Eco-conscious multidisciplinary design optimization of Airborne Wind Energy System (drag power kite) using Life-Cycle Assessment

M.Sc. thesis proposal, TUM Wind Energy Institute in collaboration with Kitekraft GmbH

Left: 3D rendering of the rigid drag power kite developed by Kitekraft. Source KiteKraft [1].

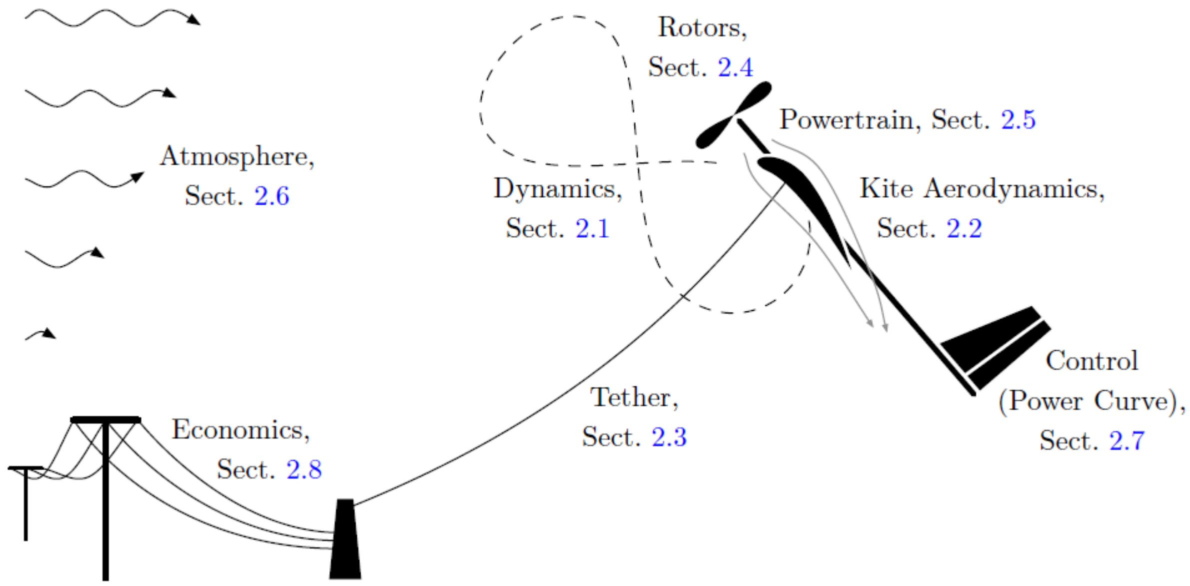
Right: Current Kitekraft Prototype parked on the ground station. Source Kitekraft [1].

Background and motivations

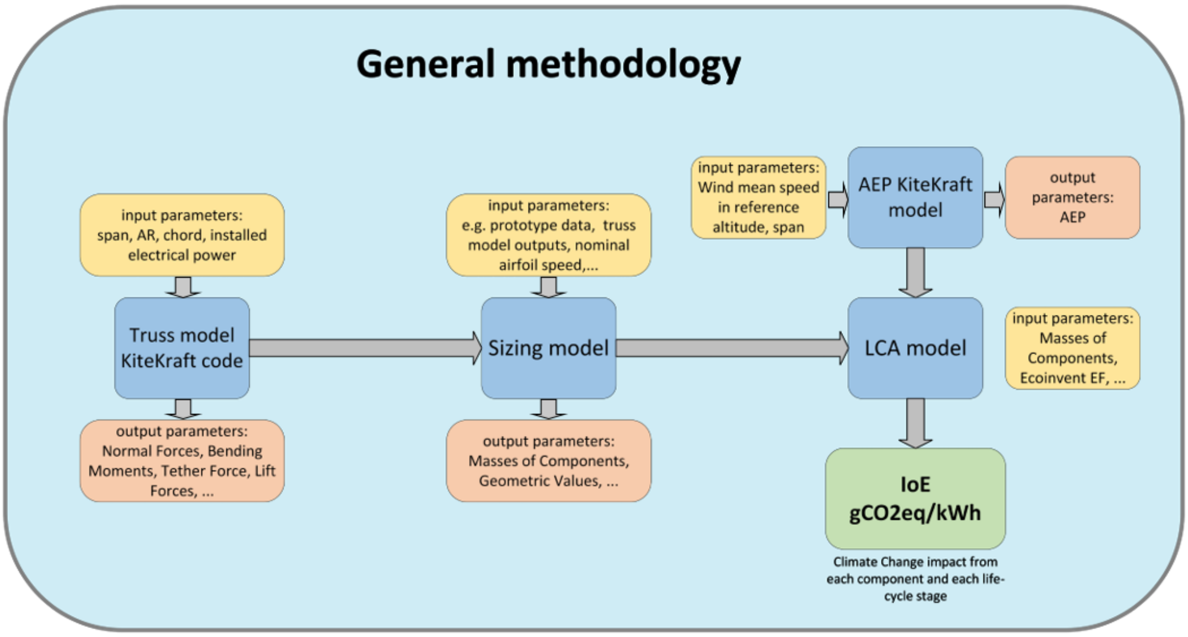
Multidisciplinary design and optimization of wind energy systems are commonly based on the minimization of the Levelized Cost Of Energy (LCOE). This has allowed a drastic decrease of the LCOE of wind energy in the last 15 years. Some modern research is however considering to base design on additional new merit that cannot be captured by the LCOE alone, as for instance market value or flexibility for system integration, going "*Beyond LCoE*" [2]. In this regard, some work has been conducted to include the consideration of the environmental impact of wind energy, limited to Greenhouse Gases emissions, into the design phase. An automated module for conventional onshore wind turbine, expanded to offshore wind plants, has been implemented to assess the Impact Of Energy (IOE, in gCO2eq/kWh) for any given turbine configuration. It uses the Life Cycle Assessment methodology. This is applied to quantify the effect of various design choices on the IOE, and conduct multi-objective optimizations together with the LCOE to identify trends and possible trade-offs [3,4].

