

SUPPLEMENTARY INFORMATION

Indonesia's Vast Off-river Pumped Hydro Energy Storage Potential

I. Summary of off-river Pumped Hydro Energy Storage (PHES) potential (Class A/B) sites

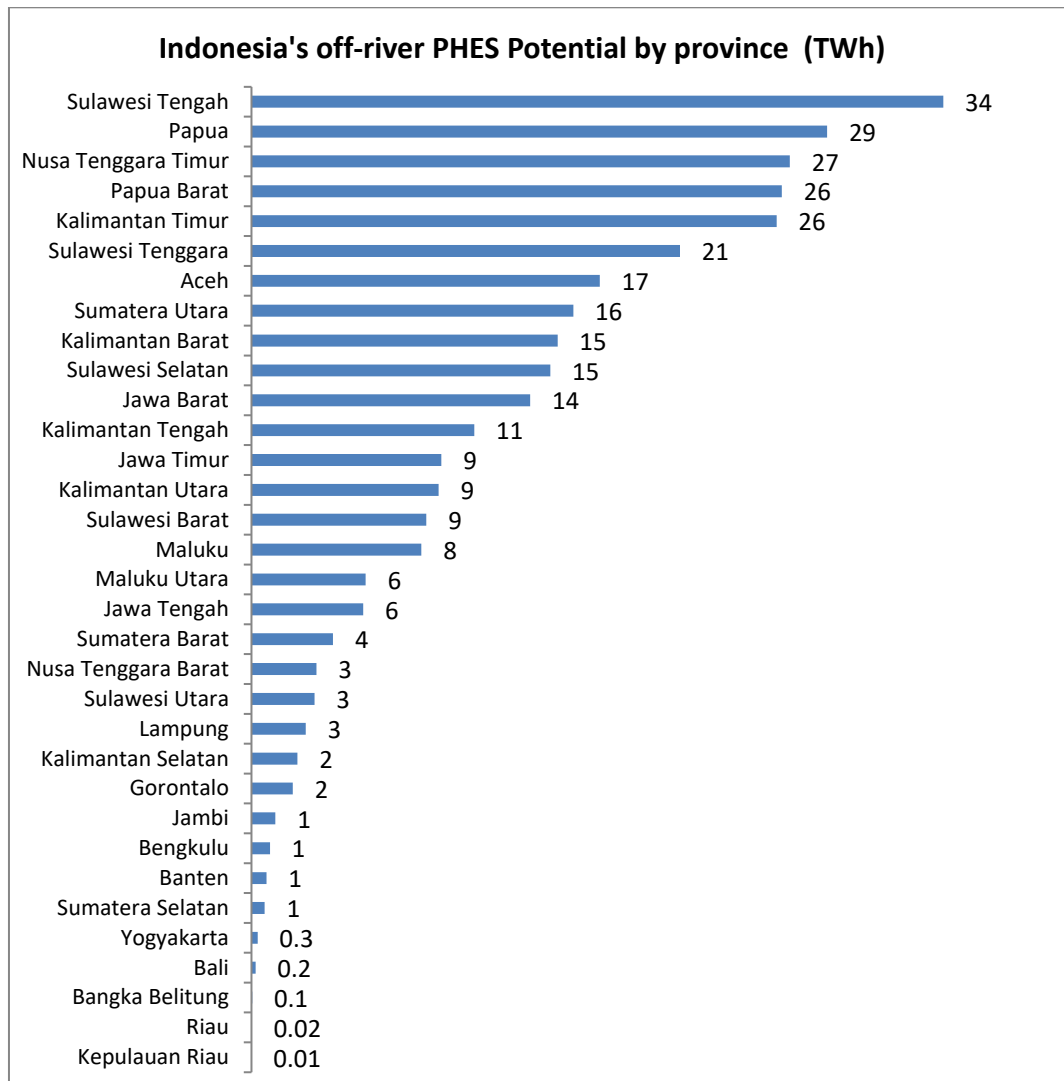


Figure S1. Indonesia's off-river PHES Potential (TWh) by Province (Cost-classes A-E). Original data from the Australian National University [Global Pumped Hydro Atlas](#).

Table S1. Off-river PHES (Class A/B) potential in Indonesia for 6 major regions and Indonesia as a whole. N is the number of sites with storage volume of 5, 15, 50 and 150 GWh. (V) refers to the total storage volume (TWh) of those sites for each reservoir size range. Larger sites often overlap smaller sites and so the total number and volume of sites that is actually available is smaller than simple addition of the 4 rows yields.

