Report 2022

Task 48

SkySailsPower on Maurtius. *Photo: Skysails Power.*

Airborne Wind Energy

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Airborne Wind Energy Systems allow wind resources to be captured at altitudes up to 600m 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 in the future energy system.

The objective of Task 48 on AWE is to tackle a variety of specific challenges on a global scale, in addition to addressing and including stakeholders who are not primarily AWE developers, i.e. policymakers, authorities, regulators and other wind energy and technology experts. Task 48 consists of five Work Packages: 1) Resource potential and markets, 2) reference models, tools, and metrics, 3) safety and regulation, 4) Social Acceptance, and 5) AWES Architectures. Furthermore, the development of various tools, papers and studies occurred throughout 2022 within Task 48 and in collaboration with other projects.

Task 48 has become a key platform for knowledge exchange within and beyond the AWE sector, helping increase awareness and expertise on the technology. The Task is supported by eleven countries (BE, CH, DE, DK, ES, IE, IT, NL, NO, UK, US) and several dozen organisations.

Introduction

Over the last years, Airborne Wind Energy (AWE) has gained traction, but it is generally still unheard of in the energy sector, furthermore, within the wind community. Therefore, the IEA Wind Task 48 is a very important platform to spread awareness and knowledge about AWE.

AWE systems make stronger and more stable high-altitude wind resources more accessible, especially in remote areas and floating offshore farms. Thus, they play an important role in the future energy mix. AWE furthermore reduces material consumption which – in combination with a higher capacity factor – has the potential to create exceptionally low LCOEs and decrease carbon and environmental impacts. So far, individual AWE units of a few hundred kW have been proven and the first systems are commercially available.

There are different concepts of AWE systems: Ground-based systems have a generator in the ground station and use a pumping cycle to reel the kite in and out. The kites can be soft kites or fixed-wing aircraft. In the case of fly-gen systems, the power is generated in the aircraft through the

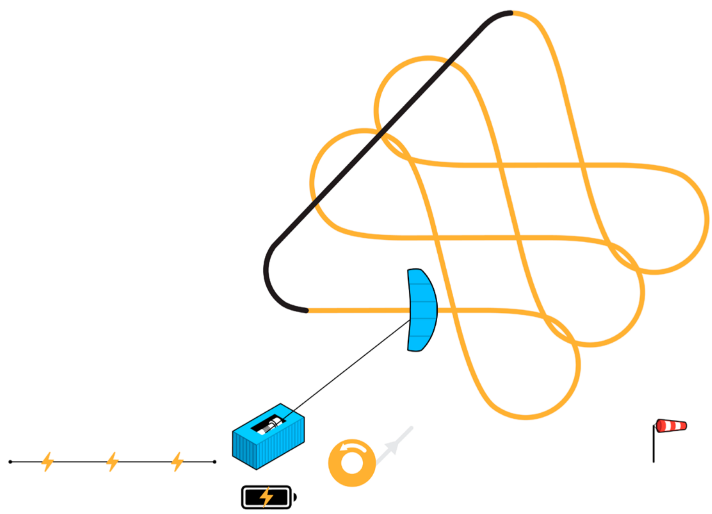

Figure 1. Pumping-system with generation on the ground. *Source: Airborne Wind Europe.*

