Proposed Floating Solar PV on Kaptai Lake

Hongwei Zhang
Energy Division, South Asia Department, ADB

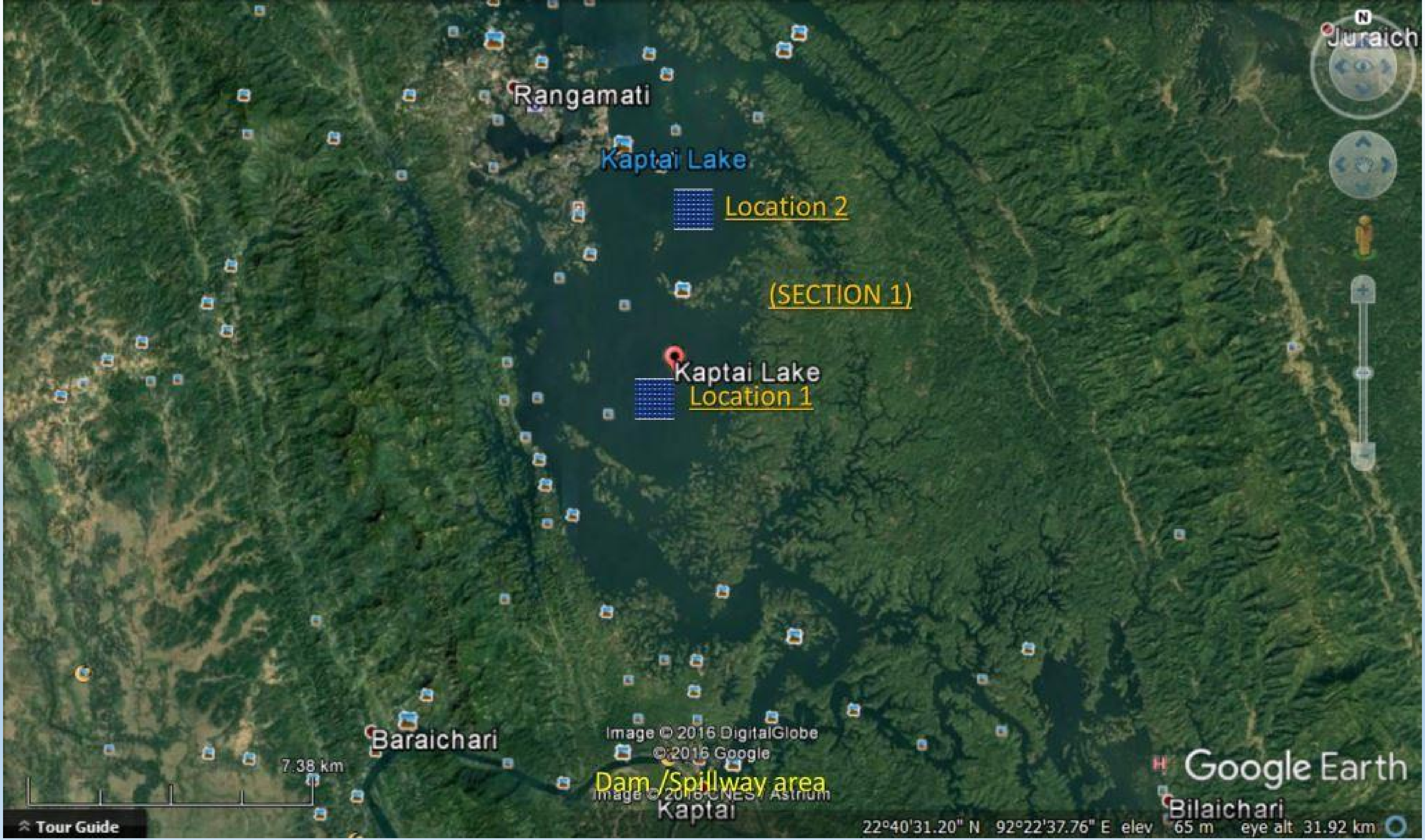
Floating solar has several benefits compared to other alternatives

