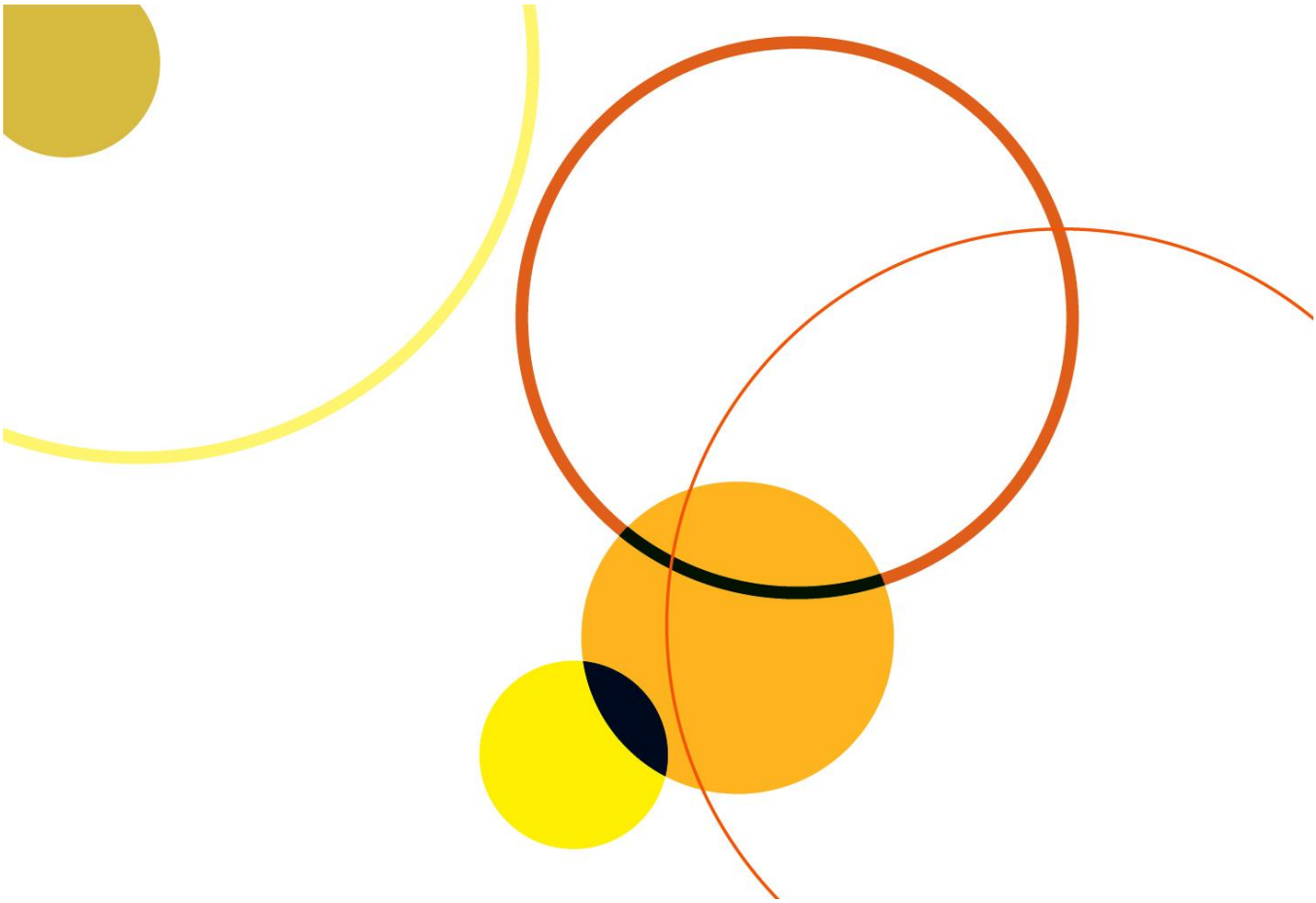
Solar boats

Business model and investment concept note - Bangladesh

February 2019



Summary

This document sets out a path for development of a commercial market for solar boats in Bangladesh. It summarises the early experience from pilots in Bangladesh, and draws on a limited set of international experience in commercialising the technology. It is intended to serve as a synthesis of current market understanding and lessons learnt from international experience, and to set out next steps that will be required to continue to support development of the sector. The strong dependence on inland water transportation in Bangladesh makes solar boats an interesting a unique possibility with the prospects of supporting broader rural development as well as reducing greenhouse gas emissions.

