# Potential for Floating Solar in Indonesia: A “quick-look” Assessment - October 2017


Representative view – **40 MW floating solar on abandoned coal mining site in Anhui Province, PRC;** this is the largest known floating solar PV installation in the world as of September 2017, Photo credit: ChinaDaily.com

## Floating & other non-conventional locations for Solar PV in Indonesia

- Non-conventional solar locations include:
  - Existing Hydro Reservoirs
  - Lakes
  - Estuaries of large rivers
  - Coastal Bays

- Potential for **several GW** at these types of sites -- these notes show indicative aggregate capacity of 975 MW at 6 sites

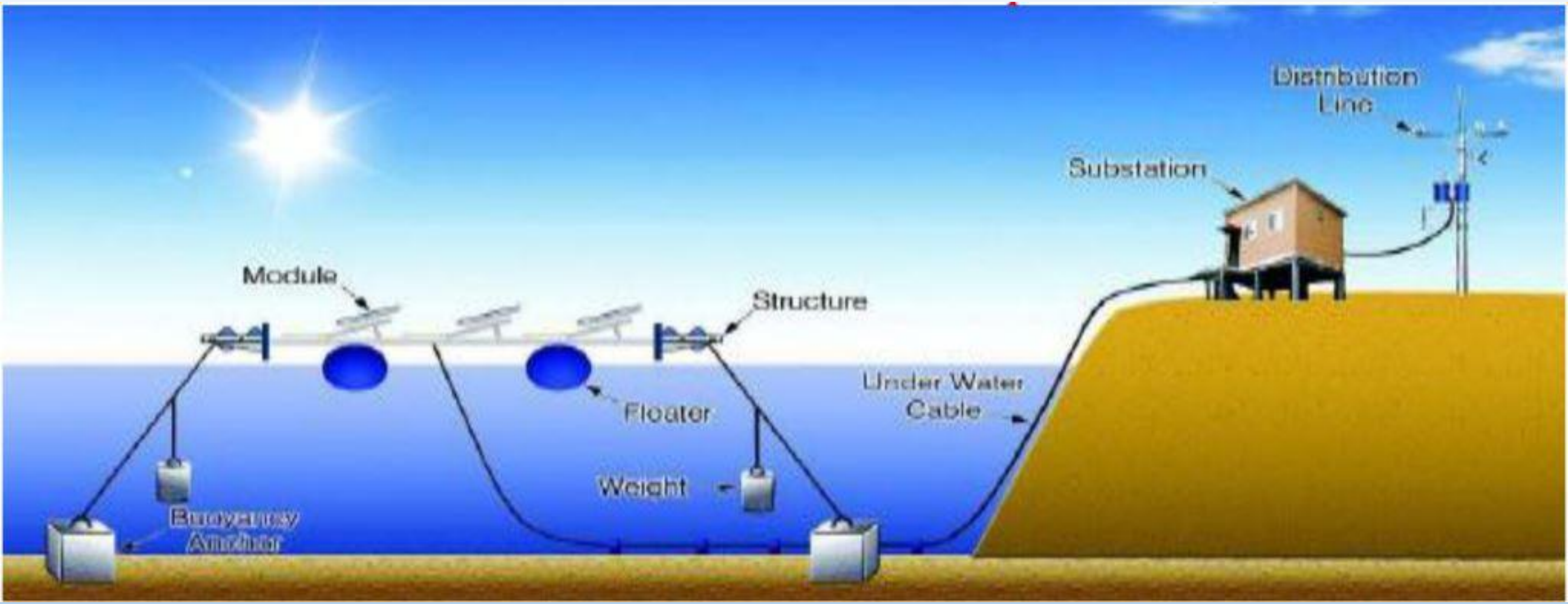
- <u>Marine</u> floating solar potential is effectively unlimited in Indonesia;
  - LCOE < diesel, based on limited commercial deployment and operational experience, e.g., Swimsol in Maldives http://swimsol.com/#lagoon

# Floating PV Systems: the basics

*Major benefits*

- Natural cooling from the water increases PV energy yield (vs. 10% penalty at some tropical sites, e.g., ground-mounted in Cambodia)
- Floating systems contribute to reducing water evaporation $\Rightarrow$ improves climate resilience of river basin with indirect benefits to and no competition with agriculture
- Fast deployment: over 1,000 MW per year installation rates are logistically feasible
- Scalable: can be built in stages to match demand growth
- Modular: build in stages to minimize initial capital and overall financing risks

# Floating Solar Power Plant Layout (elevation view)




Source: *International Journal of Current Research and Modern Education (IJCRME) ISSN (Online): 2455 – 5428 & Impact Factor: 3.165 Special Issue, NCFTCCPS - 2016*

# Floating Solar PV Systems – Installations

*United Kingdom*:

6.3 MW on a water reservoir in London (Thames Water)

*Japan*:

2.3 MW, Kasai City, Japan

*Singapore*:

World's largest testing center for floating solar PV systems is a collaborative effort of Singapore's Economic Development Board (EDB), Public Utilities Board (PUB) and Solar Energy Research Institute of Singapore (SERIS)

