Report 2023

Task 48

SkySails Power System in operation.

Airborne Wind Energy

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Airborne Wind Energy Systems enable the capturing of wind resources at altitudes up to 800m while significantly reducing the amount of material input.

Through its scalability, the Airborne Wind Energy (AWE) technology opens up new markets and locations for wind energy which allows AWE to play a significant part of the future energy system.

The objective of Task 48 on AWE is to tackle technological, regulatory and policy challenges on a global level, addressing and including stakeholders such as AWE developers, suppliers, policy makers, authorities, regulators and other wind energy and technology experts.

Task 48 consists of five Work Packages: i) Resource Potential and Markets; ii) Reference Models, Tools and Metrics; iii) Safety and Regulation; iv) Social Acceptance and Environmental Impacts; v) AWES Architectures.

Various tools, papers and studies have been developed throughout 2023 within Task 48 and in collaboration with other projects.
Task 48 has become a key platform for knowledge exchange about AWE, enhancing awareness and expertise on the technology.

The Task is supported by eleven countries and dozens of organisations.

In **WP1 on Resource Potential and Markets**, in collaboration with the Horizon Europe project MERIDIONAL, the impact of inflow on the performance of AWE systems is simulated.

Various studies have focused on the AWE deployment potential. For instance, TU Delft has used the Calliope energy system model to predict the deployment of AWE in the European renewable energy system until 2050 [11]. Other studies have analysed the potential locations where AWE could be deployed, e.g. in Germany [Coca 5], or in off-grid systems [14]

The joint project of TU Delft and Politecnico de Milano on the reference economic model for AWE systems has been continued in 2023. The study will be available in Q2-2024 [23; forthcoming in 2024].

Table 1. Countries Participating in Task 48.

COUNTRY/SPONSOR	INSTITUTION(S)
Belgium	Airborne Wind Europe; University of Ghent; KU Louvain
Switzerland	EPFL; ETH Zürich; PSI; Swiss Federal Office of Energy; Swiss FOCA; Twingtec AG; UASolutions
Germany	Enerkite GmbH; FGW; Fraunhofer ISI; kiteKRAFT; Leibniz University of Hannover; RWE; RWTH Aachen; Skysails GmbH; Uni Bonn; University of Applied Sciences Munich; University of Bonn; University of Freiburg; University of Halle; University of Stuttgart
Denmark	DTU
Spain	CT Ingenieros; someAWE; UC3M
Ireland	MaREI Research Centre; BlueWise Marine; University College Cork; Mayo County Council; RWE Ireland; University of Limerick; SEAI; University College Cork
Netherlands	Kitepower/ enevate ; TNO Wind Energy; TU Delft
Norway	Kitemill AS; NTNU Trondheim; University of Bergen
United Kingdom	ORE Catapult; University of Strathclyde; Windswept
United States	Colorado State University; FAA; North Carolina State University; NREL; SNL; UCSB; University of Dayton; University of Michigan; University of Washington; Windlift; Worcester Polytechnic Institute

Within **WP2 on Reference Models, Tools and Metrics** examples of TU Delft's work are the simulation models for soft-wing kites [12] [4] [18], fixed-wing kites [9] [13] and hybrid kites [3]. The Sensor Fusion Technique is a combination of multiple sensors to overcome individual inaccuracies and limitations and allows prediction of wind and aerodynamic characteristics and the state of the kite at the same time. A notable contribution to the understanding of wake effects of AWES was published by Polimi [20]. Aeroacoustics of AWE Systems were investigated by TU Delft [2].

In **WP3 on safety and Airspace Integration**, the White Paper on AWE Airspace Integration [1] was expanded upon in collaboration with TwingTec in a project co-funded by Swiss FOCA. The development of AWE-specific standards as part of IEC-61400 and/or unmanned aircraft systems has been started, among others with ORE Catapult [forthcoming]. The SORA process for AWES was detailed in Salma [15].

In **WP4 on Social Acceptance and Environmental Impacts**, the results of the survey conducted with local residents around the SkySails site in Klixbüll (Germany) were published in 2023 [16]. The work benefits from collaboration with the Horizon project, JustWind4All.

Within the WP4 sub-group on Life Cycle Analysis, a number of LCA studies have been carried out, with several publications forthcoming [10] [21].

WP5 on AWES Architectures has finalised the AWE classification within the design space, i.e. the different concepts of AWE systems, as well as the report on relevant Performance Assessment Criteria where novel KPIs were defined [20]. WP5 works closely with University of Freiburg [17] [6].

Highlight(s)

The Task 48 continues to be an important platform in facilitating collaboration among experts and stakeholders and increasing knowledge on Airborne Wind Energy. The exchange with Task 41 (Distributed Wind), Task 50 (Hybrid Plants) and Task 28 (Social Acceptance) as well as other publicly funded projects (like MegaAWE, MERIDIONAL, JustWind4All, NEON, BORNE, etc.) helps create a global AWE community.

WP1 presents the open-source tool chain AWERA to compute the wind resource classification/representation and power harvesting estimation for AWES at specific sites or an entire area. In WP2, the open-source tool chain MegAWES provides a model of a megawatt-class airborne wind energy system based on rigid wing technology.

The already available LCA case study results of rigid and soft wing AWE electricity show that environmental impacts are generally at a low level due to the low material use. Material intensity of AWE electricity ranges from 1-3 kg/MWh, compared to ca. 6-7 kg/MWh for a HAWT. Impacts on climate change are around or below 10 g CO2-eq/kWh.

AWE has potential to reduce energy system costs due to a high capacity factor, and that onshore AWE may in many locations be the preferred technology, even at higher cost. However, comparable spatial capacity density (MW/km2) needs to be proven.

The site assessment study for Germany revealed that there are several thousand suitable sites available with a potential of several dozen gigawatts.

For single off-grid hybrid systems, significant reductions in the cost of electricity are possible by shifting from purely diesel-based electricity generation to a hybrid power system comprising AWE, solar PV, batteries and diesel.

Outcomes and Significance

Benefits of the results include:

- The White Paper on AWE Airspace Integration has become the base document for all discussions around that topic. It thus helps to define new regulation for AWE systems.
- The first peer-review study on a survey on social acceptance for AWE represents cutting-edge research on social acceptance for innovative renewable energy technologies such as AWE. In conjunction with Task 28 it provides solid evidence and expertise for future projects, showing also that this topic is taken serious by the AWE sector.
- The work on Prospective Life Cycle Assessment (pLCA) is a novel method which includes e.g. learning curves, scaling rates, changes in the supply chains and energy sector. Harmonised guidelines for such pLCA will ensure the creation of robust and comparable study results not only for AWE but also for other innovative technologies.
- As shown in the reference list, a large number of peer-reviewed papers on AWE support its technological significance and impact.

Next Steps

WP1 will continue to interface with the Horizon Europe project, Meridional, expanding our understanding of using AWE systems for airborne wind energy harvesting. The country mapping will be updated and further information on entry markets will be developed with the Interreg North-West Europe project, DEM-AWE.

WP2 will define the reference economic model and develop case studies. Of central importance for companies is a validated digital twin of their system, allowing them to accelerate the development.

In WP3, the various permitting procedures in different jurisdictions will be further investigated and joined conclusions and recommendations will be developed. The process to develop AWE standards within the IEC 61400 framework will be initiated.

In WP4, collaboration with the Horizon Europe project, JustWind4All, will continue. A survey on AWE acceptance in county Mayo in Ireland is on the way and work on LCA and Prospective LCA will continue.

The next step of WP5 is to define and describe the various AWE archetypes in more detail.

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