# Sourojan: A Low Cost and Profitable Solar Boat for Coastal Tourist Areas

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***Abstract*—The pursuit of technology to enhance quality of life is a central focus across various research disciplines. Particularly in coastal tourism areas, the economic sustainability heavily relies on boats. The development of a low-cost solar-powered boat as an innovative solution to the challenges faced by coastal tourism areas reliant on fossil fuels. Escalating fuel prices and resource limitations have prompted the need for alternative energy sources to sustain economic activities in these regions. Our research focuses on introducing a solar-powered boat that aims to replace conventional fossil fuel-based boats, thereby reducing operational costs and improving profitability for boat operators. This solution integrates photovoltaic arrays and battery storage to harness solar energy effectively. Our findings indicate that the proposed solar engine boat offers better performance and profitability compared to traditional octane-based boats. This transition not only addresses environmental and economic concerns but also contributes to the socioeconomic upliftment of communities dependent on coastal tourism.**

***Index Terms*—Solar Energy, Low-cost and Profitable Boat Prototype**

## I. Introduction

Tourism plays a pivotal role in the economic landscape of nations, often serving as a significant driver of growth and development. Numerous countries rely heavily on the tourism sector as a key contributor to their overall economic prosperity. For instance, Malta, Croatia, Thailand, Jamaica, and Iceland are among the top five nations globally whose economies are notably reliant on tourism [1]. Concurrently, countries such as the United States, China, Germany, Japan, and the United Kingdom are recognized for possessing substantial tourism industries [1]. Additionally, there are countries actively transitioning their primary economic focus toward tourism, with Abu Dhabi serving as a noteworthy example of this trend.

Coastal areas comprising seas, rivers, and islands represent significant assets for the tourism industry. The emergence of novel destinations, increased opportunities for adventurous activities, and a growing interest in wildlife observation (such as birds, whales, and corals) continue to sustain the appeal of coastal resorts, attracting a substantial proportion of global tourists annually. For instance, as per the European Commission (1998), 63% of European vacationers exhibit a preference for coastal destinations. This trend is reflected on a global scale, with international arrivals (defined as arrivals from foreign countries) demonstrating a consistent upward trajectory, rising from 25 million in 1950 to exceeding 700 million in 2002, showcasing an average annual growth rate of 6.6% [2]. Researchers indicate that in 2006, approximately 350 million tourists will be visiting the Mediterranean coastal region alone by 2020 [3]. The Mediterranean basin, when regarded as a unified geographical entity, stands as the preeminent global tourism locus, garnering approximately one-third of the world's international tourists, constituting 306 million out of 980 million worldwide. Moreover, it yields in excess of a quarter of international tourism revenue, totaling 190 billion Euros out of 738 billion Euros worldwide. Projections indicate that the Mediterranean region is poised to attain 500 million international tourist arrivals by the year 2030 [2]. Notably, the vitality of coastal tourism is closely intertwined with maritime infrastructure, particularly boats, which play a pivotal role in facilitating tourists' exploration of the natural splendor found in coastal areas.

Boats serve as a primary source of livelihood for communities residing in proximity to seas, rivers, and islands. They constitute an integral aspect of their daily activities, facilitating the transportation of essential commodities across water bodies. Regions reliant on boats often boast renowned seafood industries that garner global recognition. Consequently, many individuals in these areas opt for fishing as their primary occupation, utilizing boats for this purpose. The predominant fuels employed in these boats are fossil-based, such as octane and diesel. However, the escalating prices of octane and diesel pose significant challenges, particularly for impoverished and less educated coastal and riverside communities. This price surge has emerged as a critical impediment to their sustenance and daily income. Consequently, there is an urgent need to explore alternative solutions to fossil fuels, aiming to reduce fuel costs and ensure the viability of these communities' livelihoods.

The exploration of alternative energy sources in maritime transportation commenced in the early 2000s with the aim of reducing reliance on natural resources and mitigating environmental impact [4]. The advent of solar energy has garnered significant attention from researchers seeking to leverage this resource across various domains. Numerous studies have ex-

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plored the feasibility of employing renewable energies such as solar and photovoltaic systems as substitutes for traditional fuels. Conversely, the escalating cost [5] and finite nature of fossil fuels have rendered their continued use increasingly challenging, prompting a shift toward renewable alternatives [6].

