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Preparation of SREP Investment Plan Bangladesh Energy Sector Development Project

Introduction

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Overview

- Scaling Up Renewable Energy (SREP) Program

- Consultant Terms of Reference

- Purpose of this Workshop

SREP Program-Overview

- The Climate Investment Funds (CIF)
  - Provide developing countries with grants, concessional loans and risk mitigation instruments
  - Funded by 14 contributor countries
  - Channeled through 5 multilateral development banks (MDBs)
  - International Bank for Reconstruction and Development (IBRD) serves as trustee and administrator
- Scaling Up Renewables (SREP) program is a window of CIF which aims to use renewable energy to create new economic opportunities and increase energy access
  - 6 initial countries: Kenya, Ethiopia, Mali, Nepal, Honduras, Maldives
  - 7 later became eligible: Tanzania, Liberia, Yemen, Armenia, Vanuatu and Solomon Islands, Mongolia
  - 14 new countries selected in June 2014 (Bangladesh is one)

SREP Program-Financing

- US$75 million as possible funding for Bangladesh
- Types of contributions:
  - Grants
  - Capital contributions: Highly concessional loans
  - Guarantees or other risk mitigation instruments
- Intended to leverage at least 4 times more financing from other multilateral development banks (MDBs), donors, and the private sector
- SREP Funds:
  - Capital Expenditure (mostly)
  - Technical assistance (to some extent)
  - Guarantees

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Consultant ToR-Tasks

- Support the Government of Bangladesh (GoB), through the Sustainable and Renewable Energy Development Authority (SREDA) to prepare a renewable energy investment plan demonstrating how SREP, donor and private finance would be used to overcome barriers to wider penetration of RE

- Phase I: Assessment of potential and costs of applicable RE technologies, prioritization in a least cost plan that meets GoB investment criteria

- Phase II: Development of draft investment plan for prioritized RE investments that can be undertaken in the period 2015-20.

Consultant ToR-Outputs

Revised Inception report	• Updated list of RE technologies & projects to be considered • Updated work plan and schedule
Phase I: Options paper*	• Background section including context, resource potential estimates, applicable legislation, existing projects and key barriers to RE development • Levelized energy costs (LECs) for each project built up from estimated cost and performance, and supply curves comparing RE options; assessments of likely environmental impacts • Project evaluation criteria agreed with GoB, applied to the RE projects in a trade-off analysis • A prioritized list of RE projects and their characteristics, including total investment costs and environmental and social impacts.
Phase II: Draft SREP IP	• Draft SREP Investment Plan based on the analysis carried out in earlier stages, and prepared in line with best practices for SREP IPs.

*For an example of the analysis undertaken during Phase I, refer to the Options Paper prepared for the Armenia SREP, at http://r2e2.am/wp-content/uploads/2013/09/SREP-Task12.pdf

Consultant ToR-Work Plan

Draft Inception Report 4/23/2015

Final Inception Report 5/7/2015

Task 1 & 2 Report 6/11/2015

Task 3 Report 6/25/2015

Draft Investment Plan 7/16/2015

Final Investment Plan 9/10/2015

2015

Week 1 | 4 | 7 | 10 | 13 | 16 | 19 | 22

Week of 6/7/2015 **Consultation Meeting #1**

Week of 7/26/2015 **Consultation Meeting #2**

Week of 9/26/2015 APPROVED **Government to endorse IP and submit to Climate Investment Funds Administrative Unit**

Inception 4/9/2015 - 5/7/2015

Task 1 Compile background information on the country and energy sector overview 4/24/2015 - 6/4/2015

Task 2 Assessment of renewable energy technologies applicable in Bangladesh 4/24/2015 - 6/4/2015

Task 3 Identify specific prospective renewable energy projects for SREP funding 4/23/2015 - 6/18/2015

Task 4 Preparation of draft SREP IP for Bangladesh 6/19/2015 - 9/10/2015

Options Paper-Purpose and Contents

- Purpose is to get stakeholder feedback on:
  - The sources used and materials reviewed. Are we missing anything?
  - Our understanding of the context. Have we understood correctly?
  - Our assumptions. Are they realistic for Bangladesh?
  - Our results.
    - Do they look reasonable?
    - What do they mean for the Investment Plan?
  - Criteria for selecting projects for the SREP Investment Prospectus
- Contents:
  - Understanding of the context (challenges and barriers)
  - Voting on ranking/selection criteria
  - Assessment of technical potential
  - Assessment of economic and financial viability
  - Assessment of environmental and social risks and opportunities
  - Discussion of ranking/selection criteria

Preparation of SREP Investment Plan Bangladesh Energy Sector Development Project

Sector Challenges and Barriers to RE Investment

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Overview

- Sector Challenges
- Barriers to Renewable Energy Investment

Sector Challenges

Key Challenges

Resource Availability

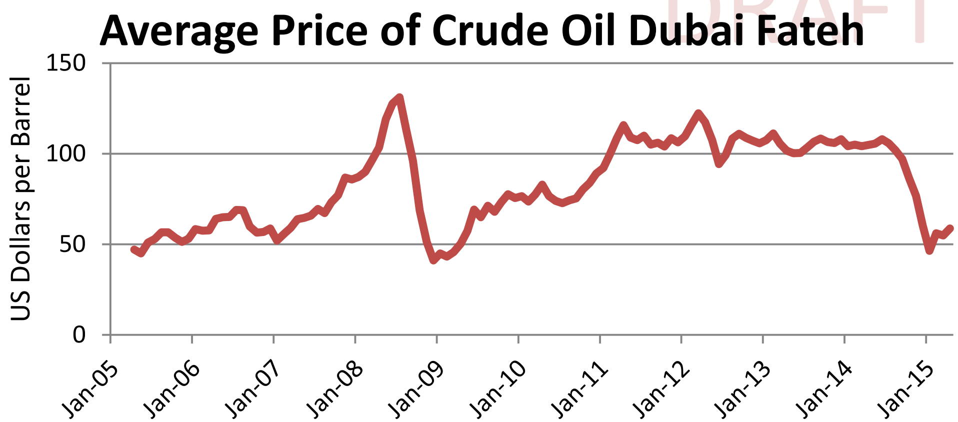
- **Natural Gas Depletion**
  - Natural gas currently makes up 62 percent of Bangladesh’s installed capacity, and as natural gas made up 70 percent of electricity production in 2014.
  - It has been estimated that Bangladesh's natural gas reserves will be depleted before 2020.
  - The uncertainty about reserves has limited the development of gas based power generation programs.

- **Biomass Availability**
  - Over 90 percent of Bangladesh households use traditional biomass for cooking, and biomass accounts for 50 percent of Bangladesh's total energy supply.
  - The common fuels used are rice husks, jute sticks, cow dung, and wood.
  - Biomass is becoming more scarce and more expensive, which is negatively impacting poor households that rely on this fuel source.

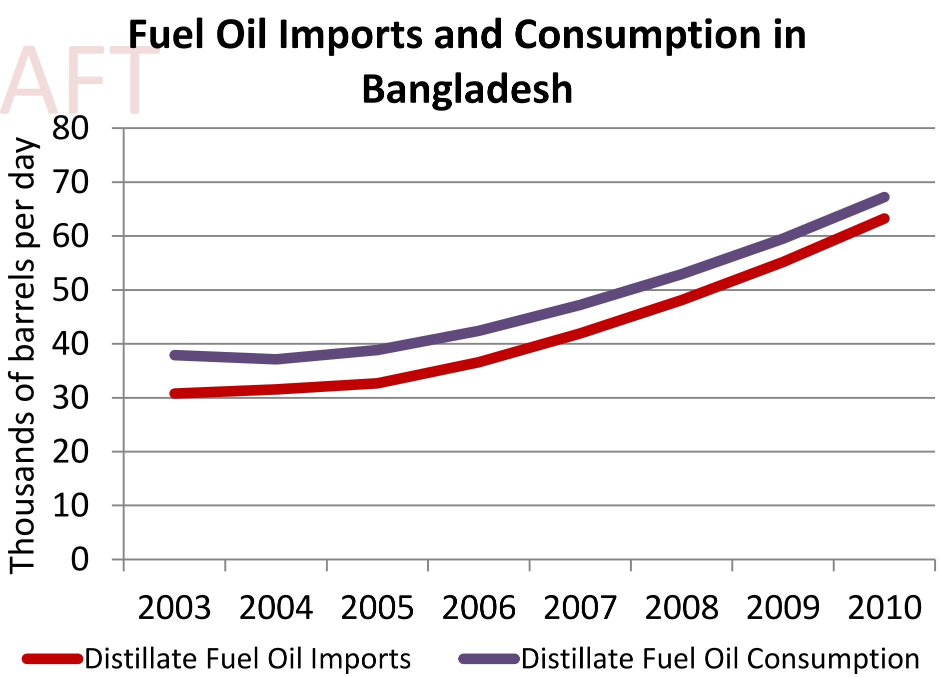
Key Challenges

Energy Security

- Fuel oil consumption is rapidly increasing due to BPDB reliance on fuel oil QRPPs, RPPs and diesel/ liquid fuel IPPs to mitigate energy shortages.
- From 2009 to 2012, the introduction of QRPPs and increase in liquid fuel based plants caused the share of oil-fired electricity to increase from 10 percent to 30 percent. This increase in oil-fired electricity contributed to the average generation cost of electricity more than doubling during that time period. Although QRPPs were originally intended as a short term solution, they continue to be used. The high cost of oil imports and the resulting high cost of electricity means that this may not be an economically sustainable solution.
- Bangladesh buys fuel oil from Malaysia's Petronas, Philippines National Oil Co, Emirates National Oil Co, Vietnam's Petrolimex, and China's Unipec.



Source: IndexMundi



Source: EIA

- Low access is the result of inadequate electrification, energy shortages, and reliance on natural gas.
- Rapid urbanization is causing demand growth, and supply is not keeping up.
- For those with access, power outages are very common during peak demand periods.

- **Donors working to increase access**
  - **ADB:** Public-Private Infrastructure Development Facility Loan (2008), Natural Gas Access Improvement Project (2010), Bangladesh-India Electrical Grid Interconnection Project (2010), Power System Expansion and Efficiency Improvement Investment Program (2012), Rural Electrification and Renewable Energy Development Project (2012)
  - **WB:** Rural Electrification and Renewable Energy Development Projects I and II (2002 and 2012)
  - **USAID:** Partners with REB and PBSs on Rural Electrification Program, Rural Energy Development Program

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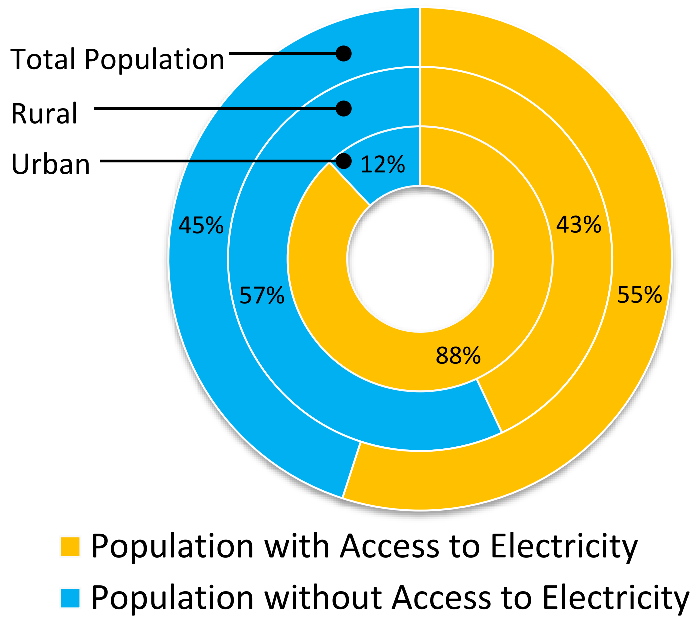
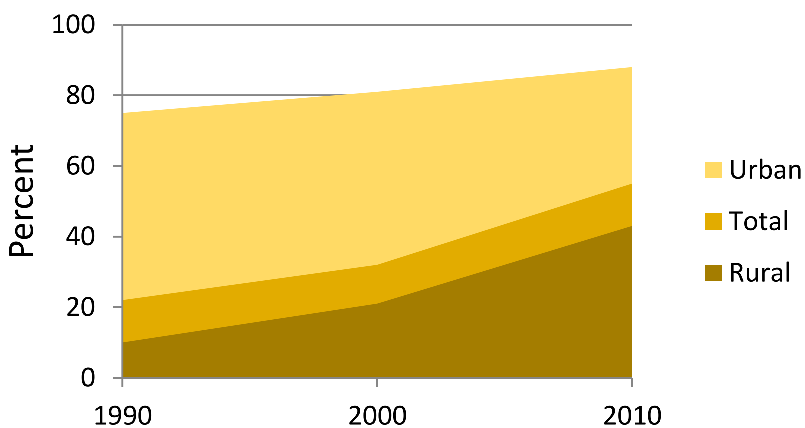
Access to Electricity (2010)



Change in Access to Electricity



http://databank.worldbank.org/data/views/reports/tableview.aspx

Several studies suggest that Bangladesh is one of the most vulnerable countries to climate change.

Two programs to address climate change include RE initiatives:

Bangladesh Climate Change Resilience Fund: The Fund was established in 2010 and is managed and implemented by the GoB, with temporary assistance from the World Bank. Energy projects include the Solar Irrigation Program, and the Rural Electrification and Renewable Energy Development II Project, both implemented by Infrastructure Development Company Ltd.

Bangladesh Climate Change Strategy and Action Plan (2008, revised 2009): The Action Plan is implemented by the Bangladesh Climate Change Trust. The Action Plan calls for the development of renewable energy, improvement to energy efficiency, and improvements in the energy consumption patterns of the transport sector.

Existing Studies:

- **Climate Change Vulnerability Index** : Bangladesh will feel the most economic impacts of climate change and Dhaka is one of the five most climate vulnerable cities in the world.
- **Fifth Assessment Report of the Intergovernmental Panel on Climate Change**: Rising temperatures are causing a shortened rice growing season in Bangladesh. The flood risk is high during the monsoon season. Dam construction and rising water levels can lead to forced migration, which most negatively impacts the poor.
- **Turn Down the Heat**: Bangladesh is particularly at risk of increased poverty headcount rate and chronic poverty in different warming scenarios, as well unavailability of clean water and sanitation.
- **World Risk report (2012)**: Bangladesh is ranked 5th on the world risk index, with a disaster risk of 20.22%. It is ranked as the 10th most exposed country to natural hazards.

Barriers to Renewable Energy Investment

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Financial and Economic Barriers

Financial and Economic Barriers
Limited fiscal space. RE is not the only important sector with funding needs. Allocations peaked in 2004 then began to fall.
Affordability of RE technologies for end-use customers. Investment in RE technology may require increase in end-user tariffs.
Limited availability of commercial lending for RE. Where available, there are low single borrower exposure limits (15%), high financing costs and short tenors loan tenors. Lending is generally on balance sheet, rather than cash flow or savings basis.
High import tariffs restrict competition in supply. For example, all biomass improved cookstoves are locally manufactured, possibly due to import tariffs being to high for foreign producers to be competitive.
Market price. High market prices and limited availability of land suitable for utility scale PV or wind development
Seasonal demand. Seasonality of agricultural activities means capacity factors of some RE technologies are low, and hence levelized cost is high.

Policy Barriers

Policy Barriers
Few policy incentives for RE. Lack of dedicated policies with specific goal to promote renewable energy.
Absence of a comprehensive legal and regulatory framework for RE. Many RE programs are technology-driven and focus on R&D, rather than promoting scale-up and commercialization. For example: -No feed-in tariffs for grid-connected RE generation (they are currently under development) -No standardized process for procuring IPPs in RE -No standardized power purchase agreement (PPA) for sale of RE generation into grid -No rules governing extension of grid to areas already served by microgrids
Incomplete coordination between involved ministries, agencies, and institutions. For example, the promise of grid extension to certain areas may inhibit investment in microgrids or other technologies.

Technical Barriers

Technical Barriers
Market not established. Lack of data and information on RE feasibility and RE experience in Bangladesh
Skilled labour. Lack of local knowledge and skills for the maintenance and repair of certain RE technologies (e.g., wind).
Limited land available for development. Where available, it may experience seasonal flooding, requiring different technical solutions.

Preparation of SREP Investment Plan Bangladesh Energy Sector Development Project

Assessment of Technical Potential

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Overview

- Solar Parks
- Distributed Solar
- Wind Parks
- Biomass and Biogas
- Microgrids
- Solar Irrigation
- Others

Summary of Technical Potential

Summary of Technical Potential

Technology	Resource	Capacity (MW)	Annual Generation (GWh)
Solar Parks	Solar	700*	1,000
Distributed Solar**	Solar	600	800
Wind Parks	Wind	650***	1250
Biomass	Rice husk	275	2050
Biogas	Animal waste	10	41
Small Hydropower Plants	Hydropower	60	200
Mini- and Micro-grids***	Hybrid	10	14
Total		2,305	5,355

*Case 1 estimate
**Includes solar irrigation potential
***Case 1 estimate
****Based on planned projects only, not a theoretical maximum potential because there is potential overlap with distributed solar systems. Either could be used to serve off-grid demand.

Solar Parks (Utility-Scale)

Existing and Proposed Projects

Project Name	Administrative Division	Resource	Project Status	Installed Capacity (MW)
Dhorola 30 MWp Solar Park Project	Rangpur	Solar PV	Under Construction	30.000
3 MWp Grid Connected Solar PV Power Plant	Dhaka	Solar PV	Under Construction	3.000
7.4 MWp Grid Connected Solar Power Plant at Kaptai Hydro Power Station Compound in Rangunia	Chittagong	Solar PV	Under Construction	7.400
Installation of 3 MWp Grid Tied Solar Park	Rajshahi	Solar PV	Under Construction	3.000
100 MWp Solar Photovoltaic Grid Connected Power Plant	Chittagong	Solar PV	Under Construction	100.000
Grid Tied Solar System	Chittagong	Solar PV	Under Construction	0.500
Ragunia 60 MWp Solar Park Project	Chittagong	Solar PV	Under Construction	60.000
Grid Connected Solar PV Power Plant for Kaptai Hydro Power Station	Chittagong	Solar PV	Under Construction	8.000
Grid Connected Solar PV Power Plant for Sharishabari, Jamalpur	Dhaka	Solar PV	Under Construction	3.000
Solar Park Project adjacent to PGCB Grid Sub-station compound	Khulna	Solar PV	Under Construction	2.000
Solar Park Project adjacent to Bangabandhu Bridge,Tangail and Sirajgonj area	Rajshahi	Solar PV	Under Construction	45.000
55 MWP Gangochora Solar Park	Rangpur	Solar PV	Under Construction	55.000

Programs and Policies

Image source: Black & Veatch

- Current government targets
  - 1677 MW by 2021
  - Of which 350 MW is owned by state-owned utility
- 500 MW program
  - Program goal of developing up to 500 MW, combination of commercial (340 MW) and social (160 MW) sector power plants
  - 135 MW of commercial installations should be Solar Parks
- Solar parks need to be developed on government owned, non-agricultural land or privately owned uncultivable land
- About 12 projects with a combined capacity of ~346 MW are currently under construction
- No solar park projects (utility-scale projects) have achieved commercial operation yet

Methodology: Overview

- Resource assessment using existing data on solar insolation:
  - SWERA/NREL study
  - SWERA/DLR study
- Results—Case 1: Apply exclusions to determine where practical areas for solar park development may be. Exclude irrigated and rain-fed cropland considering general guidance from GoB for solar parks
- Results—Case 2: Same as Case 1, but including irrigated and rain-fed cropland
- Develop design assumptions
- Estimate capacity factors using PVsyst Modeling software

Exclusions:

- Slope >=5%
- Forests
- Wetland
- Urban areas
- Historical flood areas (2000-2014)
- Distance from the nearest Transmission line > 20 km
- Military bases (when available)
- Protected areas

Methodology: Sources

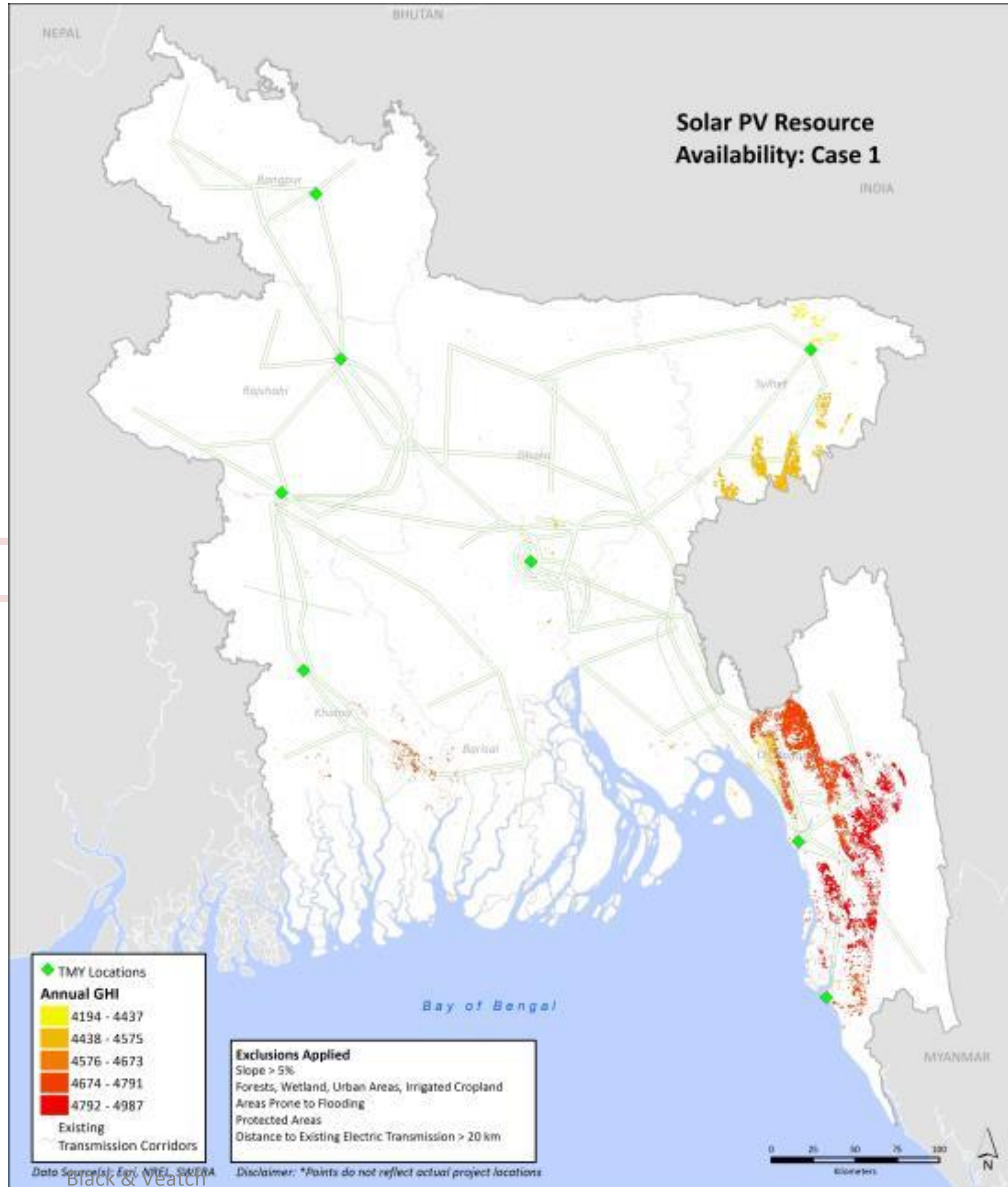
- Black & Veatch chose the SWERA – NREL data set due to the availability of Typical Meteorological Year (TMY) data files that is a better representation than a single historical year.
- SWERA – NREL data includes the TMY for eight locations as shown in the map.

