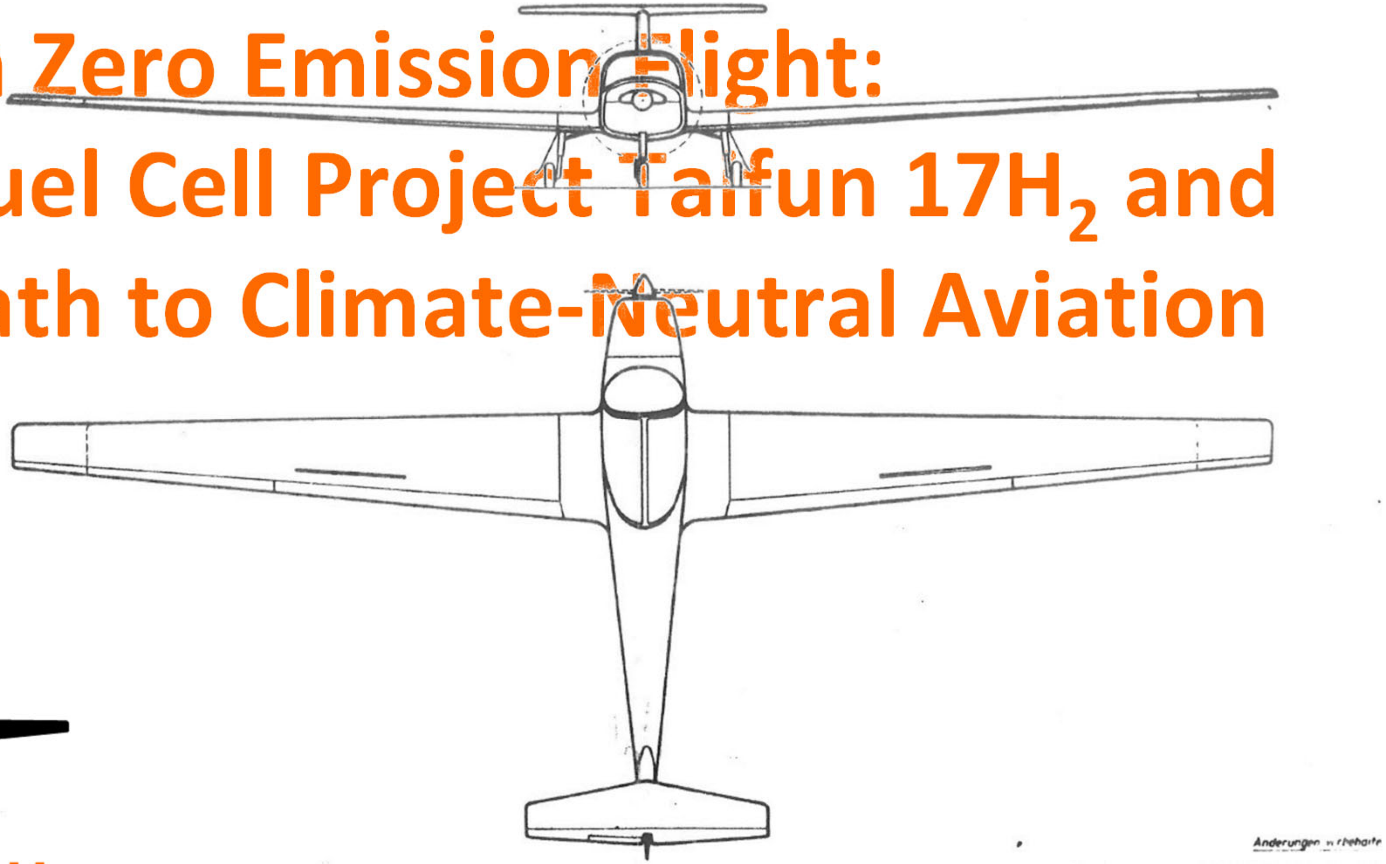
Vision Zero Emission Flight: The Fuel Cell Project Taifun 17H_2 and the Path to Climate-Neutral Aviation

