Interactive Commentary on "*Improving mid-altitude mesoscale wind speed forecasts using LiDAR-based observation nudging for Airborne Wind Energy Systems*"

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Abstract

We have observed a large number of scientific and patent publications focused on high-altitude wind exploitation, reflecting a truly exponential trend. KiteGen, as the first global entity to produce energy using this revolutionary method, finds itself in a difficult position following the massive amount of material produced by third parties and the consequential technical inaccuracies desperately needing rectification. The latter has a detrimental effect on the potential acceptance of the concept and occasionally leads to technological nonsense, weakening the potential for widespread common awareness of this powerful technology that has the potential to enable global transition from fossil fuel energy sources. We have observed that, due to the absolute originality and novelty of this concept, there is a lack of qualified peer review, and blatant errors have been propagated and transferred, undisturbed, from one poorly informed publication to another, with no-one critically re-analyzing their stratified assumptions. We have also observed that these same errors have confused the informal competition that has grown over time around our project, among what seems a hundred actors, leading to the copious physical development of low TPL[1] and/or unfeasible or extremely deficient alternative architectures.

KiteGen has long refrained from scientific communication due to the absolute certainty of our original and long-established architectural and scientific consistency, but having the devil hiding in the details of the technological issues, this certainty has correctly governed and become involved daily in our developmental activities.

If it could be agreed as true that KiteGen is now the premier exercise in applied technology and good engineering practices, it would ensure the large-scale production of generating equipment and the resulting sustainable energy therefrom. Obviously, we do not claim that everything has been perfected; further improvements are probable and desirable, *but* in classic Pareto progression. The subject paper, despite the voluminous data and formal processes involved, is an example of a misguided effort that fails to produce significant forward progress in this scientific and technological domain and risks becoming completely out of sync and out of the dynamic range of most of the architectures and technology cited in block by the article. We hope that our position will be widely accepted through reading and understanding the comments we make available in this paper, accompanied by the appreciation of the articulation of this logical, albeit rare, thinking in professional and strategic energy planning.

Keywords: Lidar, Sodar, troposphere, altitude, wind, KiteGen, electrical, energy, baseload, storage, HAWES, Capacity Factor.

[1] Technology Performance Level, the most useful parameter assessing and comparing new energy concepts.

Interactive Commentary on "Improving Mid-altitude Mesoscale Wind Speed Forecasts Using LiDAR-based observation nudging for Airborne Wind Energy Systems"

Method

The article is certainly of good quality, providing precious original data and measurements, that can be profitably added to the collection of previous work in general to state definitively and positively that high-altitude wind must be considered a new and inexhaustible source of energy that also totally solves the energy storage issue. However, the wind turbine-minded mindset of the authors should be noted, which emphasizes wind stability classes rather than the opportunity to increase the capacity factor by exploiting the freedom choose the various operational heights of tropospheric wind. While the site's location regarding wind stability is important for wind turbines, not only for productivity but also for structural resistance evaluation, it is completely negligible for effective High Altitude Wind Energy System (HAWES) architectures where dynamic lightness and swiftly responsive numerical control allow for immediate feedback and adaptive strategies. Furthermore, the authors' over-simplified model of HAWES leads to inappropriate recommendations and the invalid/improper use of this valuable data-set, resulting in several orders of magnitude out of the dynamic of the devices[4], resulting in unfortunate and useless, though sophisticated, elaboration of their findings. The difference of the article's evaluations from reality is so great that it prevents us from going further in any analysis; in the meantime recommending giving up on data massaging or model nudging, at least in the HAWES domain.

As a suggestion for further investigation that your skilled team may conduct, we believe that your work would be very useful in validating the assumptions made by Archer C., Caldeira K. (2009) [3], at mid-altitude mesoscale, regarding competitive or collaborative comparisons between the array of traditional systems, and the opportunities to exploit the naturally-stored energy in geostrophic wind by means of High Altitude Wind Energy Systems. LiDAR-based observations from two or more geographically-distant locations would assess the capability of the winds in the troposphere to provide at least minimally-required power 99.9% of the time when two appropriately-distanced power harvesting devices are interconnected and simultaneously utilized as one.

High-Altitude Wind Equipment, Design And Architectures.

Text quoted from page 2 paragraph 5:

"Unlike conventional wind energy which has converged to a single concept with three blades and conical tower, several different AWES designs are under investigation by numerous companies and research institutes worldwide (Cherubini et al., 2015). Various concepts from

ring shaped aerostats, to rigid wings and soft kites with different sizes, rated power and altitude ranges compete for entry into the marketplace. Since this technology is still in an early stage, none are commercially available."

