IEA Wind Task 48
Airborne Wind Energy

iea wind

Kick-off Meeting (online)
27-28 October 2021

Airborne Wind Europe

TU Delft Delft University of Technology

NC STATE UNIVERSITY

NREL NATIONAL RENEWABLE ENERGY LABORATORY

RWTH AACHEN UNIVERSITY

Agenda

- Welcome and introduction
- News from the AWE Sector
- WP1 Resource potential and markets
- WP2 Reference models, tools and metrics
- WP3 Safety and regulation
- WP4 Public Acceptability
- WP5 AWES Architectures
- Organisational topics

A way to collaborate : the New Task 48 on Airborne Wind Energy of IEA Wind

- The IEA Wind TCP is an international co-operation platform within the IEA framework
- It shares information and research activities to advance wind energy research, development and deployment in member countries.
- Currently 26 contracting parties from 21 countries

- Large majority voting in favour of the new Task 48
- 4-year period: 2021 – 2025
- Kick-off meeting 27-28 October 2021

Five Work Packages

WP0: Task coordination	WP1: Resource potential and markets	WP2: Reference models, tools and metrics	WP3: Safety and regulation	WP4: Public Acceptability	WP5: AWES architectures
• Organisation & management of Task • Communication • Website • Dissemination	• AEP prediction for selected sites & toolchain documentation • Global high-altitude wind resource atlas • Recommendation on AWE entry-markets	• Common definition of metrics and KPIs • Joint reference model(s) • Centralized design tool • Simulation vs. test flights comparison	• Concept of operations and risk assessment • Airspace integration concept • Benchmarking concepts for safe automatic operation	• Life-Cycle Analysis • Repository of survey and studies • Guidelines for site selection, sound measurement and impact mitigation • Circular Economy	• Design space representation • Market specific deployment recommendations • AWES R&D state, trends and needs • Portal for AWES engagement and development potential
• Task reporting • Communication outputs	• AEP prediction toolchain • Economic metrics	• Definitions • Centralized design tool database	• Whitepaper on AWES safety	• LCA of AWE • Repository of surveys & studies	• Guidelines

Agenda

Wednesday, October 27, 2021		
Introduction		
14:15 CET	Check-in	All
14:30	Welcome and short meeting overview	Kristian Petrick, *AWEurope*
14:35	Introduction about IEA Wind and Tasks	Stephan Barth, *IEA Wind TCP Chair*
14:50	News from the AWE sector	Kristian Petrick, *AWEurope*
Session 1		
15:00	**WP1 Resource potential and markets**	Roland Schmehl, *TU Delft*
15:15	**WP2 Reference models, tools and metrics**	Chris Vermillion, *NC State University (US)*
15:30	Break (10 min.)	
15:40	**Moderated Break-out sessions on the two presented topics (45 min.)**	
16:25	Plenary with main results of break-out groups	
16:50	Short summary of the day	Kristian Petrick, *AWEurope*
17:00	Close of day	

Agenda

Thursday, October 28, 2021		
14:15 CET	Check-in	All
14.30	Welcome and Recap of Day 1	Kristian Petrick, *AWEurope*
Session 2		
14:40	**WP3 Safety and regulation**	Dieter Moormann, *RWTH Aachen*
15:00	**WP4 Public Acceptability**	Kristian Petrick, *AWEurope,* Helena Schmidt, *TU Delft*
15:15	**WP5 AWES Architectures**	Christof Beaupoil, *someAWE*
15:30	Break (10 min.)	
15:40	**Moderated Break-out sessions on the presented topics (45 min.)**	
16:25	Plenary with main results of break-out groups	
Final Session		
16:35	Organisational topics: How to join Task 48	Stefanie Thoms, *AWEurope*
16:45	Discussion and consensus among all participants	Kristian Petrick, *AWEurope*
17:00	Event close	

Working together – some housekeeping rules

- Stay on topic
- Keep interventions short
- Follow the process
- Be critical but don’t discredit other people’s work
- Keep distribution lists short

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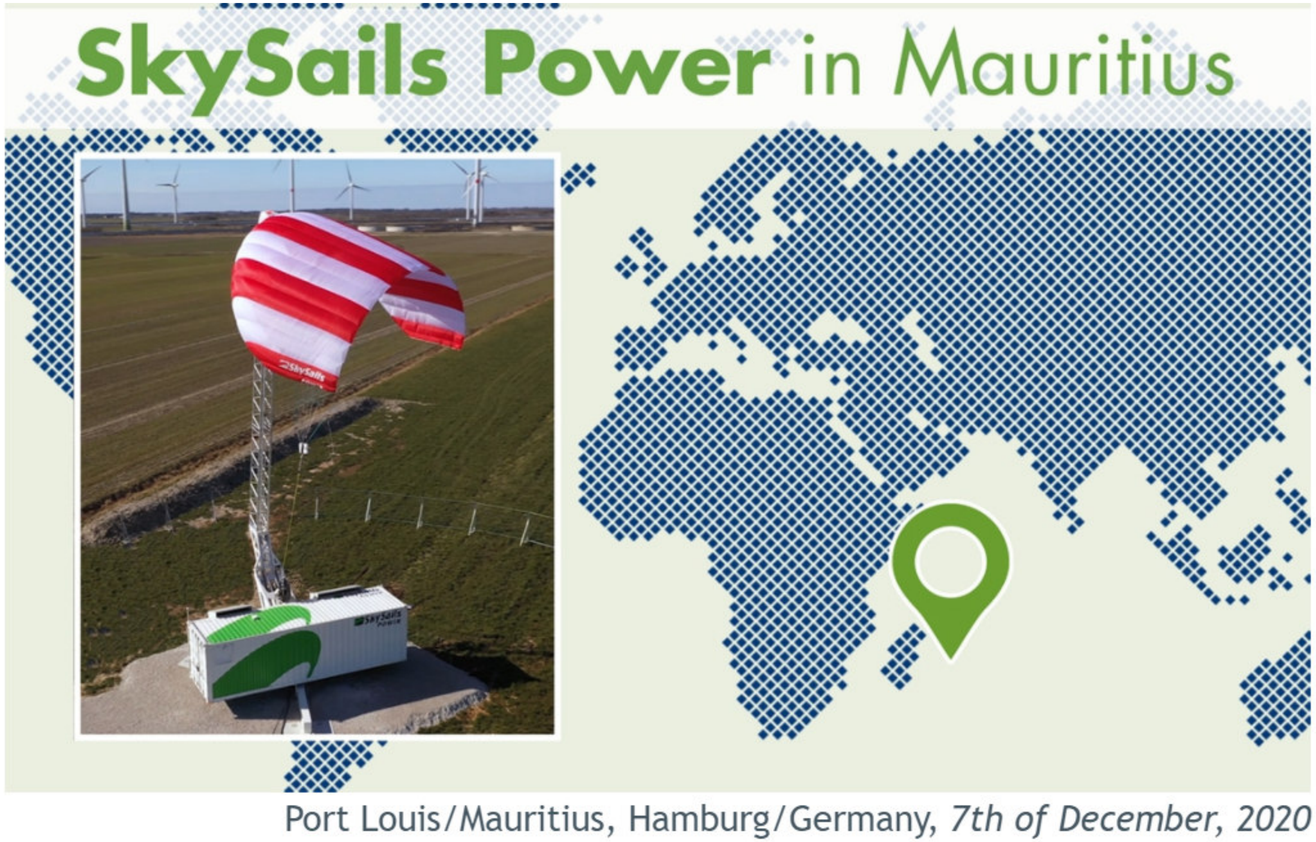
Airborne Wind Energy companies continue to develop different concepts: Soft, semi-rigid and fixed-wings; ground-gen vs. fly-gen

The first commercial AWE systems are already today competitive in markets with diesel-based power generation



Skysails system
~150 kW

https://www.skysails-group.com/index.html?artikel=Kite-Power-For-Mauritius

Achievements of the AWE Sector – selected examples

Automatic flight

2008 – Makani
2008 – SkySails – 1 MW*
2012 - TU Delft – 1h – 20 kW
2012 – Enerkite (05/2008 ≤ 1hr)
2012 – Ampyx – 15 kW
2013 – Kitemill - 5kW
2016 – Kitepower – 25m²
2019 – Skypull – 1 kW

Automatic operation in major operational phases

2008 – Makani – x kW (soft kite)
2008 – SkySails – 1 MW*
2012 – Enerkite – 30 kW, 3d
2015 – Ampyx – 15 kW
2016 – SkySails – 50 kW
2017 – Kitemill 5kW, (2021 - 20kW)
2018 – Kitepower
2019 – Kitepower – 100 kW
Until 2020 – Ampyx – 500+ L&&
2020 – Skypull – 1 kW

Full proof-of-concept

2015 – Ampyx – 15 kW
2016 – SkySails – 50 kW
2017 – Kitemill – 5 kW
2018 – TwingTec: Rigid Wing -VTOL – Groundbased Generation – 2 kW
2020 – Ampyx – SORA compliant flight ops
2020 – Skypull – 1 kW

Operational hours

2018-20 – Kitepower – ~180 – 100 kW (> 1000 hours overall)
By 2020 – Ampyx - ~100h
By 2020 – Kitemill- ~100h
By 2020 – SkySails – >10.000 h

Commercial systems in operation

2008 - SkySails 1 MW*
2021 – Skysails 150 kW

< 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021

Operation for multiple days

2008 – SkySails – 1 MW*
2013 – Enerkite – 30 kW 3d
2014 – Enerkite in Winter 3d
2020 – SkySails – 200 kW

Automatic operation during night

2008 – SkySails – 1 MW*
2013 – Enerkite – 72 hours
2018 – Kitepower – x kW
2019 – Makani – 600 kW
2020 – SkySails – 200 kW

