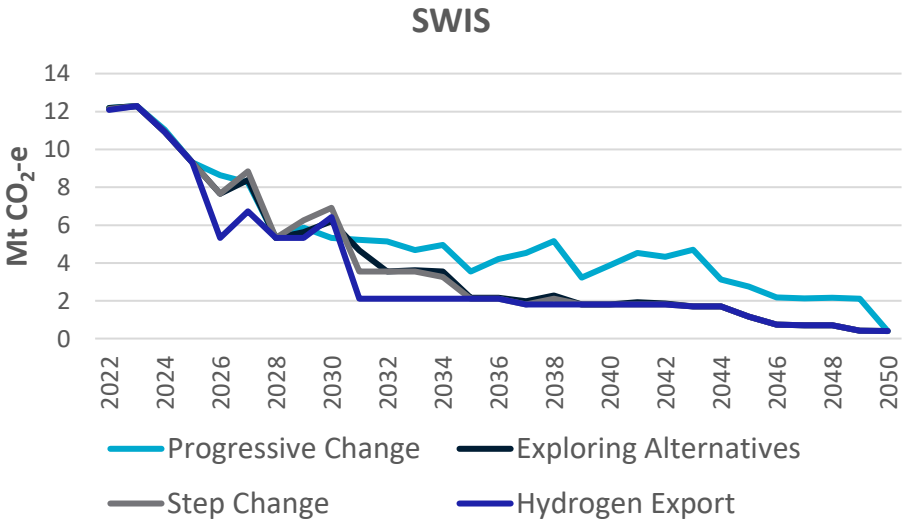




PRELIMINARY

Power sector emissions

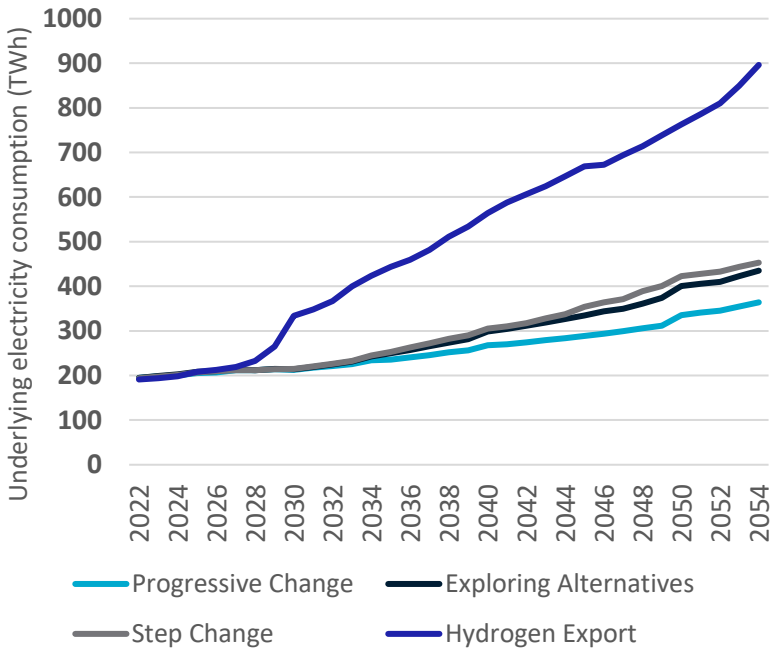




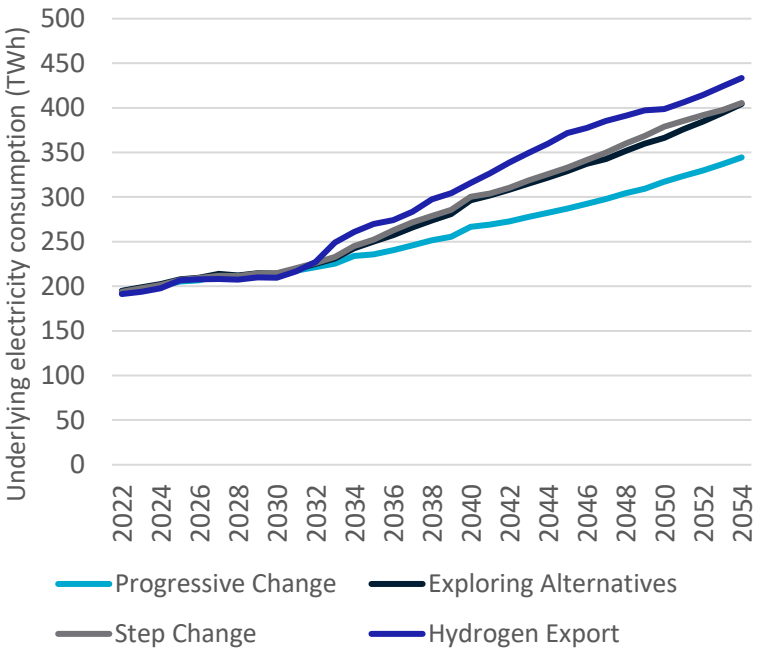
PRELIMINARY

Electricity consumption in the end-use sectors (NEM states)

Including for hydrogen production



Excluding for hydrogen production

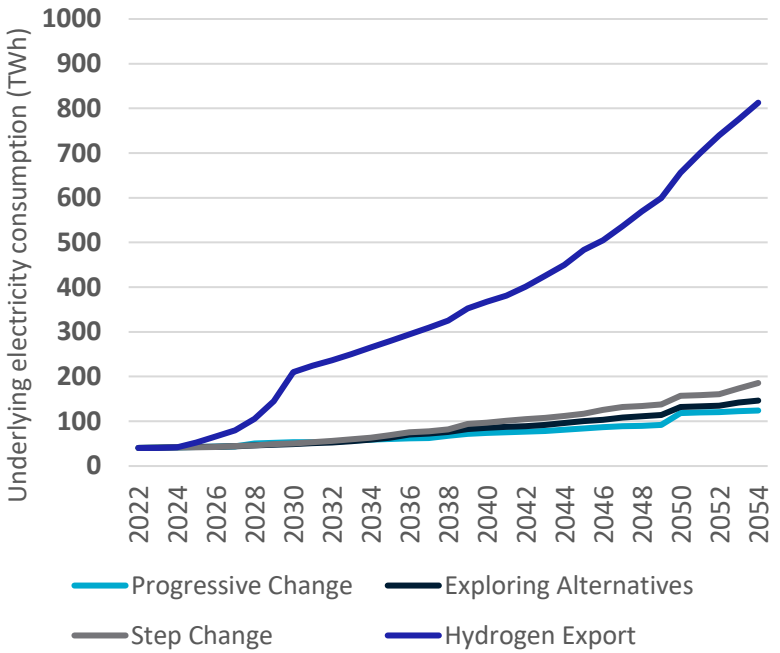


(Charts on different scales)

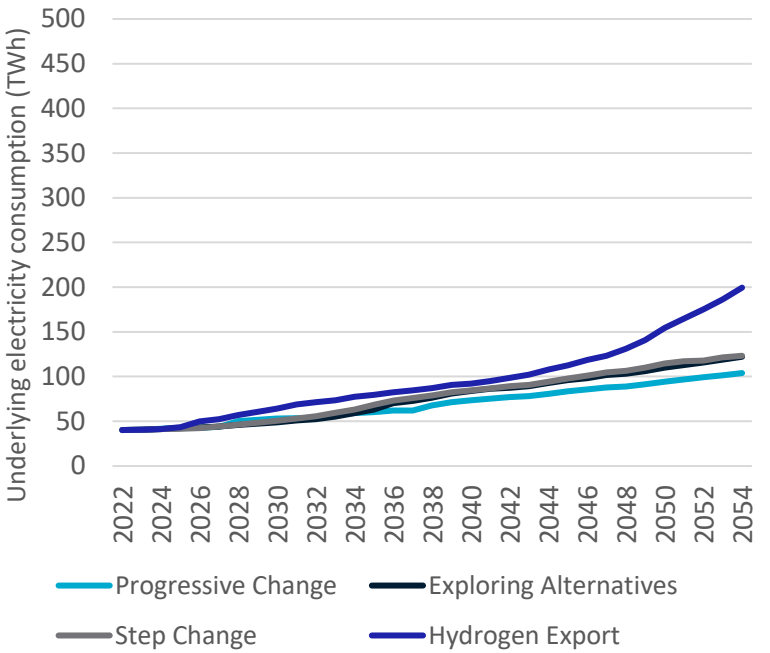
PRELIMINARY

Electricity consumption in the end-use sectors (WA)

