Electric-powered air traffic network with integrated aircraft-battery modelling

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Outline

Introduction

Methodology

- Air traffic modelling
- Aircraft modelling
- Battery modelling

Results and discussions

- Fleet operation results
- Battery degradation results

Conclusions

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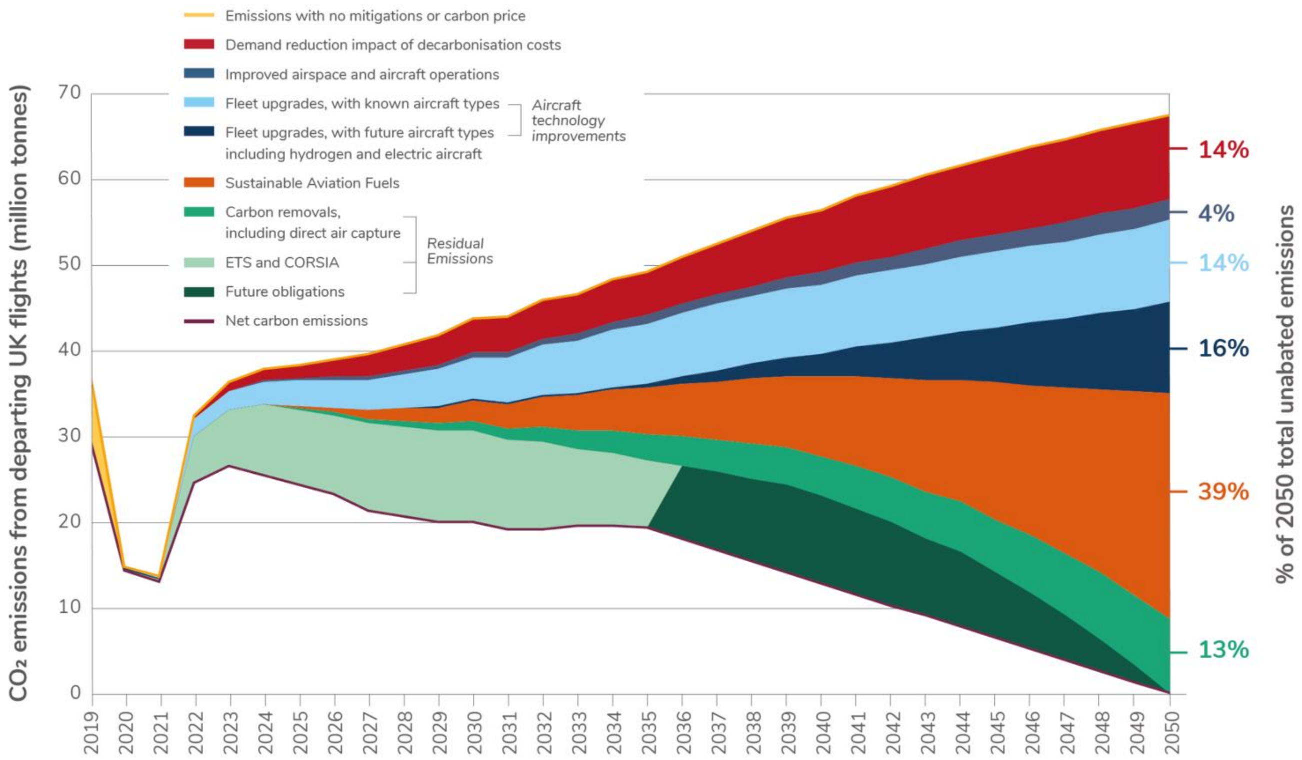
Intruduction

Sustainable aviation targets

- Net-zero CO2 emissions by 2050

Hybrid electric aircraft

- Studies have been conducted with different levels of technologies assumptions on mainly battery specific energy, 300 Wh/kg, 500 Wh/kg, 1000 Wh/kg……
- Integrated design and studies with both the macro side (air traffic) and micro side (battery model) are rare.
- This work focuses on a general assessment of emissions reduction through the adoption of hybrid/electric aircraft in the context of Swedish domestic air traffic, and route-specific battery degradation results.



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Air traffic modelling

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Traffic demand

- Historical flight data in 2024 used
- Annual increase of 1,3% assumed
- Focus on Arlanda airport and domestic flight demand

Table 1: Air traffic scenarios.