Kitegen financed this (Cherubini et al. 2015) [2] study, as reported in the acknowledgments of the same, without exerting any pressure on the authors regarding the content, in the conviction it would enable the reader to make an independent comparison among the different technology proposals. To any skilled technician in the art capable to evaluate, the differences and various advantages of the architecture proposed by KiteGen are blatantly clear. We have already experienced several learned opinions that confirm KiteGen has not only the best architecture, but also the only one feasible on an industrial scale while simultaneously fulfilling grid requirements. Other available meta-indicators show an overwhelming convergence toward the concepts patented by KiteGen, such as the number of new patent applications replicating our approach, and the numerous independent scientific publications addressing our architecture. Surprisingly, the requisite technological skills needed to guide and discern among alternatives don't seem widely evident among academia and researchers, even in works/papers like this one where our interactive commentary is addressed despite revealing volumes of good data and astute formal processes.
KiteGen, as a pioneer, first in producing energy with this new concept, fully patented, and first completing the research, including a 10-year continuous assessment of the architectures, cannot anymore accept, without some reaction, the informal competition around our proprietary technology and the misguided "information" delaying its understanding and acceptance .
From (Cherubini et al. 2005), the classification of flygen and groundgen is clear, as the different wings or wind-harnessing devices, propeller adopted or different rotokite concepts.
The inadequate buoyancy of helium-filled blimps, a few N per cubic meter unit, cannot withstand the very high horizontal force of the wind, correctly reported and highlighted in the article, which implies the altitude cannot be arbitrarily chosen by the control of such devices. Other dysfunctions will occur for rigid flat wings that cannot structurally withstand the forces without unacceptable weight (longeron beam) or flexible fabric wings that cannot maintain sufficient aerodynamic efficiency or survive the forces and aerodynamic stress required for energy production. In particular, there is the recent demonstration corresponding to the conclusion of the applied research conducted by KiteGen, which delivers the complete and validated projection of generators on an industrial scale, which will put an end to architectural speculation, as this development demonstrates adherence to the best possible specifications in terms of LCA and energy quality, outperforming the matured wind turbines both in onshore and offshore applications by a thousand times.

It seems impossible to avoid the (*false, but overwhelming*) politically-correct urge to set aside/ignore the comparisons or architecture adoption to the focus on the most promising concept. There remains the need to stress, in any case, the introduction of robust scientific criteria, stated with certainty and generally requiring that such an analysis must be specifically tailored to each of the architectures and harnessing strategies depicted, instead of generically considering the domain as a whole. Each architecture has different requirements and behavior within wind forces and speeds and different capacity factors. For example, the paper's authors deduced and recommended an ideal and quite precise operating altitude of 200-400 m with a computed wing of 28 of gliding factor. Such a wing, in a pumping kite architecture, will fly in crosswinds at speeds of 100m/s and over. The suggested altitude provides a very tight cone of operation, which would require the wing to maintain an excessively tight direction-changing path in airspace and an impractical few seconds to complete a stroke inside the lemniscate (the characteristic "eight"-shaped path).

Accurate Data of High Altitude Wind; Is It required?

Text quoted from page 2 paragraph 10:

"Developers and operators of large conventional wind turbines, AWES and drones require accurate wind data to estimate power and mechanical loads."

This statement is absolutely wrong, and risks concealing one of the primary architectural advantages of KiteGen. The KiteGen design concept is totally different because it does not have fixed structures that have to withstand the worst weather conditions that occur once in decades. It starts from an arbitrary design choice of the nameplate power of the generator, without having to take into account historical wind data. Thus, the structural cost of the generator is merely a linear function of the chosen design power specifications, not the imposed safety factor for a structure that must withstand all weather conditions.

Currently, our 100 sqm wing is equipped with a 16 mm diameter 3GPa ultimate tensile-strength line. The force may reach up to 600 kN before breaking[4]. When the wind is strong enough, the wing may exert forces certainly greater than the line's ultimate tensile strength. The order of magnitude of such exceptional forces can raise the power of a single-wing high-altitude wind generator close to 900 MW; thus 30MN of traction, as also stated in the subject article preprint, confirming this finding. This is valid and generally correct only from a physical and geometrical point of view. Obviously, the technology cannot follow those requirements so closely. Another issue is the Capacity Factor of the machines which needs to be maximized for weak winds rather than preventively over-engineered for optimization in strong winds.

Thus, it is not practical to apply the features of wing/wind system interaction to the specifications of the generator. It is better to find a compromise with reduced power that is more easily manageable and can be engineered/produced with a greater Capacity Factor because it requires less wind speed.

