Bangladesh Solar Irrigation Pump (SIP) Site Prioritisation Tool

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based on a decision of the German Bundestag

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putting economics to good use
Contents

1. Background
2. Key findings
3. Tool structure and methodology
4. Outputs and user interface
5. Caveats and limitations
6. Grid Integration of SIPs
7. Discussion points
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
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

Bangladesh Solar Irrigation Pump (SIP) Site Prioritisation Tool
This monthly surplus power varies substantially across PBS. Example 2
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.

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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 2km$^2$ grid cell (400 hectares).
Outputs and user interface
Users can toggle between settings on four key scenarios

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>Switch</th>
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</thead>
<tbody>
<tr>
<td><strong>Crop patterns</strong></td>
<td>Current crop coverage for each cell, in each month of the year</td>
<td>Baseline: represents current crop coverage for each cell, in each month of the year</td>
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<tr>
<td><strong>Low pump costs</strong></td>
<td>Pump costs scaled on a unit cost based on required system size, based on current costs in Bangladesh</td>
<td>Reduction in components of 42%. No reduction in operating costs</td>
</tr>
<tr>
<td><strong>High irrigation prices</strong></td>
<td>Mid-point of IDCOL irrigation prices per crop type, which are applied to all grid cells (no regional variation in prices modelled)</td>
<td>Upper end of current IDCOL prices per crop type</td>
</tr>
<tr>
<td><strong>High surplus power price</strong></td>
<td>Baseline assumed tariff of 2.5 BDT per kWh sale of surplus power to the main grid</td>
<td>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.</td>
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</table>
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).

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 individual SIP (three phase).

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 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
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 sites / 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.
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 IDCOL price for each crop per ha per season and 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
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