- Use of idling surfaces $\Rightarrow$ no direct competition with agriculture or other land use
- Natural cooling from the water increases PV energy yield by up to 10%
- Floating panel structures contribute to reducing water evaporation
- Fast deployment - over 1,000 MW per year is logistically feasible
- Scalable - can be built in stages mirroring increasing demand
- Modular - can be built in stages to minimize initial capital and to reduce financing risks
- Key additionality/synergies from deploying solar in conjunction with hydropower

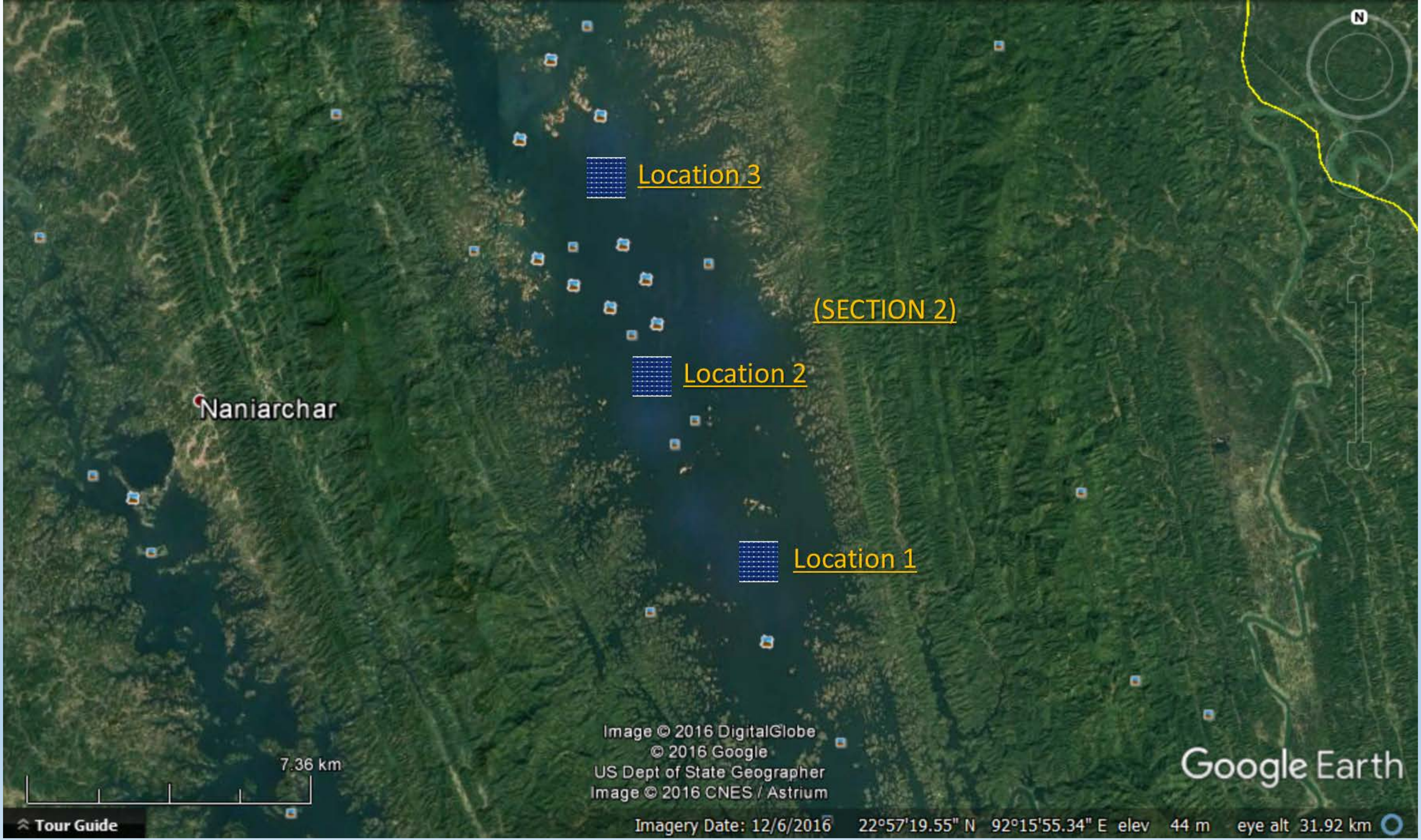
Kaptai Dam Installation Overview

- **Kaptai Dam** is on the Karnaphuli River at Kaptai, 65 km upstream from Chittagong in Rangamati District, Bangladesh.
- The only hydroelectric power station in Bangladesh, completed in 1962.
