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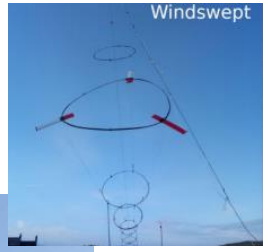
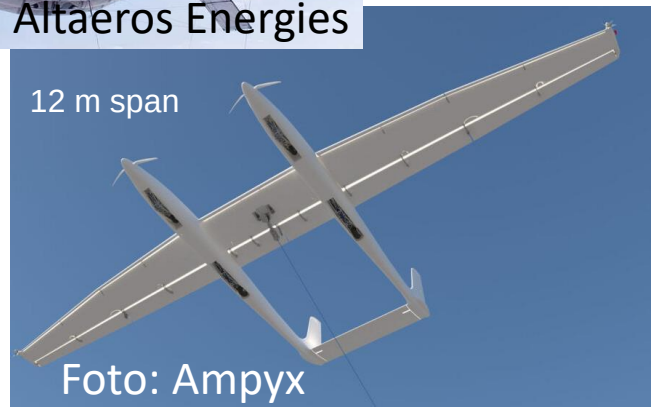
ENERWING

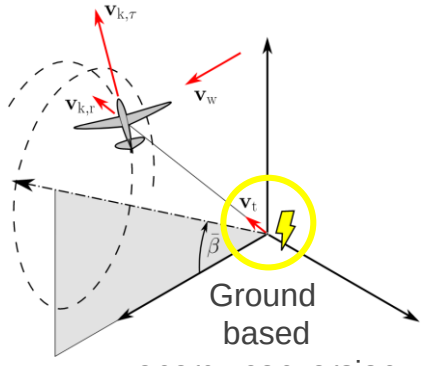
ENERWING –
Innovative Airborne Wind Energy Systems

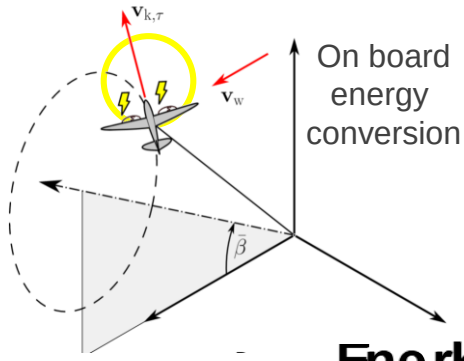
F. Breipohl
M. Kleineberg

Airborne Wind Energy (AWE) Systems









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https://awesco.eu/awe-explained/

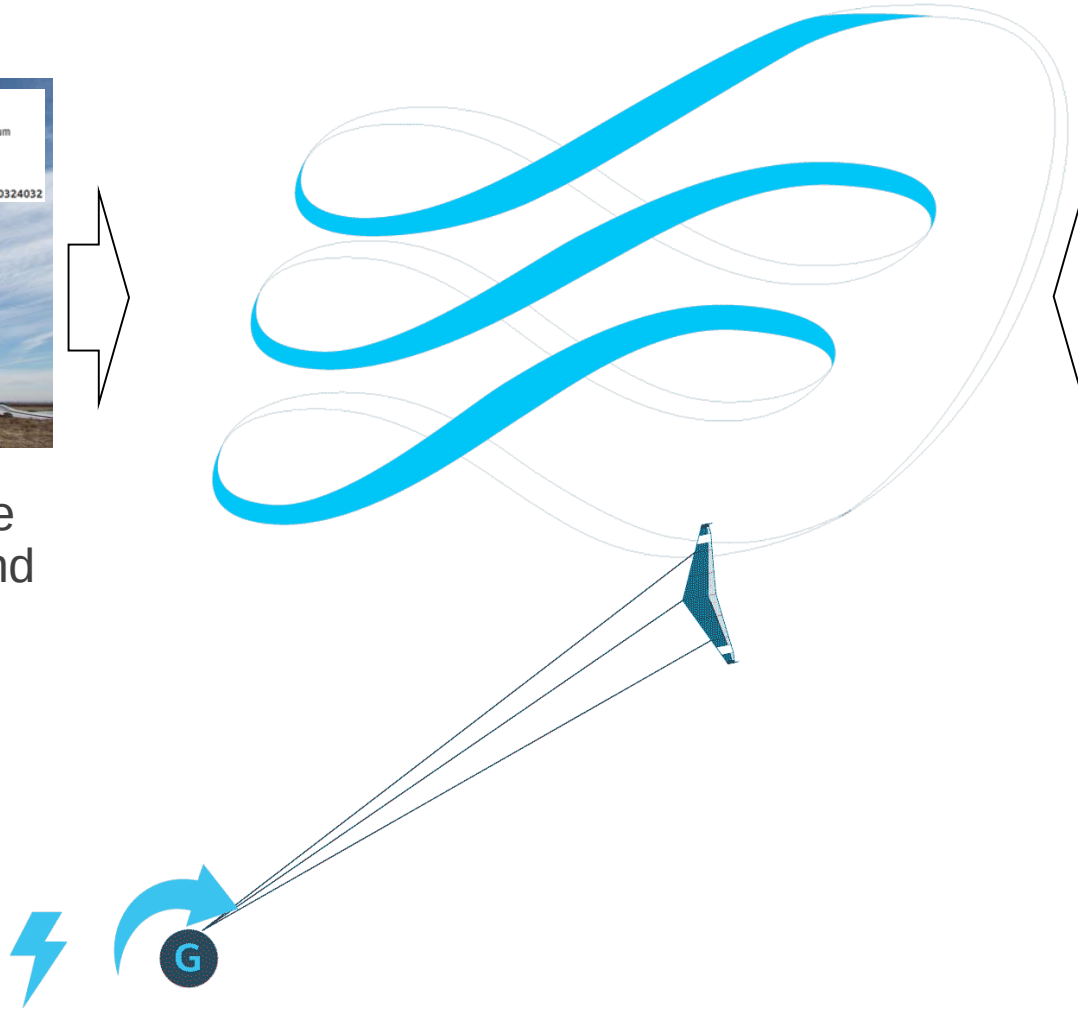
ENERWING – Wind Energy Harvesting with an Airborne Platform

Characteristics

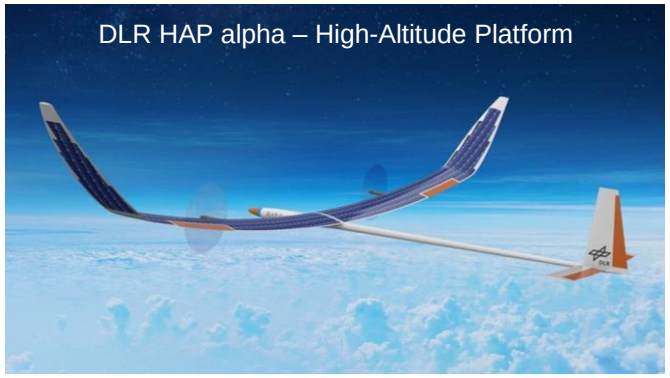
Wind Turbine

500kW Wind Energy Turbine with 3 GFRP rotor blades and conventional generator

- Robustness
- Cost Efficiency
- Typ. Elevation 100 m



Unmanned Aerial Vehicles



Energy autarkic High Altitude Platform prototype with solar cells and Li-Ion batteries

- Extreme Weight Demands
- Air Worthiness
- Operating Hight: 20.000 m

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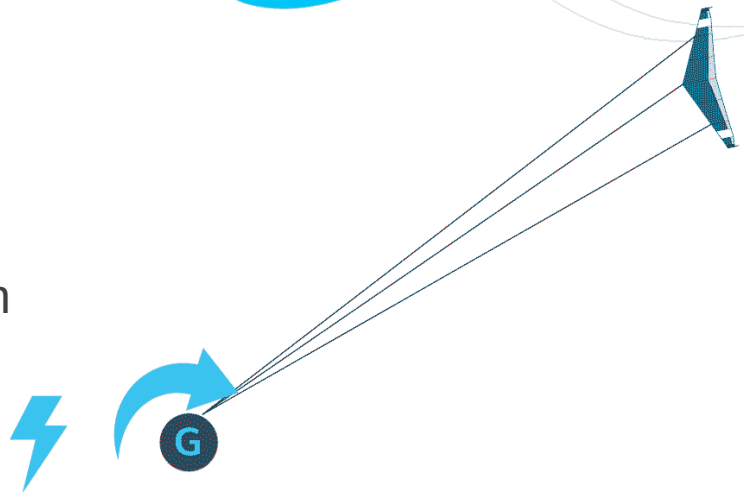
ENERWING – Wind Energy Harvesting with an Airborne Platform

