

U-Space II

Maximum total range of eVTOL under consideration of realistic operational scenarios



[1]

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Agenda



1. Introduction

2. State of the Art

3. Methodology

4. Results

5. Conclusion & Next Steps



Introduction



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Current Status

3rd Dimension of Mobility

- Increasing urbanization of cities
- Countermeasure for gridlocks in megacities
- New business opportunity
- Electrification of air traffic

eVTOL

Aim



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Introduction



Current Status

Aim

Problem

No realistic evaluation for
the range of eVTOLs



Aim

Technical feasibility
Operational aspects

- Concept comparison
- Validity check

Global objectives

- energy demand & consumption
- realistic ranges
- emergency procedures
- weather influences

Agenda



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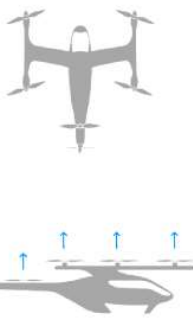
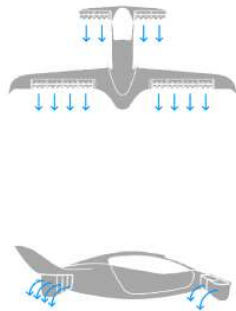
State of the Art



eVTOL

Battery technology

Gap-Analysis

	Multicopter	Lift + Cruise	Tilt Rotor	Ducted Vectored Thrust
Aircraft				
UAM	✓	✓	✓	✓
RAM	✗	✓	✓	✓

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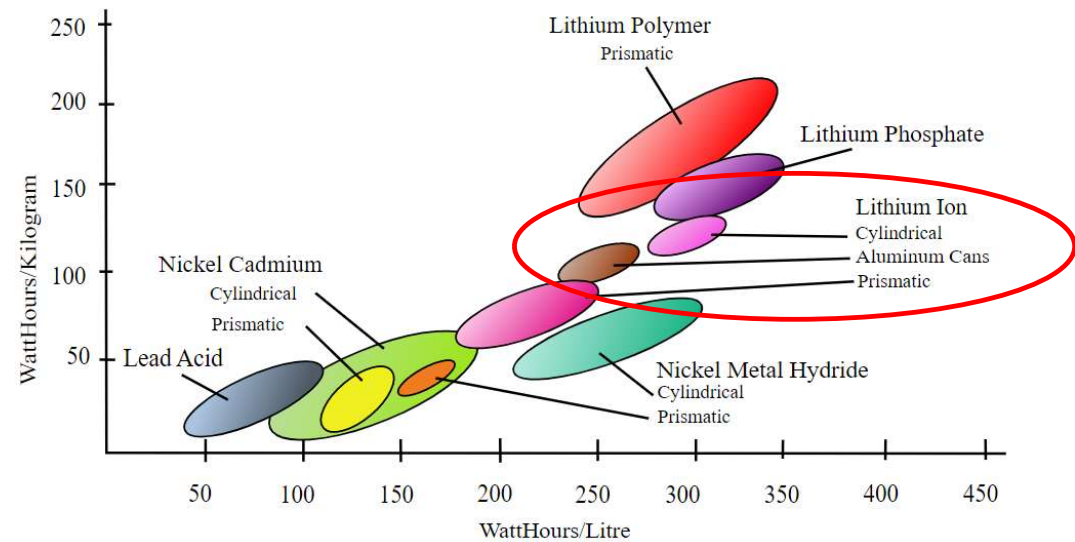
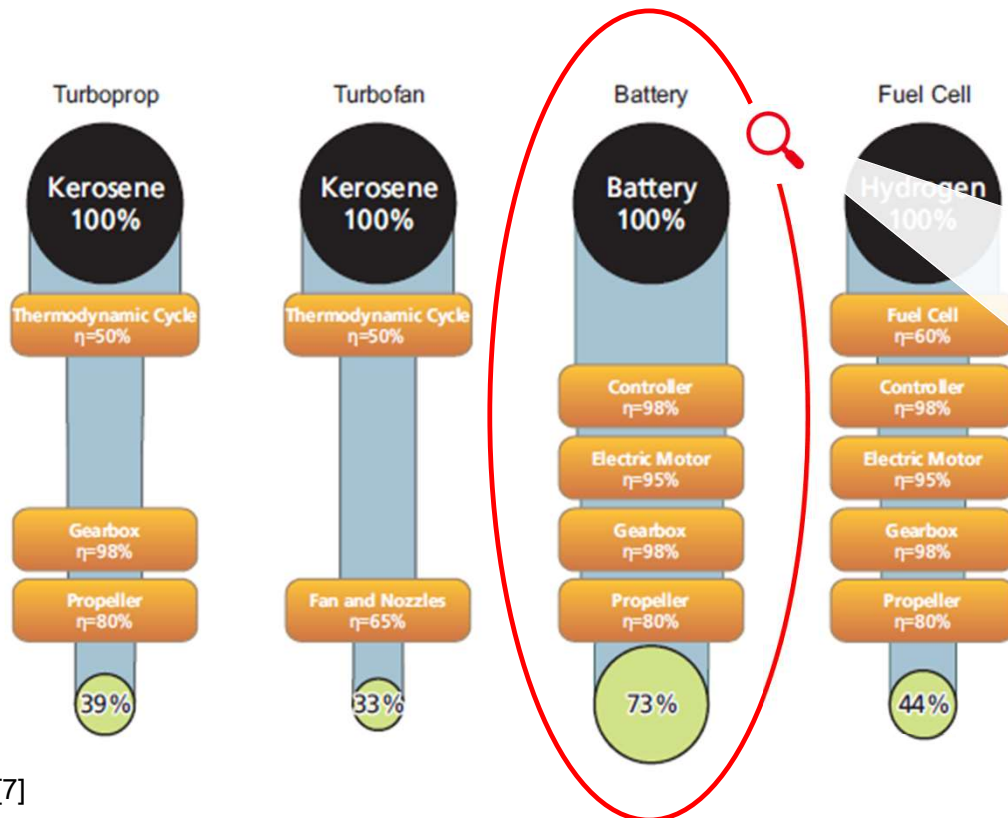
State of the Art



