



Assessment of Offshore Wind Energy Potential and Technical Feasibility of a Proposed Wind Farm in Basra Coastal Waters, Iraq

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DOI: <https://doi.org/10.68050/JAMS.2026.682>

Received: 24 September 2026; Accepted: 30 September 2026; Published: 06 October 2026

ABSTRACT

The expanding global demand for sustainable electrical energy has accelerated the deployment of offshore wind power systems. Despite rapid international adoption, offshore wind energy remains unexplored in Iraq, where energy generation remains heavily dependent on conventional, high-emission fossil fuels. This study provides a preliminary technical resource assessment and feasibility analysis for establishing an offshore wind farm in the Iraqi coastal waters of Basra along the Arabian Gulf. High-resolution meteorological datasets (MERRA-2 and ECMWF) covering May to July 2023 were analyzed to evaluate site suitability, wind resource characteristics, and potential electrical yield. A 10 MW offshore wind power plant comprising ten 1.0 MW Leitwind LTW80 LS39.0 Class IIA wind turbines arranged in a regular 2×5 grid layout with 1000 m inter-turbine spacing was modeled to optimize power output while mitigating aerodynamic wake losses. At a 50 m reference height, the mean wind speed was determined to be 7.5 m/s, dominated by prevailing northwesterly wind directions. The total estimated Annual Energy Production (AEP) reached approximately 63,945 MWh/year, with a peak monthly output of 71,799.94 MWh/year equivalent observed in June. Monthly capacity factors ranged from 48.40% to 81.96%, confirming high resource efficiency during peak national demand periods. Numerical modeling of acoustic propagation confirmed that ambient operational noise levels remain within international environmental thresholds. These findings demonstrate that offshore wind generation in the northern Arabian Gulf is technically viable and offers significant strategic value for diversifying Iraq's national energy portfolio.

Keywords: Offshore Wind Energy; Wind Resource Assessment; Offshore Wind Farm; Renewable Energy; Basra; Iraq; Wake Effect; Capacity Factor.

INTRODUCTION

Rising global anthropogenic greenhouse gas emissions have driven surface temperature increases of 1.0–2.0 °C, accelerating severe climate changes globally. Because over 40% of global carbon dioxide emissions stem from heat and electricity generation, the rapid transition to scalable, low-carbon renewable energy systems is critical. Among commercial renewable technologies, wind power is recognized for its technical maturity, structural scalability, and economic viability.

Offshore wind power offers distinct physical advantages over onshore installations, including higher, less turbulent mean wind speeds, reduced aerodynamic fatigue loading, and smaller terrestrial footprint constraints. Locating power plants offshore also minimizes visual and low-frequency acoustic disturbances near populated areas, enabling the deployment of larger, higher-capacity modern turbines. Furthermore, advancements in floating offshore wind turbine (FOWT) platforms allow deployment in deeper marine environments where offshore wind regimes are optimal.

Despite these global developments, offshore wind energy deployment requires significant capital expenditure (CAPEX), specialized marine installation vessels, complex offshore subsea cabling, and logistically challenging operations and maintenance (O&M) programs. Optimizing wind farm layout and turbine positioning is therefore essential to maximize aerodynamic yield, minimize internal wake interference, and reduce the levelized cost of energy (LCOE).

In Iraq, national energy generation remains dependent on direct hydrocarbon combustion, contributing to substantial greenhouse emissions and seasonal supply deficits. Iraq's marine coastline along the northern Arabian Gulf near Basra presents an unstudied area for offshore wind exploitation. While preliminary land-based studies exist, dedicated technical studies evaluating the wind regime and aerodynamic turbine performance in the Iraqi offshore zone have not been published.

This study evaluates the technical feasibility and power production potential of a hypothetical 10 MW offshore wind farm situated in the coastal waters off Ras Al-Bisha, Basra, Iraq. By integrating reanalysis meteorological datasets (MERRA-2 and ECMWF), turbine selection criteria, spatial micro-siting, wake dynamics, and acoustic propagation modeling, this work establishes a scientific baseline for marine renewable energy development in the region.

