
UBER

future matters
Innovation und Zukunftsforschung

Zukunft der Luftfahrt

Dipl.-Ing. Morell Westermann

Futurist und Partner, Future Matters

Future Research & Corporate Foresight

2008

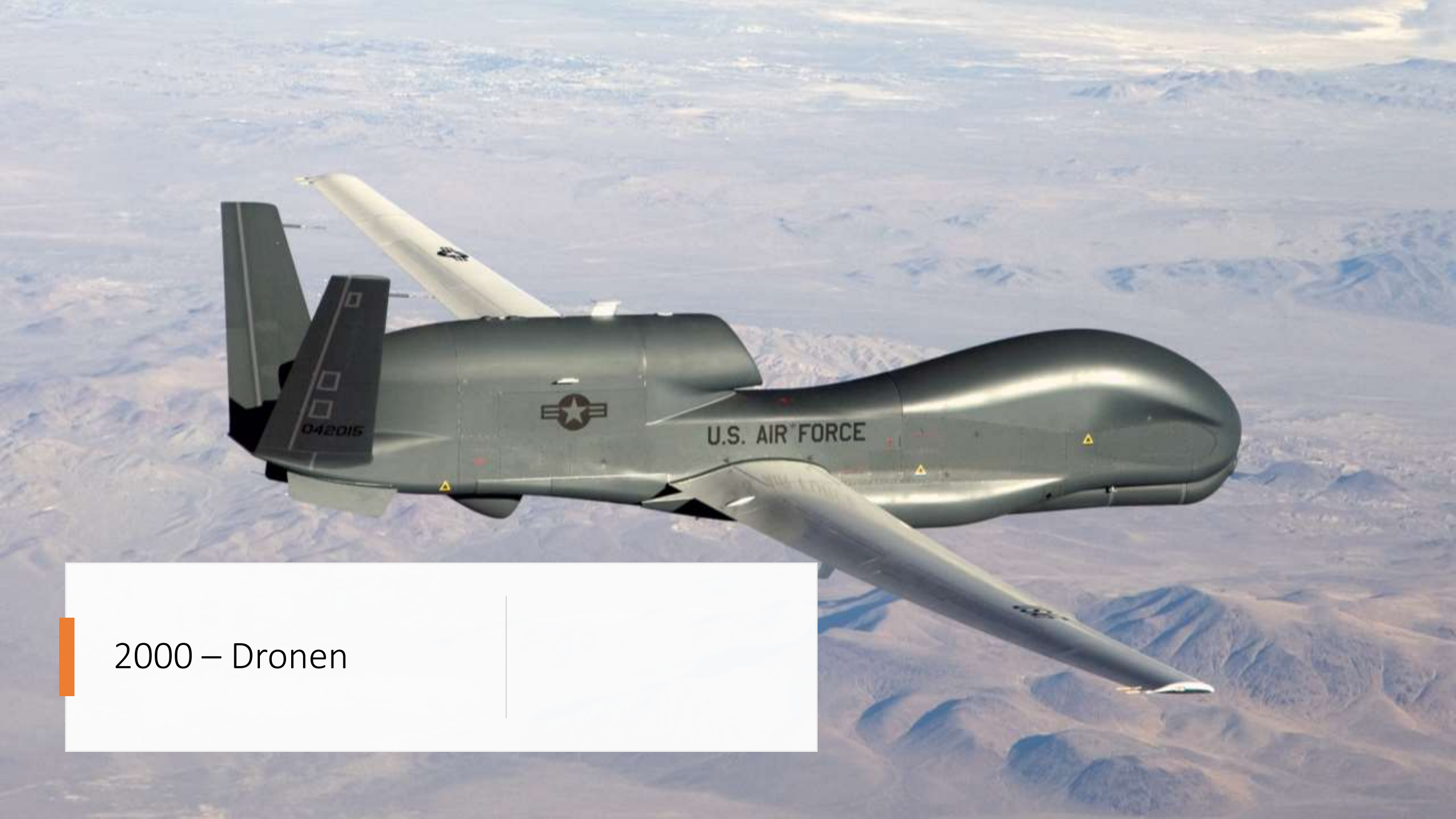
2018

EVIATION ALICE


G-AMLV

1903 – 60 Sekunden
250 Meter

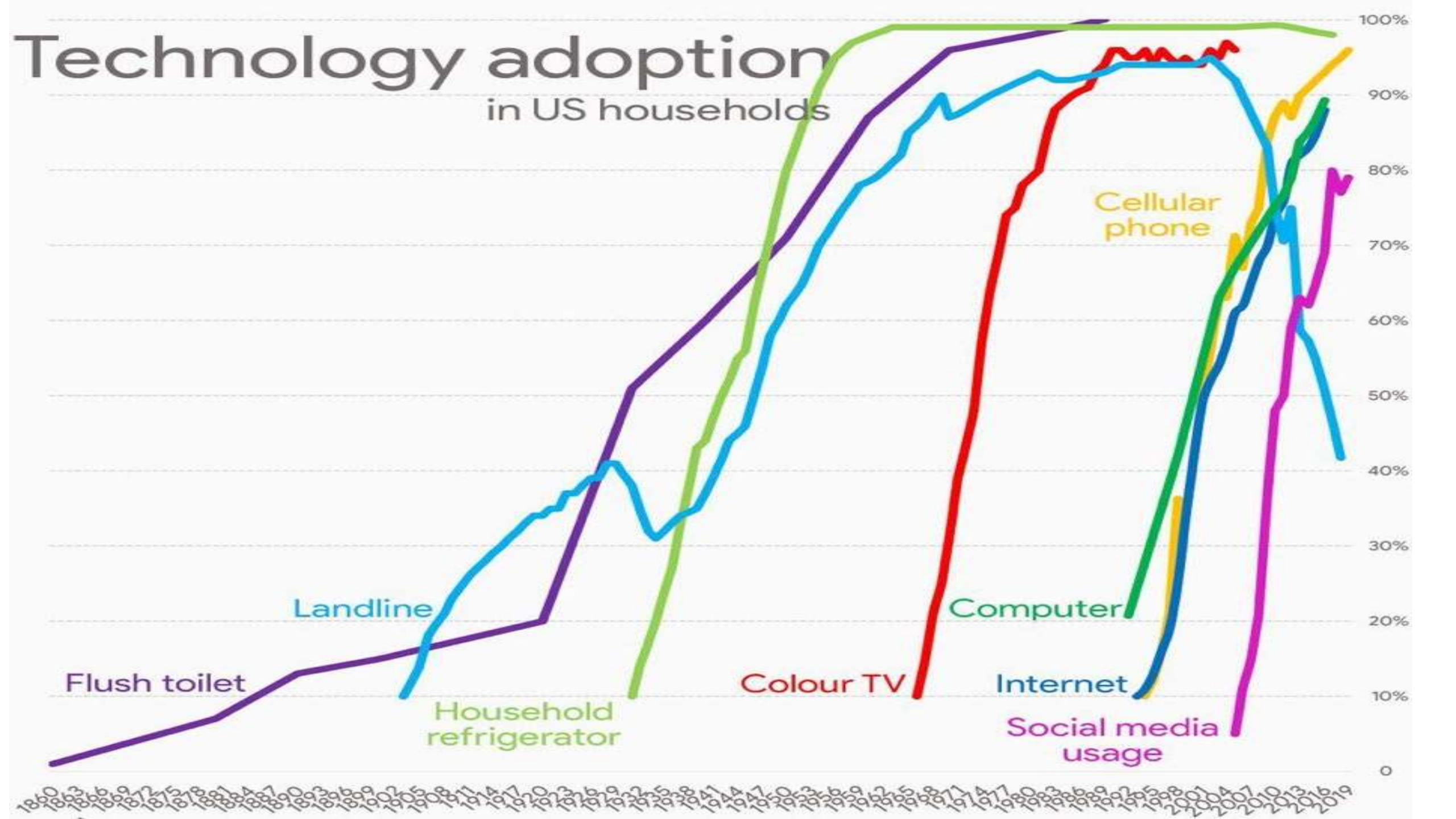
1969 – 66 Jahre später



2000 – Dronen

2016 – Volocopter

2019 – Lilium


Technology adoption
in US households
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0
Flush toilet
Landline
Household refrigerator
Colour TV
Computer
Cellular phone
Internet
Social media usage
1860
1863
1866
1869
1872
1875
1878
1881
1884
1887
1890
1893
1896
1899
1902
1905
1908
1911
1914
1917
1920
1923
1926
1929
1932
1935
1938
1941
1944
1947
1950
1953
1956
1959
1962
1965
1968
1971
1974
1977
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007
2010
2013
2016
2019

170 Firmen entwickeln VTOL

EVA X01

Flexcraft

JAXA Hornisse

Jetoptera Personal Drone

HopFlyt Venturi

Moller M200 Skycar

Moller M400 Skycar

Pop.Up Next

Neoptera eOpter

Ray Civil VTOL Aircraft

Skylys Airspeeder

SAMAD Starling Jet

Hoversurf Formula

Samson Sky Switchblade

Vickers WAVE eVTOL

Rolls-Royce eVTOL

Sabrewing Draco-2

Flyter 120–420

Flyter 720-200

NFT ASKA

Wingless eVTOLs

Alauda Airspeeder

Bartini Flying Car

Boeing Cargo Air Vehicle (CAV)

Dekatone Flying Car

UrbanAero CityHawk

EAC Whisper

PAL-V

SkyPod

PAVX

Astro Elroy

Vertical Aerospace eVTOL

Koncepto Millenya

Varon Vehicles V200

Ghost X V 2.2

Imaginactive Onyx

FlytCycle Aerospace

DaVinci ZeroG

Hoversurf Hoverbike

Flike

Kalashnikov Hover Bike

Neva AirQuad One

Trek Aerospace FlyKart 2

TAMU Harmony

Cartivator SkyDrive

PSU Blue Sparrow

Georgia Tech Hummingbuzz

Assen Aero A1

VIMANA AAV

Sting VTOL

Terrafugia Transition

Dufour aEro2

Zenith Altitude EOPA

Verdego Aero PAT200

Terrafugia TF-2

PteroDynamics Transwing

Terrafugia TF-X

Airbus CityAirbus

AeroMobil 4.0 STOL

VRCO NeoXCraft

AeroMobil 5.0 VTOL

AIRIS AirisOne

XTI Trifan 600

ASX MOBi-ONE

Aurora Lightning Strike XV-24A

Autonomous Y6S

DeLorean Aerospace DR7

DIGI Droxi

Airbus Vahana

Boeing PAV

Bell Nexus Air Taxi

Kittyhawk Cora

Ehang 184

Joby Aviation S4

KittyHawk Flyer

Lilium Jet

Volocopter 2X

Workhorse SureFly

Opener BlackFly

Aston Martin Volante

Karem Butterfly

EmbraerX

Pipistrel 801 eVTOL

Jaunt Air Mobility eVTOL

Skai by Alaka'i Technologies

Beta Technologies Ava

LIFT Hexa

Strengths, weaknesses and potential applications of five electric aircraft architectures

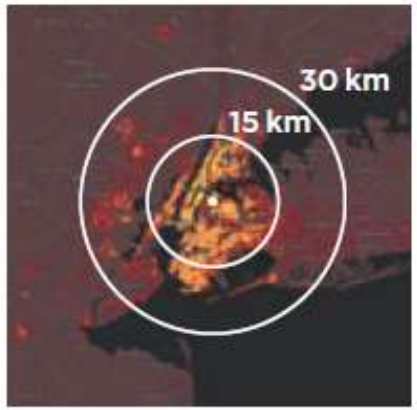
Aircraft architecture	 Highly distributed propulsion concepts (multicopters)	 Quadcopters	 Hybrid concepts	 Tilt-wing/convertible aircraft concepts	 Fixed-wing vectored thrust concepts
Disc loading					
Hovering efficiency					
Downwash speed & noise					
Forward flight speed & efficiency					
Gust resistance and stability					
Preferred use case	Air taxis (inner-city point-to-point services)	Air taxis and airport shuttles	All	All	Airport shuttles and intercity
Time to Market	**~2y**	**~2y**	**~5y**	**~5y**	**~3y**