eVTOL

Battery technology

Gap-Analysis



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State of the Art



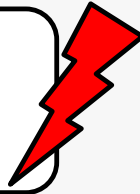
eVTOL

Battery technology

Gap-Analysis

Problem

- No calculations for eVTOLs:
- Power and energy requirements
 - Realistic range



Flight Dynamics Helicopter

- Momentum theory
- Energy theorems
- Thrust of propellers and rotors
- Drag polar
- Lift-to-drag ratio



Power demand - Hover flight

$$P_S = MTOW * g * \sqrt{\frac{MTOW * g}{2 * \rho * A_r}} * \frac{1}{\eta_S}$$

Power demand - Cruise flight

$$P_R = MTOW * g * \frac{1}{\varepsilon_R} * v * \frac{1}{\eta_R}$$

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Methodology

Derivation / Calculation

Selected Scenarios

eVTOL Performance Data

Output

Range Equation

$$R = \varepsilon_R * \eta_R * \left(\frac{\mu_A * e_A}{a} - \frac{t_s}{\eta_s} * \sqrt{\frac{MTOW * g}{\alpha_v * \rho * A_r}} \right)$$

Realistic range
max. possible hovering time



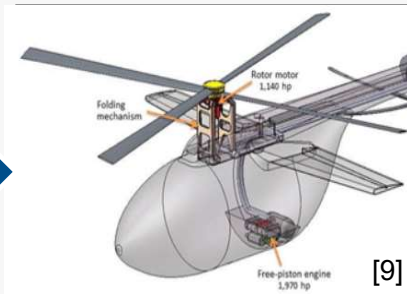
Hover flight

$$E_S = MTOW * g * \sqrt{\frac{MTOW * g}{\alpha_v * \rho * A_r}} * \frac{1}{\eta_s} * t_s$$