Per year	Scenario 1 2024	Scenario 2 2035	Scenario 3 2050+
Passengers	2031871	2342074	2842773

Fleet composition

- Historical fleet movements at Arlanda used
- A20N model used for representing the twin-jet narrow body aircraft, including B738, A20N, A320, B38M, A321, A319, A21N
- AT72 model used for representing reginal turboprops
- Hybrid aircraft followed the development routine set by Heart Aerospace for ES-30

Table 2: Historical fleet composition at Arlanda airport for year 2023.

Aircraft type	Number of movements
B738	39236
A20N	37839
A320	25798
CRJ9	16130
B38M	10253
AT72	9576
A321	7474
F50	5133
A319	3921
A21N	3422
Other	30473
Total	189255

Aircraft modelling

Hybrid electric aircraft

- Retrofitting from Dornier 328
- Simulated using Pacelab APD
- Two generations of aircraft modelled

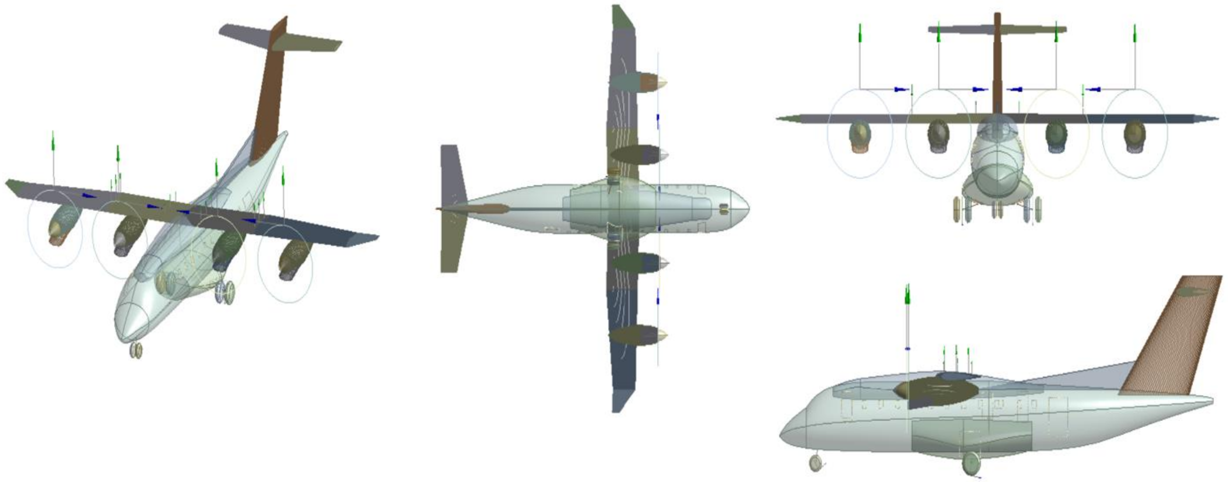
Table 3: Hybrid electric aircraft key parameters.

	Scenario 2 2035	Scenario 3 2050+
MTOW (*kg*)	15223	17464
Battery specific energy (Wh/kg)	400	600
Battery mass (kg)	2265	3107
Fuel capacity (L)	1026	1817
Hyrbid range (km)	400	800
Electric range (km)	200	400

