Innovating Solar Energy Development through Floating Photovoltaic Technology

Regional Knowledge and Support Technical Assistance
Afghanistan, Azerbaijan, Kyrgyz Republic

Cindy Cisneros Tiangco, PhD
Senior Energy Specialist.
Asian Development Bank

ESCC
CAREC ENERGY SECTOR COORDINATING COMMITTEE

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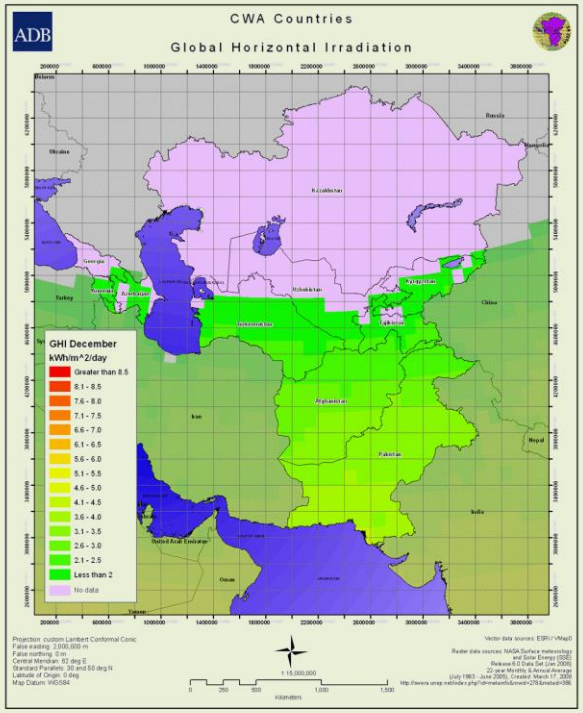
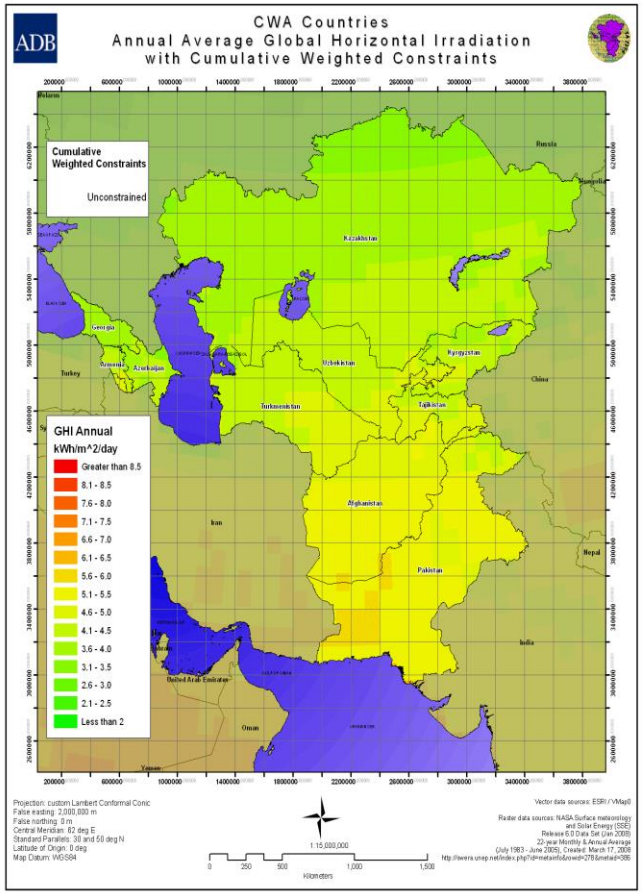
Central and West Asia Solar PV Resources

Monthly variation of Theoretical Global Horizontal Irradiation in the Region (solar photovoltaic potential)



GHI data based upon 12 year half hourly satellite images; Validated by 92 measuring stations worldwide.
Accuracy of GHI estimates is around +/- 5%; provides good quality prediction of long term average irradiance
For more details see
http://www.3tier.com/static/ttcms/us/documents/publications/validations/3TIER_Global_Solar_Validation.pdf

Average Annual Global Horizontal Irradiation In the Region with Cumulative constraints



Weighted exclusion factors applied for:

