Australian National University

Pumped hydro energy storage: A key enabler of high penetration of wind and PV in Australia's electricity network

EESA 2018

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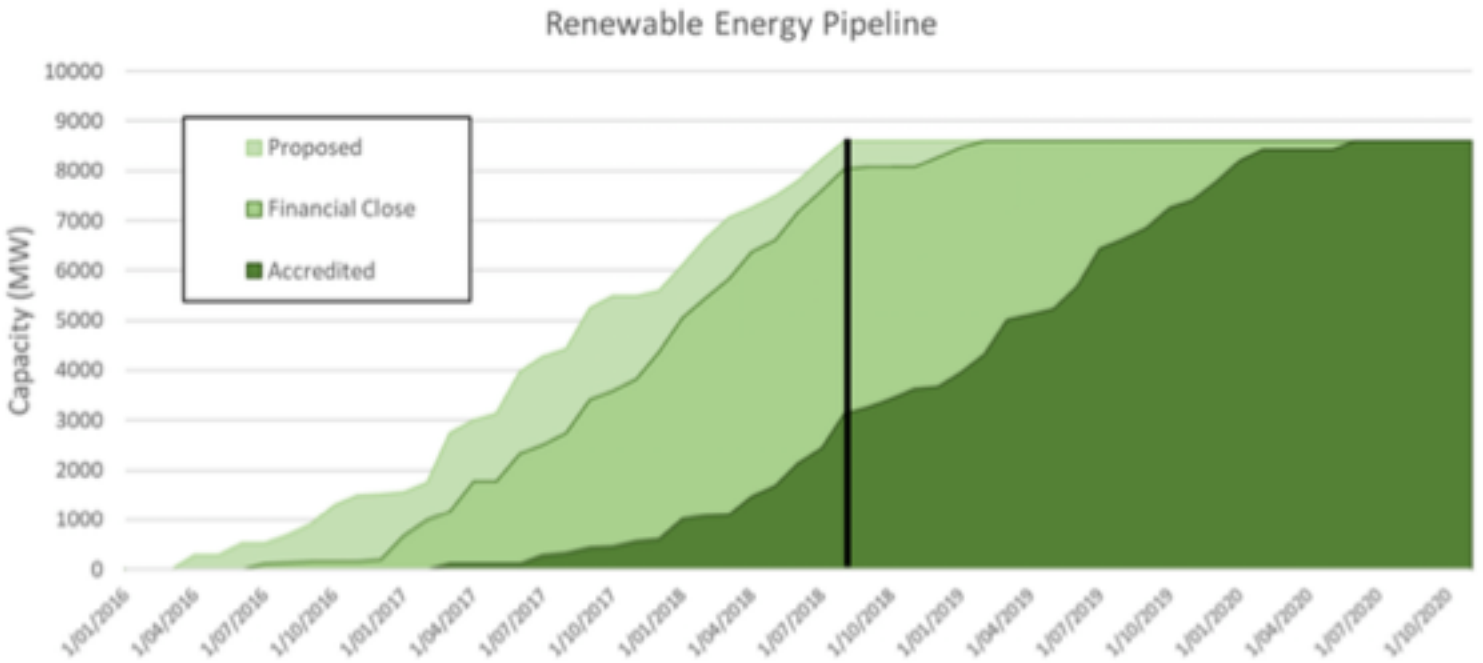
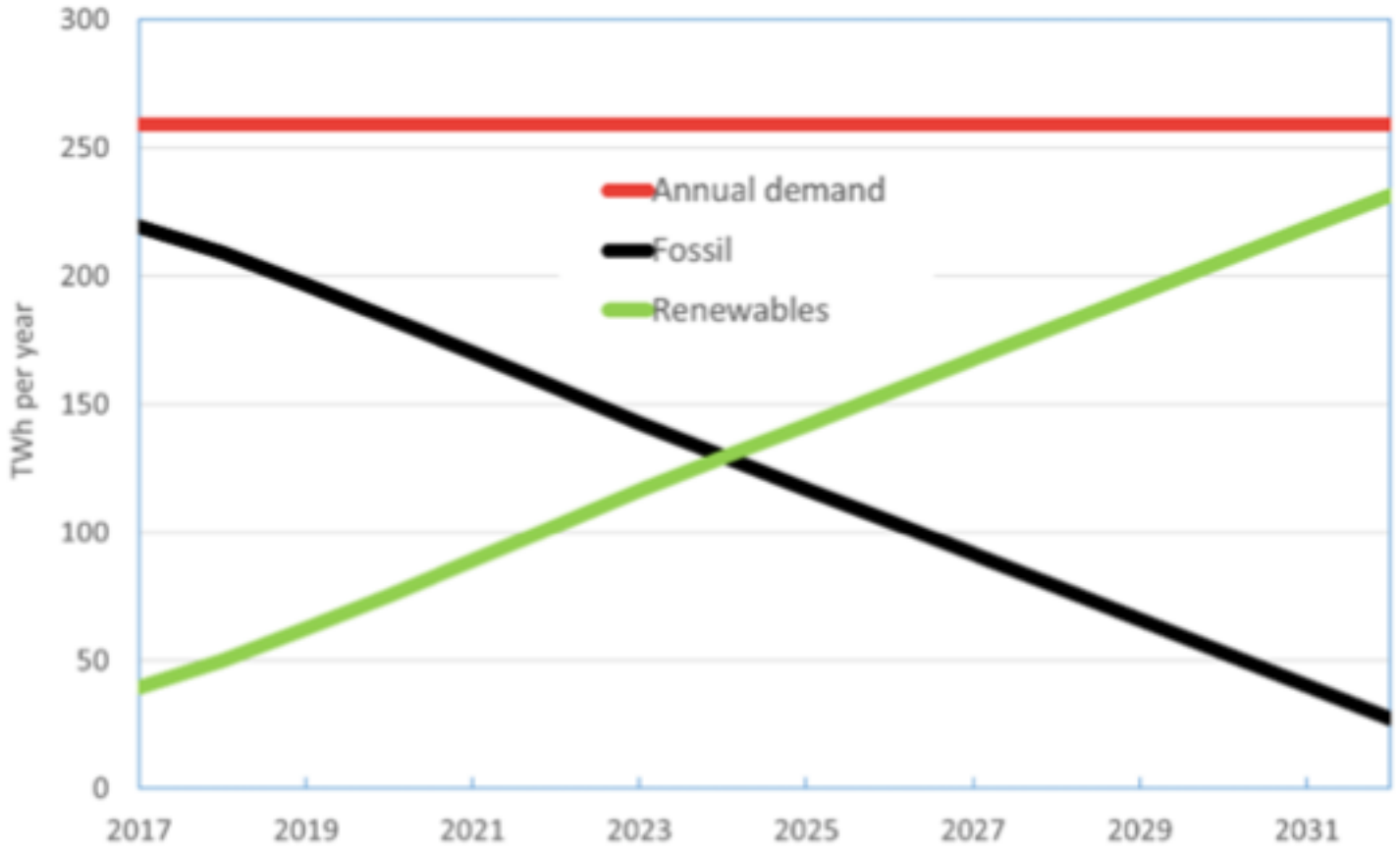
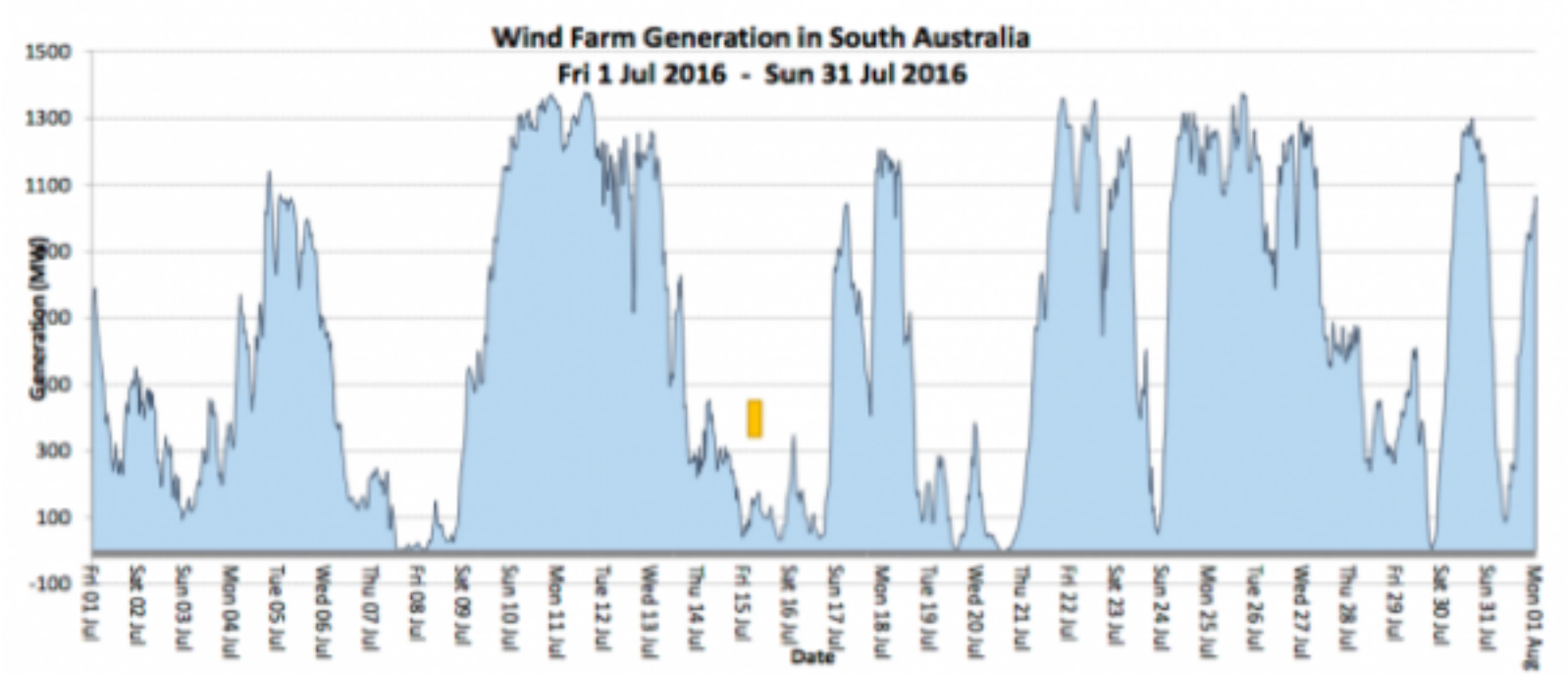
Australia's variable renewables – large scale installs (CER data)