Roland Berger

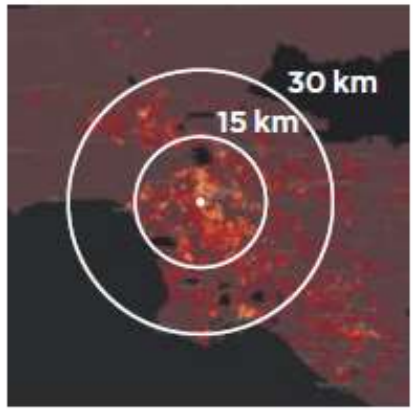

ABC 7 Los Angeles
abc NEWS

GIS population density of selected cities of our top 100 city list

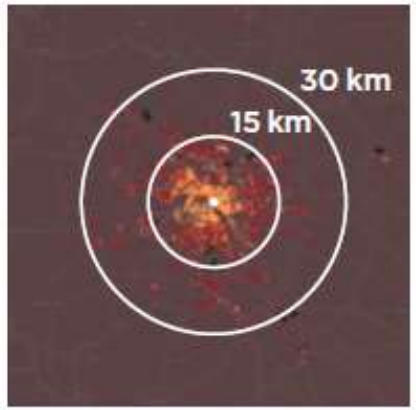
New York City
(18 m population)



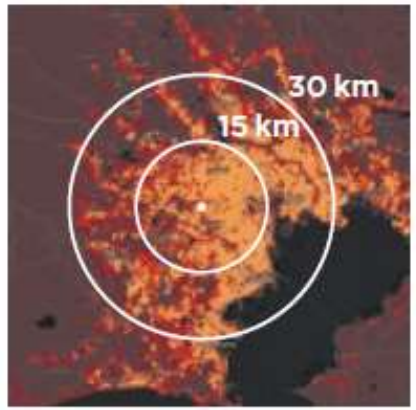
Los Angeles
(12 m population)



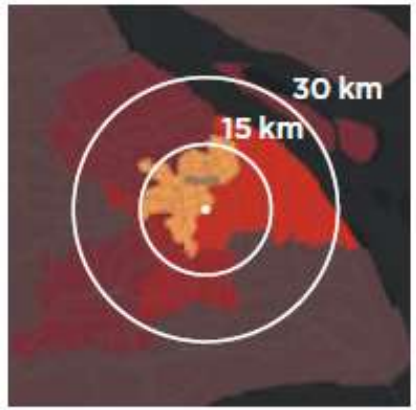
Paris
(11 m population)



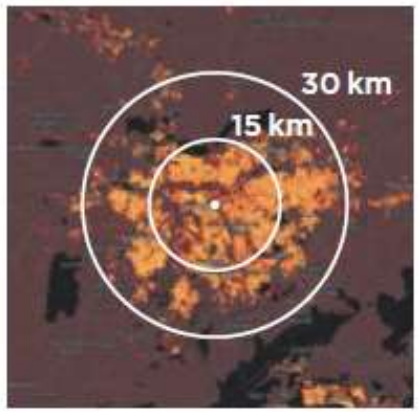
Tokyo
(38 m population)



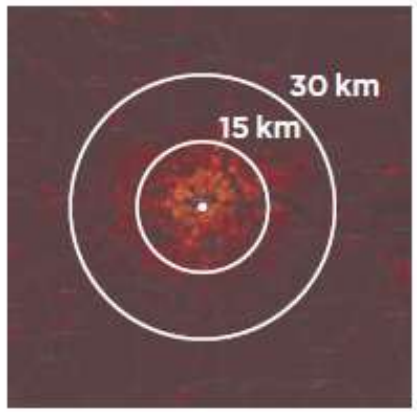
Shanghai
(24 m population)



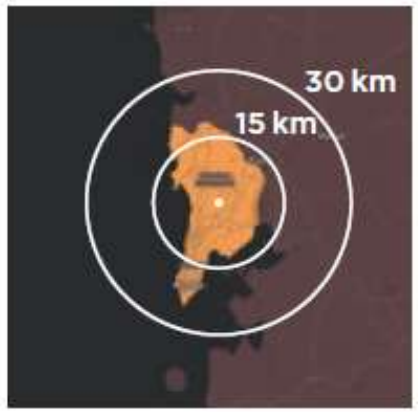
São Paulo
(21 m population)



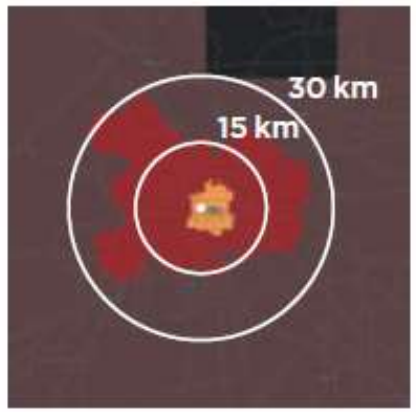
London
(10 m population)



Mumbai
(21 m population)

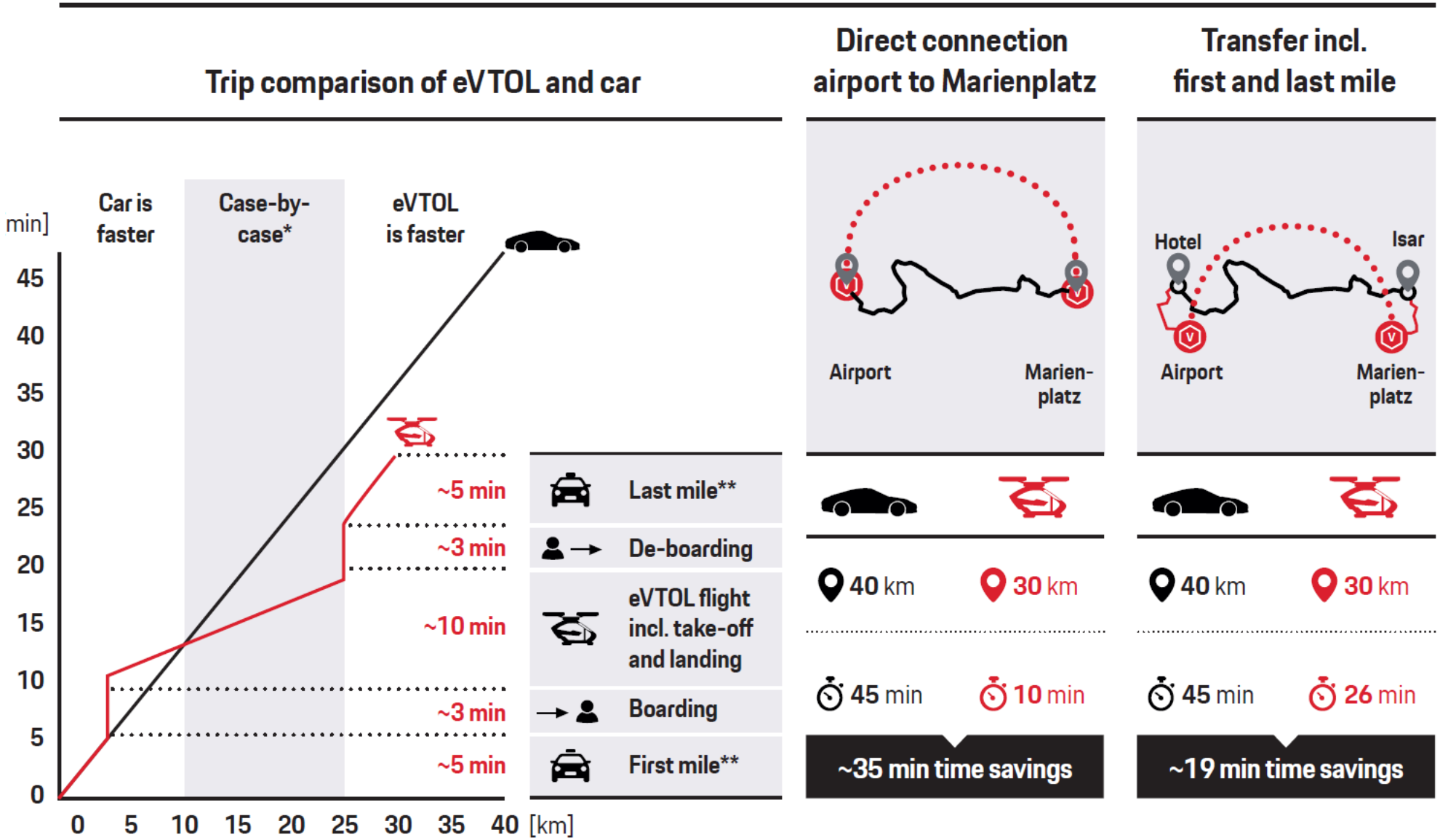


Beijing
(22 m population)



Population Density
(in ppl/km^2)

- 30,000–150,000
- 7,000–30,000
- 5,200–7,000
- 3,350–5,200
- 1,500–3,350
- 0–1,500



* Depending on congestion and minimum time savings to accept transfer connection with ride-and-fly
** Depending on location of vertiport

Graphic: Porsche Consulting

Figure 11. Getting in and getting on: drones beat cars when it comes to travel time, as with this example in Munich.