- Turbines are 2x40 MW and 3x50 MW for a **total installed 230 MW**, commissioned between 1962 and 1988
- Earth-fill embankment dam with reservoir (known as Kaptai Lake):
  - Water storage capacity 6,500 million m3; Surface area 600 km2
  - Reservoir average flow of 16,000 million m3/year or 510 m3/s
  - Dam is 671 m long and 46 m high
  - Spillway is 227 m long, capacity of 16,000 m3/s through 16 gates
- Preliminary Google Earth prints show 5 potential areas, each of which can support 100 MW floating solar generation (to scale depictions on following slides) – Potentially, much more than 100 MW can be installed in future phases, as total lake area is over 600 km2

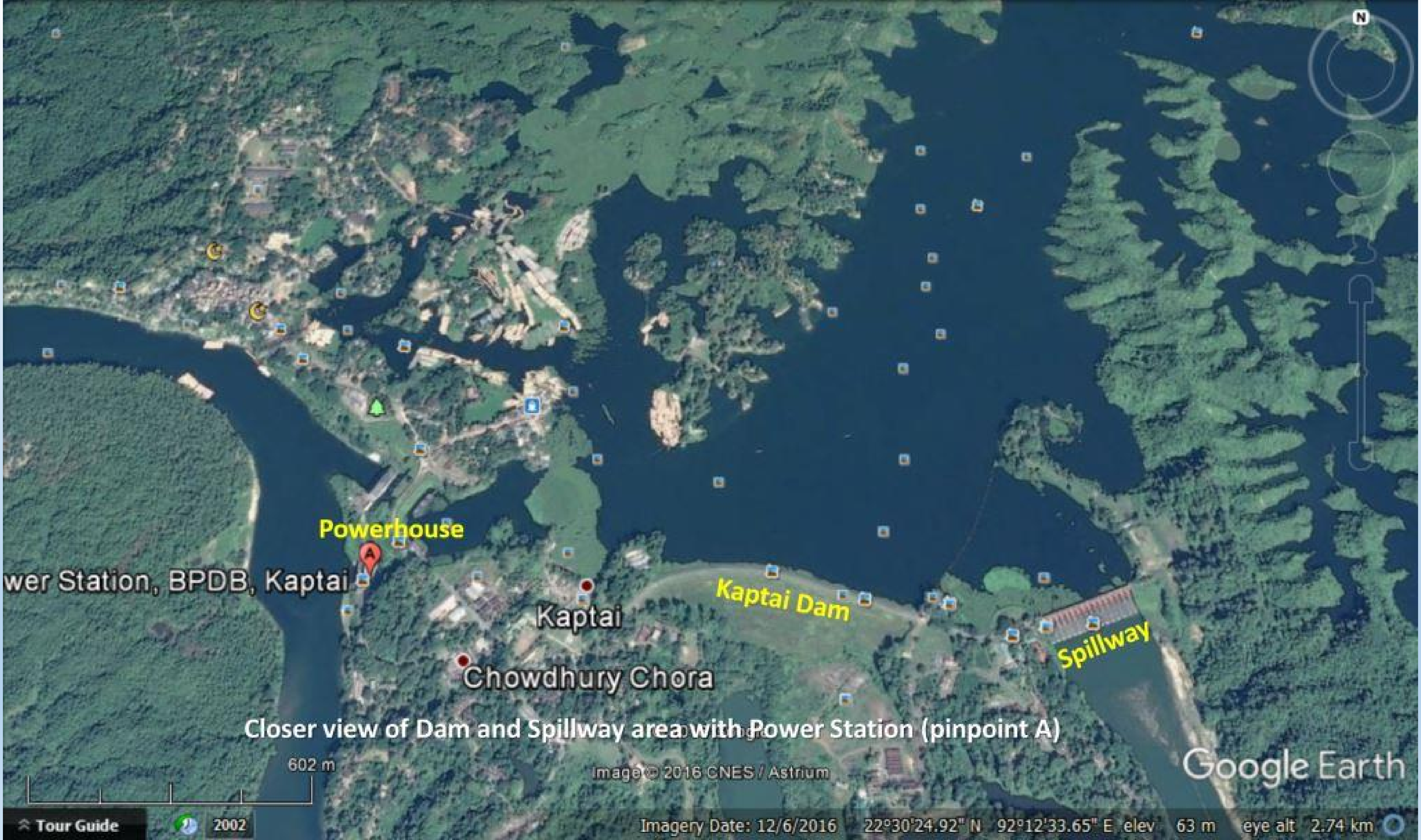
Overview Region Map showing Dam/Spillway (pinpoint A) and potential floating solar locations (Section 1 and 2)



