Bangladesh Solar Irrigation Pump (SIP) Site Prioritisation Tool

29 October 2019

Supported by:

Federal Ministry
for the Environment, Nature Conservation,
Building and Nuclear Safety

based on a decision of the German Bundestag

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Contents

Background

Project Background – third phase of work with IKI funding, supporting GoB and others in developing sustainable finance for sustainable energy markets

- This study is financed by the International Climate Initiative (IKI) and implemented by PwC and their appointed consultants, Vivid Economics and NACOM

- Third phase of work under this IKI funding

  - **Phase 1** supported the Government of Bangladesh in identifying three priority sectors in its NDC: (i) Power, (ii) Industry, (iii) Transport

  - **Phase 2** supported SREDA in developing an overview of the current market, market potential, business models, and investment case for (i) solar mini-grids, (ii) solar irrigation, (iii) solar boats

  - **Phase 3** supports SREDA, IDCOL, project developers and investors to scale up the market of solar irrigation pumps from c. 1,500 now, to up to 25,000 over the next five years

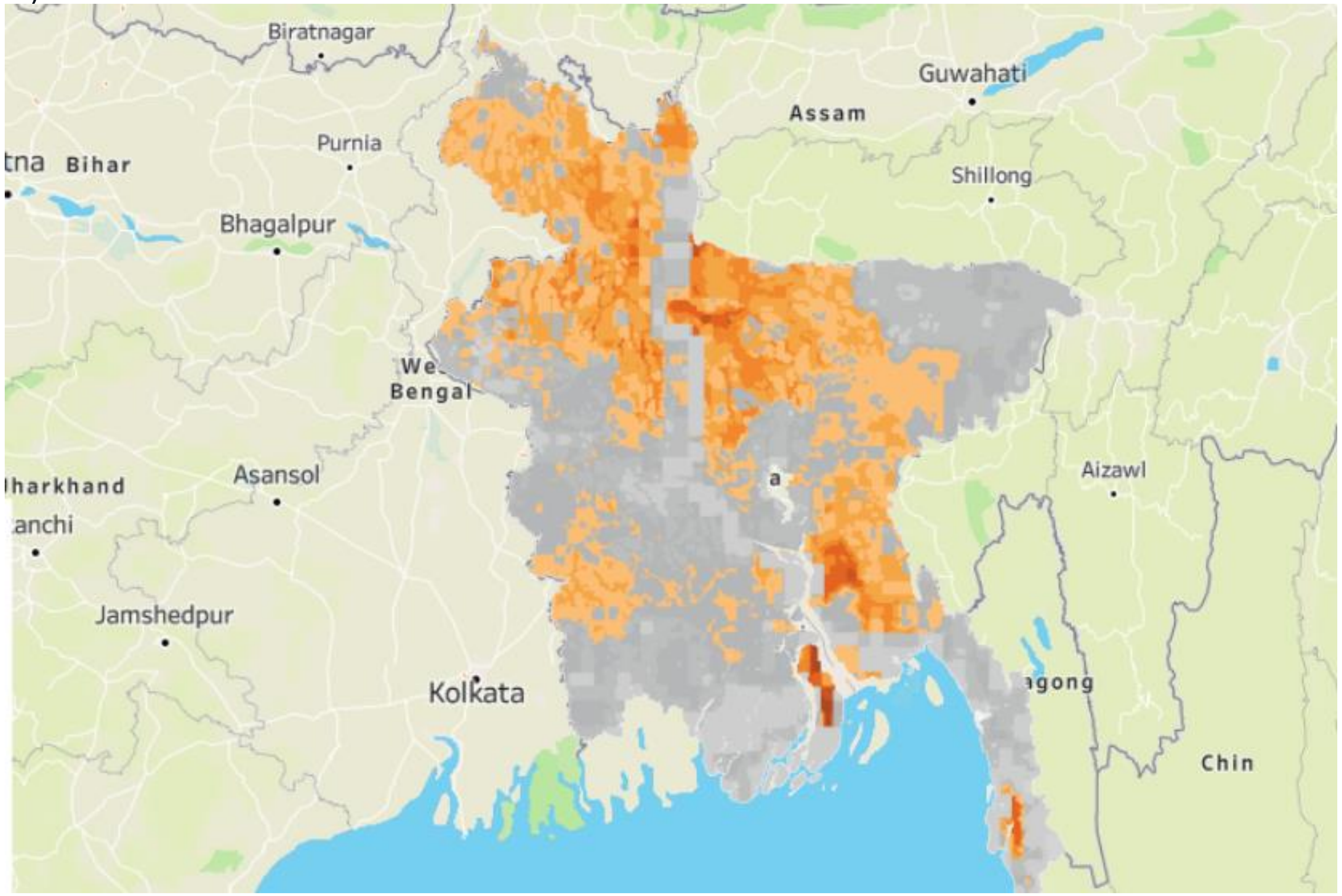
Project Background – our previous phase of work resulted in some clear recommendations for the SIP sector

- Key priority is to operationalise the policy to enable sale of surplus power from SIP panels to the main grid. This will need:
  - Grid integration guidelines (developed), and technical pilots (ongoing)
  - Net metering policy and policy on connection charges and tariffs for sale of power
  - Determination of economic viability of connecting pumps to sell power to the grid, and to consider alternative sources of revenue generation (supported by this study)
- Need to identify areas of potential for promotion of solar irrigation – SREDA to work with Power Division, BADC and others (supported by this study)
- While cost of replacement and repairs is not a major challenge facing SIPs, continuing to work to reduce operating costs would help make the business model bankable

Key findings

Solar irrigation has large technical potential – prioritising the most economically attractive locations is key to achieving scale and unlocking finance

- A total technical potential demand of up to 110,000 SIPs (average size of 25 kWp panel), with installed capacity of over 3 GW (peak)



The most attractive regions for SIPs are in the North and North West of Bangladesh