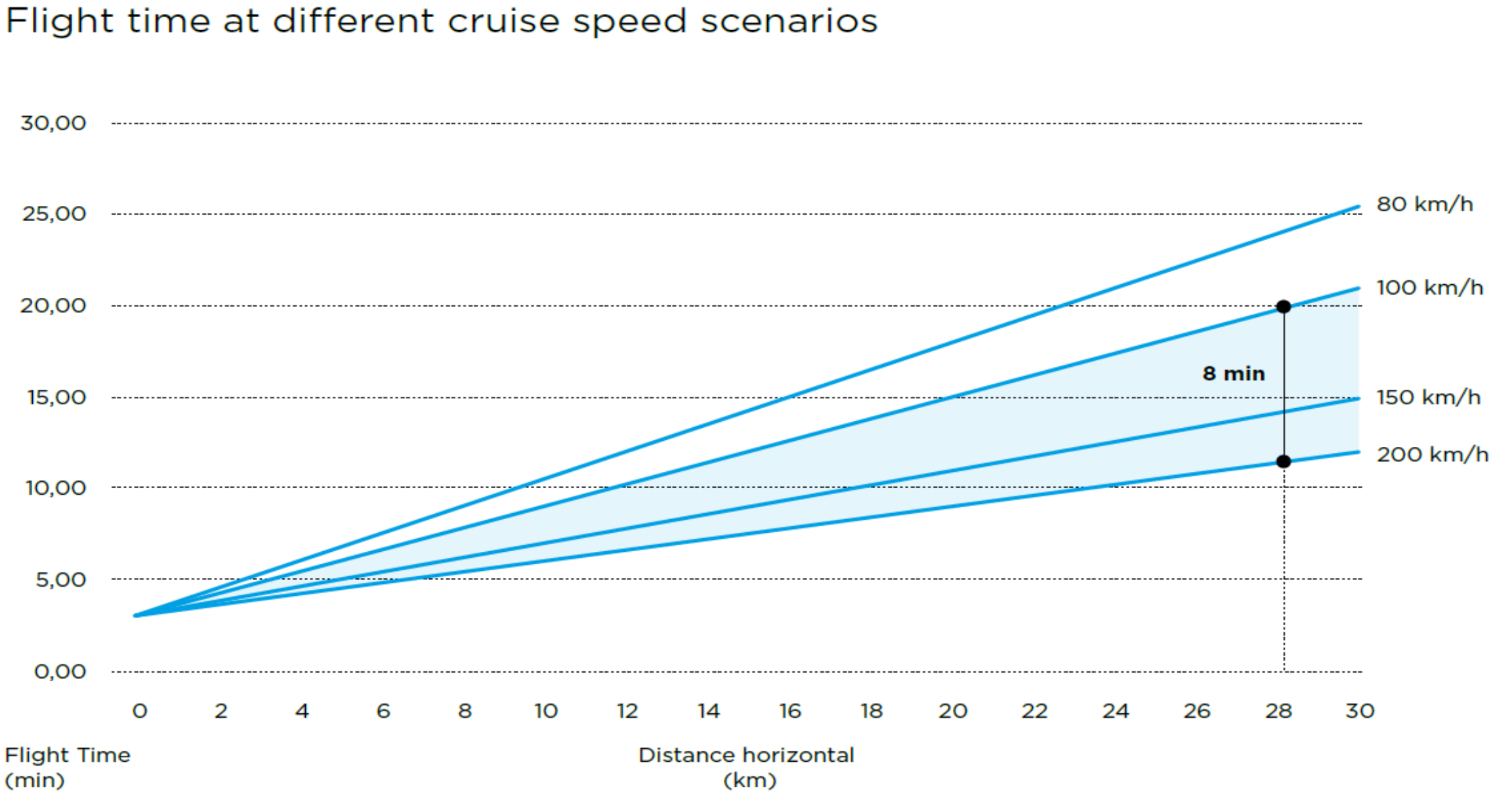


Figure 12 Travel time savings relative to speed of travel

Passenger drones

Starting in 2025

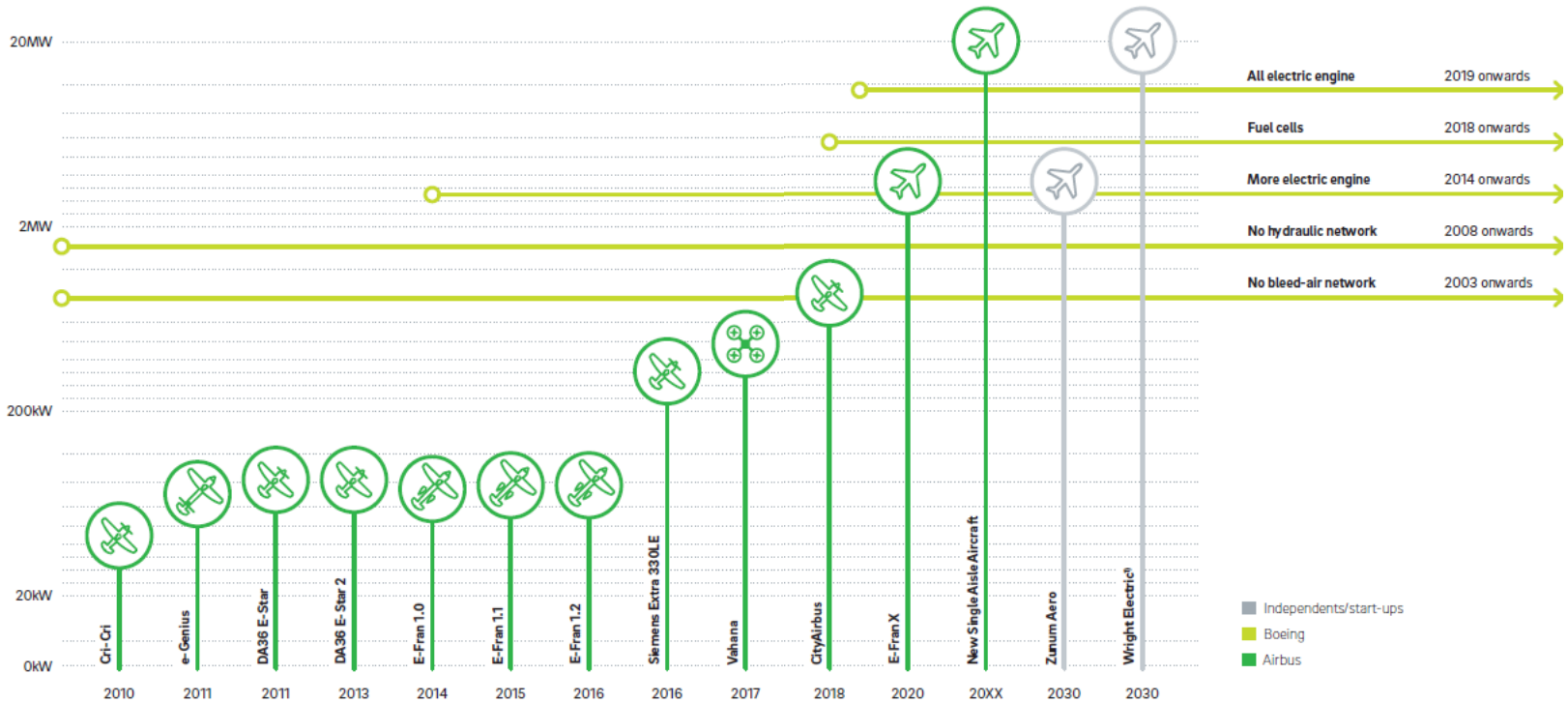
Air taxis

Electric VTOL in 2035

23,000 units

Passenger market 2035*

32 billion



Die magischen 500 Wh/kg

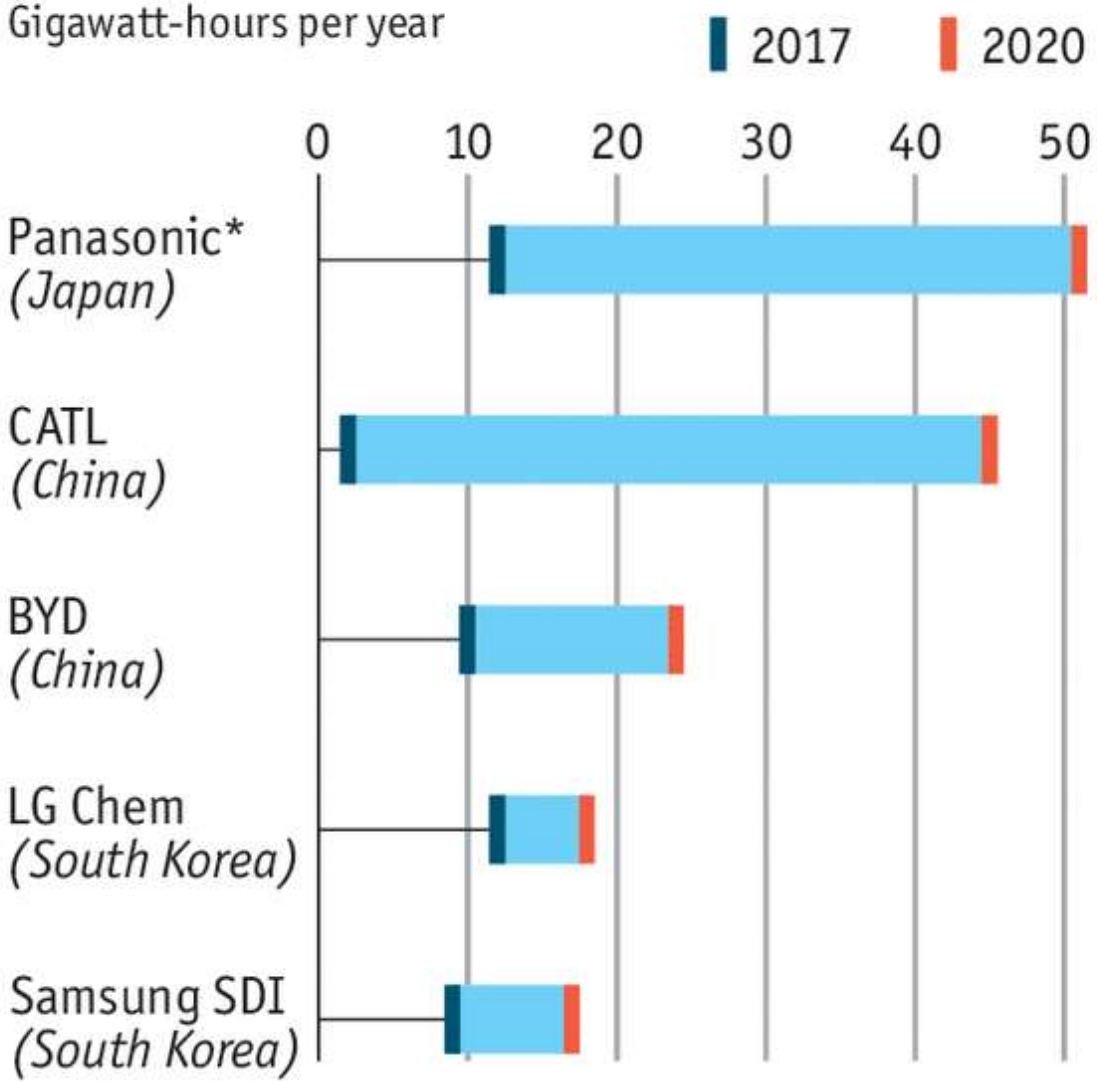
	Lycoming	Siemens
Gewicht (kg)	138 kg	50 kg
Leistung (kW)	119 kW	260 kW
Treibstoff (für ca 1h)	40 kg	550 kg (75kWh)
Gewicht Antrieb	178 kg	600 kg
Leistungsgewicht	0,6 kW/kg	0,4 kW/kg
Wirkungsgrad	~25%	~77%

Die magischen 500 Wh/kg

	Lycoming	Siemens
Gewicht (kg)	138 kg	50 kg
Leistung (kW)	119 kW	260 kW
Treibstoff (für ca 1h)	40 kg	**350 kg (75kWh)**
Gewicht Antrieb	178 kg	**400 kg**
Leistungsgewicht	0,6 kW/kg	**0,6 kW/kg**
Wirkungsgrad	~25%	~77%

Manufacturing capacity

Gigawatt-hours per year



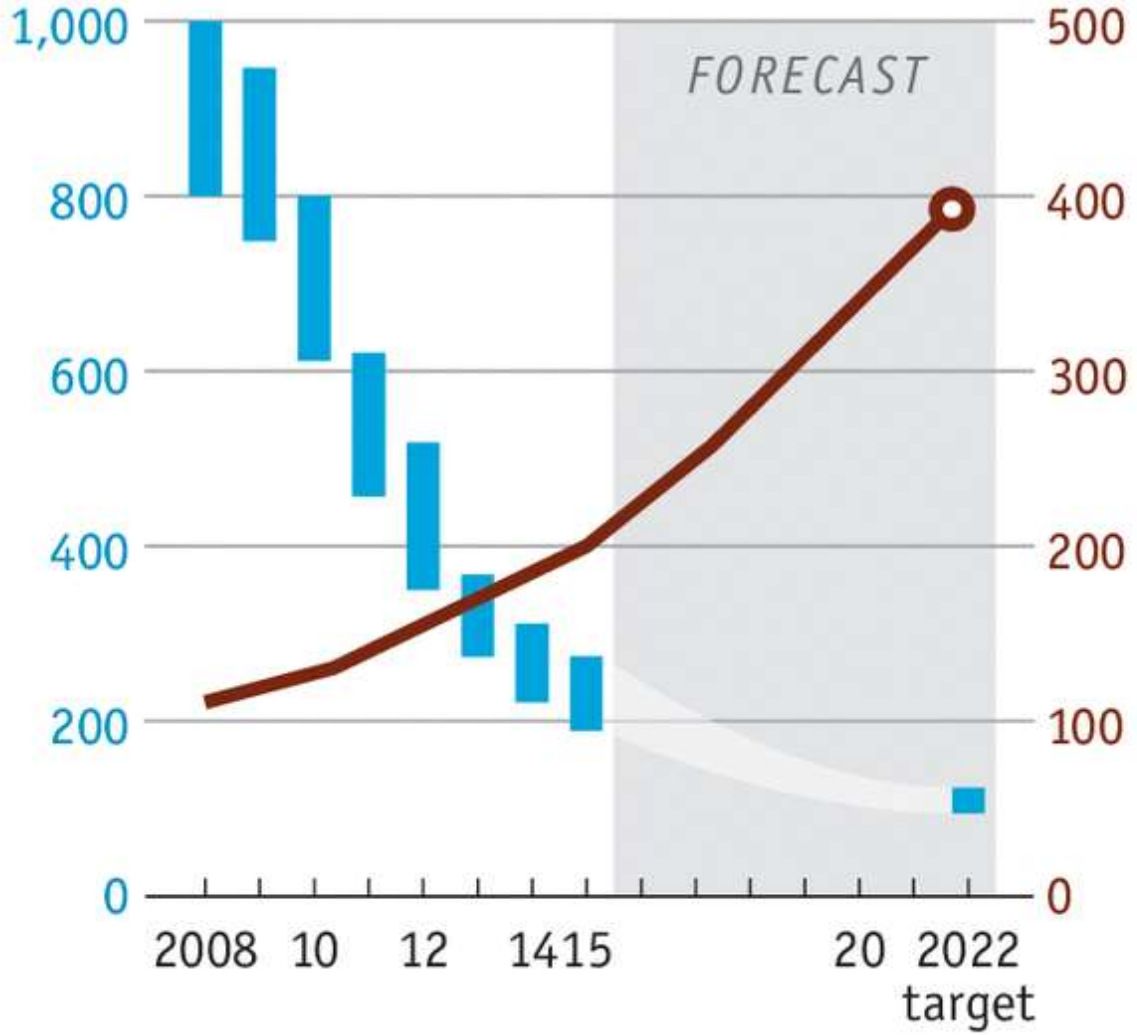
Sources: Cairn ERA; US Department of Energy