Current trajectory >> 50% by 2030



Intermittent Renewables



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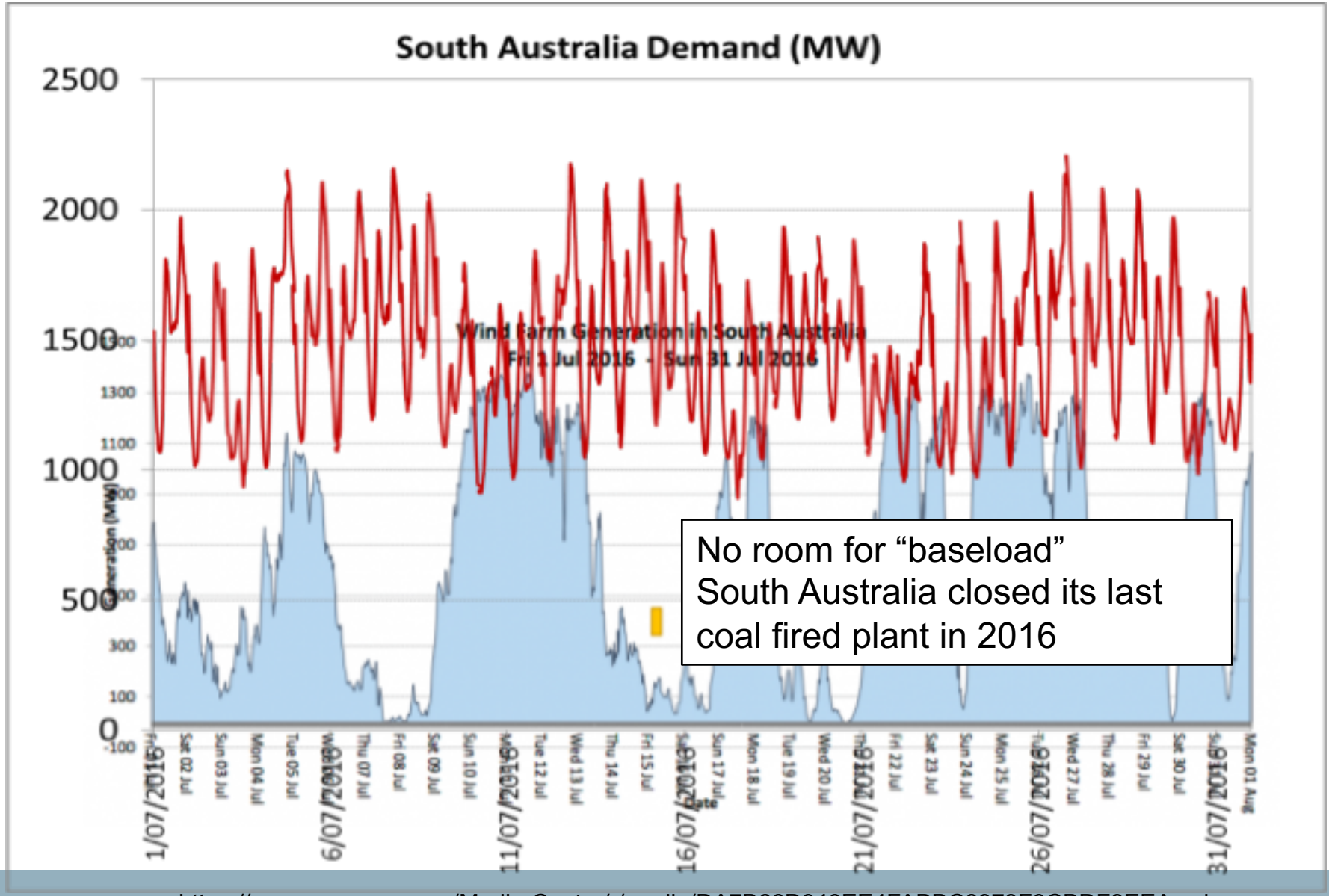