http://news.nus.edu.sg/highlights/11022-floating-solar-panels-make-waves

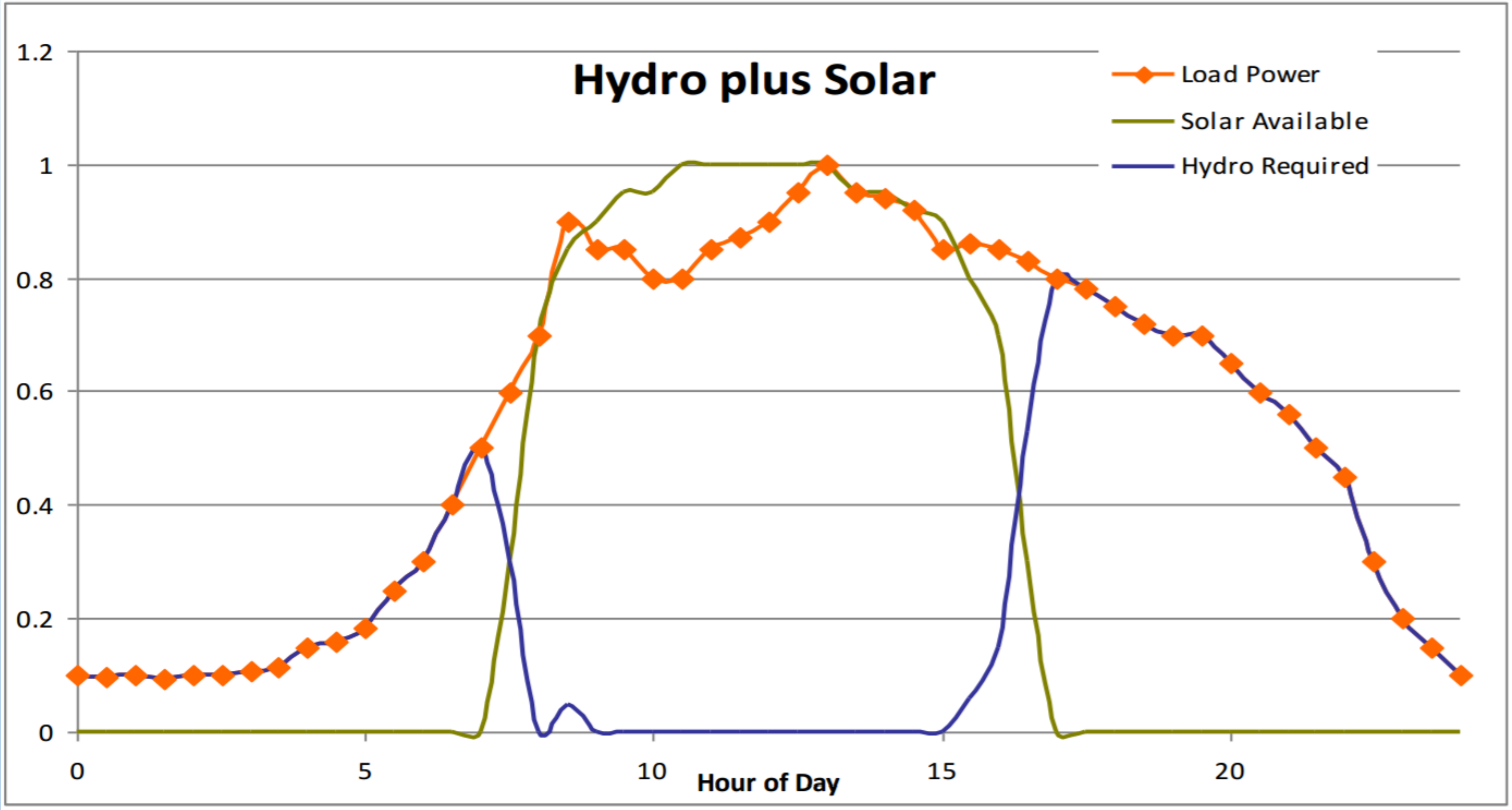
# Hybrid Hydro-Solar Energy Systems

A Hybrid Energy System consists of two or more renewable energy sources used together to provide increased system efficiency, and greater balance in energy supply.

In a Hydro-Solar Hybrid Energy System, hydroelectric power is integrated with solar PV installed on floating structures in an existing reservoir. Key advantages include:

1. **Increased power capacity and energy output with same footprint** – power density is increased; water flow can be reduced as solar ramps up
2. Hydropower generation's quick ramping serves as **energy storage** to balance variable solar output
3. Floating solar marginally **reduces water evaporation**
4. **Existing transmission lines** can be upgraded if necessary at lower cost than greenfield transmission capacity

# Typical load and production profiles for Hydro+Solar



# Water Use Efficiency: Synergy of Hydro-Solar Combination

**Total energy delivered from the original hydro plant can be enhanced significantly by adding the floating solar on the reservoir surface**

- Typical hydro designs are based on 50% plant load factor, e.g., 100 MW project produces 438,000 MWh per year
