TECHNICAL CONCEPTS OF AIRPORT INFRASTRUCTURE FOR CHARGING BATTERY-ELECTRIC AIRCRAFT

Svetla Käck

Swedish National Road and Transport Research Institute (VTI)

Presentation at FT2025, October 2025

TECHNICAL CONCEPTS OF AIRPORT INFRASTRUCTURE FOR CHARGING BATTERY-ELECTRIC AIRCRAFT

Outline:

Background (Research area and Project)

Technical concepts + Evaluation Criteria, Examples (Hypothetical operational scenarios with example assumptions)

Next steps (Future projects)

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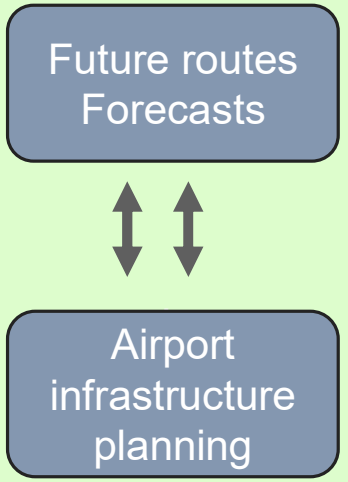
John Nilsson (Swedavia)

Presentation at FT2025, October 2025

RESEARCH AREA BACKGROUND

- Role of Battery Electric Aircraft in future aviation ?
  - Powertrain & Charging infrastructure developments
  - Charging loads and needs? → Grid load and Energy storage
- Several main factors and many other considerations:
  - turnaround times; # simultaneous aircrafts at the airport
  - Flexibility; Automation; Costs;
  - Safety and Security; Regulations; etc

Airport perspective:



Landscape:
* Technology dvpt
* Regulations
* …

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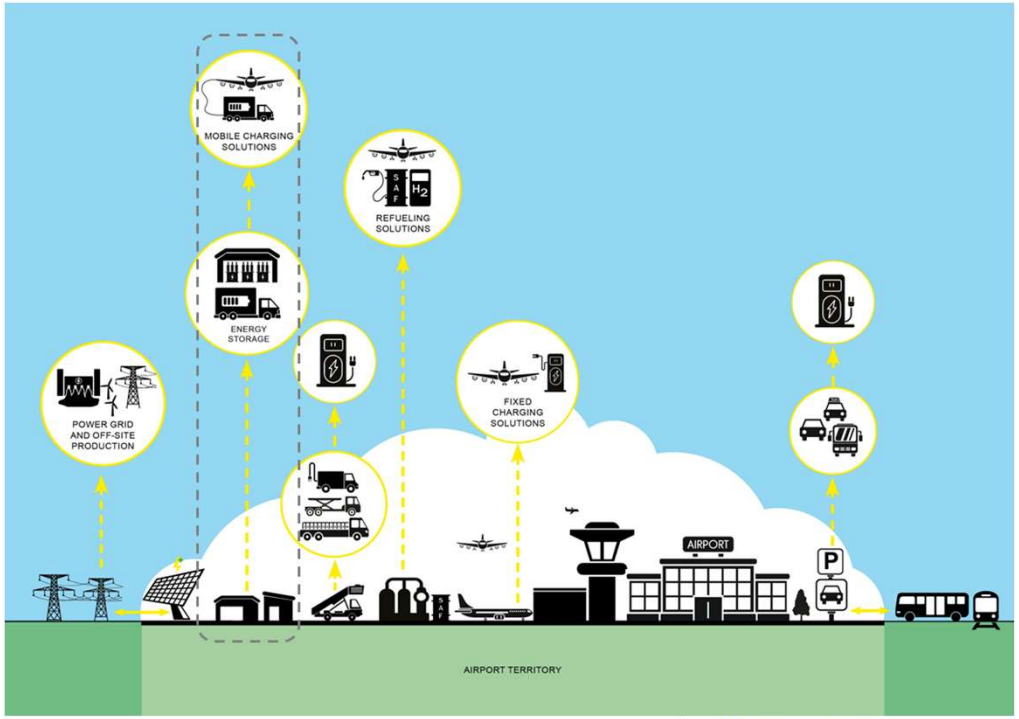
PROJECT BACKGROUND

Part of FAACE: FLEXIBLE AND AUTOMATED AIRCRAFT CHARGING VIA ENERGY STORAGE AT AIRPORTS

- Project financed by **Trafikverket**, 09-2023→06-2025.

  Partners: VTI, LTU, Heart Aerospace, Swedavia, Einride

  Reference group: Trafikverket, Swedish Electromobility Centre, Skellefteå kraft, Skellefteå airport, Volvo CE, Transportföretagen

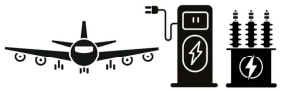


Focus: Innovative charging solutions at airports enabling flexibility in terms of charging location and grid connection

Aspects:

- Airport as Energy Hub
- **Technical Concepts and flexibility at airports**
- Electromagnetic compatibility
- Bussiness models

TECHNICAL CONCEPTS

	DIRECT FROM GRID	ENERGY STORAGE
MOBILE MCS	 MOBILE MCS AND TRANSFORMER	 MOBILE MCS WITH ENERGY POWER BANK
FIXED MCS	 FIXED MCS AND TRANSFORMER	 FIXED MCS

Four main combinations:

- Fixed or mobile MCS-charger (megawatt charging systems)
- With or without battery storage

System components & variants:

- Planes, ground vehicles, fixed and mobile power electronics – transformers, inverters, cables..
- Connection options: extra variants
- Assumptions relating
  - Specifications
  - Charging procedure