Design / Manufacturing

Wind Turbine

- Bonded GFRP-sandwich shells & GFRP-spar
- Shells and spars produced in resin infusion technology



Unmanned Aerial Vehicles

- Bonded sandwich ribs and tubular spar elements
- Machined sandwich panels
- Prepreg-layup spars

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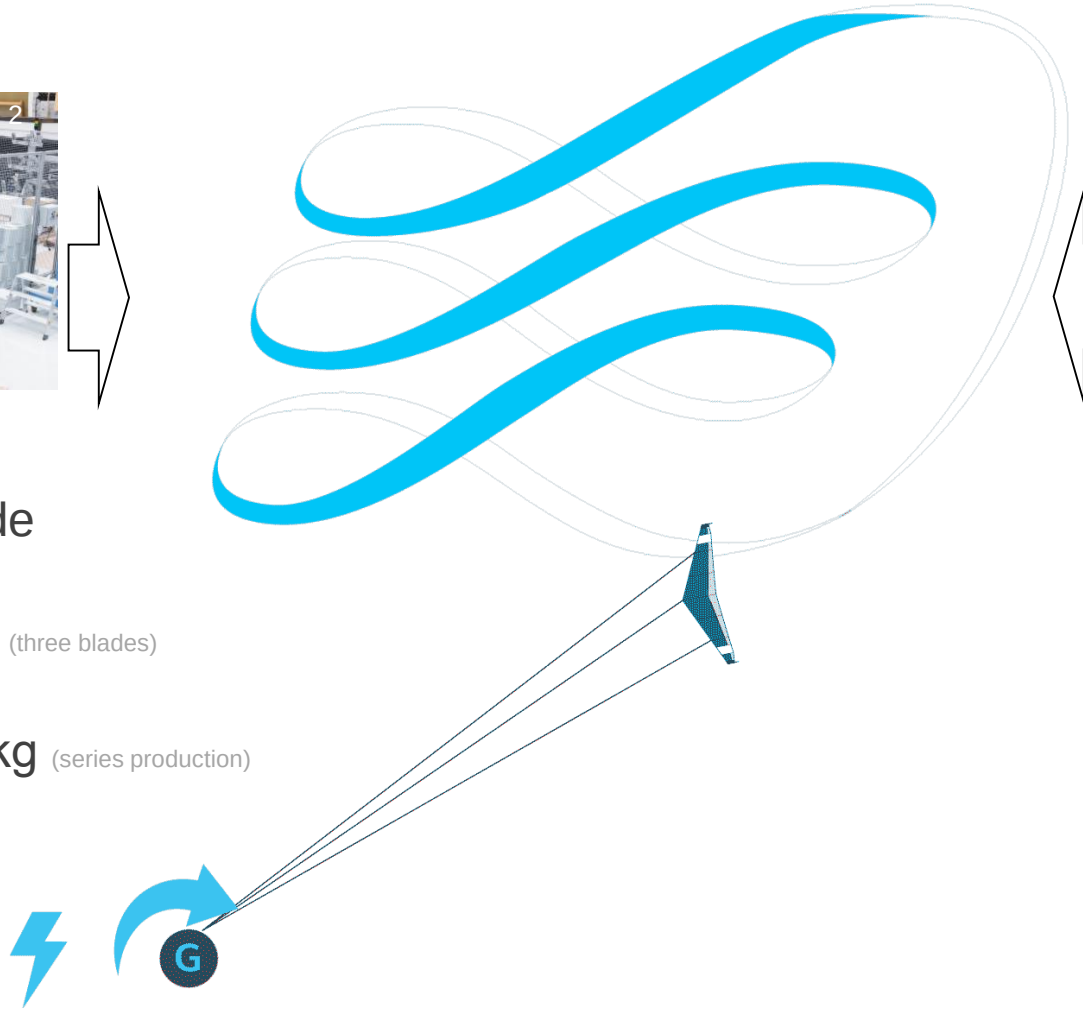
ENERWING – Wind Energy Harvesting with an Airborne Platform

Key Pertformance Indicators

Wind Turbine

Gefördert durch:
Bundesministerium für Wirtschaft und Energie
Förderungskennzeichen: 0324032

- Mass: 1.800 kg, 20 m blade
- Power output: 3 x 167 kW (three blades)
- Production cost: ca. 10 €/kg (series production)
- Lifetime: ca. 20 years



Unmanned Aerial Vehicles

- Mass: 36 kg, 27 m wing
  (Mass of solar cells (ca. 8 kg) & batteries not included)
- Solar power output: 8 kW
- Production cost: >10.000 €/kg
- Lifetime: *“we will see …”*

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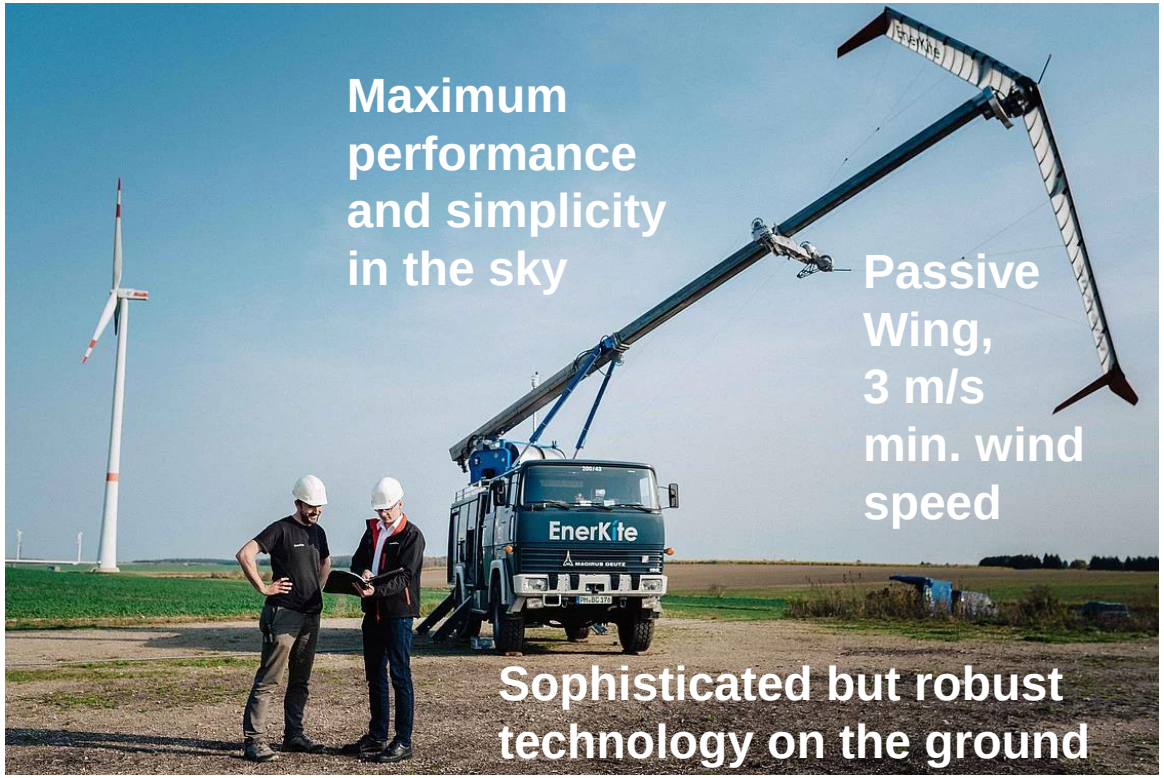
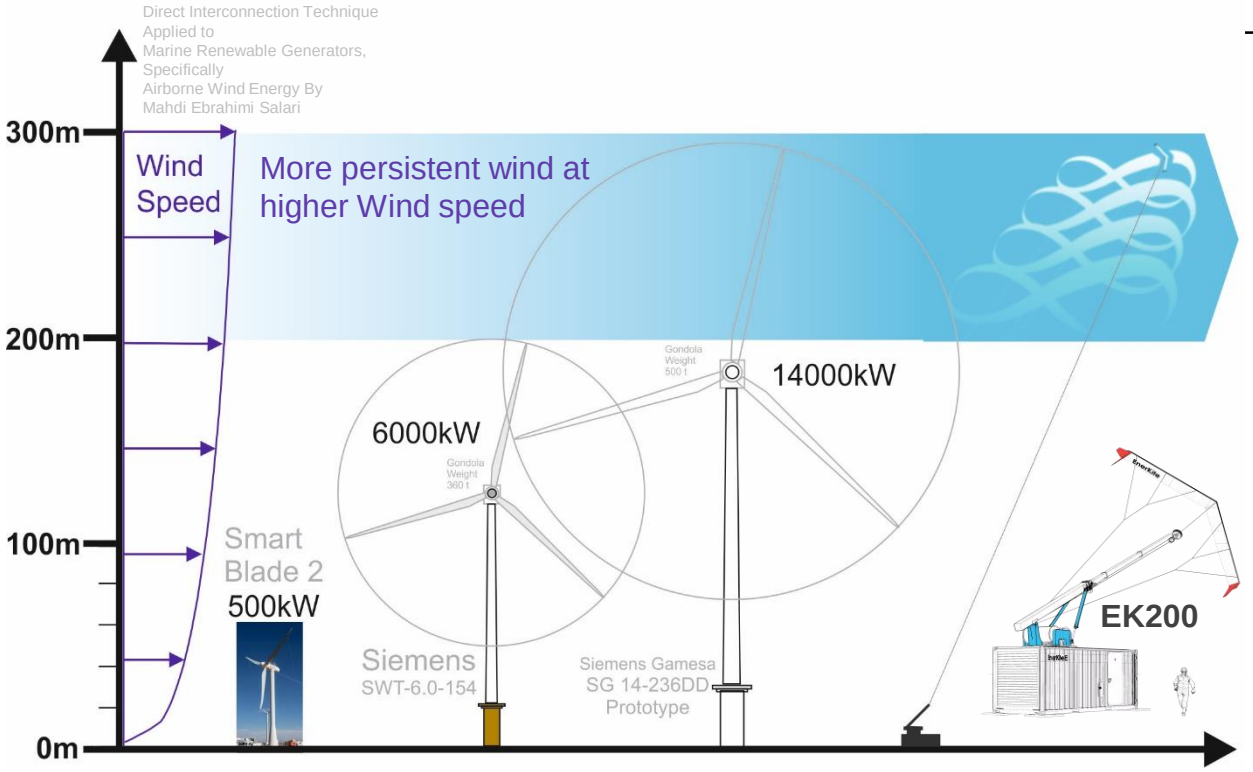
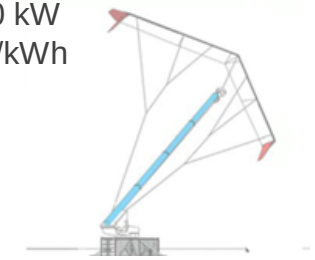
ENERWING – Status & Perspective