Conventional aircraft A20N and AT72

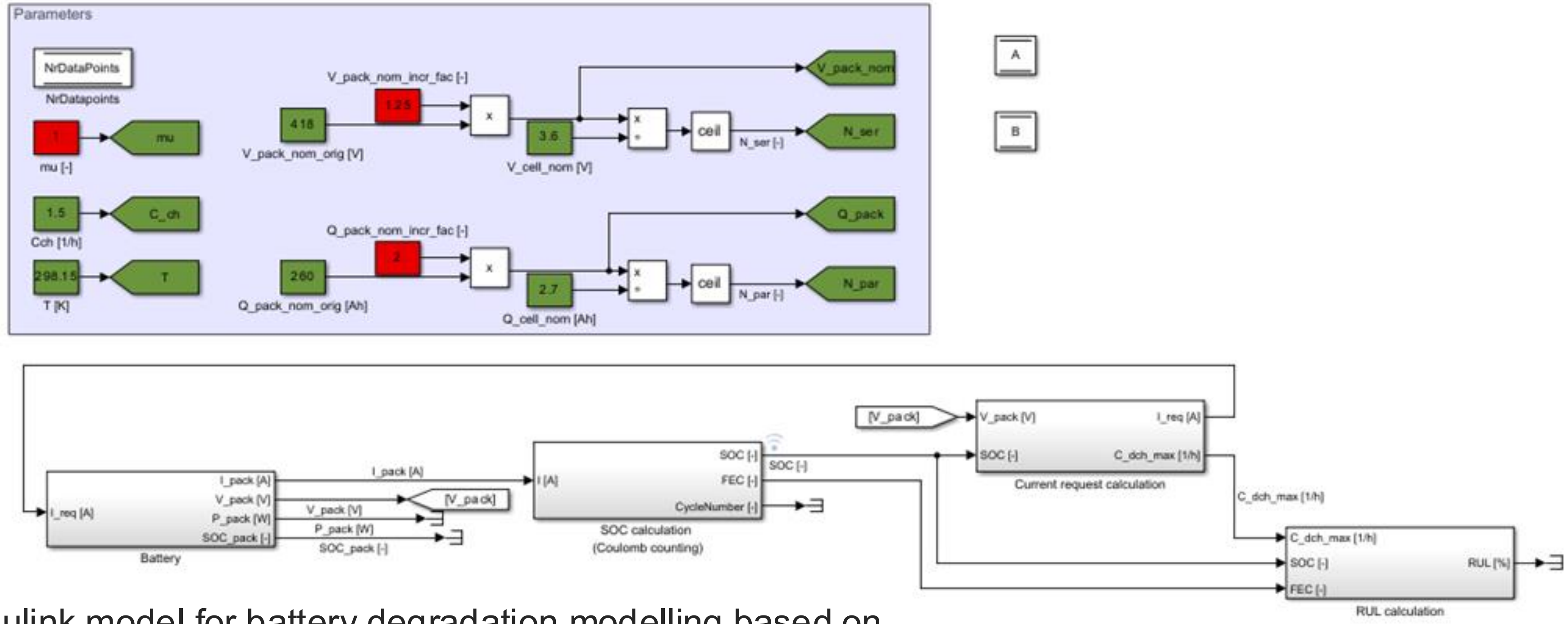
Data from 'EMEP/EEA air pollutant emission inventory guidebook 2019' used

Source: https://skybrary.aero/aircraft/d328



Battery modelling

- Lithium Nickel Manganese Cobalt Oxide (NMC) battery model used
- key stress factors such as full equivalent cycles (FEC), operating temperature, state-of-charge (SOC), depth-of-discharge (DOC), and charge/discharge current rate
- Calendar aging is not included.
- 1.5 C charging rate applied
- Initial state of charge always 100%.
- Minimum depth of discharge 20%.



Matlab Simulink model for battery degradation modelling based on

J. Olmos, I. Gandiaga, A. Saez-de-Ibarra, X. Larrea, T. Nieva, and I. Aizpuru, "Modelling the cycling degradation of Li-ion batteries: Chemistry influenced stress factors," Journal of Energy Storage, vol. 40, p. 102765, 2021.

