| Program Profile | | |
|---|---|---|
| Program | Program name | "Modelling and Assessment of A Hybrid System for OTEC and Wind Energy at Bangladesh's Coastal Region " |
| | Category | A1 |

| Summary of Program | |
|---|---|
| Program Name | "Modelling and Assessment of A Hybrid System for OTEC and Wind Energy at Bangladesh's Coastal Region " |
| Category | A1 |
| Abstract of Program | This study presents the modeling and assessment of a hybrid renewable energy system that integrates Ocean Thermal Energy Conversion (OTEC) with wind energy to support power generation along the coastal region of Bangladesh. Given that OTEC plants require continuous external electricity to operate subsystems such as seawater pumps, heat exchangers, and control units, this work proposes the use of a co-located wind energy system to fulfill that demand. A 100 MW OTEC plant is simulated to evaluate hybrid configuration with wind-supplied auxiliary power and conventional configuration relying on grid-based fossil electricity. Machine learning algorithms are employed to forecast ocean thermal gradients and wind speed using multi-year historical datasets. Emission analysis is performed to quantify the carbon footprint of conventional auxiliary power consumption, which is then compared against the wind-assisted operation to determine net emission reduction. The novelty of this work lies in the integrated hybridization of OTEC and wind energy, a configuration not previously explored in marine renewable energy systems. This hybrid system can be established as a scalable, low-carbon energy solution for coastal and island regions with access to both oceanic and wind resources. |

| Details of Program | | |
|---|---|---|
| Planning | | |
| Objectives | Long-term Goals | • Establish a scalable hybrid marine energy framework for coastal Bangladesh and other tropical regions.<br>• Promote resilient, low-carbon energy infrastructure that reduces vulnerability to climate impacts (storms, coastal erosion).<br>• Advance industry innovation and infrastructure (SDG 9) through AI-driven hybrid marine energy forecasting and integration.<br>• Ensure sustainable use of ocean resources (SDG 14: Life Below Water) without ecological disruption.<br>• Provide a replicable model for integrating OTEC with wind and potentially other renewables in underserved coastal zones globally.<br>• Contribute to Bangladesh's energy security and sustainable development, while supporting multiple UN SDGs in the long term. |
| | Short-term Targets | • Conduct feasibility studies for OTEC (Ocean Thermal Energy Conversion) integration in Bangladesh's coastal areas.<br>• Develop and test machine learning models for forecasting oceanic and atmospheric conditions to support adaptive system operation.<br>• Design and simulate a hybrid OTEC–wind energy model to address OTEC's dependence on continuous external power. |

| | | |
|---|---|---|
| | | • Evaluate operational reliability and efficiency of the hybrid system under local climatic and oceanographic conditions.<br>• Align project outcomes with SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action) by reducing fossil-based dependence in renewable setups. |
| | Rationale | Bangladesh’s coastal regions face a unique convergence of challenges- persistent energy poverty, unreliable grid connectivity, and heightened vulnerability to climate change impacts such as storms and erosion. Despite abundant marine and wind resources, conventional renewable systems in these areas often underperform due to intermittency and operational constraints. Ocean Thermal Energy Conversion (OTEC) offers a promising alternative but remains limited by its dependence on external grid power, which undermines its sustainability. Integrating wind energy as a dedicated auxiliary source can overcome this limitation by ensuring continuous operation of critical OTEC subsystems while maintaining a zero-emission profile. Coupled with machine learning–based forecasting for adaptive management, this hybrid system provides a resilient and scalable solution tailored to coastal Bangladesh. The research not only addresses immediate energy access challenges but also contributes to long-term climate action, sustainable infrastructure development, and responsible ocean resource utilization in line with global sustainable development goals. |
| Subject (Leader) | Initiator(s) | Taher Hasan Nakib |
| | Champion(s) | Taher Hasan Nakib |
| Environment | Nature/Society | Coastal regions of Bangladesh face acute energy insecurity, compounded by rising sea levels, cyclones, and erratic grid access. These areas lack stable electricity to power water systems, health facilities, and critical infrastructure. By modeling a hybrid Ocean Thermal Energy Conversion (OTEC) and wind energy system, this project offers a sustainable, zero-emission power alternative for vulnerable coastal populations. The system reduces dependency on fossil fuels for auxiliary OTEC operations, strengthens climate resilience, and ensures cleaner energy access for underserved communities. |
| | Industry/Market | The proposed hybrid model introduces a scalable and modular marine renewable energy solution suitable for Bangladesh’s energy-deficient coastal belt. The system’s modularity allows phased deployment aligned with regional demand. Forecasting tools developed using machine learning (ML) enable optimized performance, making the technology attractive for private-sector renewable energy firms and green infrastructure investors. By eliminating the need for conventional auxiliary power, the project significantly improves the economic feasibility of OTEC plants and sets a precedent for integrated clean energy systems in South and Southeast Asia. |
| | Citizen/Government | This project aligns with Bangladesh’s National Solar Energy and Renewable Energy Policy and supports SDG 7 (Affordable and Clean Energy), SDG 13 (Climate Action), and SDG 14 (Life Below Water). It provides a viable policy model for low-carbon coastal electrification. Engagement with the Sustainable and Renewable Energy Development Authority (SREDA) and the Ministry of Power, Energy and Mineral Resources will help inform national energy planning and promote future adoption of hybrid marine technologies. |

