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Airborne Wind Energy – The Future of Wind Energy?

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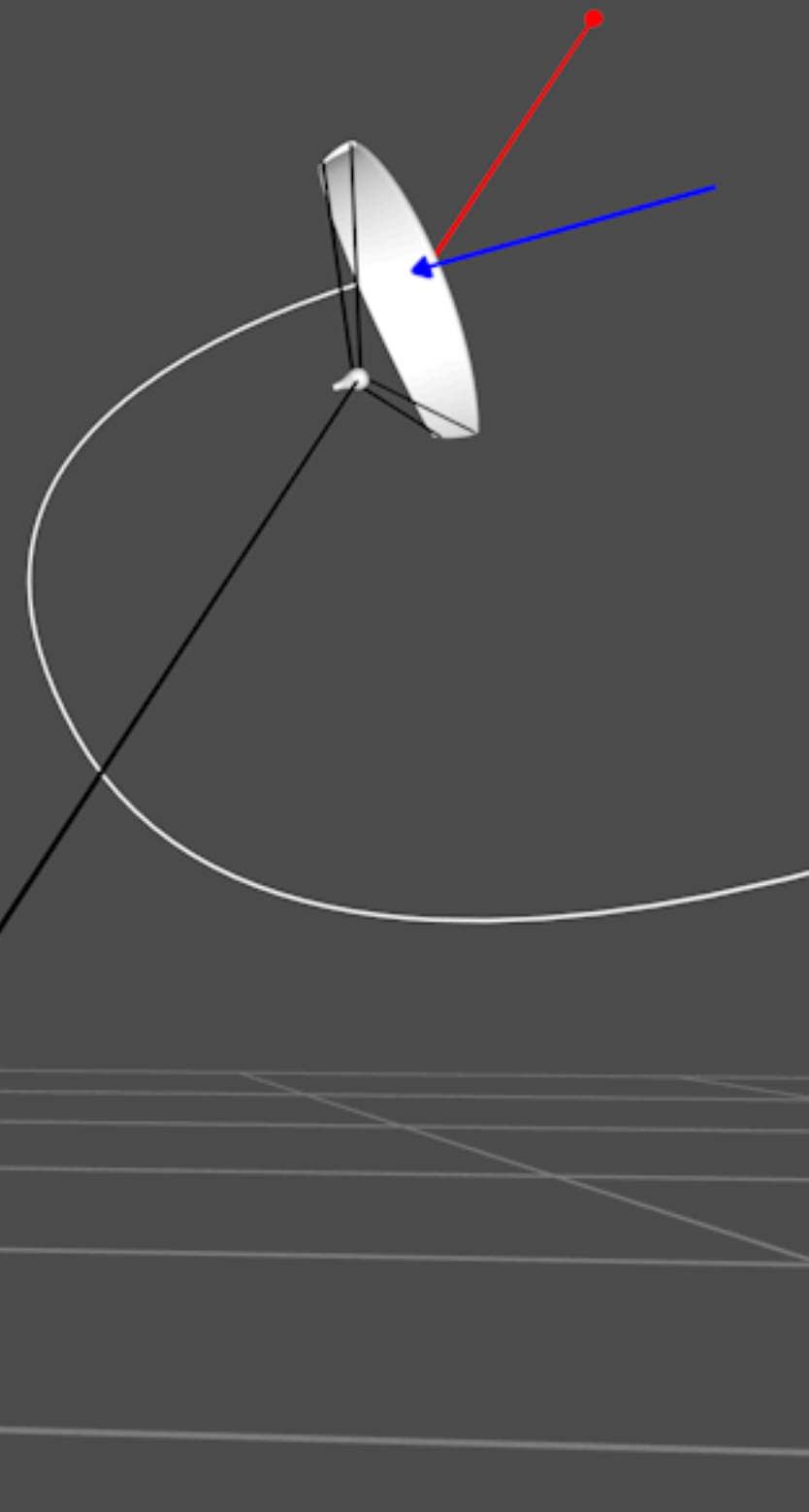
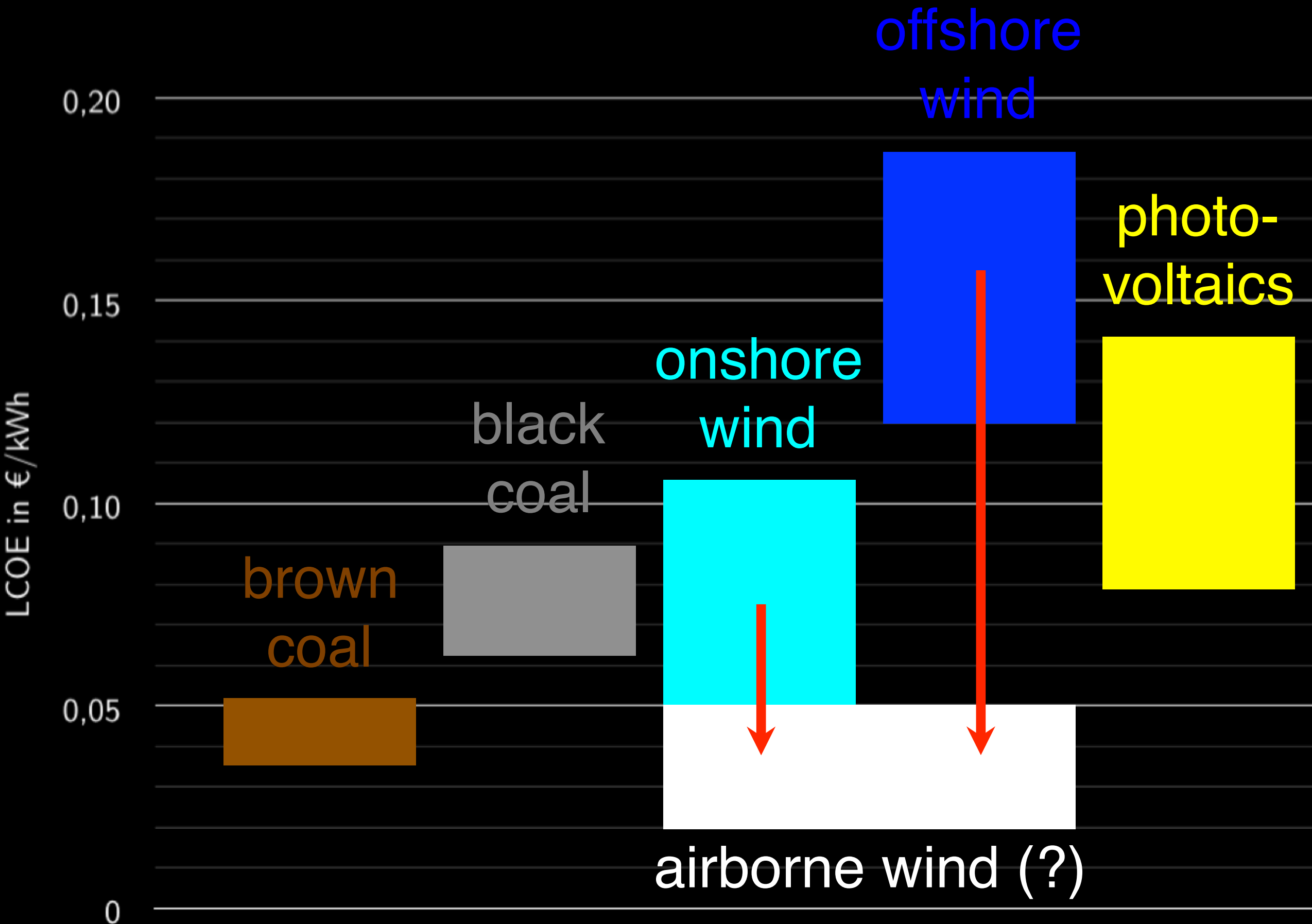




