EGU General Assembly 2020

CLIMATE ANALYTICS

Integrating energy sectors in a state-resolved energy system model for Australia

Dr. Tino Aboumahboub[a], Prof. Dr. Robert Brecha[a,b], Dr. Andreas Geiges[a], Dr. Matthew Gidden[a,c], Himalaya Bir Shrestha[a] , Dr. Bill Hare[a]

[a] *Climate Analytics gGmbH, Berlin, Germany*
[b] *Physics Department, Renewable and Clean Energy Program, Hanley Sustainability Institute, University of Dayton, Dayton, USA*
[c] *International Institute for Applied Systems Analysis, Laxenburg, Austria*

European Geosciences Union General Assembly, Session Spatial and Temporal Modelling of Renewable Energy systems, Online, 7 May 2020

tina.aboumahboub@climateanalytics.org

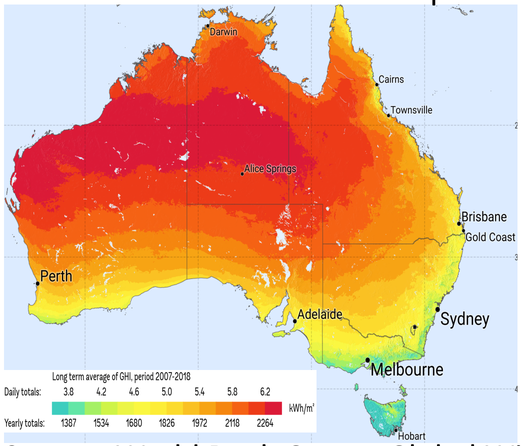
Contents

- Motivation
- Methodology
- Scenario narrative
- Model results
- Summary and Outlook

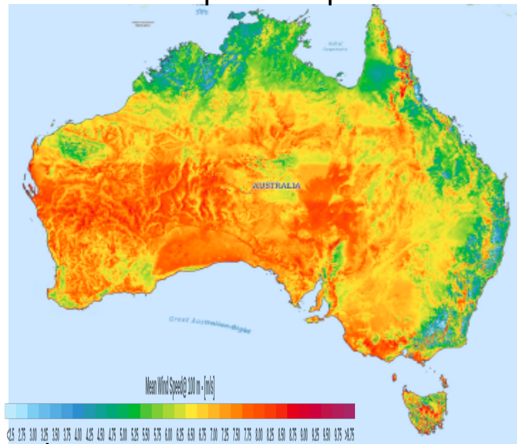
Motivation

Australia is characterized by an extensive, untapped renewable potential

Global horizontal radiation Map



Mean Wind Speed Map

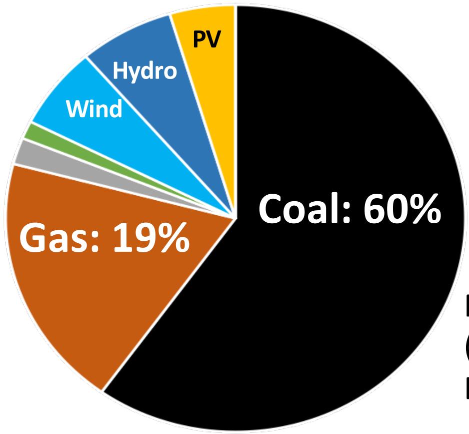


Source: World Bank Group, Global Wind/Solar Atlas

Resource	Potential
Wind onshore	23,990 GW
Utility PV	122,348 GW
Rooftop PV	178 GW
Sustainable biomass	417 TWh (73 TWh for electricity

Sources: Roberts et al., 2019; Teske et al., 2019; Teske et al., 2016

Current power generation fleet is dominated by coal and natural gas (80% share in total) with broad state-level discrepancies

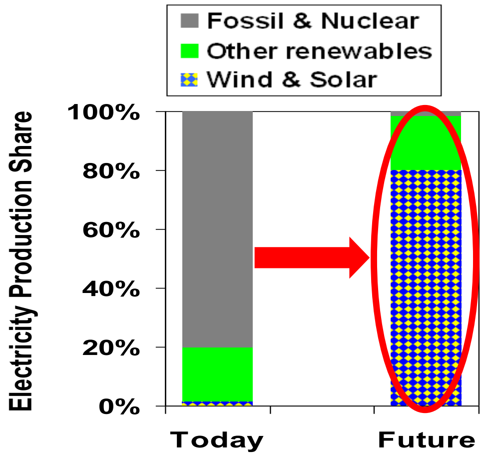


Power generation fuel mix in AUS, 2018 (source: Australian Energy Statistics, DEE, 2019)

Motivation

- Achieving the Paris Climate Agreement Goals requires substantial changes to the energy system globally with OECD regions at the forefront
- How to ensure security of supply with increasing shares of intermittent renewable sources?
- Proposed solutions to fill the flexibility gap, making the full renewable supply system achievable:
  - ➢ Cross-sectoral integration: Broad (direct) electrification of entire energy system, extensive use of renewable-based synthetic fuels/hydrogen as a fuel across all energy sectors (indirect electrification)
  - ➢ Use of hydrogen for long-term storage of renewable power
  - ➢ Cross-regional integration: Reinforcement of transmission grid

→ **Central question**: What is the cost-optimal configuration of a renewable-based Australian energy system in line with the PA temperature target and the transformation pathway?



