61. AMAP Kolloquium

Transition to carbon free materials

Uwe Ahrens

X-Wind Powerplants GmbH

X-Wind Technology

As powerful as nuclear power

As quiet as a whisper

As visible as a glider

Energy without regret

X-Wind

"A breakthrough that could power the world "

NATIONAL GEOGRAPHIC

And an analysis by Garrad Hassan concludes:

“HAWE (High Altitude Wind Energy) systems have the potential to take energy generation from wind into a new dimension; unlocking resources with far greater potential energy than so far realised.”

Table of contents

- The problem

- The physics of the solution

- The economic aspects

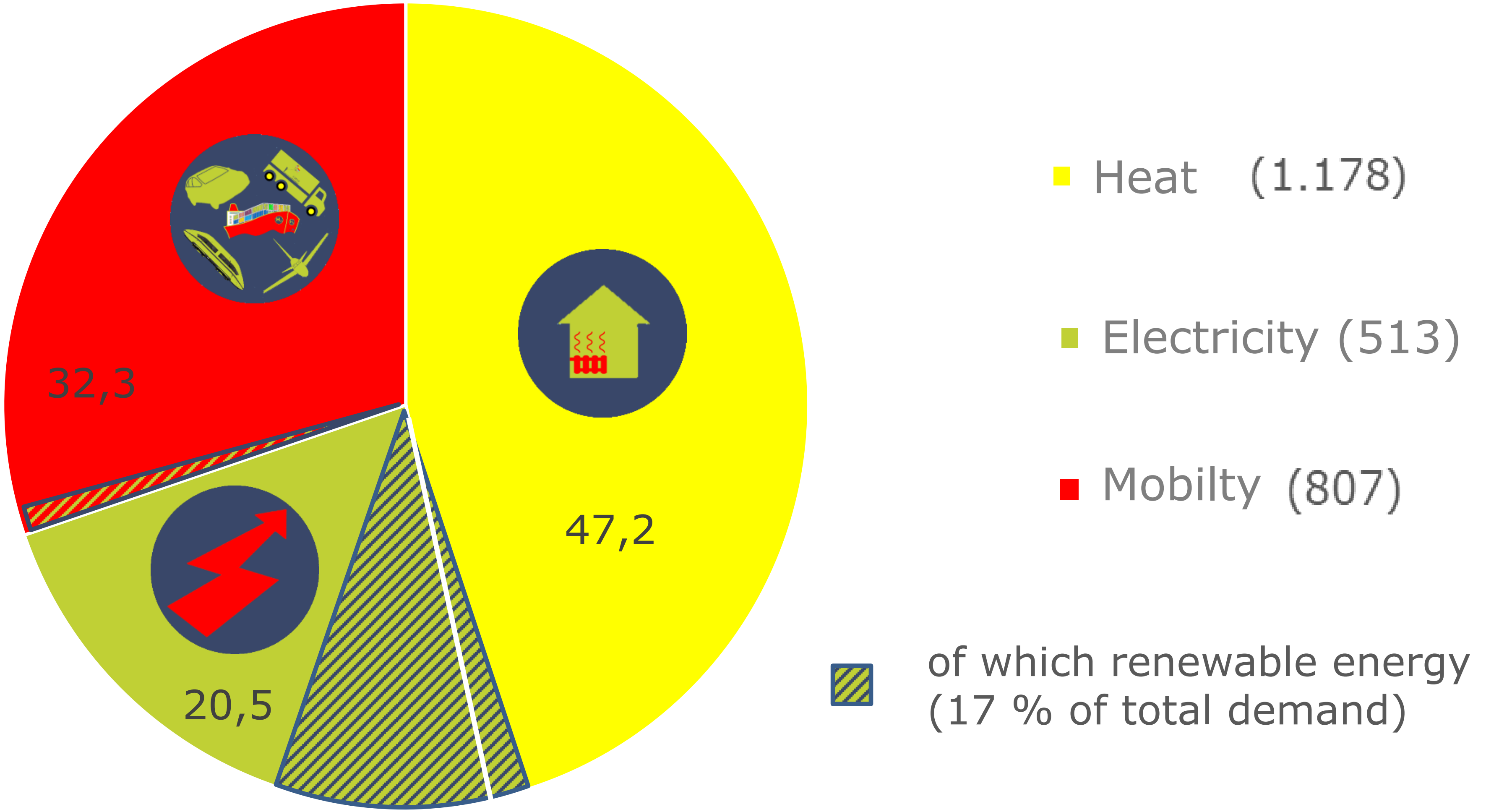
- The legal aspects
- The social aspects

- The potential for the aluminum industry

Missing sources, expert opinions or graphics will be supplied on request.
Further information is marked on the relevant pages and can be found under the respective number (xx) in the appendix.

The problem: More than 80% of our energy needs are still produced by fossil fuels.

Final energy consumption by sector 2019 D in %.
(total 2.498 TWh/a)

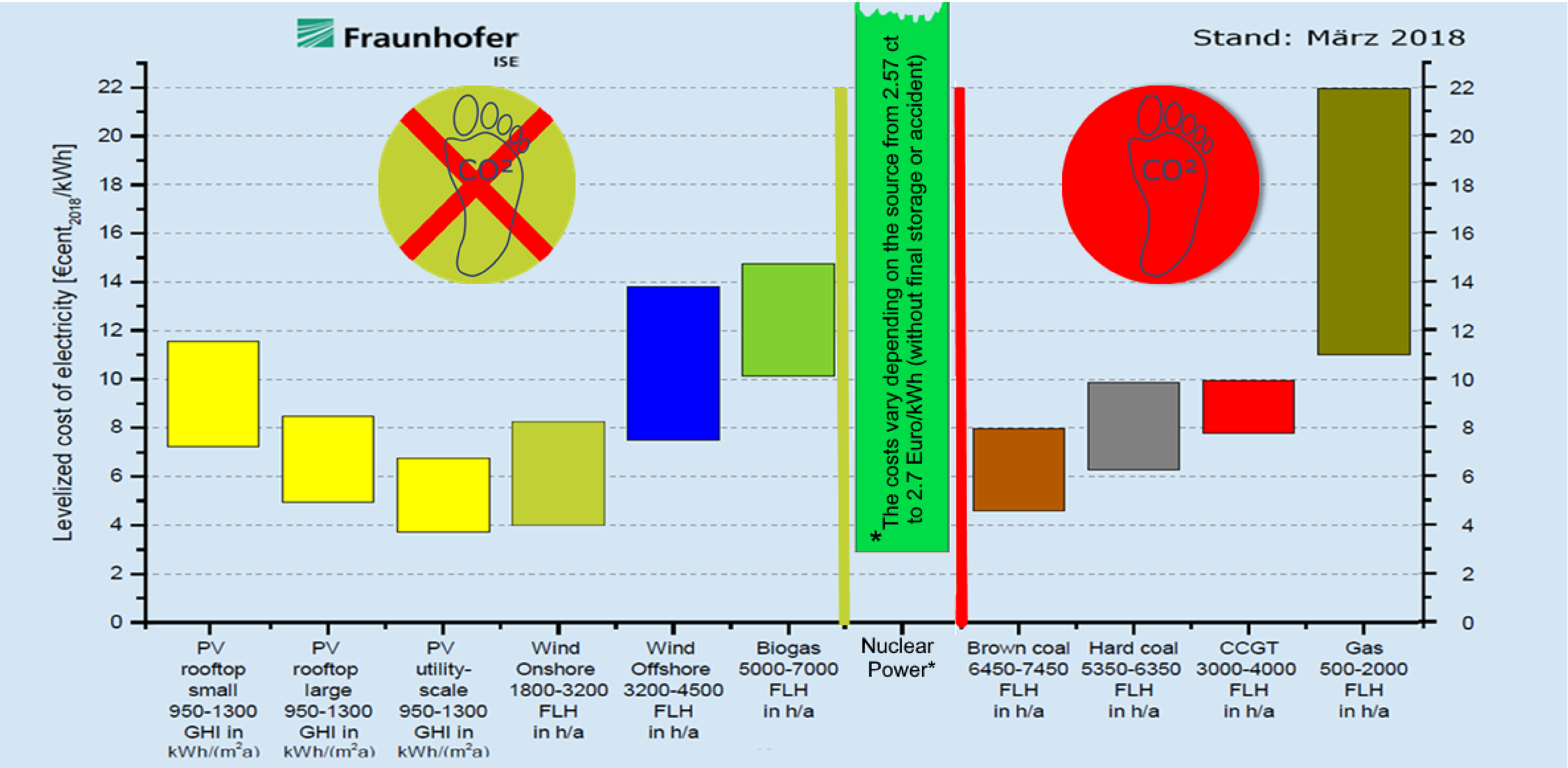


Sources: https://www.umweltbundesamt.de/themen/klima-energie/erneuerbare-energien/erneuerbare-energien-in-zahlen#statusquo (Anteile Erneuerbare Energie nach Sektor: Wind 42,1%; Wärme 14,5%, Mobilität 5,6%; Jahresbedarf Strom 601 TWh; Wärme 1.205 TWh; Mobilität 782 TWh; Gesamt 452 TWH Erneuerbare Energie)

If we are going to meet this
over 80% of our energy needs
with renewable sources,
we need competitive technology.

The current cost of electricity

Comparison of electricity production costs (LCOE EUR per KWh)

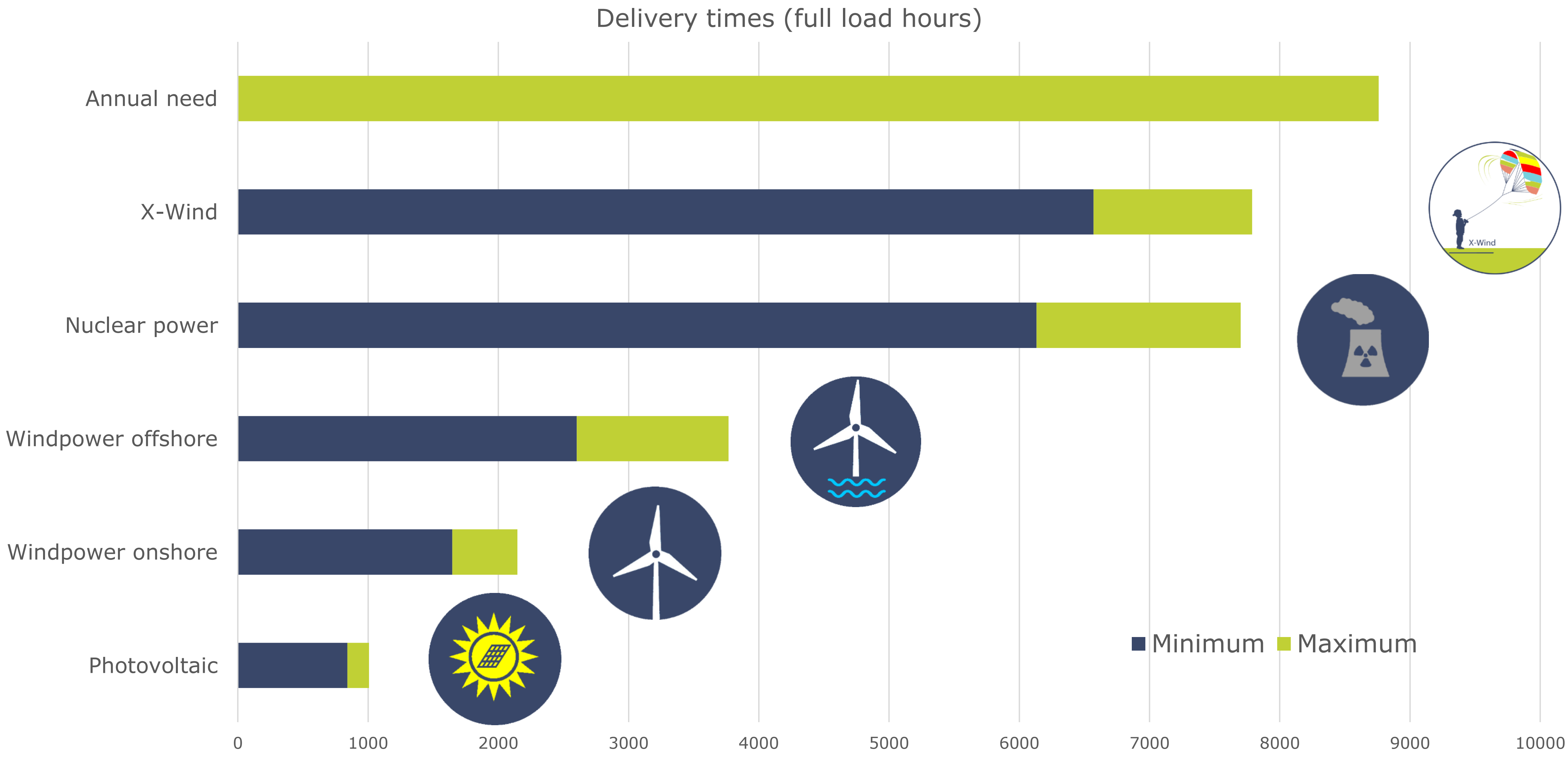


Source: Fraunhofer ISE – Studie März 2018,

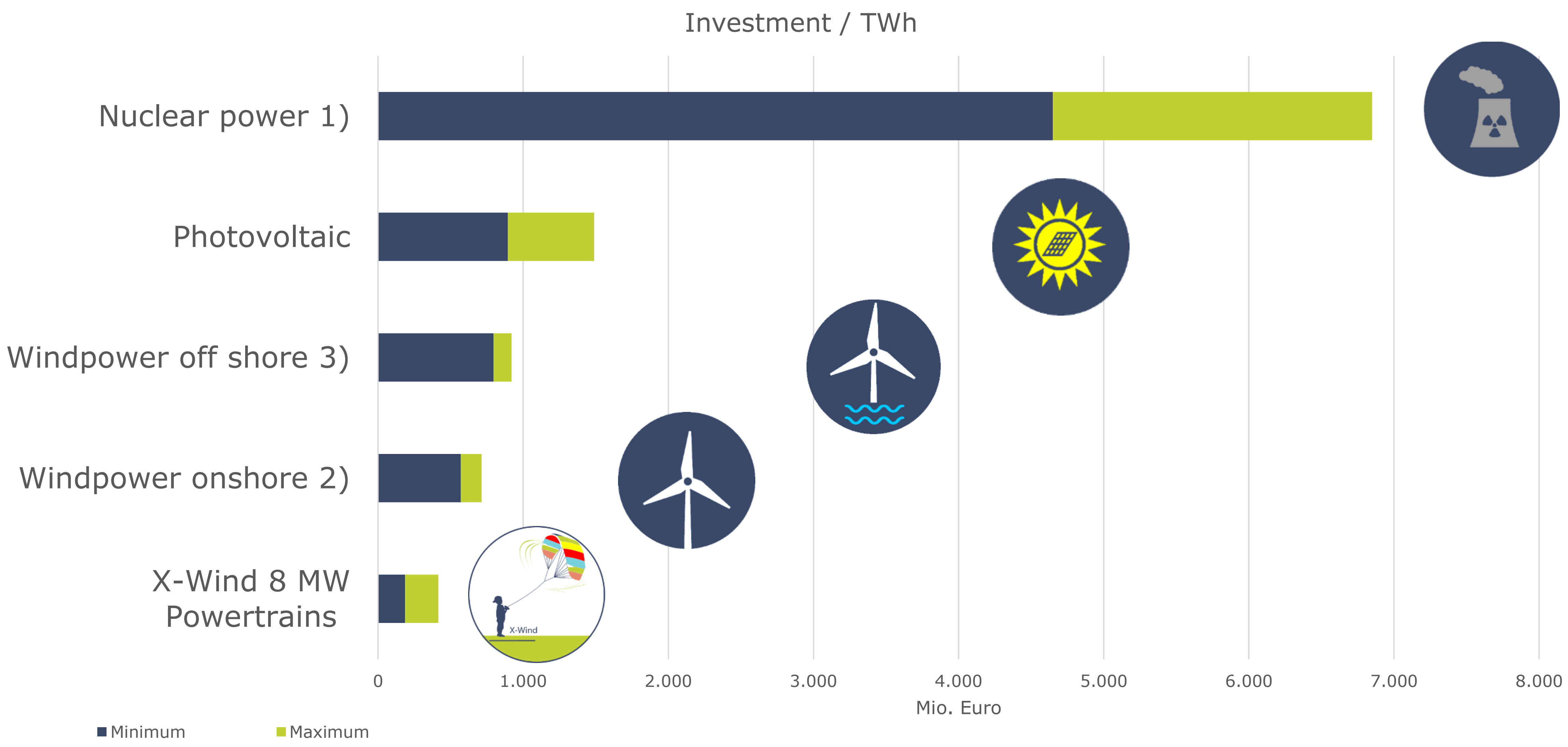
According to this diagram,
one might assume that cost-effective renewable energy sources already exist.
If we only build enough additional plants, we will become CO_2-free.

But it's not that simple. Unfortunately, the most economical renewable energy sources only provide electricity for a limited time of the year. That's why we need additional expensive storage!

Delivery times CO_2 free electricity production

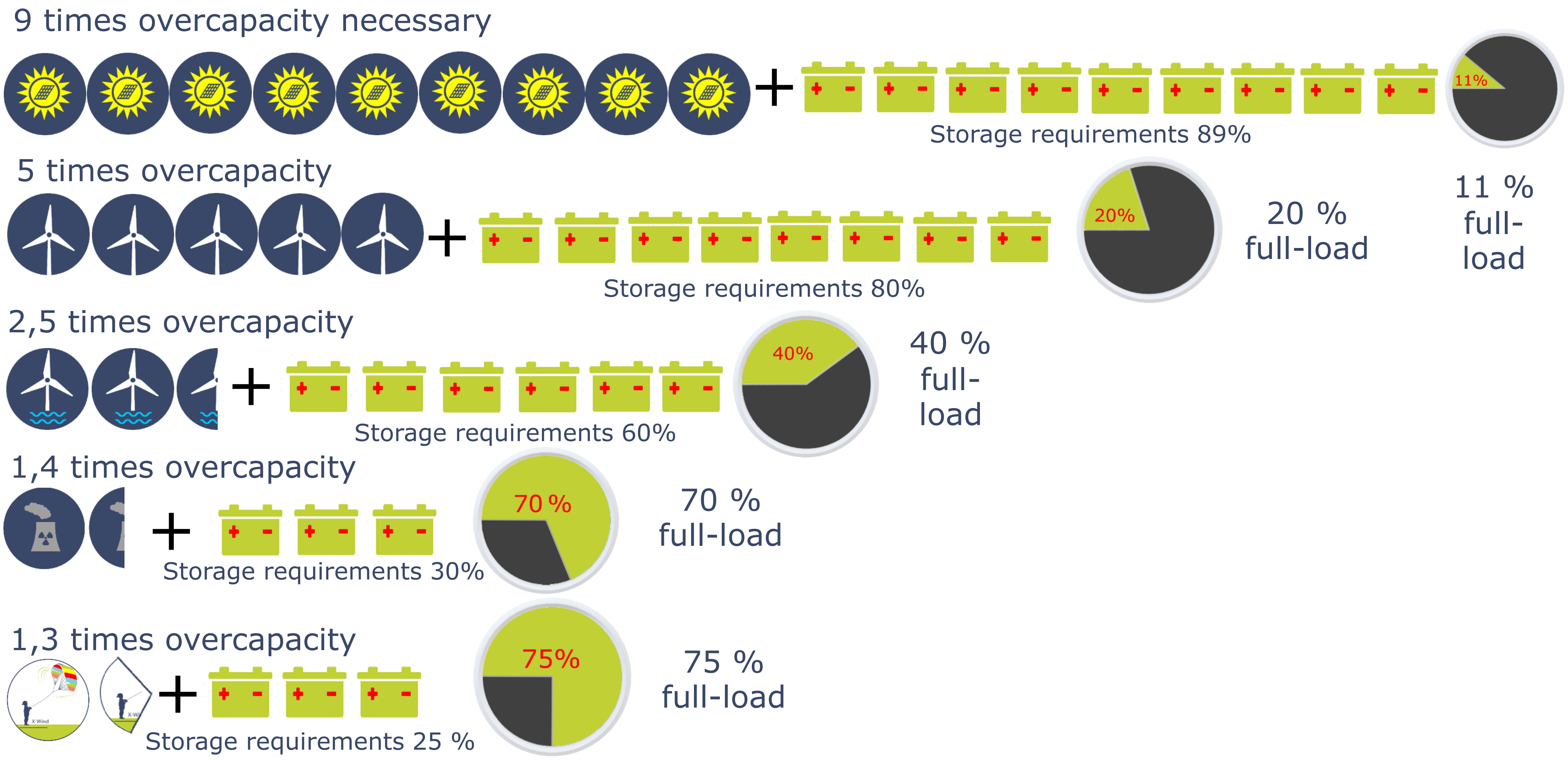


Comparison of investment costs



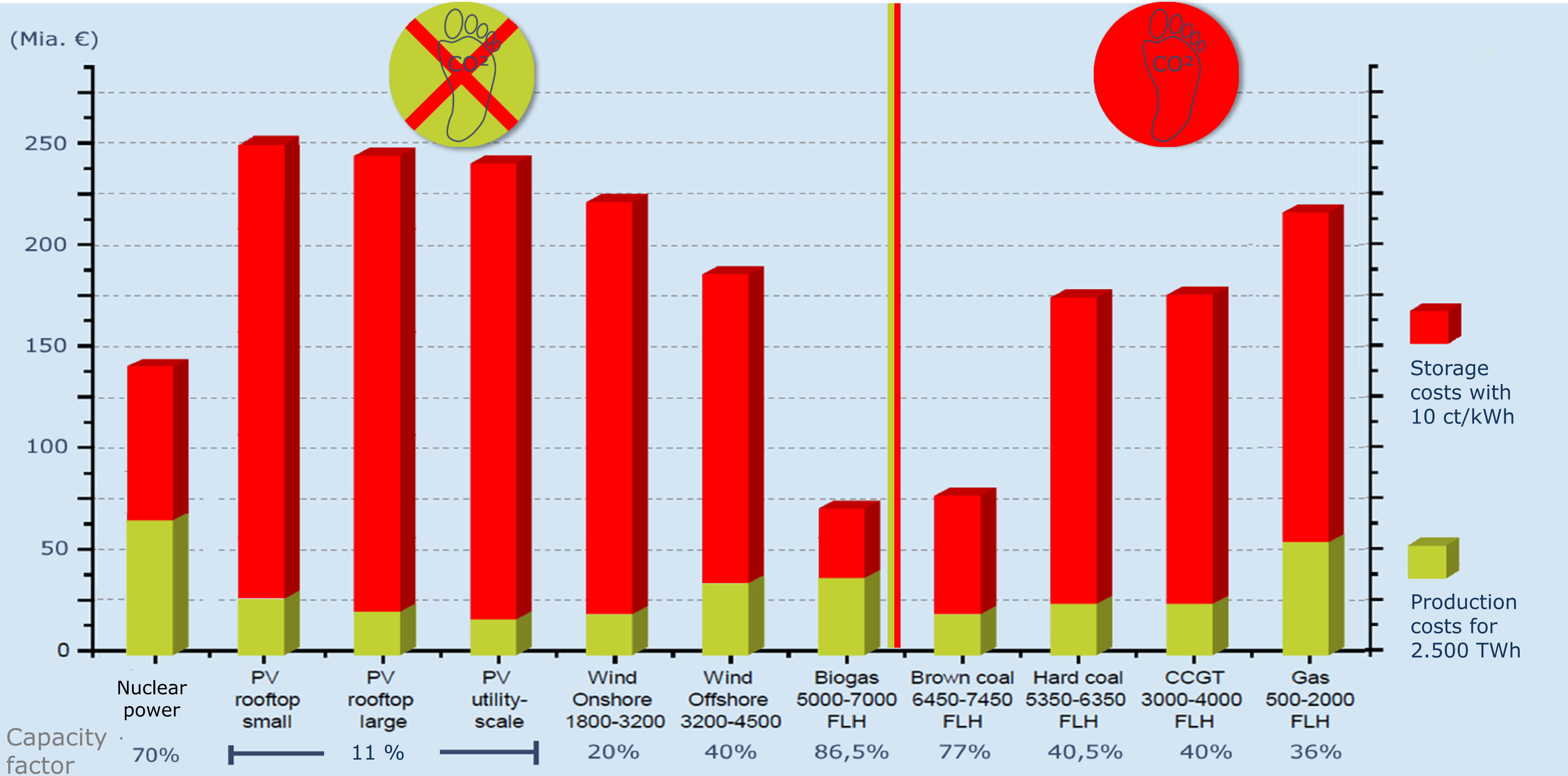
Source: 1) https://de.wikipedia.org/wiki/Kernkraftwerk, Range 4.650 to 6.850 €/kWh; 2) http://windmonitor.iee.fraunhofer.de/windmonitor_de/3_Onshore/5_betriebsergebnisse/3_investitionskosten/

Investment and storage technology requirements for 100% CO2-free electricity [1)]



1) Biogas production plants are not suitable for full supply due to the negative effects of monocultures and the high land requirements

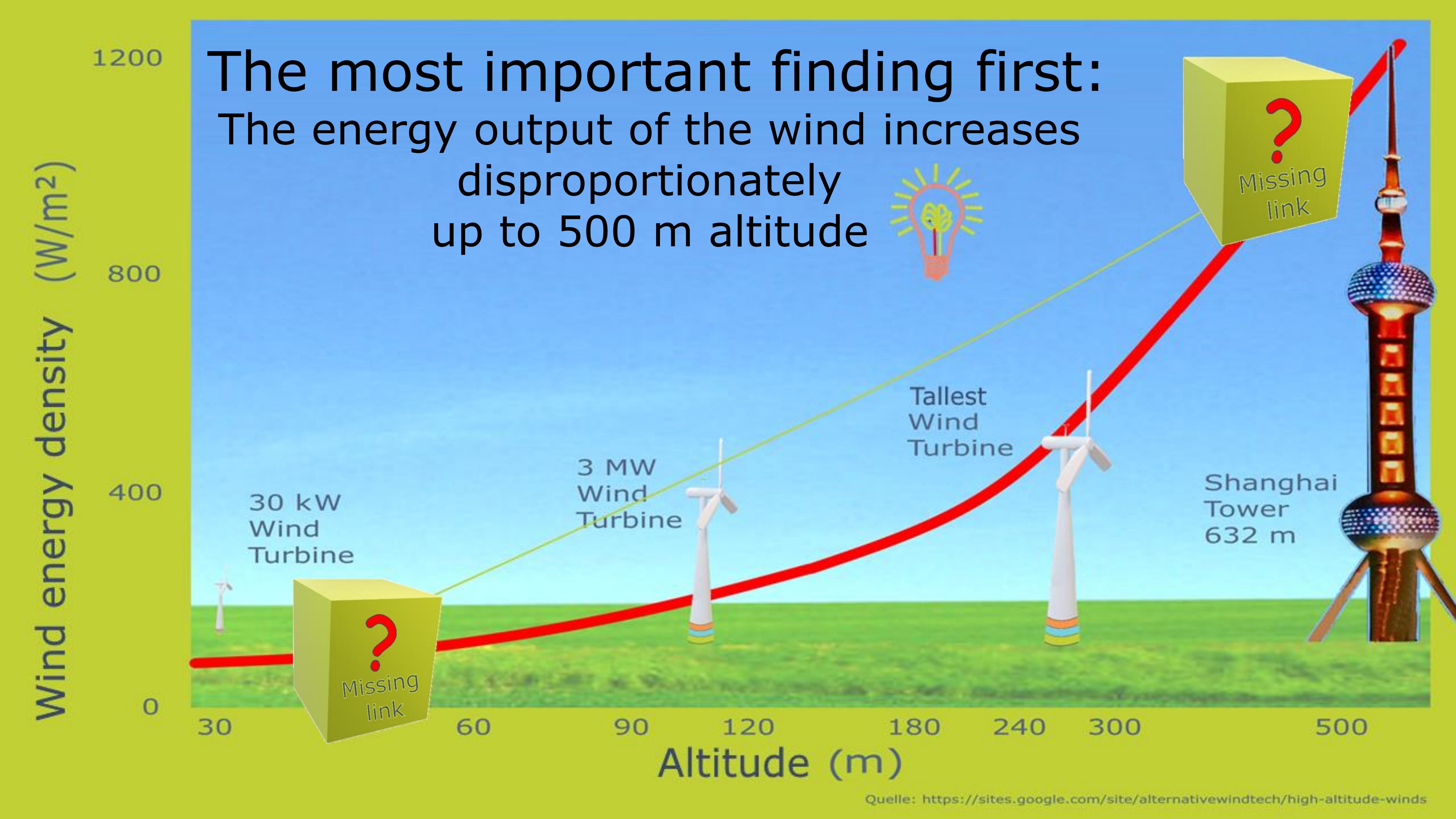
The problem: The cost driver for CO2-free energy supply are the storage costs