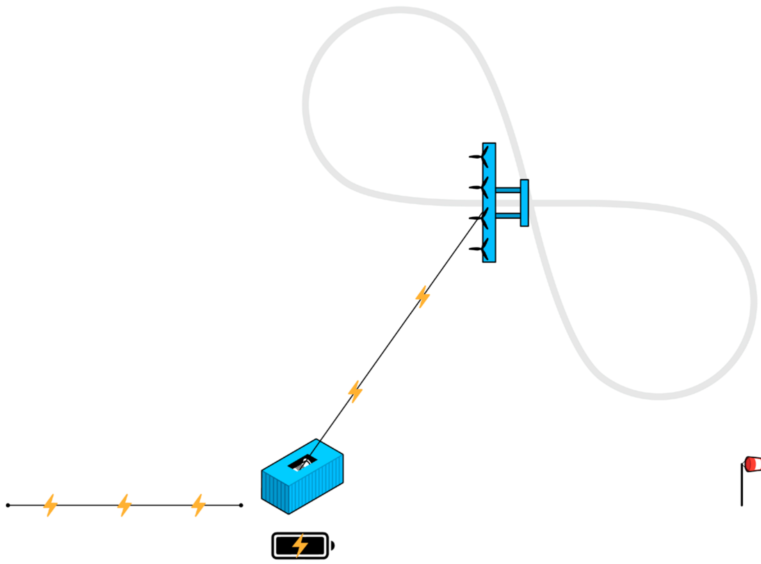

Figure 2. Generation in the air. *Source: Airborne Wind Europe.*

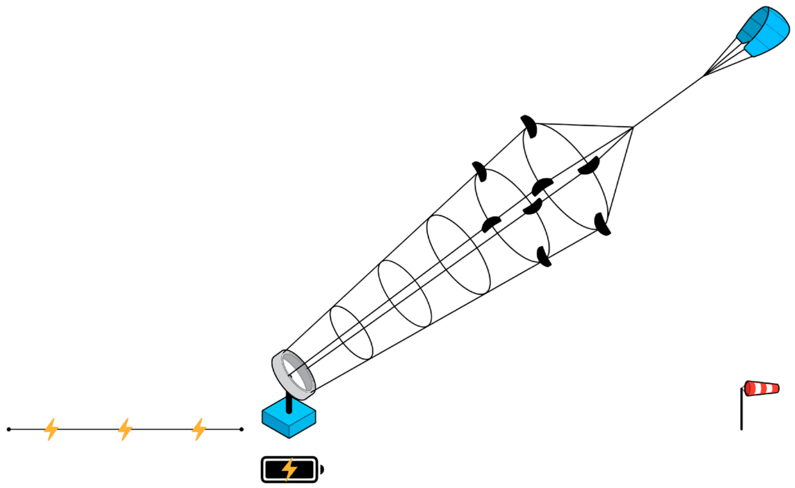

Figure 3. Rotary system with generation on the ground. *Source: Airborne Wind Europe.*

rotors and generators on board and the electricity is evacuated through the tether to the ground station. Rotary systems use a lifter kite and generation on the ground.

Task 48 aims to find solutions for various challenges in the following five work packages:

1. Resource potential and market.
2. Reference models, tools and metrics.
3. Safety and regulation.
4. Social acceptance.
5. AWES architectures.

The work packages involve several research institutes as well as all relevant AWE technology developers. It reaches out to utilities, suppliers,

Table 1. Countries participating in Task 48.

	COUNTRY/SPONSOR	INSTITUTION(S)
1	**Belgium**	Airborne Wind Europe, FOD Economie, University of Gent
2	**Switzerland**	EPFL, ETH Zürich, PSI, Skypull SA, Swiss Federal Office of Energy, Swiss FOCA, Twingtec AG, UASolutions
3	**Germany**	Enerkite GmbH, FGW, Fraunhofer ISI, FZ Jülich, kiteKRAFT, Leibniz University of Hannover, Oceanergy, RWE, RWTH Aachen, Skysails GmbH, Uni Bonn, University of Applied Sciences Munich, University of Bonn, University of Freiburg, University of Halle, University of Stuttgart
4	**Denmark**	DTU
5	**Spain**	CT Ingenieros, CIEMAT, CEDER, Siemens Gamesa, someAWE, UC3M
6	**Ireland**	MaREI Research Centre, University College Cork, Mayo County Council , RWE Renewables, SEAI, University of Limerick
7	**Italy**	Kitenergy, Politecnico di Milano
8	**Netherlands**	Kitepower, Mozaero, TNO Wind, TU Delft
9	**Norway**	Kitemill AS, University of Bergen
10	**United Kingdom**	ORE Catapult , University of Strathclyde, Windswept
11	**United States**	Colorado State University, North Carolina State University, NREL, SNL, UCSB, University of Dayton, University of Washington, Windlift, Worcester Polytechnic Institute

and project developers, in addition to policymakers, authorities, regulators, and other wind energy and technology experts.

Progress and Achievements

In WP1 on resource potential, the wind resource plots for selected sites in Europe and the US were refined and improved. The AWE Resource Analysis tool AWERA (https://github.com/awegroup/AWERA) was developed to assess the potential of AWES on large geographical and temporal scales. The tool uses a clustering technique for vertical wind profiles to substantially accelerate AEP calculations and develop insights into how the vertical wind profile affects energy harvesting [9].

A reference economic model for airborne wind energy systems is currently being developed as a joint project of TU Delft and Polimi [6,7].

Furthermore, a country mapping (https://airbornewindeurope.org/studies-papers/awe-country-mapping/) was carried out showing entry markets for AWE. It contains information on AWE potential, policies, regulations, stakeholders, and opportunities as well as a rating that allows for a quick comparison among countries and for identifying areas of improvement.

In WP2 on reference models, tools and metrics, the terms and definitions elaborated by the AWEurope Working Group have been agreed upon: https://airbornewindeurope.org/resources/glossary-2/.

The NREL methodology of "Technology Performance Levels" (TPLs) will be applied.

