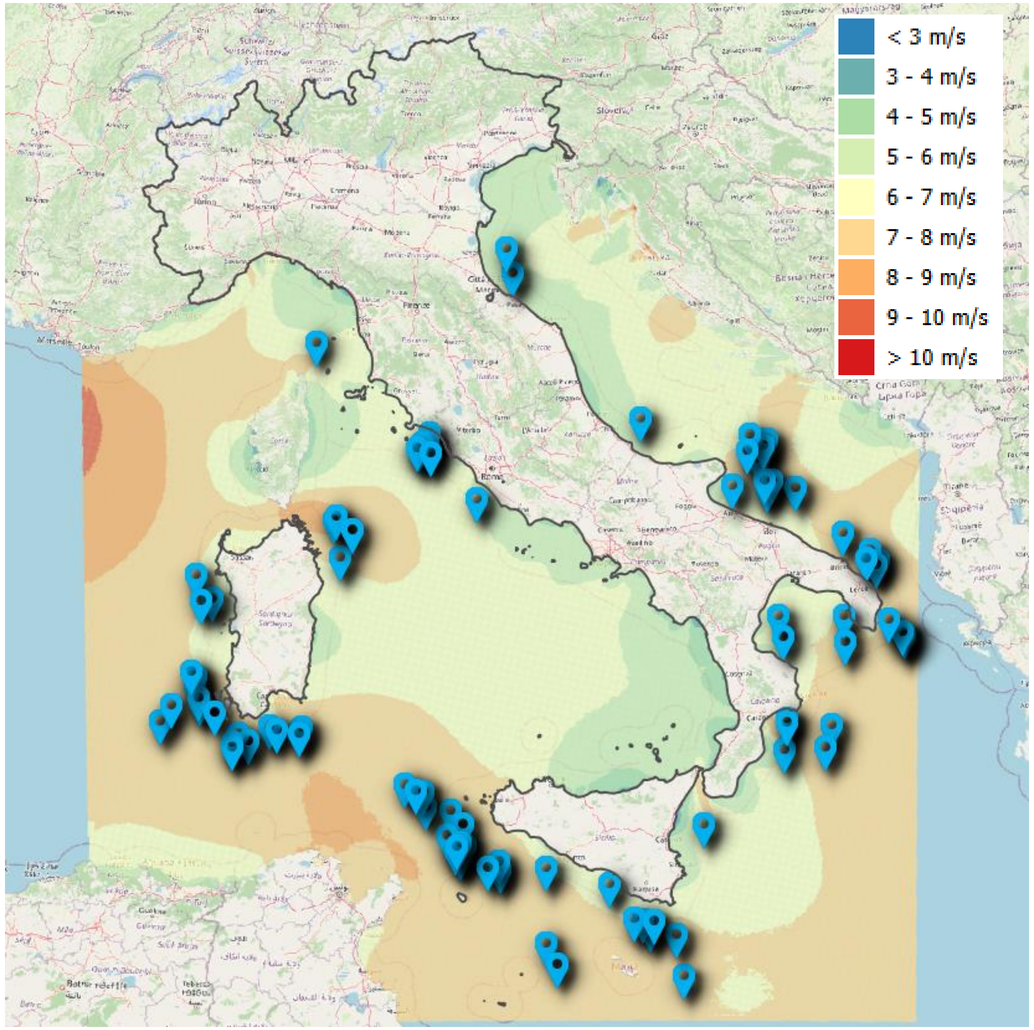
Offshore Hybrid Systems based on Floating Wind Farms in Italy: Techno-Economic Considerations and Preliminary Results