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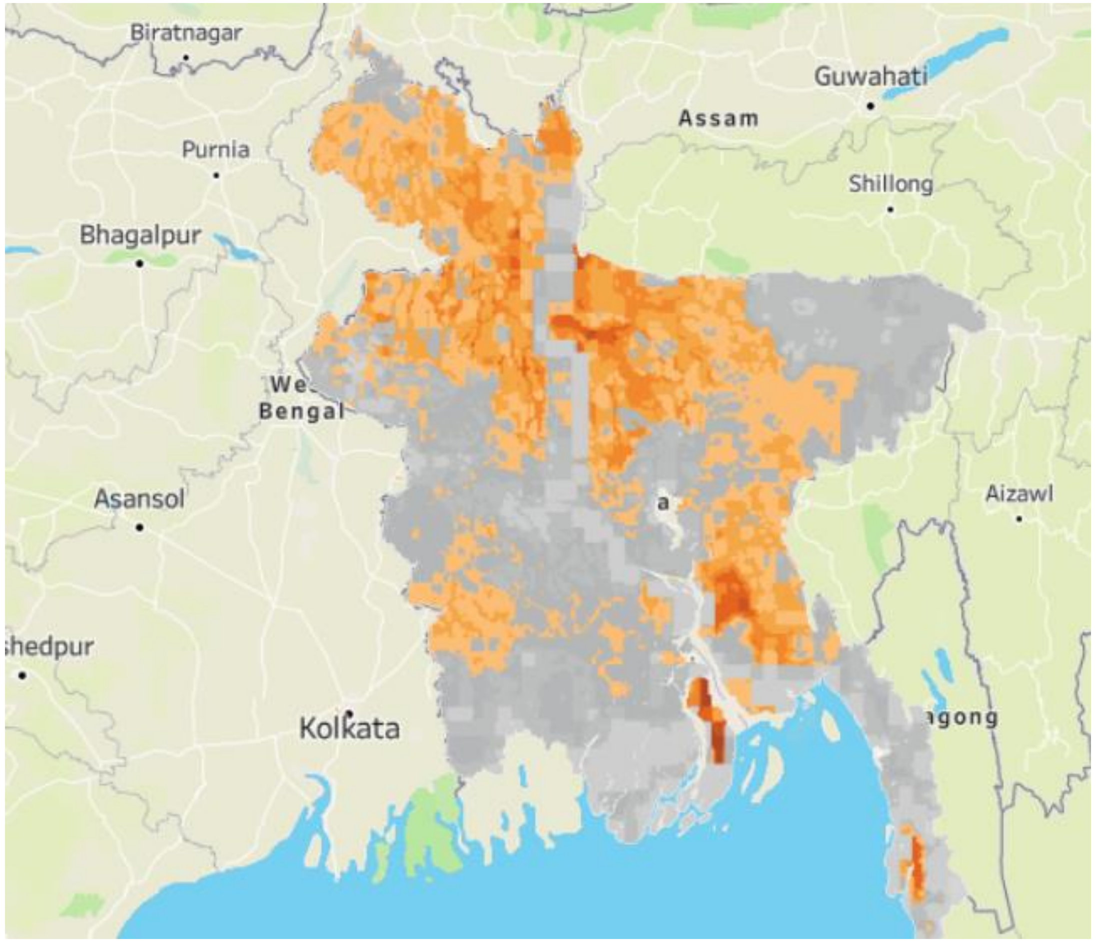
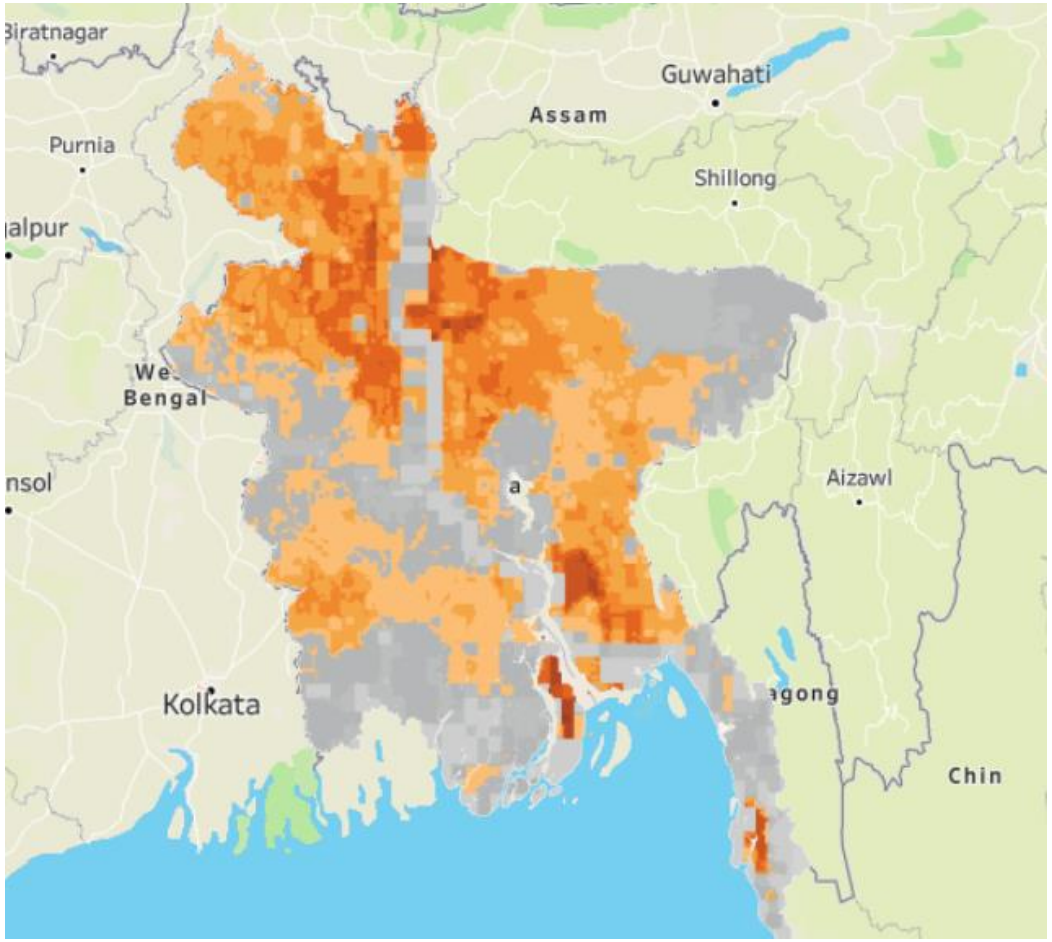
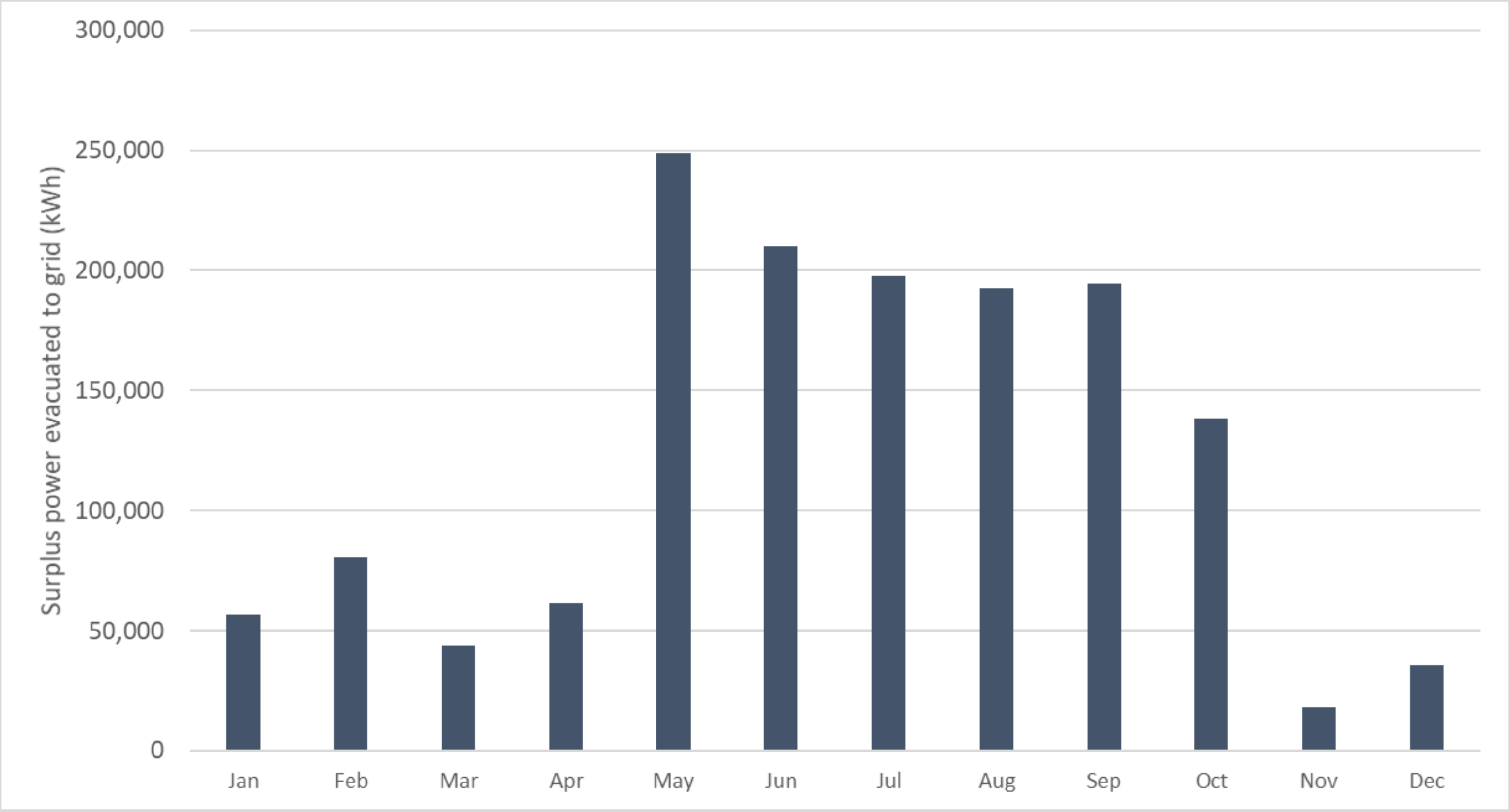
Sale of surplus power to the grid could make an important contribution to the commercial viability of SIPs and would affect the most attractive locations