Introduction

EGU General Assembly 2020
CLIMATE ANALYTICS

Long-term energy system modelling

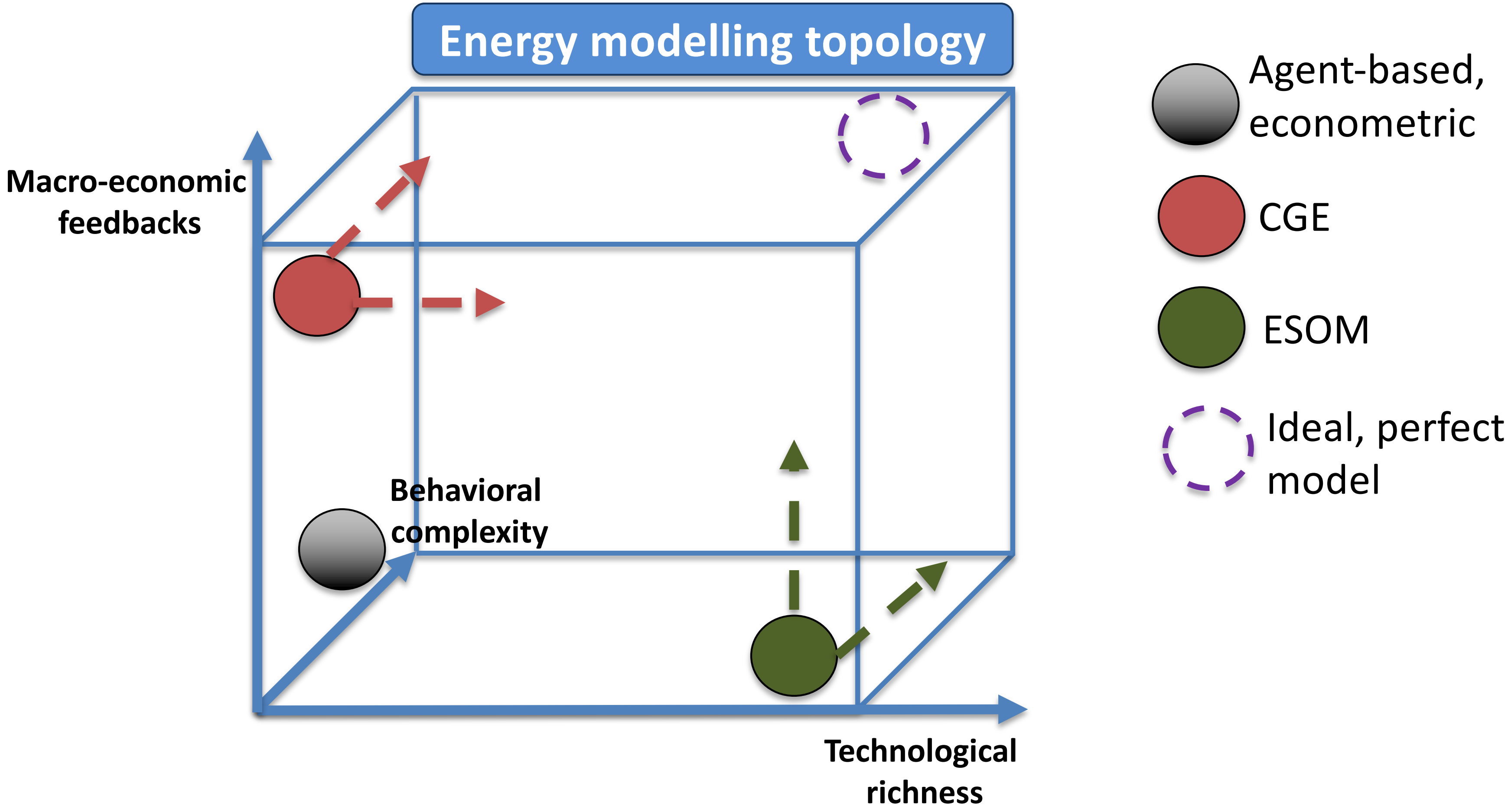
- Energy policy across the globe faces challenges
- Securing access to energy and mitigating climate change are key policy goals
- Mitigation efforts & energy system infrastructure require long-term planning
- Several complex issues needs consideration (energy/climate policies, economic growth, technology development, resource potential/reserves, flxibility gap at high VRE* shares, storage needs)