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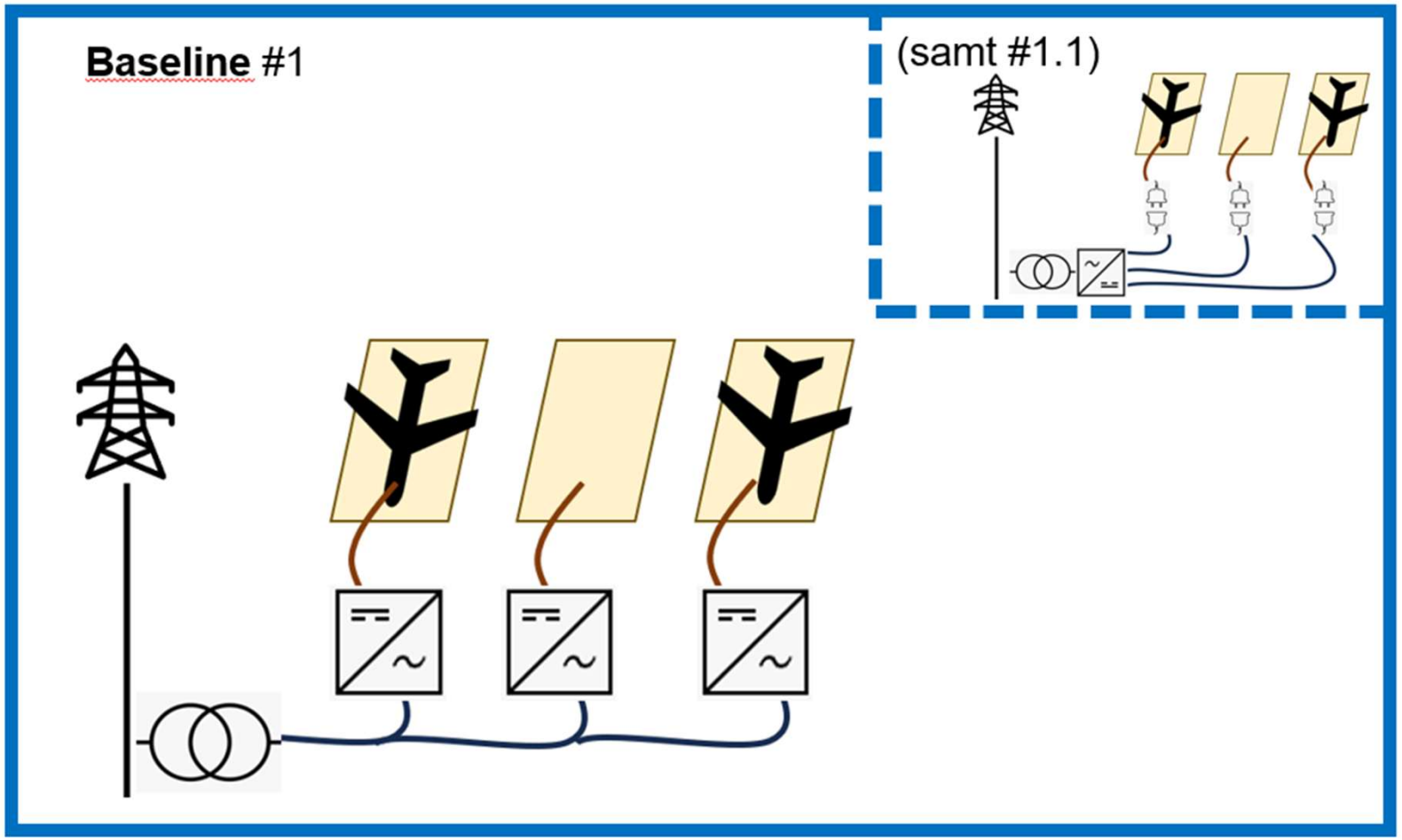
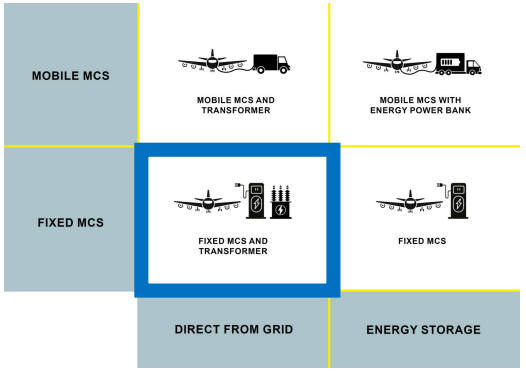
TECHNICAL CONCEPT IMPLEMENTATION





Concept characteristics, Advantages and disadvantages

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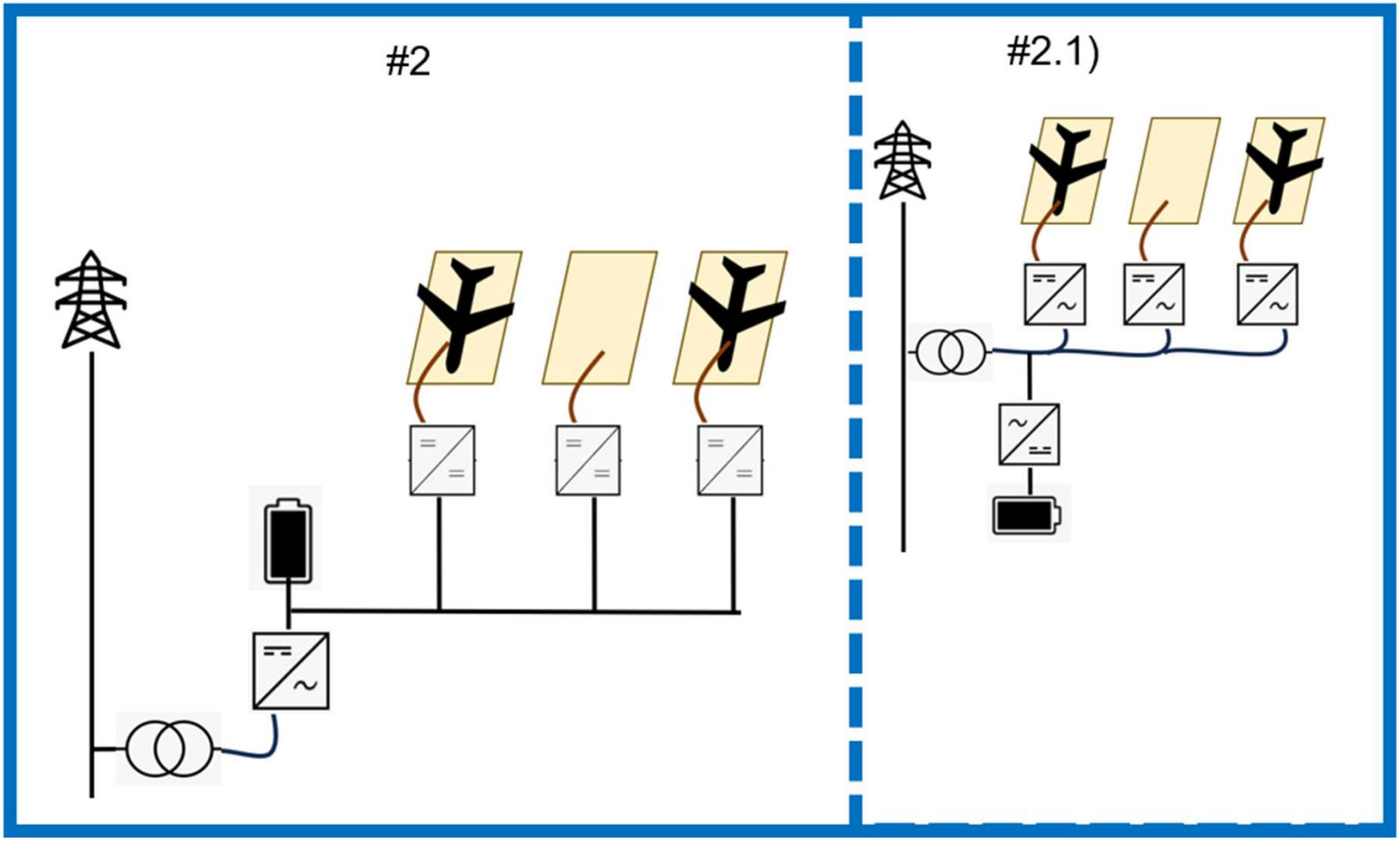
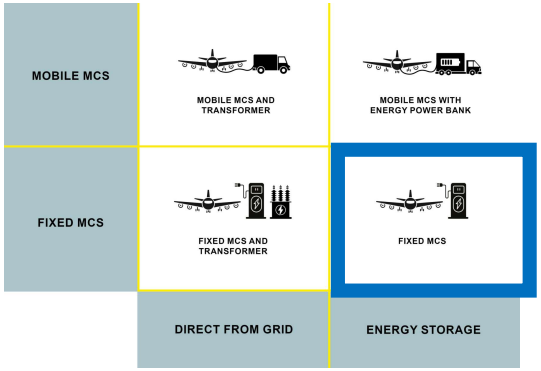
TECHNICAL CONCEPT IMPLEMENTATION