Following such design guidelines, it is the generator that shapes the dynamics of operation, controlling the lines through its system of pulleys. It is not necessary nor useful to have a full wing-speed-and-force profile dependent on the available natural resource. The arbitrarily chosen 3 MW nameplate generator will currently manage up to 300 kN of force (50% of the maximum load of the line) when the wind speed does not exceed 15 m/s. By regulating the operating altitude and wing flying position/orientation (pose) relative to the wind direction, sporadic stronger winds can be avoided and/or mitigated.

Stronger and Constant High Altitude Wind Isn't the Original Enabling Factor

Text quoted from page 2 paragraph 10:

"[Developers] They currently rely on oversimplified approximations such as the logarithmic wind profile (Optiset al., 2016) or coarsely resolved reanalysis data sets (Archer and Caldeira, 2009) as the applicability of conventional spectral wind models (Burton, 2011) have not been verified for these altitudes."

This statement is also not true and, again, potentially undermines the integrity of, and professional work accomplished, by KiteGen. We have already observed such an attitude in other publications where the authors try to gain some additional credibility, attempting to criticize the proceeding developments, their motive not clear [6].

At KiteGen, we prefer to be asked timely questions about our technical opinions or doubts about our assertions rather than be surprised after-the-fact. This is an open invitation to meet the team. In any case, it is a great opportunity to continue the discussion of this unprecedented opportunity.

KiteGen relies on two features/achievements regarding wind availability, which are precise and certainly not an oversimplification or approximation:

1) Tethered airfoils can generate far more power than wind turbines simply because they can sweep a greater area for an equivalent or reduced expenditure of resources, since they would not incur the cost of the tower or be limited to the blade sizes that towers must accommodate. It is easy to compute such an increase in performance through Betz laws. In particular, the flying wings expose a lower Betz efficiency, compensated for by the larger area swept, which allows it to outperform the energy-harnessing potential of the wind turbine blades by a factor of three, assuming equal conditions of wind speed and aerodynamic surface.

2) In 2003, KiteGen, in collaboration with Dutch astronaut Wubbo Ockels [1], gained insight into the potential of high, or tropospheric, winds; stronger and more constant than biosphere winds; then, in 2009, sought and obtained a study from an Italian research centre [5], providing

great amounts of data gained in Italy using Sodars, that made us fully aware of the greatly multiplied advantages at previously unforeseen and unexpected altitudes, creating a definitive and satisfactory solution to the wind issue.

Multiplying the threefold increase of performance due the “Betz” advantage, with an eightfold minimum increase of wind power at altitude, we obtain an astonishing exploitable natural resource that is at least *24 times* the typical wind turbine’s harnessable power. This fact suggested that it was better to focus all efforts on the challenge of industrial-scale harnessing technology.

Finally Some Positive Remarks Regarding the Technology

Text quoted from page 16 paragraph 5:

“Therefore, AWES need to be able to operate in a wide range of wind speeds or be controlled in a way that they avoid extreme conditions. The 12 months NoOBS simulation shows lower wind speeds than the 6 months simulations as the included summer months generally have lower wind speeds due to higher probability of unstable stratification. The Weibull fit of this simulation tends to overestimate higher wind speeds and underestimate low wind speeds at all altitudes.”

Text quoted from page 24 paragraph 10:

“Using a simplified AWES model, assuming a constant tether length of 1500 m and neglecting drag and weight all data sets suggested an optimal operating altitude between 150 and 400 m. However, since stratification leads to a vast range of wind speed profiles AWES greatly benefit from dynamically adapting their operating altitude to maximize power production and minimize losses”