Airborne Wind Energy Systems (AWES) are a very promising rising technology for electricity generation. The company Kitekraft develops a rigid Drag Power Kite, illustrated above. It has the important economic and environmental benefits to delete the need for a material-intensive tower (and thus save up to 95% of materials used for the same power output). For this reason, studies have shown that AWES are expected to have much lower IOE (gCO2/kWh) than conventional wind turbines [8,9, 10, 11].

Kitekraft has developed a detailed multidisciplinary module for the design optimization of this technology to estimate performances, material requirements and costs [5]. A following work has linked this model to Life Cycle Assessment to estimate the IOE of three defined kite models (fixed configurations) [12]. The present proposed work should review, validate and/or improve these results (kite masses, GHG values, energy yield model). And going one step further, conduct continuous optimizations of design variables (mostly kite span, aspect ratio, chord, installed electrical power, and more to be further determined) based on minimizing the costs and environmental impact of the produced electricity. LCA studies have been conducted on AWES to compare it with conventional turbines [8, 9, 10], but the added value of this work would be to implement it in an automated design environment in order to study design drivers, trends and optima.



Overview of the available module for Multidisciplinary Optimization of Drag Power Kites [6]



Schematization of the automatized LCA framework developed for Airborne Wind Energy, to be further improved and applied for design analysis [11]

Goals

- Review of the available module for the multidisciplinary design of Drag Power Kite, and further development (masses estimation with the help of a structural model of the kite airframe, annual energy production model, change model to be able to handle continuous kite sizes not just concrete ones, upscaling of prototype to larger size generation units).
- Parametric study on the effect of design choices (materials, variable optimizations as aspect ratio span or power rating) on the life-cycle GHG emissions of Drag Power Kites, single-objective and multi-objective optimizations based on costs and environmental impact.

Requirements

- Good basis in mechanical (structural) and electrical engineering
- Background in electricity generation system
- Interest in multidisciplinary system engineering and design
- Prior experience in other projects (e.g., Hyperloop, TUFast, or similar) is beneficial
- Good understanding of coding (Matlab most beneficial, C++ possibly beneficial)
- Knowledge in wind energy systems is beneficial, knowledge in AWES is not required but would be beneficial
- Knowledge in Life Cycle Assessment methodology is beneficial

About Kitekraft

Kitekraft is a TUM-Spinoff that was founded in 2019. Kitekraft is developing advanced wind power systems: power-generating kites, a.k.a. flying wind turbines, that require 10x less construction material compared to conventional wind turbines. A Kitekraft unit will generate electricity cleaner, almost invisible, and at least 50% cheaper than conventional wind turbine of the same power rating, and eventually cheaper than any other alternative. Kitekraft develops and will build, sell, and operate flying wind turbines in the 100kW to 5MW+ range, for both grid-scale energy production and off-grid applications. Come work with us!

Further information:
www.kitekraft.de

Contact

If interested, please send your CV and course records to:

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References

[1] Kitekraft GmbH (https://www.kitekraft.de/)

[2] Dykes, K., Kitzing, L., Andersson, M., Pons-Seres de Brauwer, C., & Canet, H. (2020). Beyond LCoE: New Assessment Criteria for Evaluating Wind Energy R&I. SETWind workshop report. https://setwind.eu/beyond-lcoe-new-assessment-criteria-for-evaluating-wind-energy-ri/

[3] Adrien Guillore, "Assessment of Life Cycle Environmental Impact, and Multi-Objective Design of Wind Turbines". M.Sc. thesis. Technical University of Munich. 2021. (available upon request)

[4] Samuel Kainz, "Combined Life Cycle Impact and Cost Assessment of Wind Energy Generation in Large-Scale Offshore Wind Farms". M.Sc. thesis. Technical University of Munich. 2022. (available upon request)

[5] Florian Bauer. “Multidisciplinary Optimization of Drag Power Kites”. Dissertation. Technical University of Munich. 2021. https://mediatum.ub.tum.de/?id=1484087

[6] Florian Bauer. Various publications on Crosswind Kite Power. https://www.ei.tum.de/eal/research/projects/research-bauer/

[7] Fagiano, L., Quack, M., Bauer, F., Carnel, L., Oland, E. Autonomous Airborne Wind Energy Systems: Accomplishments and Challenges. Annual Review of Control, Robotics, and Autonomous Systems, 2022, 5:1, https://www.annualreviews.org/doi/10.1146/annurev-control-042820-124658

[8] 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.

[9] Stefan Wilhelm, “Life Cycle Assessment of Electricity Production from Airborne Wind Energy”. M.Sc. thesis. University of Technology Hamburg, 2015. https://tore.tuhh.de/handle/11420/1305

[10] Luuk van Hagen, “Life Cycle Assessment of Multi-Megawatt Airborne Wind Energy”. M.Sc. thesis. Delft University of Technology. 2021. https://repository.tudelft.nl/islandora/object/uuid:472a961d-1815-41f2-81b0-0c6245361efb?collection=education

[11] Irene Morlando Cervero, “Eco-conscious design evaluation of Airborne Wind Energy Systems (drag power kite) using Life Cycle Assessment”. M.Sc. thesis. Technical University of Munich. 2022. (available upon request)