Many nations are already experiencing the tangible benefits of renewable energy vis-à-vis fossil fuels [7]. Researchers are actively engaged in designing and developing models that aim to supplant fossil fuels with solar energy in both land-based vehicles and maritime vessels [8]. One promising approach to harnessing solar energy on ships involves utilizing catamaran boats with flat top structures to accommodate solar panels. Moreover, the efficiency of solar energy extraction from these panels can be enhanced through quadratic Maximization Maximum Power Point Tracking (MPPT) algorithms executed by KY converters, which then convert the generated energy into AC voltage using multilevel inverters [9].

Bangladesh, situated in South Asia, is characterized by its dense population, low-lying geography, and predominant riverine landscape, boasting a 580 km (360 miles) coastline along the northern edge of the Bay of Bengal [10]. The nation's topography is largely defined by the expansive delta plains formed by the Ganges (Padma), Brahmaputra (Jamuna), and Meghna Rivers, along with their numerous tributaries, encompassing approximately 80% of its territory [11]. Notably, Bangladesh is home to Cox's Bazar, hosting the world's largest sea beach, attracting significant settlement and activity along its riverbanks and coastal areas [12].

The communities residing in these regions are predominantly characterized by low socioeconomic status and limited educational opportunities. Their livelihoods are intricately linked to the rivers and sea, particularly reliant on boats for transportation, trade, and fishing activities essential for their daily sustenance. However, the reliance on traditional boats fueled by octane and diesel has posed challenges, given the escalating costs and the finite supply of octane, contributing to economic strains for these communities [13].

In response to these challenges, our research endeavors focus on the development of a cost-effective and sustainable solution in the form of solar-powered boats.This paper introduces a cost-effective prototype designed to substitute fossil fuels with renewable energy sources in maritime transportation, specifically focusing on boats. Solar energy is proposed as the primary energy source for such vessels. By harnessing solar energy as the primary fuel source, these boats aim to reduce reliance on octane while simultaneously providing a more profitable and efficient alternative for riverine and coastal communities. The primary goal of our design initiative is to alleviate the financial burdens associated with boat usage, thereby improving the quality of life for those residing in proximity to rivers and seas, ultimately fostering economic stability and enhanced well-being. The research emphasizes minimizing the initial construction expenses of these boats while also conducting a comparative analysis of the day-to-day operational costs between the proposed renewable energy system and traditional fossil fuel systems. The result analysis presented in this study suggests that adopting the proposed system would yield profitability with more speed for boat operators.

The subsequent sections of this paper are organized as follows: Section II provides an overview of existing research on solar-powered boats. Section III presents an analysis of survey findings conducted in developing countries like Bangladesh regarding the usability of solar boats. Section IV elaborates on the methodology employed in the development of our proposed solar engine boats. Section V analyzes the results derived from our research. Finally, in Section VI, we summarize our research findings and discuss potential avenues for extending this research.

## II. Related Work

Several research initiatives have focused on advancing methodologies in boat construction, leading to notable developments such as the creation of an autonomous sailing vessel known as the "ASV Roboat" [14]. This vessel's navigation is entirely managed by a set of autonomously operating technical systems. The ASV Roboat has successfully completed extended research missions in the Baltic Sea and has achieved recognition by winning multiple international competitions in robotic sailing in recent years. During these missions, a hydrophone attached to the boat's keel recorded acoustic signals from several whales, resulting in the collection of valuable data regarding the presence of these marine animals in the sea.

Juraci Carlos de Castro Nóbrega et al [15] designed a small solar boat design which focuses on developing a methodology for simple, step-by-step calculations for solar boats, taking into account considerations such as clean energy usage, minimal boat weight, and cost-effective fabrication. Factors considered include boat weight, sheet specifications, materials used, propulsion systems, solar panel requirements, battery capacity, engine specifications, and ultimately, the commercial pricing of the boat. The Nautilus, designed as a solar-powered pleasure boat, is primarily intended for day and weekend trips. However the building cost of the boat is extremly high for applying them in developing countries.