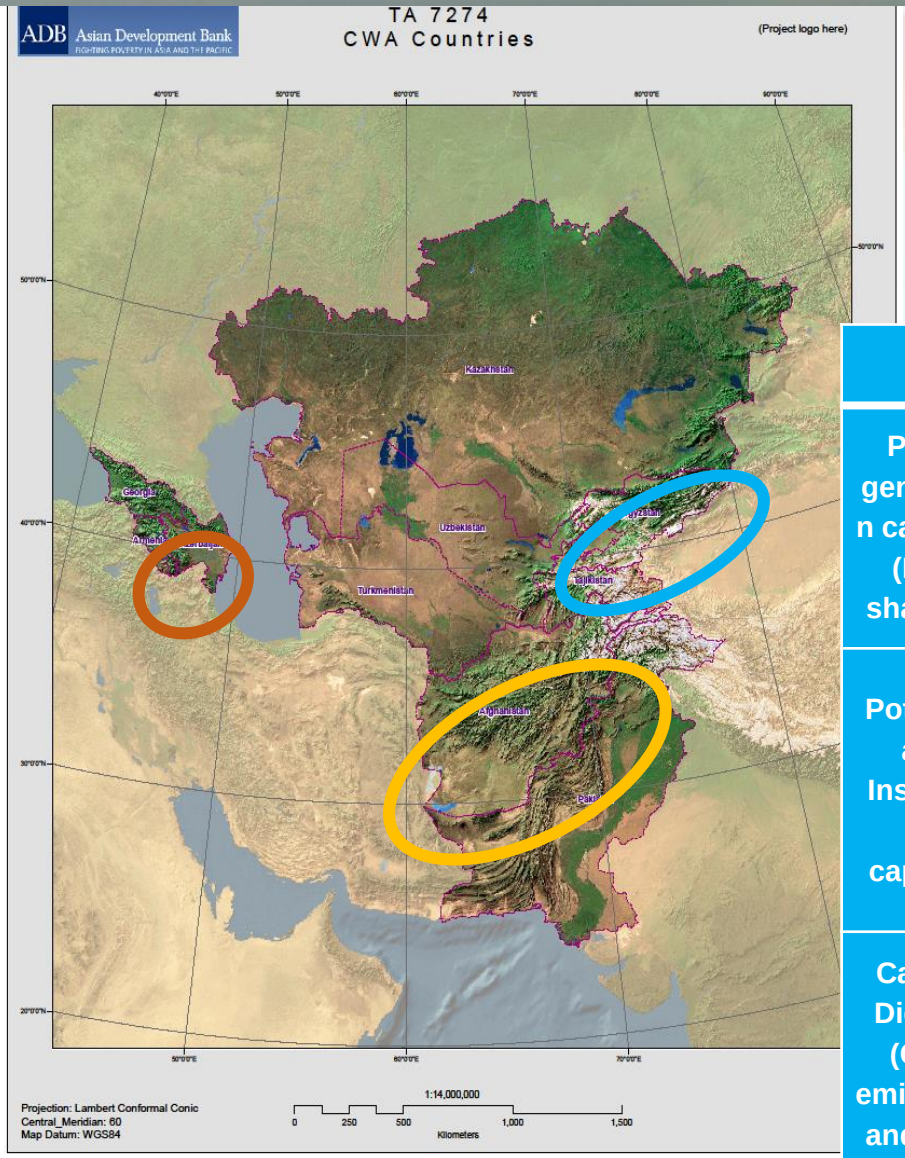
Practical Resources:

- *Airports/runway alignments, railroads, urban areas, pipelines*
- *National borders (5 km buffer)*
- *Areas with population density > 100 persons/km^2*
- *Areas >20km away from roads (for construction access)*
- *seismic danger areas*
- ***Areas with elevation >3000m or slopes >10%***

Ecological Resources

- *Snow and ice areas, shifting sand dunes and salt pans, tundra, swampland, All environmentally protected areas*

Generation mix, potential and installed capacity, NDC targets – (AFG, AZE, KGZ)



Southwest Asia – **Afghanistan**, Pakistan

Caucasus – Armenia, **Azerbaijan**, Georgia

Central Asia – Kazakhstan, **Kyrgyz Republic**, Tajikistan, Turkmenistan, Uzbekistan

		Afghanistan	Azerbaijan	Kyrgyz Republic
Power generation capacity (MW, share %)	Total	520	7,905	3,786
	Thermal	200 (38.5%)	6,764 (85.5%)	716 (18.9%)
	Hydro	254 (48.9%)	1,105 (14%)	3,070 (81.1%)
	Wind	-	-	
	Others	65 (12.5%)	35 (0.5%)	
Potential and Installed PV capacity	Technical Potential	220,000 MW	115,200 MW	267,000 MW
	Installed capacity	A 20MW ADB financed project is being tendered	Around 35MW	None
Carbon Dioxide (CO_2) emissions and NDC targets	million tons CO_2[a]	8.66	32.73	7.05
	Tons CO_2/capita[a]	0.27	3.36	1.19
	NDC[b]	-13.6% by 2030	-35% by 2030	-11.4% to -13.75% by 2030

Proposed KSTA Reg: Floating Solar Energy Development – (AFG, AZE, KGZ)

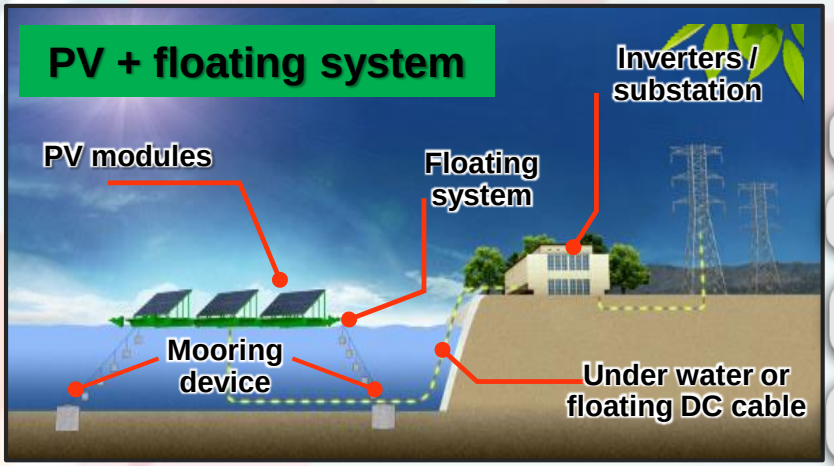
Rationale

- CWRD countries are heavily reliant on either fossil fuels, hydropower, or imported fuels and power, which make them carbon-intensive, energy insecure, and vulnerable to climate and external supply shocks.
- Solar potential is untapped due to lack of technical skills and knowledge on new technologies, costs, benefits and financing options.
- **The cost of solar energy has decreased** rapidly in recent years, offering impetus for these countries to **diversify** to indigenous low-carbon technologies to **enhance energy security and reduce emissions**.
- Undiversified power supply in target countries: Azerbaijan, 85% fossil fuels; Kyrgyz Republic, 90% hydro; Afghanistan, 80% imported
- Significant potential for replication in Kazakhstan, Georgia, and Pakistan, and rest of Asia.