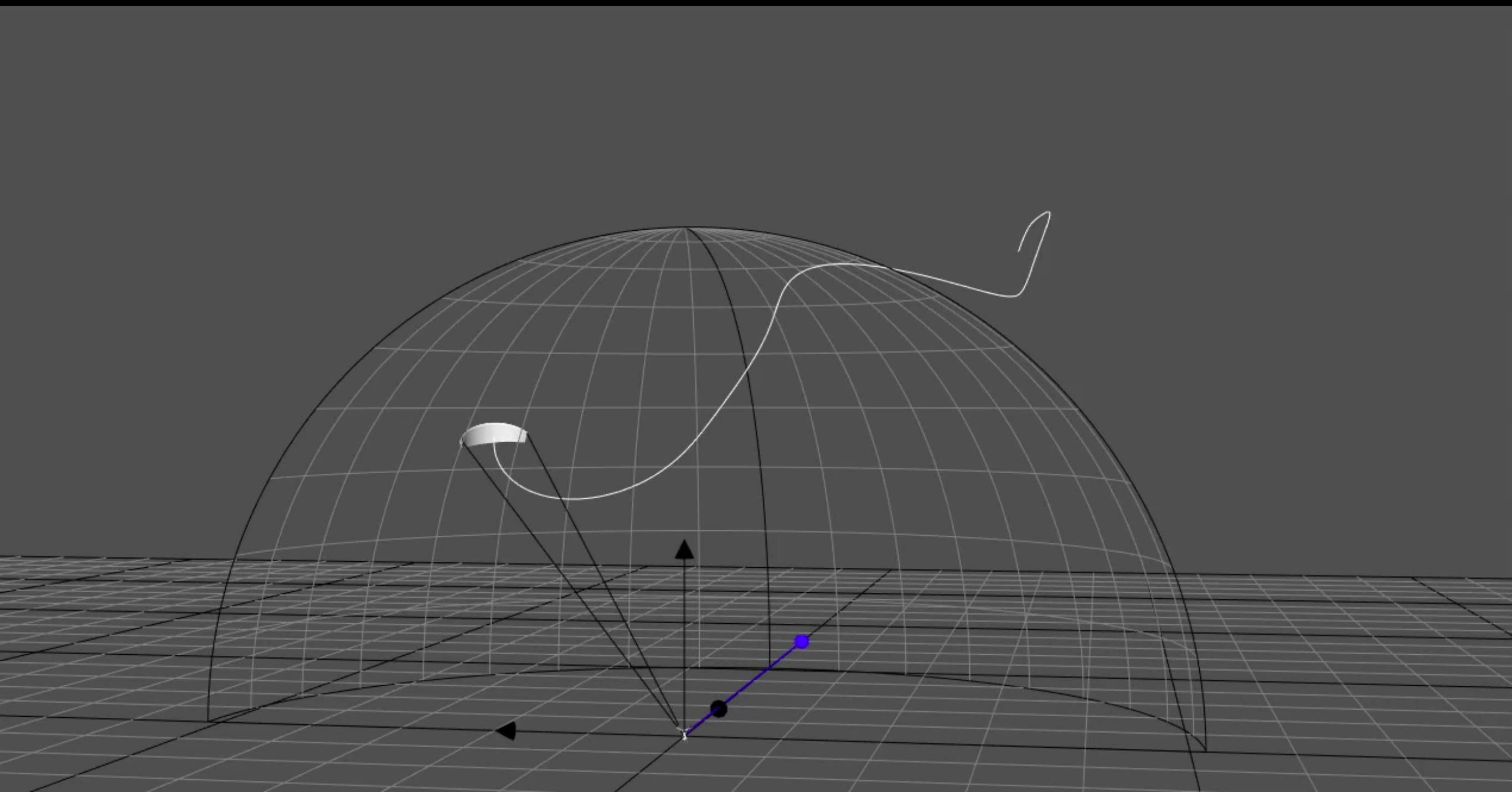
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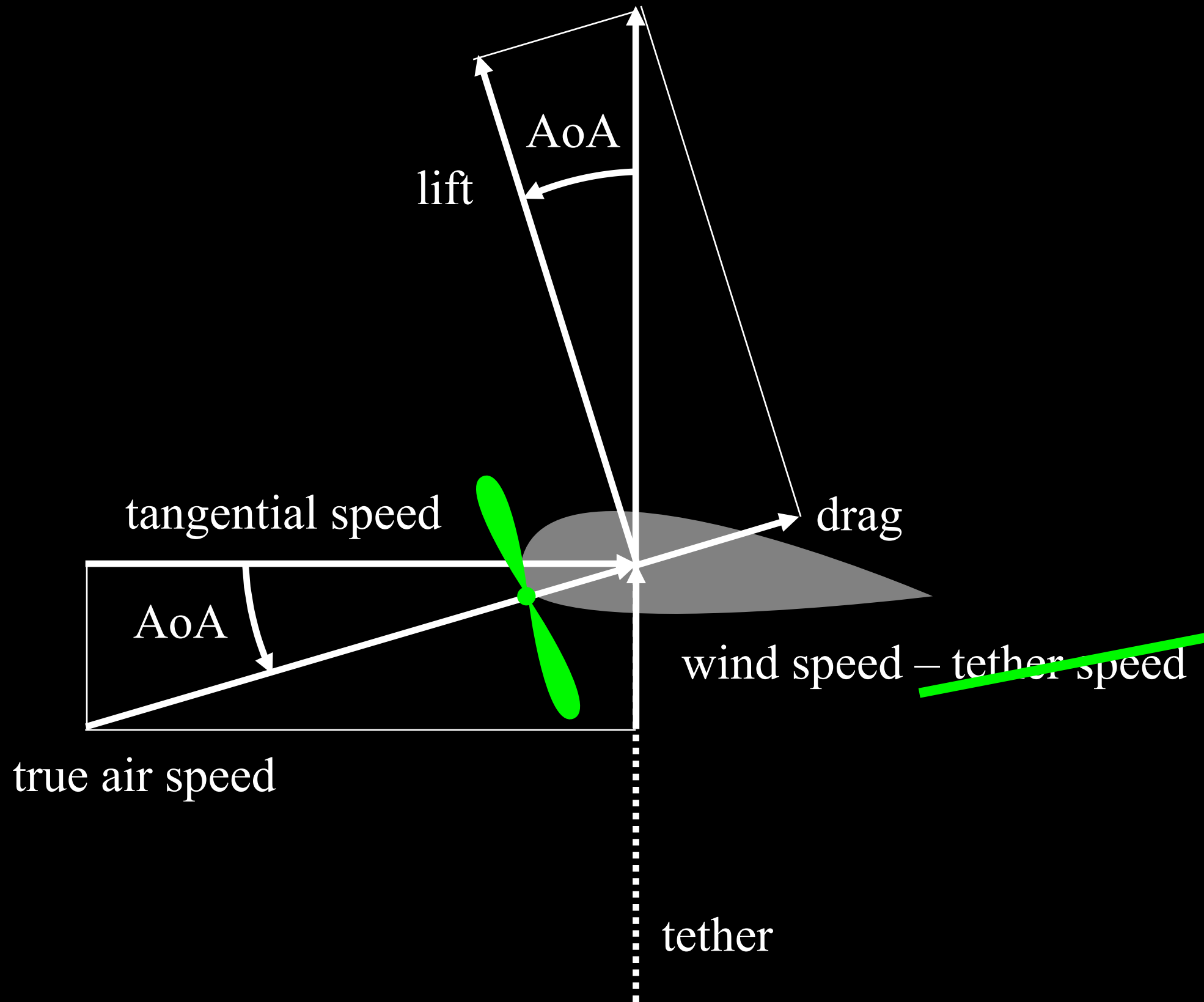