Concept characteristics, Advantages and disadvantages

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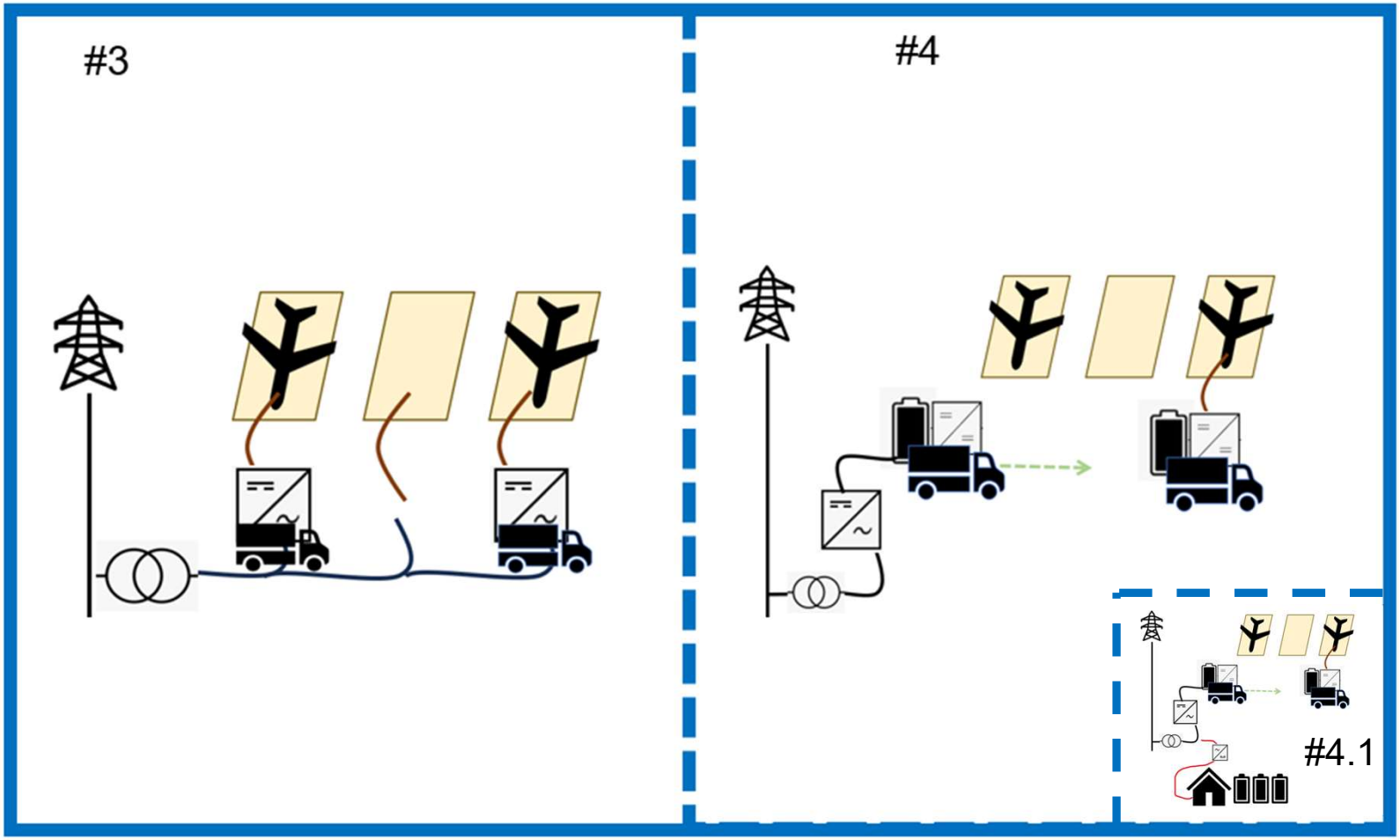