<table>
<tr><td rowspan="3">Resources</td><td>Human resources</td><td>The project requires researchers with expertise in thermal engineering and energy modeling. Additional support may come from data analysts familiar with Python and MATLAB.</td></tr>
<tr><td>Financial resources</td><td>Funding is needed for software licenses (ANSYS, MATLAB, TRYNSYS), publication fees, and possibly conference travel for dissemination.</td></tr>
<tr><td>Technological resources</td><td>Access to historical wind and sea temperature data (NOAA, BMD). MATLAB, Python (TensorFlow/Keras) or equivalent tools for ML modelling. Ocean energy simulation tools (HOMER Pro, MATLAB Simulink). Hybrid system model setup and validation framework. Emission factor datasets and carbon accounting tools.</td></tr>
<tr><td rowspan="3">Mechanism</td><td>Strategy (Weight/Sequence)</td><td>High Weight / Early Execution:<ul><li>Integration of wind turbines as dedicated auxiliary power source for OTEC plants</li><li>Application of LSTM or similar deep learning models for ocean and wind forecast</li><li>Modular 100 MW system simulation to evaluate performance under hybrid and non-hybrid scenarios</li><li>Emission impact quantification by comparing fossil-supplied vs wind-supplied auxiliary loads</li></ul>Medium Weight / Parallel Execution:<ul><li>Forecasting accuracy is critical to ensure system reliability and energy balance</li><li>Wind-OTEC matching logic is key to maintaining uninterrupted OTEC function</li><li>Emission reduction analysis provides policy leverage and climate impact justification</li></ul>Lower Weight / Later Execution:<ul><li>Historical data collection for ocean and wind conditions</li><li>Development and training of ML forecasting models</li><li>Simulation of hybrid and baseline (non-hybrid) OTEC system performance</li><li>Emission factor analysis and carbon offset calculation.</li></ul></td></tr>
<tr><td>Organization</td><td><ul><li>Core Research Team: Led by the principal investigator with expertise in thermal engineering and computational modeling.</li><li>Supporting Roles: Student researchers for simulation and data analysis.</li><li>External Input: Guidance from industry stakeholders and experienced researcers.</li><li>Responsible Institution: World University of Bangladesh, with academic oversight and administrative support for project execution.</li></ul></td></tr>
<tr><td>Culture</td><td><ul><li>Collaborative: Exposure to interdisciplinary domains: marine energy, wind power, ML forecasting.</li><li>Innovation-Oriented: Promotes the adoption of advanced simulation technologies as alternatives to costly experimental testing.</li></ul></td></tr>
<tr><td colspan="3">Doing</td></tr>
</table>