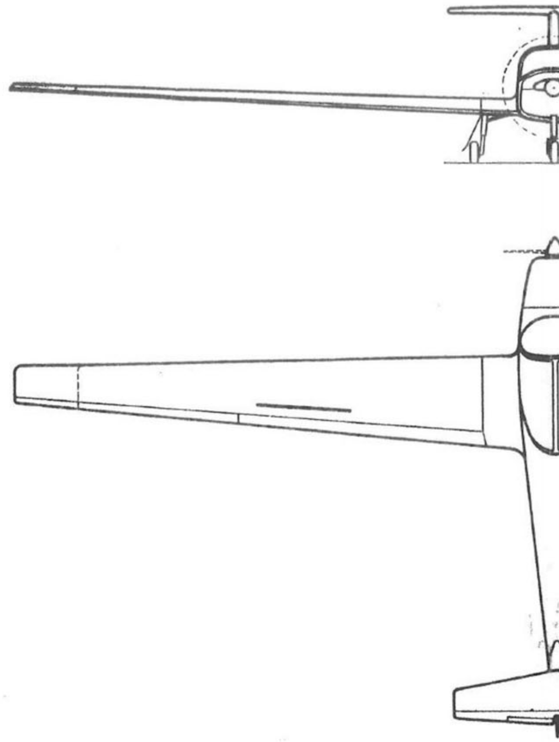


taifun 17 H_2

Paulus/ Jantsch/ Wirth

Agenda

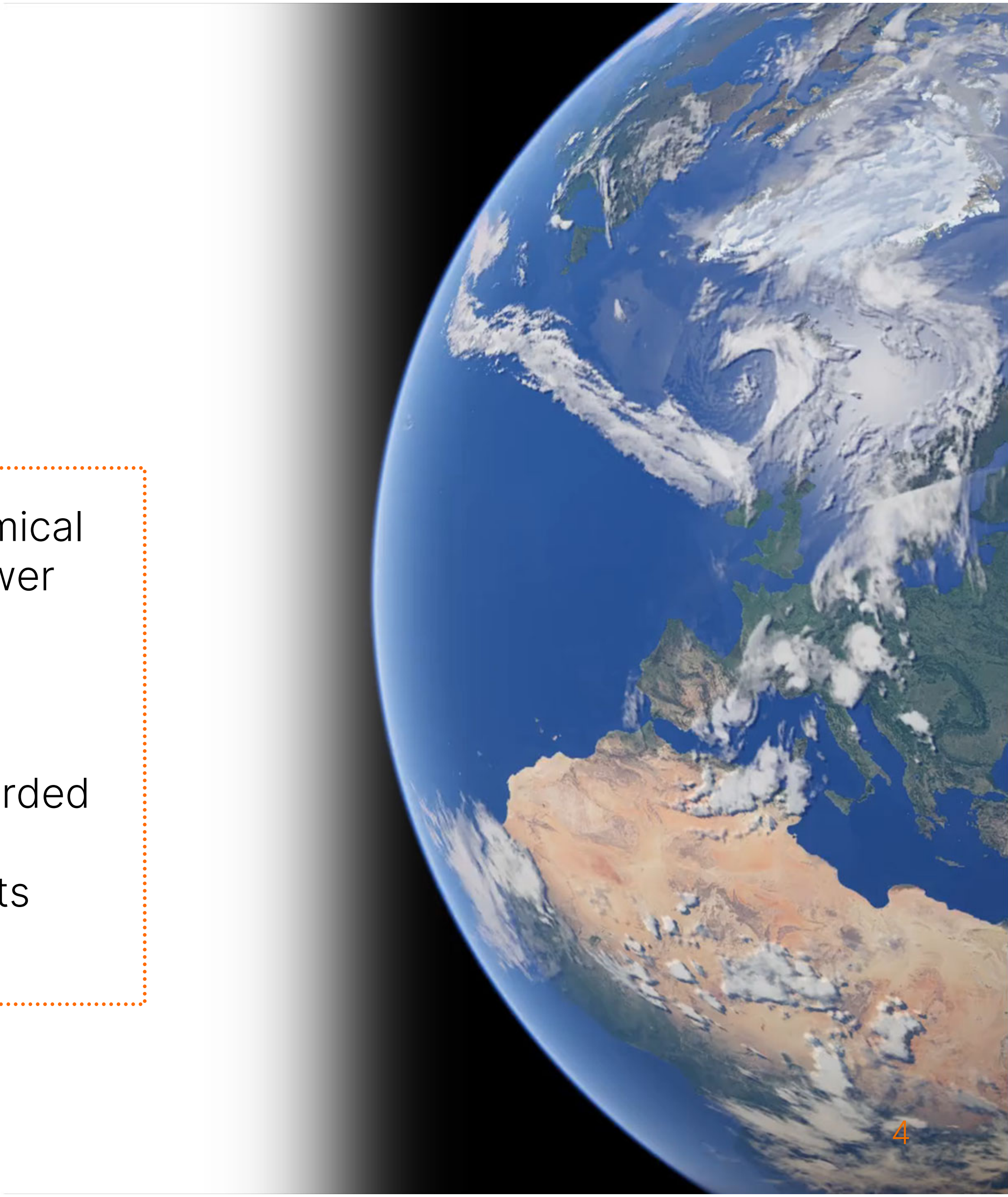
- THWS
- Motivation: CO_2 in Aviation
- Status Update Project Taifun 17H_2
- Propulsion System Comparison
- Outlook Fueling Station



About Us

thws
Technical University
of Applied Sciences
Würzburg-Schweinfurt

- Initially founded as separate technical, economical and art institutes in the 19th Century in the lower Franconia region of Germany.
- Was restructured into a University of Applied Sciences (FH) during 1971
- On the 1st of January, the university was accorded the status of a Technical University of Applied Sciences (TH), and its name was changed to its current form.