If all available surplus power is evacuated from the grid, there will be substantial seasonal variation

- For example, Dinajpur PBS, for 6 months of the year, exports are between 7% and 30% of the power made available in the peak month
- This corresponds to the period when SIPs are most available to evacuate power to the grid. However, the seasonal variation in the annual load curve is far less than the seasonal variation in the power available from SIPs



This monthly surplus power varies substantially across PBS. Example 1

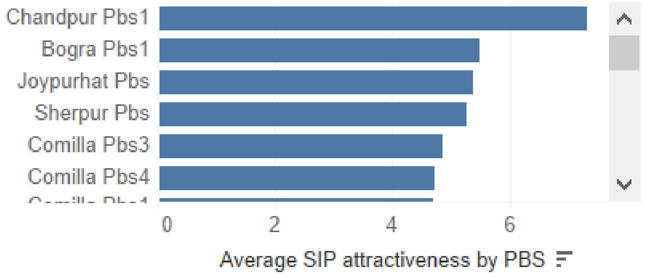
PBS-level Data

This page allows results to be viewed at a PBS level.
The 'SIP installation potential' and 'Average SIP attractiveness' boxes at the top of this page show these values for each PBS in Bangladesh. The summary data in the lower section of this page will update according to the PBS selected in the dropdown list below. Roll over the map to view the location data for each grid cell within the PBS. The Cell ID can be used to cross reference with other pages of this tool.

SIP installation potential

	SIP potential	Cumulative SIP Potential
Thakurgaon Pbs	3,913	3,913
Patuakhali Pbs	3,192	7,105
Naogaon Pbs 1	2,931	10,036
Mymensingh Pbs3	2,679	12,715
Naogaon Pbs 2	2,672	15,387
Rangpur Pbs1	2,512	17,899
Kurigramlalmonirhat P..	2,492	20,391
Dinajpur Pbs1	2,484	22,875

Average SIP attractiveness



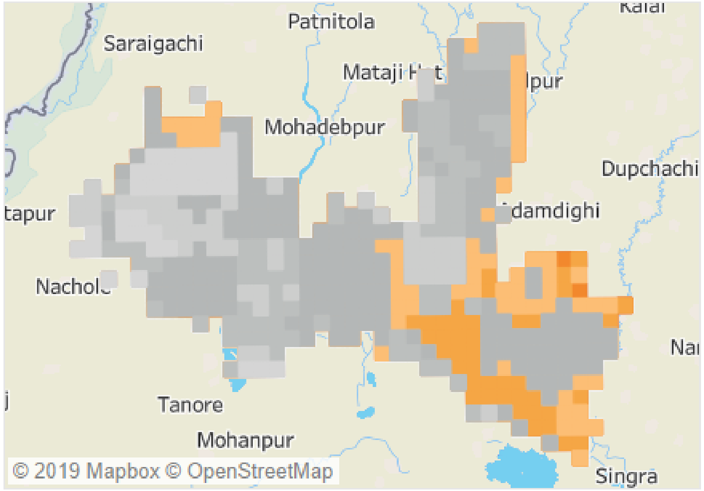
PBS1
Naogaon Pbs 1

PBS-level information for Naogaon Pbs 1

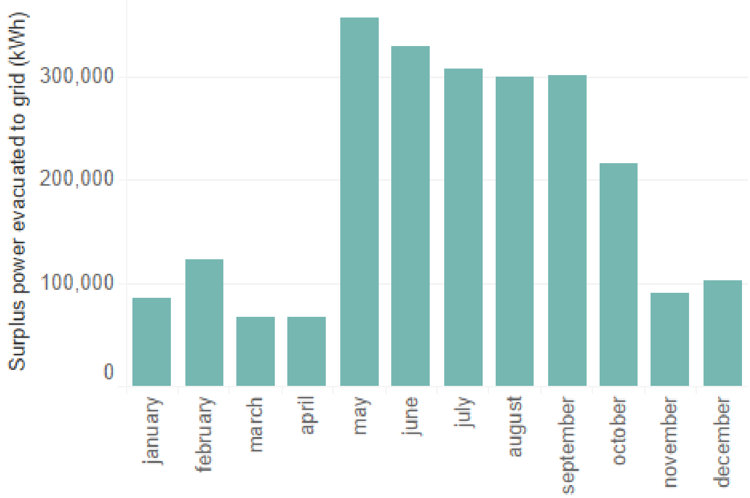
SIP potential	2,931
Number of ADB Pumps	0
Number of Existing Diesel Pumps	22,782
Power Evacuated to the Grid MWh/y	70,426

Map view: PBS level

Search by Cell ID:



Surplus power evacuated to the grid in Naogaon Pbs 1



This monthly surplus power varies substantially across PBS. Example 2

PBS-level Data

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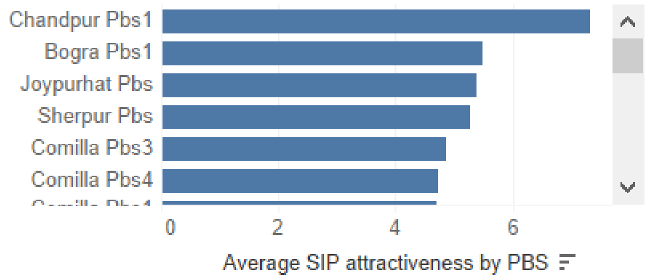
Average SIP attractiveness