The WP assesses the state-of-the-art simulation approaches, tools, and platforms available globally. Among those are, for example, the Julia Kite Power tool which is a reference model to improve quality assurance https://github.com/ufechner7.

The MegAWES reference model and simulation framework for a future utility-scale AWES (https://github.com/awegroup/MegAWES) is a Matlab/Simulink model that includes an aeroelastic wing spanning 42.5m, a point mass model to describe the flight dynamics of the tethered aircraft, a discretised tether, and simple controller to fly circular trajectories with a short retraction phase per circle.

The aircraft model was upgraded from point mass to rigid body, accounting for translational and rotational degrees of freedom [4], [5].

In WP3 a white paper on AWE Airspace Integration was developed in collaboration with TwingTec in a project co-funded by Swiss FOCA. It provides a general framework for AWE systems that have to deal with energy system standards, such as IEC-61400 for wind generators, in addition to standards and regulations related to unmanned aircraft systems like EU-2019/947 [2].

In WP4 regarding social acceptance, a literature review assessed the current knowledge base on the social acceptance of AWE. A systematic literature search led to the identification of 40 relevant publications that were reviewed [8].

An interview-based survey study was conducted among residents

Figure 4. Computer rendering of the MegAWES reference model.

by local organisations. Accordingly, structured, in-person interviews took place in the participants' homes. The journal manuscript discussing the results of the study is currently in preparation.

Within the WP4 sub-group on Life Cycle Analysis, a paper was finalised regarding the Life Cycle Analysis of a fixed-wing AWE system. The paper was based on a Master Thesis at TU Delft and further developed under the MegaAWE project, Furthermore, the LCA process has been initiated.

WP5 on AWES architectures developed an overview of the design space which considers the various different concepts of AWE systems.

Performance assessment criteria and metrics are being developed for the purpose of performing a trade-off analysis between implementation options in the AWE design space. These include efficiency, reliability, availability, complexity, automatability, scalability, airborne mass, durability, ductility, safety, potential, cost, and investability.

Highlight(s)

Task 48 has proven to be an important platform for bringing experts and stakeholders together while increasing the visibility of Airborne Wind Energy. Furthermore, the exchange with Task 41 (Distributed Wind), Task 50 (Hybrid Plants) and Task 28 (Social Acceptance) is seen as beneficial for all participants.

The study by BVG Associates, "Getting Airborne – The need to realise the benefits of airborne wind energy for net zero", showed that AWE can reach 1 GW of installed capacity by 2031 and several hundred GW by 2050, provided that the required funding for R&D and price support is made available by governments.

The life-cycle analysis showed that the specific AWE configuration could save up to 70% of materials and reduce the GHG potential by about 40% compared to a Horizontal Axis Wind Turbine [1].

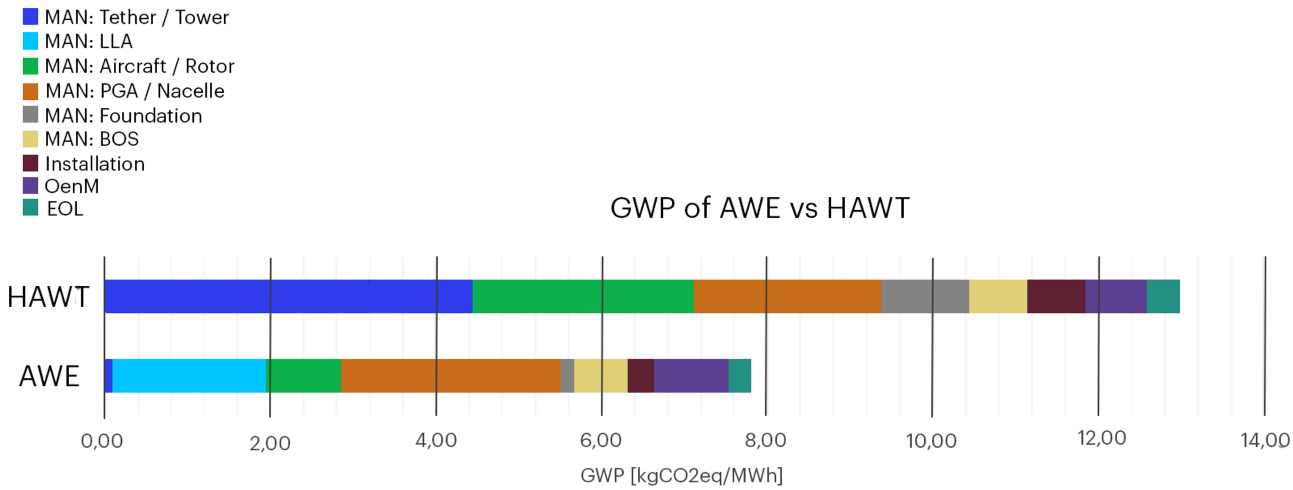

Figure 5. LCA Analysis: Global Warming Potential of an AWE system compared to a Horizontal Axis Wind Turbine (HAWT) system. *Source: v. Hagen, AWEurope et al. 2021/2022.*

Further research by PSI supports these findings, but more research on other AWE configurations, such as soft kites, is required.