Francesco Lanni

16th January 2025

Offshore Wind Projects in Italy – Key Insights

EIA stage Projects



Facts

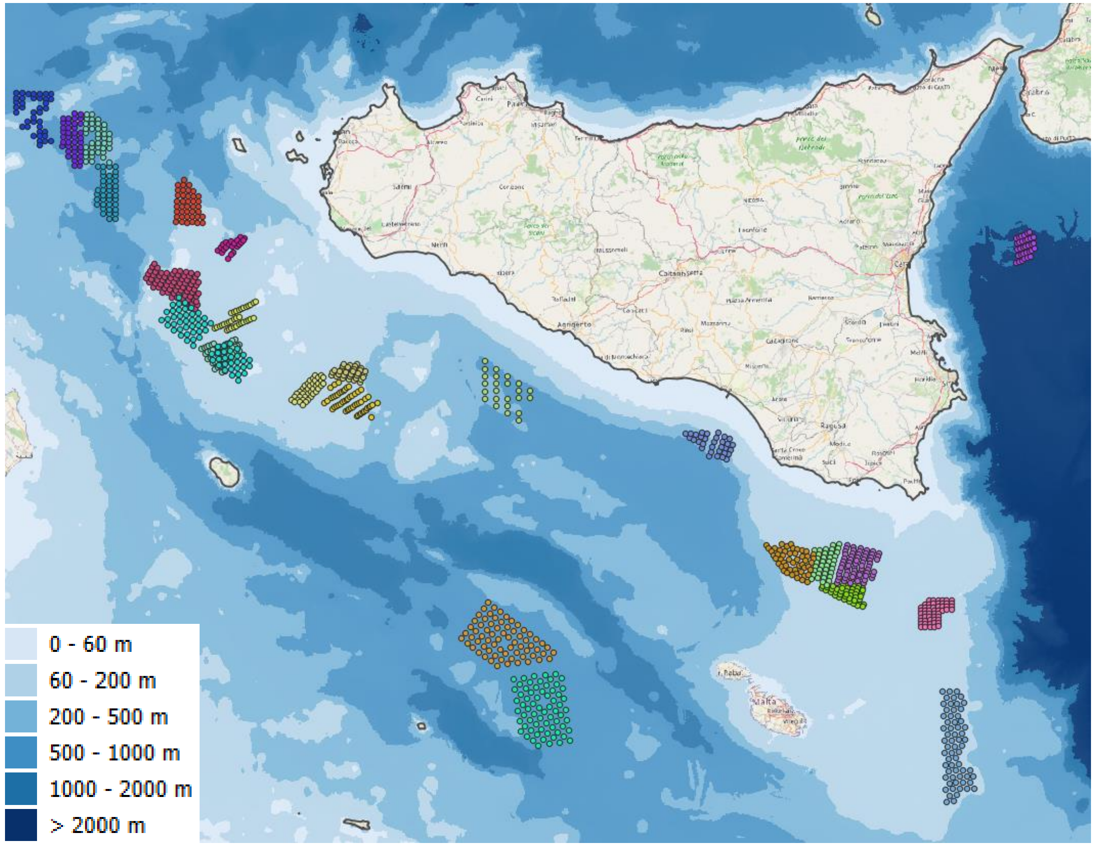
- 84.37 GW of connection requests submitted to the Italian TSO
- 95% of the requests are for floating offshore wind farms (FOWFs)
- Projects concentration in regions with the highest average wind speeds
- Several large-scale projects are currently in the pipeline