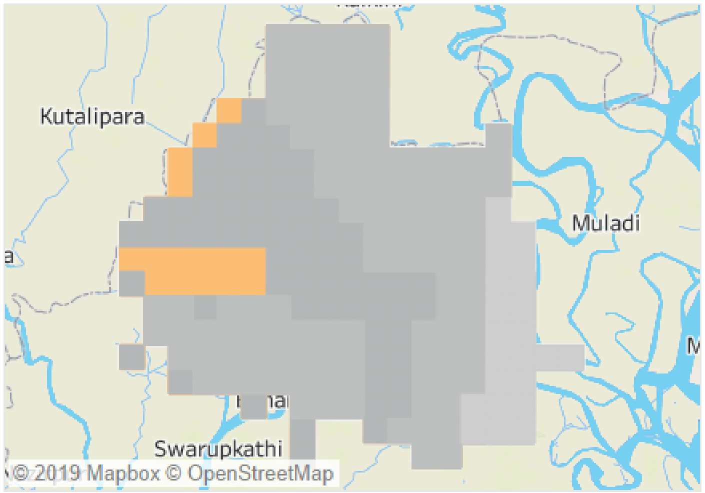
PBS1
Barisal Pbs2

PBS-level information for Barisal Pbs2

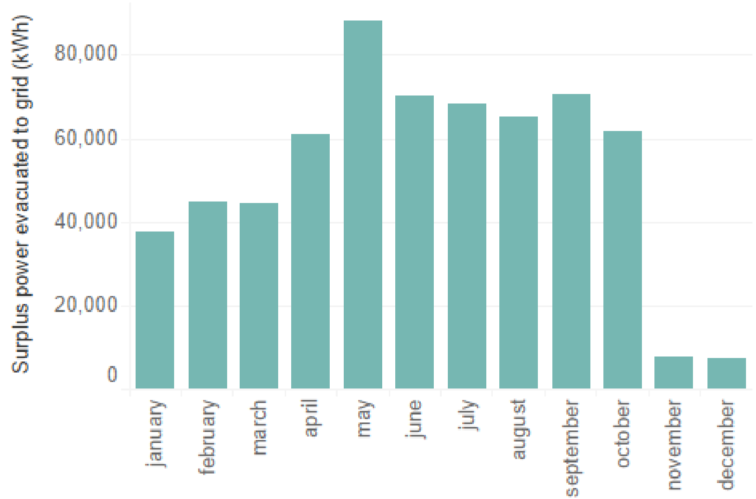
SIP potential	667
Number of ADB Pumps	0
Number of Existing Diesel Pumps	2,751
Power Evacuated to the Grid MWh/y	18,805

Map view: PBS level

Search by Cell ID:



Surplus power evacuated to the grid in Barisal Pbs2



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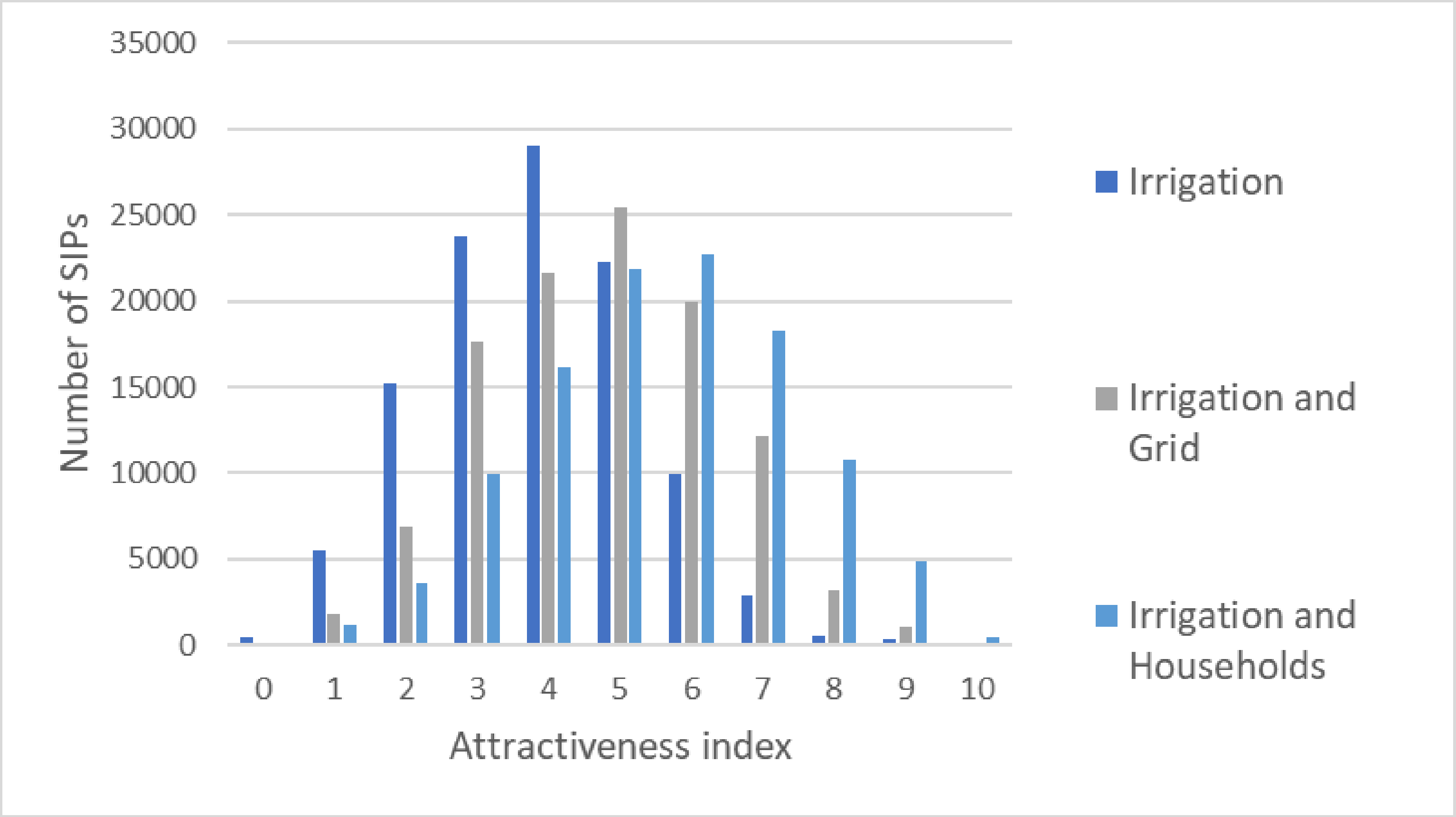
On the basis of current trials, connection of a single pump to the 11 kV distribution network is unlikely to be economically viable

- At present, IDCOL is piloting one technical trial to connect a 25 kWp pump to the 11 kV distribution network.
  - The cost of the project is estimated to be around BDT 2 million, of which up to 25% comprises research and project development costs for this first trial version.
  - Revenue generating potential, over the lifetime of a typical 25 kWp system, of c. BDT 5 million, of which just 0.5 million comes from the sale of surplus electricity to the grid.

- However, there are a couple of options that could make connection to the local grid and sale of surplus power economically feasible.
  - Connection to local 400 V lines should be investigated. This should help reduce the cost of inverters and transformers required.
  - Forming a 'cluster' of SIPs should be considered, as the 'fixed' costs of connection to the grid can then be shared across multiple individual pumps.
  - Finally, policy makers need to consider the potential prices at which surplus power could be sold to the grid to ensure efficient outcomes. Policy stability and transparency is important to encourage investment

- There is also the possibility of alternate sales of surplus energy to the local community, through local battery storage.

