Unlocking clean energy, GHG reduction and better livelihood potentials in rural areas of Bangladesh: Exploring Agrivoltaics as a potential game changer

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1. Current Approach towards Low Carbon Development in Bangladesh

Bangladesh has emerged as one of the fastest-growing economies in the 21st century, and the country has now set an ambition to be a high-income country by 2041 (Vision 2041, GoB). The Government of Bangladesh (GoB) is not only focusing on fueling its economic growth but is also making environmental sustainability even more of a priority. For instance, although Bangladesh's overall contribution to global carbon emissions is very small, the country has been striving for sustainable and low-carbon development. The GoB's updated Nationally Determined Contribution (NDC) expresses an enhanced 'greenhouse gases' (GHG) emission reduction target of 89.47 metric tonnes of carbon dioxide equivalent ($MtCO_2e$), i.e., equivalent to 21.85% of business-as-usual emissions by 2030 (NDC 2021, GoB). To diversify the energy generation sources (currently fossil fuel dominant), the Honorable Prime Minister of Bangladesh stated at COP26 that the country would aim to cover 40% of its power generation with renewable energy (RE) by the year 2041 (UNFCCC, 2021). Accordingly, the Government of Bangladesh adopted the Mujib Climate Prosperity Plan 2022-2041 (MCPP) in February 2022 where it included a phase-wise target of 40% RE by 2041, 50% by 2060, and 100% in the long term, considering diversified sources of RE, including solar, wind and hydrogen energy sources, subject to receiving support from international resources (MCPP 2022, GoB). The Mujib Climate Prosperity Plan, 8th Five Year Master Plan, Delta Plan, National Adaptation Plan, Perspective Plan, and updated Bangladesh Climate Change Strategy and Action Plan also echo the genuine need for speedier execution of RE, as an effective means for the development of sustainable energy sources while achieving GHG reduction targets of NDC holistically. Nonetheless, issues like land shortage, absence of integrated plans, limited penetration of innovative RE technology coupled with inadequate grid integration of RE and lack of enabling policies, business models and sources of financing continue to be serious impediments for scaling up different solar-based RE energy solutions in Bangladesh.