Flight in offshore conditions

2003 – SkySails – 40 kW*
2019 – Makani – 600 kW

*: vessel propulsion system

Airborne Wind Europe – members and collaboration

Airborne Wind Europe

KITEMILL · SkySails POWER · EnerKíte · ampyx power · TWINGTEC WIND ENERGY 2.0 · KITEPOWER · Windswept & Interesting · KITE//KRAFT · SKYPULL · POLITECNICO MILANO 1863 · RWTH AACHEN UNIVERSITY · TU Delft

Member of: WindEurope MEMBER · eawe european academy of wind energy

(Planned) collaboration: ETIP Wind EUROPEAN TECHNOLOGY & INNOVATION PLATFORM ON WIND ENERGY · iea wind · CLEAN ENERGY FOR EU ISLANDS

Public stakeholders involved in airborne wind energy (selection)

European Commission

HORIZON 2020

Interreg North-West Europe
EUROPEAN UNION

Bundesministerium für Wirtschaft und Technologie

Bundesministerium für Bildung und Forschung

Department for Business, Energy & Industrial Strategy

ADEME
Agence de l'Environnement et de la Maîtrise de l'Energie

eXIST
Existenzgründungen aus der Wissenschaft

ESF
Europäischer Sozialfonds für Deutschland

Netherlands Enterprise Agency

Interreg North-West Europe Project MegaAWE (2020 – 2024): Partners

Regions

provincie Zuid Holland
EnergieAgentur.NRW
Bord na Móna Naturally Driven
Région Bretagne
AD'OCC Région Occitanie
Comhairle Contae Mhaigh Eo Mayo County Council

User partners (utilities, site owners, applications)

RWE
nexstep
enel Green Power
TKI Wind op Zee Topsector Energy

AWES sector organization

Airborne Wind Europe

Innovation Catalysts

BlueWise Marine
Catapult Offshore Renewable Energy
Elfi Tech
ECN
Bretagne Développement Innovation
EASA
EMEC The European Marine Energy Centre Ltd

Technology Providers (OEMs)

ampyx power

AWES supply chain

Siemens
Parkburn Precision Handling Systems
Stellar Space Industries
InfraCore company
S.A.B.C.A.

AWEC: 22-24 June 2022

Call for abstracts Submission Deadline: 7 January 2022, www.awec2021.com

AIRBORNE WIND ENERGY CONFERENCE 2021

Politecnico Milano
Italy, 22-24 June2022

Home | Call for Abstracts | Photo competition | Book of Abstracts | Committee | Contact

Welcome to AWEC 2021

Due to the continued uncertainty over the pandemic, the 9th International Airborne Wind Energy Conference (AWEC 2021) at the Politecnico Milano will be postponed to 22-24 June 2022

One of the traditional key objectives of the conference is to meet physically, to network and to exchange ideas. Due to the ongoing worldwide pandemic, the risk is still very high that this will not be possible at the start of September 2021. We have tried to mitigate this by planning the conference as a hybrid event, accommodating also online participation, however, to target an event with physical presence of a larger group of people we would need to already have the

Organizers

POLITECNICO MILANO 1863

Airborne Wind Europe

TU Delft

eawe european academy of wind energy

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Questions to be answered (from task proposal)

- **How to deploy AWE for maximum impact on reducing CO_2 emissions?**
- **Where does AWE provide a good business case and at which size?**
- **How does the cost of AWES scale with size?**

Overarching goals (from task proposal)

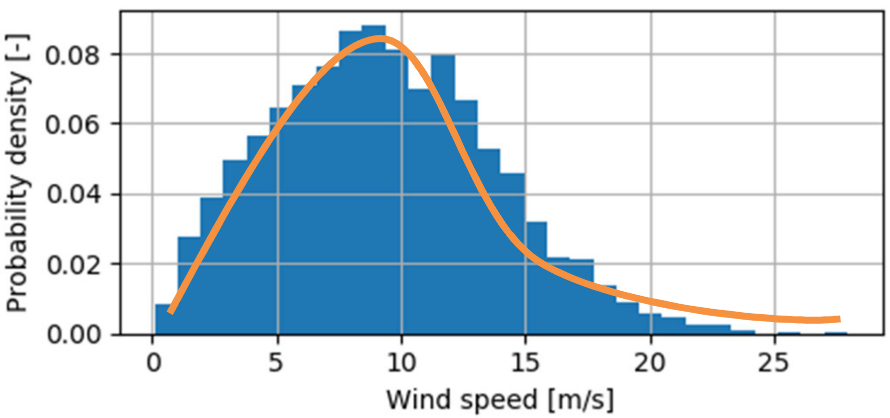
- **Goal 1 – Develop a global higher-altitude wind resource atlas for altitudes (up to ~1 km).**
- **Goal 2 – Create a techno-economic toolchain for AWE that allows developers to assess how expensive a system is expected to be and how expensive it can be to be economically viable, based on the market.**
- **Goal 3 – Consider AWE systems on individual system and on wind park level and their potential contribution to future energy systems.**

Techno-economic toolchain – overall needs

- **Entire toolchain needed from the prediction of the wind resource to the use in the energy system.**
- **Some technical aspects of the system and its operation can be analyzed standalone.**
- **To assess business case also costs and market behavior need to be integrated.**
- **What are the decisive metrics that drive the AWES design (at different scales)?**

Common practice: wind resource representation for fast AEP predictions of AWE systems

Weibull distribution of wind speed close to ground



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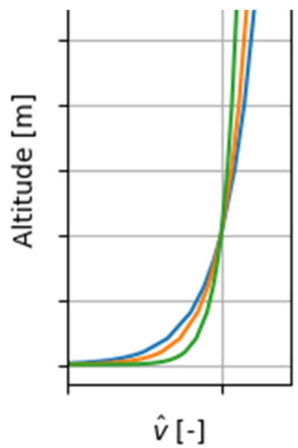
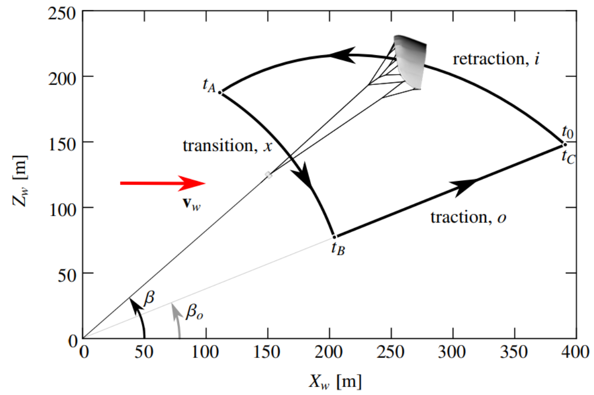
Log profile





Source: Van der Vlugt et al. – Quasi-Steady Model of a Pumping Kite Power System

Mark Schelbergen, TU Delft

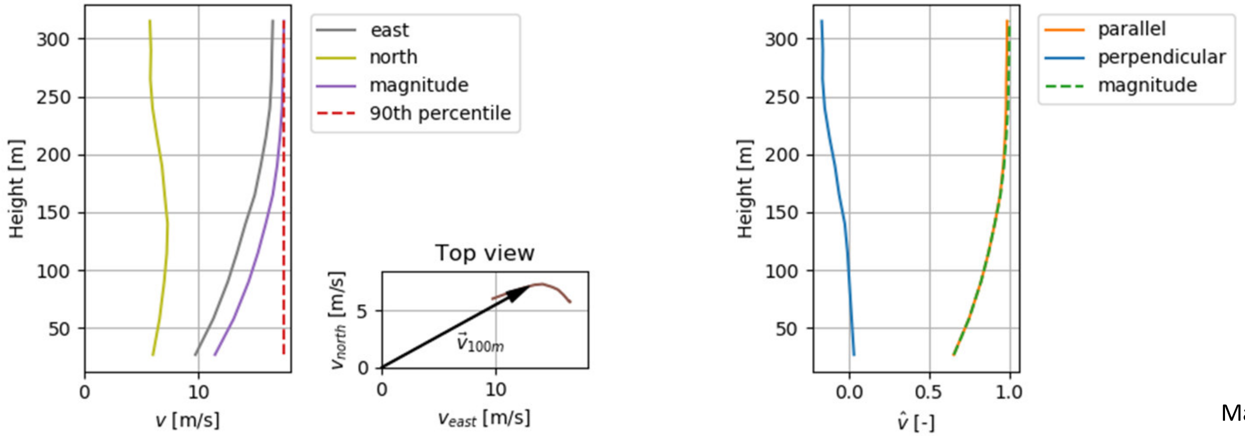
New approach: increase accuracy by using multiple realistic wind profile shapes from data

Data should include wind speeds/ directions at multiple heights

- ERA5 reanalysis data
  - 1979 to 3 months of real time
  - 31 km grid
  - Local terrain is not resolved
- LiDAR observations
  - Poor availability
  - Good accuracy