Challenges to Address

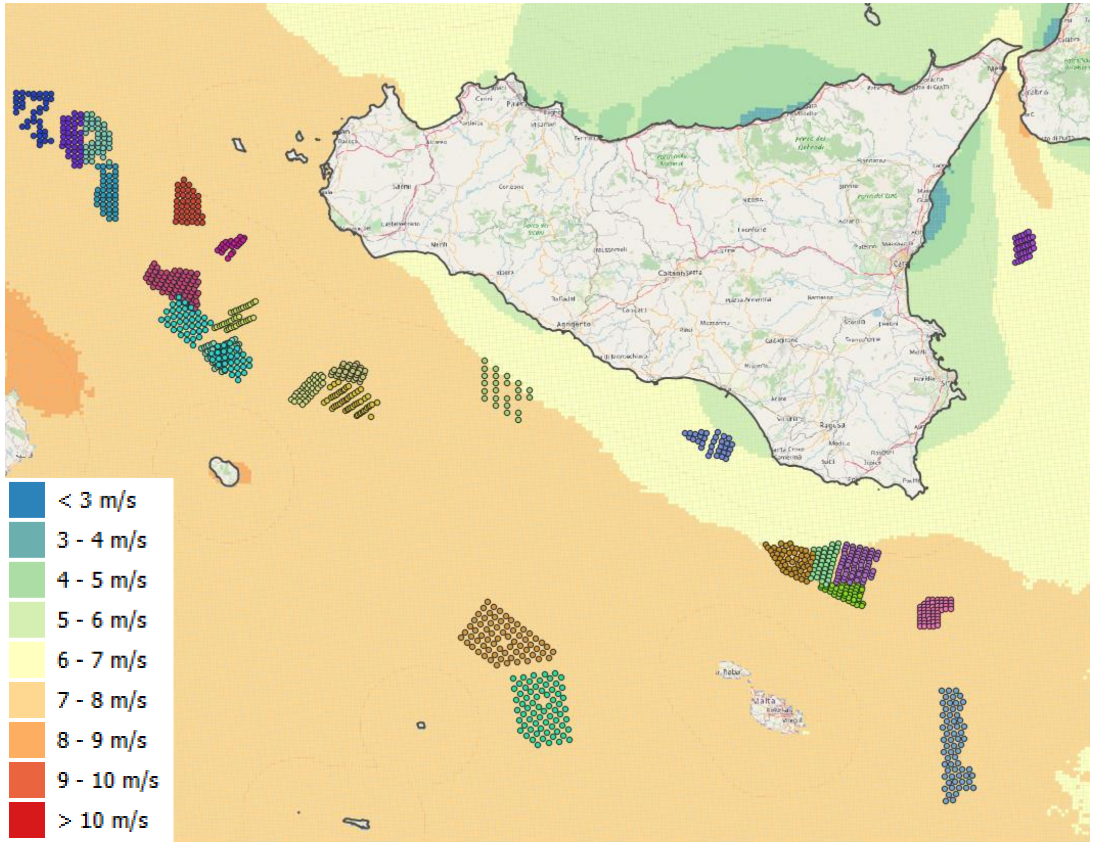
- High costs
- Significant sea area occupied
- Coexistence with other marine activities
- Risk of grid congestion
- Social Acceptance

Offshore Wind Projects in Sicily

Bathymetry



Average Wind Speed



Offshore Renewable Hybrid Systems

Research Focus: Techno-economic analysis of offshore hybrid renewable energy systems integrating multiple technologies, including wind turbines, floating photovoltaic (PV) modules, and wave energy converters. The systems also incorporate energy storage solutions and hydrogen production facilities for enhanced performance and sustainability.

Potential Benefits

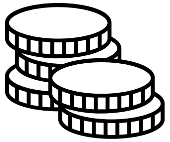
- ✅ Increased energy yield
- ✅ Better predictability
- ✅ Smoothed power output
- ✅ Shared infrastructure and logistics
- ✅ Lower system costs
- ✅ Environmental benefits

Potential Barriers

- ❌ Technology maturity
- ❌ High costs
- ❌ Conflicts with other activities
- ❌ Complex regulations
- ❌ Environmental impacts
- ❌ Social acceptance

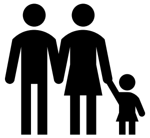
Metrics Used

Financial & Economic Parameters



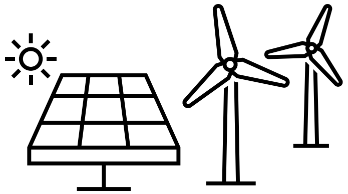
- NPV (Net Present Value)
- LCOE (Levelized cost of energy)
- IRR (Internal Rate of Return)
- PBT (PayBack Time)
- LCOH (Levelized Cost of Hydrogen)

Socio-Economic Criteria



- Household equivalent consumptions
- CO_2 emissions
- Full Time equivalent job created estimation

