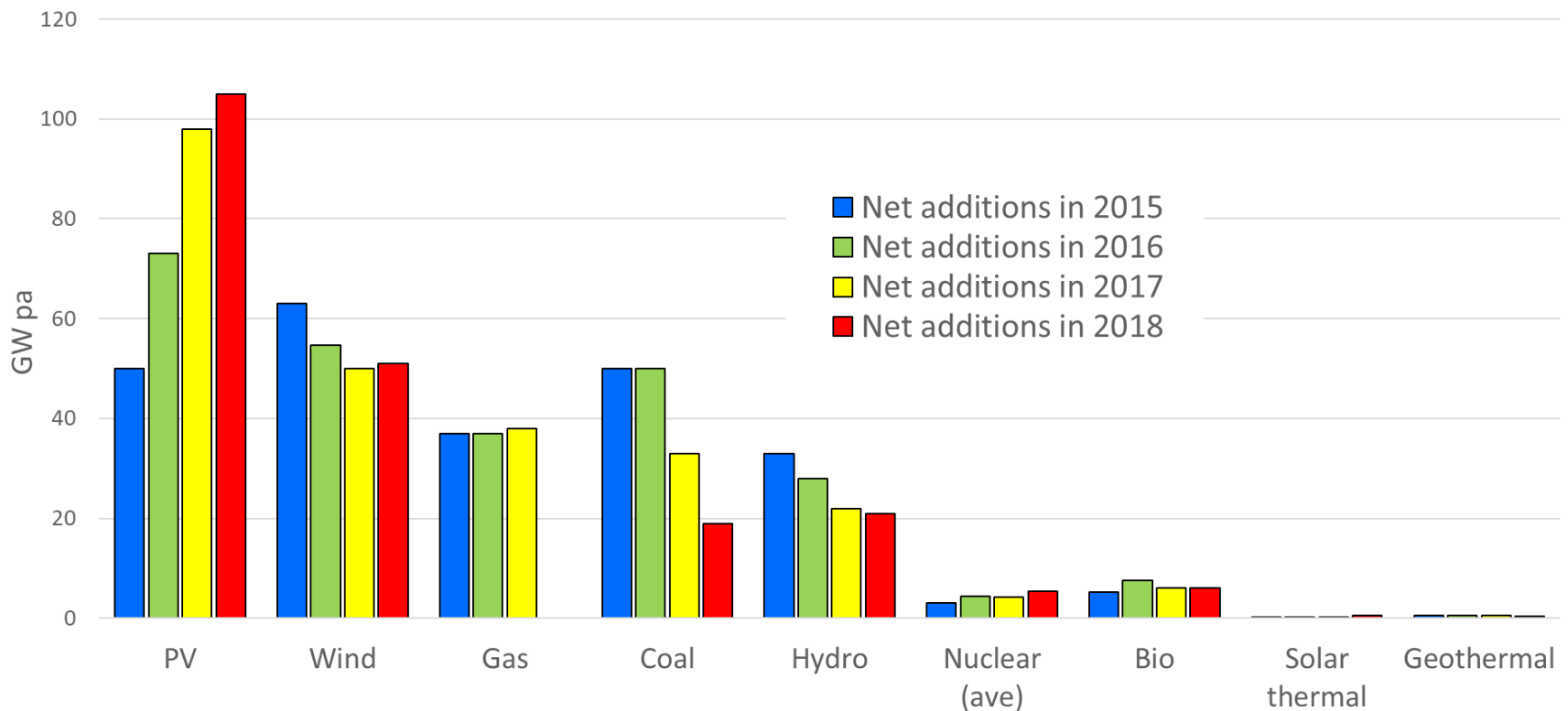


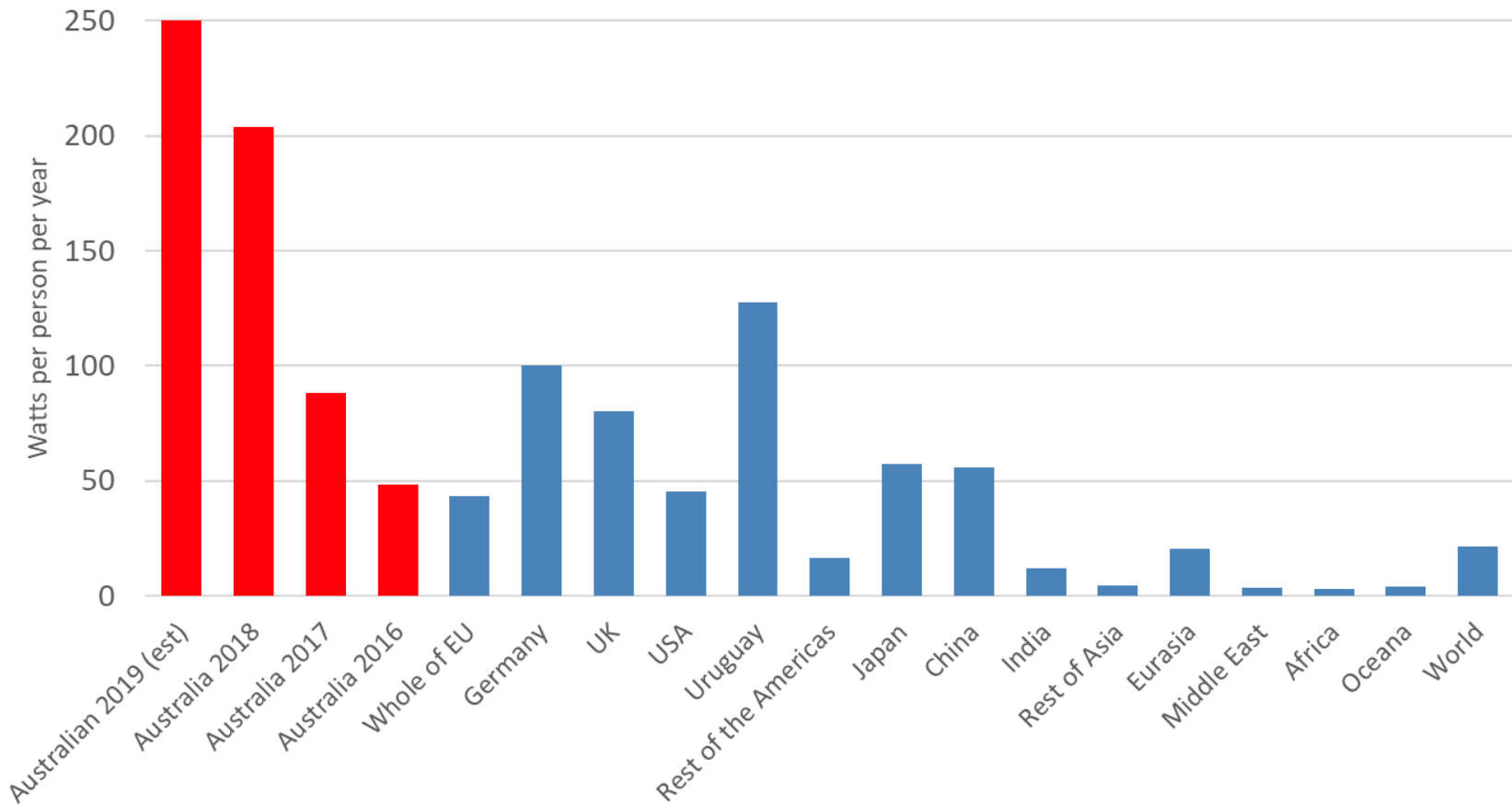
Development of a Global Atlas of Off-River Pumped Hydro Storage

Dr Matthew Stocks and Prof Andrew Blakers, ANU
Hans Naeff and James Currie, Black and Veatch

Solar PV and wind leading world's new generation capacity



World per capita renewable installations





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

Head: 500 m

Water volume: 6 Gigalitres