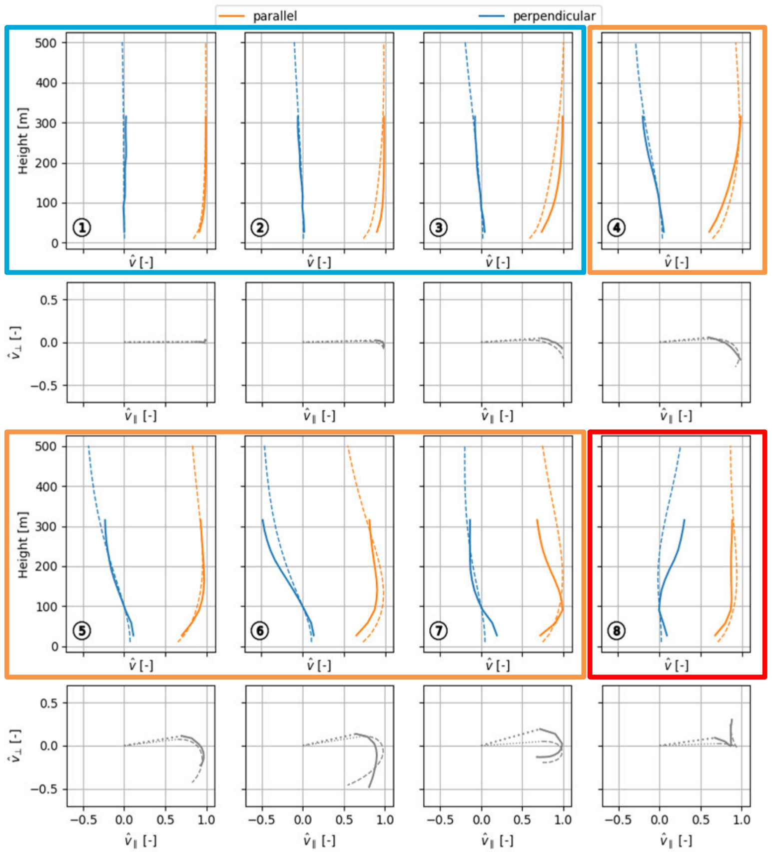
Obtaining **wind profile shapes**

- LiDAR data is hourly averaged
- Wind speed variation is expressed by parallel & perpendicular components w.r.t. 100 m wind speed
- Wind profiles normalised using 90th percentile of wind speed magnitudes



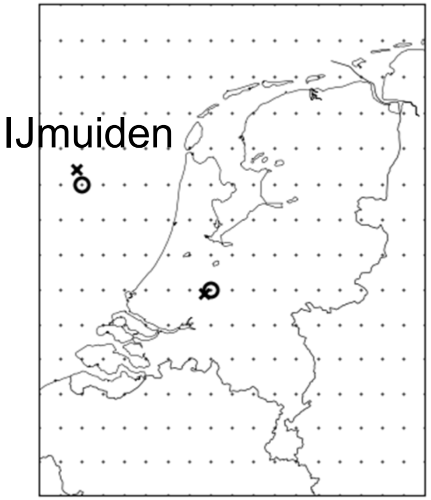
Mark Schelbergen, TU Delft

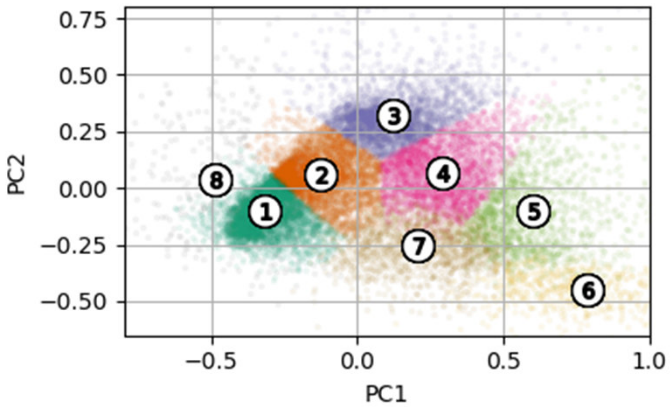
Example: eight cluster profiles for Dutch offshore location



IJmuiden:

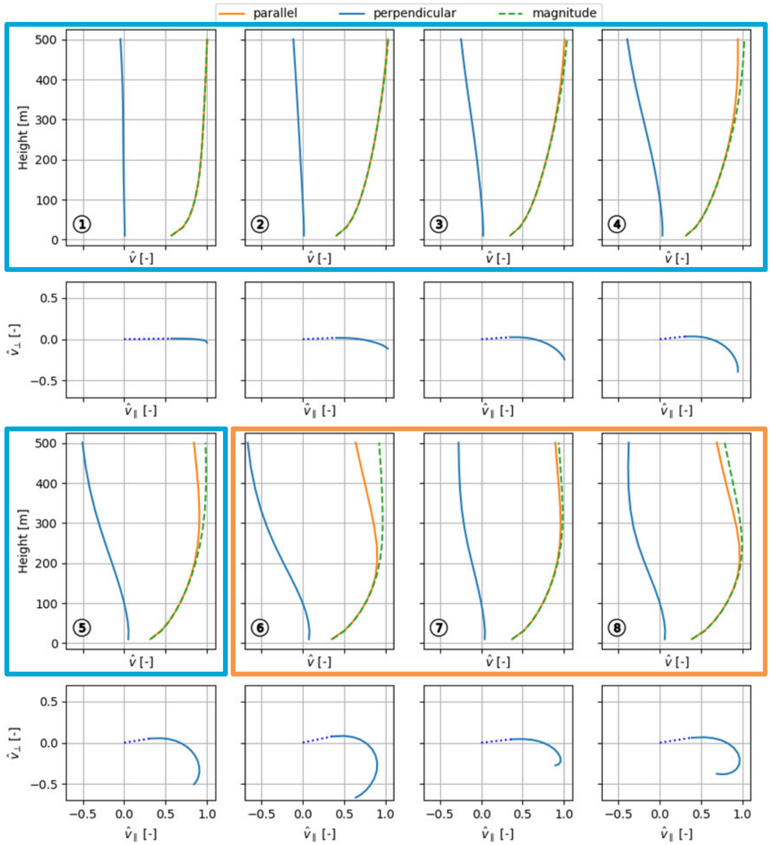
- #1-3: Log profiles (blue)
  → #1: highly dense cluster
- #4-7: Low level jets (orange)
- #8: Distinct kink (red)
- LiDAR data yields similar clusters





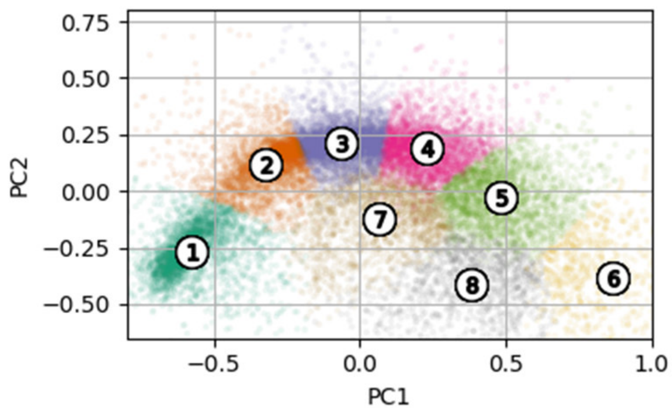
Mark Schelbergen, TU Delft

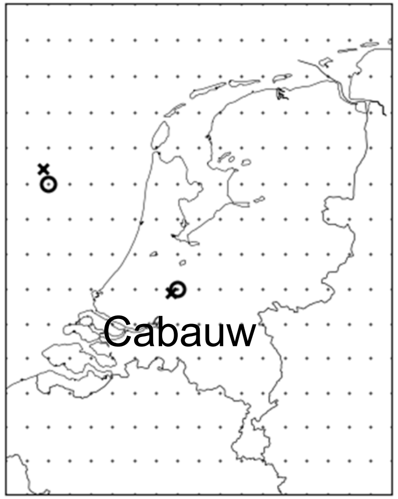
Example: eight cluster profiles for Dutch onshore location



Cabauw:

- #1-5: Log profiles (blue)
- #6-8: Low level jets (orange)

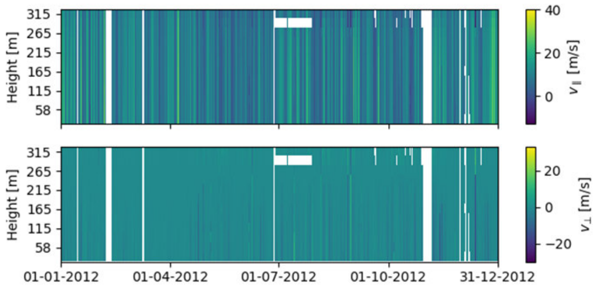




Mark Schelbergen, TU Delft

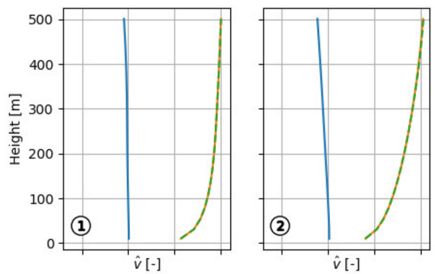
Summary cluster procedure

- ~99% of data variance is retained by 5 principal components
- Dominant wind profile shape clusters
  - Offshore: low-shear log profile
  - Onshore: high-shear log profile
- Good agreement ERA5 with LiDAR clusters
- Compact wind resource representation is obtained