Power Generation Performance Indicators



- Hybrid Power Variability Index expressed as the Relative Mean Deviation of the power generated from the Hybrid System
- Capacity Factor

we move rsearch

Data Source

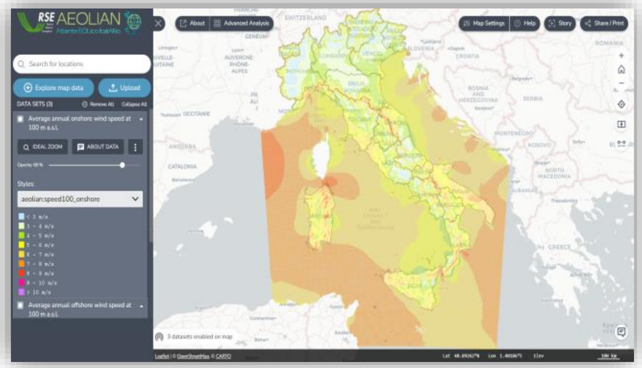
MERIDA

DATASET: 1990 – 2019

RESOLUTION: 4 km

- Air temperature at 2 m (**T2M**)
- Global Horizontal Irradiance (**GHI**)
- Global solar direct Irradiance (**DNI**)
- Global solar diffuse Irradiance
- Overall precipitation
- Wind direction and intensity at 10 and 100 m

AEOLIAN



DATASET: 1990 – 2019

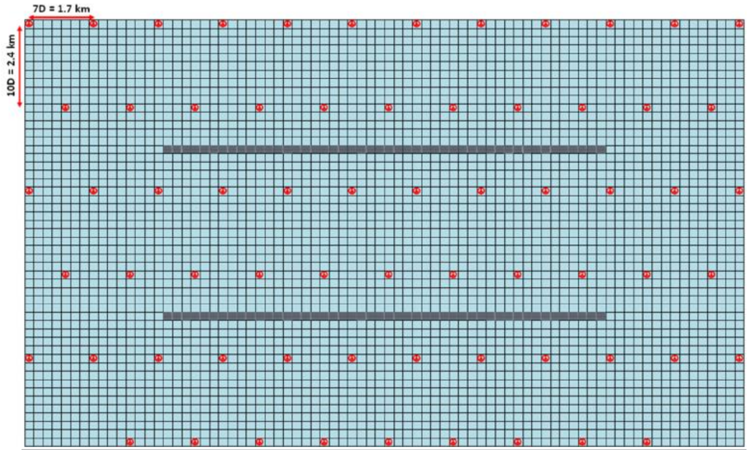
RESOLUTION: 1.3 km

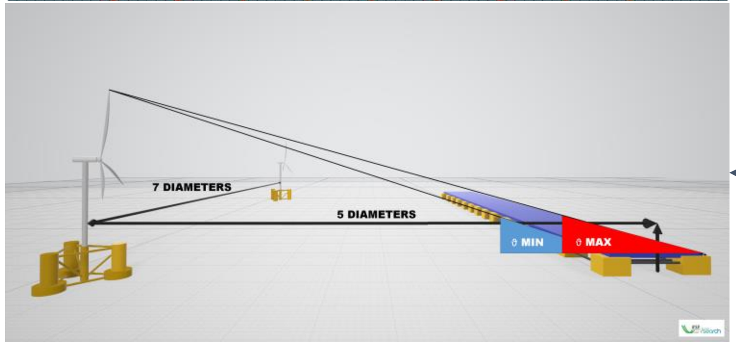
- Wind speed at different levels (50, 75, 100, 125, 150 m a.s.l./a.g.l.)
- Specific Power production [MWh/MW]
- Weibull Distribution
- Elevation/Bathymetry
- Distance to Primary Substation

