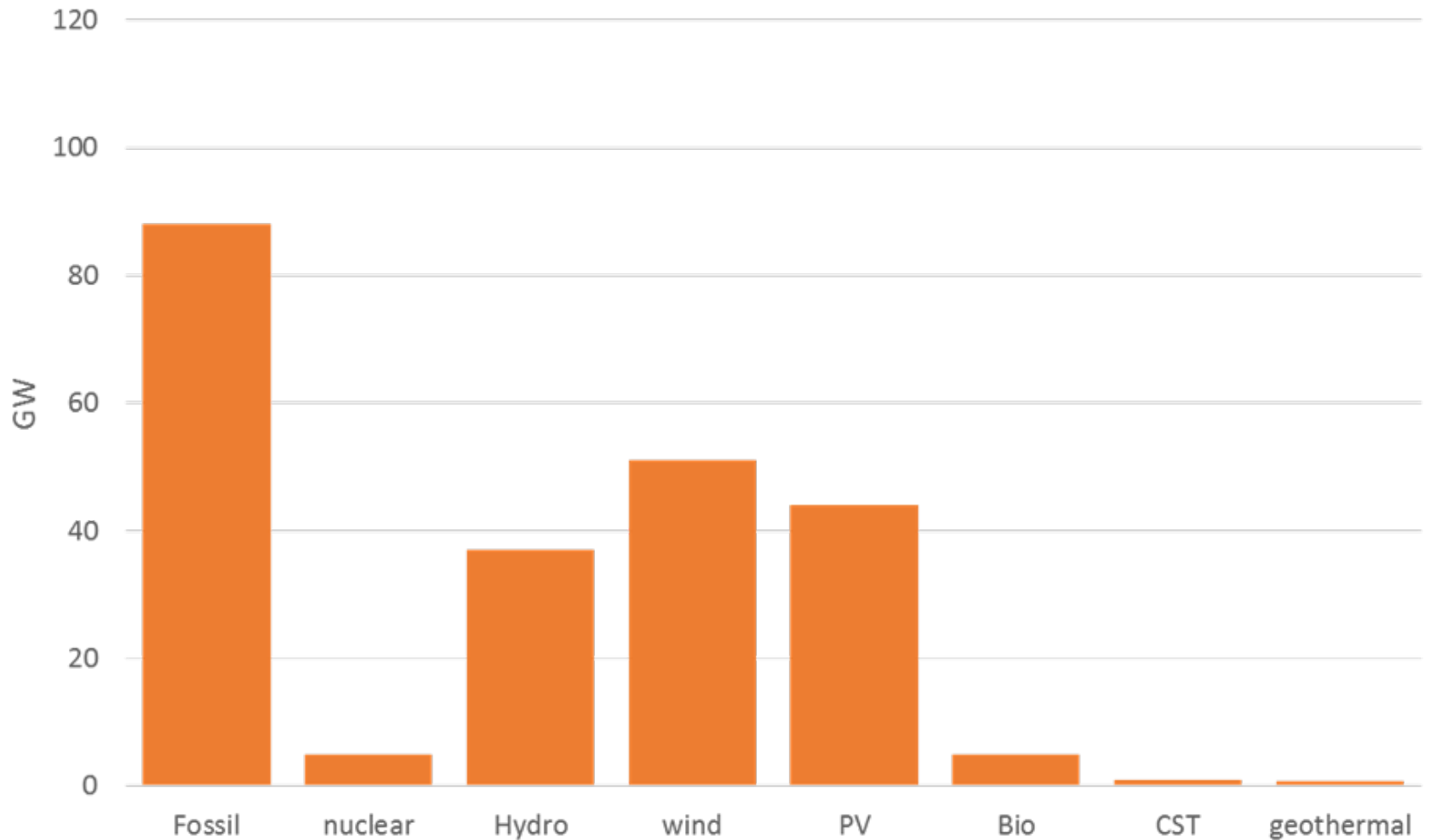




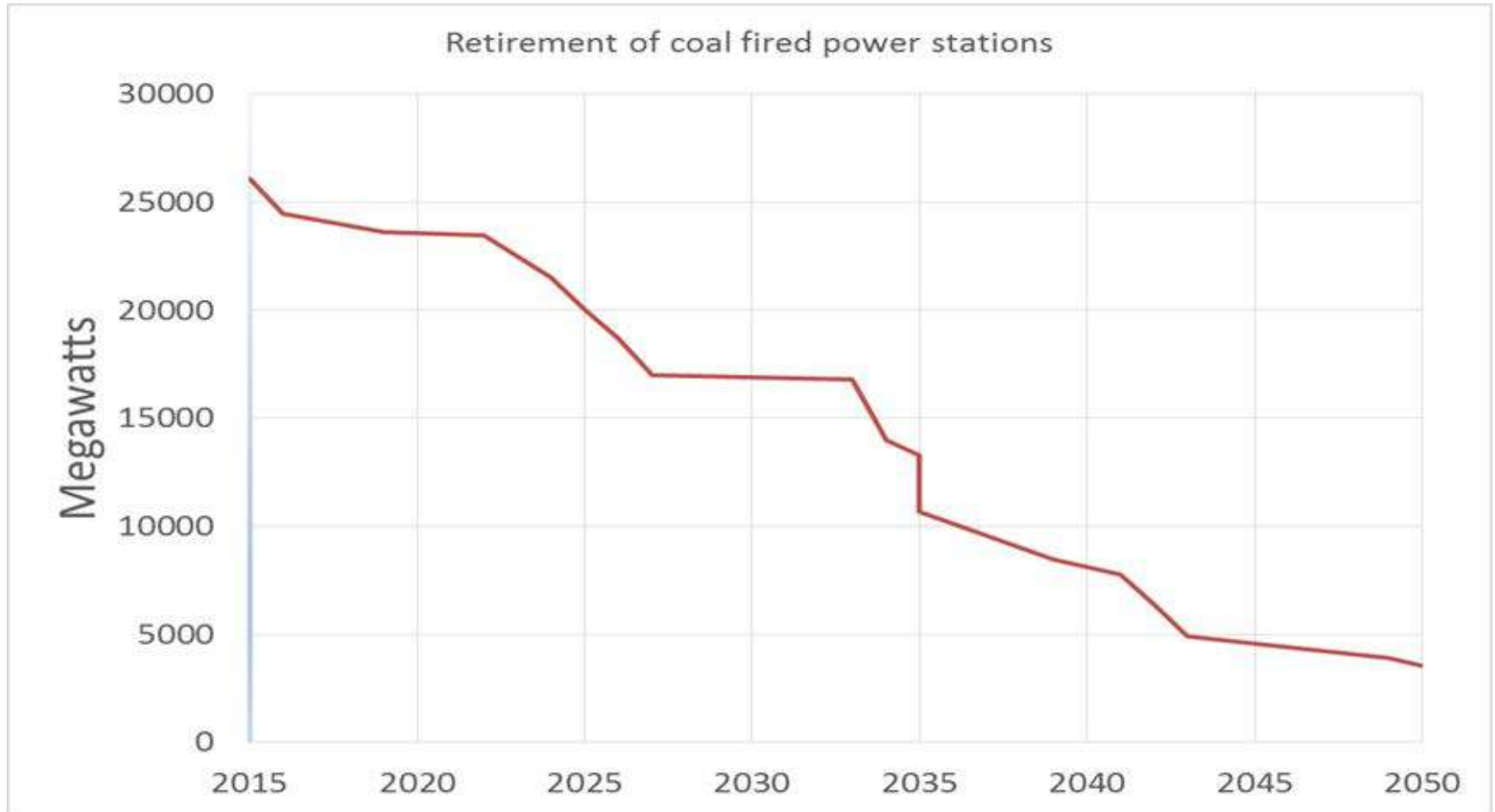
# **Off-River Pumped Hydro Energy Storage**