Storage volume (GWh)	Indonesia N (V)	Sumatera N (V)	Java N (V)	Kalimantan N (V)	Sulawesi N (V)	Bali Nusa Tenggara N (V)	Maluku N (V)	Papua N (V)
5	148 (0.7)	14 (0.1)	2 (0.01)	16 (0.1)	42 (0.2)	2 (0.01)	2 (0.01)	70 (0.4)
15	943 (14)	120 (2)	27 (0.4)	115 (2)	429 (6)	19 (0.3)	34 (0.5)	199 (3)
50	1457 (73)	206 (10)	70 (3.5)	285 (14)	487 (24)	57 (3)	84 (4)	268 (13)
150	1559 (234)	206 (31)	174 (26)	321 (48)	358 (54)	181 (27)	63 (10)	256 (38)

II. Location and indicative land prices of four PHES examples

In this and subsequent sections, detailed information about four hypothetical PHES systems is presented. This information comprises:

- Location (latitude and longitude)
- Energy storage volume (50 or 150 GWh)
- Synthetic images of each system showing the upper and lower reservoirs, the tunnel route and the reservoir walls
- Reservoir land categorisation and land acquisition cost estimation
- Land categorisation and rainwater estimation in the water catchment area
- Nearby road and transmission infrastructure

Table S2. Indicative land prices in the vicinity of four example PHES systems. In each case, the land costs are the median of about 30 recent sales in and around the site of the hypothetical reservoirs

	Jembrana Regency, Bali Province	Wonosobo Regency, Central Java	Banjar Regency, South Kalimantan Province	Samosir Regency, North Sumatera
Latitude	8.30271°S	7.51855°S	3.07506°S	2.64608°N
Longitude	114.77750°E	109.85212°E	115.45065°E	98.84176°E
Storage volume (GWh)	50	150	150	150
Undeveloped land (\$/m ²)	35	44	11	46
Residential land (\$/m ²)	171	196	125	160

III. Analysis of a 50 GWh PHES site in Jembrana Regency, Bali Province

More detailed information for this site is presented in the paper.