Anyone of these are to-scale depictions of potential 1 km x 1 km locations for a 100 MW floating array



Anyone of these are to-scale depictions of potential 1 km x 1 km locations for a 100 MW floating array



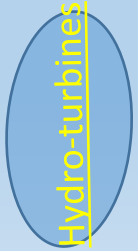
Closer view of Dam and Spillway area with Power Station (pinpoint A)

Potential 20 MW and 7.4 MW Floating Solar PV Sites at Kaptai Reservoir

Site 1: 7.4 MW floating solar PV placement adjacent to 7.4 MW ground mounted solar PV

Site 2: 20 MW of floating solar PV in BPDB jurisdiction reservoir area maintaining requisite clearances

Possible layout of 50 MW Floating Solar PV at Kaptai Reservoir Karnaphuli Hydropower Plant Jurisdiction

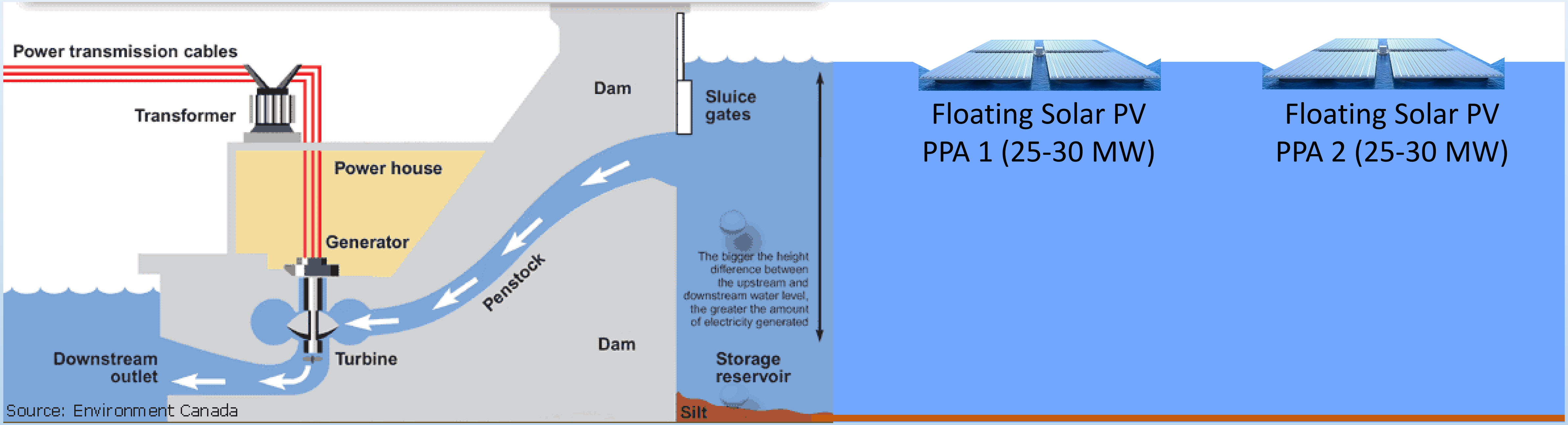


Hypothetical Future 500 MW + 500 MW Floating Solar PV at Kaptai Reservoir

Possible PPP Project Structure for Floating Solar

Public $$

Private $$



GOB + ADB Public Sector Finance --> GOB uses for:

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

Generation by IPPs. GOB provides:

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

GOB 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.

