# Response to reviewers of wes-2020-123

Markus Sommerfeld

July 15, 2022

## Author response

Dear reviewers,

Thank you very much for your very detailed and helpful comments to our manuscript, “Scaling effects of fixed-wing ground-generation airborne wind energy systems”, wes-2020-123.
Most comments have been implemented into the manuscript and highlighted in the marked-up version. We hope that the paper will meet your standards. The reviewers will receive individual responses to their comments.
Sincerely, Markus Sommerfeld

# Response to reviewer 1 of wes-2020-123

Markus Sommerfeld

July 15, 2022

## Author response

Dear reviewer 1,

Thank you very much for your very detailed and helpful comments to our manuscript, "Scaling effects of fixed-wing ground-generation airborne wind energy systems", wes-2020-123.
All, but 2 comments have been implemented in the latest version of the manuscript. Please see our response below.

Sincerely, Markus Sommerfeld

## 1 Reviewer comments

### 1.1 Specific comments

Line 6 Add a section for the nomenclature in the beginning of the paper.

- not implemented, not common for wes publications

Line 61 "from small to to utility",

- implemented

Line 249 "the chosen initialization The optimization . . . ",

- implemented

Line 388 "rated power. Beyound rated . . . .", etc . . .

- implemented

Line 70 , it is recommended to move the paragraph "For a detailed description of the WRF model and clustering algorithm see Sommerfeld et al. (2020)." To the section 2.

- implemented

- It is an optional for the author to add the mathematical model for the cited paper where you used as a reference model.
  - not implemented to not increase the length of the paper even more.

# Response to reviewer 2 of wes-2020-123

Markus Sommerfeld

July 15, 2022

## Author response

Dear reviewer 2,

Thank you very much for your very detailed and helpful comments to our manuscript, “Scaling effects of fixed-wing ground-generation airborne wind energy systems”, wes-2020-123.
We understand that the high amount of system configurations lead to a lot of content and complexity. But the contribution of this paper is to compare realistic performance of many different AWES configurations subject to realistic wind conditions. For that reason the initial title of the paper included a “design explaration” of rigid wing AWES.
There is a misunderstanding regarding non-converged solutions and “outliers”. Non-converged solutions are not included in the results and plots, i.e. data point not displayed in figures. They are the result of infeasible boundary conditions e.g. too low wind speeds at which the AWES cannot operate. Outliers on the other hand, are feasible solutions that are within in the constraints of the optimization (e.g. tether tension, tether speed, operating conditions etc.) Most of these solutions are the result of the system de-powering above rated wind speed. In these cases the optimizer finds trajectories, which is within constrains, but differ from the expected trajectory in operating height, tether length etc. This becomes difficult for higher wind speeds because some constraints, e.g. tether tension, is active.
The manuscript went through several rounds of major revisions by multiple reviewers and the editor since its initial draft more than years ago. Most of the original code and result files were lost during a computer crash. As a result, much of the code had to be re-written and the computationally expensive and time consuming optimizations had to be re-run, after I moved to a new country. We would like to avoid running additional optimizations, because of the significant afford that is associated with additional optimizations and their post-processing.

Sincerely, Markus Sommerfeld

# 1 Reviewer comments

## 1.1 Specific comments

Line 6 comma at line 6 and line 8 should not be there. Also the two “-“at line 8.

– implemented

Line 13 missing a space

- implemented

Line 31 please check all the websites references. The dates are misleading.

- implemented

Line 121 Is there any reference for the reel-out and in speed? The results you show (e.g. Figure 6) seem extremely dependent on these values. Are these values scaling with size? I would expect that with a generator up scaling the drum diameter would also increase and thus these values, for the same drum angular velocity. Maybe you can add a comment here.

Line 124 Can you elaborate a bit more on the tether diameter design? It is not clear to me what it the procedure. Is it an iterative procedure?

Line 144 Eq. 4 is not necessary

- was put on request of previous reviewer

Line 146 The total drag coefficient does not depend only on these three parameters, as you mention in the sentence after. Please rephrase.

- implemented

Line 193 The citation goes before, when talking about the $CD^{tether}$ of the QSM.

- implemented and rephrased the tether model description

Line 195 "This leads to an underestimation of total tether drag at the aircraft" Not clear what "this" refers to.

- rephrased

Line 197 I don't understand why, if you have a tether model, you don't apply all external forces (including weight and inertial) to the element's nodes. Can you explain? Are inertial forces on the tether included in the analysis?

- rephrased the tether model description. All forces are applied to the nodes.

Line 202 This information has already been given in 3.1. Please do not repeat. It makes more sense here.

- implemented

Line 225 Can you give the two power harvesting factor values?

- implemented

Fig 4 Maybe these plots could go to an appendix as they are standards results and some discussions removed.

- not implemented, I'd rather keep them here

Line 234 remove "The wind field is assumed to be constant for every optimization.": it is obvious and stated in the previous sentence

- implemented

Line 252 ”because lift-to-tether drag ratio scales linearly with wingspan.” wing area maybe.

- implemented

Line 294 There should be physical or modeling/optimization reasons for this. Please elaborate on it. It is important to give an interpretation to optimal trajectory, otherwise we cannot trust the results.

