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“The potential and role of pumped hydro energy storage to support Indonesia’s energy transition”

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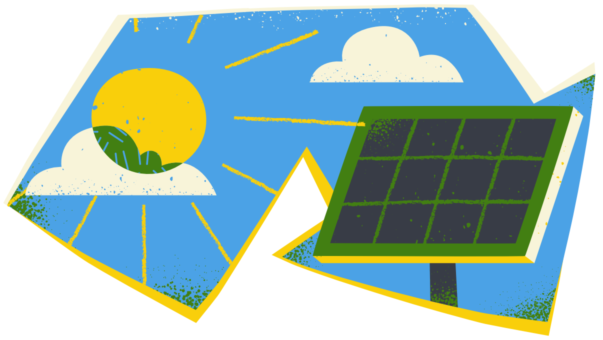

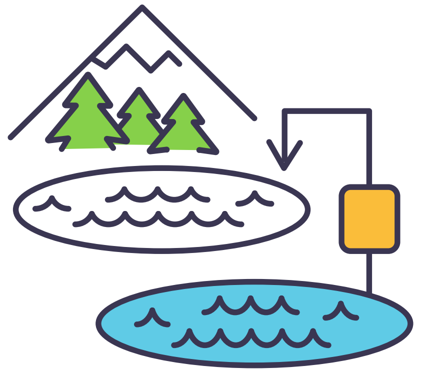