Parameter	SWERA - NREL	SWERA - DLR
Grid Size	40 km	10 km
Length of data	1985-1991	2000,2002 and 2003
Model used	CSR Model (Climatological Solar Radiation)	From Satellite images
Uncertainty	10%	NA
Length of period	6 yrs	3 yrs
Availability of Typical Meteorological files	Yes	No

Results—Case 1

- Excludes irrigated Crop Land
- 1% of area assumed developable
- 25 MW per sq km on remaining land
  - Includes mitigation factor for trees, shrubs, roads, structures, and other land uses

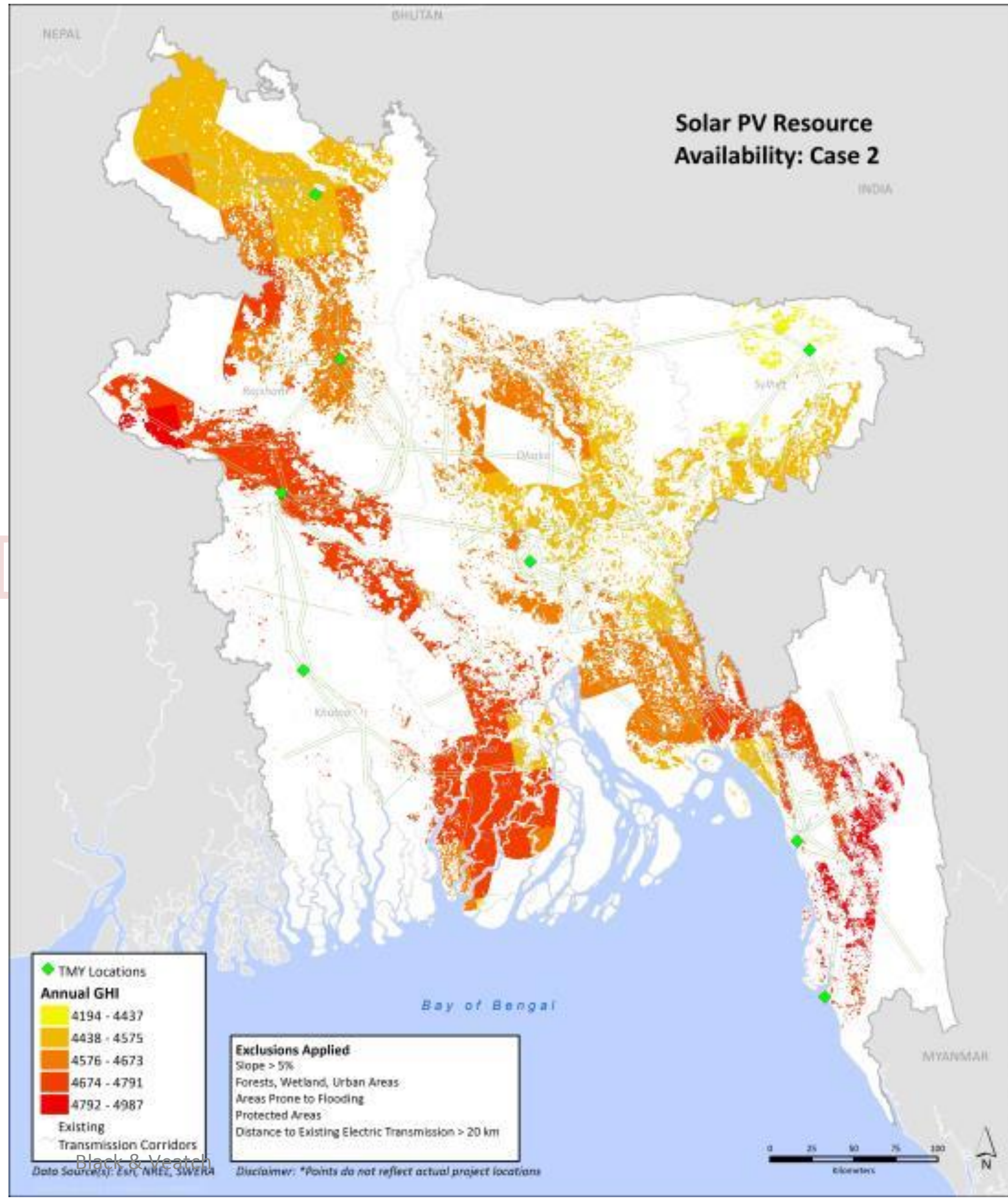
Division	Sum of SQKM	Potential (MW)
Barisal	29	7
Chittagong	2,100	525
Dhaka	37	9
Khulna	100	25
Rajshahi	2	0
Rangpur	2	1
Sylhet	547	137
Total		704



Results—Case 2

- Includes irrigated Cropland
- 1% of area assumed developable
- 25 MW per sq km on remaining land
  - Assumption accounts for trees, shrubs, roads, structures, and other land uses

Division	Sum of SQKM	Potential (MW)
Barisal	4,068	1017
Chittagong	6,833	1708
Dhaka	6,736	1684
Khulna	482	121
Rajshahi	5,846	1461
Rangpur	7,689	1922
Sylhet	1,950	487
Total		8401



Design Assumptions

- Ground mounted
- Orientation
  - Fixed tilt at 25 degrees
  - Azimuth at 0 degrees (South facing)
- Ground Coverage Ratio – 45%
- Inverter loading ratio - 1.3
- Module Technology – Polycrystalline 305 W modules

Loss Factors	%
Shading	2.6%
IAM factor	2.7%
Soiling	1.0%
PV loss due to Irradiance level	0.7%
PV loss due to temperature	7.4%
LID loss	1.5%
Module Array Mismatch loss	1.0%
Ohmic wiring loss	1.3%
Inverter Efficiency loss	4.2%
Availability loss	2.0%
AC wiring loss	0.3%
Transformer loss	0.6%

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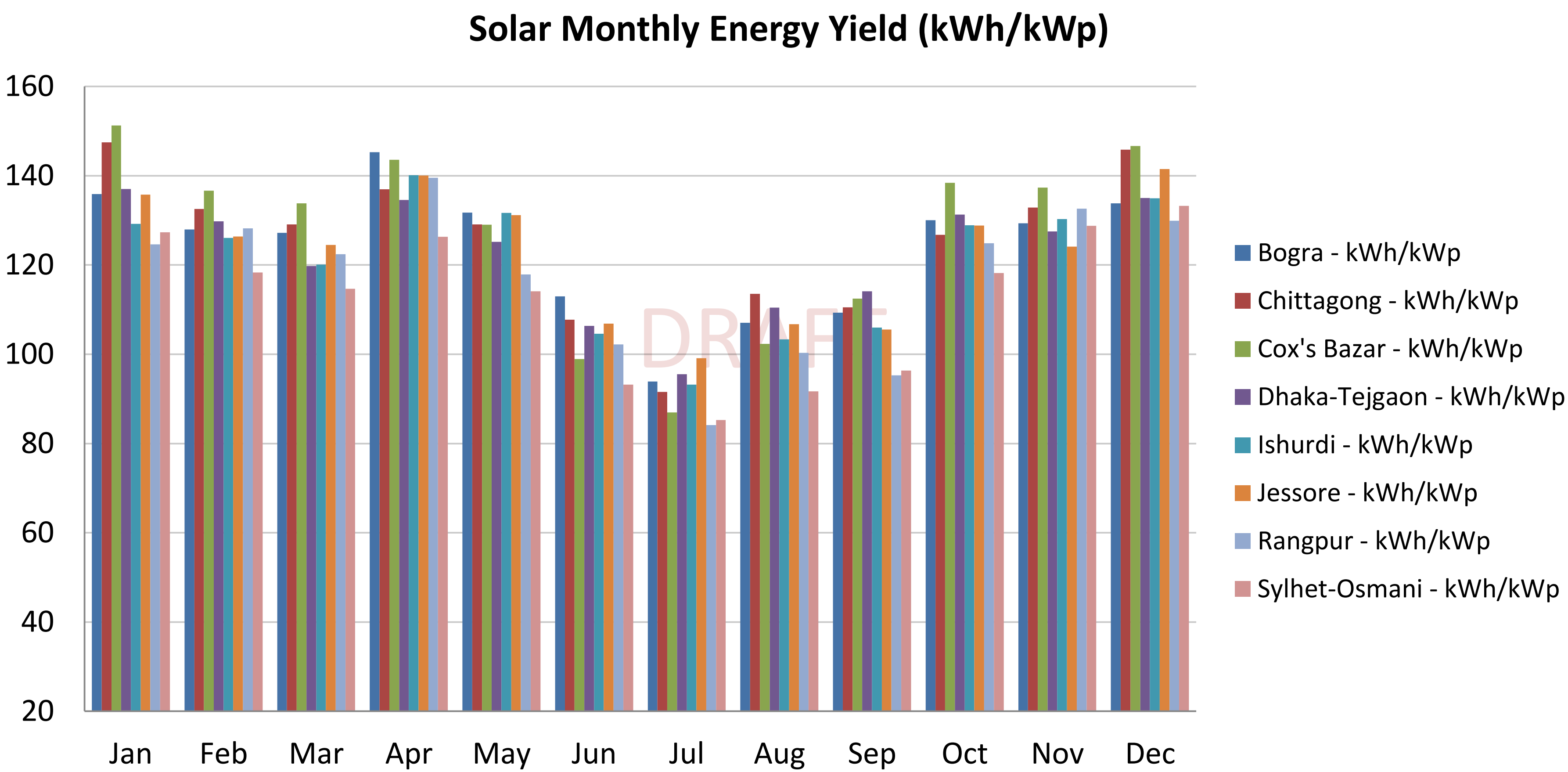
Estimation of Capacity Factors

TMY Location	Division	DC Capacity Factor (%)
Bogra	Rajshahi Division	16.9%
Chittagong	Chittagong Division	17.2%
Cox's Bazar	Chittagong Division	17.3%
Dhaka - Tejgaon	Dhaka Division	16.7%
Ishurdi	Rajshahi Division	16.5%
Jessore	Khulna Division	16.8%
Sylhet - Osmani	Sylhet Division	15.4%
Rangpur	Rangpur Division	16.0%
Chittagong	Barisal Division*	17.2%

*Barisal Division is assumed to have same resource as Chittagong site due to proximity

Estimation of Capacity Factors

Rainy season between June to September shows a drop in monthly energy yield



Source: Black and Veatch modeling on TMY data, using PVSyst.

Distributed Solar PV

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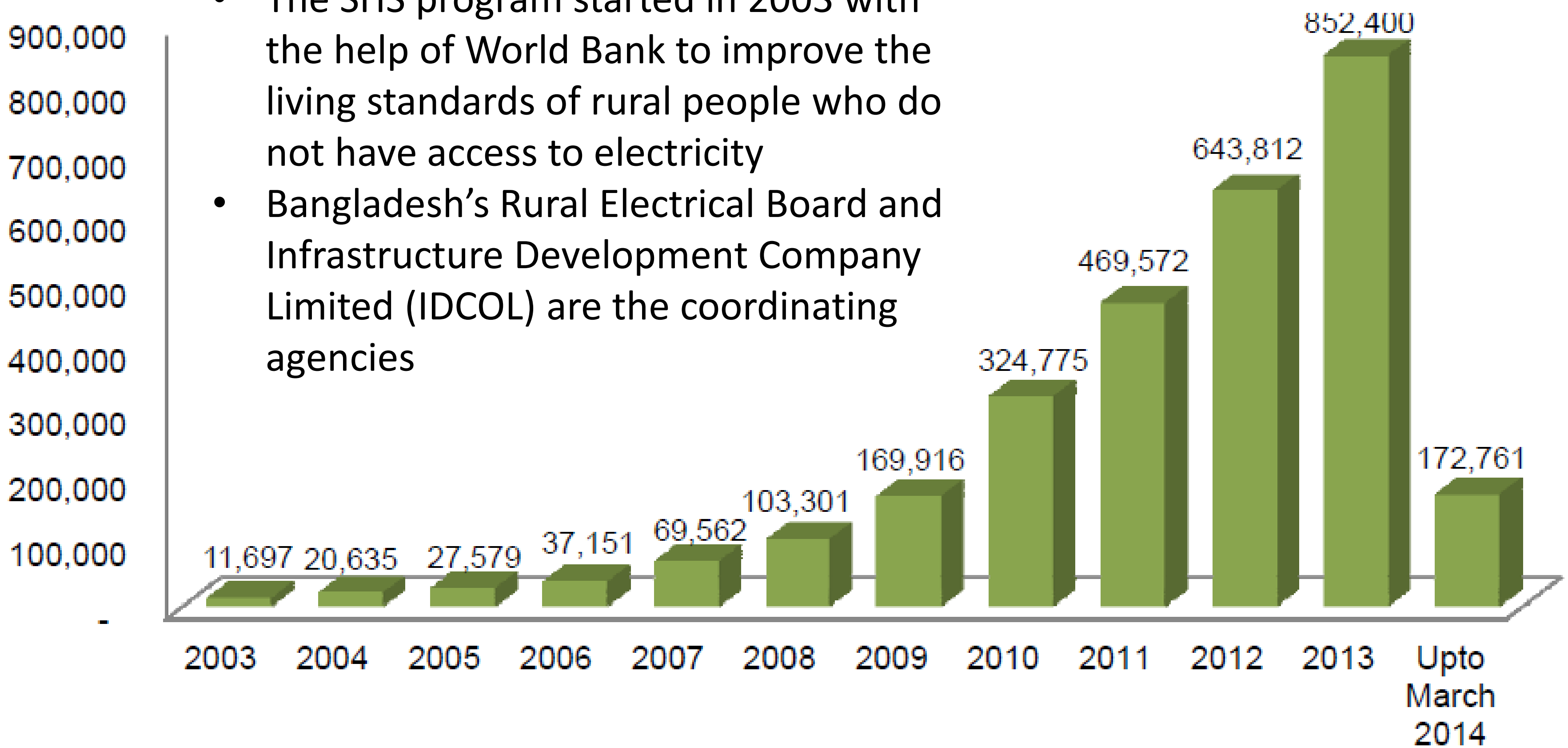
Existing and Proposed Projects

Solar Home Systems (SHS) installation status

- The SHS program started in 2003 with the help of World Bank to improve the living standards of rural people who do not have access to electricity
- Bangladesh's Rural Electrical Board and Infrastructure Development Company Limited (IDCOL) are the coordinating agencies



Source: Monirul Islam, 2014.

Programs and Policies

Program Name	Type	Goal	Status (active or completed)
Diffusion of Renewable Energy Technologies (Pilot Project) - Aided by France. (1993-94 to 1997-98)	SHS	806 SHSs	Completed
Diffusion of Renewable Energy Technologies-2nd phase. (1999-00 to 2006-07)	SHS	1200 SHSs	Completed
Rural Electrification Through Solar Energy (IDA) (2002-03 to 2007-08)	SHS	12,400 SHSs	Completed
Electrification in local area (Upazila complex) by using Solar Energy (2011-12 to 2012-13)	Rooftop systems	15 x 30 kW systems (450 kW)	Completed

MOPEMR "500 MW Solar Programme 2012-16."

Commercial Projects

Type of Project	Capacity Addition in MW
Solar Irrigation	150
Solar Mini Grid	25
Solar Park	135
Solar Roof-top Residential and Commercial Building	10
Solar Roof-top Industrial Building	20
Total (MW)	340

Social Sector Projects

Type of Project	Capacity Addition in MW
Solar Electrification in Health Centers	50
Solar Electrification in Remote Educations Institutions	40
Solar Electrification at Union e-Centers	7
Solar Electrification in Religious Establishment	12
Solar Electrification at Remote Railway Stations	10
Solar PV System in Government and Semi-Government offices	41
Total (MW)	160

Design Assumptions

- Rooftop Solar Systems
  - Grid-connected systems
  - Typically mounted on building rooftops and all or most of the energy is consumed on site
- Solar Home Systems (SHS)
  - Off-grid systems targeted at rural areas where people have no access to electricity
  - Systems typically include battery energy storage and appliances that include CFL/LED lights, fan, refrigerator etc.

20.16 kWp PV Solar Power System at Honorable Prime Minister's Office, Dhaka

120 Wp Solar Home System at Juraichari, Barkal, Thanchi Upazila of CHT

Design Assumptions

- Design Assumptions
  - Orientation
    - Fixed tilt at 10 degrees
    - Azimuth at 0 degrees (South facing)
  - Roof Coverage Ratio – 70%
  - Inverter loading ratio - 1.3
  - Module Technology – Polycrystalline 305 W modules
- High shading loss factor assumed due to likely of suboptimal location of solar panel

Loss Factors	%
Shading	7.0%
IAM factor	3.1%
Soiling	1.0%
PV loss due to Irradiance level	0.7%
PV loss due to temperature	7.3%
LID loss	1.5%
Module Array Mismatch loss	1.0%
Ohmic wiring loss	1.2%
Inverter Efficiency loss	4.1%
Availability loss	1.9%
AC wiring loss	0.3%

Estimation of Capacity Factors

TMY Location	Division	DC Capacity Factor (%)
Bogra	Rajshahi Division	15.7%
Chittagong	Chittagong Division	16.0%
Cox's Bazar	Chittagong Division	16.1%
Dhaka - Tejgaon	Dhaka Division	15.6%
Ishurdi	Rajshahi Division	15.4%
Jessore	Khulna Division	15.6%
Sylhet-Osmani	Sylhet Division	14.2%
Rangpur	Rangpur Division	14.9%
Chittagong	Barisal Division*	16.0%

*Barisal Division is assumed to have same resource as Chittagong site due to proximity

Wind Farms (Utility-Scale)

Existing and Proposed Projects

There have been several small projects developed (10kW range; one 900 kW), with a few larger projects in development or planned, ranging from 60 to 200 MW.

1000 kW Wind Battery Hybrid on Kutubdia
Image source: BPDB, Implemented projects

Rendering of 60 MW Cox's Bazaar Project
Source: Wind Power Engineering and Development

Project Name	Administrative Division	Resource	Project Status	Installed Capacity (MW)
60 MW Wind Power Project in Cox's Bazar	Chittagong	Wind	Under Construction	60.0
Grid connected Wind Plant at Muhuri Dam area	Chittagong	Wind	Complete	0.9

Methodology: Overview

- <u>Resource assessment:</u>
  - Reviewed SWERA and Wind Energy Resource Mapping (WERM) program but
    - These sources incorporate data collected at 25 meter height or lower.
    - Extrapolation of 25-meter data to an 80 meter hub height introduces considerable uncertainty, and without accompanying statistics such as wind shear values and wind speed distributions energy calculations also have high uncertainty.
  - Instead chose AWS Truepower's WindNavigator data product:
    - AWS WindNavigator data is available at 80 meters above ground level, and includes mean wind speed, wind speed distribution, wind rose, and diurnal pattern.
    - Wind speed is modeled by AWS using NCEP and NCAR reanalysis data, and has an estimated uncertainty of 0.5 to 0.7 m/s in this region.
  - Note:
    - USAID, together with NREL, is currently conducting a robust wind resource assessment campaign throughout the country,
    - Once available, these data will be very useful in improving wind energy estimates throughout Bangladesh.

Methodology: Overview (Cont.)

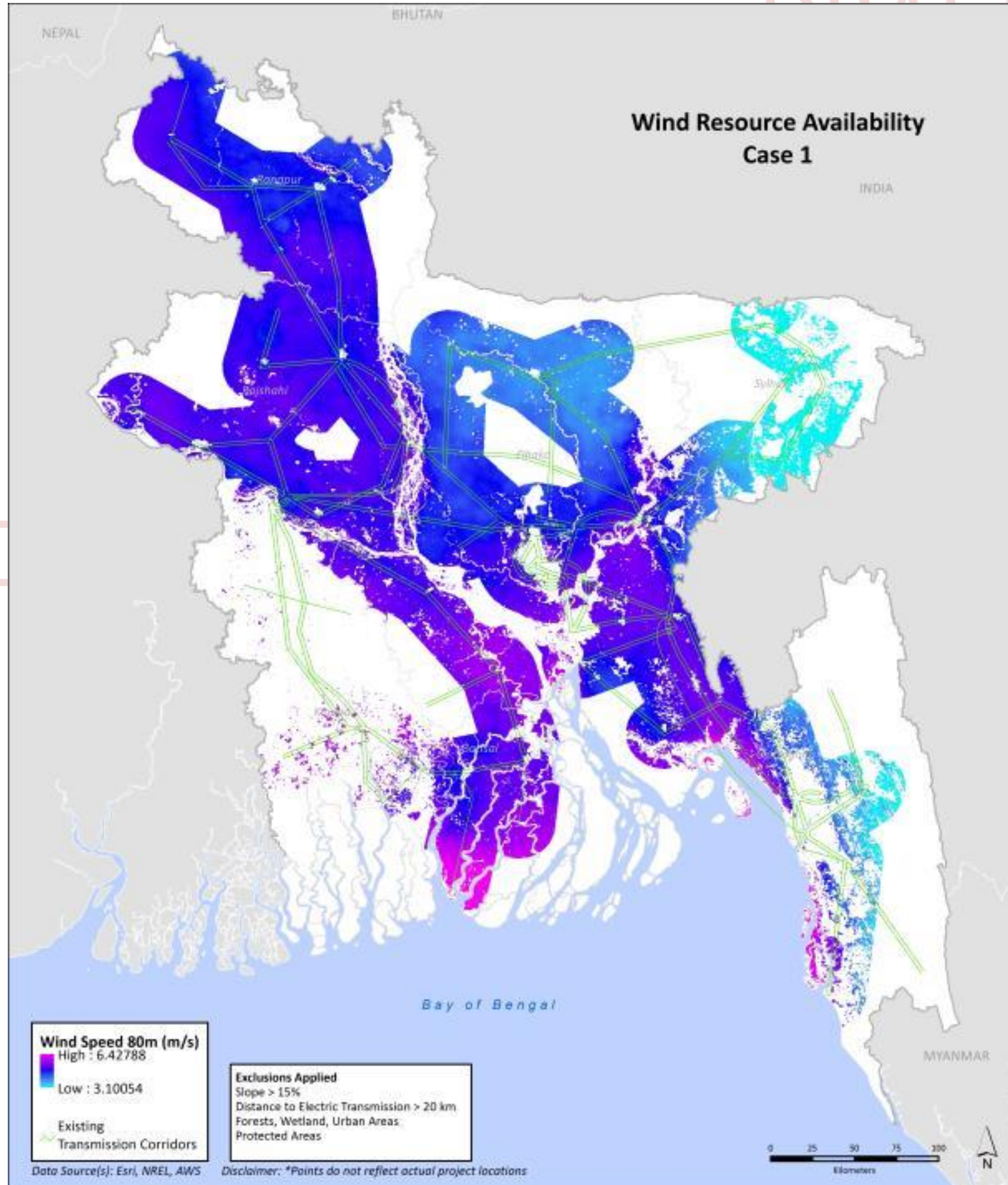
- Results—Case 1: Apply exclusions to determine where more practical areas for wind park development may be*
  - Distance from the nearest Transmission line > 20 km
  - Slope >=15%
  - Exclude protected areas
  - Forests
  - Wetland
  - Urban areas
- Results—Case 2: Additional mapping to exclude areas prone to flooding
- Develop design assumptions
- Estimate capacity factors using PVsyst Modeling software

*Transport, logistics, delivery constraints were not considered

Results—Case 1

Case 1:

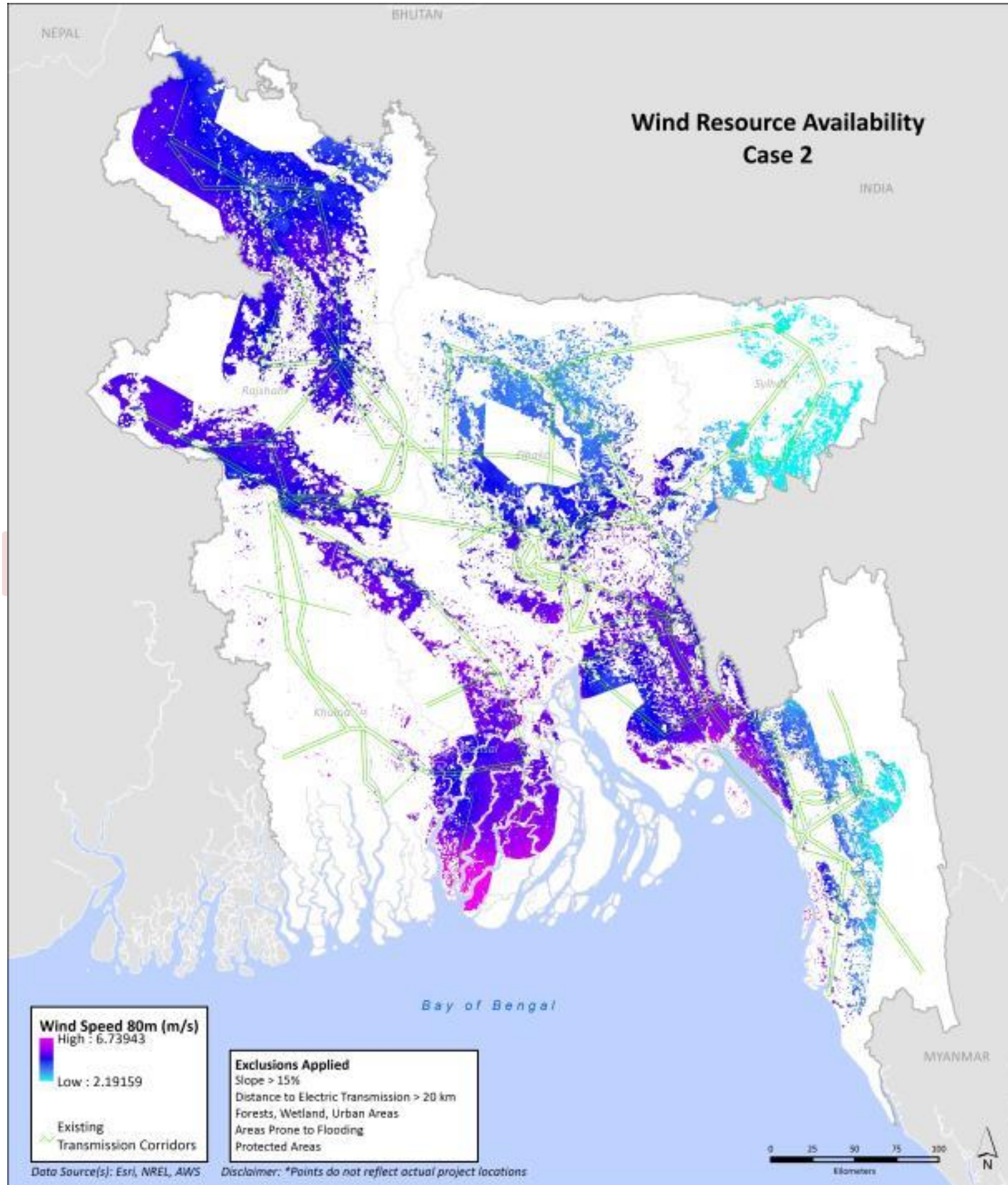
- Excluding forests, urban areas, protected areas, steep inclines
- Including areas <= 20 km from transmission lines



Results—Case 2

Case 2

- Primary wind zones are in coastal regions
- Risks associated with developing in areas prone to flooding:
  - Foundation stability
  - Electrical system integrity
  - Erosion (increased foundation design cost, construction cost)
- Thus, additional exclusion layer applied for flood areas



