Renewable Energy Data, Analysis, and Decisions Viewed through a Case Study in Bangladesh

Preprint

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National Renewable Energy Laboratory

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1 Abstract

Government representatives from developing countries around the world have signaled their intention to transition their energy sectors to rely on cleaner sources of electricity generation for a variety of reasons such as: complying with their Nationally Determined Contributions (in support of the Paris Climate Agreement), increasing energy security, or reducing air pollution. Renewable energy resources are increasingly a cost competitive option for new electricity generation. Evaluating renewable energy potential is an important element of increasing these technologies in their electricity generation mix. Goal setting, policymaking, grid modeling, and investment decisions that will enable renewable energy development all depend upon or are improved by the existence and quality of renewable energy resource data. This paper aims to summarize the relationship between renewable energy data, analysis, and decision making for developing countries seeking to transition their energy sector and to consider Bangladesh as a case study of a country that has worked with development organizations and the National Renewable Energy Laboratory to develop a national inventory of solar and wind resource data to enable critical decision making.

2 Introduction

Four decision areas are key to countries transitioning to higher penetration levels of renewable energy: target setting, policymaking, investment, and power sector planning (Sadie Cox et al. 2018). Decisions that are data-driven reflect appropriate ambition, maximize cost-effectiveness, and enable successful implementation of renewable energy investments.

The quality, characteristics, and accessibility of data can affect the type and quality of renewable energy decisions within a country. The relative maturity of the in-country renewable energy market is an important factor in determining the characteristics of data that will best inform decision making: countries that have less mature renewable energy markets may be less in need of the sophisticated datasets that enable grid modeling for high penetration variable renewable energy integration than those countries with more mature or rapidly growing renewable energy markets (Sadie Cox et al. 2018). Sophisticated, accessible, high-quality renewable energy datasets are a key enabler of rapid clean energy transitions (Kathleen Araujo 2014).

Bangladesh has relatively little installed renewable energy capacity, accounting for only 3% of its installed electricity capacity (Shariful Islam Sharif et al. 2018). The Government of Bangladesh has a goal of generating 10% of its electricity from renewable energy by 2020, which is detailed in the Power System Master Plan("Bangladesh Renewable Energy Targets" 2012) ("Power System Master Plan 2016 Summary" 2016). This will require a significant increase in renewable energy capacity. Through a partnership between the Government of Bangladesh, the United States Agency for International Development (USAID), the United States Department of Energy's National Renewable Energy Laboratory (NREL), NREL has created the Renewable Energy Data Explorer (RE Explorer) for Bangladesh, a web-based application whose purpose is to enable policy makers and the private sector to better conduct the analyses and support the decisions that will help expand the country's renewable energy market (Mark Jacobson et al. 2018).[1] Bangladesh is an excellent example of a country that has renewable energy ambitions, but previously lacked the underlying data to make enabling decisions. This conference paper will further detail the relationship between data, analysis, and decision making for renewable energy development in Bangladesh.

[1] www.re-explorer.org. The Renewable Energy Data Explorer is a user-friendly geospatial analysis tool for analyzing renewable energy potential and informing decisions. Developed by the National Renewable Energy Laboratory (NREL) and supported by the U.S. Agency for International Development (USAID), Renewable Energy Data Explorer performs visualization and analysis of renewable energy potential that can be customized for different scenarios.

3 Methods

NREL partners with USAID to identify and deliver technical contributions and solutions that can help accelerate a transition to clean energy in partner countries. When conducting work in Bangladesh, NREL drew upon concepts developed through the USAID-NREL Partnership's Renewable Energy Explorer, a web-based platform which links energy transitions, decision making, analysis, and high-quality renewable energy and related data. The Renewable Energy Explorer leverages NREL's long history in the United States of pioneering work that develops and disseminates state-of-the-art renewable energy data and tools that enable decision making. The team identified Bangladesh as an early stage country in terms of renewable energy transition because of its relatively small installed renewable energy capacity. Through a multi-year data development process, the NREL team developed and published renewable energy data and data analysis tools for Bangladesh. This section reviews the methodologies used, drawing on previously published work in each of these areas.