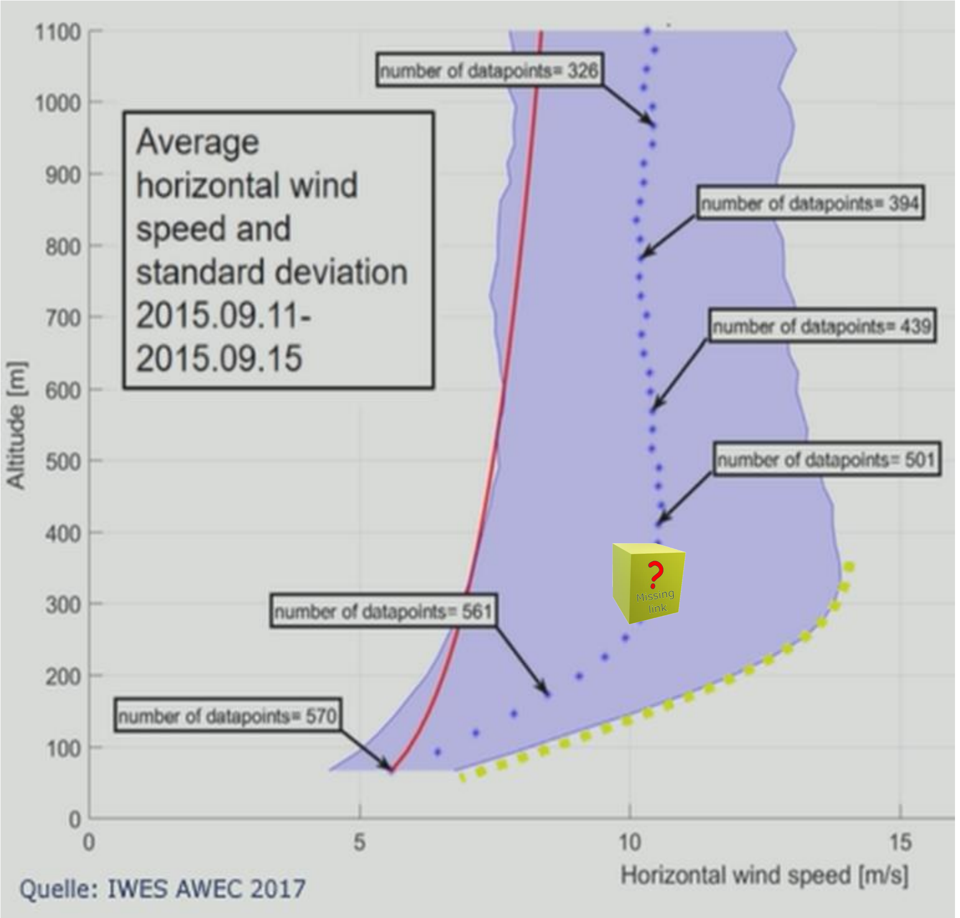
Quelle: https://de.wikipedia.org/wiki/Stromgestehungskosten

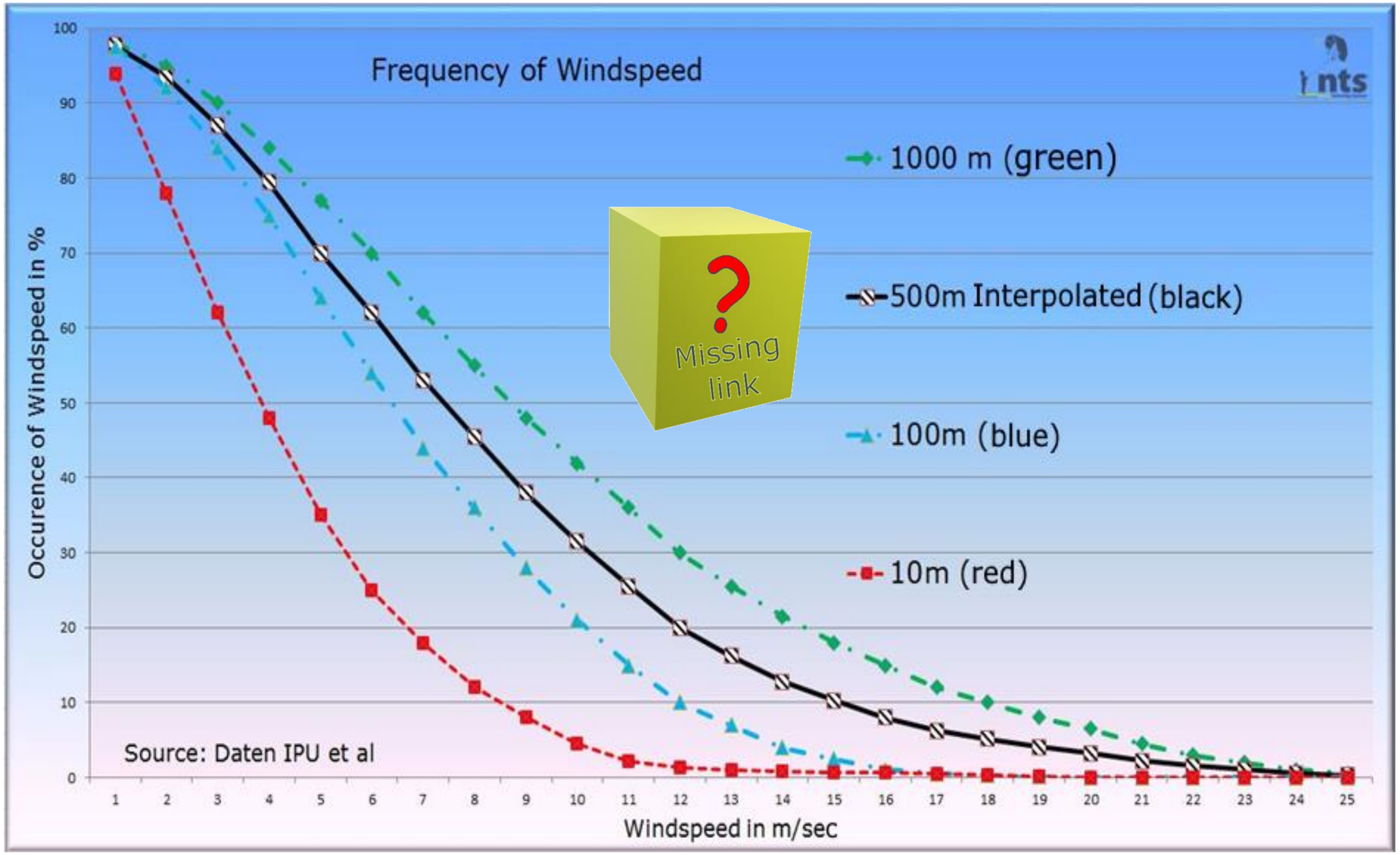
The physics of solutions

There is a gap in a green energy source that is competitive and produces enough full load hours


The most important finding first:
The energy output of the wind increases
disproportionately
up to 500 m altitude
Wind energy density (W/m²)
1200
800
400
0
Missing link
30 kW
Wind
Turbine
3 MW
Wind
Turbine
Tallest
Wind
Turbine
Shanghai
Tower
632 m
Missing
link
30
60
90
120
180
240
300
500
Altitude (m)
Quelle: https://sites.google.com/site/alternativewindtech/high-altitude-winds

Another advantage of altitude. The wind is not only 2 to 3 times stronger, but also blows much more frequently

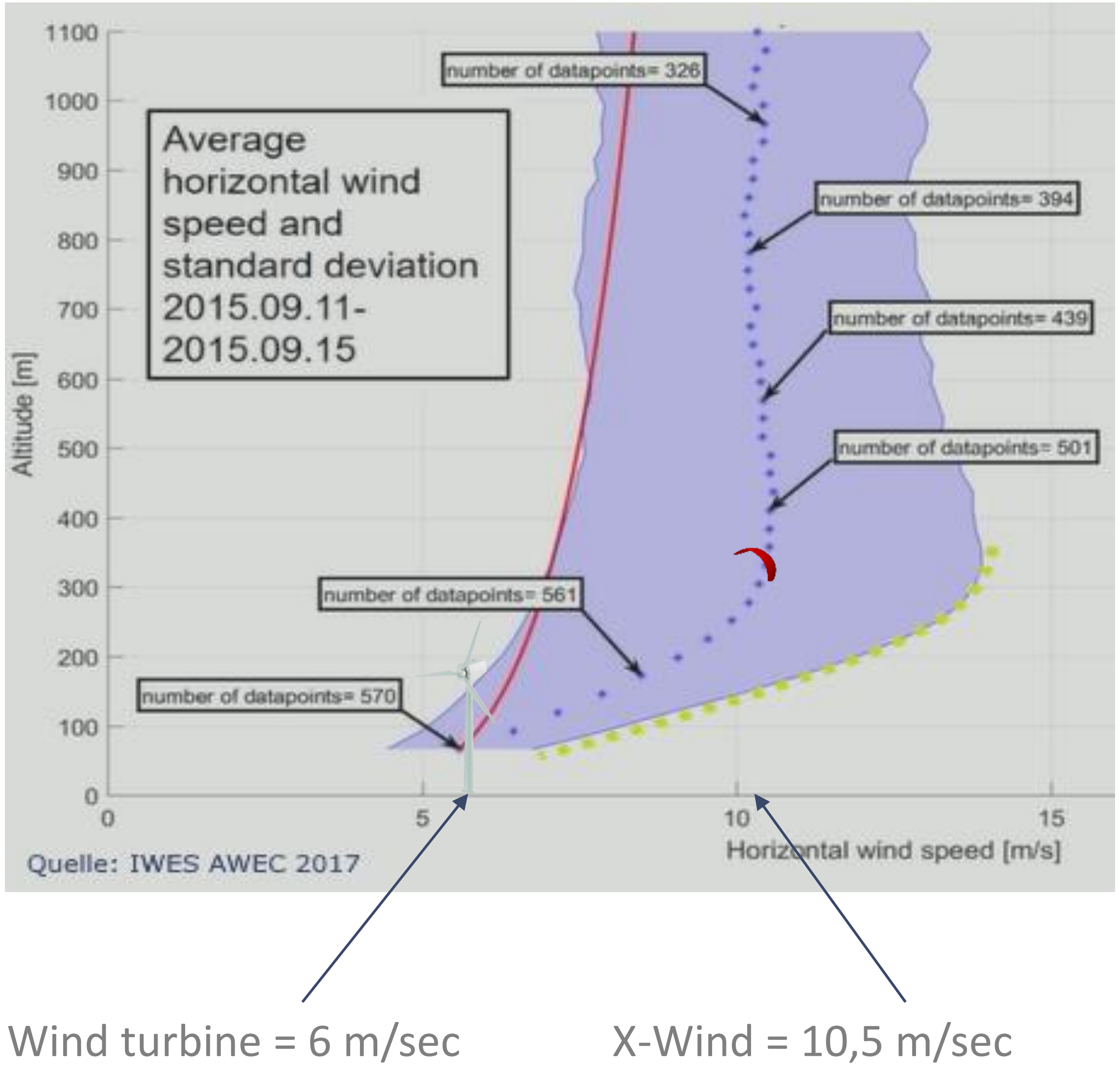




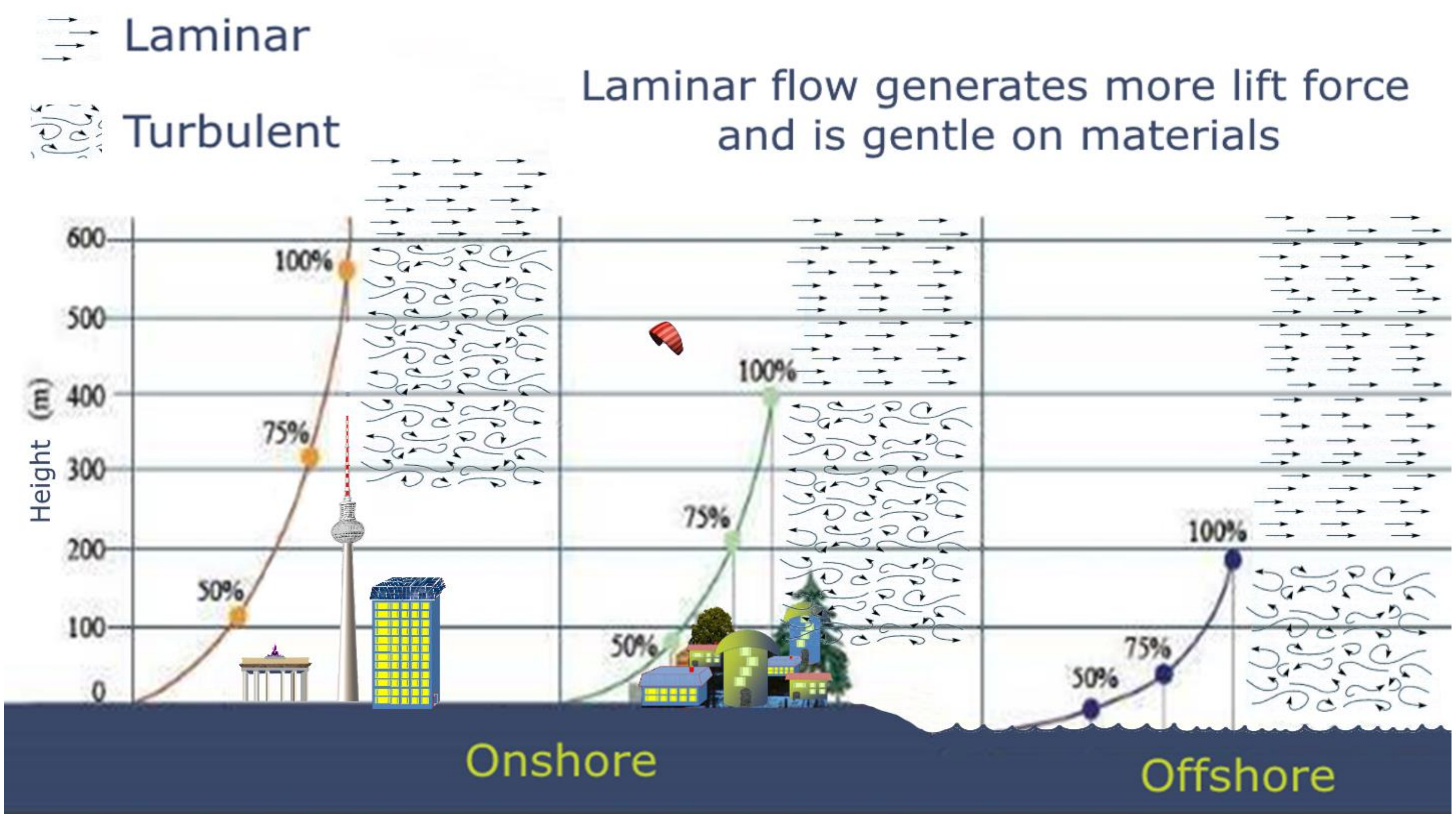
The average wind speed (Wv) at altitudes between 300 and 500 m is 10.8 m/sec. Modern conventional wind power operates at an average height of 143 m (average Wv = 7.4). Energy production ratio to height wind is consequently:
10.8*10.8*10.8 / 7.4*7.4*7.4 = 1260 / 405 > 3. Due to the altitude difference, factor 3 in energy harvesting.

Higher winds are better, stronger and more consistent

- Wind farms can hardly go much higher, because of their need for an expensive tower
- X-Wind reaches up to 500m, with its Dyneema ropes
- 75% more wind speed > 500% more energy (cubic increase of energy 6*6*6=216; 10,5*10,5*10,5=1158; factor > 5)

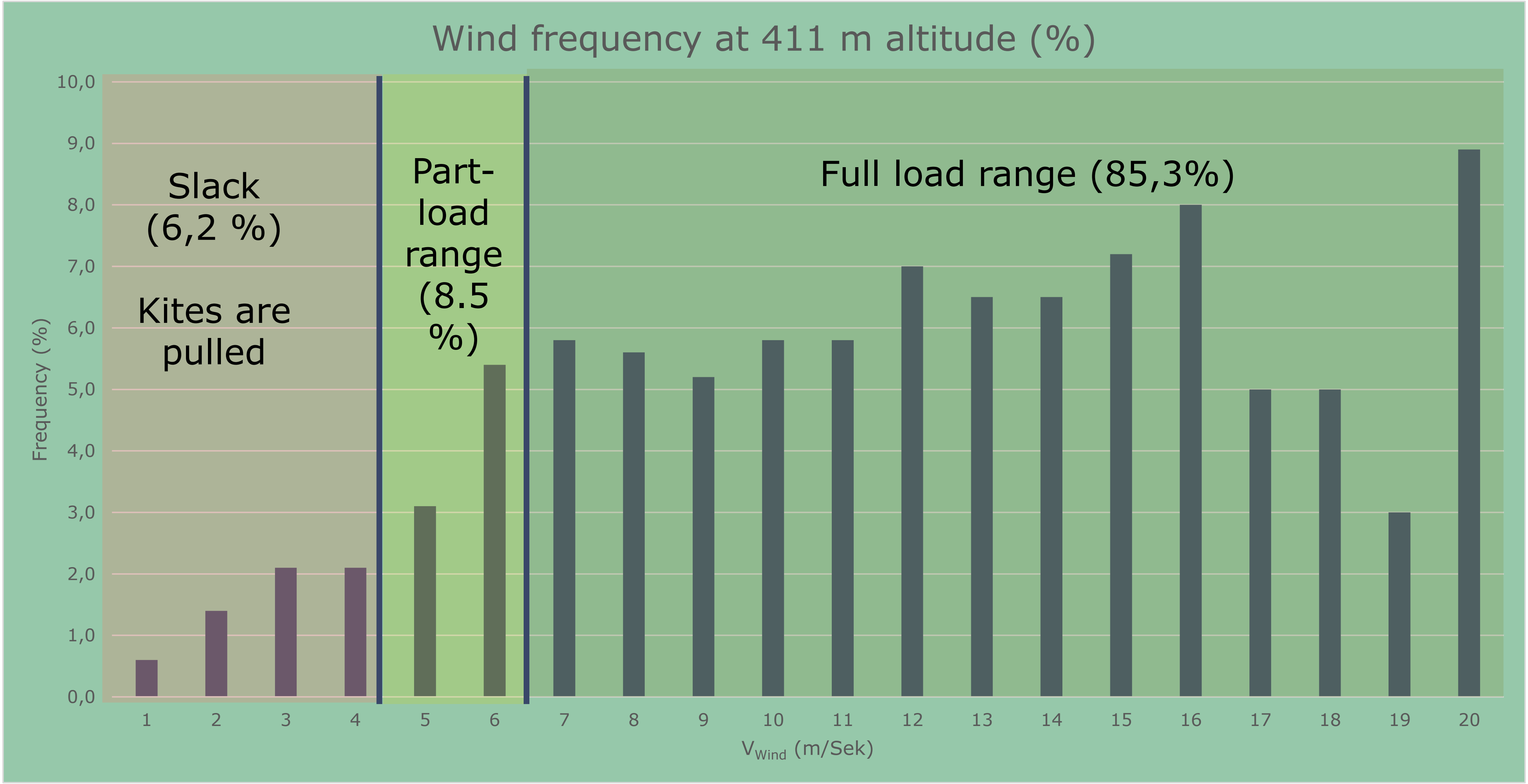


Wind quality also increases with altitude



Note: In order to be able to operate completely in the laminar flow range, conventional wind turbines would have to have hub heights of 500 to 700 m in the onshore area. In the off shore area, this would still be 300 m for 8 MW turbines. With the ultra-light ropes, high-altitude wind turbines can always harvest at the optimum height.

The X-Wind data for capacity factor calculation



Source: Fraunhofer IWES AWEC 2017, 30 years average

Note: Taking into account the yield from the partial load range, the full load range is 89%.
For risk minimization, 75% capacity factor is calculated!

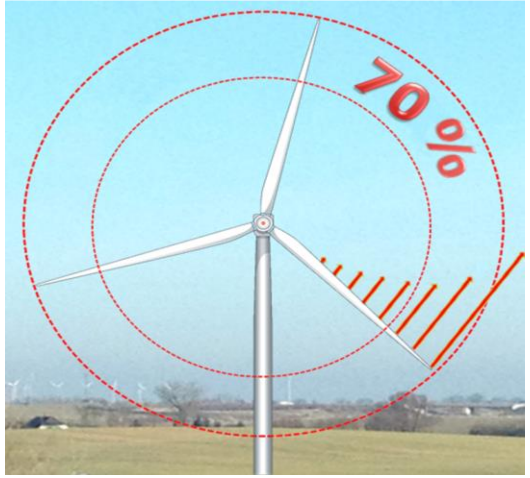
How to harvest the energy at altitude?

Of course, we could build the towers of the wind turbines even higher. But unfortunately, they are already at their strength or economic limit.

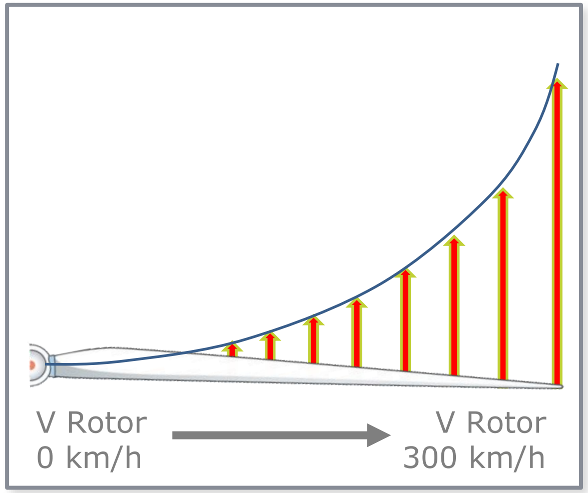
Harvesting is easier with a flying device

AWE Airborne Wind Energy: simple physics and dispensing the unnecessary

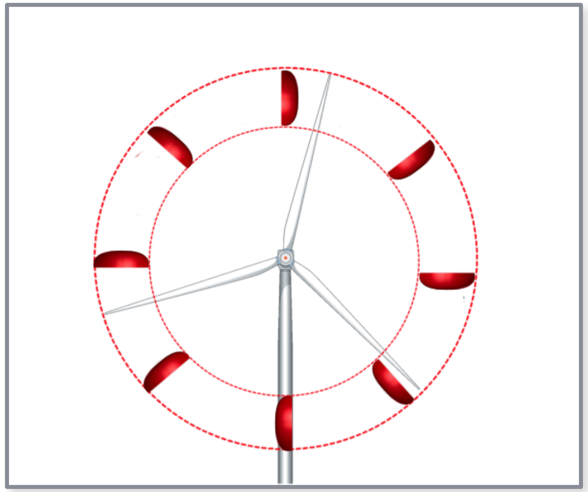
The torque for power generation comes mainly from the blade tips



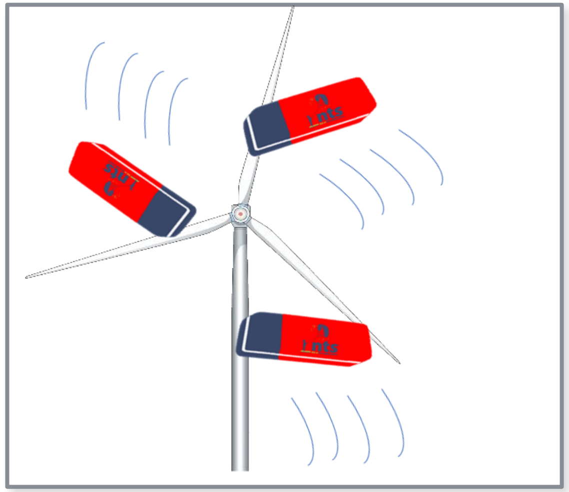
The lift force distribution on the rotor blade of a wind turbine



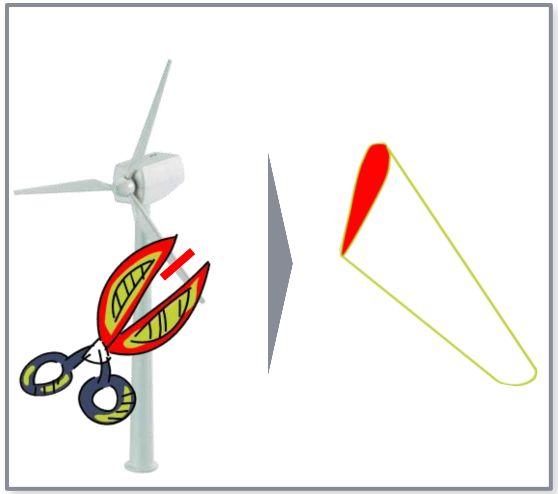
Consequently: The blade tips essentially provide the energy



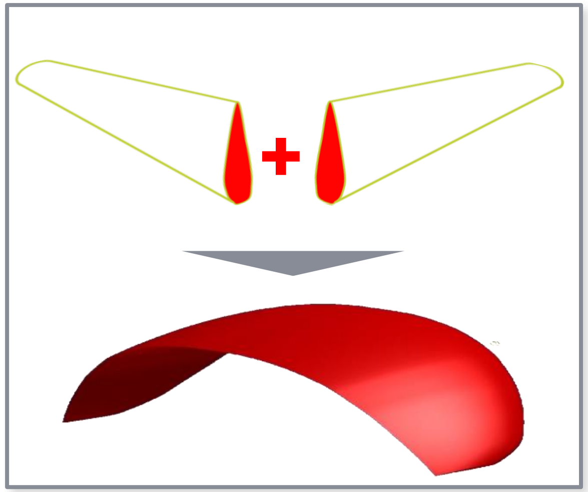
Required are only the blade tips and the generator



Cut through the rotor blade of a wind turbine

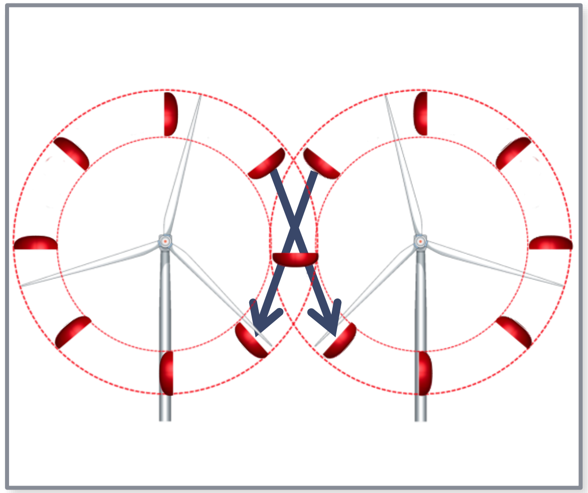


Two blade tips form a flying wing or kite



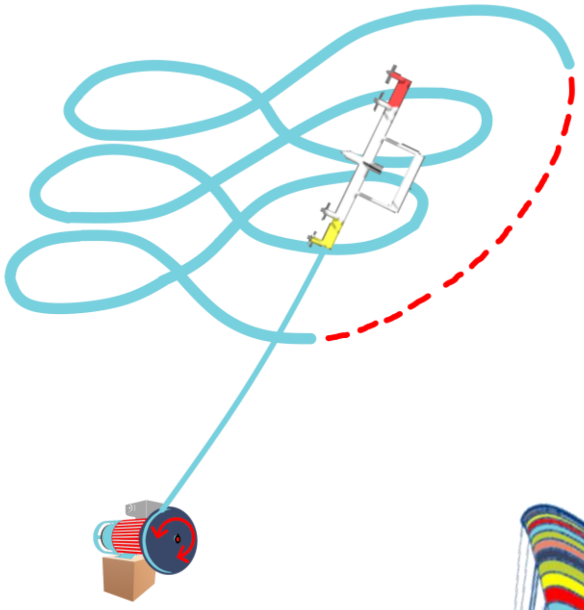
Optimal kite flight path is a lying 8

The lying 8 corresponds to the blade tip movement of two wind turbines

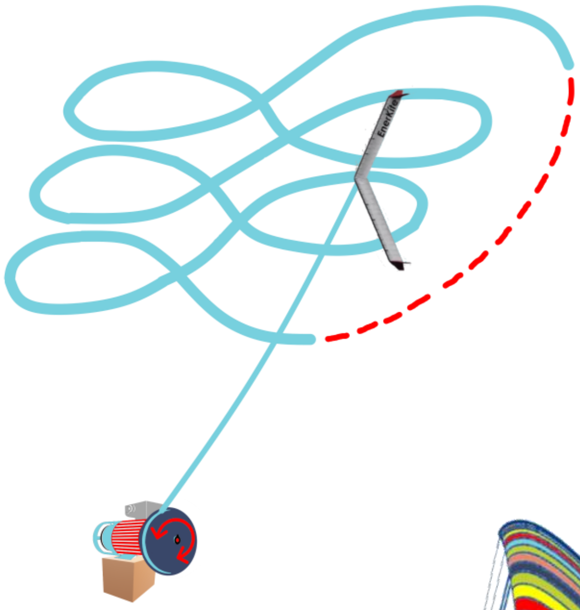


AWE = Airborne Wind Energy

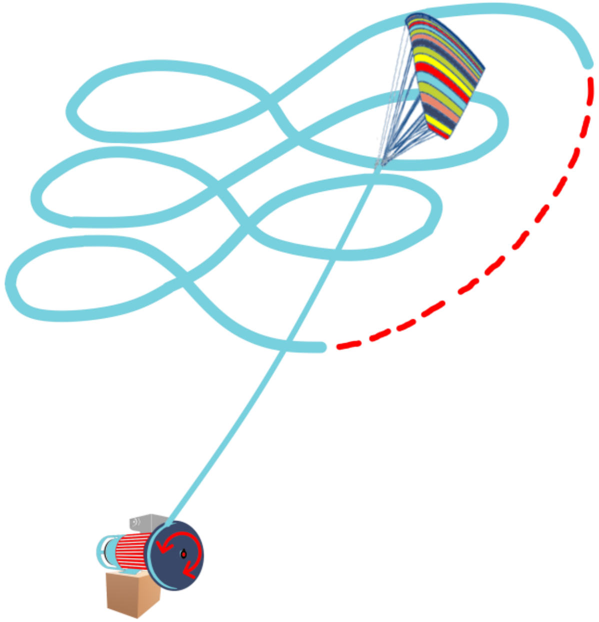
What are the German approaches to harvesting?