Approach and Components:

- Pilot testing and scaling up of emerging ‘floating‘ solar photovoltaic (FPV) technology;
- business models formulation to encourage private sector participation;
- institutional capacity building (hands-on training through pilots, regional training via CAREC, study tours to leading FPV countries)

Floating PV Technology

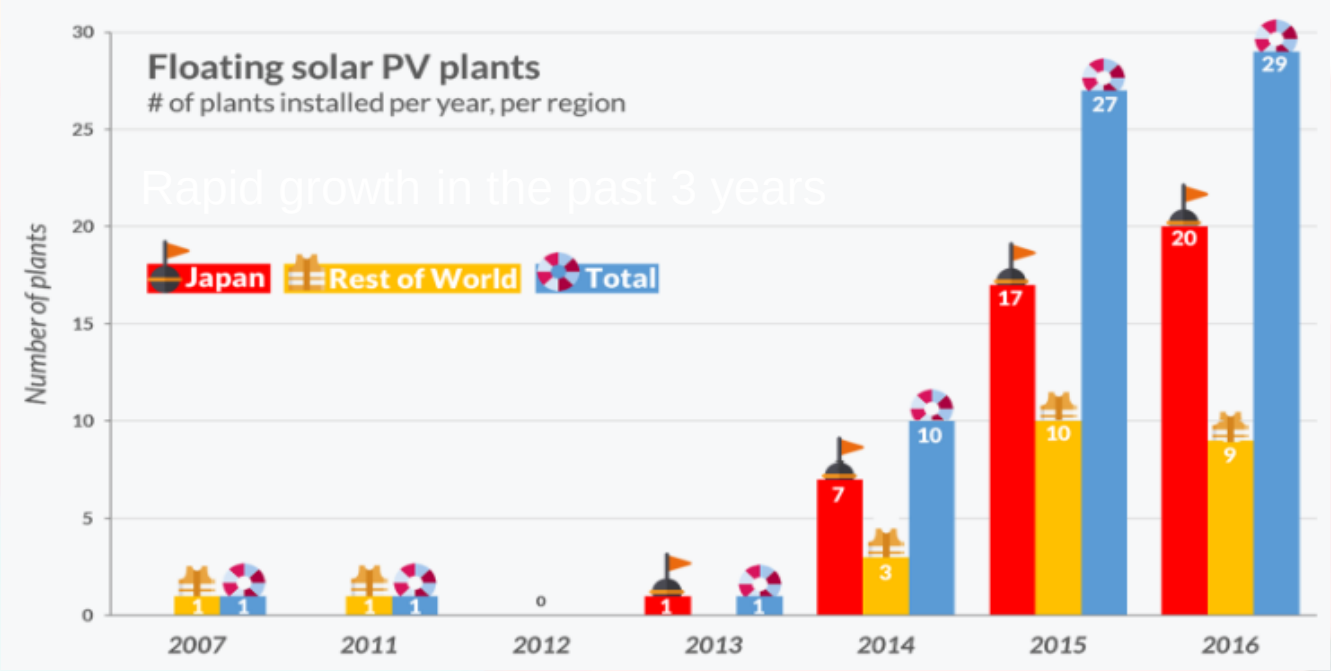


Core technology

- PV suitable for water environment
- Stable floating system
- Mooring device to adapt to changes in water level
- Under water or floating cable connection to the local power grid

Development Status

Compared to over 300GW installed land-based PV capacity worldwide, only 70 FPV plants totaling 200 MW were in operation by end of 2017. Japan has the most number of plants. China has the largest at 40 MW and is now constructing 150 and 70 MW plants. Several small plants are in operation or under construction in Italy, Singapore, South Korea, UK, and USA.



Source: www.solarplaza.com; true figures as of April 2016. Over 70 installations worldwide by end 2017