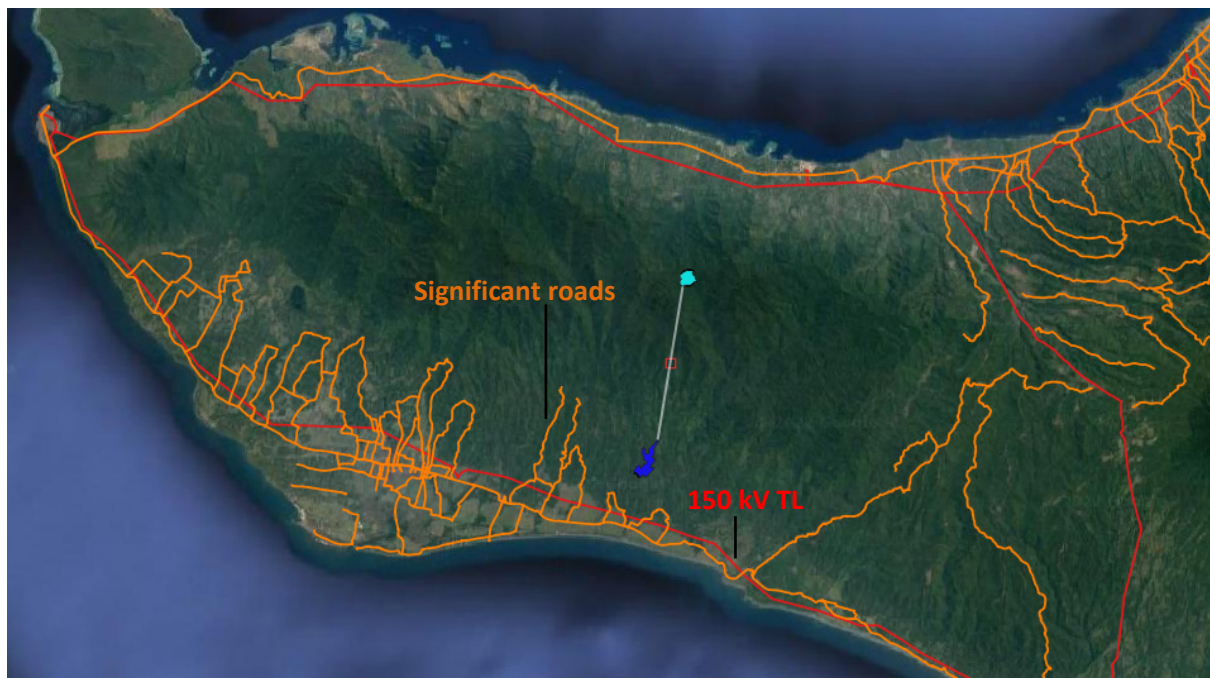


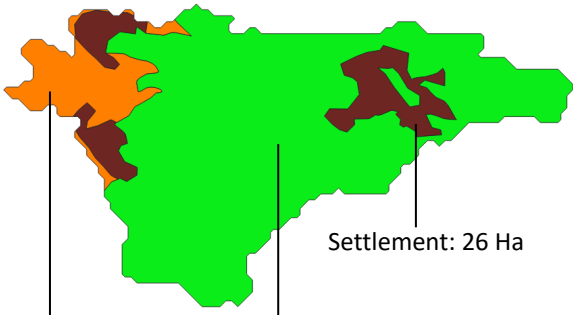
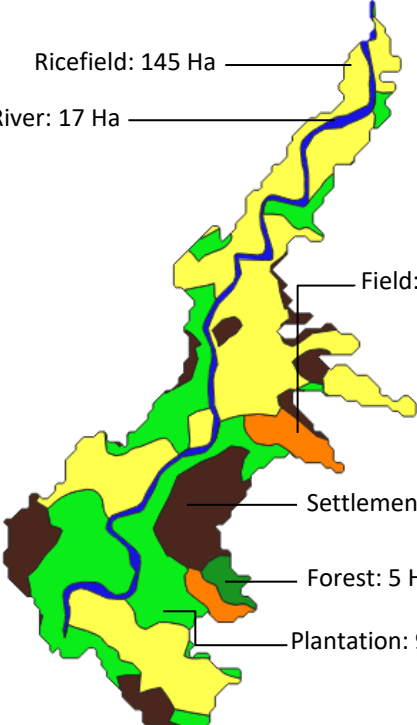
Figure S2. Infrastructure near the potential PHES site in Jembrana Regency, Bali Province. Distance from the lower reservoir to the nearest nearest transmission line (150 kV) is 2.8 km. Distance to the nearest road is 0.3 km.

IV. Analysis of a 150 GWh PHES in Wonosobo Regency, Central Java Province



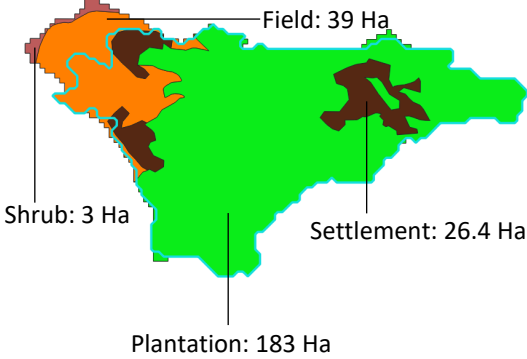
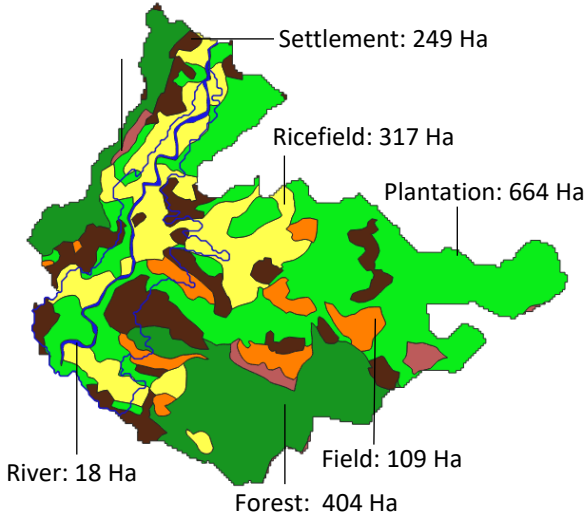
Figure S3. 150 GWh PHES site in Wonosobo Regency, Central Java, Province. Image from [NationalMap](#) and original data from the Australian National University [Global Pumped Hydro Atlas](#).

Table S3. Reservoir land categorisation and land acquisition cost estimation for an example PHES system in Wonosobo Regency, Central Java.