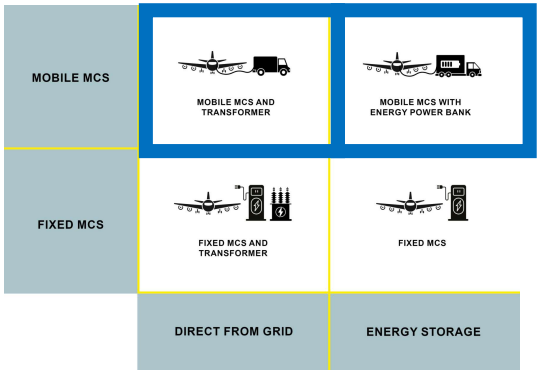

Concept characteristics, Advantages and disadvantages

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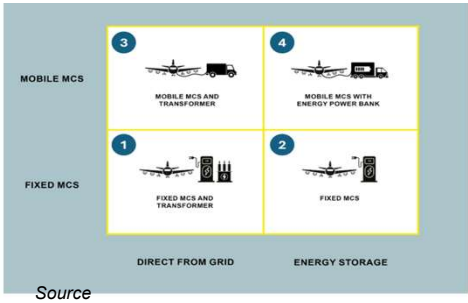
COMPARATIVE ANALYSIS EVALUATION CRITERIA



Source : VTI

Comparative analysis of the charging infrastructure concepts, identified relevant ***Evaluation Criteria***

Quantitative:

Installed Charging Power (# charging stations + power per station)
Energy efficiency (grid to aircraft, not including aircraft losses)
Energy storage capacity

Semi-quantitative:

Equipment area required, costs (general estimates)

Qualitative:

Electromagnetic compatibility considerations
Possibility off cutting load peaks via energy storage;
Possibility to participate in extra energy services
Flexibility to ramp up and down the charging capacity at the airport
(In extension also including moving equipment to other airports)

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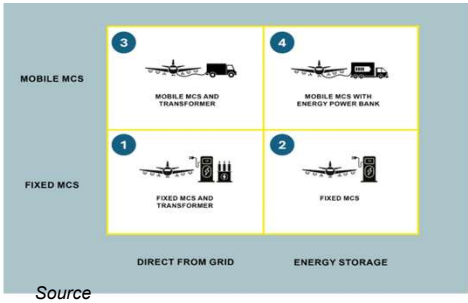
COMPARATIVE ANALYSIS EXAMPLE

Example: comparing energy efficiency.

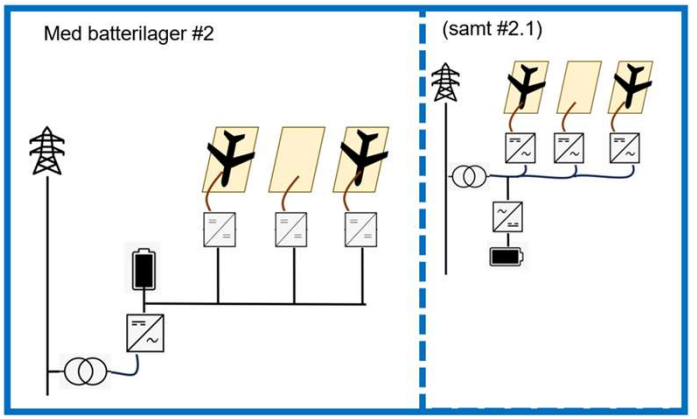
Example to the right:
”Straight forward” comparison of energy efficiency. concepts 2 and 2.1

Calculations must still make certain assumptions about componenent efficiencies, reasonable battery usage, etc.



Source : VTI

Technical concept description:
#1 & #1.1: Fixed charger charging directly from the grid (main/several outlets)
#2 & #2.1: Fixed chargers with battery storage (on DC or AC side)
#3: Mobile charger
#4 & #4.1: Mobile charger and energy storage (different options)



$$\eta_{\#2,max} = \eta_{AC/DC} \cdot \eta_{DC/DC} = 0.95 \cdot 0.96 \approx 0.91$$
$$\eta_{\#2,min} = \eta_{AC/DC} \cdot \eta_{DC/DC} \cdot \eta_{BESS} = 0.95 \cdot 0.96 \cdot 0.93 \approx 0.85$$
$$\eta_{\#2.1,min} = \eta_{AC/DC}{}^{3} \cdot \eta_{BESS} = 0.95^{3} \cdot 0.93 \approx 0.79$$

$$\eta_{\#1} = \eta_{\#3} = 0.95$$
$$\eta_{\#4} = \eta_{\#2.1} \approx 0.79$$

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CONCEPT ANALYSIS

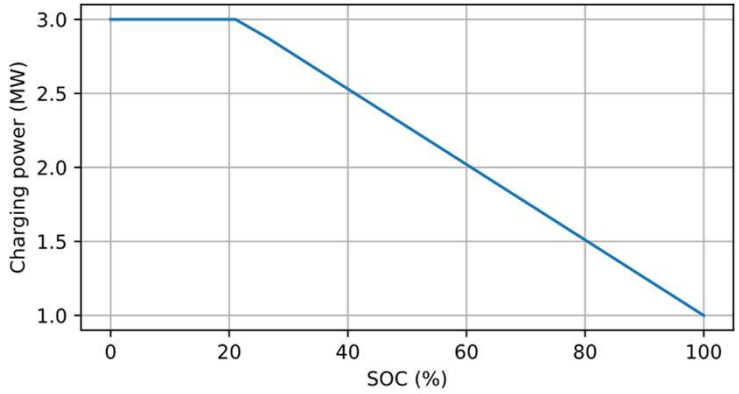
HYPOTHETICAL OPERATIONAL SCENARIOS – AIRPORT AND AIRCRAFT ASSUMPTIONS

- Large airport (example ARN)
- Medium international airport
- Regional airport with good access to an electric grid
- Regional airport with weaker grid

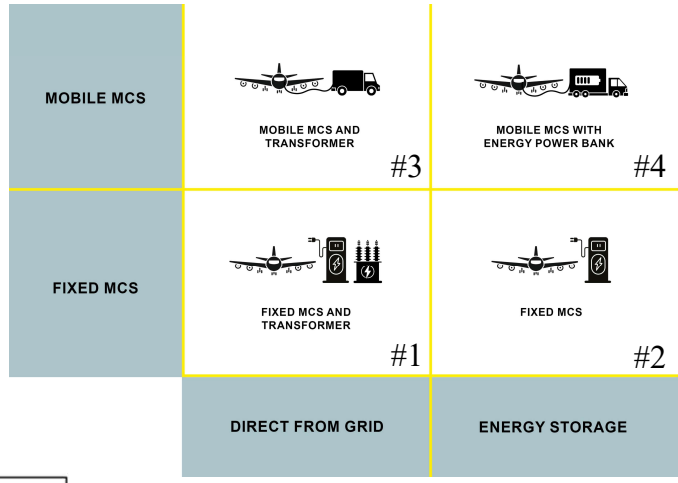
Airport	Charging capacity available	#aircraft charging simultaneously
Small	2 MW	1-2
Medium	5 MW	2-3
Large	15 MW	3-5