3.1 Data, analysis, and decision making for renewable energy transitions

NREL researchers, in partnership with USAID, have developed the Renewable Energy Explorer, a platform that is focused on linking high-quality renewable energy data and analysis to decision making for renewable energy transitions. This work recognizes the importance of high-quality renewable energy data and related datasets. Figure 1 shows the relationship between data and the most common categories of renewable energy decision making through the Data, Analysis, and Decisions Nexus.

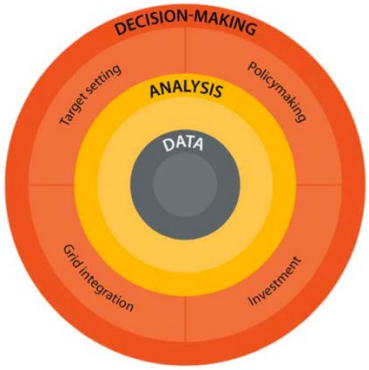

Figure 1: Data, Analysis, Decisions Nexus, reprinted from Sadie Cox et al., 2018

As renewable energy markets mature, the analyses conducted to support higher penetrations of renewable energy (especially variable renewable energy) often becomes more complex. The type of data required to support analysis and decision making often increases in complexity as well. Figure 2 demonstrates this relationship. For the purposes of this figure, an early-stage market is typically one that has relatively low penetration of renewable energy relative to its size, little experience with renewable energy project development, and little experience operating power systems with variable renewable energy.

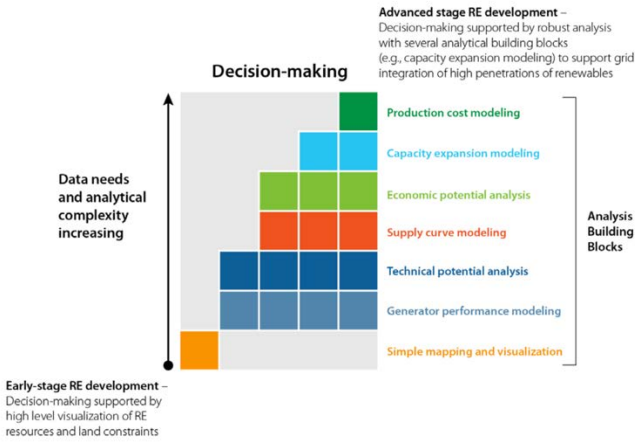

Figure 2: Analysis building blocks to support renewable energy decisions, reprinted from Cox et al 2018[2]

Drawing from the data, analysis, decisions nexus methodology and approach, the NREL team and the Government of Bangladesh, in partnership with USAID, recognized that to better guide decision making in Bangladesh and conduct analysis related to renewable energy decisions, accessible and high-quality renewable energy resource data were needed.

In Bangladesh, the NREL technical team matched the relative stage of renewable energy market development with appropriate technical interventions. Bangladesh has a very nascent renewable energy market. While Bangladesh does have renewable energy targets established, near-term decision making will include crafting policies to encourage renewable energy development and providing tools to help the private sector enter the market. Prior to this work, the foundational data for governments, private sector developers, and financiers to make these decisions did not exist in Bangladesh.

3.2 Assessing the Wind Potential in Bangladesh

NREL, in partnership with USAID, undertook a wind assessment for Bangladesh. Jacobson et al. (2018) provides a detailed description of the methodology used and the comprehensive results of the assessment. The assessment followed a two-pronged approach: 1) NREL researchers conducted sophisticated resource modeling using a numerical weather prediction model; and 2) the modeled data were validated by a ground measurement campaign, using information collected by nine meteorological sites located in all representative geographical regions of the country. For the ground measurement campaign, seven meteorological towers and one remote-sensing, sonic detection and ranging unit (deployed at two sites) collected the data over the course of 3 years.

[2] Each of these types of analysis and their relationship to data and the types of decisions they can help support are detailed in Renewable Energy Data, Analysis, and Decisions: A Guide for Practitioners (Sadie Cox et al. 2018).