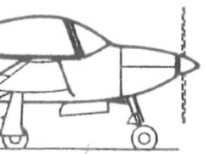
Motivation

- CO_2-emissions 2022 [1]:
  - overall: 38,5 bn. tons CO_2
  - transportation: 8 bn. tons CO_2
  - aviation: 0,9 bn. tons CO_2

- emissions in g per passenger and kilometer [3]:
  - long-haul flights: 150
  - short-haul flights: 156
  - domestic flights: 255

Project Taifun 17H_2

wingspan: 17 m
start of development: September 2022
vision: local hydrogen production on airfields in order to fly CO_2-free.



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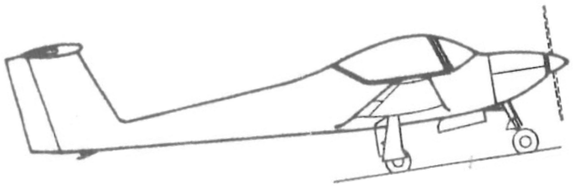
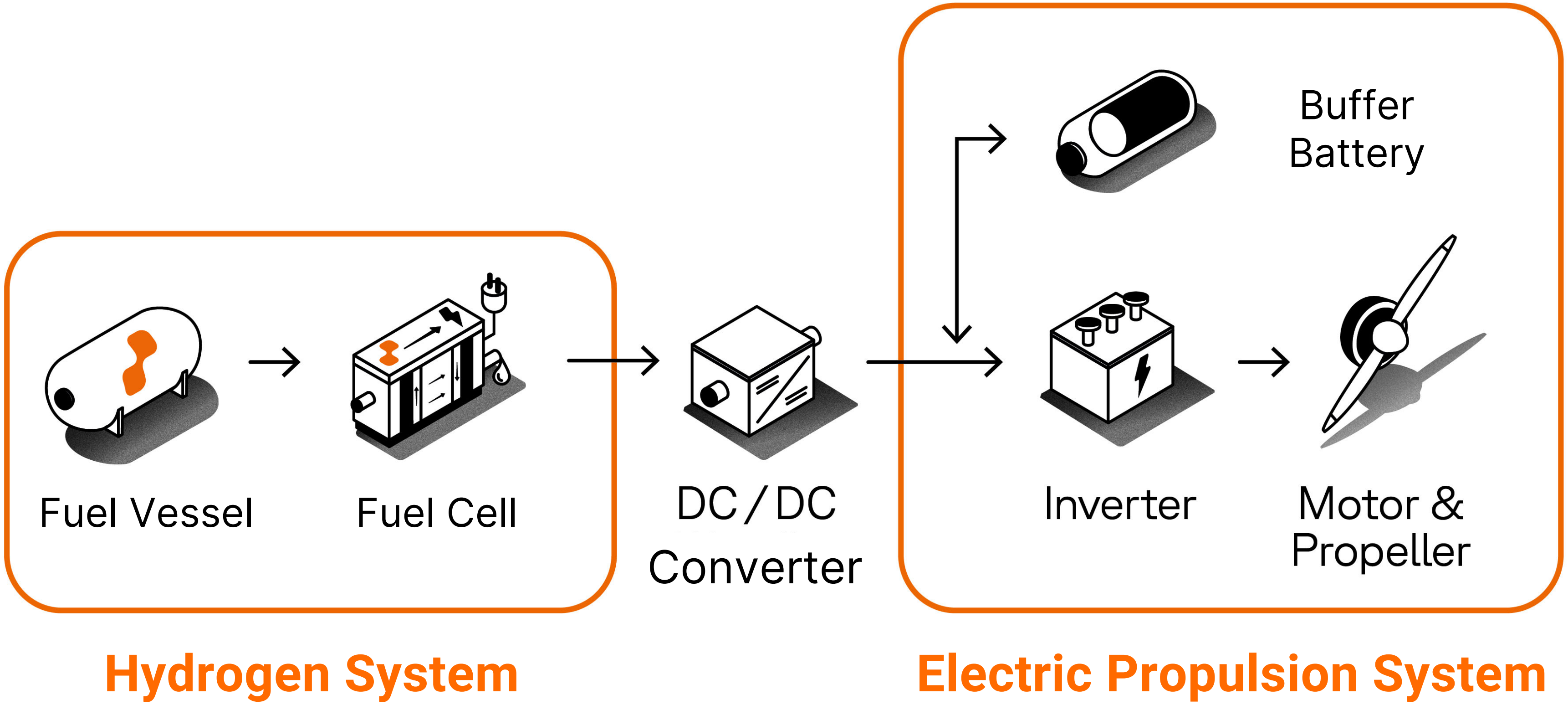
Project Taifun 17H_2