Upper reservoir	Lower reservoir
 <p>Field: 23 Ha</p> <p>Plantation: 182 Ha</p> <p>Settlement: 26 Ha</p>	 <p>Ricefield: 145 Ha</p> <p>River: 17 Ha</p> <p>Field: 15 Ha</p> <p>Settlement: 54 Ha</p> <p>Forest: 5 Ha</p> <p>Plantation: 96 Ha</p>

Upper reservoir	Lower reservoir
<u>Land acquisition:</u> <ul style="list-style-type: none"> - Field: 23 Ha, \$44/m², \$10 million - Plantation: 182 Ha, \$44/m², \$80 million - Settlement: 26 Ha, \$196/m², \$53 million 	<u>Land acquisition:</u> <ul style="list-style-type: none"> - Forest: 5 Ha, \$44/m², \$2 million - Plantation: 96 Ha, \$44/m², \$42 million - Field: 15 Ha, \$44/m², \$7 million - Ricefield: 145 Ha, \$44/m², \$44 million - Settlement: 54 Ha, \$196/m², \$109 million - River: 17 Ha, \$44/m², \$7 million
Total land acquisition cost: \$373 million	

Table S4. Land categorisation and rainwater estimation in the water catchment area for an example PHES system in Wonosobo Regency, Central Java.

Upper reservoir watercatchment area	Lower reservoir watercatchment area
<p>Upper reservoir watercatchment area is 251 Ha.</p>  <p>Field: 39 Ha Shrub: 3 Ha Settlement: 26.4 Ha Plantation: 183 Ha</p>	<p>Lower reservoir watercatchment area is 1795 Ha.</p> <p>Shrub: 36 Ha</p>  <p>Settlement: 249 Ha Ricefield: 317 Ha Plantation: 664 Ha River: 18 Ha Field: 109 Ha Forest: 404 Ha</p>
<p><u>Rain water (2201mm/year):</u></p> <ul style="list-style-type: none"> - Field: 39 Ha, 0.2 GL per year - Plantation: 183 Ha, 1.6 GL per year - Settlement: 26.4 Ha, 0.1 GL per year - Shrub: 3 Ha, 0.01 GL per year 	<p><u>Rain water:</u></p> <ul style="list-style-type: none"> - Forest: 404 Ha, 3.6 GL per year - Plantation: 664Ha, 5.8 GL per year - Field: 109 Ha, 0.5 GL per year - Ricefield: 317 Ha, 2.8 GL per year - Settlement: 249 Ha, 1.4 GL per year - River: 18 Ha, 0.4 GL per year - Shrub: 36 Ha, 0.1 GL per year
Total annual rainwater from watercatchment area: 16.2 GL	

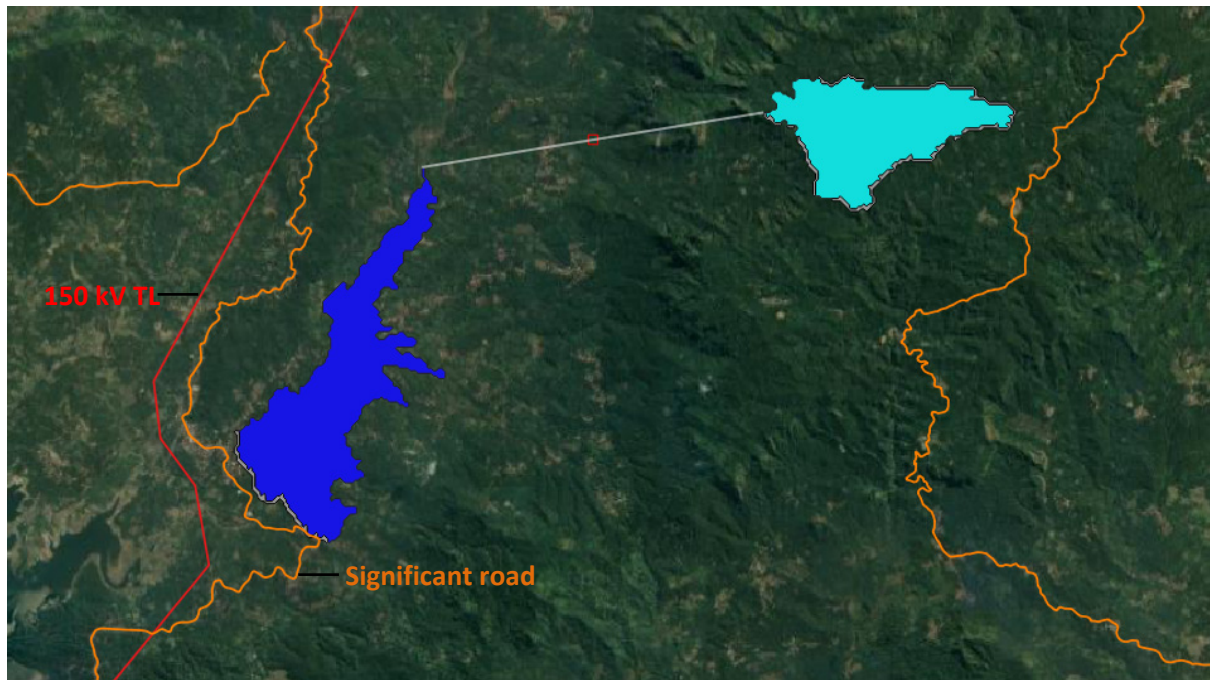


Figure S4. Infrastructure near to the PHEs site in Wonosobo Regency, Central Java. From the lower reservoir to the nearest 150 kV transmission line is 0.7 km. A road is adjacent to the lower reservoir.