MATERIALS AND METHODS

Site Description and Wind Data Acquisition

The target geographic location is situated approximately 5 km offshore from Ras Al-Bisha in the Basra Governorate, within the territorial waters of the Iraqi sector of the Arabian Gulf. This location offers open sea exposure, shallow bathymetry suitable for fixed-bottom foundations, and proximity to regional onshore electrical transmission infrastructure in southern Iraq.

High-resolution reanalysis datasets were compiled from NASA's Modern-Era Retrospective Analysis for Research and Applications, Version 2 (MERRA-2) and the European Centre for Medium-Range Weather Forecasts (ECMWF). The data spanned three summer months (May–July 2023), coinciding with Iraq's annual peak electrical demand. Hourly time-series parameters extracted at a reference hub height of 50 m included:

- Horizontal wind speed (v , m/s): Extracted directly at reference altitude.
- Wind direction (θ , degrees): Evaluated in 12 sector direction roses.
- Ambient air density (ρ , kg/m³): Accounting for regional marine atmospheric dynamics.
- Wind shear exponent (α): Determining vertical velocity profile power laws.

Wind speeds were extrapolated across varying height levels using the standard power-law profile:

$$v(z) = v_r \cdot (z / z_r)^\alpha$$

Where $v(z)$ is the wind speed at target height z , v_r is the velocity at reference height z_r (50 m), and α represents the atmospheric stability factor.

Wind Turbine Model Selection

The Leitwind LTW80 LS39.0 Class IIA wind turbine was selected for the simulated offshore deployment based on its low cut-in velocity and suitability for moderate-wind marine environments. The operational and technical specifications of the selected turbine are listed in Table 1.

Table 1. Technical specifications of the Leitwind LTW80 LS39.0 wind turbine.

Parameter	Value / Specification
Rated Electrical Power	1.0 MW
IEC Wind Class	Class IIA
Rotor Diameter	80 m



Hub Height	65 m
Cut-in Wind Speed	3.0 m/s
Rated Wind Speed	~10.5 m/s
Cut-out Wind Speed	25.0 m/s
Marine Protection Standard	Corrosion-resistant offshore coating system

Wind Farm Micro-Siting, Wake and Acoustic Modeling

A 10 MW generation capacity was configured using ten 1.0 MW turbines arranged in a 2×5 rectangular grid. An inter-turbine separation distance of 1000 m (equivalent to 12.5 rotor diameters, 12.5D) was selected to minimize upstream wake-velocity deficits and aerodynamic turbulence interactions.

Wind resource distribution, velocity fields, and array wake interactions were modeled numerically. The power generated by each individual turbine (P_i) as a function of local inflow wind speed (v_i) was derived using the non-linear power curve relation:

$$P_i(v_i) = 0.5 \cdot C_p \cdot \rho \cdot A \cdot v_i^3$$

Where C_p is the turbine power coefficient and A is the swept area ($\pi R^2 = 5026.5 \text{ m}^2$). Noise emission dispersion was calculated across the spatial domain to evaluate offshore environmental impact, assuming an operational sound power level conforming to standard marine noise control guidelines.

RESULTS AND DISCUSSION

Analysis of Marine Wind Resource Characteristics

The meteorological evaluation shows a consistent offshore wind resource during the May–July assessment period. At a reference height of 50 m, the observed overall mean wind speed was 7.5 m/s. Measurements reflect high diurnal stability with maximum velocities coinciding with afternoon and evening thermal grid demand spikes.

Directional analysis indicates a strong, unimodal prevailing wind vector from the North-West sector ($\sim 300^\circ$ – 330°), characteristic of the regional Shamal wind regime. This low directional variability reduces yaw tracking losses and optimizes array orientation.