Hybrid System: OWF and PVF

Generated and Transmitted Power

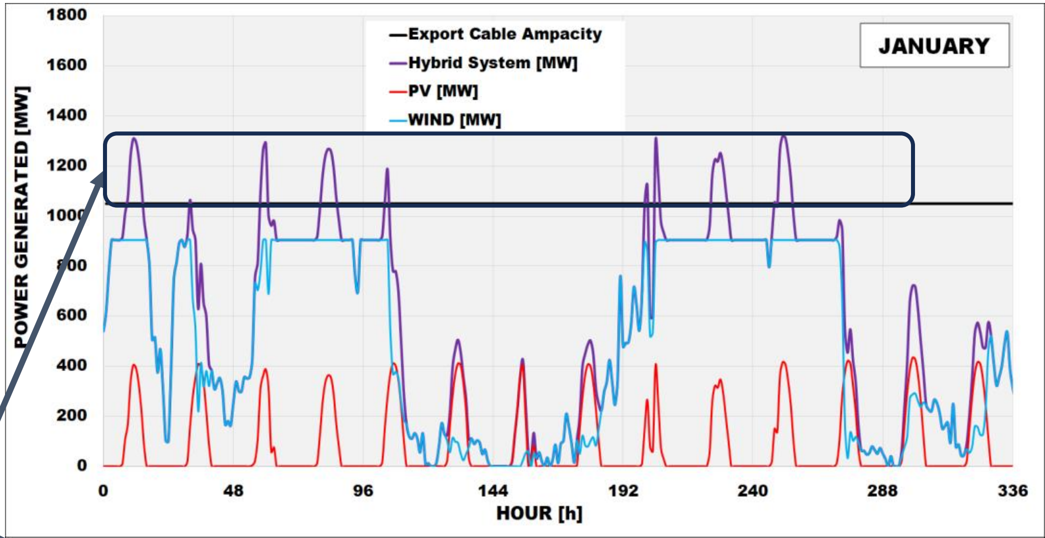
Parameters	Wind Farm	PV Farm
Size [MW]	1005	1005
Single Device Size [MW]	15	0.0004
Device model	IEA-15-240-RWT	SUNPOWER MAXEON 400W
Export Cable Ampacity [MVA]	1050	

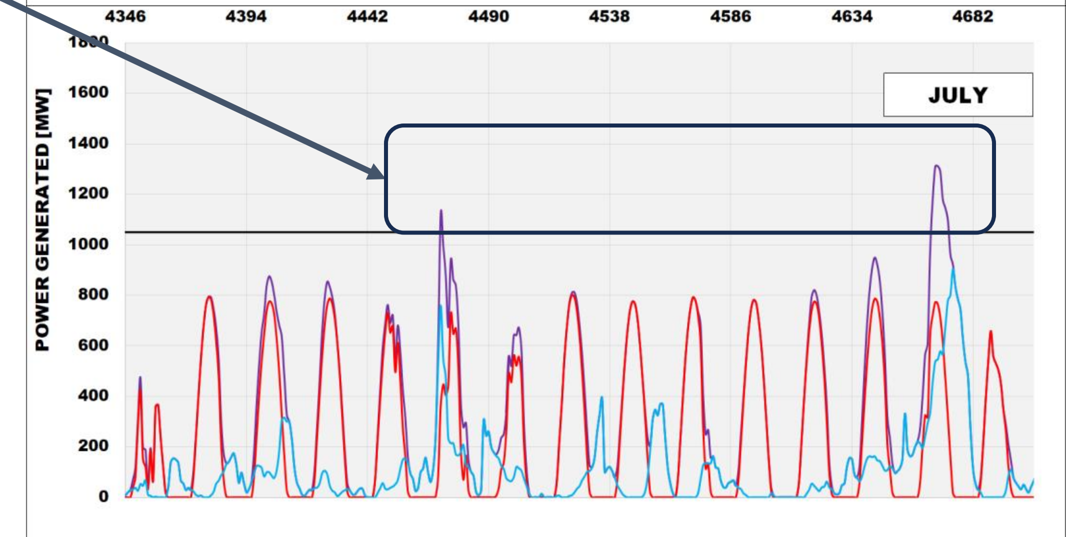




Yearly Energy Overproduction: Only **3.74%** of the total generated power exceeds the export cable's ampacity

Shadowing Losses: Less than **1%**





Hybrid System: OWF and PVF

HIGH-COST UNCERTAINTY: Due to non-commercial technologies and limited data availability in the literature

Floating Offshore Wind: Pre-commercial Stage

Floating PV: LOW TRL

Parameters	UNIT	WIND FARM (Stand Alone)	PV FARM (Integrated)	PV FARM (Stand Alone)
Lifetime	Years	30	30	30
WACC	%	7	7	7
CAPEX	M€/MW	3.05	1.96	2.13
OPEX	%	5	3	3
NAET	MWh/y	3222595	1349350	1349350
sLCOE	€/MWh	124.1	161.4	175.7
sLCOE Hybrid System	**€/MWh**	**142.1**		