**August 2015**

# New generation capacity world wide 2014



# Retirement of coal fired power plant



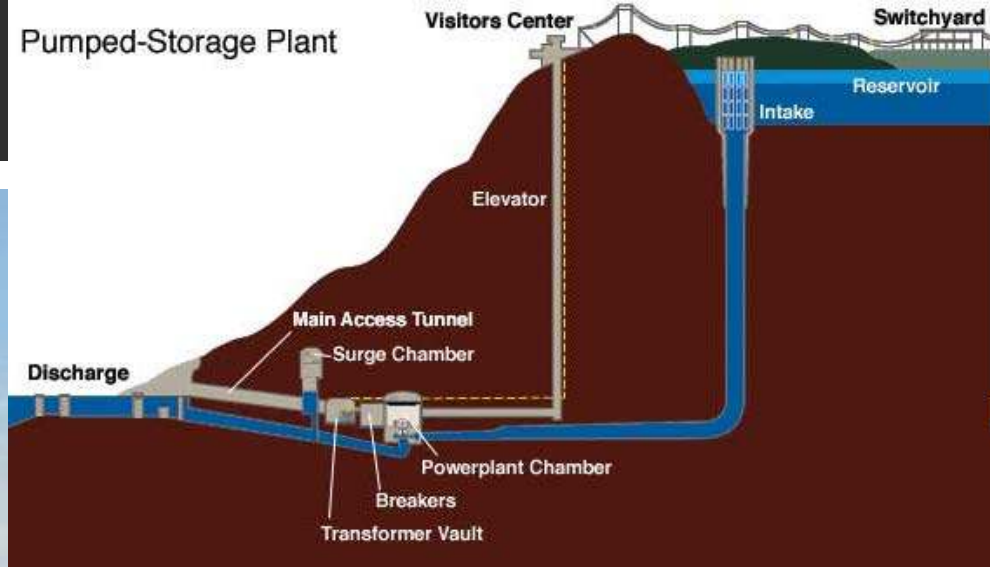
# Electricity reliability for 50-100% renewable energy penetration

- Wide geographical dispersion
- Technical diversity
  - Wind, photovoltaics, hydro, solar thermal, biomass
- Shift loads from night to day
- Mass storage
  - Pumped hydro – 99% of all storage
  - Advanced batteries, flywheels, molten salt etc



