WESC 2023

23 - 26 MAY | GLASGOW, UK

Assessment of sustainable solutions for floating offshore wind through an LCOE/LCA tool developed in the context of the European project COREWIND

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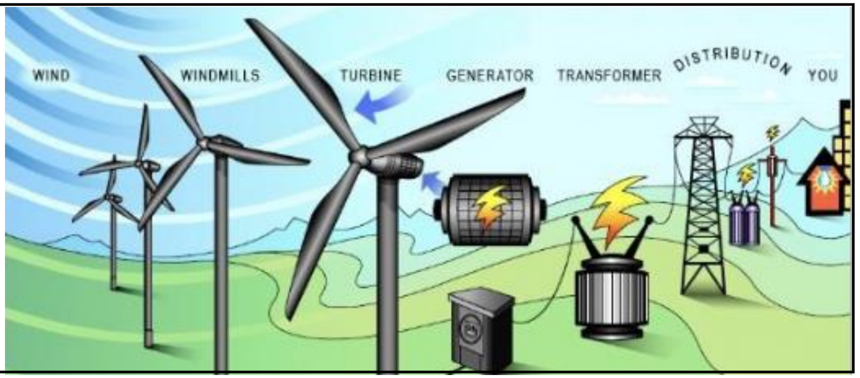
IREC
Shaping Energy for a Sustainable Future

corewind
COST REDUCTION OF
FLOATING WIND TECHNOLOGY

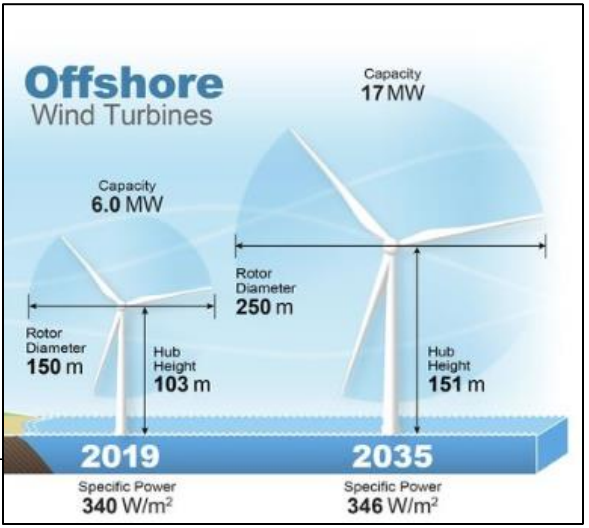
Introduction

- Offshore wind power is seen as key player in the energy transition towards a carbon-neutral economy



https://oemr.idaho.gov/sources/re/wind/

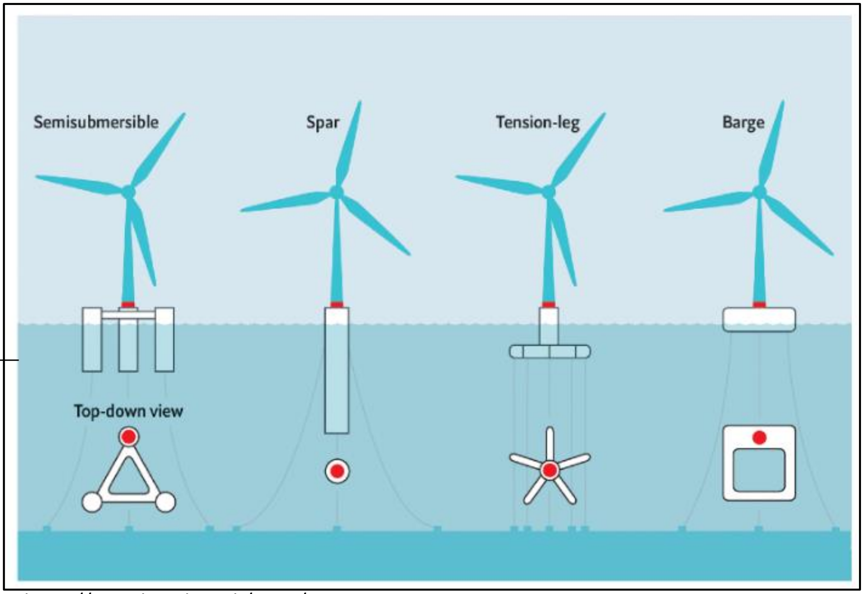
- Fixed-bottom technologies dominate the offshore wind industry but are only appropriate for water depths below 60 meters.



https://www.nature.com/articles/s41560-021-00810-z

- Floating platforms allow overcoming this restriction.

"Using floating substructures in the offshore wind power industry still presents techno-economic and environmental issues"



https://encyclopedia.pub/entry/39927

IREC Shaping Energy for a Sustainable Future

Total Budget
€ 5 031 858,75
Duration 2019 -2023

corewind
http://corewind.eu/

HORIZON 2020

The **COREWIND project** provides disruptive and cost-effective solutions for floating offshore wind technology, leading to costs lower than 100€/MWh, by developing innovative research, modelling and optimization for concrete-based floating substructure concepts.

FowApp concept

LCOE approach
(CAPEX, OPEX, DECEX, AEP)
LCA methodology
(ISO 14040/44:2006)

Devel. → Production → T&I → O&M → Decomm. → EoL

Library

- Component specifications
- Site bathymetry and wind climate
- Heavy equipment and vessels
- Material and energy inventory

FowApp

Economic results (LCOE) and Environmental impacts (LCA)

- Costs
- Energy (AEP)
- Climate Change
- Mineral resources Depletion
- Ecosystem damage