The market for these boats is at a very early stage of development, but the technology holds strong potential to deliver financial, environmental and social benefits. Bangladesh is a riverine country, and diesel powered boats are often used as a means of transport. Solar boats could replace these ferries, reducing both emissions from and costs associated with diesel combustion. They could also be utilised in tourism services, particularly in ecologically sensitive areas.

The government has begun exploring this market by commissioning the first solar boat pilot program in Bangladesh, but further research remains to be undertaken to deploy this technology at scale. The Sustainable and Renewable Energy Development Authority (SREDA) has worked with the United Nations Development Program (UNDP) to fund the construction of five boats of varying sizes over the course of 2018. These boats are currently undergoing testing, with three of the five now in operation.

It is too early to conclude on the commercial viability of the technology at this stage – and further pilots will need to be undertaken. A business model could be explored along the lines that have been used for solar mini grids and solar irrigation, drawing on concessional finance from IDCOL. However, the costs and revenue streams are too uncertain at present to know how well any future business model will function.

Section1 summarises the current market conditions and first pilot program in Bangladesh, providing insight into the market context. Section 0 provides a brief summary of experience from other countries in the region. Section 3 describes the potential to scale the market, and improve bankability of projects based on experience in Bangladesh and lessons learned from international case studies.

1 Market potential and overview of pilot project

Solar boats are particularly relevant for Bangladesh, a riverine country where water transport is widespread and often the most affordable option. Bangladesh has approximately 800 rivers, covering a length of 24,140km, and boats are commonly used to travel short distances as passenger / commuting between riverside villages, as well as for fishing. These boats and ferries are powered by diesel, which is expensive and energy inefficient. They also disrupt marine environments, and contribute to air pollution. SREDA estimates that about 500,000 of these boats could be converted from diesel to solar.

Five pilot projects are being developed by SREDA, with support from UNDP. The five pilot boats have been funded by the Global Environment Facility, through the Sustainable Renewable Energy Power Generation (SREPGen) project, with the objective of trialling different technical designs. Three boats are currently being leased to Hatirzheel lakefront in Dhaka, Panama Lake in Narayanganj and Foy's Lake in Chittagong where they are being used under a demonstration initiative. The two remaining boats have faced technical design difficulties and are not currently operational.

The existing pilot boats were tested on relatively calm lakes; transport along rivers with more demanding current and surface water conditions may not be as favourable. The intention of the existing pilots is to study the suitability of the technology used on each boat to draw lessons learned, and to develop a prototype boat which could be used as a model to be deployed at large scale to replace the 500,000 currently diesel operated boats.

There are also trials ongoing of other technologies, which could be combined with solar technology. For example, using fibre based hulls is being considered, and could be combined with solar power. The lighter fibre boats could require less energy to operate, making them more energy efficient.

1.1 Commercial aspects

The five boats in the SREPGen pilot projects range in size from 1,430W to 2,340W, carrying 12 to 30 passengers. The capital cost of each boat is between USD 5,000 and USD 10,000, while the operating and maintenance costs are less well known as the pilot is still in the early stages.

The boats are a solar-diesel hybrid, with the current investment models assuming that half of the energy required can be generated by solar power, with the remainder using a diesel motor. The accuracy of this technical assumption will need to be verified through the pilots, and further trials if needed, as it has a large bearing on the project returns, which will affect the attractiveness to private investors.

As well as the five UNDP supported pilot projects, a team at the Bangladesh University of Engineering and Technology (BUET) has also developed a solar boat to replace diesel commuter ferries. The solar boat is similar in size and dimension to a traditional Bangladeshi ferry in rural areas, carrying 10-12 passengers, and is powered by four 250 W solar panels with a maximum distance of 60 km on a single charge.

Table 1. Technical and commercial parameters of solar boats in Bangladesh

Parameter	Description
Number of diesel boats that could be converted	500,000 diesel boats currently in operation that could be replaced
Typical size of the boat	Boats are of varying sizes, passenger capacity ranges from 12-30 people
Solar capacity	SREPGen pilot boats range from 1,430 W to 2,340 W
Solar – Diesel mix	50% solar and 50% diesel
Distance travelled and speed	The boats can travel between 40-60 kms on solar and have a maximum speed of 10-14 kmph
Customer segment targeted	Rural residents travelling between riverside villages
Sponsors and equipment suppliers	The market as at a very early stage of development with just five boats operational so far. These have been developed by Solar E Technology under the Sustainable Renewable Energy Power Generation (SREPGen) pilot programme.

1.2 Financing structures

The pilot program has been entirely grant funded by the Global Environment Facility through the SREPGen project. However, the long term intention is to develop a business model which can attract commercial finance, and can be deployed at scale.