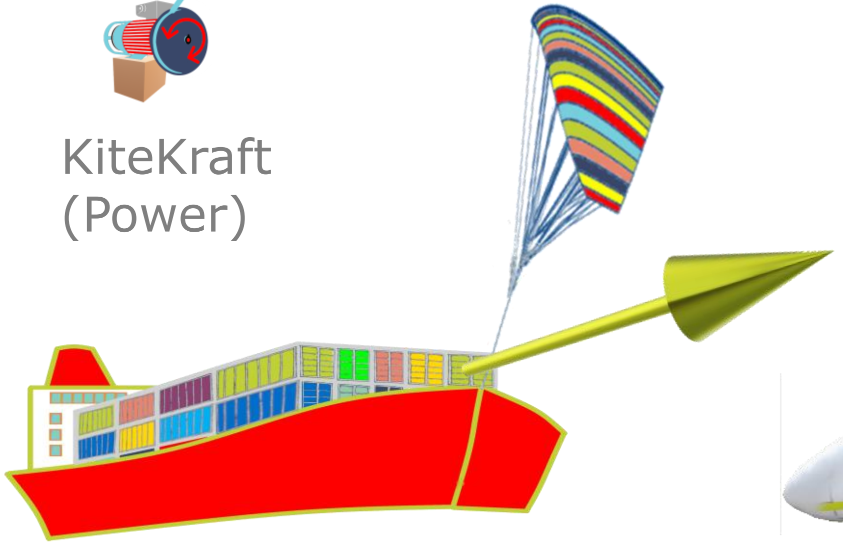
KiteKraft
(Power)



Enerkite
(Power)



Skysails Power
(Power)

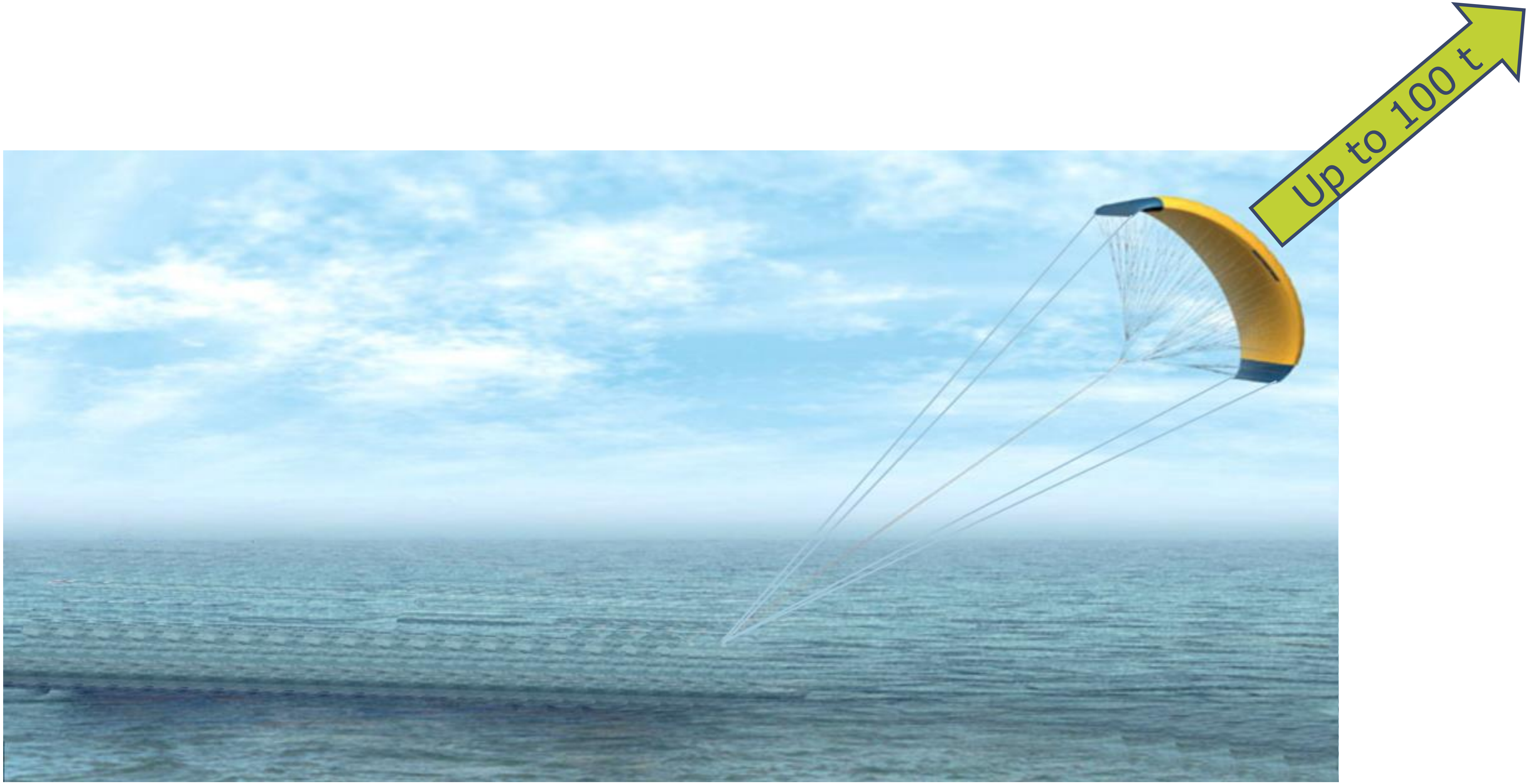


Skysails Marine
(Kinetic Energy)

X-Wind Powerplants
(Power)

The power of the kites is already used professionally

Source: Airseas


Up to 100 t


Up to 100 t

The X-Wind solution

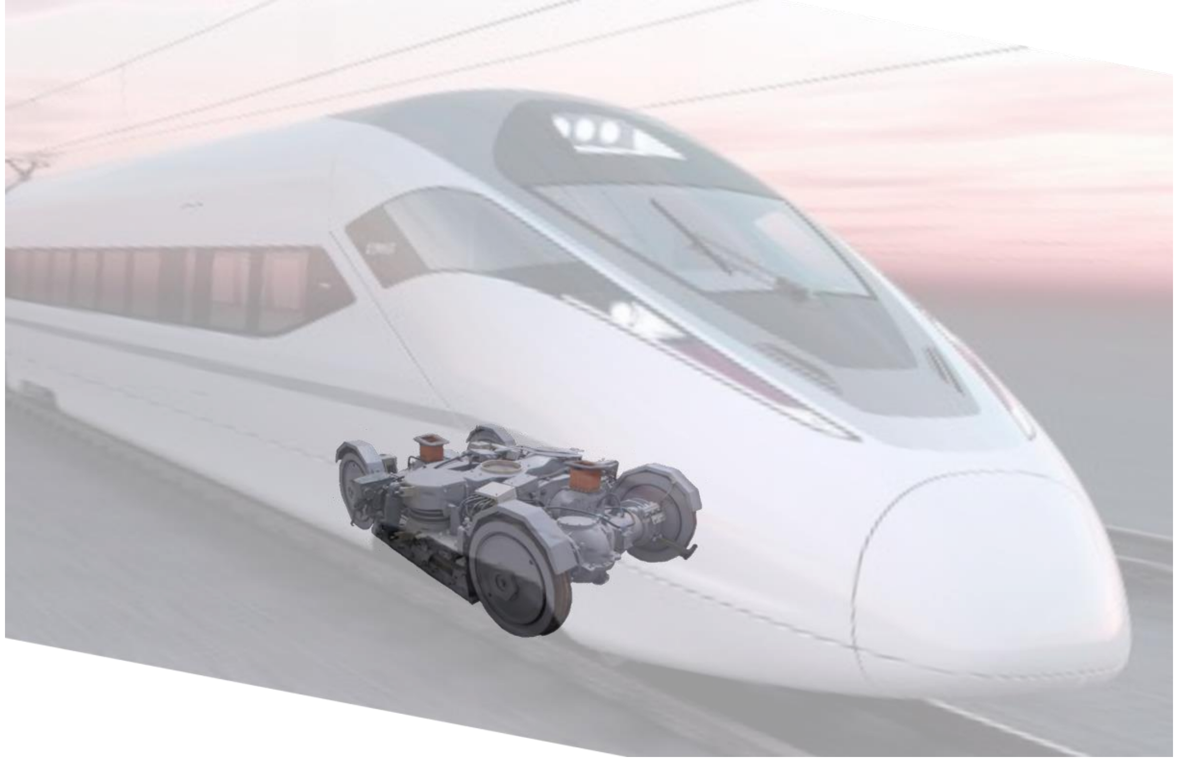
We assemble two proven technologies

Kites are already used to pull ships

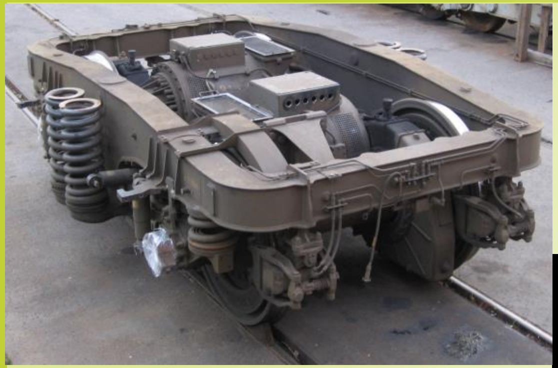
+

Generators from standard train bogies produce electricity by braking

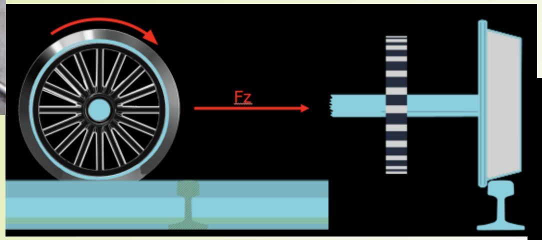
Source: Airseas



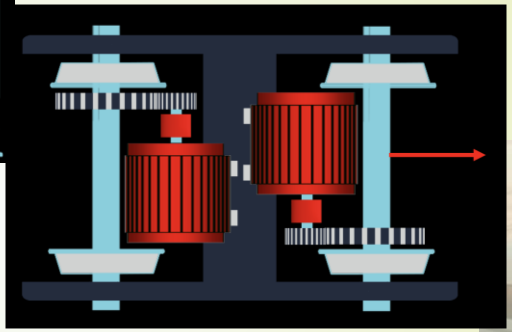
X-Wind Technologie – Stromerzeugung und Netzeinspeisung



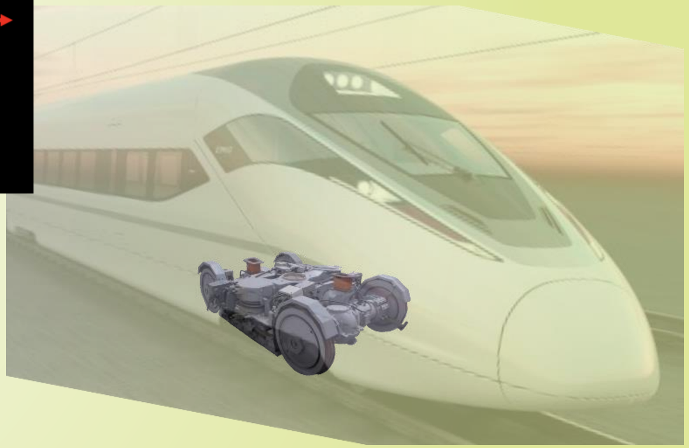
X-Wind uses conventional motor bogies for its powerunits



When motor bogies are pulled, the tractive force is converted into torque

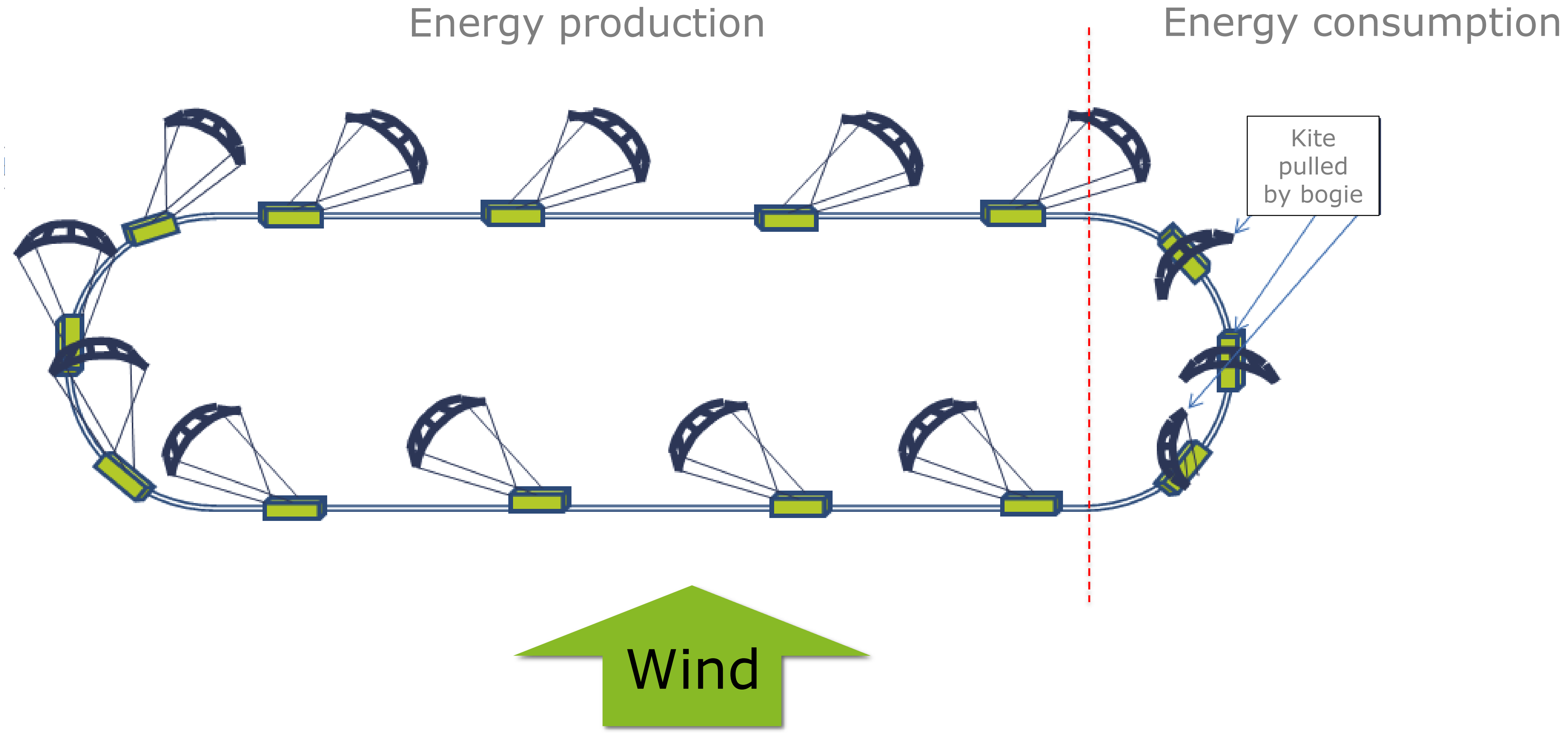


The torque is converted into electricity.



The electricity is fed into the grid via conductor rails

Kites circle on a closed track, like vessels on the sea



Fully automated departure –
and landing with standard hydraulic crane

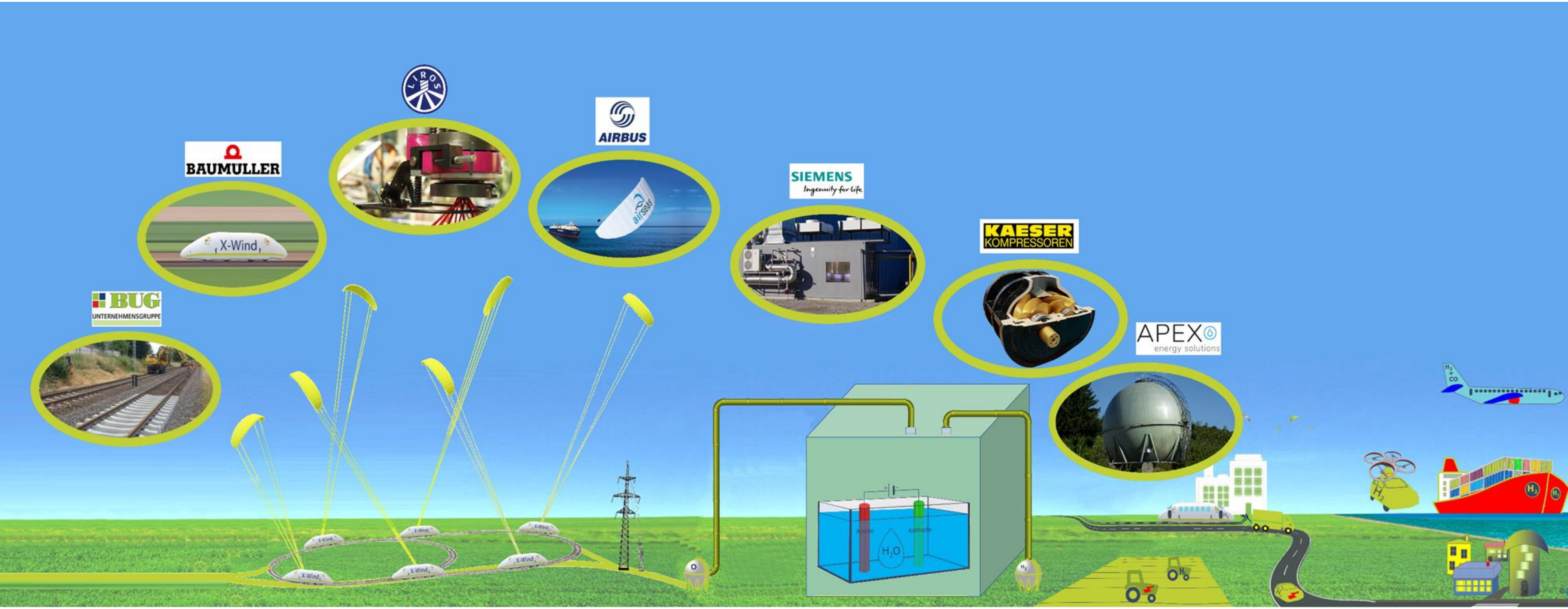
Departure position

Inflation

Departure

Machinery and equipment of a power plant based on X-Wind technology for green hydrogen

X-Wind is our invention and patented worldwide - we are a system integrator of proven technologies



Switches, conductor rails, tracks and network integration

Control system, generator, take-off and landing unit

Balance line material, control and hauling ropes

Energy-kite and bridle lines

Electrolyzer

Compressor

Hydrogen-storage and logistics

Consumers

The economic aspects

- Energy balance
- Material balance
- Power potential
- Emissions
- Landscape change
- Energy production costs
- Full load hours
- Storage potential
- Investment costs
- Operating costs
- Deconstruction costs
- Climate impact costs

The legal aspects

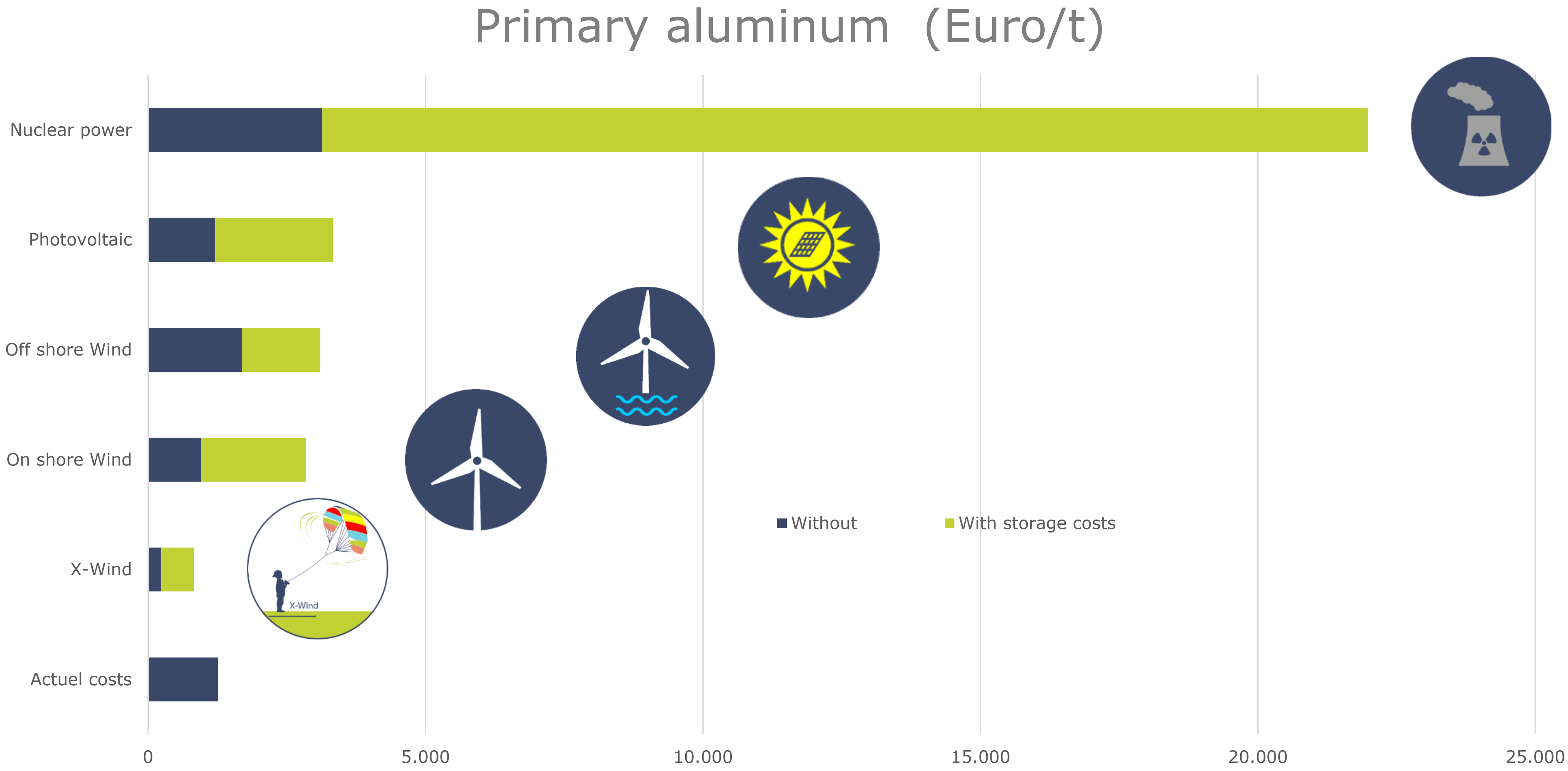
- Necessary permits
  - Aeronautical aspects (no-fly zone / aeronautical obstruction)
  - Distance regulations
  - Noise emissions
  - Shading aspects (stroboscopic effect / shading)
  - Property requirements
  - Afifaunistic expertise
  - Recycling requirements
  - Deconstruction obligation

The social aspects

- Landscape disturbance
- Noise emissions
- Shading aspects (stroboscopic effect / shading)
- Land consumption
- Airspace impairment
- Endangerment of flora and fauna
- Material consumption and reusability
- Need for deconstruction
- Impact on electricity bill

Energy costs for 1 t primary aluminum (Euro)

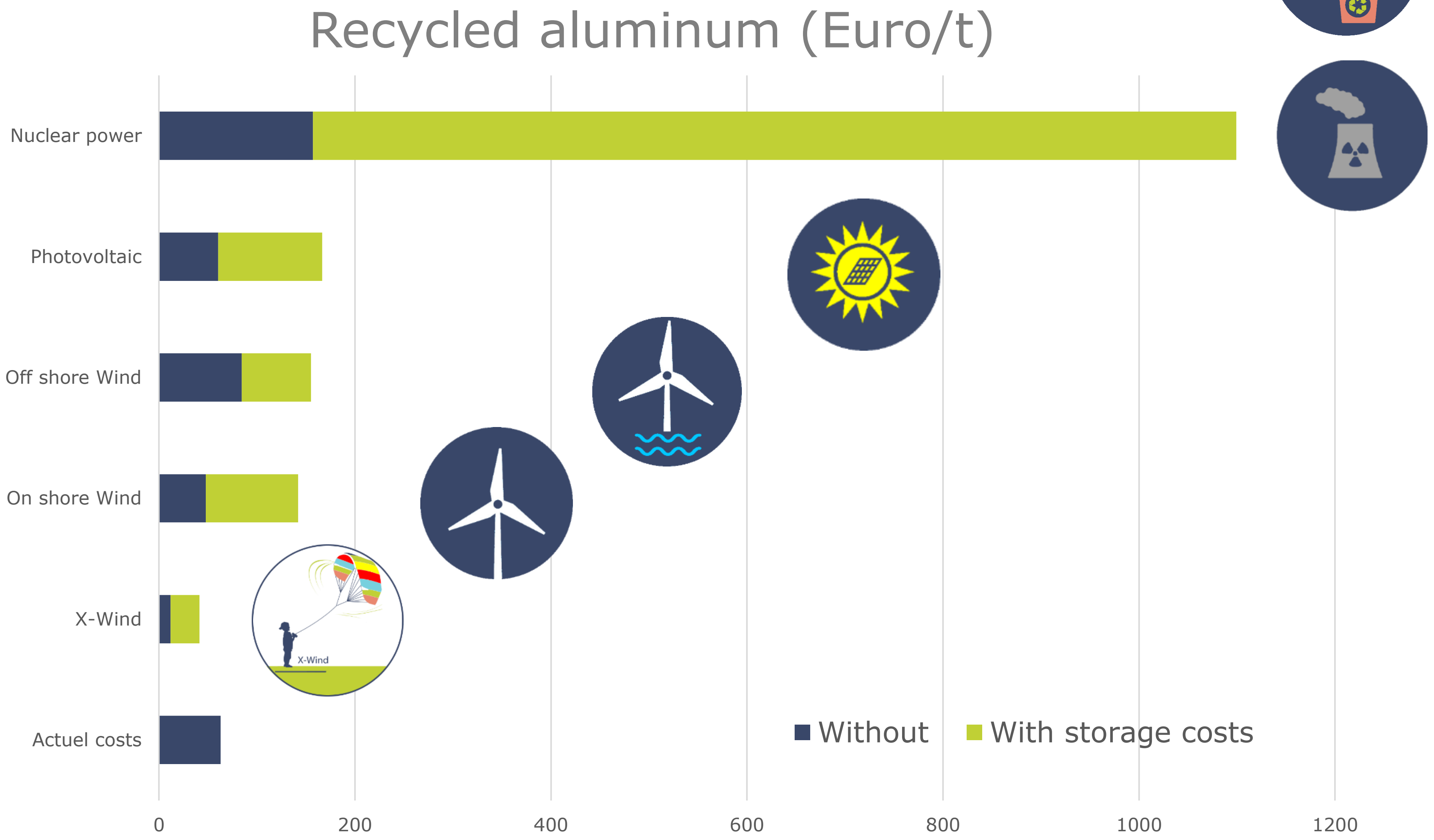
Actual costs
1.250 Euro/t*



* https://de.wikipedia.org/wiki/Aluminiumh%C3%BCtte (15,7 MWh/t; actual costs 8 ct/kWh costs for nuclear power 20 ct/kWh)

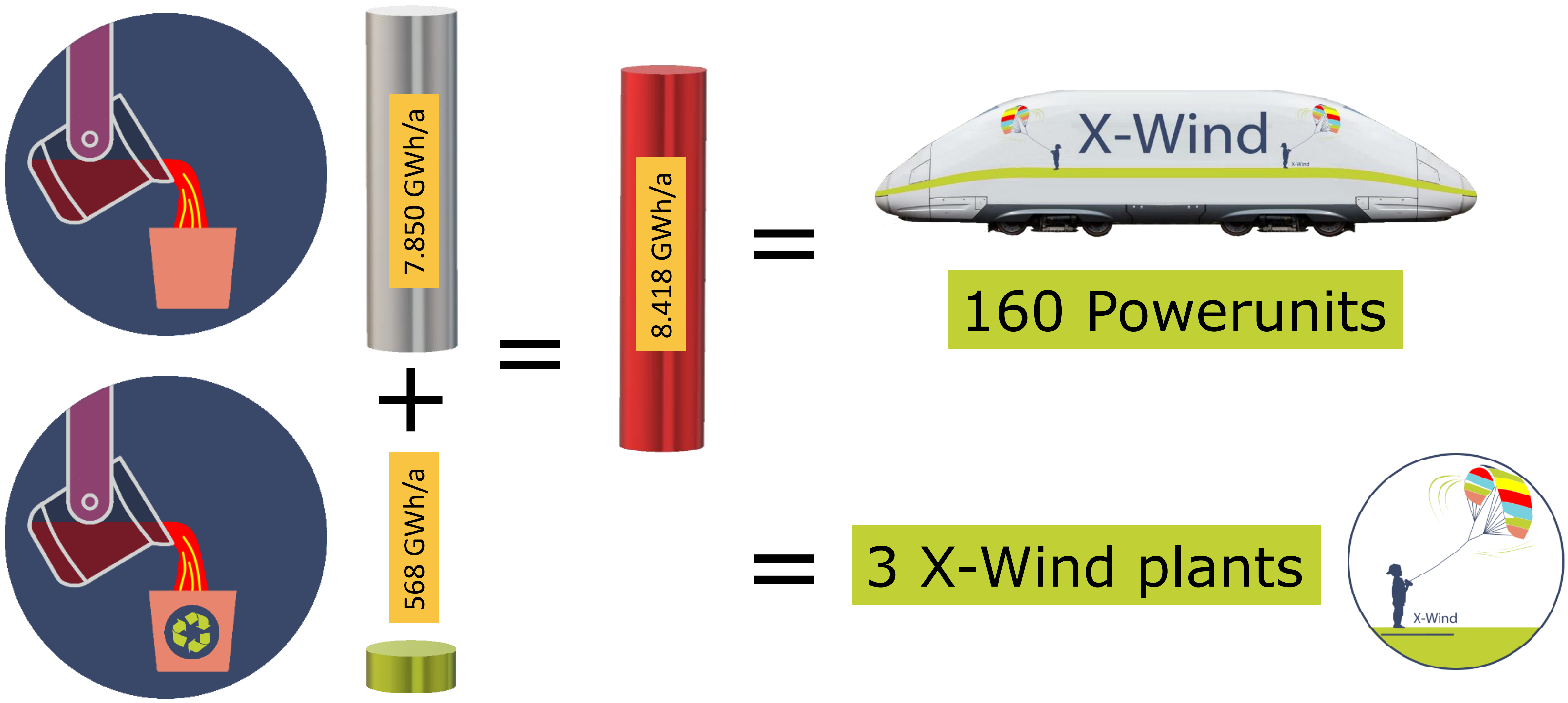
Energy costs for 1 t recycled aluminum (Euro)

Actual costs
63 Euro/t*



* https://de.wikipedia.org/wiki/Aluminiumrecycling: Aluminum recycling requires only 5% of the energy used in primary production. (785 kWh/t)

Annual need aluminum industry germany

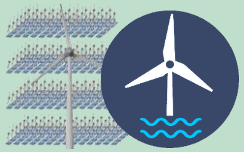
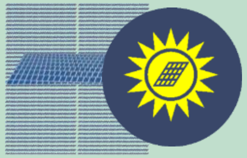


Germany produces approx. 500,000 tons of aluminum. The production of one ton of primary aluminum requires an average of 15,700 kWh of electrical energy.Germany produced approx. 723,000 tons of recycled aluminum in 2016. The production of one ton of primary aluminum requires an average of 785 kWh of electrical energy. Alternatv 600 on shore Wind power plants with 8 MW each.