The advancement of technology in the realm of solar-powered boats is a topic of ongoing development. Kurniawan et al. [16] discuss the utilization of a quadratic Maximum Power Point Tracking (MPPT) system to optimize solar energy efficiency through solar panels, particularly in situations with rapid changes in solar irradiation. Mahmud et al. [17] emphasize the critical need to gradually reduce dependence on conventional energy sources while promoting renewable energy alternatives. They highlight the potential of solar energy in ships for inland navigation, particularly in emerging nations, as a means to reduce reactionary energy reliance and overall costs.

Nasirudin et al. [18], [19] introduce a two-stage optimization process for solar-powered ships. The first stage involves optimizing the boat size to minimize thrust power requirements using the Golden Section procedure. The second stage focuses on optimizing the size of the photovoltaic (PV) system to determine the number of PV modules and batteries required while minimizing costs, employing the Simplex procedure.

Spagnolo et al. [20] propose a Solar-Electric Ship designed for transferring excursionists along coastal areas, canals, and ponds. Their system aims to replace conventional energy sources with electric power, albeit with a slight reduction in power output, without significantly altering the weight and dimensions of the ship.

Rodrigues et al. [21] note that during the design phase, increasing the area for solar panels was necessary to ensure optimal machine performance. They also emphasize the importance of using lightweight and cost-effective materials in boat construction, such as wood and fiberglass, due to their affordability and low weight. Additionally, they mention the challenges posed by environmental conditions such as low irradiation caused by shadows and rainfall in certain areas, which can impact solar energy generation.

## III. SURVEY

The user acceptance of novel technology within river and sea environments constitutes a pivotal determinant for the efficacy of our design. Consequently, we intend to conduct a comprehensive survey encompassing river and sea zones to assess the necessity of the proposed system for boat reconstruction and to gauge public receptiveness. Our survey will target specific locations proximate to rivers and seas, allowing us to delve into the intricacies of the prevailing challenges. Notably, we have identified Rangamati, Bandarban, and Cox's Bazar in the Chittagong region as focal points for our investigation.

Rangamati and Bandarban are characterized by hilly terrains, hosting numerous rivers, both known and lesser-known. Conversely, Cox's Bazar boasts the distinction of being home to the world's longest sea beach, offering a prime vantage point for evaluating maritime conditions. Notably, within these areas are designated locales known as "JELEPOLLI," where fishermen reside. Our inquiries with these communities have yielded insights into the specifications of their current boat fleets. According to our findings, the initial investment for these boats amounts to 1,50,000 BDT, with a maximum attainable speed of 8.33 km/h and a carrying capacity of up to 500kg. Additionally, these boats require 5 liters of octane fuel daily, priced at 110 BDT per liter, along with associated maintenance costs.

TABLE I: Monthly Maintenance Cost of the Current boats

| Field of Cost Monthly | Daily Cost Price | Annual Cost Price |
|---|---|---|
| Fuel Cost | 550 BDT(Daily) | 1,98,000 BDT |
| Maintenance Cost | 1000 BDT (Monthly) | 12,000 BDT |
| Square Parts Expenditure | | 10,000 BDT |
| **Total Annual Cost** | | **2,20,000 BDT** |

Their annual total income remains relatively stable, with earnings of 1000 BDT per day equating to an annual income of 3,60,000 BDT. Consequently, their annual profit from existing boats amounts to 1,40,000 BDT (3,60,000 BDT - 2,20,000 BDT). However, escalating octane prices and limited supply are eroding this profit margin significantly. This challenging scenario has prompted discussions regarding our proposed boat system, which involves an installation cost of 2,53,000 BDT—considerably higher than the current boats showing in table I.

Nevertheless, our system eliminates the need for octane fuel, thereby replacing the entire annual fuel cost. Additionally, maintenance costs for our boats are substantially lower. Consequently, the annual profit derived from our boats surpasses that of the current models. Furthermore, the new boats boast a speed of 10 km/h, significantly faster than the current ones, which translates to increased daily income potential.

Upon presentation of these advantages, the fishermen expressed keen interest in adopting our boats over their current ones, citing potential benefits to their annual profits and overall quality of life. While the initial installation cost is substantial, we aim to implement cost-minimization strategies. However, the potential for a significant increase in profit easily justifies this upfront investment. Overall, the consensus among fishermen in the area is that the adoption of our proposed solar-powered boats will enhance their annual profits and significantly improve their livelihoods.