V. Analysis of a 150 GWh PHES site in Banjar Regency, South Kalimantan Province

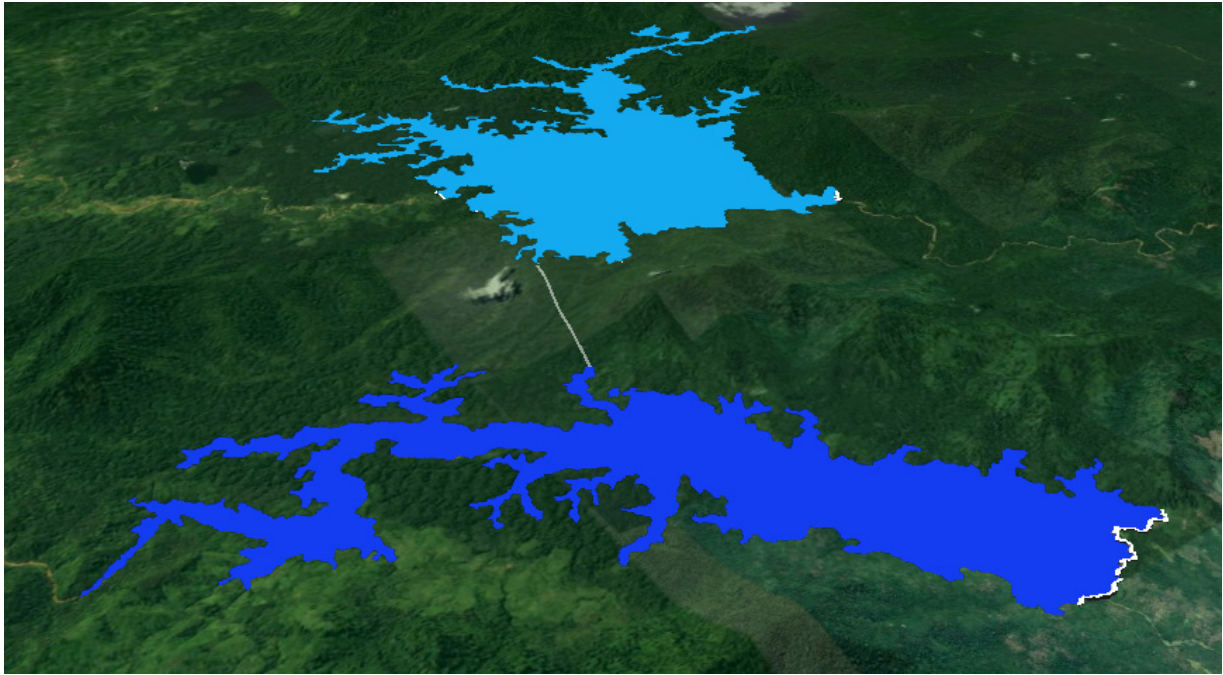


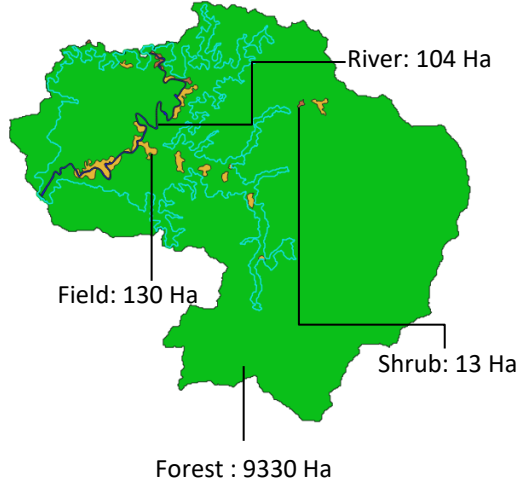
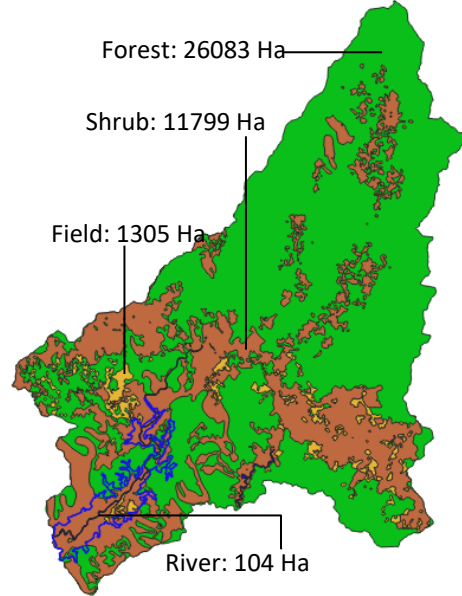
Figure S5. 150 GWh PHES site in Banjar Regency, South Kalimantan Province. Image from [NationalMap](#) and original data from the Australian National University [Global Pumped Hydro Atlas](#).