Including for hydrogen production



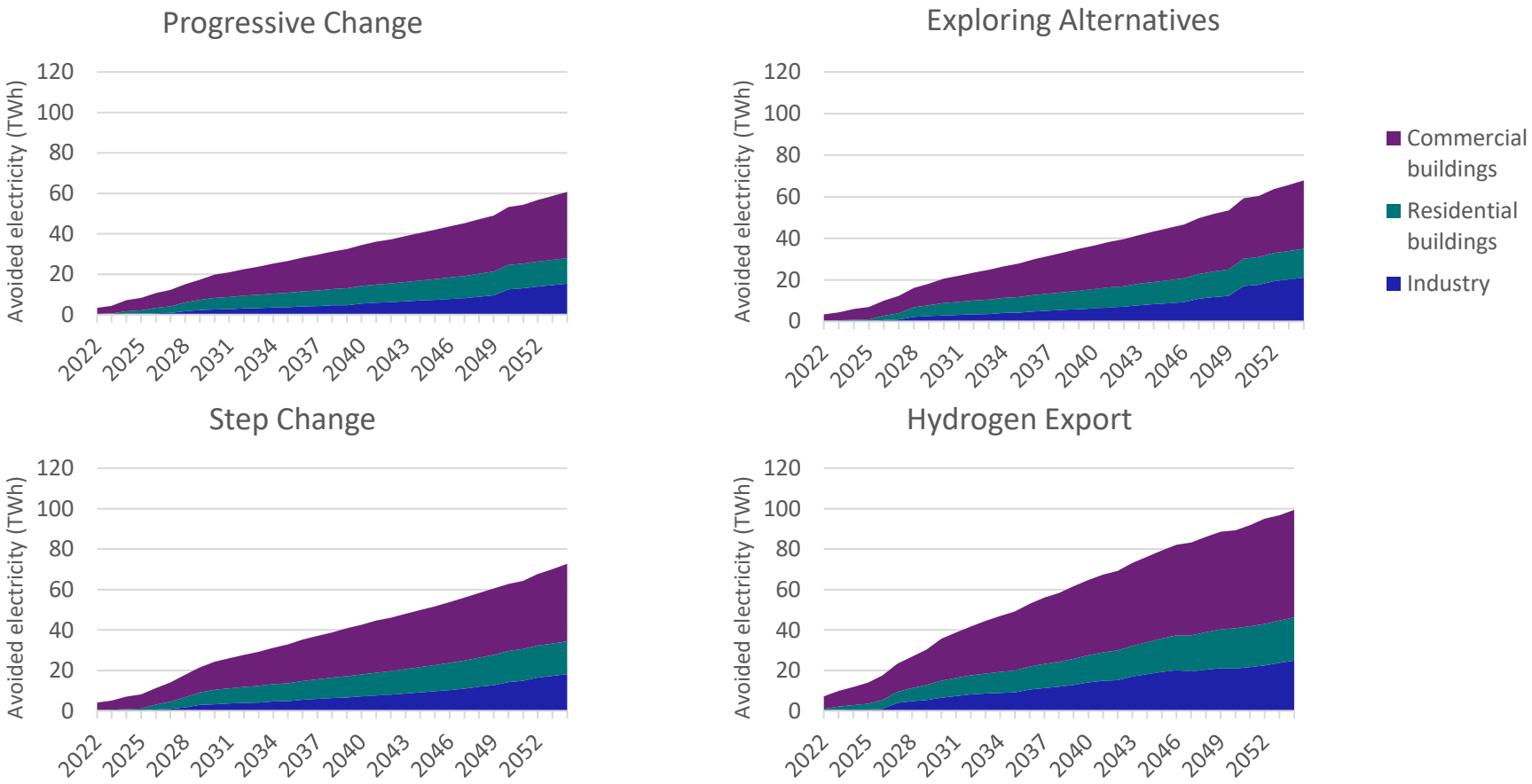
Excluding for hydrogen production



(Charts on different scales)

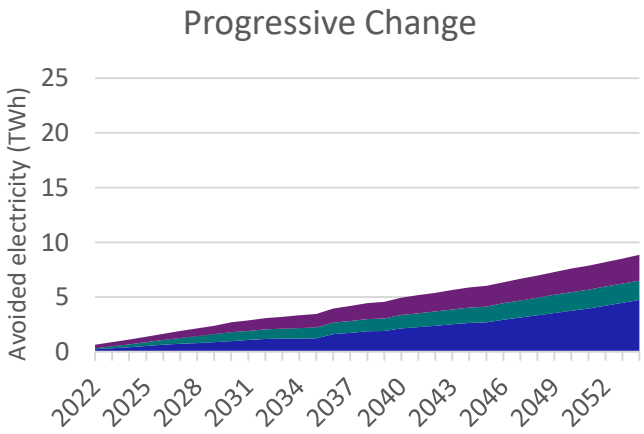
Energy efficiency – NEM states

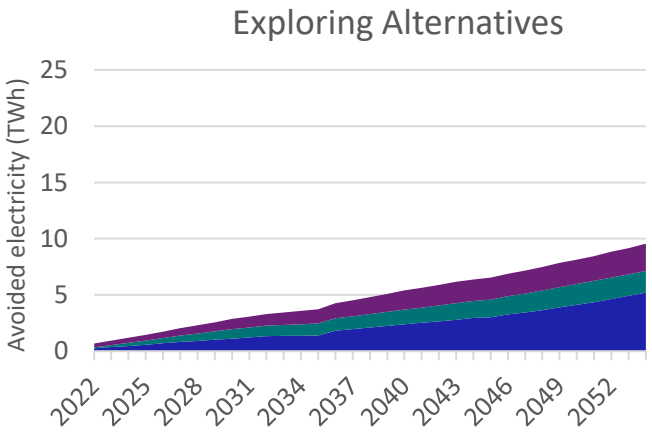
PRELIMINARY



Energy efficiency – WA

PRELIMINARY

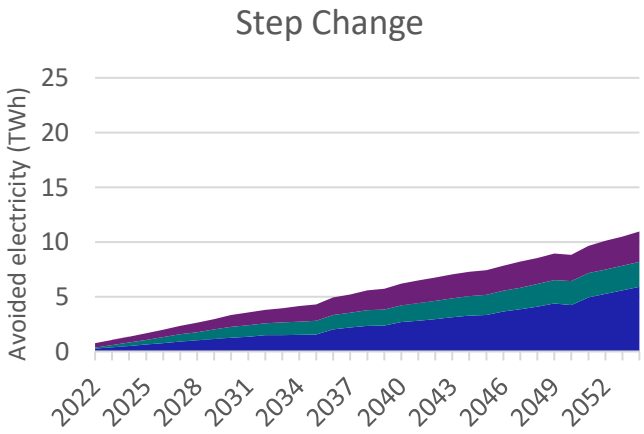


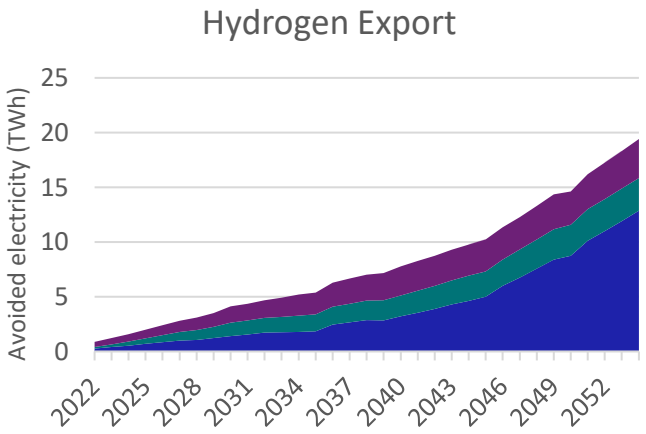


Commercial buildings

Residential buildings

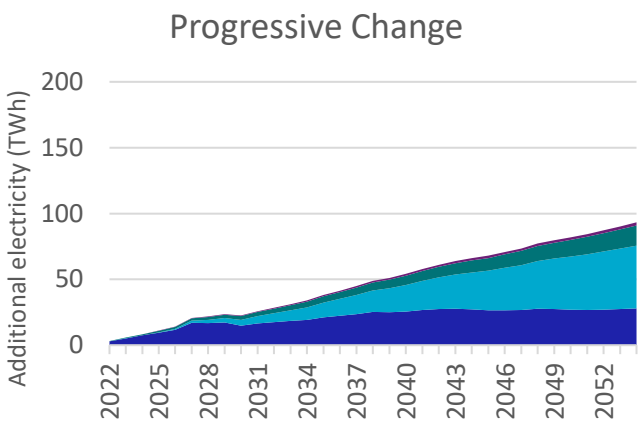
Industry

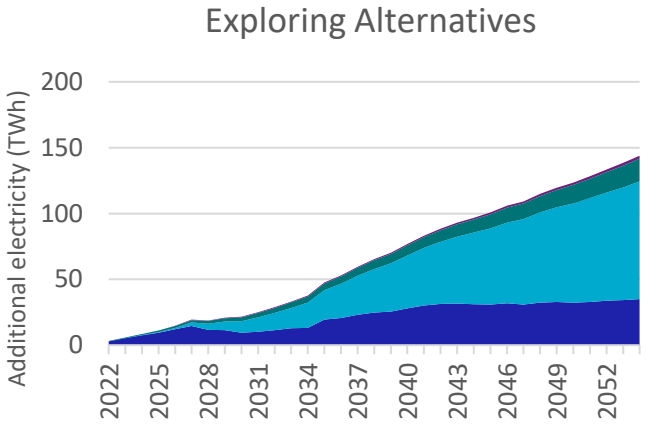




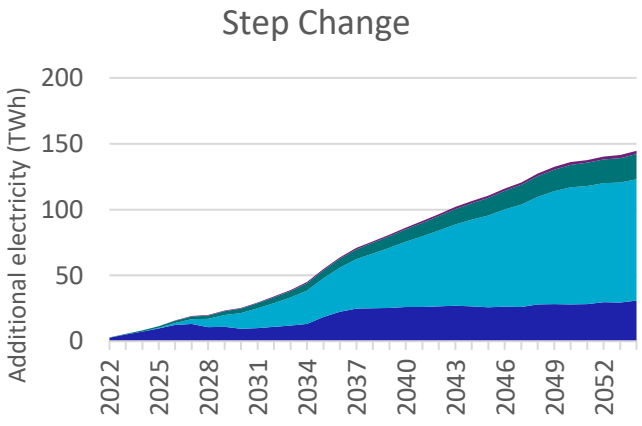
Electrification – NEM states

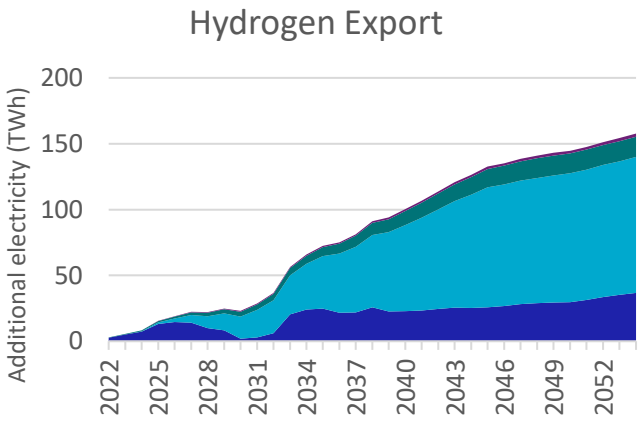
PRELIMINARY





Commercial
Residential
Transport
Industry

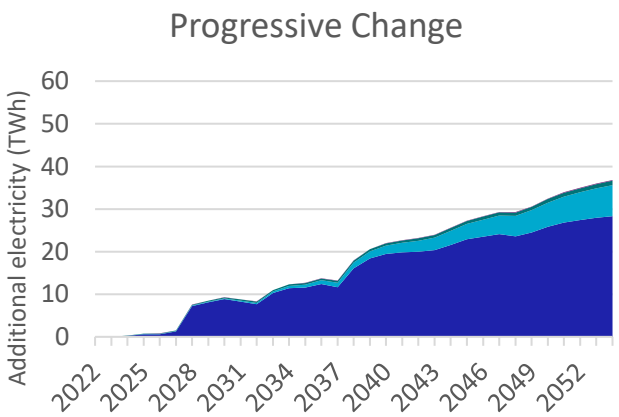


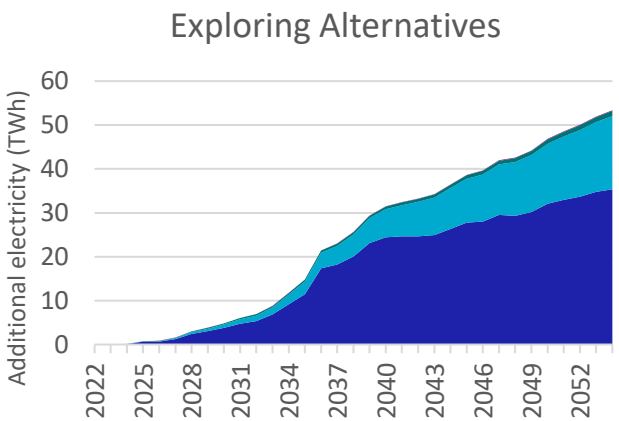


Includes costed electrification in buildings & industry, and increased electricity demand in transport