- Solar PV plant load factor is typically 15 - 20%, e.g., a 100 MW PV plant produces 131,400 – 175,200 MWh per year – up to 40% of a 100 MW hydro plant output
- Some hydro plants have greatly reduced output during dry season
- Since annual water flow through a hydro system is the rate-limiting factor for energy output (MWh), a co-located solar component will allow increased dispatch-able energy production, making full use of existing grid connection(s)

# Considerations for Floating Solar

➢ Hypothetical 100 MW project of floating solar PV requires:

1. **$105 million estimated investment**

   Installed capacity assumed to require 2 hectare / MW (0.5 MW / hectare)

   1 km x 1 km area required for 50 MW capacity

2. **Based on a moderate solar irradiance zone**

✓ **Minimal environmental or social impacts** based on current deployments (limited publications available)

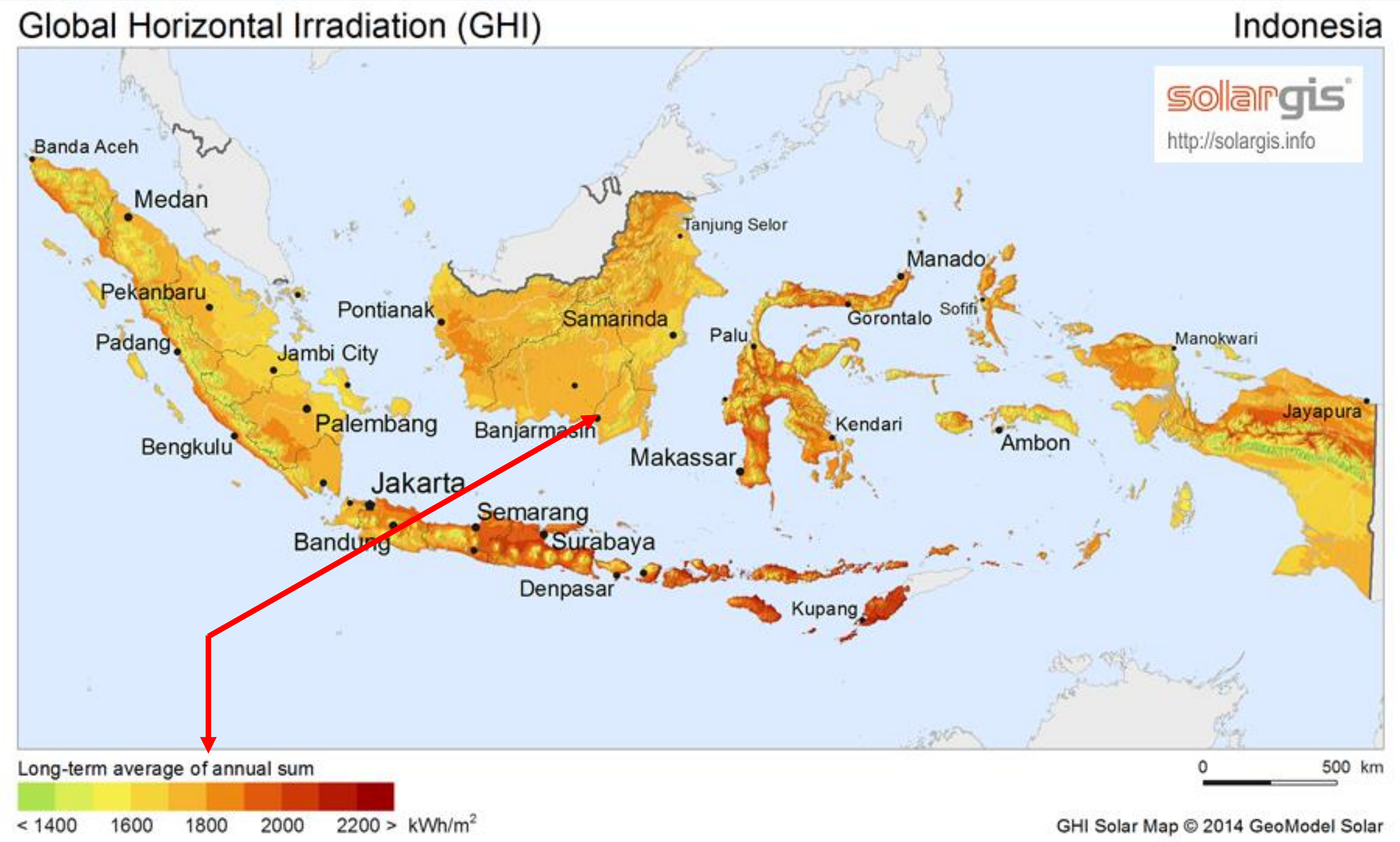
- Indicative sites shown in these notes show different fractions of reservoir or water body used; general rule of thumb is 1-2% of available water surface for floating solar
- Floating solar will not displace people or submerge land
- Floating solar will reduce evaporation