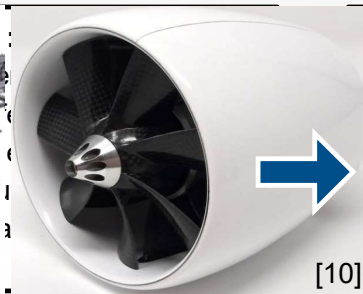
Realization

Derivation of energy demand

Hover flight
Cruising flight
Provided energy



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Realistic influencing factors

Temperature
Winds

Knowledge

Power requirements of a VTOL

eVTOL characteristics
realistic references (study)

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Quelle: Experteninterviews
founding members

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Methodology



Derivation / Calculation

Selected Scenarios

eVTOL Performance Data

Sensitivity analysis

- Flight altitude of 500 m ASL (Air density)
- Hover Time
- Weather Data based on CDC-OpenData of the DWD from Frankfurt
 - Air temperature
(5% coldest | average | 5% warmest)
 - Wind speed
(none | 5% windiest | average | max)
- Battery Development - Year

Parameter	Selected conditions			
Hover time	1 min	2 min	5 min	10 min
Air Temperature	10,4 °C	-9,1 °C	39,4 °C	
Headwind speed	0 m/s	4,9 m/s	10,1 m/s	20 m/s
Year	2021	2025	2030	2050

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Methodology



Derivation / Calculation

Selected Scenarios

eVTOL Performance Data

eVTOL Architecture	eVTOL Specifications						
	PAX	MTOW [kg]	Speed [km/h]	Battery mass [kg]	Hover efficiency	Cruise efficiency	Drag ratio
Multicopter	2	900	100	180	0,70	0,50	4
Multicopter – coaxial	2	600	100	100	0,55	0,48	4
Quadcopter	4	2200	120	800	0,55	0,40	2
Lift & Cruise 1	2	800	180	200	0,70	0,50	9
Lift & Cruise 2	2	1442	180	400	0,70	0,50	11
Vectored Thrust (SF)	5	3500	300	900	0,60	0,60	17
Tilt Rotor	5	1815	322	400	0,70	0,46	15

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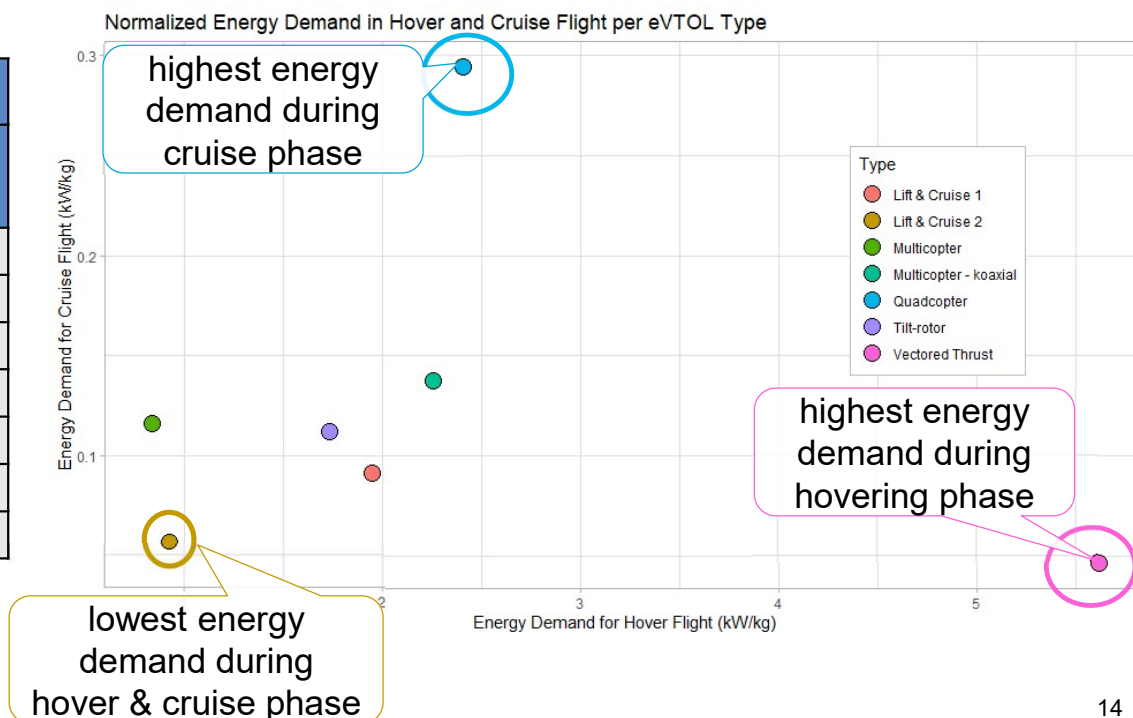