FowApp concept

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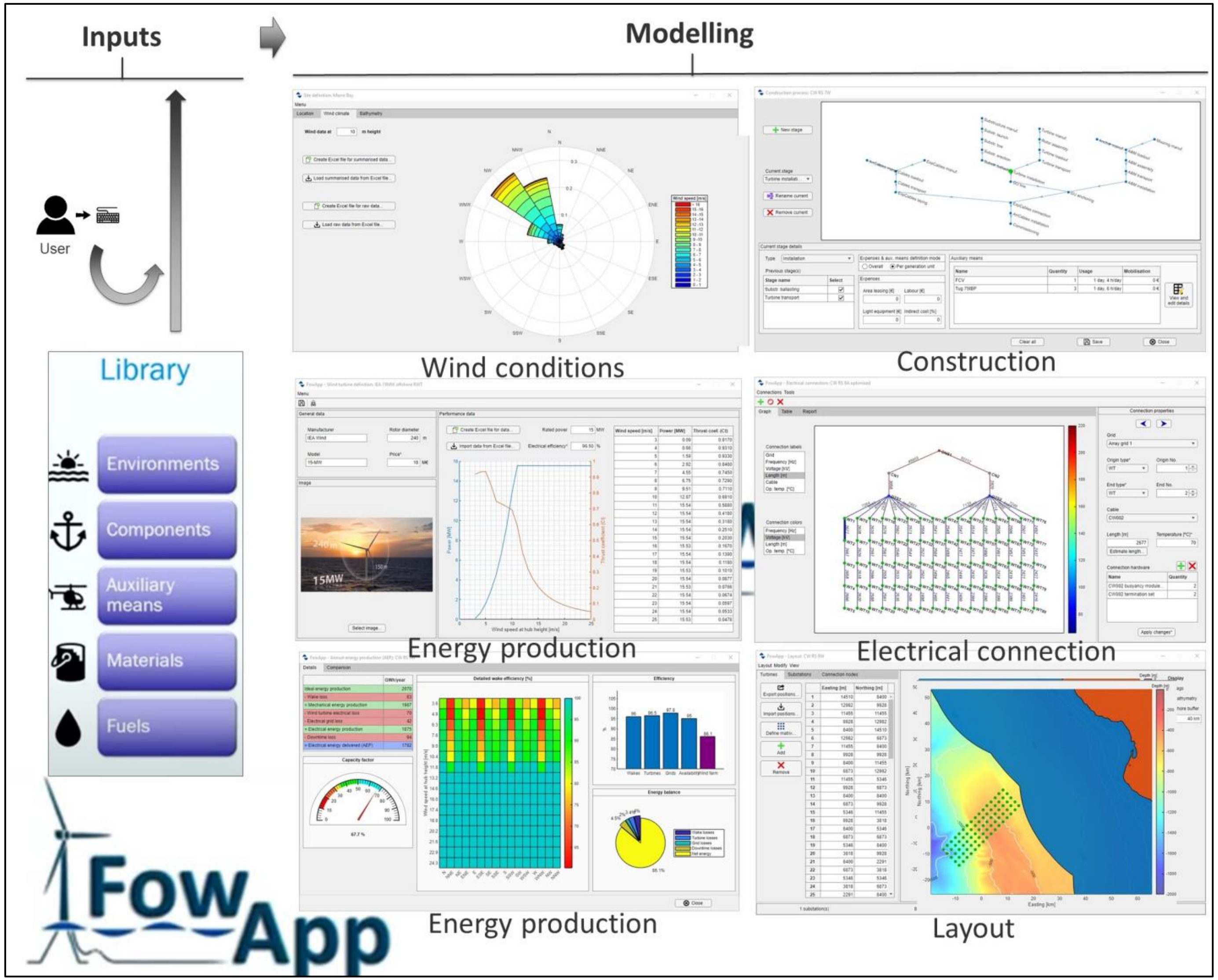
Friendly interface for the user to introduce data and update the windfarm model



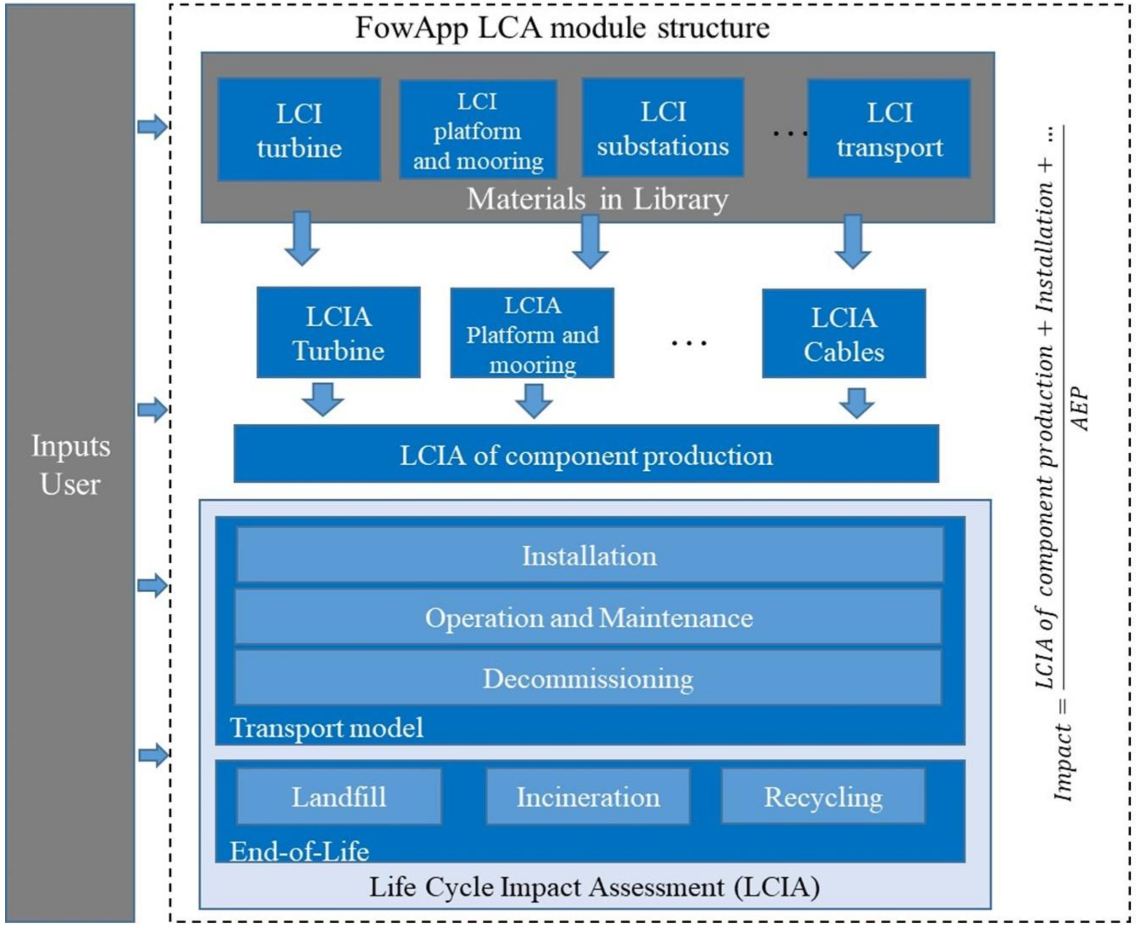
"The tool's framework takes into account all the life cycle phases to provide overall results as well as results broken down by stages, components, and materials"