Image source: http://windcluster-bw.de/wp-content/uploads/2013/01/windpark_ochsenfurt-erlach.jpg



Data source: Kost, C. et al.: "Stromgestehungskosten Erneuerbare Energien", Study, Fraunhofer-Institut, 2013.





$$\text{true air speed} \approx (\text{wind speed} - \text{tether speed}) \frac{\text{lift}}{\text{drag}}$$

maximum power=

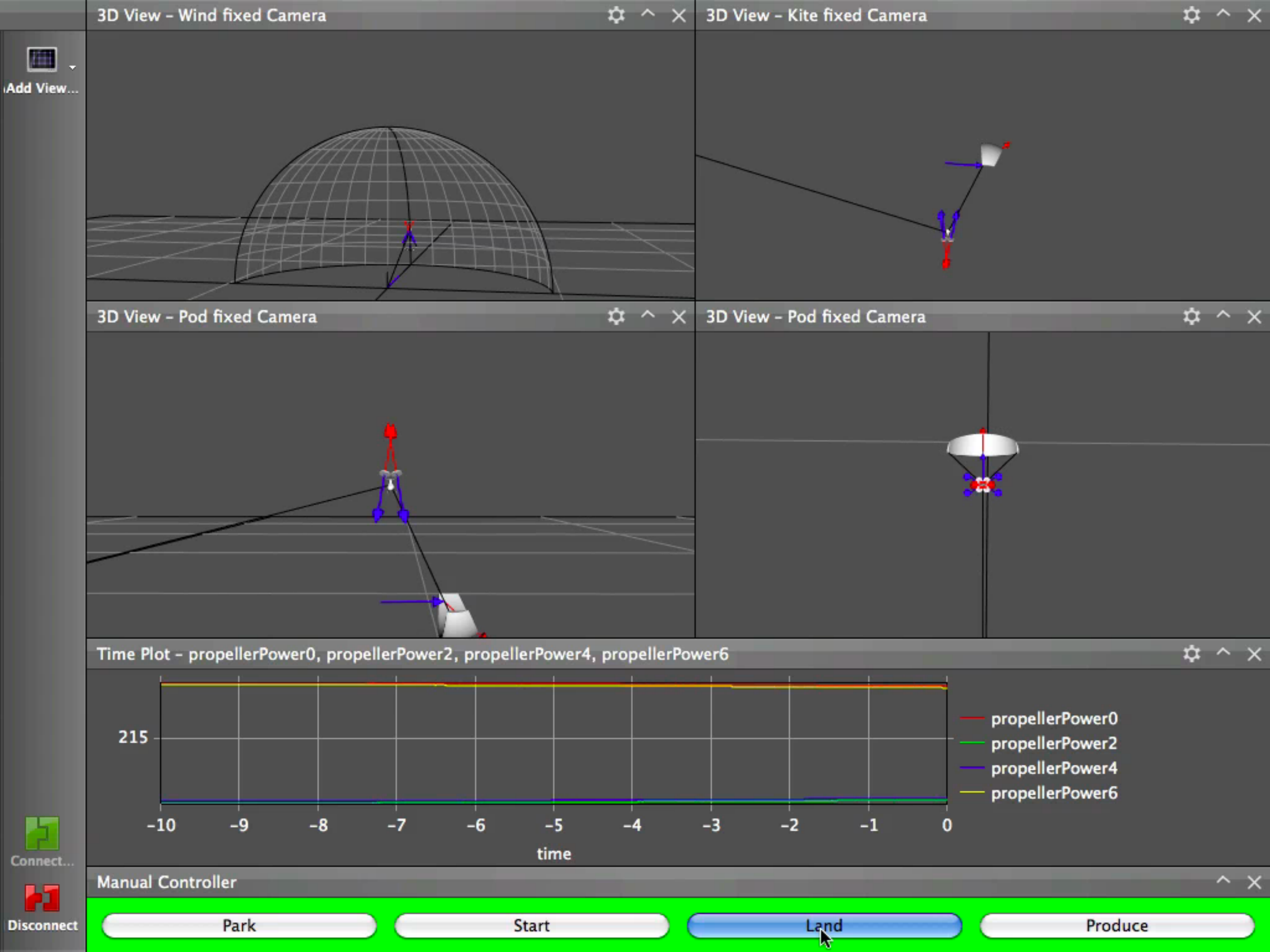
$$5.5 \text{ MW}$$

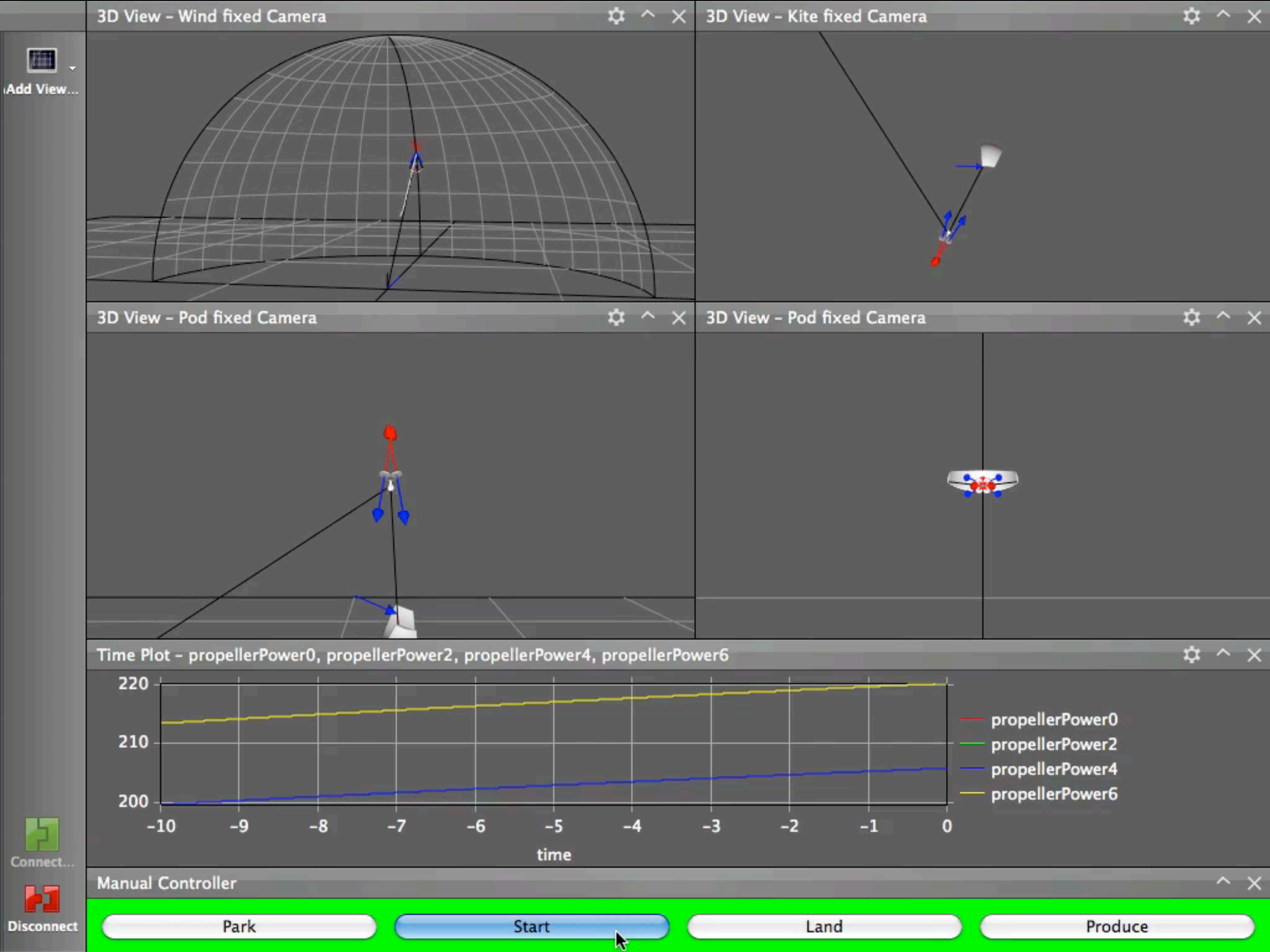
1.2 kg/m^3

12 m/s

100 m^2

$0,15$









Requirements  quantitatively: low LCOE

 ...achievable qualitatively with:





-  high reliability (particularly no crashes)
-  full automation
-  long life time (20 years)
-  high energy density (handling of an autonomous flying object)



Image source: Ahrens et al.: "Airbrone Wind Energy", Springer, 2013, p. 494

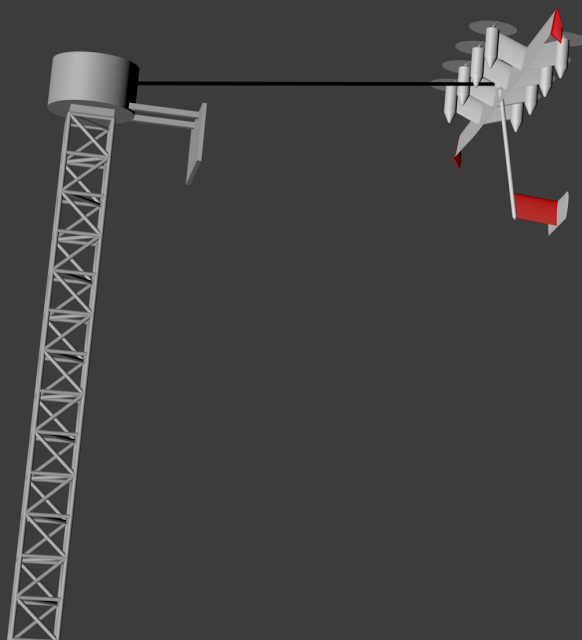


Image source: <http://windswept-and-interesting.co.uk/wp-content/uploads/2015/04/testing-daisy-large.jpg>



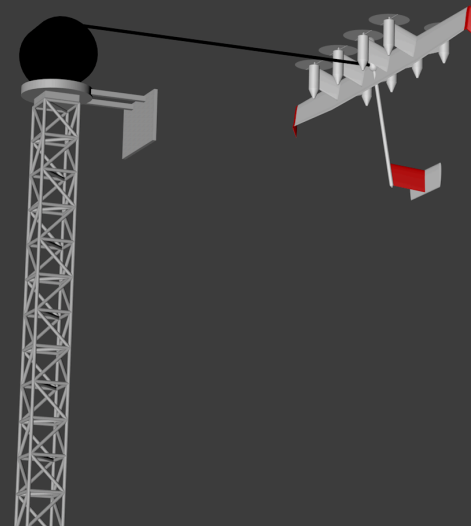
Image source: Ahrens et al.: "Airbrone Wind Energy", Springer, 2013, p. 502

Crosswind Kite Power with Rigid Kite

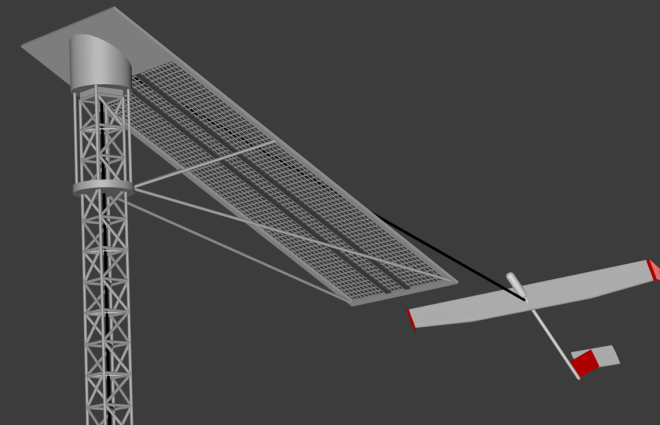


onboard generation

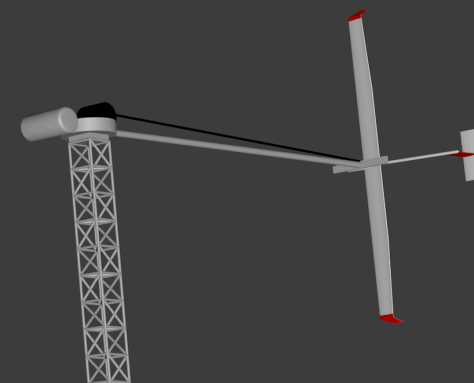
multicopter
take off & landing



multicopter
take off & landing



catapult
take off & landing



centrifugal
take off & landing



Image source: Roland Schmehl (Ed.) "Airborne Wind Energy Conference 2015 Book of Abstracts", p. 16, 2015.
Online available: repository.tudelft.nl/view/ir/uuid:7df59b79-2c6b-4e30-bd58-8454f493bb09