A possible next step would be to trial a small number of boats using IDCOL concessional finance. For example, existing financial analysis from consultants working for the SREPGen project suggest a financing structure with 40% grant, 40% concessional loan and 20% equity would generate payback periods of around three to four years.[1]

The capital costs for the solar boats, including the photo-voltaic (PV) panels and boat frames, are grounded in the pilot projects, and may therefore be relatively robust. As the technical design of the boats evolve these will need to be updated.

The operating cost assumptions are less robust, as the trials have not been in operation long enough to have full confidence in the long term maintenance and running costs. They include a number of assumptions that are yet to be tested, and which could have important impacts on the payback period and rates of return. The current financial models do not appear to include the cost of staff to operate the boat – and when these are included the net present value (NPV) becomes negative.

[1] SREPGen Project. (2018). *Development of PV solar boat in Bangladesh*.

Table 2. Financial parameters for boats in Bangladesh

Parameter	Description
Estimated total project cost	812,082 BDT (9,680 USD) for a 30 passenger boat 484,296 BDT (5,775 USD) for a 12-14 passenger boat Approximately 40% of the cost relates to building the hull (i.e. the structure of the boat), and the remaining 60% is the cost of solar conversion. Converting existing boats therefore can result in significant cost saving.
Operating costs	Diesel costs per litre of BDT 70 per litre Ghat fee of BDT 200 per day Maintenance of 600 to 1,000 per month depending on boat size Battery replacement costs of BDT 96,000 every three years All costs except battery costs rising 3% per year
Structure of financing (equity | debt | grant)	20% equity | 40% debt | 40% equity
Financiers	This table sets out a trial IDCOL financing structure – grant and concessional loan potentially provided by GEF / SREPGen
Terms of loan	6% interest, repayment made over 8 years
Asset life (boat and panels)	15 years

1.3 Product and pricing

The current financial modelling model proposes a fare of 10-12 BDT per person per trip as the primary mode of revenue generation. The fare will increase by 3% each year, in line with inflation. The boat will operate 8 trips a day of an average 10km each, for 335 days a year, resulting in a projected annual income of 804,000 BDT (or approximately 9,590 USD) if each trip is operated at full capacity (30 passengers). The tariff and distance is based on current ferry services provided by diesel boats in Bangladesh, and it is assumed the same price could be charged for a solar powered ferry boat.

As with the cost assumptions above, ticket pricing and boat utilisation assumptions will need to be tested. For example, they assume a ticket price based on survey data from a selection of inland waterway ferries, and an average occupancy rate of 80%, operating for 335 days of the year. These appear optimistic rather than conservative, and commuter ferries will need to be trialled before the market can attract private investment and scale up.

Table 3. Pricing structures and revenue generation for solar boats in Bangladesh

Parameter	Description
Product for end users	End users pay a fare for each trip
Structure of end user tariffs	Fare per person per trip is 10 BDT, raising at 3% each year (in line with inflation)

Parameter	Description
Number of trips per year	2,680 trips (8 trips per day, operating 335 days a year)
Revenue collection model	Ticket price is collected on board before the trip

1.4 Socioeconomic and environmental benefits

Solar-diesel hybrid boats can deliver important environmental and socioeconomic benefits, including a saving of approximately six tonnes of CO2 equivalent per boat annually, and the mitigation of adverse health effects of diesel combustion.[2] There are around 500,000 diesel powered boats which could potentially be converted to run on solar power. This would reduce carbon emissions by around 3 Mt of CO2 equivalent.[3] Converting all 500,000 boats would achieve 25% of Bangladesh's Nationally Determined Contribution (NDC) pledge of reducing emissions from the power, transport and industry sectors by 12 Mt of CO2 equivalent by 2030.[4] They also produce less noise than diesel engines and do not pollute water, resulting in less harm to marine life. In addition to the environmental benefits, solar boats increase energy security, reduce health risks caused by diesel combustion, and could provide a bankable business model for passenger and commercial transport on inland waterways.