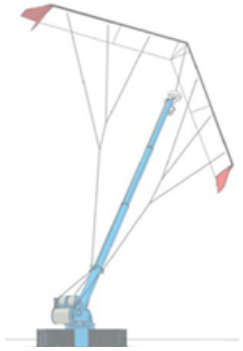




EK1M
500 kW
5ct/kWh



EK4M
2000kW
3ct/kWh



Nominal Power: 100 kW
Wing: 30 sqm
Energy gen. cost: 9 ct/kWh
Form Factor: 20 ft Cont.
Mass: 12,5 t

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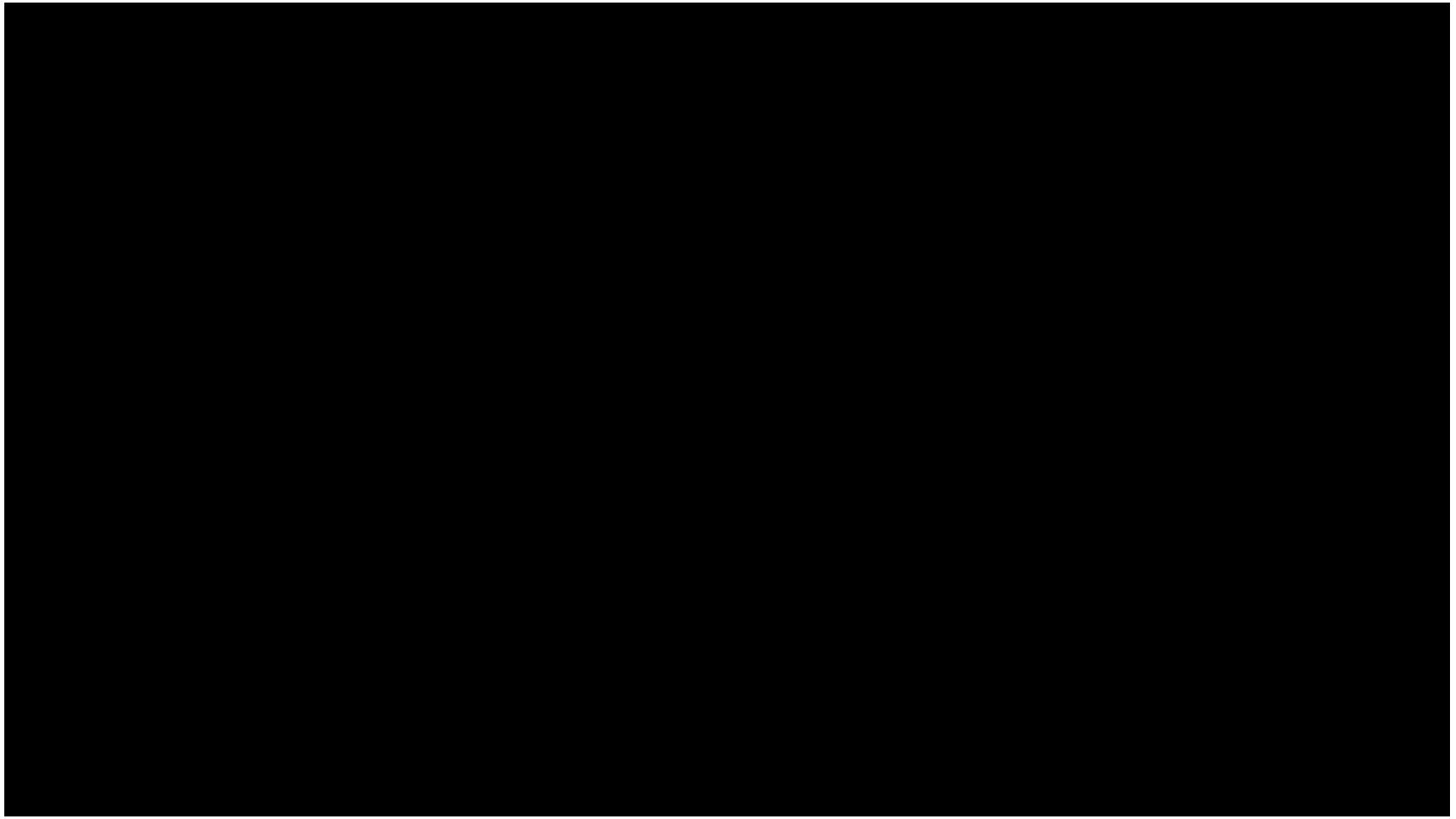
ENERWING – Status & Perspective



