Airborne Wind Energy

Course introduction

Roland Schmehl

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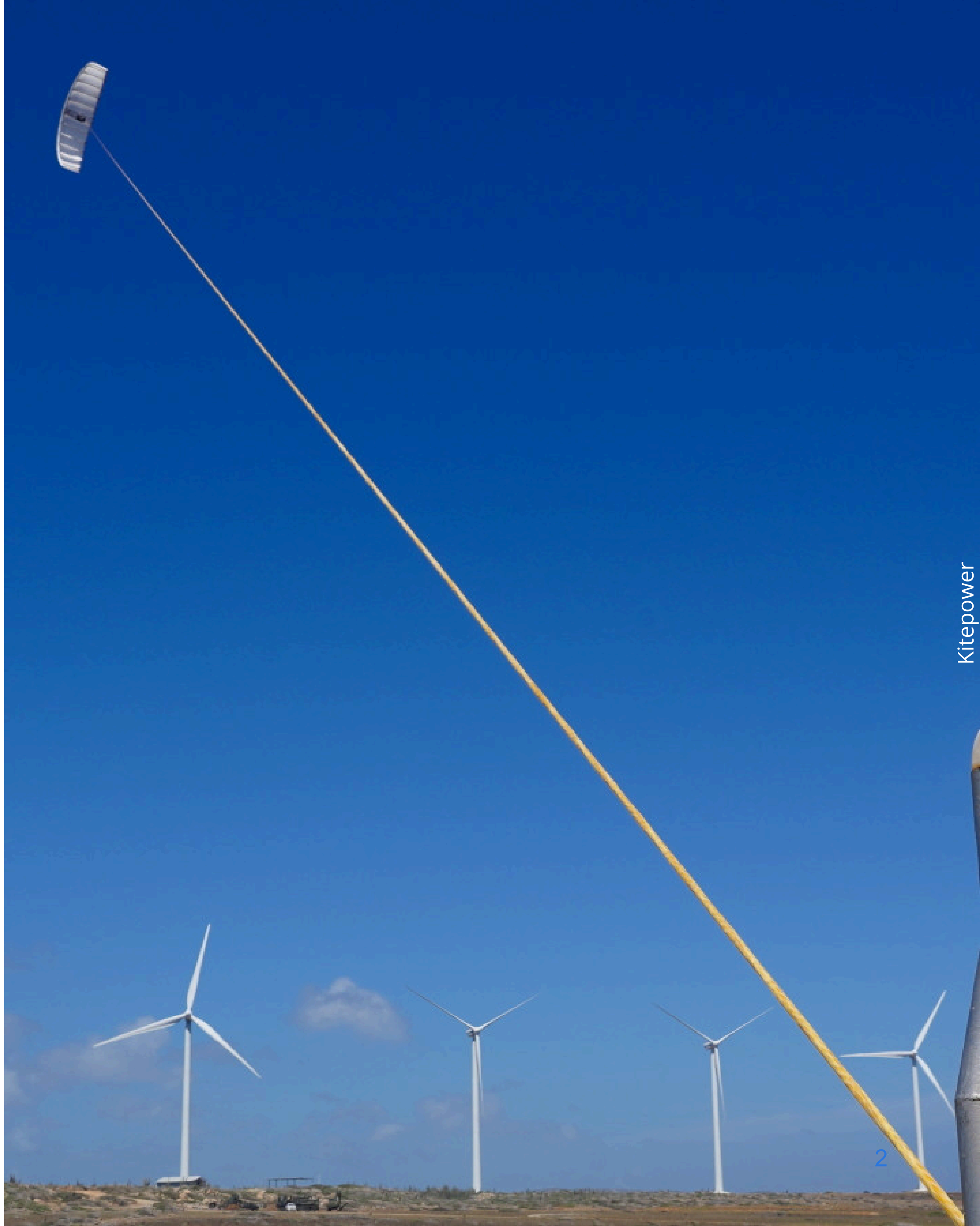
TU Delft

Outlines

- Instructors & students
- Who are we?
- Scope & learning objectives
- Structure & resources
- Beyond the course


Kitepower

Slide navigation

- HTML-slides are implemented in Reveal.js.
- Preferably use Google Chrome or Firefox because Safari (Apple) does not implement all required Web-Standards.
- Page Up and Page Down (or arrow keys) step through slides.
- Esc toggle 2D slide grid overview.
- F11 or f/Esc toggle fullscreen mode.
- S view speaker notes (needs your explicit permission to open pop-up window).
- opens navigation menu.
- opens new white board.
- activates pens on current slide.
- save white boards.