And another important advantage:
The controllability

- < 15 seconds for idle
- < 15 seconds to cull energy from grid by roughly
  50% of the installed capacity
- < 15 seconds to full power production
- No production interruption in case of service or maintenance of the Power units
- Continuous adjustable between -50% and 120% of installed capacity
- Kite size change < 20 Minutes

Market – Performance of Technologies in Germany

	• 1 nuclear powerplant • 9 TWh	• 4 X-Wind powerplants • each 43 powerunits • 8MW generators • 75% capacity factor	• 316 wind turbines • offshore • 8MW generators • 40% capacity factor	• 1797 pv parks • 5MWp • 10% capacity factor
	 ≈	 ≈	 ≈	
installed power	1.167 MW	1.367 MW	2.530 MW	8.560 MWp
generated energy	8.985 GWh	8.985 GWh	8.985 GWh	8.985 GWh
full-load hours	7.700 h	6.570 h	3.550 h	1.010 h
space requirement	1.59 km²	3.52 km²	50 km²	395 km²
invest w/o space	> 40 Mrd EUR	> 1.75 Mrd EUR	> 7 Mrd EUR	> 10 Mrd EUR

X-Wind is a game changer technology!

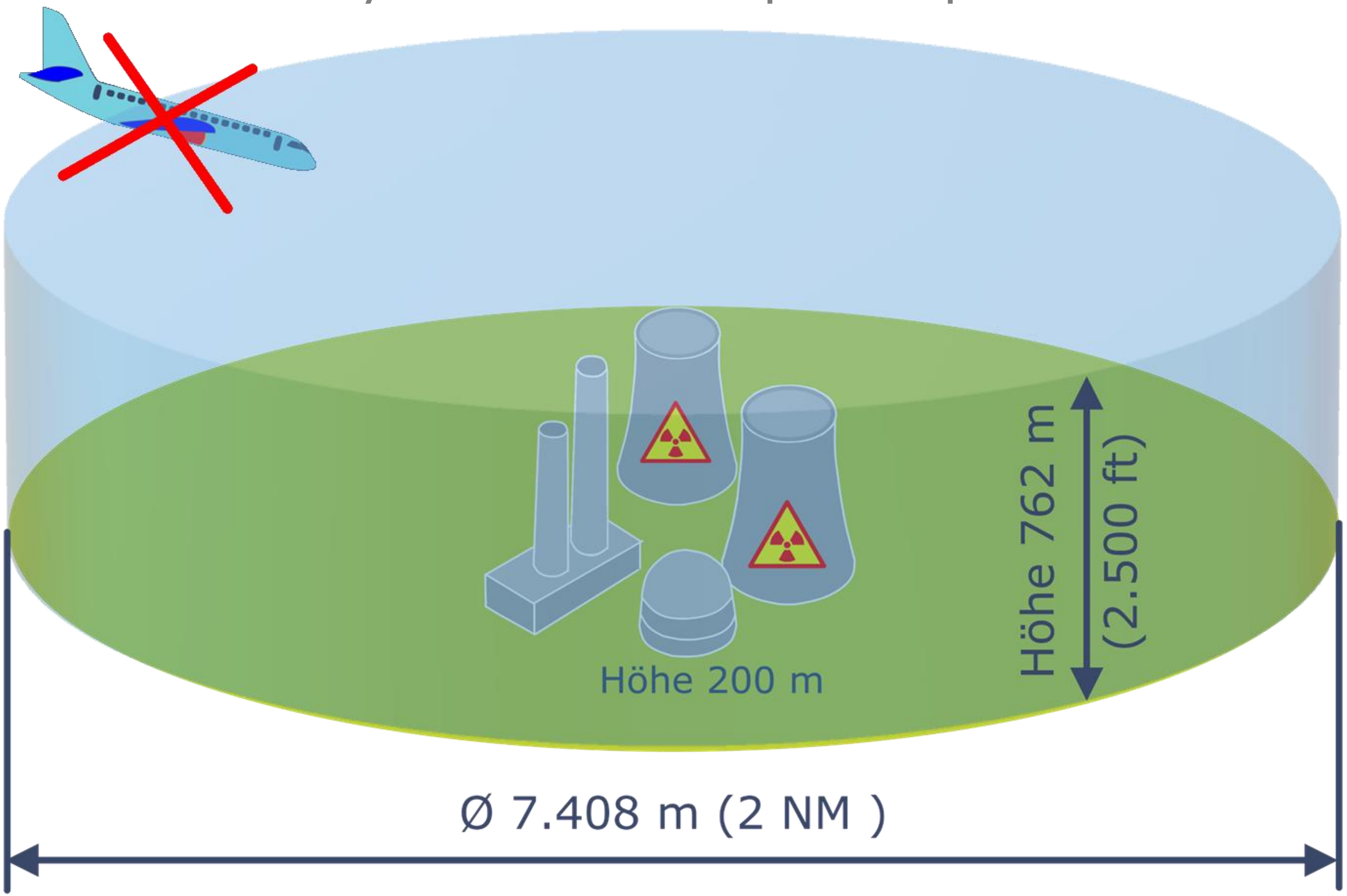
- generated energy in the table applicable for 1.3 mio single-person households

projection on Germany

- area size: 357.386 km²
- population: 83 mio
- total energy consumption: 513 TWh with 50% covered by renewable sources
- 95 X-Wind powerplants would cover the remaining part fully with renewable energy
- 760 additional X-Wind powerplants needed to cover heat and mobility consumption of 2.000 TWh
- according space needed would sum up to net 750 km² = 0.2 $^0/_0$ Germany‘s total area

(The 7,700 full load hours of the nuclear power plants are taken from the literature. Calculations of actual full load hours over more than 10 years show a realistic value of 70%).

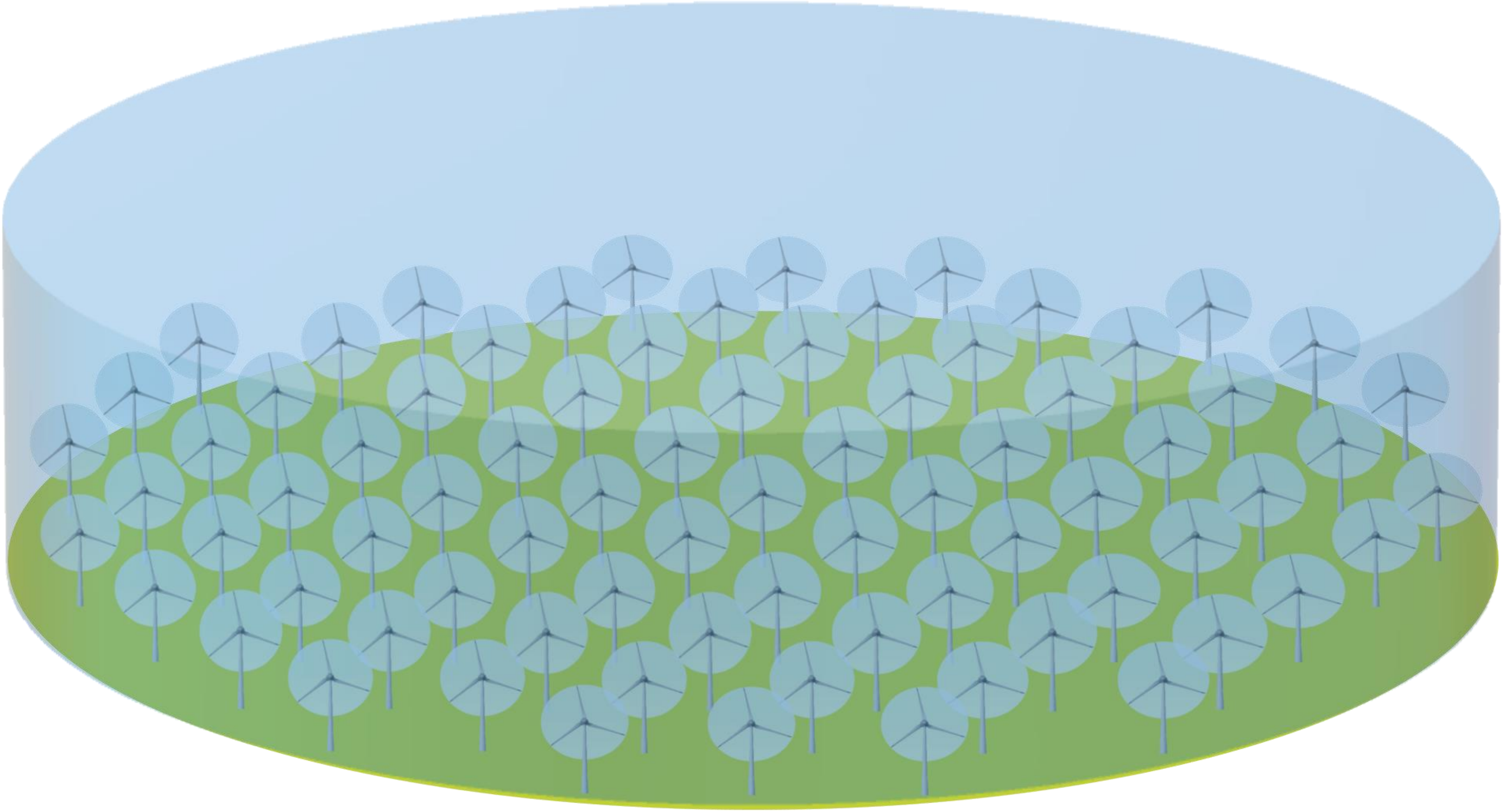
No fly zone nuclear power plant



Post-use no-fly zone nuclear power plant with on shre Wind power

No-fly zone for a nuclear power plant (Example: Grohnde, 10.5 TWh electricity production)[1)]

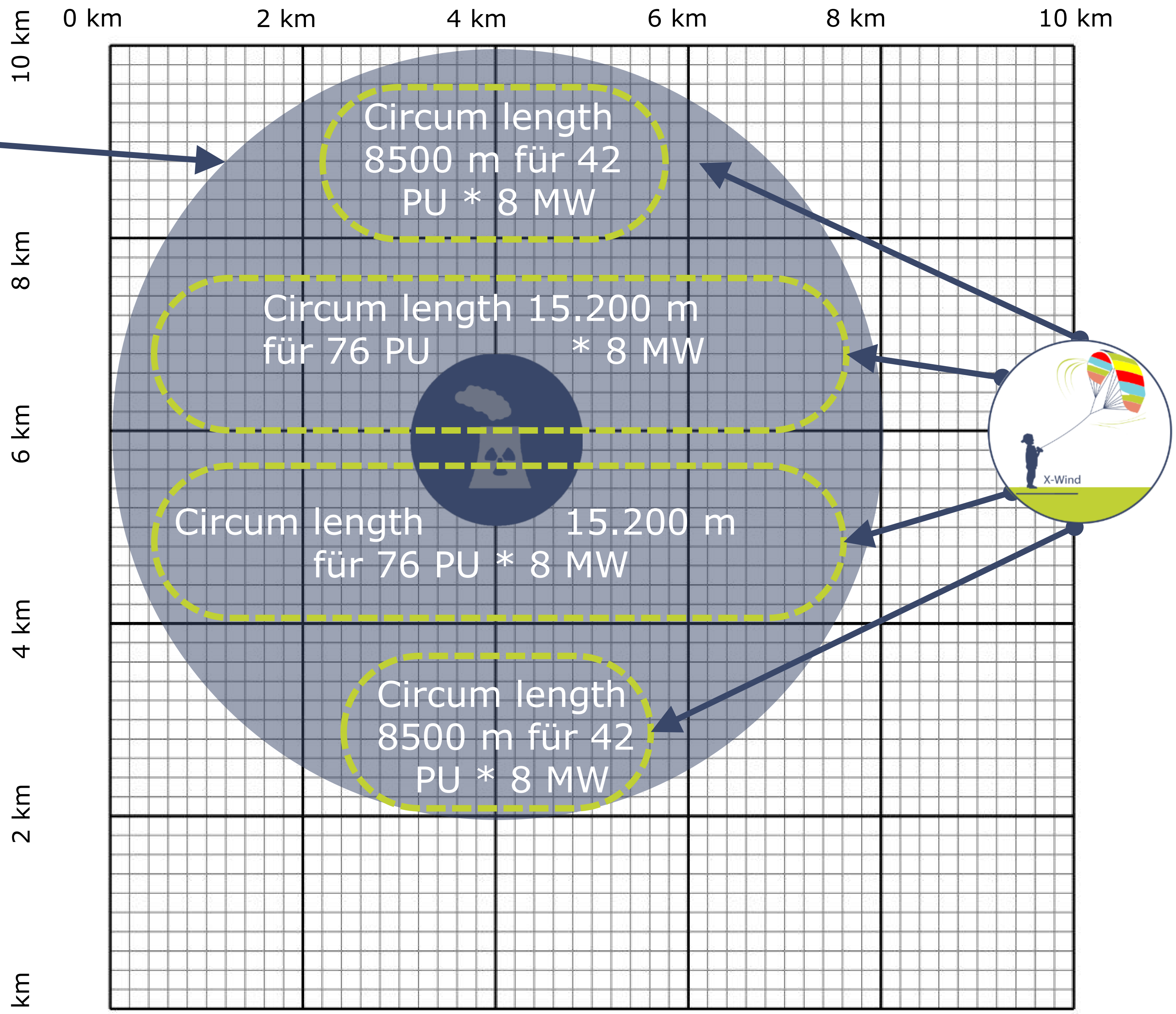
Area potential for 82 16 MW wind turbines = 1,312 MW corresponding to 2.3 TWh electricity production) [1)]



If the wind turbines MySE 16.0-242 (supplied by MingYang with a capacity of 16 MW and a rotor diameter of 242 m), which are currently the largest, were to be used, only one fifth of the existing infrastructure would be usable. And also only to 20% of the yearly full load hours.

1) Capazityfactor 20% corresponding to 1,752 full load hours

- No-fly zone for a nuclear power plant (example: Grohnde, Germany 10.5 TWh electricity production) [1)]
- Area potential for 4 X wind turbines (236 power units with 8 MW capacity each = 1.888 MW installed power corresponding to 12.4 TWh electricity production)



Quelle: 1) https://de.wikipedia.org/wiki/Kernkraftwerk_Grohnde

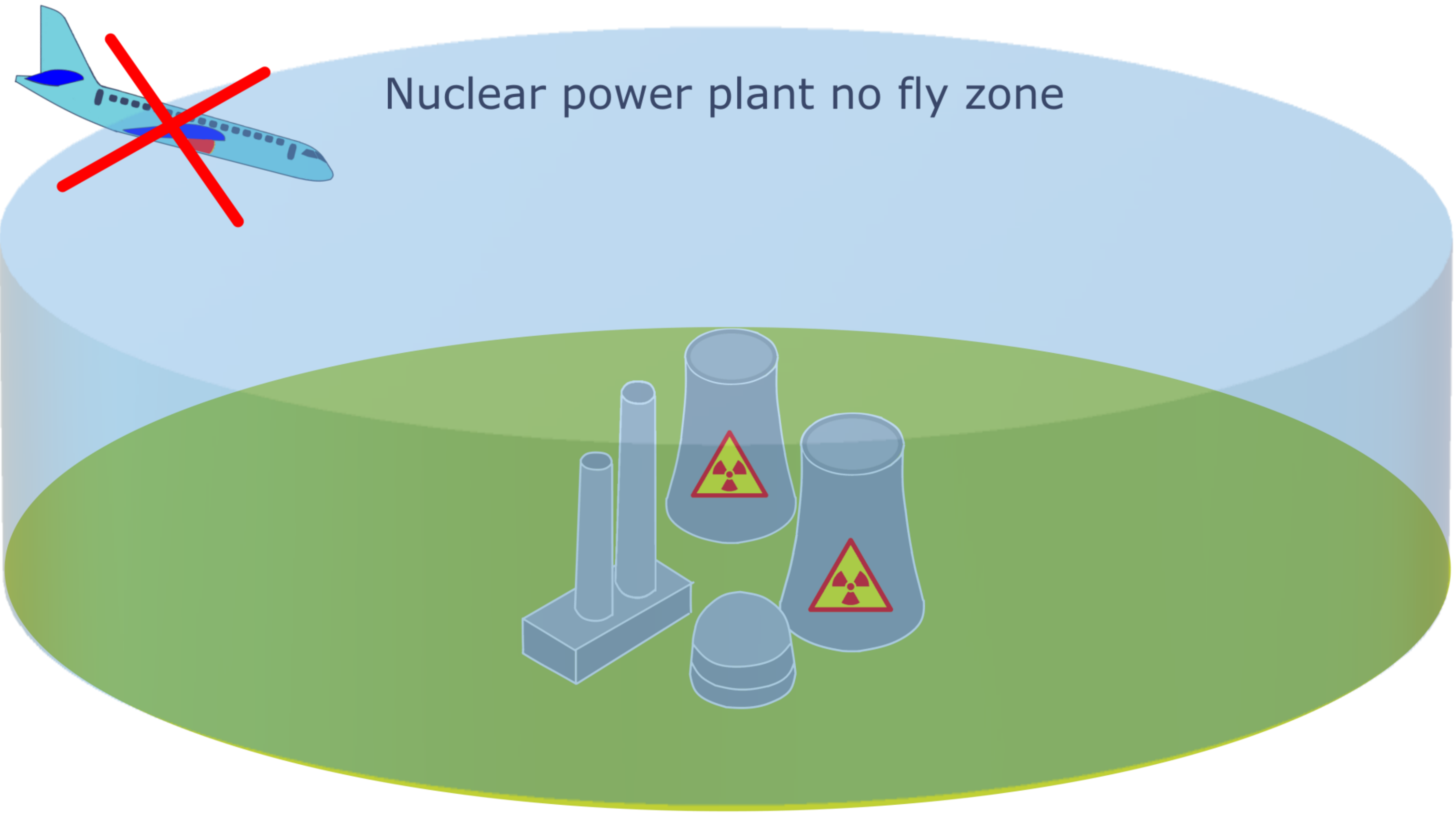
An energy source more powerful than a single nuclear power plant

No-fly zone for a nuclear power plant

(example: Grohnde, Germany, 10.5 TWh electricity production)[1]

Area potential for 4 X-Wind plants

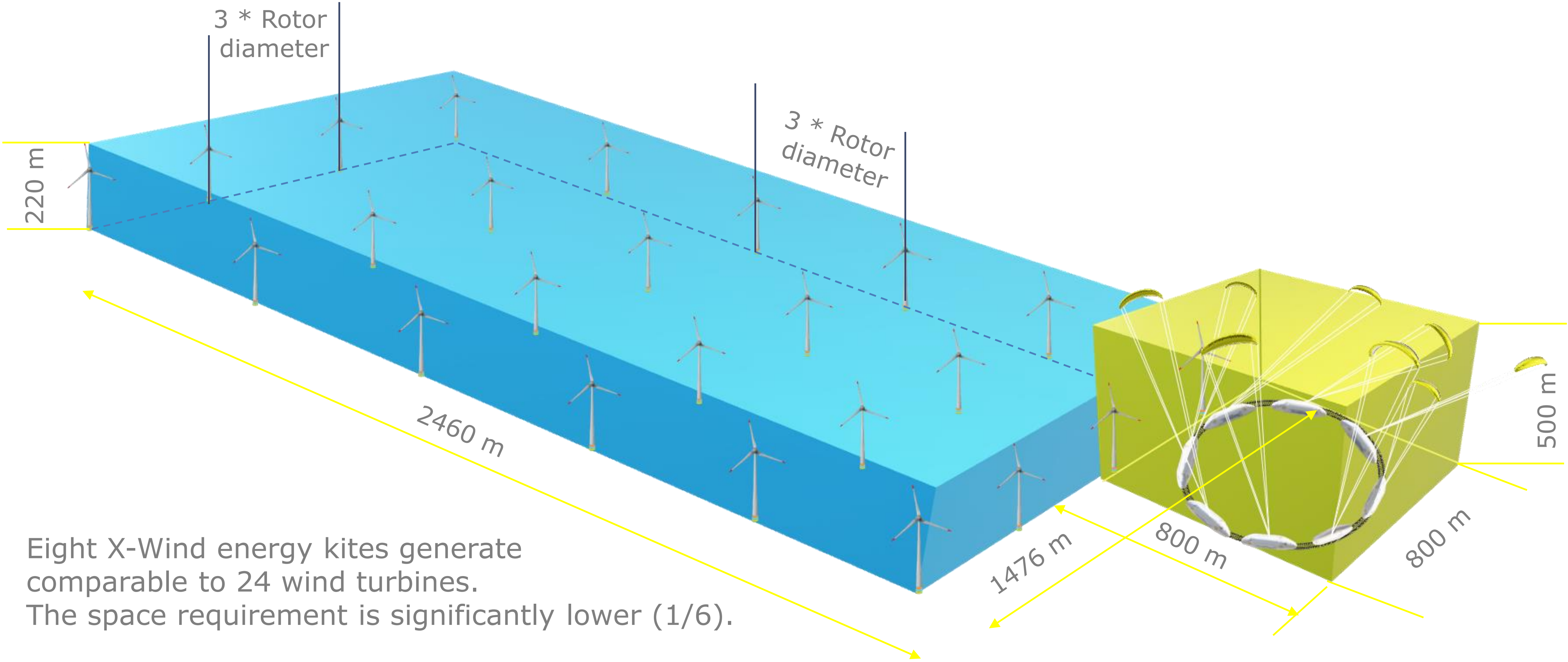
(236 powerunits with 8 MW capacity each = 1,888 MW installed power corresponding to 12.4 TWh electricity production)



Since 1968, there have been 42 airplane hijackings. What if....[2]

Source: 1) https://de.wikipedia.org/wiki/Kernkraftwerk_Grohnde; 2) https://de.wikipedia.org/wiki/Liste_von_Flugzeugentf%C3%BChrungen

Space requirement:

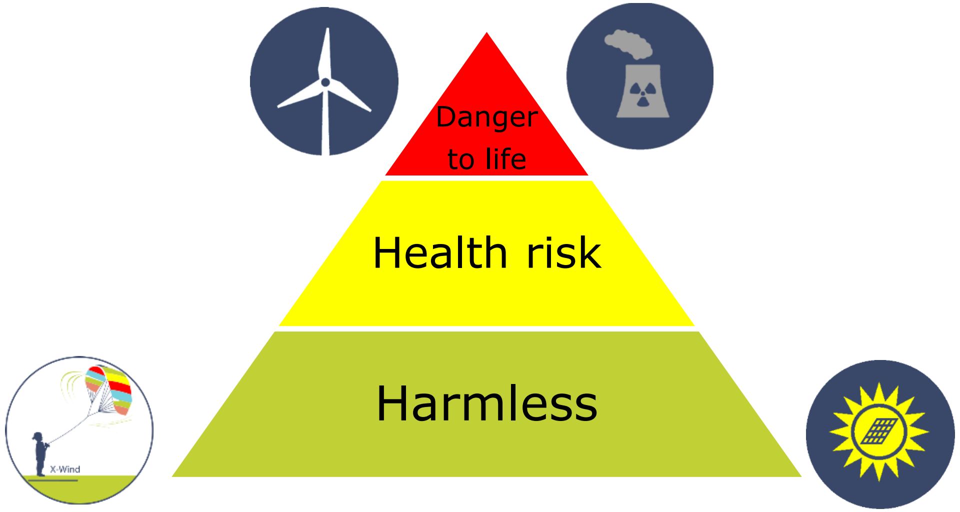


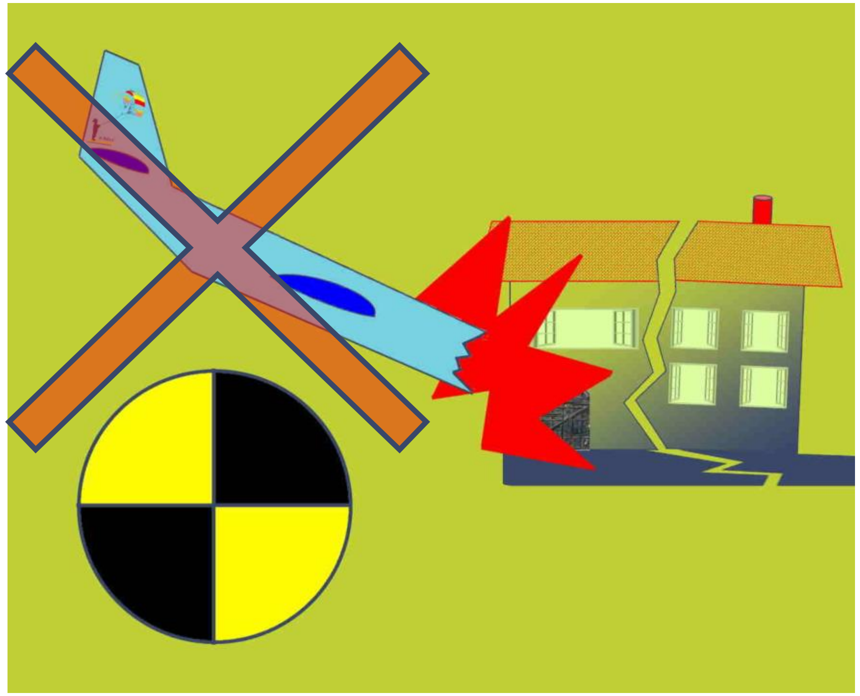
Eight X-Wind energy kites generate comparable to 24 wind turbines.
The space requirement is significantly lower (1/6).

X-Wind foundation area requirement approx. 1/3

Safety precautions

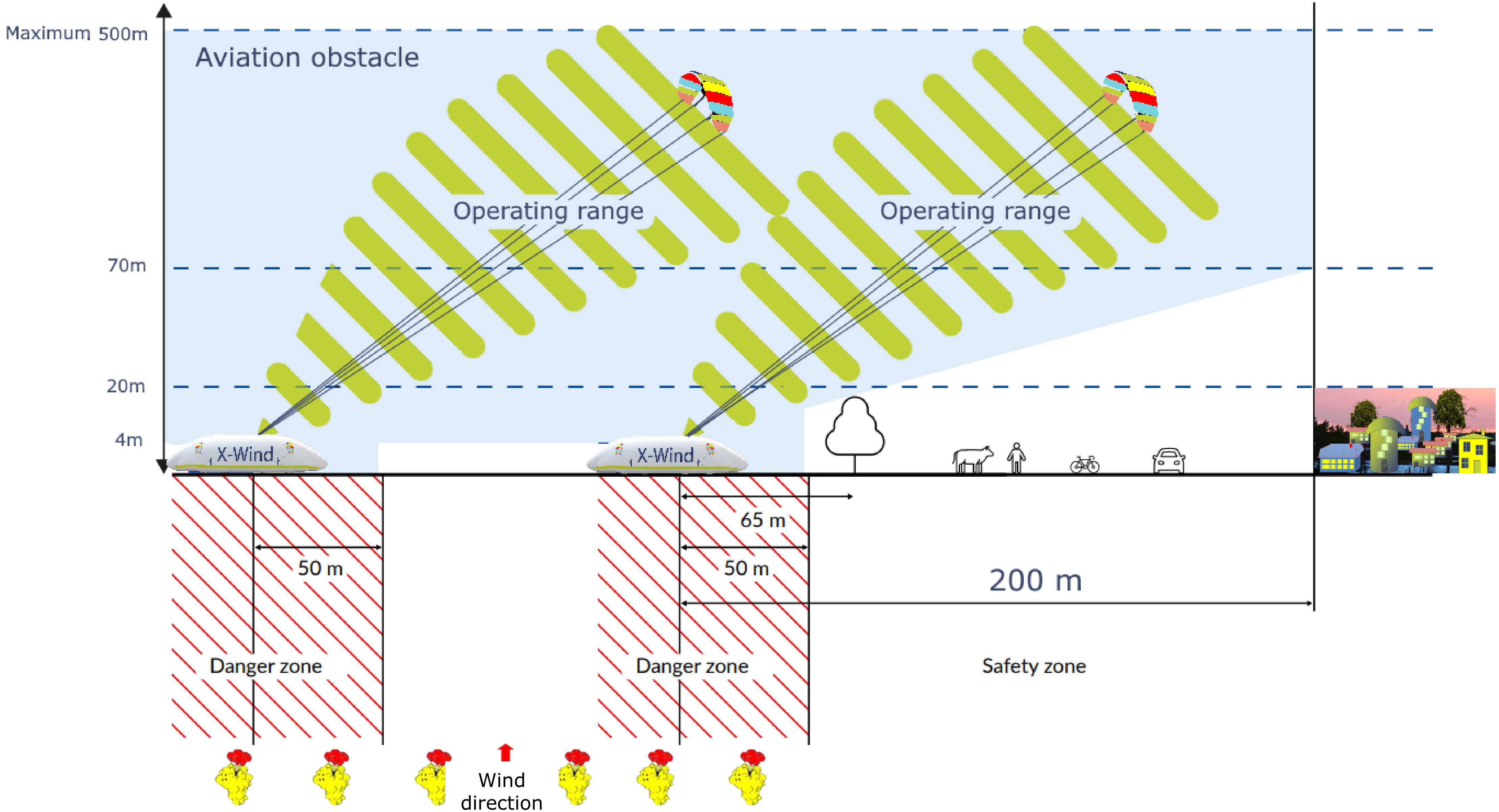
- Safety during extreme gusts
  - 1. safety against rope break slip clutch
  - 2. adjustment of angle of attack every 1/100 sec.
  - 3. emergency landing with maximum speed 50 m/sec (< 14 sec.)
- Collision protection
  - Fencing
  - Video surveillance and motion sensors
  - Distance sensors for owerunit with emergency stop and emergency landing
- Derailment safety
  - Regular wheel abrasion measurement
  - Rail vibration monitoring
  - Rail and switch heating
- Steering error
  - Redundant position monitoring (GPS and polar coordinate determination of the actual and target position of the kites)
- Emergency landing system
  - FLARM with emergency landing with maximum speed 50 m/sec (< 14 sec.)