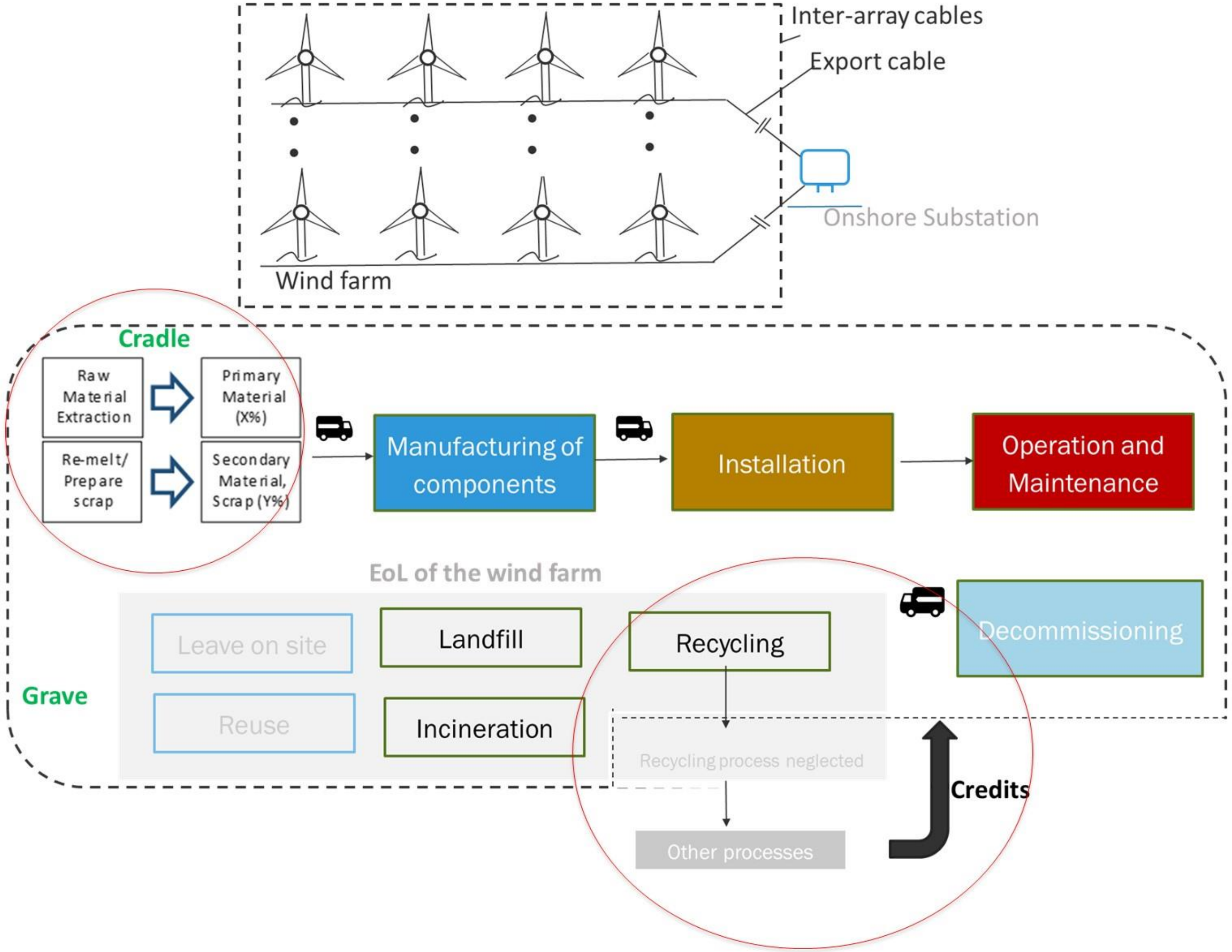
Main characteristics

- Import/export capabilities
- Integrated calculations
- Detailed Annual Energy Production calculation
- Economic analysis, including LCOE calculation
- Full LCA cradle-to-Grave approach

FowApp concept

Comprehensive LCA model to find the floating wind technology with circular economy principles





Key common specifications for LCOE and LCA models in FowApp study case

Study case platform

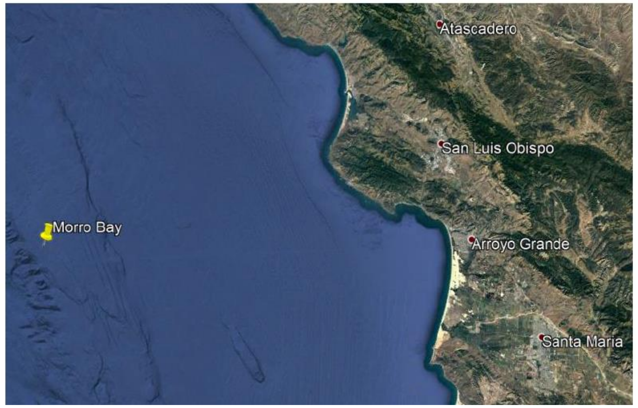
Monolithic concrete spar
Platform - **WindCrete**

Study case turbine

The IEA 15MW reference wind turbine

Key common specifications for LCOE and LCA models in FowApp study case

Sites



Site 1: Gran Canaria, Canary Islands (Spain), 200-meter depth. Distance to shore: 10 km. Sandy soil.