- Energy system optimization models (ESOM) as long-term energy planning tools provide essential insights into these challenges
- Key Characteristics, advantages of ESOM:
  - ✓ high level of detail related to energy sectors, technologies
  - ✓ High temporal resolution
  - ✓ High geographical detail: moving from global, regional modelling to individual countries and regions
  - ✓ assessing energy system integration impacts of VERS and system adaptation needs: storage/ transmission extension

* VRE: Variable Renewable Energy Sources

Introduction

Three-dimensional assessment of energy-economy models



Source: Based on Hourcade et al. (2006)

Methodology

OSeMOSYS (Open Source Energy Modelling System)

- OSeMOSYS is a full-fledged systems optimization model for medium, long-term energy planning
- Deterministic, linear cost-optimization model
- Paradigm comparable to TIMES and MESSAGE
- Open source → no upfront financial investment
- Less significant learning curve and time commitment to build and operate
- Provides a flexible framework to build technological features of various interacting energy sectors and regions → allows a systematic analysis of implications of sector-coupling and cross-border integration

Methodology

Model Structure

Input parameter

- Demand
- Load and renewable supply profiles (per model region and timestep)
- Techno-economic parameters (fuel prices, costs, efficiency)
- Existing infrastructures
- Limits to capacity expansion (renewable potential, political circumstances)
- Further scenario-specific assumptions (CO_2 budget)

Australian Energy Modelling System (AUSeMOSYS)

- Linear Optimization (GNU Math Prog, GLPK Solver)
- Based on open Source energy modelling framework OSeMOSYS
- Multi-regional (7 regions)
- Multi-sectoral (Electricity, Transport, selected industry sectors)
- Time horizon: 2015-2050
- Sub-annual tiem resolution: variable, reduced hourly resolution (282 h), 8 time slices

Minimization of total syste costs
Subject to boundary conditions:

Supply >= demand

Properties of generation processes | Properties of storage processes | Properties of transport processes

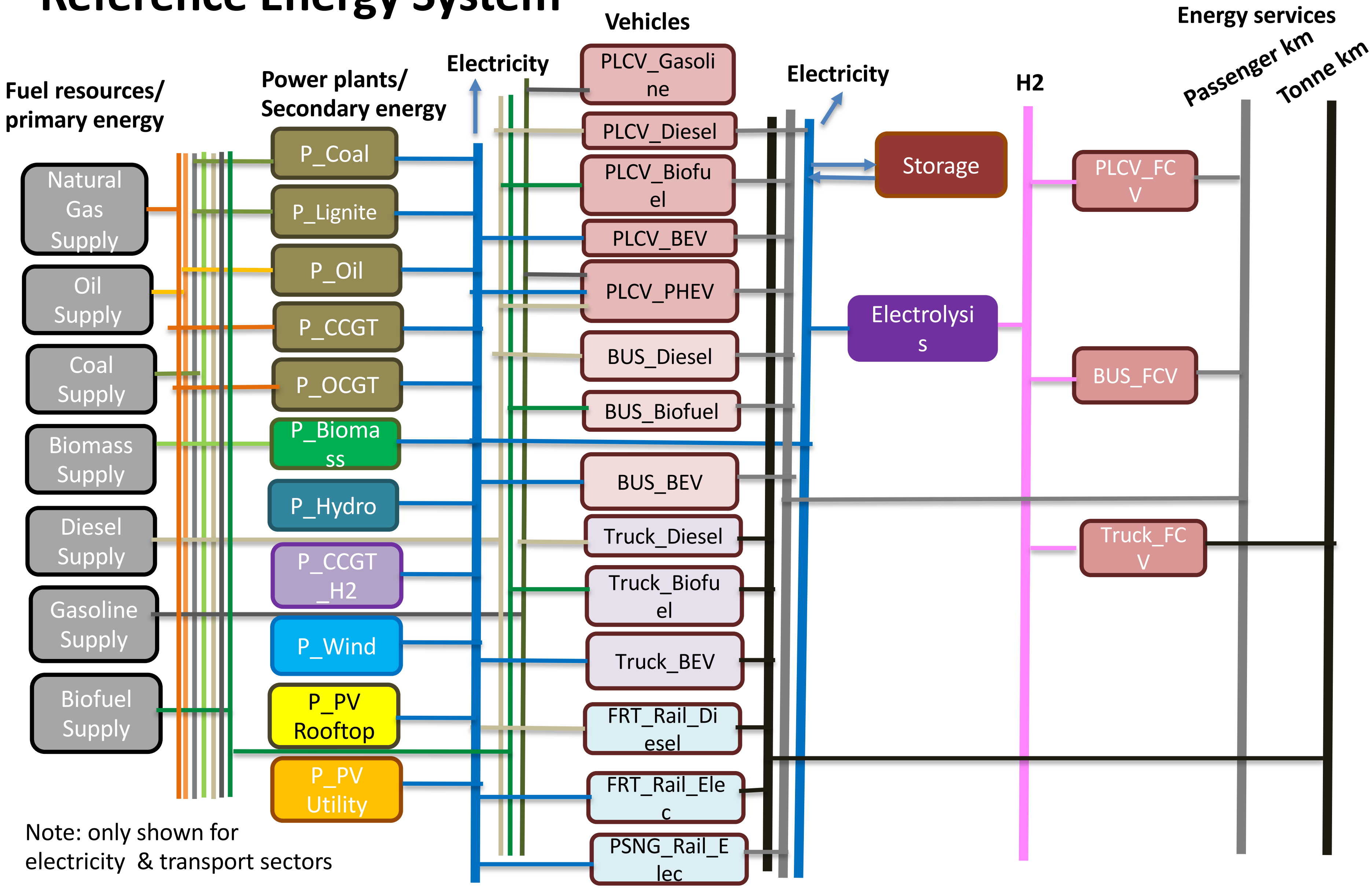
Emission budget constraints, limits to infrastructure extension (potential, political), energy/environmental policy/targets