## IV. METHODOLOGY

### A. Block Diagram

"Fig 1" illustrates the schematic diagram of the proposed system. Within this figure, photovoltaic arrays are depicted as capturing and storing solar energy from the sun. The Maximum Power Point Tracking (MPPT) refers to an algorithm integrated into charge controllers. This algorithm is designed to optimize the extraction of the maximum available power from the PV module under specific operating conditions. The voltage level at which the PV module can generate the highest power output is commonly referred to as the maximum power point or peak power voltage.

The maximum power output of a solar system is subject to fluctuations due to variations in solar radiation, ambient temperature, and the temperature of solar cells. Utilizing MPPT technology, we ascertain whether the energy generated by the photovoltaic arrays is sufficient to propel the boat or if additional power from the batteries is necessary. A charge controller, also known as a charge regulator or battery regulator, plays a pivotal role in regulating the flow of electric current to and from batteries. Its primary functions include preventing overcharging, safeguarding against over voltage which could diminish battery performance or longevity, and mitigating potential safety hazards.

The charge controller receives information via management control to either charge the battery or directly supply power for propulsion. When energy from the photovoltaic array is directed towards a fully discharged battery bank, the charge controller monitors the energy inflow during the charging process. Upon reaching full charge, the energy flow is diverted

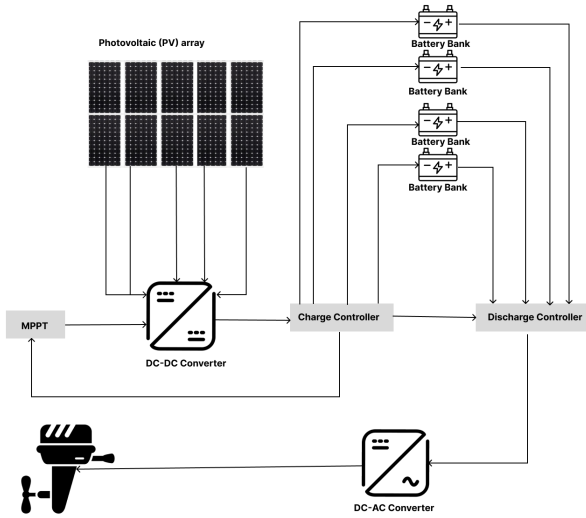


Fig. 1: Block Diagram of the Proposed System

to another fully discharged battery bank. In the absence of fully discharged battery banks, the charge controller redirects the energy flow either to loads via a discharge controller or to the grid if connected.

The discharge controller manages the discharge of a single battery bank at a time. During discharge, it measures the energy flow and compares it with data stored during the previous charging cycle. This comparison allows for the assessment of battery aging and determination of actual stored energy capacity.

### B. Driving Algorithm

The breakdown of our driving algorithm for a solar-powered boat based on "Fig 2" is elaborated below:

- **Charging from Solar Cells :** The batteries start charging whenever sunlight is present and the solar cells are actively generating electricity.
- **Low Charge Level Handling :** If the charge level of the batteries is equal to or less than 30%, the load (which could be the boat's motor or other systems) operates directly without storing any additional charge in the battery.
- **Moderate to High Charge Level Handling :** When the charge level of the batteries reaches or exceeds 30%, the system switches to a mode where batteries are both charging from solar cells and discharging to power the load.
- **Storage Voltage Activation :** When the charge voltage level reaches 30% above the threshold, the load is powered using stored energy from the batteries rather than directly from the solar cells.
- **Completion of Operation :** The operation of the solar-powered boat continues following these steps until the task or journey is completed.

This algorithm ensures efficient utilization of solar energy by dynamically managing the charging and discharging of batteries based on their charge levels. It optimizes energy usage to prolong the operation of the boat while maintaining a reliable power supply for propulsion and onboard systems.