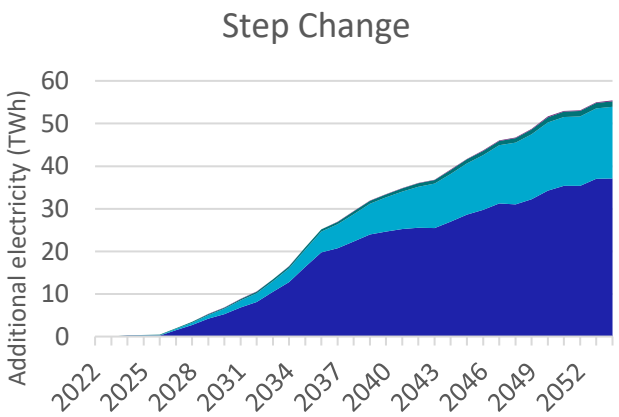
Electrification – WA

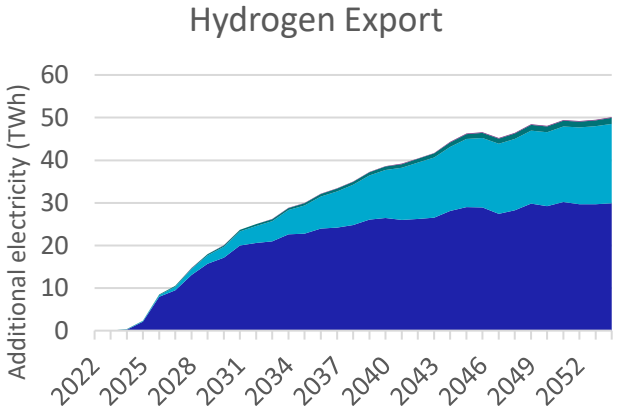
PRELIMINARY





Commercial
Residential
Transport
Industry

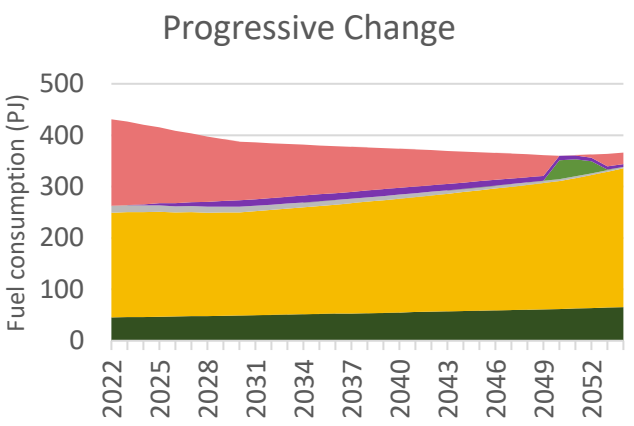


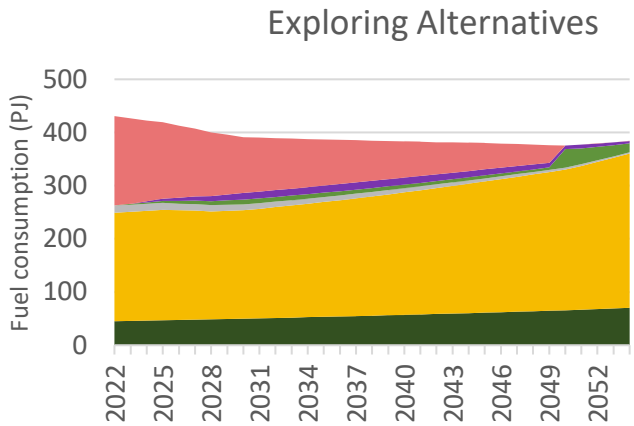


Includes costed electrification in buildings & industry, and increased electricity demand in transport

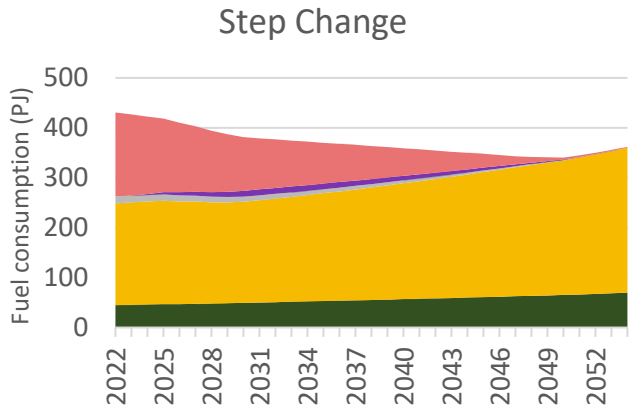
Fuel Share in Residential Buildings – NEM states

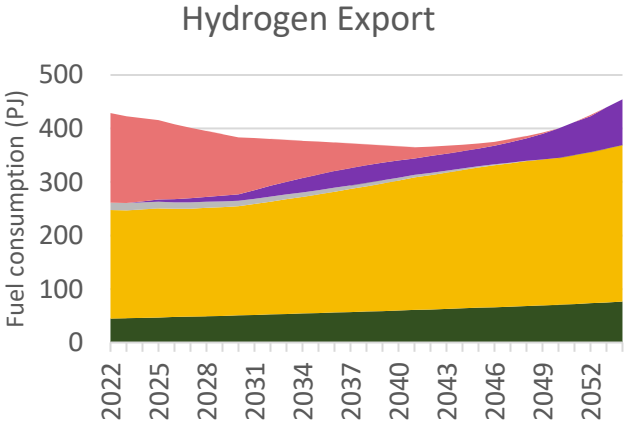
PRELIMINARY





Natural gas
Hydrogen
Biomethane
LPG
Electricity
Biomass (wood*)

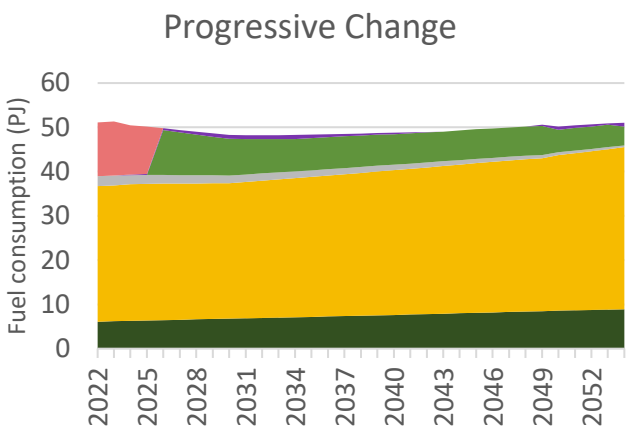


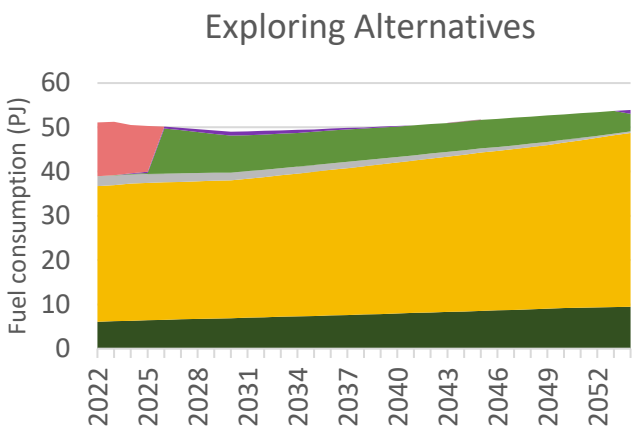


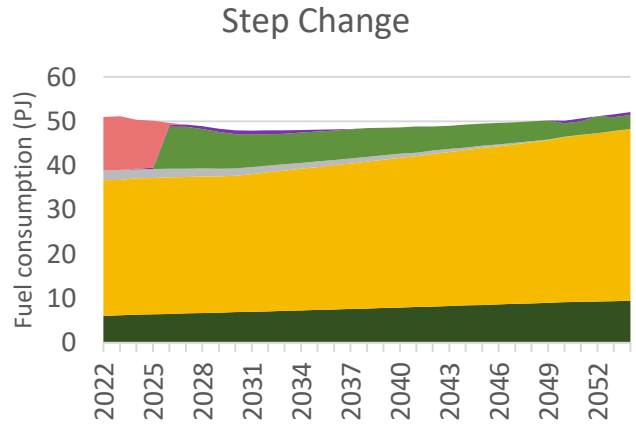
**Wood is considered a zero carbon fuel in Aus-TIMES and therefore does not switch as a result of any emissions constraints. Wood is used for a small percentage of useful heat production in Australian homes – however its contribution appears disproportionately high in the final energy mix due to the very poor efficiency of wood heating.*

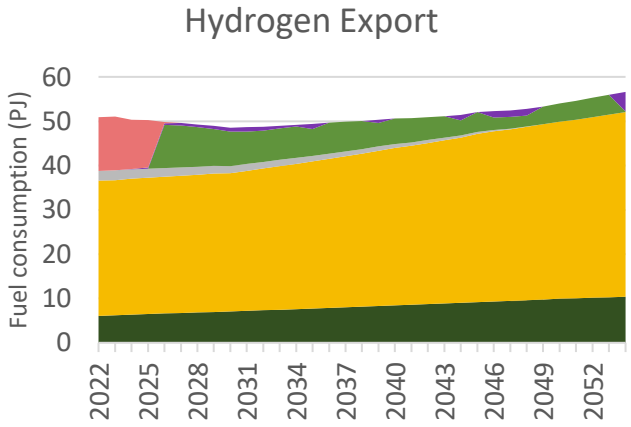
Fuel Share in Residential Buildings – WA

PRELIMINARY









- Natural gas
- Hydrogen
- Biomethane
- LPG
- Electricity
- Biomass (wood*)