Results

- Total and new capacities (by technology, fuel, energy sector, region)
- Final and primary energy demands, (broken down by fuel, technology, energy sectors, region
- Total and new transmission grid capacity
- Energy-related CO_2 emissions
- Overall costs

Methodology

Reference Energy System



Note: only shown for electricity & transport sectors

Scenario narrative

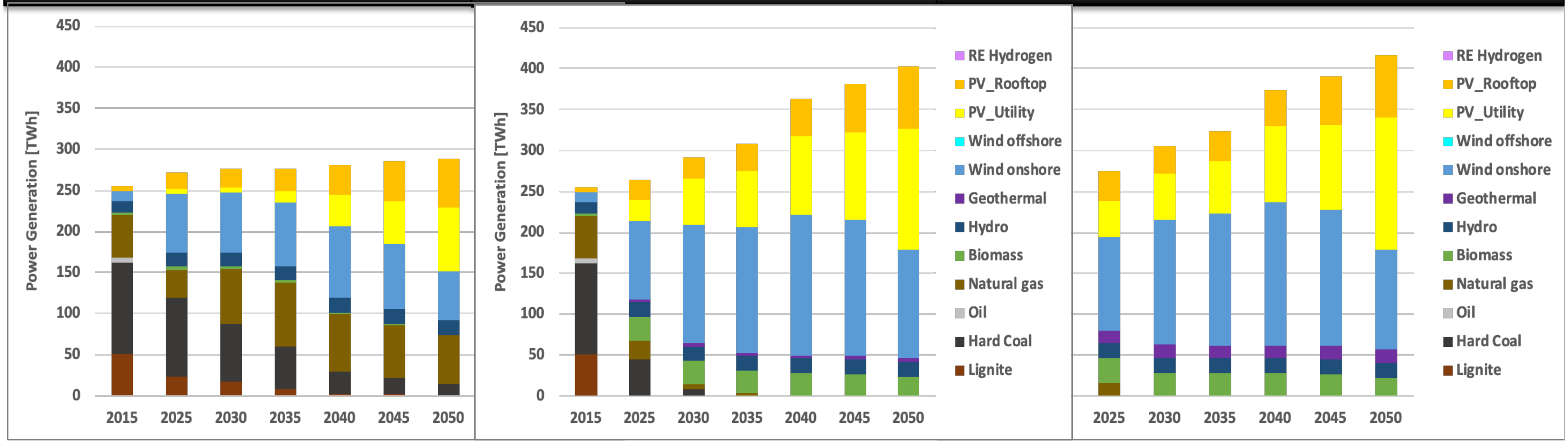
	Limited mitigation effort	1.5℃	1.5℃ - High ambition
Global climate target and Australia's contribution		480 $GtCO_2$ (2018-2050) based on IPCC SR1.5 AUS: 3.6 $GtCO_2$ (2018-2050)	440 GtCO2 (2018-2050) based on IPCC SR1.5 AUS: 3.2 $GtCO_2$ (2018-2050)
Energy system: Energy technology change	Slow: Dominance of fossil fuel/emission-intensive technologies similar as today, thus the extensive renewable potential in Australia remains untapped	Rapid: Renewable transition dominates the transformation pathway with low/zero emission (renewable) technologies achieve market competitiveness at a high pace. This is supported by ambitious costs declines, high efficiency and expolitation of fuel switch potential as well as market penetration of novel technologies.	
Energy system: sectoral integration	No/very limited level of cross-sectoral integration	Strong electrification of end-use sectors (PtG, H2Steel, H2Cement, BEV, FCEV)	
Nation-wide interconnectivity and inter-regional power trade	National power transmission network as of today	Constrained reinforcement of NEM-wide trans grid (maximum annual capacity growth rate of 10% p.a.)	