- potential of CO_2-saving in general aviation
- development of a hydrogen based propulsion system for lightaircrafts
- implementation in TMG Taifun 17
  - two seats
  - MTOW: 850 kg
  - max. speed: ~160 km/h
  - max. power output: 60-70 kW
- hybrid system with buffer battery for takeoff-power



Project Taifun 17H_2



FAQ

Feasability and Practicability

Project Taifun 17H_2

Different requirements to the fuel cell in aviation compared to lab environment

- space reduced→ packaging
- weight critical→ reduction of components
- temperature (-10 < 40 °C)
- lower atmospheric pressure, e.g. 0,697 bar (a) @FL100 and lower density (0,905 $\frac{kg}{m^3}$)

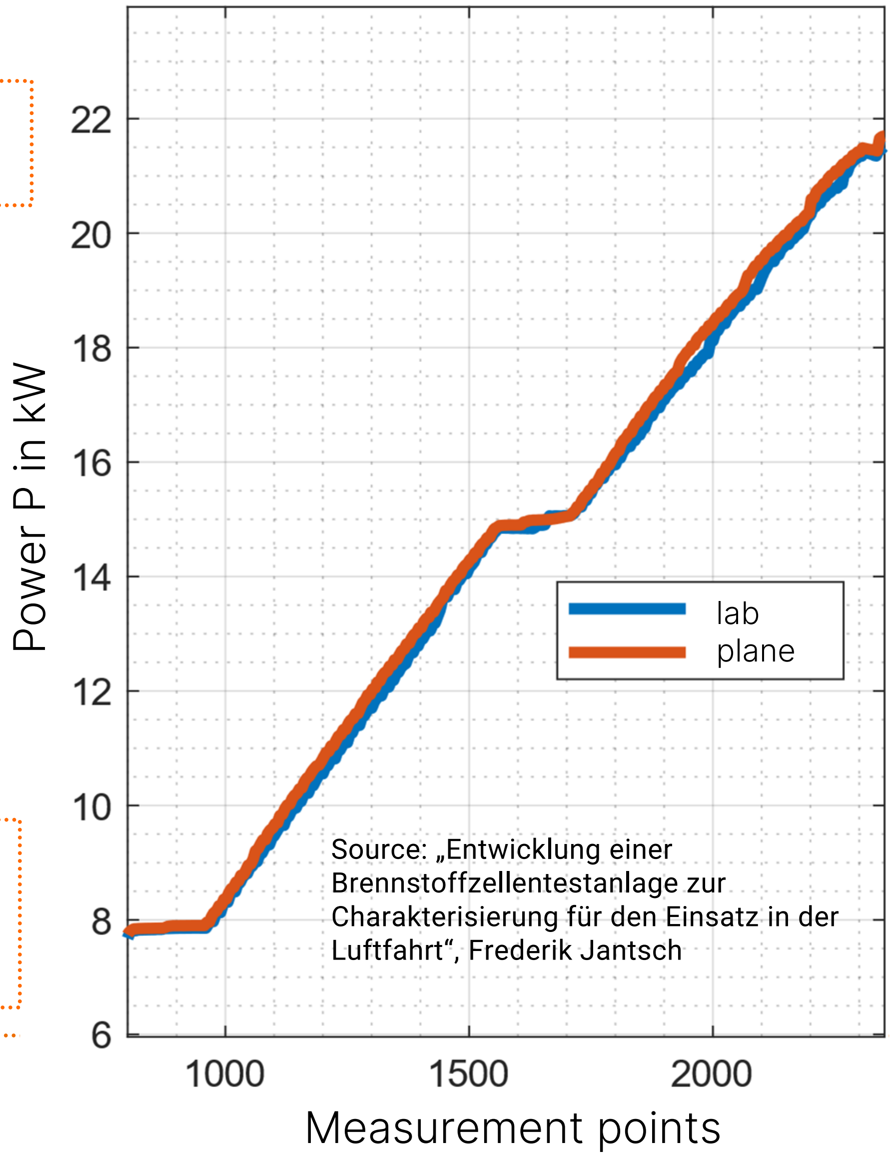
Quelle: „Entwicklung einer Brennstoffzellentestanlage zur Charakterisierung für den Einsatz in der Luftfahrt", Frederik Jantsch

Project Taifun 17H_2

Question: Is preheating in the plane necessary?

current I in A	$1 < I < 180$
λ_{air}	≈ 2.2
rel. humidity in %	≈ 70
$\dot{m}_{air}$ in $\frac{sl}{min}$ at $I < 60\ A$	300
$\dot{m}_{air}$ in $\frac{sl}{min}$ at $I > 60 \ldots 275$	$300 \ldots 2000$
$p_{hydrogen}$ in bar(a)	≈ 1.5
p_{air} in bar(a)	≈ 1.4
starting temp T_{lab} in °C	70
starting temp T_{plane} in °C	10