Battery cost

Worldwide, $/kWh

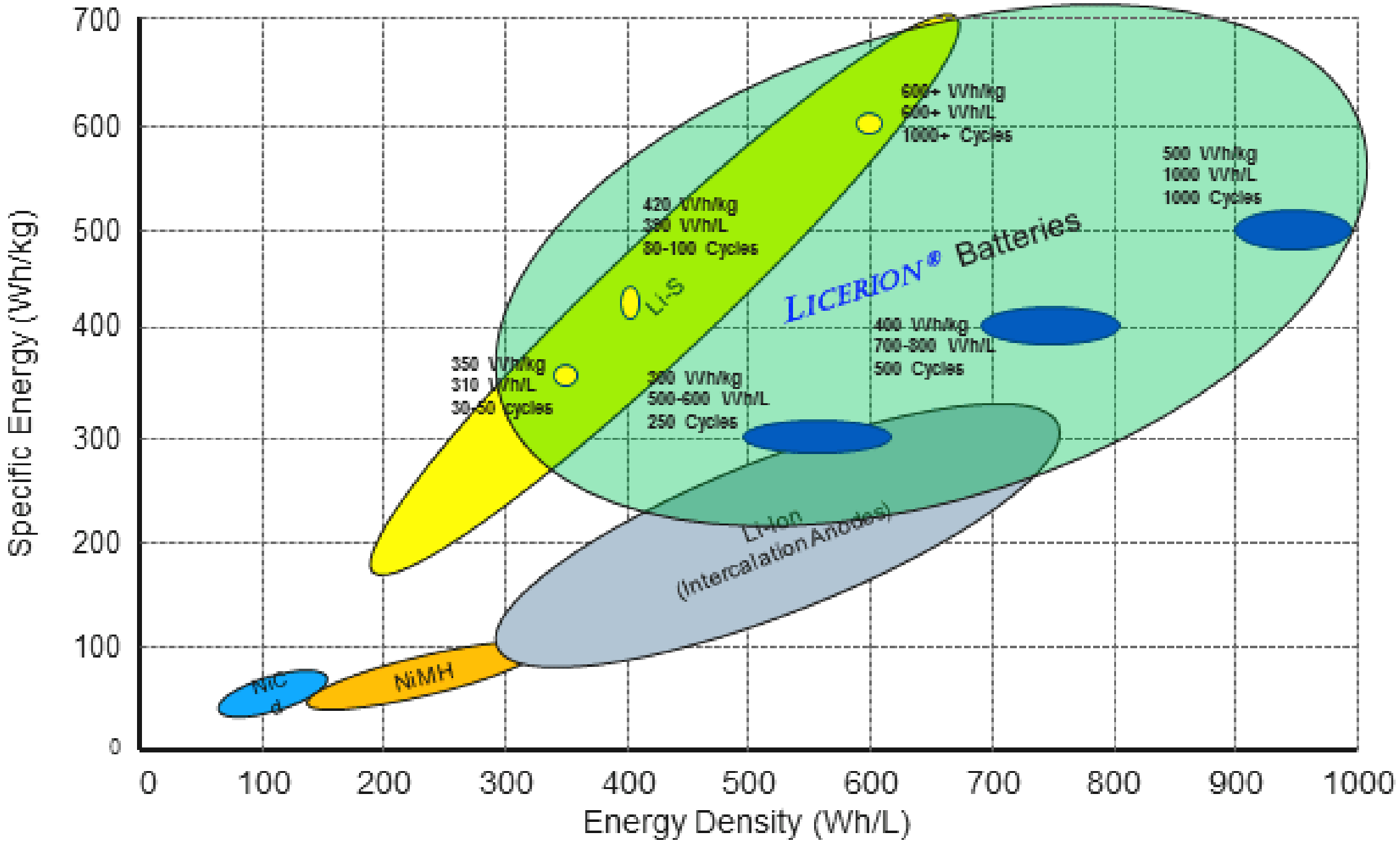
Battery energy density

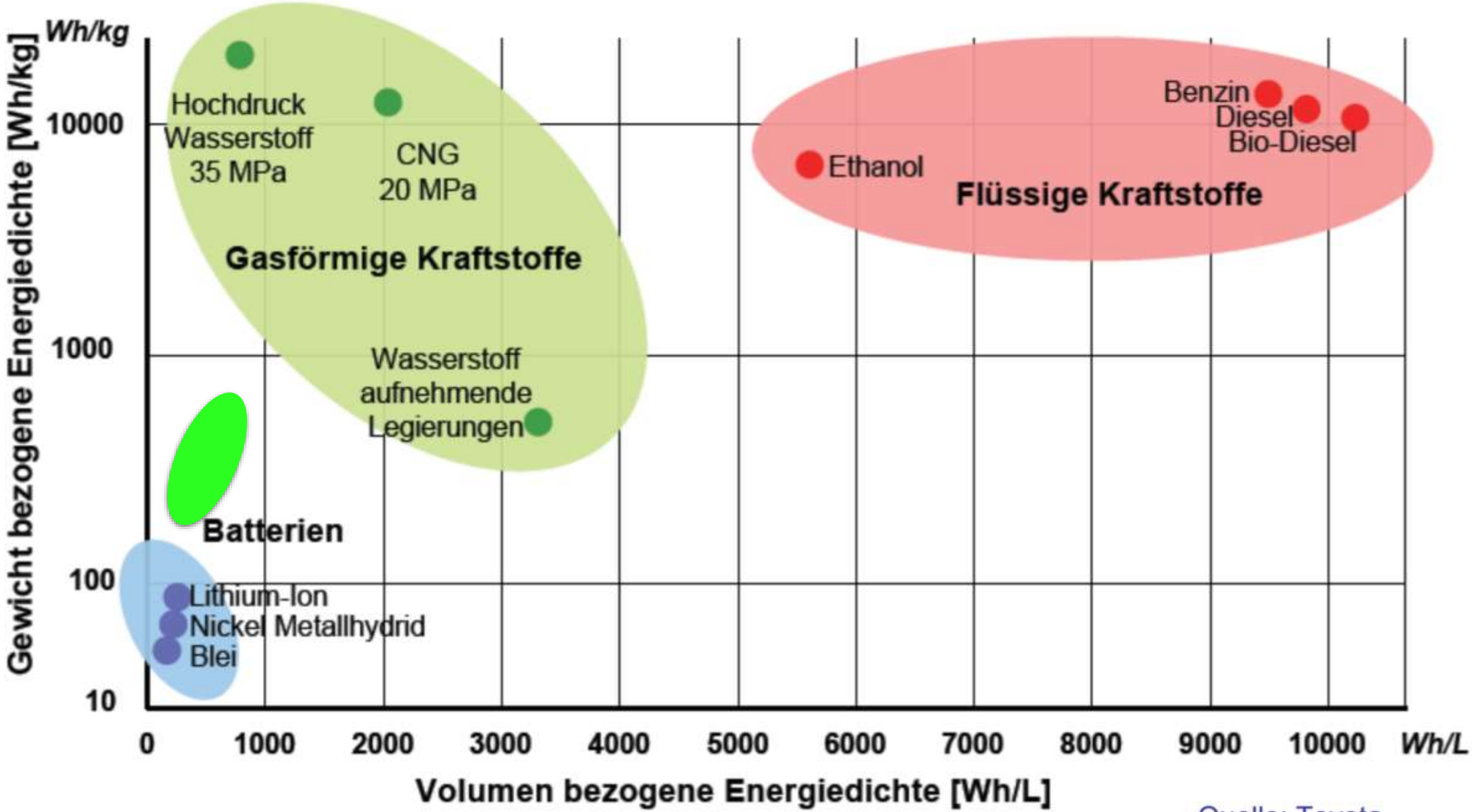
Watt-hours per litre



*Includes Tesla gigafactory

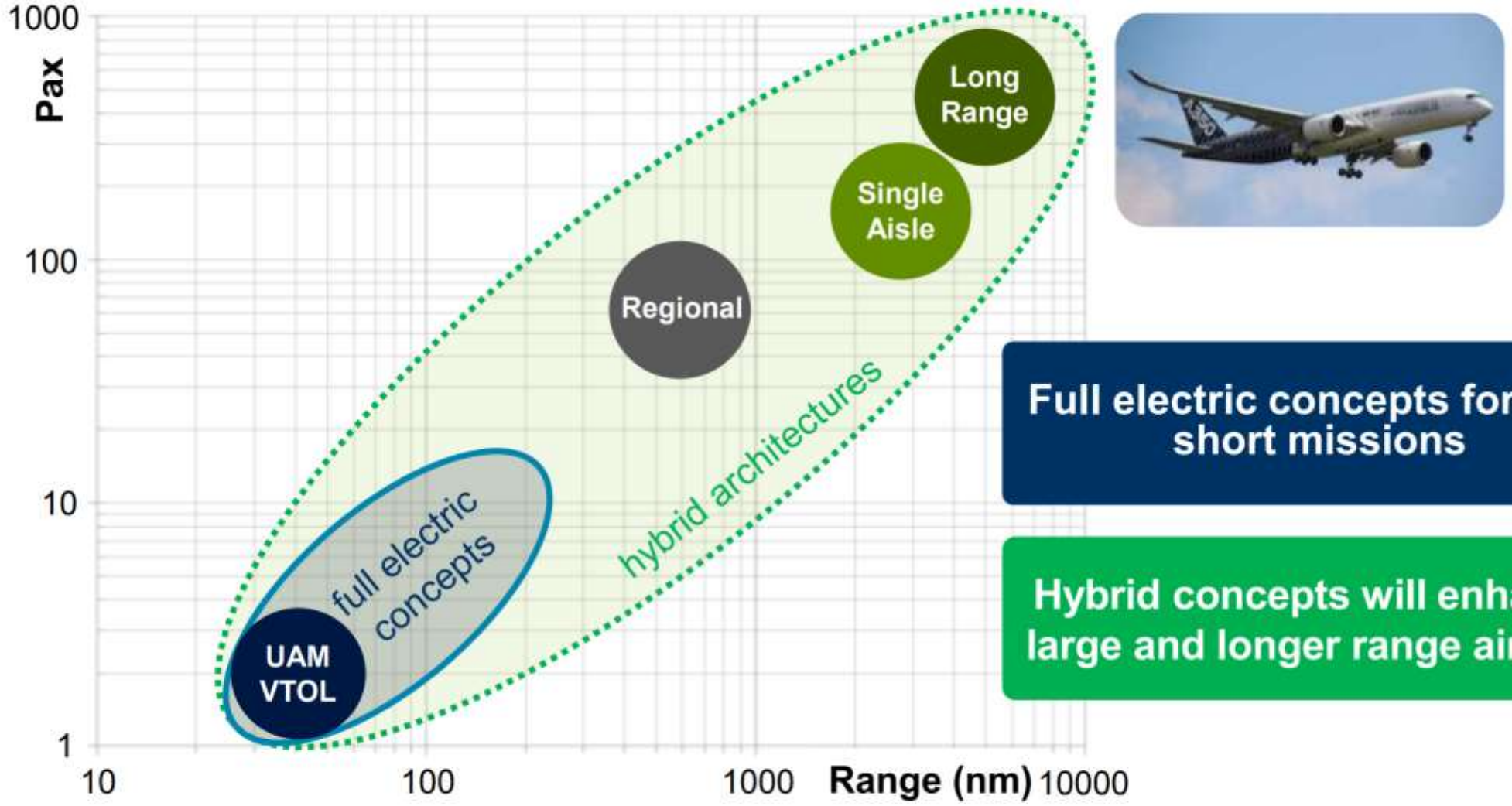
Economist.com


Specific Energy (Wh/kg)
Energy Density (Wh/L)
0
100
200
300
400
500
600
700
800
900
1000
600+ Wh/kg
800+ Wh/L
1000+ Cycles
500 Wh/kg
1000 Wh/L
1000 Cycles
420 Wh/kg
390 Wh/L
80-100 Cycles
Li-S
LICERION® Batteries
400 Wh/kg
700-800 Wh/L
500 Cycles
350 Wh/kg
310 Wh/L
30-50 cycles
360 Wh/kg
500-600 Wh/L
250 Cycles
Li-Ion
(Intercalation Anodes)
NiMH
NiCd