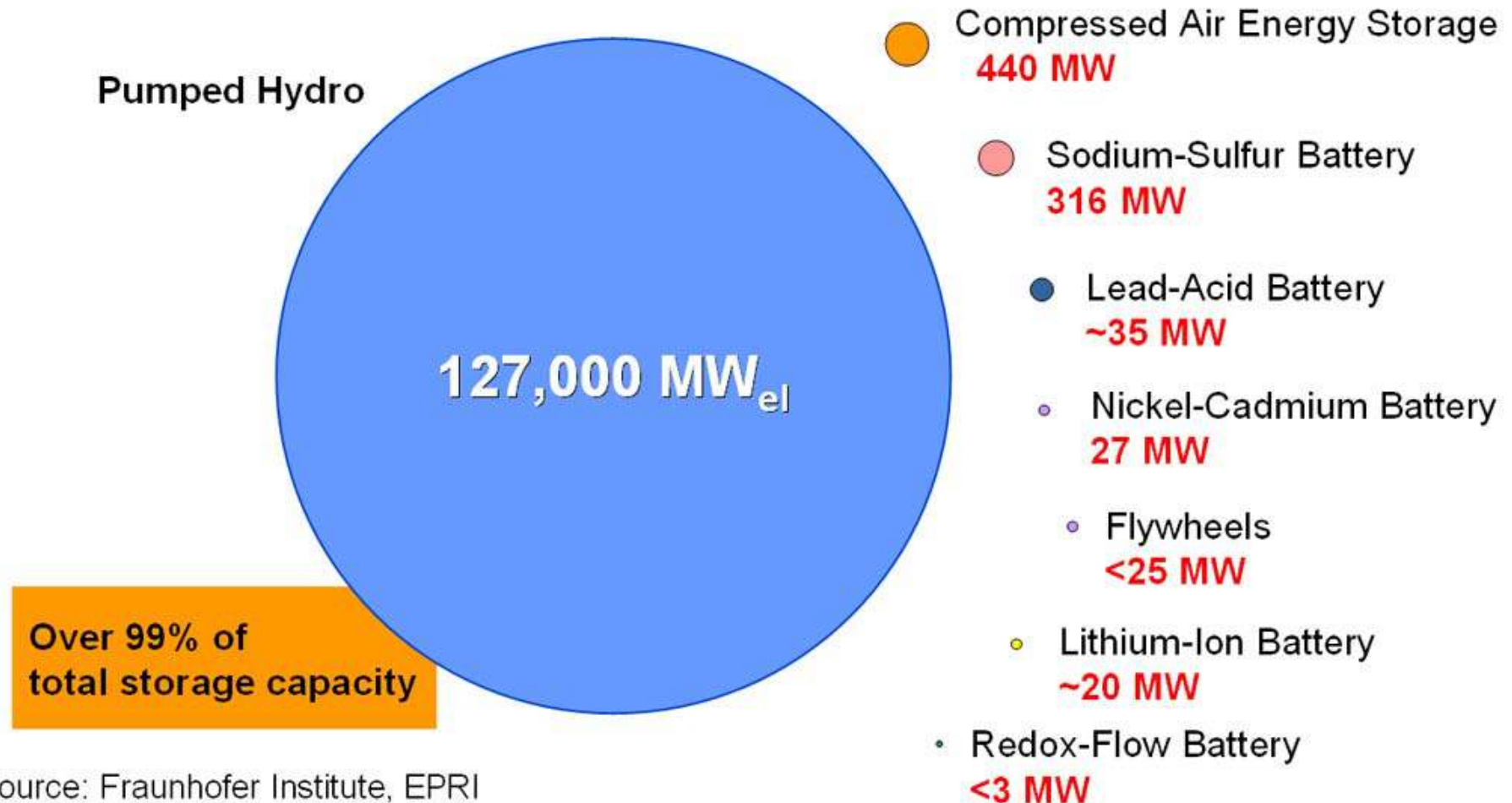
Australian  
National  
University

# Pumped hydro 1500 MW at Tumut 3



# Energy Storage

## Worldwide installed storage capacity for electrical energy



Source: Fraunhofer Institute, EPRI

# Off-river Pumped Hydro Energy Storage

- PHES is 99% of all energy storage (160 GW)
  - much cheaper than alternatives
- Most PHES is on-river – with limited further prospects
- Off-river, there are unlimited excellent sites
- Misconceptions:
  - *“Pumped hydro storage is at a mature stage of development, but there are limited locations where these facilities can be built”*
  - *“... further deployment of pumped hydro is severely limited by geographical and environmental site requirements ...”*
  - *“Australia is flat and arid and has little potential for more hydro”*
- Storage of a few hours most important
  - Spinning reserve, constrained transmission lines, time-shifting wind and PV
  - Morning and evening demand peak, wind lulls and short term clouds
  - Outages
  - Time to bring up low duty cycle coal/gas/biomass plant



# Off-river PHES

- A pair of “turkey nest” “farm dams”
- Small reservoirs (hectares); large power (100 MW)
- Hundreds of good sites
  - Reservoir on top of a hill → large head (300-900m)
  - Avoid flood control costs
- Example
  - Twin 5 Ha reservoirs
  - 15m deep, 600m head
  - 200MW for 5 hours