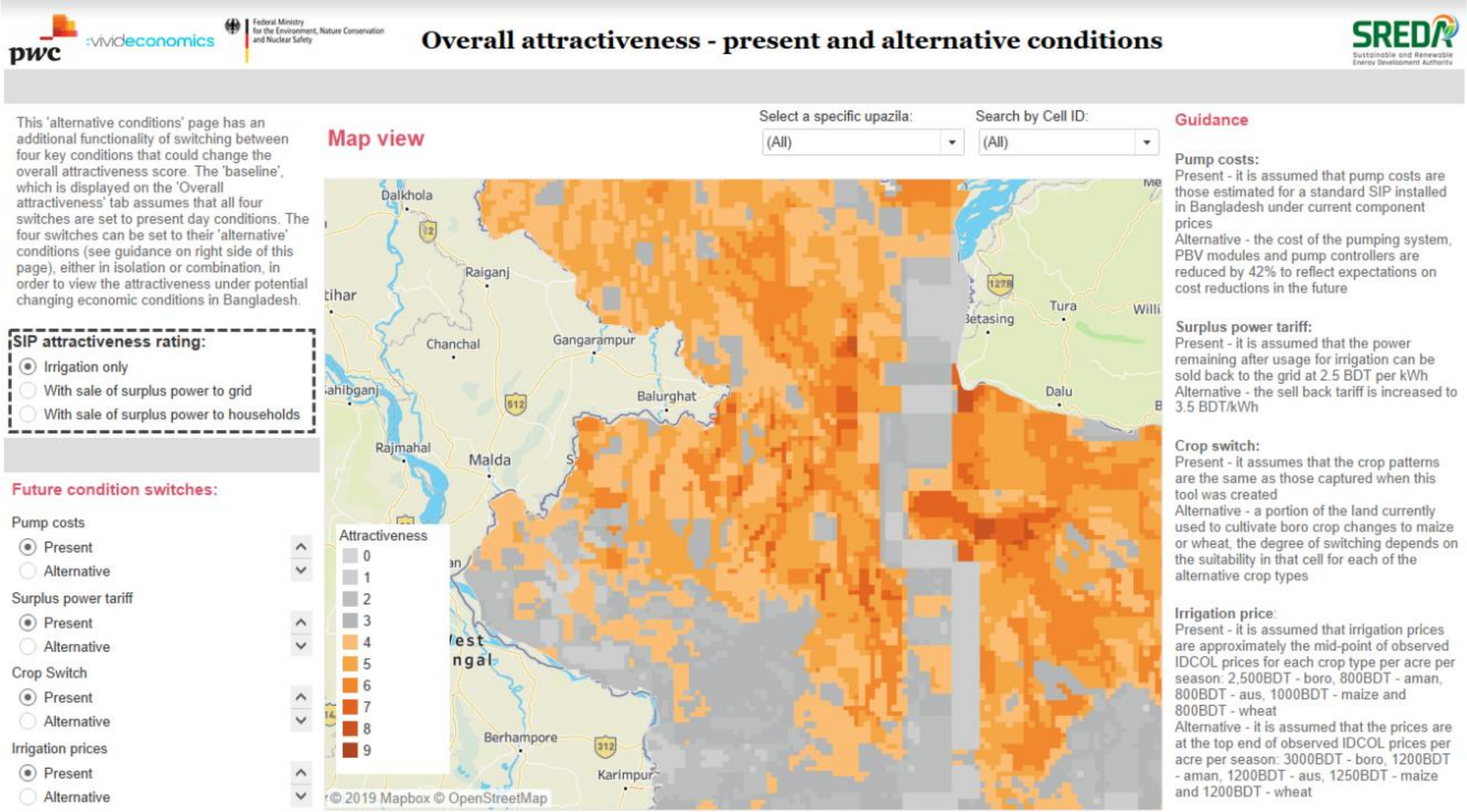
The attractiveness of sites increases if connections to the grid or households can be facilitated



Attractiveness	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Irrigation	411	5550	15177	23717	29065	22227	9921	2914	532	347	0
Irrigation and Grid	52	1783	6856	17628	21656	25446	19963	12204	3144	1075	54
Irrigation and Households	30	1150	3643	9963	16194	21853	22723	18243	10797	4838	427

Tool structure and methodology

The core objective of this project was to develop a tool that allowed for SIP site prioritisation across Bangladesh



The tool combines GIS data, economic modelling, national experience, and international evidence, to reveal sites that are most attractive for SIPs

Bangladesh GIS data – model and calibration

- Solar radiation intensity
- Topography
- Groundwater depth
- Salinity
- Arsenic
- Agricultural crops and yields
- Existing Irrigation Pumps

- Population Density
- Electricity grid

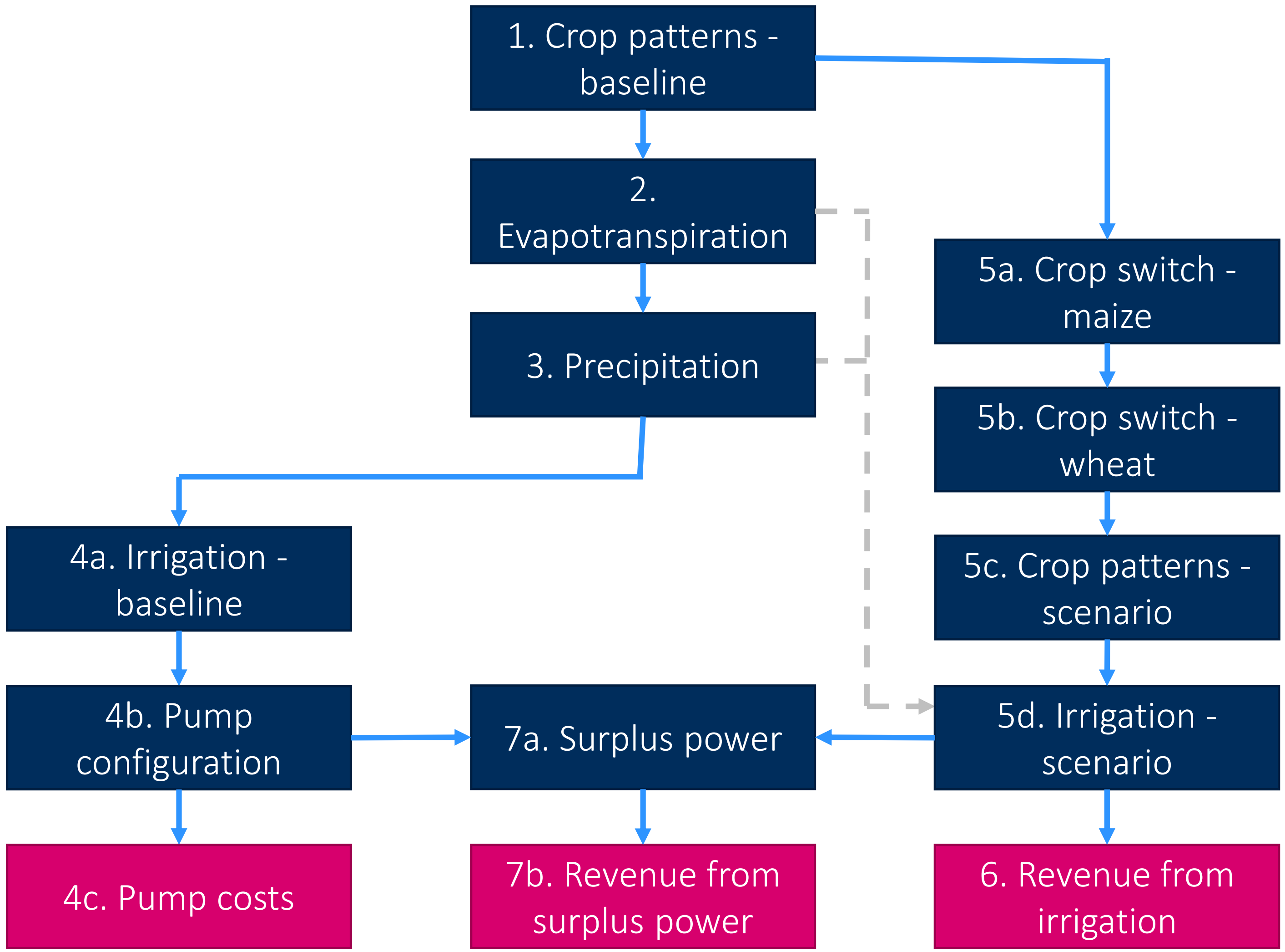
National experience and programmes

- SREDA
- IDCOL
- BADC
- Power Division
- Private sector investors and operators

International evidence on SIPs

- Engineering, Agriculture and Economics literatures
- International Organisations

The Excel model calculates irrigation demand, revenue, and cost of deploying SIPs in each 2km² grid cell (400 hectares)



Outputs and user interface

Users can toggle between settings on four key scenarios

	Baseline	Switch
Crop patterns	Current crop coverage for each cell, in each month of the year	Baseline: represents current crop coverage for each cell, in each month of the year
Low pump costs	Pump costs scaled on a unit cost based on required system size, based on current costs in Bangladesh	Reduction in components of 42%. No reduction in operating costs
High irrigation prices	Mid-point of IDCOL irrigation prices per crop type, which are applied to all grid cells (no regional variation in prices modelled)	Upper end of current IDCOL prices per crop type
High surplus power price	Baseline assumed tariff of 2.5 BDT per kWh sale of surplus power to the main grid	As an indicative higher tariff, we have included sale at 3.5 BDT per kWh, which is the current price farmers pay for electric irrigation, and is still far below the bulk power prices.