Results



Energy Demand > Hover Time > Temperature & Wind > Battery Development

eVTOL Architecture	eVTOL Specifications			
	MTOW [kg]	η_S	η_R	Drag ratio
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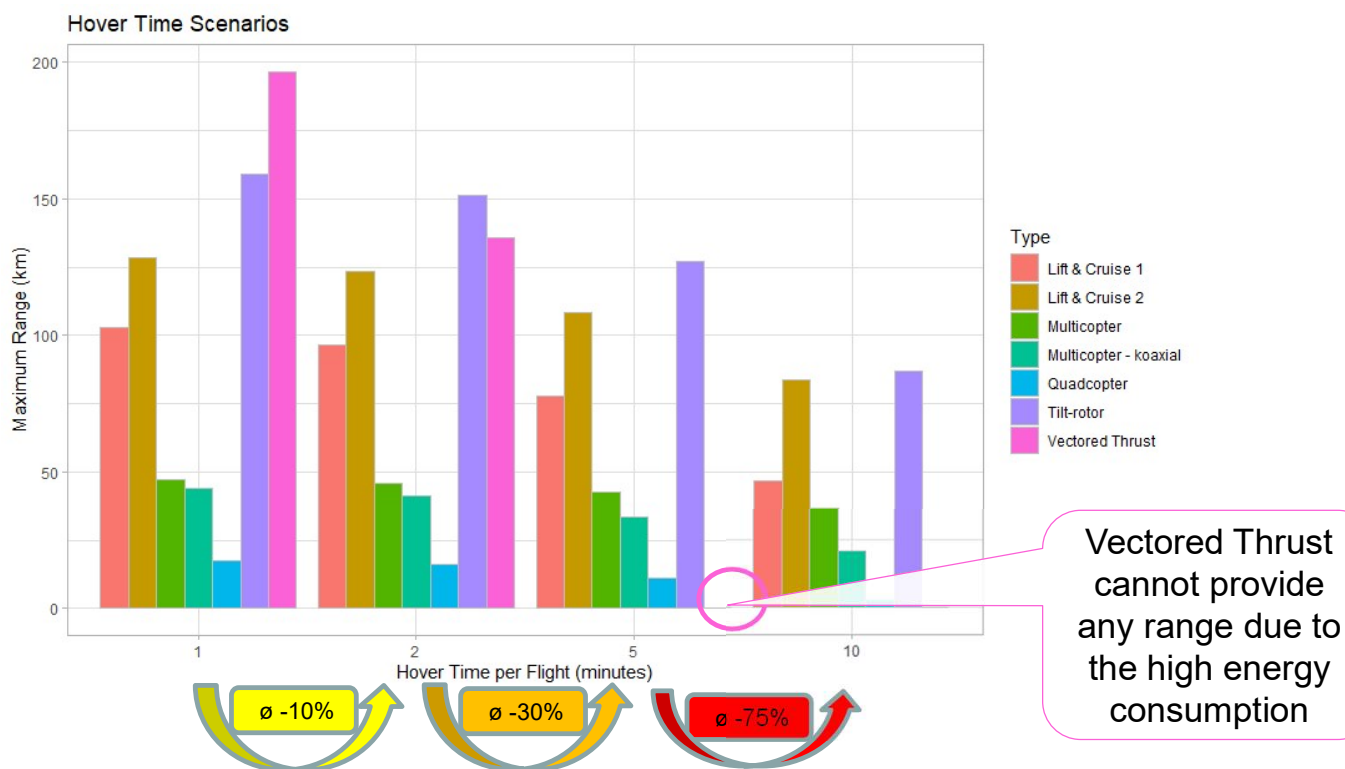
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Results