- external heating is only necessary for removing ice
- effects of degradation were not taken into account



Source: „Entwicklung einer Brennstoffzellentestanlage zur Charakterisierung für den Einsatz in der Luftfahrt“, Frederik Jantsch

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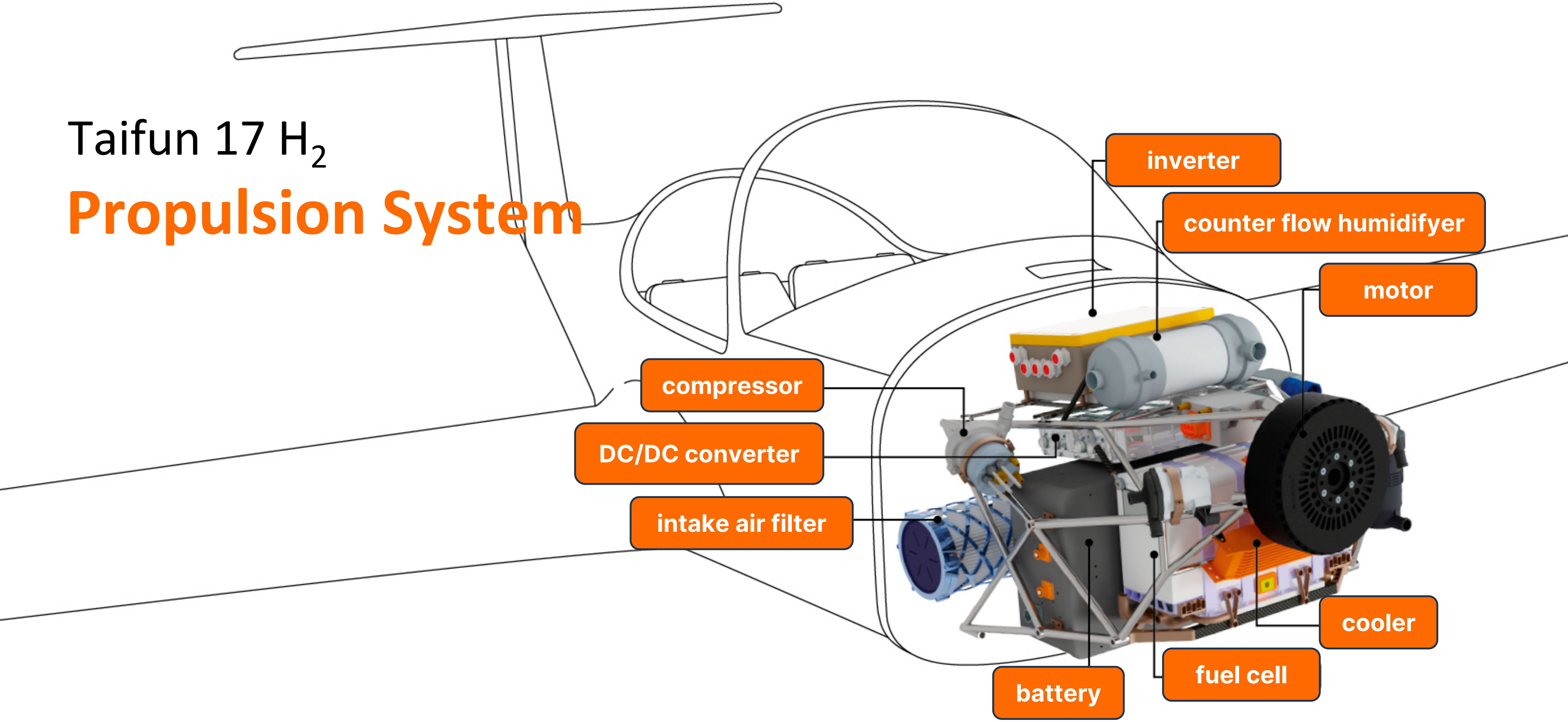
Taifun 17 H_2