Table S5. Reservoir land categorisation and land acquisition cost estimation for an example PHES system in Banjar Regency, South Kalimantan Province, Indonesia

Upper reservoir	Lower reservoir
<div>Forest : 1792 Ha</div> <div>Shrub: 11 Ha</div> <div>River: 38 Ha</div> <div>Field: 109 Ha</div>	<div>Shrub: 918 Ha</div> <div>Forest : 264 Ha</div> <div>Field: 109 Ha</div> <div>River: 55 Ha</div>

Upper reservoir	Lower reservoir
<u>Land acquisition:</u> <ul style="list-style-type: none"> - Forest: 1792 Ha, \$11/m², \$193 million - Field: 109 Ha, \$11/m², \$12 million - River: 38 Ha, \$11/m², \$4 million - Shrub: 11 Ha, \$11/m², \$1 million 	<u>Land acquisition:</u> <ul style="list-style-type: none"> - Forest: 264Ha, \$11/m², \$28 million - Field: 78 Ha, \$11/m², \$8 million - River: 55 Ha, \$11/m², \$6 million - Shrub: 918 Ha, \$11/m², \$99 million
Total land acquisition cost: \$351 million	

Table S6. Land categorisation and rainwater estimation in the water catchment area for an example PHES system in South Kalimantan

Upper reservoir watercatchment area	Lower reservoir watercatchment area
<p>Upper reservoir watercatchment area is 9513 Ha.</p>  <p>Forest : 9330 Ha</p> <p>Field: 130 Ha</p> <p>River: 104 Ha</p> <p>Shrub: 13 Ha</p>	<p>Lower reservoir watercatchment area is 39292 Ha.</p>  <p>Forest: 26083 Ha</p> <p>Shrub: 11799 Ha</p> <p>Field: 1305 Ha</p> <p>River: 104 Ha</p>
<u>Rain water (2625 mm/year):</u> <ul style="list-style-type: none"> - Forest: 9330 Ha, 98 GL per year - Field: 130 Ha, 1 GL per year - River: 41 Ha, 1 GL per year - Shrub: 13 Ha, 0.1 GL per year 	<u>Rain water:</u> <ul style="list-style-type: none"> - Forest: 26083 Ha, 274 GL per year - Field: 1305 Ha, 7 GL per year - River: 104 Ha, 3 GL per year - Shrub: 11799 Ha, 47 GL per year
Total annual rainwater from water catchment area: 430 GL	