- This is likely caused by the longer reel-in period required to return the aircraft to its inital position. Because the tether tension is consistently high during reel-out (Figure 7 (a)), the reel-out speed remains high as well, leading to a longer reel-out length (Figure 7 (f)).As a result, the last loop is “carried over” to the reel-in period, which would not be done for real deployed systems.
- this only seems to happen for HL and high wind speeds. High wind speeds → high const force → no need to reduce reel-out speed to maintain high force → more reel-out length → longer reel-in distance to return to init pos → one loop gets carried over to reel-in period, long reel-in time

Line 295 These considerations should be moved to future works.

- implemented

Fig 7 I don’t understand why there are points with the same x coordinate.

- Different wind speed profile shapes have similar reference wind speeds $U_{\mathrm{ref}}(100 \text{ m} \leq z \leq 400 \text{ m})$ which leads to multiple values on the same x coordinate.

Line 334 The optimization is a deterministic process. If we change one parameter defining the optimization (e.g. wind speed), the optimal results should be a continuous function of this parameter. If we find a discontinuity, we need to understand why. Can the wind speed discretization be increased to have points closer to the outliers?

- The wind speed profiles implemented into the optimization are very different in shape and magnitude, in contrast to simple log profiles where it is possible to increase the fidelity. These discontinuities are due to the high variation in wind conditions. Completely different profile shapes, can have similar average wind speed ($U_{ref}$). By increasing the amount of optimized wind profiles we would find that the results form are within a bandwidth from an average curve.
- Added a line in the beginning of the “Results and discussion” section: The dotted lines that connect the data points are only their to better visualize the data and do not indicate a smooth continuity between data points.
- if this does not satisfy your comment we could remove the dashed and dotted lines in between data points, but we would prefer to keep them.

Line 362 same comment as before on the discontinuities

- Same as above

Line 368 maximum wind speed of the dataset (otherwise the maximum wind speed is related to extreme events)

- implemented

Tab 2 The overbar on P should not be there

- added overbar over other P for power since it is the cycle-average power

Line 396 maybe eq 9 and 10 can be removed to save space. they are well known.

- yes, they are well known, but I would like to keep them in to avoid ambiguity

Line 408 wrong measurement units

- implemented

Fig 14 can you indicate in the legend at which wind speed the first plot is done?

- clarified. These figures show the averaged weight and drag over the entire wind speed range to give a general trend.
- More details on how these results evolve over reference speed can be found in Figure 15

Line 560 should not be there

- implemented

# Response to reviewer 3 of wes-2020-123

Markus Sommerfeld

July 15, 2022

## Author response

Dear reviewer 3,

Thank you very much for your very detailed and helpful comments to our manuscript, "Scaling effects of fixed-wing ground-generation airborne wind energy systems", wes-2020-123.
Your comments have been implemented in the latest version of the manuscript and wording has been refined. Please see our response below.

Sincerely, Markus Sommerfeld

## 1 General comments

- The results might be far off from reality as the reference aircraft, the AP2, is a first demonstrator of a company. The mass scaling might therefore be significantly different from 2.7 – 3.3. The company had different goals in mind for this demonstrator then it would have for a commercial system. I would like to see this stated better in the paper.
  - implemented
- I miss in the conclusion a statement where the effect of the assumptions are stated, especially on the awebox side, so the reader knows again what should be taken into account when reading each of the separate conclusions.
  - Model assumptions are stated in the beginning of the conclusion section.

### 1.1 Specific comments

Line l83 Why is it sorted by the wind speed of 200m? The operational altitude you consider is higher.

- implemented

Line 108 wast → vast

- implemented

Line 110 can not → cannot

- implemented

Line 112 How do you justify the feasibility? You use simplifications to set up the OCP right in awebox. Inelastic tether etc.

- rephrased

Figure 3 It might be good to show which systems are measured, and which ones are estimated/hypothetical.

- implemented

Line 194 Is the aircraft and ground station a tether mass point? If not, what is done with half the tether segment at the ground and at the kite, which is then not assigned to a tether mass. If not taken into account, this produces inaccuracies in the total weight of the tether.

- rewrote tether section. Yes, half of the tether mass at each endpoint (node) is assigned to either the kite or the ground.

Line 202 How are the reeling speed and acceleration constraints determined?

- implemented
- They are very similar to the constraints used in the references of the AP2 reference model (Ampyx, 2020; Licitra, 2018; Malz et al., 2019 - line 118). They were also confirmed during conversations with Ampyx and ground station manufacturers.

Line 468 As the purpose of this paper is to show trends when scaling, the explanation for the increase should be tested in this paper. Possibly by starting the optimisation from different points and see if they converge to the same. This way you might be able to spot other local minima or when it converges to the same, it might be a different cause.

- Starting the optimization from different initial guesses is possible, but beyond the scope of this paper. Doing this for approx 30 profiles, 6 designs, 2 sets of aerodynamic coefficients and 2 locations is not feasible.

Figure 15 I miss the explanation of the oscillations that happen at higher wind speeds, sorry if I missed this, then clarifying it better could prevent that. Also, why D/L and not L/D like the conventional way. As the axis is in percent, it might confuse the reader it is actually a value with no unit.

- Deviation from the expected trend lines are likely caused by the wind speed profile shapes and variations in optimized trajectory, especially towards higher wind speeds. To stay within the constraints, the optimizer determines trajectories which vary in shape, operating altitude and tether length from the typical trajectories found at lower wind speeds.
- Total drag also includes tether drag and is therefore not the typical L/D of an airplane. We chose to display D/L, to use a consistent denominator when plotting W/L and D/L. Furthermore, we believe that this presentation better communicates the weight and total drag limitation of AWES (for this design).