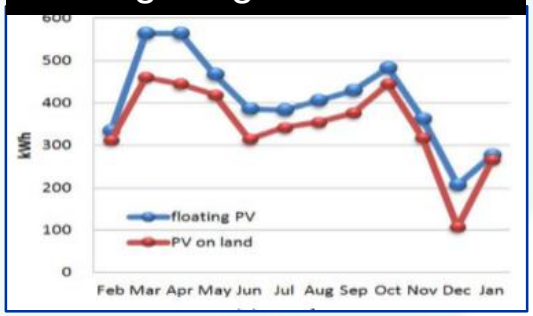
Benefits of Floating PV Systems

Economic

Environmental

Water surface use vis-à-vis requirement for land

Higher efficiency / higher generation

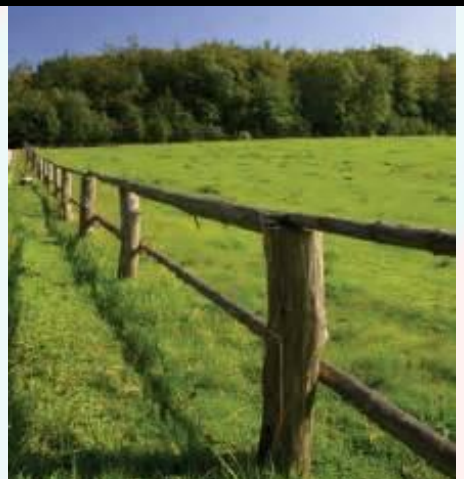


- due to natural cooling effect of water on the panels and elec equipment

Social

- **Land optimization**
- **Water conservation**
- **Clean energy production**
- **Power in remote areas**
- **Climate friendly**

Forests & farmlands conservation

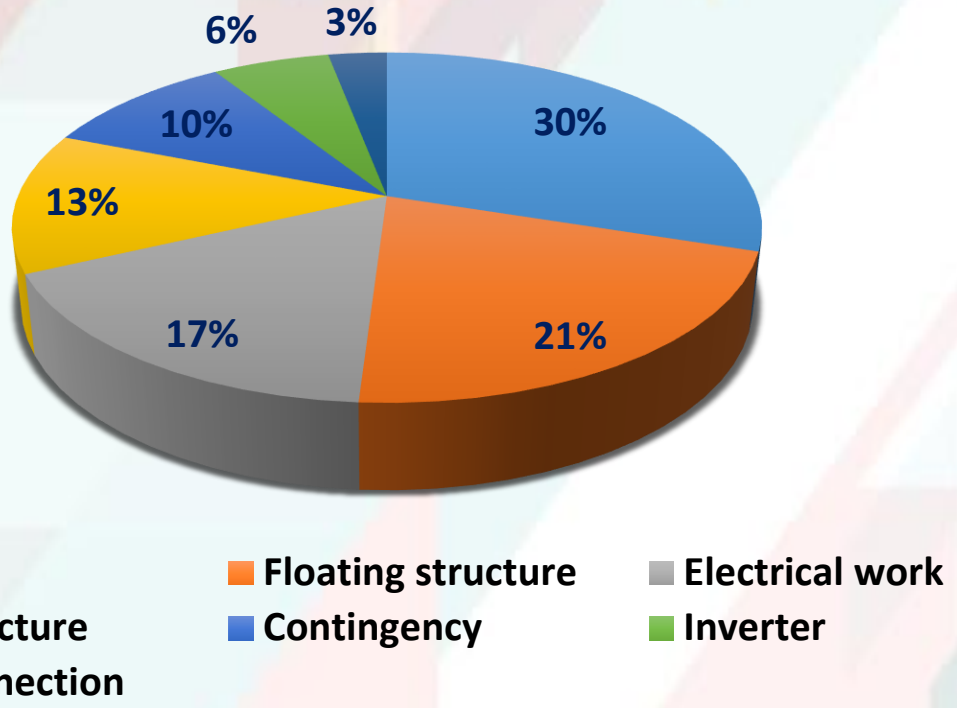


Water retention / healthy ecosystems

FPV advantages over land-based PV.

- frees up land for other uses and saves on land acquisition or preparation and civil works cost;
- allows higher yields (15% more) due to the cooling effect of water, which could make up for its higher cost;
- conserves water through reduced evaporation;
- is quick to install; and,
- addresses energy-water-food- climate nexus.

FPV System Cost Breakdown



- App. 1.135 USD/Wp - (module cost 0.34 USD/Wp)
- Grid-connection highly project dependent
- No purchase of land, no civil works / ground preparation

Source: SERIS

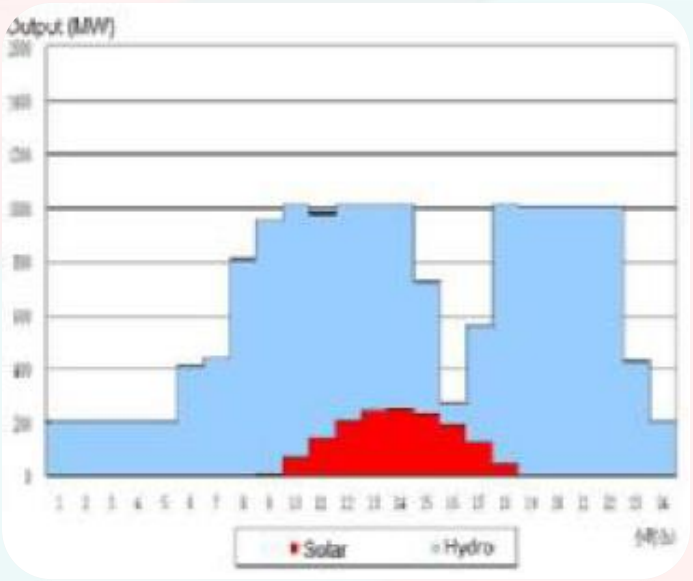
PV/FPV and Hydropower Synergy

Advantages:

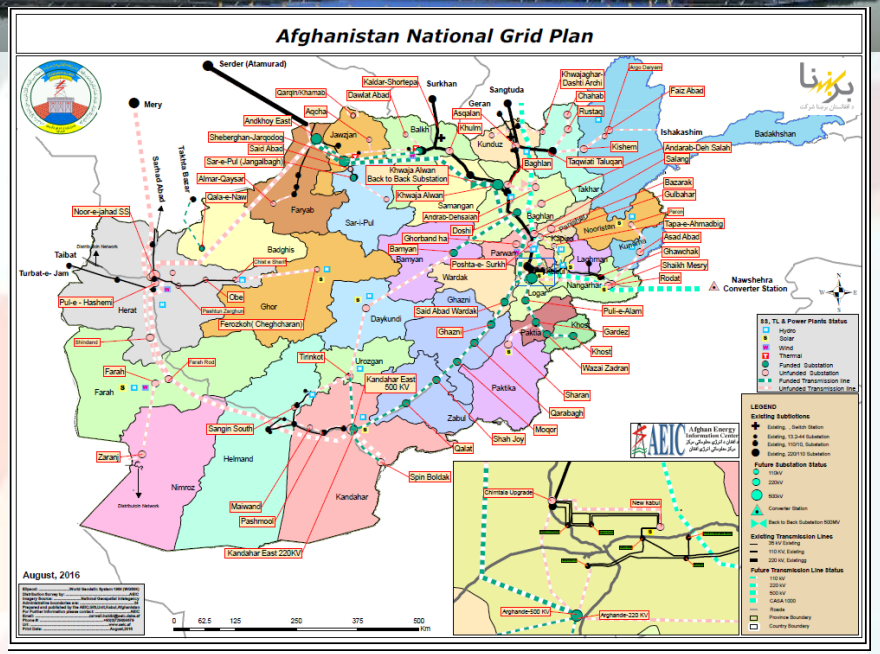
- Existing electrical infrastructure (substation, switchgear, transmission,)
- Complementary operation (especially during dry season)
- Less evaporation; water conservation

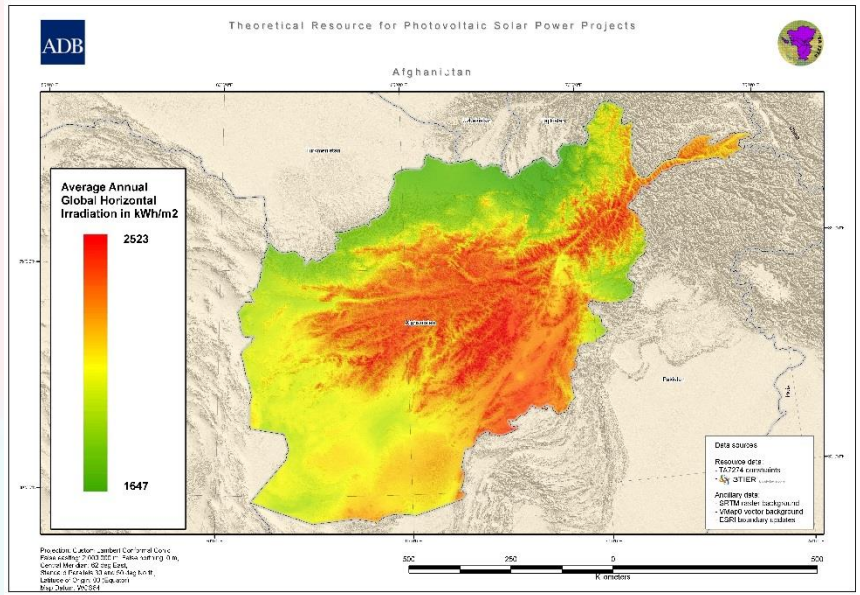
EXAMPLE: LONGYANGXIA HPP, CHINA

- HPP: 1 280 MW (4 x 320 MW), 5 942 GWh/year
- PV: 850 MW, 1 322 GWh/year



Pilot countries - Afghanistan





- Only 30% of population connected to the grid (among the lowest globally; targets 83% by 2030)
- Installed capacity only 519 MW

  265 MW Thermal (diesel and furnace oil), with **generation cost of $0.25-$0.35 per kWh;**

  254 MW Hydro needing or under rehab
- **Imports 80% of power supply** from Turkmenistan, Iran, Tajikistan and Uzbekistan

  1,250 MW Signed PPSAs:
  TAJ 300 MW – seasonal (hydro); UZB 300 MW
  TKM 300 MW (up to 500 MW); IRAN 150 MW
- imports bill increased 14 times from $16 million in 2007 to $224 million in 2016.
- Insufficient and unreliable supply affecting access to health services, education, and sanitation and restricts economic growth.
- aims to diversify into renewable energy but the long-standing unrest hinders development
- Security risks and rugged terrain
- **2,500 MW Suppressed demand ;**
- **Island grids**