Combined reservoir area: 105 Ha

1 GW power rating (6 hours)

Upper reservoir

Lower reservoir

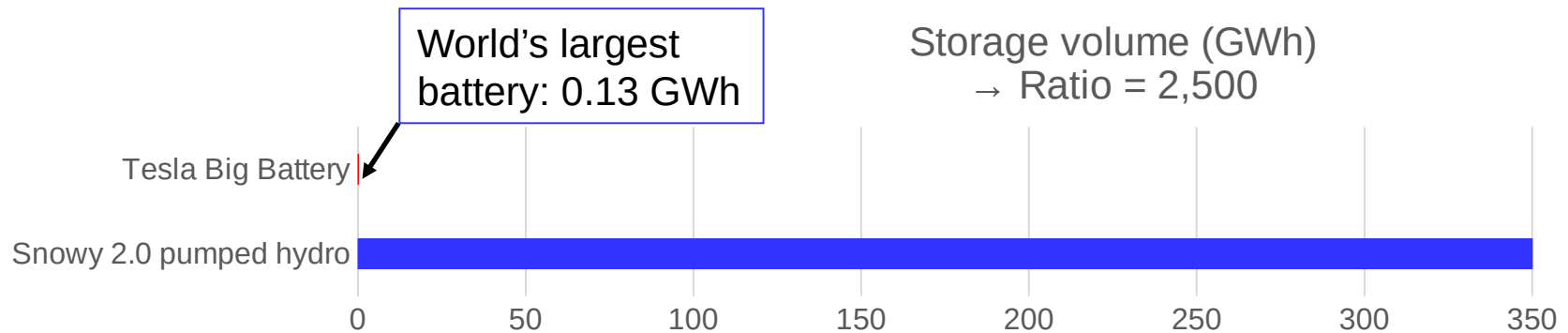
Presenzano

Presenzano, Italy

Google Earth

Pumped hydro atlas

- Off-the-shelf, lowest-cost technology
 - 180 GW already installed
 - No arm-waving about large future cost reductions
- 100-1,000 times larger storage than batteries



- However, location driven by local topography
- Concerns regarding large-scale hydro development