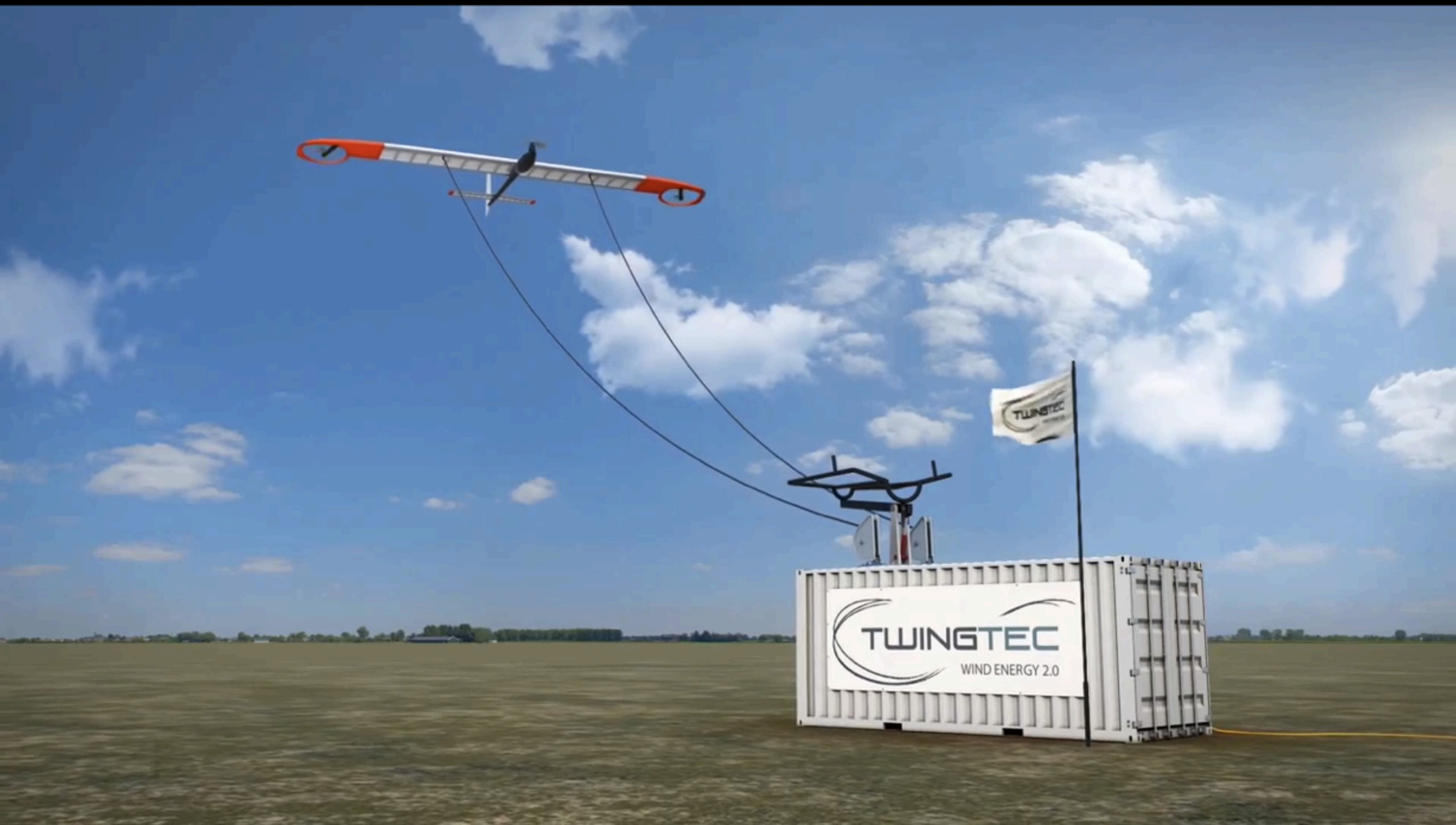


Image source from: <https://www.youtube.com/watch?t=71&v=WXuYjvzeUbA>

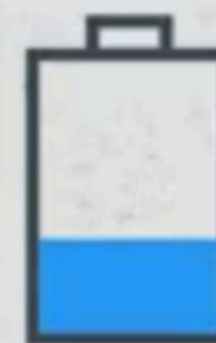


Image source from: <https://collegerama.tudelft.nl/Mediasite/Play/2ebb3eb4871a49b7ad70560644cb3e2c1d>