Model results

Development of total electricity production fuel mix

- Electricity demand for electrification of coupled end-use sectors under stringent CO_2 budget, leads to doubling of final electricity demand.
- In “1.5°C” scenario, RE share reaches to 100% by 2040 (95% in 2030); “1.5°C – higher ambition” achieves full RE supply in 2030.
- Large investments into wind and solar PV play a dominant role in decarbonizing Australia’s energy system.
- 87-89% of produced electricity in 2050 comes from wind and solar energy complemented by smaller contributions from geothermal, hydro, and biomass.

Limited Mitigation Effort	1.5°C	1.5°C - High ambition

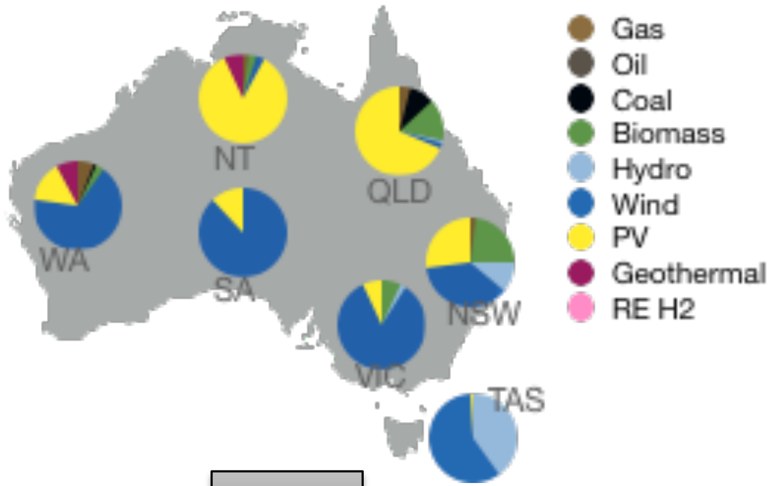


Model results

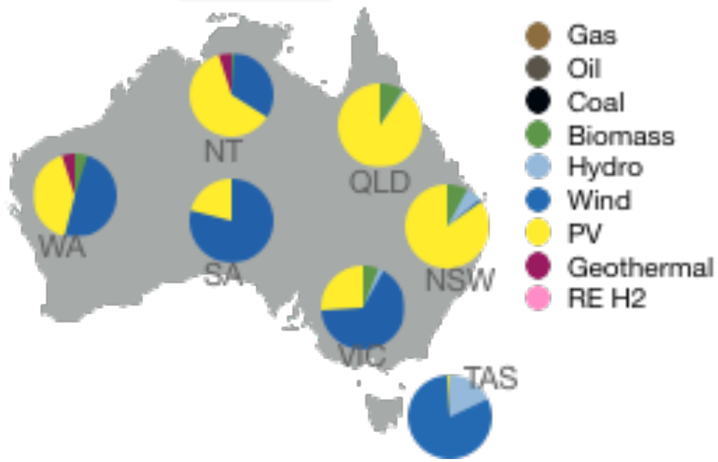
Regional distribution of power production mix in 1.5℃ Scenario

- All regions move towards full renewable supply
- Even states with dominating share of coal today (NSW, QLD, VIC) incorporate a renewable share of 87% -100% by 2030
- In WA and NT, renewable share rises to 93-98% by 2030
- The VRE (variable RE) mix optimized according to regional potentials
- High wind shares in TAS, VIC, SA
- Solar PV dominating in NSW, QLD also in WA, NT