Pumped Storage Examples, Lu et al, 2018

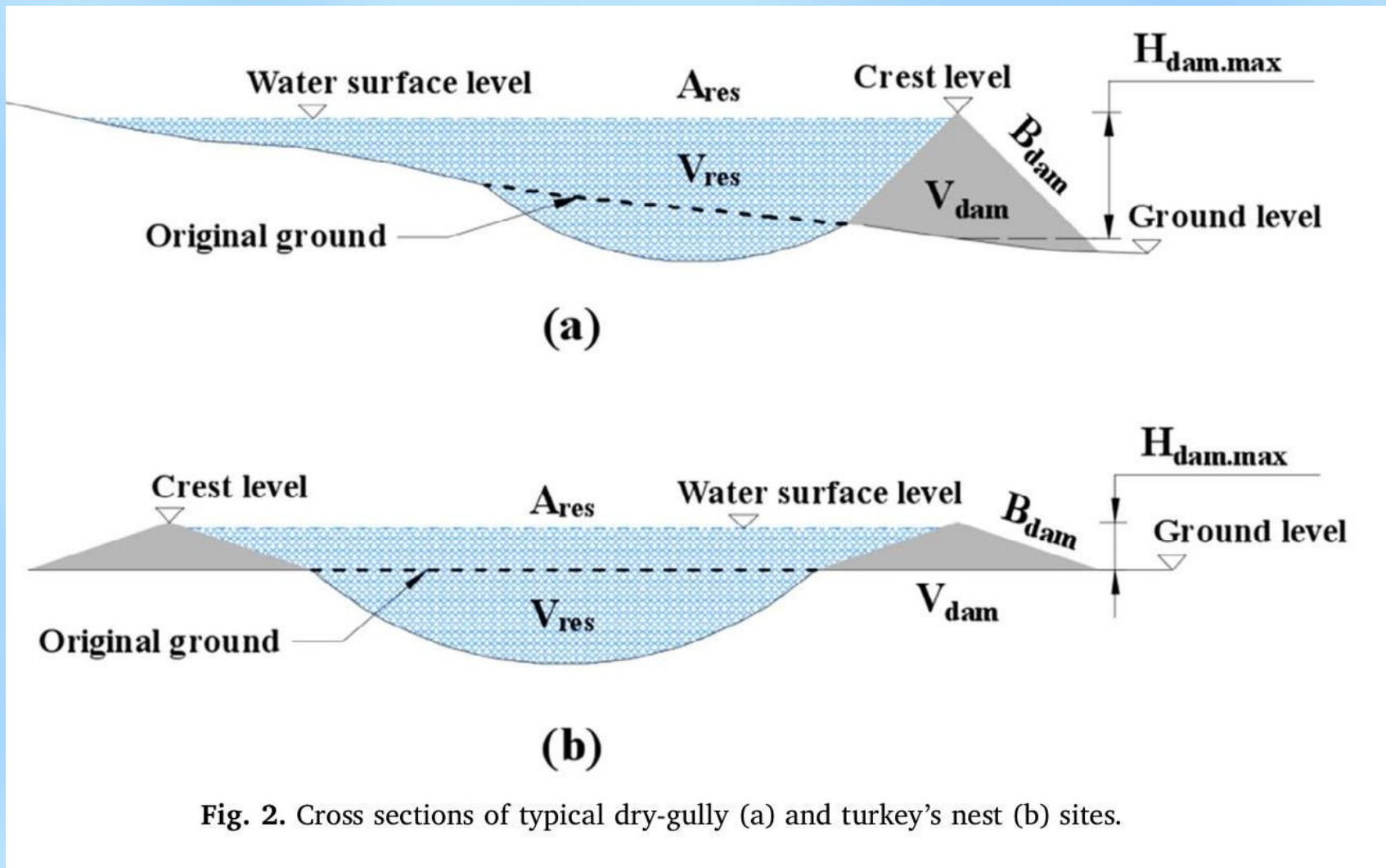


Fig. 2. Cross sections of typical dry-gully (a) and turkey's nest (b) sites.

PHES Site searching

Identify reservoirs locations

- Model watershed
- Simulate 5 -100m dams

Pair reservoirs

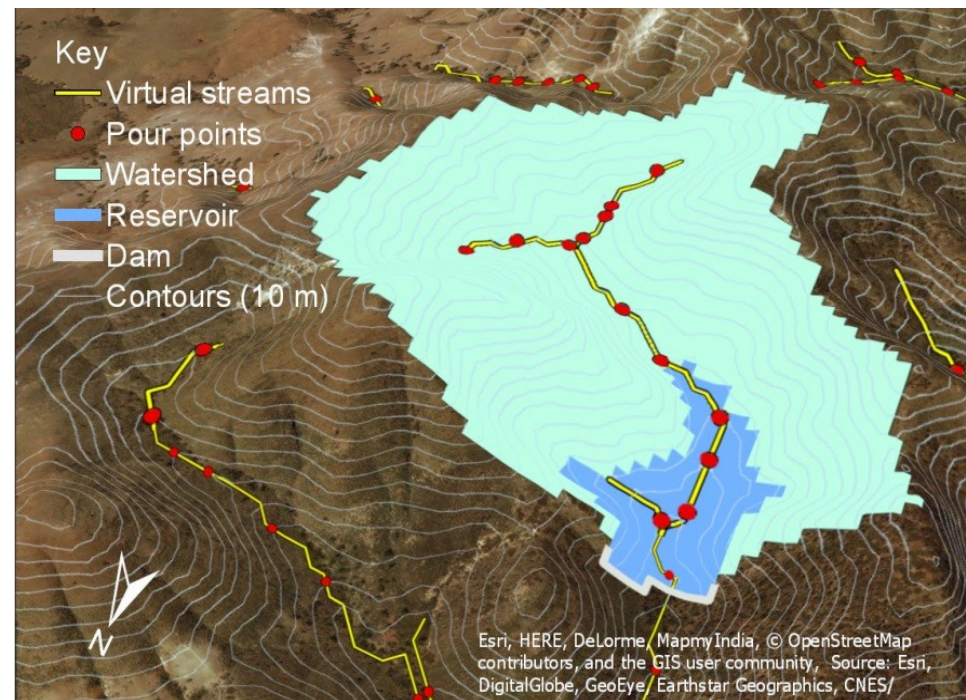
- 100-800m head
- Adjust both dam heights for storage target (e.g. 5 GWh)