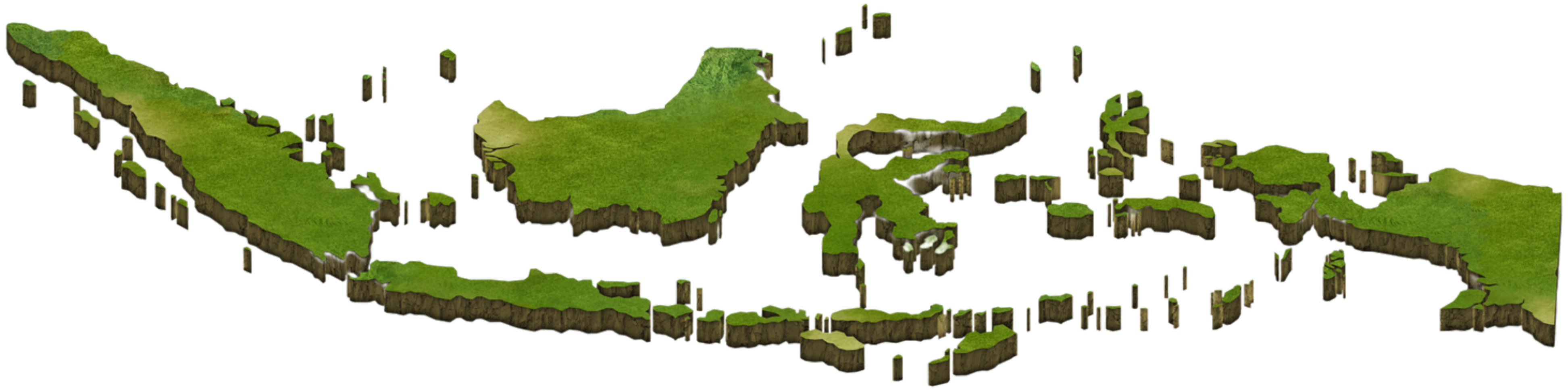

100% RENEWABLE ENERGY
ANU College of Engineering & Computer Science

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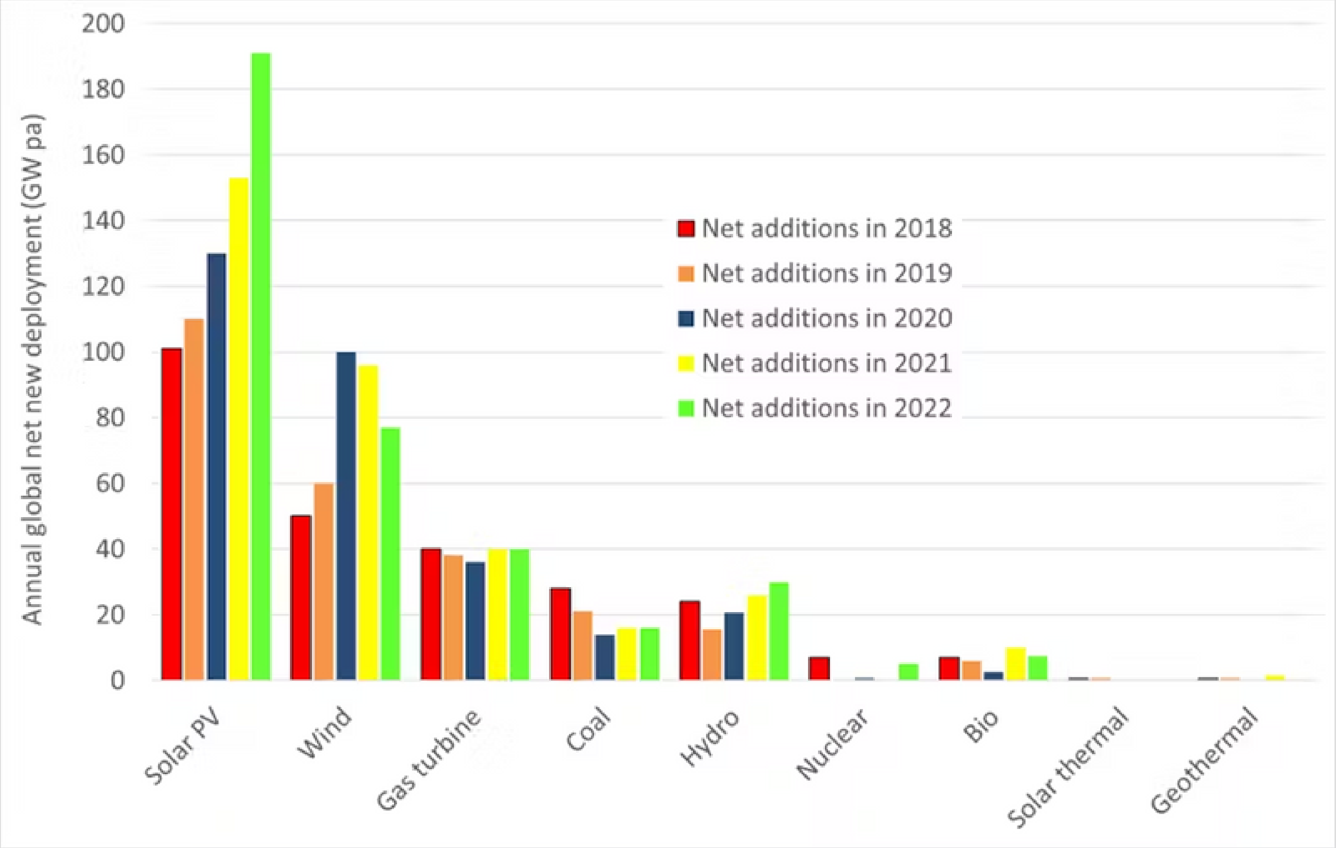
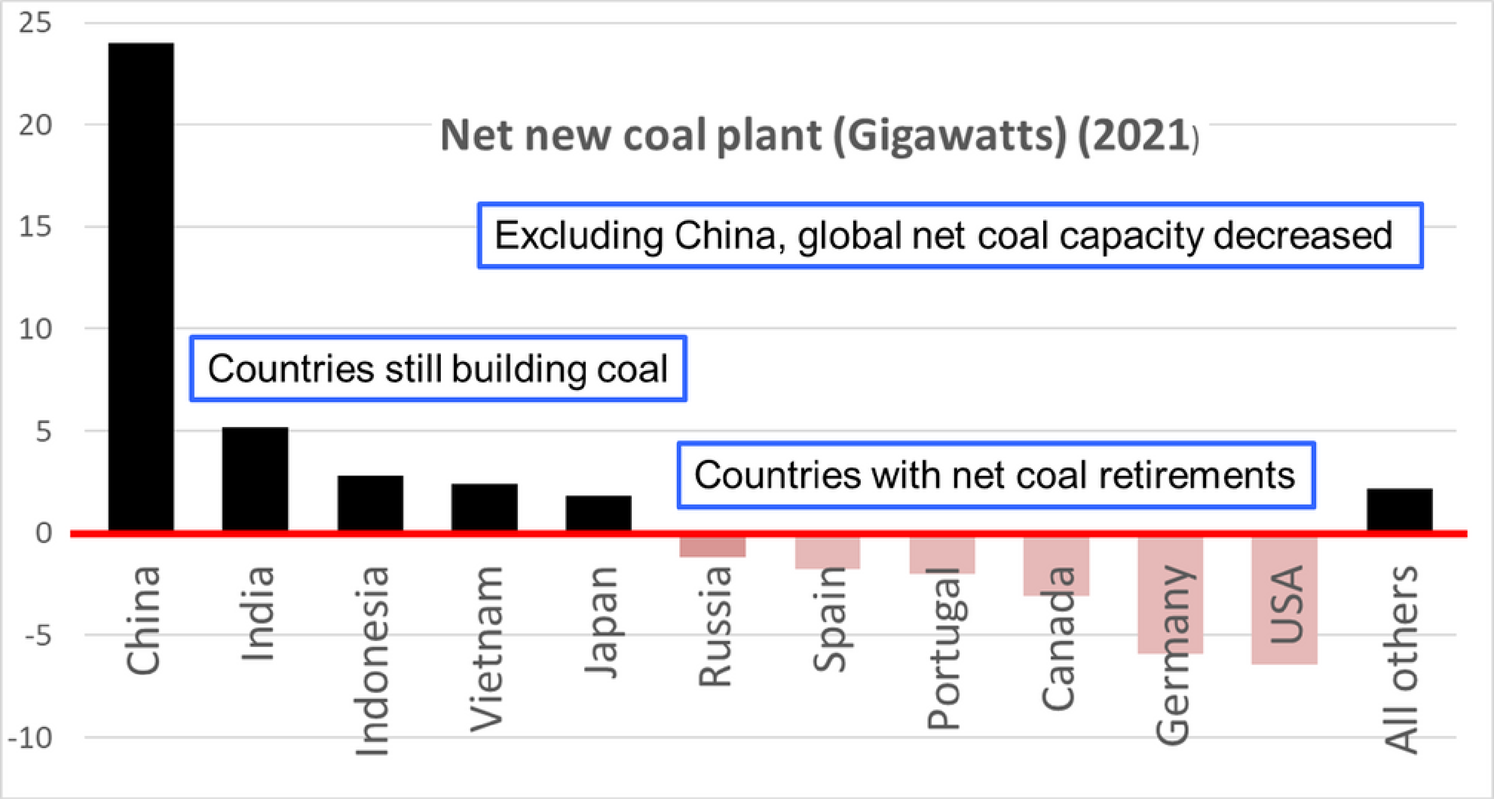
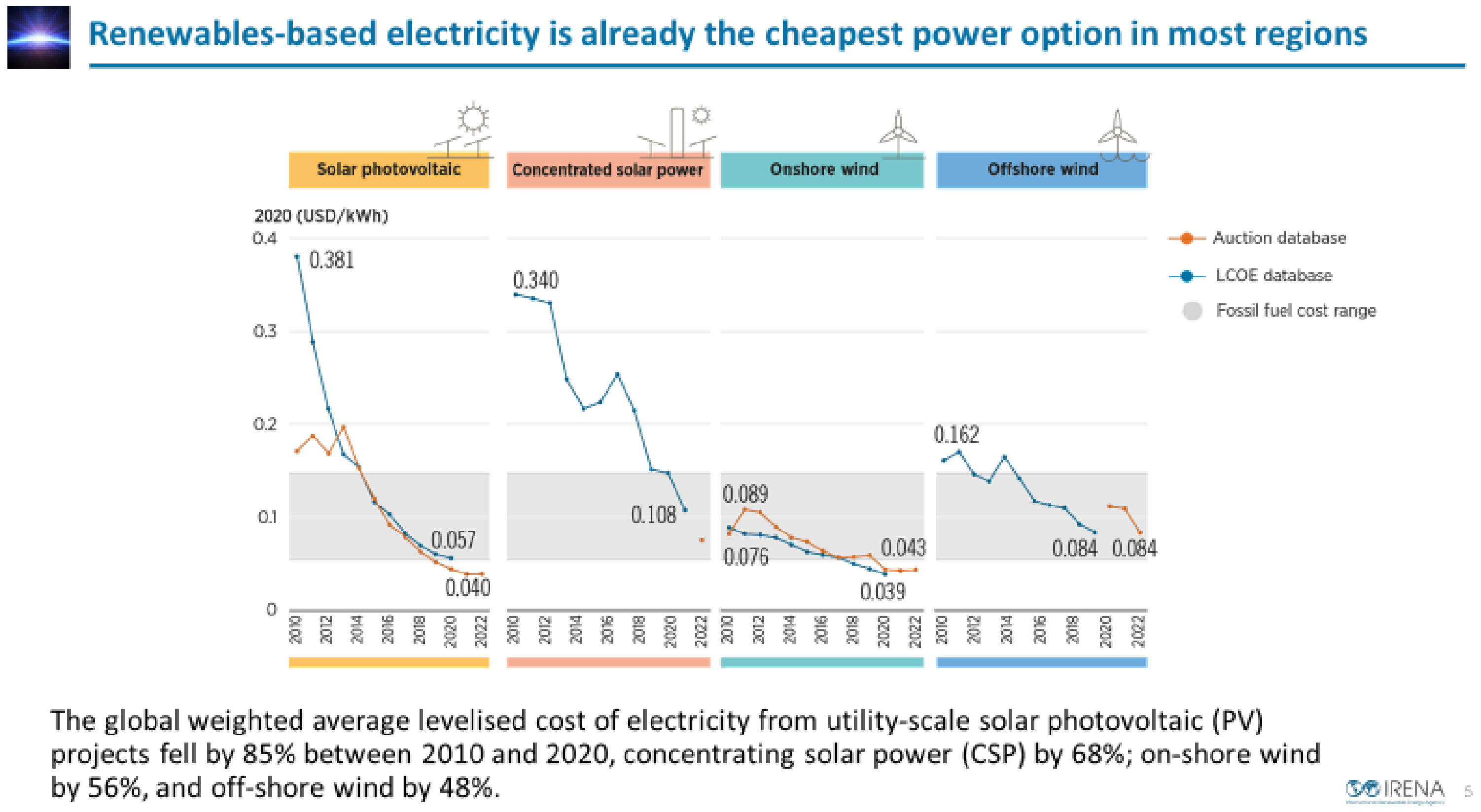