Site 2: Morro Bay, California (US), 870-meter depth. Distance to shore: 60 km. Sandy soil.

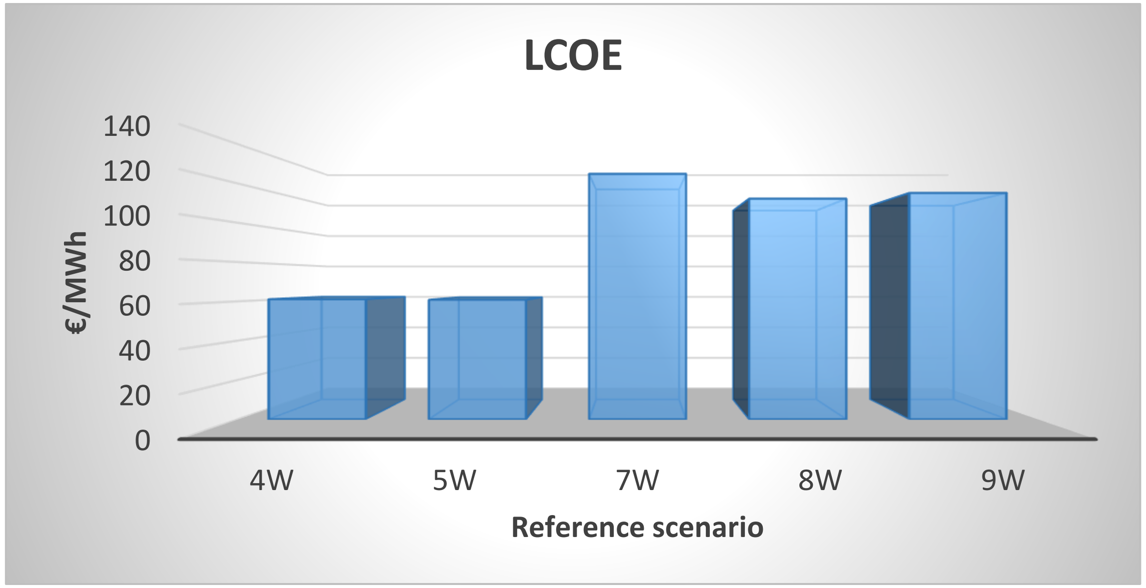
Functional unit: 1MWh of generated wind energy

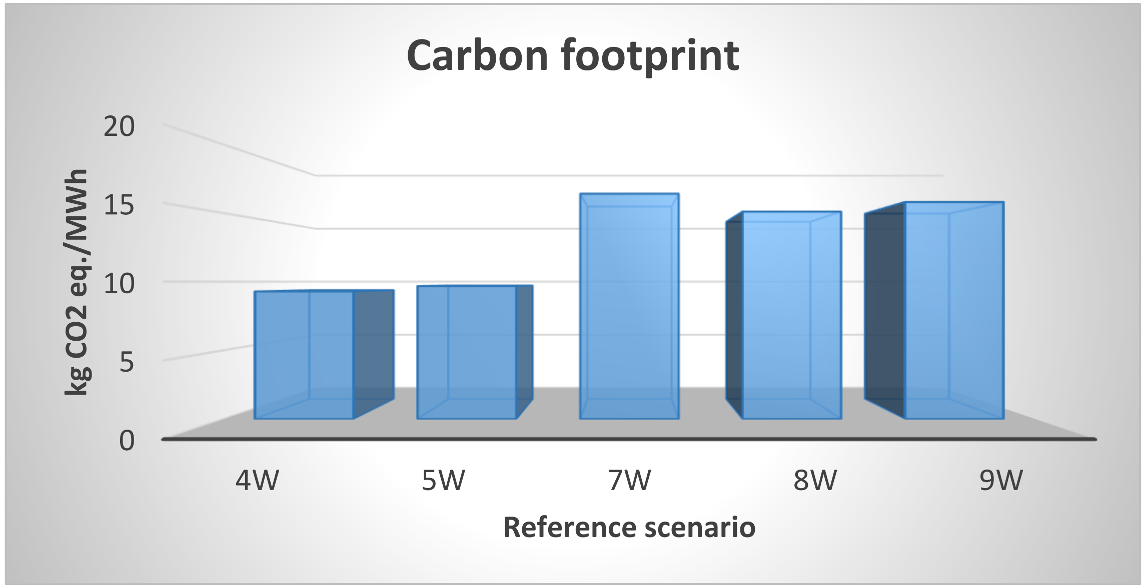
Reference flows: materials, energy, emissions and costs involved in the life cycle stages: raw material extraction, production, transport, installation, operation and maintenance, decommissioning and end of life

Scenarios

Scenario	Location	Capacity	Grid connection
4W	SE of Gran Canaria	60 MW (4 WT)	Single string to onshore substation
5W		300 MW (20 WT)	5 strings to onshore substation
7W	Morro Bay	60 MW (4 WT)	Single string to onshore substation
8W		300 MW (20 WT)	5 strings to offshore substation, plus export cable to onshore substation
9W		1200 MW (80 WT)	16 total strings to 2 offshore substations, plus export cables to onshore substation

Baseline results





- The average LCOE of the five reference scenarios studied is 94.8 €/MWh
- The main drivers of the LCOE are the AEP and the CAPEX
- The OPEX and DECEX have smaller impacts due to the WACC used: 10%

- The environmental impact results depend on each scenario, with variations on the impact categories analysed

CO_2 eq emissions
<< 20 gCO_2 eq/kWh

Results by life cycle stages for Gran Canaria (scenario 5W as an example)