Bundeela Pondage (Shoalhaven PHES system) is artificial



# Lake Burrendong wind farm – 320m head



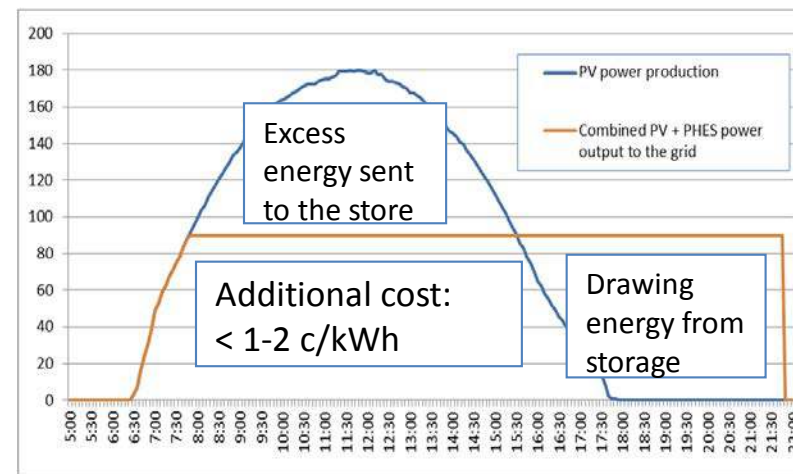
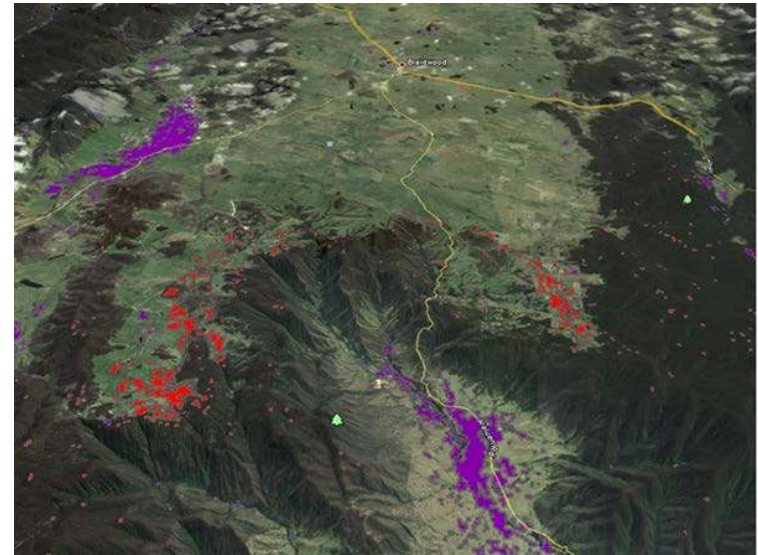
# Water and environment

- Environment
  - Exclude national parks and sensitive areas
  - Hectare-scale reservoirs, small footprint
- Water
  - Water recycled, supplemented with local runoff
  - 1000 MWh PHES system near Whyalla in SA
    - Water requirement = 0.03% of SA Water sales
    - 25 times smaller than a coal power plant per GWh



# Off-river Hydro Storage

- Spinning reserve for SA
- More wind utilisation in WA
- Better price for load-following output rather than wind/sun following
- Avoid duplication of a powerline by trimming sun/wind peaks
- Reduce transformer & powerline size/cost by sending half the power to storage and only half to load in real time
- PV/wind/storage precincts
- Arbitrage between on/off peak
  - buy low, sell high
- Facilitate 50-90% PV/wind penetration



# Example cost calculation

Generator/pump capacity: 200 MW

Head: 600 m

Round trip storage efficiency: 80%

Reservoirs: two, each 5 Hectares, 15m deep (200 MW for 5 hours)

Pipe length: 3km; Transmission line length: 5km; New road construction: 5km

Empty/fill cycles per day: 2

Nominal discount rate: 10% (inflation rate: 2.5%)

System lifetime: 50 years; O&M: 1% per year of the capital cost

System cost: \$1100/kW

➔ **Storage cost: \$33 per MWh** (for energy that is actually stored)