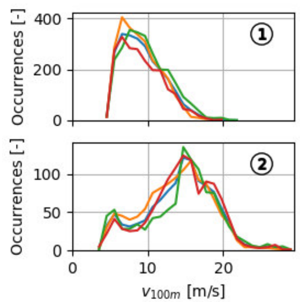
1 year of wind data
8760 hourly samples

replaced by



Wind profile shapes
k clusters

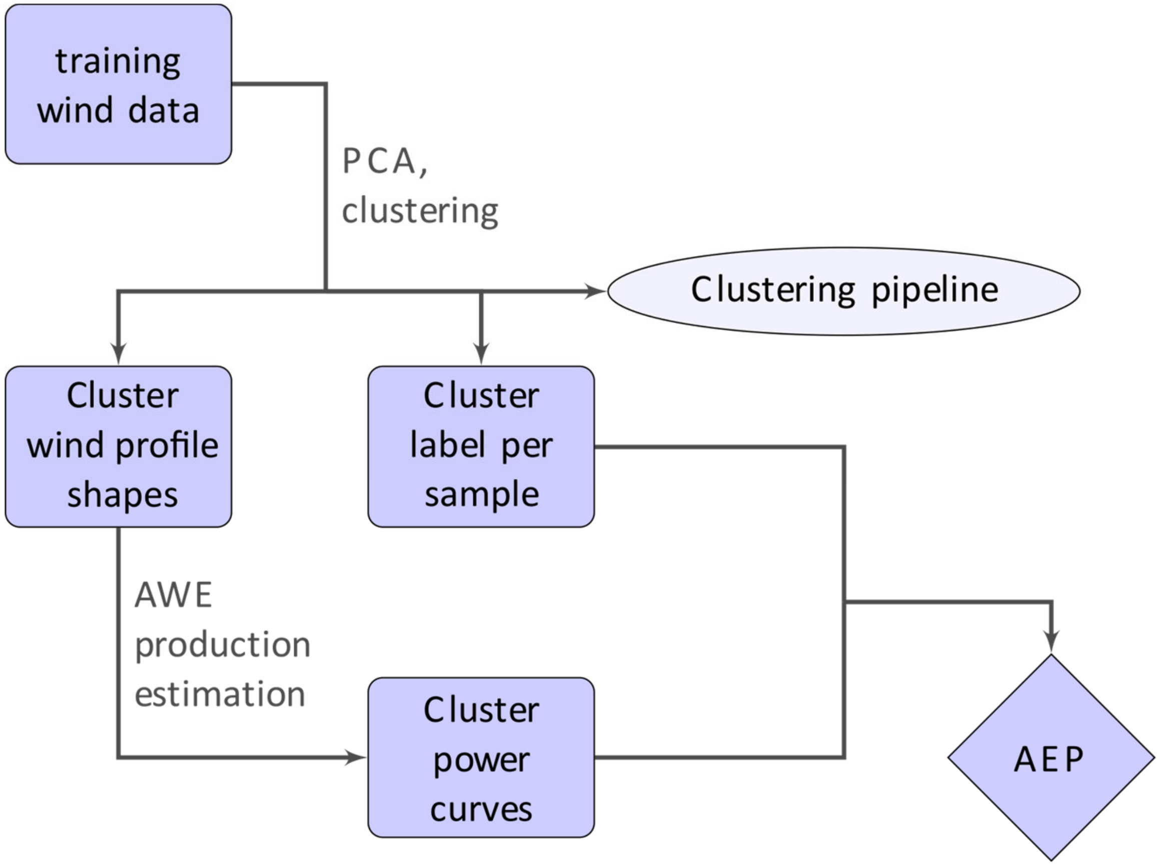
x



Corresponding distributions
n wind speed bins

Mark Schelbergen, TU Delft

General framework implementation



Performance for single location and one year of data (HPC, 40 cores, 700 GB RAM):

- Predict clusters: **12 s** -> AEP from clustering
- Run QSM on ERA5 data directly: **730 h**
  - 5 min per sample * 24 * 365
  - ranges from about 0.5 min – 10 min

Lavinia Thimm, University of Bonn

General framework for power harvesting characteristics

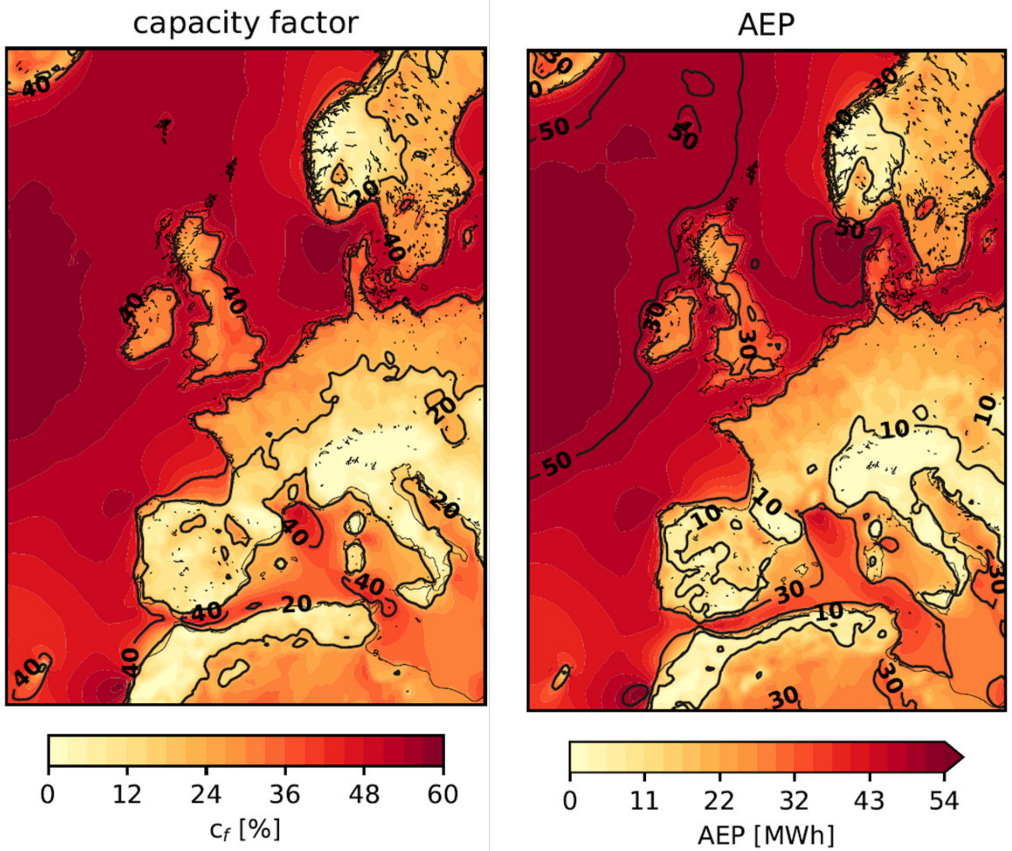
- representative wind profiles (Clustering)
- power curves (power vs wind speed) for each cluster (optimization/simulation)
- possible integration of
  - new/different production models
  - new location wind data
- uncertainty estimates (w.r.t. complete simulations)
  - hourly energy production estimates for required locations
  - European/world-wide maps of aep/hourly energy production

Now: Europe

- 0.25 deg x 0.25 deg **ERA5** reanalysis hourly data 2010-2020
- **QSM** simulation with optimized flight path.

Lavinia Thimm, University of Bonn

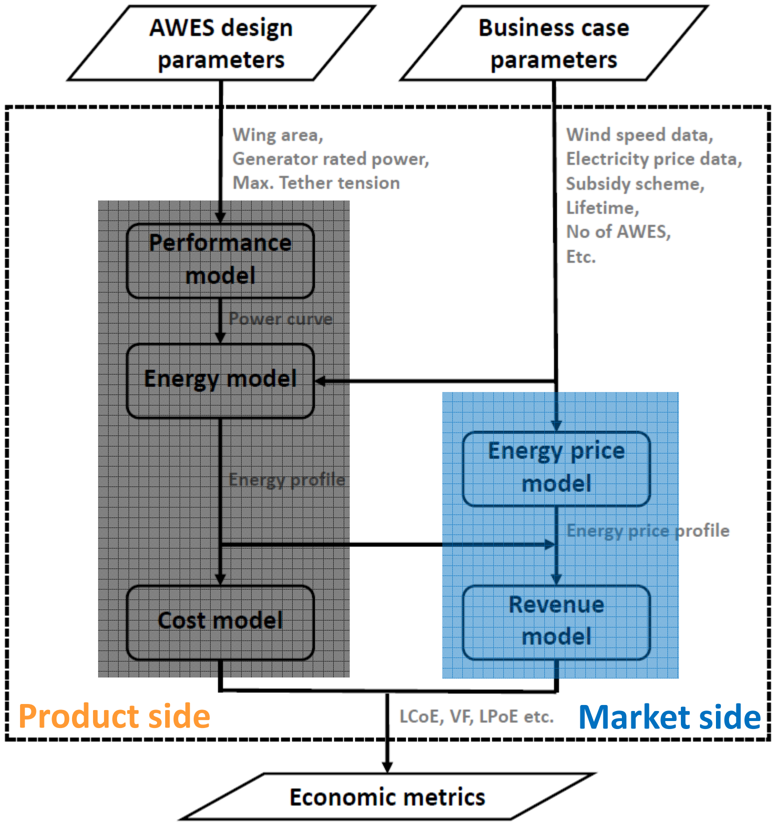
European AWE production potential (provisional)



- 5000 location training, full prediction C_f and AEP
- **Disclaimer: Results are provisional**, showing a low C_f above onshore regions. That is because the optimization objective was only to maximize AEP, disregarding any generator limits! Including a generator limit would reduce AEP and increase C_f.
- Such an effect would result from minimizing the LCOE, and an even stronger effect when maximizing profit.