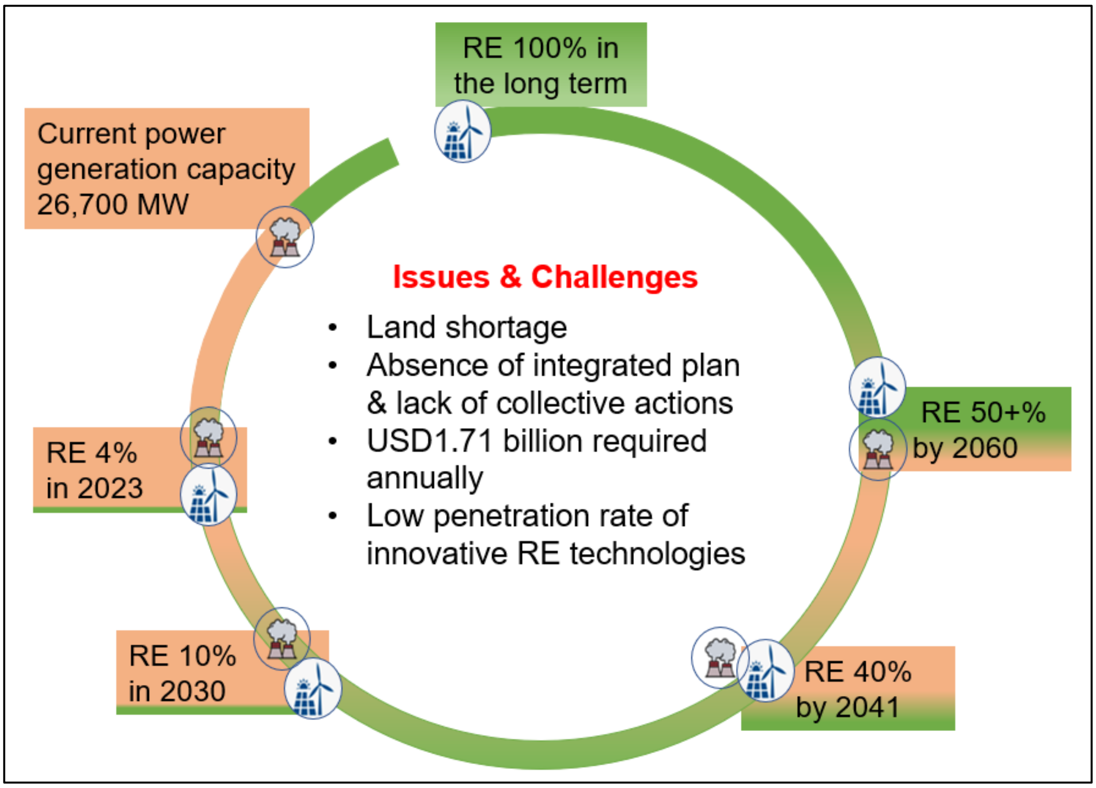


Figure 1: *A chronology of the GOB's vision toward becoming carbon neutral*

Efforts towards Low Carbon Transition: In line with the country's vision and ambitions towards becoming carbon neutral, the Prime Minister of Bangladesh instructed officials to take the necessary steps towards ensuring that all irrigation pumps in the country are powered using solar energy (*https://bdnews24.com/bangladesh/2ybbsmsf5b*). In a meeting of the Executive Committee of the National Economic Council on 20 June 2023, the Prime Minister also solicited the Agriculture Minister to take steps to construct solar panels at safe heights above vegetable and fisheries farms.

Thus far, Bangladesh has achieved considerable success in providing clean energy access to its rural off-grid population through the solar home system programme. The Infrastructure Development Company Limited (IDCOL), along with the GoB agencies and associated stakeholders, disseminated over 6 million solar home systems (SHSs) with an aggregated installation of around 200-megawatt peak (MWp) (SREDA, 2023). The success of the off-grid electrification programme inspired the GoB, financial institutions and development partners to extend the scope of SHS to other forms of decentralised RE solutions, such as solar irrigation pumps (SIPs), solar mini-grid, community electrification and solar street lights. To reduce the huge subsidies on diesel-based irrigation and to make agriculture clean and environment-friendly, the GoB engaged with IDCOL, BADC, BREB and BMDA-run programmatic intervention, to support the installation of around 3000 SIPs with an aggregated system size of 53 megawatts (MW) in different areas of the country (SREDA, 2023). The sole purpose of these SIPs is to provide irrigation water for cultivation purposes. However, most of the installed SIPs cannot operate year-round as the demand for irrigation is at maximum capacity for Boro (dry season) rice cultivation alone. On the other hand, Amon (wet season) rice is partially rain-fed, and cash crops require less water than rice cultivation (CERSAL, 2018). As such, SIPs are mostly a commercial RE solution and require significant grant subsidy and soft financing support for their sustainable business operation.

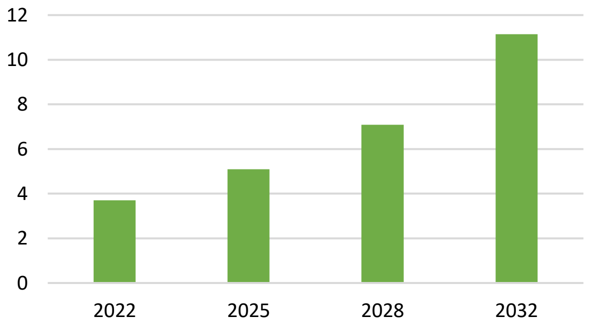
Is there a feasible solution? To maximise the utilisation of SIPs and to ensure efficient land use management for RE generation, the symbiotic use of agricultural lands to simultaneously yield food and solar energy, commonly referred to as 'agrivoltaics', is emerging as a game changer. By implementing this type of dual land use, the competing demands for land use between food production and RE development could be effectively managed (NREL, 2020). Additionally, agrivoltaics are an effective solution to address underutilisation of SIPs and to enhance farm-based incomes from selling the produced energy via the grid system or to other users. Furthermore, effective implementation of agrivoltaics will not only contribute towards local/national clean energy transition, but will also complement the goals set out in the Paris Agreement to limit global temperature increase to 1.5°C above pre-industrial levels, as well as contributing to achieving the Sustainable Development Goals (SDGs).