Quelle: Toyota

Hybridisation landscape

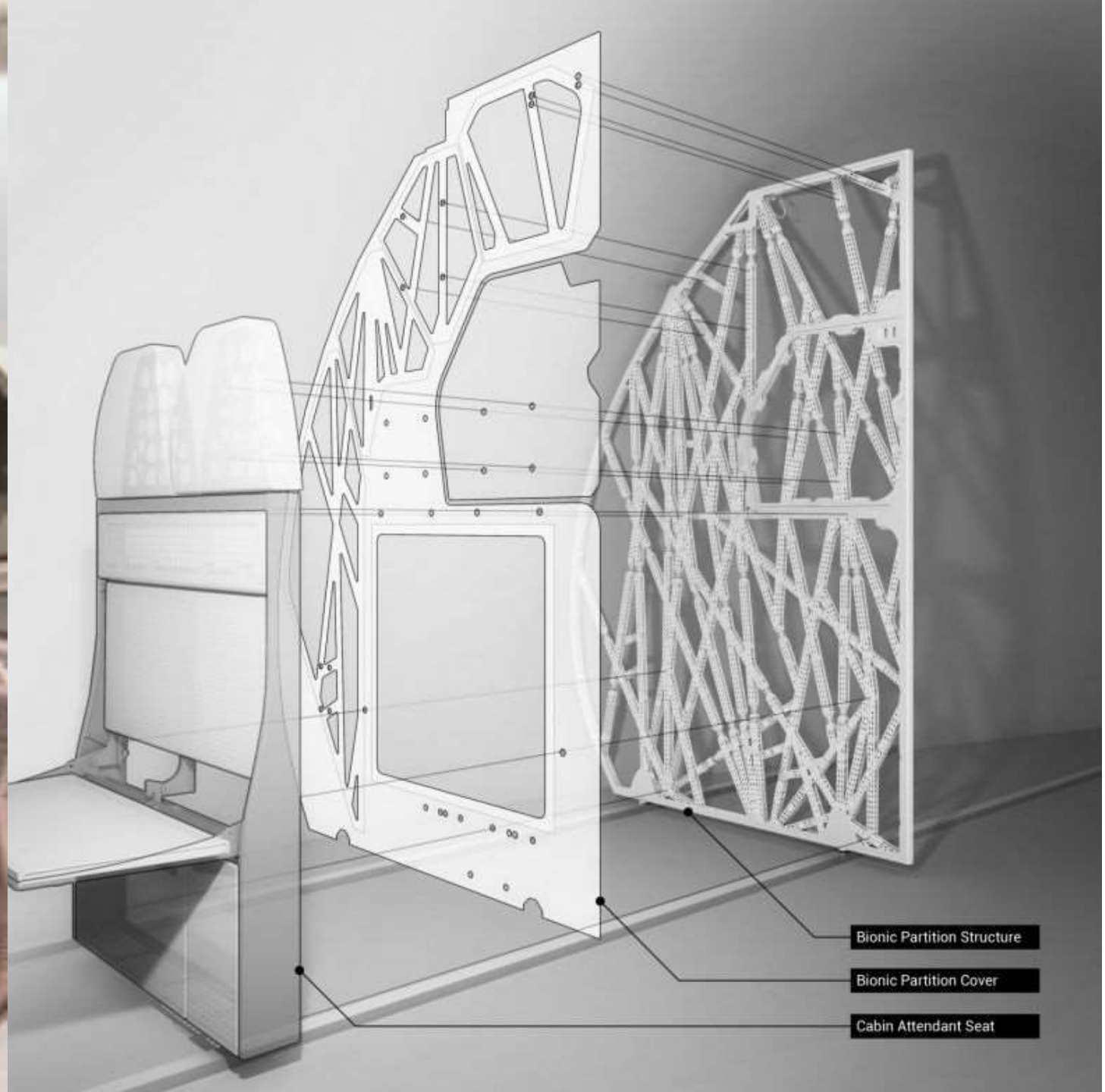


Full electric concepts for very short missions

Hybrid concepts will enhance large and longer range aircraft

UAM: Urban Air Mobility
VTOL: Vertical Take-off & Landing

AIRBUS


Bionic Partition Structure
Bionic Partition Cover
Cabin Attendant Seat


www.fliegerschule-wasserkuppe.de
Discus-2c FES
FLIEGERSCHULE Wasserkuppe

Motorisierung.
Engine Data.

	E-Antrieb 8+31=39kg **FES**	Fossil 30+10=40kg (8.5l/h) **Turbo**
Triebwerk *Engine Type*	FES-DIS-M100	Solo 2350
Max. Leistung *Max. Power*	22 kW / 30 PS *30 hp*	15,3 kW / 20,8 PS *20.5 hp*
Motorgewicht *Engine Weight*	ca. 8 kg *17.7 lb*	ca. 30 kg *66 lb*
Propeller *Propeller*	2-Blatt Faltpropeller *Foldable 2-blade propeller*	Asymmetrischer 5-Blatt Falt-propeller *Asymmetrical foldable 5-blade propeller*
Batteriekapazität / Tankinhalt *Battery / Tank Capacity*	4,2 kWh *4.2 kWh*	13,5 Liter *3.57 US Gallons*
Batteriegewicht *Battery Weight*	31 kg *68.3 lb*	
Ladezeit, abhängigkeit von Ladegerät *Charging Time, depending on charging power*	5-6 Stunden *hours* @ 600 W 3 Stunden *hours* @ 1200 W	


483887


PIPISTREL
pipistrel-usa.com
pipistrel-usa.com
Langelaan Aeronautics LLC
N448EC


ALPHA
ELECTRO

Human Powered Multicopter

Jet Pack

like a glider	**Noise**	like a racing car
balanced	**Noise spectrum**	very disturbing
0.7 kW	**Power required**	150 kW

Figure 4 Difference in noise lifting the same payload (Source: Aerovelo, Martin Jet Pack)

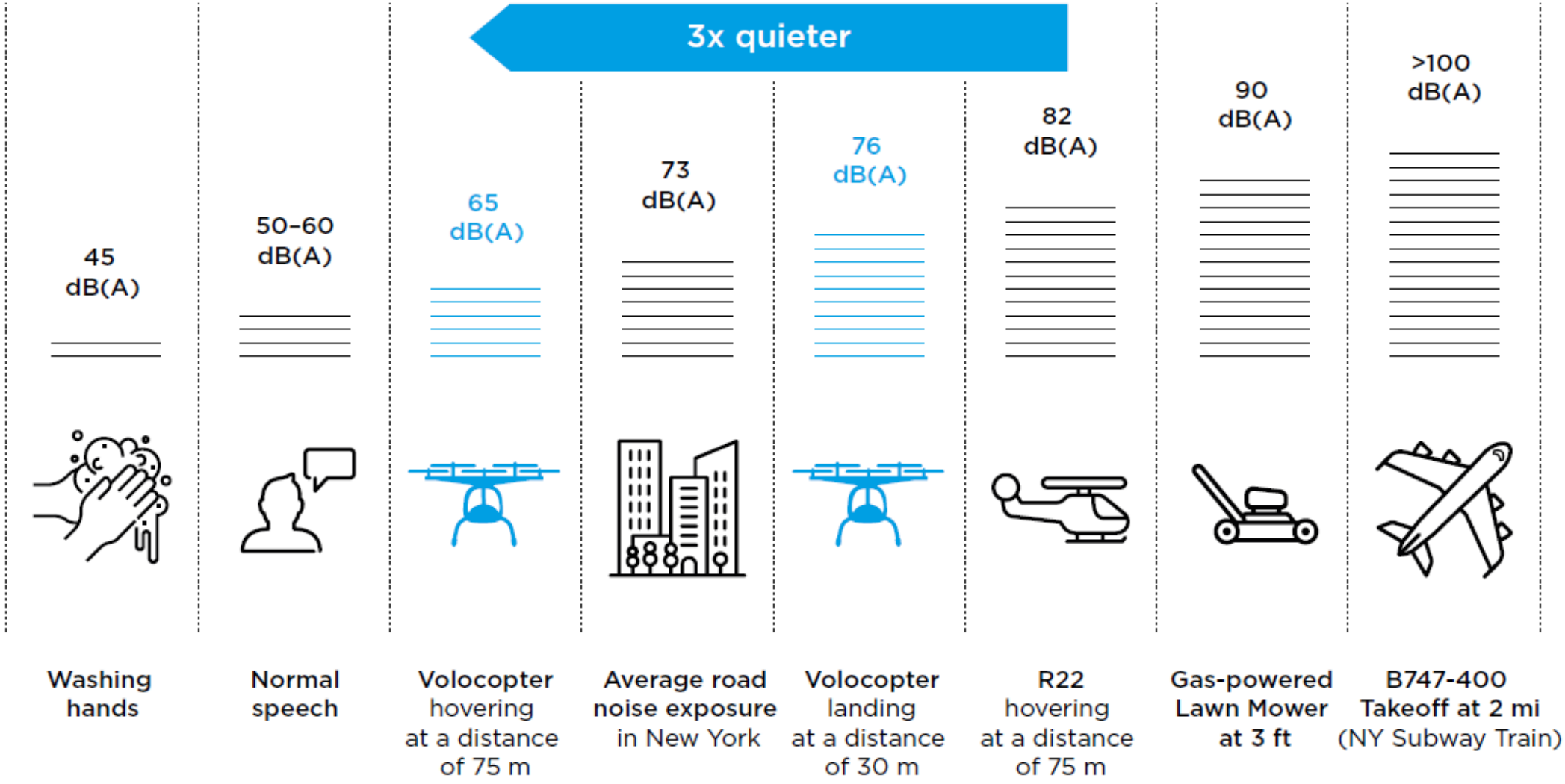


Figure 5 The Volocopter can be integrated into the city without adding significantly more noise pollution