Apply cost model

- “A” to “E” ranking (or reject)

Key information recorded

- Reservoir volume and area, dam line and volume, reservoir shape file, etc



Cost model

Model developed for Australian Government funded project

- Reservoir pair
- Water conveyance (~~penstock or tunnel~~)
- Power house (pump/turbine, generator, switchyard)
- ~~Services (roads, water, transmission)~~

Key relationships (head, power, separation, dam volume) used for global search ranking

Reservoir Pair

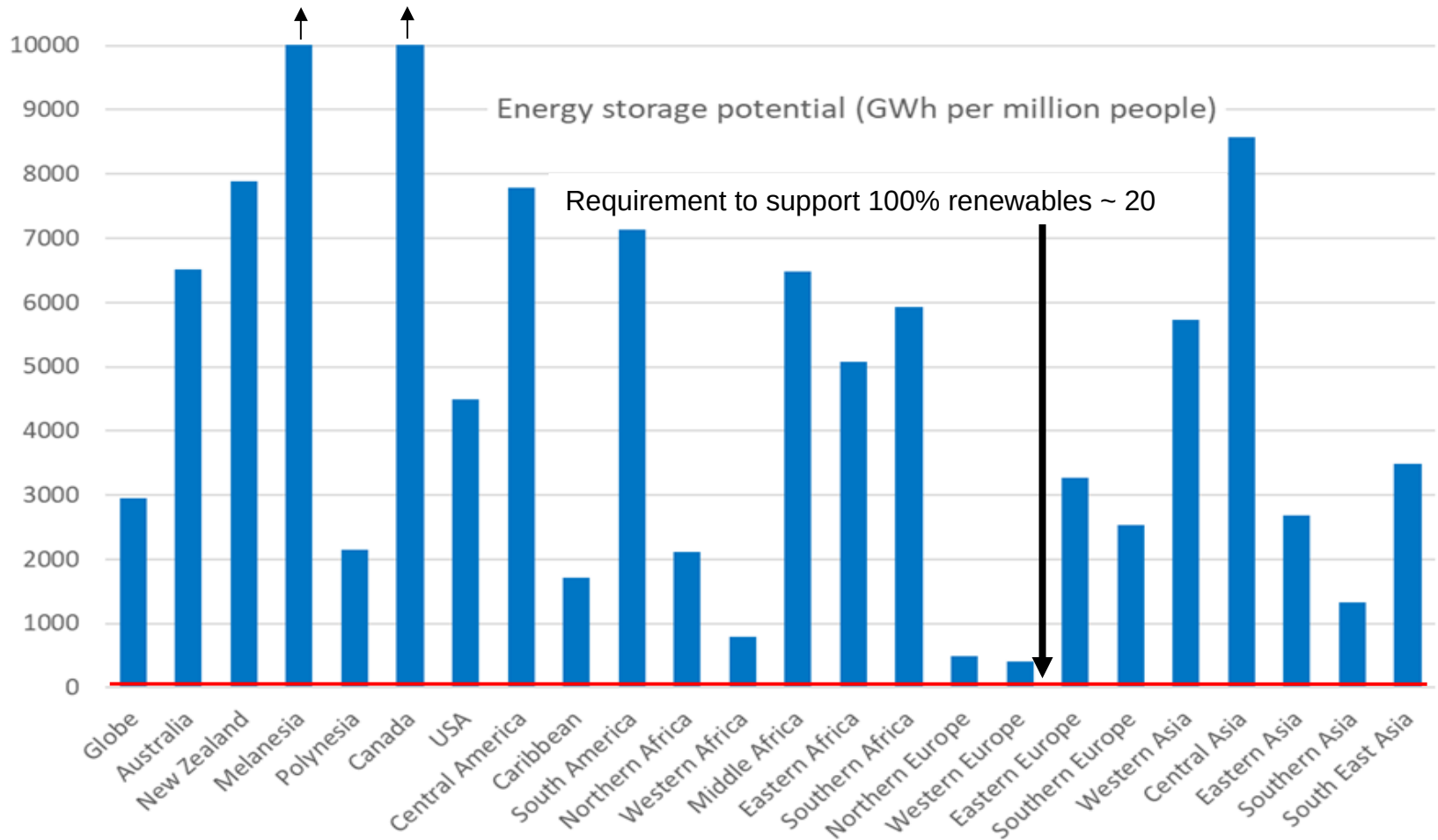
- Clay core rockfill dam 10-100 m high
 - Material borrowed from reservoir
- 3:1 batter slope
- 2 m deep foundation excavation
- Crest width: 8 m
- Concrete spillway designed to cope with flood or pumping (whichever is larger)