Propulsion System



Project Taifun 17H_2

Humidification Systems

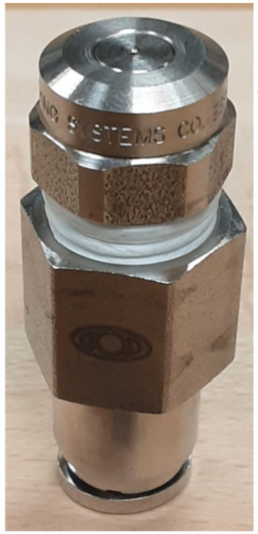
Currently: Counterflow humidification

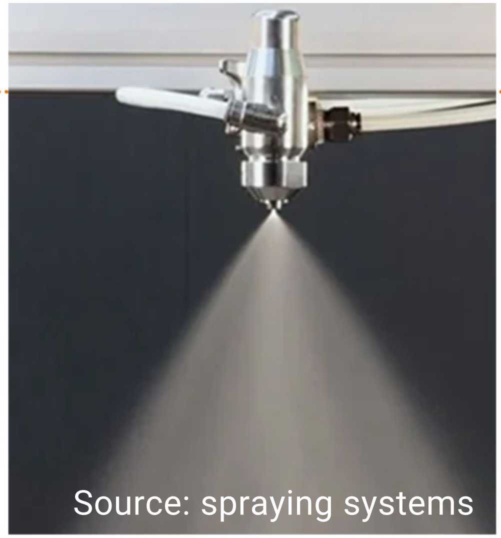
Future: Active humidification

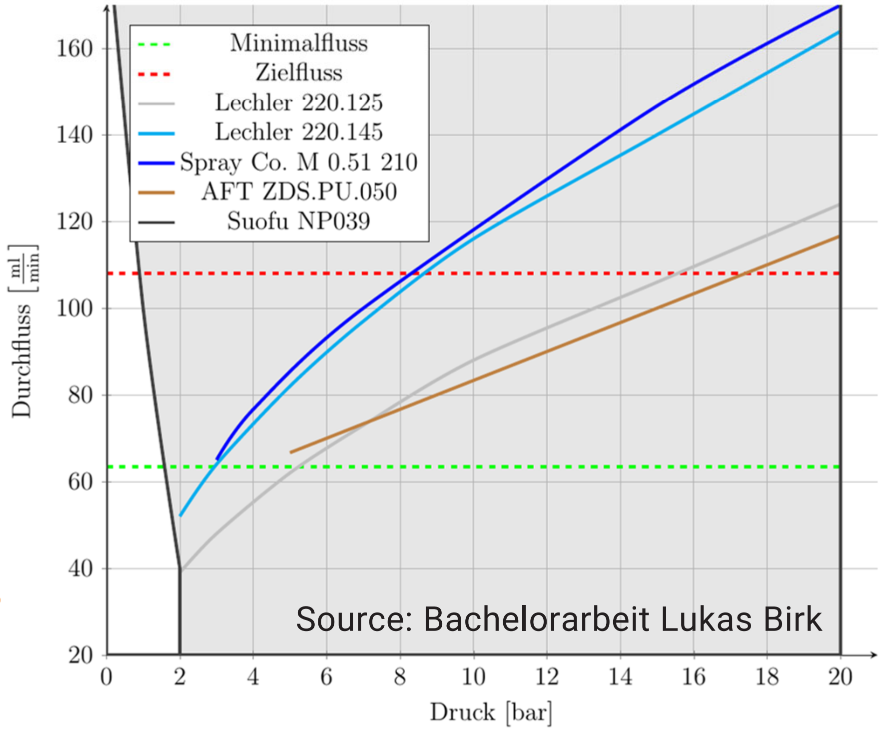
- precise moisture control
- reaching FC peak performance
- weight reduction of propulsion system
- additional passive cooling through evaporation

Advantage:

- no need for an intercooler
- very dynamic humidity-control
- sufficient humidification guaranteed
- weight reduction







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FAQ

Sustainability and Efficiency

Comparison of Energystorage/Propulsion

three goals:

- functionality
- efficiency
- cost

	specific energy density	tank-to-prop efficiency	purchase cost
e-Fuel	11,5 kWh/kg	35 %	120.000€
H_2-IC	33,33 kWh/kg	35 %	150.000€
H_2-FC	33,33 kWh/kg	≥50%	300.000€
battery	0,15 kWh/kg	≥85%	200.000€

Comparison of Energy Storage/Propulsion

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battery	0,15 kWh/kg*	≥85%	200.000€

*including battery housing

FAQ

Cost and Profitability

Comparison

General Conditions for the Comparison

Operation conditions:

- 300 h/a
- avg. ~50 kW of power

propulsion variants	est. fuel consumption	fuel prices
Rotax 912 iS	16,5 l/h	2,50 €/l
Rotax 912 iS eFuel	16,5 l/h	4,25 €/l*
Rotax 912 iS H_2	4,3 kg/h	3 €/kg
60 kW electric	58,8 kWh/h	0,32 €/kWh
60 kW FC-electric	3 kg/h	3 €/kg