Tool demo

- Crop patterns vary across Bangladesh – we have a basic estimate of where five major crop types are grown
- Combining crop patterns with precipitation, and availability of surface water and ground water, gives an estimate of irrigation requirement
- Solar irradiation is quite variable across the year – which affects system design as pumps need to be able to meet peak demand for irrigation
- The attractiveness of different sites can be seen in the baseline scenario
- This can be compared to the attractiveness with sale of surplus electricity to the grid
- Alternative scenarios can be considered
- Outputs at the PBS level

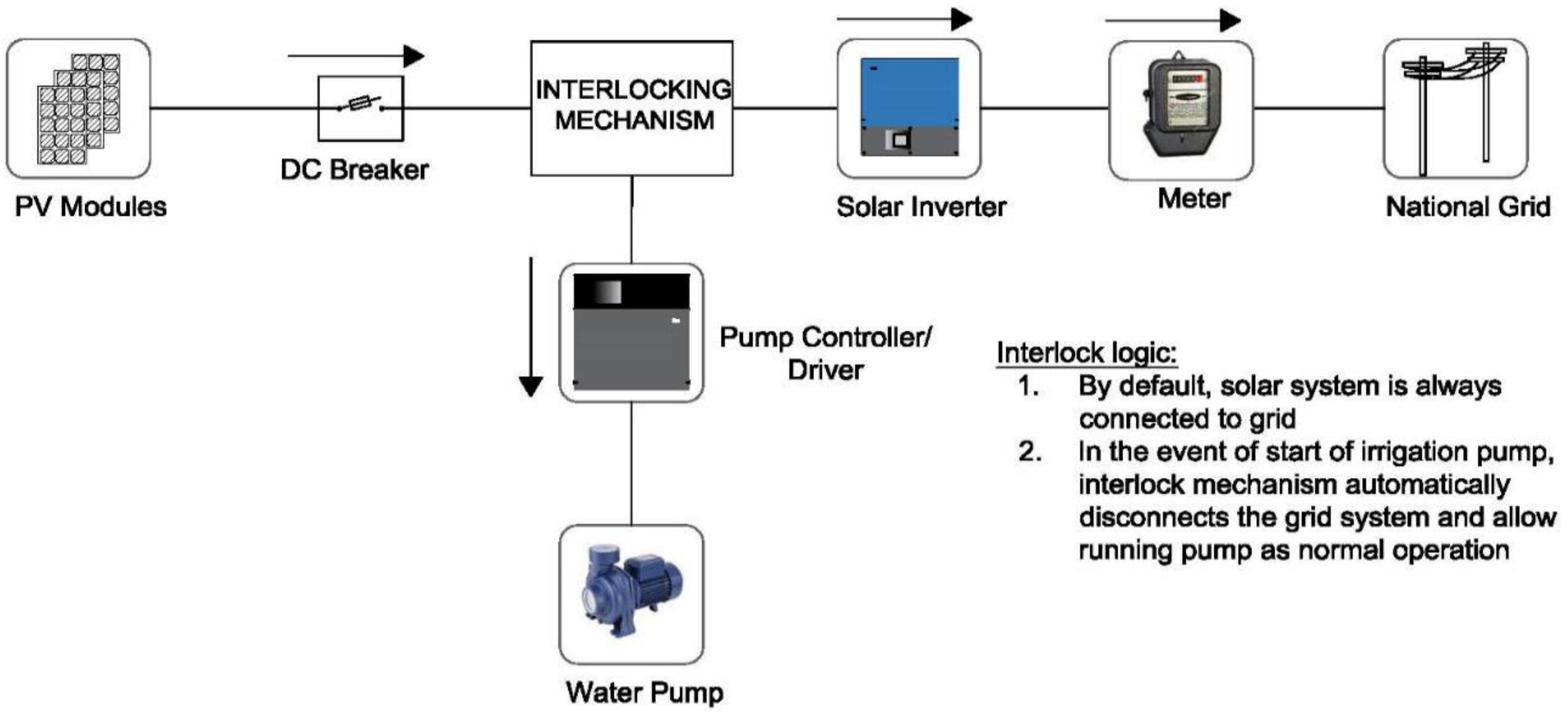
Caveats and limitations

While this model presents an aggregation of a wide number of datasets, it has limitations

- Flood risk
- Groundwater Stress
- Size of pumps and economies of scale
- Exclusion factors for arsenic, salinity, slope
- Costs of connecting SIPs to the grid & assumption of 100% sell-back
- Data aggregation
- Competition

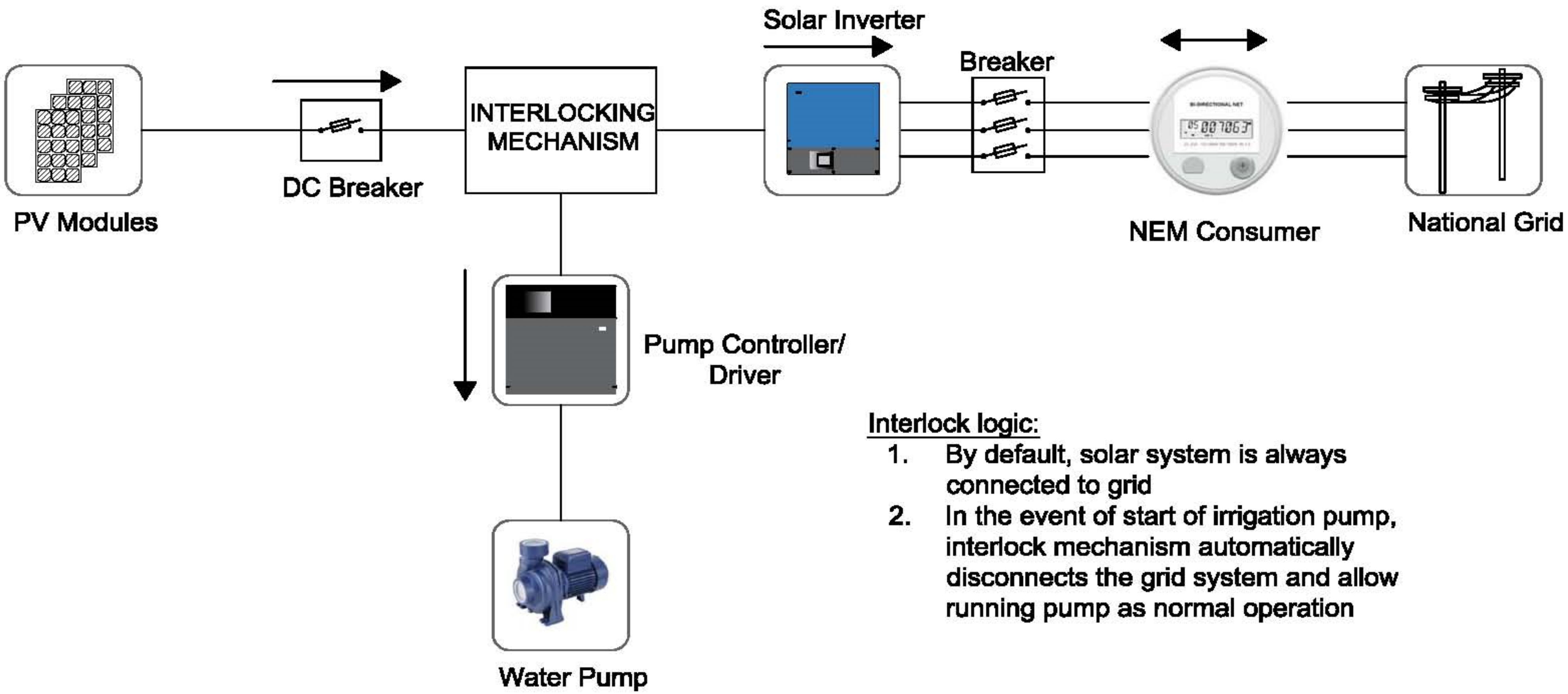
Grid Integration of SIPs

Grid Integration of SIPs Guidelines (Draft): Integration



Schematic diagram of grid integration of individual SIP (single phase).