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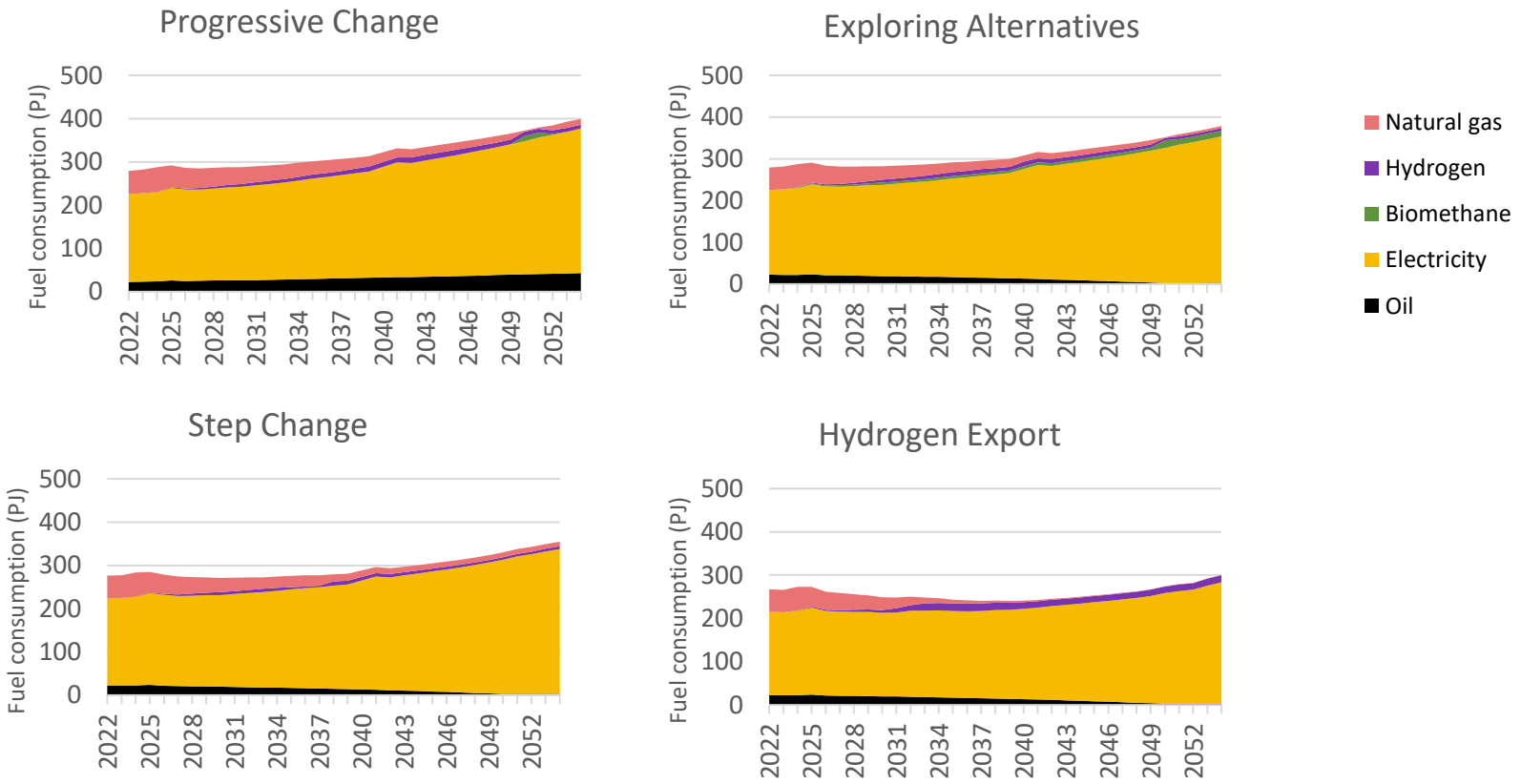
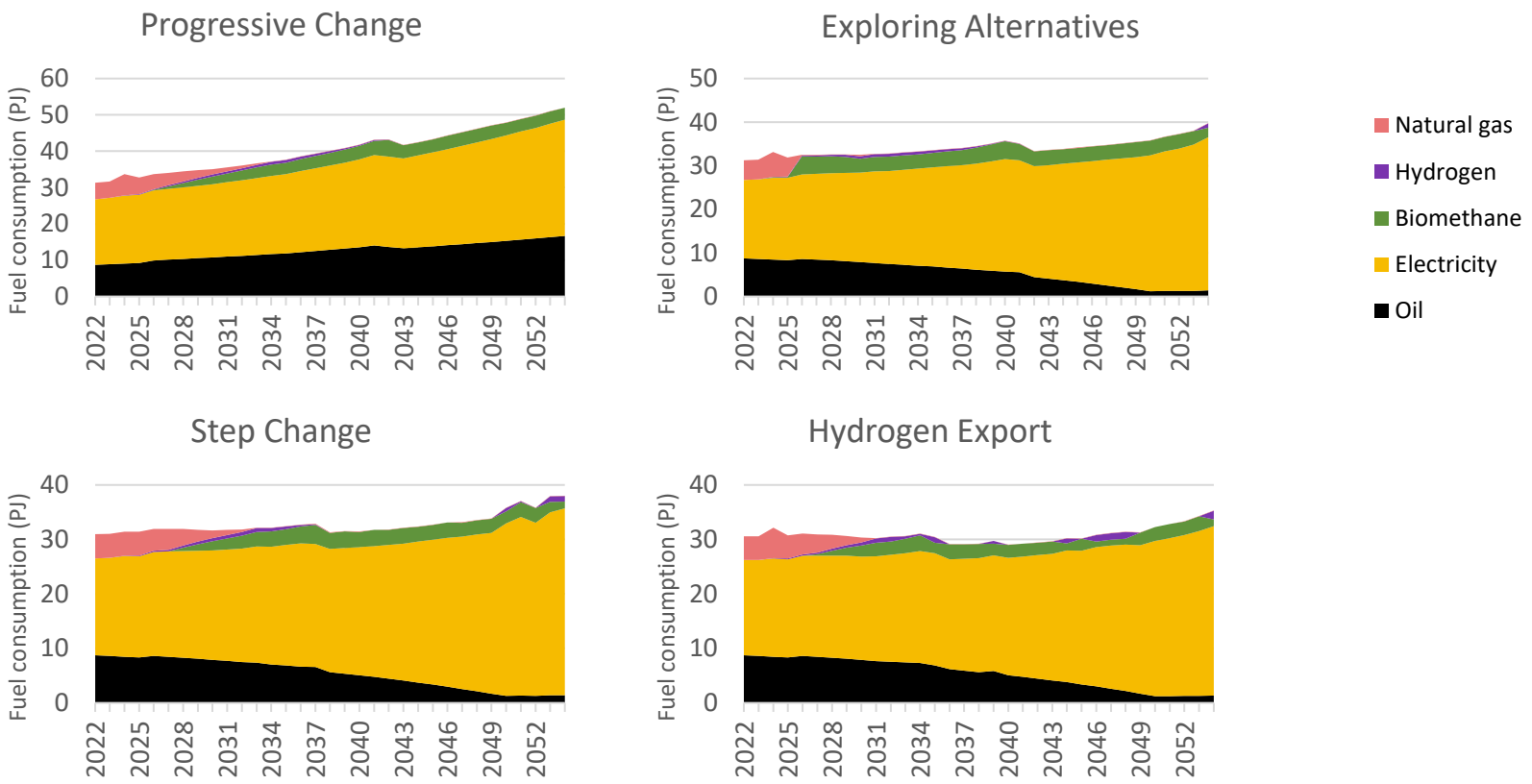
Fuel Share in Commercial Buildings – NEM states