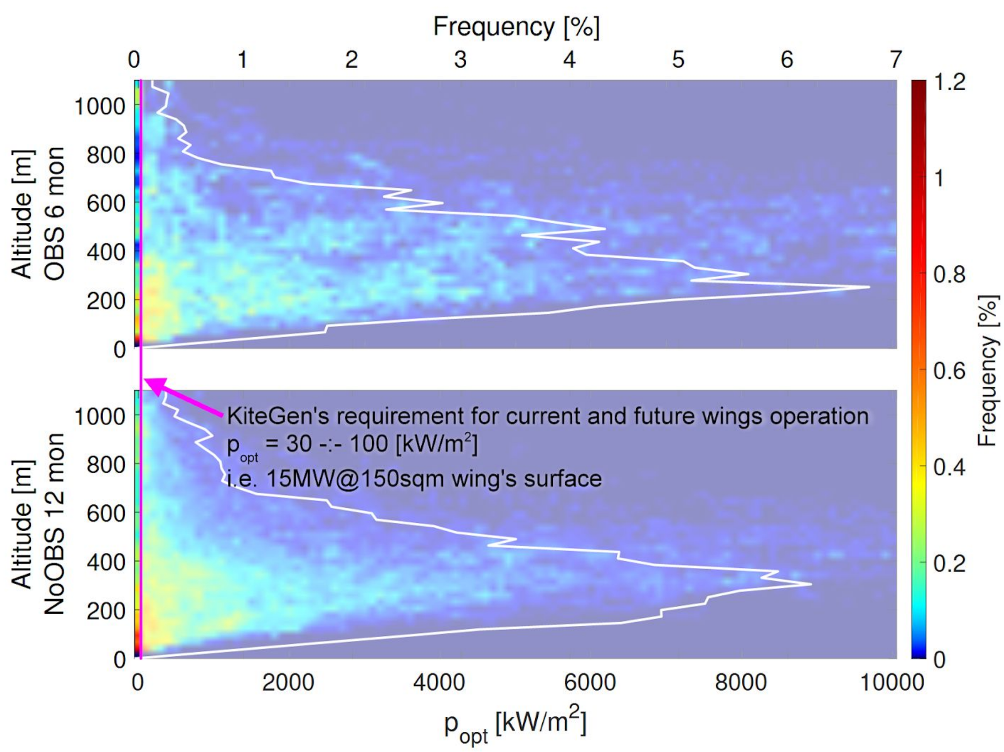
Disregarding the fallacy of the over-simplification of the tropospheric wind generation model, those observations are certainly true, and finally desirable and quite easy to obtain. The wing’s directional freedom effectively deals with extreme conditions and provides an effective adaptation opportunity. Stronger winds will not be exploited by regulating the operative altitude and/or the wing flying position compared to the wind direction (exiting the power spot by not flying crosswind). That being said, there are a lot of automatic controls and engineering solutions to ensure safety and to manage modulation, transient conditions and all the possible issues that may arise when dealing with this natural resource.

Optimal Operating Altitude and Power Production: Is It Really Required?

Text quoted from page 22 paragraph 5:

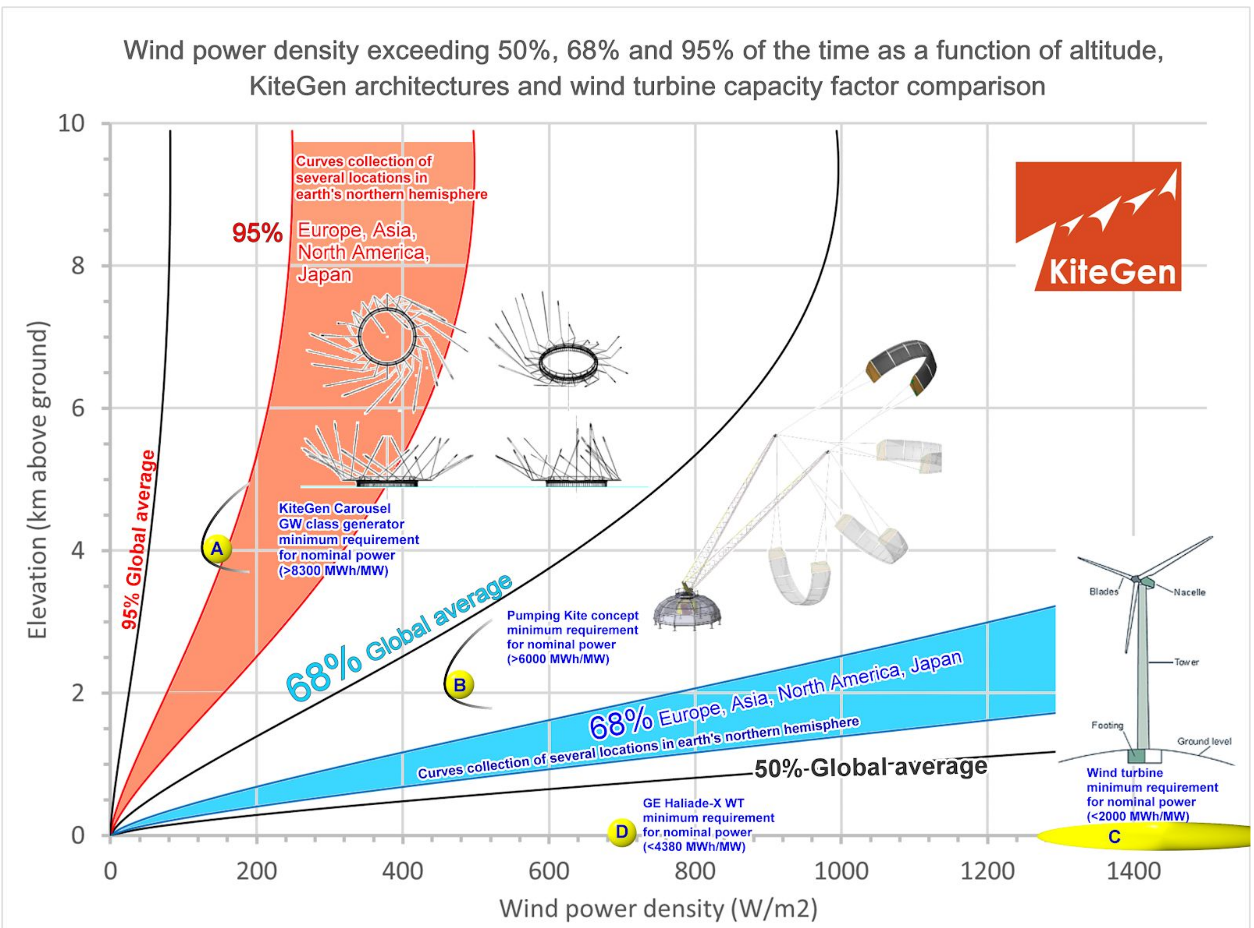
"Figure 13 summarizes the probability distribution of optimal operating altitude and optimal power with the white solid line showing the cumulative frequency of optimal operating altitude. Both simulations for this particular location and time period show similar trends with the most probable optimal altitude between approximately 200 and 400 m. Times of very high traction power are fairly rare and likely associated with low level jets. Lower power at higher altitudes is caused by the misalignment losses. Here we assume a constant tether length of 1500 m."