1 Harvest + Retraction Cycle per minute

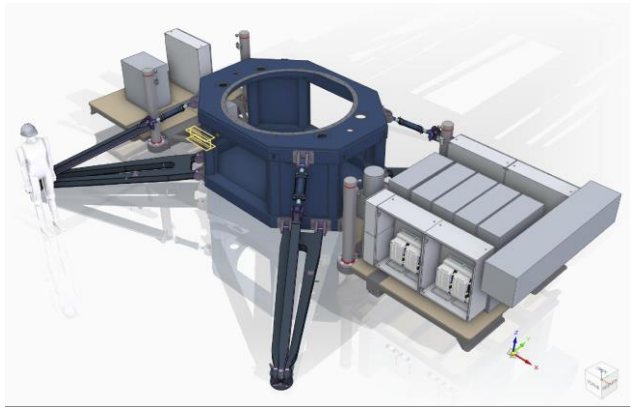
420.480 Cyc./year

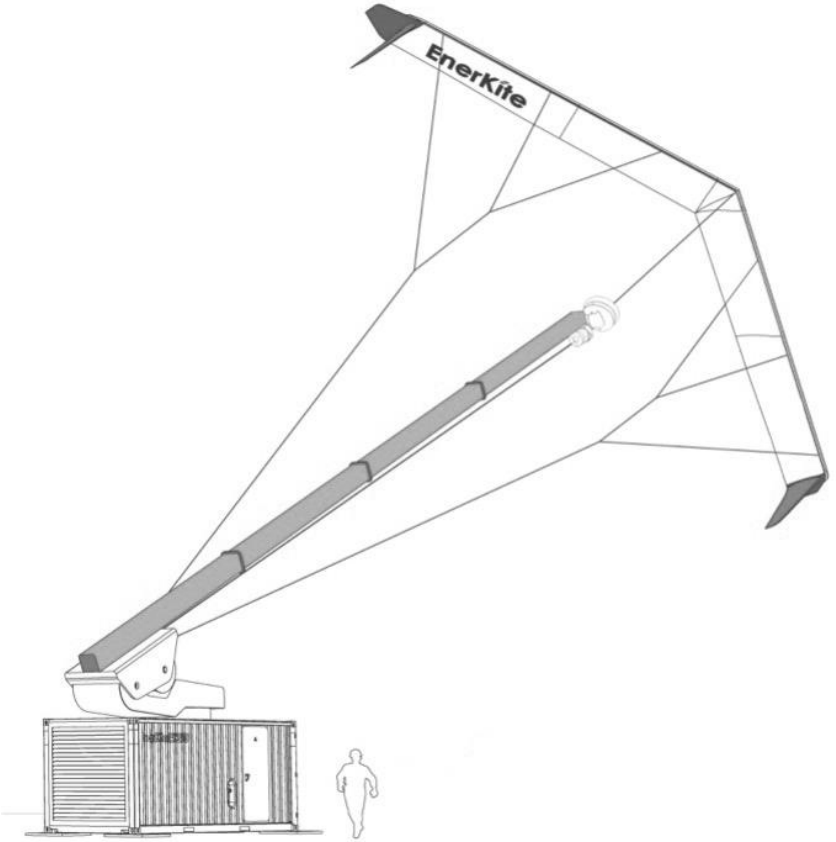
4.204.800 Cyc./Lifetime

Ready for Product-Development

Technical proof of concept – fully autonomous operation 2021 -2022

Airborne Wind Energy
ENERWING





Test System

EK30 30 kW 2012 - 2022

Prototype

EK30 V3 2023

EK200 P
100 kW 2024

Series Product

EK 200 100 kW 2026

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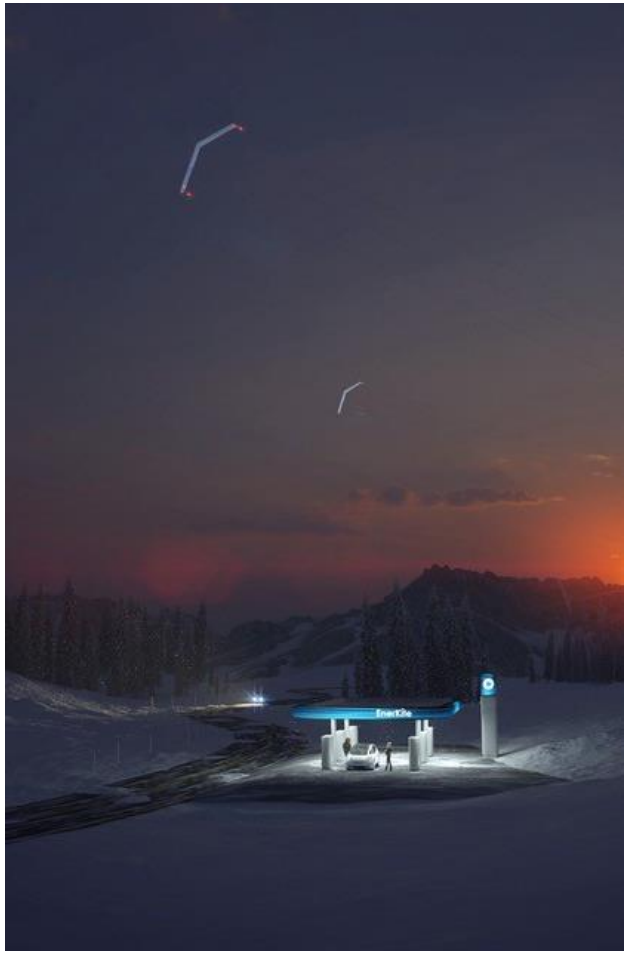
ENERWING – Application (Huge Market potential)

The three relevant target markets for the 100kW-EnerKíte system are:

- **Self supply** – Pilotproject at an organic farming operation in Brandenburg
- **Micro-Grids** – Pilotproject with e.disnatur in Brandenburg
- **E-Mobility** – Pilotproject with VW Elli



ENERWING – Application (Huge Market potential)

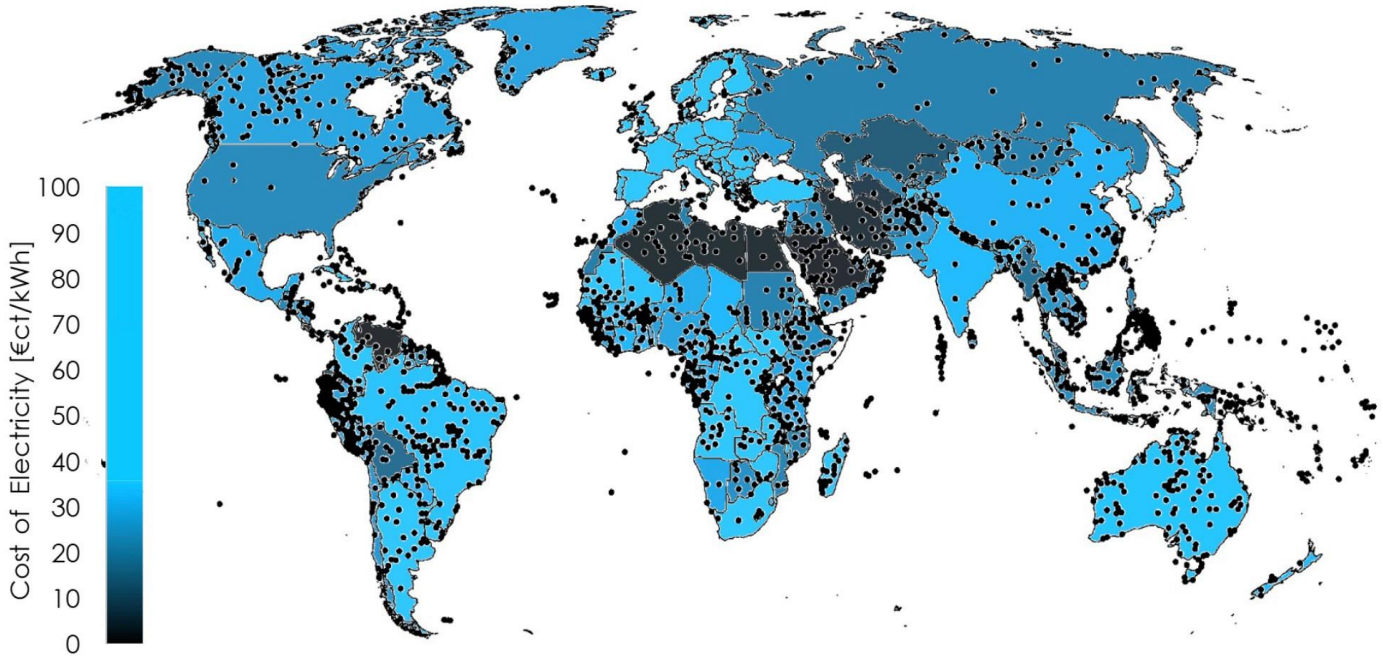
John Deere:

Werk Mannheim

- 3.200 Workers
- 40.000 Tractors/Year
- Bis zu 180 Tractors /Day

- Motors from France
- Cabins from Bruchsal/Germany
- Up to 30.000 Parts per tractor
- Duration of Assembly 4h