2030



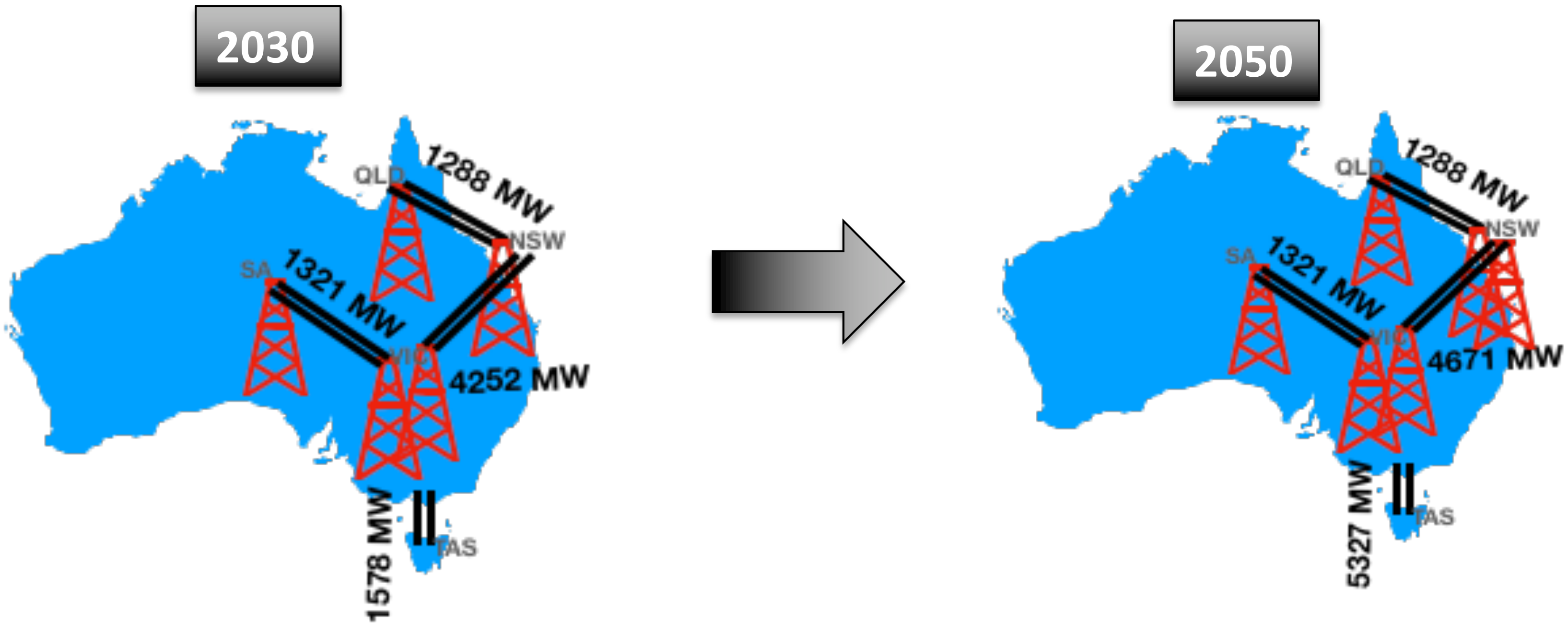
2050



Model results

Inter-regional power transmission capacities in 1.5°C Scenario

- Extensive reinforcement of power transmission grid required to balance the VRE supply
- Total cross-regional transmission capacity doubles by 2030 and almost tripling in 2050