Instructors & students

Dr. Roland Schmehl

- MSc in Mechanical Engineering from University of Karlsruhe (KIT)
- PhD in Fluid Dynamics from University of Karlsruhe (KIT)
- Studied & worked in Phoenix, AZ, and Los Angeles, CA
- PostDoc at European Space Agency (ESA)
- Software Architect at TNO Automotive Safety Solutions (now Siemens)
- Associate Professor at Aerospace Engineering, TU Delft

- More than 122 peer-reviewed publications
- NWO project NEON, EU projects AWESCO, REACH, MERIDIONAL and AWETRAIN
- Board of Directors Airborne Wind Europe, WP1 lead IEA Wind Task 48
- Co-Founder Kitepower

- Research areas:
  - Airborne wind energy, all aspects
  - Computational aeroelasticity and fluid-structure interaction

Dr. Daniele Ragni

- MSc in Thermo-Mechanical Engineering from Universitá Politecnica delle Marche, Ancona
- Researcher at German Aerospace Center (DLR), Göttingen
- Researcher at NLR and DNW, the Netherlands
- PhD in Aerospace Engineering from TU Delft
- Associate Professor at Aerospace Engineering, TU Delft

- NWO projects Sealant, THAMES, IPER-MAN
- EU projects ENODISE, SMART ANSWER, Herwingt
- ERC Consolidator Grant MORASINA
- Co-Founder Muteskin

- Main research areas:
  - Aeroacoustics
  - Noise from the interaction of rotors with airframe components

Oriol Cayon, MSc

- MSc (EWEM) in Aerospace Engineering from TU Delft
- MSc (EWEM) in Wind Energy from DTU
- PhD Candidate at Aerospace Engineering, TU Delft

- EU project MERIDIONAL

- Research areas:
  - Airborne wind energy, wind physics & flight dynamics of soft kites

Students

- MSc track **Aerodynamics & Wind Energy** (TU Delft Aerospace Engineering)
- MSc track **Sustainable Energy Technology** (4TU)
- MSc track **Rotor Design** (European Wind Energy Master EWEM)?
- Various other TU Delft MSc tracks that accept the course as elective
- PhD researchers as part of their Graduate School training

Course is followed by students from various engineering backgrounds

- Not required is specialized aerospace engineering knowledge, but ...
- you should be familiar with fundamental mathematical and physical concepts

Who are we?

TU Delft AWE Research Group

@ AWEC 2026 in Porto

Kitepower - our spin-off company

@ Schiehal in Delft

Photo courtesy Thijs van Reeuwijk

Scope & learning objectives

Scope

- AWE conversion concepts
- Key elements of AWE systems
- Potential & technical challenges
- Industrial developments & academic research
- Theory of tethered flight
- Performance estimation
- Wind resource at higher altitudes
- Scaling up & wind parks
- Economic assessment & markets
- Environmental footprint
- Legislation & certification
- Social acceptance
- Kite design
- Kite flight dynamics, aerodynamics & aeroelasticity

Course learning objectives

- Differentiate the **working principles** of AWE concepts (how)
- Understand the **challenges** and **opportunities** for AWE (why)
- Develop an overview of the **AWE sector** and understand what the different academic and industry players are working on (who & where)
- Identify the **technology readiness level** of AWE concepts (when)

- Develop **modeling approaches** for tethered flight
- Develop **operation approaches** for AWE systems
- Predict the **electrical power output** of AWE systems
- Idendify the **design** and **operating parameters** affecting the power output
- Understand the **influence of the wind field**, changing in altitude and time, on the power output

- Understand how **kite design** affects power output and steering characteristics
- Understand the **aerodynamics** and **wing deformation** of flexible membrane kites

Structure & resources

Structure

- **Lectures 1-3: From kites to airborne wind energy**
  Introduce AWE, and present a historical perspective on kites, and a portfolio of current prototypes.
- **Lectures 4-6: Physics of tethered flight**
  Cover the physics of tethered flight and systematically develop a quasi-steady theory of energy harvesting with kites. A particular focus is on the quasi-steady flight condition.
- **Lectures 7-10: Energy harvesting with kites**
  Describe the practical operation of AWE systems and the performance and potential of the technology in the future energy system. This includes (lecture 8) a workshop in a Jupyter notebook (Python).
- **Lectures 11-12: Kite design, aerodynamics and aero-structural dynamics**
  Detail the flying components of AWE systems, with a focus on the flight dynamic, structural dynamic, and aerodynamic behavior.
- **Lecture 13: Exam preparation**

Each lecture takes 2 × 45 minutes.