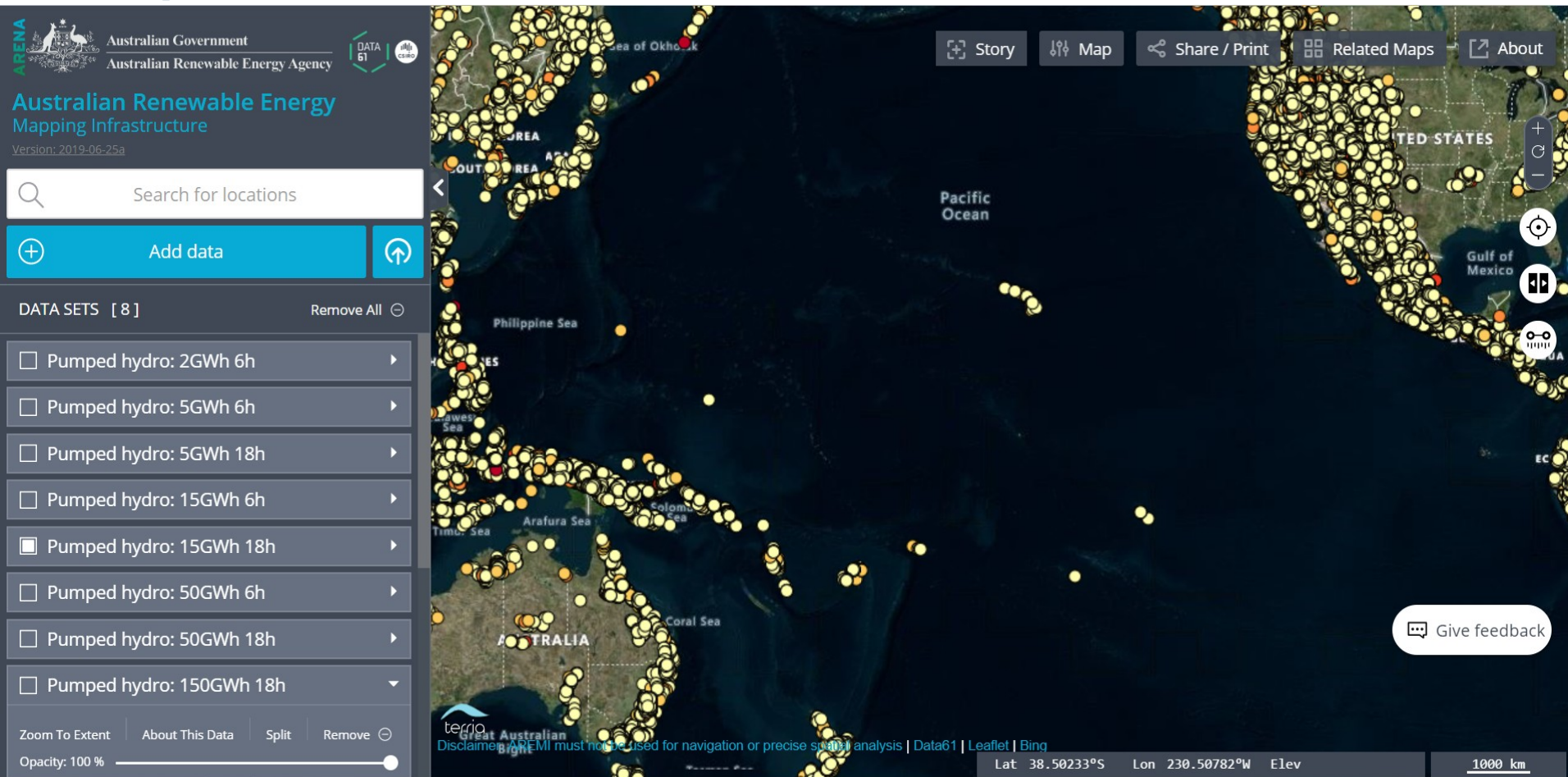
Conveyance - Powerhouse - Switchyard

- Tunnel
 - Vertical shaft and horizontal tunnels
- Excavated powerhouse.
 - Machine hall, transformer hall, electrical equipment tunnels, access/construction tunnels, cable and ventilation tunnel
 - Excavation, stabilization (shotcrete, rock bolts) and pavement
- Twin pump-turbine/motor-generator, variable speed.
- Inlet valves, transformers, cranes, ancillary mechanical and electrical equipment, switchyard

>600,000 unique sites with 23,000 TWh of storage



Open online access to full database



Australian Government
Australian Renewable Energy Agency

AREMI
DATA 61

Australian Renewable Energy
Mapping Infrastructure
Version: 2019-06-25a

Search for locations

Add data

DATA SETS [8] Remove All

- Pumped hydro: 2GWh 6h
- Pumped hydro: 5GWh 6h
- Pumped hydro: 5GWh 18h
- Pumped hydro: 15GWh 6h
- Pumped hydro: 15GWh 18h
- Pumped hydro: 50GWh 6h
- Pumped hydro: 50GWh 18h
- Pumped hydro: 150GWh 18h

Zoom To Extent About This Data Split Remove

Opacity: 100 %

terro Great Australian
Map of Australia
Disclaimer: AREMI must not be used for navigation or precise spatial analysis | Data61 | Leaflet | Bing