Potential FPV Sites – Afghanistan

Qargha reservoir

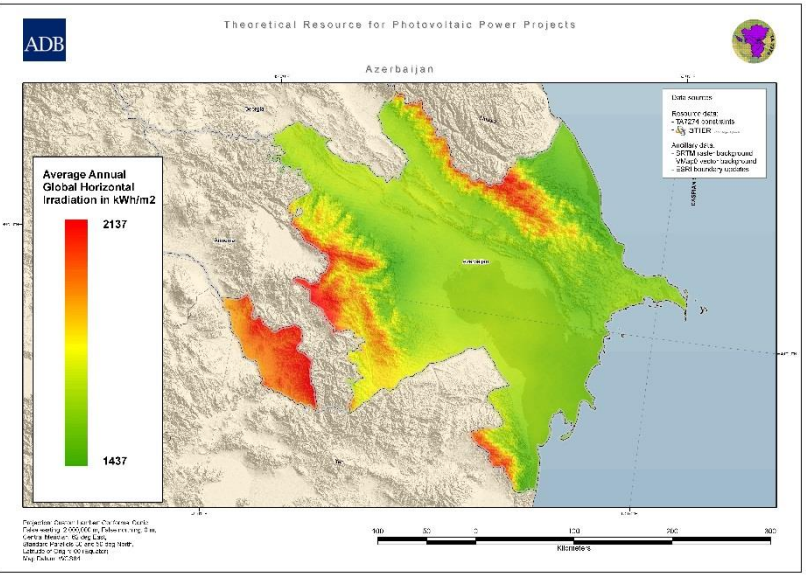
- 15km west of Kabul. recreational area also used for trout fishing and hatchery
- Is planned (i) to provide additional drinking water to Kabul, (ii) irrigation to expand horticulture, and (iii) feed a hydropower plant
- Below marked polygon is 10 ha; theoretically can fit a maximum 10MW* of FPV

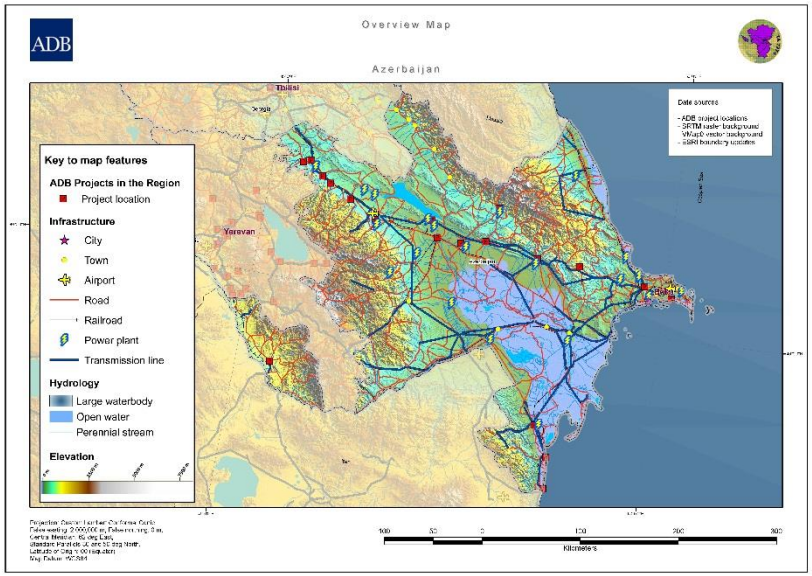
Naghlu reservoir

- 40km east of Kabul. Equipped with electrical infrastructure via the country's largest HPP (100 MW)
- 20MW ADB funded ground-mounted PV plant will be built 2km from the reservoir
- Below marked polygon is 200 ha; theoretically can fit maximum of 200 MW*

** FPV typically needs 1-2 ha per MW*

Pilot countries - Azerbaijan





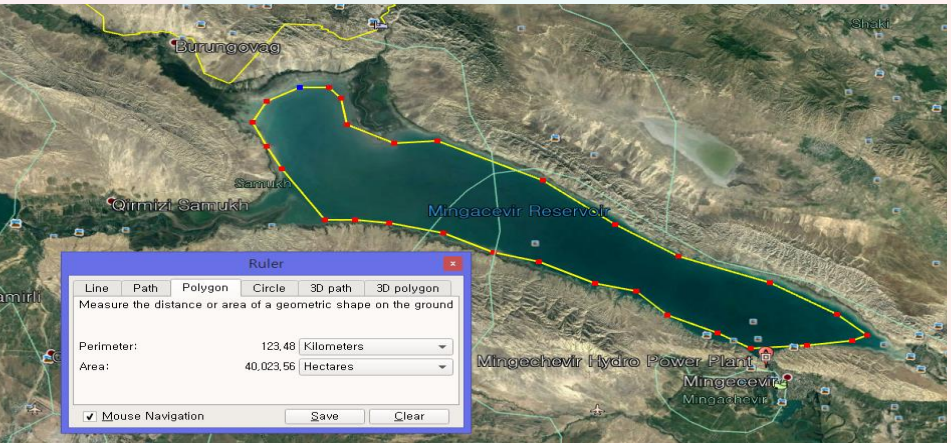
- Energy resource-rich and one of the world's oldest oil producing countries
- Power generation installed capacity of 7,400MW with 100% electrification. ***Generation capacity is 85% fossil fuel****, 14.9% hydro and negligible share of other renewables.*
- Azerbaijan plans to increase the share of renewable energy sources to 20% by 2020
- **Energy policy** - aims to increase renewable energy capacity to 2.5GW by 2020 including 600MW of solar PV. The solar PV capacity is around 35MW
- **INDC:** 35% reduction in the level of GHG emission by 2030, compared to 1990.
- **Solar PV -** operational solar module maker, Azguntex LLC, which owns a 75MW solar panel manufacturing facility since 2012. The Azguntex was established by the State Agency on Alternative and Renewable Energy sources.
- Irradiation: 1,400 – 1,500 kWh/m^2.year