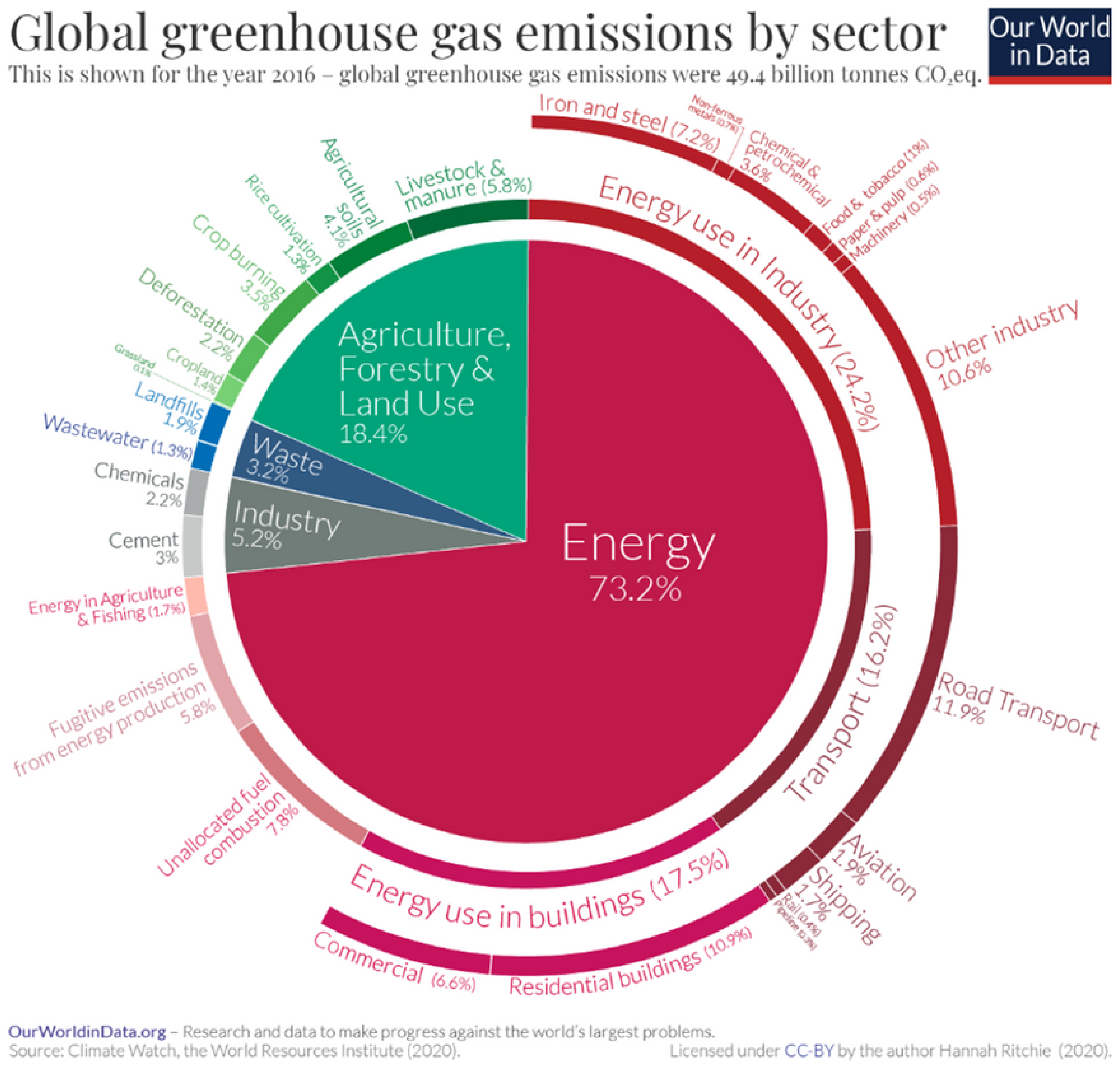




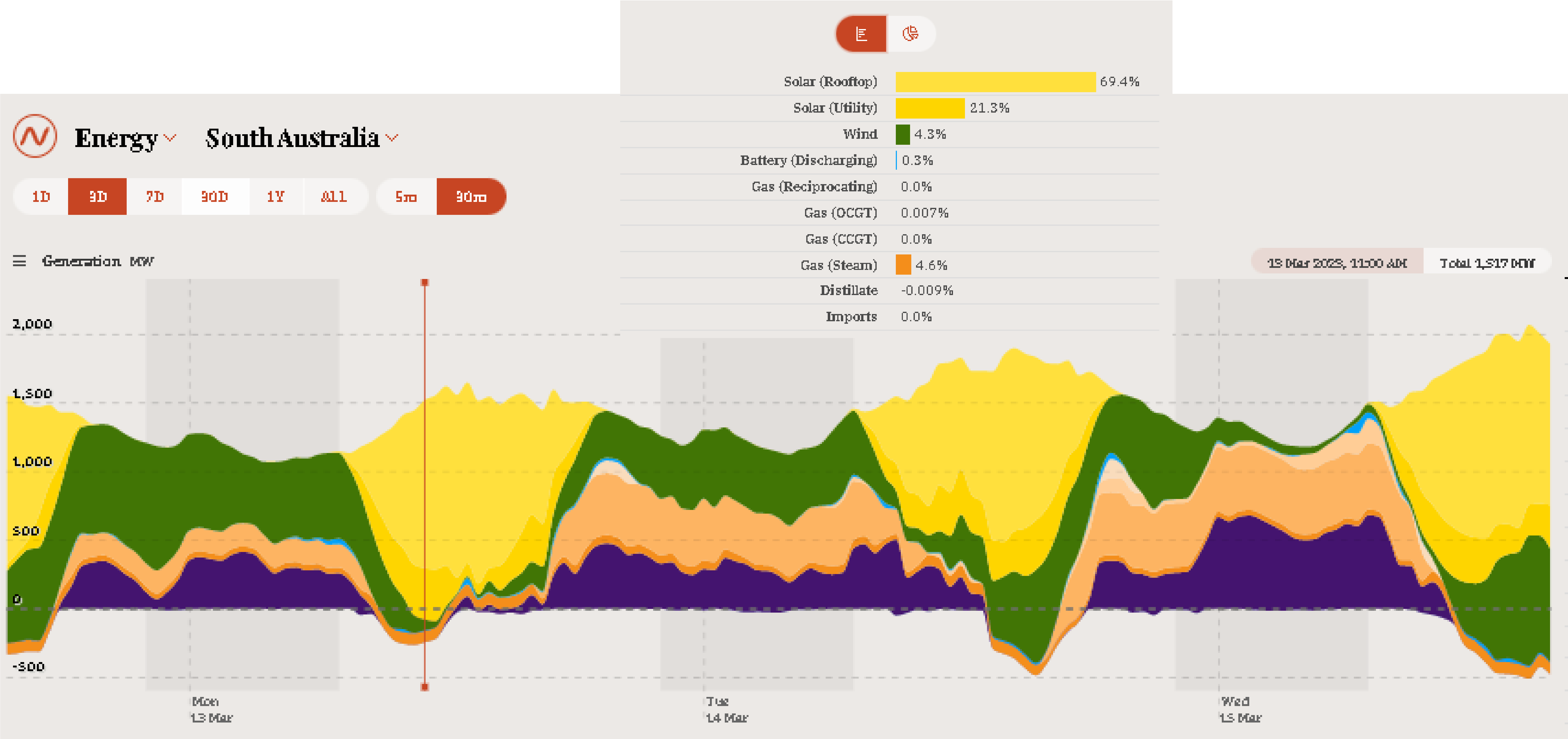
As you can see, cheap solar is overtaking all other new-build energy sources.

Is 100% Renewable Energy system feasible?

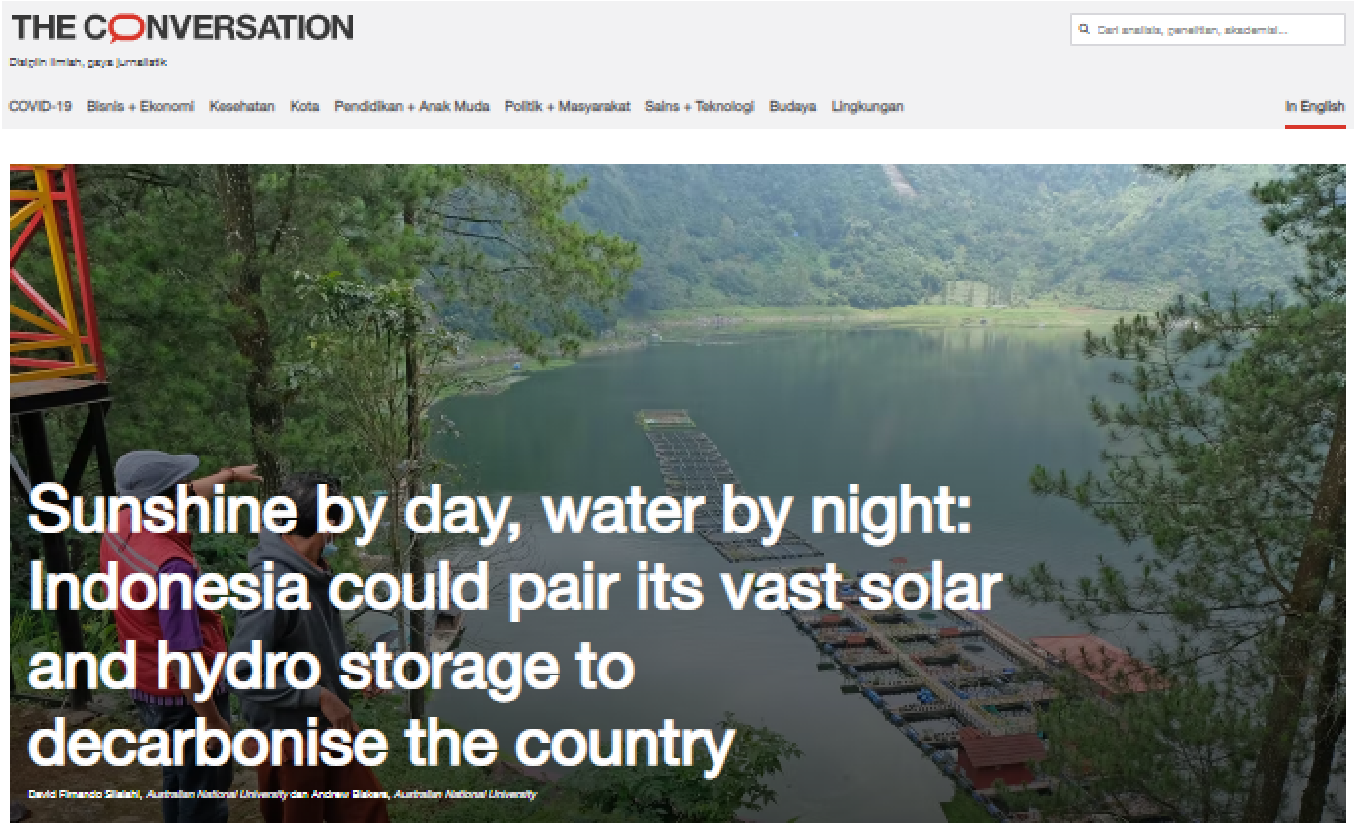
- Coal, oil and gas cause ¾ of global greenhouse emissions
- Solar PV and wind are by far the best prospect for rapidly driving coal, oil and gas out of the economy. Silicon solar cells are 95% of the market.
- All required generation and balancing technology is off-the-shelf
- The evidence of 100% Renewable Energy is technically and economically feasible goes beyond academic studies. 97% of **Scotland** electricity consumption in 2020 was from renewable energy, primarily wind coupled with hydroelectricity. 72% of **Danish** domestic electricity supply mainly from wind. **South Australia** generated 71% of its annual electricity demand from wind and solar PV with **100% renewable supply over 10 days.**