Lat 38.50233°S Lon 230.50782°W Elev 1000 km

Story Map Share / Print Related Maps About

Give feedback

<http://re100.eng.anu.edu.au/global>

<https://nationalmap.gov.au/renewables/#share=s-oDPMo1jDBBtwBNhD>

Pumped Hydro Sites – 15 GWh, 18h - UK

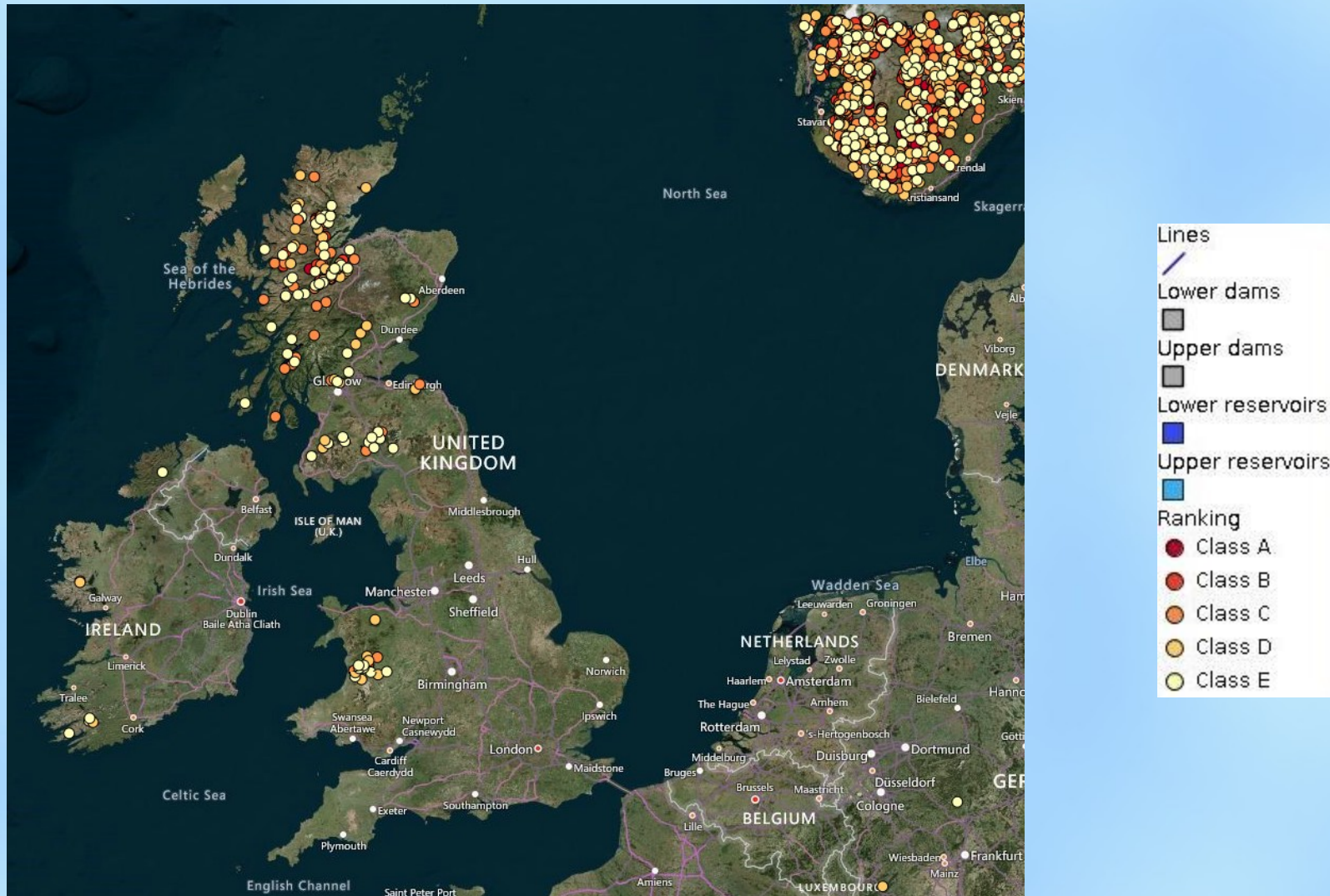