PRELIMINARY



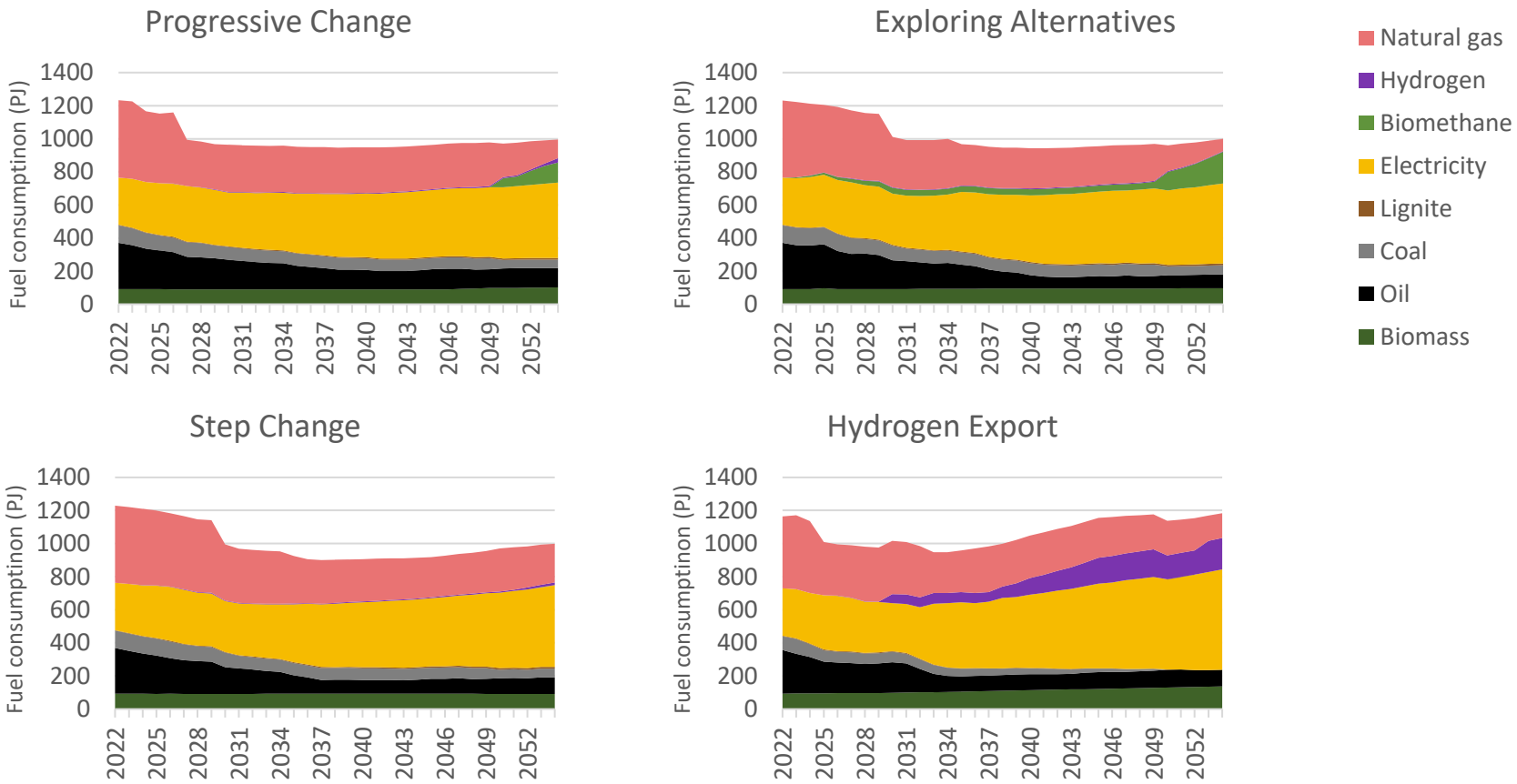
Fuel Share in Commercial Buildings - WA

PRELIMINARY



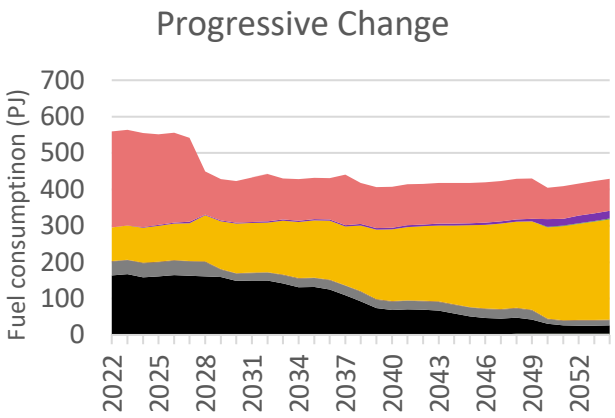
Fuel Share in Industry – NEM states

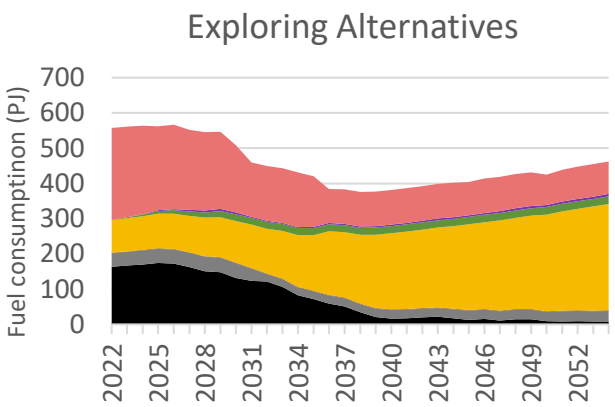
PRELIMINARY



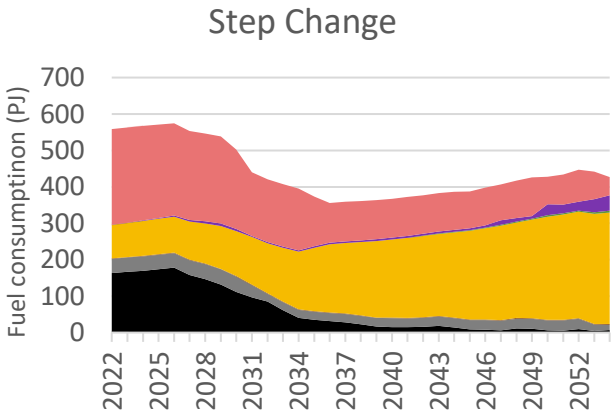
Fuel Share in Industry – WA

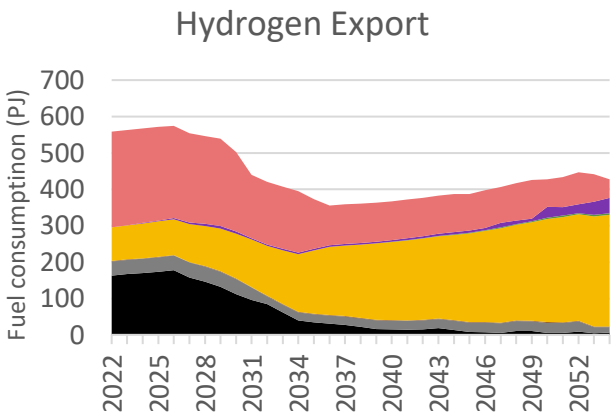
PRELIMINARY





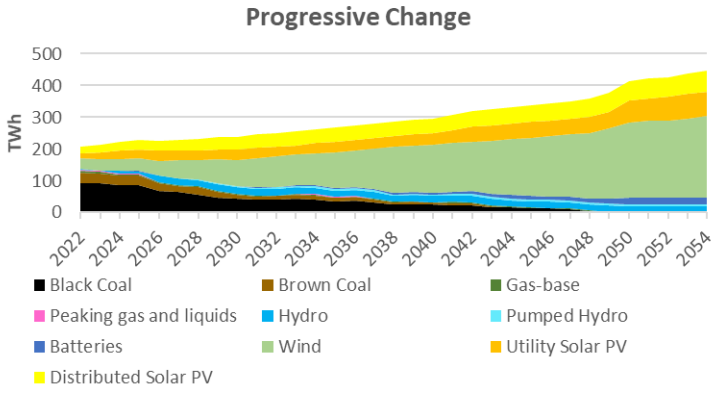
- Natural gas
- Hydrogen
- Biomethane
- Electricity
- Lignite
- Coal
- Oil
- Biomass