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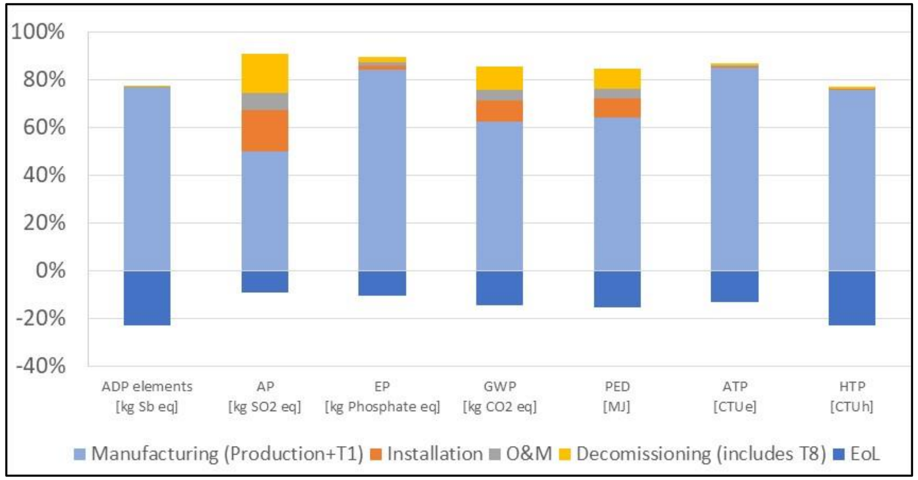
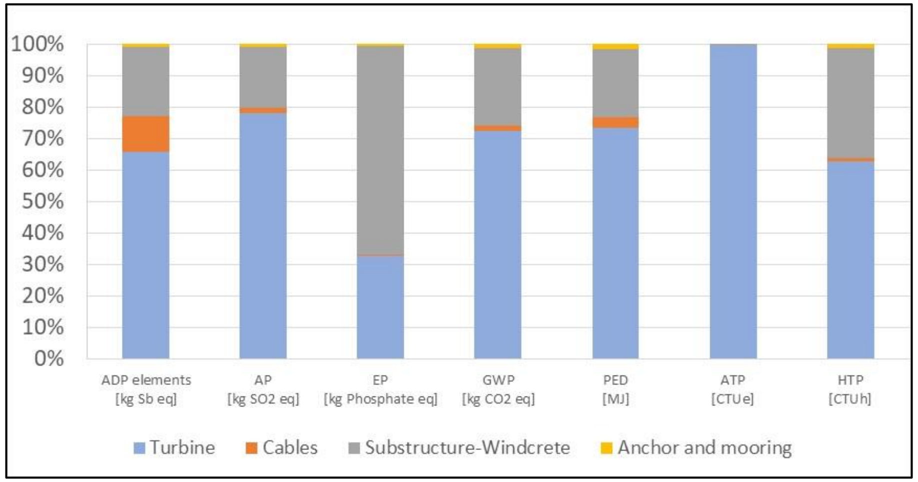
Overall Life Cycle Results



Manufacturing stage



Substructure manufacturing by materials

Impact category	Slag	Unreinforced concrete	Steel	Energy for manufacturing	TOTAL
ADP elements [kg Sb eq/MWh]	8.08E-07	3.67E-06	8.95E-06	2.25E-11	1.34E-05
AP [kg SO_2 eq/MWh]	4.90E-04	7.42E-04	4.08E-03	1.30E-07	5.31E-03
EP [kg PO4 eq/MWh]	1.41E-02	2.90E-04	2.52E-03	1.53E-08	1.69E-02
GWP [kg CO_2 eq/MWh]	**6.97E-02**	**3.81E-01**	**1.00E+00**	**6.66E-05**	**1.45E+00**
PED [MJ/MWh]	2.78E+00	2.14E+00	1.52E+01	1.74E-03	2.01E+01
ATP [CTUe/MWh]	3.07E-04	1.30E-04	6.61E-04	1.14E-07	1.10E-03
HTP [CTUh/MWh]	2.32E-12	5.63E-12	1.59E-10	1.05E-14	1.67E-10

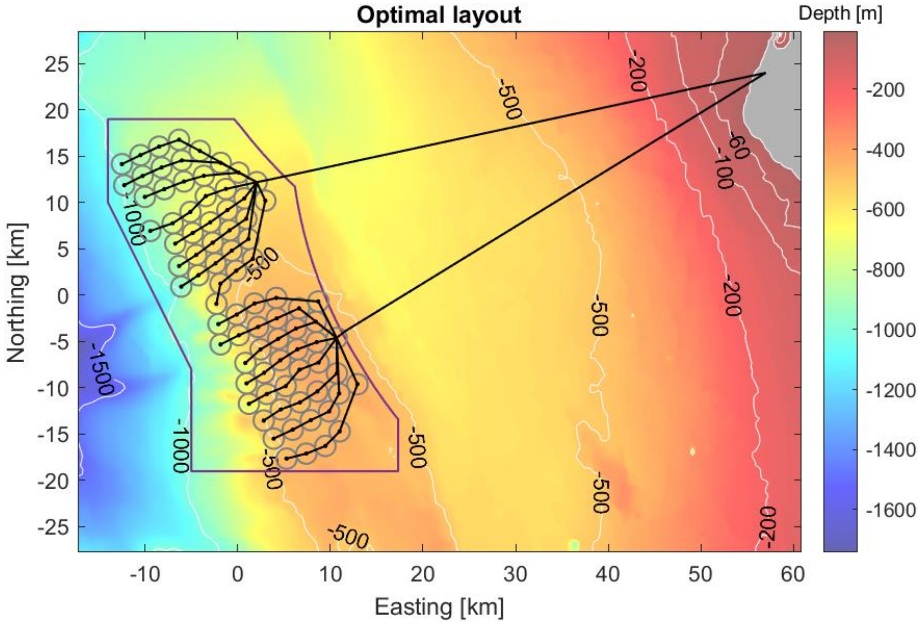
- Manufacturing is the dominant stage in the environmental overall LCA results
- EoL stage brings benefits due to recycling credits in all environmental impact categories studied
- The turbine has a greater impact than the floating substructure in almost all impact categories during the manufacturing stage, hence the importance to use concrete
- Green steel should be used instead of steel in the substructure to reduce its impact since steel has the highest impact