Schedule

- Lecture 1: 04-09-2026, 10:45-12:30, AE Hall E
- Lecture 2: 11-09-2026, 10:45-12:30, AE Hall E
- Lecture 3: 18-09-2026, 10:45-12:30, AE Hall E
- Lecture 4: 25-09-2026, 10:45-12:30, AE Hall E
- Lecture 5: 02-10-2026, 10:45-12:30, AE Hall E
- Lecture 6: 09-10-2026, 10:45-12:30, AE Hall E
- Lecture 7: 16-10-2026, 10:45-12:30, AE Hall E

- Lecture 8: 13-11-2026, 10:45-12:30, AE Hall E
- Lecture 9: 27-11-2026, 10:45-12:30, AE Hall E
- Lecture 10: 04-12-2026, 10:45-12:30, AE Hall E
- Lecture 11: 11-12-2026, 10:45-12:30, AE Hall E
- Lecture 12: 18-12-2026, 10:45-12:30, AE Hall E
- Lecture 13: 08-01-2027, 10:45-12:30, AE Hall E

- Exam: 29-01-2027, 13:30-16:30, CEG-Instruction Room 1.95 (23 HG.1.95)

Resources

Brightspace: AE4T40 Airborne Wind Energy (2026/27 Q1)

- Classroom lecture slides & video recordings + additional material
- Literature collection: book chapters and journal papers
- Exam collection: more than 11 years of exams with solutions

Book of Abstracts of the Airborne Wind Energy Conferences 2011-2026

Airborne Wind Energy Conference

AWEC 2026 in Porto

Airborne Wind Europe

Association of the airborne wind energy (AWE) sector, promoting the development and deployment of AWE Systems. Airborne Wind Europe encourages collaboration and exchange between technology developers, policy makers, research institutes and universities, as well as other stakeholders like public administration and authorities, suppliers, utilities, energy consumers, investors and financial institutions.

IEA Wind Task 48 “Airborne Wind Energy”

International co-operation of 11 countries and sponsor members that share information and research activities to advance wind energy deployment. Task 48 has four work packages on important aspects of airborne wind energy.

WP0: Task coordination	WP1: Materials, Manufact. & Supply	WP2: Models and tools	WP3: Regulation and deployment	WP4: Social Acceptance
• Organisation & management of Task • Website • Social media • Communication • Dissemination • Exploitation	• Materials & Design • Life-Cycle Analysis • Definition of test strategies for material and critical components • Manufacturing • Supply Chain • Standardization & certification	• Joint reference models • Integrated design and analysis workflo • Design & analysis tools • Control models • Grid integration • Wind resources	• Safe Airspace Integration and regulation • Siting and permitting • Market preparation • Standardization	• Framing, Narratives, • Socio-Political and Institutional Acceptance • Local Acceptance • Participation, Benefit-Sharing, and Co-Creation • Dynamics of Acceptance • Sound Emissions • Environmental Impacts
• Task reporting • Communication outputs	• Componentatalogue • LCA • Materail catalogue • Testing standards	• Ref. model workshop • MDAO framework • Power curve simulations • Control ref. Model • Farm-level deliverable • Grid integration model	• Recomd. Practices on airpsace integration & on permitting • Market-entry studies • First approved AWE standards	• Guidelines for design • Synthesis report • Comparative case studies • Repository surveys & envirnomental studies

Social media

@kite_power
@rolandschmehl
@laddermill

- News about recent developments
- Photo and video footage from testing
- Documentaries

Pulling Power from the Sky

The Story of Makani

"We were glued to the screen"

"I meant to just watch the preview but I watched the whole film"

"Simultaneously heartbreaking and super inspiring, had me on the edge of my seat a few times"

Beyond the course

Internships & graduation projects

Industry
- Kitepower (NL)
- Skysails (DE)
- Enerkíte (DE)
- Kitenergy (IT)
- Kitemill (NO)
- Windlift (US)

Academia
- University of Ghent (BE)
- DTU Wind (DK)
- University of Stuttgart (DE)
- TU Munich (DE)
- Munich University of Applied Sciences (DE)
- University of Freiburg (DE)
- Eastern Switzerland University of Applied Sciences (CH)
- Politecnico Milano (IT)
- UC3M Madrid (ES)
- University of Montpellier (FR)

AWETRAIN: EU-funded Doctoral Network

- Marie Skłodowska-Curie Action in the EU Horizon Europe framework program
- Partners
  - Technical University of Denmark (DTU) - coordinator
  - Delft University of Technology (TU Delft)
  - Munich University of Applied Sciences (HM)
  - Politecnico di Milano (Polimi)
  - Kitemill AS
  - Kitepower BV
  - Airborne Wind Europe

- https://awetrain.eu

AWETRAIN: Research topics

1. The impact of unsteady atmospheric flows on AWE (DTU)
2. Robust operation of AWE in low and high wind speed conditions (Kitemill & DTU)
3. Robust autonomous control of an onboard generation AWE system (Polimi)
4. Fully autonomous AWE operation over long time horizons (Polimi)
5. Optimal scaling and clustering for AWE (TU Delft - AE)
6. Wind farm optimization and operation (Polimi)
7. AWE operation for grid serving behaviour (Kitepower & TU Delft)
8. Reliable and functional electrical systems for AWE (HM)
9. The mutual impact of AWE based plants on the electricity grid
10. The economic potential of AWE in the European electricity grid (DTU)
11. Strategies for AWE commercialisation (TU Delft - TPM)
12. Achieving technological legitimacy for AWE from both a local planning and broader social-political context (DTU)

Questions?

r.schmehl@tudelft.nl