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Fleet operation results

2024 Scenario

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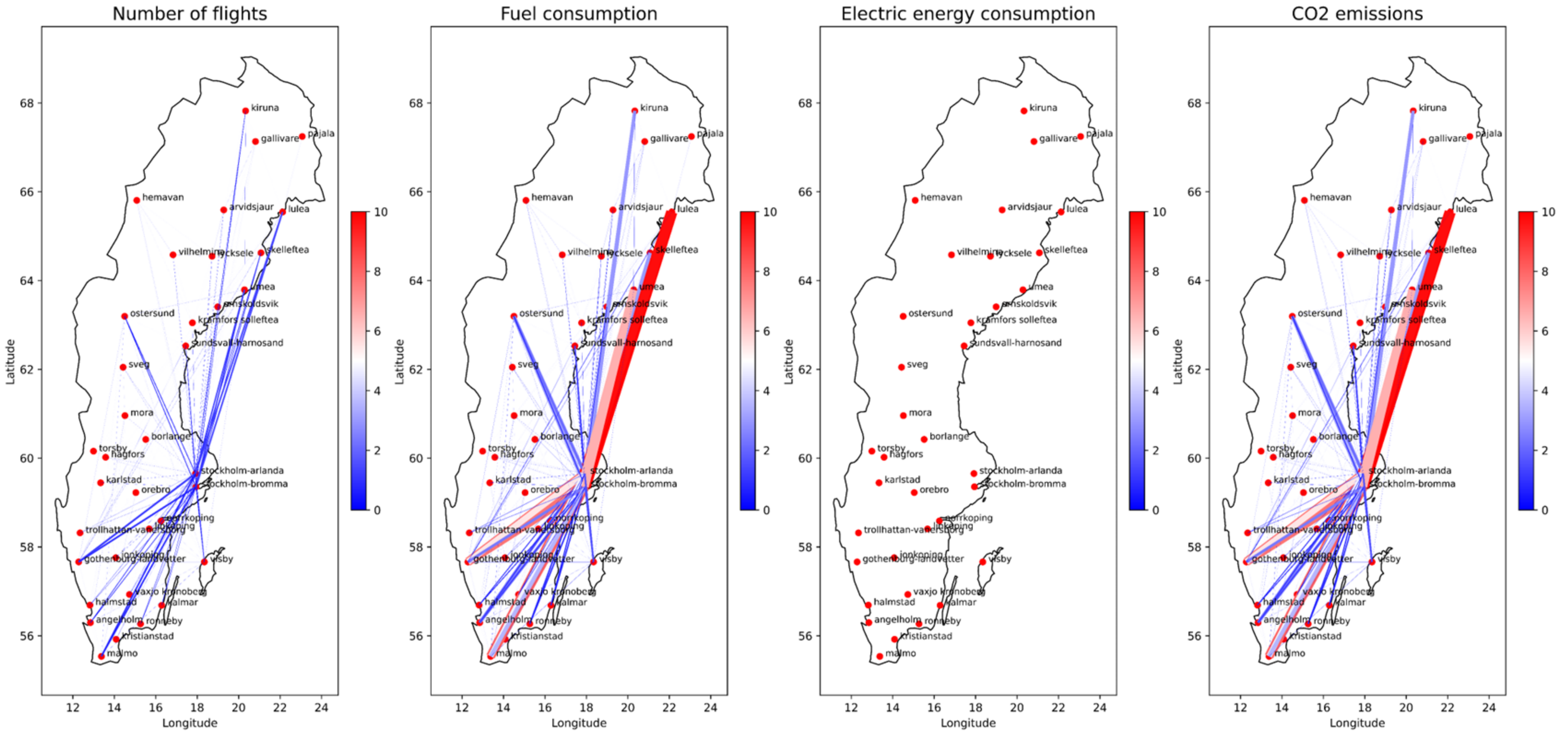

Fleet operation results

2035 Scenario – with first generation hybrid electric aircraft

In total, 13% reduction in annual CO_2 emissions from operations from domestic flight demand has been observed.

Per year	Scenario 1 2024	Scenario 2 2035	Scenario 3 2050+
Passengers	2031871	2342074	2842773
Arrivals	24742	57531	169775
Departures	25831	46803	174062