Prior to this wind assessment, wind resource data for Bangladesh was between 10 and 15 years old. The modeled data was developed using less sophisticated techniques that didn't account for things like surface roughness. The observational data available for Bangladesh was recorded at 30m to 50m hub heights, too low for state-of-the-art technology (see section 5 below). In addition, this wind assessment combined modeled and observation data, resulting in a comprehensive dataset for Bangladesh.

In addition to the wind resource datasets, other relevant datasets were compiled. These datasets are presented in section 4 below but include items such as other renewable energy resource data, political boundaries, population density, water bodies, etc. The resulting wind dataset and other relevant data layers are published in the Renewable Energy Data Explorer.

4 Results

As a result of NREL's work in Bangladesh, renewable energy resource data and related GIS datasets are available to policymakers, planners, developers, investors, technical experts, consultants, and academics via the Renewable Energy Data Explorer for Bangladesh. Figure 3 is a visualization of the wind resource data, the ground measurement locations, and two related geospatial datasets: transmission lines and cities.

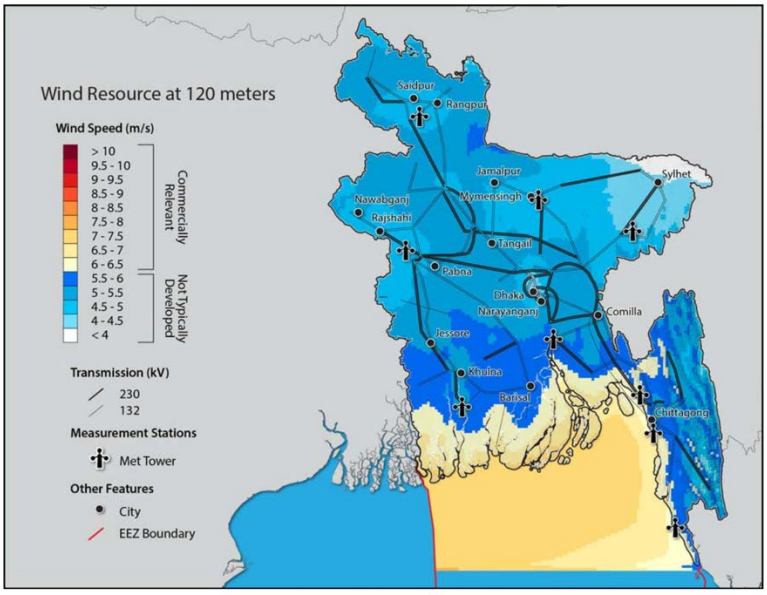

Figure 3: Bangladesh wind resource map and measurement locations (Mark Jacobson et al. 2018)

Table 1 summarizes the data and associated metadata available in the RE Data Explorer for Bangladesh.

Table 1: Datasets available in Renewable Energy Data Explorer for Bangladesh

Dataset	Metadata
Onshore and offshore wind data at 30m, 80m, 100m, 120m, and 160m hub height (wind data includes several parameters such wind speed, wind power density, etc.)	NREL developed this data using the Weather Research and Forecasting (WRF) model http://www.wrf-model.org and Climate Forecast System Reanalysis data were used as boundary and initial conditions. Observational data (surface reports, radio-soundings, aircraft reports and satellite winds) from the National Center for Atmospheric Research's historical database, as well as the local observations collected by NREL, were assimilated by means of the Four-Dimensional Data Assimilation (FDDA) algorithm.
Direct and global solar data[3]	Long-term yearly average of daily totals of direct normal irradiation (DNI) in kilowatt-hour per square meter. This data layer represents an output from the global solar model developed and owned by Solargis. It was commissioned by The World Bank with funding from the Energy Sector Management

[3] Direct normal radiation is radiation that comes directly from the sun, wherever it might be in the sky. Diffuse radiation is radiation that has been scattered and hits the earth's surface diffusely from many directions. Global solar data is made up of both of these.