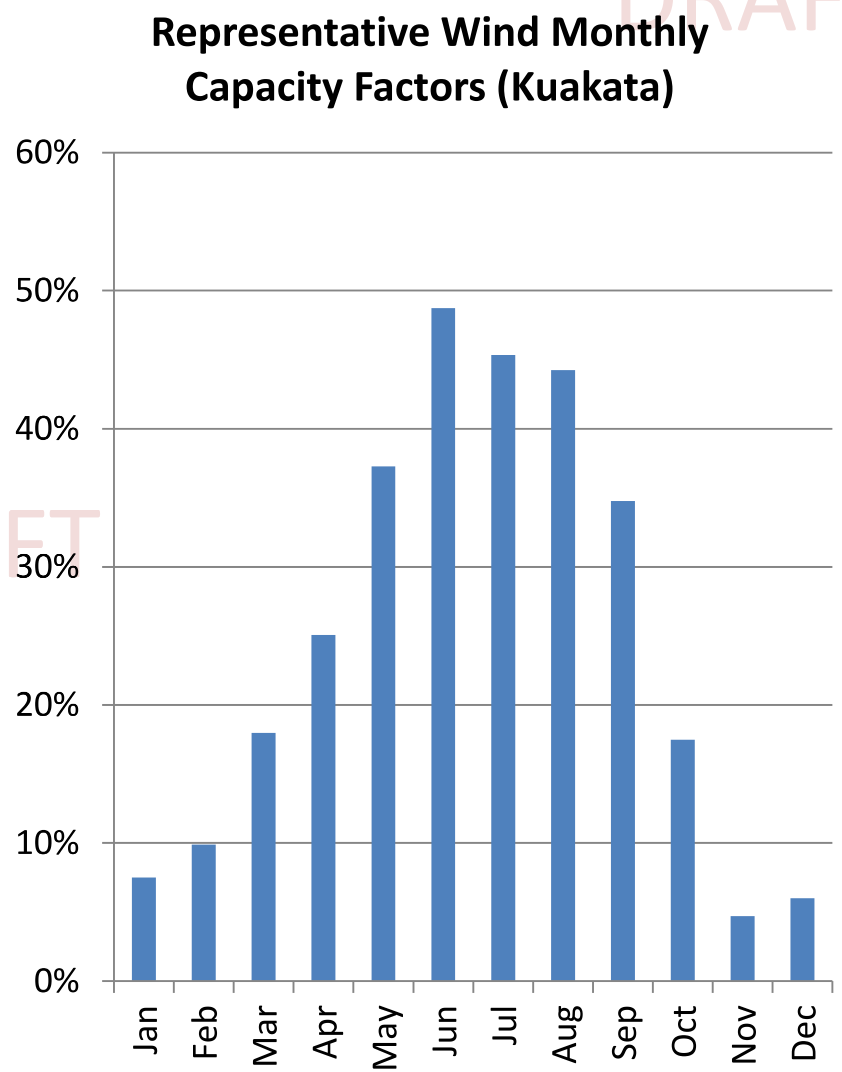
Design Assumptions

- Design parameters for maximum gusts
  - Class III turbine likely suitable for this regime
  - Maximum 50-year 3-second gust: 52.5 m/s
  - May require high-wind protection operational modes
- Foundation design must be customized to site conditions (unstable soil, erosion, flooding, sand)
  - Likely higher construction costs
  - Increased blade degradation due to sand (may require blade reinforcement / protective coatings)

900 kW Grid Connected Wind Power Plant at Muhuri Dam, Feni

Estimation of Capacity Factors

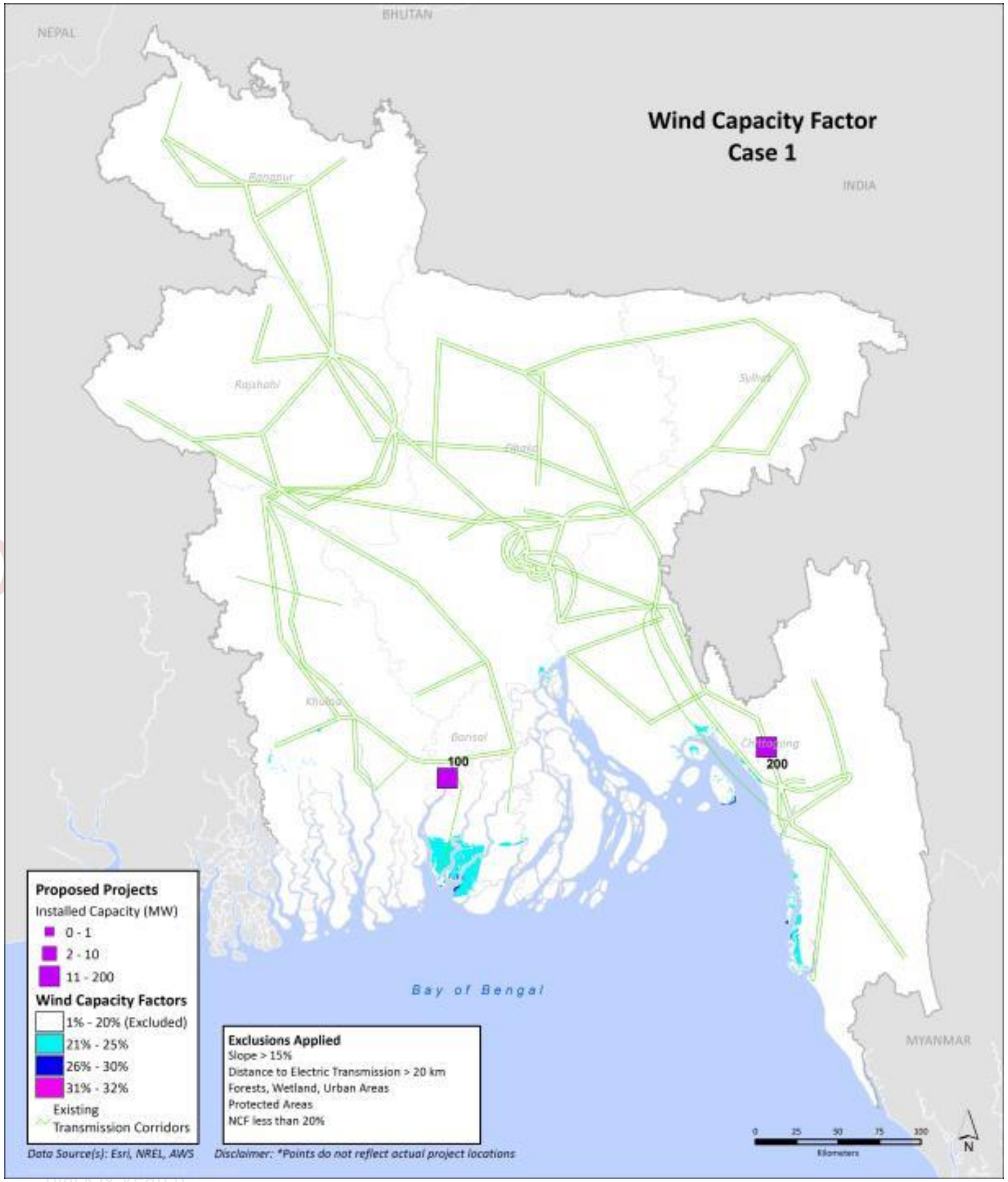
- Black & Veatch calculated Net Capacity factor (NCF) combining:
  - Wind speed distributions in the AWS wind map
  - Representative class III wind turbine power curve (Suzlon S97 2.1 MW)
- Gross-to-net losses are estimated to be 18%, including assumptions for:
  - Wake loss, turbine availability, utility downtime, electrical efficiency, blade degradation, high temperatures, extreme weather, and power curve performance.
  - Actual gross-to-net loss will vary by project design, operation, and other factors.



Estimation of Capacity Factors: Case 1

	20 - 25%	25 - 30%	TOTAL
sqkm	796.9	29.3	826.2
MW	1992	73	2065
weighted avg CF	22%	26%	22%
Buildable MW*	996	37	1033

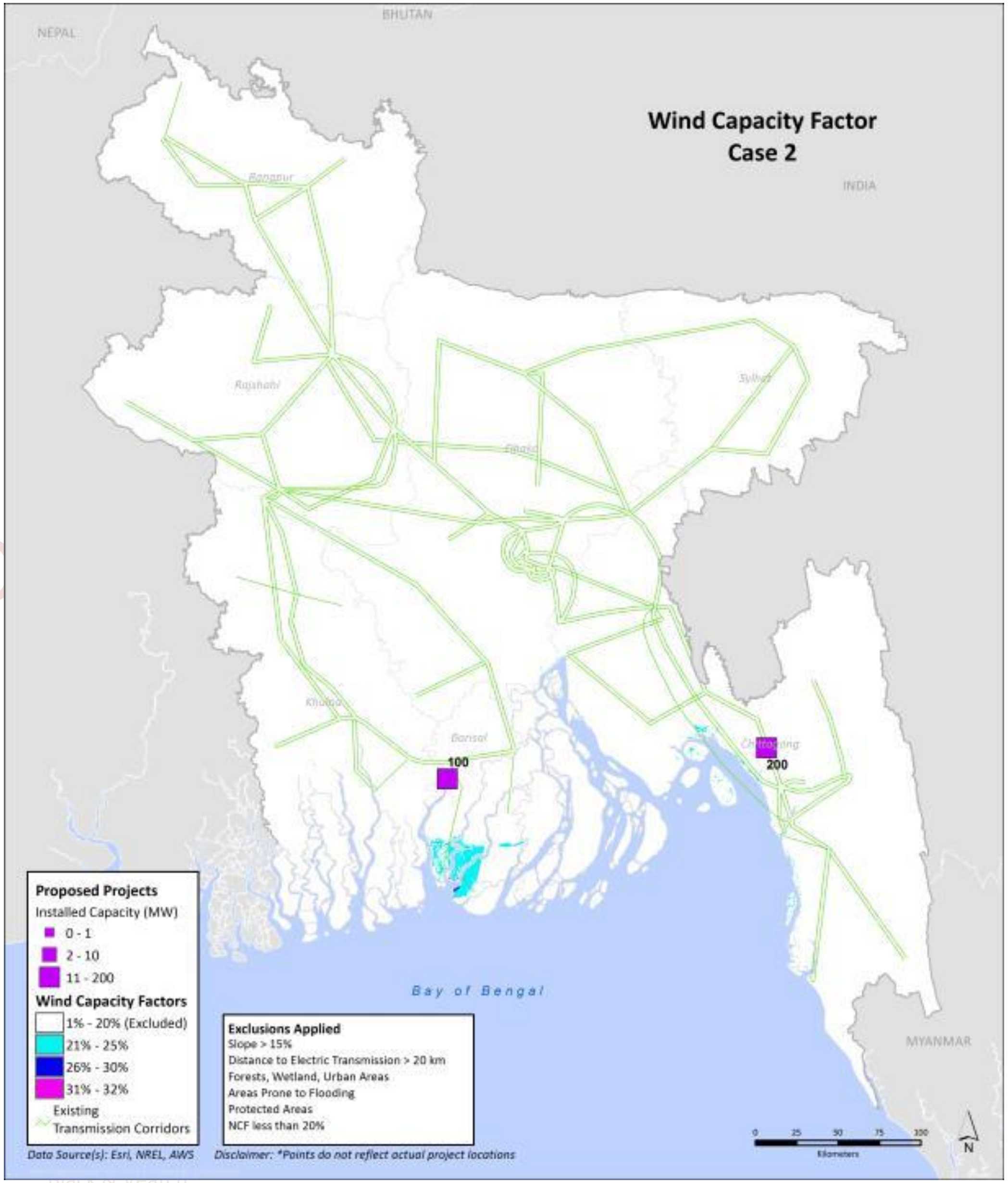
*Buildable MW assumes 50% of available land coverage



Estimation of Capacity Factors: Case 2

	20 - 25%	25 - 30%	TOTAL
Barisal			
Net Capacity Factor	22%	26%	
Buildable MW	531	13	544
Chittagong			
Net Capacity Factor	21%	25%	
Buildable MW*	93	0	93

*Buildable MW assumes 50% of available land coverage



Biomass and Biogas

Existing and Proposed Projects

Biomass

IDCOL has funded two rice hull gasifier units in Bangladesh:

- Kapasia 250 KW (completed)
  - Uses 70/30 syngas/diesel
  - Designed to operate baseload
  - Commissioned in 2007, but recent report indicates only one unit of 56 kW is in operation
- Thakurgaon 400 kW (committed)
  - Plant expected to produce 918 tons of precipitated silica, a commodity used in multiple applications, thus has some commodity value
  - Electricity to supply adjacent silica production plant and other surrounding buildings
  - Proposed to operate on 100% syngas

Biogas

- IDCOL has also funded biogas digester systems using poultry manure as feedstock
  - Sited at commercial poultry farms, supplying on-site and community load
  - System sizes range between 25 to 450 kW with capacity factors between 25 to 95 percent
  - Additional revenue opportunity from fertilizer bi-product
- IFC has also reported installations of 250 waste-to-electricity projects for small and medium enterprises, but data on these projects could not be found.

Resource Assessment: Biomass

Source: Bangladesh Forest Division, 1999.

- Of 63 districts, forests in 37 districts are partially or completely protected under the 20th, 4th and 6th amendments of the Forest Act (Source: Bangladesh Bureau of Statistics)
  - Of remaining areas, there is limited woody biomass opportunity
- Forestry export data shows very little in terms of wood residue production per year (source: Food and Agriculture Organization of the United Nations) http://www.fao.org/forestry/country/57025/en/bgd/)
- Based on the "Global Alliance for Clean Cookstoves" study, we expect that most woody biomass fuel is being used for cooking fuel

Resource Assessment: Animal Waste

- Livestock farming in Bangladesh are segmented into Commercial and Subsistence Farming
  - Commercial operations represent more centralized, higher head count per site
  - Thus, greater opportunity for consolidation of biomass for electricity production
- For subsistence farms, cookstoves may be a more appropriate application of anaerobic digestion than electricity production.

	Average Headcount per Farm	
Livestock	Commercial	Subsistence
Cattle/Buffalo	10-20	2-3
Fowl/Duck	300-500	5-10

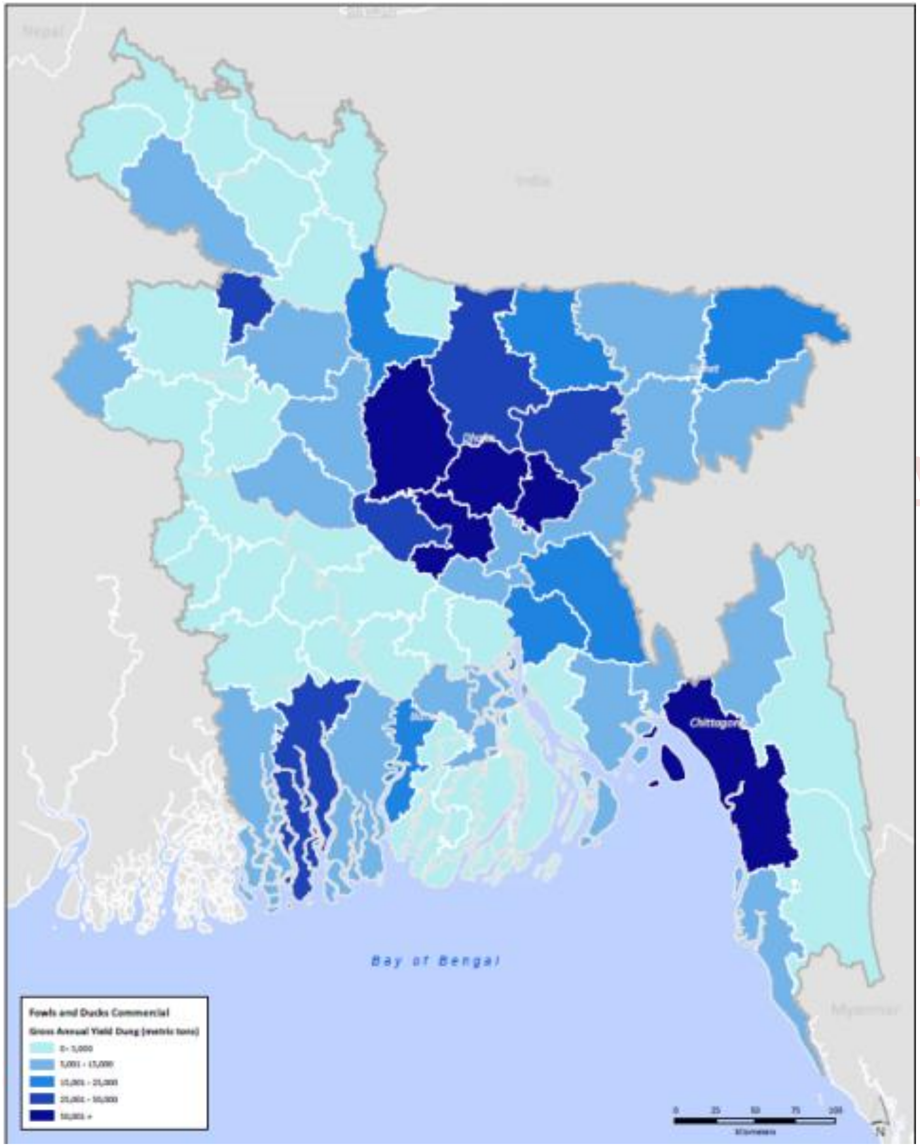
Source: BBS, 2011.

Figure 5-1 Cattle dung is the major feeding of domestic biogas plants in Bangladesh

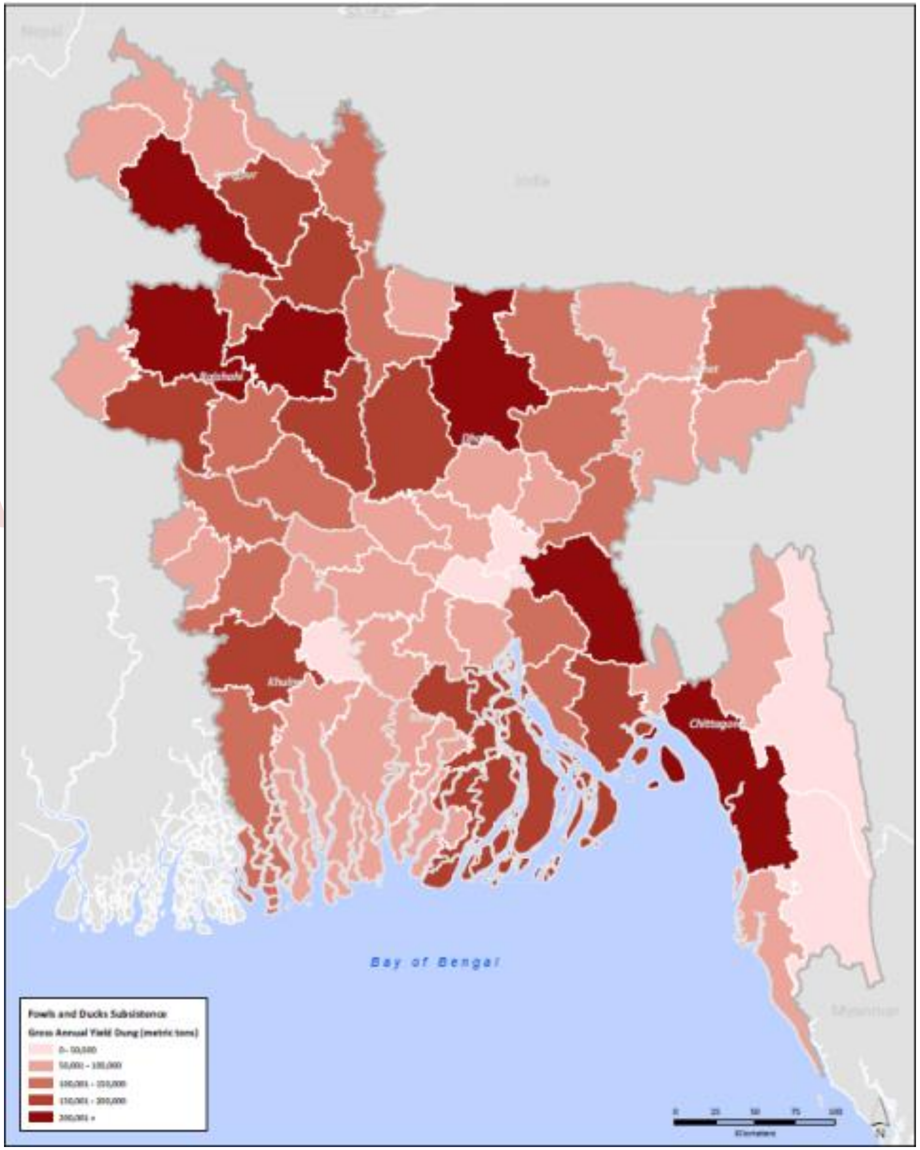
Resource Assessment: Animal Waste

Fowl & Duck

Commercial Farming



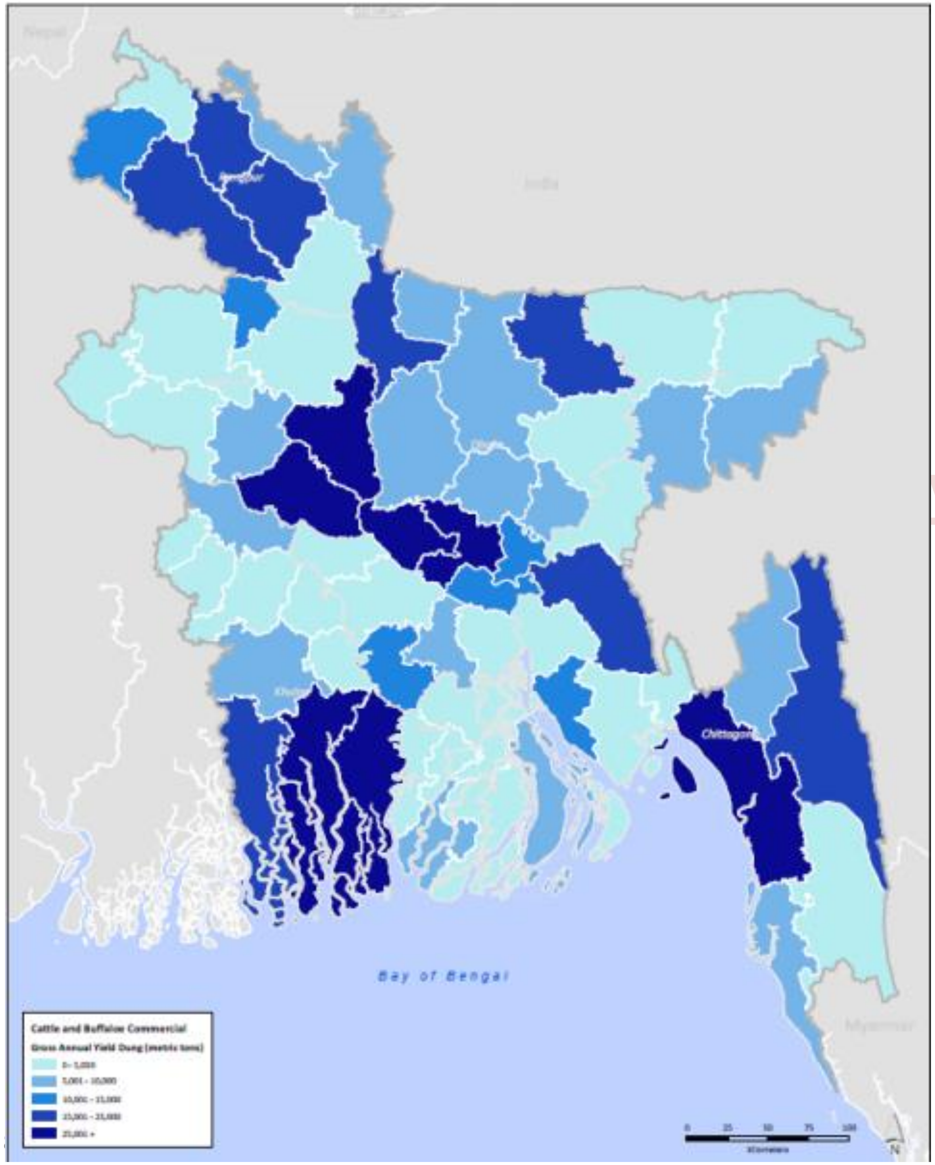
Subsistence Farming



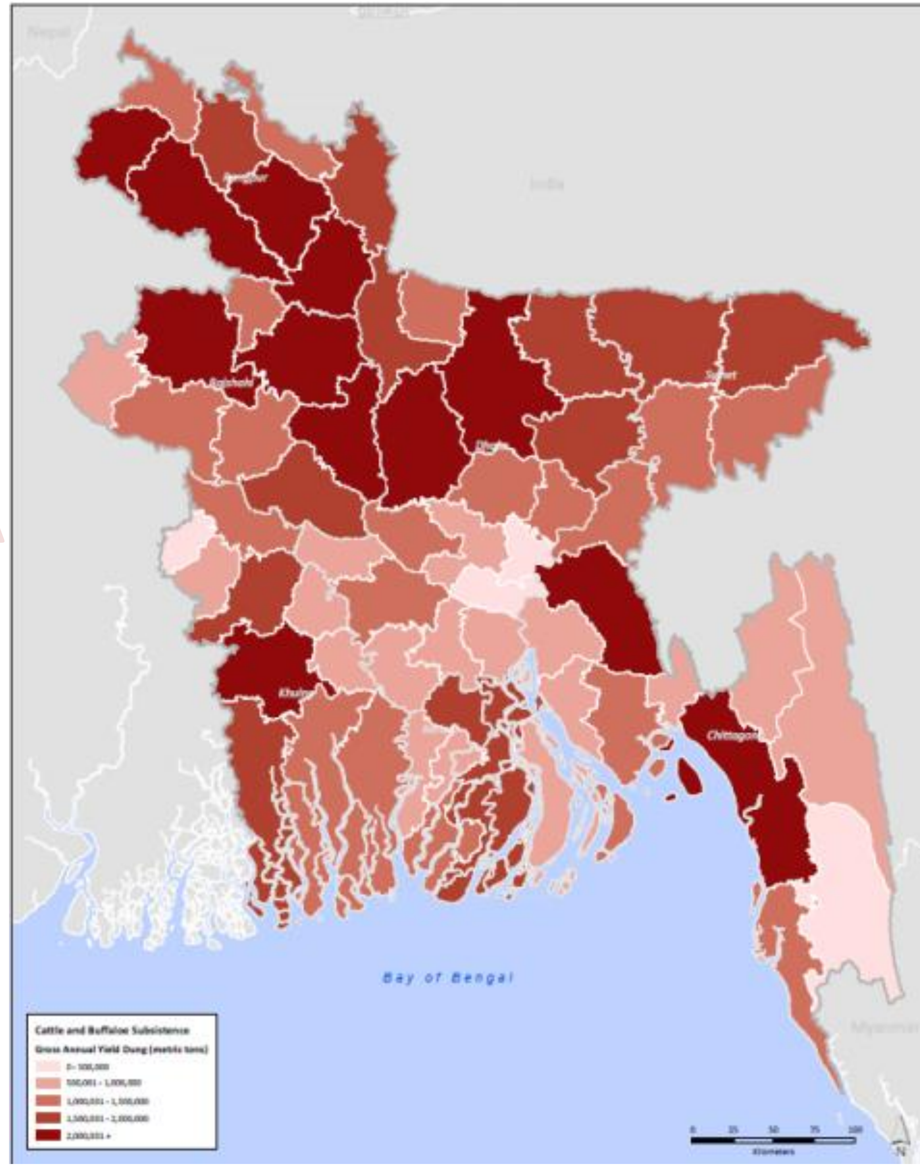
Resource Assessment: Animal Waste

Cattle & Buffalo

Commercial Farming



Subsistence Farming



Assumptions: Animal Waste

Calculations	Factors	Source
Number of head of Livestock		Bureau of Statistics, Agricultural Statistics, 2011
Yield of manure per head by animal type	0.01 tons (cattle) 0.12 kg (poultry)	Netherlands Development Organization, Domestic Biogas in Bangladesh, 2005
Manure digester conversion from ton of waste to m3 biogas	47 m3/ton (cattle) 200 m3/ton (poultry)	Netherlands Development Organization, Domestic Biogas in Bangladesh, 2005
Methane content in biogas assumed	50%	Black & Veatch
Reciprocating engine efficiency	10,000 btu/kWh	Black & Veatch