Figure 2: Picture of an agrivoltaics site in Aomori Prefecture of Japan

2. About Agrivoltaics

Referred to as a practice of co-locating solar panels and agricultural crops on the same land, agrivoltaics consist of two key components: agriculture and photovoltaics. These two sectors have traditionally been separate and competing entities, and an argument is often made that fields of solar arrays generally replace farmland. The National Renewable Energy Laboratory (NREL) categorises agrivoltaics as one of the three types of 'low impact solar' development methodologies. "Solar-centric" refers to low-lying panels that keep vegetation intact as ground cover. This is different to the traditional method that requires removal of ground cover and usually topsoil for large solar farms, resulting in extensive soil disruption (NREL, 2020; UMass, CEE, 2019). "Vegetation-centric" designs place solar arrays near crops but do not interfere with them. An example of vegetation-centric is installing solar panels in the unirrigated corners of pastures that use center-pivot irrigation (CPI), also called "unused" agricultural land. Correspondingly, agrivoltaics are categorised as "co-location designs" or "dual use" and are configured to maximise the output of both agriculture and solar (NREL, 2020). Over the years, the practice of agrivoltaics has established technical as well as financial viability alongside other forms of decentralised RE solutions in many ways. Unlike other forms of land-based solar solutions, agrivoltaics cause minimal or no land-use change, and enable farmers to secure a second line of revenue by selling clean electricity.

Figure 3: Agrivoltaics Market Size to 2032
(USD Billion)
(Source: www.recedenceresearch.com)

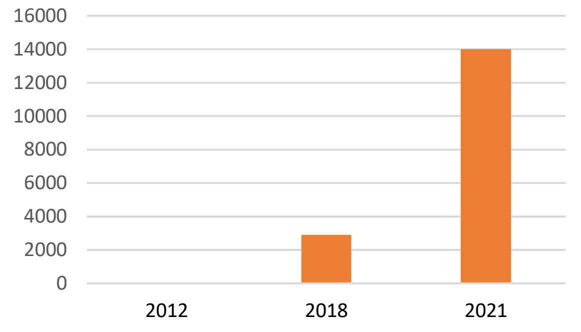


What are the Global Trends?

According to the Precedence Statistics (2023), the global agrivoltaics market size was valued at USD 3.7 billion in 2022 and is predicted to reach around USD 11.14 billion by 2032 with a compound annual growth rate (CAGR) of 11.7% from 2023 to 2032. The market forecast for agrivoltaics indicates its strong future potential to be promoted as a sustainable RE solution benefitting a range of stakeholders, including farmers, the private sector and policymakers.

According to Statista, in 2021, the cumulative agrivoltaics capacity installed worldwide amounted to roughly 14 Gigawatts. This figure increased from approximately 2.9 Gigawatts in 2018. North America and Europe were the regions that held the largest share of the world's agrivoltaics market in 2021. The cumulative installed agrivoltaics capacity (in MW) worldwide from 2012 to 2021 is shown in Figure 4. As clearly observed, there was a sharp growth in agrivoltaics installation between 2018 and 2021

Figure 4: Agrivoltaics Capacity
(Megawatts) (Source: Statista)



Considering global trends, the EU countries are currently at the forefront in terms of installing agrivoltaic systems. By 2022, the installed capacity in the EU was around 211 GWDC. A recent EU study (EU Science Hub, 2023) revealed that if agrivoltaics were installed in just 1% of agricultural land currently in use, this could result in approximately 944 GWDC of installed capacity. This amounts to half of the capacity possible with traditional ground-mounted PV systems (around 1,809 GWDC on the same surface area). However, it would still be greater than the 720 GWDC capacity foreseen by 2030 in the EU Solar Energy Strategy.