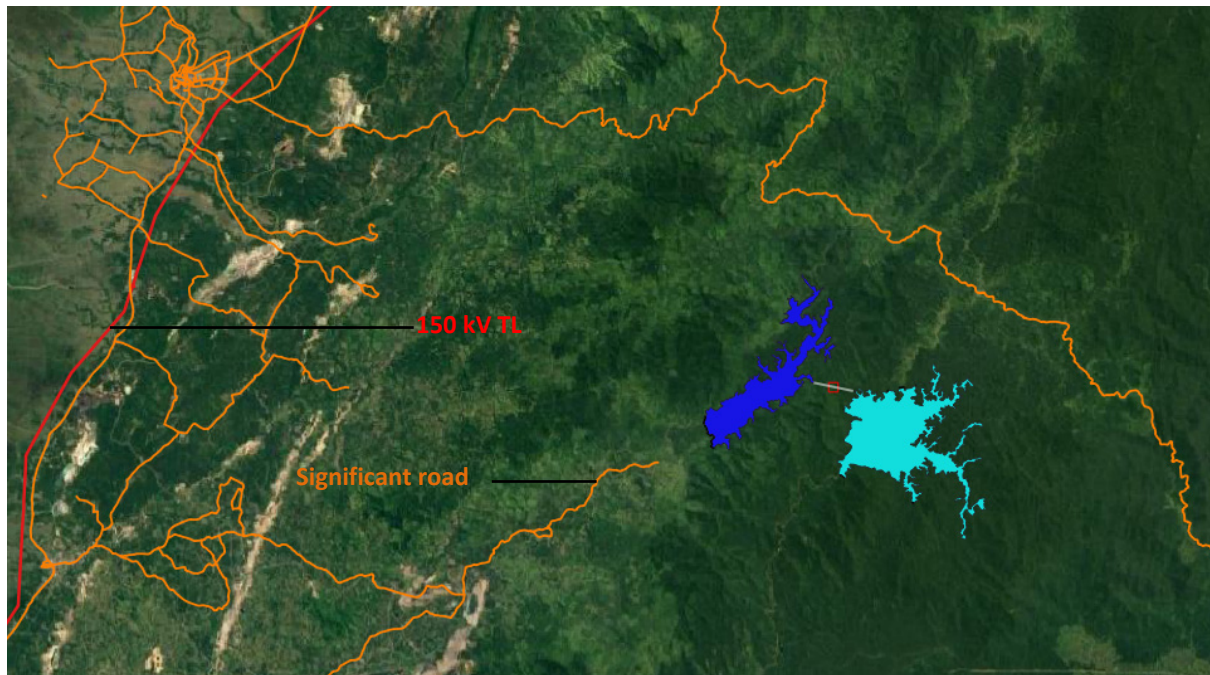


Figure S6. Infrastructure near to the PHES site in Banjar Regency, South Kalimantan. Distance from the lower reservoir to the nearest nearest transmission line (150 kV) is 31 km. Distance to the nearest road is 6 km.

VI. Analysis of a 150 GWh PHES site in Samosir Regency, North Sumatera Province

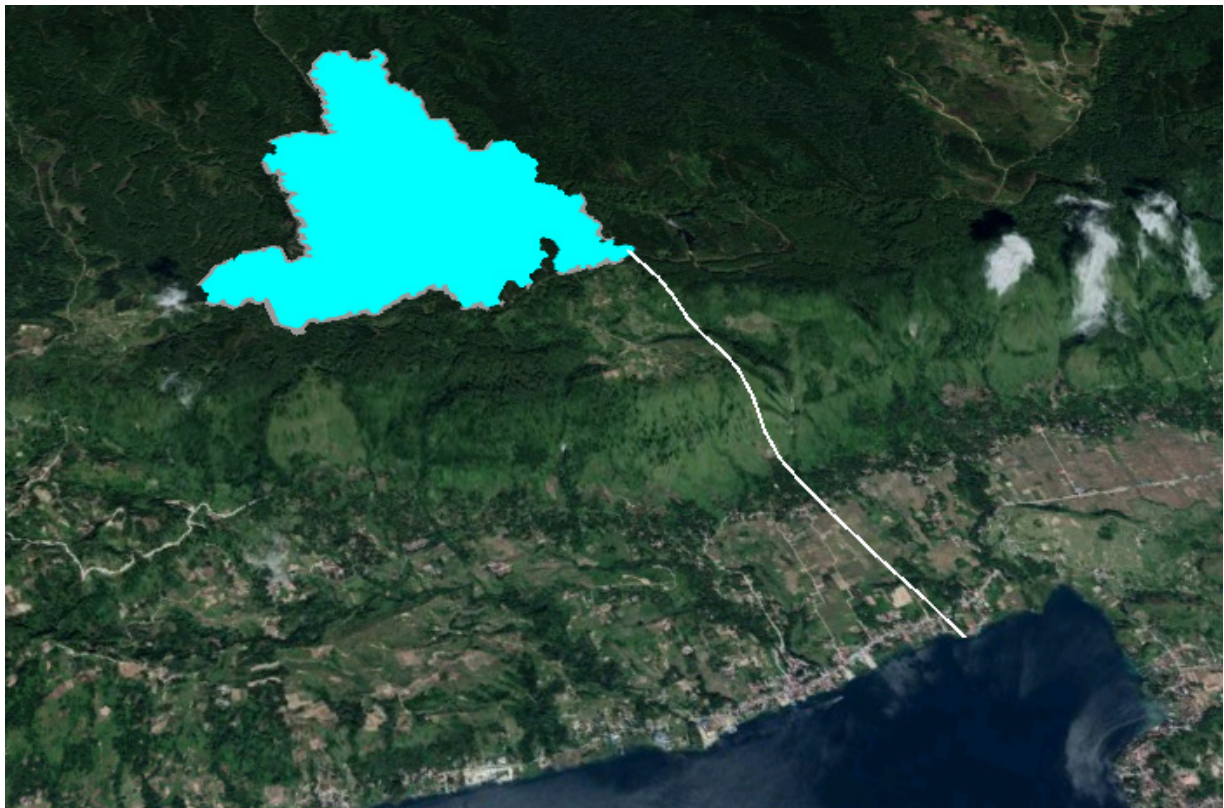
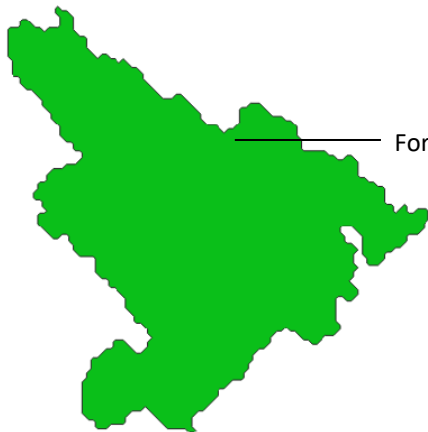