Commercial Poultry Operation in Bangladesh
http://discovering-bangladesh.blogspot.com/2011/10/our-future-plan.html

Results: Biomass (Rice)

	Rice Husk (Process Residue)	Rice Straw (Field Residue)
Dry Crop Residue Per Year (tons)[1]	10,130,000	25,310,000
HHV (MJ/kg)	16	16
Gross Potential (mmBtu)	139,363,715	348,202,924
Gross Potential (MWh)[2]	4,084,517	10,205,244
Potential Energy (MWh)[3]	2,042,258	Excluded
Potential Capacity (MW)	274	0

[1]Das, Kumar, and Hoque, 2014.
[2]Heat Rate 13,648 btu/kWh
[3]Assume 50 % of Rice Husk is available for electricity generation. Assume zero percent for rice straw because field residue is impractical to collect and transport to centralized area

- Rice is the largest agricultural crop in Bangladesh
- Rice byproducts consist of rice straw and rice husk, though rice straw is more beneficial left in the field for fertilizer or used as direct cooking fuel. Thus, rice straw not included in technical potential assessment.
- Assumed only 10 percent of technical energy potential are located at sufficiently large commercial operations to host a digester for electricity production. Assumed capacity factor of 50%.

Results: Biogas

*Capacity potential from commercial livestock operation estimated total of 9.4 MW**

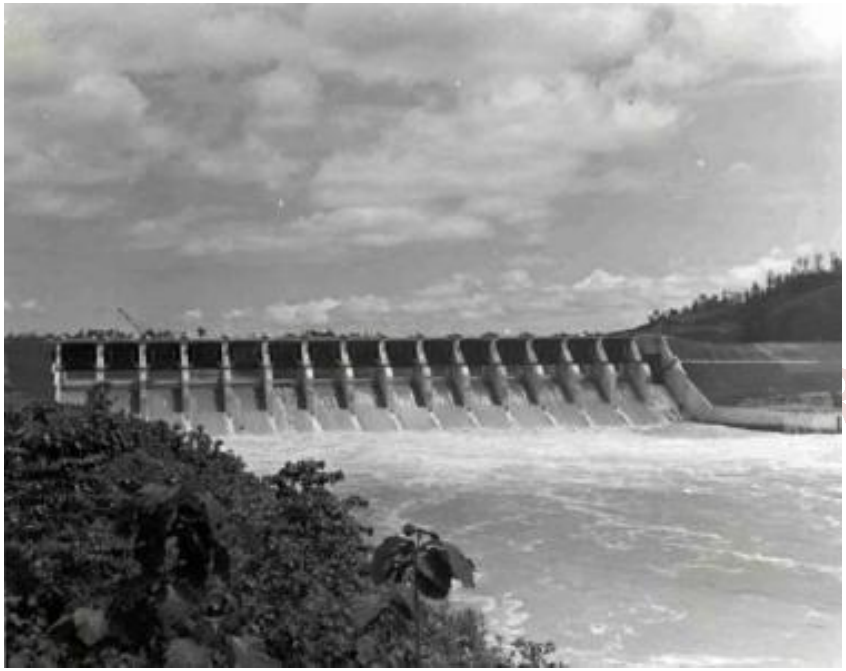
	Technical Potential (MWh)		Estimated Capacity Potential (kW)	
Division	Commercial Cattle & Buffalo	Commercial Fowl & Duck	Commercial Cattle & Buffalo	Commercial Fowl & Duck
Barisal	1989	16189	45	370
Chittagong	11364	69243	259	1581
Dhaka	18452	188138	421	4295
Khulna	11095	26983	253	616
Rajshahi	15999	33193	365	758
Sylhet	1383	18946	32	433
			1376	8052

*As for biomass, also assumed that only 10 percent of technical energy potential are located at sufficiently large commercial operations to host a digester for electricity production, and plant capacity factor of 50%.

Small Hydropower

Existing and Proposed Projects

Small Hydro



Kaptai 230 MW Hydropower Project

- Karnaphuli project, or Kaptai project, is located on River Karnafuli, 70 km upstream of Chittagong City.
- Many expansion/capacity addition projects proposed at this location (Source: USAID/Nexant, 2003)
  – Addition of two 50 MW turbine generator units is proposed
  – Detailed engineering study completed by Tokyo Electric Power Services Company (TEPSCO) in 1998 not available.
  – Project could likely be developed within 5 years.

Existing and Proposed Projects (Cont.)

Mini-Hydro

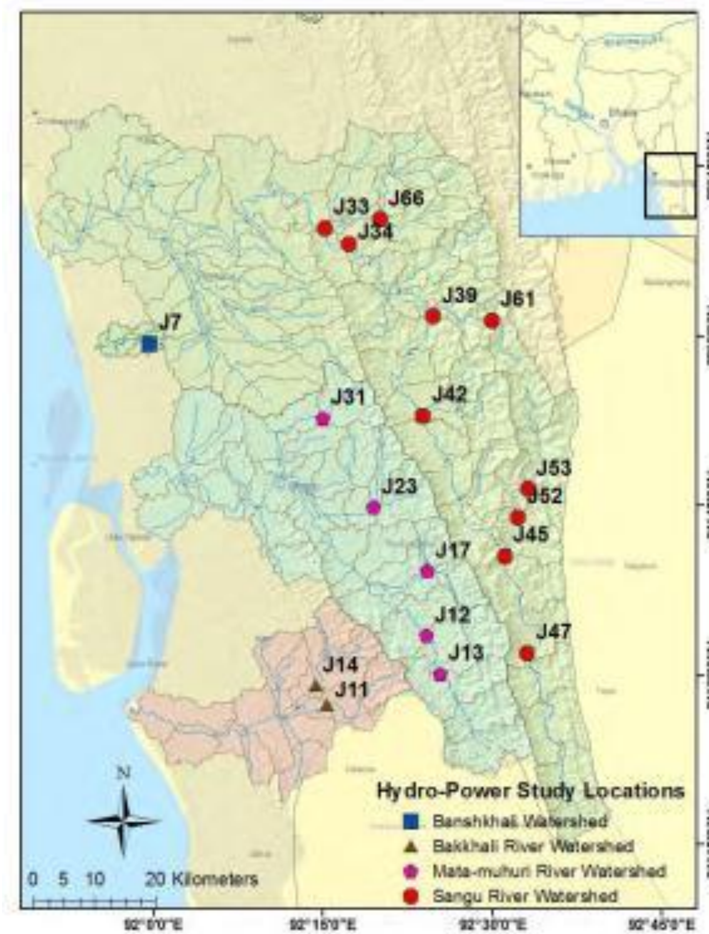
10 kW Bamerchara Micro-hydro Plant

Source: Razan et al., 2012.

- Existing 10 kW Bamerchara Micro-hydro Plant
- Proposed Project: 70 kW Mohamaya Irrigation-cum-Hydro Power Project

Resource Assessment

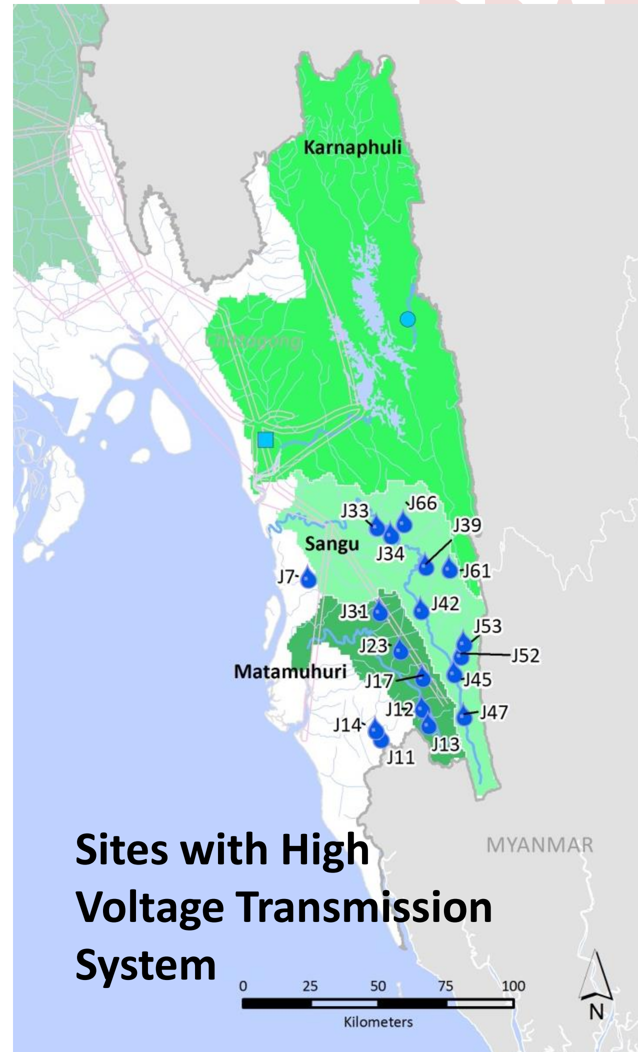
- Ministry of Power, Energy and Mineral Resources funded 2014 study by Stream Tech with following objectives:
  - Quantitatively determine annual hydropower potential at different locations along Sangu, Matamuhuri, and Bakkhali Rivers, and Banshkhali Eco-park stream
  - Identify run-of-river or impoundment type plant locations and turbine sizes optimizing the energy production
- Topographic analysis performed using Geographic Information System (GIS) based Digital Elevation Model (DEM) data to determine the available gross hydraulic head
- Hydrologic model was developed to simulate the river flows at the selected sites over a 15-year period
  - Observed stream flow data (2003 -2012) from the Bangladesh Water Development Board (BWDB) was used for validation and calibration of the hydrologic model



Source: StreamTech, Inc. *"Study on Prospective Hydroelectricity Generation in Southeast Bangladesh,"* 2014

Assumptions & Results

River	Site	Head (m)	Distance to Trans-mission (km)	(MW)	(MWh)*
Sangu	J33	12	13.9	5.79	20,302
Sangu	J34	20	16.6	7.68	26,909
Sangu	J39	70	21.1	20.88	73,150
Sangu	J42	60	10.8	13.59	47,623
Sangu	J45	20	8.6	2.89	10,129
Sangu	J47	40	7.2	1.87	6,550
Sangu	J52	20	14.2	0.68	2,379
Sangu	J53	30	17.6	0.82	2,885
Sangu	J61	40	28.0	0.41	1,430
Sangu	J66	20	23.0	0.81	2,819
Matamuhuri	J12	20	6.4	0.92	3,210
Matamuhuri	J13	15	8.1	0.53	1,871
Matamuhuri	J17	50	0.1	1.04	3,643
Matamuhuri	J23	50	1.5	0.85	2,961
Matamuhuri	J31	10	0.2	0.1	361
Bakkhali	J11	10	25.3	0.1	355
Bakkhali	J14	10	24.9	0.13	444
Banshkhali	J7	12	4.6	0.01	30
Total				59.1	207,051



*Assumes 40 percent operating time. Stream Tech study showed higher capacity resulted in lower capacity factor. Thus, sizing of ROR needs to be balanced against capacity factor from an economic standpoint.

Microgrids (Hybrid Systems)

Existing Projects: Solar Minigrids

Project Name	Administrative Division	Resource	Project Status	Installed Capacity (MW)
141 kWp Shouro Bangla Ltd mini grid	Dhaka	Solar Mini Grid	Complete	0.141
100 kWp GHEL Solar Mini Grid project	Chittagong	Solar Mini Grid	Complete	0.100
141 kWp Hydron Bangladesh Pvt. Ltd. Solar Mini Grid	Rajshahi	Solar Mini Grid	Complete	0.141
100 kWp PGEL solar mini grid project	Chittagong	Solar Mini Grid	Complete	0.100
Solar Mini Grid Power Plant	Chittagong	Solar Mini Grid	Under Construction	0.500
Solar Mini Grid Power Plant	Chittagong	Solar Mini Grid	Under Construction	0.500
Renewable Energy Based Power Generation Pilot Project in Remote Haor Area	Sylhet	Solar Mini Grid	Under Construction	0.650
177 kWp Solar Electro Bangladesh Ltd Solar Mini Grid	Barisal	Solar Mini Grid	Under Construction	0.177
158.3 kWp GRAM er Alo Ltd. solar mini grid	Rangpur	Solar Mini Grid	Under Construction	0.158
148.5 kWp AVA Development Society Solar Mini Grid	Rajshahi	Solar Mini Grid	Under Construction	0.149

Existing Projects: Larger Microgrids

Bangladesh has some experience with larger microgrids, on the islands of Kutubdia and Hatyia:

- 1 MW Wind Battery Hybrid Power Plant at Kutubdia Island
- A 4.2 MWp Hatiya Off-Grid Solar PV Hybrid System with HFO/Diesel Based Engine Driven Generator in Hatiya Island is under construction

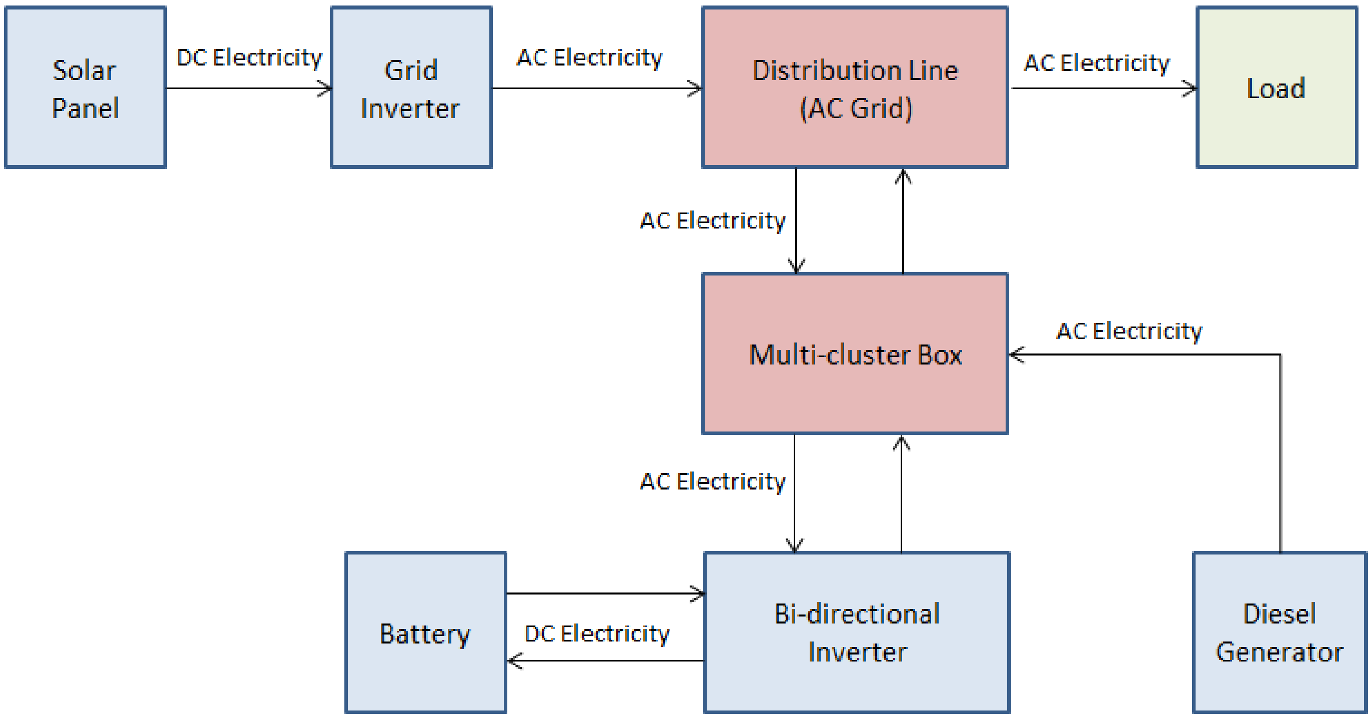
100 kW Wind Battery Hybrid Power Plant at Kutubdia

Design Assumptions

- The solar mini grid projects are mainly targeted at remote areas where no grid expansion is planned for the next 15-20 years

- Under the 500 MW program, a target of 25 MW has been set for these projects
- The solar mini grid projects are typically in the range of 100-200 kWp

Typical Solar Mini-grid Design



Source: Monirul Islam, 2014.

Solar Irrigation & Drinking Water Pumps

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Existing and Proposed Projects

Project Name	Administrative Division	Resource	Project Status	Installed Capacity* (MW)
AVA	National	Solar Irrigation Pump	Complete	0.0688
ARS-BD	Khulna	Solar Irrigation Pump	Complete	0.084
GRAM Project I	Rangpur	Solar Irrigation Pump	Complete	0.032
Gram Project II	Rangpur	Solar Irrigation Pump	Under Construction	0.1152
SDRA	Rangpur	Solar Irrigation Pump	Complete	0.0056
RCNSL	Rangpur	Solar Irrigation Pump	Complete	0.0056
GHEL I	Rajshahi	Solar Irrigation Pump	Complete	0.0336
GHEL II	Rangpur; Rajshahi	Solar Irrigation Pump	Under Construction	0.084
GHEL III	Rangpur; Rajshahi	Solar Irrigation Pump	Under Construction	0.14
RREL	Rangpur; Khulna	Solar Irrigation Pump	Under Construction	0.148
4SL	Rangpur	Solar Irrigation Pump	Under Construction	0.0056
NUSRA	National	Solar Irrigation Pump	Complete	0.0472
REB Project 1 & 2	National	Solar Irrigation Pump	Complete	5.36
Mazand-project I	Khulna	Solar Irrigation Pump	Complete	0.02016
Mazand-project II	Khulna	Solar Irrigation Pump	Under Construction	0.01344
Mazand-project III	Khulna	Solar Irrigation Pump	Under Construction	0.01344
RDF Project I & II	Khulna	Solar Irrigation Pump	Complete	.02016
RDF Project III	Khulna	Solar Irrigation Pump	Under Construction	0.02016
AID Project I	Khulna	Solar Irrigation Pump	Under Construction	0.00672
AID Project II	Khulna	Solar Irrigation Pump	Under Construction	0.00672
Solargao Project I	Rangpur	Solar Irrigation Pump	Under Construction	0.45696
Solargao Project II	Rangpur	Solar Irrigation Pump	Under Construction	0.0672

*Note: Installed solar capacity of pump systems was not available for all projects. Assumed 6.72 kWp per solar pump for projects without capacity information.

Programs and Policies

<u>Irrigation Facts</u>

- 1.61 million irrigation pumps (1.34 million diesel; 0.27 million electricity)
- Diesel irrigation pumps use approximately 1 million tons/year of diesel fuel ($900 million)
- Government spends $280 million per year to subsidize diesel fuel used for irrigation

Source: GPOBA, 2015

Source: GPOBA

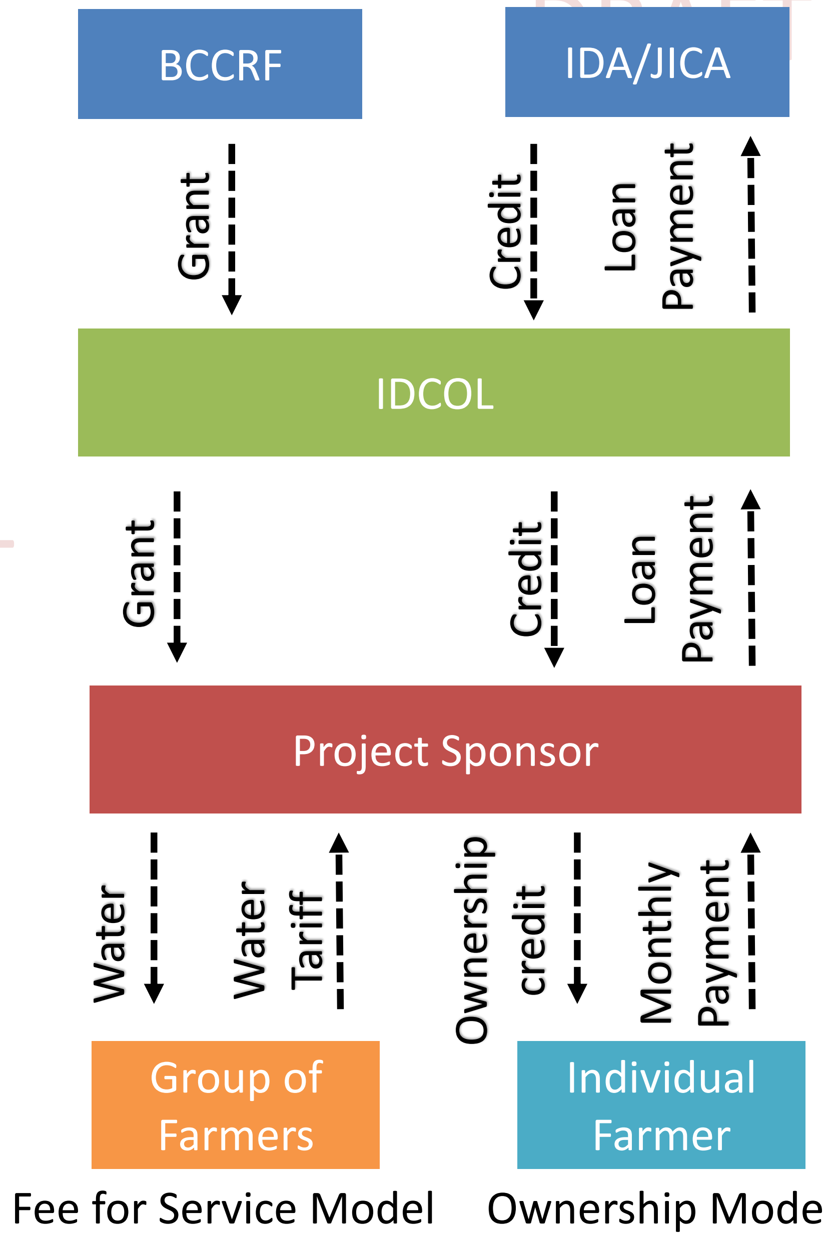
- Solar irrigation pumps can be used to replace existing diesel based pumps
- The World Bank/GPOBA's Solar Irrigation Project aims to install more than 1300 solar irrigation pumps
  - $24.5 million in grants available through Bangladesh Climate Change Resilience Fund (BCCRF)
  - JICA and IDA providing concessional loans

- Project is being implemented by IDCOL
  - IDCOL has set target to install 1550 solar irrigation pumps by 2017
  - 124 solar irrigation pumps approved, 45 installed
- Private sponsors install, operate, and maintain solar irrigation pumps
  - Incentives for sponsors include grants from BCCRF (up to 50% of project costs) and low cost financing
  - Sponsors required to provide at least 20% of project costs as equity

Programs and Policies

IDCOL programs provides grants and loans for solar irrigation projects

- Grant funds and credit are passed from IDCOL to project sponsors
  - Project sponsors make loan payments to IDCOL
  - IDCOL makes loan payments to IDA and JICA
- IDCOL has two business models:
  - Fee for service (large pumps, groups of farmers). Sponsors retain ownership of pumps and sell water to farmers.
  - Ownership (small pumps, individual farmers). Sponsors sell pumps on credit to farmers, farmers make monthly payments to sponsor.