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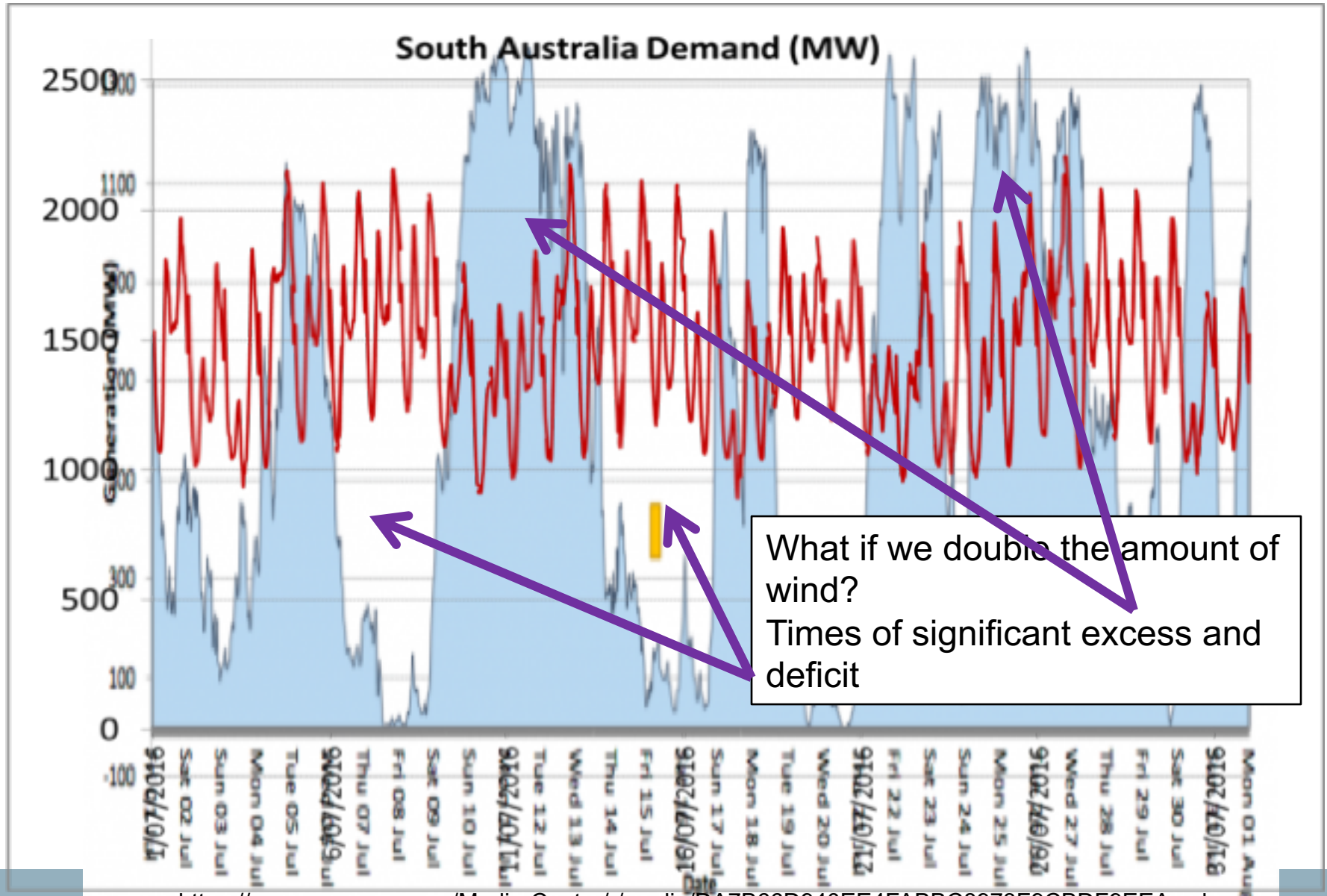

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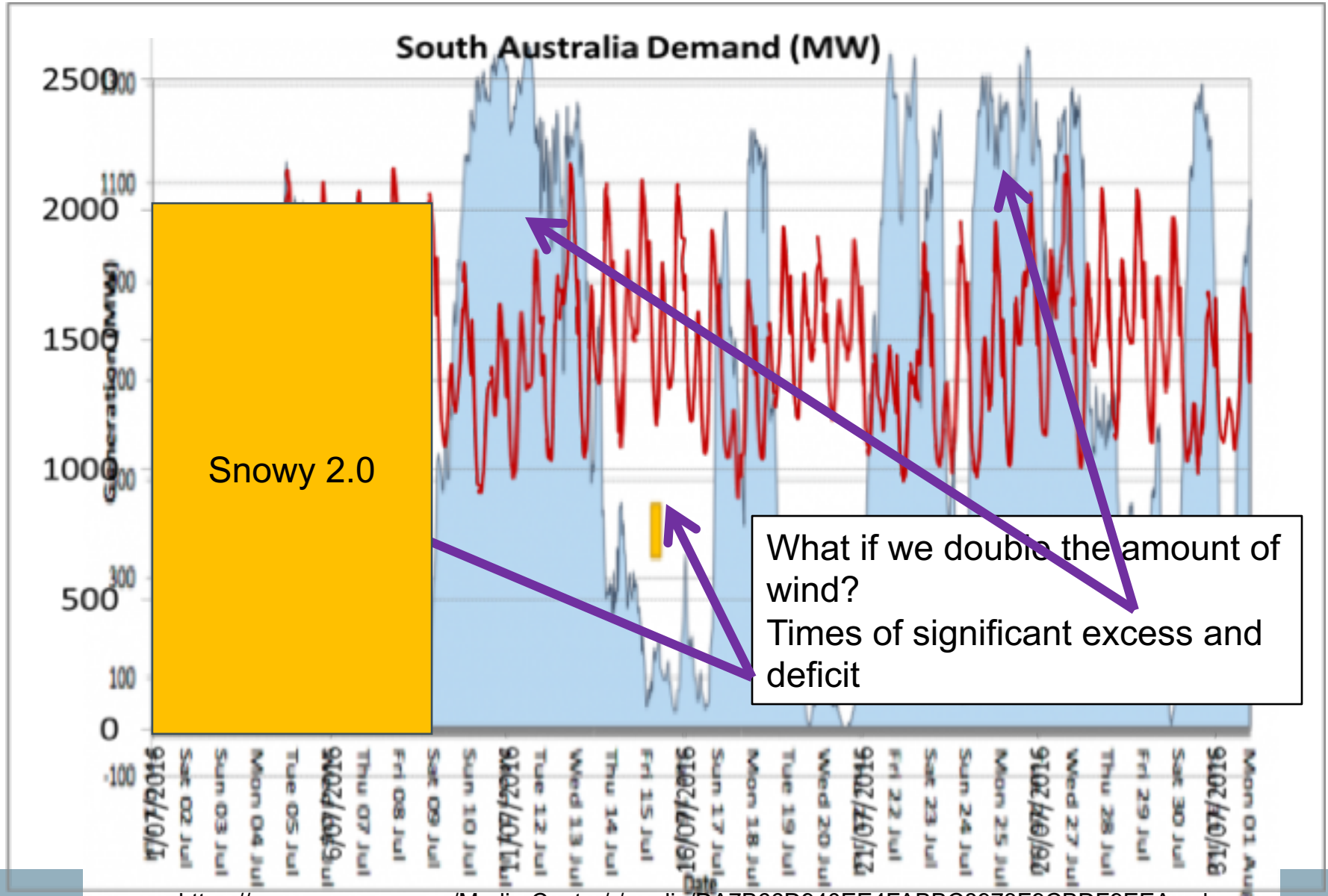