Figure S7. 150 GWh PHES site in Samosir Regency, North Sumatera Province. Image from [NationalMap](#) and original data from the Australian National University [Global Pumped Hydro Atlas](#).

Table S7. Reservoir land categorisation and land acquisition cost estimation for an example PHES system in North Sumatera

Upper reservoir	Lower reservoir
 <p>Forest : 411 ha</p>	<p>Lake Toba</p>
<p><u>Land acquisition:</u> Forest: 411 Ha, \$46/m², \$188 million</p>	<p><u>Land acquisition:</u> - Lake Toba is utilised as the lower reservoir, thus cost of land acquisition for lower reservoir can be avoided.</p>

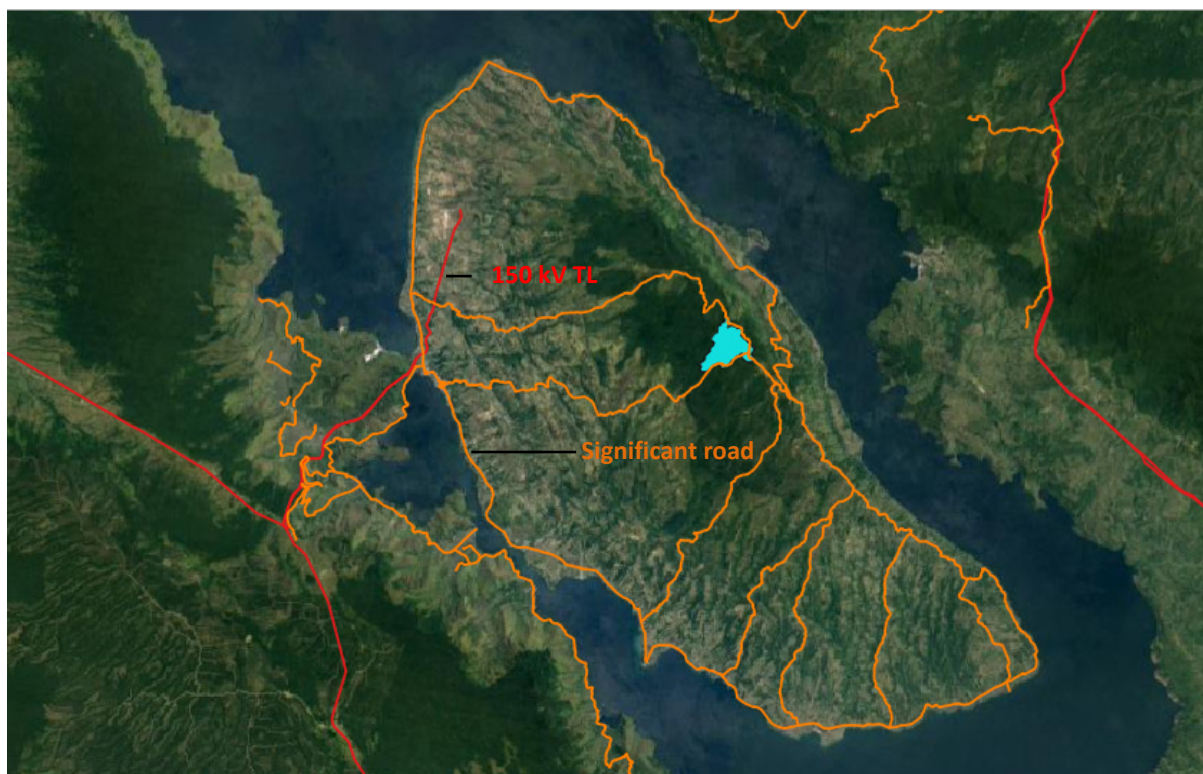


Figure S8. Infrastructure near to the PHES site in Samosir Regency, North Sumatra. Distance from the lower reservoir (Lake Toba) to transmission (150 kV) is 17 km.