Design Assumptions

- Total of 1426 solar irrigation pumps included in 14 projects
  - IDCOL target of 1550 solar irrigation pumps, less 124 committed projects used as basis
  - Projects grouped by administrative division and large and small pumps
  - Installations per division determined by allocating solar irrigation pump installations proportionally by number of eligible hectares*
  - Two pump sizes selected from GPOBA material on Solar Irrigation in Bangladesh

System Type	Solar PV Capacity
Large (Multiple Farmers) Pump	11 kWp
Small (Single Farmer) Pump	4 kWp

Source: MAKS Group BD

*GPOBA notes that eligible areas must have the potential to grow 3-4 crops per year.

Other Technologies

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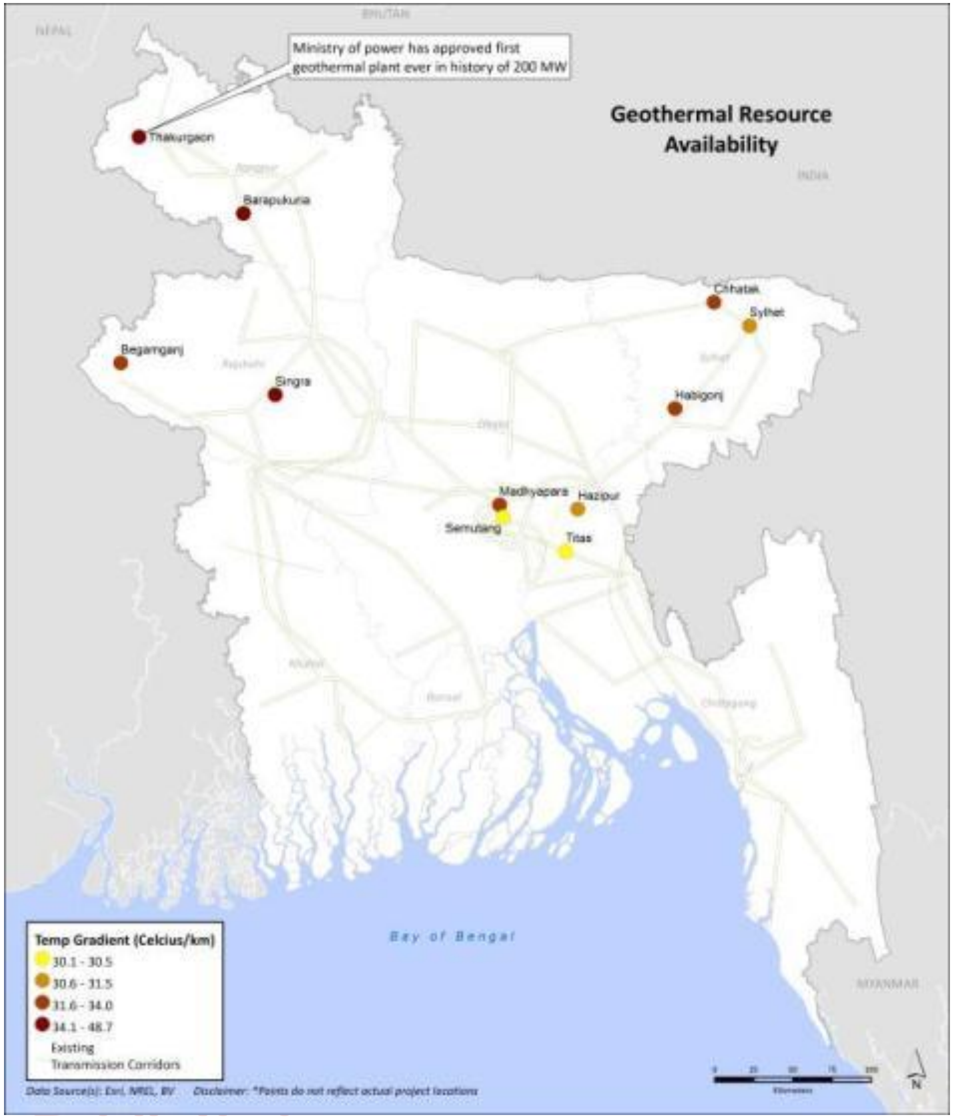
Geothermal



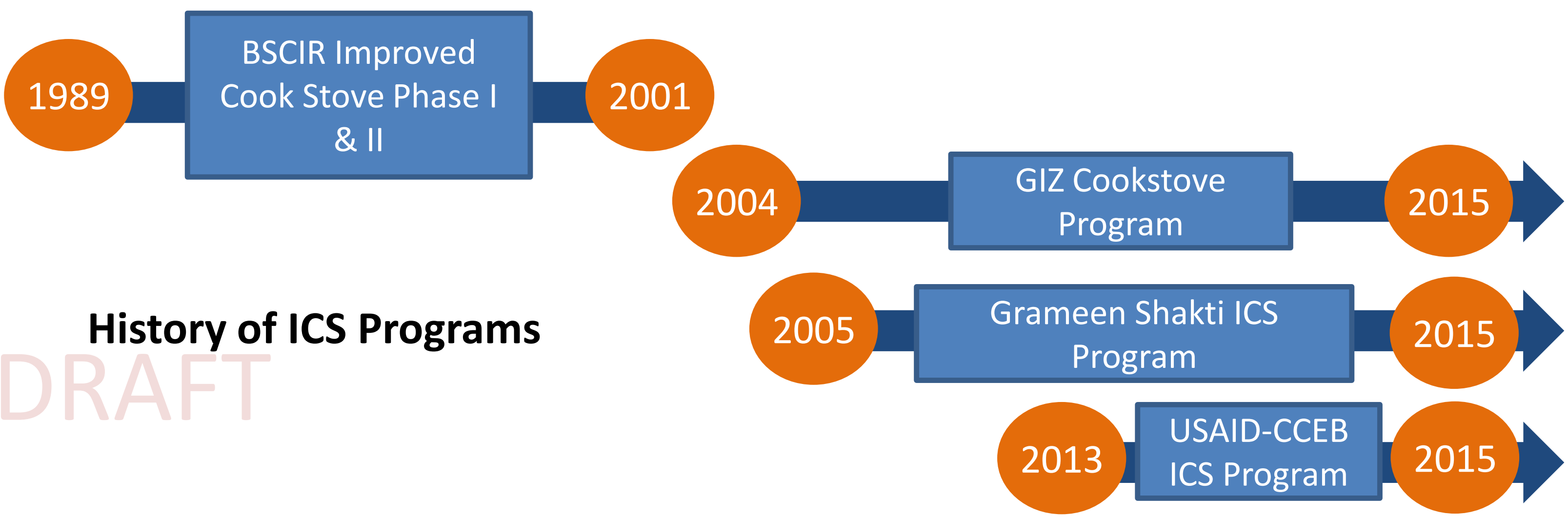
- Bottom Hole Temperature (BHT) of 13 deep wells drilled for petroleum exploration in northeastern part of Bangladesh measured temperature gradient in each well at depths of 3000 to 15,000 m (Khandoker and Haque 1984).
- Temp gradient of 30 deg C per km or more is recommended for further study (see map)
- Well sites appear to be in close proximity to existing transmission system
- However, extensive investments in studies and well drilling will still be necessary to confirm resource adequacy
- Ministry of power had approved first geothermal plant ever in history of 200 MW, but project cancelled due to economics.

Clean Cook Stoves

- Improved Cook Stoves (ICS) are up to 50% more efficient compared to traditional stoves and provide health benefits due to lower toxin emissions into the home
- ICS projects have been some of the most successful energy initiatives in Bangladesh with more than 510,000
- Market for clean cook stoves remains strong:
  - Existing penetration rate of ICS is only 3% of cookstove market
  - Country Action Plan for Clean Cookstoves (2013) aims to achieve 100% penetration with **30 million ICS** by 2030
  - Additional market potential of **20 million ICS** when households using more than one stove are taken into account

Recent ICS Programs

Project	ICS	Status
GIZ, Bondu Chula	3,300,000	2017 target
USAID-CCEB, Market Analysis and Development for ICS	1,600,000	2017 target
Grammen Shakti, Dissemination of ICS	910,000	Current Installs
BCSIR, Carbon emission mitigation program	28,000	Complete (2013)

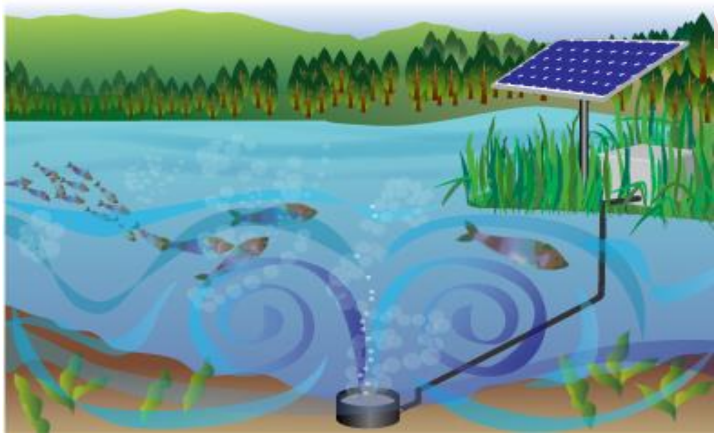


History of ICS Programs

Solar Boats and Fish Pond Aerators

Source: Shidhulai Swanirvar Sangstha

- Solar PV can be used to provide social services to rural communities.
- Shidhulai Swanirvar Sangstha has used solar PV technology to provide electric power on a fleet of 111 boats that serve as:
  - Health clinics
  - Schools
  - Libraries
  - Adult education centers.



Source: Solardirect.com

- An estimated 1.3 million fish ponds in Bangladesh use diesel and electric pumps to aerate.
- PV-powered aeration systems are seen as a possible alternative to existing diesel pumps.
- Low utilization rate of pumps (2-3 hours daily) potentially hurts financial viability.

Appendix: List of Projects Considered

List of Projects Considered

Resource ID	Technology	Unit capacity	Total Net Capacity	Capacity factor	Heat rate (BTU/kWh)	Fuel type	Fuel cost (US$/kWh)	Construction Start Year	Years Construction	Asset life (Years)
Rice Husk Gasifier	Biomass Gasifier	0.4	274	0.85	13648	Rice Husk	0	2016	1	10
SEAL Thakurgaon Rice Husk Gasifier	Biomass Gasifier	0.4	0.4	0.85	13648	Rice Husk	0	2016	1	10
Small Barisal Digester Power	Digester Power	0.025	0.415	0.5	12000	Manure	0	2016	1	15
Small Chittagong Digester Power	Digester Power	0.025	1.84	0.5	12000	Manure	0	2016	1	15
Small Dhaka Digester Power	Digester Power	0.025	4.716	0.5	12000	Manure	0	2016	1	15
Small Khulna Digester Power	Digester Power	0.025	0.869	0.5	12000	Manure	0	2016	1	15
Small Rajshahi Digester Power	Digester Power	0.025	1.123	0.5	12000	Manure	0	2016	1	15
Small Sylhet Digester Power	Digester Power	0.025	0.465	0.5	12000	Manure	0	2016	1	15
7.5 MWp Hatiya Off Grid Wind-Solar Hybrid with HFO/Diesel Based Engine	Microgrid	7.5	7.5	0.17	0	Hybrid	0	2016	1	20
Off Grid Solar- Diesel based Hybrid Power Plant in Kutubdia Island	Microgrid	1	1	0.1391	0	Hybrid	0	2016	1	20
Large Solar Home Systems	SHS	0.00013	150	0.15	0	Solar	0	2016	1	20
Small Solar Home Systems	SHS	0.00005	150	0.15	0	Solar	0	2016	1	20

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List of Projects Considered

Resource ID	Technology	Unit capacity	Total Net Capacity	Capacity factor	Heat rate (BTU/kWh)	Fuel type	Fuel cost (US$/kWh)	Construction Start Year	Years Construction	Asset life (Years)
Bakkhali J11 Small Hydro	Small hydro	0.1	0.1	0.4	0	Hydro	0	2016	2	30
Bakkhali J14 Small Hydro	Small hydro	0.13	0.13	0.4	0	Hydro	0	2016	2	30
Banshkhali J7 Small Hydro	Small hydro	0.01	0.01	0.4	0	Hydro	0	2016	2	30
Matamuhuri J12 Small Hydro	Small hydro	0.92	0.92	0.4	0	Hydro	0	2016	2	30
Matamuhuri J13 Small Hydro	Small hydro	0.53	0.53	0.4	0	Hydro	0	2016	2	30
Matamuhuri J17 Small Hydro	Small hydro	1.04	1.04	0.4	0	Hydro	0	2016	2	30
Matamuhuri J23 Small Hydro	Small hydro	0.85	0.85	0.4	0	Hydro	0	2016	2	30
Matamuhuri J31 Small Hydro	Small hydro	0.1	0.1	0.4	0	Hydro	0	2016	2	30
Mohamaya Irrigation-cum-Hydro Power Project	Small hydro	0.07	0.07	0.4	0	Small hydro	0	2016	2	30
Sangu J33 Small Hydro	Small hydro	5.79	5.79	0.4	0	Hydro	0	2016	2	30
Sangu J34 Small Hydro	Small hydro	7.68	7.68	0.4	0	Hydro	0	2016	2	30
Sangu J39 Small Hydro	Small hydro	20.88	20.88	0.4	0	Hydro	0	2016	2	30
Sangu J42 Small Hydro	Small hydro	13.59	13.59	0.4	0	Hydro	0	2016	2	30
Sangu J45 Small Hydro	Small hydro	2.89	2.89	0.4	0	Hydro	0	2016	2	30
Sangu J47 Small Hydro	Small hydro	1.87	1.87	0.4	0	Hydro	0	2016	2	30
Sangu J52 Small Hydro	Small hydro	0.68	0.68	0.4	0	Hydro	0	2016	2	30
Sangu J53 Small Hydro	Small hydro	0.82	0.82	0.4	0	Hydro	0	2016	2	30
Sangu J61 Small Hydro	Small hydro	0.41	0.41	0.4	0	Hydro	0	2016	2	30
Sangu J66 Small Hydro	Small hydro	0.81	0.81	0.4	0	Hydro	0	2016	2	30

List of Projects Considered

DHInfrastructure
Economics & Finance

Resource ID	Technology	Unit capacity	Total Net Capacity	Capacity factor	Heat rate (BTU/kWh)	Fuel type	Fuel cost (US$/kWh)	Construction Start Year	Years Construction	Asset life (Years)
Barisal Small Irrigation Pumps	Solar irrigation pumps	0.004	0.004	0.16	0	Solar	0	2016	1	20
Barisal Small Irrigation Pumps	Solar irrigation pumps	0.011	0.011	0.16	0	Solar	0	2016	1	20
Chittagong Small Irrigation Pumps	Solar irrigation pumps	0.004	0.004	0.16	0	Solar	0	2016	1	20
Chittagong Small Irrigation Pumps	Solar irrigation pumps	0.011	0.011	0.16	0	Solar	0	2016	1	20
Dhaka Small Irrigation Pumps	Solar irrigation pumps	0.004	0.004	0.156	0	Solar	0	2016	1	20
Dhaka Small Irrigation Pumps	Solar irrigation pumps	0.011	0.011	0.156	0	Solar	0	2016	1	20
Khulna Small Irrigation Pumps	Solar irrigation pumps	0.004	0.004	0.156	0	Solar	0	2016	1	20
Khulna Small Irrigation Pumps	Solar irrigation pumps	0.011	0.011	0.156	0	Solar	0	2016	1	20
Rajshahi Large Irrigation Pumps	Solar irrigation pumps	0.011	0.011	0.157	0	Solar	0	2016	1	20
Rajshahi Small Irrigation Pumps	Solar irrigation pumps	0.004	0.004	0.157	0	Solar	0	2016	1	20
Rangpur Small Irrigation Pumps	Solar irrigation pumps	0.004	0.004	0.149	0	Solar	0	2016	1	20
Rangpur Small Irrigation Pumps	Solar irrigation pumps	0.011	0.011	0.149	0	Solar	0	2016	1	20
Sylhet Small Irrigation Pumps	Solar irrigation pumps	0.004	0.004	0.142	0	Solar	0	2016	1	20
Sylhet Small Irrigation Pumps	Solar irrigation pumps	0.011	0.011	0.142	0	Solar	0	2016	1	20

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List of Projects Considered

Resource ID	Technology	Unit capacity	Total Net Capacity	Capacity factor	Heat rate (BTU/kWh)	Fuel type	Fuel cost (US$/kWh)	Construction Start Year	Years Construction	Asset life (Years)
Baraka Renewable Energy Limited Solar Mini Grid	Solar Mini Grid	0.167	0.167	0.17574	0	Solar	0	2016	1	20
G-Tech Solutions Ltd Solar Mini Grid	Solar Mini Grid	0.16775	0.16775	0.179227	0	Solar	0	2016	1	20
Intraco Limited Solar Mini Grid	Solar Mini Grid	0.2	0.2	0.16	0	Solar	0	2016	1	20
Parasol Energy Ltd Solar Mini Grid	Solar Mini Grid	0.1875	0.1875	0.18366	0	Solar	0	2016	1	20
Solargao Limited Solar Mini Grid	Solar Mini Grid	0.13	0.13	0.179348	0	Solar	0	2016	1	20
Superstar Renewable Energy Limited Solar Mini Grid	Solar Mini Grid	0.2	0.2	0.156	0	Solar	0	2016	1	20
Tauras Energy Limited Solar Mini Grid	Solar Mini Grid	0.15	0.15	0.156	0	Solar	0	2016	1	20
Barisal Solar Park	Solar Park	10	7.168438	0.172	0	Solar	0	2016	1	20
Chittagong Solar Park	Solar Park	10	524.8824	0.173	0	Solar	0	2016	1	20
Dhaka Solar Park	Solar Park	10	9.311726	0.167	0	Solar	0	2016	1	20
Khulna Solar Park	Solar Park	10	25.01486	0.168	0	Solar	0	2016	1	20
Payra Solar Power Park	Solar Park	50	50	0.172	0	Solar	0	2016	1	20
Rajshahi Solar Park	Solar Park	10	0.404329	0.169	0	Solar	0	2016	1	20
Rangpur Solar Park	Solar Park	10	0.503404	0.16	0	Solar	0	2016	1	20
Sirajgonj Solar Park	Solar Park	7.5	7.5	0.165	0	Solar	0	2016	1	20
Sylhet Solar Park	Solar Park	10	136.8092	0.154	0	Solar	0	2016	1	20
Thakurgaon Sadar 5 MW Solar Park	Solar Park	5	5	0.16	0	Solar	0	2016	1	20

List of Projects Considered

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Resource ID	Technology	Offgrid	Unit capacity	Total Net Capacity	Capacity factor	Heat rate (BTU/kWh)	Fuel type	Fuel cost (US$/kWh)	Construction Start Year	Years Construction	Asset life (Years)
Large Solar Rooftop	Solar rooftop	0	0.035	150	0.15	0	Solar	0	2016	1	20
Small Solar Rooftop	Solar rooftop	0	0.005	150	0.15	0	Solar	0	2016	1	20
Barisal High Wind Speed Parks	Wind Park	1	10	13	0.2563	0	Wind	0	2016	1	20
Barisal Low Wind Parks	Wind Park	1	50	531	0.2244	0	Wind	0	2016	1	20
Chittagong Low Wind Parks	Wind Park	1	50	93	0.2145	0	Wind	0	2016	1	20
Kuokata Wind Project	Wind Park	1	100	100	0.25	0	Wind	0	2016	1	20
Parky Beach Wind Project	Wind Park	1	200	200	0.22	0	Wind	0	2016	1	20

6/8/2015

Preparation of SREP Investment Plan Bangladesh Energy Sector Development Project

Economic and Financial Viability

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PSL
Engineering consulting firm
in Bangladesh.
Dedicated to energy and sustainable development.
PROKAUSHALI SANGSAD LTD.

Overall Approach to Costing

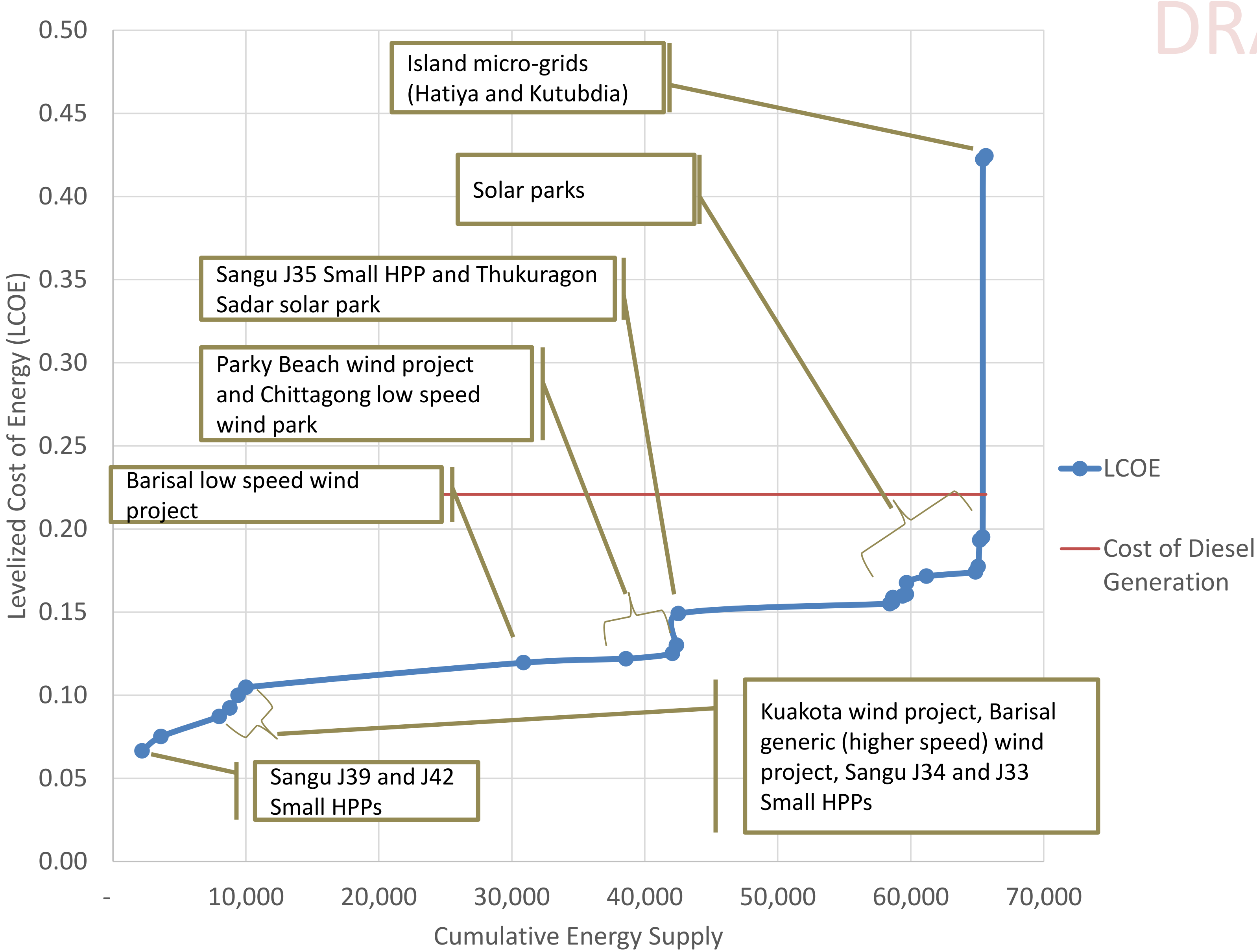
- Use data from existing projects or plans in Bangladesh
- Amend or update as necessary
- Fill data gaps based on benchmarks in the region, or internationally
- Include specific "planned" projects plus generic projects, up to total estimated technical potential
- Compare on levelized cost basis

Economic Viability

Assumptions:

- Social opportunity cost of capital = 10%
- Present value taken over life of asset
- Comparison to cost of diesel generation (current marginal cost of production)