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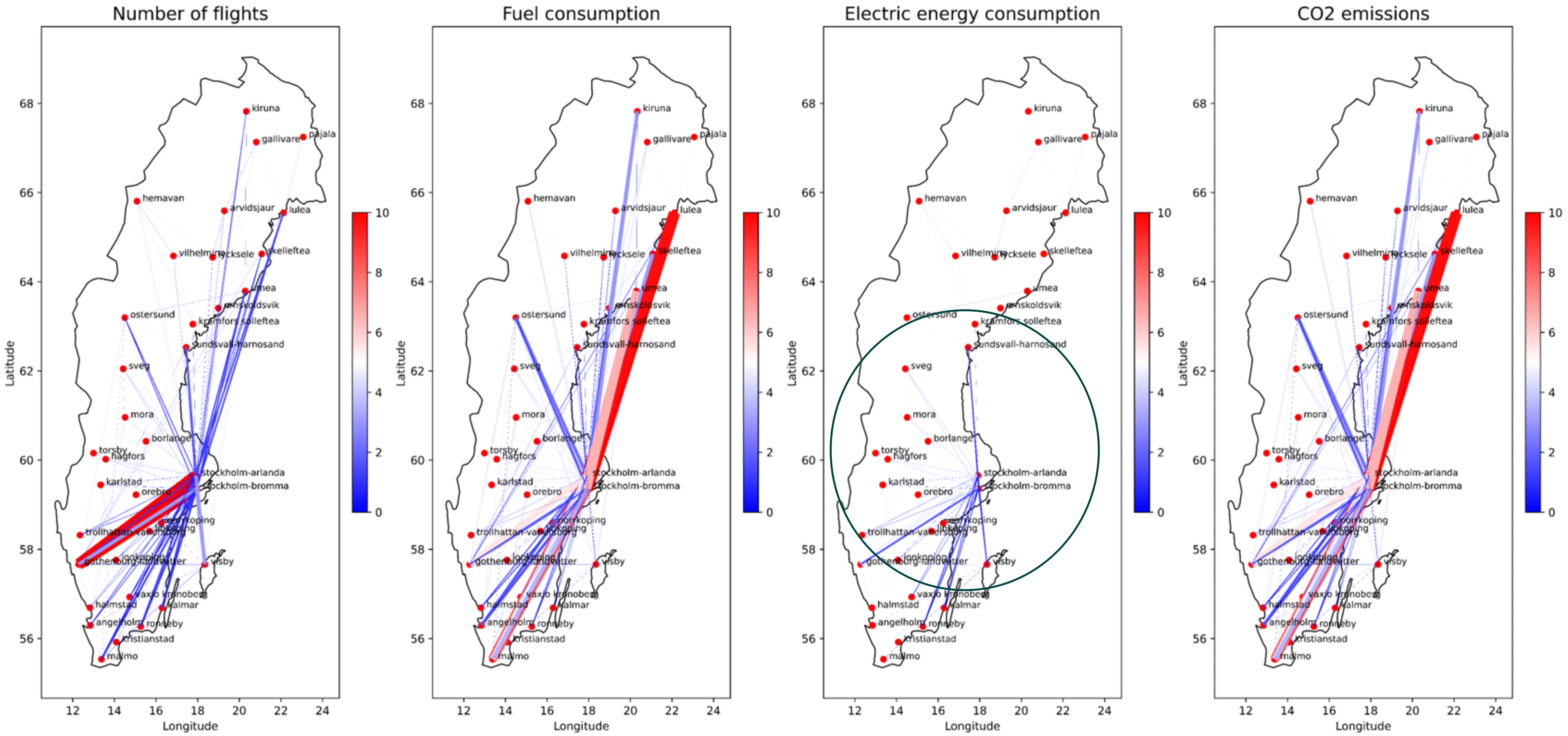

Fleet operation results

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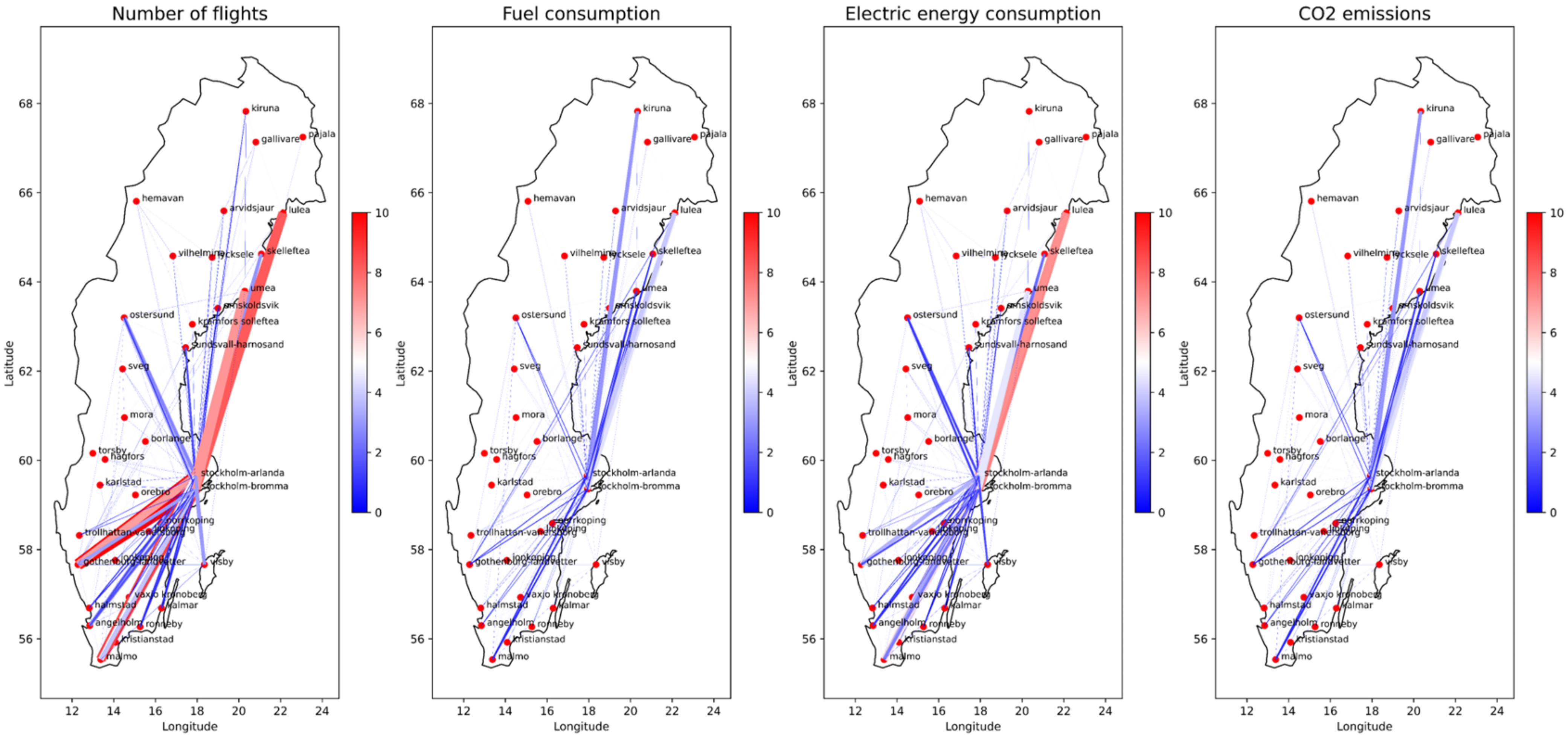
2050 Scenario – with the second-generation hybrid electric aircraft