Energy
Tasmania
Consumption
Generation
Export
1D
3D
7D
30D
1Y
ALL
5m
30m
Generation MW
14 Mar 2023, 4:00 PM
Total 1,294 MW
1,500
1,000
500
0
-500
Mon 13 Mar
Tue 14 Mar
Wed 15 Mar
Price $/MWh
$113.00
300
200
100
0
Temperature °C
Av 22.0°C
20
10
14 Mar 2023, 4:00 PM AEST
Default
Power MW
Contribution to generation
Av.Value $/MWh
Sources 1,528 $113.00
Solar (Rooftop) 76 4.9% –
Wind 86 5.6% –
Hydro 1,367 89.4% –
Gas (OCGT) -0.2 -0.01% –
Imports 0 –
Loads -234
Exports -234 –
Net 1,294
Renewables 1,528 100.0%
1,528 MW


Energy
South Australia
1D
3D
7D
30D
1Y
ALL
5m
30m
Generation MW
Solar (Rooftop) 69.4%
Solar (Utility) 21.3%
Wind 4.3%
Battery (Discharging) 0.3%
Gas (Reciprocating) 0.0%
Gas (OCGT) 0.007%
Gas (CCGT) 0.0%
Gas (Steam) 4.6%
Distillate -0.009%
Imports 0.0%
13 Mar 2023, 11:00 AM
Total 1,317 MW
2,000
1,500
1,000
500
0
-500
Mon
13 Mar
Tue
14 Mar
Wed
15 Mar

Sunshine by day, water by night



	Power (MW)	Annualized Cost ($/kWh)	Life span	Efisiensi	Response Time
PHS	100-5000	19 $/kWh	40	82%	s-min
LIB	0-100	78 $/kWh	10	85-90%	20ms-s
RFB	0.03-3	116 $/kWh	20	70-80%	< 1 ms

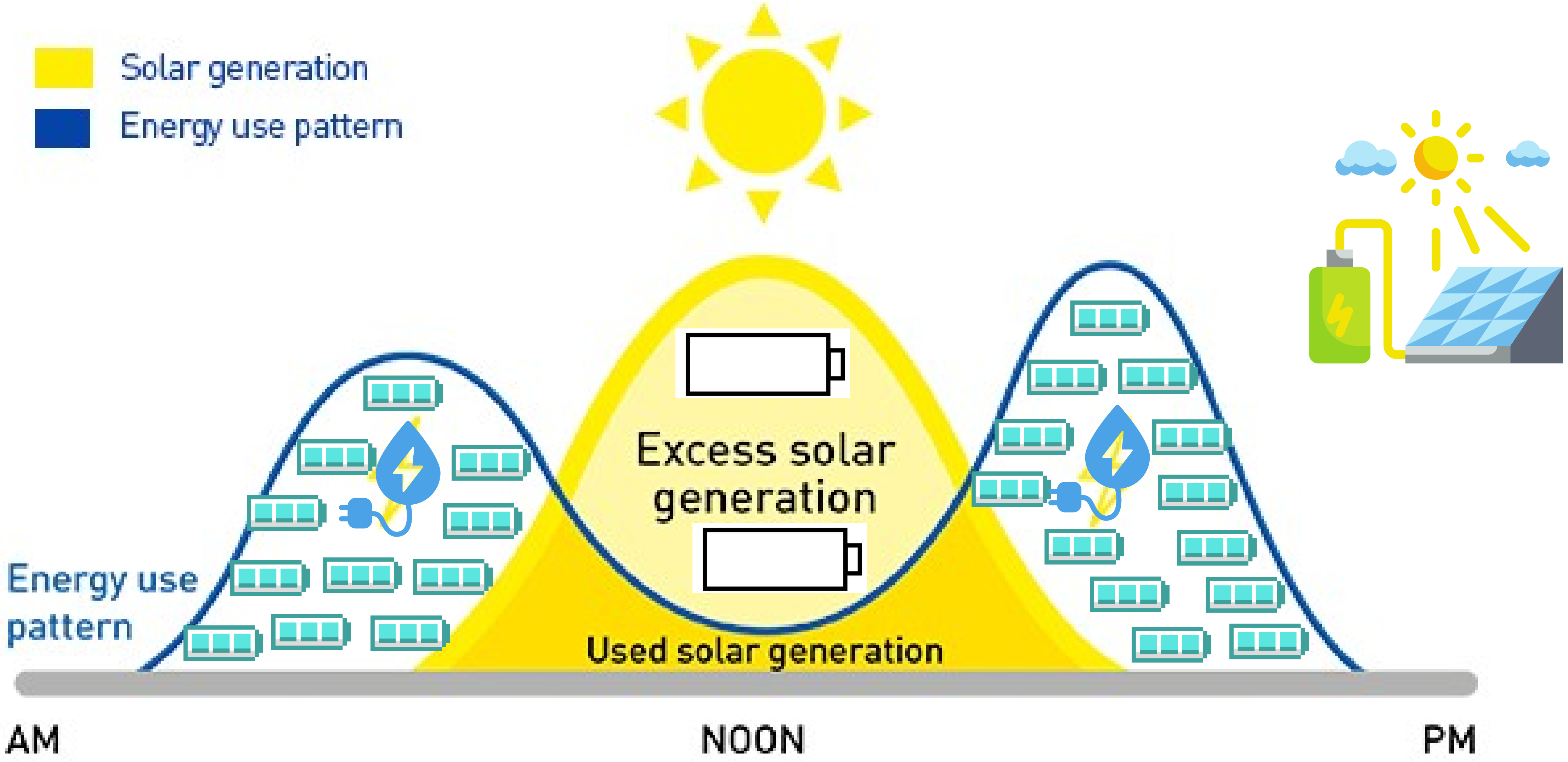


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Table 2. Estimated storage requirements (days) for several regions for 100% renewable energy (primarily solar and wind with existing hydro and bio).