Potential FPV Sites – in Azerbaijan

Lake Boyukshor

- Salt lake located in the north of Baku
- Surface area: 10.6 km^2(or 1,062 ha)
  - Largest of 9 lakes in the Absheron peninsula
- Relatively shallow; max. depth is 4.2m and only 0.5 ~ 1.7m at the shoreline
- Had known to be heavily polluted with municipal wastes and oil effluents*; Restoration project cleaned 300 ha between 2012-2015*
  - Boulevard, promenade and park created
  - FPV system could be used to power the street lights of boulevard area or pumps
- Electrical substation is located close by
- Colored polygon is 1km^2 (or 100 ha); theoretically, can fit 100 MW (1-2 ha/MW)

Mingachevir reservoir



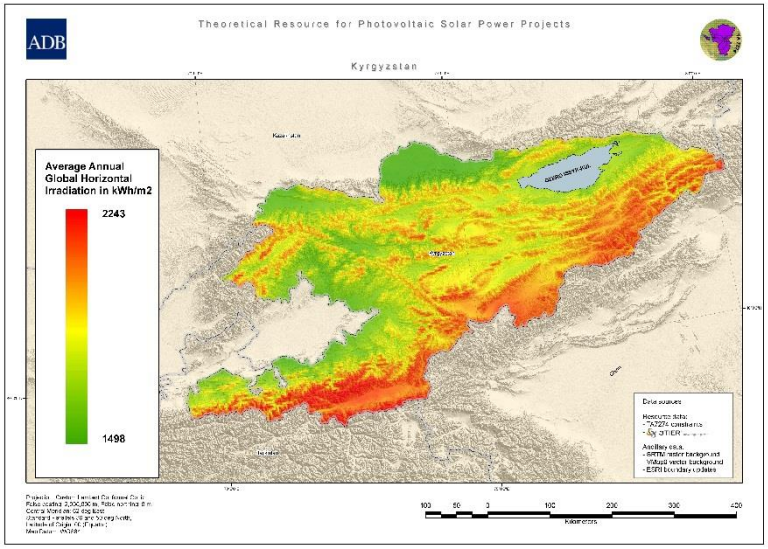
The Mingachevir HPP is the largest in the country, with an installed capacity of 420 MW. The reservoir is built in 1953, is 75m at maximum depth and the capacity of 15.73 km^3. Average depth is 26m and the shore length is 247 km. The overall area of the reservoir is 605 km^2. (Theoretical capacity: 40,000 hectares = **40 GW**)

Pilot countries - Kyrgyz Republic

Land area: approx 200,000 km^2
Population: 6 million people

Primary energy sources:
- **oil (32.7%)**
- **coal (31%)**
- **hydro (30.3%)**
- **natural gas (6%)**

Electric power sources:
- **hydropower (89.94%)**
- **coal (7.26%)**
- **oil (<1%)**
- **natural gas (<1%)**



	Biomass	Solar PV	Wind	Small Hydro
Installed Renewable Electricity Capacity 2012 in MW	0	0	0	41.4
Technical Potential for Installed Renewable Electricity Capacity in MW	200	267,000	1,500	1,800

Sources: EBRD (2009); Botpaev et al. (2012); Ministry of Energy of the Kyrgyz Republic (2010); Hoogwijk and Graus (2008); Hoogwijk (2004); JRC (2011); SRS NET & EEE (2008); EIA (2013); Renewable Facts (2013); EIA (2010); World Bank (2014); DESERTEC (2012); and UNDP calculations.

Toktogul HPP and Reservoir

Hydropower plant

- The largest and most important power plant in the Kyrgyz Republic
- In service since 1978
- 1,200 MW - 4 x 300 MW
- 4,400 GWh per year (40% of domestic power)
- Substations: 500 kV and 110/10 kV

Reservoir

- Area: 284.3 km2
  - Space for app. **20GW** of FPV (in theory)
- Irradiance: 1,657 kwh/m^2,yr
- Total reserve capacity: 19.4 km^3
  - Actual capacity: 14 km^3
- Water level: 827 – 900m above sea level
  - Maximal water depth: 120m
- 827M (above sea level) regarded as a “death level”
  - Occurs app. every 10-12 yrs