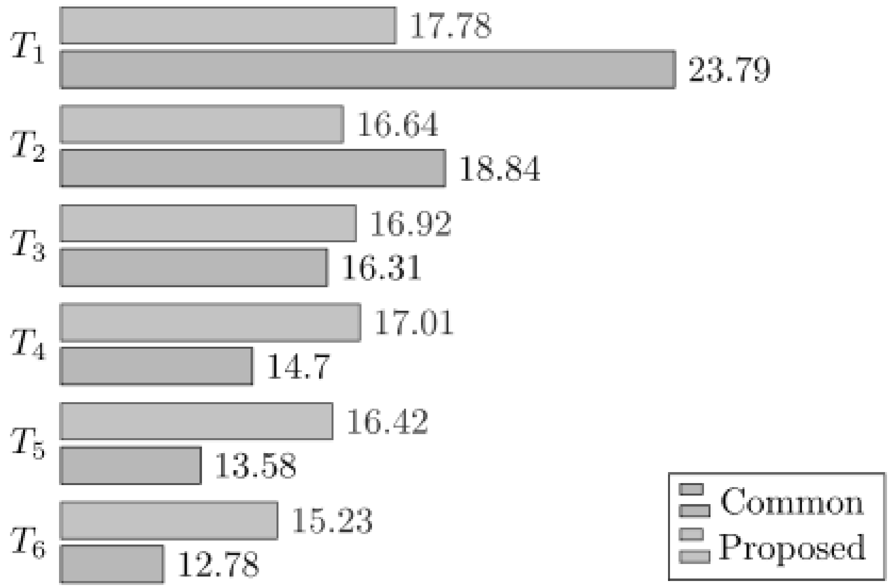
Innovations and optimisations for cost reduction to be applied in FowApp

Workshops and Surveys to identify Cost Reduction Opportunities (main outcomes)

Main innovations and optimisations

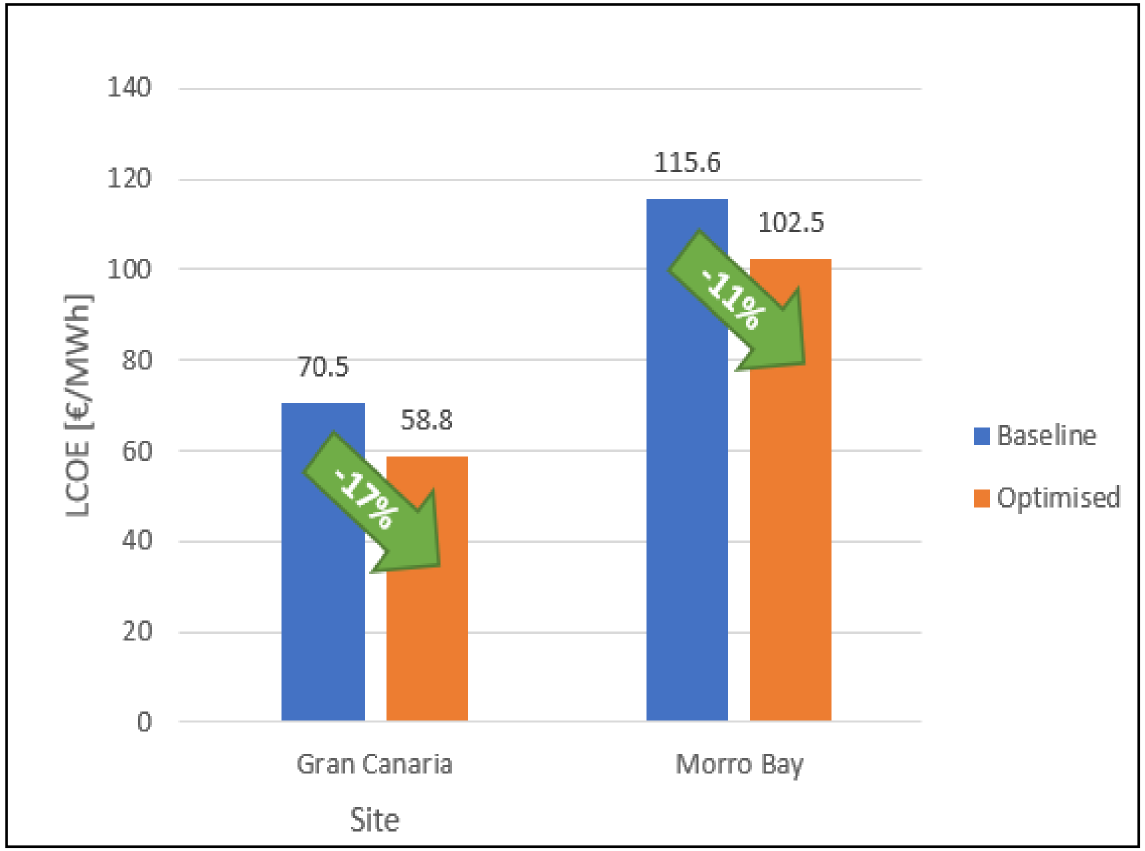
- Layout optimisation
- WindCrete reuse
- Station system peak load reduction
- Improved maintenance strategies
- Windfarm control for life extension