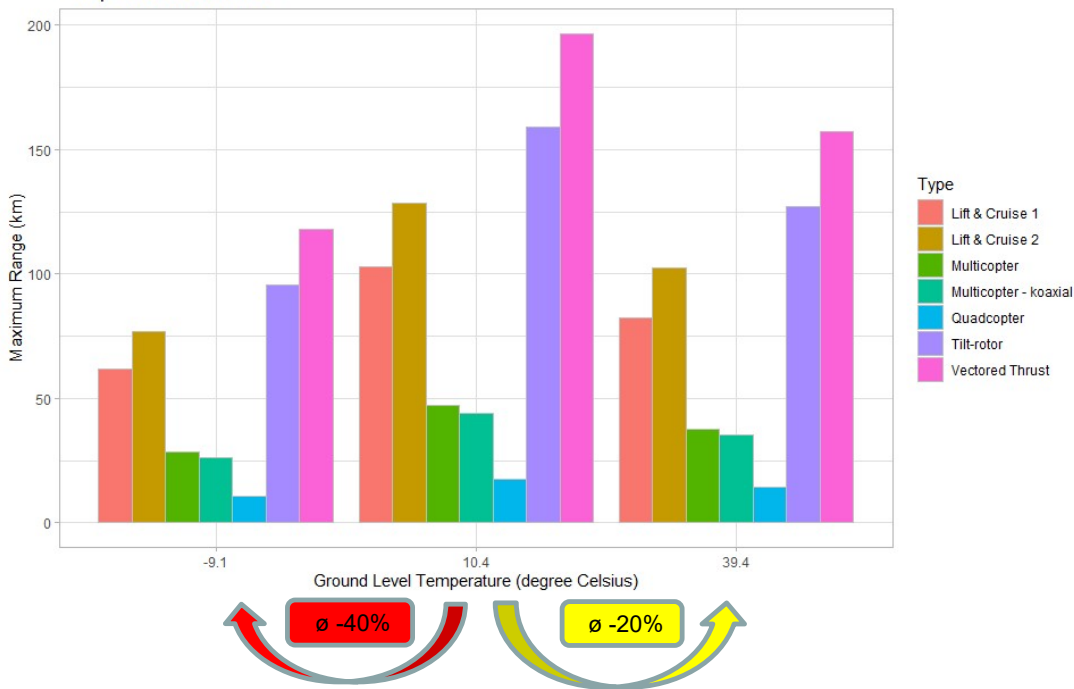
Energy Demand > Hover Time > Temperature & Wind > Battery Development