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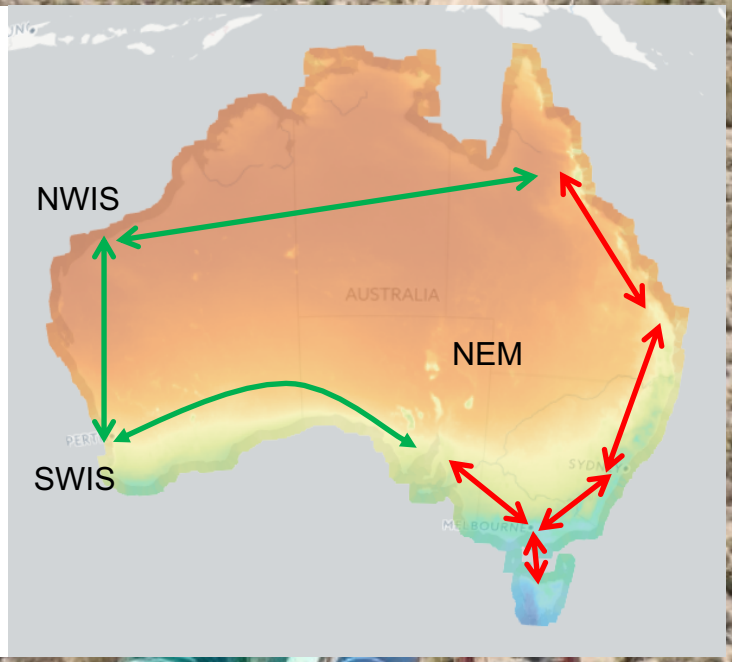
Stabilize 100% renewable electricity

- Technical diversity
  - 90% PV and wind (+ existing hydro & biomass)
- Wide geographical dispersion (million km^2) hugely reduces required storage
  - Smoothing-out local weather
- Demand management
  - Shift loads from night to day, interruptible loads
- Mass storage
  - Pumped hydro: 95% of all storage
  - Advanced batteries

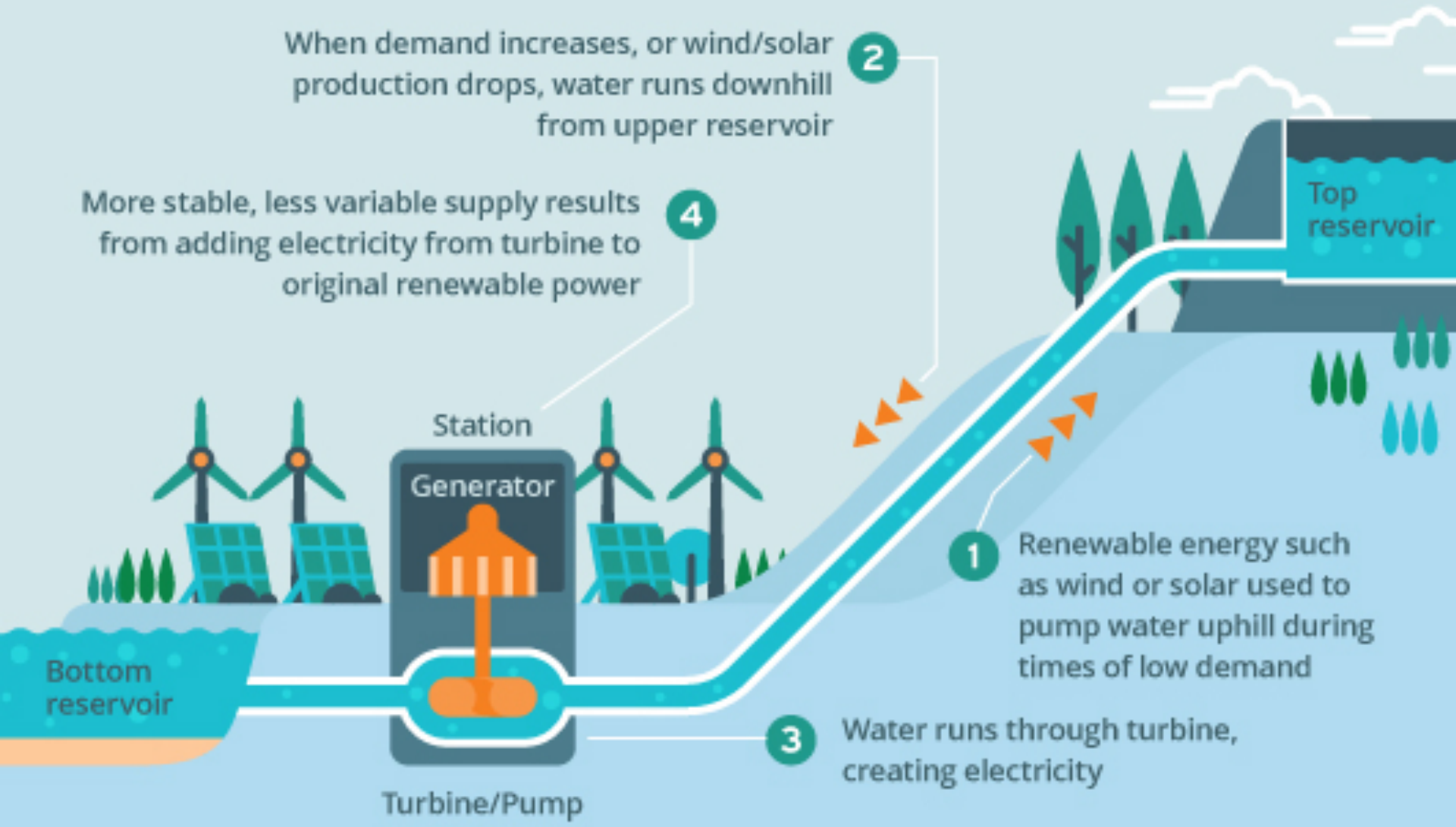
High voltage DC transmission (HVDC)