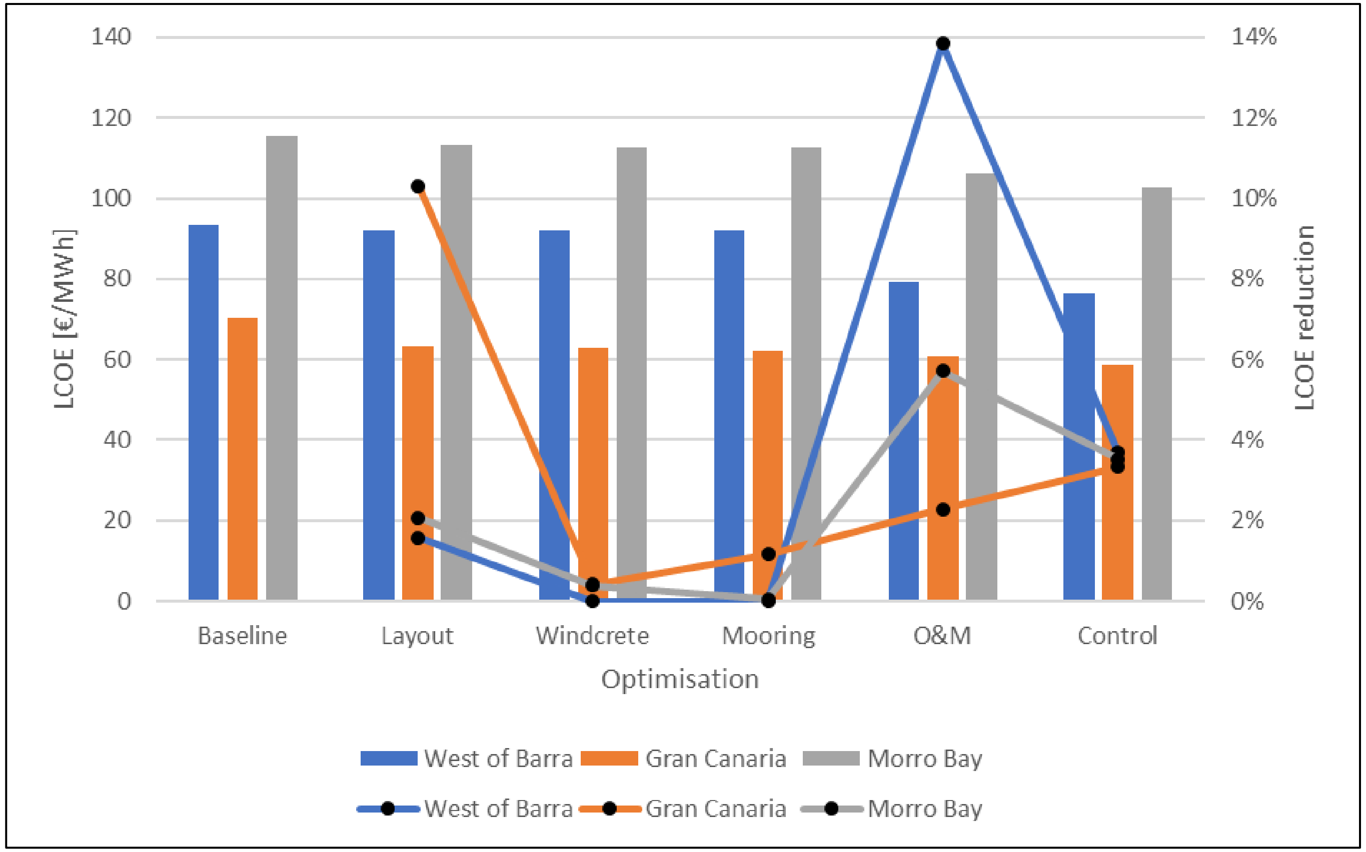




Optimised LCOE and LCA results in FowApp

LCOE results





Optimised LCOE and LCA results in FowApp

LCA results and other environmental parameters

5.0%
Energy payback time reduction
=> **1.32 years**

18.2%
Energy return on investment increase
=> **22.0**

15.2%
Global warming potential reduction
=> **11.6 kg CO_2 eq./MWh**

14.9%
Primary energy demand reduction
=> **170 MJ/MWh**

15.3%
Acidification potential reduction
=> **0.0424 kg SO_2 eq./MWh**

11.4%
Aquatic toxicity potential reduction
=> **0.193 CTUe/MWh**

Conclusions

- The average LCOE of all the reference scenarios studied is 99.7 €/MWh, that went down to 86.6 €/MWh after optimisation
- The LCOE optimisation leaded in some cases to a reduction of the energy yield due to the purchasing costs
- The layout optimisation and the maintenance improvements had the highest effect on the LCOE reduction
- All scenarios are below 20 gCO_2 eq/kWh (average of 12 gCO_2 eq/kWh)
- Optimising the LCOE resulted in significant reduction of the environmental impacts

Next steps / topics that could be further investigated

- Developing new materials for blades that can withstand harsh marine environments, reduce maintenance cost, be reusables and recyclable
- Improving turbine designs to increase efficiency and reduce costs
- Design new technologies for monitoring wind turbines remotely
- Developing new installation techniques that can reduce costs and minimize environmental impact
- Analyse technical, statistical, organizational or market factors to establish the main parameters that influence the economies of scale of floating wind farms