Image credit: Data61 hosting and Bing Map background
www.energypolicy.co.uk

Pumped Hydro Sites – UK

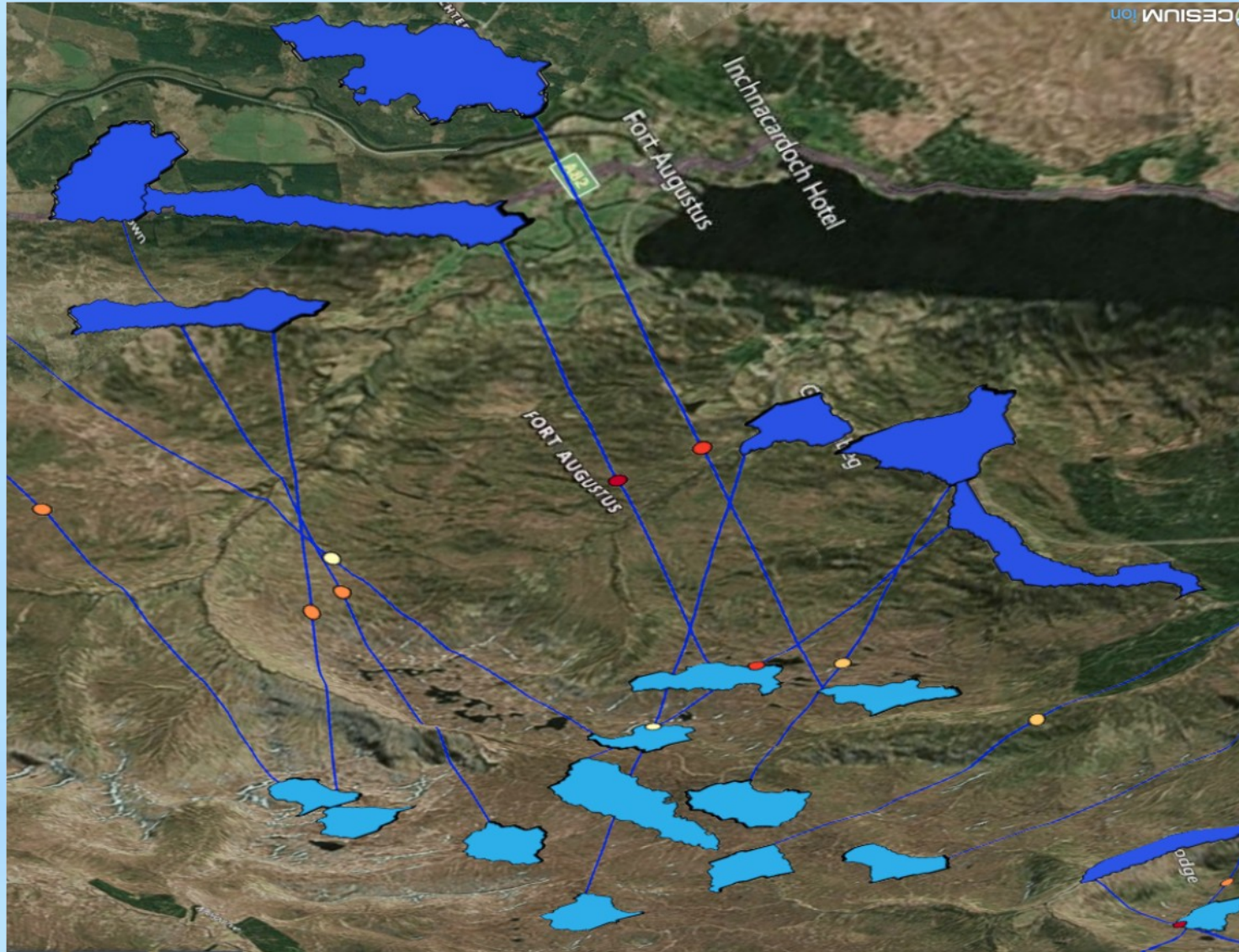
195 sites with 6047 GWh

of which

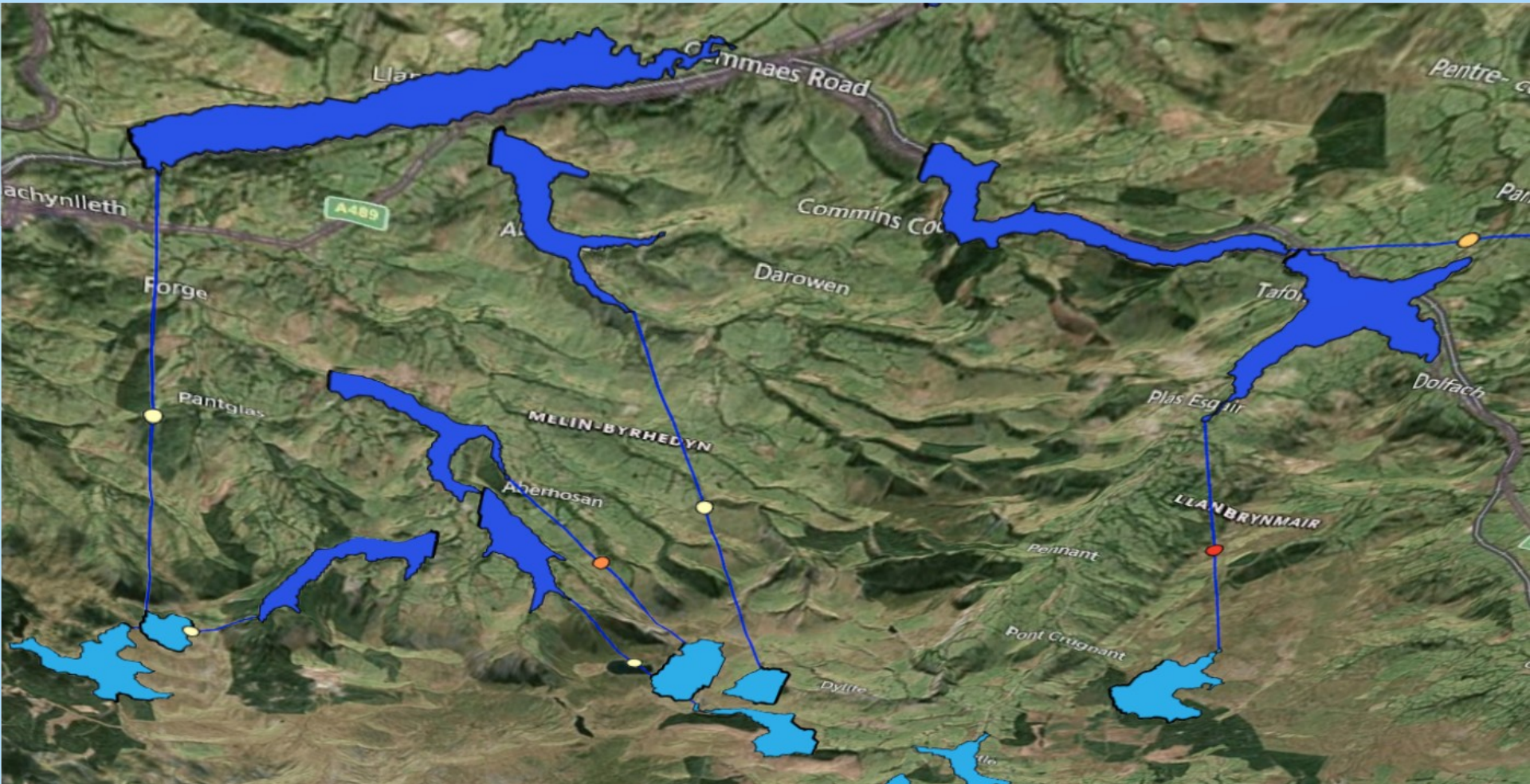
Class A	0 GWh
Class B	500 GWh
Class C	1355 GWh
Class D	992 GWh
Class E	3200 GWh