➔ Far cheaper than batteries

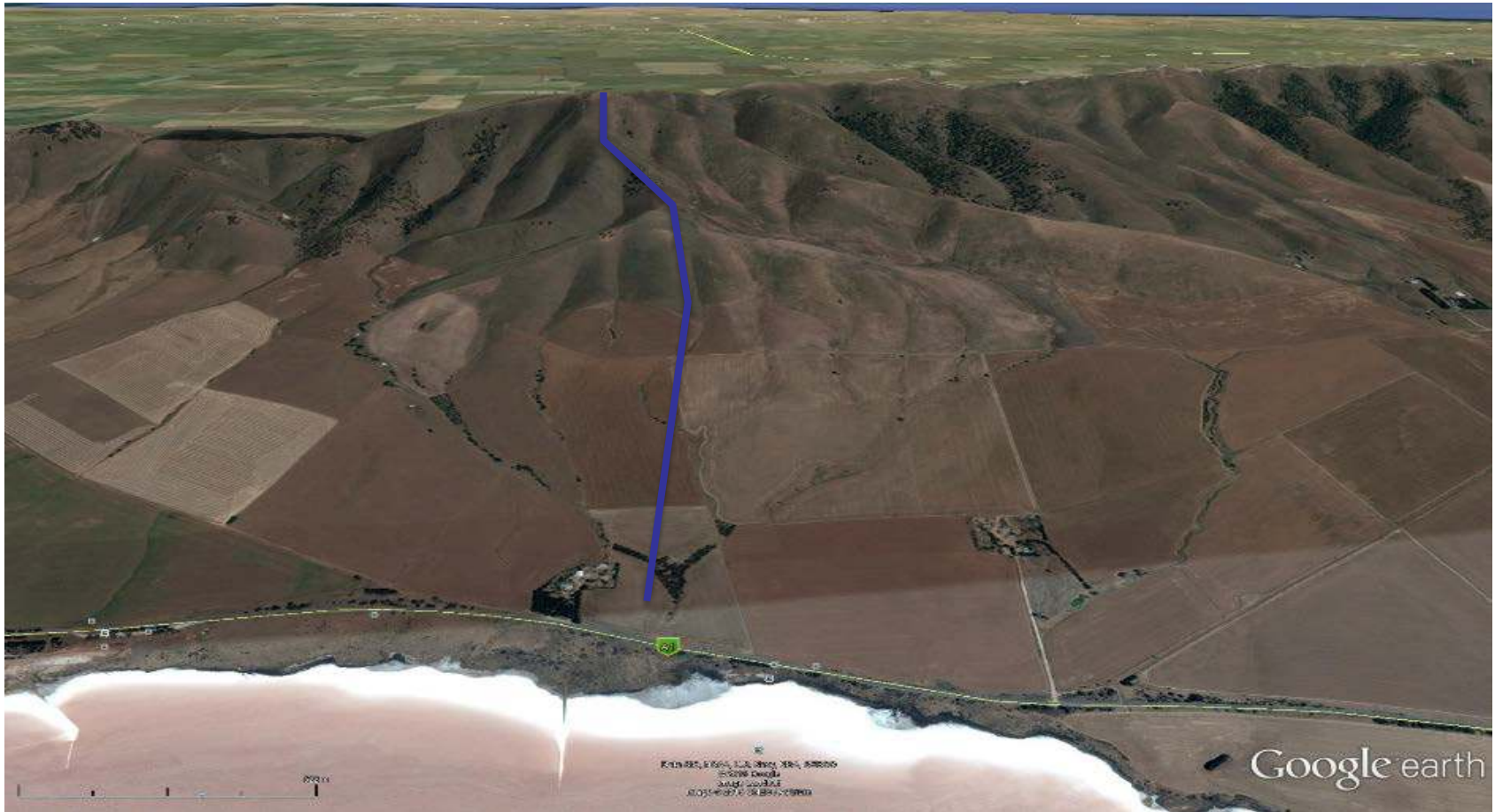
# South Australia - spinning reserve



*Hills east of Whyalla with up to 600m head (vertical scale exaggerated)*