Beyond COREWIND

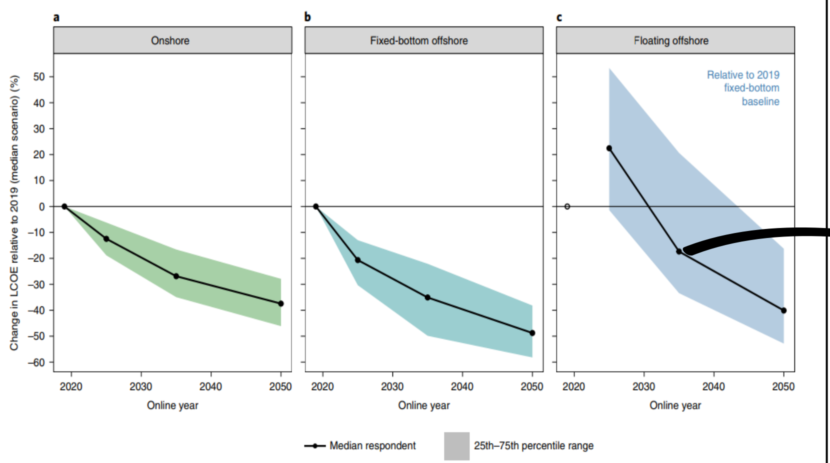
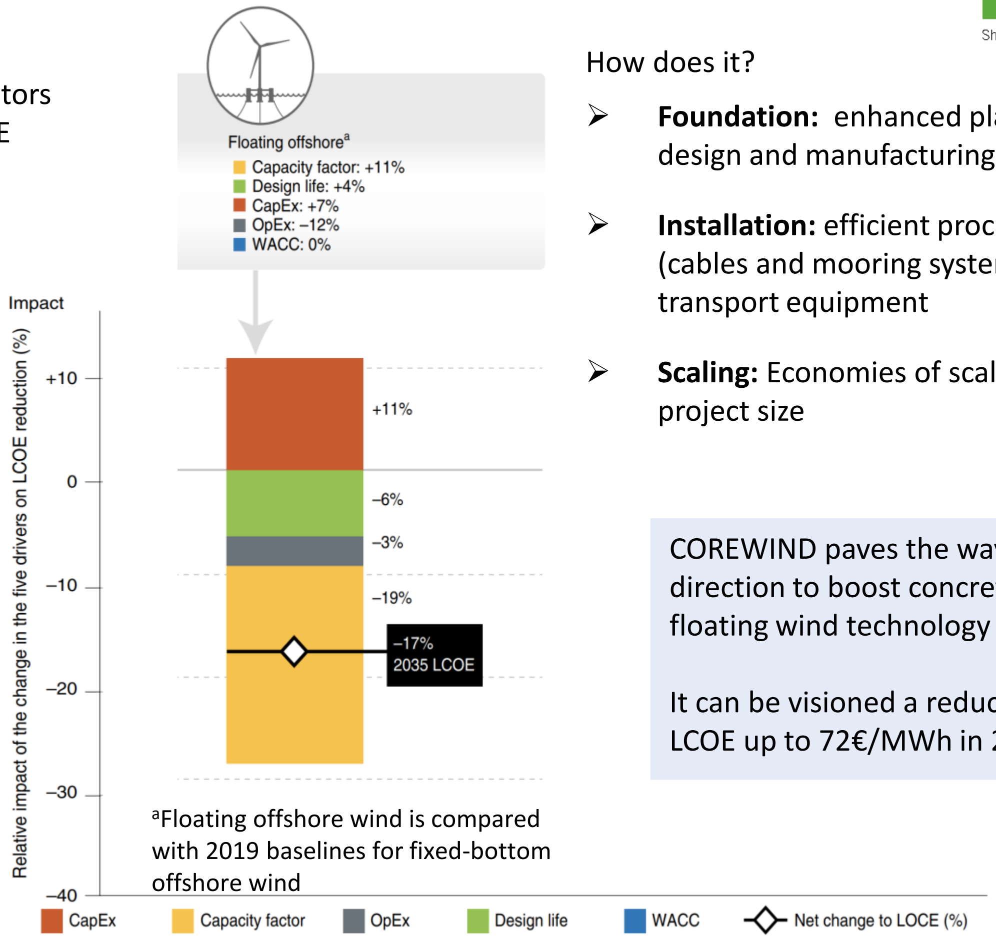


Fig. 2 | Expected LCOE changes in the median scenario in percentage terms relative to 2019 baseline values. a–c, From the 2020 elicitation, the medians of expert responses in terms of percentage LCOE reductions are shown by the lines/markers, and the shaded areas represent the 25th–75th percentile ranges of all responses for the median scenario. Panels show results for onshore (**a**), fixed-bottom offshore (**b**) and floating offshore (**c**) wind. Floating offshore wind changes are compared with expert-specific 2019 baselines for fixed-bottom offshore wind, depicted in the figure as the empty circle; given the nascent state of floating offshore wind, experts predict that LCOE in 2025 will be higher than 2019 fixed-bottom costs.

These are the main factors that influence the LCOE reduction



How does it?

- **Foundation:** enhanced platform design and manufacturing
- **Installation:** efficient processes (cables and mooring system) and transport equipment
- **Scaling:** Economies of scale via project size

COREWIND paves the way in this direction to boost concrete-based floating wind technology

It can be visioned a reduction of LCOE up to 72€/MWh in 2035

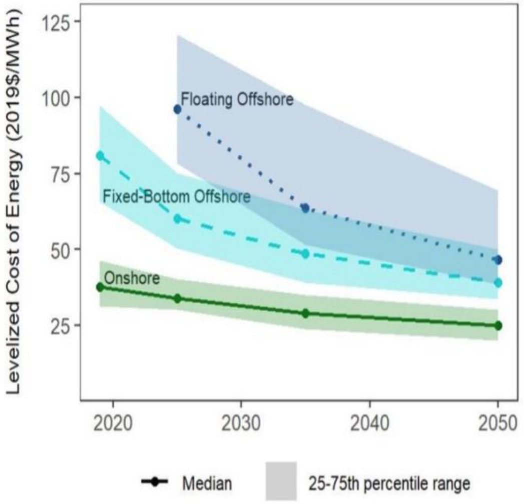


Figure 1. Experts anticipate substantial cost reductions for onshore, fixed-bottom offshore, and floating offshore wind power, but there is considerable uncertainty in those future costs. (Credit: Berkeley Lab)

COREWIND 2022

87€/MWh

COREWIND comes forward with the low-cost scenario expected in 2025, which reflects what might be possible with greatly enhanced research, development and innovation

FowApp is a practical and holistic tool that can be used to analyse LCOE and conduct LCA to give engineers and decision-makers insights into floating offshore wind farms

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THANK YOU FOR YOUR ATTENTION!

COST REDUCTION OF FLOATING WIND TECHNOLOGY

Disclaimer:

This project has received funding from the European Union's Horizon 2020 Research and Innovation programme under grant agreement No 815083.