High voltage DC transmission (HVDC)

- Transmit gigawatts over thousands of km
- Up to +/- 1.1 million volts
- Loss: 10% between Pilbara and Townsville
- >200GW of HVDC systems worldwide
- Examples
  - Basslink (Vic-Tas): 400kV, 290km, 500MW
  - ABB (China): **1100kV, 3000km, 12GW**



PUMPED HYDRO STORAGE - HOW IT WORKS

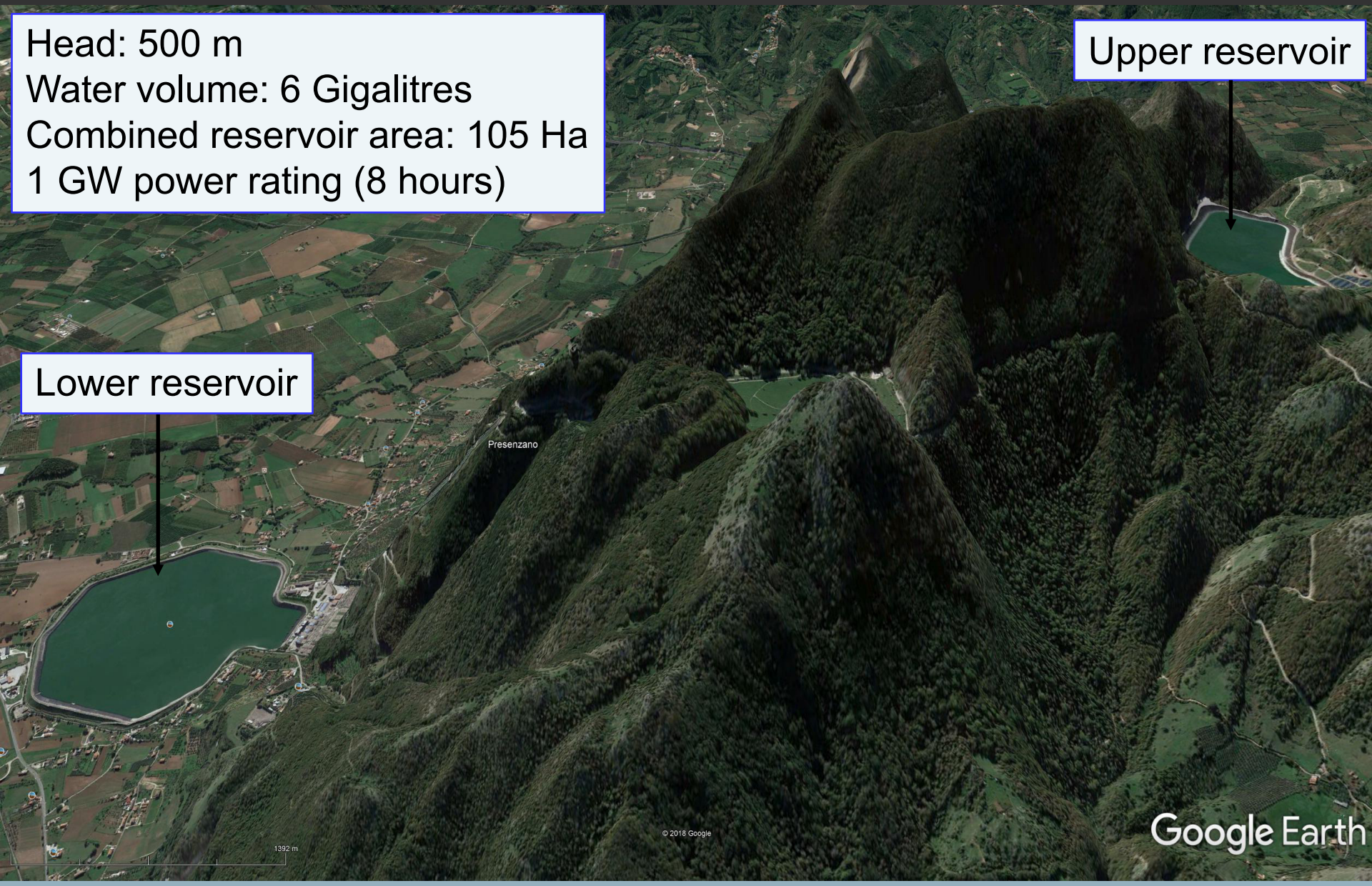


Australian Government
Australian Renewable Energy Agency
ARENA

On-river pumped hydro storage: Tumut 3

Head: 151 m
Water volume: 6 Gigalitres
Combined reservoir area: 1936 Ha
1.5 GW power rating

Off-river pumped hydro, Presenzano, Italy



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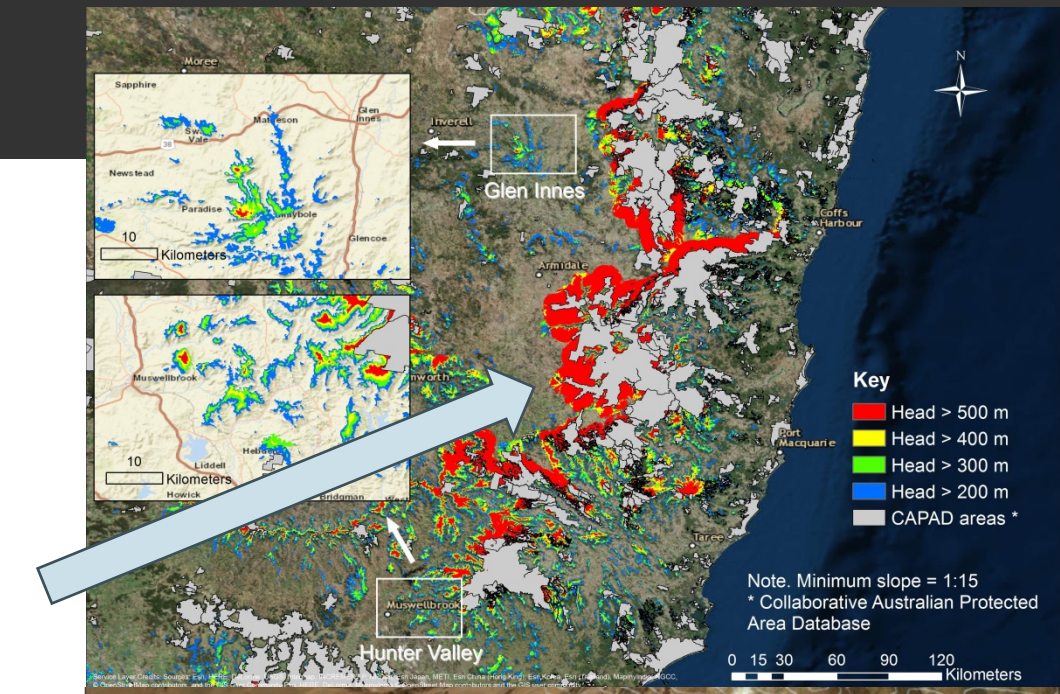
STORES Atlas
Site searching