Table 4. Summary of socioeconomic and environmental benefits of solar boats in Bangladesh

Parameter	Description
Environmental benefits	Reduces air pollution Reduces greenhouse gas emission from diesel combustion (approximately 5,900 kg of CO2 equivalent reduced annually per boat) Reduces the effects of water and noise pollution on marine life
Socio-economic benefits	Mitigates the adverse impacts of diesel combustion on health (such as lung disease, respiratory illnesses and allergies) Researchers at BUET estimate that boatmen can earn 67% more than from a diesel powered boat by using a solar powered boat.[5]

[2] Emissions reduction calculated on the basis of avoided diesel boat emissions as per SREDA. (n.d.). Brief on solar boats, page 2. Retrieved from http://www.sreda.gov.bd/d3pbs_uploads/files/Solar Boat_Write-up for SREDA website (1).pdf

[3]SREDA. (n.d.). Brief on solar boats. Retrieved from http://www.sreda.gov.bd/d3pbs_uploads/files/Solar Boat_Write-up for SREDA website (1).pdf

[4] Ministry of Environment and Forests (2015). Intended Nationally Determined Contribution.

[5]Lutful Kabir, S. M., Alam, I., Rezwan Khan, M., Hossain, M. S., Rahman, K. S., & Amin, N. (2017). Solar powered ferry boat for the rural area of Bangladesh. *2016 International Conference on Advances in Electrical, Electronic and Systems Engineering, ICAEES 2016*, 38–42. https://doi.org/10.1109/ICAEES.2016.7888005

2 Summary of international experience

The use of solar boats is still in its infancy internationally, although trials in India and Vietnam have been promising. The pilot projects in these countries serve as proof of concept, with the technology having been implemented successfully in individual cases. However, there has been no large scale or long term trial to date.

Box 1. **Key insights from international experience in developing solar boats**

- Solar boats have applications in public transport as well as tourism. They have not been used as fishing boats thus far, likely because they cannot withstand the stronger currents associated with open water where most fishing activity takes place.
- Solar boats deliver greater financial return over their lifetime as compared to diesel boats, despite the higher initial capital investment required. This is due to low operational and maintenance costs.
- Manufacturers such as NavAlt in India have developed commercially successful prototypes, in particular a 75 passenger ferry costing approximately BDT 20 million ($238,000).

The most successful application of this technology has been a daily commuter ferry, christened Aditya, run by the Kerala State Water Transport Department (SWTD) in India. The 75 passenger ferry is powered by a 20 kW solar panel, and can run for between 5-6 hours without fuel. The boat has a 50kWh battery pack on board to store solar energy collected during the day, but also provides a 'plug and charge' option for cloudy days when it has to be charged via a grid connection. Aditya was a new build vessel manufactured by a local company, NavAlt Solar.

While the solar ferry has higher capital costs, it has drastically lower operating costs due to the savings on diesel. Aditya cost approximately 17 million INR to construct, compared to 15 million INR for an equivalent diesel boat (20 million BDT vs 18 million BDT), and was funded by the SWTD with a 30-50% subsidy from the Ministry for New and Renewable Energy. The boat saves the government about 42,000 litres of diesel a year (which would otherwise cost 2.2 million INR or 2.6 million BDT). Tickets are priced at 4 INR (5 BDT) per 15 minute journey.

Tram Chim National Park in Vietnam operates six solar boats for eco-tourism, but this technology is not wide spread. The technology was developed by Vietnamese farmers in the Dong Thap province, and later adopted by the national park to provide a quiet boat service that does not disturb the ecosystem.[6] The boats are capable of running at 20 kmph (approximately 10 knots), and are powered by two solar panels, and two batteries to store the energy.[7]The solar boats at Tram Chim national park are at least partially funded by fees charged for use. Each 35 minute tour costs 700,000 VND (about 31 USD).[8]

[6]Tourism Cambodia. (2015). Solar boats set sail in Vietnam. Retrieved from https://www.tourismcambodia.com/news/worldnews/18284/solar-boats-set-sail-in-vietnam.htm

[7]International Business Times. (2015). Solar-powered boat capable of 20kph invented by Vietnamese farmers. Retrieved from https://www.ibtimes.co.uk/solar-powered-boat-capable-20kph-invented-by-vietnamese-farmers-1505437

[8]Vietnam National Administration of Tourism. (2015). Eco-friendly tour launched at Tram Chim National Park. Retrieved from http://www.vietnamtourism.com/en/index.php/news/items/9838 http://www.vietnamtourism.com/en/index.php/news/items/9838

3 Potential to develop the business model at scale and next steps

To continue to develop the technology and business models for solar boats, the following steps will be required:

1. **Technical specification of boats suitable for inland waterways.** This may follow an evaluation of the five pilot boats already trialled, incorporating the best attributes. It could also include trial of new technologies which may be better suited to some specific challenges of operating in inland waterways (for example potentially fibre boat bodies combined with solar panels). The current trials have been new build solar-diesel hybrids – it may be worth exploring the possibility of retrofitting existing boats if this could be cost effective.