# Cost Estimate for 100 MW system

| | Cost for 100 MW [US$ million] | US$/W* |
|---|---|---|
| Module | 34.0 | 0.34 |
| Inverter | 9.0 | 0.09 |
| Electrical work | 19.6 | 0.20 |
| Total PV equipment | 62.6 | 0.63 |
| Floating structure | 16.9 | 0.17 |
| Anchoring | 4.2 | 0.04 |
| Total floating PV | 83.7 | 0.84 |
| Grid connection cost | - | - |
| Infrastructure | 21.0 | 0.21 |
| Total investment cost | 1,04.7 | 1.05 |

- ❑ Based on these assumption and the available solar resources, the cost of solar electricity would be in the range of: **US$ 0.075 / kWh**
  - ❖ Note: NOT including subsidized or concessional financing opportunities
  - ❖ Based on estimates prepared for Sambor Hydropower reservoir site in Cambodia

# Insolation > 1800 kWh/m$^2$ / y in Kalimantan & Sulawesi

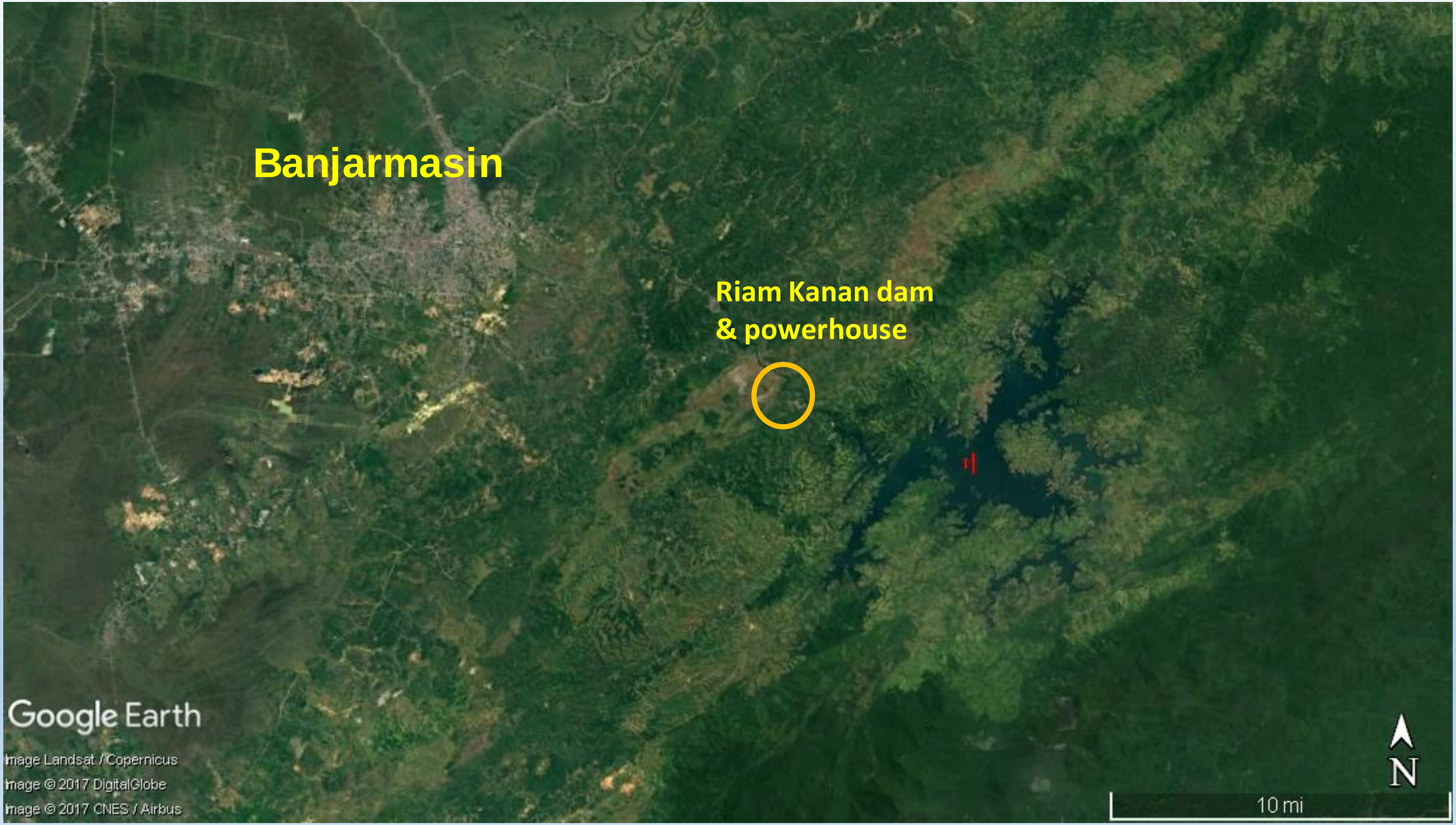



Picture source: SolarGIS, Irradiance source: Meteonorm

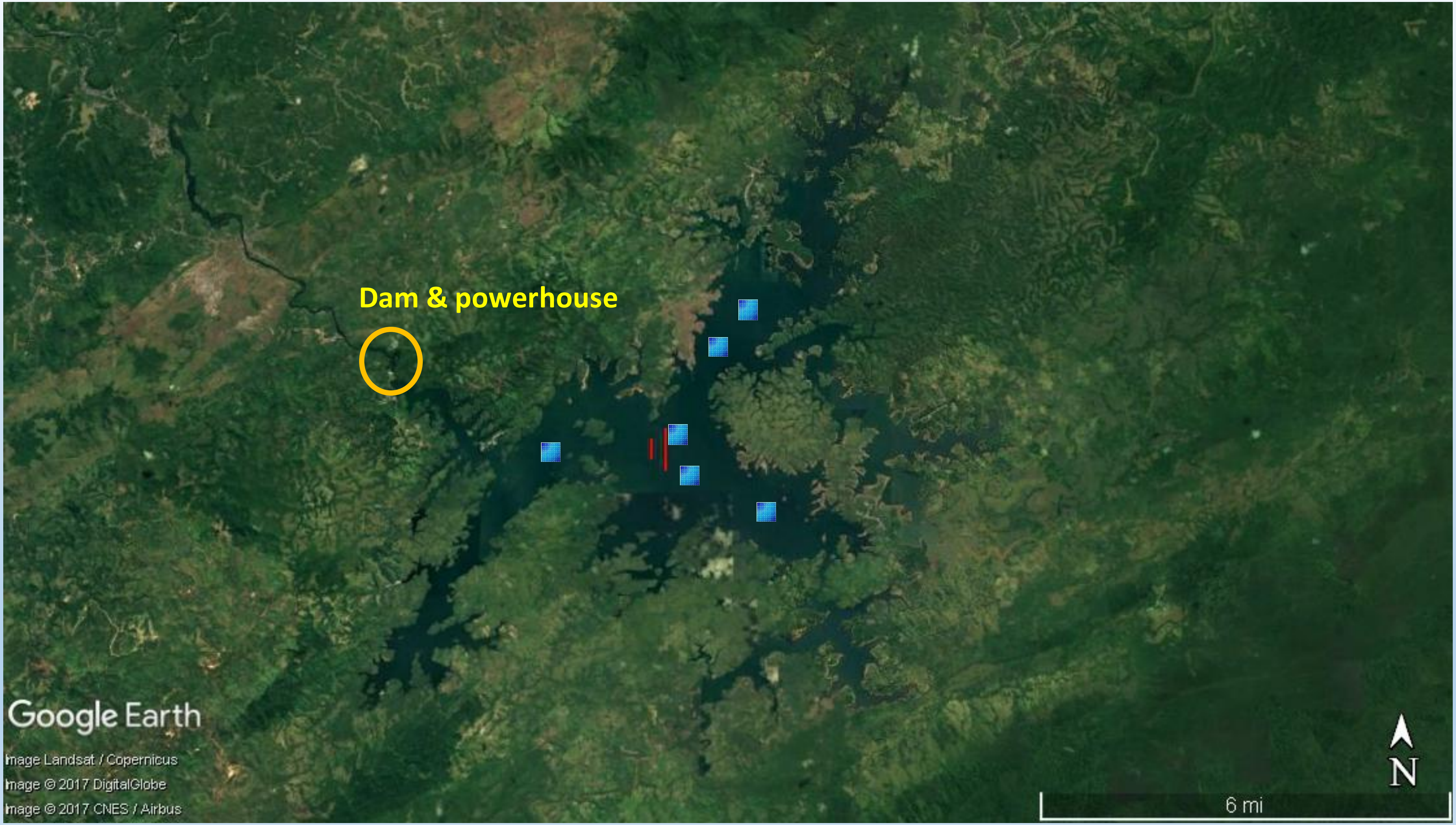
# Site 1: Riam Kanan hydropower, South Kalimantan

- Riam Kanan hydroelectric power project east of Banjarmasin
- Initial operations began in 1973
- Installed electric capacity of 30 MW (3 x 10 MW)
- 42 meters net head, 87 m3/sec design discharge, 103 GWh/year
- 80 km2 (8000 hectares)
- Key assumptions: 2 hectares/MW PV
  - Using maximum 2% of reservoir area to minimize potential environmental and social impacts ~ 80 MW
  - If no area constraints, < 7% of reservoir area will support 4 x 50 MW units + 6 x 12.5 MW = 275 MW
- Opportunity for major overhaul of hydro-generation?
- Storage may be required if solar capacity is much larger than hydro capacity
- Opportunity to deploy prototype electric/hybrid tourist boats?