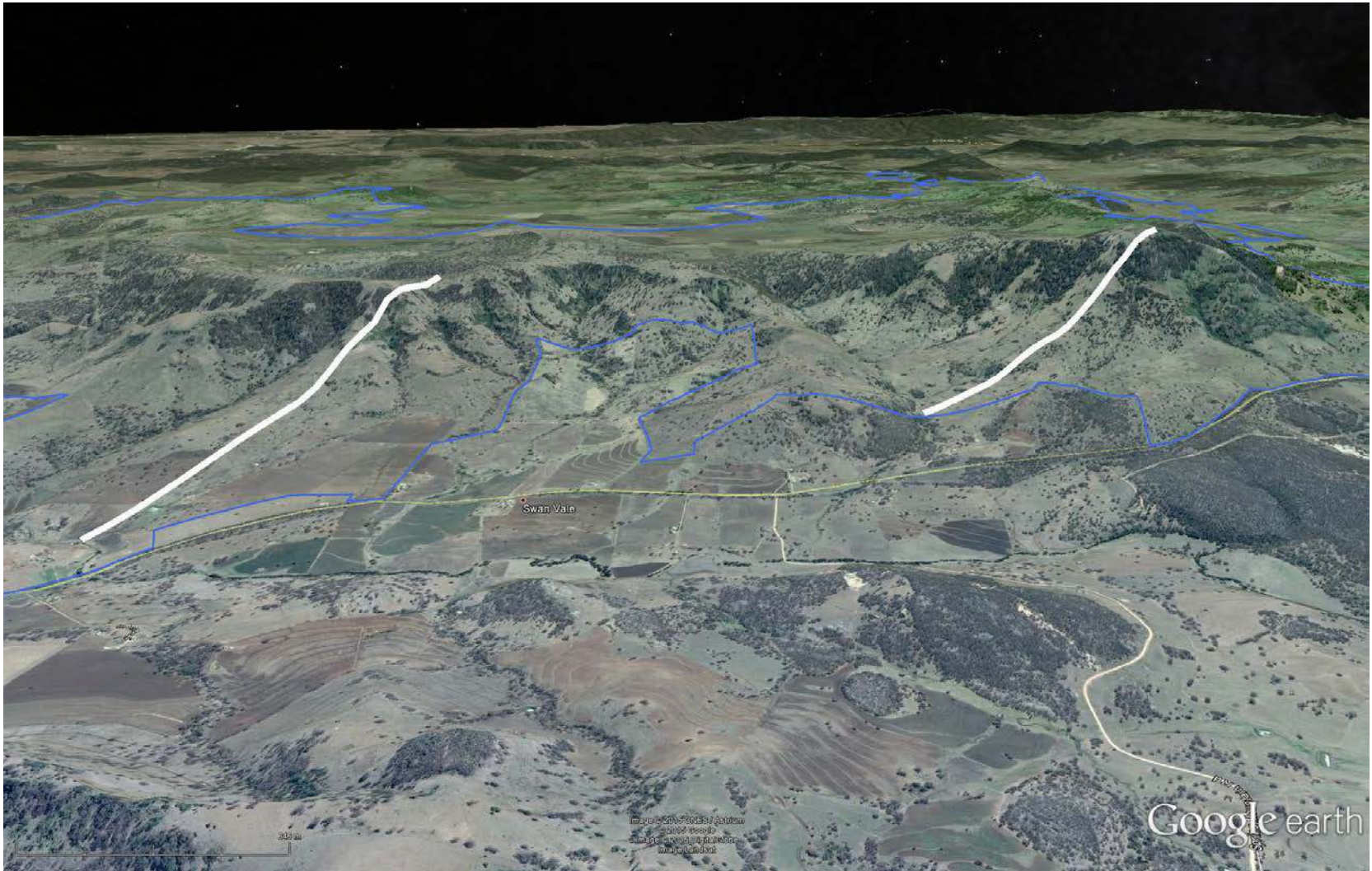
# Snowtown windfarm (370 MW, South Australia)



*Notional 5km long pipe; altitude difference 300m; twin 3 Hectare dams; 3 hours @ 200 MW*