Lavinia Thimm, University of Bonn

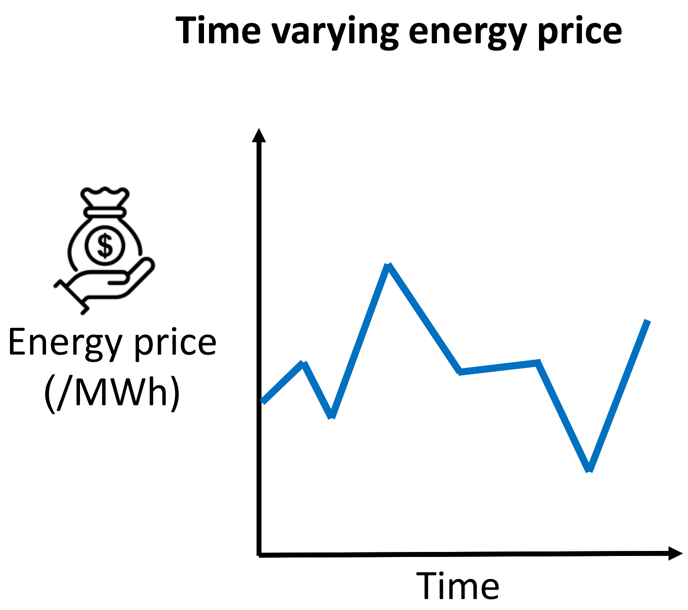
System sizing tool-chain

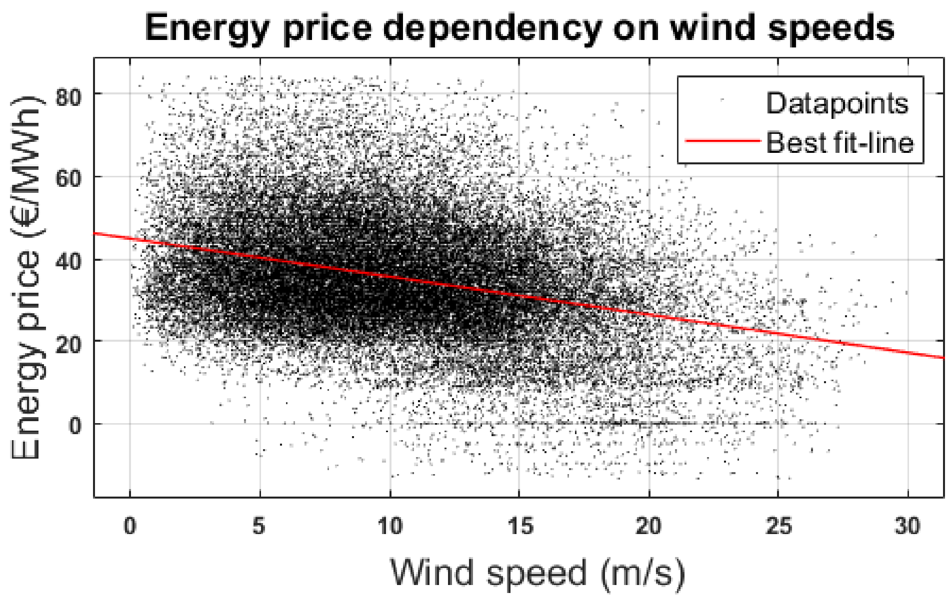


- **Technical feasibility** of AWE is proven
- **Commercial viability** of AWE is not yet proven
- Understanding the **design drivers** for future large-scale AWE systems is the key

Rishikesh Joshi, TU Delft

Influence of the electricity market





Energy sold during low wind speeds has higher value than energy sold during high wind speeds

Rishikesh Joshi, TU Delft

Value driven system design

- Necessity of designing systems **beyond LCoE**
  - Time dependent revenue generation capability is not captured
  - Contribution to grid stability is not captured
- Drivers like **LPoE, capacity factor, frequency and voltage regulation** will become more relevant in future
- Different markets will have **different design drivers**
  - Utility-scale (>10MW)
  - Off-grid/micro-grid (<1MW to multiple MW)
  - Frequency and voltage regulation
  - Power to gas (e.g. Hydrogen)

Rishikesh Joshi, TU Delft

Difference between of WP1 and WP2

- Both work packages cover simulation tool chains which can make a differentiation challenging.
- Activities in WP1 are generally geared towards developers to make fast assessments of deployment scenarios, that involve component and system sizing steps and optimization of system operation.
- In addition to the technical modeling (WP2), WP1 will also include economic modeling.
- For that reason, lower fidelity models will have to be used, that are individually validated in WP2.

Expected participant contributions WP1

Country	Organisation	Project(s)	Planned project end year
BE	Airborne Wind Europe	Interreg NWE MegaAWE, WP T3, LT: entry markets, AWE scenarios Work in AWEurope Working Group on roadmap	2023
DE	Uni Bonn	Inhouse funding	2025
DE	Reiner Lemoine Institute	AWE toolchain for off grid market - tbc	2021
DK	DTU	In-house funding ; (other EUDP/IEA task cross-over) (proposals with cross-over)	2025; (2022) (20xx)
IT	Politecnico di Milano	Self-funded research activities simulation-based AWES availability study	2025
NL	TU Delft	PhD project & inhouse funding	2024
NL	TU Delft (with Ampyx Power & Kitepower)	NEON (2 PhD projects)	2025
NL	Ampyx Power	Interreg NWE MegaAWE, WP T1-T3	2023
NL	Kitepower	Identification of pilot locations and development of offgrid business case	2023

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Overarching goals (Per the task proposal)

- **Goal 1 – Create common metrics, terminology, and key performance indicators (KPIs)**: "Identify commonly used metrics and key performance indicators, and identify gaps between available metrics and the quantification need of functional requirements."
- **Goal 2 – Create common design tools and a centralized design tool database**: "Determine the state of the art of globally available simulation approaches, tools, and platforms. Identify gaps in the simulation tool landscape and initiate simulation tool development activities ranging from collaborative development to simulation competitions with embedded use of the developed reference models as test cases."
- **Goal 3 – Develop a common reference models**: "Develop key airborne wind energy technology concept reference model(s) for (distinctly different) fundamental airborne wind energy technology archetypes."

Common terminology, metrics and KPIs

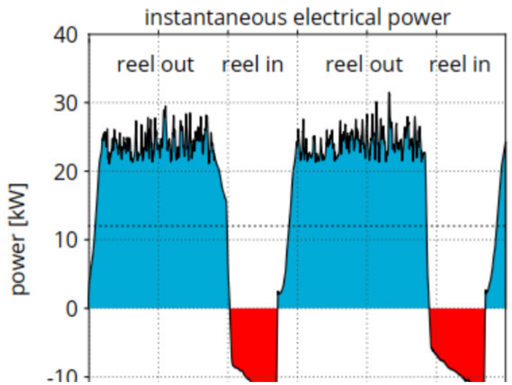
Suggested starting resource: Airborne Wind Europe Glossary: Defines AWE standards relating to:

- Power terms
- KPIs
- Operational phases
- Trajectories
- Wind speeds
- Flight volumes and areas
- Categories of kites

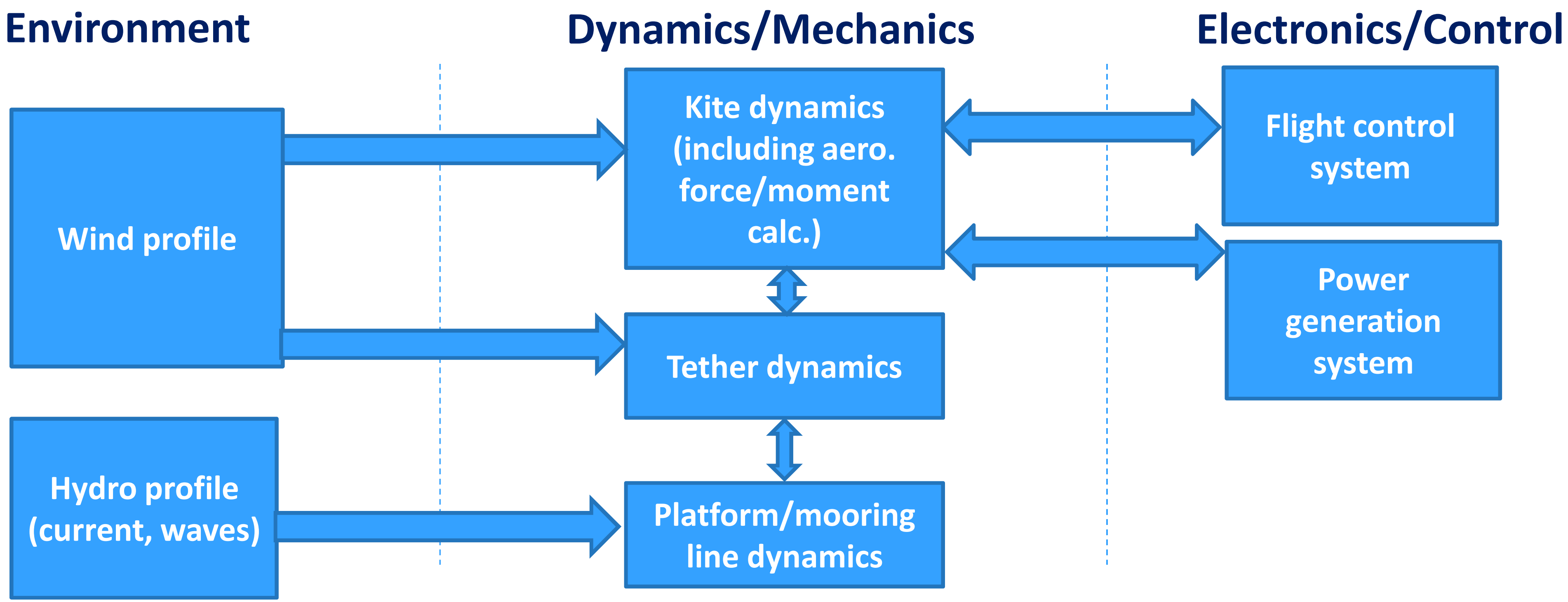
Power terms

> Average Cycle Power / Electrical Average Power

Symbol: $P_{e,avg}$
Definition: Energy over one Power Cycle trajectory divided by the Cycle trajectory time. [kW]
Notes:
Figure 1: The figure shows the instantaneous electrical power measured at the generator/motor of the AWES for a ground wind speed of 6 m/s (normally a wind speed given at pattern trajectory height would be better).