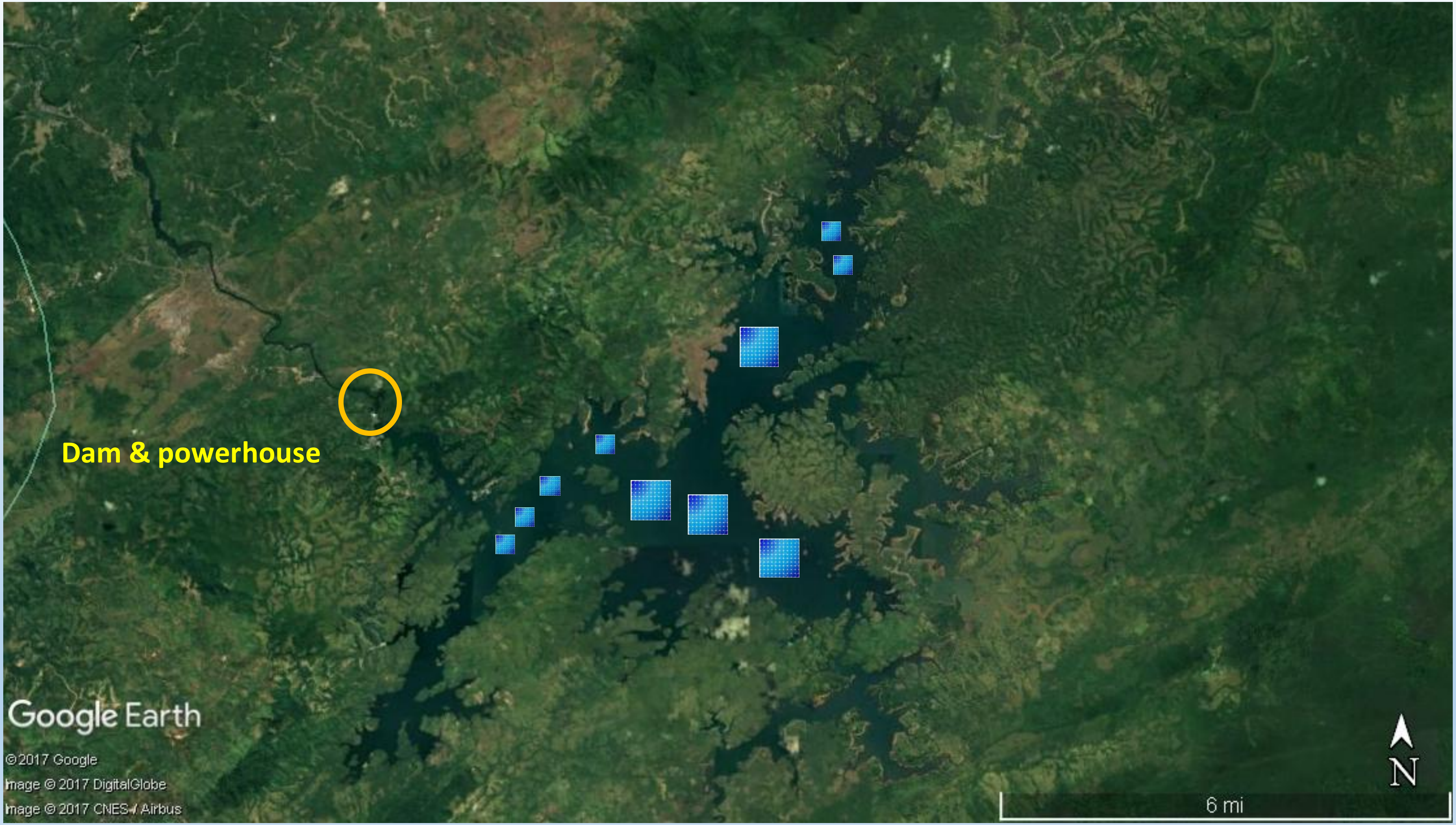
# Riam Kanan 30 MW hydropower plant east of Banjarmasin, South Kalimantan



# Riam Kanan:  < 2% of reservoir area, 6 x 12.5 MW units = 75 MW



# Riam Kanan:  no area constraints 4 x  50 MW units + 6 x 12.5 MW units = 275 MW




# Site 2: Pamona 2 hydro, C. Sulawesi

- Pamona 2: 195 MW (3 x 65 MW) on Poso River; uses natural outflow from Danau Poso
- Registered as CDM project in 2012
- Danau Poso 323 km2 (32,300 hectares)
- Key assumptions: 2 ha/MW PV, use maximum 1% of reservoir area to minimize potential environmental and social impacts > 150 MW
- Image shows 3 x 50 MW floating solar units, using < 1% of reservoir area
- Requires smart grid to integrate solar and hydro output

# Site 3: Estuary at Balikpapan, East Kalimantan

- Key assumptions:
  - 2 hectares/MW PV
  - Degraded water quality => no size limit based on environmental impacts
- Indicative layout of 8 x 12.5 MW units = 100 MW (next slide)
- Design & siting issues:
  - Sites can be identified which do not affect boat/ship traffic
  - Need bathymetry survey
  - Storage / smart grid kit may be required for grid integration
  - Water quality – brackish / marine conditions may increase installed cost relative to fresh water
- Opportunity to deploy prototype electric/hybrid ferry boats?