Supply Curve: Grid-connected



Supply Curve: Offgrid

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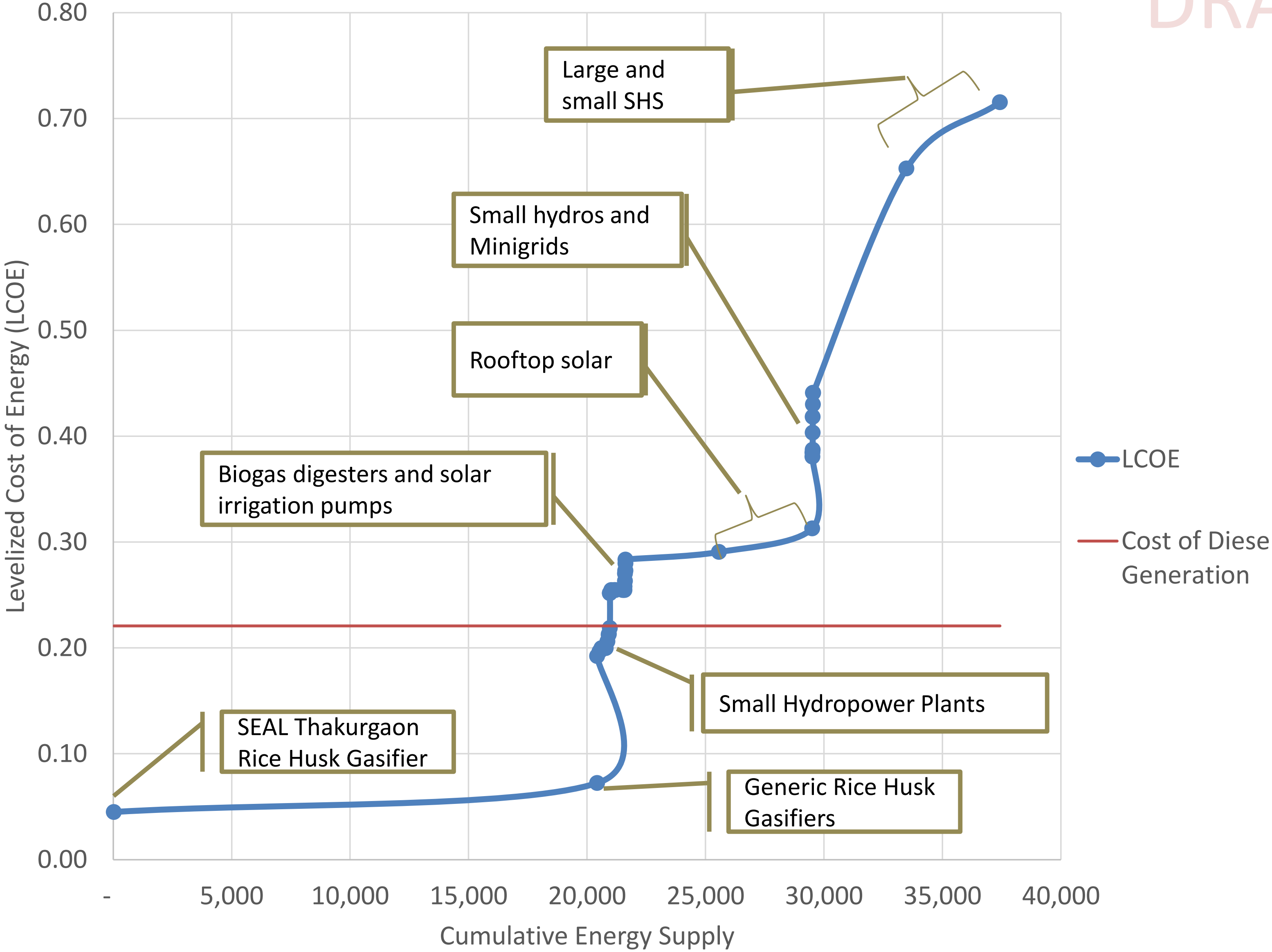

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Financial Viability

Assumptions:

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- 70/30 Debt Equity Ration
- Cost of debt = 13%
- Cost of equity = 20%
- Tenor of debt = 20 years
- Equity return over life of asset
- Comparison to cost of diesel generation (current marginal cost of production is financial cost to Government, if not to customers)

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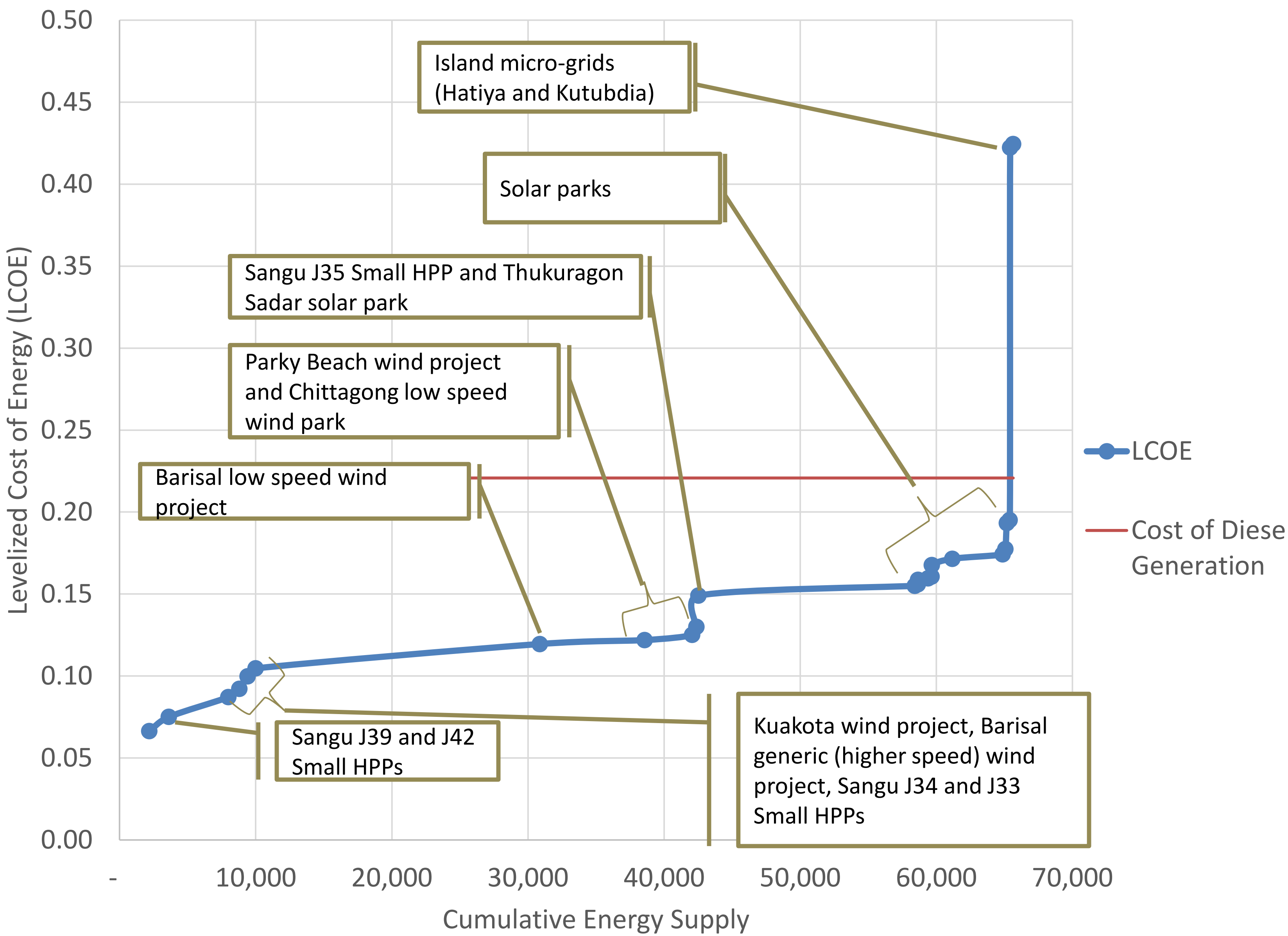
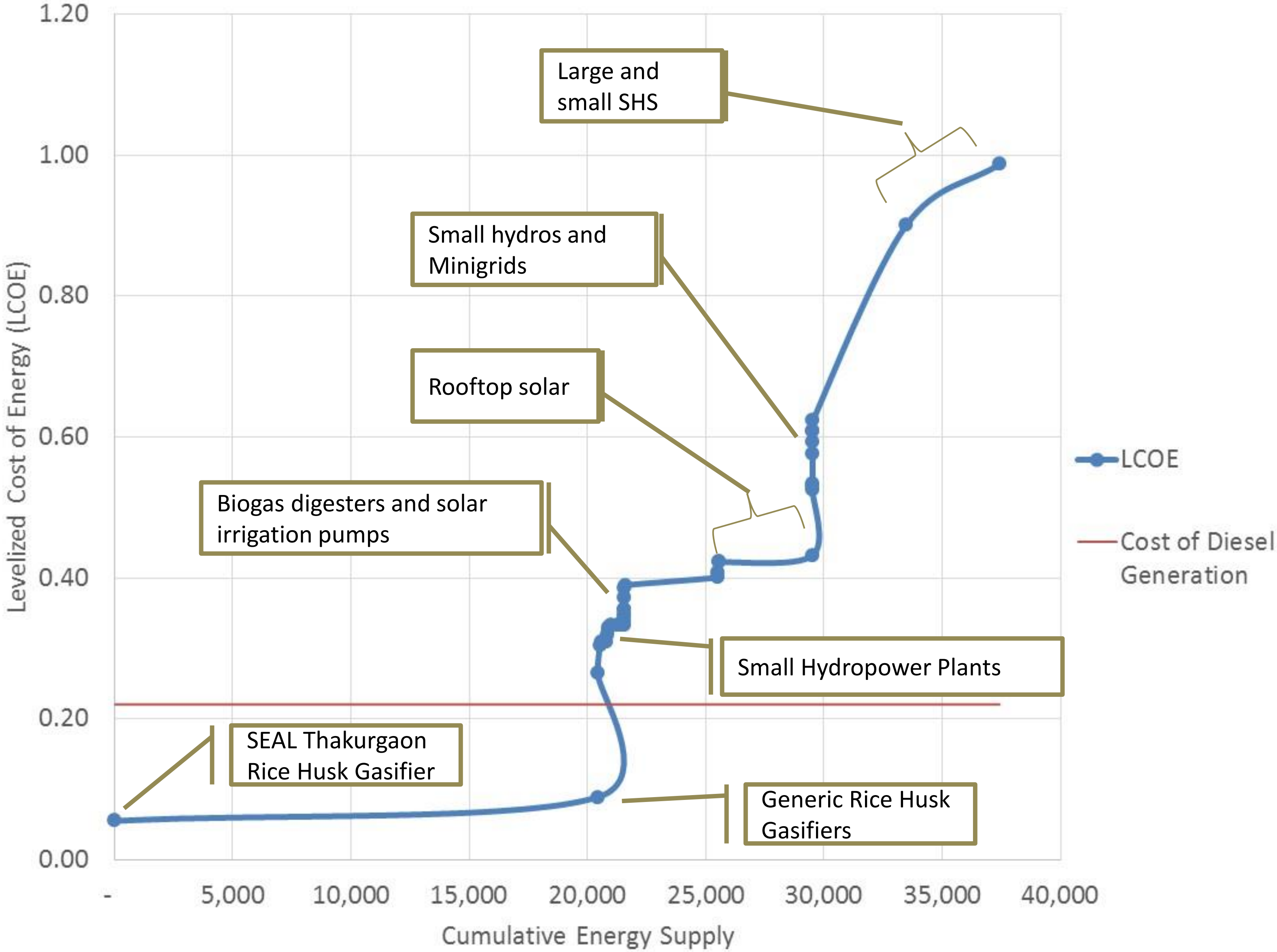
Supply Curve: Grid-connected



Supply Curve: Offgrid



Underlying Cost Assumptions

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Assumptions: Solar Parks

- Solar park projects under have reported costs ranging from $1.8 to $4.3 per Wp
  - Costs were not size dependent
  - Unclear whether higher cost projects include interconnection/system upgrade costs
- $2 per Wp is closer to recent solar PV costs, so we included multiple generic projects

Planned Solar Park Costs

Division	District	Upazila/ Village	Installed Capacity (MW)	US$/W	Fixed O&M ($/kW-yr)*	Capacity Factor (DC)
Rajshahi	Sirajganj	Sirajgonj Sadar	7.50	$2.40	$15	16.5%
Barisal	Patuakhali	Kolapara	50.00	$2.20	$15	17.2%
Rangpur	Thakurgaon	Thakurgaon Sadar	5.00	$1.78	$15	16.0%
Generic	All	All	704.00	$2.00	$15	As per district

*Black & Veatch estimate, based on experience with other projects.

Assumptions: Rooftop Solar

- GoB 500 MW Solar program for Residential/Commercial buildings and Industrial buildings define systems
  - Residential & Commercial Roof-top systems
    - Capacity >1 kWp
    - Tied to the grid and the use of the battery is discouraged
  - Industrial Roof-top systems
    - Capacity >10 kWp
    - Electricity generated from these systems may be consumed by the owner or may sell it to the respective distribution companies.
- Limited historical data available for systems installed in Bangladesh, but costs below are representative of simple rooftop systems with little or minimal roof retrofits/enforcements

Planned Rooftop Solar Costs			
	Typical Size (kWp)	Cap cost ($/Wp)	O&M ($/kW-Year)
Generic Small Solar rooftop	1-10	$3.50	$10
Generic Large Solar rooftop	10-50	$3.25	$10

Assumptions: Solar Home Systems

- Solar modules, batteries, charge controller, dc/dc converter, equipment enclosure, wiring and CFL light set (Source: IDCOL Solar Program)
  - Battery rating recommended to be 1.5 Ah per Wp
  - Battery replacement (5 years warranty).
  - Provisions for buyback of batteries and replacement at end of life (Source: Bangladesh Institute of Development Studies, 2013)
  - DC/DC Converter (3 year warranty)
- SHS reported costs
  - 10 to 130 Wp with cost of $131 to $956 (Source: Global Alliance for Clean Cookstoves)
  - 50 Wp is $380-$420 (Source: IDCOL)

Planned SHS Costs				
	Typical Size (Wp)	System Cost (US$)	Cap cost ($/Wp)	O&M ($/kW-yr)
Generic Small SHS	50	$400	$8.00	$300
Generic Large SHS	130	$950	$7.30	$250

Assumptions: Wind Farms

- Kuakata 100 MW wind project has reported cost of $1.63/W, while Cox's Bazar is $2/W
- Current Indian Project Costs are ~$1.3/W, among the lowest in the world
  - Potential to reduce wind costs if Indian experience and market conditions can be realized in Bangladesh.
  - Established wind turbine manufacturers in India
- However, given the construction in coastal zones and emerging wind industry in Bangladesh, Black & Veatch believes a cost of $2 per W is a more reasonable estimate for wind projects sited along the coast
- Fixed O&M cost estimate includes O&M contract, parts replacement, personnel while considering extreme weather risk and lower labor costs. Does not include land lease or any taxes.

Planned Wind Farm Costs

Project Name	Net Capacity (MW)	Capital Cost ($/W)	Fixed O&M ($/kW-yr)	Capacity Factor
Wind Power Project at Parky Beach area, Anawara in Chittagong on IPP basis	200	$2.00	$35.00	22.00%
Kuakata 100MW Wind Project	100	$1.63	$35.00	25.00%
Generic Barisal and Chittagong Wind Projects	574	$2.00	$35.00	Various

Assumptions: Small Hydro

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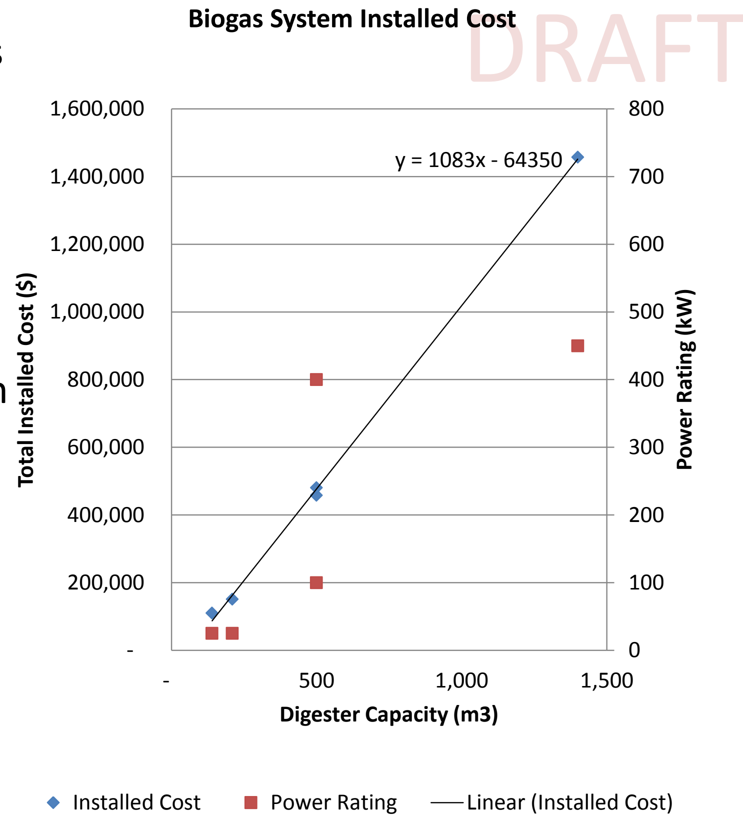
- Checked against international cost curves from IRENA
- FOM, assumed 3% of Capital Cost for systems greater than 1 MW and 4% of Capital Cost for systems under 1 MW.
- Interconnection cost adder assumes new 230 kV substations are required ($3million) and gen-tie line to get project to grid ($50k per km). Microgrid adder assumed similar to other hybrid microgrids where there is unserved load in close proximity.
- Assumes systems 1 MW or greater can be grid connected, while smaller systems are used to serve microgrids.

Site	Capacity (MW)	Deploy-ment Type***	Genera-tion Capital Cost ($/W)	Inter-connection or Microgrid Adder ($/W)**	Fixed O&M* ($/kw-year)
J33	5.79	Grid	$2.50	$0.64	$75
J34	7.68	Grid	$2.40	$0.50	$72
J39	20.88	Grid	$1.90	$0.19	$57
J42	13.59	Grid	$2.10	$0.26	$63
J45	2.89	Grid	$2.90	$1.19	$87
J47	1.87	Microgrid	$3.20	$2.38	$96
J52	0.68	Microgrid	$4.10	$2.38	$164
J53	0.82	Microgrid	$3.90	$2.38	$156
J61	0.41	Microgrid	$4.50	$2.38	$180
J66	0.81	Microgrid	$3.90	$2.38	$156
J12	0.92	Microgrid	$3.80	$2.38	$152
J13	0.53	Microgrid	$4.30	$2.38	$172
J17	1.04	Microgrid	$3.70	$2.38	$111
J23	0.85	Microgrid	$3.90	$2.38	$156
J31	0.1	Microgrid	$6.20	$2.38	$248
J11	0.1	Microgrid	$6.20	$2.38	$248
J14	0.13	Microgrid	$5.90	$2.38	$236
J7	0.01	Microgrid	$10.30	$2.38	$412

Note: Numerous studies have been conducted on Bangladesh's waterways in the past, but no site engineering evaluation has yet been conducted nor engineering design-based cost estimates have been developed for these sites. Actual costs and capacities may be significantly different than shown above.

Assumptions: Biogas

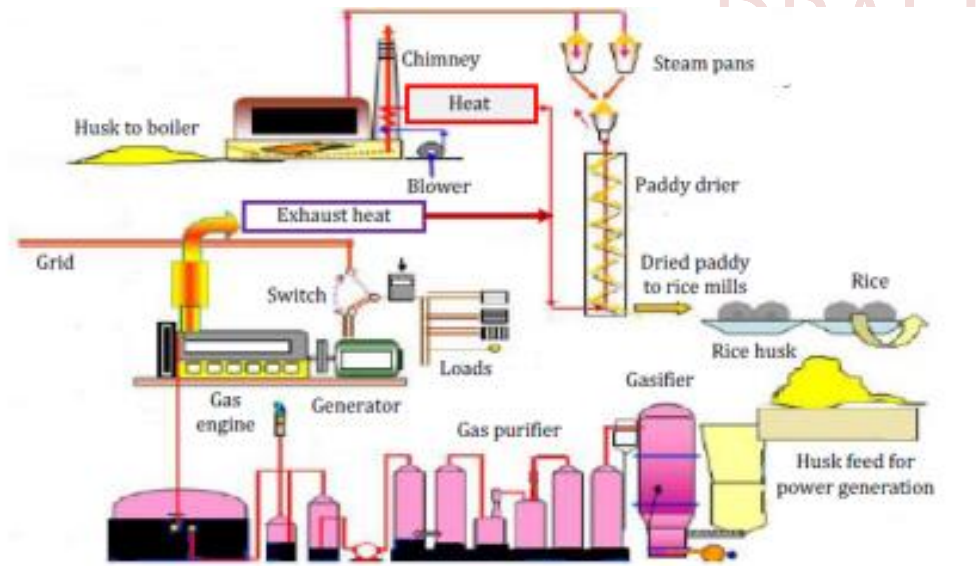
- Costs linear to digester capacity, but per unit cost increases with capacity
- Resource assumptions: 200 m^3 of biogas per ton of poultry waste and 1.8 kWh per m^3
- Operation and maintenance assumptions:
  - Biogas from chicken litter will produce biogas with high H_2S levels; requires scrubbing of gas before operating in reciprocating engine
  - Reciprocating engine assumes frequent engine maintenance required
- Additional value from fertilizer byproduct is assumed to offset any variable O&M related to startup
- Interconnection cost adder same as for mini-grids



Planned Biogas Projects							
Project Name	Capital cost ($/w)	Microgrid cost adder ($/w)	MW	FOM ($/kW-year)	VOM ($/kWh)	Project Life (years)	Capacity Factor
Generic biogas projects	$6.10	$2.38	9.4	$125	net zero	15	50%

Assumptions: Biomass

- Costs will be similar to SEAL Rice Husk Gasifier in Thakurgaon, funded by IDCOL
- Short project life considering operational history of similar plants
- Variable O&M assumed to be offset by sale of Silica byproduct when possible
- Interconnection cost adder same as for small hydro with 10 km gen-tie line required
- Rice husk also has value as a cooking fuel, but fuel cost assumed to be 0.*



Schematic diagram of rice husk gasification power plant in Bangladesh
Source: Halder, 2014.

Planned Biomass Projects							
	Capacity (MW)	Capital Cost ($/w)	Grid-tie Cost Adder ($/kW-yr)	FOM ($/kW-year)	VOM ($/kWh)	Capacity Factor	Project Life (years)
Generic Rice Husk Gasifier Projects	247	$2.10	1.25	$187	net zero	85%	10

*Rice husk briquettes have a market value of $80 to $130 per ton (source: Global Alliance for Clean Cookstoves, 2012)

Assumptions: Solar Mini-grids

- A typical solar mini grid consists of solar panels, battery, diesel generator and inverter
- Battery replacement (5 year warranty) and diesel generator maintenance contributes to Fixed O&M
- Diesel generator component intended only to supplement the minigrid when solar energy is not available (cloudy, rainy days) and batteries have been drained.
- Excludes diesel costs
- Optimization of diesel generator and battery charging/discharging should be part of the minigrid design to minimize inefficient operating levels of the diesel generator, but no

Project Name	Division	District	Upazila/ Village	Installed Solar Capacity (MW)	US$/W	Fixed O&M ($/kW-year)	Capacity Factor
Baraka Renewable Energy Limited Solar Mini Grid	Dhaka	Narayanganj	Nooner Tek	0.17	$5.48	$124	17.57%
G-Tech Solutions Ltd Solar Mini Grid	Dhaka	Jamalpur	Islampur	0.17	$5.14	$175	17.92%
Solargao Limited Solar Mini Grid	Rajshahi	Sirajganj	Rupshar Char	0.13	$5.18	$203	17.93%
Parasol Energy Ltd Solar Mini Grid	Khulna	Kushtia	Daulatpur	0.19	$5.21	$175	18.37%
Intraco Limited Solar Mini Grid	Chittagong	Noakhali	Nijhum Dwip	0.20	$5.13	$175	16.00%
Tauras Energy Limited Solar Mini Grid	Dhaka	Faridpur	North Channel	0.15	$5.13	$175	15.60%
Superstar Renewable Energy Limited Solar Mini Grid	Dhaka	Manikganj	Baghutia	0.20	$5.13	$175	15.60%

Example: Sandwip Mini-Grid

Revenue Trend of Mini Grid Service

- Sustained business of PGEL.
- Operating costs totally recovered.
- Debt service coverage of IDCOL of $74,000
- In 2013 operating cost: 25% revenue.
- Risk management: local bank is being used for monthly bill collection.
- Load management:
  - Battery SOC priority
  - CFL and LED
  - Timing for large load

	2011	2012	2013
Total Revenue ($)	24,446	39,138	44,319
Connection fee	33%	11%	4%
Electricity Sale	67%	89%	96%
Total Operating Cost ($)	4,891	9,248	11,527
Diesel	1%	20%	25%
Others site expenses	43%	31%	15%
Salary	56%	49%	60%

Assumptions: Large Micro-grids

- Two additional microgrids have been proposed on the two islands of Hatiya (1 MWp) and Kutubdia (4.2 MWp)
- Estimates based on the reported cost of the solar hybrid microgrid under construction in Kutubdia with adjustments for wind
- Excludes diesel costs
- Solar hybrid performance in Kutubdia assumed to perform similar to solar minigrids in operation on the same island

Project Name	Division	District	Upazila/ Village	Installed RE Capacity (MW)	US$/W	Fixed O&M ($/kW-year)	Capacity Factor
7.5 MWp Hatiya Off Grid Wind-Solar Hybrid with HFO/Diesel Based Engine	Chittagong	Noakhali	Hatiya	7.50	$5.38	$150	17.00%
Off Grid Solar- Diesel based Hybrid Power Plant in Kutubdia Island	Chittagong	Cox's Bazar	Kutubdia	1.00	$4.38	$150	13.91%

Assumptions: Solar Irrigation Pumps

- Project cost based on estimates from GPOBA:
  - Large 11 kWP pump: $36,000
  - Small 4 kWP pump: $4,000
- Cost components included in estimate:
  - Land & land development
  - Solar panel
  - Pump
  - Controller
  - Mounting structure
  - Accessories
  - Civil works
  - Boring
  - Buried pipe
  - Transportation, Installation, & Erection

Project Name	Solar Pumps	Capacity (MW)	Deploy-ment Type***	Generation Capital Cost ($/W)
Rajshahi Small Irrigation Pumps	134	0.011	Off-Grid	$2.25
Chittagong Small Irrigation Pumps	97	0.004	Off-Grid	$2.25
Dhaka Small Irrigation Pumps	170	20.88	Off-Grid	$2.25
Khulna Small Irrigation Pumps	139	13.59	Off-Grid	$2.25
Sylhet Small Irrigation Pumps	25	2.89	Off-Grid	$2.25
Rangpur Small Irrigation Pumps	112	1.87	Off-Grid	$2.25
Barisal Small Irrigation Pumps	51	0.68	Off-Grid	$2.25
Rajshahi Large Irrigation Pumps	114	0.82	Off-Grid	$3.27
Chittagong Small Irrigation Pumps	83	0.41	Off-Grid	$3.27
Dhaka Small Irrigation Pumps	144	0.81	Off-Grid	$3.27
Khulna Small Irrigation Pumps	118	0.92	Off-Grid	$3.27
Sylhet Small Irrigation Pumps	21	0.53	Off-Grid	$3.27
Rangpur Small Irrigation Pumps	95	1.04	Off-Grid	$3.27
Barisal Small Irrigation Pumps	43	0.85	Off-Grid	$3.27