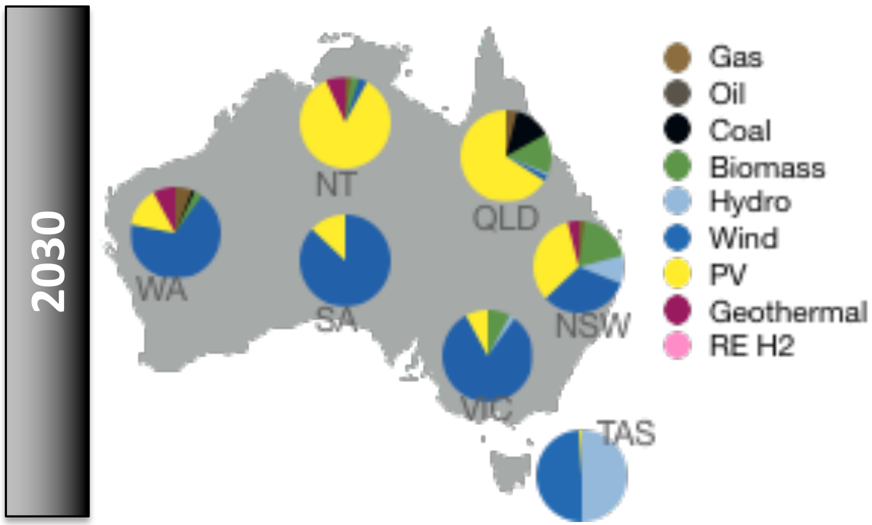


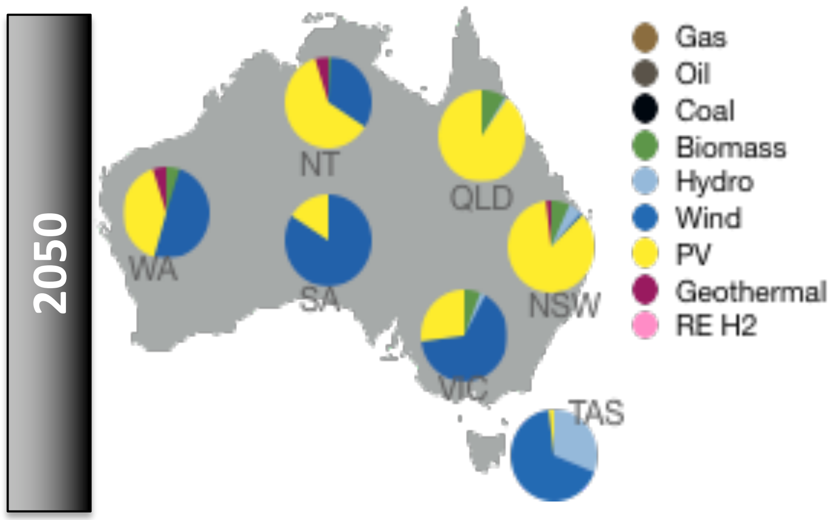
Model results

Sensitivity cases

<u>Low interconnection case</u>: reducing maximum TR capacity growth rate to 5% p.a. Rest of assumptions remain the same as “1.5°C” scenario.

- Transmission grid in high VRE scenarios is mainly applied to smoothen wind power variability in spatial dimension
- Wind energy has a systematic disadvantage in low-connection cases
- Cost-optimal VRE mix (% of total VRE production): Wind 59% & PV 41% (2030); Wind 32% & PV 68% (2050) (*core scenario: Wind: 64% & PV: 36% (2030) Wind: 37% & PV: 63% (2050).*





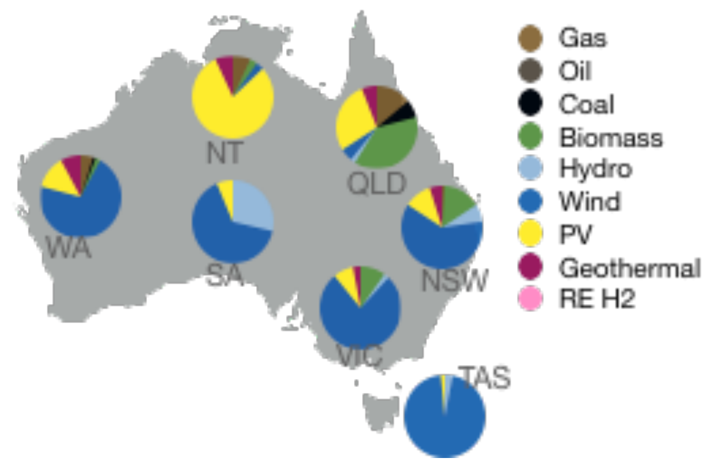
Model results

Sensitivity cases

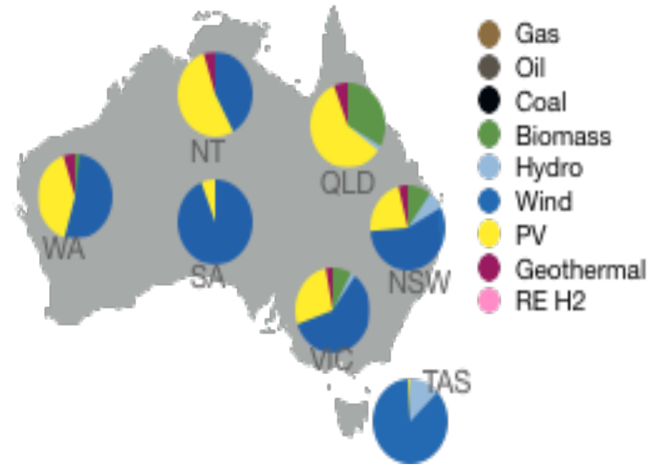
Higher storage and solar PV costs

- Costs assumptions have no impact on total renewable share → full RE supply is still achieved in 2040 (95% renewable share in 2030) as stringent CO_2 budget acts as the major driver of decarbonization.
- Solar PV share in total produced electricity reduces to 14% by 2030 (28% in "1.5°C" scenario), wind share increases to 58% (50% in "1.5°C" scenario).
- Share of non-VRE sources including biomass and geothermal energy also slightly increase in comparison.
- Cost-optimal VRE mix (% of total VRE production): Wind 81% & PV 19% (2030); Wind 72% & PV 28% (2050)