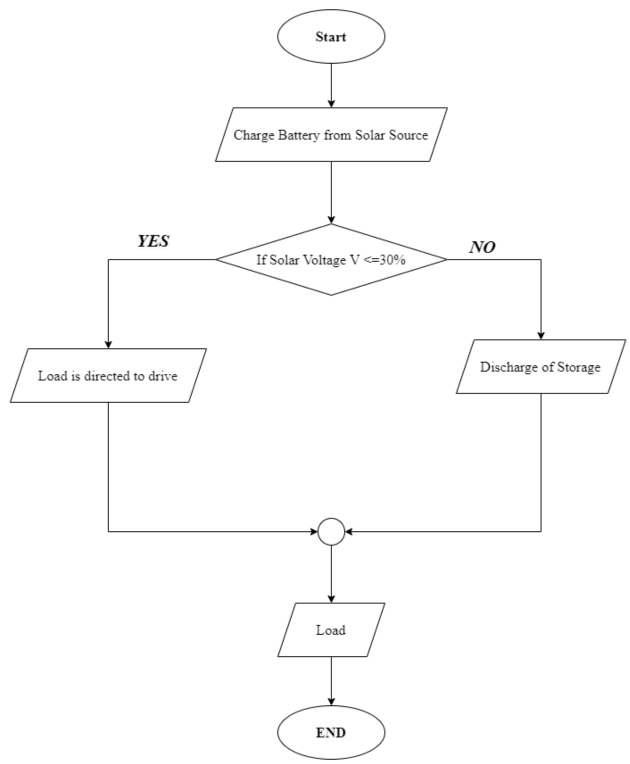


Fig. 2: Driving Algorithm of Sourojan

### C. Cost Analysis of the proposed system

Our research objectives included optimizing the cost efficiency of solar boat construction through the utilization of economically viable equipment that maintains performance standards. Certain components, such as the hull, motor, and propeller, are ubiquitous across various boat types, while labor costs may fluctuate based on geographical location. Table II enumerates the equipment employed in our prototype along with their corresponding market prices. The estimated total cost of our solar boat amounts to 2,53,400 BDT (approximately 3,000 USD). Noteworthy advantages of these solar-powered vessels include their one-time investment nature, obviating substantial fuel expenses, and requiring minimal maintenance expenditure. Additionally, they boat has a capacity to transport up to 5-6 passengers and carry loads weighing up to 550 kg per trip.

## V. Result Analysis

### A. Float Testing

The prototype underwent testing in a controlled aquatic environment, specifically a river. The visual representation of

TABLE II: Budget Calculation for Prototype Model

| ITEM NAME | UNIT | MODEL | PRICE |
|---|---|---|---|
| Battery ( 12v 200Am) | 4 pcs. | U27-36XP model. | 12000x4=48000/= |
| Solar panel | 500 watt 1pcs. | 1.580mm X 798mm X 46mm | 100000/= |
| Hull | 1 pcs. | Original wood | 70000/= |
| Motor | 1 pcs. | Model-ST335xU | 15000/= |
| Labor Cost | 4 Person. | N/A | 20000/= |
| Propeller | 1 pcs. | 5 Inch | 400/= |
| **Total Annual Cost** | | | **2,53,400 BDT** |

Fig. 3: Solar Electric Boat(Sourojan) Prototype

the proposed solar boats can be observed in "Fig 3". During testing, the boat operated autonomously without a driver, successfully navigating the pool in manual mode. This initial test yielded highly satisfactory results, indicating a robust performance capability.

Upon analysis, it was noted that the boat demonstrated an operational duration of 5 hours within the river environment, as depicted in "Fig 4". This duration sufficed to ascertain the efficacy of the solar panel in charging the onboard batteries. However, there arose a potential concern regarding the preset maximum charging threshold. It was speculated that this threshold might be set excessively high, potentially impeding the boat's ability to simultaneously navigate and charge. This inference was complicated by the fluctuation in battery voltage, particularly when subjected to variable loads. Further investigation and refinement of the charging threshold are deemed necessary to optimize the boat's operational efficiency.

Fig. 4: Floating successfully in the pool

### B. *Performance Comparison of Proposed System*

Boats play a vital role in the economic dynamics of coastal tourism regions. The functionality of these areas is heavily reliant on maritime vessels, with the primary propulsion source being octane fuel. Challenges such as escalating costs and restricted availability of octane fuel are compounded by environmental concerns stemming from the emission of CFC gases during its combustion. Our research endeavors to address these issues by proposing a solution that not only mitigates the challenges associated with rising costs and limited supply of octane fuel but also prioritizes environmental safety. Table III presents a comparative analysis between the current conventional octane engine boats and our proposed solar-powered boats. Upon thorough examination of the data, our findings shown in "Fig 5" demonstrate that solar-powered boats offer a cost-effective and economically viable alternative for coastal tourism regions while also contributing positively to environmental preservation.