Quelle: Volocopter Whitepaper

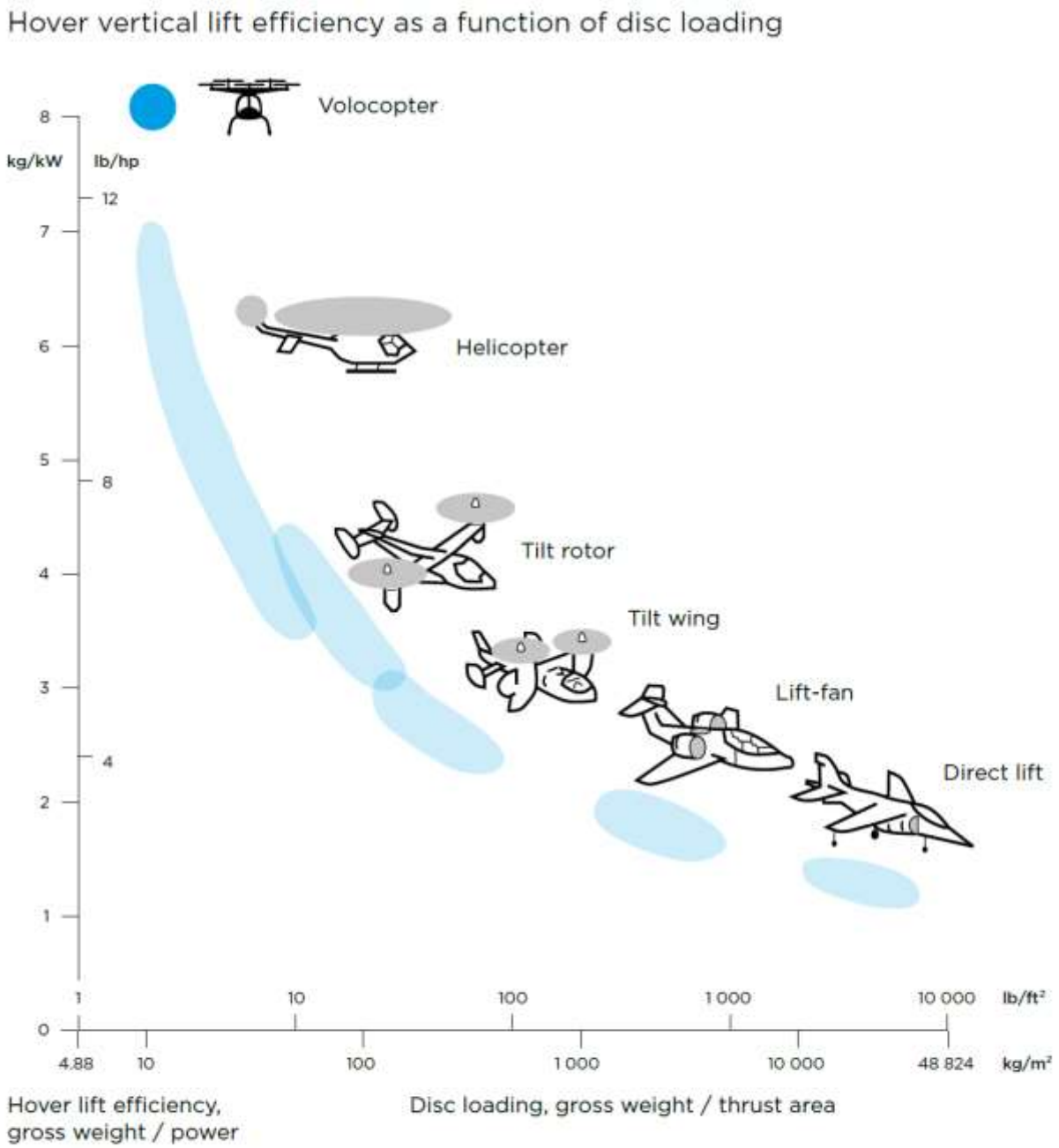
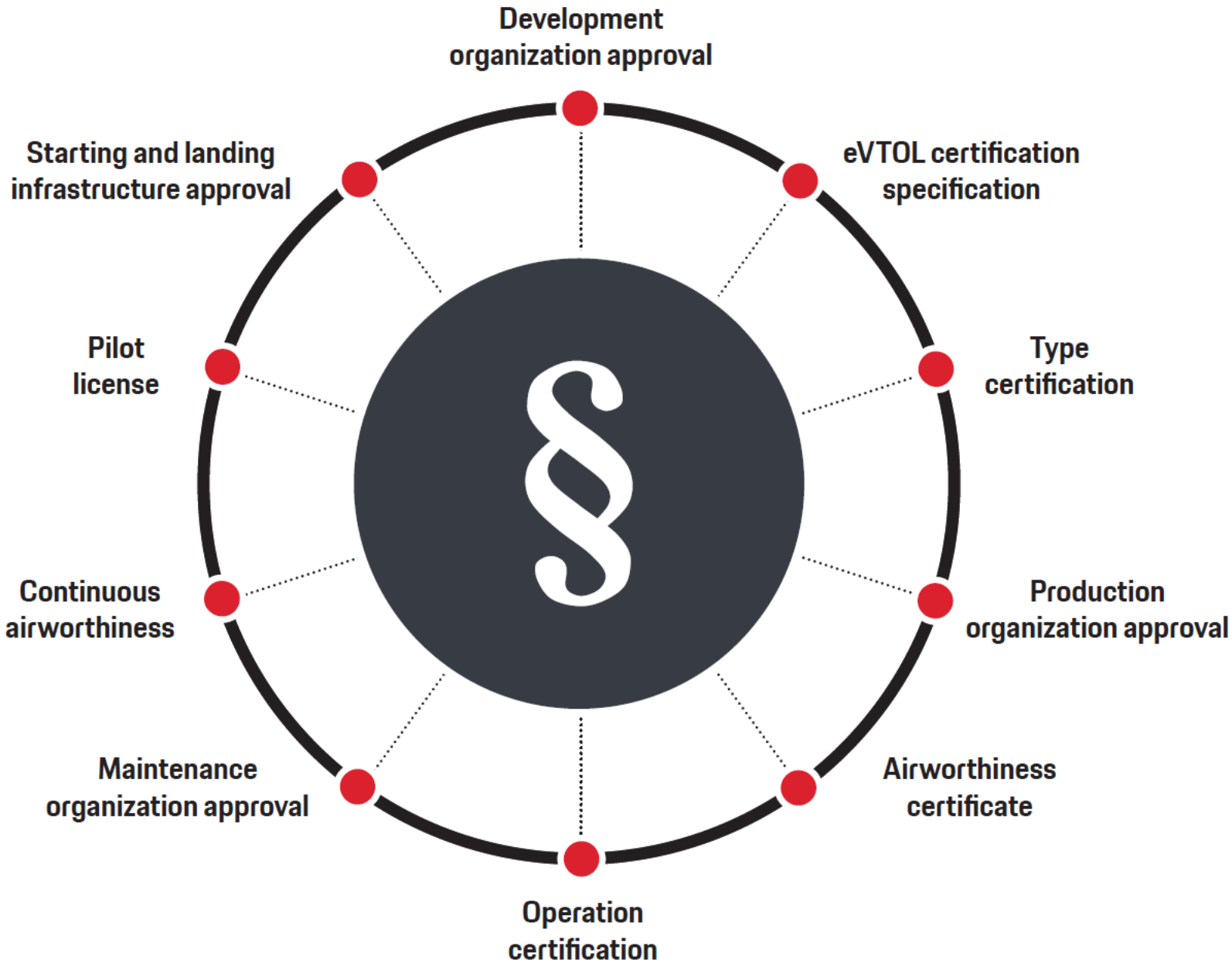


Figure 13 Lift efficiency in vertical take-off and landing (Source: NASA, edited by Volocopter)

Quelle: Volocopter Whitepaper

Sicherheit ist nicht verhandelbar

Certification and law

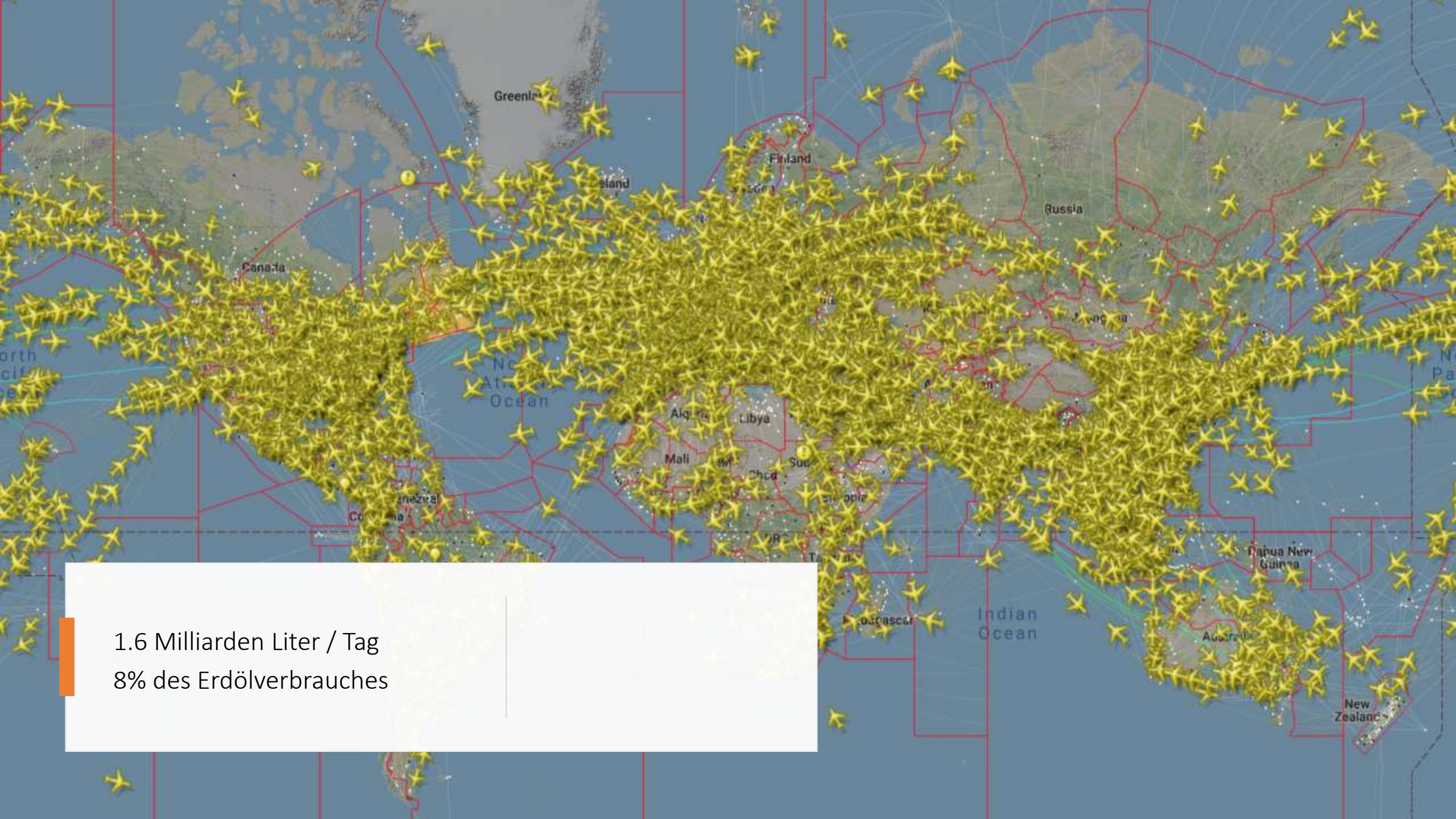



HDG
APR
NAV
HDG
CRS1
FD
BANK
AP
YD
XFR
ALT
VS
ALT SEL
VNV
SPD
FMS
MAN
FLC
CRS2
EMERGENCY AUTOLAND
DISPLAY BACKUP
FUEL TEMPERATURE LIMIT
JET A -34° C TO 50° C
JET A-1 -41° C TO 50° C
TOTAL USABLE FUEL CAPACITY 1742 LBS(790.1 KG)
Miles Remaining
--- Miles
EMERGENCY AUTOLAND ACTIVE
Total Fuel Remaining
2.4 Hours
CALCULATING ETA...
Piper
EMERGENCY AUTOLAND
HAS BEEN ACTIVATED
No Action Required
GARMIN
Turning Right in
5 Minutes
EMERGENCY AUTOLAND ACTIVE
Descending in
5 Minutes
CALCULATING ETA...
Speed
210
200
170
160
Altitude
4900
4800
4680
4500
287°
Enroute to New Century Aircenter – Olathe, KS