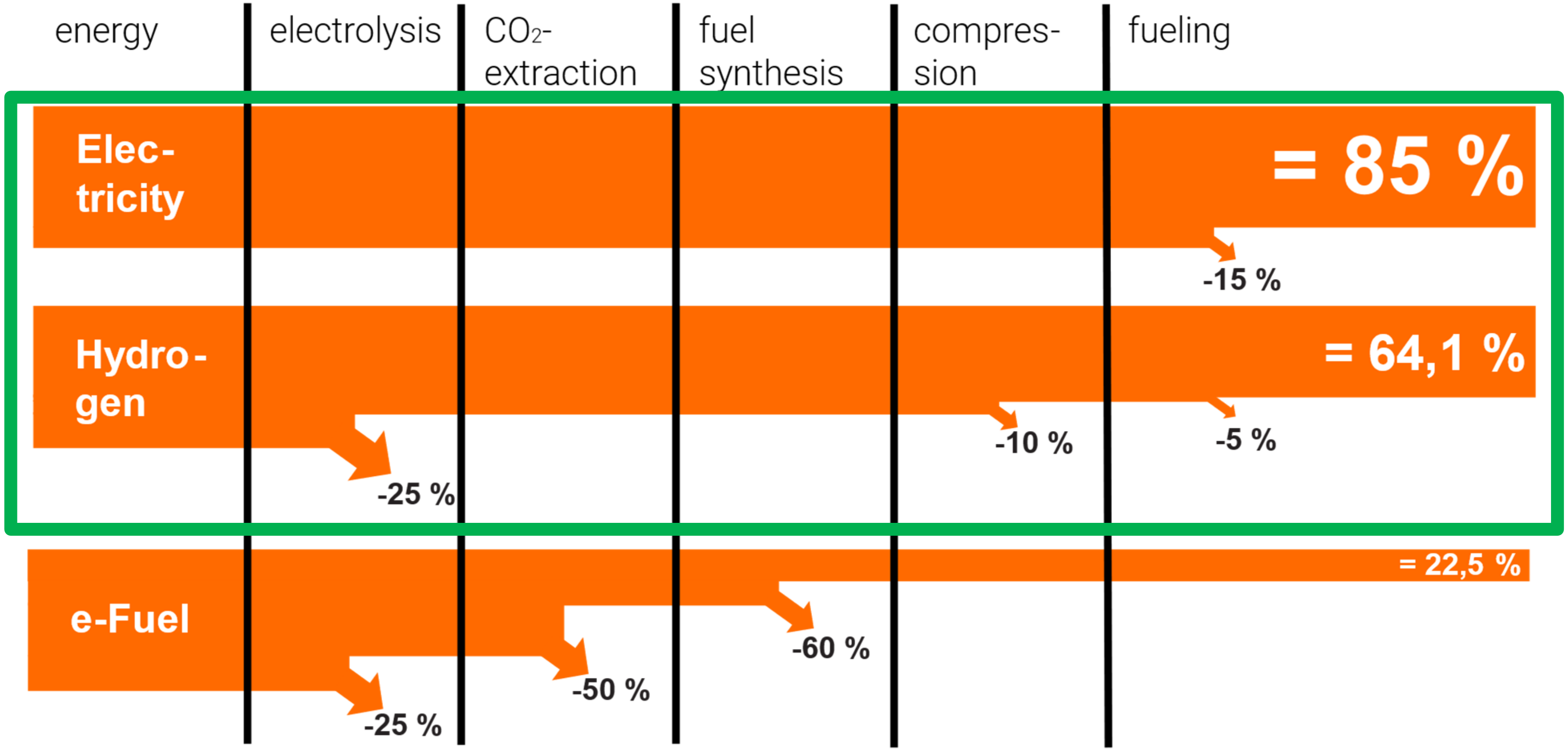
*calculation for local production with feed-in payment of solar energy