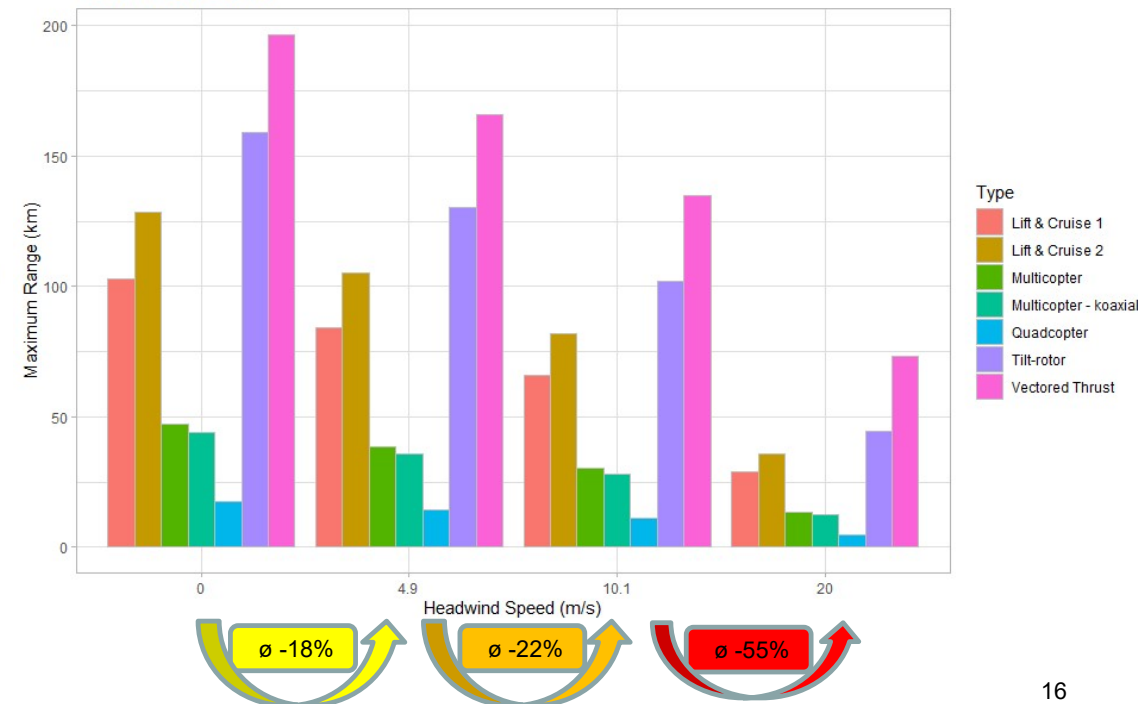
Results

Energy Demand > Hover Time > Temperature & Wind > Battery Development

Temperature Scenarios



Headwind Scenarios



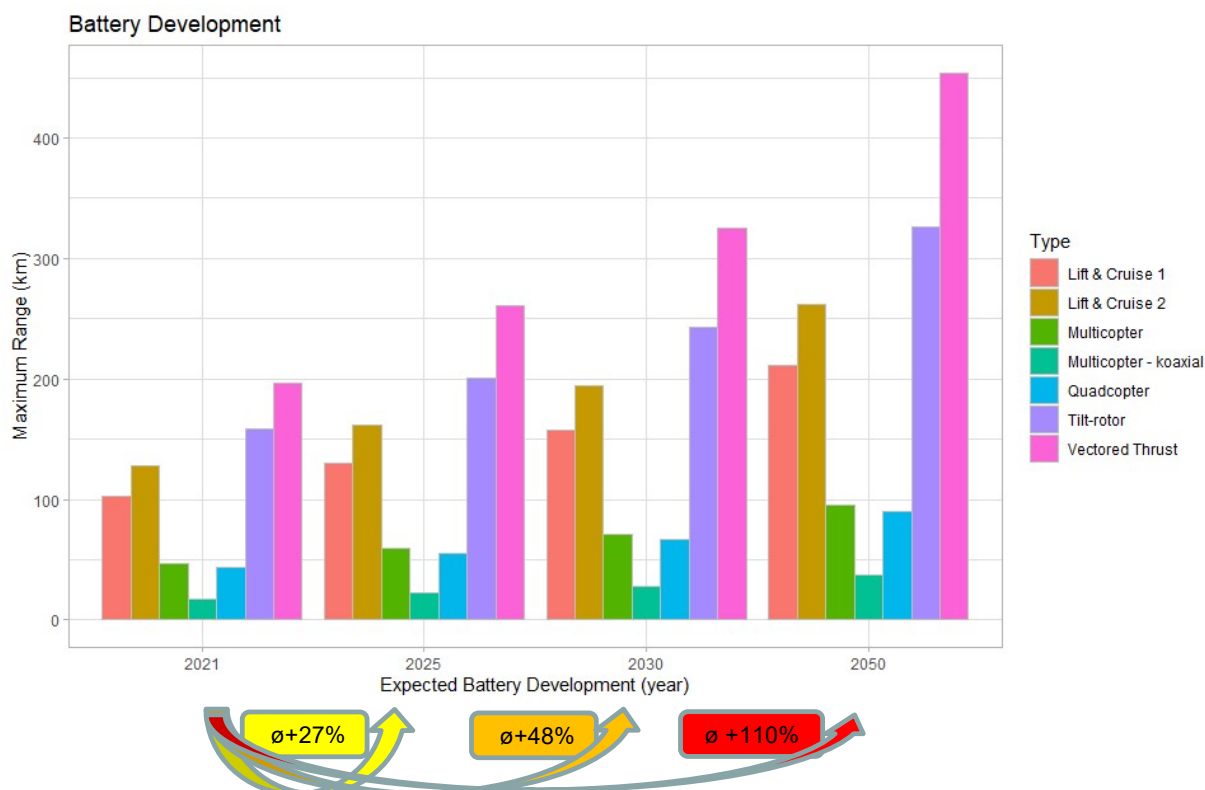
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Results