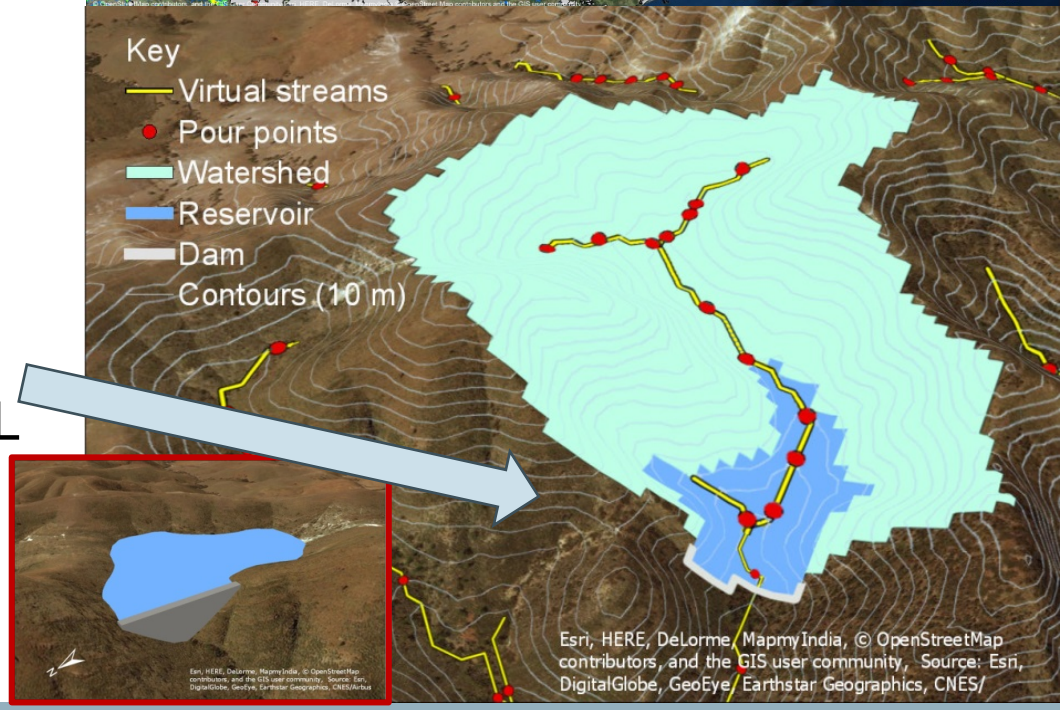
Upper reservoirs

- Identify potential regions
  - >300m head, >15% slope
  - Exclude protected areas

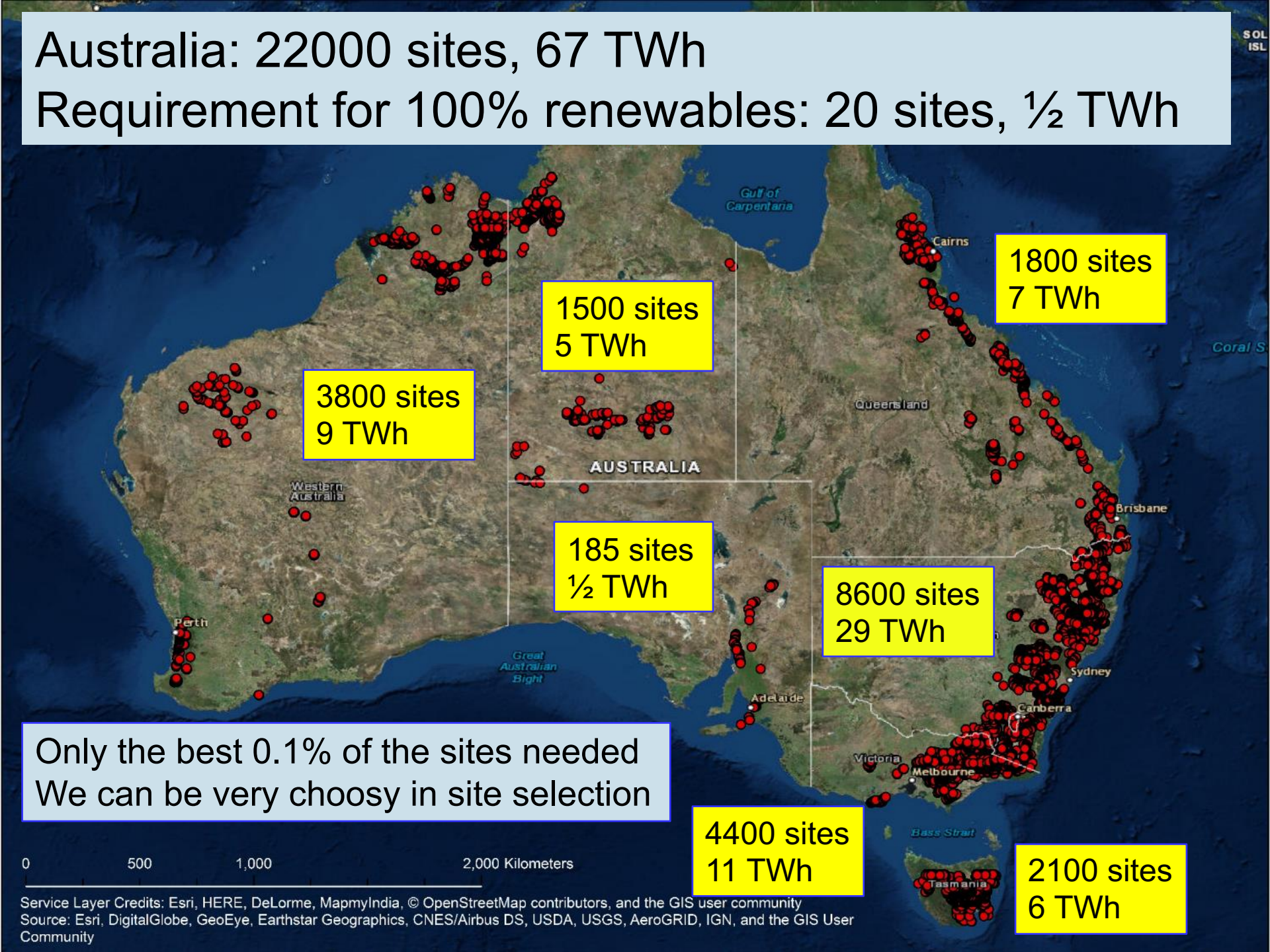
Identify reservoirs locations

- Model watershed
- Simulate 40m dam
- Identify locations with >1GL of storage (~1GWh)