Mini Grids only: 220 Bn. $ in 12 y to 2030



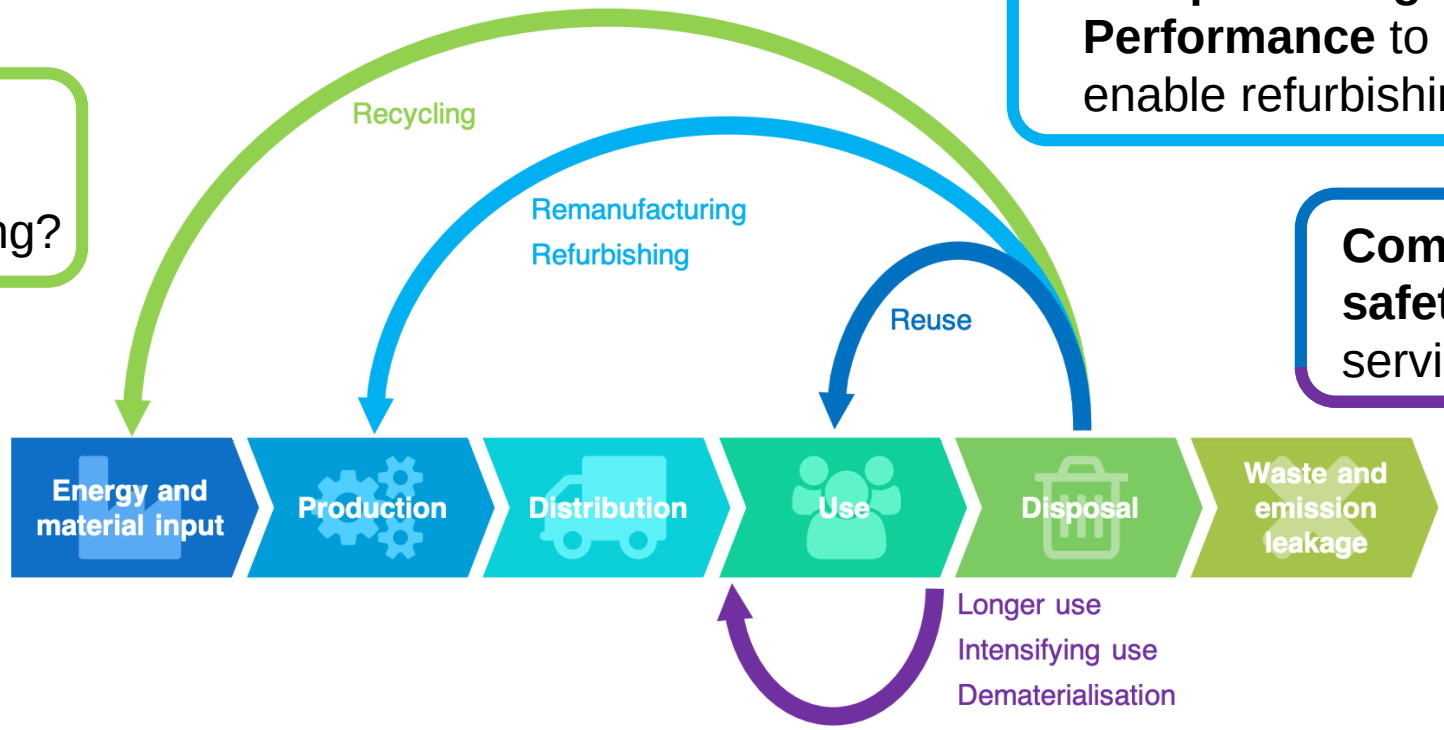
ENERWING – Sustainable Composite Wing Structure

“Re”-cycling
or
“Down”-cycling?

Circular Economy of Airborne Applications

Compromising Performance to enable refurbishing?

Compromising safety due to unknow service history?



Geissdoerfer, M., Pieroni, M.P., Pigosso, D.C. and Soufani, K. (2020). "Circular business models: A review" (PDF). Journal of Cleaner Production. 277: 123741. doi:10.1016/j.jclepro.2020.123741. S2CID 225282542.

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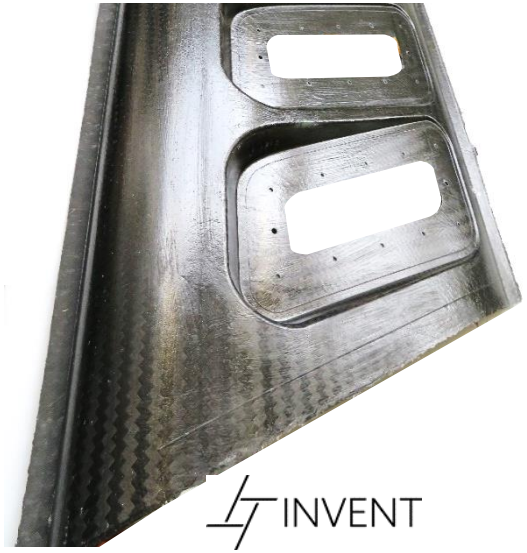
ENERWING – First Prototypes



“Integral-Monocoque Design”:

- Full exploitation of composite 3D-shaping advantage enables robust, light weight design
- Precise aerodynamic shape at the sensitive leading edge

“Differential Spar & Rib Design”:

- Standard tube and plain sandwich-panels can be produced in a cost efficient way
- Semi-finished products and airfoil design can easily be varied adapted and scaled
- No extensive tooling required

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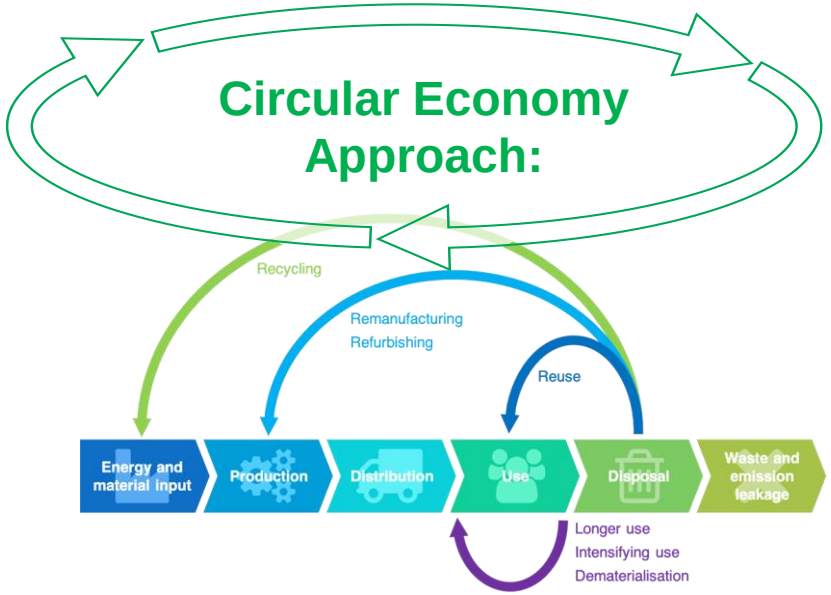
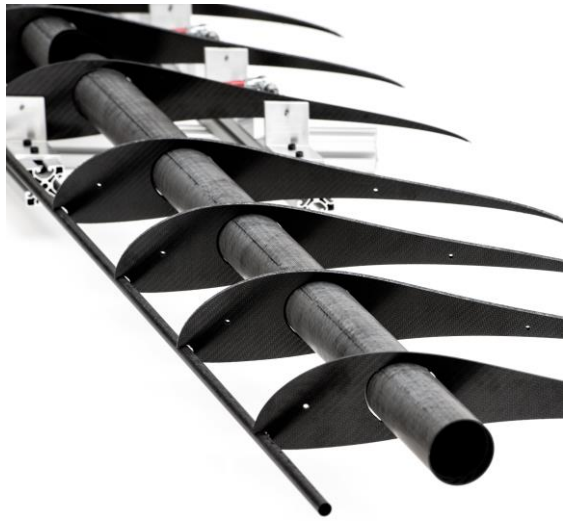
ENERWING – First Prototypes