3. System requirement for Agrivoltaics

- Above are solar panels; below are rice fields, crops, and vegetables or aquatic products.
- Condition: Crop fields are suitably located or strategically grouped to be able to dispatch electricity from the agrivoltaics site to nearby distribution grid systems.
- Agrivoltaics can supply electricity to onsite loads located nearby, including e-rickshaw charging stations (if appropriately designed to meet the duty cycle of batteries), paddy thrashers, SIPs or houses with three-phase connections.
- Implementation area: 50-300m^2 (equivalent to 10-20 KWp) (Neefjes & Xuyên 2020)
- Panel height: 2.5-4m above the ground covering 50-80% of the area (Neefjes & Xuyên 2020)

Prospects for Farmers

Benefits

- Possibility to co-own solar power system and earn revenue benefits from selling surplus electricity.
- Can receive system protection and maintenance fees; part of land-use cost.
- Possibility to use electricity from agrivoltaics at prices equal to those purchased through net metering.
- Inheritance model after 20 years of operations.
- Can optimise efficient use of land and ensure better land-use than SIPs.

Risks

- Covered crop/livestock productivity may be affected during first year & only within solar PV setting.

Prospects for Investors

Benefits

- Benefit from surplus electricity sales to grid system. However, this profit can be considered for overall payback of system.
- Pilot agrivoltaics project can generate data evidence on actual yield loss due to shade created by solar panels on different crops such as rice, vegetables, cash crops, and aquatic products, that can potentially be grown under solar panels.

Risks

- Strength of steel frame and concrete columns of system may be affected by impact of acid sulphate soil or flooding.
- Farmers may change land use or transfer land-use rights to others.

Prospects for Government of Bangladesh

Benefits

- Benefits include GoB fuel subsidy removal and complementing clean energy goals, avoiding land intensive utility scale solar projects and ensuring better land-use management.
- Complementing the SDG goals ensuring livelihood benefits for the rural population.

Risks

- Slight reduction in food production (slightly lower crop yield).
- Reduced area available for planting (slight reduction) due to solar panel placement.
- Some portions of the crop field can be inaccessible if agrivoltaic system is not carefully designed.

4. Potential of Agrivoltaics implementation in Bangladesh

According to the Minor Irrigation Survey Report 2018-19 (BADC, 2020), the net cultivable area of Bangladesh is about 85,85,207 hectares (ha), about 65% of which is extensively irrigated during Boro rice season, partially for Amon and other cash crops. During FY2019-20, Bangladesh produced 453.44 lakh metric tonnes (MT) of food grains, of which Aus accounted for 30.12 lakh MT, Amon 155.02 lakh MT, Boro 201.81 lakh MT and Wheat 12.46 lakh MT. Similarly, the demand for irrigation water has been increasing due to high crop intensity. In light of that, the simultaneous production of crops and solar electricity in the same land parcel holds huge potential to unlock multiple co-benefits, including economic growth and clean electricity for farmers and renewable energy investors. Moreover, agrivoltaic technology can be applied extensively in cultivation without any major disruptions to current agriculture practices. It can also supply sufficient electricity to run SIPs and support other onsite agri-based applications, as well as enable farmers and project developers to sell surplus electricity to the grid system.

Irrigation Landscape of Bangladesh: In FY 2018-19, approximately 37,634 deep tube wells, 13,57,532 shallow tube wells and 1,87,188 low lift pumps were in operation in Bangladesh. This equipment provided irrigation to about 73.09% of the total irrigated area covered by groundwater. The remaining 26.91% is covered by surface water. About 1,585,413 of the pumps used in irrigation season are operated by diesel engines and about 21.55% are operated by electricity and solar energy. The total diesel consumption in 2020 for irrigation in Bangladesh was 1.19 million tonnes, which emitted around 3.5 million metric tonnes of CO_2 (BADC, 2020).