Assumptions:

- 30 minute turn-around
- Charging power (1 MWh in 30 minutes):



CONCEPT ANALYSIS
HYPOTHETICAL SCENARIOS



Concept	Key requirement	Small airport (2 MW, 2 aircraft)	Medium airport (5 MW, 3 aircraft)	Large airport (15 MW, 5 aircraft)
#1 – Fixed charger per slot	Grid power only	60 min turnaround (limited power)	39 min turnaround	Meets 30 min requirement
#2 / #2.1 – Fixed + BESS	Grid + stationary storage	One BESS (≥4 MW / 1 MWh)[2]	One BESS (≥4 MW / 750 kWh)	Grid power sufficient; BESS optional
#3 – Mobile charger	Grid power + mobile chargers	2 vehicles needed	3 vehicles	5 vehicles
#4 – Mobile BESS	Mobile storage + chargers	2 vehicles with 1 MWh BESS each	3 vehicles with 1 MWh BESS each	5 vehicles with 1 MWh BESS each

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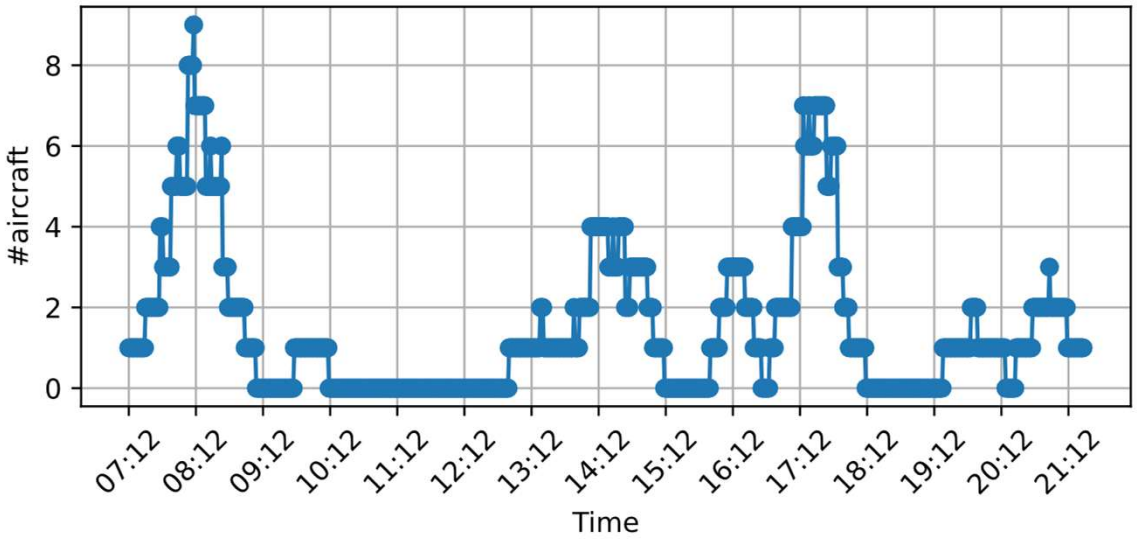
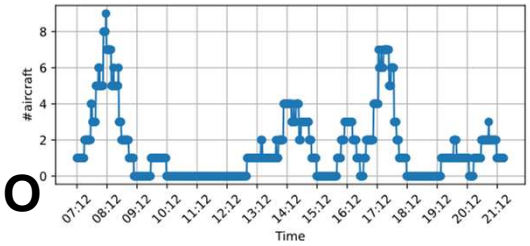
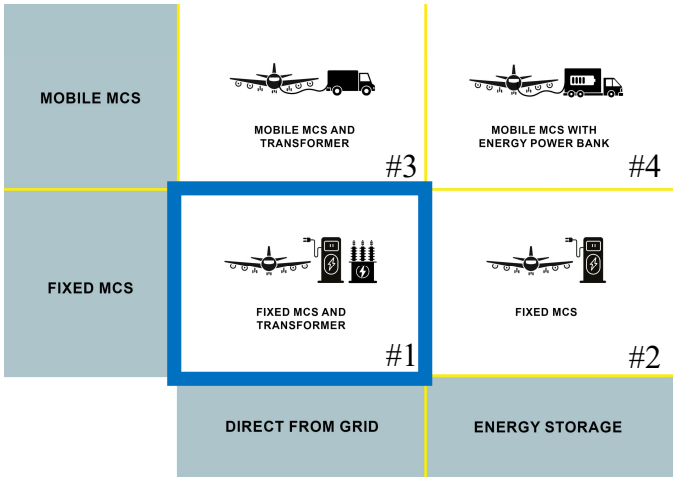
CONCEPT ANALYSIS
HIGH AIRCRAFT DENSTITY SCENARIO

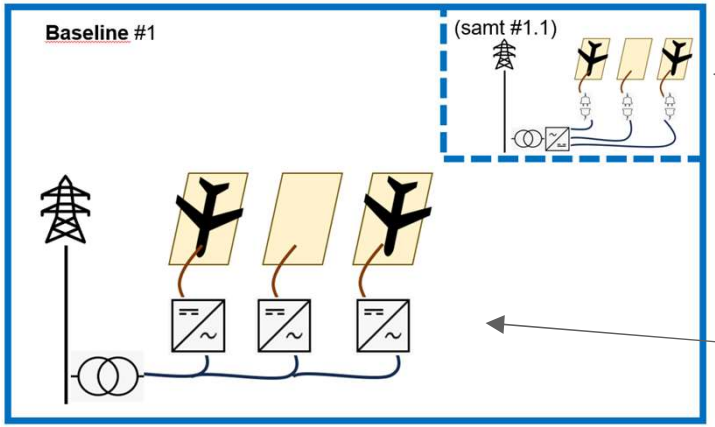


MOBILE MCS	MOBILE MCS AND TRANSFORMER #3	MOBILE MCS WITH ENERGY POWER BANK #4
FIXED MCS	FIXED MCS AND TRANSFORMER #1	FIXED MCS #2
	DIRECT FROM GRID	ENERGY STORAGE