EnerKite

Automatischer Start auch bei Flaute am Boden

Phase 1
Rotationsstart

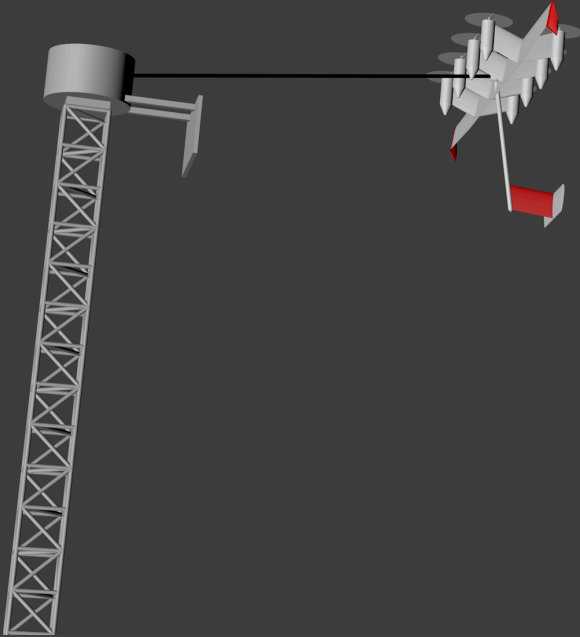
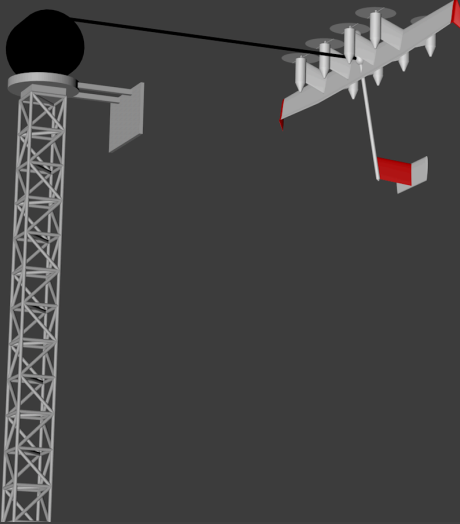
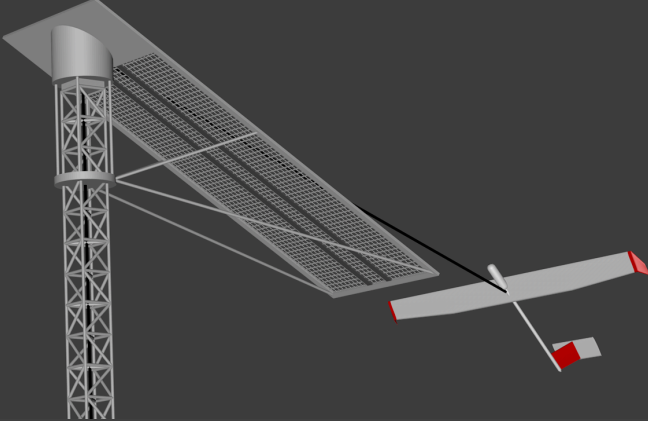
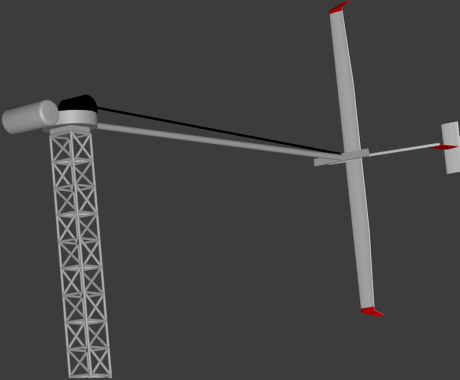