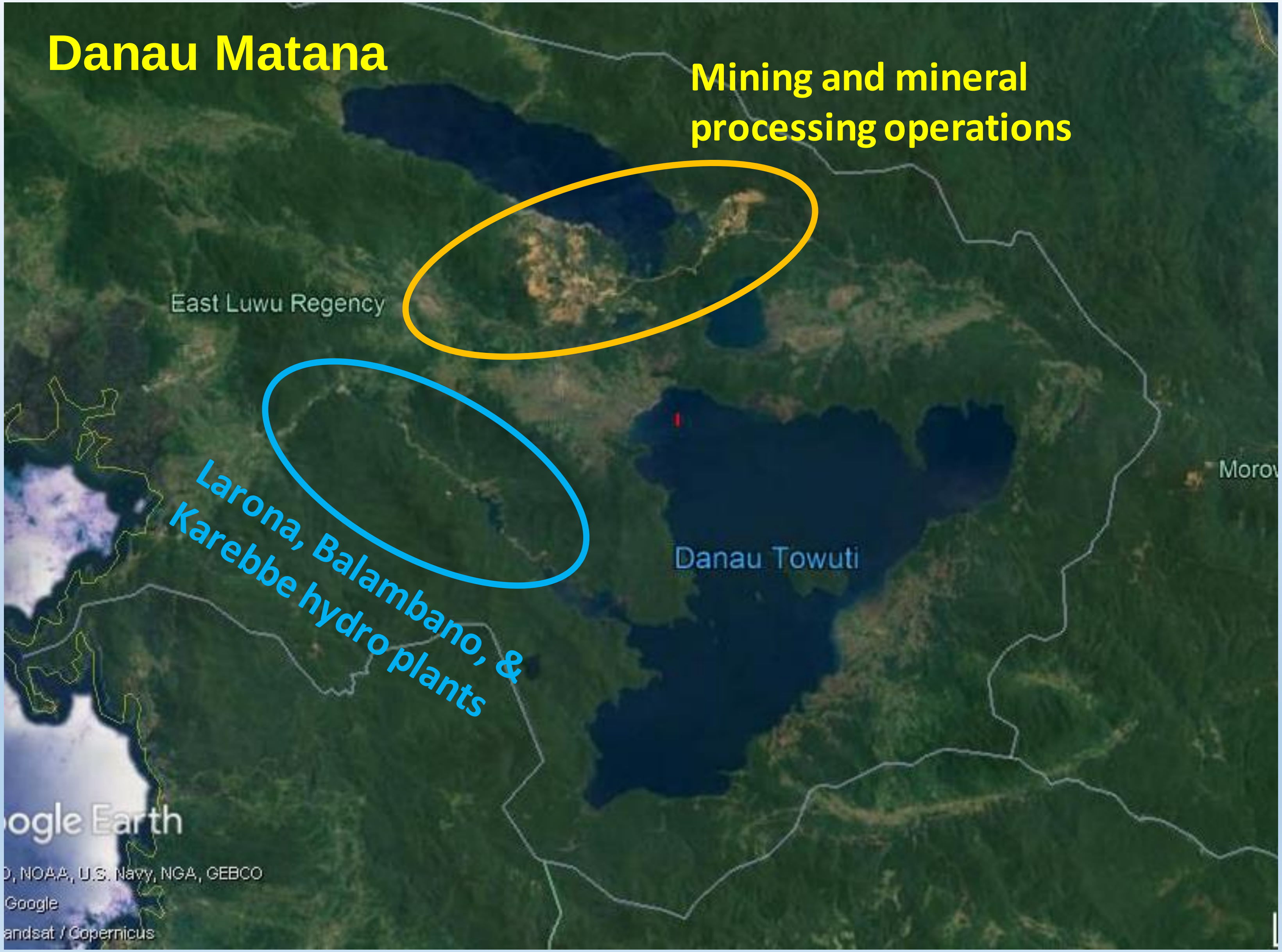
# Balikpapan, East Kalimantan

# Balikpapan 8 x 12.5 MW = 100 MW (assumes sites are not in boat/ship channels)

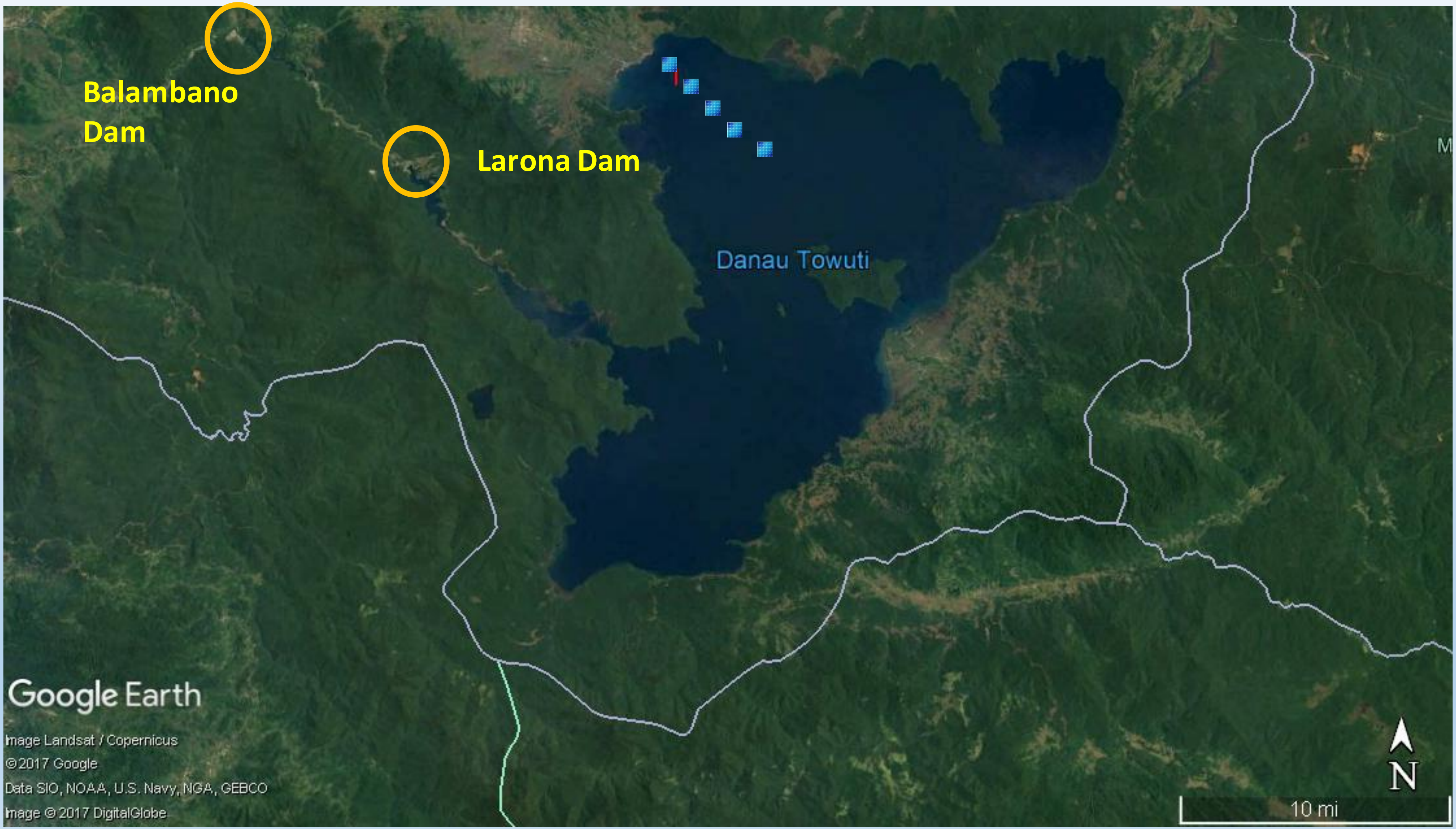
# Sites 4 & 5: Danau Towuti, Central Sulawesi

- Larona 195 MW run-of-river plant (3 x 65 MW), Powerhouse is ~ 5 km downstream of diversion site
- Balambano 140 MW run-of-river plant (2 x 70 MW), ~ 5 km downstream of Larona powerhouse
- Karebbe 90 MW, downstream of Balambano
- The 3 hydro plants provide power for PT Vale nickel ore processing at Soroako
  - Possible to use Danau Towuti 561 km2 (56,100 hectares) ??
  - Or Danau Matana 164 km2 (16,400 ha) which has been directly impacted by mining and mineral processing operations ??
- Key assumptions: 2 hectares/MW PV, use 1% of reservoir area in Danau Towuti and use < 2% of Danau Matana
- Opportunity for major overhaul of hydro-generation at Larona (initial operations in 1979) and Balambano (initial operations in 1999)?
- Smart grid required to integrate solar & hydro output
- Opportunity to deploy prototype electric/hybrid tourist boats at Danau Towuti