The empirical wind speed frequency distribution matches the operating characteristics of the selected Class IIA turbine. The highest frequency of occurrence fell within the 7.0–11.0 m/s speed range. Because this range encompasses the rated speed threshold of the LTW80 LS39.0 turbine ($\approx 10.5 \text{ m/s}$), the site enables high power conversion efficiency.

Wind Farm Yield and Performance Assessment

The simulated performance parameters for the proposed 10 MW offshore wind power plant are summarized in Table 2.

Table 2. Simulated monthly power production, equivalent annualized yield, and capacity factors.

Month	Monthly Yield (MWh)	Equivalent AEP (MWh/year)	Capacity Factor (CF)
May	3,600.50	42,395.25	48.40%
June	5,901.40	71,799.94	81.96%



July	5,761.50	70,100.12	80.02%
Period Average	5,087.80	63,945.10	70.13%

Power output increased substantially from May into June and July, yielding high capacity factors of 81.96% and 80.02%, respectively. These high values demonstrate that peak marine wind power generation coincides with Iraq's maximum summer grid loading, driven by domestic cooling demands.

Micro-Siting, Wake Interference, and Environmental Impacts

The simulated gross energy yield of the array across all 12 wind directional sectors reached 15.92 GWh during the three-month period. Array wake losses were calculated at 0.12 GWh, corresponding to a total energy loss due to wake interference and wind speed deficit of 0.74%.

This low array wake loss confirms that a 1000 m (12.5D) grid spacing is sufficient to allow downstream velocity recovery in this prevailing wind regime. Individual turbine capacity factors exhibited high spatial uniformity (78%–83%), further verifying the effective aerodynamic layout.

Acoustic modeling shows that sound levels decay rapidly with marine distance. Standard operational noise dropped below 40 dBA within 500 m of the array boundaries, confirming minimal noise disturbance to onshore communities or nearshore habitats.

Integration, Challenges, and Ecological Considerations

Deploying offshore wind projects in the Iraqi coastal sector presents several technical and environmental considerations:

- **Marine Environment and Logistics:** High sea-surface temperatures, salinity, and potential dust deposition necessitate specialized anti-corrosion coatings and sealed nacelles. Marine geotechnical surveys are required to select appropriate foundation types (e.g., monopiles or jacket structures).
- **Environmental and Ecosystem Dynamics:** Construction and operation may affect local marine ecosystems. Although offshore structures can function as artificial reefs and increase localized habitat heterogeneity, baseline marine impact assessments are necessary to protect local benthic and avian species.
- **Strategic Grid Complementarity:** High summer production profiles suggest that offshore wind integration can complement thermal power generation, lower fuel consumption, and support Iraq's long-term decarbonization targets.

CONCLUSION

This study provides a technical feasibility assessment of offshore wind energy potential in the Basra coastal waters of Iraq along the northern Arabian Gulf. Key findings include:

- The 50 m mean wind speed of 7.5 m/s with a prevailing northwest direction demonstrates suitable wind conditions for offshore energy generation.
- The proposed 10 MW wind farm (ten 1.0 MW Leitwind turbines in a 1000 m spaced grid) achieved an estimated Annual Energy Production of ~63,945 MWh/year, with capacity factors exceeding 80% during peak summer months.
- Spatial optimization restricted array wake losses to 0.74%, confirming high layout efficiency. Acoustic modeling verified that noise emissions remain within standard environmental limits.

RECOMMENDATIONS FOR FUTURE RESEARCH

1. Collect multi-year (5–10 years) continuous in-situ meteorological mast and LIDAR measurements to evaluate inter-annual resource variability.
2. Conduct comprehensive geotechnical and bathymetric surveys off Ras Al-Bisha to guide foundation design.
3. Execute detailed techno-economic analyses (Levelized Cost of Energy) and full Environmental Impact Assessments (EIA) to evaluate marine ecosystem interactions and commercial viability.

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