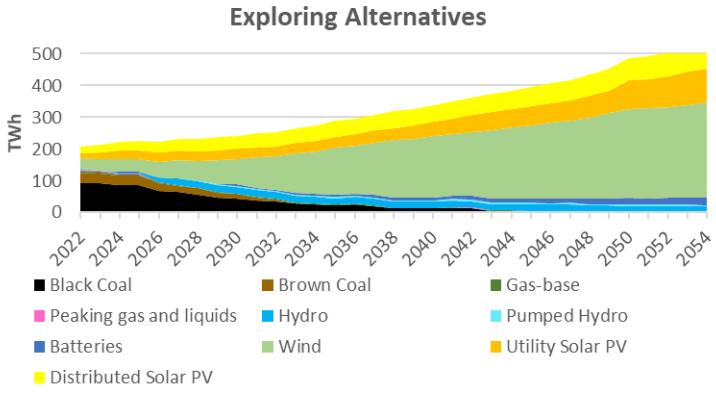


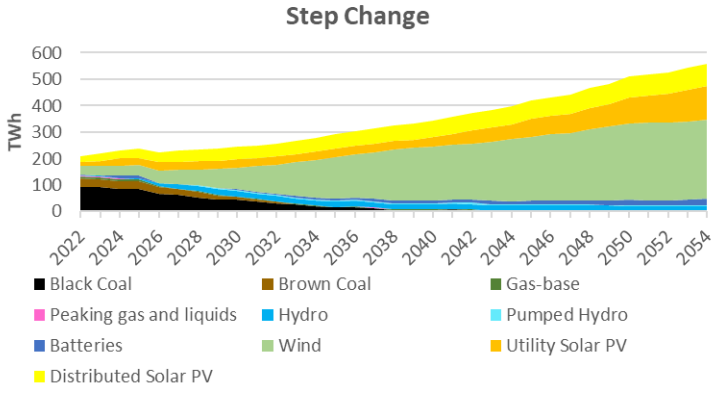


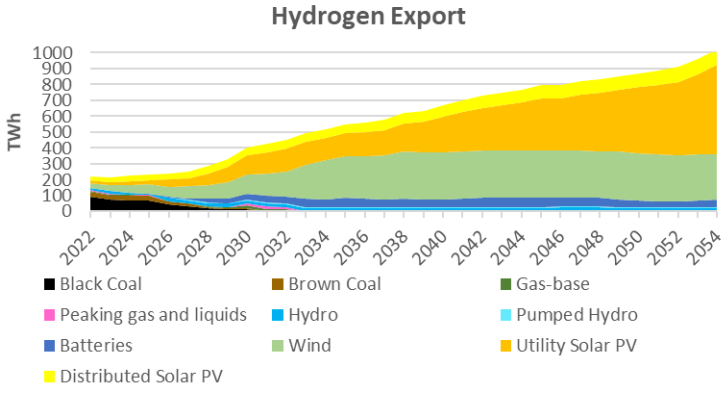
Electricity generation - NEM

PRELIMINARY



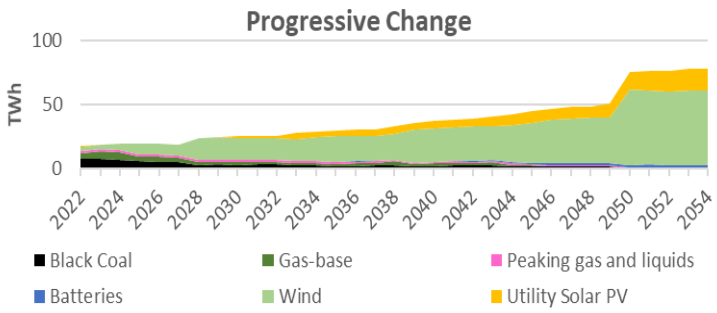


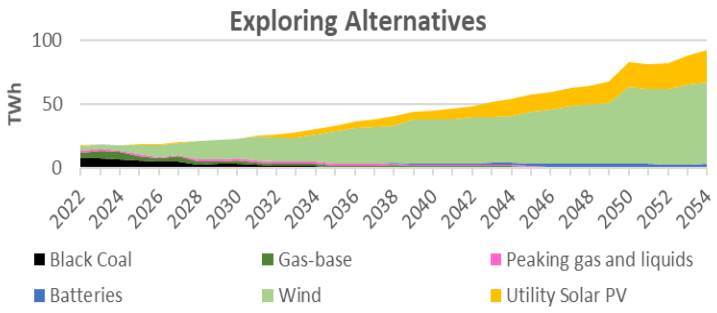


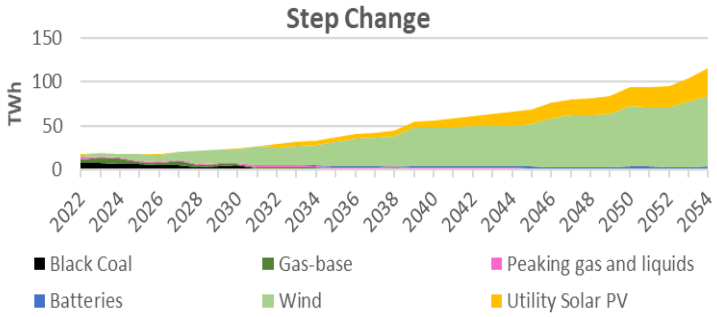


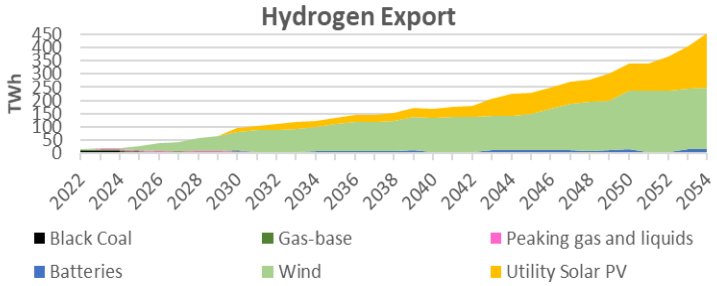
Electricity generation - SWIS

PRELIMINARY



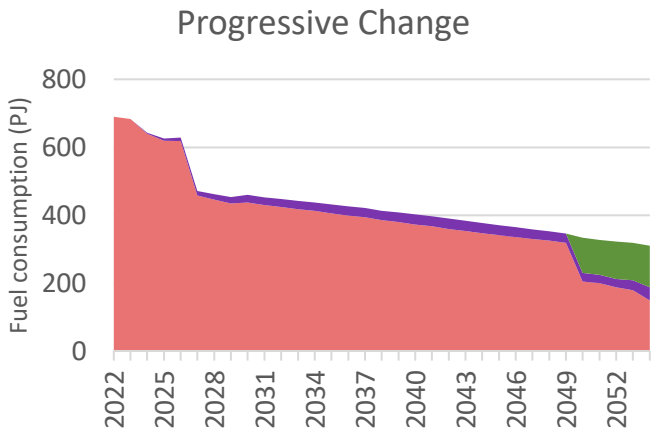


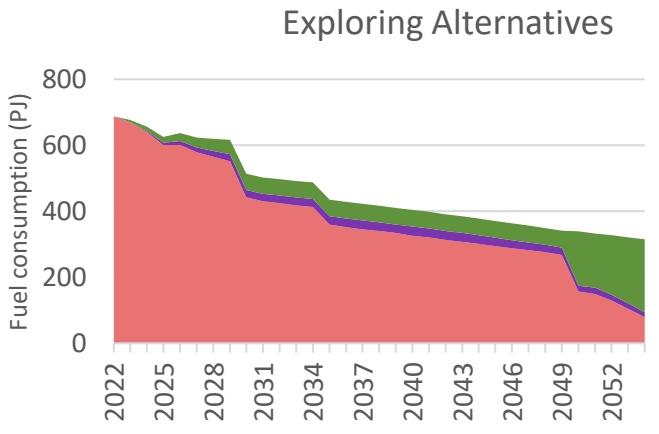


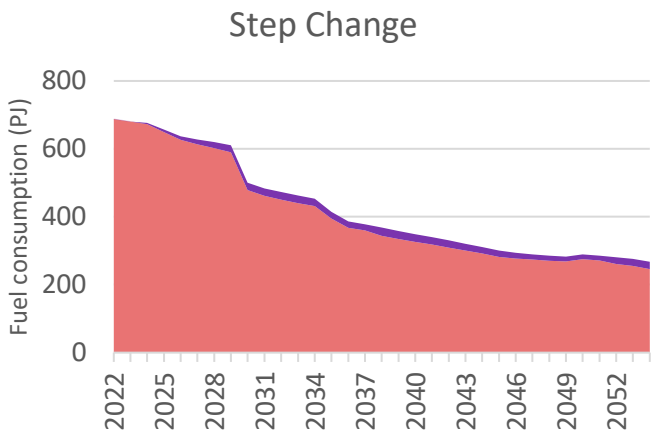


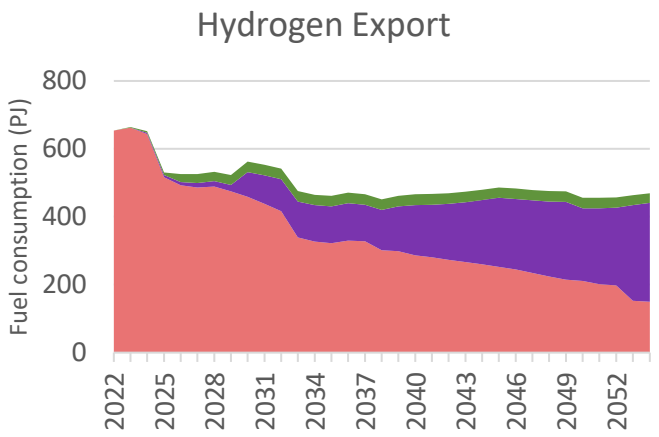
Gaseous fuel mix (NEM states)

PRELIMINARY







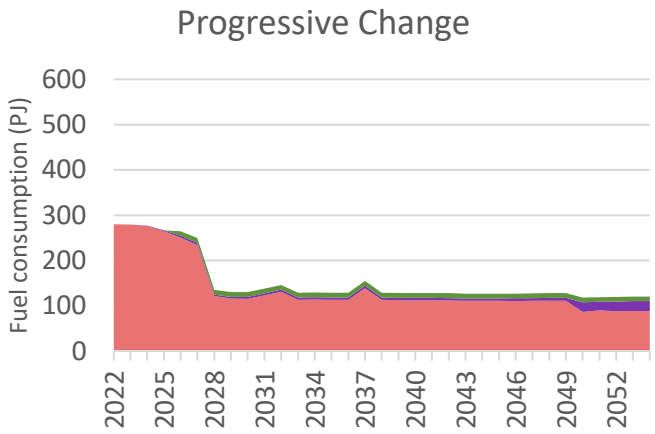


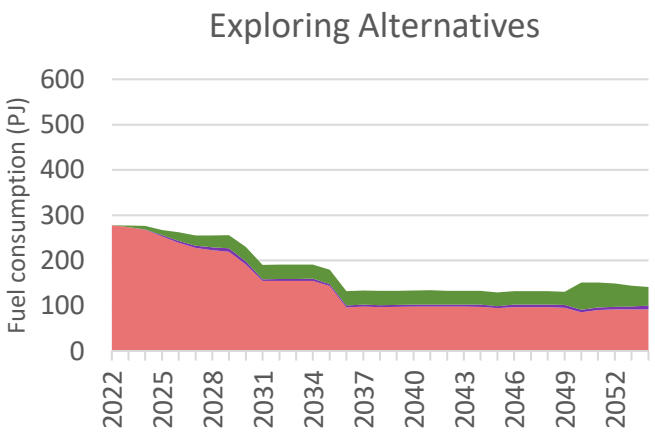
Biomethane
Hydrogen
Natural gas

Includes gaseous fuel consumption in industry, residential and commercial buildings.

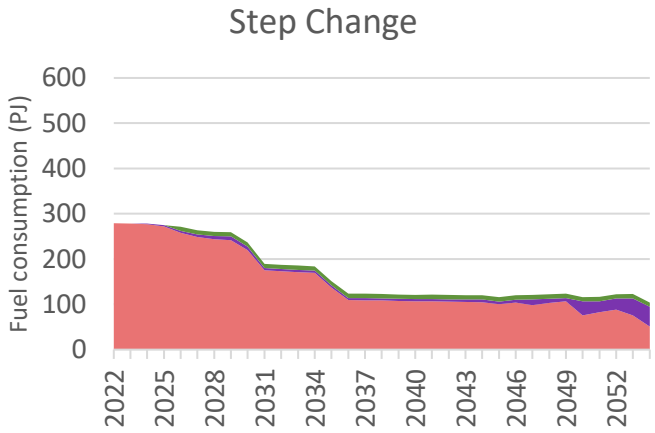
Gaseous fuel mix (WA)

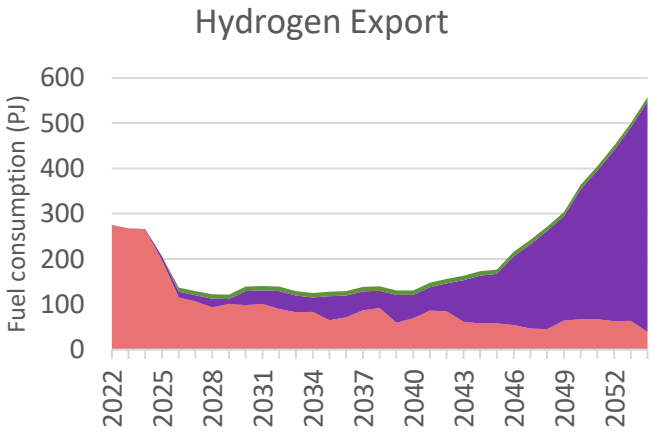
PRELIMINARY





Biomethane
Hydrogen
Natural gas

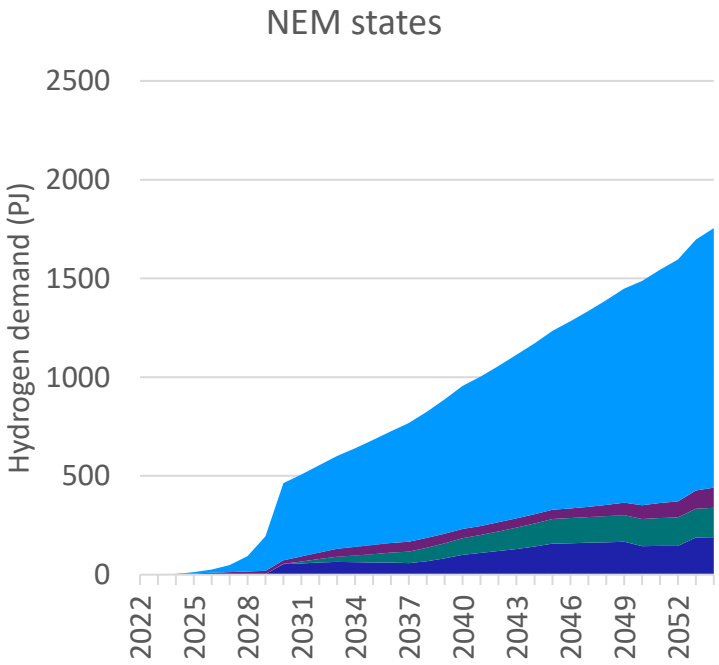


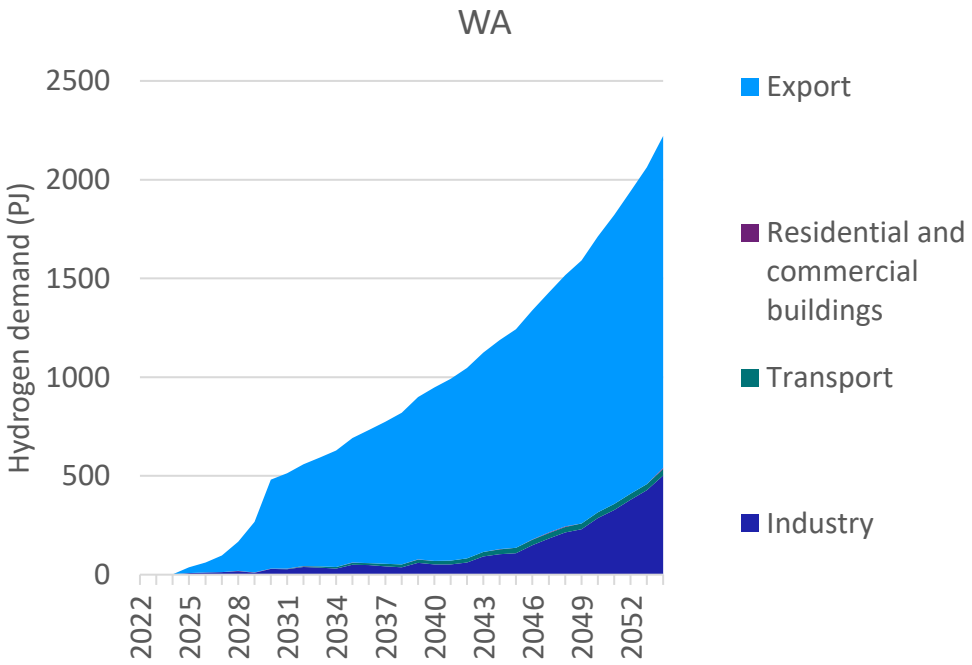


Includes gaseous fuel consumption in industry, residential and commercial buildings.