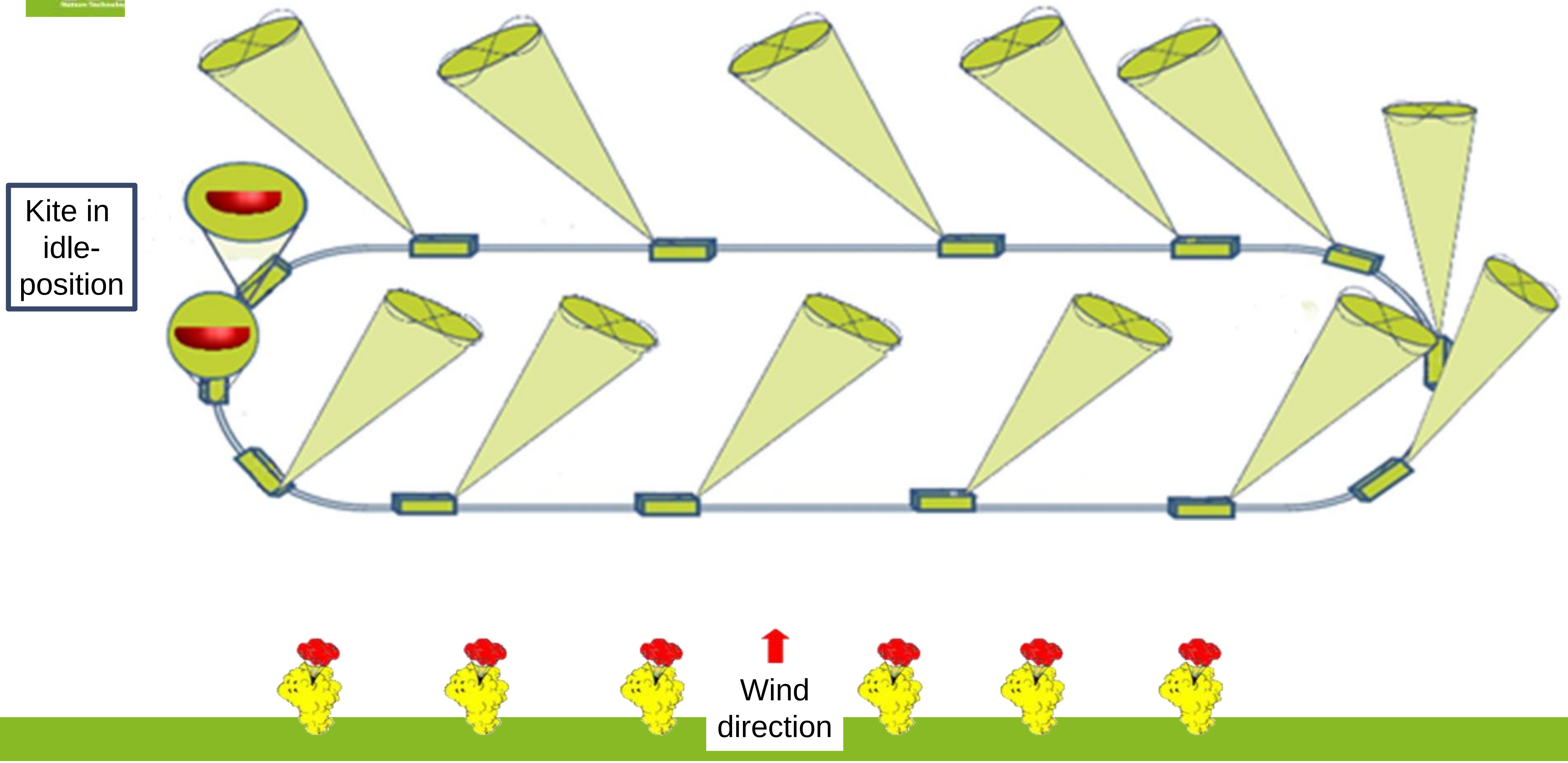


Link to Crash Test X-Wind: https://www.youtube.com/watch?v=UewN2tuaasc

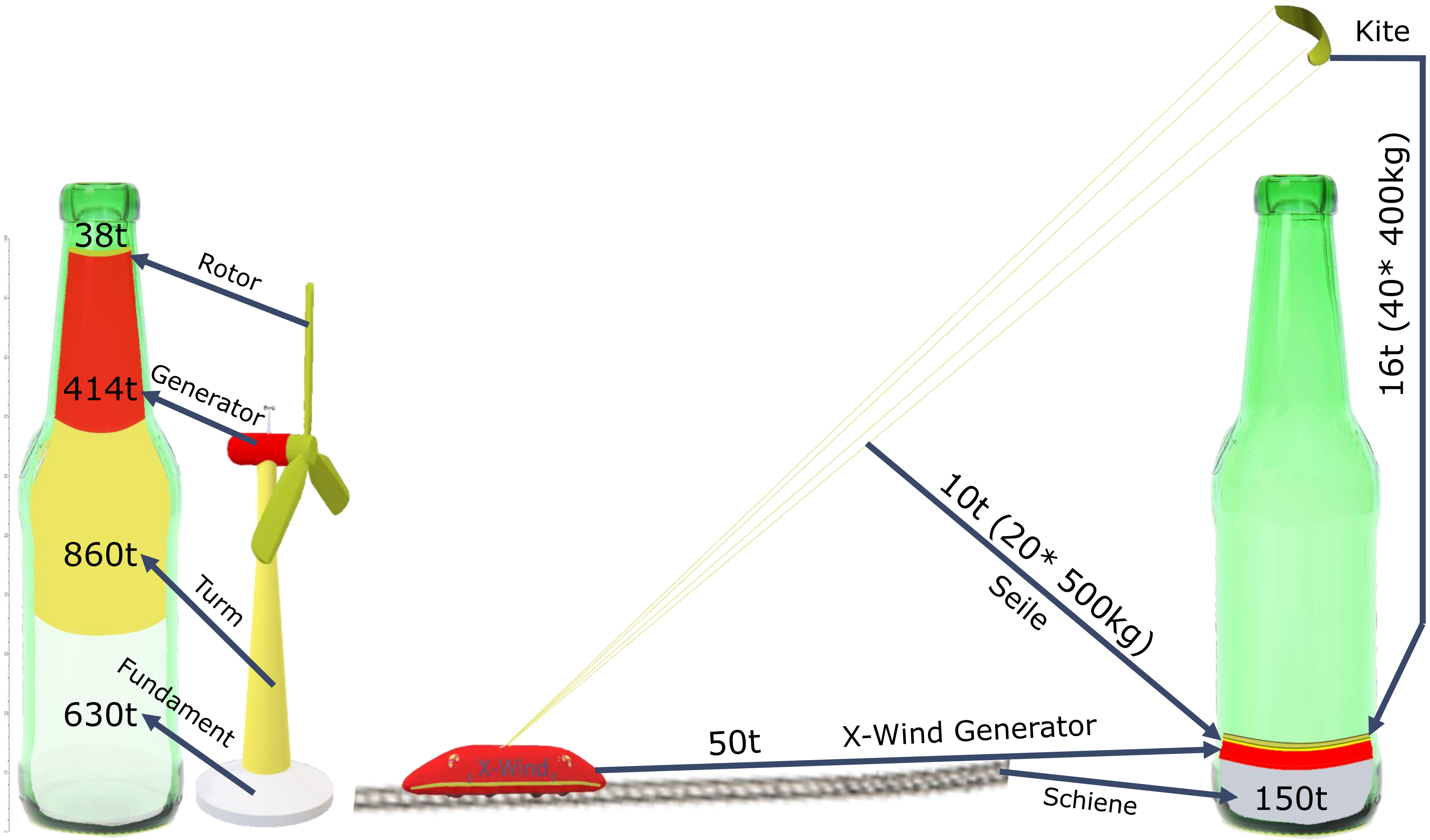
Safety distances:



Entanglement excluded:



Comparison use of resources (less 90%)



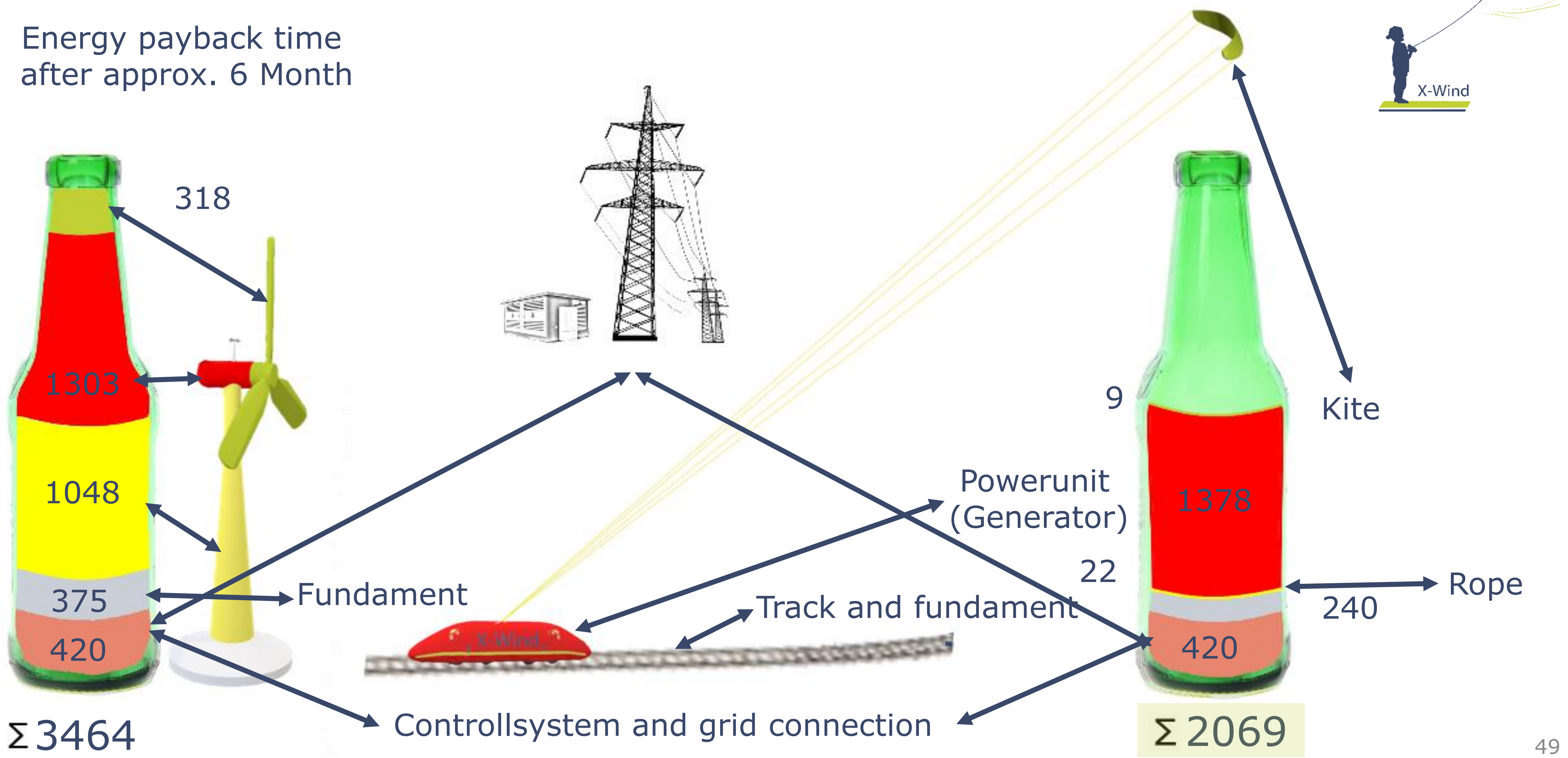
Σ 1950 t

Σ 226 t

Quelle: https://ressourcen.wupperinst.org/downloads/MaRess_AP2_4.pdf

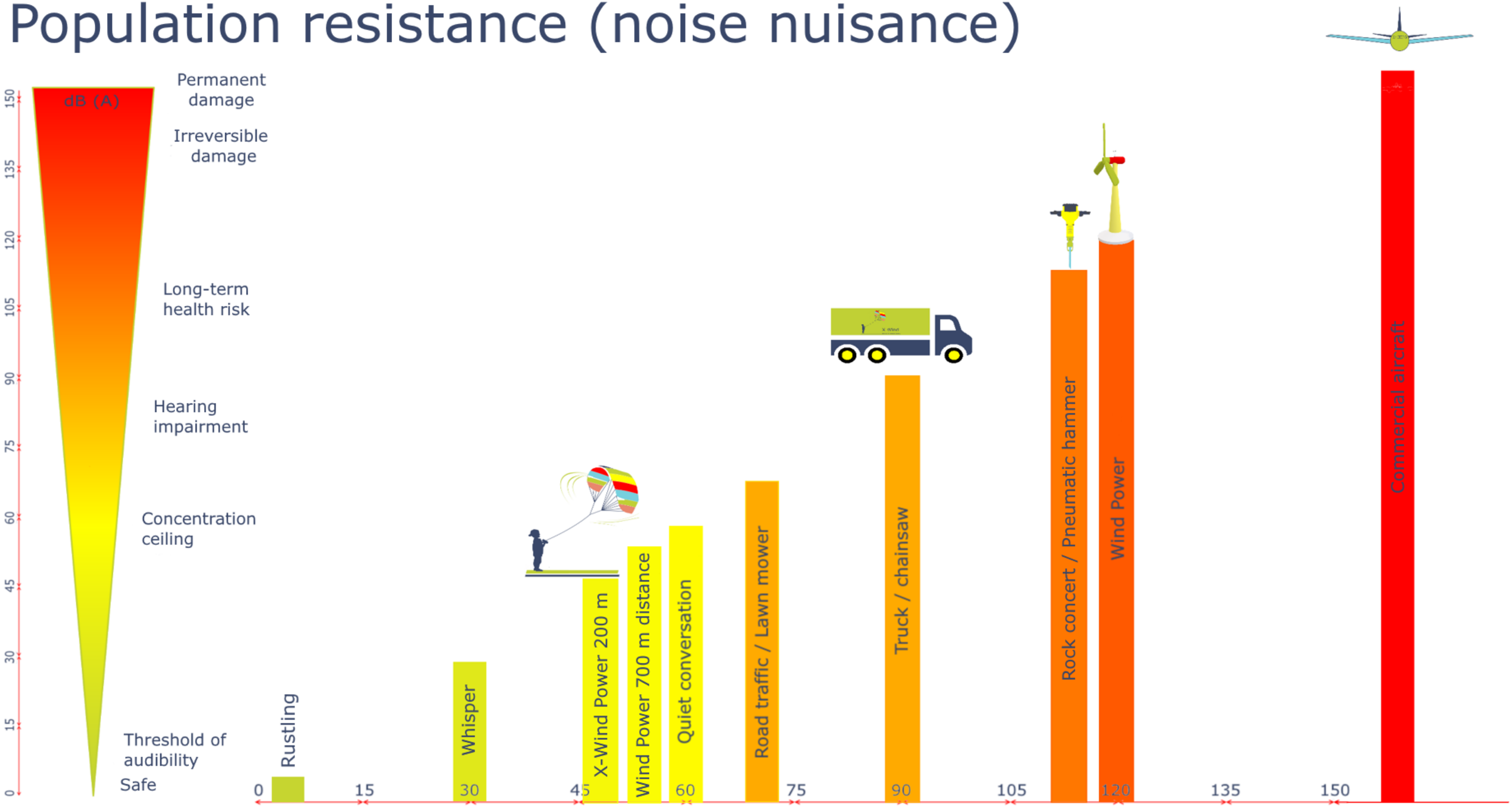
Life cycle assessment (MWh)

Energy payback time
after approx. 2 Month



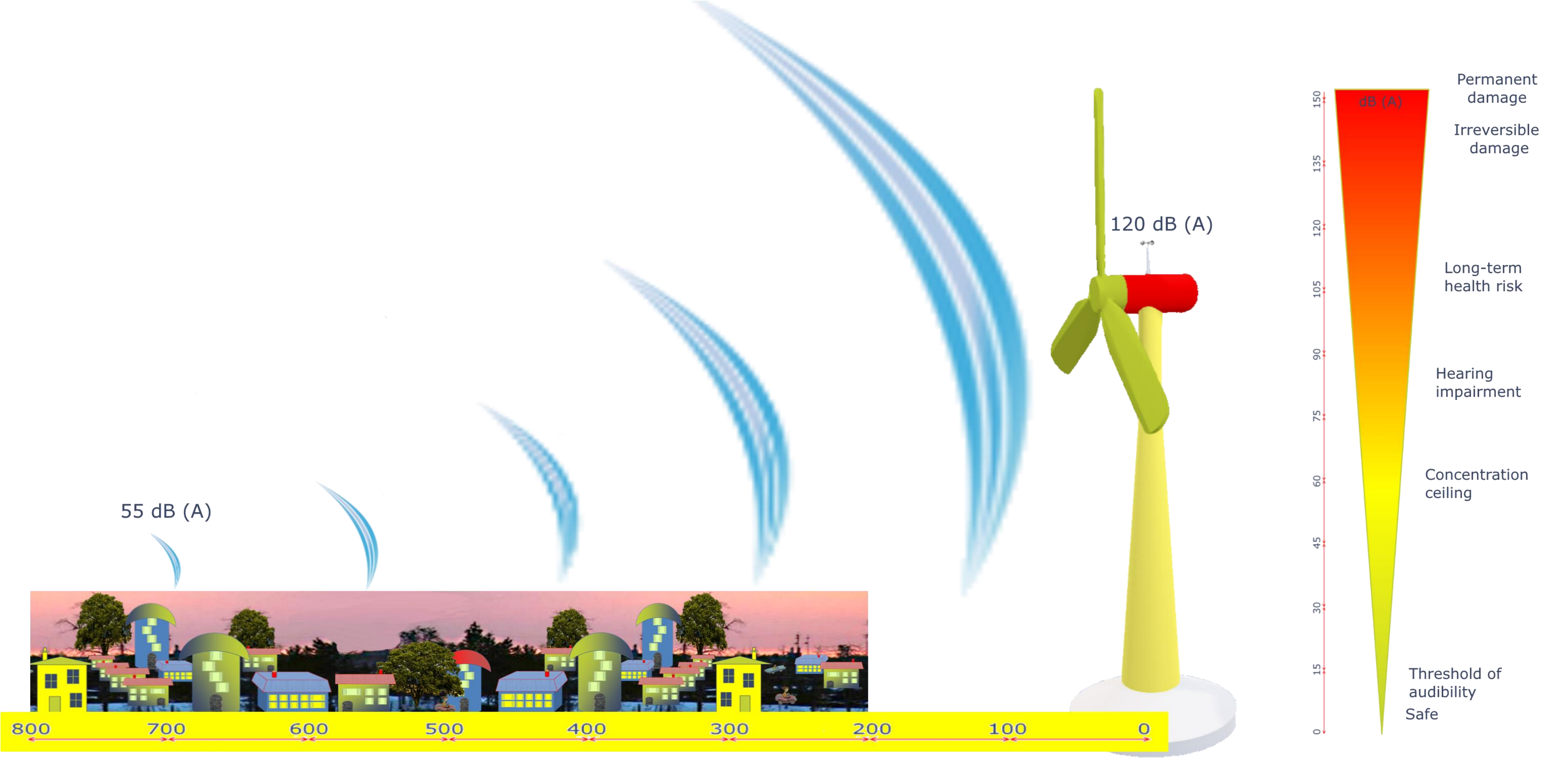
Quelle: https://ressourcen.wupperinst.org/downloads/MaRess_AP2_4.pdf

Population resistance (noise nuisance)



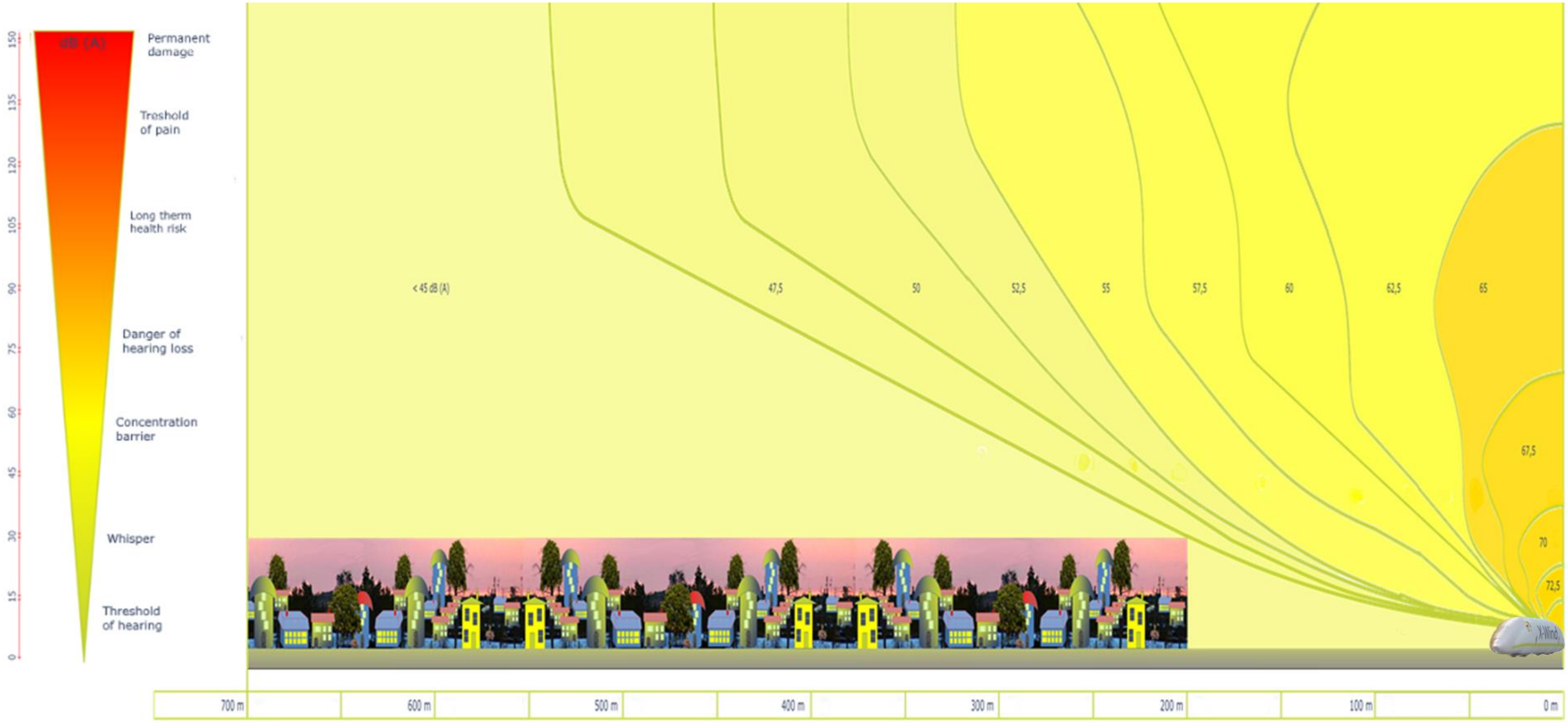
Quelle: https://www.fensterblick.de/schallschutzklassen-fenster.html
Priv. Doz. Dr. Kai J. Lorenz

Noise level conventional wind turbines



Quelle: http://www.ig-windstill.de/hintergrund.html

Noise level X-Wind Powerunit

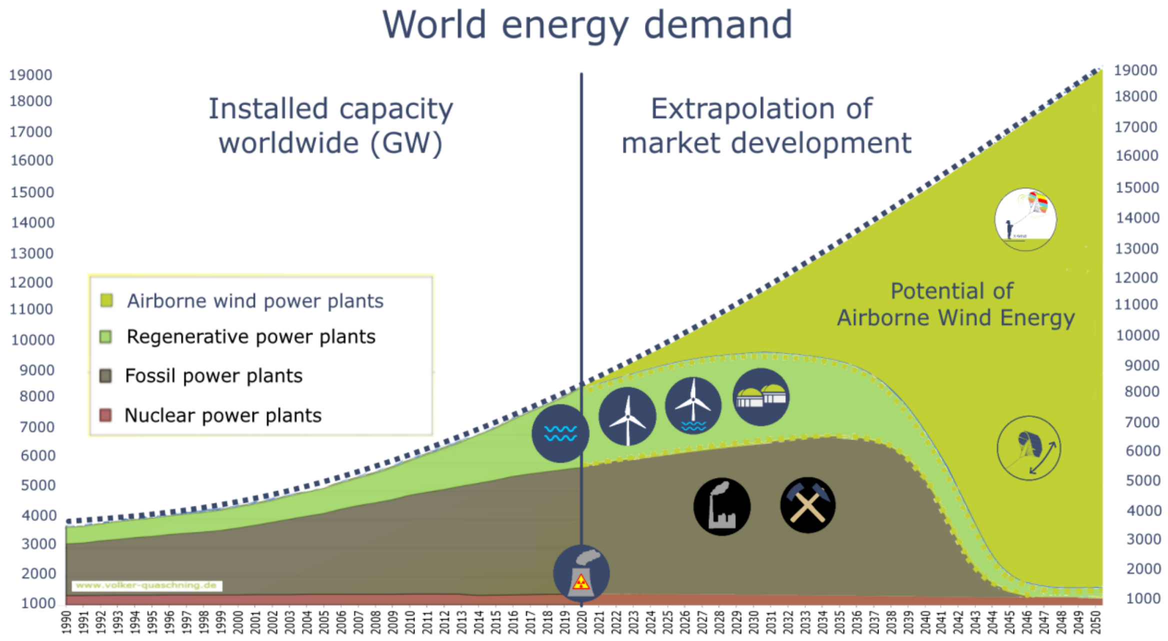


https://www.forschungsinformationssystem.de/servlet/is/49310/

Landscape impact

X-Wind Landscape

Market – Enormous Potentials for X-Wind



Multi-billion Euros revenue potentials for X-Wind:

- growing global energy demand
- call for green hydrogen
- smart financings of coal-fired and nuclear reactor dismantlings

Many untapped opportunities for X-Wind to create growth!