27,382

Lifesaving Deliveries by Drone


prime

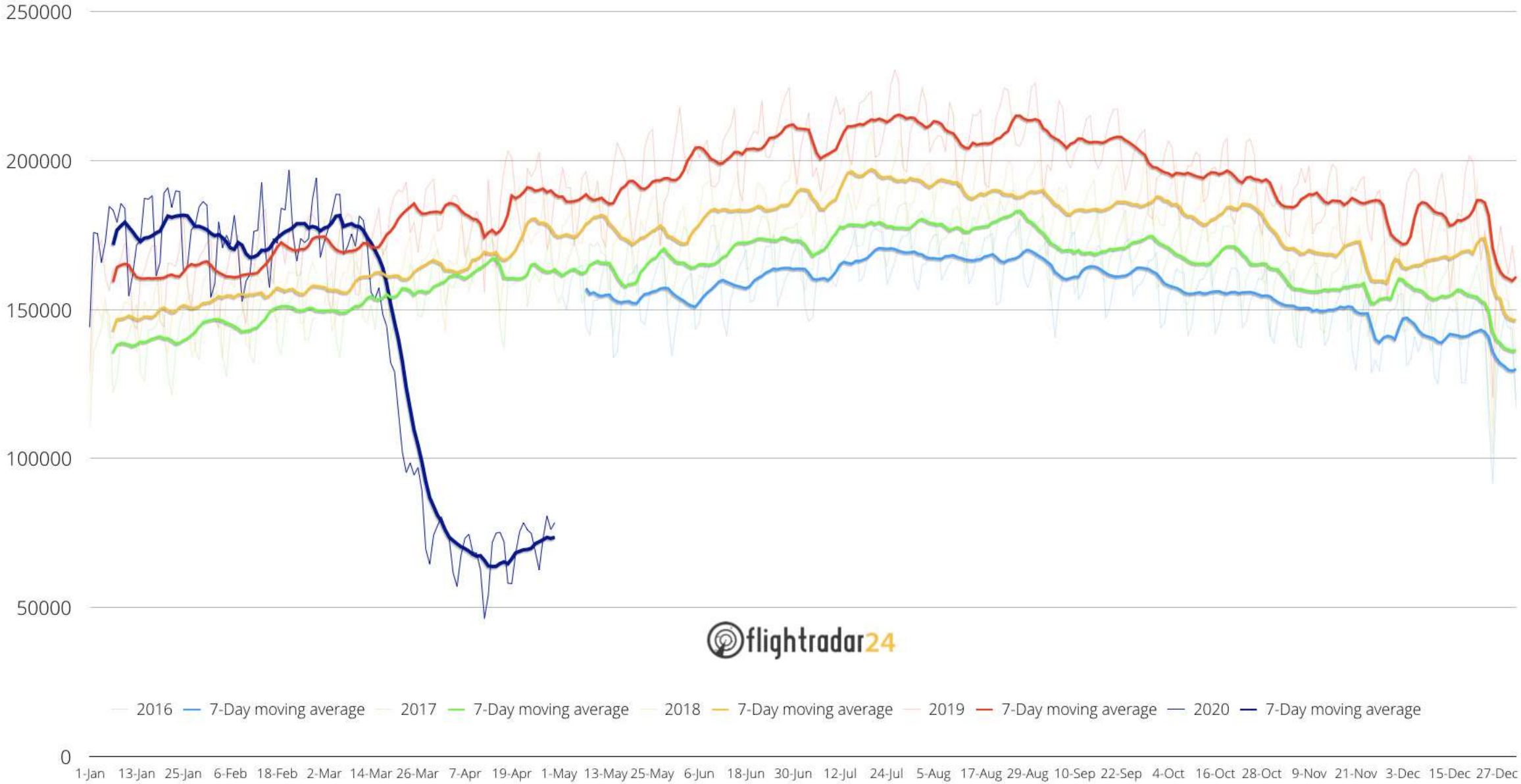


1.6 Milliarden Liter / Tag

8% des Erdölverbrauches


flightradar24

7-day moving average of total flights tracked by Flightradar24
May 2016-April 2020




SWISS
SWISS
SWISS
SWISS
STAR ALLIANCE
SWISS
SWISS
edelweiss
SWISS
SWISS
HB-IJE
SWISS
HB-IJD

ENTWICKLUNG DER WELTWEITEN CO_2-EMISSIONEN*

* Gemessen an den CO_2-Emissionen aus der Verbrennung fossiler Brennstoffe

Quelle: Internationale Energieagentur (IEA) 2018, Daten für 2016

Klimaschutz-Portal.aero

ENTKOPPLUNG DES KEROSINBEDARFS VOM VERKEHRSWACHSTUM

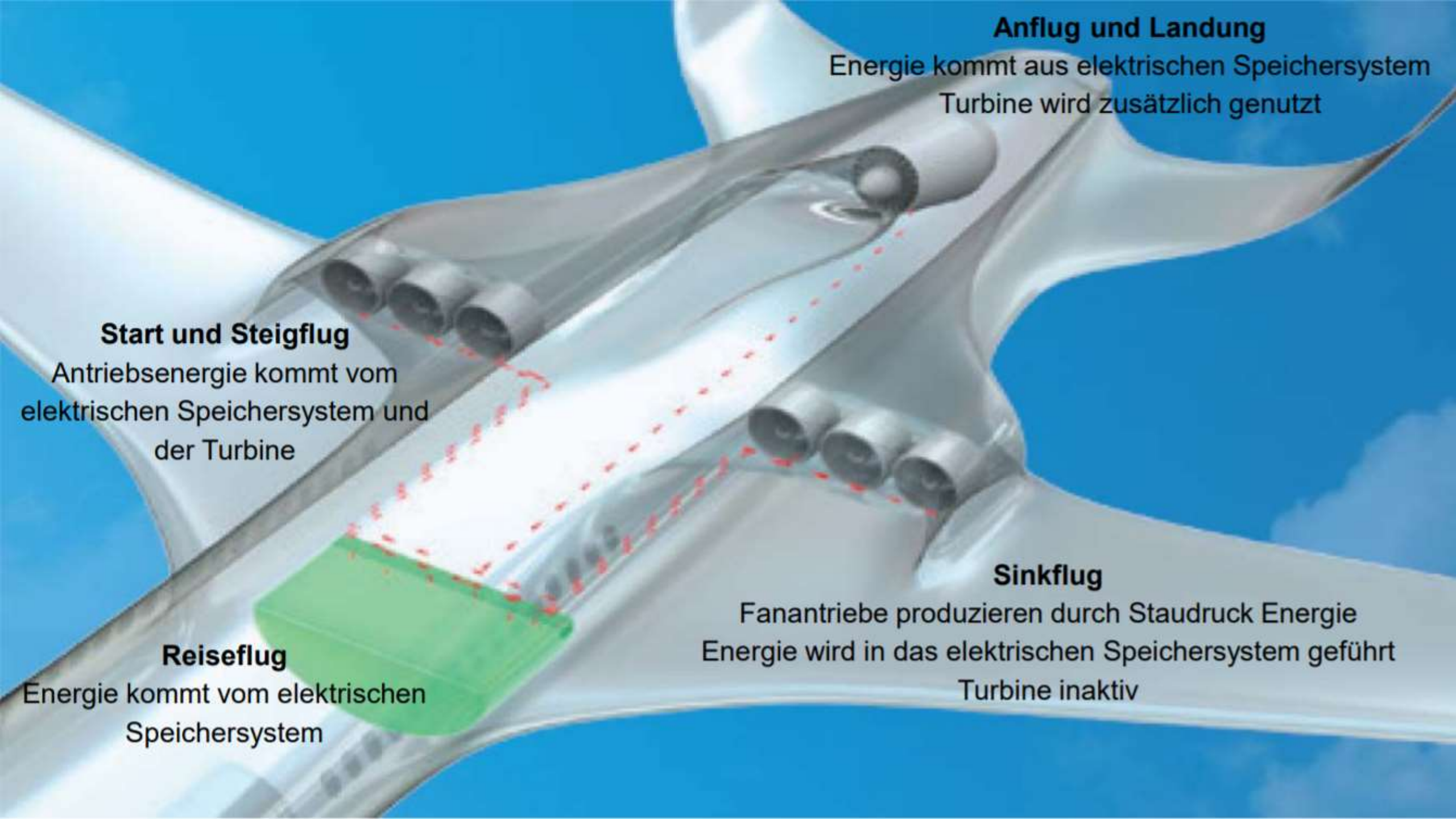
* Das Verkehrswachstum und der Kerosinbedarf beziehen sich auf die gesamte Verkehrsleistung aller Abflüge von Flughäfen in Deutschland.

Quelle: Bundesverband der Deutschen Luftverkehrswirtschaft (BDL) auf Grundlage der Daten von destatis und dem Umweltbundesamt (UBA)

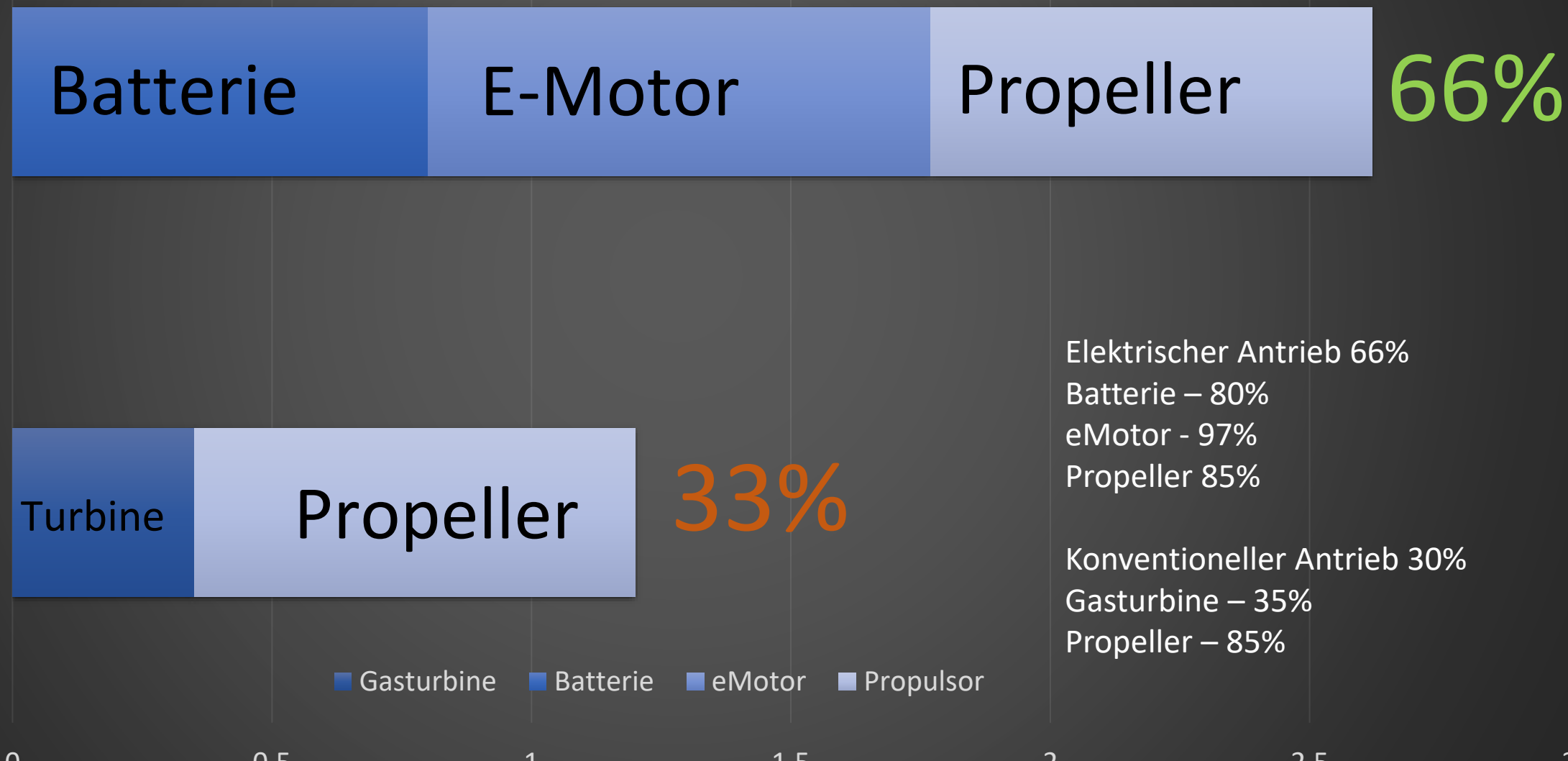
Klimaschutz-Portal.aero

Klimawirkung Luftverkehrs

Verbrauch steigt


Anflug und Landung
Energie kommt aus elektrischen Speichersystem
Turbine wird zusätzlich genutzt
Start und Steigflug
Antriebsenergie kommt vom elektrischen Speichersystem und der Turbine
Sinkflug
Fanantriebe produzieren durch Staudruck Energie
Energie wird in das elektrischen Speichersystem geführt
Turbine inaktiv
Reiseflug
Energie kommt vom elektrischen Speichersystem