Tool development – Overall needs



- You're probably thinking "that's exactly what our tool does…although there are some bugs and limitations"
- Need to work collaboratively to build a common toolset (and appropriately allocate credit across the group)

Tool development – Some existing frameworks (United States)

- KiteFAST
  - Full suite of required tools implemented, generally at relatively high fidelity
  - Significant “glue code” interfacing between tools (specific issues interfacing with Makani controller)
  - Solver robustness issues to be sorted out
  - Limited funding for development moving forward
- NC State KiteSim
  - Full suite of required tools implemented at medium fidelity; aerodynamic modelling significantly simpler/lower fidelity than KiteFAST
  - Fully implemented in Simulink environment
  - Validated for an undersea kite (“wind” environment replaced with ocean current)
- Windlift/FS-One Simulator
  - Does not characterize the floating platform (yet); other components modelled at relatively high fidelity
  - Understandably proprietary – However, Windlift is available for consultation/support in tool development

Tool development – Some existing frameworks (EU)

- MegAWES
  - Fully implemented in MATLAB/Simulink
  - Choice of point-mass or 6-DoF rigid body dynamics
  - Designed for pumping cycle operations
  - Does not characterize (to best of knowledge) floating platform dynamics yet
- LASKA
  - Characterizes ground-gen and fly-gen configurations
  - Lagrangian formulation for tether modeling
- AWEbox
  - Largely an optimal control design tool for AWE systems
  - Applicable to multi-kite designs

Tool development – Existing sub-modules that can be integrated into a common tool

- Fast aerodynamic solvers:
  - KiteAeroDyn (Using the Nonlinear Weissinger Method)
  - Other solvers in place by Enerkite, Ampyx, and TU-Delft

- Flight control systems/software:
  - Makani flight control system
  - NC State hierarchical path-following flight controller (fully implemented in the NCSU package)
  - AWEbox for formulating optimal kite control
  - MegAWES control system developed by Rapp et. al.

Reference models – Overall proposal

Reference model 1: Ground-gen (pumping cycle) soft kite (possible basis for reference model: TU-Delft v3 ktie)

Reference model 2: Ground-gen (pumping cycle) rigid wing (possible basis: AP2 or AP4)

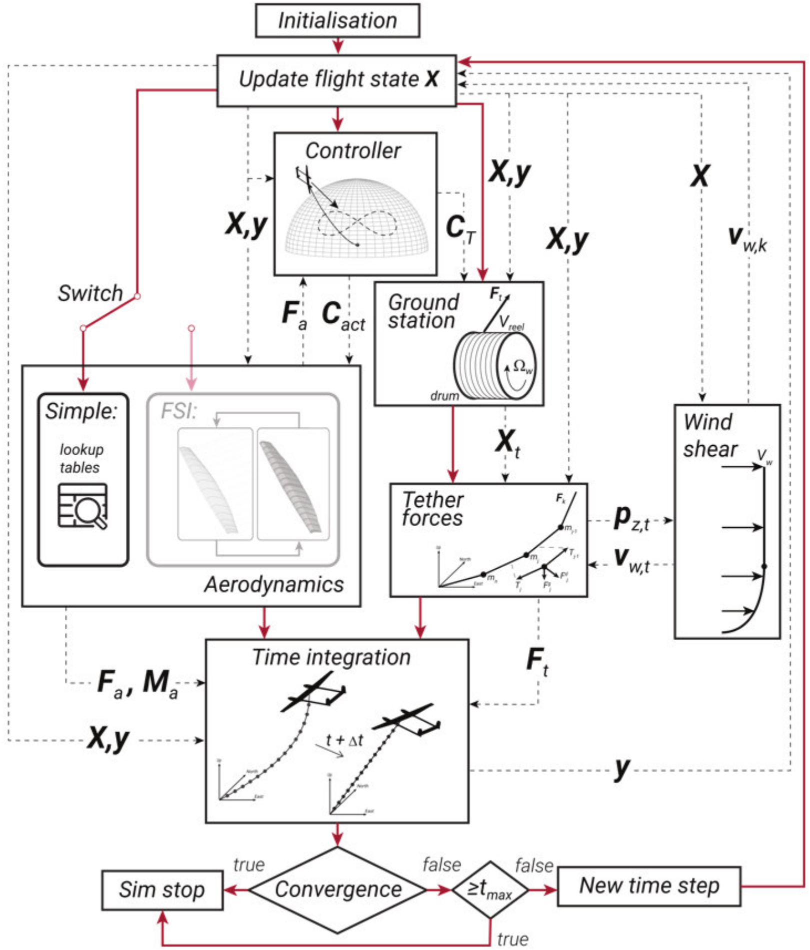
Reference model 3: Fly-gen rigid wing (possible basis: M600 or Windlift APG)

D. Eijkelhof, "Design and Optimisation Framework of a Multi-MW Airborne Wind Energy Reference System," TU Delft Aerospace Engineering, 2019.

Reference models – Existing ground-gen rigid reference model candidate

Delft/ETH-Zurich/DTU
Multi-Megawatt Reference Model:

- Part 1: System definition
  - Based off of the Ampyx AP4
  - Ground-gen, rigid wing system
  - 3.8 MW cycle-averaged power output
  - Wing area = 150 m^2
- Part 2: Tailored simulation and optimization framework



D. Eijkelhof, "Design and Optimisation Framework of a Multi-MW Airborne Wind Energy Reference System," TU Delft Aerospace Engineering, 2019.

Reference models – Existing reference model candidate

Makani M600:

- System fully defined
- Control software released
- Serves as the basis for NREL KiteFAST

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- Organisational topics

Five Work Packages

WP0: Task coordination	WP1: Resource potential and markets	WP2: Reference models, tools and metrics	WP3: Safety and regulation	WP4: Public Acceptability	WP5: AWES architectures
• Organisation & management of Task • Communication • Website • Dissemination	• AEP prediction for selected sites & toolchain documentation • Global high-altitude wind resource atlas • Recommendation on AWE entry-markets	• Common definition of metrics and KPIs • Joint reference model(s) • Centralized design tool • Simulation vs. test flights comparison	• Concept of operations and risk assessment • Airspace integration concept • Benchmarking concepts for safe automatic operation	• Life-Cycle Analysis • Repository of survey and studies • Guidelines for site selection, sound measurement and impact mitigation • Circular Economy	• Design space representation • Market specific deployment recommendations • AWES R&D state, trends and needs • Portal for AWES engagement and development potential
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Topics and objectives (1)

How to deploy Airborne wind energy:

- safely
- feasible / efficiently
- affordable?

With respect to different AWE operational approaches

- offshore vs. onshore / areas with significant aircraft operations
- soft kite vs. fixed-wing

adequate safety guidelines shall be elaborated.

Topics and objectives (2)

- Aim is to trigger and where possible contribute to the development of international standards and guidelines for AWE, e.g. within the IEC-61400 for wind generators and aviation related standards such as EU-2019/947(rules and procedures for the operation of unmanned aircraft) or EU-2021/664 (Regulatory Framework U-space) and/or corresponding FAA standards and national standards.

- Aim is to develop guidelines for their adaption to AWE technology with respect to safety and regulation where necessary or appropriate for a smooth AWE deployment in Europe and worldwide.

- Aim is to elaborate regulatory guidelines on how AWE should be treated regarding ground safety, airspace integration (including segregation) in collaboration with the European Union Aviation Safety Agency (EASA) and the Federal Aviation Authority of the US (FAA), national, and regional aviation and permitting authorities.
  It shall be considered that both approaches (AWE system as UAS vs. AWE system as obstacle) are valid approaches depending on CONOPS and region of operation.

Concept of operations (CONOPS):

- Deriving guidelines for (standardized) CONOPS including
    - emergency response plans
    - maintenance
    - …
- for different AWE approaches
    - offshore vs. onshore / areas with significant aircraft operations
    - soft kite vs. fixed-wing
- depending on
    - power generation systems regulation
    - aviation regulation
    - health, safety and environment (HSE)

Deliverables

- D3.1 Whitepaper on AWES safety
- D3.2 Concept of operations (CONOPS) and guidelines on risk assessments (e.g. SORA)
- D3.3 Airspace integration concept
- D3.4 Benchmarking concepts for safe automatic operation

Milestones

- M3.1 Whitepaper on AWES safety published
- M3.2 Event with air safety stakeholders to discuss findings and deliverables

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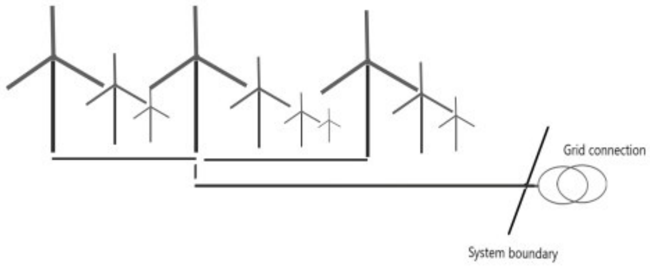
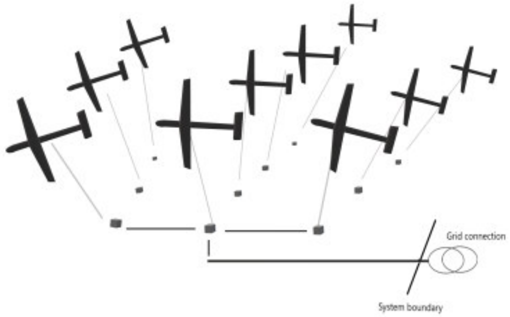
Questions to be answered: What are AWE benefits for and impacts on society and environment?