Comparison

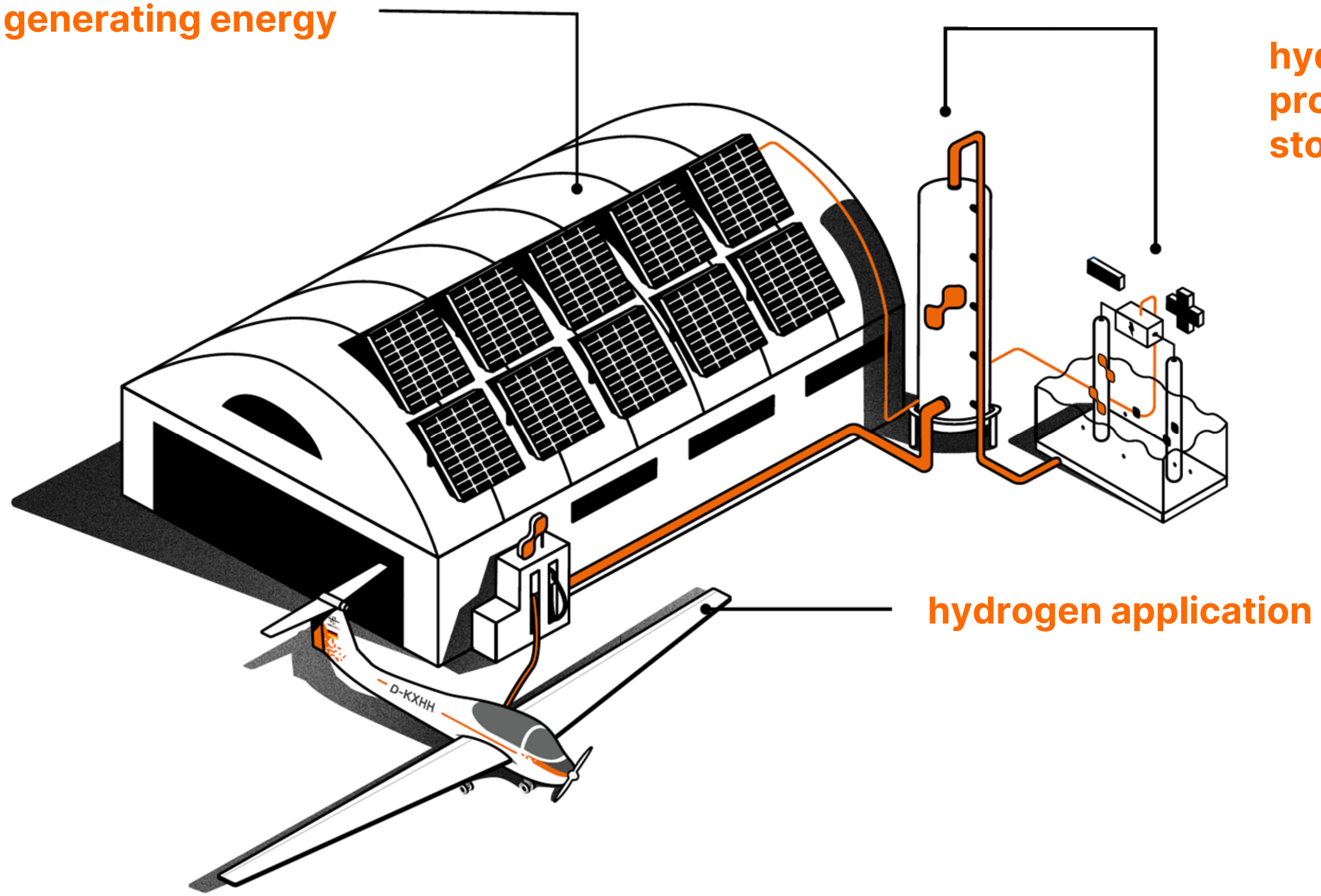
concept	purchase	maintenance p.a.	fuel cost p.a.	cost per hour @15 years
912 iS	120.000 €	3.500 €	12.516 €	80,06 €
H2 IC	150.000 €	4.000 €	3.857 €	59,53 €
H2 FC	300.000 €	2.500 €	2.700 €	84,00 €
electric	200.000 €	2.500 €	5.647 €	71,60 €
912 iS e-Fuel	120.000 €	3.500 €	21.278 €	109,26 €

Fuel Production

Process Steps with Well-to-Tank Efficiency



Vision Zero Emission Flight



Calculation example

Location Information

location	airport Friedrichshafen	airfield in lower Franconia	unit
electricity demand	1460,76	50	MWh
energy price	250	320	€/MWh
hours of sunshine	1700	1600	h/a
peak power (@ 2% area utilization)	2	0,09	MWp
area	150	6,8	ha
avg. savings	365.190	16.000	€/a

Calculation example

Use Case 1

- no electrolysis
- overflow 100 % in-feed
- in-feed payment = 50 €/MWh

	investment	ROI
Friedrichshafen	2.000.000 €	5 years
lower Franconia	~91.000 €	5 years

Calculation example

Use Case 2

- with electrolysis incl. peripherals and installation
- hydrogen production for winter season
- overflow* 100 % in-feed
- in-feed payment = 50 €/MWh

	investment	ROI
Friedrichshafen	~ 2.9 Mio €	7,7 – 7,8 years
lower Franconia	~ 150.000 €	8,7 – 8,8 years

*excl. amount of hydrogen for winter season

Calculation example

Use Case 3

- with electrolysis incl. peripherals and installation
- overflow* 100 % hydrogen production and selling
- hydrogen selling price = 3-8 €/kg

	investment	ROI
Friedrichshafen	~ 2.9 Mio €	6,3 – 7,5 years
lower Franconia	~ 150.000 €	6,9 – 8,5 years

*excl. amount of hydrogen for winter season

Summary

- high potential of CO_2 savings
- adaptive approach to the evaluation of fuel cells in aviation
- hydrogen as promising compromise between range and efficiency
- ROI of << 8 years in specific cases possible
- biggest challenges:
  - acceptance among the population
  - negativity against changes in technology
  - high investment costs

FAQ

Challenges and Outlook


Hydrogen Aircraft