Dataset	Metadata
	Assistance Program (ESMAP) under a global initiative on Renewable Energy Resource Mapping.("Bangladesh - Solar Radiation Measurement Data" 2017)
Power Plants	The Global Power Plant Database is an open-source, open-access dataset of grid-scale (1 MW and greater) electricity generating facilities operating across the world. The Database currently contains over 28,500 power plants in 164 countries, representing about 80% of the world's capacity. Entries are at the facility level only, generally defined as a single transmission grid connection point. Generation unit-level information is not currently available. The methodology for the dataset creation is given in the World Resources Institute publication A Global Database of Power Plants. ("Global Power Plant Database" 2018)
Transmission Lines	Power transmission lines, Bangladesh Power Development Board (1996-1997)[4].
Power Plants and Substations	Grid substations. Bangladesh Power Development Board (date unknown, prior to 2005)[5].
Elevation	Terrain elevation in meters and derived percent slope. U.S. Geological Survey GTOPO30 dataset (1993).
Land Use	Land use/land cover categories, U.S. Geological Survey Global Land Use/Land Cover dataset (1993)("USGS EROS Archive - Land Cover Products - Global Land Cover Characterization (GLCC)," n.d.).
Protected Areas	Database of protected areas of International Union for Conservation of Nature (IUCN) categories I through VI, other protected areas, and areas defined under international agreements. The World Database on Protected Areas (WDPA). ("Protected Area Categories" 2019), ("WDPA" 2019)
Rivers	Major rivers. Bangladesh Water Resources Planning Organization (1997). ("Water Resources Planning Organization," n.d.)
State Boundaries	First level internal administrative boundaries. ESRI ArcWorld Supplement (1998).
Country Boundary	Country level administrative boundaries. ESRI ArcWorld Supplement (1998).
Roads	National and regional road network of Bangladesh, and the feeder type A roads (roads connecting Thana HQ with the existing road network). Bangladesh Department of Roads and Highway (Date unknown, prior to 2005).
Cultural Landmarks	Cultural landmarks of Bangladesh. Pennsylvania State University Libraries, Pattee Maproom (1997).
Airports	Aerodrome locations, including all airports and airfields. Bangladesh Civil Aviation Authority (date unknown, prior to 2005).
Cities	Populated places in Bangladesh. Pennsylvania State University Libraries, Pattee Maproom (1997).

[4] Data provided to NREL by Government of Bangladesh
[5] Data provided to NREL by Government of Bangladesh

The Renewable Energy Data Explorer for Bangladesh give users the ability to conduct technical potential analyses, through which users can develop and compare scenarios to understand the potential renewable energy capacity (megawatt) and annual generation (gigawatt hour per year) based on system performance for a particular location or area and after excluding geographical barriers to renewable energy deployment (e.g. water bodies, protected areas, etc.) Figure 4 graphically depicts how technical potential is derived. The process begins with the renewable energy resource potential for a particular area and then exclusions are applied, for example, the land area with water bodies is removed, as is the land area with protected areas. After the user excludes all the appropriate land areas, the result is technical potential.

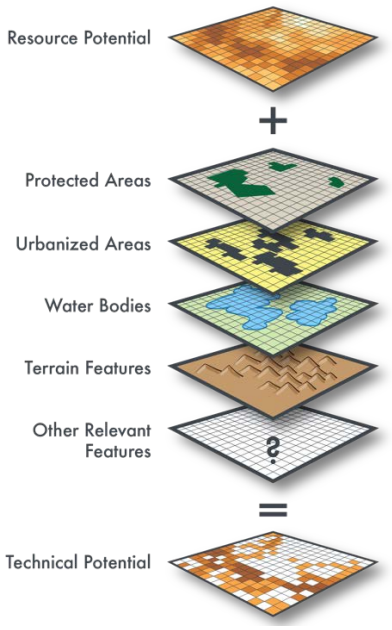

Figure 4: Technical potential analysis process, source: NREL

5 Discussion

The existence of high-quality clean energy resource data and related GIS datasets may play an important role in accelerating clean energy transitions. Decision making for clean energy target setting, policymaking, grid integration, and investments is improved by access to high quality renewable energy resource data. Inaccurate, outdated, or incomplete datasets can greatly affect the quality of analysis and hence the wisdom of the resulting decisions. Further, quality decisions increase the chances of early successful deployment of clean energy deployment. The failure of early projects in a nascent industry may slow market growth for these technologies(Md. Alam Hossain Mondal, et al. 2010).