1. **Site selection:** What are key features that AWE sites should fulfil? Which sites already developed for conventional wind could be used for AWE?
2. **Local perceptions** regarding visual impacts and safety aspects: How will neighbouring communities perceive AWE?
3. **Acoustic emissions:** How should sound emissions be measured? How can they be reduced?
4. **Impacts on birds, bats**, other fauna including marine habitats in case of offshore
5. **Public engagement, participation, and compensation in AWE project**: How do local communities want to be involved in the decision-making and operation of AWE projects? Which types of compensation would local communities like to receive and how can they be implemented? What differences may there exist to other renewable energy projects?
6. **Life-Cycle Analysis (LCA):** What is the carbon and environmental footprint of AWE compared to other energy technologies? How can it be further reduced? Which components and materials have the highest impact?
7. **Circular Economy**: How can AWE systems be designed to reduce material consumption through repairability, re-use, recycling?

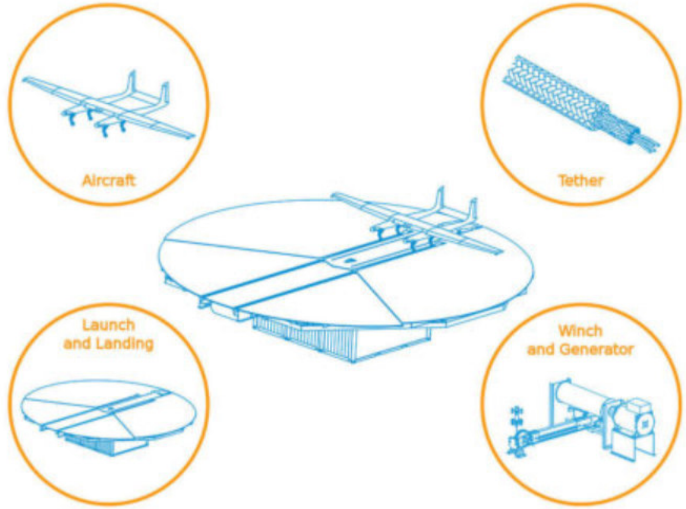
Life-Cycle Analysis: Comparing a hypothetical commercial fixed-wing 5MW AWE system with a reference 5MW HAWT in a wind farm of 10 units (50 MW)



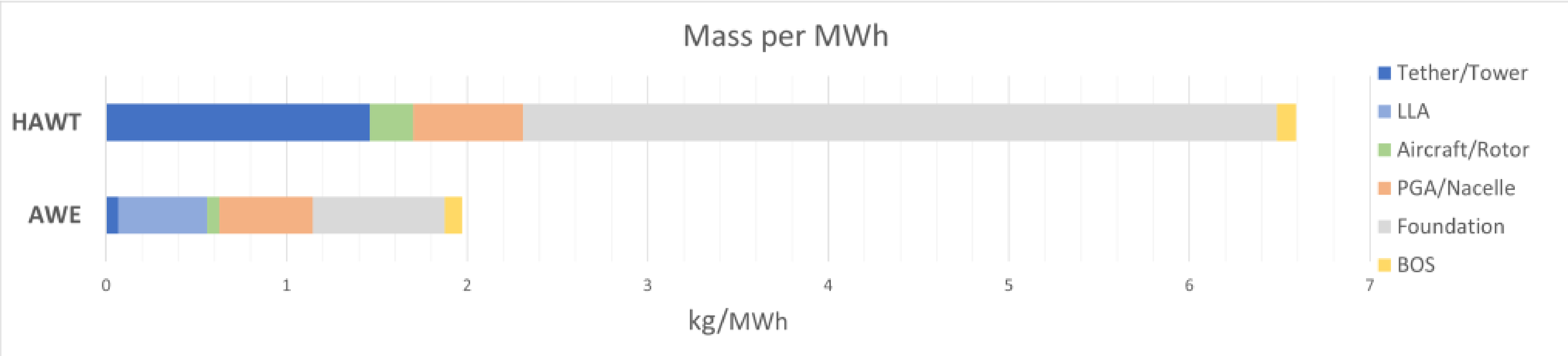
(a) HAWT farm



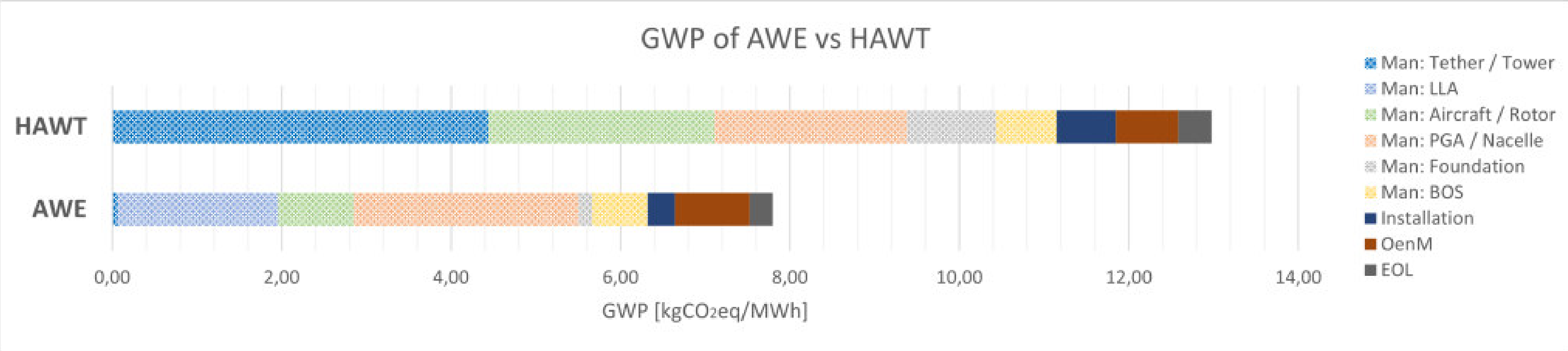
(b) AWE farm



The mass of the AWE system is a third of the HAWT

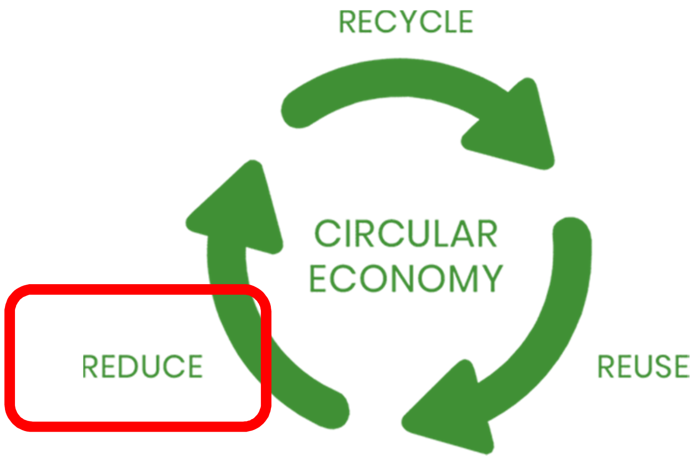


The Global Warming Potential (GWP) of the AWES is 40% lower than the one of HAWT

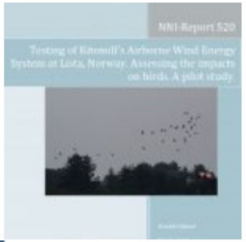


LCA exercise – conclusions and recommendations

- AWE represents a step-change towards a Circular Economy
  - AWE consequently applies the 'reduce' rule
- AWE OEMs can benefit from LCAs in system design
  - Re-thinking design solutions and materials
- LCAs for different AWE system concepts are needed
  - Soft-wing vs. fixed-wing
- Policy makers to acknowledge the potential of AWE
  - Provide funding for R&D and incentives for grid-connected AWE

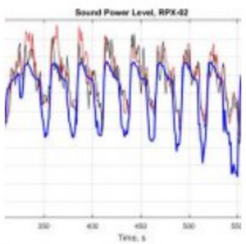


The first studies on impacts on bird & bats as well as sound have been collected



NNI Report 520 – 2018 – Testing of Kitemill AWES at Lista_Norway_ Assessment of impacts on birds_A pilot study_ December 2018

Bruinzeel et al. 2018_Ecological Impact of AWE (PDF)



Noise measurements
Makani 2020_TheEnergyKiteReport_Part3_Noise Measurements RPX-02

Bird and Bat Conservation Plan, Makani 11/2018

What is public acceptability and why is it relevant?

- Working group renamed into “public acceptability” because the term “social acceptance” is conceptually weak:
  - Other social responses to technology ignored (e.g., support, uncertainty, ignorance)
  - Normative top-down perspective on how people relate to the energy system maintained
  - Burden placed on the host communities, although project developers and authorities also influence public responses
- The term public acceptability is more broad
  - Goes beyond mere acceptance (e.g., opposition, rejection, engagement) and includes potential responses on different levels (i.e., cognitive, emotional, behavioural)
- Public acceptability is a function of an individual’s perceptions of an energy technology
  - Interactions with other actors, and the wider social, cultural, political context
- Energy systems are embedded within society
  - So lacking public support can delay or prevent the implementation of an energy technology
- Research must look beyond mere acceptance
  - To realize a sustainable energy transition, people need to change their behaviour and not just accept an energy project

What has been written about public responses to AWE?

- Systematic Google Scholar search: Out of 348 only 38 papers relevant
- 5 recurring topics regarding acceptability
  - Visual impacts
  - sound impacts
  - Ecological impacts
  - Safety/reliability concerns
  - Siting decisions
- Lack of empirical data
- Optimism bias in the field: complexity of public acceptability is underestimated (this can hinder deployment)
- Need for social scientific research to get a more accurate view on public responses to AWE

What is known about the acceptability of wind turbines?