- according to annual researches of BP, the worldwide energy consumption increases by 1-3%
- leading nations push to cover the energy need through renewable sources
- ➢ **Potential: X-Wind can help to meet the additional energy demand**

- energy strategies of policy makers encompass the production of hydrogen as part of their decarbonization goals
- ➢ **Potential: X-Wind is ideal to produce 100% green hydrogen**

- while global energy demand grew by 2.9% in 2018 the global CO2-emissions increased by 2% in the same period
- energy generation through fossil fuels is still common around the world
- ➢ **Potential: X-Wind can help to substitute energy capacities of fossil fuels when dismantling coal-fired powerplants**

- around 500 nuclear powerplants around the globe are still in use of which 300 shall be shut down in the next 20 years
- ➢ **Potential: X-Wind can help to replace energy capacities of nuclear powerplants and to finance the complex dismantling of reactors**

X-Wind Technology Patents

The most important world markets in our hands!
The X-Wind technology is patented for 80% of the world markets

USA

China

Russia

Europe

Turkey

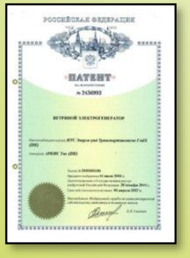
Indonesia

South africa

India

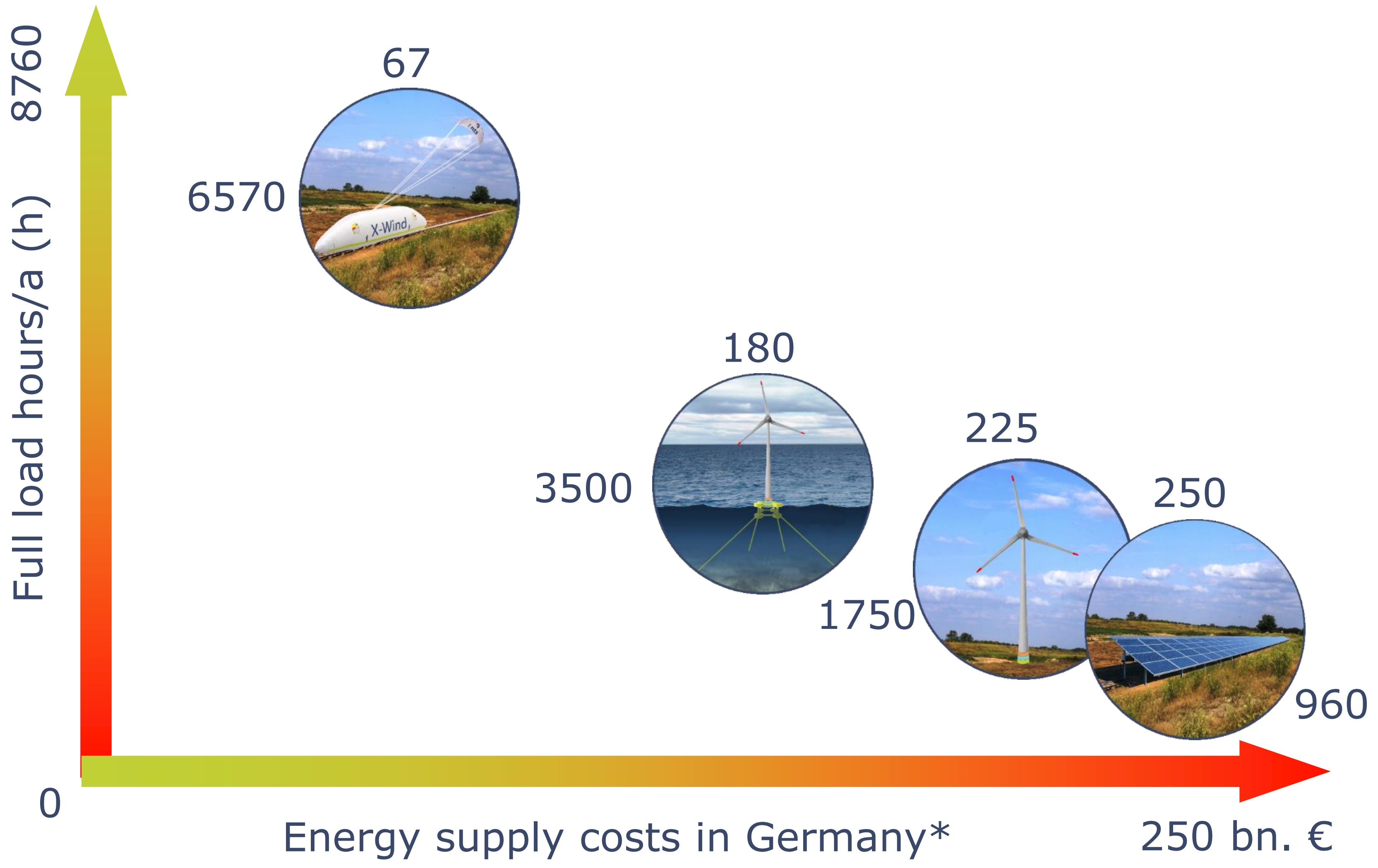
Australia

Morocco




Our key arguments



- Almost invisible in the landscape
- Almost noiseless for residents and nature
- Bird-, bat- and insect-friendly
- Resource-saving, all parts recyclable
- Cheaper than all other energy sources

* The calculation is based on the assumption that the respective source would cover Germany's entire energy demand

Summary

- Less material consumption (**- 90 %** compared to classic wind turbine)
- Energy recovery in 2 months (conventional wind towers in 6 months)
- Durability almost unlimited (all X-Wind modules are renewable)
- Low production costs (LCOE < **2ct/kWh**, LCOH <**1,5 €/kg**)
- Very high full-load hours (up to **7.385** hours/year)
- Low maintenance and service costs
- Secure and high yield opportunities
- Same energy performance (compared to classic Nuclear power plants)

Our sustainability goals

Quell… //de.wikipedia.org/wiki/Ziele_f%C3%BCr_nachhaltige_Ent…ung

Team

Uwe Ahrens
CEO

Uwe is the CEO of X-Wind Powerplants. He is a creative full-blooded entrepreneur who thinks outside the box. His passion in the glider to look at the world from a different perspective led him to study lightweight construction technology at the TU Berlin. Uwe developed artificial joints for humans, founded his first company in 1989 to market his patents and placed his company successfully on the Frankfurt Stock Exchange in 1999 and switched to the company's supervisory board from his CEO position in 2005. With less operational tasks, he was soon mandated by his daughters to invent an affordable renewable energy source. He then founded X-Wind Powerplants and developed a great enrgy producing technology. Born in Lower Saxony, he now lives in Berlin.

Ertu Taner
COO

Ertu joined Uwe to develop X-Wind as COO. More than 20 years as a partner alongside of Prof. Dr. Christian Schwarz-Schilling, a former German Minister for Post and Telecommunications, Ertu has earned entrpreneural mindset from scratch. He enjoys the analysis of companies' challenges in their corporate and financial development and evolves strategies when working with company owners and their management. Ertu creates and utilizes networks to guide clients into emerging markets and into China. Considering local business circumstances, regulations and players Ertu has led numerous tech companies successfully into their target markets in Europe, Africa, Middle-East and Asia. He resides in Bavaria with his family. He studied Economics in Constance and in Bonn with a concentration on Game Theory.

Harouna Reichelt
CTO

Uwe is the CEO of X-Wind Powerplants. He is a creative full-blooded entrepreneur who thinks outside the box. His passion in the glider to look at the world from a different perspective led him to study lightweight construction technology at the TU Berlin. Uwe developed artificial joints for humans, founded his first company in 1989 to market his patents and placed his company successfully on the Frankfurt Stock Exchange in 1999 and switched to the company's supervisory board from his CEO position in 2005. With less operational tasks, he was soon mandated by his daughters to invent an affordable renewable energy source. He then founded X-Wind Powerplants and developed a great enrgy producing technology. Born in Lower Saxony, he now lives in Berlin.

X-Wind is supported by many partners

ThyssenKrupp

BWE
Bundesverband WindEnergie

EUROPÄISCHE UNION
Europäischer Fonds für regionale Entwicklung
Investition in Ihre Zukunft

EFRE
...eine Chance durch Europa!

LIROS

Autodesk

swing

Hapag-Lloyd

BSR

DSM

Fraunhofer
IPA

AIRBORNE WIND ENERGY
CONSORTIUM

FIM

Blickle®

JOHANNES HÜBNER
GIESSEN
renewable energy

BEUTH HOCHSCHULE FÜR TECHNIK BERLIN
University of Applied Sciences

kfw
FÖRDERBANK

ISW Institut für Steuerungstechnik
Universität Stuttgart

TU berlin
Technische Universität Berlin

Investitionsbank Berlin

Cooperation opportunity Reallabor

- The goals are:
  - Maintain and expand technology leadership in Germany
  - Move from isolated individual projects to a systemic approach
  - Set industrial standards
  - Enable sustainable business models
  - Realize cross-sector CO2 savings
  - Regulatory learning, i.e. reviewing the energy industry framework
- Funding of up to 15 million Euros per partner (max. 25 million Euros total)

Funding program for demonstration of innovative low-carbon technologies

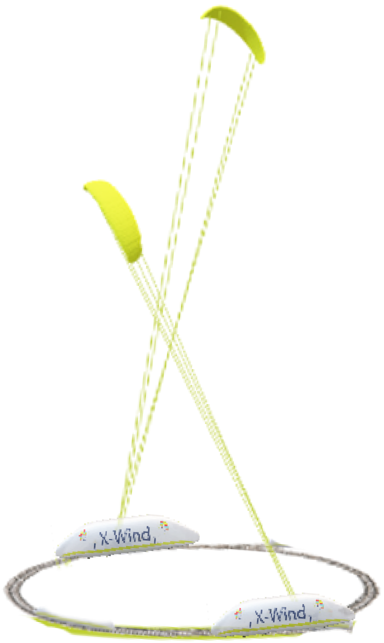
- Funding rate of 60%
- No upper limit
- Small consortia possible
- For member states of the EU emissions trading scheme
- Focus on breakthrough technologies for:
  - Renewable energy,
  - Energy storage,
  - Carbon capture, utilization (CCU) and storage (CCS),
  - Low-carbon technologies and processes in energy-intensive industries (incl. products that substitute CO2-intensive products)

Cooperation opportunity goals

- Feasibility study for the elaboration of the parameters for the supply of renewable electricity to the aluminum industry
- Setting up the conditions for the establishment of a real laboratory
  - Place, space and infrastructure requirement
  - Time, finance and man power demand
- Construction of the first X-Wind Plant for the base-load capable supply of renewable electricity
- Evaluation of the results and planning for the expansion of the concept

Technical and commercial characteristics* of demonstration plant and commercial plant

2 Step implementation X-Wind



Demonstration plant

Quantity of Powerunits:	2
Installed capacity:	2 MW
Property size :	1 km²
Track legth:	2.400 m
Land use:	4.000 m²
Power production:	13 GWh/a
Investment:	8 Mio. Euro

Expansion to commercial size

Additional quantity of Powerunits:	10
Additional installed power:	80 MW
Power production :	525 GWh/a
Investment :	98 Mio. Euro

Scientific basics, films and further literature:

https://www.youtube.com/watch?annotation_id=annotation_3302915765&feature=iv&src_vid=swr-Nq7S3KU&v=pRRFaf2GiuU (Deutsche Version)

https://www.youtube.com/watch?v=9D0JIB6hYc4 (German Television News)

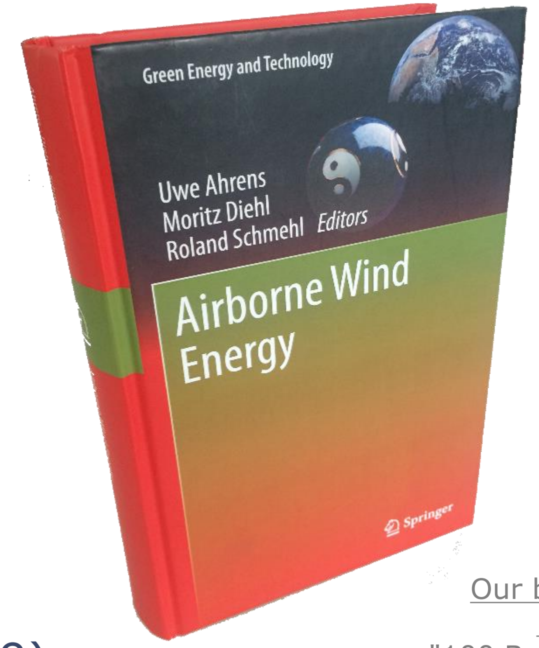
https://www.youtube.com/watch?annotation_id=annotation_3883640407&feature=iv&src_vid=pRRFaf2GiuU&v=swr-Nq7S3KU (English Version)

Crash test :
https://www.youtube.com/watch?v=mhHlpEG0OuU

- Loyd Miles, 1980 Crosswind Kite Power
- Adams, 2010 Fluidmechanik
- Gambier et al, 2012 IWES Fraunhofer

  Tagungsband 1 and 2
- Ahrens, Diehl, Schmehl

  2013, Airborne Wind Energy (ISSN 1865-3529)



We are very happy.
Our book on high-altitude wind technology
made it to number 10 among the
"100 Best Renewable Energy Books of All Time"!

- Schmehl 2018, Airborne Wind Energy (ISBN 978-981-10-1947-0)

Facility spectrum

*Number of Powerunits:	Installed output per power unit			
	1 MW	2 MW	5 MW	8 MW
	Electricity production (GWh/a) at 75% capacity factor			
5	33	66	164	263
10	66	131	329	526
15	99	197	493	788
20	131	263	657	1.051
25	164	329	821	1.314
50	329	657	1.643	2.628

Ask for an offer

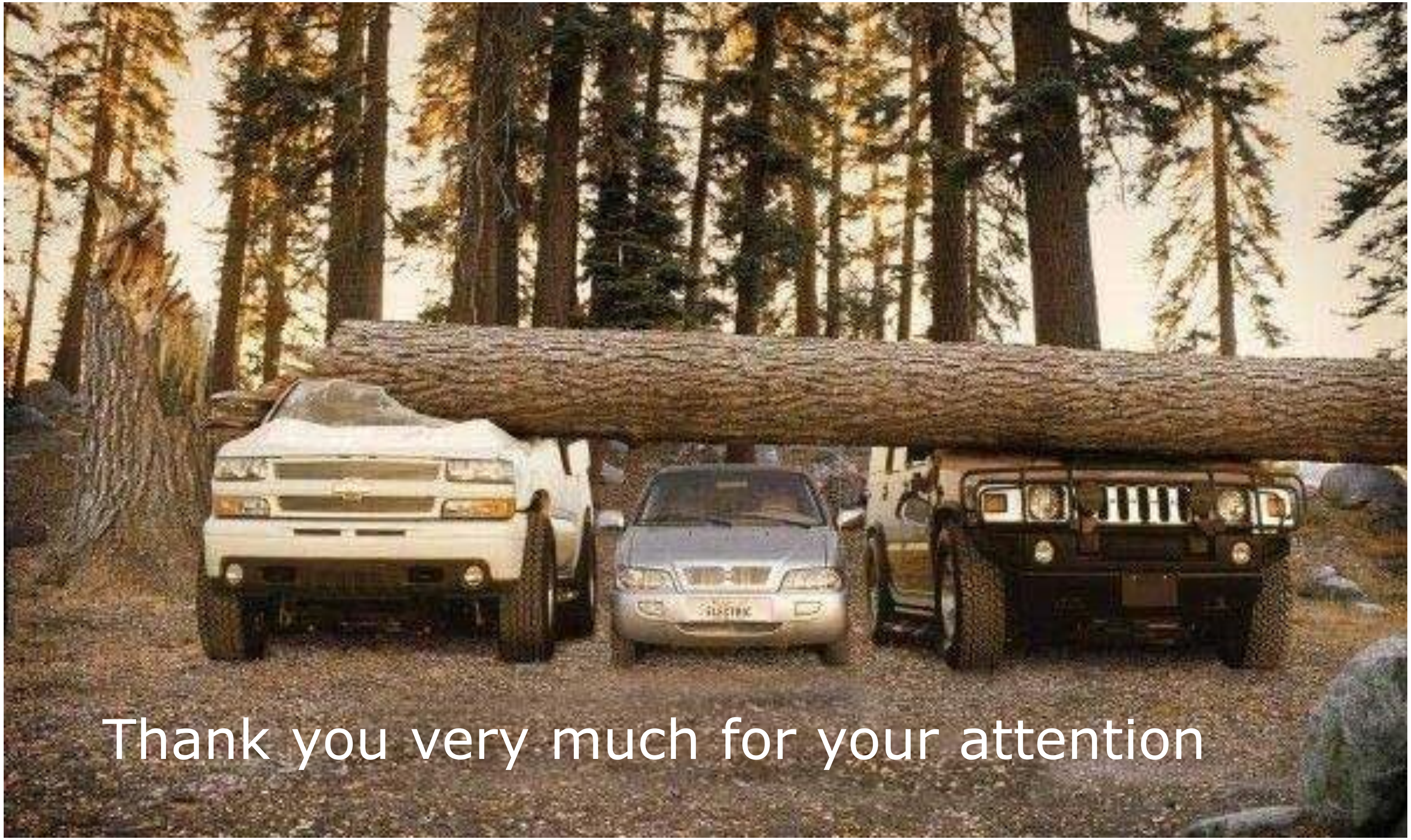
Number of Powerunits:	Hydrogen production (t) at 75% capacityfactor and 50 kWh/kg			
	1 MW	2 MW	5 MW	8 MW
5	657	1.314	3.285	5.256
10	1.314	2.628	6.570	10.512
15	1.971	3.942	9.855	15.768
20	2.628	5.256	13.140	21.024
25	3.285	6.570	16.425	26.280
50	6.570	13.140	32.850	52.560

At the same time, around 8 times the amount of oxygen is produced.

Tel.: +49 172 7266233
uwe.ahrens@x-wind.de
www.x-wind.de

* Means the number of energy generators comparable to the number of wind turbines of a wind farm with the respective installed capacity

Height is important



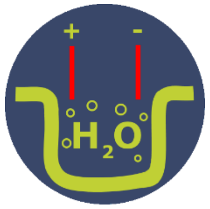
Übersicht der verwendeten Energie-Icons:

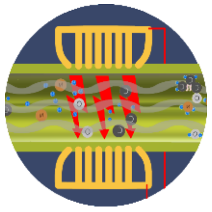
* AWE = Airborne Wind Energie

Übersicht der verwendeten Icons:

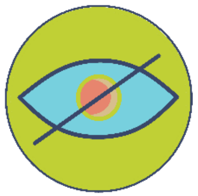

Höhen-
wind


Strom-
netz


Elektro-
lyse


Plasma-
lyse

Wasser-
stoff

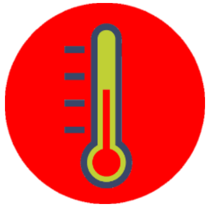

Nahezu
unsichtbar


Flüster-
leise


Flauna-
freundlich


CO_2-
frei

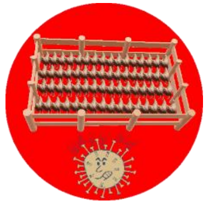

Günstiger


Erd-
erwärmung


Trinkwasser-
verknappung

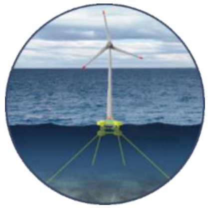

Land-
verlust


Klima-
migration


Massen-
tierhaltung


Pandemien


X-Wind


Off shore
Wind


On shore
Wind


Photo-
voltaik


Elektrizität


Mineralöl

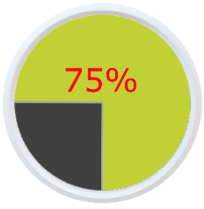

Tankstelle
Mineralöl


Ladestation
Strom

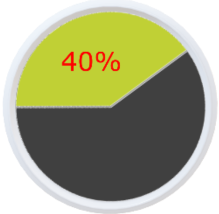

Tankstelle
Wasserstoff


Wasserstoff
PKW

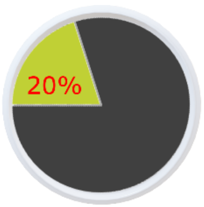

Wasserstoff
LKW



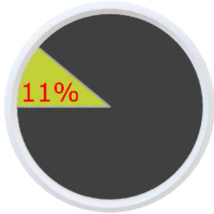
Liefer-
zeit 75%



Liefer-
zeit 40%



Liefer-
zeit 20%



Liefer-
zeit 11%


Wärme


Trink-
wasser

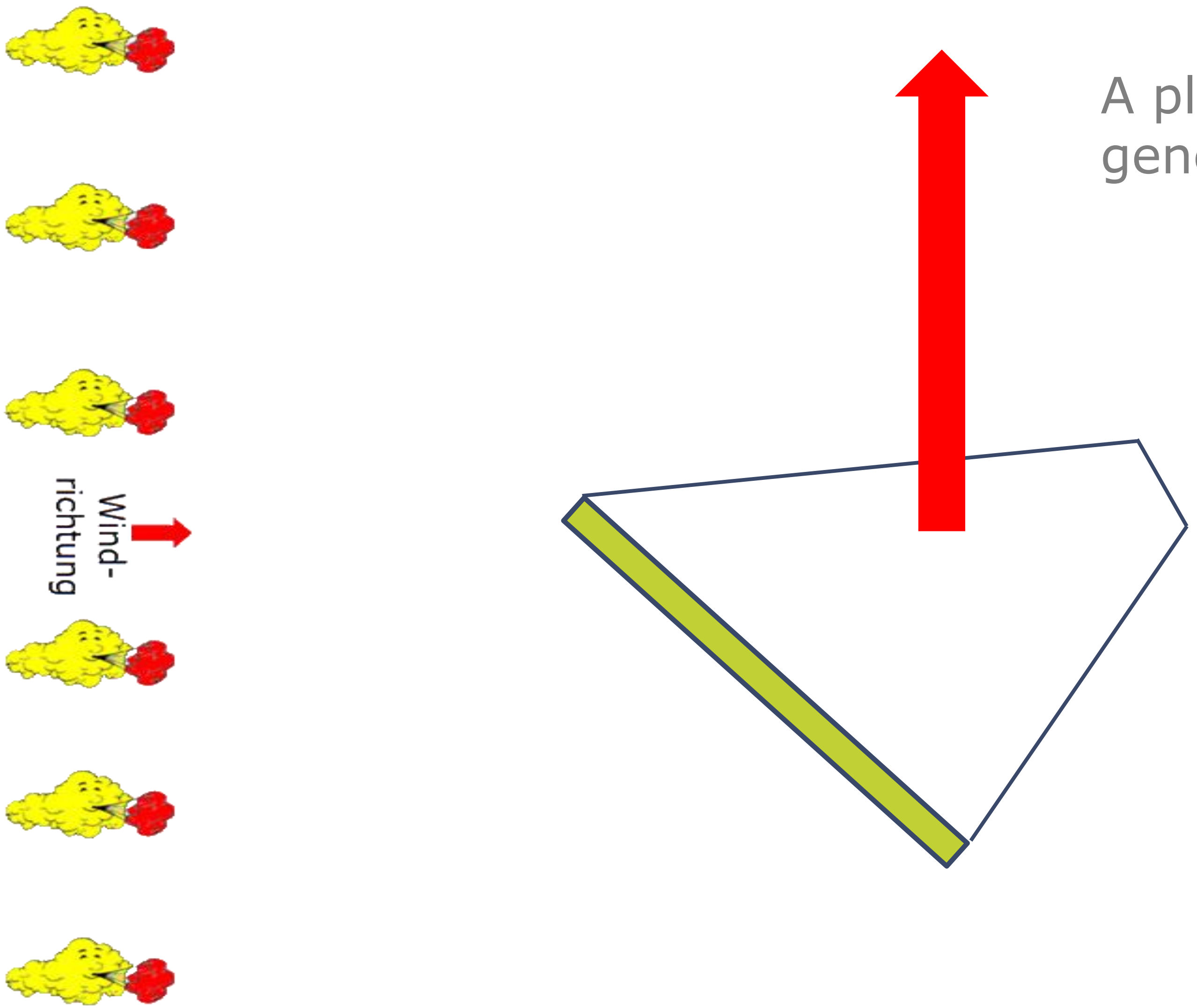

Abwasser


Wasserstoff
Flugzeug


Wasserstoff
Zug

Back up

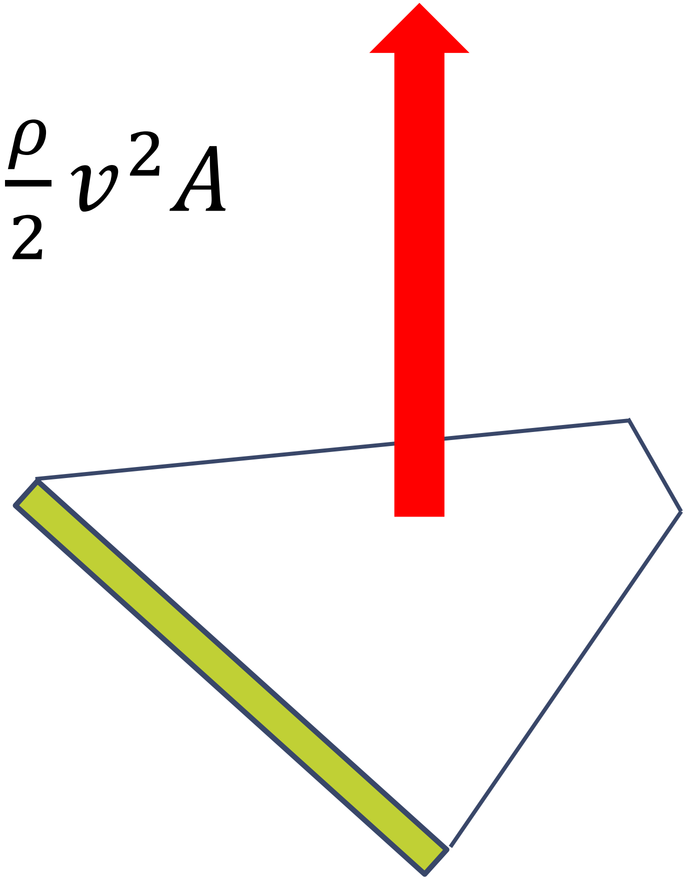
Lift force



A plank in the wind generates a force

Lift force

$$Fa = C_a \frac{\rho}{2} v^2 A$$



This force (Fa) = buoyancy force, is calculated from various factors

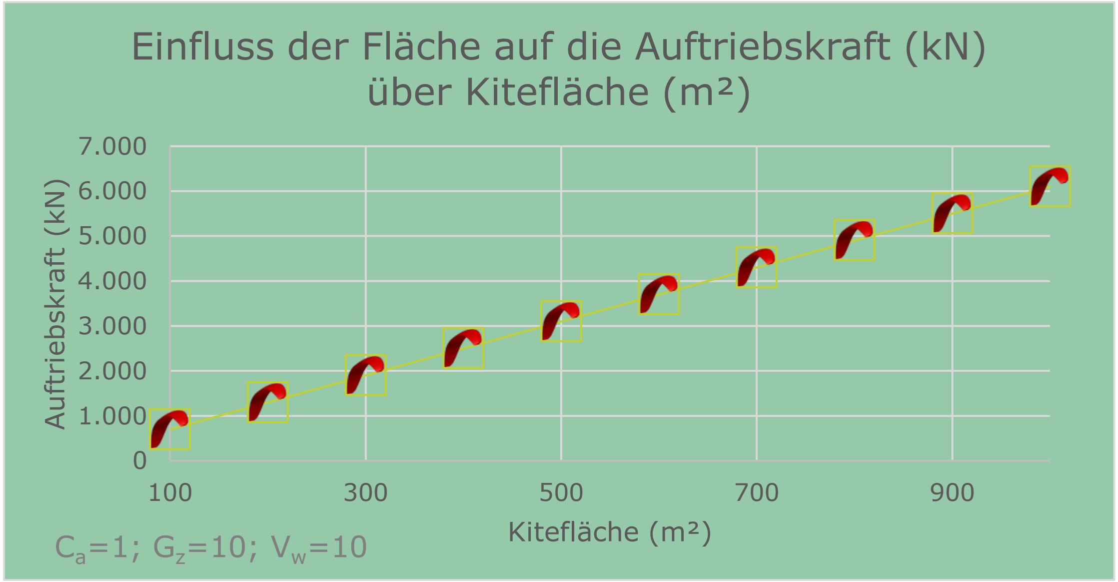
Ca = Lift coefficient

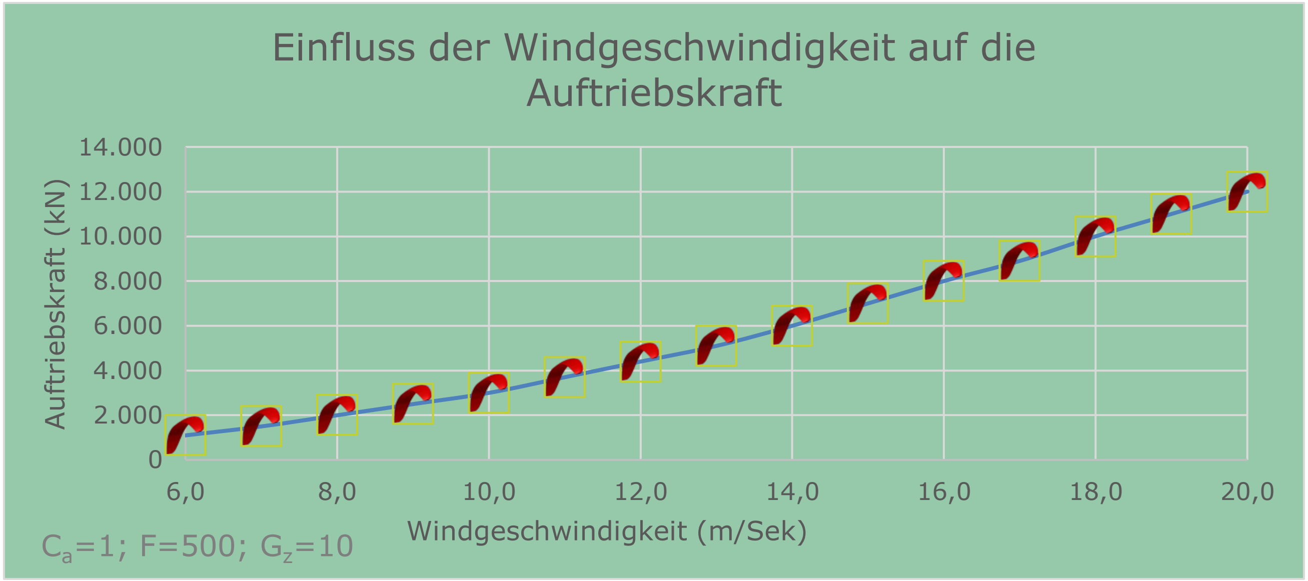
$\frac{\rho}{2}$ = Air density

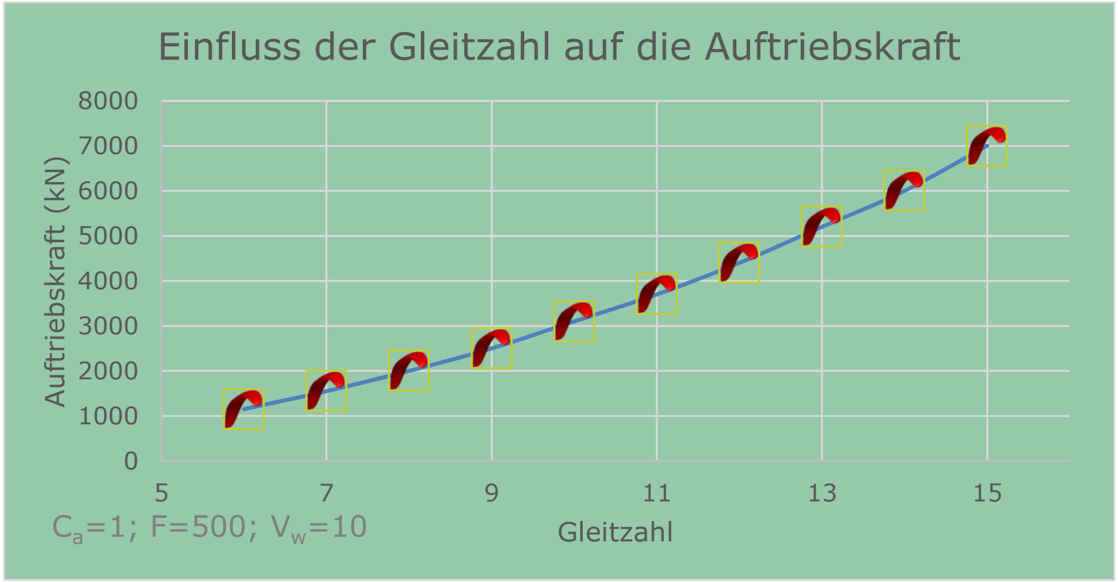
V = Air velocity

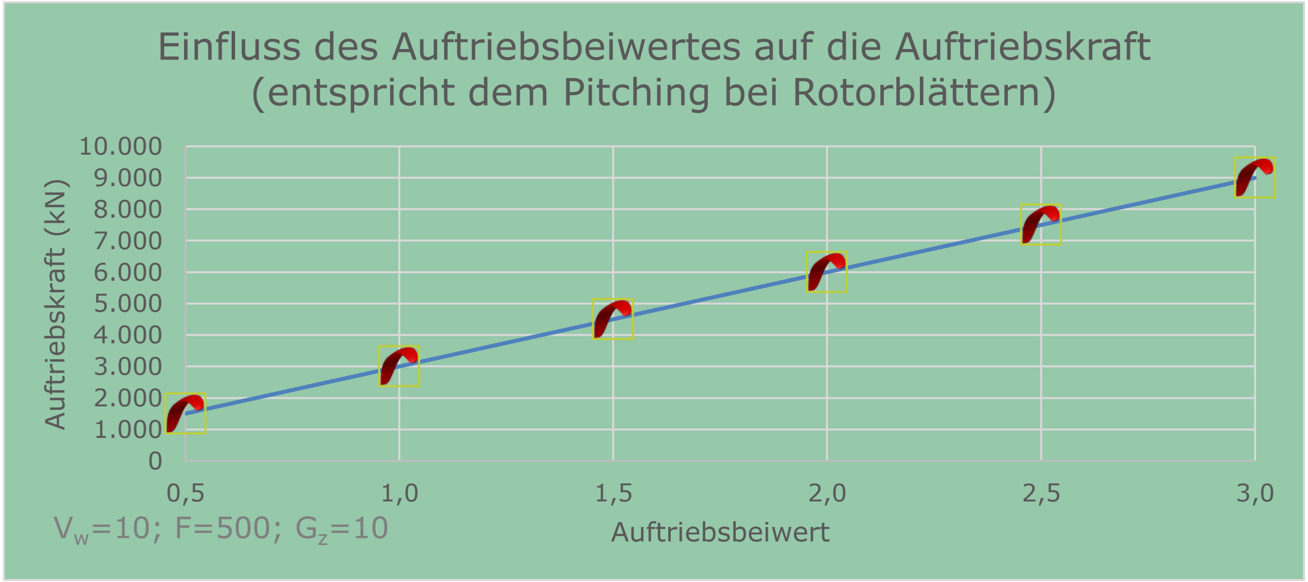
A = Airfoil area

Die Kite Auftriebskraft Parameter:



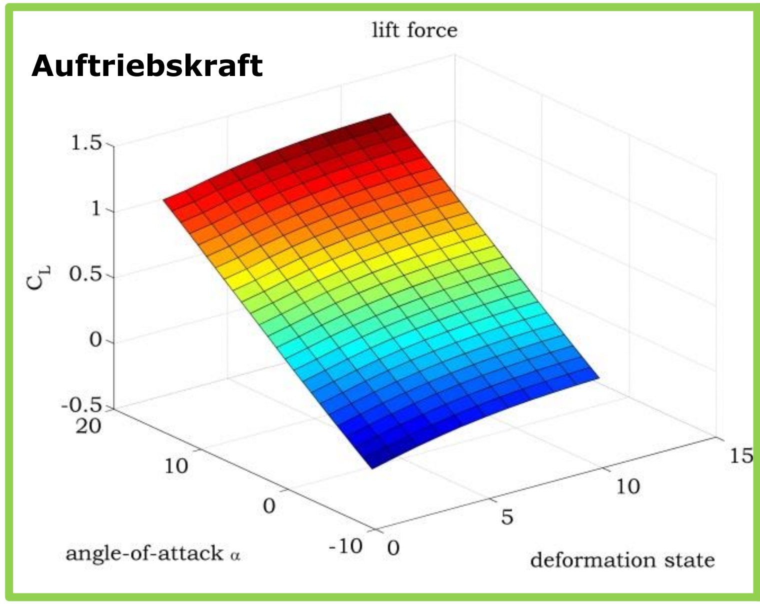


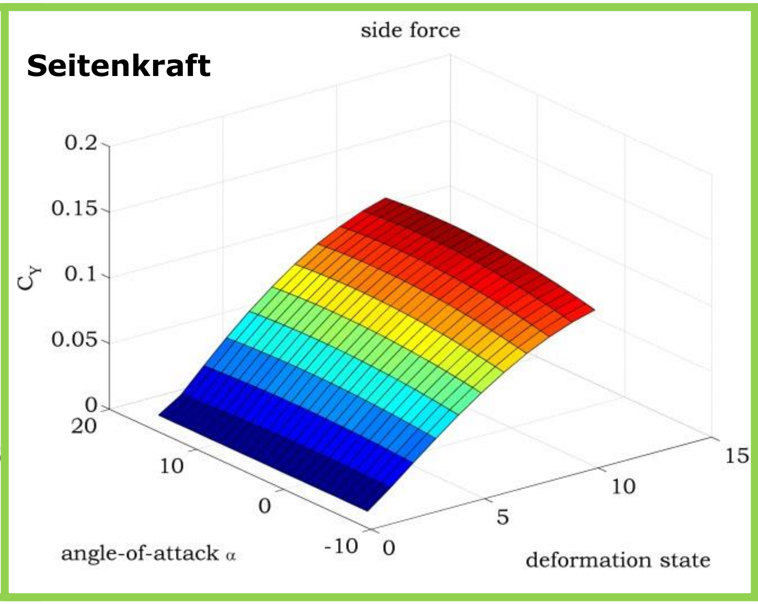


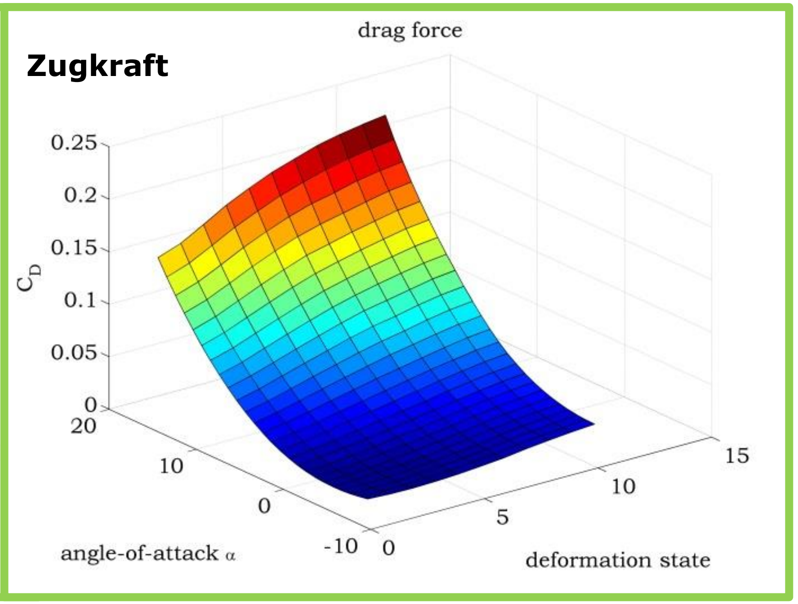


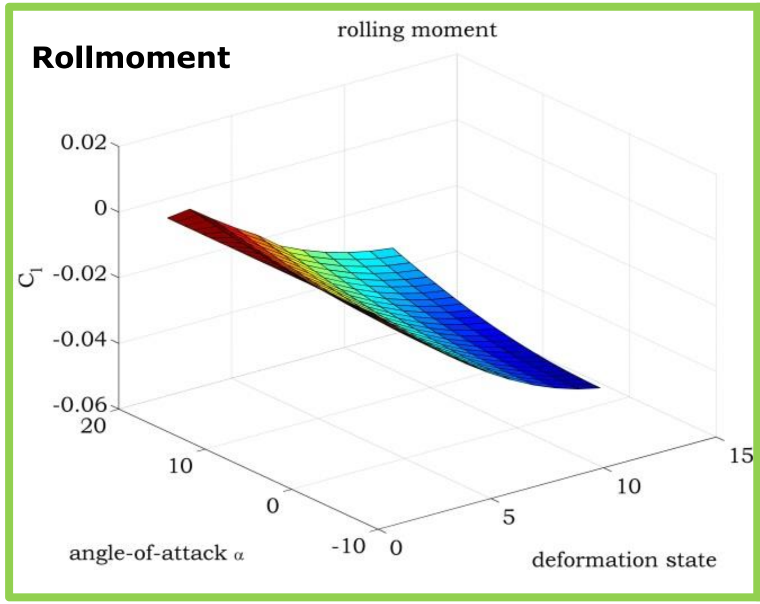
Quelle: Berechnungsgrundlagen Datei „Auftriebskraft Parameterstudie.xlsx“

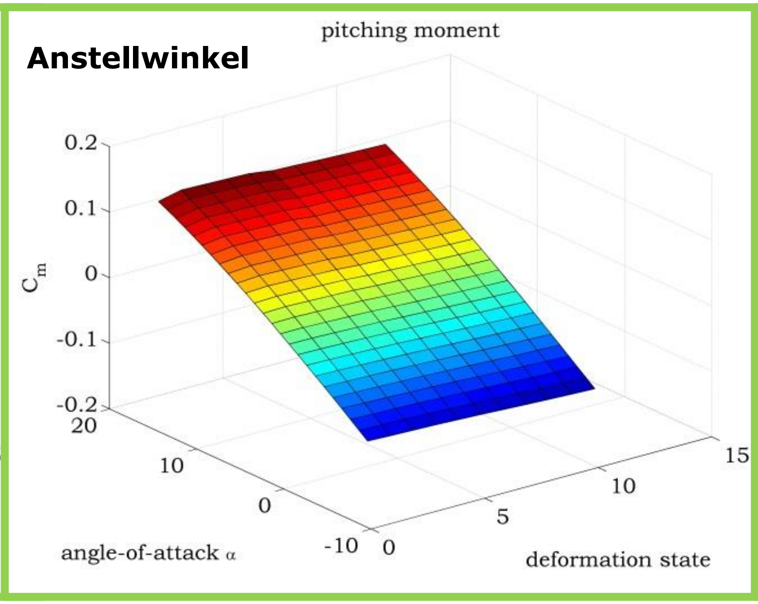
Die weiteren Kite Parameter:

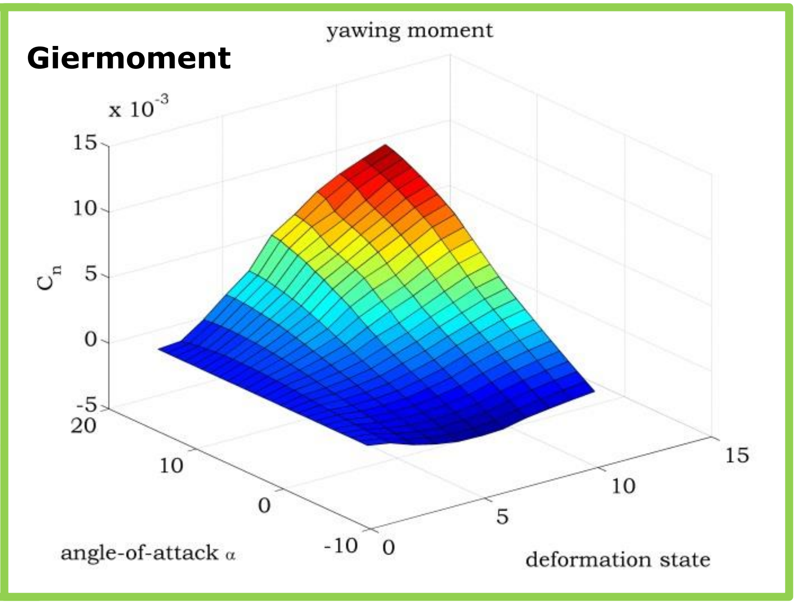




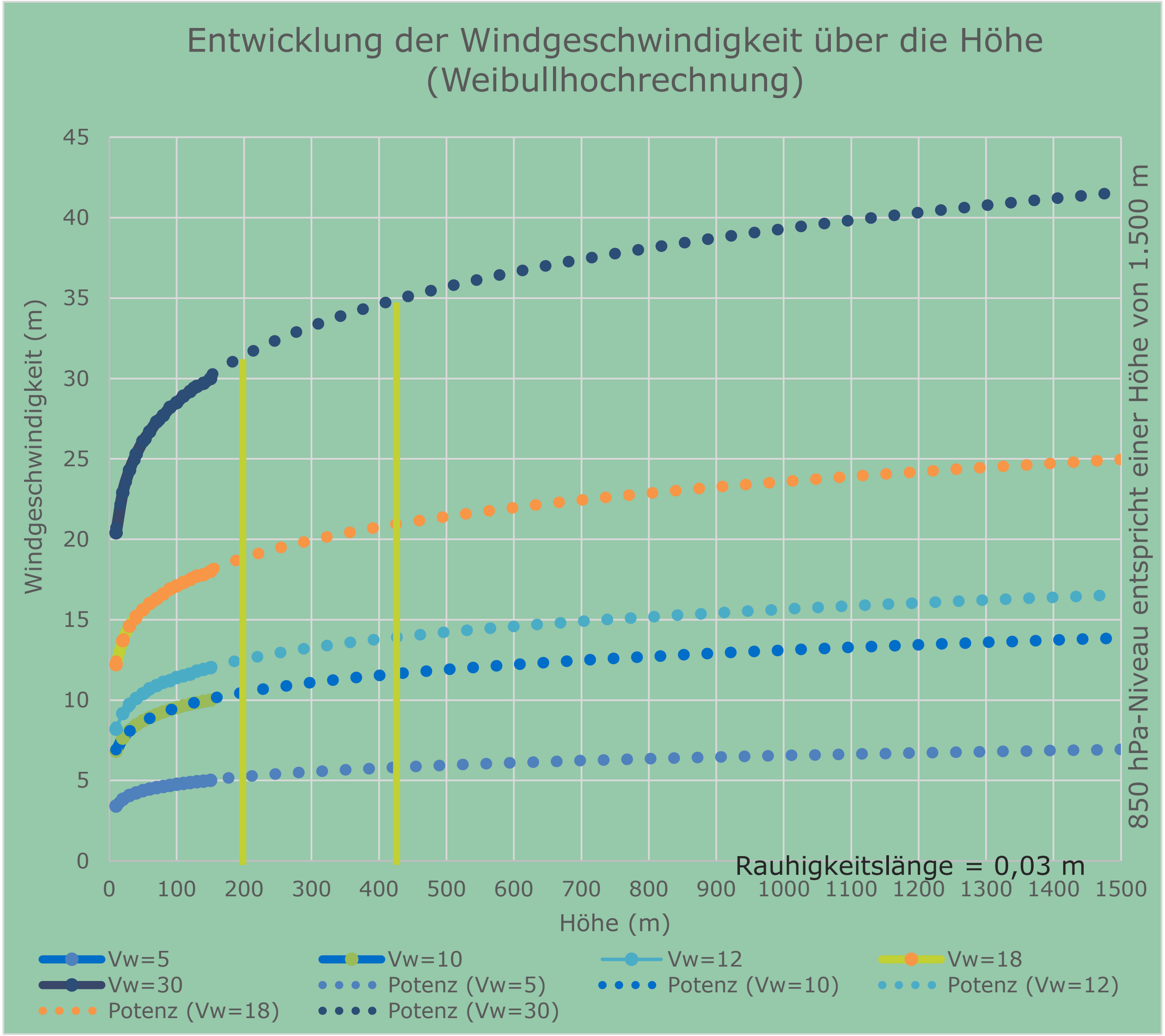


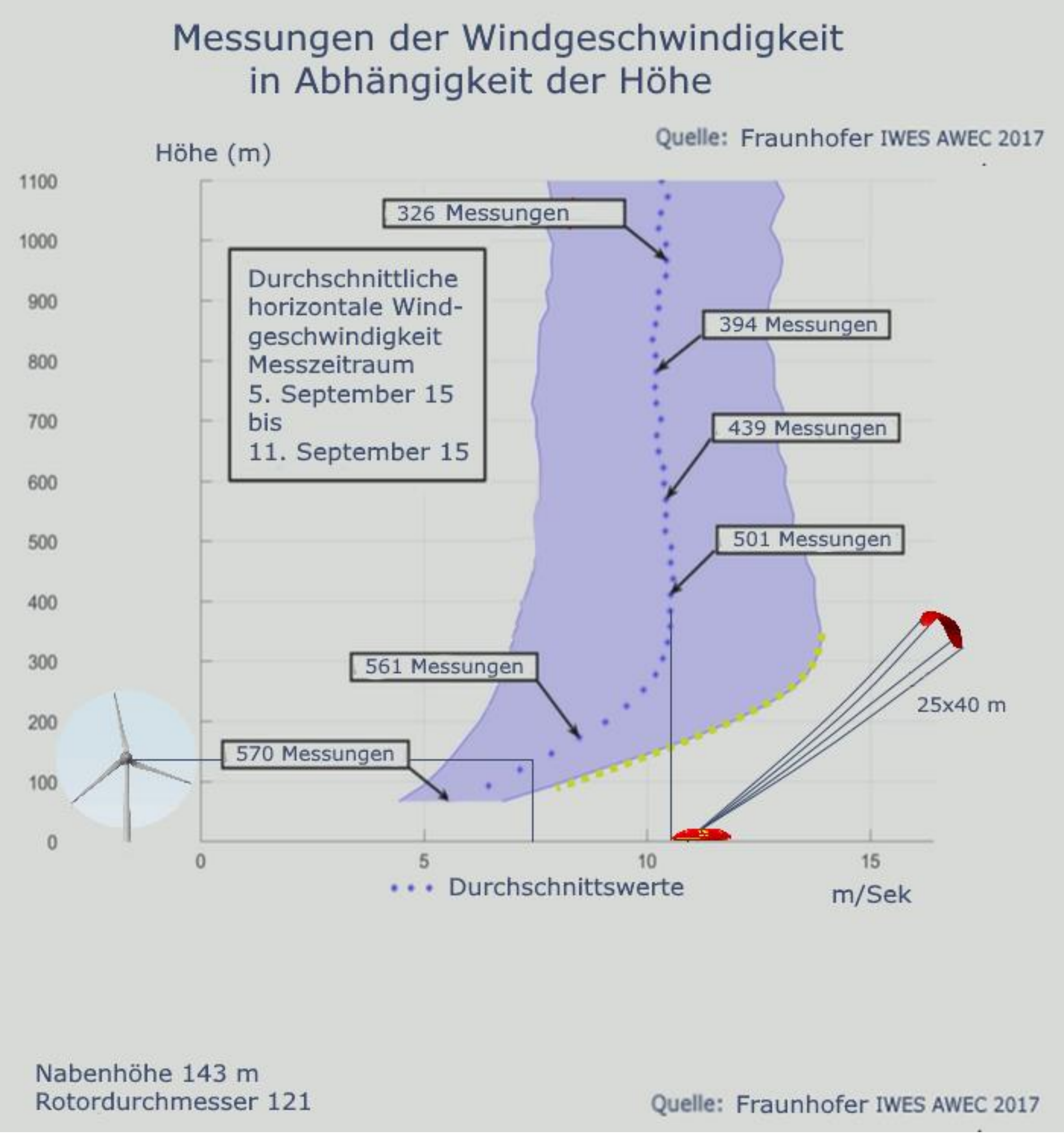






Die wichtigsten Winddaten



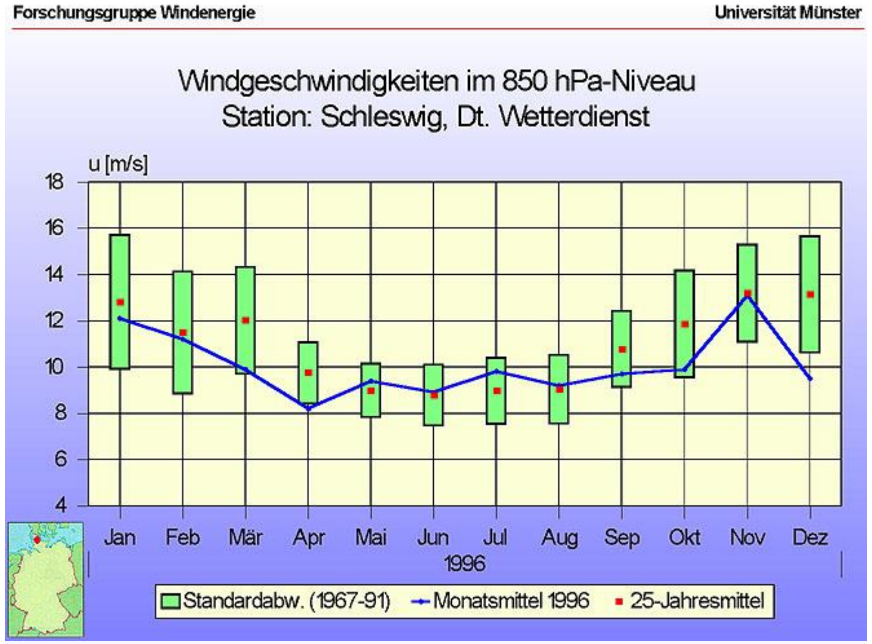


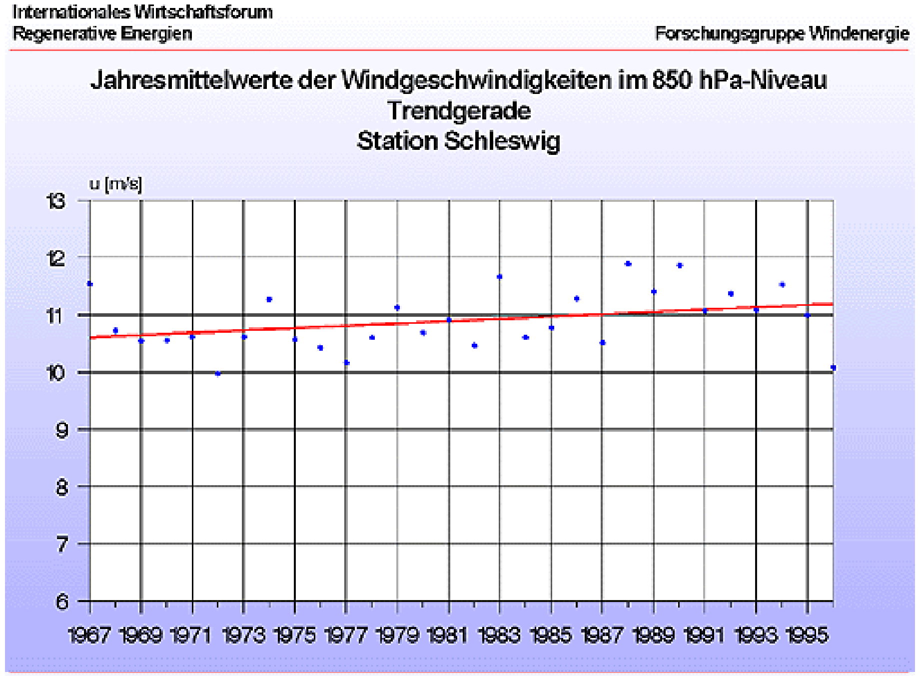
Quelle: https://wind-data.ch/tools/profile.php mit Regressionsanalyse ab 150 m.

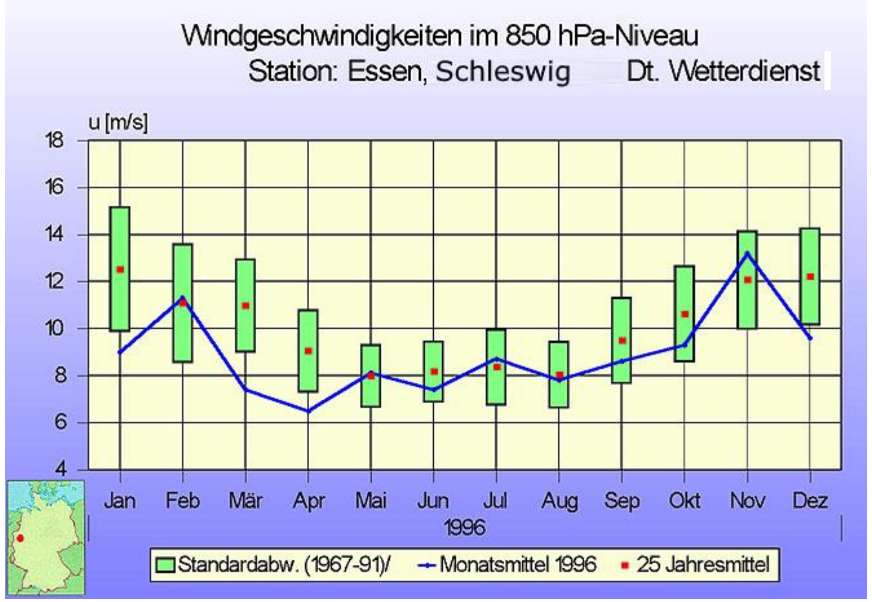
Anmerkung: Konventionelle Windkraftanlagen schalten bei ca. 12,5 m/Sek ab. X-Wind bei 35 m/Sek. Die hellgrünen Linien markieren den Arbeitsbereich der X-Windanlagen. Produktion auch bei 0 Bodenwind!

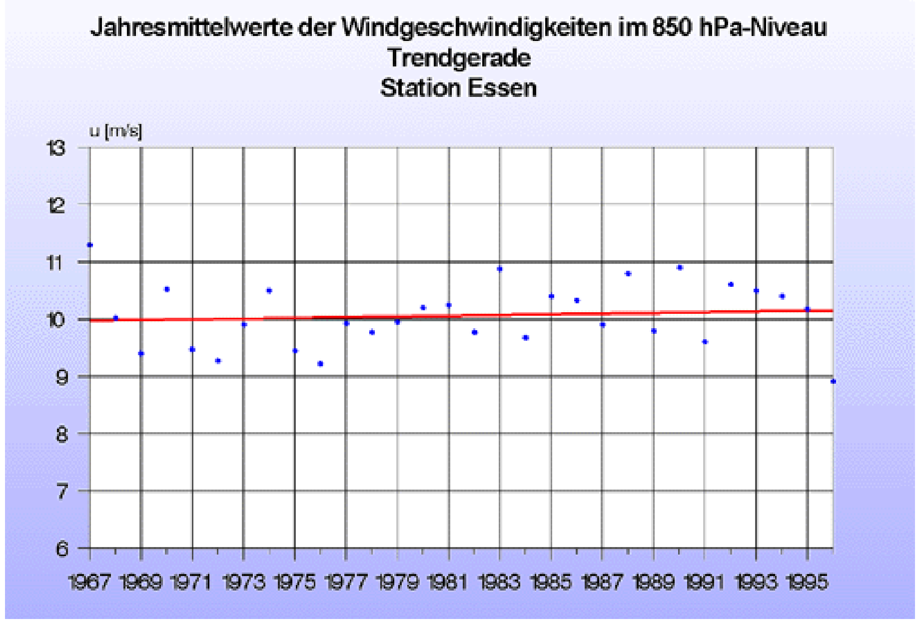
Die wichtigsten Winddaten zur Höhenwindnutzung

Das 850 hPa-Niveau entspricht einer Höhe von 1.500 m. Aus der IWES-Studie und mit diesen 4 Diagrammen wird belegt, dass die durchschnittlichen Windgeschwindigkeiten sowohl über die monatlichen als auch über die langjährigen Messungen nicht unter 8 m/s liegen.