Wind speeds and hence wind resource can vary significantly at different heights. Figure 5 shows two wind maps for Bangladesh, one depicting wind speeds at 30m hub height and one depicting wind speeds at 160m hub heights, the former being similar to a map available for Bangladesh prior to this wind assessment[6]. The wind maps are data products generated from the Renewable Energy Data Explorer for Bangladesh. They visually illustrate wind resource: the darker the blue, the faster the wind speed and the better the wind resource. Modern wind turbines range in hub heights from approximately 80m to 160m. If decision makers are using the wind data from the map on the left, clean energy deployment may be impeded across all four decision making areas: target setting and policymaking may not be reflective of available wind resource; investors and wind developers may geographically limit their prospecting unnecessarily; and grid integration modeling such as production cost modeling may not characterize the wind resource correctly.

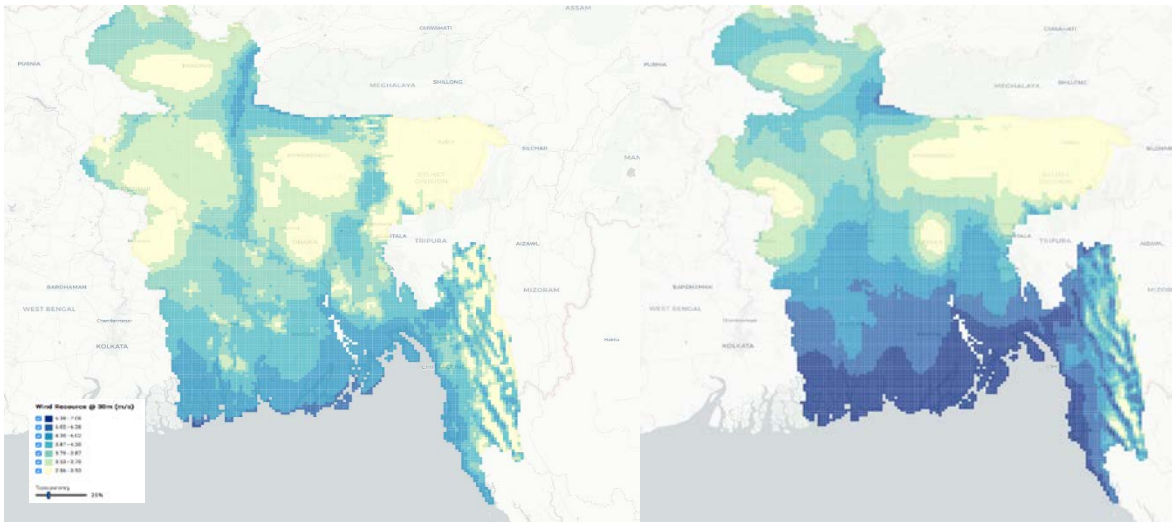

Figure 5: 30m hub height (left) and 160m hub height (right) wind speed data for Bangladesh from the RE Data Explorer

[6] On a wind turbine, the hub is at the center of the blades. Hub height refers to the height at which that hub will be for a given wind turbine. ("Anatomy of a Wind Turbine" 2010)

Figure 6 adapts Figure 1 to the Bangladesh context with potential analyses needs to inform decision making.