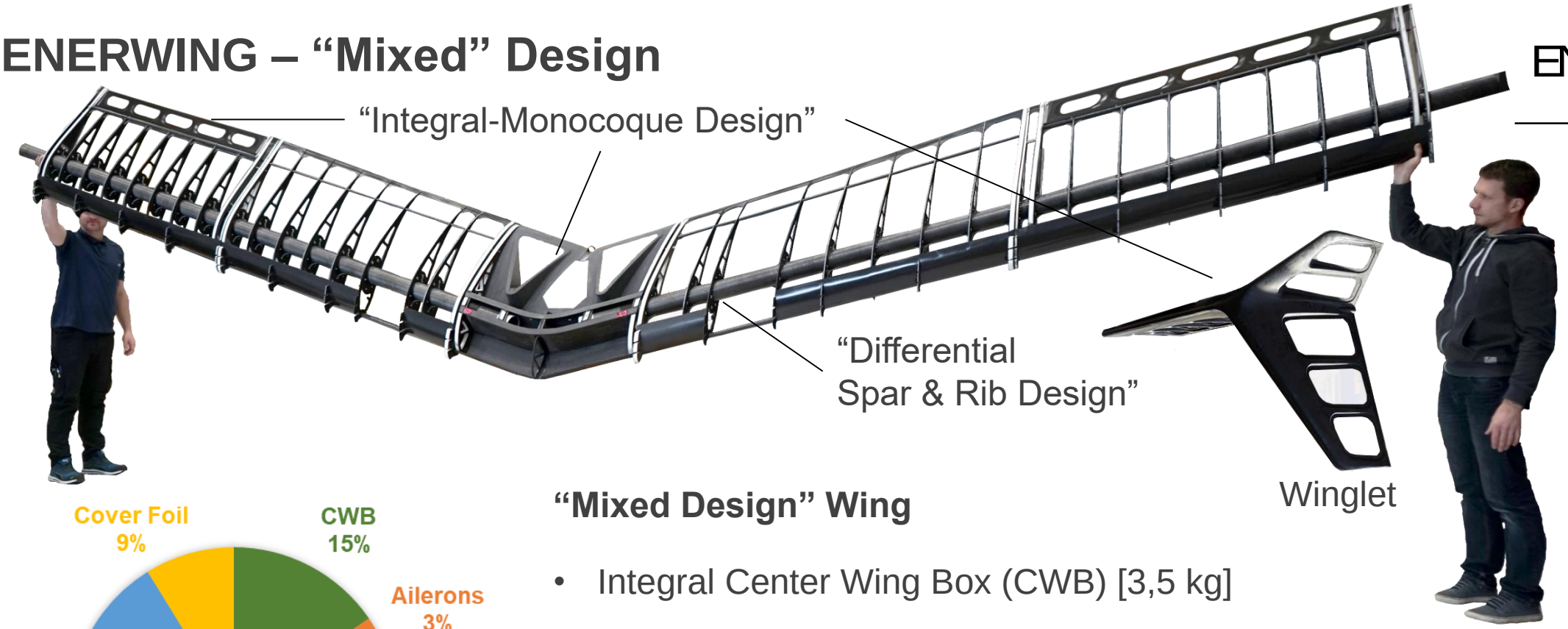
“Integral-Monoqoque Design”:

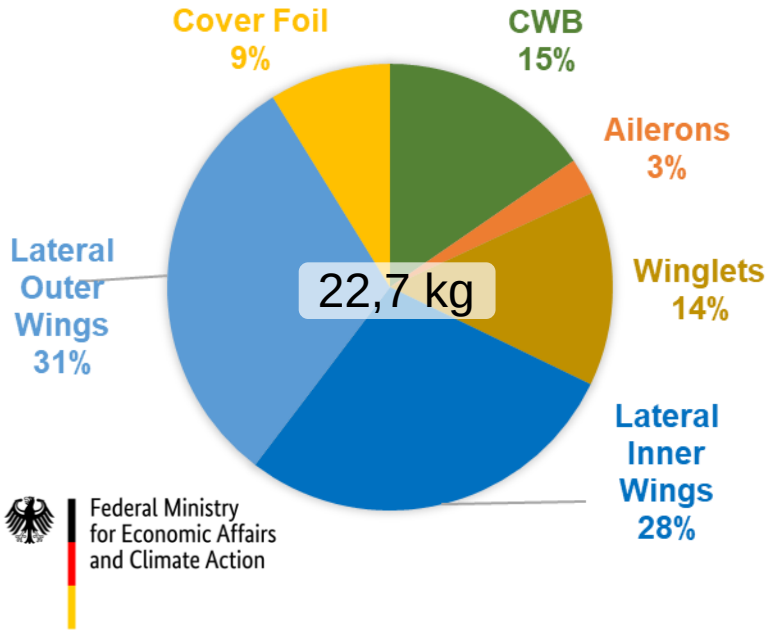
Aerodynamically efficient wing to maximise energy harvesting → opt. Utilisation

“Differential Spar & Rib Design”:

Energy efficient, automated production of simple standard components → opt. Production

ENERWING – “Mixed” Design





“Mixed Design” Wing

- Integral Center Wing Box (CWB) [3,5 kg]
- Integral ailerons [2 x 0,3 kg] & winglets [2 x 1,6 kg]
- Differential inner lateral wing segments [2 x 3,2 kg]
- Differential outer lateral wing segments with ailerons [2 x 3,5 kg]
- Aerodynamic Cover Foil [2,0 kg]

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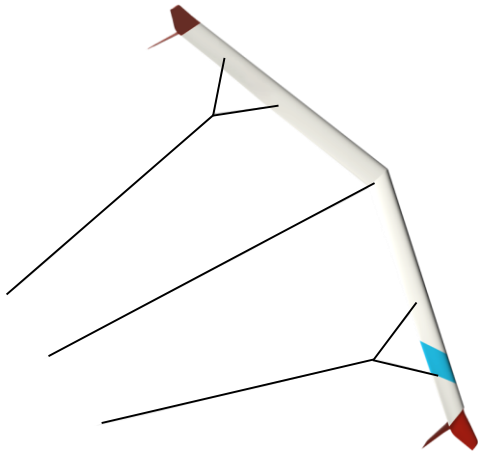
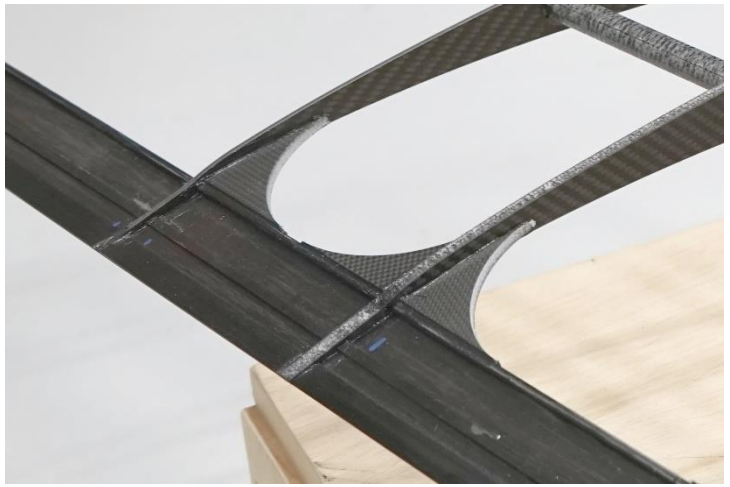
ENERWING – “Mixed” Design

Critical Wing Details
Differential outer lateral wing

- Slat attachment / foil cover
- Spar to rib attachment
- Aileron bearing
- Trailing edge reinforcement
- Adjustable tether joint