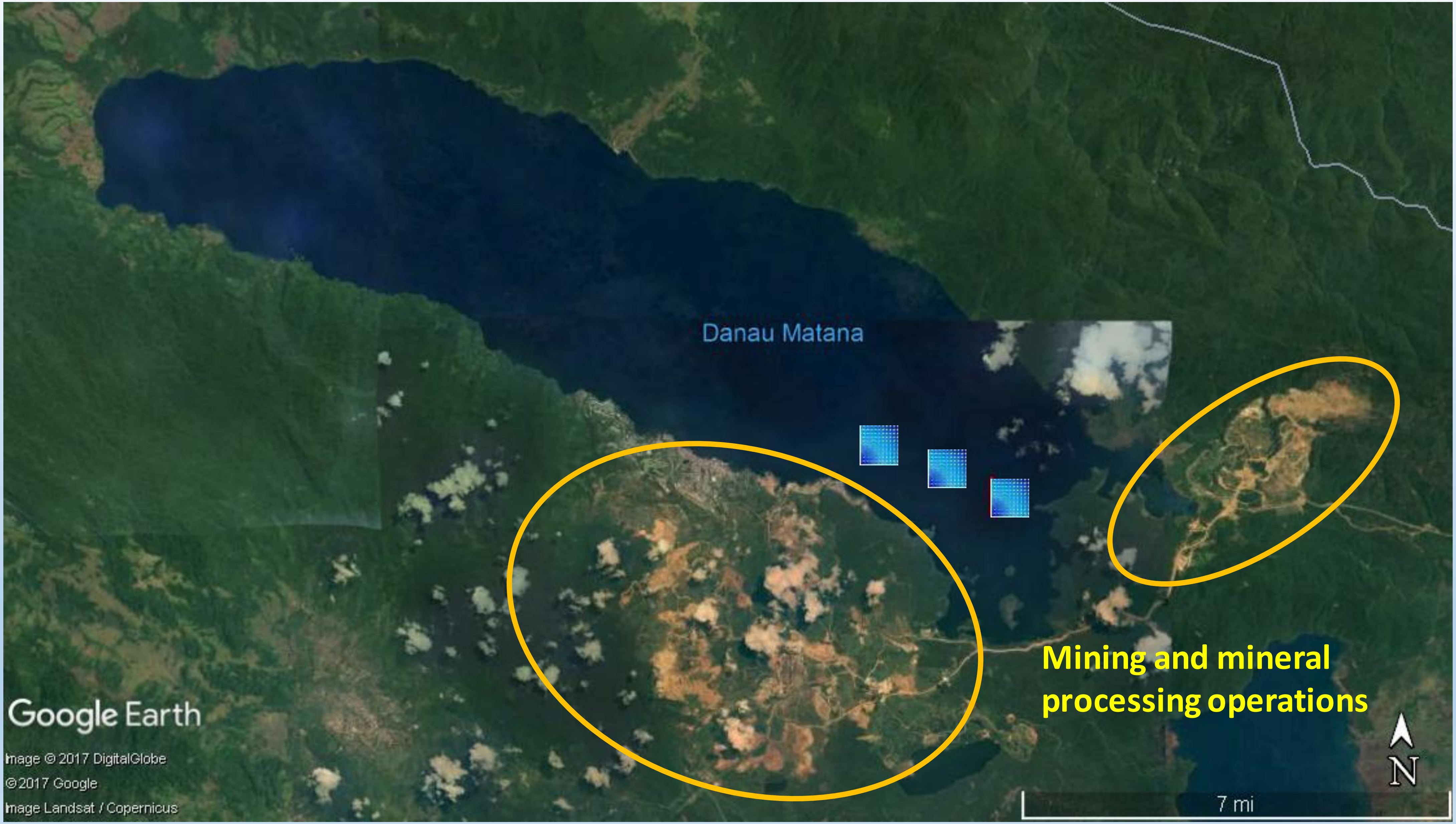
# Danau Matana and Danau Towuti area, Central Sulawesi



# Site 4: Danau Towuti ~ 1% of lake area for 5 x 50 MW = 250 MW



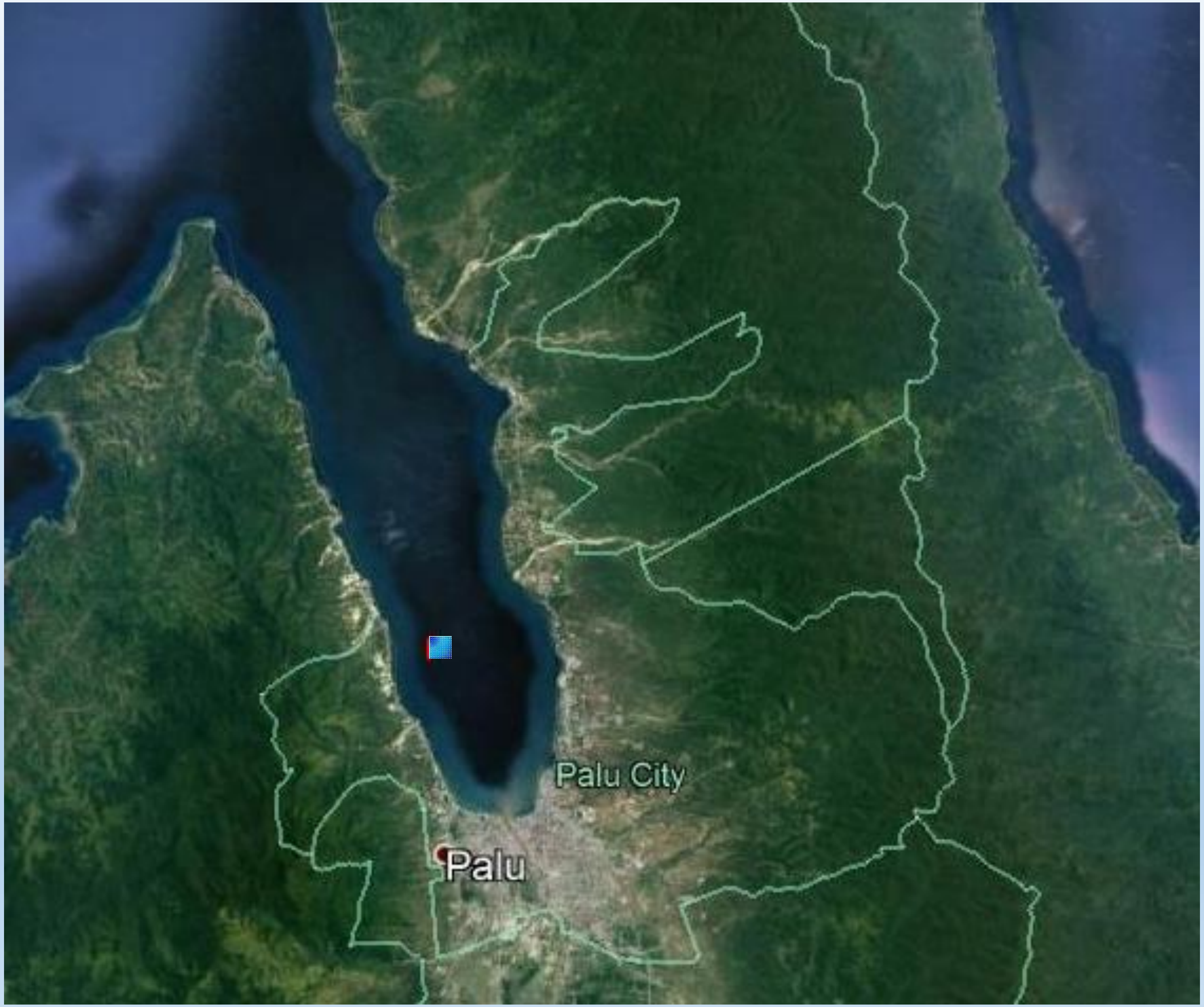
# Site 5: Danau Matana – 3 x 50 MW solar using < 2% of lake area