| | |
|---|---|
| Launch date | September 2025 |
| Responsible organization | World University of Bangladesh |
| Program content and process | The program will begin with a comprehensive assessment of the coastal energy landscape in Bangladesh, including resource mapping of thermal gradients and wind availability, as well as analysis of current infrastructure vulnerabilities. This will be followed by the conceptual design of a hybrid OTEC–wind system, focusing on integrating wind power as a dedicated auxiliary source for OTEC subsystems. Advanced machine learning models will be developed and trained on regional oceanic and atmospheric datasets to enable accurate forecasting and adaptive system operation. Simulation studies will then be conducted to evaluate technical performance, efficiency, and resilience under varying climatic conditions. In parallel, environmental impact assessments will be carried out to ensure ecological sustainability. The process will culminate in a techno-economic analysis to determine feasibility, scalability, and alignment with the UN Sustainable Development Goals, with recommendations for pilot-scale deployment in coastal Bangladesh. |
| Key highlights of the content/process | • Addresses energy poverty and grid instability in Bangladesh's coastal regions.<br>• Proposes a hybrid OTEC–wind energy system to ensure continuous, zero-emission operation.<br>• Utilizes machine learning forecasting for oceanic and atmospheric conditions to enable adaptive management.<br>• Enhances resilience against climate change impacts such as storms and coastal erosion.<br>• Integrates techno-economic and environmental assessments for feasibility and sustainability. |
| Differences from traditional approaches | Unlike conventional OTEC systems that rely on grid-supplied or fossil-based auxiliary power, this project integrates wind energy as a dedicated, renewable power source for critical OTEC subsystems (pumps, heat exchangers, and control units). The use of machine learning to forecast both ocean thermal gradients and wind profiles enables dynamic load matching and predictive energy management. This hybridization strategy allows complete off-grid operation, decarbonizes OTEC support systems, and unlocks new deployment opportunities in remote and island regions. |
| Progress as of today | • Initial literature review completed on OTEC dynamics, wind integration.<br>• Historical ocean datasets collected for Bangladesh's southern coastal zones.<br>• Preliminary ML models (LSTM-based) are being trained for temperature gradient and wind forecasting. |
| Problems in implementation | • Ensuring temporal synchronization between wind energy availability and OTEC load demand.<br>• Limited high-resolution oceanographic data for deep-sea modeling.<br>• Integration complexity between OTEC infrastructure and wind turbine systems. |
| Approaches to solve the problems | • Use of predictive ML models (LSTM) to anticipate and align energy availability with demand. |

| | |
|---|---|
| | • Fusion of global (NOAA) and local datasets to reconstruct detailed sea temperature profiles.<br>• Modular design of hybrid system with energy storage buffer for operational flexibility. |
| Completion date, if completed | September 2026 (expected) |
| Seeing | |
| Impacts on students | • Exposure to interdisciplinary domains: marine energy, wind power, ML forecasting.<br>• Hands-on experience with hybrid system modeling and simulation.<br>• Opportunity to contribute to climate-resilient infrastructure development. |
| Impacts on professors | • Strengthens the university's profile in marine and renewable energy research.<br>• Opens pathways for international collaborations in ocean and coastal sustainability.<br>• Positions the institution as a pioneer in hybrid energy modeling in South Asia. |
| Impacts on university administration | • Enhances the university's research profile in renewable and sustainable energy, particularly in emerging marine energy technologies.<br>• Strengthens the institution's global visibility by aligning with cutting-edge interdisciplinary research (energy systems, AI, climate resilience).<br>• Supports the university's contribution to UN Sustainable Development Goals, showcasing commitment to global challenges.<br>• Attracts opportunities for international collaboration and funding from governments, NGOs, and industry stakeholders.<br>• Builds capacity in advanced machine learning and hybrid energy system modelling, boosting the university's academic and technical expertise.<br>• Provides a platform for publications in Q1 journals and high-impact conferences, improving institutional rankings and reputation. |
| Responses from industry/market | • High interest from renewable energy developers working in island electrification<br>• Potential for public-private partnerships to deploy pilot-scale hybrid plants.<br>• Opens doors for coastal infrastructure firms to integrate zero-emission technologies. |
| Responses from citizen/government | • Positive alignment with Bangladesh's Renewable Energy Policy and Power Sector Master Plan.<br>• Potential incorporation into coastal electrification programs and blue economy initiatives.<br>• Support expected from Sustainable and Renewable Energy Development Authority (SREDA). |
| Measurable output (revenues) | • Simulated operation of a 100 MW OTEC–Wind hybrid plant.<br>• Forecast accuracy metrics of ML models for ΔT and wind speed. |