Batterie



Leistung KW

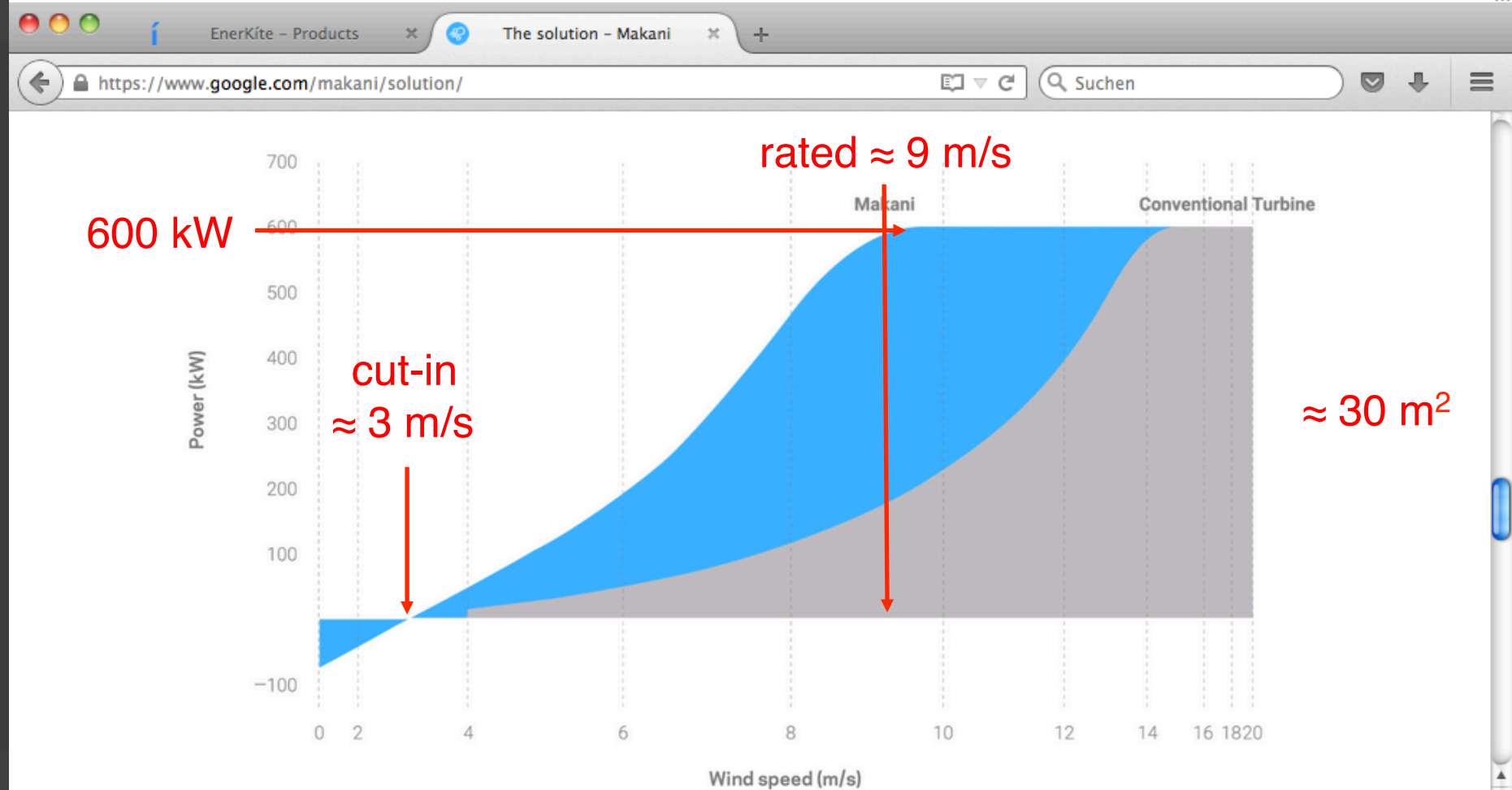
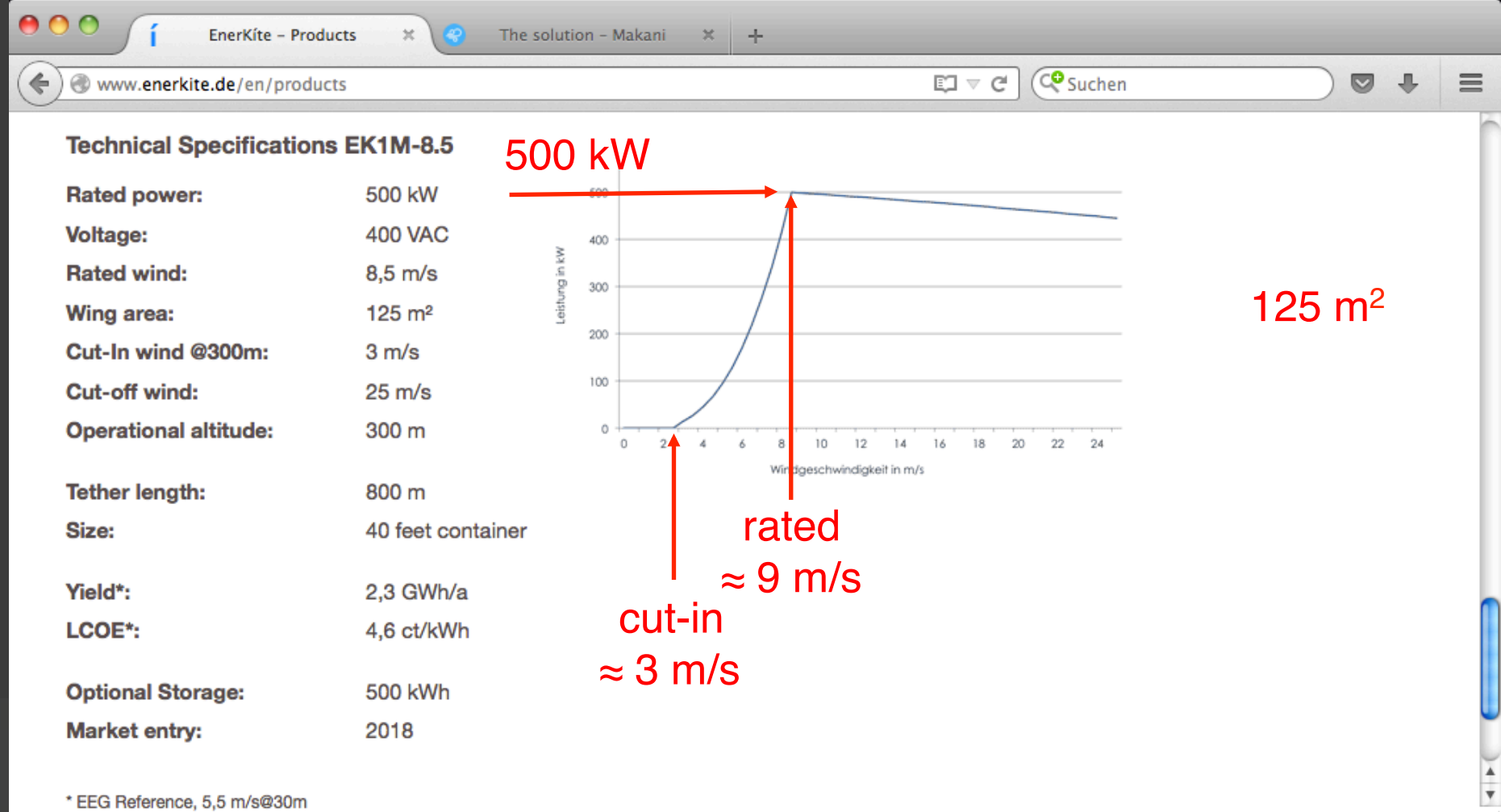
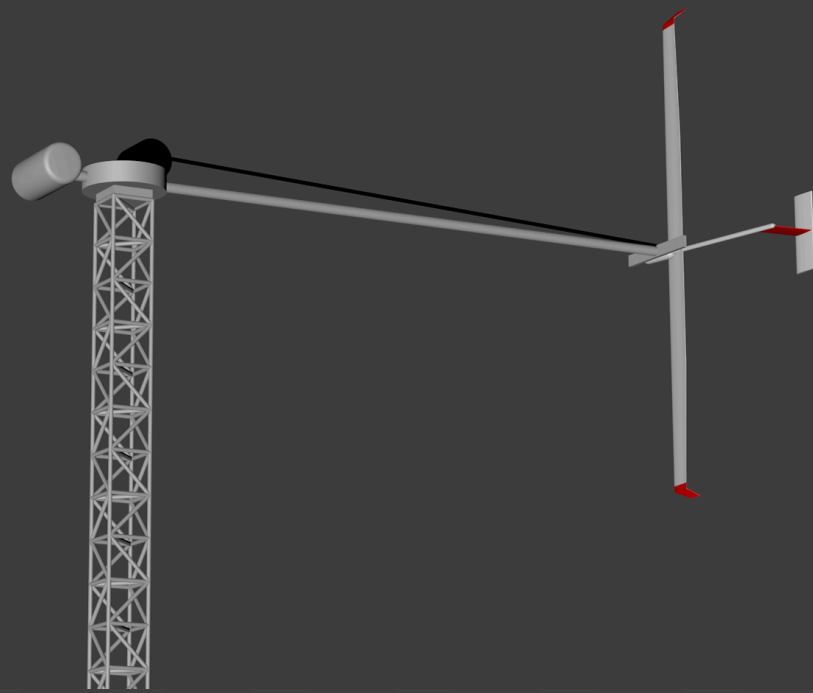
Crosswind Kite Power with Rigid Kite

					
onboard generation		ground generation			