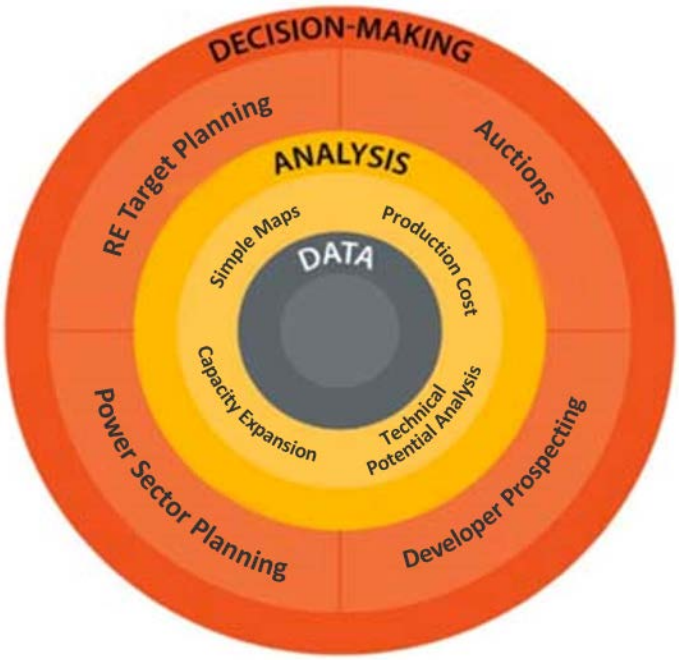

Figure 6: Data, Analysis, Decision-Making Nexus adapted to Bangladesh

Bangladesh's wind energy market is relatively undeveloped. Prior to the wind resource data development work described here, Bangladesh had set renewable energy targets. In order to reach those targets and encourage wind development in Bangladesh, policymakers may need to consider implementing incentives to encourage wind development. Policies of interest may include reverse auctions, renewable energy zones[7], renewable portfolio standards, and many others. In addition, wind developers considering investing in Bangladesh need to make decisions about the most promising places to develop. Having access to high-quality renewable energy resource data and complementary datasets (such as transmission system data) facilitates and accelerates the prospecting phase.

The RE Data Explorer for Bangladesh provides renewable energy resource data and related GIS datasets to support policy making that encourages private sector engagement and developer prospecting activities. As the amount of variable renewable energy generation in Bangladesh increases, more complex system modeling and analysis may be needed, which in turn may require higher temporal resolution data to enable accurate treatment of variable renewable energy on this system.

[7] See Renewable Energy Zone Transmission Planning Process https://www.nrel.gov/docs/fy17osti/69043.pdf

Table 2 summarizes how a few different audiences may use the Renewable Energy Data Explorer Tool.

Table 2: Potential audiences and Example uses of the Renewable Energy Data Explorer

Audience	Example use of the RE Data Explorer for Bangladesh
Policymaker	Early-stage analysis for various types of policies, including reverse auctions, renewable energy zones, renewable portfolio standards, etc.
Power Sector Planner	Appropriate treatment of renewable energy resources to help develop plans for a more diverse and cleaner power sector, including transmission development
Developer	Early stage prospecting activities
Investor	Verification of developer-provided project finances

Because renewable energy resource data and associated GIS datasets are key to clean energy transitions, making this data available to countries around the world is important. A key feature of the Renewable Energy Data Explorer for Bangladesh is that much of the data is downloadable for free, and technical potential analysis can be done within the tool by anyone via the website, which is freely accessible.

6 Conclusion

As Bangladesh seeks to comply with its commitment to the Paris Agreement and increase its resilience and national security, renewable energy is an important option. To better assess the potential for renewable energy to meet Bangladesh's development goals and conduct analysis of appropriate strategies, Bangladesh needs robust renewable energy resource data, related GIS datasets, and easy-to-use data analysis tools. The analysis that can be done with these resources supports data-driven decision making that helps accelerate renewable energy transitions. When renewable energy resource data is made public, it can serve academia and research institutions as well as private sector renewable energy developers and investors.

This paper summarized the relationship between renewable energy data, analysis, and decision making for developing country stakeholders seeking to transition their energy sector and considered Bangladesh as a case study of a country that has worked with development organizations and NREL to develop a national inventory of solar and wind energy resource data to enable decision making critical to clean energy transition.

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