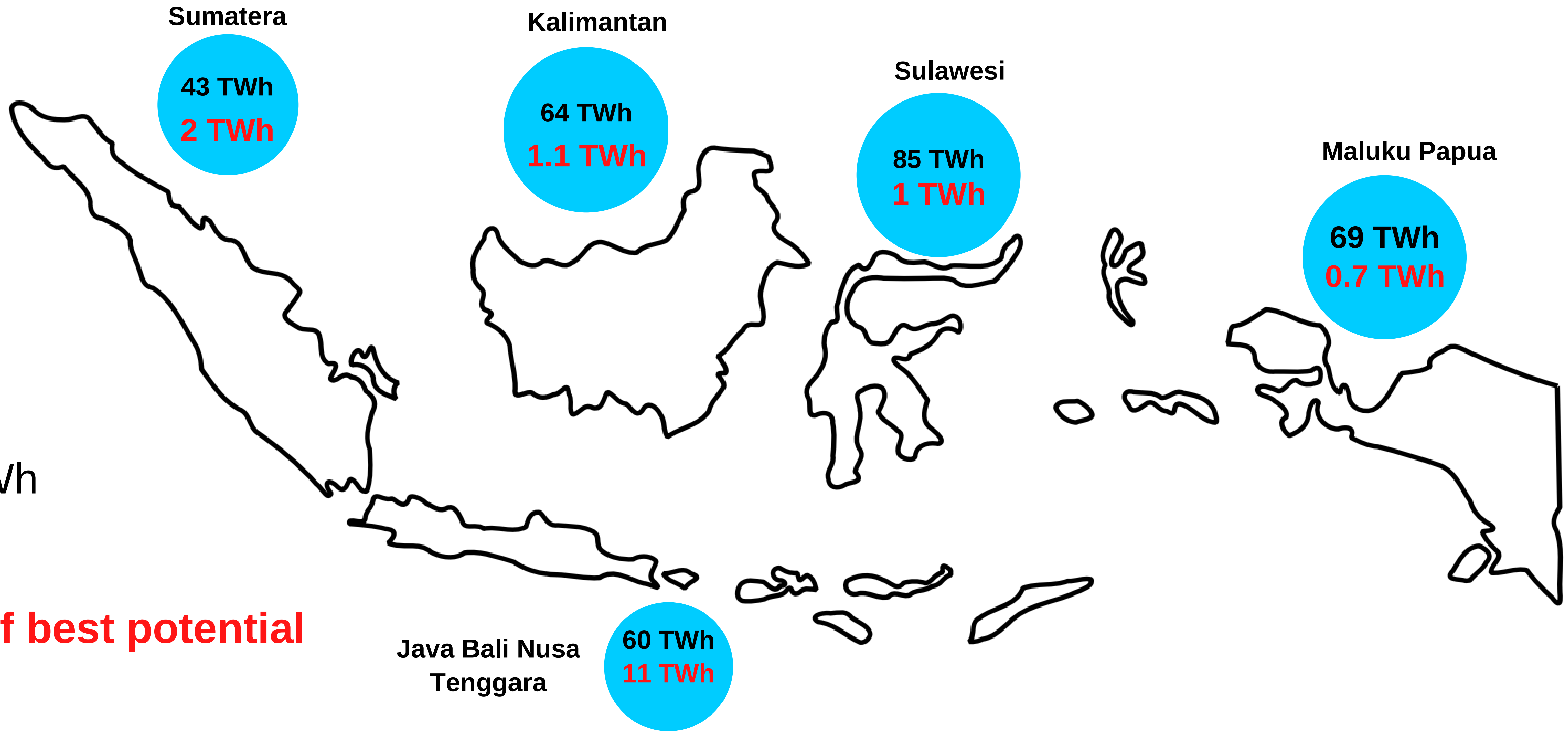
Author	**Blakers et al., (2017) [12]**		**Lu et al., (2021) [9]**		**Lu et al., (2021) [23]**		**Cheng et al., (2021) [24]**	
Studied country/region	Australia		Australia		Southeast Asia		Japan	
Scope of study	Electricity		Energy		Electricity		Electricity	
Annual Demand (TWh)	205		393		7524		896	
Energy Storage (GWh)—min/max	407	574	321	2049	15,506	44,707	2069	13,750
Estimated required storage (day)	0.7	1.0	0.3	1.9	0.8	2.2	0.8	5.6

How large the required storage for 100% RE Indonesia?

Table 7. Storage requirements for 100% renewable electricity in Indonesia

10 MWh - baseline	Annual demand (TWh)	PHES (GW)	PHES (TWh)	Storage duration (hour)
Sumatera (A)	726	218	2.0	9
Java Bali Nusa Tenggara (B)	2,065	728	10.7	15
Kalimantan (C)	206	61	1.1	17
Sulawesi (D)	247	78	1.0	12
Maluku Papua (E)	115	44	0.7	16
Total (A+B+C+D+E)	3,358	1,129	15.5	14
Indonesia super grid	3,358	1,031	10.3	10