multicopter take off & landing		multicopter take off & landing		catapult take off & landing	
1 line		1...3 lines		1...3 lines	

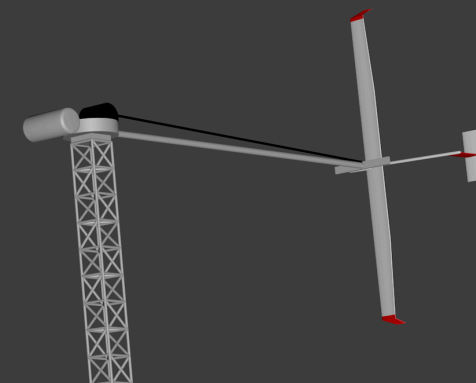
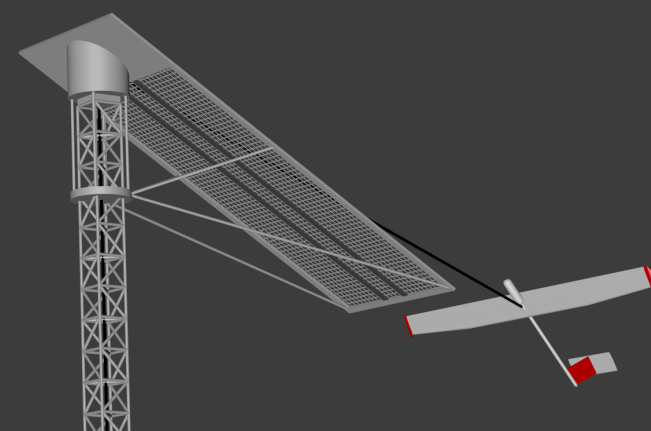
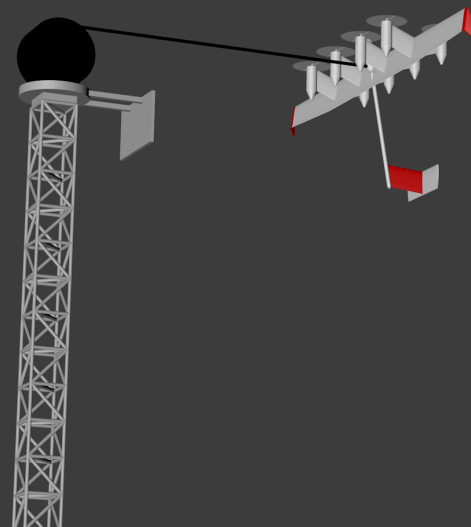
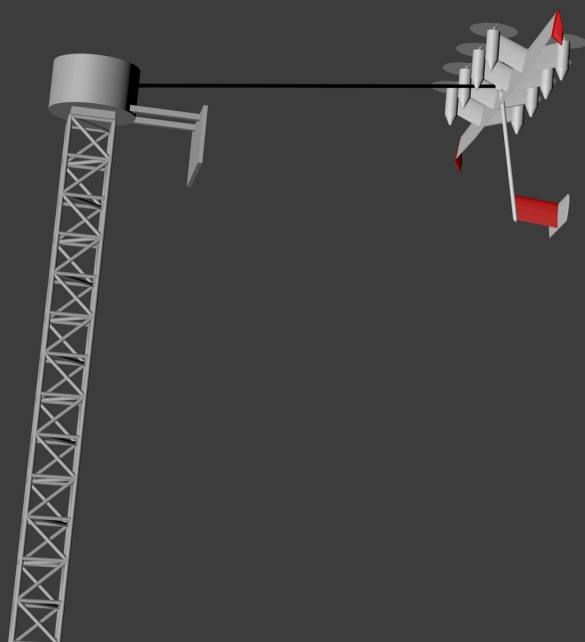
high reliability?