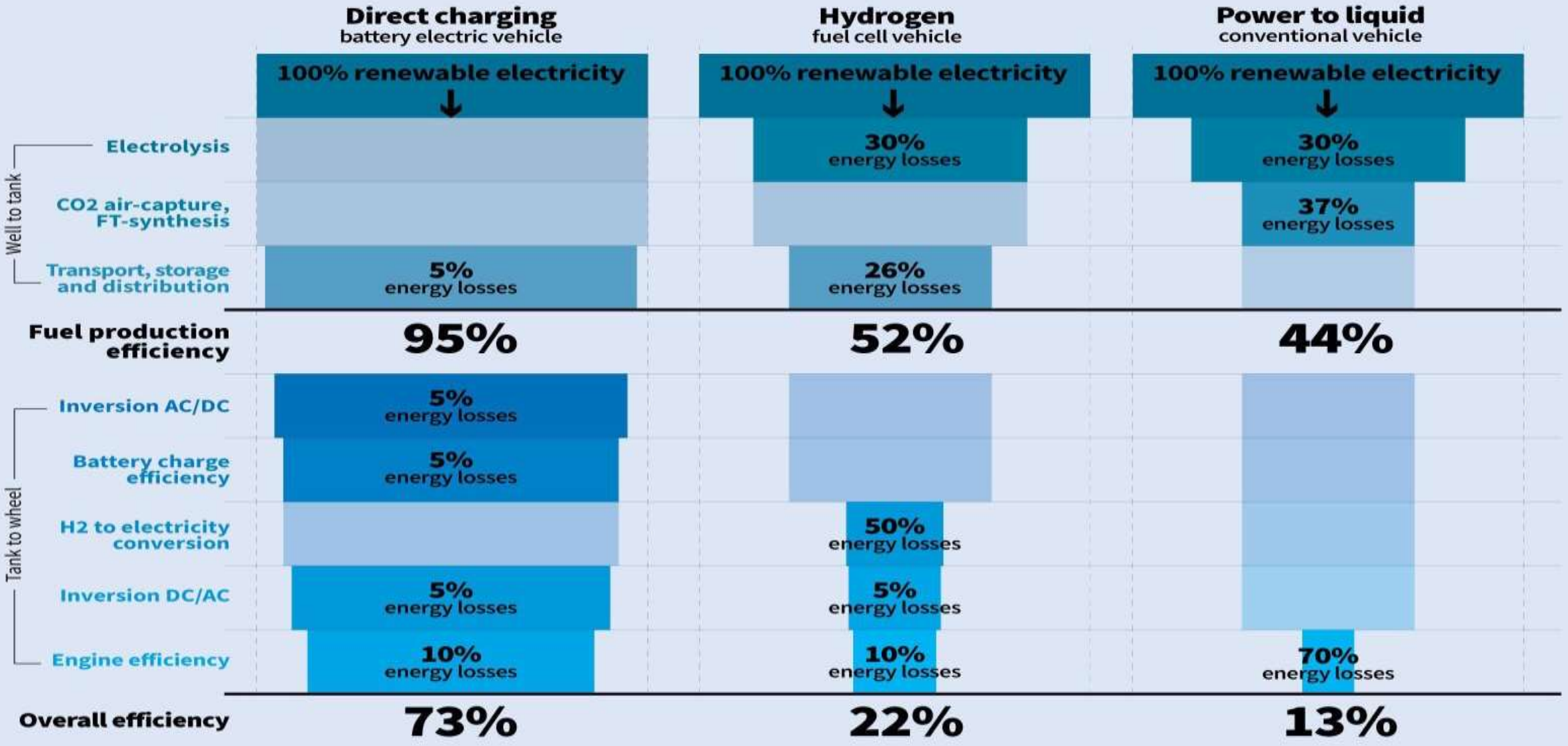
Wirkungsgrad elektrisch - fossil



Elektrischer Antrieb 66%
Batterie – 80%
eMotor - 97%
Propeller 85%

Konventioneller Antrieb 30%
Gasturbine – 35%
Propeller – 85%

Cars: Battery electric most efficient by far

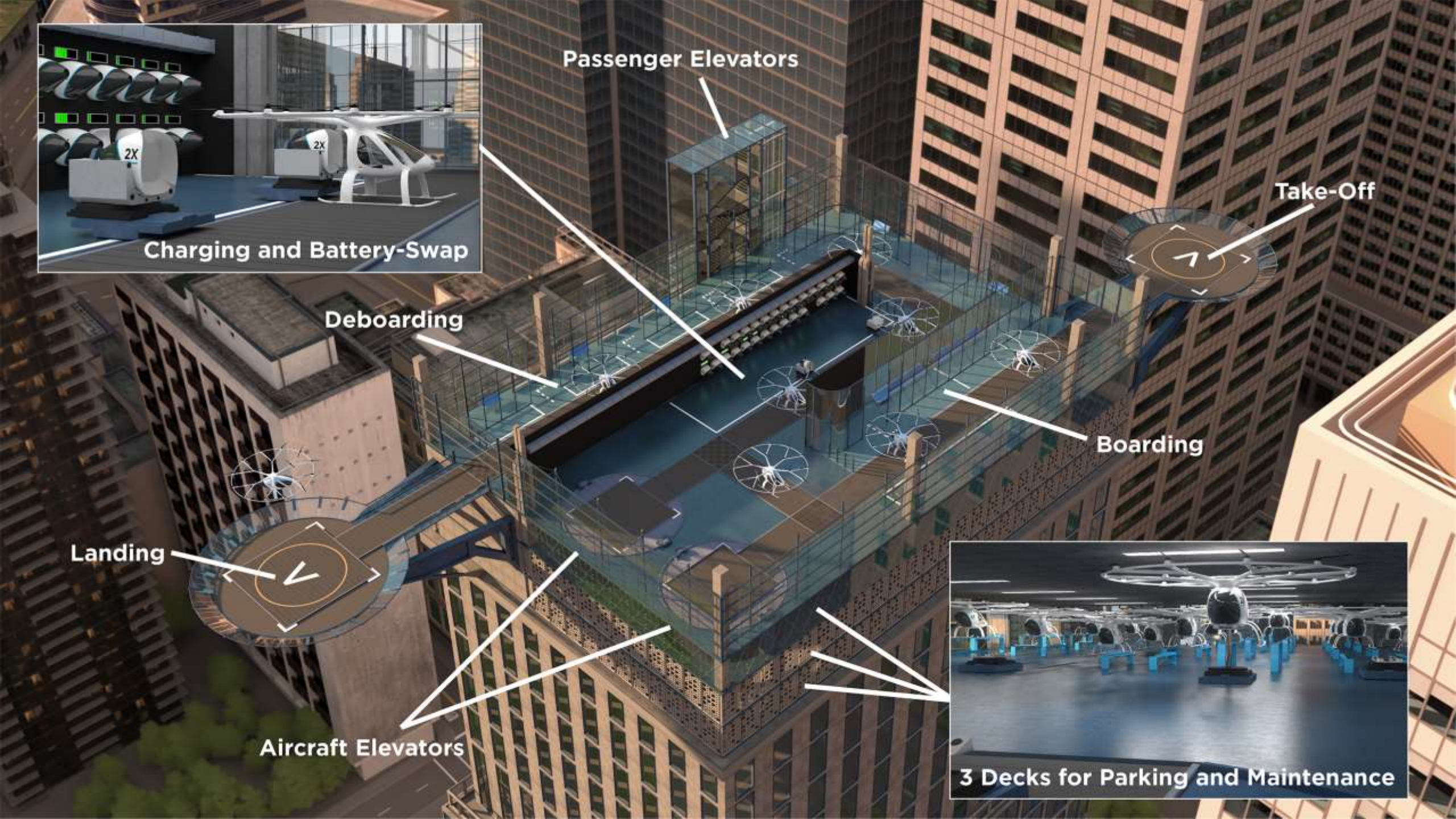


TRANSPORT & ENVIRONMENT @transenv @transenv transportenvironment.org

Source: WTT (LBST, IEA, World bank), TTW, T&E calculations


CO_2
H_2O
H_2
SYNFUEL
SYNFUEL


Uber
Uber

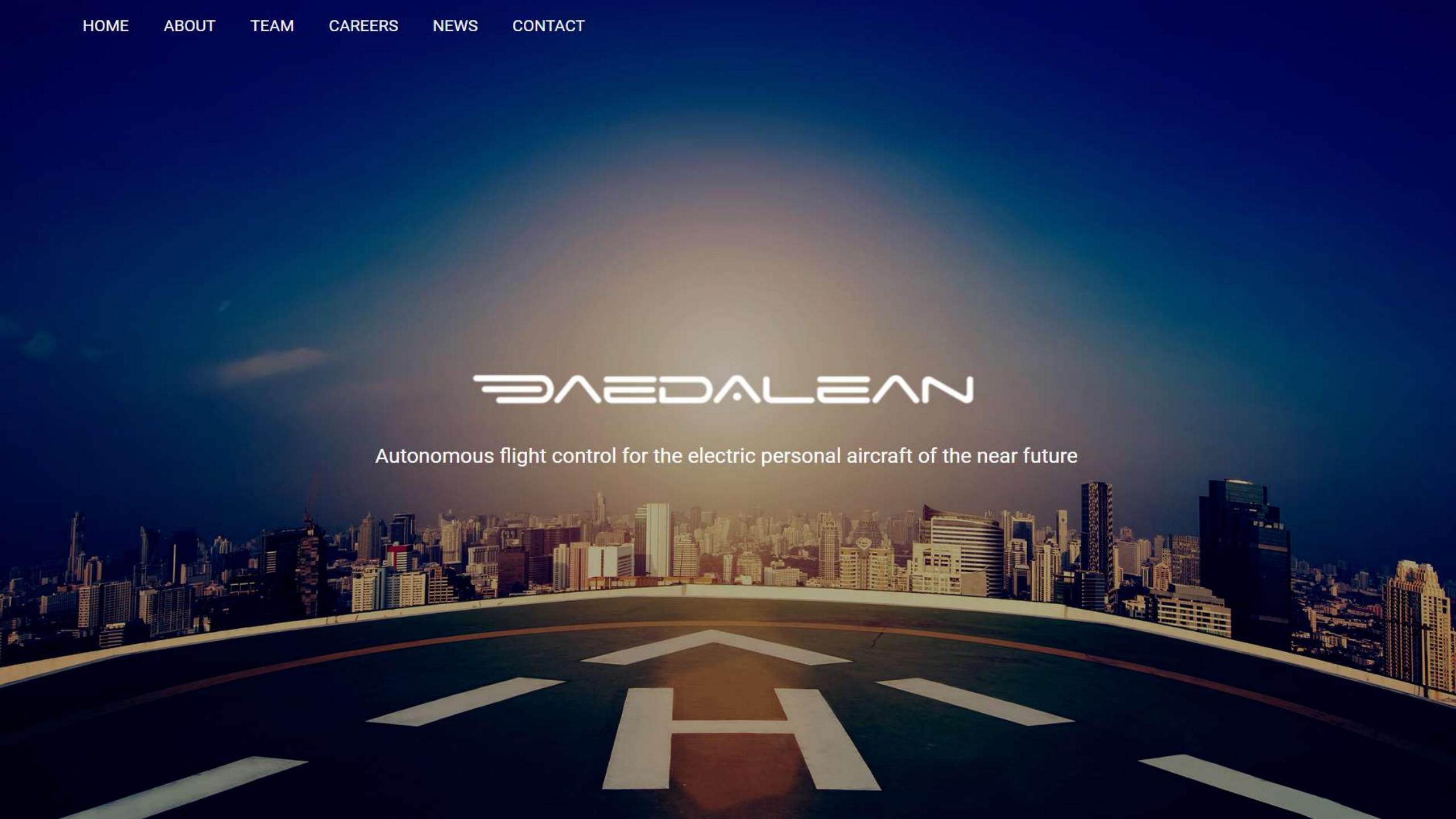

Charging and Battery-Swap
Passenger Elevators
Take-Off
Deboarding
Boarding
Landing
Aircraft Elevators
3 Decks for Parking and Maintenance


VOLOCOPTER
IN COLLABORATION WITH
Skyports
VOLOPORT


2X
2X


UBER
Uber
CORGAN


Uber
Uber
Uber
HUMPHREYS & PARTNERS ARCHITECTS


DAEDALEAN
Autonomous flight control for the electric personal aircraft of the near future


Uber
Gannett Fleming


N302VX
EXPERIMENTAL

Morell Westermann

+41-79-8446065

mo@morellife.com

Twitter: @morellwest

Blog: www.morellife.com

Podcast: CLEANELECTRIC