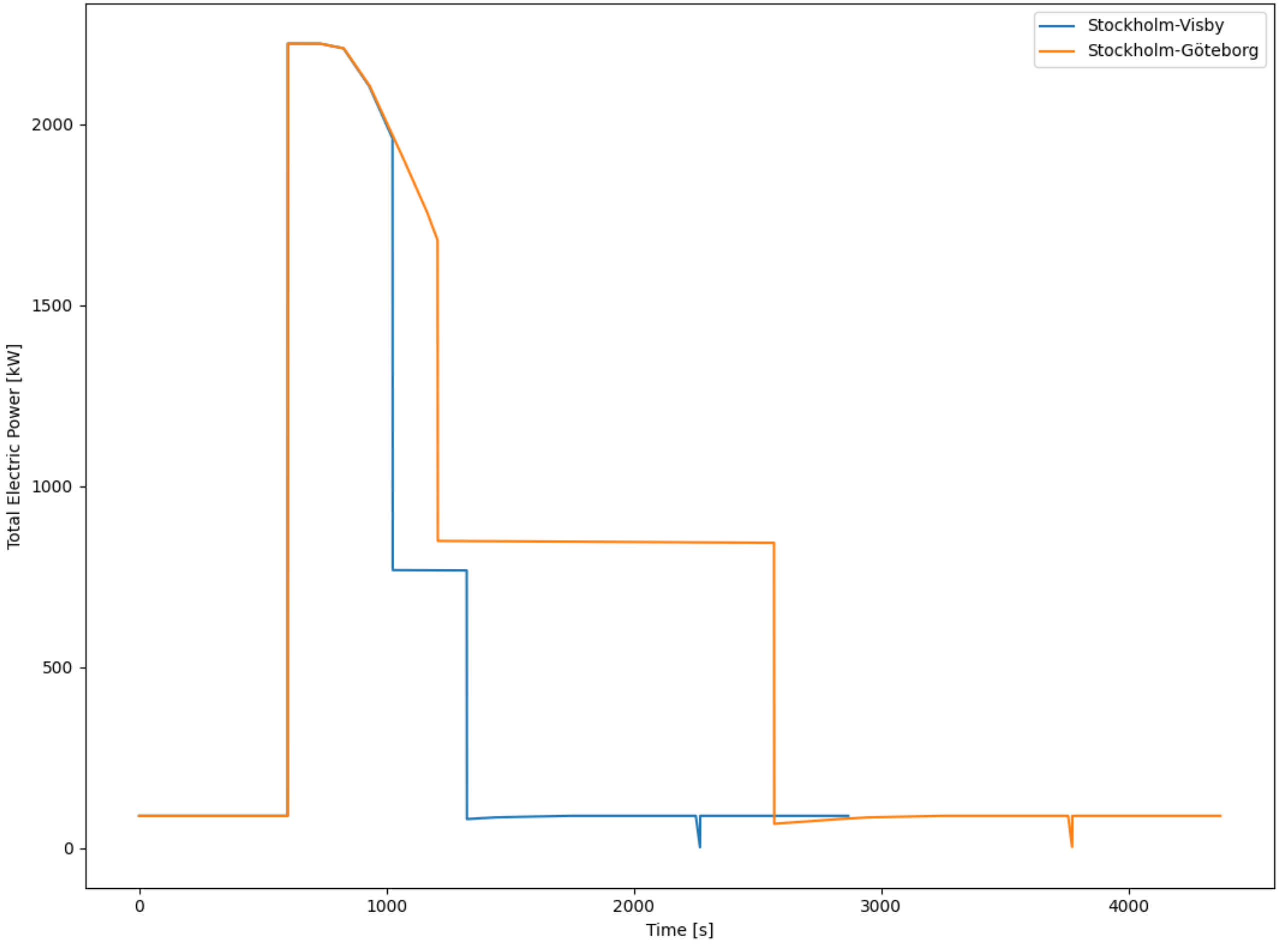
- more than 90% of coverage of domestic air traffic demand.
- total reduction of 73% annual CO2 emissions from operations.