<u>Negative influences</u>

- Visual impacts and changes to the landscape (often moderated by annoyance/general attitude)
- sound impacts (correlated with annoyance)
- Self-reported health complaints (likely moderated by annoyance)
- Strong place attachment and identity (mixed evidence)
- …

<u>Positive influences</u>

- Perception that planning process/decision-making is fair (i.e., procedural justice)
- Perceptions that distribution of costs/benefits is fair (i.e., distributive justice)
- Financial compensation (mixed evidence)
- Public participation
- Community ownership models
- …

- Public acceptability is not just determined by characteristics of a given technology or energy project but also psychological factors and processes (e.g., general attitude towards technology, interactions with responsible parties).
- There is no one-size-fits-all solution because acceptability highly depends on situational factors.

Research recommendations

- Assess the (changing) needs, concerns, motivations and experiences of different stakeholders
  - E.g., project planners, companies, scientists, local residents, policy makers, environmental organizations, journalists
- Examine the interactions between the different stakeholders
  - Relational factors also influence public responses
- Consider the wider social, cultural and environmental context which shapes project acceptability
  - E.g., policy context, characteristics of local places and communities

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Objectives according to WP

- D4.1 LCA for AWE and conclusions
- D4.2 Repository of surveys and studies on public acceptability and impacts on birds/bats
- D4.3 Guidelines for site selection, sound measurement and environmental impact mitigation measures
- D4.4 Circular economy / cradle-to-cradle aspects for AWE, incl. design process

Preliminary PhD Research Plan (Helena Schmidt, TU Delft)

- Duration PhD project: May 2021 – April 2024
- 2021
  - Literature review on public acceptability of AWE (will be submitted this November to Energies' special issue on AWE)
- 2022-2023
  - Survey/interviews of residents around test sites (MegaAWE Ireland, Skysails Germany), ideally before operation commences and again later on at same test site
  - Interviews with other stakeholders (e.g., developers,, researchers, authorities, NGOs)
  - 2-3 publications
- 2023-2024
  - Experimental or intervention study among general public (e.g., test informational intervention; influence of different AWE designs on public responses)
  - 1 publication

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Question to be answered: Which AWES Architectures exist and how do they compare?

1. **AWE Design space** exploration
2. Identify **Reference models**
3. Tradeoff analysis between **implementation options**
4. Project **Evolution / Development** history / Reasoning
5. Categorizing working and proposed **AWES architectures**
6. Evaluating **applicability, performance and impact metrics** across AWES architectures
7. Highlighting **resources** linked to defined AWES architectures
8. Highlighting **potential for further investigation**

Classifications

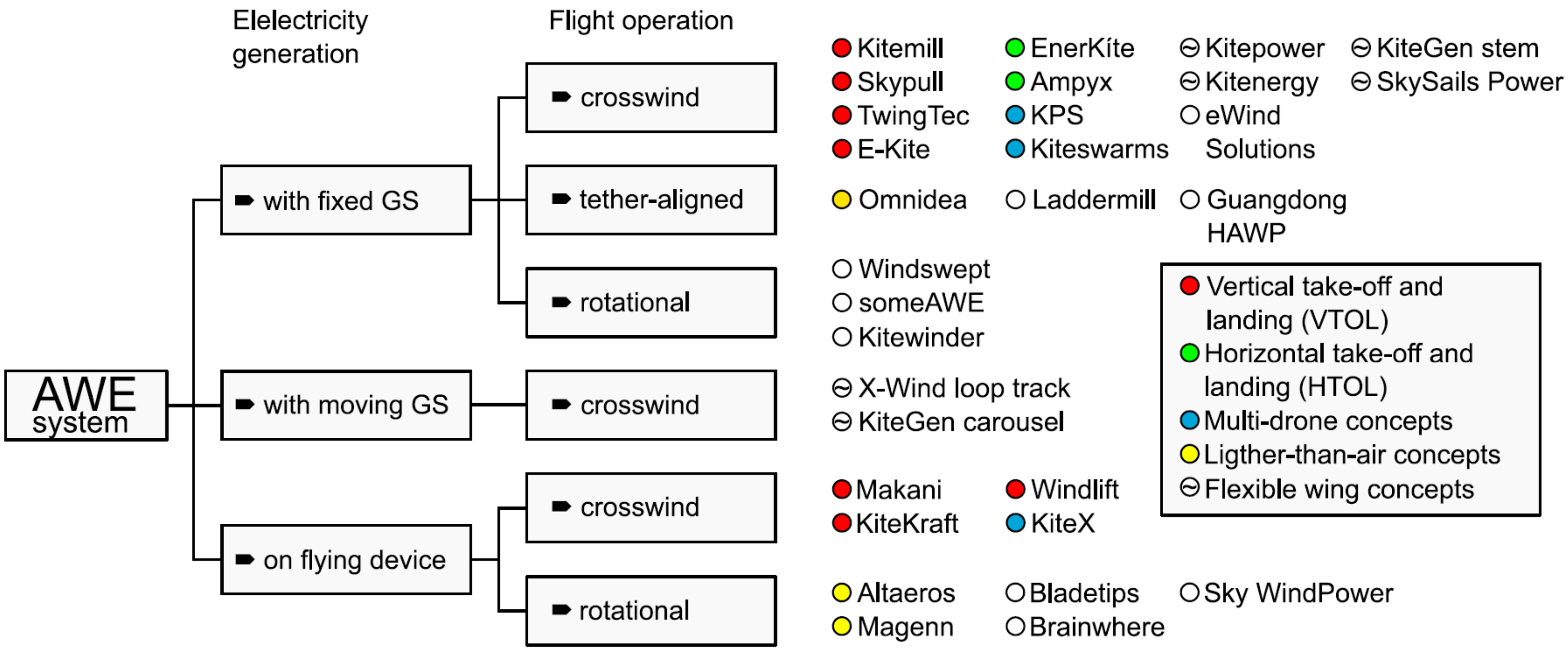

Fig. 2. Classification of AWE concepts (Schmehl, 2019).

Design space dimension

- Wing (wing(s), rotor(s), rigid/flexible, …)
- Energy transfer (tether (pull, belt, phased tugs, torsion), electric, pneumatic, hydraulic, electromagnetic, …)
- Lift (buoyant, aerodynamic, separate from wing, …)
- Generator (electromagnetic, piezoelectric, thermoelectric, photoelectric, non-electric power, …)
- Control (passive, active)
- Number of tethers (0, 1 -n)
- Launching (catapult, carrier, rotational, pilot/lifter , VTOL, phased tugging/pumping, wind generators, on board propulsion, …)
- …

Metrics

- Efficiency
- Reliability
- Availability
- Complexity
- Automatability
- Scalability
- Airborne Mass
- Durability
- Ductility
- Safety
- Potential
- Cost
- Investability
- …

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Objectives according to WP

- D5.1 Design space representation
- D5.2 Application / market specific recommendations on AWES deployment
- D5.3 Oversight on AWES R&D state, trends and needs
- D5.4 Definition and specification of a portal for identifying AWES engagement and development potential

Preliminary Research Plan

Organisation	Project(s)
Airborne Wind Europe	Interreg NWE MegaAWE
DTU	Inhouse funded research activities on AWE kite design
someAWE S.L.	Rotational AWEs
Politecnico di Milano	Self-funded research activities on safe operation of automatic AWES
TU Delft	NEON
Kitemill	KM2 project and concept choices
Windswept&Interesting	10kW Kite Turbine Development
University of Strathclyde	Improved design and control of AWES in floating platform systems
NREL	Tbd
kPower	Kite Networks

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How to join Task 48

1) Your country is already participating.

Contact the Operating Agent or WP Leaders.

2) Your country is not yet participating

Contact the Operating Agent Kristian Petrick/ Stefanie Thoms. Several institutions of a country should gather to express interest to their Exco member in order to approve participation.

https://iea-wind.org/task48/

To participate in the research activities of Task 48, researchers must reside in a country that participates in the IEA Wind Agreement **and** has agreed by official letter to participate in Task 48.

The participating member country of the IEA Wind TCP must designate a lead institution that agrees to the obligations of Task participation (pay the annual fee and agree to perform specified parts of the work plan).

We look forward to making this new Task fly!

Task 48 | IEA Wind TCP (iea-wind.org)

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Task addresses all four objectives of the IEA Strategy

1. **Maximize the value of wind energy in energy systems and markets:** In the mid- to long-term AWE is intended to play an important role in energy systems, integrating potentially almost base-load power like output. Also, in markets in remote areas and offshore AWE can become a key technology.
2. **Lower the cost of land-based and offshore wind energy:** While AWE will not yet be ready to contribute the lower energy costs in the short term, it is considered to make a substantial contribution to making wind energy to become the most cost-competitive energy from 2030 onwards.
3. **Facilitate wind energy deployment through social support and environmental compatibility:** The AWE Task will investigate environmental impacts and public acceptance of AWE in a proactive and transparent way.
4. **Foster collaborative research and the exchange of best practices and data:** Early joint standardization of certain system components and regulatory requirements will help AWE develop faster, avoiding complications at a later stage.

2019–2024 Research Priority Areas:
The AWE Task addresses…

“2. Advanced Technology” as AWE is a pre-competitive and potentially disruptive innovation. The collaboration of partners in a Task will help overcome especially technological and regulatory challenges and thus facilitate commercialization of AWE systems. In the mid-term this will lead to lower generation costs from wind and tapping into new markets/locations. A collaborative research Task could lead, for instance, to a Task deliverable like Recommended Practices to inform international standards for AWE.

“1. Resource and Site Characterization” due to the access to high-altitude wind resource;

“3. Energy Systems with High Amounts of Wind” because AWE provides an alternative, potentially base-load and thus complementary generation profile;

“4. Social, Environmental, and Economic Impacts” because it will help regulatory authorities making informed decisions on AWE permitting and safety;

“5. Communication, Education, and Engagement” because the Wind TCP could not be the definitive source for wind R&D expertise without considering AWE.