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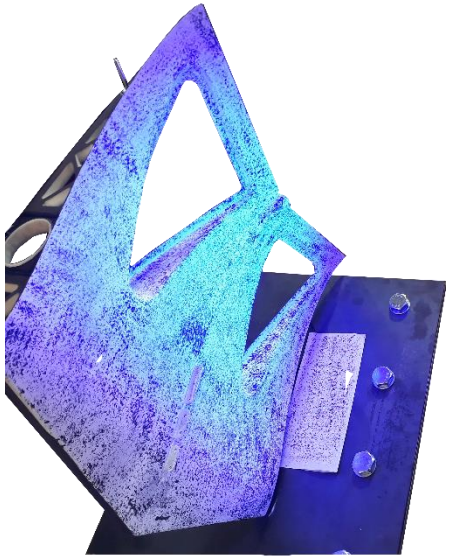
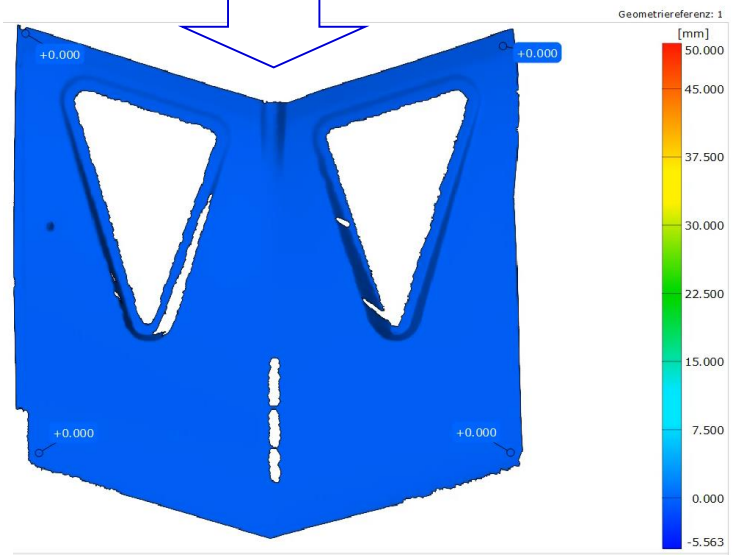
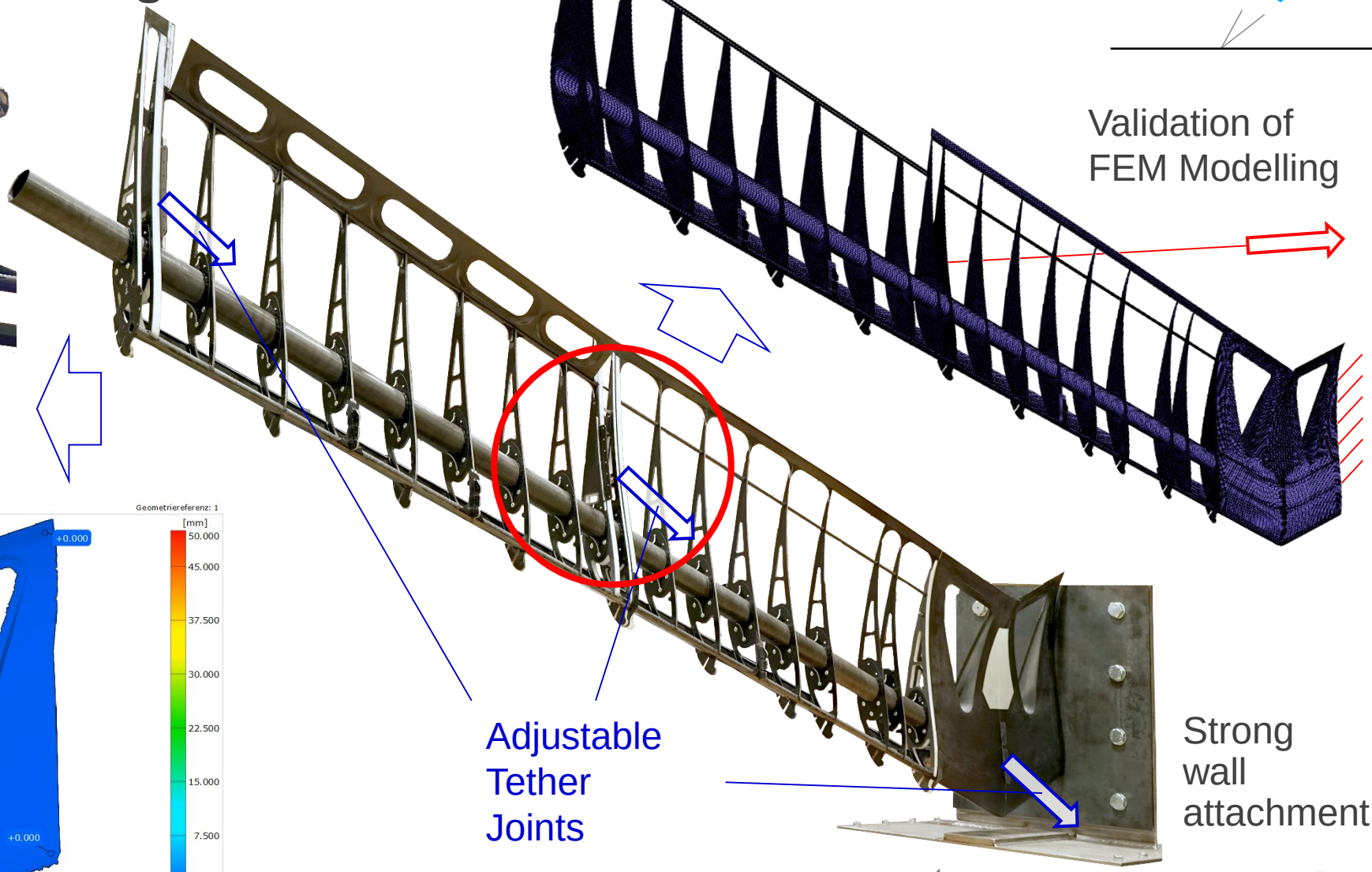
ENERWING – “Mixed” Design



GOM
ARAMIS
Analyses





Validation of
FEM Modelling

Adjustable
Tether
Joints

Strong
wall
attachment

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ENERWING – Fully integral Monocoque - Gridshell