Grid Integration of SIPs Guidelines (Draft): Integration



Schematic diagram of grid integration of individual SIP (three phase).

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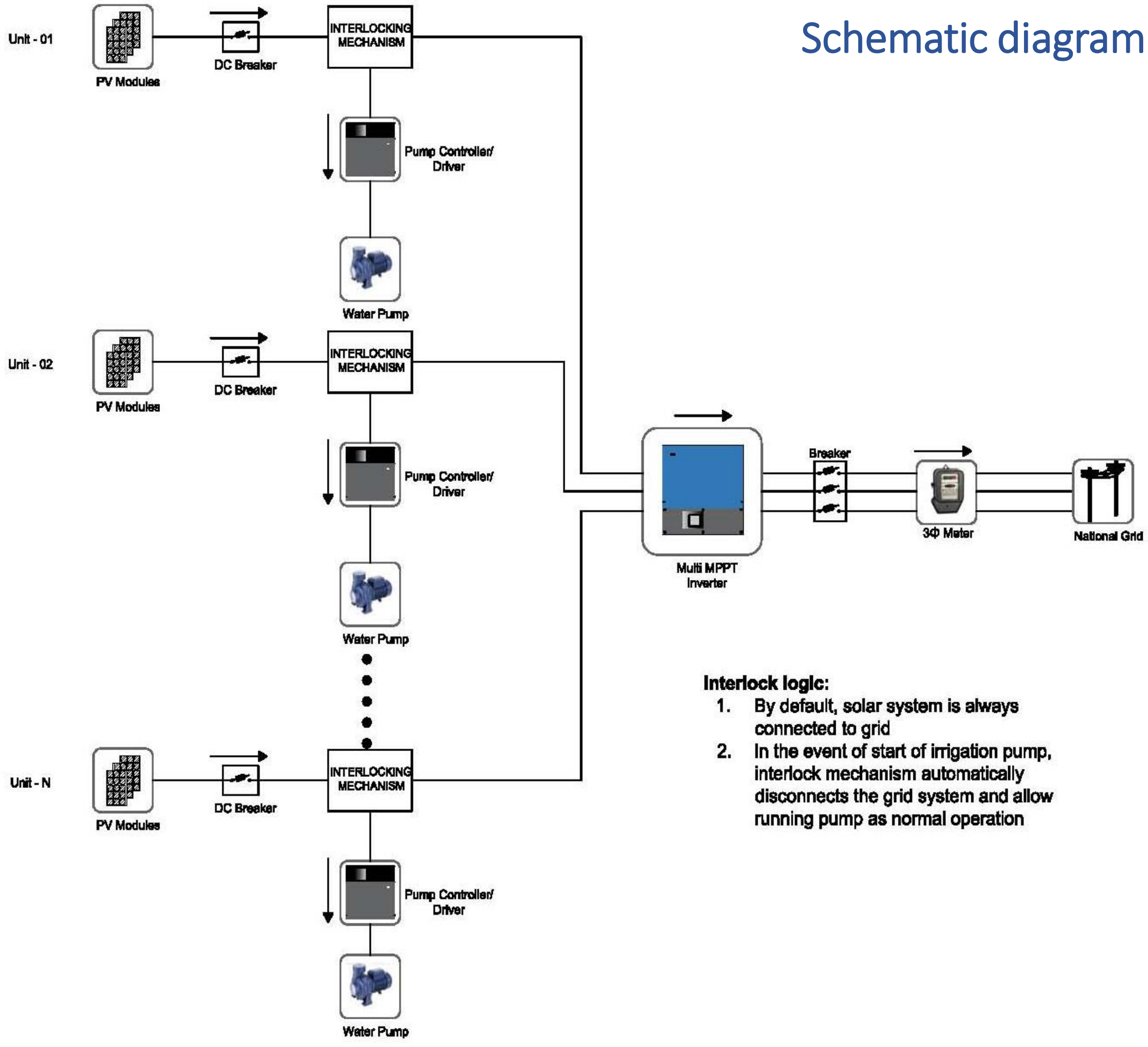
Grid Integration of SIPs Guidelines (Draft): Integration

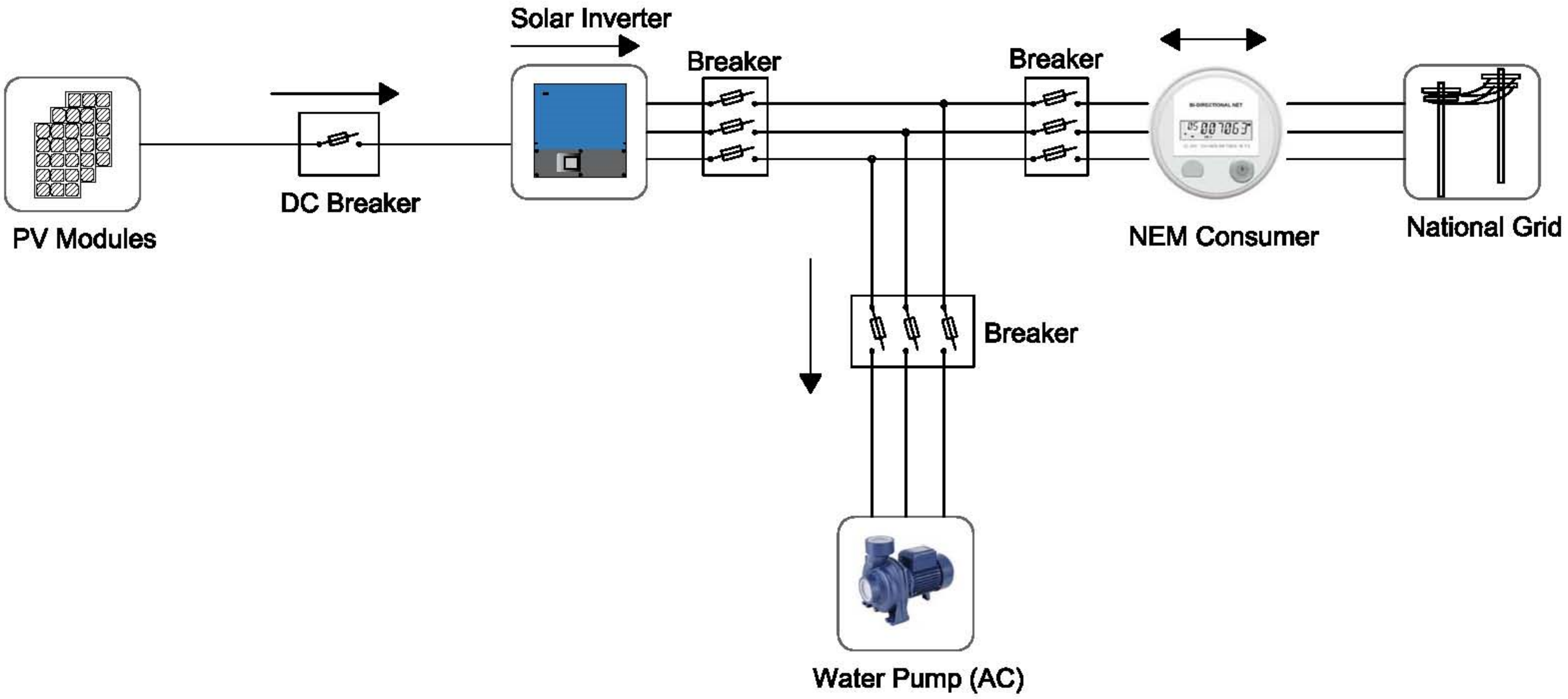
Schematic diagram of grid integration of SIP cluster.