Battery degradation study

Two missions in 2035 scenario selected

- Stockholm-Visby
  - Pure electric flight
  - Hybrid flight
- Stockholm-Göteborg
  - Hybrid flight



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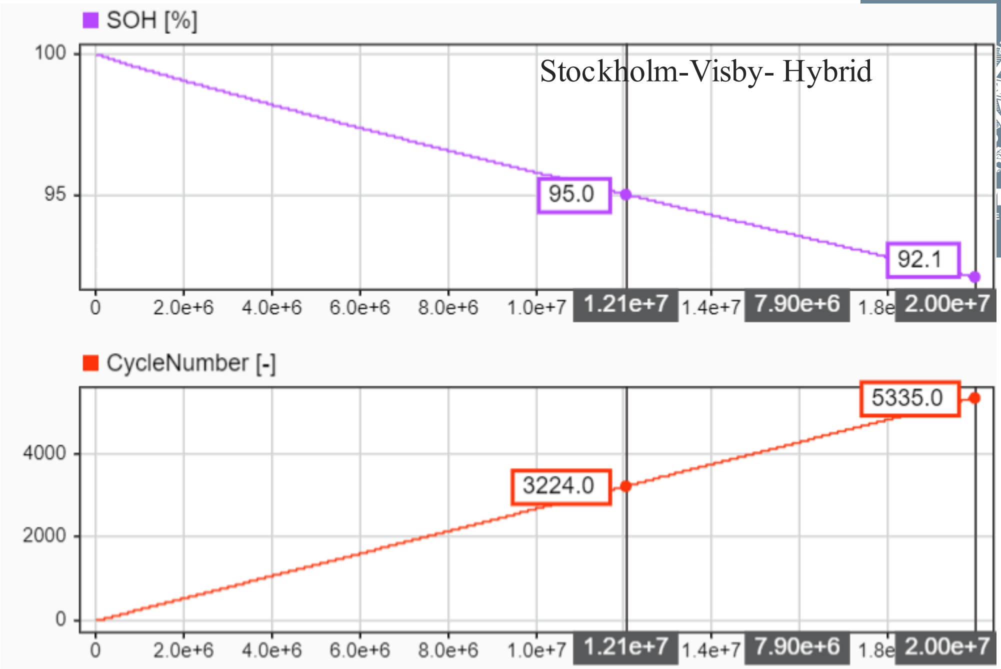