full automation?

high energy density?

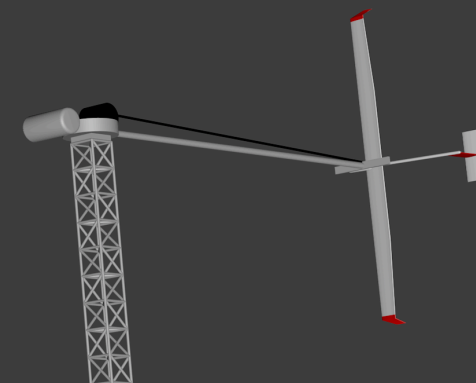
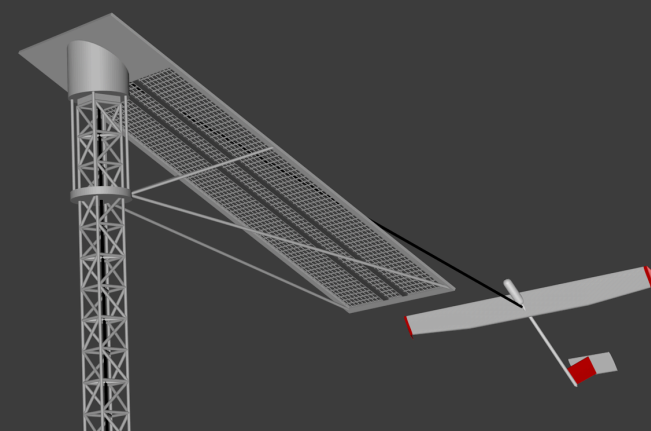
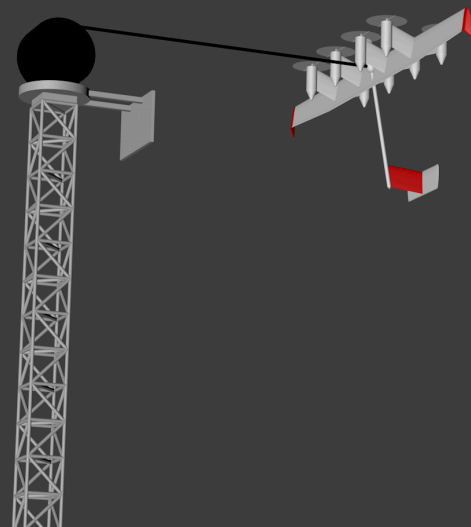
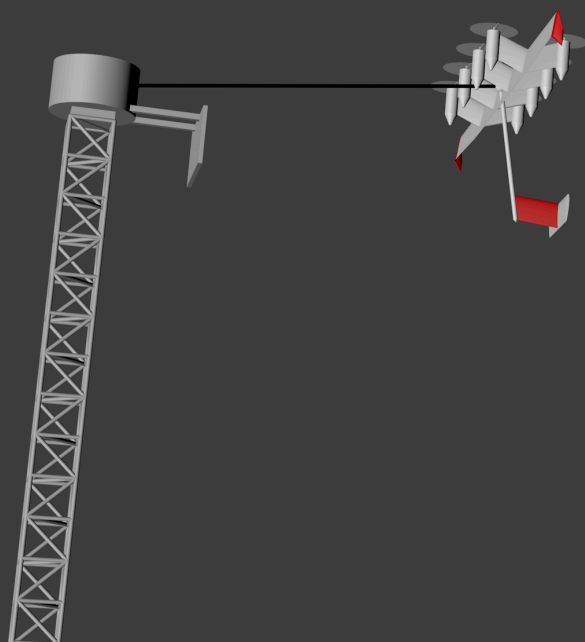


Crosswind Kite Power with Rigid Kite



onboard generation		ground generation	
multicopter take off & landing		multicopter take off & landing	
1 line		1...3 lines	
fail-save to hover		fail-save to hover	if all controls on kite: fail save to horizontal landing otherwise: must keep flying tethered
no reeling: simple control, simple ground station, more average power, power more continuously		reeling: more complex control, more complex ground station, less average power, heavily fluctuating power	
tether-cables as lightning conductors (?)		no solution for lightning protection yet, except landing	
simple take off & landing, automation proven		simple take off & landing, automation proven, but: propellers are extra	complex take off & landing, automation to be proven
all sensors, actuators and controls on kite		if 3 lines: all sensors, actuators and controls on ground	
		if 1...2 lines: real time wireless communication link between ground & kite required	
high airborne mass & tether drag		(very) high airborne mass (or high complexity)	low airborne mass and low tether drag if 1 line
high speed low torque drive train but: more complex power electronics & tether		low speed high torque drive train (size, costs etc. ~ torque)	
noise (?)		noise not an issue	

Crosswind Kite Power with Rigid Kite



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no reeling: simple control, simple ground station, more average power, power more continuously		reeling: more complex control, more complex ground station, less average power, heavily fluctuating power	
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**Let's build
drones!**

**Let's build
BIG
drones!**

**Let's build
BIG, TETHERED
drones!**

Let's build
BIG, TETHERED, PEACE-
drones!



Let's build
BIG, TETHERED, PEACE-
drones!
(WITHOUT SELFIE-FUNCTION)



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