Indonesia's Vast Off-River PHES Potential



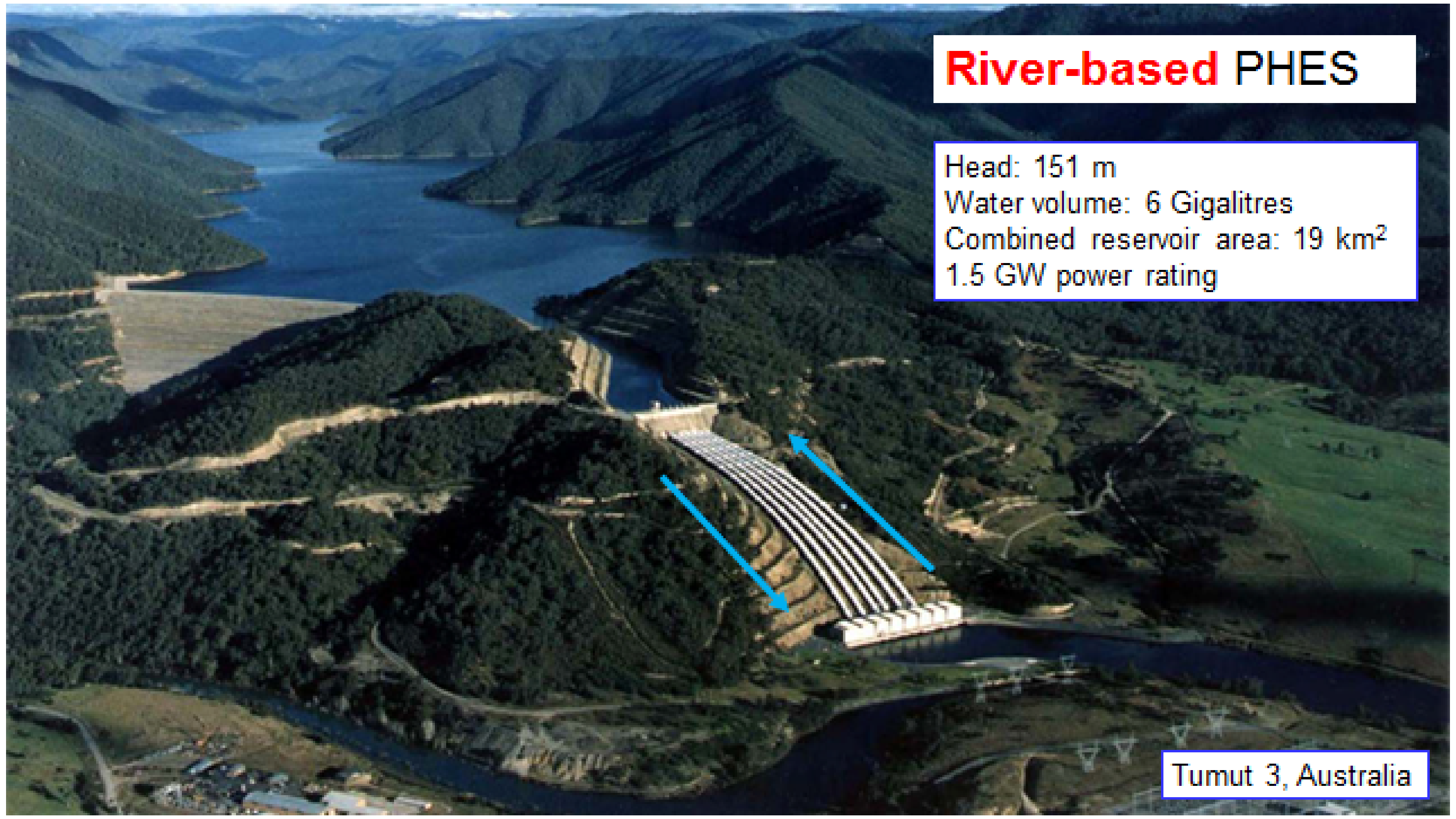
Available potential (class A-E): 821 TWh

Best potential (class A-B): 321 TWh

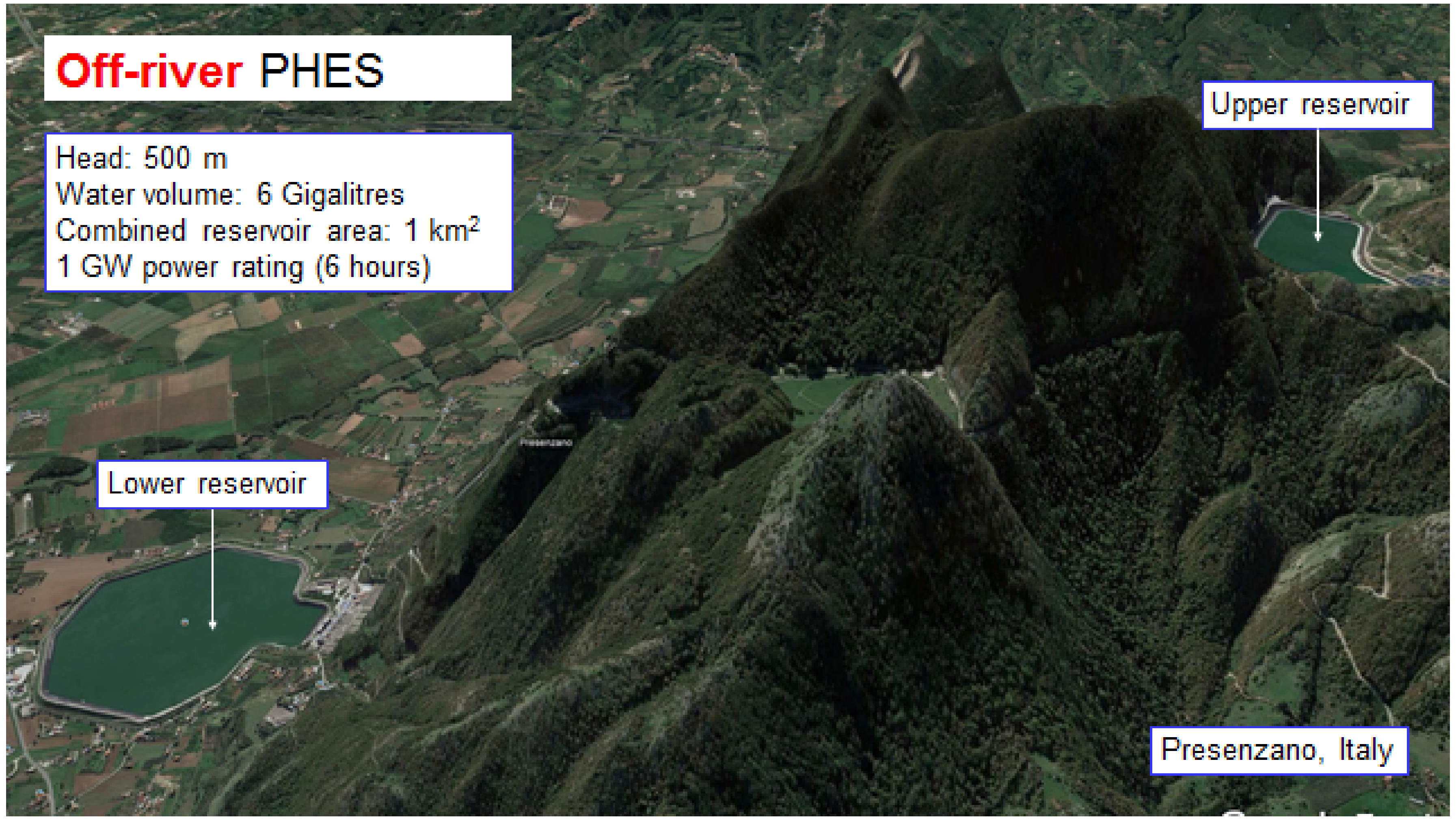
Requirement (10 - 16 TWh): 3 - 5% of best potential