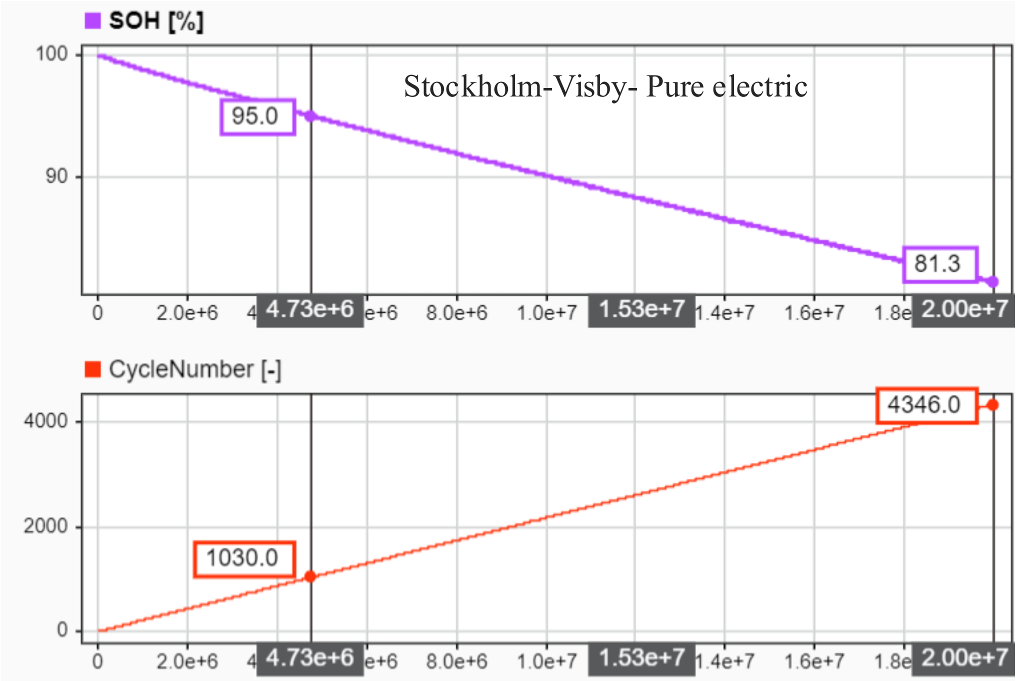

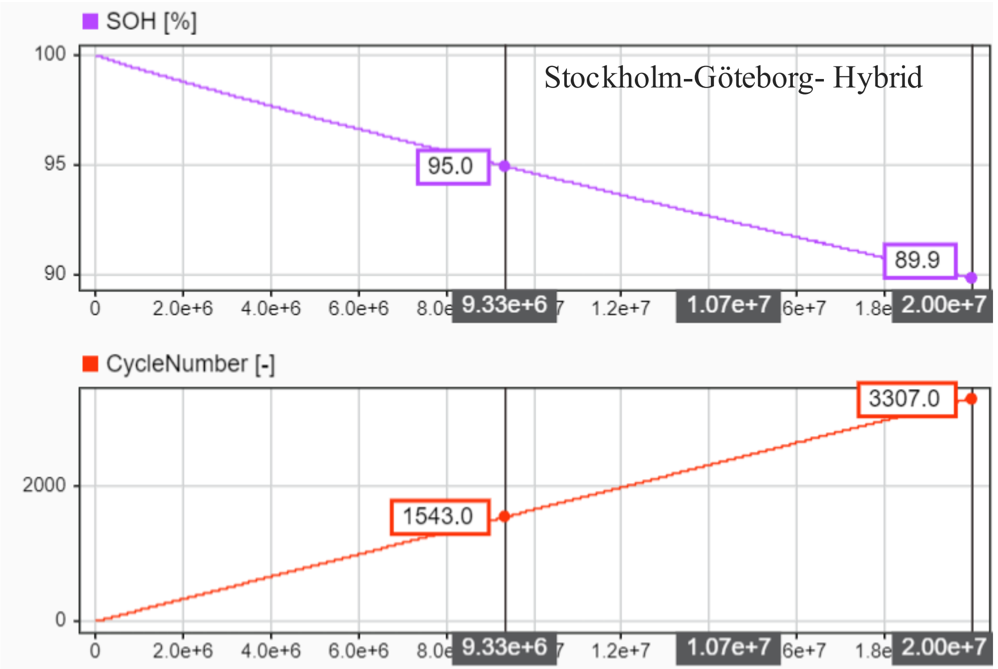

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- Regional benefits are anticipated with the advancement of battery technology by year 2035.
- Aggressive/radical battery innovations demand to achieve overall environmental benefits.
- Utilization of low-capacity hybrid electric aircraft in existing centralized airports presents high challenges in air traffic management and infrastructure upgrade due to enormous increase of flight numbers.
- Route-specific battery degradation modelling presents high challenge to pure electric operations, low flexibility of hybrid electric aircraft to be used for different missions and routes, and high cost due to the need of replacing battery systems to meet mission requirement and reserve fuel requirements.
- Hybridization flexibility and step use of the aircraft could be beneficial.

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Thank you for your attention!