CONCEPT ANALYSIS
HIGH AIRCRAFT DENSTITY SCENARIO

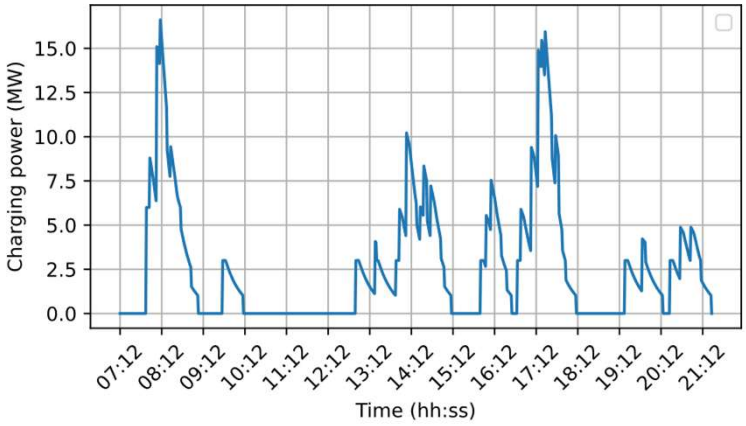






$P_{installed}$ ~ 16 MW

$P_{installed}$ = 21 MW



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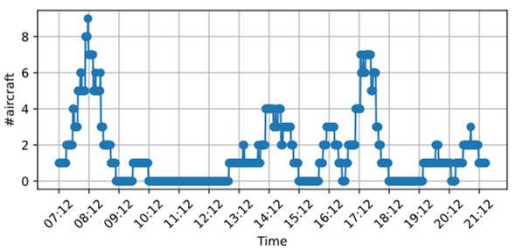
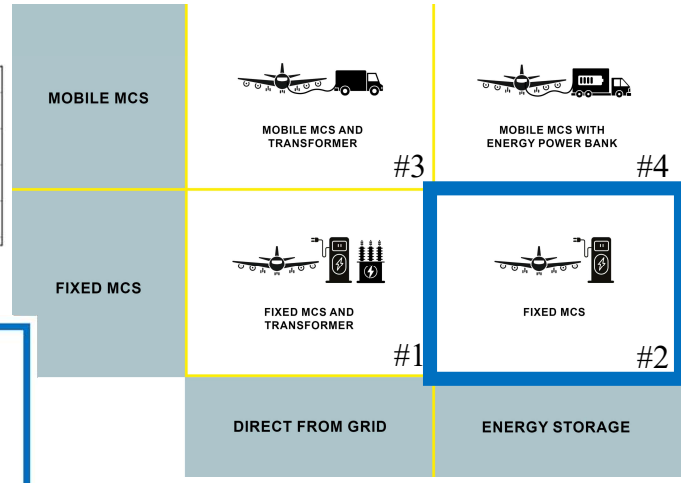
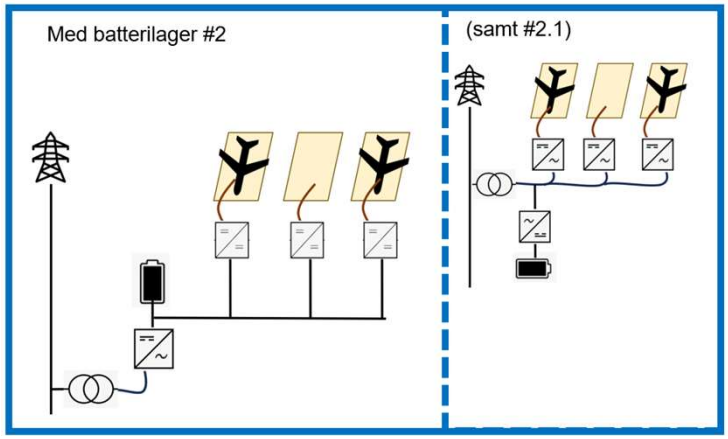
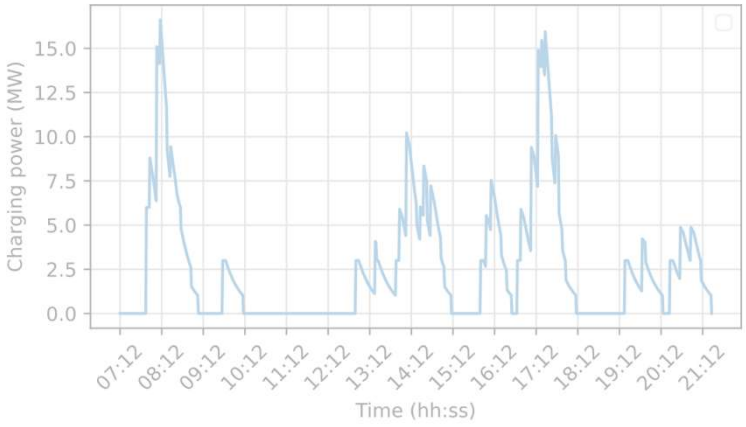
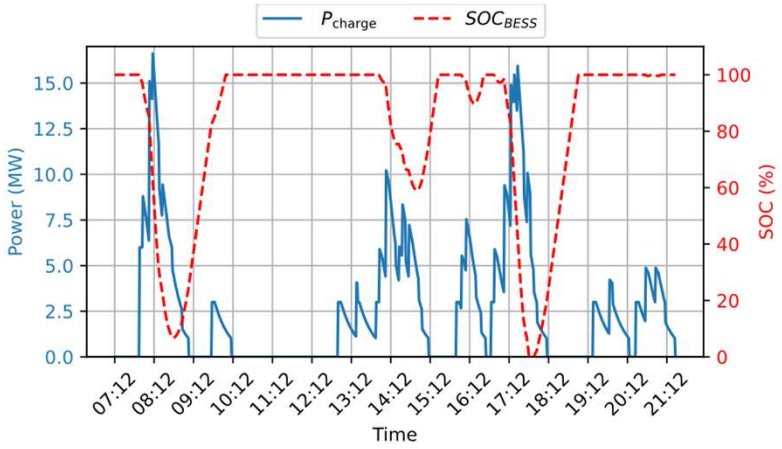