Hydrogen demand (*Hydrogen Export scenario*)

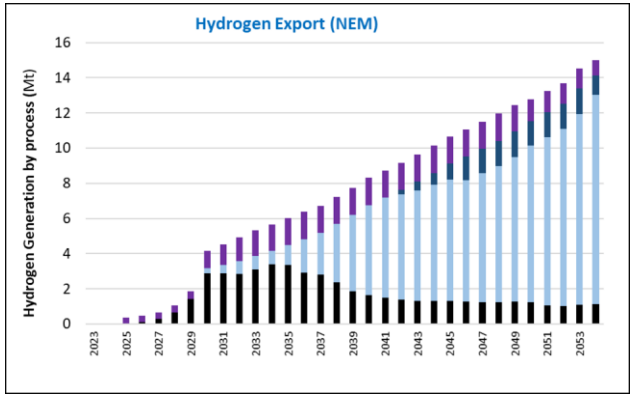
PRELIMINARY

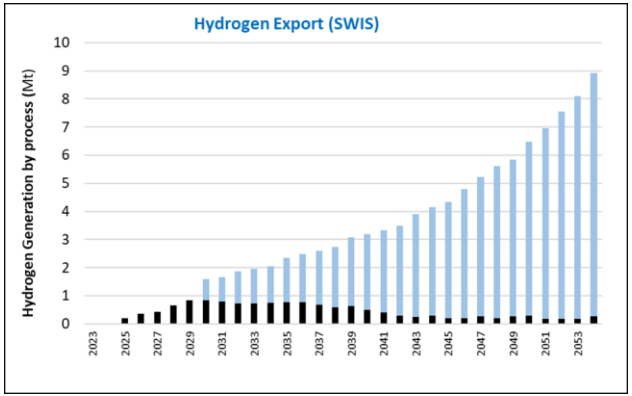


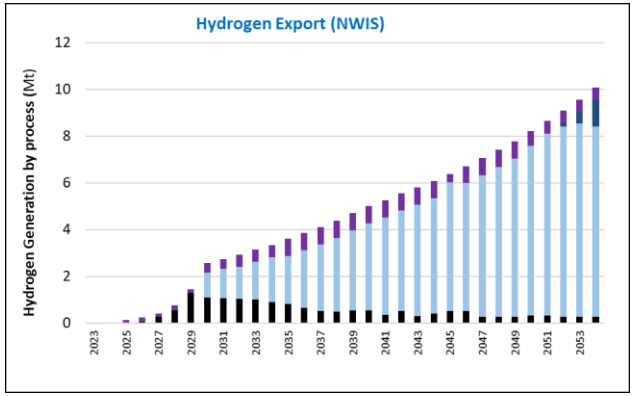


PRELIMINARY

Hydrogen production (*Hydrogen Export scenario*)







■ Alkaline Electrolysis ■ PEM Electrolysis ■ Steam Methane Reforming ■ Steam Methane Reforming CCS

Grid-connected electrolysers, does not include electrolysers connected to non-regulated (or privately owned) networks

Next steps

- These are preliminary results and updates are required
- More details will be released in the report
- Revisit assumptions based on FRG and AEMO feedback
- Updates from other consultancies (Macroeconomic and gas price projections, DER/EV uptake)

Thank you

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Modelling Manager

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Appendix

End-use sectors – key input data sources

- **Baseline energy and emissions data**
  - Australian Energy Statistics
  - National Greenhouse Gas Inventory
  - National Greenhouse Accounts factors
  - Commercial Buildings Baseline Study (2012)
  - Residential Energy Baseline Study (2021)

- **Emissions abatement technology parameters**
  - Low Carbon, High Performance (2016)
  - Decarbonisation Futures (2020)
  - Wide range of scientific literature, cost databases for industry

- **Activity growth**
  - ABS Household Projections (2016)
  - Commercial Buildings Baseline Study (2012)
  - Australian National Outlook (2019)
  - BIS Oxford Economics (as provided by AEMO)

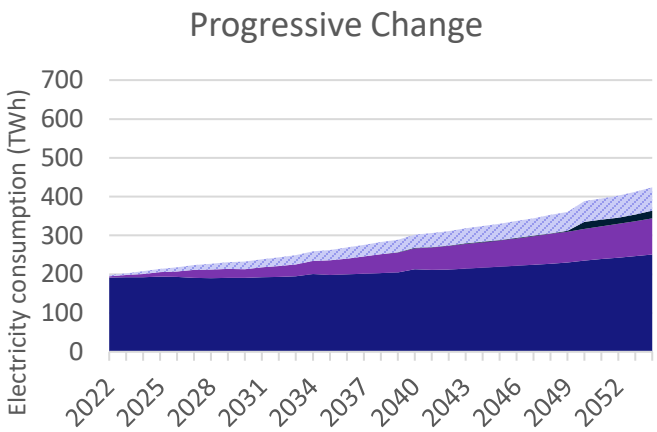
Electricity – key input data sources

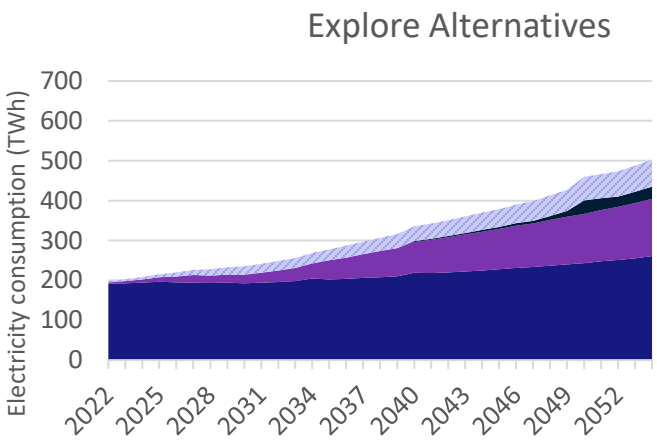
- **ISP assumptions workbook (NEM)**
  - Existing generators capacities, cost and performance
  - Expected closure years
  - Committed projects
  - Regional reserves
  - Renewable traces
  - Regional cost factors
  - Emission factors
  - QRET, VRET, TRET, NSW *Electricity Infrastructure Investment Act 2020*

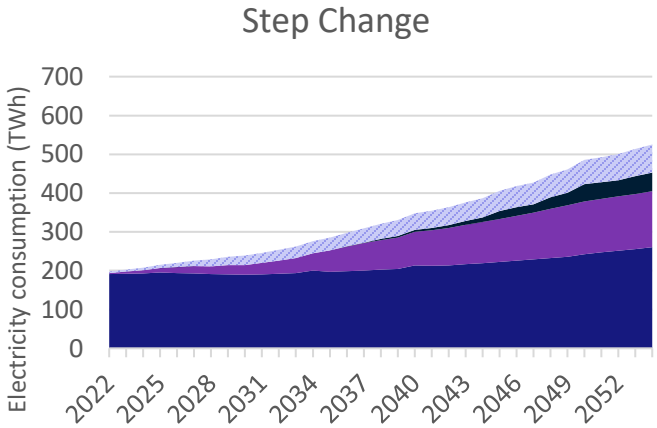
- **2020 Whole of System Plan (SWIS)**
  - Existing generators capacities, cost and performance
  - Expected closure years (updated by WA Gov announcement)
  - Committed projects (from 2021 RCM certification)
  - Regional reserve
  - Emission factors

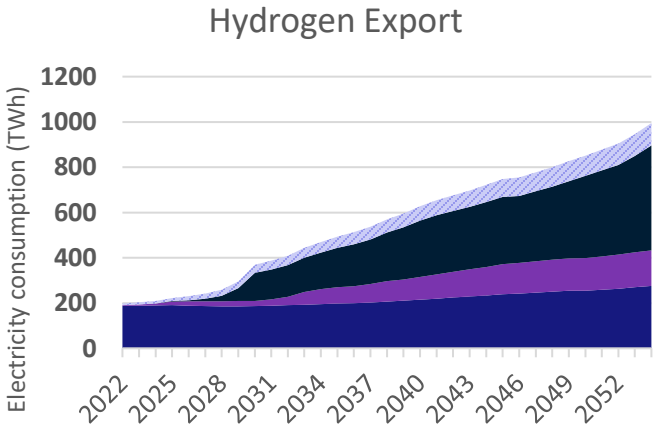
Composition of underlying electricity consumption (NEM)

PRELIMINARY









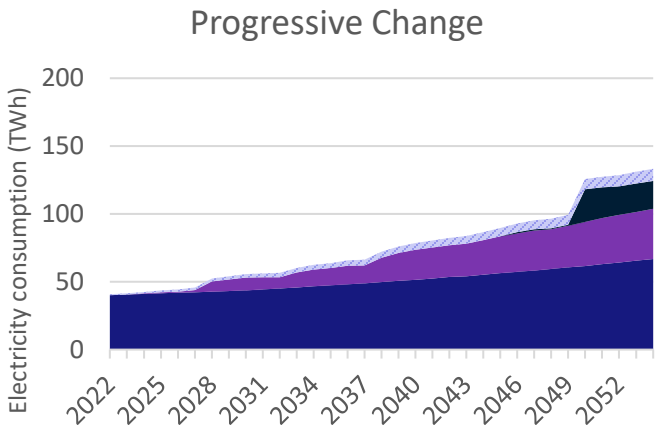
- Energy efficiency (avoided)
- Electricity for hydrogen production
- Electrification*
- Underlying electricity demand