2030



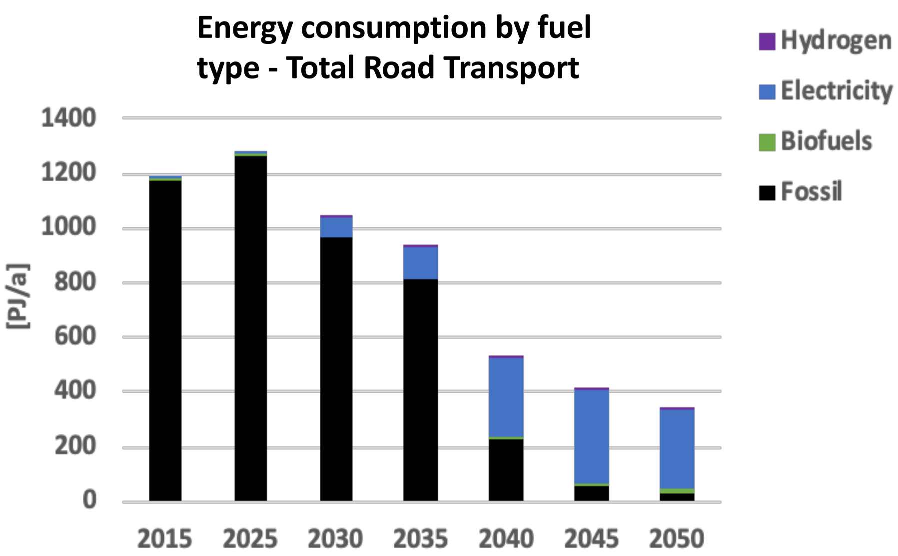
2050

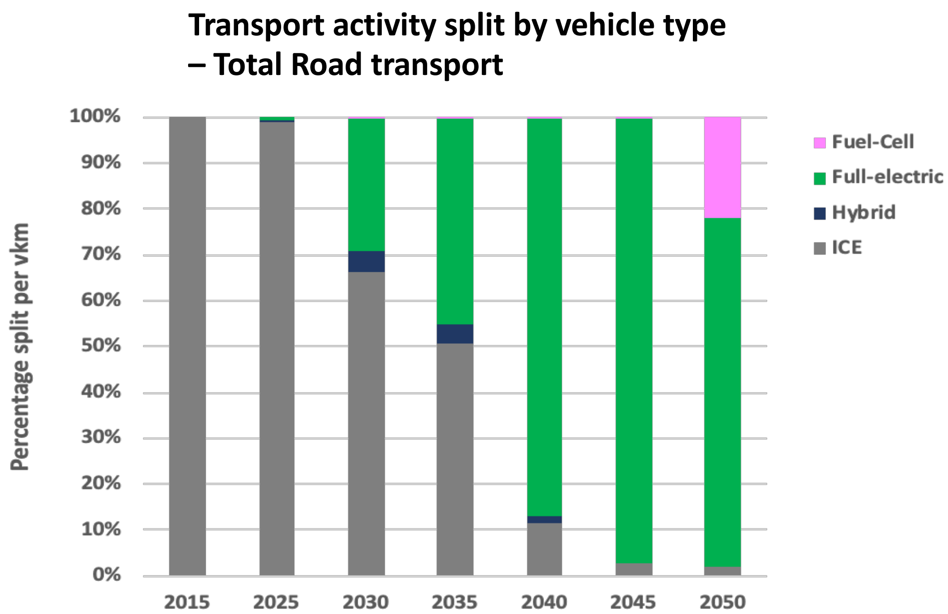


Model results

Low-carbon transformation of linked energy sectors - Mobility sector

- "1.5°C" scenario: Energy use decreases significantly (60% reduction in 2040 rel. to 2015). Major driving factor is increase of EVs, using siginifcantly less energy per km driven compared to conventional ICEs.
- Also fuel mix undergoes a significant transition: in particuluar use of electricity also biofuels and hydrogen rises significantly over the modeled horizon, replacing fossil fuels.
- Share of EVs (BEV, PHEV) in road transport rises to 33% in 2030; 88% by 2040 and 97% by 2045. Hydrogen phases in by 2050, accounting for 22% of road transport activity.





Summary and Outlook

- ✓ Multi-regional, multi-sectoral energy system optimization model developed – case of Australia.
- ✓ The model applied for scenario analysis of deep decarbonization of Australia’s energy system inline with the Paris Agreement climate target.

Next steps…

- ➢ Modelling of further sector coupling options: Linking electricity and industry sectors (steel, cement, etc.)
- ➢ Further scenario analysis