Furthermore, Boro rice, being the most water intensive crop, requires intermittent flooding irrigation several times during the entire cropping period. Due to the impacts of climate change, Amon rice cultivation also requires partial irrigation, and the same applies for maize and wheat. Therefore, the demand for increased irrigation has been met by fossil fuel diesel or by electricity, both of which generate GHG emissions and cause local environmental pollution.

To encourage farmers for adopting sustainable agriculture practices, around 3,000 SIPs have been installed in different parts of Bangladesh (SREDA, 2023). Many more are necessary to completely replace the nearly 1.33 million diesel irrigation pumps that are in operation. In this regard, agrivoltaics can serve as an effective solution to support the speedier installation of SIPs, while creating synergies between agri-practices and clean energy generation. Markedly, the agrivoltaics solution causes little or no intervention to the existing agricultural land use and hence can be installed on the top of existing fields to feed electricity to the surrounding cluster of SIPs. Alternatively, many of those SIPs may need to be installed in a decentralised manner, meaning that they will not be able to effectively contribute to the supply of surplus clean electricity flowing to the distribution grid system and therefore will remain underutilised.

Why should Agrivoltaics be implemented to enhance crop cultivation?

- Can reduce significant crop loss due to less or no intervention to existing land use and can increase crop yields, especially for shade-loving crops or crops that require partial shading (NREL, 2020).
- Can ensure higher economic returns for farmers and investors.
- Can lower evaporative water loss in agricultural lands by providing partial shading.
- Provides steady income stream from sale of electricity or tax credits for renewable energy, potentially offsetting costs of farming, making it more affordable, and mitigating risk of seasonal crop loss/failure.
- Can create significant green jobs in rural areas and stimulate local economy, requiring installers, technicians and field level people to maintain systems.
- Can significantly complement country’s energy transition and net-zero goals.

5. Agri-voltaic Potentials in Bangladesh towards GHG reduction and better livelihoods

- *Electricity generation potential of agrivoltaics can vary depending on the country's land use pattern, agri-practice, solar irradiance profile, electricity evacuation complexity, etc.*

- *A recent EU study (EU Science Hub, 2023) on agrivoltaics indicated the potential of 0.6 MW/ha installation for electricity generation. On the other hand, a pilot agrivoltaics project implemented in Japan has been producing approximately 0.2 MW/ha. Considering a conservative approach like in Japan, the total amount of cultivable land in Bangladesh could produce up to 1,715,324 MW, which is about 61 times more than the currently installed electricity generation capacity (28,134 MW) of Bangladesh. Further assessment is necessary to pinpoint the actual electricity generation potential of agrivoltaics (MW/ha). However, it is clear that if the potential of agrivoltaics can be harnessed properly, it could make significant contributions to achieving both Bangladesh's RE target (40% of total electricity mix by 2041) as well as the country's net-zero ambitions by 2050 or 2060.*

Based on this initial estimation, a comparison is made between MW vs Land for agrivoltaics under the two different RE target scenarios (40% vs tentative net-zero target) set out by the Bangladesh Government. The required land is shown to meet these targets in the Figure 5.