According to the reviewed literature, social acceptance of AWE appears to be optimistic. However, it lacked scientific evidence to back up its claims. Therefore, further collaboration in joint projects with Task 28 members and through the Horizon Europe project, JustWind4All, has been initiated.

Outcomes and Significance

The most important outcomes from Task 48 include:

- The MegAWES reference model and simulation framework offers, like the NREL 5MW wind turbine, a relatively detailed reference model of a multi-megawatt AWE system. It can also be used to test concepts in the early stages of development without the excessive costs of building a real system. Currently, it is used by several research groups and development teams around the world.
- The white paper on AWE Airspace Integration will support the elaboration of regulatory guidelines on how AWE should be treated regarding ground and air safety and discuss findings with EASA, FAA, national and regional aviation, and permitting authorities.

- Social acceptance of a novel technology like AWES is key. Therefore, further research using approved methodological methods is important.

- The WP4 subgroup on Life-Cycle Analyses brings together expertise from different fields to increase the number of LCAs for different AWE configurations, thus further researching how to reduce the environmental impacts of AWES.

Next Steps

- WP1 will collaborate with the Horizon Europe project, Meridional, which focuses on resource assessments, including high altitude winds, which will provide input to Task 48.

- WP2 will work on further developing the MegAWES reference model and simulation framework. A review of the current definitions of terms, as well as the extension of definitions to new terms, will be continued.

- In WP3 the white paper on AWE Airspace Integration will be further discussed and developed with stakeholders.

- In WP4 more surveys and interviews will be conducted in collaboration with the Horizon Europe project JustWind4All. Several new LCA studies are on the way, coordinated by PSI.

- WP5 will finalise the AWE classification before focusing on the application of KPIs and Technology Performance Indicators.

References

[1] Airborne Wind Europe (2021), Life-Cycle Assessment of an Airborne Wind Energy System, Interreg NWE - MegaAWE project. Petrick, K., van Hagen, L., Schmehl, R., Wilhelm, S. AWEurope, 2021: Life-Cycle Assessment of an AWE System - Airbornewindeurope

[2] Airborne Wind Europe (2023), Safe Operation and Airspace Integration of Airborne Wind Energy Systems – White Paper of the AWE industry. Petrick, K., Houle, C. https://airbornewindeurope.org/studies-papers/safe-operation-and-airspace-integration-of-airborne-wind-energy-systems/

[3] BVG Associates on behalf of Airborne Wind Europe, "Getting airborne – the need to realise the benefits of airborne wind energy for net zero", September 2022. https://airbornewindeurope.org/wp-content/uploads/2023/03/BVGA-Getting-Airborne-White-Paper-220929.pdf

[4] Eijkelhof, D., Rapp, S., Fasel, U., Gaunaa, M., Schmehl, R. (2020), Reference Design and Simulation Framework of a Multi-Megawatt Airborne Wind Energy System. Journal of Physics: Conference Series 1618, 032020 (2020). https://doi.org/10.1088/1742-6596/1618/3/032020

[5] Eijkelhof, D., Schmehl, R. (2022), Six-Degrees-of-Freedom Simulation Model for Future Multi-Megawatt Airborne Wind Energy Systems. Renewable Energy 196, 137–150 (2022). https://doi.org/10.1016/j.renene.2022.06.094

[6] Joshi R, Trevisi F, Schmehl R, Croce A, Riboldi CED. A Reference Economic Model for Airborne Wind Energy Systems. Airborne Wind Energy Conference. https://doi.org/h3c2. (2021).

[7] Joshi R, Trevisi F. Reference economic model for airborne wind energy systems. Zenodo. https://doi.org/10.5281/zenodo.8114627. (2023).

[8] Schmidt, H. et al. (2022), The Social Acceptance of Airborne Wind Energy: A Literature Review. https://www.mdpi.com/1996-1073/15/4/1384

[8] Thimm, L., Schelbergen, M., Bechtle, P., Schmehl, R. (2022),The Airborne Wind Energy Resource Analysis Tool AWERA. In: the 9th international Airborne Wind Energy Conference (AWEC 2021) Book of Abstracts, 22-24 June 2022, Milan. http://resolver.tudelft.nl/uuid:ba0c7fb2-baff-4110-9a51-c27a8498663b

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