"Indonesia's Vast Off-River Pumped Hydro Energy Storage Potential"
Energies 15, no. 9: 3457. https://doi.org/10.3390/en15093457

PHES - on river



PHES - off river



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Off-river PHES is affordable!

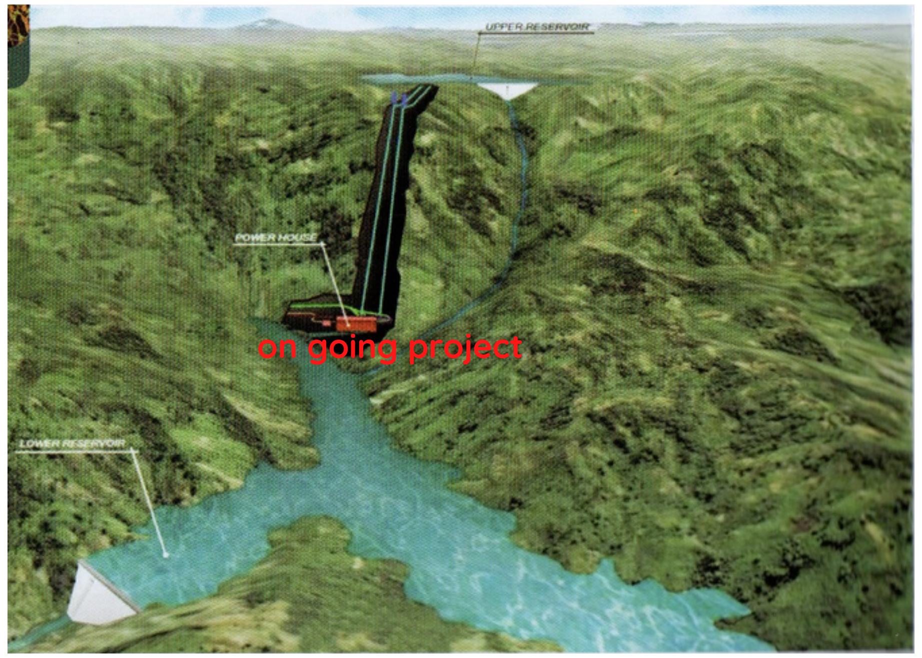
Tesla Battery cost

Megapacks	Capacity (MWh)	Price	Price/kWh
1	3.0	$1,235,890	$406
2	6.1	$2,269,770	$372
5	15.2	$5,579,470	$366
10	30.5	$9,999,290	$328
50	152.4	$43,362,720	$285
100	304.8	$85,227,950	$280
1,000	3,047.6	$848,135,990	$278

*1,000 max

source: https://www.thestreet.com/tesla/news/new-tesla-megapack-details-price

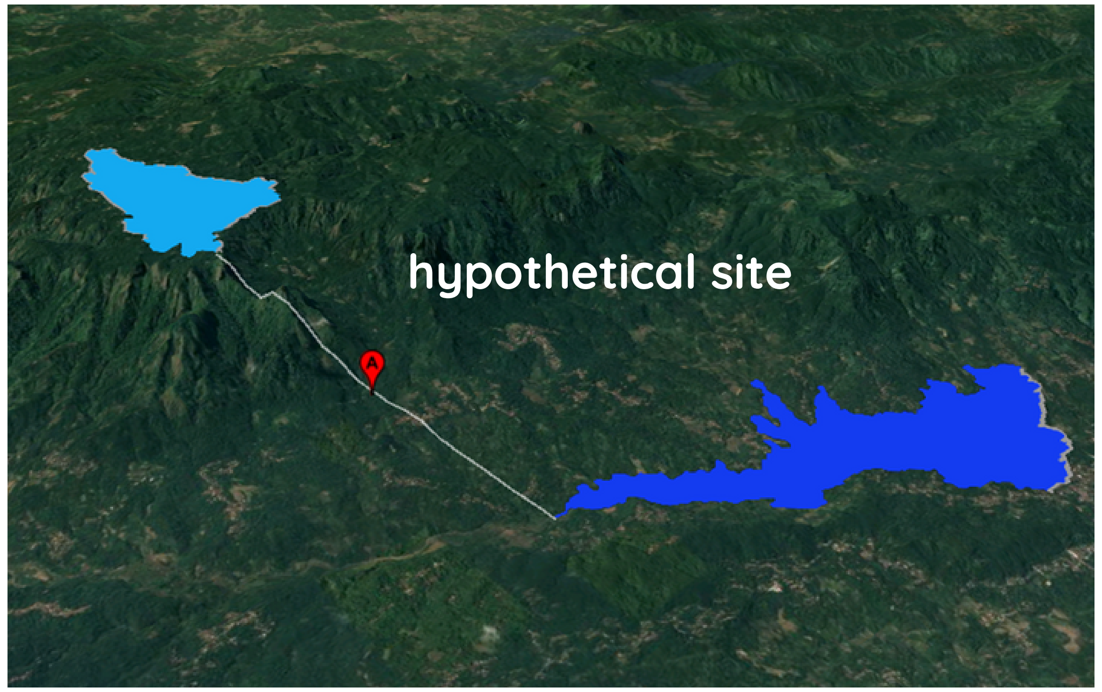
US$ 280 million per GWh



1 GW (8 GWh), US$ 800 million

US$ 100 million per GWh

Upper Cisokan PHES, West Java



7.5 GW (150 GWh), US$ 9.4 billion

US$ 39 million per GWh

Off-rive PHES, Central Java

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Bluefield PHES (on - going research)