This article is addressing a wind resource assessment totally outside of the KiteGen dynamic, unfortunately risking to be useless to both developers and researchers in general, which again falls into the error of inappropriate exaggeration. Although theoretically correct, the proposed wind environments for deployment are technologically unreachable. In fact, our 100 m2 wing, according to the authors, would reach a peak of 900MW. In short, a single wing would generate power almost equivalent to that from a *nuclear power plant*!
The out-of-scale wing 8-9MW/m^2 must be compared with the desired trend in wind turbine to reduce the specific power addressed, and the requirement of our giant wing that is even lower: 30kW/m^2 of wing surface or 300W/m^2 of specific power of the wind front



Subject article figure 13 here modified to highlight the scale mismatching

The plausibility of the project needs to preserved by correcting such inaccuracies, arguing the uselessness of this approach and introduce and make it clear that the most valuable feature of KiteGen is its baseload behavior, which is achieved without forcing it into optimization. It is better to avoid exploiting intense wind and address development toward obtaining nominal power with weak or very weak winds. Losing wind power when it is excessive, on the other hand, can be quite easily addressed, even though this was the biggest obstacle during the operation of our research prototypes, regularly leading to damaging some components of the equipment.



The KiteGen Carousel is superior to the best baseload power plants, including coal, gas and nuclear. The data are coming from several available data and reanalyses. The pink area depicts wind speeds available in the temperate zones of the planet, actually better with respect to the global average. This means that the KiteGen Carousel needs a very low wind speed (about 7 m/s on average) to work at high capacity for more than 8300 hours per year, even at altitudes less than 3000 m, especially in energy intensive areas of the world (yellow balloon “A”). The pumping kites need more power density to work at a capacity factor greater than 6000 hours per year at even lower altitudes (about 10 m/s on average - yellow balloon “B”). Wind turbines work for 2000 equivalent hours per year, requiring a minimum wind speed of 12-14 m/s or 1100-1646 W/m2 to provide nominal power and is also reported the recent announced prototype of GE Haliade-X (yellow balloon “D”) that is claimed to have a potential capacity factor of 63% or 5500h in very lucky sites. The Haliade-X abnormal data is in fact a merely and different commercial strategy, if compared to competitors, the turbine is geometrically and economically a 36 MW wind machine with the nameplate derated to 12 MW, this adjust the denominator of the CF formula (MWh/MW), unfortunately the expected manufacturing batch cost per unit is close to 150M€ while the prototype including the industrial tooling was announced at 400M€, skyrocketing the LCOE of the envisageable batch produced units to over €300/MWh, two order of magnitude higher compared to the LCOE of the “dematerialised” KiteGen Carousel.

The extreme optimization issue is a common thread to practically all the (pseudo) scientific articles generated by third parties which ignores grid requirements and energy quality, then is easily ridiculed, consequently leading to the potentially damaging underestimation of the value of the project, thus sharing the same errant promotion of photovoltaic and conventional wind turbines, when KiteGen is obviously the long-awaited solution to such issues.

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