Requirement for 100% RE ~ $20 \times 70 = 1400$ GWh

Pumped Hydro Sites – Examples Scotland



Pumped Hydro Sites – Examples Wales



Existing and selected proposed interconnectors

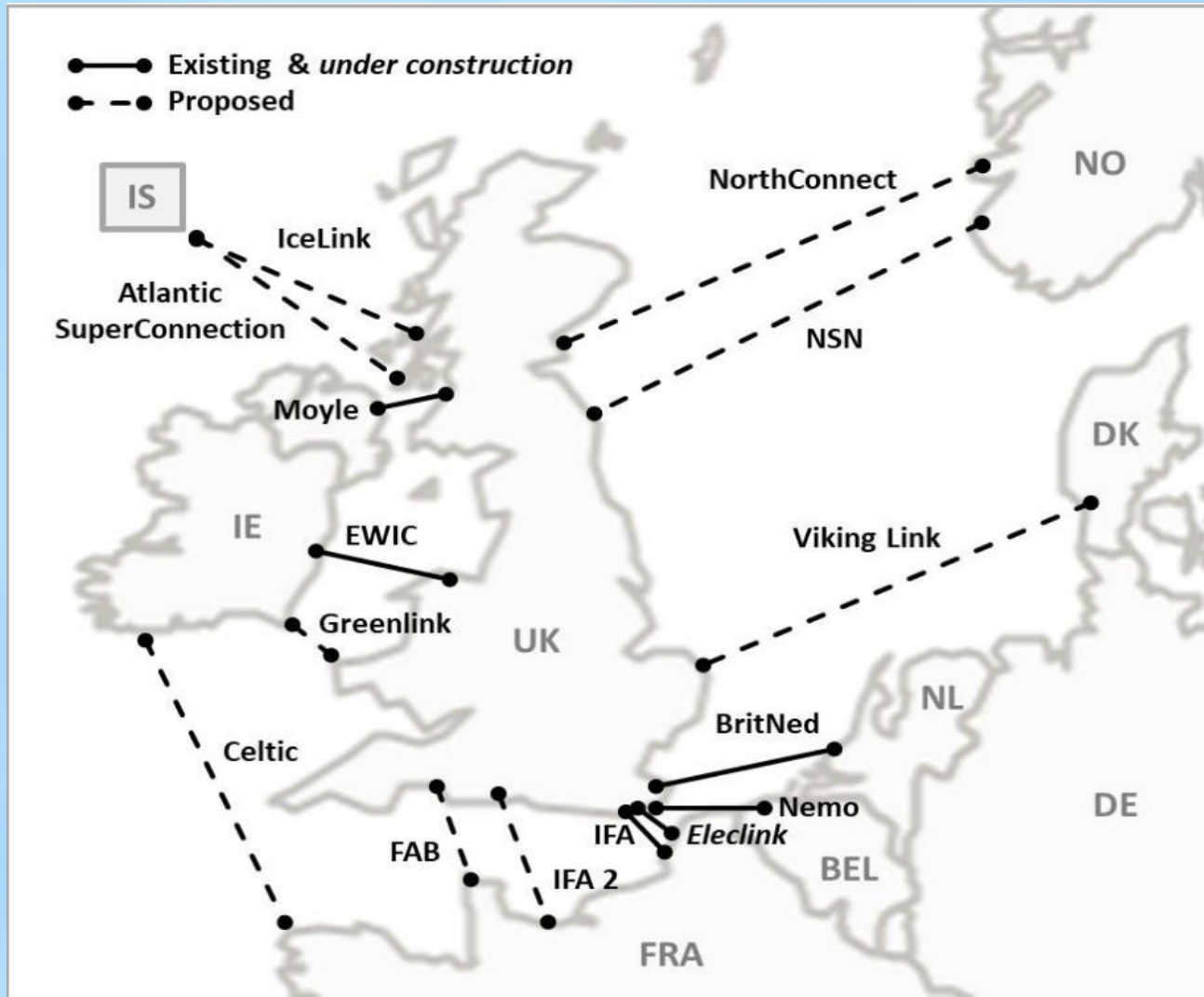


Image credit: UK-EU ELECTRICITY INTERCONNECTION:..., E3G, January 2019

Summary

- Variable renewables growing rapidly
- Pumped hydro well-placed to support transition
- Global off-river atlas developed
 - 600,000 sites with >23,000 TWh storage
 - Full visualisation from global to local scale
- Including for UK
 - 195 sites with ~ 6 TWh, 6000 GWh storage
 - Requirement for 100% RE ~ $20 \times 70 = 1400$ GWh

Development of a Global Atlas of Off-River Pumped Hydro Storage Questions?



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Thanks to ARENA for support of atlas development