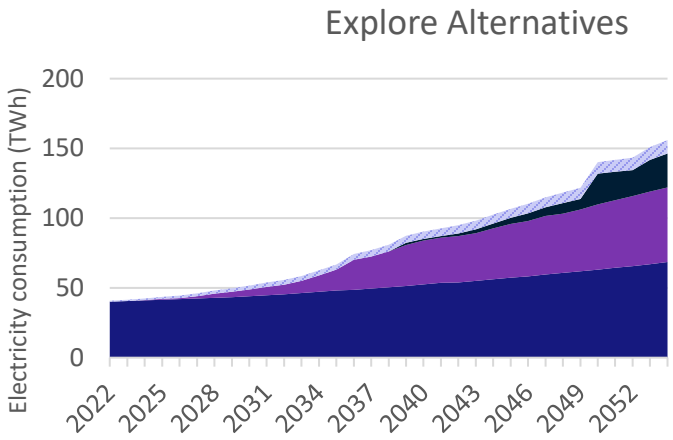
**Includes costed electrification in buildings & industry, and increased electricity demand in transport*

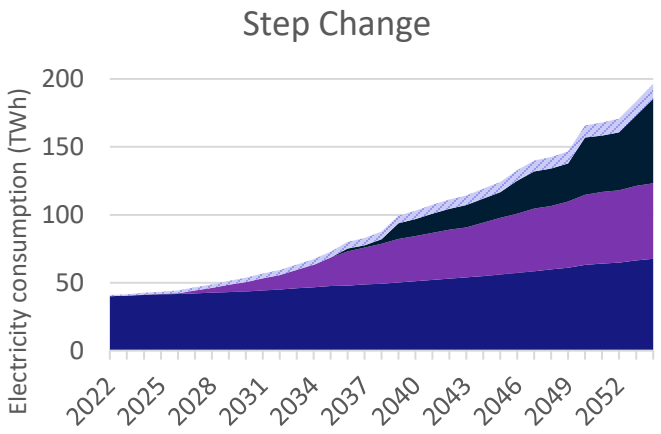
Note different scale for Hydrogen Export scenario

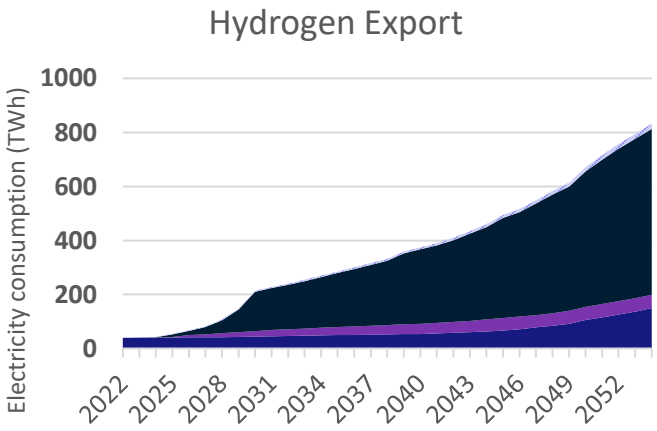
Composition of underlying electricity consumption (WA)

PRELIMINARY









- Energy efficiency (avoided)
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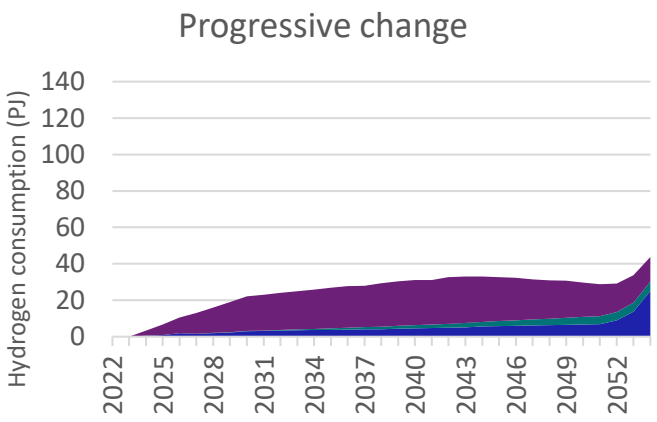
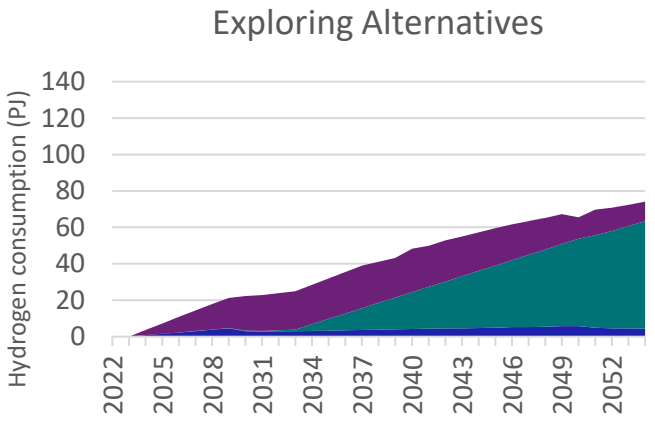
Note different scale for Hydrogen Export scenario

Domestic hydrogen demand – NEM states

PRELIMINARY

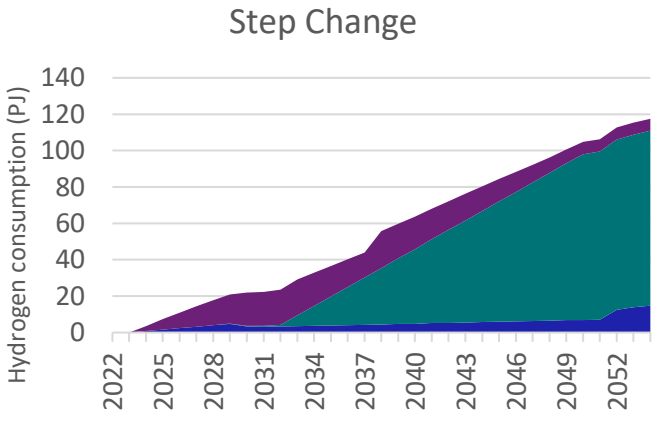


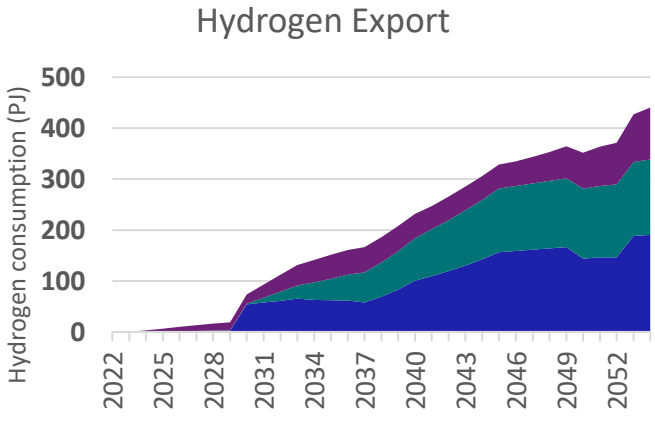


Residential and commercial buildings

Transport

Industry

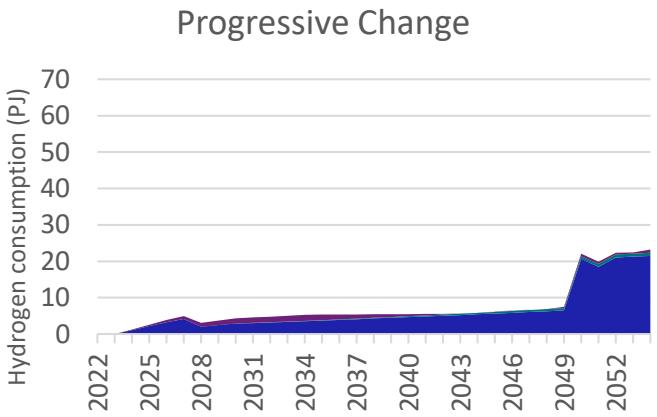


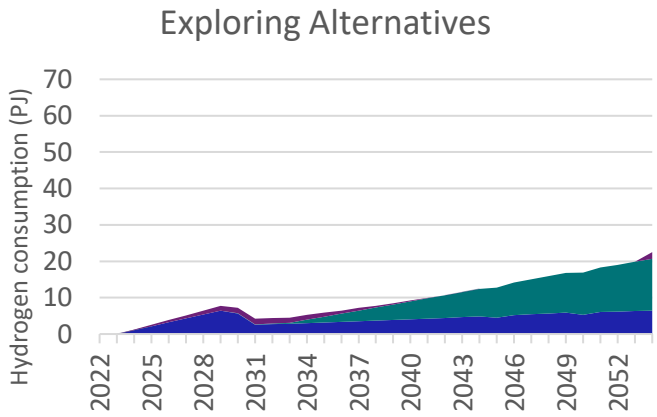


Please note different scale of Y-axis for Hydrogen Export

Domestic hydrogen demand – WA

PRELIMINARY

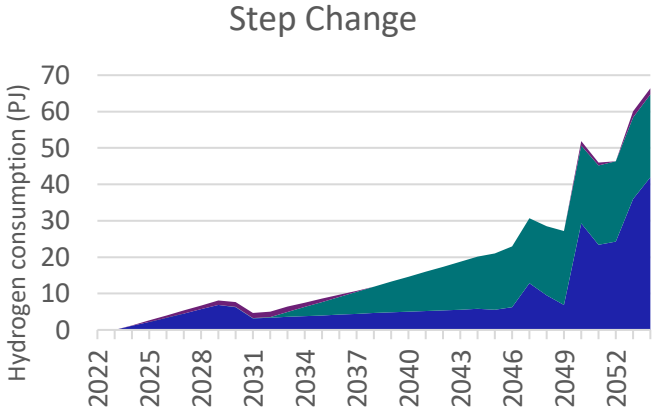


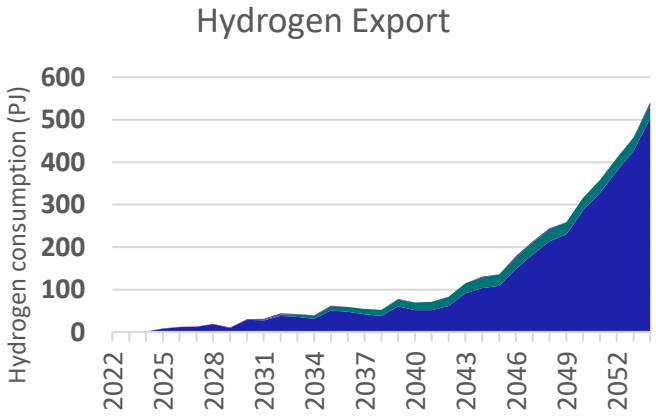


Residential and commercial buildings

Transport

Industry





Please note different scale of Y-axis for Hydrogen Export