<table>
<tr><td></td><td><ul><li>Emission reduction calculations comparing fossil-powered vs wind-powered auxiliary loads.</li><li>Trained energy modeling professionals and technical capacity building.</li></ul></td></tr>
<tr><td>Measurable input (expenses)</td><td>Software Licenses<ul><li>MATLAB, Python ML libraries, and specialized simulation tools</li><li>Estimated Cost: Moderate</li><li>Justification: Essential for hybrid system modeling, AI-based forecasting, and performance optimization.</li></ul>Human Resources<ul><li>Involvement of research assistants, graduate students, and faculty supervision</li><li>Estimated Cost: Moderate to High</li><li>Justification: Critical for technical expertise, skill development, and producing quality academic outputs.</li></ul>Computing Resources<ul><li>Access to high-performance servers, cloud computing platforms, or advanced workstations</li><li>Estimated Cost: Moderate</li><li>Justification: Required for handling data-intensive simulations and training machine learning models efficiently.</li></ul>Data Acquisition and Management<ul><li>Oceanic and atmospheric datasets (satellite data, meteorological archives, open-source databases)</li><li>Estimated Cost: Low</li><li>Justification: Most data sources are freely available, but require preprocessing, storage, and quality checks for reliable use.</li></ul>Prototype Development and Validation<ul><li>Small-scale or conceptual prototype design for proof-of-concept validation</li><li>Estimated Cost: Medium to High</li><li>Justification: Strengthens credibility, provides practical evidence of feasibility, and increases potential for external funding.</li></ul>Publication and Dissemination<ul><li>Journal submission fees, conference participation, and knowledge-sharing events</li><li>Estimated Cost: Low to Moderate</li><li>Justification: Ensures visibility, academic recognition, and broader dissemination of research findings.</li></ul>Contingency and Miscellaneous<ul><li>Unforeseen expenses such as workshops, collaborations, or minor technical adjustments</li><li>Estimated Cost: Low</li><li>Justification: Offers flexibility to address unexpected requirements without hindering progress.</li></ul></td></tr>
<tr><td>Cost-benefit analysis for effectiveness</td><td><table><tr><th>Item</th><th>Cost/Investment</th><th>Benefits</th></tr><tr><td>Software licenses (MATLAB, Python ML libraries, simulation tools)</td><td>Moderate</td><td>Enables hybrid system modeling, AI forecasting, and performance optimization</td></tr></table></td></tr>
</table>

| | | |
|---|---|---|
| Researcher time and training | Moderate to High | Skills in marine energy, AI, and hybrid integration; publications; student involvement |
| Computing resources (servers/workstations/Colab Pro+) | Moderate | Supports large-scale simulations, ML training, and data-intensive analysis |
| Validation data (oceanic & wind datasets, satellite data, meteorological archives) | Low (mostly open-source, some institutional data access) | Ensures accurate forecasting and credibility of results |
| Environmental and feasibility assessments | Moderate | Guarantees ecological sustainability and practical deployment potential |

| | |
|---|---|
| **Future Planning** | |
| Where does the project go from here? | • Extend the simulation to other coastal and island locations across the Bay of Bengal.<br>• Explore hybrid integration with solar PV or battery storage systems.<br>• Collaborate with government and international donors for pilot plant deployment.<br>• Develop training and policy briefs for national adoption.<br>• Publish forecasting models and system architecture as open-access tools. |
| **Addendum** | |
| Exhibits, pictures, diagrams, etc. | N/A |
| Reports, mimeos, monographs, books, etc. | It is expected to publish one more Scopus-indexed scientific articles within a year months. |
| Others which may help explain the program (including website links) | A final report will be submitted to the university for record-keeping purposes. |