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Comparative Techno-Economic Analysis of Offshore & Onshore Wind Farms in Zafarana, Egypt Using the System Advisor Model (SAM)

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INTRODUCTION & AIM

Egypt targets **42% renewable electricity by 2035** — wind is central to that push, and Zafarana is one of the country's premier corridors.

Onshore sites at Zafarana are approaching land saturation; the adjacent **Gulf of Suez offshore resource (>10.5 m/s)** remains largely unexploited.

Aim: use SAM to test, head-to-head, whether offshore's higher energy yield economically outweighs its higher capital cost for two matched 200 MW farms.

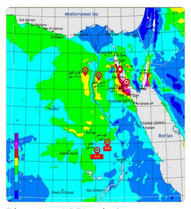

Fig. 1 — NREA wind resource map; Zafarana / Gulf of Suez corridor highlighted.

42% Egypt's renewable electricity target by 2035 — the policy backdrop for this study.

METHOD

Two **200 MW** case studies in SAM's **Single Owner** model — Onshore (Zafarana zone) vs Offshore (10 km out, Gulf of Suez, ~25 m depth).

Same turbine for both: **200 × Mitsubishi MWT-1000A** (1.0 MW, 61.40 m rotor).

Hub height & shear tuned per site: **90 m / α=0.14** onshore vs **120 m / α=0.11** offshore.

Global Wind Atlas data · 11.02% losses · 25-yr horizon @ 8% discount rate.

Configure Single-Owner Model → Define 200 MW Scope → Input Global Wind Atlas Data → Apply Wind Shear (α) → Configure MWT-1000A → Set Hub Height 90/120 m → Apply 11.02% System Loss → Input CapEx & O&M → Simulate in SAM → AEP · LCOE · NPV · IRR

TURBINE & SITE SPEC — MITSUBISHI MWT-1000A	
Rated power / Rotor	1.0 MW / 61.40 m
Turbines installed	200 (→ 200 MW)
Hub height on / off	90 m / 120 m
System loss factor	11.02%
Analysis / discount	25 yrs @ 8%

RESULTS & DISCUSSION

Two matched 200 MW farms. Same turbine. Same SAM model. Only the site changes.

ONSHORE — ZAFARANA			OFFSHORE — GULF OF SUEZ	
280.6 GWH / YR	$342.6M CAPEX	vs	$806.2M CAPEX	445.7 GWH / YR
10.22¢ REAL LCOE / KWH	9.8 yr PAYBACK		17.5 yr PAYBACK	17.71¢ REAL LCOE / KWH

ENERGY YIELD

445.7 GWh/yr offshore vs **280.6** GWh/yr onshore → **+58.8%**

Capacity factor: **25.4%** offshore vs **16.0%** onshore

Offshore output leads in **every** sampled month — steadier, less intermittent

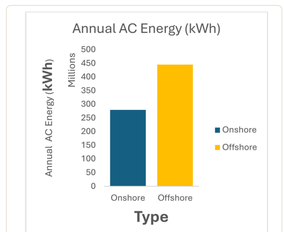

Fig. 2 — Annual AC energy, onshore vs offshore.

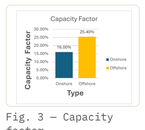

Fig. 3 — Capacity factor.

Fig. 4 — 4-month trend.

CAPITAL COST

$806.2M offshore vs **$342.6M** onshore → **+135%** CapEx

Subsea foundations, marine-grade cabling & vessel day-rates drive the gap

Offshore O&M also higher — harder, costlier to service at sea

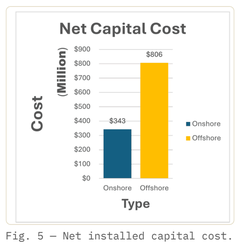

Fig. 5 — Net installed capital cost.

LCOE & PAYBACK

Real LCOE: **17.71¢**/kWh offshore vs **10.22¢**/kWh onshore — **~74%** costlier

Payback: **17.5 yrs** offshore vs **9.8 yrs** onshore

Onshore = faster return, lower financial risk *today*

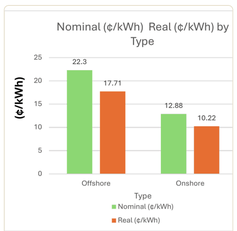

Fig. 6 — Nominal & real LCOE.

CONCLUSIONS

Technology: offshore wins — **+58.8%** energy, **+9.4-pt** capacity factor. Gulf of Suez confirmed world-class.

Economics: offshore loses — **+135%** CapEx drives LCOE to 17.71¢/kWh and a 17.5-yr payback, vs 10.22¢/kWh / 9.8 yrs onshore.

Near-term call: build onshore. Offshore stays strategic for the 2035 target as costs localize.

FUTURE WORK / REFERENCES / ACKNOWLEDGMENT

Future work: reduce offshore CapEx; explore onshore–offshore hybrid systems to improve project economics.

References: [9] NREL, System Advisor Model (SAM), Golden, CO, USA. [20] Tumse S., "Comparative Analysis of Global Onshore and Offshore Wind Turbines," Sustainability, 16(15), 2024.

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