Export cable not considered: 0,17 M€/MW

Once integrated, it is reduced by the untransmitted yearly energy (3.74%)

Weighted on the NAET

NAET: *Net Annual Energy Transmitted* in the export cable

Hybrid System: OWF and PVF

HIGH-COST UNCERTAINTY: Due to non-commercial technologies and limited data availability in the literature

Floating Offshore Wind: Commercial Stage

Floating PV: Pre-Commercial Stage

Parameters	UNIT	WIND FARM (Stand Alone)	PV FARM (Integrated)	PV FARM (Stand Alone)
Lifetime	Years	30	30	30
WACC	%	5	5	5
CAPEX	M€/MW	3.05	1.96	2.13
OPEX	%	5	3	3
NAET	MWh/y	3222595	1349350	1349350
sLCOE	€/MWh	109.4	138.8	151.0
sLCOE Hybrid System	**€/MWh**	**124.2**		

Export cable not considered: 0,17 M€/MW

Once integrated, it is reduced by the untransmitted yearly energy (3.74%)

Weighted on the NAET

NAET: *Net Annual Energy Transmitted* in the export cable

Hybrid System: OWF and Li-ion ESS

Hypothesis

- Dedicated onshore Battery Energy Storage System (BESS) with capacity sized on curtailment
- Cost of the BESS is 130 €/kWh
- Three Annual Wind Energy curtailment values equal to 5% (blue), 10% (orange), or 15% (green)
- Two differenct curtailment distribution:
  - *Homogeneous distribution* (S1), the curtailed energy is equally distributed throughout the year
  - *Seasonal distribution* (S2), the planned reduction of power output is concentrated during the summer
- No Remuneration for Curtailed energy
- Wind energy Feed in Tariff = 185 €/MWh

$$NPV = \sum_{t=1}^{n} \frac{CF_t}{(1+i)^t} - CAPEX$$

The adoption of a storage system is always convenient regardless of the curtailment distribution throughout the year.