# Site 6:  Palu Bay, Central Sulawesi

- Large bay > 25 km from north-to-south, > 5 km from east-to-west > 125 km2
- Protected on 3 sides; ship traffic concentrated on east side, north of Palu city center
- Key assumptions:  2 hectares/MW PV, use 1% of bay to minimize potential environmental and social impacts ~ 125 hectare
- Next slide shows indicative installation of 1 x 50 MW unit
- Smart grid required to integrate solar & hydro output

# Palu Bay 1 x  50 MW PV – using < 1% of area of the bay



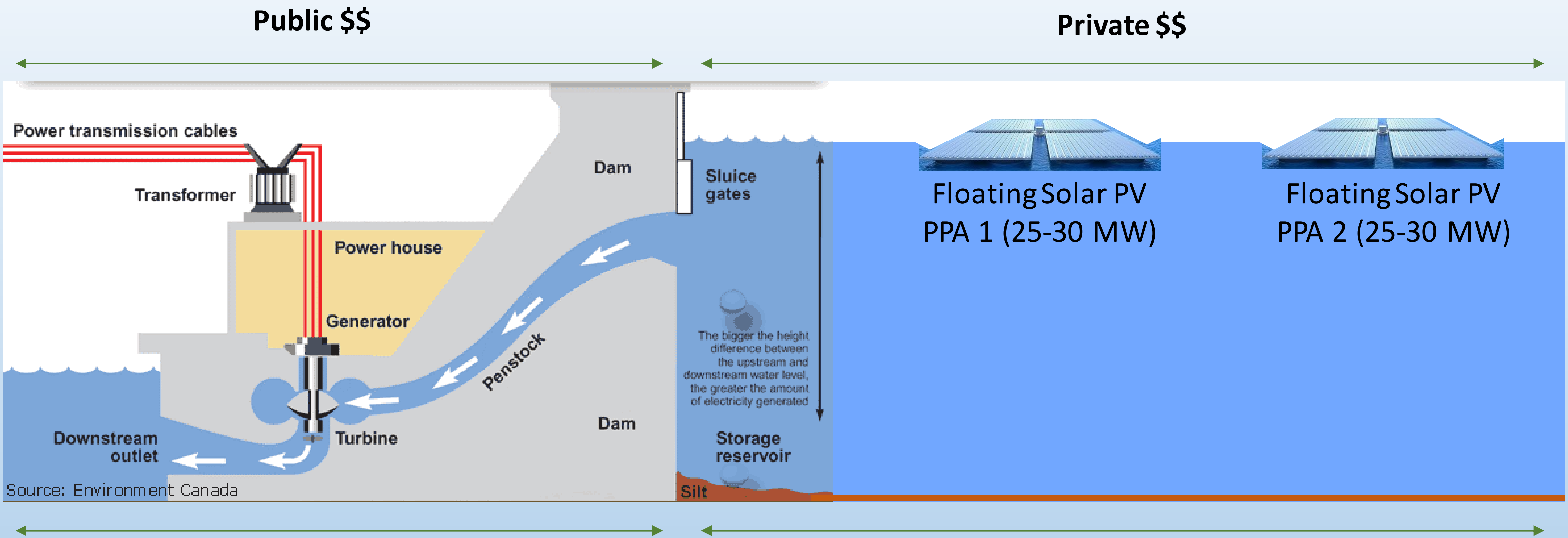
## Conclusion

Floating Solar PV is a good solution to add large amounts of solar generation capacity, rapidly, cost effectively, and with minimal adverse social or environmental impacts

Summary of benefits:

- ✓ Additional electricity generation capacity
- ✓ Optimal hybrid of solar + hydro power generation
- ✓ Ease of grid integration – Existing transmission lines at hydropower sites (upgrade only if needed)
- ✓ Modular – implement in stages possible to match demand and funding
- ✓ Fast deployment
- ✓ Economically attractive
- ✓ Minimal environmental or social impacts

# Solar Parks Model for Floating Solar




Government + ADB Finance --> Government uses for:

1. Grid Connection and other Infrastructure
2. Transmission upgrade if needed
3. Hydro-generation upgrade if needed

Generation by IPPs. Government provides:

1. Reservoir space "concession" to locate floating PV
2. Bankable power purchase agreement (PPA)



Government leads development to reduce risks, creating a platform for competitive tendering of multiple PPAs, each for 30 MW to 50 MW. Build on experience in India, Cambodia and several other countries.

# Potential Risks and Mitigation Measures

| Potential Risk / other issues | Possible Mitigation |
|---|---|
| Limited operational experience – no long-term environmental impact analyses | • Begin with pilot deployments in areas with no ecological sensitivities<br>• Employ rule of thumb of 1-2% of available reservoir area |
| Catastrophic failure of floatation systems | • Use modular construction to limit the size of individual "rafts" so that catastrophic failure of 1 raft does not crash entire system<br>• Utilize expertise on floating systems from other sectors (offshore oil & gas, marine engineering, prior experience with barge-mounted power plants, etc.)<br>• No deployment in areas with active boat/ship traffic |
| Higher than expected O&M costs | • Include extended warranty and O&M period in EPC contracts<br>• Allow pass-through of additional O&M costs in power purchase agreements |
| First-mover risk<br>("it hasn't been done because it will not work") | • Mobilize concessional finance to cover additional risks and costs on 1st projects |

# Next steps

Feasibility study for pilot projects including:

- Initial cost-benefit analysis of construction and operation of floating solar vs. alternatives (e.g. ground-mounted solar, other forms of generation, etc.)
- Grid integration assessment for specific sites
- Assess options for storing any excess solar output
- Create a power operations and dispatch model for the combined operations of solar + hydro and solar + grid to determine economically optimal joint operating regime