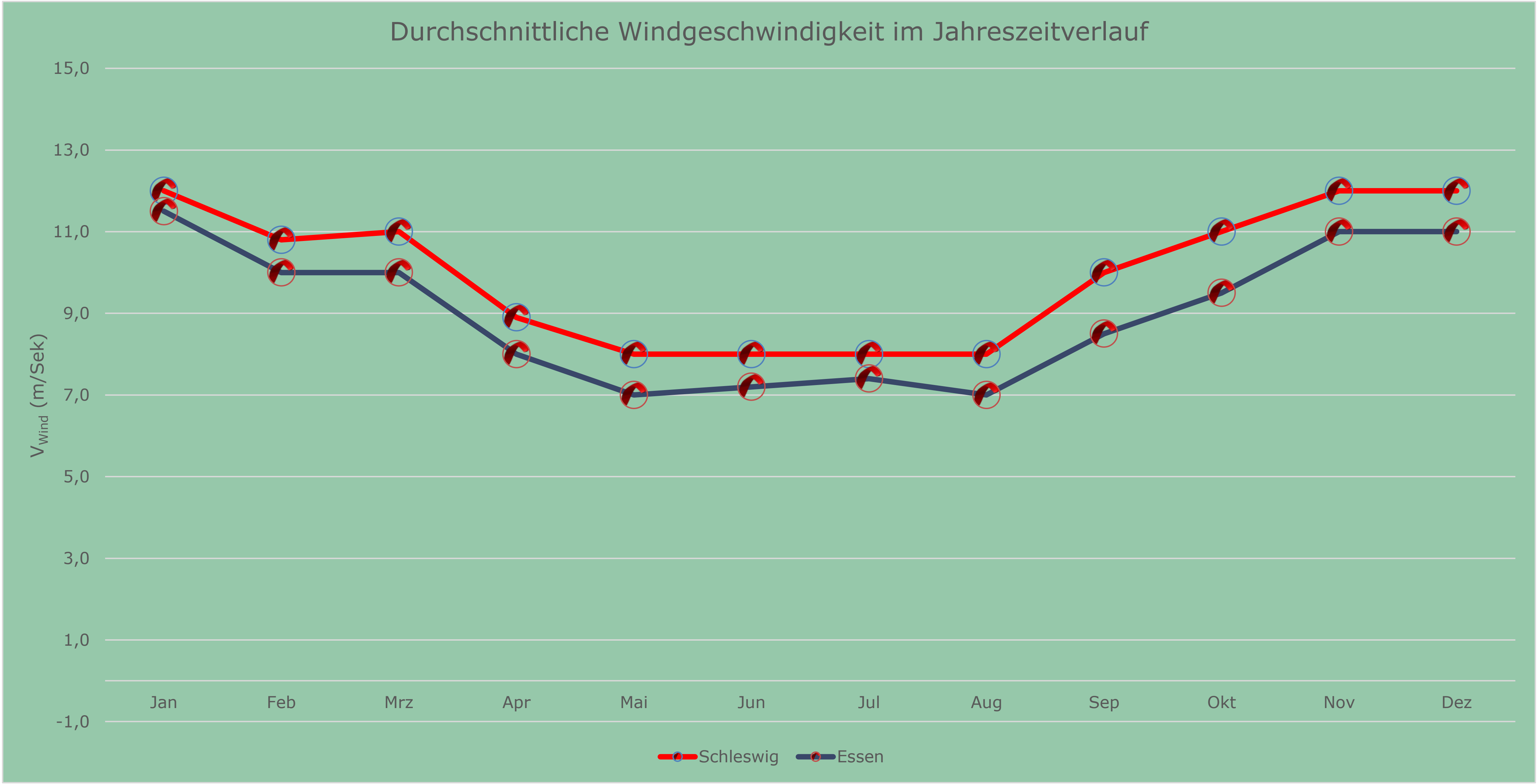






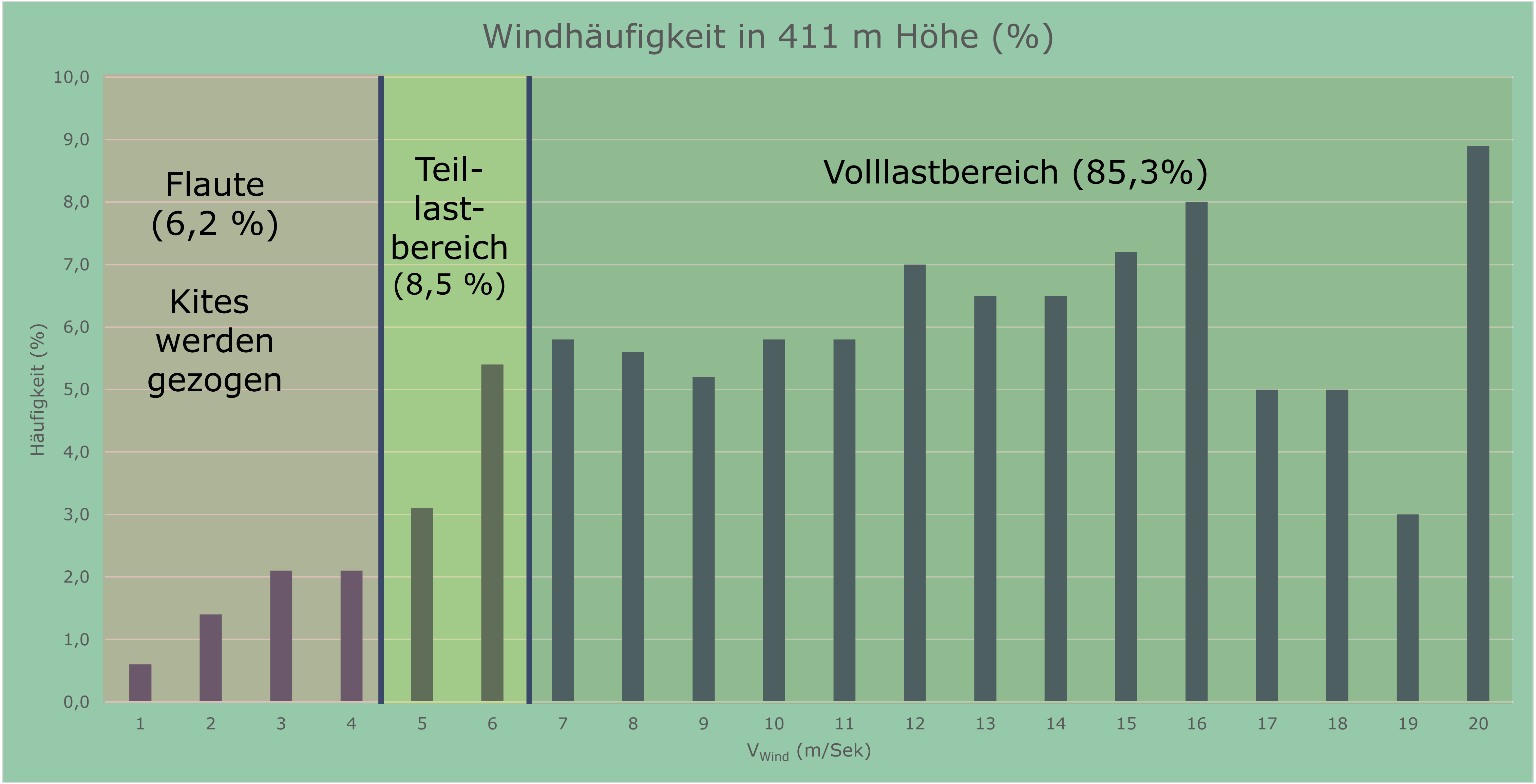


Die X-Winddatenannahmen zur Ertragsrechnung



Quelle: Deutscher Wetterdienst Anmerkung: Die Werte sind über die Weihbullkurven auf 500 m Höhe umgerechnet. Kalkulationsdetails: Ertragsbasiskalkulationen Essen und Schleswig

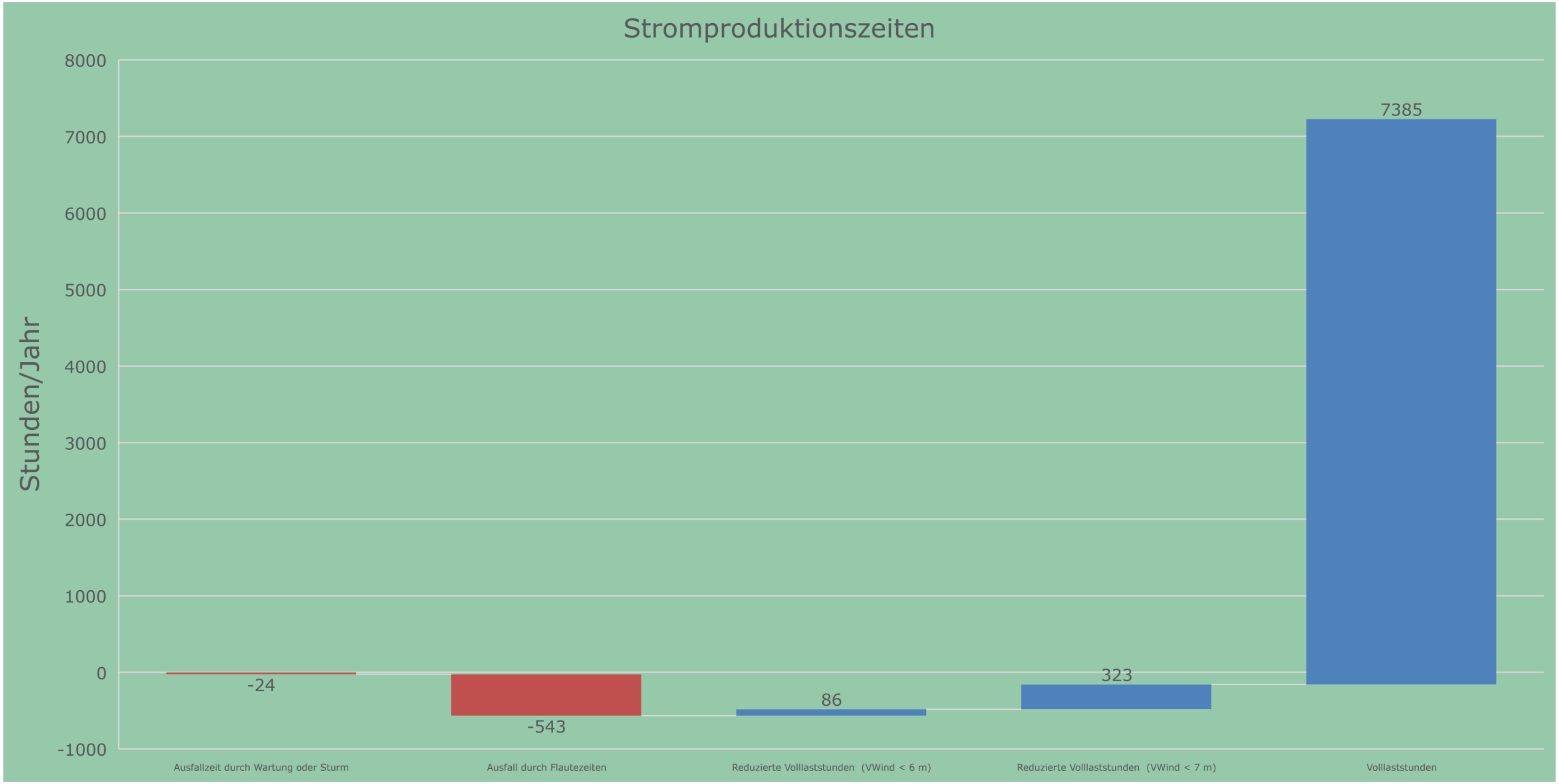
Die X-Winddaten zur Ertragsrechnung



Quelle: Fraunhofer IWES AWEC 2017

Anmerkung: Unter Berücksichtigung des Ertrages aus dem Teillastbereich liegt der Volllastbereich bei 89 %.
Zur Risikominimierung wird mit 75% Kapazitätsfaktor gerechnet!

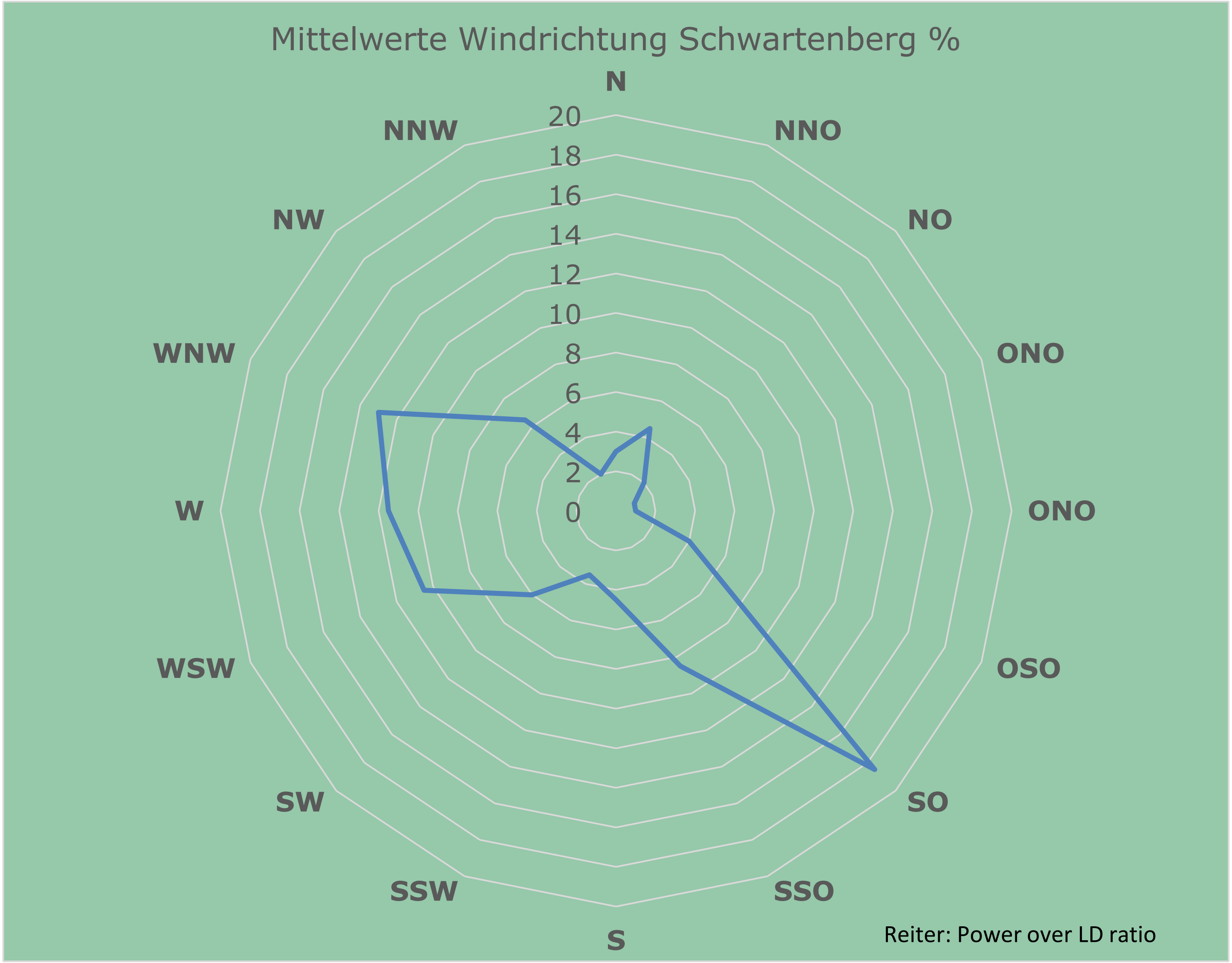
Die X-Winddatenannahmen zur Ertragsrechnung

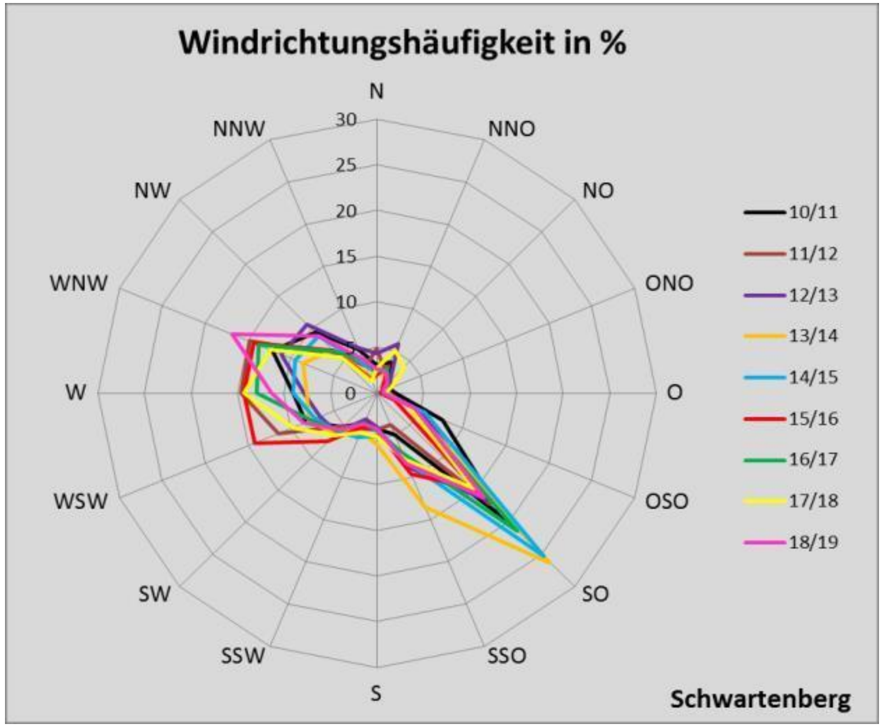


Quelle: Fraunhofer IWES AWEC 2017 / Deutscher Wetterdienst

Anmerkung: Für die Teillastbereiche wurden reduzierte Volllaststunden berechnet.

Streckenverlaufoptimierung





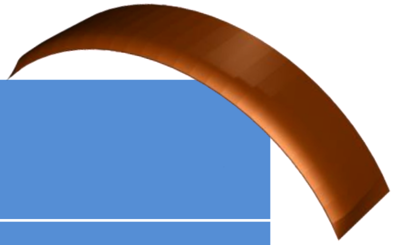
Kitedaten*

1 MW

2 MW

5 MW

8 MW

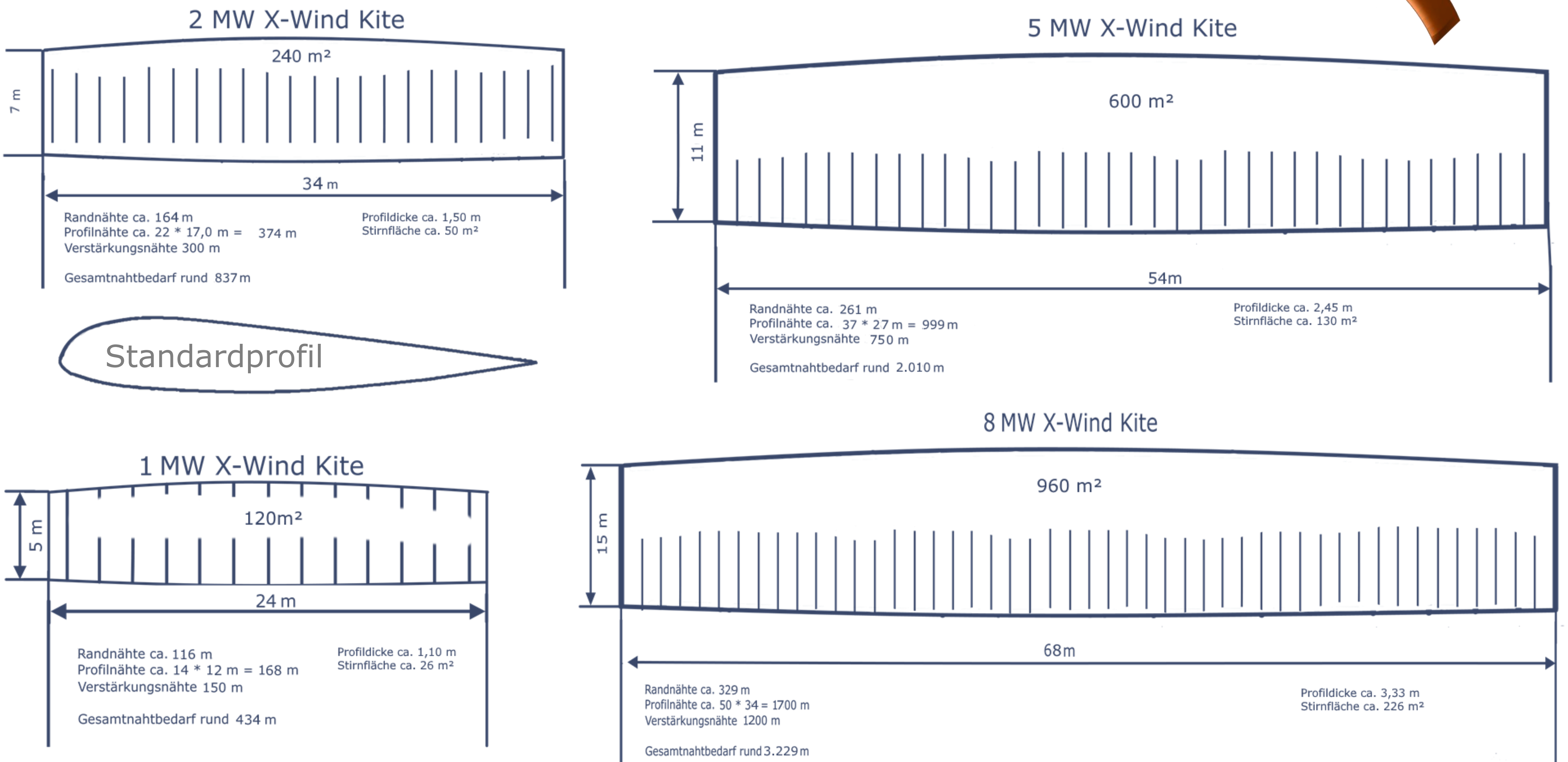


Kite	120 m²	240 m²	600 m²	960 m²
Breite	24 m	34 m	54 m	68 m
Tiefe	5 m	6,6 m	11 m	14 m
Gewicht	8 kg	14 kg	33 kg	65 kg
Naht-länge	434 m	837 m	2.010 m	3.230 m

Streckung ~ 4,5
Material Dyneema® Composite Fabric CT, 18 bis 26g/qm 1,37 m breit
Alternativ
Hochleistungssegeltuch (bis 240 g/m²). Führt zu einem maximalen Kitegewicht von bis zu 600 kg

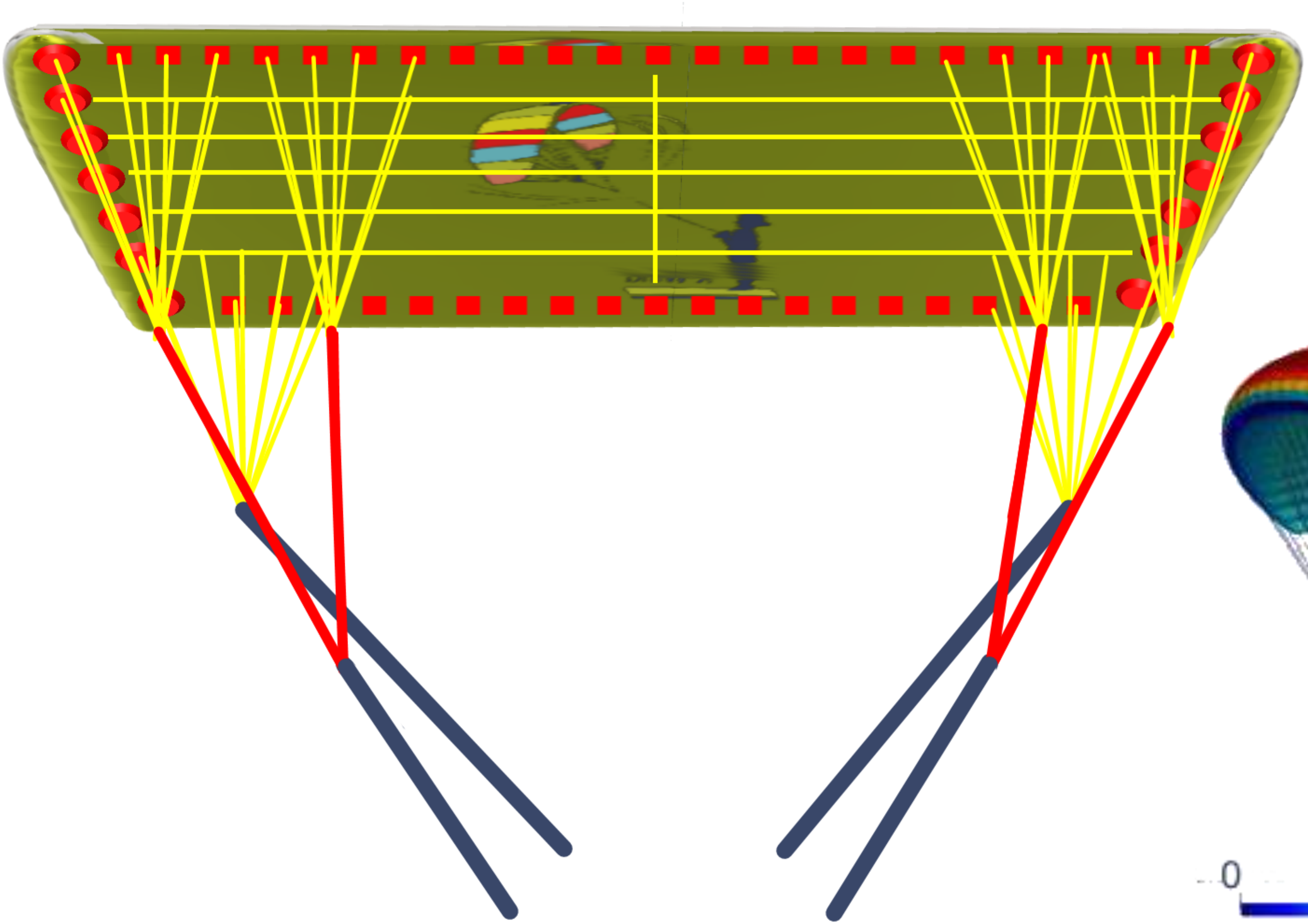
* Siehe auch X-Wind Datenblatt OTHE005002

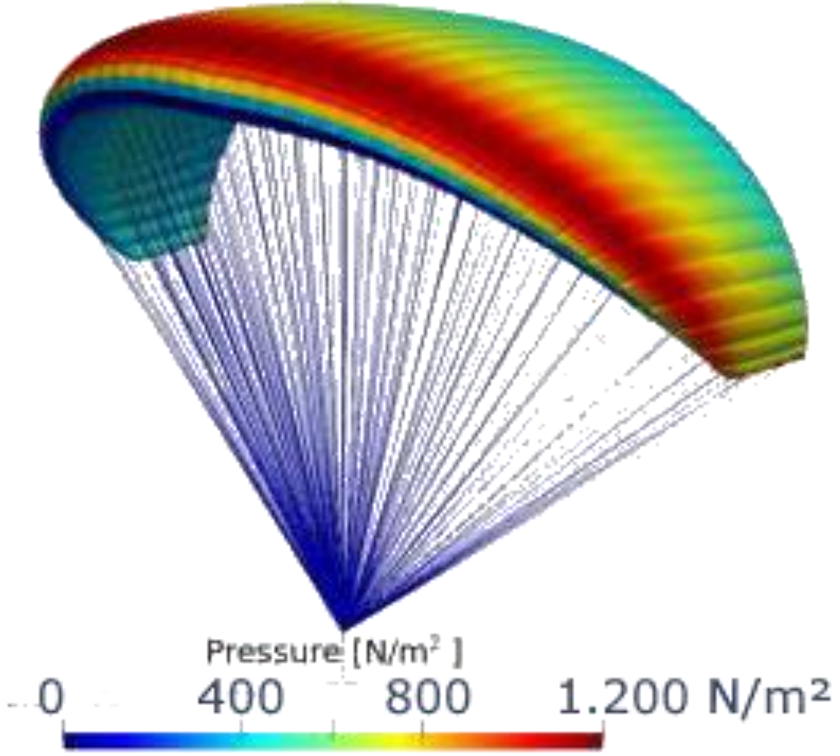
X-Wind Kite Schnittmuster



Bilddatei: Kiteabmessungen und Schnittmuster.png

X-Wind Waagleinen Prinzip





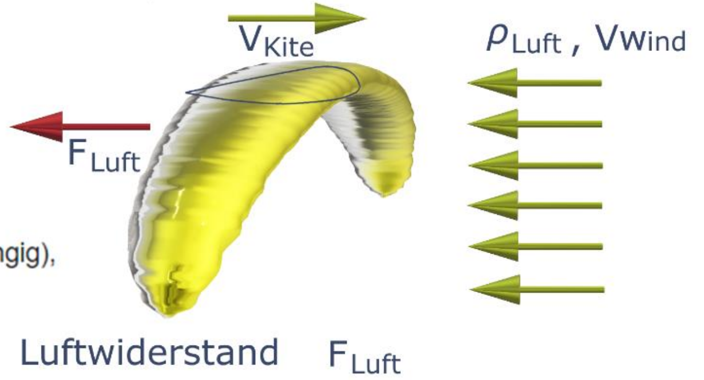
Anmerkung: X-Wind arbeitet mit einem 4 Leinenkonzept. Diese ermöglicht eine höhere Wendigkeit und größere Pitchwinkel. Die mittleren Waagleinen sind zur Vereinfachung der Darstellung nicht skizziert.

X-Wind Leerlaufwiderstandsabschätzung

- Der **Luftwiderstand** steigt quadratisch mit der Fahrgeschwindigkeit und ist abhängig von der aerodynamischen Form des Fahrzeuges (Luftwiderstandsbeiwert) und der Luftdichte:

$$F_{\text{Luft}} = c_{\text{W}} \cdot A \cdot \frac{\rho_{\text{Luft}} \cdot v_{\text{rel}}^2}{2}$$

F_{Luft}	Luftwiderstandskraft in [N]
ρ_{Luft}	Luftdichte in [kg/m³] (auf Meereshöhe bei 20 °C etwa 1,2 kg/m³)
c_{W}	von der Form des Fahrzeuges abhängiger Strömungswiderstandskoeffizient/Luftwiderstandsbeiwert (geringfügig geschwindigkeitsabhängig), dimensionslos [-]
A	Projizierte Stirnfläche (Stirnfläche im Schattenriss) in [m²]
v_{rel}	Relativgeschwindigkeit $(v_{\text{Fzg}} + v_{\text{Wind}})$ des Fahrzeuges in [m/s]



Bilddatei: Luftwiderstandsformel.png

Notwendige Energie für den Leerlaufbetrieb pro Stunde		
Powerunit 1 MW =	11,4	kWh
Powerunit 2 MW =	15,0	kWh
Powerunit 5 MW =	26,3	kWh
Powerunit 8 MW =	38,9	kWh

Bemerkung: Voraussetzungen: V_{Wind} < 4 m/Sek. Powerunit Geschwindigkeit 5 m/Sek.
Detailrechnung Datei: 2021-05-01 Basisdatensammlung NTS 33, Reiter PM Zugkraft