2. **Trials and ticketing for inland waterways, not for eco-tourism market.** While the existing trials are showing success operating on lakes and for eco-tourism, the large scale market potential is in application as commuter ferries on inland waterways. While these markets have existing ticketing and pricing for diesel boats, trials will need to be carried out to make sure the solar boat technologies can support a similar occupancy level, reliable trips per day, and can generate the same ticket prices and revenue. At the moment this is assumed on the basis that the solar boats would act as a replacement for diesel ferries, with equivalent pricing and revenue generation, which should be tested in a small number of pilot projects.

3. **Robust financial modelling to identify key parameters to determine suitable business models and financing structures.** The focus to date has largely been on technology trials, and this first step still needs to be developed further before a commercial market can be established. More structured technical and financial analysis will need to be undertaken to identify the key assumptions and parameters which are currently uncertain and could have important implications for financial returns. For example, as described above, the ranges around operational costs and revenue generating potential are largely unknown at the moment, and even a small variation in the assumptions behind these parameters could have a large impact on the financial returns to potential investors.

4. **Assess interest from financiers (IDCOL) and project developers to develop commercial model.** We understand that initial conversations have been held with IDCOL to investigate setting up a financing structure similar to that used for solar mini-grids and solar irrigation. This should be explored further and a number of issues worked out. Such as:
    - what will be the term of loans, and grace period?
    - who will provide the grant and concessional loan finance?
    - Is there an active market of project sponsors, technology providers, and capacity to operate and maintain the boats?

   A similar discussion could be had with Bangladesh Bank, to understand how solar boats could be included in their green financing scheme.

Once these further exploratory studies are completed, the business models should be revisited, and an investment case presented to national and international investors.

Annex: List of Key Sources for Solar Energy Projects

	Institution	Role	Relevant personnel and Contact information
1.	Power Division	Policy maker for Power Sector, renewable energy generation and energy efficiency. Oversees all activities related to power generation, transmission and distribution, incentive mechanisms and R&D	Mohammad Alauddin, Joint secretary (Renewable Energy) Biddut Bhaban, Power Development Board, Abdul Gani Road, Dhaka Tel: 02-9574406 Email: mohammad_alauddin4124@hotmail.com
2.	Sustainable Renewable Energy Development Authority (SREDA)	Coordinates, conducts R&D on renewable energy and energy efficiency and mobilizes investment for renewable energy projects	Siddique Zobair, Additional Secretary, Energy Efficiency & Conservation IEB Building (9 & 10th floor) Ramna, Dhaka-1000 Tel: +8802-55110340/+88-02-55110335 Ext -130 Email: siddique.zobair@gmail.com
3.	Infrastructure Development Company Limited (IDCOL)	Promotes, develops and finances infrastructure including renewable energy, and energy efficient projects	Farzana Rahman (Senior Vice President and Unit Head (Investment) Renewable Energy) UTC Building, 16th Floor, 8 Panthapath, Kawran Bazar, Dhaka-1215, Bangladesh Tel. 88-02- 9102171-8/261 Email: frahman@idcol.org
4.	Bangladesh Bank	Central bank and apex regulatory body for the country's monetary and financial system, finances renewable energy projects	Qazi Mutmainna Tahmida (Joint Director, Sustainable Finance Department) Motijheel, Dhaka Bangladesh Tel: 88-02-55665001-20 Email: qm.tahmida@bb.org.bd
5.	Bangladesh Agricultural Development Corporation (BADC)	Promotes agriculture development, including financing of solar irrigation pump projects	Md. Shah Alam Siddiqui (Chief Engineer) Krishi Bhaban 49-51, Dilkusha Commercial Area Dhaka-1000 Tel: 9556080-7 E-mail: info@badc.gov.bd
6.	Bangladesh Rural Electrification Board (BREB)	Distributes electricity to rural communities, shareholder of solar energy and, contracts, finances and sets up solar energy projects	Sayed Mahbubur Rahman, Director (Technical) Head Office, Nikunja-2, Khilkhet, Dhaka-1229 Tel: 88-02-8916424-28 Email: rebdirpp@gmail.com
7.	Bangladesh Infrastructure Finance Fund Limited (BIFFL)	This Non-Banking Financial Institution issues bonds and debt instruments and equity offerings for infrastructure projects	S. M. Farmanul Islam, Executive and CEO, Borak Unique Heights, Level-3, 117 Kazi Nazrul Islam Avenue, Eskaton Garden, Dhaka Tel: +880-2-8333238-9Email: ceo@biffl.org

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Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

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

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

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