E_{BESS} = 4.5 MWh





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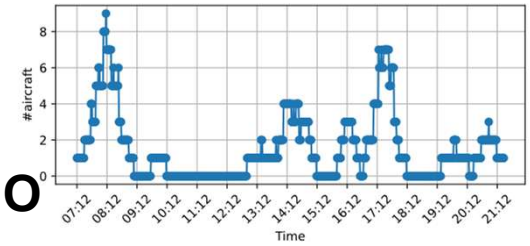

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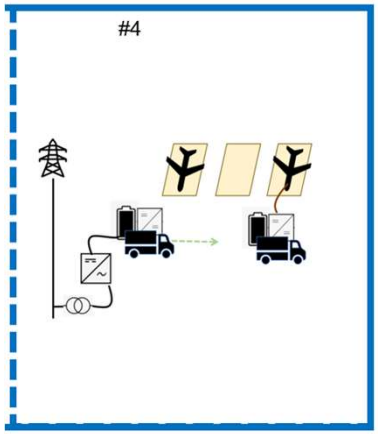
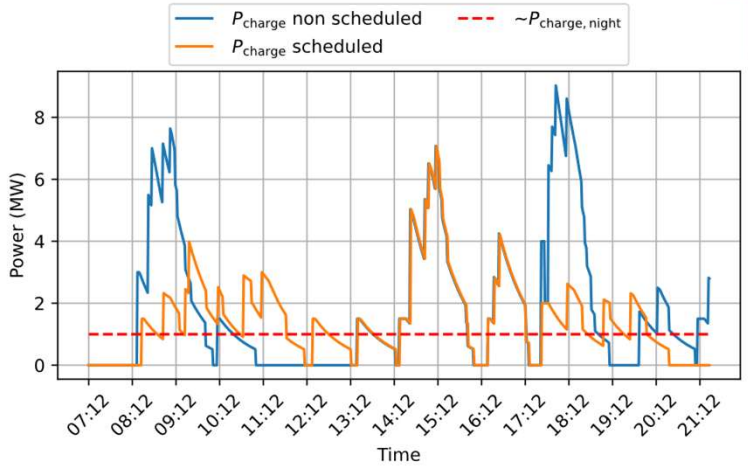
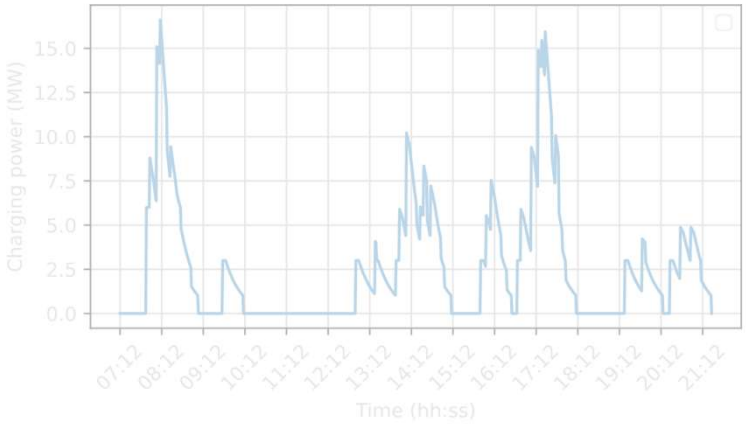
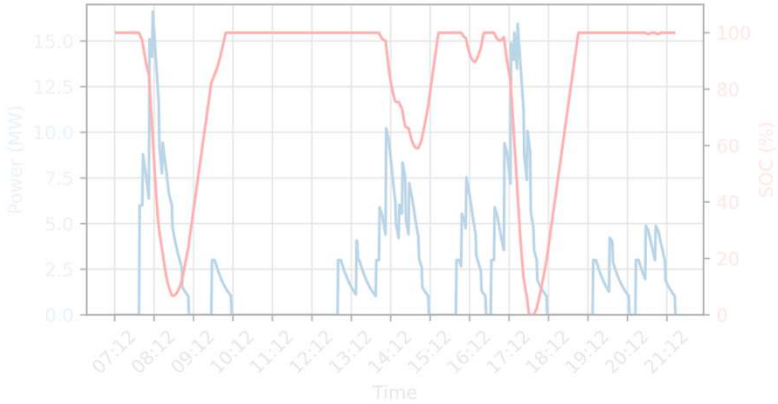




#vehicles = #aircraft$_{maximum}$





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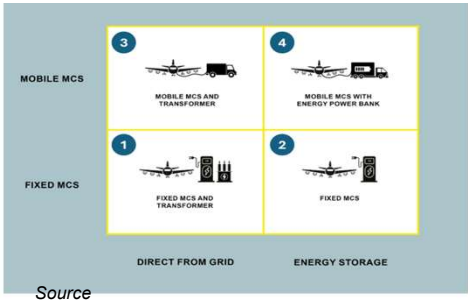
CONCEPT COMPARISSON SUMMARY



Source : VTI

No one-fits-all solution, different concepts match different purposes, trade-offs:

- Direct grid supply → high efficiency, but cannot fulfil turnaround time at small/medium aiport of insufficient power
- BESS → peak shaving, high discharge C-rate required
- Mobile BESS equipment → flexibility, charging challenge moved from aircraft to BESS

- Other aspects - EMC considerations, approximative costs, etc

- (Combination of concepts possible, could explore further possible design spaces and operational assumptions)