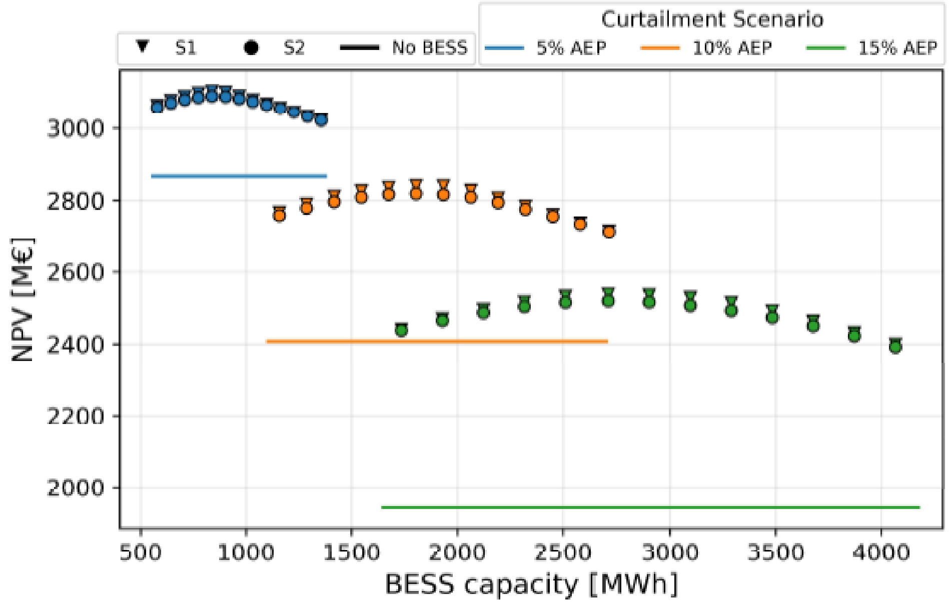


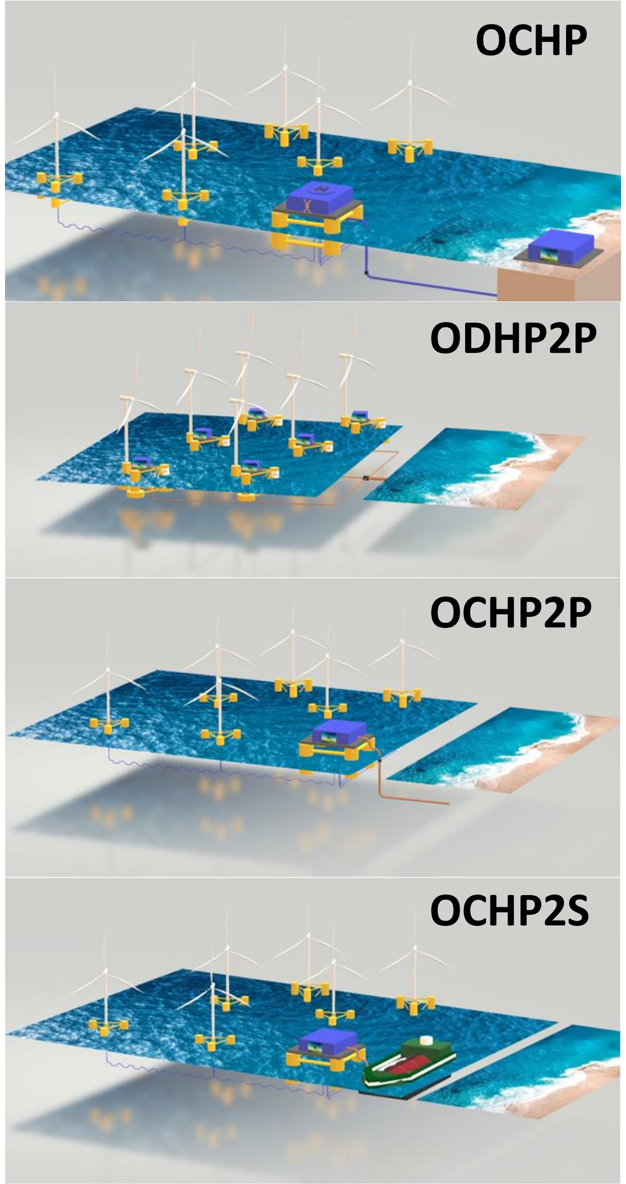
Figure 5: NPV of the wind farm with an E_{cost} of 0% of the LCOE and an ESS cost of 130 €/kWh.

Hybrid System: OWF and Green Hydrogen Production

Different solutions were analyzed using the simple Levelized Cost of Hydrogen, where the OPEX essentially represents the cost of the electricity used to power the electrolyzers.

$$sLCOH = \frac{CRF \cdot CAPEX + OPEX}{H_{2\ prod}} \quad \left[\frac{€}{kg}\right]$$

- **OCHP**: *Onshore Renewable Centralized Hydrogen Production*
- **ODHP2P**: *Offshore Renewable Decentralized Hydrogen Production with Pipeline*
- **OCHP2P**: *Offshore Renewable Centralized Hydrogen Production with Pipeline*
- **OCHP2S**: *Offshore Renewable Centralized Hydrogen Production with Storage*



KEY INSIGHTS AND NEXT STEPS

Key Insights:

The study provides an overview of various scenarios and methodological approaches for offshore hybrid systems in Italy

Emphasis is placed on the versatility and adaptability of the analytical frameworks presented

The work serves as a valuable reference for institutions and stakeholders exploring hybrid offshore energy solutions

Next Steps:

Further refinement of the models under analysis

Comprehensive optimization of the hybrid system performance

Enhanced system complexity through the integration of additional technologies

This work has been financed by the Research Fund for the Italian Electrical System under the Three-Year Research Plan 2022-2024 (DM MITE n. 337. 15.09.2022) in compliance with the Decree of April 16th. 2018

Contatti

Rimani sempre aggiornato con RSE perché

#wemoversearch

Francesco Lanni

Francesco.lanni@rse-web.it

www.rse-web.it

@Ricerca sul Sistema Energetico - RSE SpA

@RSEnergetico

RSE SpA - Ricerca sul Sistema Energetico