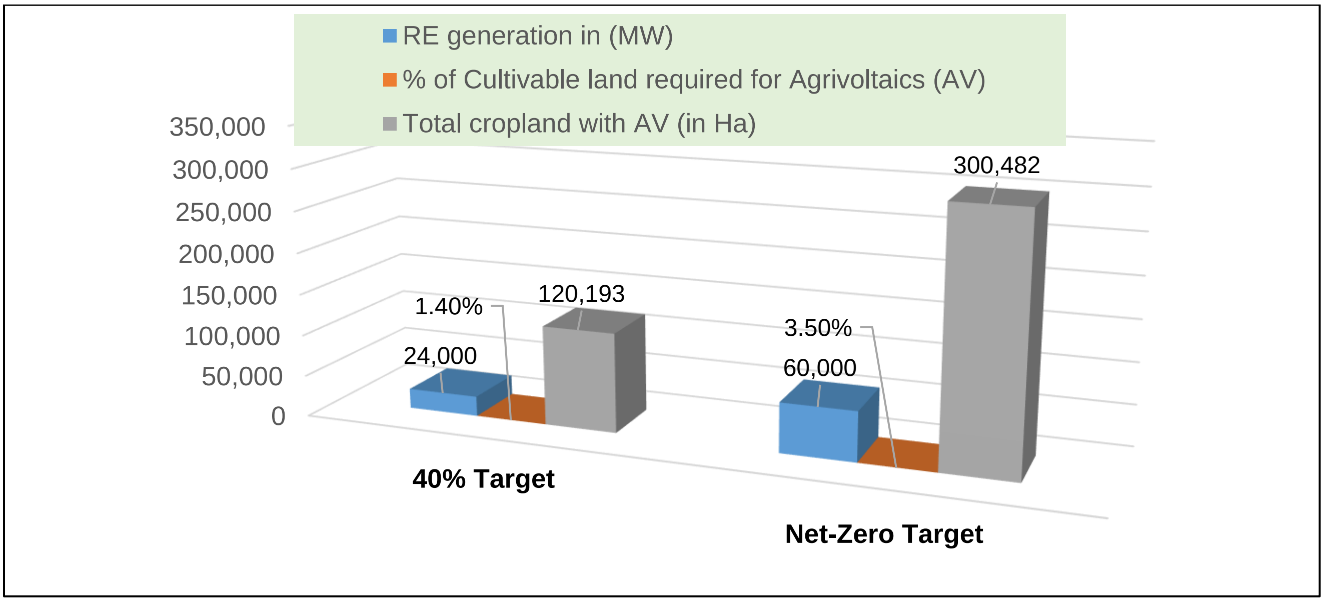


Figure 5: Potential of Agrivoltaics in Bangladesh, under two scenarios: 40% Target vs Net-Zero Target

6. Co-benefits for different stakeholders

The installation of solar panels in agricultural areas not only helps the transition to a low-carbon energy system, but it will also reduce the reliance on fossil fuels and the consequent carbon emissions associated with conventional methods of producing power. As such, agrivoltaic systems also hold huge potential to help revitalise rural communities by enhancing agricultural productivity, conserving water resources and mitigating climate change.

To highlight an example from Aomori Prefecture, Japan, there is an ongoing agrivoltaics project by Aomori Kenmin Energy Inc. in the Towada region in Hachinohe. Under this project, the amount of annual rent paid to the farmers for the solar panel installation is estimated to be three times their usual earnings from cultivation, despite only a 20% reduction in agricultural yield. In this way, the project has been serving as a win-win situation, as the land ownership remains with the farmers who also earn a profit, while the private sector benefits through the revenue generated by selling the produced electricity. This shows that the nature of financial benefits varies based on system size and load factor especially depending on how much surplus electricity is delivered to the grid system, after meeting different onsite purposes.

7. Way Forward

For materialising the potential of agrivoltaics in Bangladesh, a sequence of interventions is necessary at different levels including evidence-based research, community engagement, policymaking, business model development and financing arrangement. A few key areas of future work in this direction are:

- Establishing technical feasibility of agrivoltaics in the context of Bangladesh
- Determining social acceptance and willingness towards agrivoltaics installation
- Field pilots for agrivoltaics systems, and further investigation based on operation data and agri productivity to assess the generation of RE and food production loss, if any
- Exploring synergies with existing government schemes on RE development, and identifying feasible financing mechanisms to upscale agrivoltaics projects
- Considering the diverse stakeholders and their interests, devising a suitable business model on agrivoltaics, duly ensuring benefit-sharing between parties.

Notably, the RE vision for Bangladesh requires significant upfront capital investment in order to be achieved within the stipulated time frame. In this regard, international funding support for clean energy generation needs to be explored in parallel with the ongoing RE financing support from the World Bank, ADB, JICA and KfW. Bilateral carbon reduction schemes under Article 6.2 of the Paris Agreement, like the Joint Crediting Mechanism (JCM) can be leveraged to source international climate financing grants to support the speedier implementation of RE installations such as agrivoltaics, which can also complement many of Bangladesh's SDG goals.

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