CONCLUSIONS

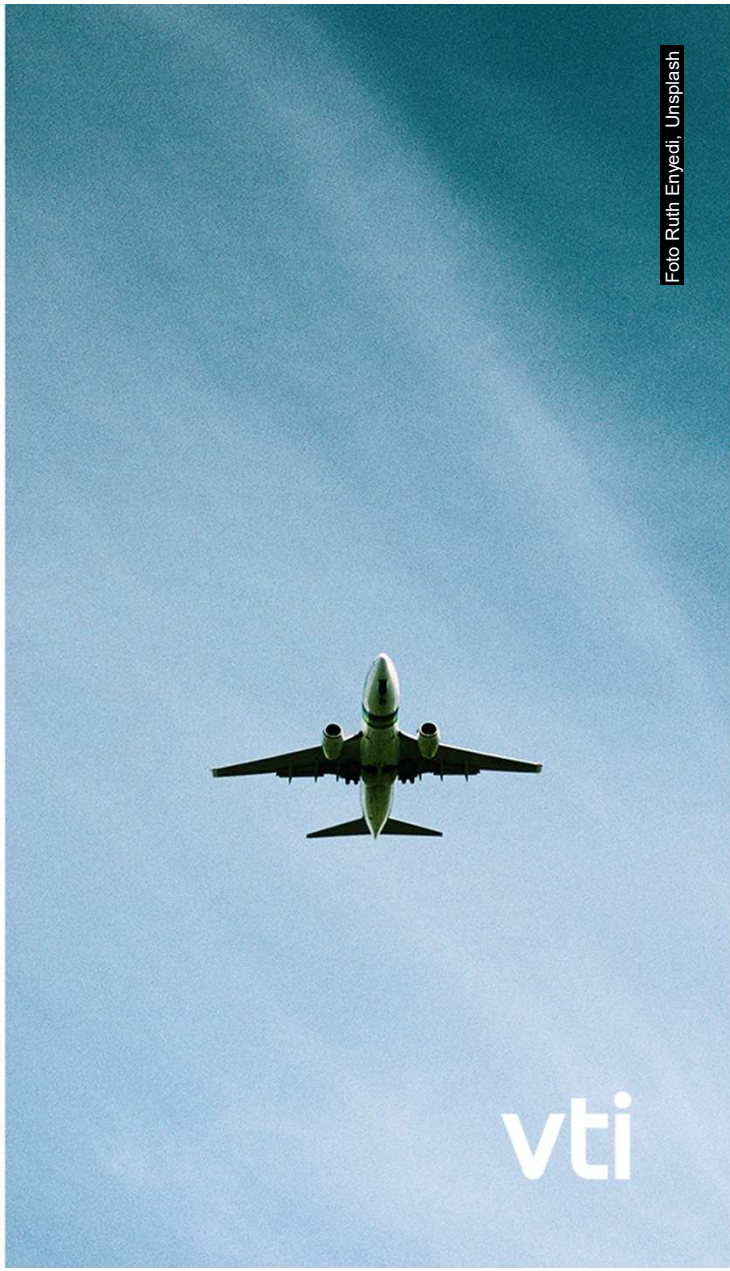
Several technical concepts topologies proposed, proposing solutions for different airport types, with varied flexibility options.

Every airport is unique, we looked at some relevant operational scenarious to reflect airport types.

Evaluation criteria were identified and partially applied in a comparative study, both quantitative and qualitative aspects are involved.

No one-fits-all solution, diferent concepts have advantages and disvantages. Must adapt charging solutions with regard to the external grid but also with regard to the cost of different charging options.

Optimal solutions would follow electric aircraft development, maintaining viable business models.



NEXT STEPS

System demonstration *of electricity storage and charging at an airport for electric flight*

- Project approved by Trafikverket, starting **2026**.
  Partners: **VTI**, LTU and Skellefteå City Airport.

- **Physical pilot** focused on **BESS** (battery electric storage system). Aims to

  1) Demonstrate how an airport BESS could support aviation electrification, and
  2) how it could Strengthen the role of airports as dual transport and energy hubs.

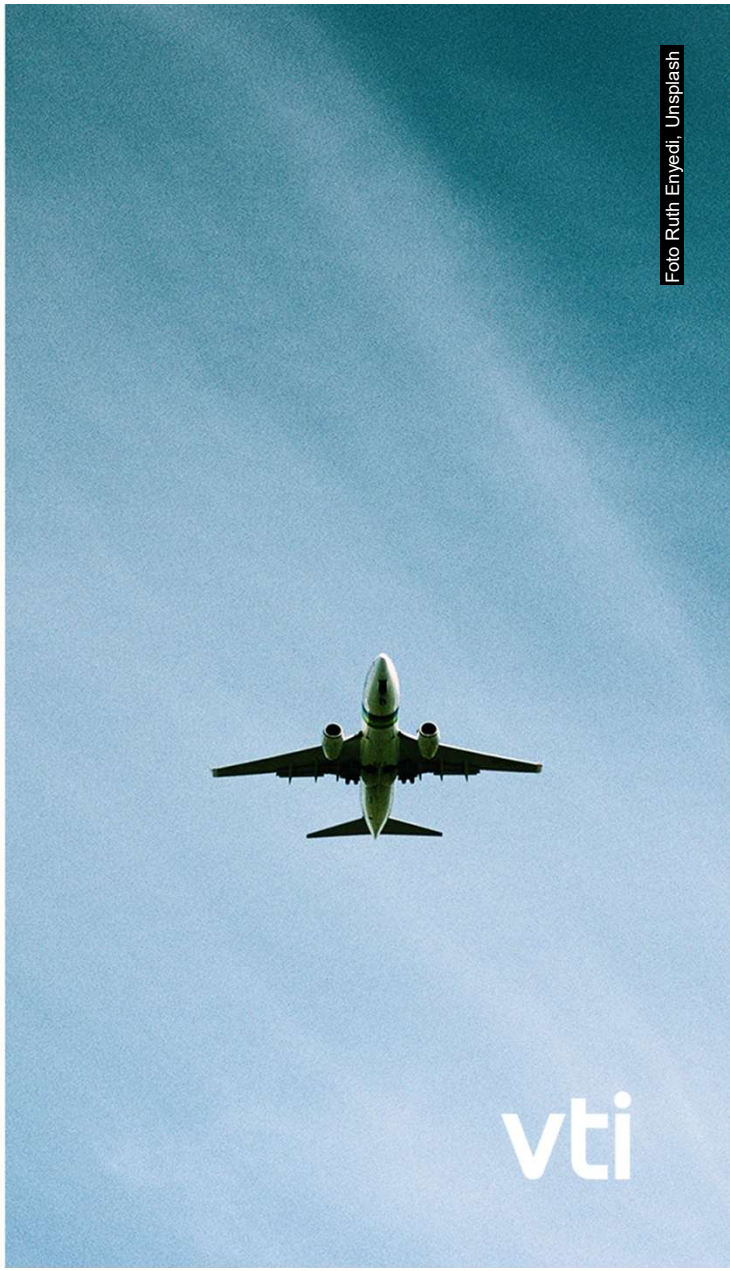
- Will simulate charging and operating conditions as realistically as possible → reduce uncertainty around the technical and operational performance of high-power electric aircraft charging alternatives, including BESS integration for both initial deployment and subsequent scaling up.

- Includes technical aspects, EMC, and logistics for turnaround, grid peak load effects.

+ analysis studies

- *Further exploration of scalability aspects, TRA2026 article submitted October 2025*

- *…*



QUESTIONS?

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