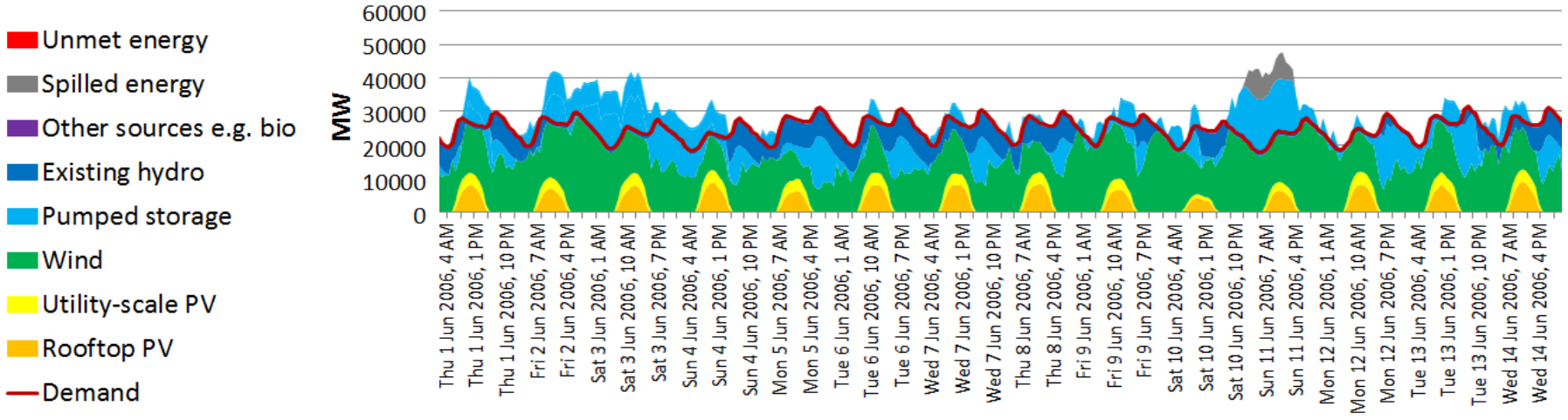


Australia: 22000 sites, 67 TWh
Requirement for 100% renewables: 20 sites, ½ TWh



Supply/demand modelling

- Optimise system for energy balance
  - Historic NEM demand data 2006-2010
  - Historic weather (wind and insolation data)
  - Retain existing hydro and biomass generation
- Use genetic algorithm to optimise wind/PV/PHES
  - Size and location



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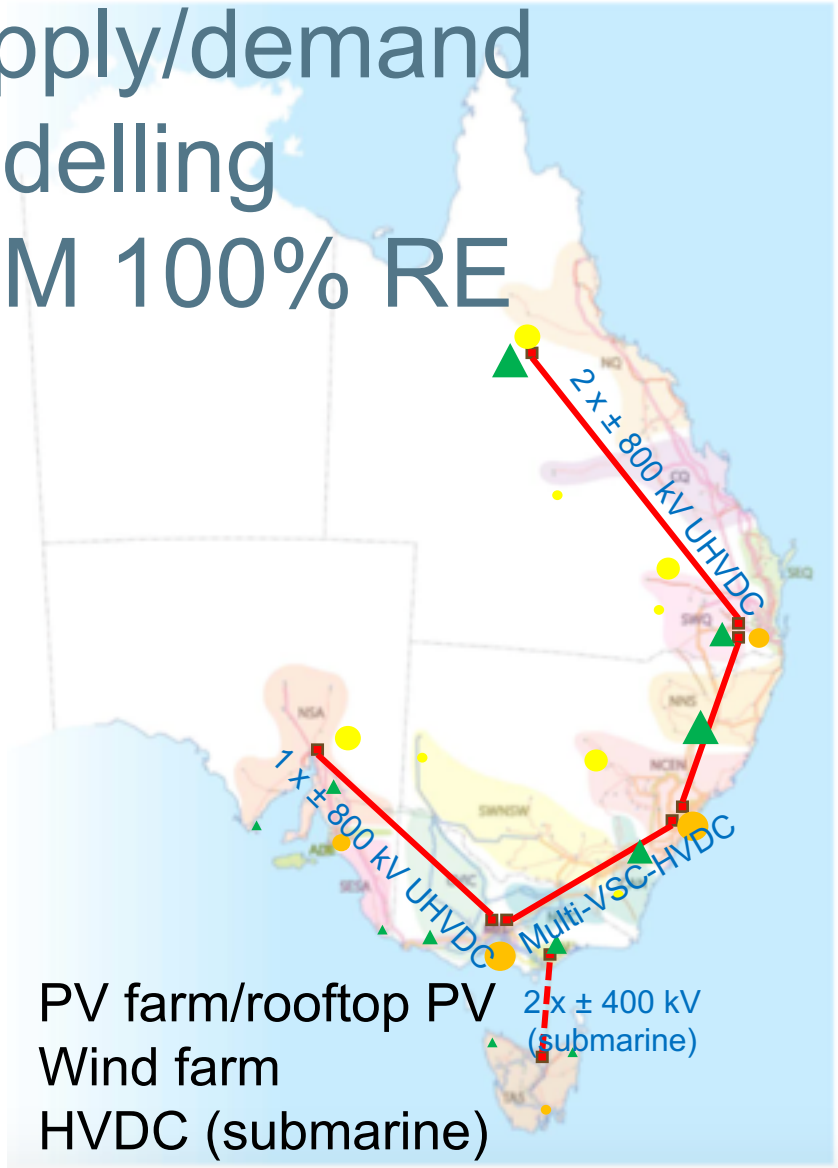
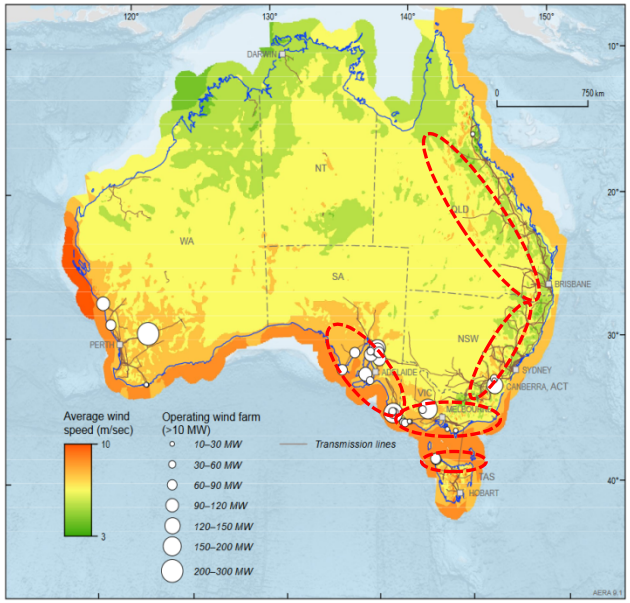
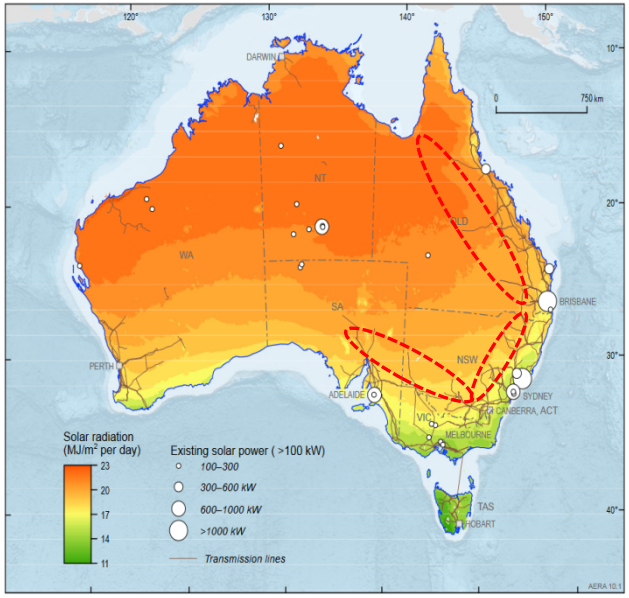
Supply/demand modelling NEM 100% RE