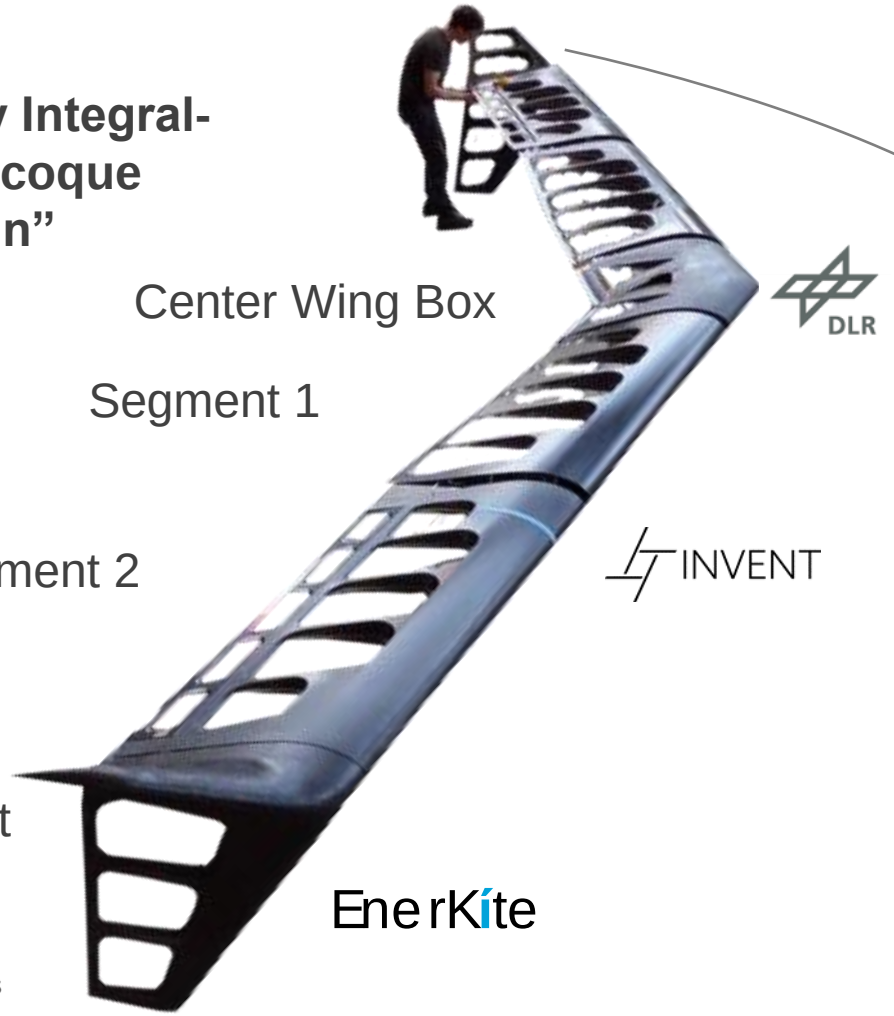
“Fully Integral-Monocoque Design” Wing

Center Wing Box

Segment 1

Segment 2

Winglet



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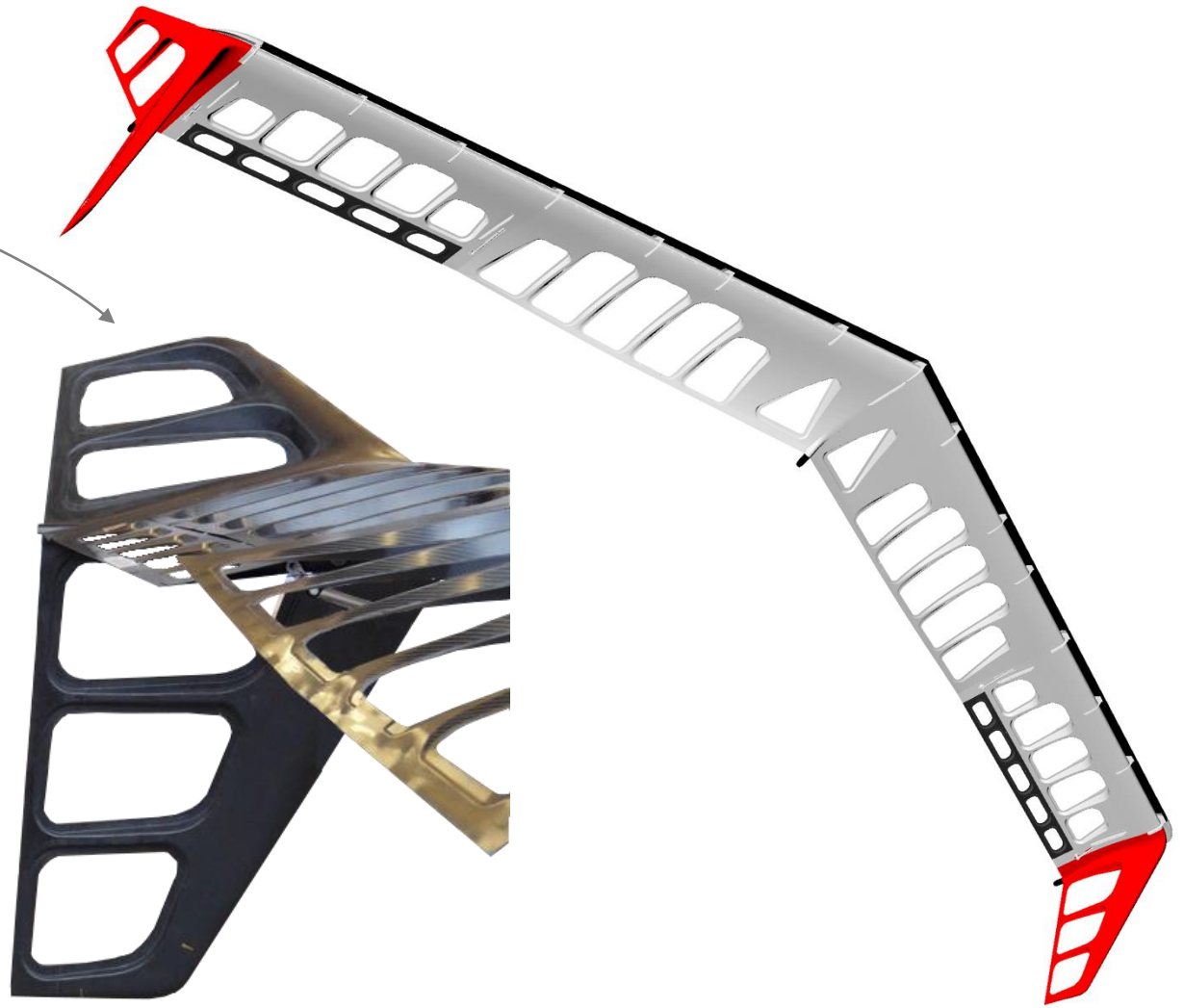

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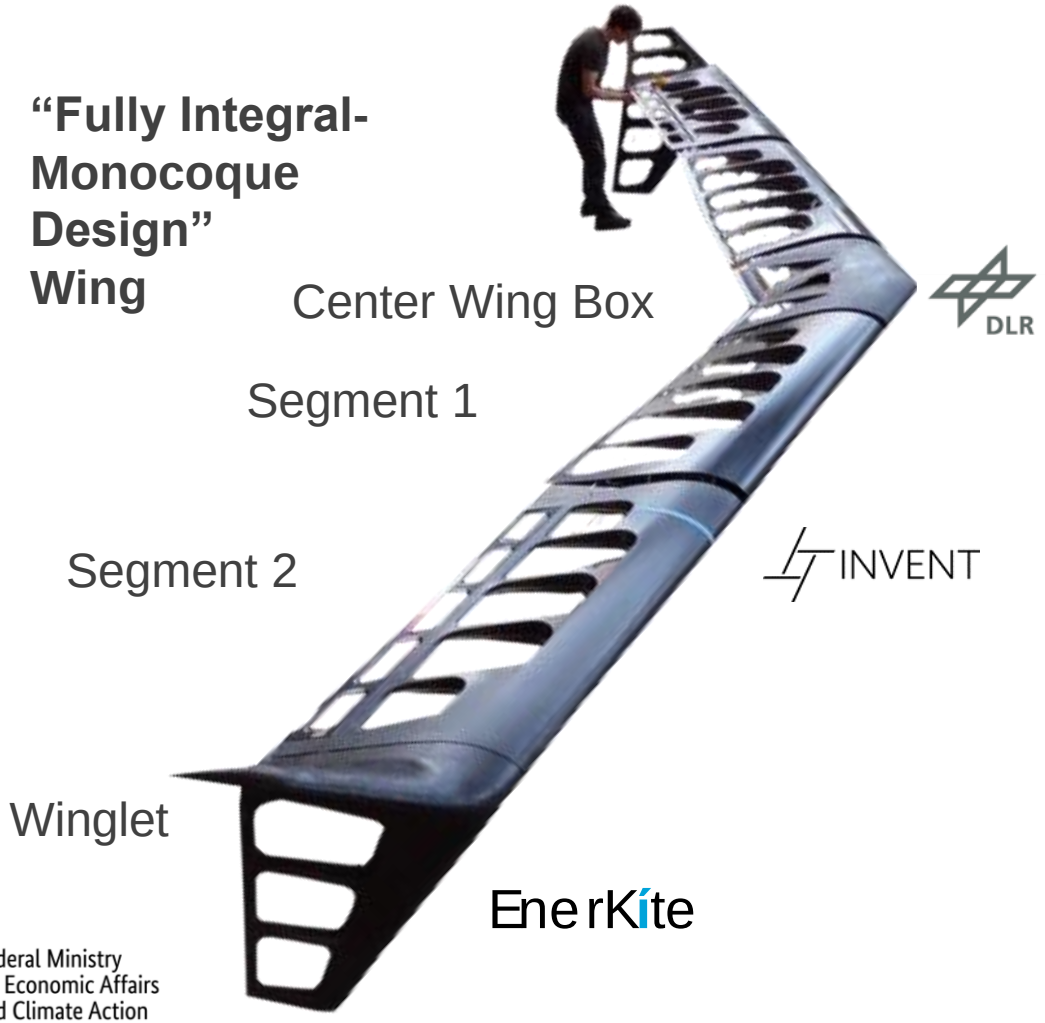
ENERWING – Fully integral Monocoque - Gridshell



- High stability and robustness with minimum structural mass
- Increased durability by reduction of components, joints and stress points
- Minimisation of material, glue, assembly time (and hence cost)
- Simplification of the bonding process and bonding paths
- Large optimization potential, by varying geometry and layup.

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ENERWING – Conclusion

Circular Economy of Airborne Applications

- “Defying Gravity” leaves **little space for ideological compromises** but **strengthening renewable energy sources is inevitable**
- Considering “Circular Economy” right from the start will **challenge frozen design principles** and can lead to significantly more sustainable and efficient applications
- **Monitoring the operational history** of the wing structure (Digital Twin) provides a bases for a lifetime extension
- **A straight forward design** and **continuous structural improvement** (e.g. based on Digital Twin data) will maximise material utilisation

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Thank you very much for your attention!

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