Energy Demand > Hover Time > Temperature & Wind > Battery Development



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Conclusion



Conclusion

Next Steps

Need

Validity check
Derivation of range for eVTOL

Realization



Technical feasibility
Operational aspects

Influential factors:

Hover time
Drag ratio
Battery capacity
spec. Energy density
Weight
Ambient temperature
Wind influences



Global objectives

- Legal basis
- Design overhaul
- Thermal management
- Energy recovery
- Traffic Management System



Local objectives

Fraport AG

- Flight operation planning
- Business & Use Cases
- Economic estimation
- Investment

Output

IMPOSSIBLE

Assumed
eVTOL commercial operations

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Next Steps

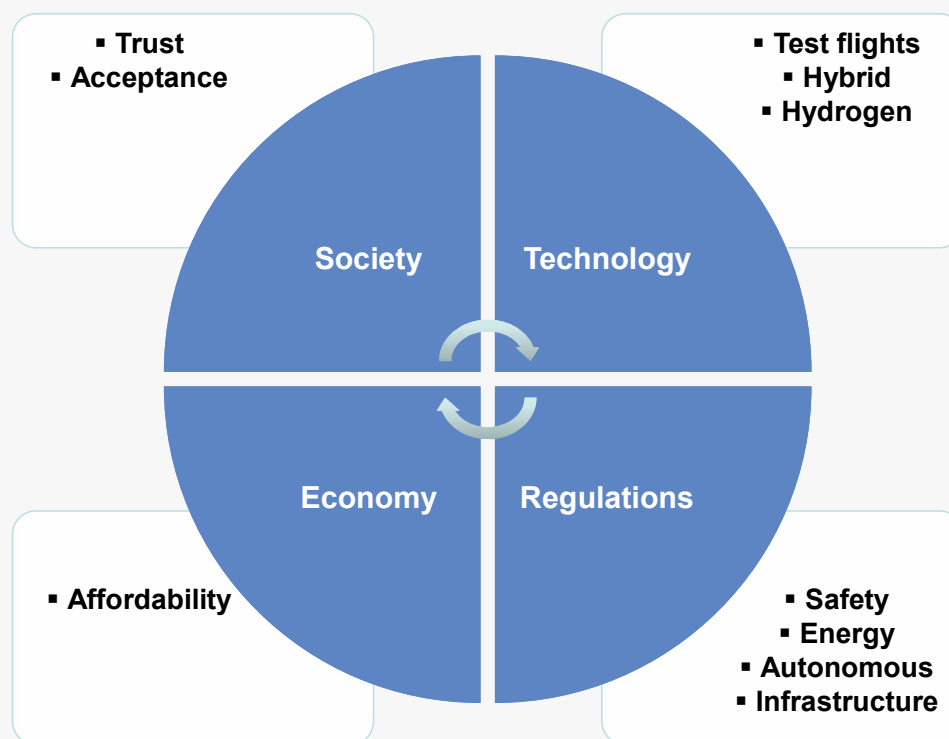


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Conclusion

Next Steps

Recommendations



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