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Appendix: LCOEs

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Economic Viability: Grid-Connected

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Resource ID	LCOE
Sangu J39 Small Hydro	$ 0.07
Sangu J42 Small Hydro	$ 0.08
Kuokata Wind Project	$ 0.09
Sangu J34 Small Hydro	$ 0.09
Sangu J33 Small Hydro	$ 0.10
Barisal High Wind Speed Parks	$ 0.10
Barisal Low Wind Parks	$ 0.12
Parky Beach Wind Project	$ 0.12
Chittagong Low Wind Parks	$ 0.13
Sangu J45 Small Hydro	$ 0.13
Thakurgaon Sadar 5 MW Solar Park	$ 0.15
Chittagong Solar Park	$ 0.16
Barisal Solar Park	$ 0.16
Rajshahi Solar Park	$ 0.16
Khulna Solar Park	$ 0.16
Dhaka Solar Park	$ 0.16
Rangpur Solar Park	$ 0.17
Payra Solar Power Park	$ 0.17
Sylhet Solar Park	$ 0.17
Sangu J47 Small Hydro	$ 0.18
Matamuhuri J17 Small Hydro	$ 0.19
Sirajgonj Solar Park	$ 0.20
Off Grid Solar- Diesel based Hybrid Power Plant in Kutubdia Island	$ 0.42
7.5 MWp Hatiya Off Grid Wind-Solar Hybrid with HFO/Diesel Based Engine	$ 0.42

Economic Viability: Offgrid

Resource ID	LCOE
SEAL Thakurgaon Rice Husk Gasifier	$ 0.05
Rice Husk Gasifier	$ 0.07
Rajshahi Small Irrigation Pumps	$ 0.19
Matamuhuri J12 Small Hydro	$ 0.20
Sangu J53 Small Hydro	$ 0.20
Sangu J66 Small Hydro	$ 0.20
Matamuhuri J23 Small Hydro	$ 0.20
Sangu J52 Small Hydro	$ 0.21
Matamuhuri J13 Small Hydro	$ 0.21
Mohamaya Irrigation-cum-Hydro Power Project	$ 0.21
Sangu J61 Small Hydro	$ 0.22
Barisal Small Irrigation Pumps	$ 0.25
Chittagong Small Irrigation Pumps	$ 0.25
Small Khulna Digester Power	$ 0.25
Small Chittagong Digester Power	$ 0.25
Small Sylhet Digester Power	$ 0.25
Small Barisal Digester Power	$ 0.25
Small Dhaka Digester Power	$ 0.25
Small Rajshahi Digester Power	$ 0.25
Khulna Small Irrigation Pumps	$ 0.26
Dhaka Small Irrigation Pumps	$ 0.26
Bakkhali J14 Small Hydro	$ 0.26
Rangpur Small Irrigation Pumps	$ 0.27
Matamuhuri J31 Small Hydro	$ 0.27
Bakkhali J11 Small Hydro	$ 0.27
Rajshahi Large Irrigation Pumps	$ 0.28
Sylhet Small Irrigation Pumps	$ 0.28
Large Solar Rooftop	$ 0.29
Small Solar Rooftop	$ 0.31
Parasol Energy Ltd Solar Mini Grid	$ 0.38
G-Tech Solutions Ltd Solar Mini Grid	$ 0.38
Solargao Limited Solar Mini Grid	$ 0.39
Banshkhali J7 Small Hydro	$ 0.40
Baraka Renewable Energy Limited Solar Mini Grid	$ 0.42
Intraco Limited Solar Mini Grid	$ 0.43
Tauras Energy Limited Solar Mini Grid	$ 0.44
Superstar Renewable Energy Limited Solar Mini Grid	$ 0.44
Large Solar Home Systems	$ 0.65
Small Solar Home Systems	$ 0.72

Financial Viability: Grid Connected

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Resource ID	LCOE
Sangu J39 Small Hydro	$ 0.10
Sangu J42 Small Hydro	$ 0.12
Kuokata Wind Project	$ 0.12
Sangu J34 Small Hydro	$ 0.14
Barisal High Wind Speed Parks	$ 0.14
Sangu J33 Small Hydro	$ 0.15
Barisal Low Wind Parks	$ 0.16
Parky Beach Wind Project	$ 0.17
Chittagong Low Wind Parks	$ 0.17
Sangu J45 Small Hydro	$ 0.20
Thakurgaon Sadar 5 MW Solar Park	$ 0.21
Chittagong Solar Park	$ 0.21
Barisal Solar Park	$ 0.22
Rajshahi Solar Park	$ 0.22
Khulna Solar Park	$ 0.22
Dhaka Solar Park	$ 0.22
Rangpur Solar Park	$ 0.23
Payra Solar Power Park	$ 0.24
Sylhet Solar Park	$ 0.24
Sirajgonj Solar Park	$ 0.27
Sangu J47 Small Hydro	$ 0.27
Matamuhuri J17 Small Hydro	$ 0.30
Off Grid Solar- Diesel based Hybrid Power Plant in Kutubdia Island	$ 0.58
7.5 MWp Hatiya Off Grid Wind-Solar Hybrid with HFO/Diesel Based Engine	$ 0.59

Financial Viability: Offgrid

Resource ID	LCOE
SEAL Thakurgaon Rice Husk Gasifier	$ 0.06
Rice Husk Gasifier	$ 0.09
Rajshahi Small Irrigation Pumps	$ 0.27
Matamuhuri J12 Small Hydro	$ 0.30
Sangu J66 Small Hydro	$ 0.31
Matamuhuri J23 Small Hydro	$ 0.31
Sangu J53 Small Hydro	$ 0.31
Sangu J52 Small Hydro	$ 0.32
Matamuhuri J13 Small Hydro	$ 0.33
Mohamaya Irrigation-cum-Hydro Power Project	$ 0.33
Small Khulna Digester Power	$ 0.33
Small Dhaka Digester Power	$ 0.33
Small Barisal Digester Power	$ 0.33
Small Rajshahi Digester Power	$ 0.33
Small Sylhet Digester Power	$ 0.33
Small Chittagong Digester Power	$ 0.33
Sangu J61 Small Hydro	$ 0.34
Chittagong Small Irrigation Pumps	$ 0.35
Barisal Small Irrigation Pumps	$ 0.35
Khulna Small Irrigation Pumps	$ 0.35
Dhaka Small Irrigation Pumps	$ 0.35
Rangpur Small Irrigation Pumps	$ 0.37
Rajshahi Large Irrigation Pumps	$ 0.39
Sylhet Small Irrigation Pumps	$ 0.39
Large Solar Rooftop	$ 0.40
Bakkhali J14 Small Hydro	$ 0.41
Bakkhali J11 Small Hydro	$ 0.42
Matamuhuri J31 Small Hydro	$ 0.42
Small Solar Rooftop	$ 0.43
Parasol Energy Ltd Solar Mini Grid	$ 0.53
G-Tech Solutions Ltd Solar Mini Grid	$ 0.53
Solargao Limited Solar Mini Grid	$ 0.53
Baraka Renewable Energy Limited Solar Mini Grid	$ 0.58
Intraco Limited Solar Mini Grid	$ 0.59
Tauras Energy Limited Solar Mini Grid	$ 0.61
Superstar Renewable Energy Limited Solar Mini Grid	$ 0.61
Banshkhali J7 Small Hydro	$ 0.62
Large Solar Home Systems	$ 0.90
Small Solar Home Systems	$ 0.99

Appendix: Cost Characteristics of Plants Considered

Cost Summary: Off-grid

Resource ID	Technology	Unit capacity	Net capacity (MW)	Fuel cost (US$/kWh)	Capital cost (US$/MW net)	Fixed O&M (US$/kW-yr)
Rice Husk Gasifier	Biomass Gasifier	0.4	274	0	3309295	125
SEAL Thakurgaon Rice Husk Gasifier	Biomass Gasifier	0.4	0.4	0	2059295	125
Small Barisal Digester Power	Digester Power	0.025	0.415	0	8480000	125
Small Chittagong Digester Power	Digester Power	0.025	1.84	0	8480000	125
Small Dhaka Digester Power	Digester Power	0.025	4.716	0	8480000	125
Small Khulna Digester Power	Digester Power	0.025	0.869	0	8480000	125
Small Rajshahi Digester Power	Digester Power	0.025	1.123	0	8480000	125
Small Sylhet Digester Power	Digester Power	0.025	0.465	0	8480000	125
Large Solar Home Systems	SHS	0.00013	150	0	7300000	250
Small Solar Home Systems	SHS	0.00005	150	0	8000000	300

Cost Summary: Off-grid

Resource ID	Technology	Unit capacity	Net capacity (MW)	Fuel cost (US$/kWh)	Capital cost (US$/MW net)	Fixed O&M (US$/kW-yr)
Bakkhali J11 Small Hydro	Small hydro	0.1	0.1	0	8580000	248
Bakkhali J14 Small Hydro	Small hydro	0.13	0.13	0	8280000	236
Banshkhali J7 Small Hydro	Small hydro	0.01	0.01	0	12680000	412
Matamuhuri J12 Small Hydro	Small hydro	0.92	0.92	0	6180000	152
Matamuhuri J13 Small Hydro	Small hydro	0.53	0.53	0	6680000	172
Matamuhuri J23 Small Hydro	Small hydro	0.85	0.85	0	6280000	156
Matamuhuri J31 Small Hydro	Small hydro	0.1	0.1	0	8580000	248
Mohamaya Irrigation-cum-Hydro Power Project	Small hydro	0.07	0.07	0	6700000	268
Sangu J52 Small Hydro	Small hydro	0.68	0.68	0	6480000	164
Sangu J53 Small Hydro	Small hydro	0.82	0.82	0	6280000	156
Sangu J61 Small Hydro	Small hydro	0.41	0.41	0	6880000	180
Sangu J66 Small Hydro	Small hydro	0.81	0.81	0	6280000	156

Cost Summary: Off-Grid

Resource ID	Technology	Unit capacity	Net capacity (MW)	Fuel cost (US$/kWh)	Capital cost (US$/MW net)	Fixed O&M (US$/kW-yr)
Baraka Renewable Energy Limited Solar Mini Grid	Solar Mini Grid	0.167	0.167	0	5479042	150
G-Tech Solutions Ltd Solar Mini Grid	Solar Mini Grid	0.16775	0.16775	0	5136731	150
Intraco Limited Solar Mini Grid	Solar Mini Grid	0.2	0.2	0	5128205	150
Parasol Energy Ltd Solar Mini Grid	Solar Mini Grid	0.1875	0.1875	0	5210644	150
Solargao Limited Solar Mini Grid	Solar Mini Grid	0.13	0.13	0	5176923	150
Superstar Renewable Energy Limited Solar Mini Grid	Solar Mini Grid	0.2	0.2	0	5128205	150
Tauras Energy Limited Solar Mini Grid	Solar Mini Grid	0.15	0.15	0	5128200	150
Large Solar Rooftop	Solar rooftop	0.035	150	0	3250000	10
Small Solar Rooftop	Solar rooftop	0.005	150	0	3500000	10

Cost Summary: Grid-Connected

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Resource ID	Technology	Unit capacity	Net capacity (MW)	Fuel cost (US$/kWh)	Capital cost (US$/MW net)	Fixed O&M (US$/kW-yr)
7.5 MWp Hatiya Off Grid Wind-Solar Hybrid with HFO/Diesel Based Engine	Microgrid	7.5	7.5	0	5380000	150
Off Grid Solar- Diesel based Hybrid Power Plant in Kutubdia Island	Microgrid	1	1	0	4380000	150
Matamuhuri J17 Small Hydro	Small hydro	1.04	1.04	0	6080000	111
Sangu J33 Small Hydro	Small hydro	5.79	5.79	0	3140000	75
Sangu J34 Small Hydro	Small hydro	7.68	7.68	0	2900000	72
Sangu J39 Small Hydro	Small hydro	20.88	20.88	0	2090000	57
Sangu J42 Small Hydro	Small hydro	13.59	13.59	0	2360000	63
Sangu J45 Small Hydro	Small hydro	2.89	2.89	0	4090000	87
Sangu J47 Small Hydro	Small hydro	1.87	1.87	0	5580000	96
Barisal Solar Park	Solar Park	10	7.168438	0	2000000	15
Chittagong Solar Park	Solar Park	10	524.8824	0	2000000	15
Dhaka Solar Park	Solar Park	10	9.311726	0	2000000	15
Khulna Solar Park	Solar Park	10	25.01486	0	2000000	15
Payra Solar Power Park	Solar Park	50	50	0	2200000	15
Rajshahi Solar Park	Solar Park	10	0.404329	0	2000000	15
Rangpur Solar Park	Solar Park	10	0.503404	0	2000000	15
Sirajgonj Solar Park	Solar Park	7.5	7.5	0	2400000	15
Sylhet Solar Park	Solar Park	10	136.8092	0	2000000	15
Thakurgaon Sadar 5 MW Solar Park	Solar Park	5	5	0	1778400	15
Barisal High Wind Speed Parks	Wind Park	10	13	0	2000000	35
Barisal Low Wind Parks	Wind Park	50	531	0	2000000	35
Chittagong Low Wind Parks	Wind Park	50	93	0	2000000	35
Kuokata Wind Project	Wind Park	100	100	0	1625000	35
Parky Beach Wind Project	Wind Park	200	200	0	2000000	35

Preparation of SREP Investment Plan Bangladesh Energy Sector Development Project

Environmental and Social Risks and Opportunities

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Overview

- Summary of the Key Environmental and Social Opportunities
  - Labour market and working conditions
  - Resource efficiency and pollution prevention
  - Community health, safety and security
  - Land acquisition and involuntary resettlement
  - Biodiversity conservation and sustainable management of living natural resources
  - Indigenous peoples
  - Cultural heritage
  - Water resources, water quality and other cross-cutting topics
- Appendix: Assessment Matrix

Solar Parks

Potential Environmental and Social Opportunities Relevant to Bangladesh

- Improved energy supply and reliability, job creation, business start-ups, skills training, empowerment of women and indigenous peoples, distribution of wealth and poverty alleviation (particularly rural areas)
- Helps minimize national and global emissions of greenhouse gases and other pollutants detrimental to climate change, human health and the environment
- Improvements to access for local community, businesses and other visitors arising from upgraded transport networks and infrastructure
- Helps minimize any extra water resource usage compared to fossil fuel based energy sources (does not require the abstraction of water for cooling unlike conventional fossil fuel power)
- Helps minimize any extra pressures on surface water quality compared to fossil fuel based energy sources (no effluent discharge)
- Potential for co-location of other activities (for example grazing/ non-mechanised farming of crops) resulting in dual benefits from the land

Potential Environmental and Social Risks Relevant to Bangladesh

- Lack of local skilled labor supply (at least initially) resulting in in-migration and possible displacement/ increased costs of living locally
- Construction noise, dust, particulate matter and other emissions resulting in nuisance/localized damage to surrounding environment
- Generation, handling, recycling/ disposal of waste, including material with hazardous contents (e.g. PV panels with silicon or cadmium)
- Short-medium term risk of soil erosion, pollution of waterbodies and faster flood water flows due to stripping of vegetation for solar arrays
- Vulnerability of infrastructure to climatic factors (such as flooding)
- Loss or fragmentation of habitats, croplands or other areas arising from development (including transmission and ancillary works); although there may be opportunities for co-locating other land-uses
- Visual impacts affecting people and landscapes

Distributed Solar PV

Potential Environmental and Social Opportunities Relevant to Bangladesh

- Increased access to energy supply, heath care improvements, skills training, poverty alleviation and empowerment of women and marginalized groups and communities in off-grid areas
- Opportunities for new and existing businesses and jobs for local people (including the supply, maintenance, operation and decommissioning of distributed solar PV equipment)
- Provides cheaper and sustainable power for irrigation equipment (high diesel prices make irrigation costly for many farmers)
- Helps minimize emissions of greenhouse gases and other pollutants detrimental to climate change, human health and the environment
- Minimal (if any) land-take requirements for equipment
- Helps minimize any extra water resource usage compared to fossil fuel based energy sources now or in the future
- Helps minimize any extra usage of conventional fuel resources in off-grid areas (such as wood, animal waste and crop residues)

Potential Environmental and Social Risks Relevant to Bangladesh

Risks associated with distributed energy are inherently smaller in scale and significance than those associated with utility-scale generation options. There are however still some risks worth noting including:

- Generation, handling, recycling/ disposal of waste, including material with hazardous contents. For example: lead acid batteries (which are often used alongside distributed solar PV panels in Bangladesh) and silicon or cadmium (which can be contained in the solar PV panels)
- Lack of local skilled people to install, operate, maintain and decommission equipment (at least initially)
- Vulnerability of infrastructure to climatic factors (such as flooding)
- Potential for local disputes over ownership, maintenance and usage of the energy resource and ancillary equipment
- Arguably, some detriment to landscapes and visual amenity through placement of energy generating equipment in rural areas (although the equipment is small-scale and such effects are largely subjective)

Wind Farms (Utility-Scale)

Potential Environmental and Social Opportunities Relevant to Bangladesh

- Improved energy supply and reliability, supports new and existing businesses, job creation, skills training, empowerment of women and marginalized groups, distribution of wealth and poverty alleviation (particularly in rural areas)
- Improvements to access for local community, businesses and other visitors arising from upgraded transport networks and infrastructure
- Helps minimize national and global emissions of greenhouse gases and other pollutants detrimental to climate change, human health and the environment
- Helps minimize any extra pressures on surface water quality compared to fossil fuel based energy sources (no effluent discharge)
- Helps minimize any extra water resource usage compared to fossil fuel based energy sources (does not require the abstraction of water for cooling unlike conventional fossil fuel power)

Potential Environmental and Social Risks Relevant to Bangladesh

- Vulnerability of infrastructure to climatic factors – e.g. cyclones, coastal erosion and flooding – requires avoidance of high risk areas or built-in resilience
- Potential considerable ancillary works required to deliver and operate turbines (e.g. harbor, road and transmission upgrades); cumulatively increasing noise, vibration, dust, air quality and other nuisance effects
- Lack of local skilled labor supply and/or local supply of turbines and ancillary equipment (at least initially) could result in in-migration, outsourcing of procurement and increased costs of living locally
- Coastal zones with unstable soils are prone to soil erosion, run-off and high salinity; issues could be exacerbated by turbine construction
- Risk of bird strike from turbines and ecosystem loss or fragmentation
- Visual impacts of turbines (including physical presence, blade glint and blade flicker) affecting people and landscapes
- Loss or detrimental effects on croplands or other important areas

Bioenergy

Potential Environmental and Social Opportunities Relevant to Bangladesh

Dairy and poultry waste (manure) for anaerobic digestion at distributed scale

- Reduction in smoke and other air quality issues within households as a result of providing alternative to traditional biomass burning
- Separated digestate can be used as a biological fertilizer or fish feed
- Use of biogas, compared to traditional methods, saves time which can be spent on education and other productive activities
- Savings in cost and natural resources (e.g. forests and trees) compared to traditional cooking fuels and diesel

Waste rice hulls for biomass gasifier at distributed scale

- Relatively clean fuel
- Potential for cheaper and sustainable power for irrigation equipment (high diesel prices make irrigation costly for many farmers)
- Large volumes of rice hull biomass available within the country (although note existing alternative uses)
- Silica byproduct have industrial applications and can be potential revenue source

Potential Environmental and Social Risks Relevant to Bangladesh

Dairy and poultry waste (manure) for anaerobic digestion at distributed scale

- Potential diversion of manure from alternative uses (e.g. as a direct fuel or as a soil fertilizer – potential to indirectly deplete soil fertility)
- Potential for pest issues (e.g. flies and mosquitoes) and odor (biogas contains hydrogen sulfide and moisture)
- Potential for human health risks and pollution to ground, water or air from inadequate storage and handling of manure and biogas
- Risks to infrastructure from climatic factors (e.g. flooding)

Waste rice hulls for biomass gasifier at distributed scale

- CO_2 emissions from power consumption during gasification process
- Potential diversion of rice hulls from baseline alternative uses (e.g. for parboiling rice or as soil fertilizer)
- Pollution risks during storage and transporting of rice hulls
- Emissions associated with combustion of syngas
- Waste disposal requirements for residual char/ash and silica (if no market)

Geothermal

Potential Environmental and Social Opportunities Relevant to Bangladesh

- Helps minimize national and global emissions of greenhouse gases and other pollutants detrimental to climate change, human health and the environment
- Improved energy supply and reliability, job creation, skills training, empowerment of women and marginalized groups, distribution of wealth and poverty alleviation (particularly in rural areas)
- Improvements to access for local community, businesses and other visitors arising from upgraded transport networks and infrastructure
- Potential to identify and record locally known and/ or previously undiscovered sites and artefacts of cultural heritage interest
- Potential to improve resilience, community awareness and preparedness for natural disasters (e.g. earthquake warning systems and response plans)

Potential Environmental and Social Risks Relevant to Bangladesh

- Drilling and other construction activities giving rise to noise, vibrations, dust, greenhouse gases, odor and other emissions
- Operational air and odor emissions (e.g. carbon dioxide and hydrogen sulfide); the magnitude of which will largely depend on whether the deployed geothermal systems are 'open-loop' or 'closed-loop'
- Places pressure on groundwater resources and groundwater quality
- Land subsidence can be caused by abstraction of groundwater
- Lack of local skilled labor supply (at least initially) resulting in in-migration and possible displacement/ increased costs of living locally
- High risk of natural disasters (e.g. earthquakes/landslides) in geothermal hotspots; it is also possible that installation measures and energy generation processes required could exacerbate the risks
- Loss or fragmentation of habitats, croplands or other areas arising from development (including transmission and ancillary works)
- Visual impacts on landscapes and local communities

Small Hydropower

Potential Environmental and Social Opportunities Relevant to Bangladesh

- More reliable energy supply leading to improvements in sanitation and quality of life (especially in remote and off-grid communities)
- Job creation, skills training, educational opportunities, empowerment of women, distribution of wealth and poverty alleviation
- Helps minimize emissions of greenhouse gases and other pollutants detrimental to climate change, human health and the environment
- Can provide cheaper and sustainable power for irrigation equipment (high diesel prices make irrigation difficult for many farmers)
- Potential localized benefits to regulation of water supply for irrigation
- Improvements to access for local community, businesses and other visitors arising from upgraded transport networks and infrastructure
- Helps minimize any extra usage of conventional fuel resources in off-grid areas (such as wood, animal waste and crop residues)
- Minimal land-take requirements for small hydro plant and ancillary infrastructure

Potential Environmental and Social Risks Relevant to Bangladesh

- Lack of local support or land access and land ownership conflicts (e.g. in Chittagong Hill Tracts) and potential displacement of local people - though this risk is less likely for small scale hydro schemes (≤ 10 MW, but more likely KW-size) considered for SREP than for large hydro
- Potential for cumulative effects to arise as a result of multiple small hydro projects acting in-combination within the same river basin
- Altered flooding regimes and flood risk areas up and downstream as a result of physical changes within the flood plain (small hydro infrastructure, such as dams and ancillary structures)
- Changes to availability of river water for baseline uses (e.g. irrigation) and river dependent flora and fauna
- Fragmentation of river habitats (relevant to small hydro projects with dams): can be partly mitigated by fish passes, but risks remain for less mobile species (e.g. freshwater mussels or aquatic flora)
- Vulnerability of infrastructure to climatic factors (e.g. flooding)

Microgrids (Hybrid Systems)

Potential Environmental and Social Opportunities Relevant to Bangladesh

- Increased access to energy supply, heath care improvements, skills training, poverty alleviation and empowerment of women and marginalized groups and communities in off-grid areas
- Provides cheaper and sustainable power for irrigation equipment within off-grid areas (diesel usage still required for backup generator)
- Opportunities for new and existing businesses and jobs for local people (including the supply, maintenance, operation and decommissioning of distributed renewable energy equipment)
- Helps minimize emissions of greenhouse gases and other pollutants detrimental to climate change, human health and the environment (although diesel usage still required for backup generator)
- Helps minimize any extra water resource usage compared to fossil fuel based energy sources now or in the future
- Helps minimize any extra usage of conventional fuel resources in off-grid areas (such as wood, animal waste and crop residues)

Potential Environmental and Social Risks Relevant to Bangladesh

Micro-grids are relatively small in scale and risk. However, the requirement for batteries, back-up diesel generators and electricity distribution lines does also present some notable risks, including:

- Use of diesel fuel (for back-up generation) resulting in localized effects to air quality, emissions of greenhouse gases and noise
- Pollution risks (to land, surface water and groundwater) due to the distribution, storage and use of diesel fuel
- Generation, handling, recycling/ disposal of waste, including material with hazardous contents. For example: lead acid batteries and silicon or cadmium (which can be contained in the solar PV panels)
- Vulnerability of infrastructure to climatic factors (such as flooding)
- Loss or disturbance of species, damage/ fragmentation of habitats, and/or loss of croplands (from structures and distribution lines)
- Visual impacts (for example from solar PV panels or blade glint from wind turbines) affecting people and landscapes

Appendix: Assessment Matrix

Social & Environmental Opportunities & Risks

The tables below sets out the potentially significant risks and opportunities, associated with each renewable energy technology, under the headings of the World Bank performance standards (known as "the World Bank performance standards") (June 2012). These headings will be used throughout the environmental and social assessment, to allow ease of cross-referencing between different documents and to aid assessment of compliance to World Bank standards. The process of identifying potential environmental and social issues and opportunities has been informed by the best practices required under European Union law; notably Directive 2014/52/EU (the 'revised EIA Directive'). The tables highlight whether a given opportunity or risk is likely to be applicable to the construction (C), operation (O) and/or decommissioning (D) stage of a project. Where there remains considerable uncertainty over whether an issue or opportunity would be relevant (for example, for micro-grids, where relevance would directly depend on the combinations of technologies deployed and their relative contributions to the micro-grid) a '?' symbol has been used.