TABLE III: Current system vs Proposed System

| Comparison Type | Current system (octane engine) | Propose System (solar boat) |
|---|---|---|
| Installation cost | 1,50,000/- | 2,53,400/- |
| Annual Fuel cost | 1,98,000/= | Free cost |
| Speed | 8.33km/h | 10km/h |
| Energy type | No renewable energy | Renewable power energy |
| Effect in enivironment | Air, water and release huge amounts of Greenhouse gasses into the atmosphere | CFC Free, so it is green technology |

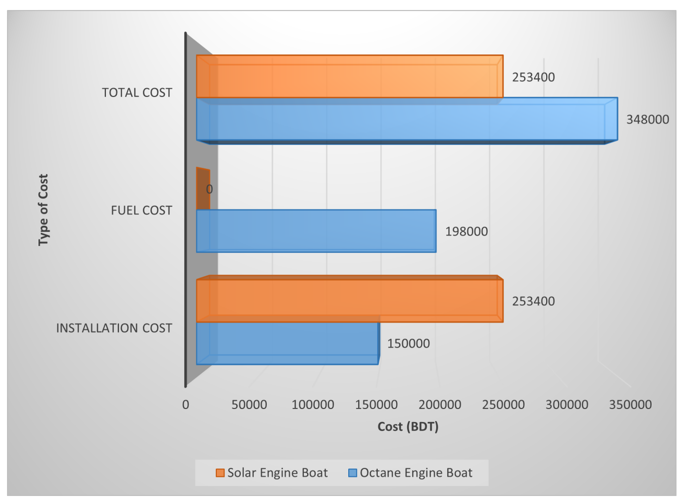


Fig. 5: Cost Comparison of Solar System with Octane System

In our analysis, we have juxtaposed the cost of our solar-powered boat, Sourojan, with that of existing solar system boats as referenced in [15] and depicted in "Fig 6". The data presented in "Fig 6" unequivocally indicates that the cost of Sourojan is substantially lower in comparison to the already established solar system boats. This outcome aligns with our primary objective of minimizing the construction costs associated with solar boats.

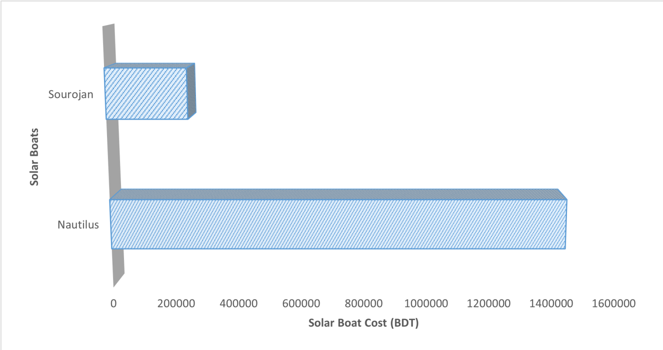


Fig. 6: Cost Comparison of Existing Solar Systems

## VI. Conclusion

Researchers across disciplines are actively engaged in addressing economic challenges by developing economically viable solutions with low costs. Understanding community perceptions towards scientific solutions for economic issues is a key focus. This study aims to design and develop cost-effective boats fueled primarily by renewable solar energy for communities in riverine and coastal tourist areas, where boats play a crucial role in the economic framework.

Our survey findings indicate that octane and diesel are the primary fuels for these boats. However, the escalating cost of octane presents a significant challenge for communities heavily reliant on these vessels. The limited availability and rising prices of octane have adversely affected profit margins, given the relatively fixed income generated from these boats. Our proposed solution involves harnessing renewable solar energy as an alternative fuel source. Solar energy is captured through photovoltaic arrays and stored in batteries. The boat utilizes energy directly from these arrays if sufficient for propulsion, while simultaneously recharging the batteries using the photovoltaic system. When solar energy is insufficient, the boat taps into stored battery energy.

This initiative offers a viable solution for reducing reliance on octane and fossil fuels in riverine and coastal communities. It addresses both environmental concerns and economic challenges arising from escalating fuel prices and limited fossil fuel resources in these regions.