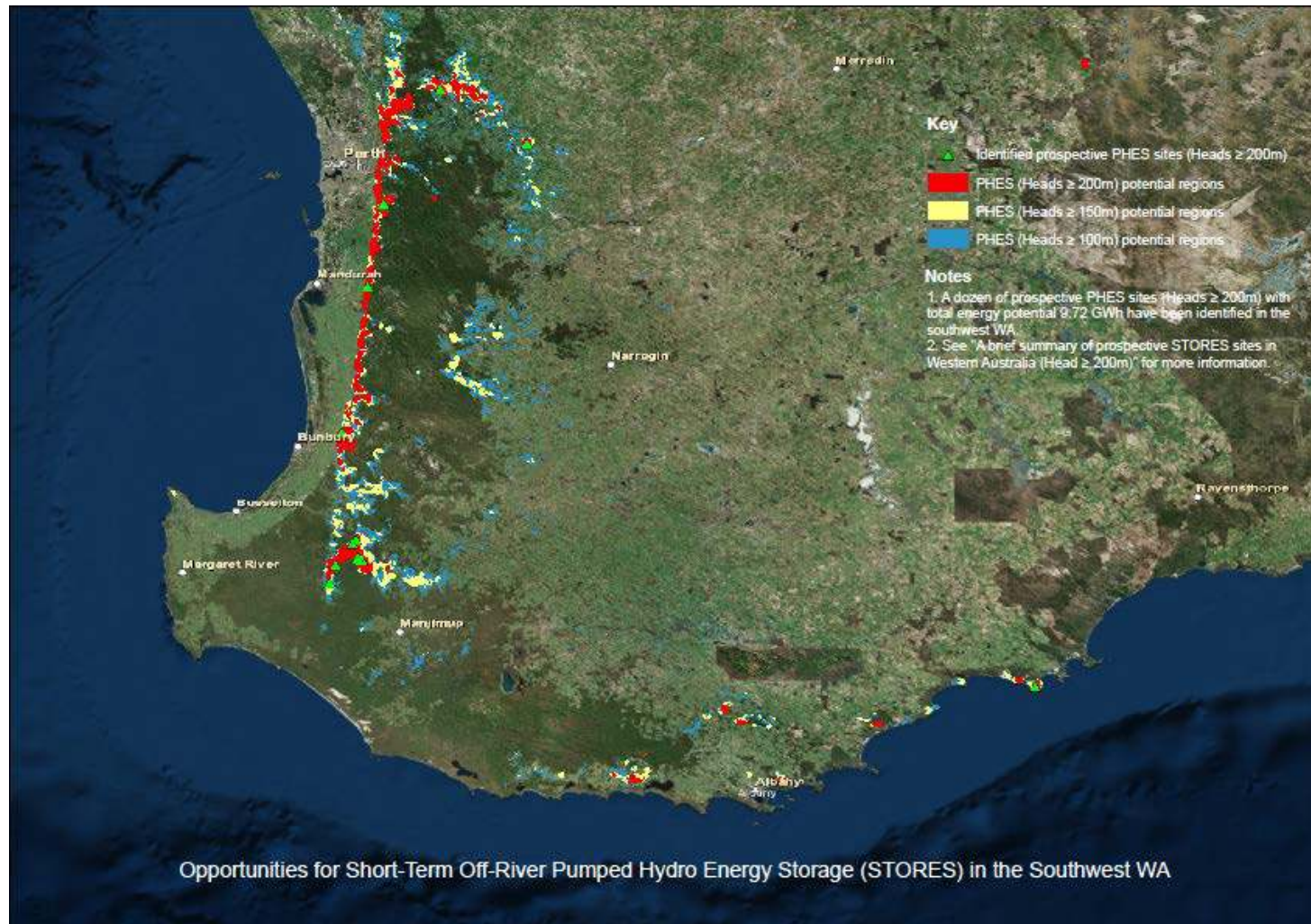


# Sapphire Wind project – 300m head





# PHES in WA - Facilitating wind and PV



# What we are doing

- Find all of the good PHES sites: a PHES Atlas
  - Exclude national parks and sensitive areas
  - Add in solar data, wind data, transmission lines
- Find PV/wind precincts
  - PHES + transmission line + good wind and sun
- Detailed market and financial analysis
  - A reliable costing tool
- Initial results
  - 100% renewable energy needs 20GW PHES
  - Adds 10-15% to total cost