Interlock logic:

1. By default, solar system is always connected to grid
2. In the event of start of irrigation pump, interlock mechanism automatically disconnects the grid system and allow running pump as normal operation

Grid Integration of SIPs Guidelines (Draft): Integration



Schematic diagram of grid integration of new SIP systems in grid areas (3 phase).

Grid Integration of SIPs Guidelines (Draft): Financial Aspects

Tariff structure

- For each billing period, the utility will conduct the energy accounting based on the tariff order issued by the Bangladesh Energy Regulatory Commission (BERC). The accounting should accommodate the grid connection types
- The pump owner (POs or farmers) will export excess electricity to the grid at the BERC approved bulk tariff
- The tariff of the exported electricity shall be at the BERC approved bulk tariff for that utility
- The tariff rates will be subject to change according to the tariff structure determined by the BERC for any particular fiscal year
- For integration of SIPs in existing grid area the accounting will follow the NEM guideline

Grid Integration of SIPS Guidelines (Draft): Financial Aspects

Energy accounting and settlement

- Utilities shall be responsible for preparing and issuing electricity bills for each billing period and conduct energy accounting on a yearly basis
- Utilities shall prepare an energy statement the components of which shall vary depending on the type of grid connection
- The utility shall settle monetary transactions at the end of settlement period on an annual basis
- The settlement period is 12 months and it will be same as the fiscal year considered by the utility

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Discussion points

A number of key questions are raised from this model

- What are the likely connection costs for sale of power to the grid identified in the technical studies? How do these compare to the potential for revenue generation at individual sits / clusters?
- How do the regions highlighted as high potential compare to expectations and experience of developers and investors?
- How should prices be designed, and adjusted dynamically, to reflect changes in circumstances over the lifetime operation of the pumps? Are prices sufficiently reactive to match farmer irrigation needs to revenue needs of pump owners?
- How to unpick subsidies for grid consumption and other energy sources so that off-grid solar is competing on a level playing field?

- Grid interconnection feasibility – how to deal with not only intermittent supply, but supply which has (quite predictable) variation across the year?
- How can the SIP market move toward more commercial business models?

This project is part of the International Climate Initiative (IKI). The German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB) supports this initiative on the basis of a decision adopted by the German Bundestag

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Annex – description of modelling steps

First, we estimate the irrigation requirement in each cell, in each month, based on current cropping patterns

- **W1. crop patterns – baseline**
  - ◊ Combines data on ha coverage for each main crop (boro, aus, aman, maize, wheat) and the crop calendar
  - ◊ Calculates coverage in ha for each crop during each month
- **W2. evapotranspiration**
  - ◊ Calculates crop evapotranspiration by multiplying reference evapotranspiration with FAO crop coefficients for each crop in each month (mm/month)
- **W3. precipitation**
  - ◊ Computes effective rainfall from mean precipitation per month using a standard formula
- **W4a. irrigation - baseline**
  - ◊ Calculates irrigation needs from the previous steps using the formula area * (crop evapotranspiration – effective rainfall)
  - ◊ The resulting numbers are converted from ha * mm/month into m^3/day and summed up across crops, yielding the daily irrigation requirement for each month and cell
  - ◊ The peak irrigation requirement over the year is used in subsequent calculations

The size of SIPs needed to meet the baseline irrigation requirement combines monthly estimates of irrigation need, power need, and available solar yield

- W4b. pump configuration
  - This steps uses the irrigation requirement calculated in W4a alongside geospatial variables to obtain the required pump and solar pv capacity to meet peak irrigation demand
  - Groundwater depth and data from IDCOL are used to calculate total dynamic head (where surface water is available, this calculation is replaced by the IDCOL estimates of the TDH required to extract surface water)
  - Average daily hydraulic load is estimated by multiplying the TDH by the daily volume of water required, alongside a number of physical constants, yielding the amount of energy in kWh required per day to meet irrigation demand – this is adjusted to account for expected combined pump and motor efficiency of 47.5%
  - Solar panel requirements are then calculated based on the previously calculated energy required, using average solar irradiation in each month, converted into hours of peak sunshine, and adjusted for expected efficiency losses
  - We are assuming a pump to PV size ratio of 50% based on the ADB's roadmap to solar irrigation and calculate the number of pumps and panels required if panels have a standard capacity of 20 kWp

The lifecycle cost of providing the baseline SIP configuration is based on a unit cost model for component parts (capex) and opex and includes financing costs

- W4c – Lifecycle costs
  - Calculates the lifecycle costs of a SIP in each cell, distinguishing between operating and capital expenditure
  - Assumption that operating expenditure is linear in energy generated (100 USD/kW per year)
  - Capital costs composed of pumping system, PV module, mounting structure, controllers, wiring and installation and water storage and distribution – also assumed to be linear in kW capacity
  - Financing structure broken down into grant, debt, and equity – 6% interest rate, 10 years debt repayment, 10% discount rate
  - NPV of cost over 20 years calculated

A separate module then estimates actual irrigation demand, accounting for farmer's changing cropping patterns

- W5a. crop switch – maize / W5b. crop switch - wheat
  - Allows for scenarios in which farmers switch to boro or maize after the SIP is installed
  - Uses data on the proportion of area of each cell that is at least moderately suitable for maize/wheat and assumes that the same proportion of boro is switched to the alternative crop
- W5c. crop patterns – scenario
  - Calculates coverage of each crop after switching
- W5d. irrigation – scenario
  - Calculates the irrigation requirement based on the alternative crop cultivation patterns
  - Feeds into revenue calculations

Revenue from water supply combines the hectare coverage of each crop type, with a fixed price set by IDCOL (or others) per acre of irrigation

- W6 – Revenue from water supply
  - Uses ha irrigated for each crop
  - Uses the medium ICDOL price for each crop per ha per season and the divides this value by the number of months in the season to obtain a monthly fee
  - Multiplies the two for each crop and sums across crops to obtain estimated revenue per month
  - Calculates NPV of revenue over 20 years, assuming 50% of annual revenue in year 1, 75% in year 2, and 100% in subsequent years, as well as a 10% discount rate

Pump configuration and actual irrigation usage are combined to provide an estimate of the surplus power that could be evacuated to other uses (kWh)

- W7a – Surplus energy
  - Calculates total energy generated by each panel during each month (based on capacity and solar irradiation) and subtract the energy needed to meet irrigation demand during that month
- W7b – Non-irrigation revenue
  - surplus power is multiplied by an assumed sale price, accounting for losses through inverters and transformers
  - Revenue streams over 20 years are calculated and discounted to obtain NPV
  - Scenarios: sale to the grid, sale to the local population

This document is an output from the Mobilising Investment project, an initiative of the Climate and Development Knowledge Network (CDKN) and Low Emission Development Strategies Global Partnership (LEDS GP) contracted through SouthSouthNorth (SSN).

The Mobilising Investment project is funded by the International Climate Initiative (IKI) of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), on the basis of a decision adopted by the German Bundestag. Delivery partners for the project include the National Renewable Energy Laboratory (NREL), Overseas Development Institute (ODI) and PriceWaterhouseCoopers UK (PwC).

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