Three overarching methods of transferring renewable energy from the source to the user are being considered for the Bangladesh SREP Investment Plan – these can be described as 'utility-scale', 'distributed' and 'micro-grids'. Utility-scale refers to the transfer of renewable energy into the country's main electricity grid. Distributed transfer of energy occurs where renewable energy solutions are used in an off-grid situation (i.e. they directly provide electricity to users within areas that do not currently benefit from connections to the main electricity grid network). Distributed renewable energy projects are smaller in scale and generally present less significant risks than those associated with utility-scale generation (this should be taken into account where risks associated with distributed technologies have been identified in the table). Micro-grids are effectively local grid networks (not connected to the country's main grid) that combine renewable energy sources, batteries and back-up generators; they are also small in scale but do have additional requirements for batteries, back-up diesel generators and local electricity distribution lines.

World Bank Performance Standards apply, in place of the World Bank environmental and social safeguard policies, to projects, or components of projects, which are owned, constructed and/or operated by the private sector. For further information see: http://go.worldbank.org/BZ9RCBSRB0 (accessed 7th May 2015).

Labour Market and Working Conditions Opportunities	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids* Incl. Battery Storage, Backup Diesel and Distribution
Potential for temporary and long-term job creation, rural enterprises, skills training and education. This includes opportunities for jobs for marginalized groups in rural areas (particularly during lean agricultural times and to help address loss of livelihood in certain rural areas, particularly due to climate change). Direct job creation in the supply chain and via waste products. For example generation of biogas from anaerobic digesters has the potential for not only green jobs but also production of organic fertilizer for crops and plants as some piloting has shown. This brings potential for poverty alleviation and increased average earnings and GVA/capita particularly in rural areas.	C, O, D	C, O, D	C, O, D	C, O, D	C, O, D	C, O, D	C, O, D
Potential for exemplar projects that demonstrate and maximize worker rights, safe and healthy working conditions and empowerment of marginalized communities and vulnerable people.	C, O, D	C, O, D	C, O, D	C, O, D	C, O, D	C, O, D	C, O, D

*Note that the 'micro-grids' category accounts for general issues and opportunities of distributed energy along with those associated with the requisite battery storage, distribution lines and back-up diesel generator that are assumed to be required for micro-grid energy generation to be effective in Bangladesh. The actual residual significance of effects arising from any given micro-grid will largely depend upon the chosen distributed renewable energy technology(s) chosen. The most likely micro-grid arrangements are considered to be 100KW – 5MW combinations of solar PV, onshore wind, batteries and back-up diesel generators with an AC distribution system.

Social & Environmental Opportunities & Risks

Labour Market and Working Conditions Opportunities Cont.	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Improvements to reliability and cost-stability of energy supply; benefitting a wide-range of economic sectors (including health services and education) and encouraging start-up of new businesses. Of particular importance are off-grid technologies in rural areas of Bangladesh.	O	O	O	O	O	O	O
Rural off-grid technologies could help provide cheaper power for irrigation. Currently irrigation has become costly for farmers due to the cost of diesel (which is in some cases has to be subsidized by the Government). (Experts believe Bangladesh can save US$ 750 million in the consumption of diesel in the agriculture sector alone by switching to renewable energy-based irrigation). *	-	O	O	-	-	O	O
Potential transport infrastructure improvements (through maintenance access to the renewable energy sites) resulting in secondary benefits to other users of transport network such as local residents, businesses and tourists.	O, D	O, D	-	O, D	O, D	O, D	O, D

*Ministry of Environment and Forests, 2012.

Social & Environmental Opportunities & Risks

Labour Market and Working Conditions Risks	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Potential lack of locally qualified/ skilled labour supply (which could potentially also result in in-migration and possible displacement of the local population and increased cost of living for the local population).	C, O, D	C, O, D	C, O, D	C, O, D	C, O, D	C, O, D	C, O, D
Risk of discrimination and health and safety risks to workers (including vulnerable workers such as children, women and migrant workers) and members of the public due to risk of weak enforcement of employment law and poor accountability in supply chain and third party contracts.	C, O, D	C, O, D	C, O, D	C, O, D	C, O, D	C, O, D	C, O, D
Possible impact on irrigation or other commercial and industrial activities due to alteration of river flows used for (e.g. mining, factories).	-	O	-	-	-	-	-
Possible diversion of agricultural residues (e.g. rice hulls or manure) from alternative uses such as soil fertilizer; with resulting indirect effects on soil fertility, food availability, land use and landscape	-	-	-	-	-	O	-

Social & Environmental Opportunities & Risks

Resource Efficiency and Pollution Prevention ***(Including Greenhouse Gas Emissions) Opportunities***	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Contribute to global and national efforts to promote sustainable energy use and reduce emissions of greenhouse gases detrimental to climate change.	O	O	O	O	O	O	O
Helps to minimize any extra river sedimentation and marine and coastal pollution that would otherwise have arisen as a result of deforestation	O	O	O	O	O	O	O

Social & Environmental Opportunities & Risks

Resource Efficiency and Pollution Prevention (Including Greenhouse Gas Emissions) Risks	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Construction-stage air emissions due to material transportation and on-site plant movements (e.g. vehicle emissions, particulate matter and dust). Also including emissions from back-up diesel generators required to support the micro-grids.	C	C	-	C	C	C	C
Generation of waste and gases, including potentially hazardous pollutants, during handling of materials and ancillary equipment. Giving rise to the need for facilities for the disposal, recycling and safe handling of waste.*	-	-	C, O, D	C, O, D	C, O, D	C, O, D	C, O, D
Risk of pollution to waterbodies (a particular concern in coastal areas of Bangladesh) arising from construction aspects such as: erosion and mobilization of sediments by construction plant; inappropriate storage of polluting materials (including diesel required for back-up generators in micro-grids); or, the exposure of pathways for pollution during installation.	C, D	C, D	-	C, D	C, D	C, D	C, O, D

*Hazardous materials which could be relevant include: silicon and cadmium (which can be present in some solar PV panels); and lead acid in batteries (which are likely to be required alongside distributed solar technologies).

Social & Environmental Opportunities & Risks

Community Health, Safety and Security (Including Risks Associated with Climate Change and Natural Disasters) Opportunities	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Provides a long-term domestic source of energy that will help stabilize energy costs, resulting in improved resiliency to health and safety hazards.	O	O	O	O	O	O	O
Improved access to and reliability of electricity (grid-connected and off-grid), in particular benefiting rural areas and hospitals with uninterruptible power supply.	O	O	O	O	O	O	O
Increased access to energy supply. Increase in new business start-ups (supplying new development and workforce) resulting in increased local tax returns and diversification of local business base (improved resilience to economic shocks).	O	O	O	O	O	O	O
Help minimize any extra air pollution compared to fossil-fuel based energy sources that would otherwise be utilized now or in the future; bringing benefits for human health.	O	O	O	O	O	O	O
Help minimize any extra noise levels compared to those that would arise from traditional (fossil fuel) technologies that would otherwise be utilized now or in the future (for example noisy diesel generators).	-	O	O	-	-	O	-

Social & Environmental Opportunities & Risks

Community Health, Safety and Security (Including Risks Associated with Climate Change and Natural Disasters) Opportunities Cont.	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Potential for revenue from the renewable energy projects to provide/ support new local health facilities and local environmental improvements.	O	O	O	O	O	O	O
Potential for improvements to community security, emergency preparedness and resilience to natural disasters through community engagement and informing activities.	O	O	O	O	O	O	O
Potential for promotion of the concepts of renewable energy, sustainable management of living resources, and adoption of practices that integrate conservation and development.	O	O	O	O	O	O	O
Bangladesh is very vulnerable to the impacts of climate change events (i.e. flooding, drought, desertification, sea level rise and salinization*). Renewable energy installations may help alleviate these impacts locally by, for example, retaining water during excessive rainfall, providing an early warning system to local residents (if the installation incorporates this);reduce local flood risk by incorporating flood risk management or urban drainage systems into scheme design; aiding rescue efforts after an event via installed new raised roads and infrastructure).	O	O	O	O	O	O	O

*Ministry of Environment and Forests, Nov 2005. : Ministry of Environment and Forest, Aug 2005.

Social & Environmental Opportunities & Risks

Community Health, Safety and Security (Including Risks Associated with Climate Change and Natural Disasters) Risks	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Disturbance to communities arising from construction (vibration, blasting, clearing & grading level site), operation and decommissioning - such as noise, traffic, vibration, odor, access and mobility concerns (including disturbance along access routes by delivery/ maintenance vehicle movements).	C, O, D	-	-	C, O, D	C, O, D	C, O, D	C, O, D
Community health concerns arising from generation of dust and other polluting airborne emissions during construction of renewable energy infrastructure, ancillary equipment, access routes and gathering and transporting residue feedstocks (including emissions from plant and vehicle emissions).	C, D	C, D	-	C, D	C, O, D	C, D	C, O, D
Where facilities are located in the floodplain, there is the potential for increased flood risk due to land-take and vegetation clearance for generation plant, materials handling and storage areas.	O	O	-	O	O	O	O
Potential changes to flooding regimes up and downstream, particularly with hydropower developments in previously undeveloped areas.	-	O	-	-	-	-	-

Community Health, Safety and Security (Including Risks Associated with Climate Change and Natural Disasters) Risks Cont.	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Potential health issues associated with electric and magnetic fields (EMF) – which are invisible lines of force emitted by and surrounding any electrical device (e.g. power transmission lines and electrical equipment) – and potential electromagnetic interference with aviation radar and telecommunication systems (including microwave, radio and television*) . Although the World Bank notes that there is a weak evidence base for health risks associated with EMF, the risk is still considered sufficient to warrant limited concern and further consideration. Projects should consider the potential exposure of the public and ensure they remain below the International Commission on Non-Ionizing Radiation Protection (ICNIRP) recommendations. Facilities (including transmission lines) should also be sited/ routed to avoid or minimize the exposure of the public. Shielding or other engineering solutions should be applied where sufficient risks are anticipated (although it is not considered likely that this would apply to the scale of projects proposed under SREP).	O	?	?	O	O	?	?

*As cited in the World Bank's Environmental, Health and Safety Guidelines for '*Electric Power Transmission and Distribution*' and '*Wind Energy*' (accessed 27 May 2015): *http://www.ifc.org/wps/wcm/connect/topics_ext_content/ifc_external_corporate_site/ifc+sustainability/our+approach/risk+management/ehsguidelines*

Social & Environmental Opportunities & Risks

Community Health, Safety and Security (Including Risks Associated with Climate Change and Natural Disasters) Risks Cont.	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Risk of damage to renewable energy infrastructure due to increased frequency and severity of floods, tropical storms (e.g. wind power infrastructure was badly damaged in the 2009 cyclone), storm surges and sea level rise associated with climate change.	C, O, D	C, O, D	C, O, D	C, O, D	C, O, D	C, O, D	C, O, D
Exacerbation of existing local environmental and resource stresses (i.e. renewable energy technologies acting in-combination with risks from climate change and natural disasters to give rise to cumulative effects). For example, diverting water flows into small hydropower holding ponds rather than making them available for irrigation during times of drought may make the impacts of the drought worse. Similarly, continuing to use agricultural waste residues as a fuel source during times where there is a shortage of agricultural waste residues for alternative uses (e.g. alternative use of rice hulls for fertilizer or parboiling rice) could make resource shortages worse.	-	O	-	-	-	O	-

Land Acquisition and Involuntary Resettlement Opportunities	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Potential for sustainable income generation for land owners and empowerment of communities; provided that cultural sensitivities are recognized. Notable area where cultural sensitivities are most pertinent include local communities where communal/ nomadic land rights are applicable. Such areas can be found within the southeastern, northwestern, north-central and northeastern regions of the country and include the Chittagong Hill Tracts, Sylhet Division, Rajshahi Division and Mymensingh District.	O	O	O	O	O	O	O
Potential opportunity for strategic planning of infrastructure investments to mitigate impacts of climate change. For example, prioritize development locations on high ground, such that safer locations are prepared to accept refugees in case of resettlement from flooding and in case of resettlement from sea level rise.	O	O	O	O	O	O	O

Social & Environmental Opportunities & Risks

Land Acquisition and Involuntary Resettlement Risks	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Potential opportunity for strategic planning of infrastructure investments to mitigate impacts of climate change. For example, prioritize development locations on high ground, such that safer locations are prepared to accept refugees in case of resettlement from flooding and in case of resettlement from sea level rise.	**O, D**	**O, D**	**O, D**	**O, D**	**O, D**	**O, D**	**O, D**
Possible conflict with land owners through loss of land (e.g. temporary or permanent loss of farmers' croplands), resettlement or displacement of other economic activities. In particular, conflict could arise in areas of community land ownership, where cultural sensitivities and landowner negotiations can be particularly difficult. For example, the Chittagong Hill Tracts which are home to groups with communal/nomadic land rights and are currently the subject of considerable Government (Army) control, including restrictions of access and movement of people into the area. It should be noted that there have been previous issues in Bangladesh associated with the need for displacement/ relocation of local peoples for large scale hydropower projects – such issues are not likely to be as relevant to the small-scale (less than 10 MW, but more likely to be in the KW range) hydropower projects considered under the SREP).	**C, O, D**	**C, O, D**	**-**	**C, O, D**	**C, O, D**	**-**	**-**
Loss/delay of resource extraction from opportunity areas for mineral extraction, agriculture, and industry due to facility footprint.	**O**	**O**	**-**	**O**	**O**	**-**	**-**

Social & Environmental Opportunities & Risks

Biodiversity Conservation and Sustainable Management of Living Natural Resources ***Opportunities***	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Prior to the construction of renewable energy project, transmission lines and ancillary works any existing contaminated land issues are likely to require remediation, resulting in an indirect improvement in the area.	C	-	-	C	C	-	C
Helps to minimize any extra demand for the coastal and terrestrial transfer of petroleum (reducing the likelihood of diesel/ oil spills) that would otherwise have arisen. This is relevant as approximately 90% of Bangladesh's oil demands are met through imports.*	O	O	O	O	O	O	?

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*Munim, Hakim, Abdullah-Al-Mamun, 2010.

Social & Environmental Opportunities & Risks

Biodiversity Conservation and Sustainable Management of Living Natural Resources ***Risks***	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Footprint of construction works and operational equipment (including ancillary infrastructure, transmission lines (where applicable) and access routes) resulting in loss of habitat, habitat fragmentation, impacts on ecosystem services and associated risks to flora, fauna soils and habitat.	C, O, D	C, O, D	-	C, O, D	C, O, D*	-	C, O, D
Soil erosion and degradation as a result of stripping of working area for infrastructure (including ancillary infrastructure, transmission lines (where applicable) and access routes).	C	-	-	C	C	-	C
Construction and maintenance activities for land-grading and foundations and in-ground equipment could disturb contaminated soils and sediments.	C, O	-	-	C, O	C, O	-	C, O
Contamination and acidification via releases from bioenergy fuel stores (e.g. agricultural waste leachate) could contaminate soils.	-	-	-	-	-	O	-
Localized erosion, compaction, salinization, sealing and/or contamination from site alteration.	C, O	-	-	C, O	C, O	-	C

*Note in particular that if horizontal geothermal systems are to be used they require a significant area of available land.

Social & Environmental Opportunities & Risks

Biodiversity Conservation and Sustainable Management of Living Natural Resources ***Risks Cont.***	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Impacts to populations of bird species due to strike associated with turbines or transmission lines. Potential impacts to bats due to vibration/noise.	O	-	-	-	-	-	?
Impacts on aquatic ecosystems, including: fish entrainment/ impingement/direct mortality; upstream/downstream flow and habitat modification; fragmentation of ecosystems from footprint (including transmission routes) and changes in water flows affecting river habitats. Loss impacts to aquatic habitat due to pipeline placement in stream or adjacent floodplain habitat.	-	O	-	-	-	-	-
Potential for ecological impacts in local water bodies as a result of sediment deposition from stormwater runoff.	O	O	-	?	O	O	-
Potential for ecological impacts in local water bodies as a result of wastewater discharges, water withdrawals.	-	-	-	-	O	-	-
Risk of harm to fauna arising from partial decommissioning – i.e. the risk that there will be residual infrastructure (including ancillary equipment such as cables, pipes and hydropower flow diversion intakes), or polluting materials, left in-situ.	D	D	-	D	D	D	D

Social & Environmental Opportunities & Risks

Indigenous Peoples Opportunities	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Empowerment of indigenous people to manage/own energy sources that are ecologically sensitive and complementary to cultural practices. Key areas where native ethnic minorities are found include southeastern, northwestern, north-central and northeastern regions of the country. These regions include the Chittagong Hill Tracts, Sylhet Division, Rajshahi Division and Mymensingh District.	-	O	O	-	-	O	O
Harness local knowledge to help reduce vulnerability of renewable energy installations to risk of natural disasters e.g. drought and flooding.	C, O	C, O	C, O	C, O	C, O	C, O	C, O

Social & Environmental Opportunities & Risks

Indigenous Peoples Risks	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Potential for ethnic disputes over placement of energy generating equipment and ancillary infrastructure (including transmission lines, where applicable). Potential for language barriers. Potential for loss of access to natural and culturally important lands and resources; and risk of degradation of cultural heritage sites. Key areas where native ethnic minorities are found include southeastern, northwestern, north-central and northeastern regions of the country. These regions include the Chittagong Hill Tracts, Sylhet Division, Rajshahi Division and Mymensingh District.	C, O	C, O	-	C, O	C, O	-	C, O

Social & Environmental Opportunities & Risks

Cultural Heritage Opportunities	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Opportunities arising (from cultural heritage surveys) to identify, document and protect culturally important areas/ artefacts for the long-term benefit of Affected Communities.	C	-	-	C	C	-	C
Potential for uncovering of previously unknown cultural heritage artefacts which could be recorded and added to Bangladesh's cultural heritage records, via excavation of ground for the development, transmission lines and ancillary equipment.	C	-	-	C	C	-	C

Cultural Heritage Risks	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Visual impact of renewable energy generation infrastructure (including roads, transmission lines and other ancillary equipment) upon the landscape (locally, and potentially across wide areas). Impacts on the scenic value and setting of Bangladesh's Reserves, Sanctuaries and National Parks (as well as infrastructure, this could include visual emissions such as geothermal steam plumes and dust).	O	O	?	O	O	O	O
Loss or damage to cultural and natural sites of outstanding value (UNESCO WHS) due to construction or operation of schemes, as well as nationally and regionally registered areas, unknown or unregistered cultural heritage sites and intangible cultural and heritage assets.	C, O	C, O	-	C, O	C, O	-	?
Visual and land access impact on recreational activities and tourism. Loss of aesthetic value for areas with tourism dependency or potential (e.g. the Sundabarns).	C, O	C, O	-	C, O	C, O	-	?

Social & Environmental Opportunities & Risks

Water Resources, Water Quality and Other Cross-Cutting Topics ***Opportunities***	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Helps minimize any extra water resource usage compared to fossil fuel based energy sources (does not require the abstraction of water for cooling unlike conventional fossil fuel power).	C, O	C, O	C, O	C, O	-	C, O	C, O
Potential for flood risk management benefits as a result of increased control over water volumes and flows (depending on design solutions)	-	O	-	-	-	-	-
Helps minimize any extra pressures on surface water quality compared to fossil fuel based energy sources (does not require discharge of treated effluents unlike conventional fossil fuel power).	O	O	O	O	-	O	O

Social & Environmental Opportunities & Risks

Water Resources, Water Quality and Other Cross-Cutting Topics **Risks**	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Impacts upon water resources during operation. Surface water abstraction, run-off and discharge leading to localized changes in river flows and morphology. Changes to river flows, both increases at low flows and decreases of high flows, as well as changes to channel morphology can be detrimental. A particular problem in drought prone areas of Bangladesh.	-	C, O	-	-	O	-	-
Potential localized operational impact due to factors such as disruption of flow, changes to flow dynamics and changes to sedimentation; leading to potential localized changes in surface water quality (e.g. Temperature, pH, Dissolved Oxygen and Suspended Solids) and altered groundwater (quality and regime) if in hydraulic continuity with surface waters affected by hydro power. A particular problem in drought prone areas of Bangladesh.	-	C, O	-	-	-	-	-
Potential for altered groundwater recharge/extraction regime if groundwater is used during energy generation (such as for steam generation or emissions cleaning) and is not later returned to the aquifer. Potential for groundwater infiltration of pollutants during construction and operation. A particular problem in drought prone areas of Bangladesh.	-	-	-	-	O	-	-

Social & Environmental Opportunities & Risks

Water Resources, Water Quality and Other Cross-Cutting Topics Risks Cont.	Onshore Wing Power (Utility-Scale)	Small Hydropower (Up to 10MW) (Distributed)	Solar Photo-Volcanic (PV) (Distributed)	Large-Scale Solar PV (Utility-Scale)	Geothermal Power (Utility-Scale)	Bioenergy From Agricultural Waste (Distributed)	Micro-Grids Incl. Battery Storage, Backup Diesel and Distribution
Potential for altered groundwater quality (e.g. temperature or pH) if groundwater is used during energy generation and is then returned to the aquifer in a different condition. A particular problem in drought prone areas of Bangladesh.	-	-	-	-	O	-	-
Emission of water effluent to rivers (following appropriate treatment) leading to potential localized changes in surface water quality (e.g. Temperature, pH, Biochemical Oxygen Demand, Suspended Solids and Ammonia).	-	-	-	-	O	-	-
Localized geological damage as a result of creating foundations for the renewable energy generation infrastructure and as a result of the laying of transmission networks.	C	-	-	C	C	-	C

Preparation of SREP Investment Plan Bangladesh Energy Sector Development Project

Prioritization Criteria

DHInfrastructure
Economics & Finance

BLACK & VEATCH
Building a world of difference.

PSL
Engineering consulting firm
in Bangladesh.
Dedicated to energy and sustainable development.
PROKAUSHALI SANGSAD LTD.

Overview

- Scaling Up Renewable Energy (SREP) Program criteria

- Examples of other criteria and rankings

- Discussion of criteria

Selection Criteria-SREP

- **Increased capacity and generation from renewable energy sources**
- **Increased access to energy through renewable energy sources**
- **Affordability**
- **Productive use of energy**
- **Economic and financial viability**
- **Leveraging of additional funds**
- **Strengthen capacity of women to be active in economic sector**
- **Co-benefits, for example:**
  - **Reduced pollution**
  - **Job creation**
  - **Better energy security and reliability**

Source: SREP Programming Modalities and Operation Guidelines, approved by the Sub-Committee in November 2010. “Types of Activities”.

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Selection Criteria-SREP

- **Improve the long-term economic viability of the RE sector**
- **Build local implementing capacity**
- **Improve the legal and regulatory enabling environment for RE**
- **Have a "transformative impact"**

Source: SREP Programming Modalities and Operation Guidelines, approved by the Sub-Committee in November 2010. "Scope of Activities".

Other Criteria-Examples

Examples (with definitions) from Armenia SREP Investment Plan

- **Potential for scale-up of the technology.** The amount of developable resource potential relative to the other technologies, as measured by production potential (GWh). Resources with higher production potential were given higher priority.
- **Market maturity/immaturity.** The extent to which the technology is used or the resource is already exploited in Armenia, or there is financing already available from other donor programs. Resources or technologies which are already well-known and well-developed in Armenia (such as small hydropower generation), were given lower priority because they already had sufficient support or private sector interest. Resources or technologies which already have financing available through other donor programs (such as geothermal heat pumps, solar thermal heating and rooftop solar PV) were also given lower priority because there is already financing available through other MDB programs (such as financing available through local banks from EBRD and IFC).
- **Cost-effectiveness.** The cost of the electricity or heat generated by the technology, as measured by the levelized energy cost (LEC).
- **Potential for job-creation.** The extent to which use of a technology or exploitation of a resource creates jobs.
- **Effect on power grid stability.** The extent to which certain technologies had a negative or positive impact on system operation and dispatch. Technologies with no impact, or a positive impact on grid stability were prioritized over those with a negative impact. The LEC is the present value of capital and operating costs for each technology, on a kWh basis.

Other Criteria-Sample Ranking

Technology	Power Grid Stability	Cost-Effectiveness	Job Creation	Scale-Up Potential	Market Immaturity	AVG RANK
Res. geothermal heat pumps	2	1	1	1	1	**1.2**
Solar thermal water heating	2	3	1	2	1	**1.8**
Fixed PV	3	2	2	2	1	**2**
Geothermal power	2	2	2	3	1	**2**
Small hydropower	1	1	2	3	3	**2**
Distributed solar PV	3	4	1	2	1	**2**
Ag. biogas-to-power	2	1	3	4	1	**2.2**
LFG biogas-to-power	2	1	3	4	1	**2.2**
Pumped storage hydropower	2	2	3	3	1	**2.2**
Wind	**3**	2	3	2	1	**2.2**

Ranking Criteria-Discussion

- Which of the above criteria should be considered for Bangladesh?

- What are other criteria that we should consider?

- Are there some criteria that are unimportant?

Thank You!

Thank you for your input and guidance!