Additionality: Hybrid Energy Systems with Hydro-Solar

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 generated by a Dam is exploited in conjunction with PV Solar Modules, installed on floating structures on the Reservoir's water surface. This setup's key incremental advantages include:

1. **Increments the overall electricity generation** from the system – water is conserved during solar output hours and can be used to enhance generation at other times
2. Hydropower generation's quick ramp capability allows for it to be leveraged as **Energy Storage**, to balance the intermittent solar resource at times of low solar generation (e.g. nights or cloudy days), as well as during system load curve peaks
3. Floating panel structure can contribute to **reducing water evaporation**, and provide a small increase in hydroelectric power available due to its pressure loading
4. **Already grid connected, so no need to lay new transmission lines**. If required, existing transmission lines can be upgraded at lower cost than greenfield transmission from remote solar sites

Water Use Efficiency: Another Synergy of Hydro-Solar Combination

Total energy delivered from the original hydro plant can be enhanced significantly by adding the Floating Solar PV on the reservoir water surface

- In most Hydro installations, it is not feasible to generate electricity at full capacity for the entire 24 hours/day throughout the year, because there is not sufficient annual flow through the catchment to maintain the average flow rate required to output the rated power. Hence the turbines and their grid transmission line are used intermittently.
    - This capacity utilisation factor for hydro is mostly under 50% worldwide and even lower in dry periods when water (the fuel) is scarce.
    - See http://en.wikipedia.org/wiki/Hydroelectric for statistics on capacity factors for whole countries' hydropower systems, showing a range from 20% to 60%, mostly around 40%.
- Since the annual water flow availability through a hydro system is the principal limit to the hydropower energy resource in that location, a co-located solar generation component can allow increased dispatch-able energy production, creating higher effective load factor of the hydro plant and grid connection.

- A hypothetical 100 MW floating solar PV project requires:
    1. **$105 million estimated investment** (10-15% more than land based)
    2. **PV solar panels occupying Lake Area of 100 hectares, i.e. 1 km x 1 km**
        1. Installed capacity assumed as 1 MW/hectare (similar to land based solar PV)
        2. Based on Bangladesh being in a moderate Solar Irradiance zone
- No adverse environmental or social impacts based on internet search
    1. While 80% of Bangladesh fisheries are inland, 100 MW needs <0.2% of lake area
    2. Floating solar will not displace any additional people or submerge additional land
- 24/7 steady generation potential at Kaptai hydro is 115 MW – based on reservoir average annual flow of 16,000 million m3 and avg. head of 25m (based on Google Earth), i.e. 50% of rated turbine capacity of 230 MW.
    - With the addition of floating solar, hydropower water consumption can be reduced during solar generation times (which corresponds to grid peak), and the increased availability of water can in turn boost the capacity factor during non-solar times.

Conclusion

Floating Solar on hydro reservoirs is a high impact solution for Bangladesh, which has a shortage of electric power and low grid penetration. Projected demand by 2030 is 34,000 MW (per ADB 2016).

Recap – Summary of benefits from floating solar in conjunction with hydroelectric generation from Kaptai hydropower plant:

- ✓ Additional electricity generation capacity
- ✓ Optimal hybrid of solar with hydro power generation – Inbuilt storage capacity
- ✓ Ease of grid integration – Existing transmission lines (upgrade only if needed)
- ✓ Modular – Implementation in stages possible to match demand and funding
- ✓ Fast deployment
- ✓ Economically attractive
- ✓ Minimal environmental or social impacts in Karnaphuli River and Kaptai Lake