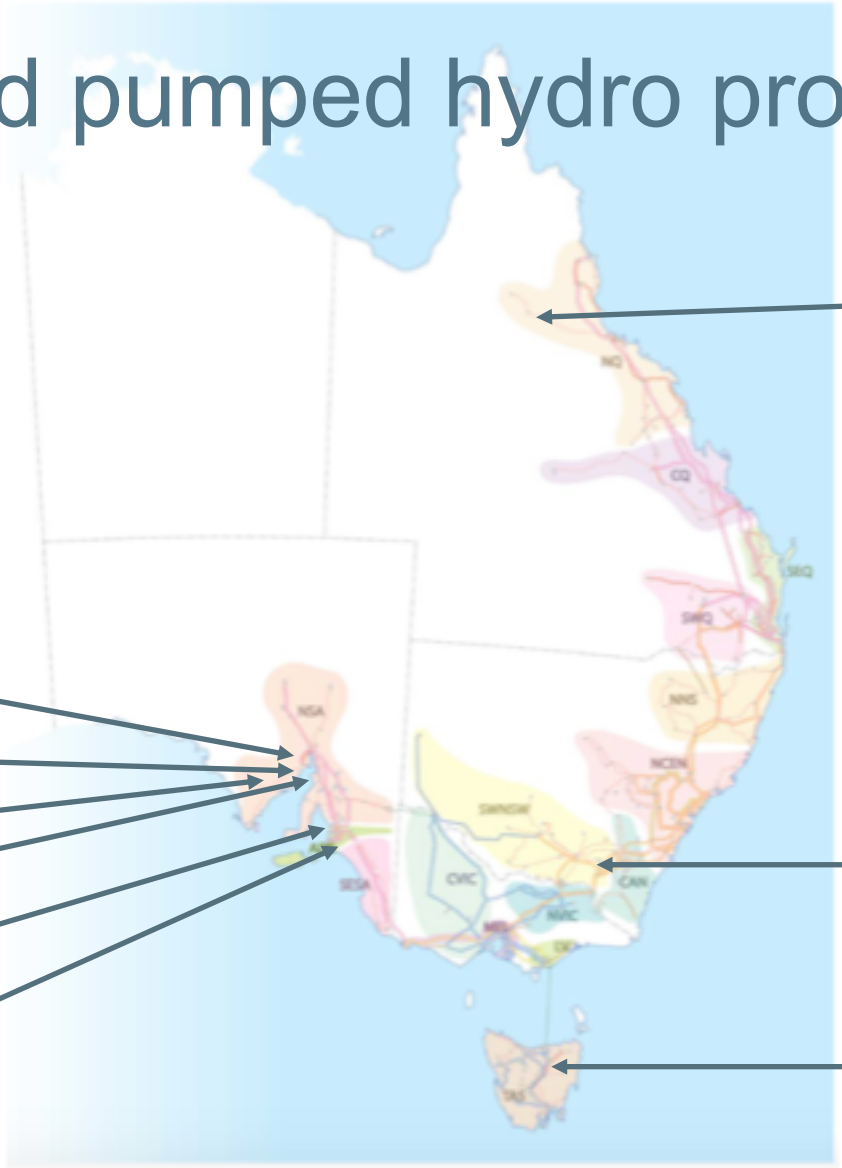
Source Australian Energy Resource Assessment (AERA) http://www.industry.gov.au/Office-of-the-Chief-Economist/Publications/Documents/GA21797.pdf

100% renewable scenarios

	PV (GW/TWh)	Wind (GW/TWh)	PHES (GW/h)	Spillage (%)	Levelised Cost of Balancing ($/MWh)	Levelised Cost of Generation ($/MWh)	Levelised Cost of Electricity ($/MWh)	PHES ($/MWh)	HVDC &AC ($/MWh)	Spillage & loss ($/MWh)
Today's costs	23 / 36	45 / 168	16 / 31	7%	**28**	**65**	**93**	14	7	7
Wind PV ~$50/MWh	30/49	43/159	17/26	9%	**25**	**50**	**75**	13	6	6
No FNQ HVDC link	28/44	46/173	16/29	13	**27**	**50**	**77**	13	5	8

No FNQ HVDC $2/MWh equates to ~$400M annual additional cost

Announced pumped hydro proposals



Kidston

Goat Hill
Cultana
Iron Duchess
Baroota
Highbury
Kanmantoo

Snowy 2.0

Battery of the Nation

Summary

- Intermittent renewables growing rapidly
- Different system operation
  - Transmission, load management and storage
- Large off-river pumped hydro resource
  - <<1% required to balance supply/demand
- Addition balancing costs modest