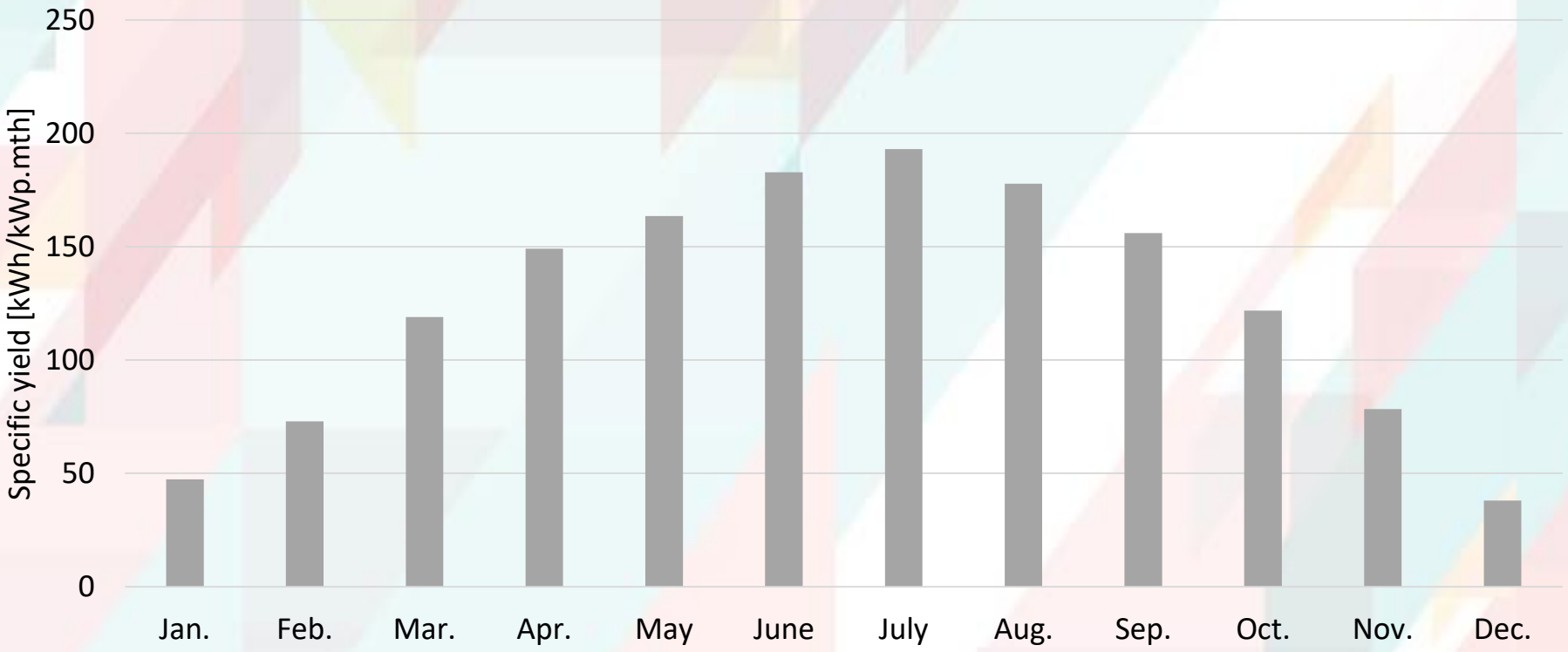
Potential Site for pilot and large scale FPV plant

- Easy connection to the grid
- Easy access
- Flat shore (for installation)
- Land owned by EPP

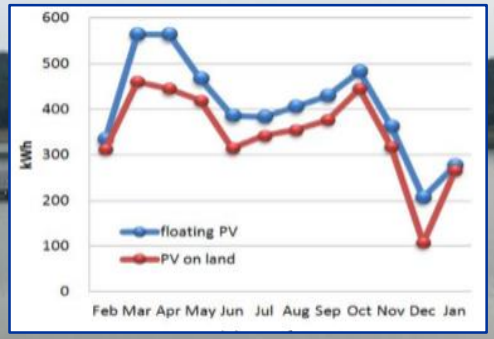
Large-scale project

- 500 kV transmission
- Irradiance: 1 657 kWh/m².yr (source: Meteonorm 7)
- Theoretical FPV capacity = over 20 GW

Preliminary Yield Estimates - KGZ



- Total year: 1,500 kWh/kWp.year or 1 MW installed = 1,500 MWh/year
- Optimal PV installed capacity for hybrid operation with HPPs must be investigated (hourly, daily, monthly and seasonal production profiles
- Potential for scale up of pilots and replication within the pilot country and elsewhere in the region will be assessed



Project sites have huge potential for scale up, replication and showcasing various configurations, uses and benefits of FPV:

1. Qargha dam and reservoir in AFG: used for recreation and trout fishing and hatchery and is planned to supply additional drinking water to Kabul, provide irrigation, and feed a hydropower plant (HPP). Water conservation is essential in this dry and rugged topography. Qargha lake could fit at least 10 MW, while the Naghlu reservoir* could theoretically fit at least 200 MW of FPV.
2. Lake Boyukshor in AZE is saline and used as a dumping site for sewage and oil effluents. FPV could demonstrate climate-resilient lake restoration while displacing fossil-based power. The lake could theoretically fit 500 MW FPV and there are 8 more such lakes in Baku.
3. The 1,200 MW Toktogul HPP and reservoir supplies 40% of KGZ power, exports power and provides irrigation water to Uzbekistan. FPV could balance the seasonality of hydro with year-round generation. The lake could theoretically fit over 20 GW of FPV.

Implementation arrangements and counterpart in-kind contribution

- ADB will be the TA executing agency working with the country executing agencies and CAREC-ESCC country focal persons.
- The counterparts are: Da Afghanistan Breshna Sherkat (DABS), the Ministry of Energy and OJSC Temiz Shahar of Azerbaijan, and OJSC Electric Power Plants (EPP) of the Kyrgyz Republic.
- he TA consultants will support TA administration and coordination, working closely with, assisting, and training the existing project management units (PMUs) in DABS, EPP and Temiz Shahar.
- The country counterparts and their PMUs will provide data, office space, and technical staff, and assist in data collection, meeting arrangements and others, needed to accomplish the tasks. The TA is expected to be implemented over 31 months.

** The ADB-funded 20 MW land-based PV plant expected to be constructed in 2018 is 2 km away from and will be connected to the 100 MW Naghlu HPP*