Although initial boat construction costs may be higher compared to conventional boats, efforts are underway to explore cost-effective materials and technologies for production. Deployment plans aim to minimize construction costs, making the proposed system accessible to individuals with varying economic backgrounds. Additionally, efforts are being made to introduce these environmentally friendly boats in riverine and coastal tourist areas, although further research is required to assess their reception and feasibility within economically disadvantaged communities in these regions.

## References

[1] howmuch.net. (2017) The travel and tourism economy. [Online]. Available: https://howmuch.net/articles/travel-tourism-economy-2017

[2] M. Honey and D. Krantz, "Global trends in coastal tourism," Center on Ecotourism and Sustainable Development, Tech. Rep., 2007.

[3] J. L. D. John Davenport, "The impact of tourism and personal leisure transport on coastal environments: A review," *Estuarine, Coastal and Shelf Science*, vol. 67, pp. 280–292, 2006.

[4] J. Fernández Soto, R. Garay Seijo, J. Fraguela Formoso, G. Gregorio Iglesias, and L. Carral Couce, "Alternative sources of energy in shipping," *Journal of Navigation*, vol. 63, no. 3, p. 435–448, 2010.

[5] Wikipedia. (2018) Gasoline and diesel usage and pricing. [Online]. Available: https://en.wikipedia.org/wiki/Gasoline_and_diesel_usage_and_pricing

[6] E. McLamb. (2011) Fossil fuels vs. renewable energy resources. [Online]. Available: https://www.ecology.com/fossil-fuels-renewable-energy-resources

[7] B. L. Xiaoling Ouyang, "Impacts of increasing renewable energy subsidies and phasing out fossil fuel subsidies in china," *Renewable and Sustainable Energy Reviews*, vol. 37, pp. 933–942, 2014.

[8] M. R. P. Samuel Freire, *Designing and Building a Solar Powered Model Boat*. International Baccalaureate Organization, 2009.

[9] A. Kurniawan, "A review of solar-powered boat development," *IPTEK The Journal for Technology and Science*, vol. 27, 04 2016.

[10] J. Cohen, "Bay of bengal cyclones," 2024. [Online]. Available: https://www.nccs.nasa.gov/news-events/nccs-highlights/bay-of-bengal-cyclones

[11] FAO, "Transboundary river basins overview-ganges-brahmaputra—meghna river basin," 2011.

[12] T. Hà, "World longest beach, cox's bazar, a must-visit place in bangladesh," 2024. [Online]. Available: https://vietnamnews.vn/life-style/1446364/world-longest-beach-cox-s-bazar-a-must-visit-place-in-bangladesh.html

[13] J. U. Chowdhury, "Issues in coastal zone management in bangladesh," *Teacher. Buet. Ac. Bd*, 2013.

[14] R. Stelzer and K. Jafarmadar, "The robotic sailing boat asv roboat as a maritime research platform," *INNOC-Austrian Society for Innovative Computer Sciences, Austria.*, 2010.

[15] J. C. de Castro Nóbrega and A. Rössling, "Development of solar powered boat for maximum energy efficiency," *International Conference on Renewable Energies and Power Quality (ICREPQ'12)*, 03 2012.

[16] A. Kurniawan, "A review of solar-powered boat development," *IPTEK The Journal for Technology and Science*, vol. 27, no. 1, 2016.

[17] K. Mahmud, S. Morsalin, and M. I. Khan, "Design and fabrication of an automated solar boat," *International Journal of Advanced Science and Technology*, vol. 64, pp. 31–42, 2014.

[18] A. Nasirudin, R.-M. Chao, and I. K. A. P. Utama, "Solar powered boat design optimization," *Procedia engineering*, vol. 194, pp. 260–267, 2017.

[19] C. V. Papade, S. S. Kulkarni, S. P. Kulkarni, and K. N. Dindure, "Design and analysis of iot-based two-seater solar boat," *International Journal of Engineering Applied Sciences and Technology*, 2023.

[20] G. S. Spagnolo, D. Papalillo, A. Martocchia, G. Makary *et al.*, "Solar-electric boat," *Journal of Transportation Technologies*, vol. 2, no. 2, pp. 144–149, 2012.

[21] E. G. Rodrigues, S. Bindu, and V. Chandran, "Design and fabrication of solar boat," *International Journal of Electrical Engineering & Technology (IJEET)*, vol. 7, no. 6, pp. 01–10, 2016.