Systems Aspects of Electric Commercial Aircraft (SAECA)

Direct Operating Cost Study

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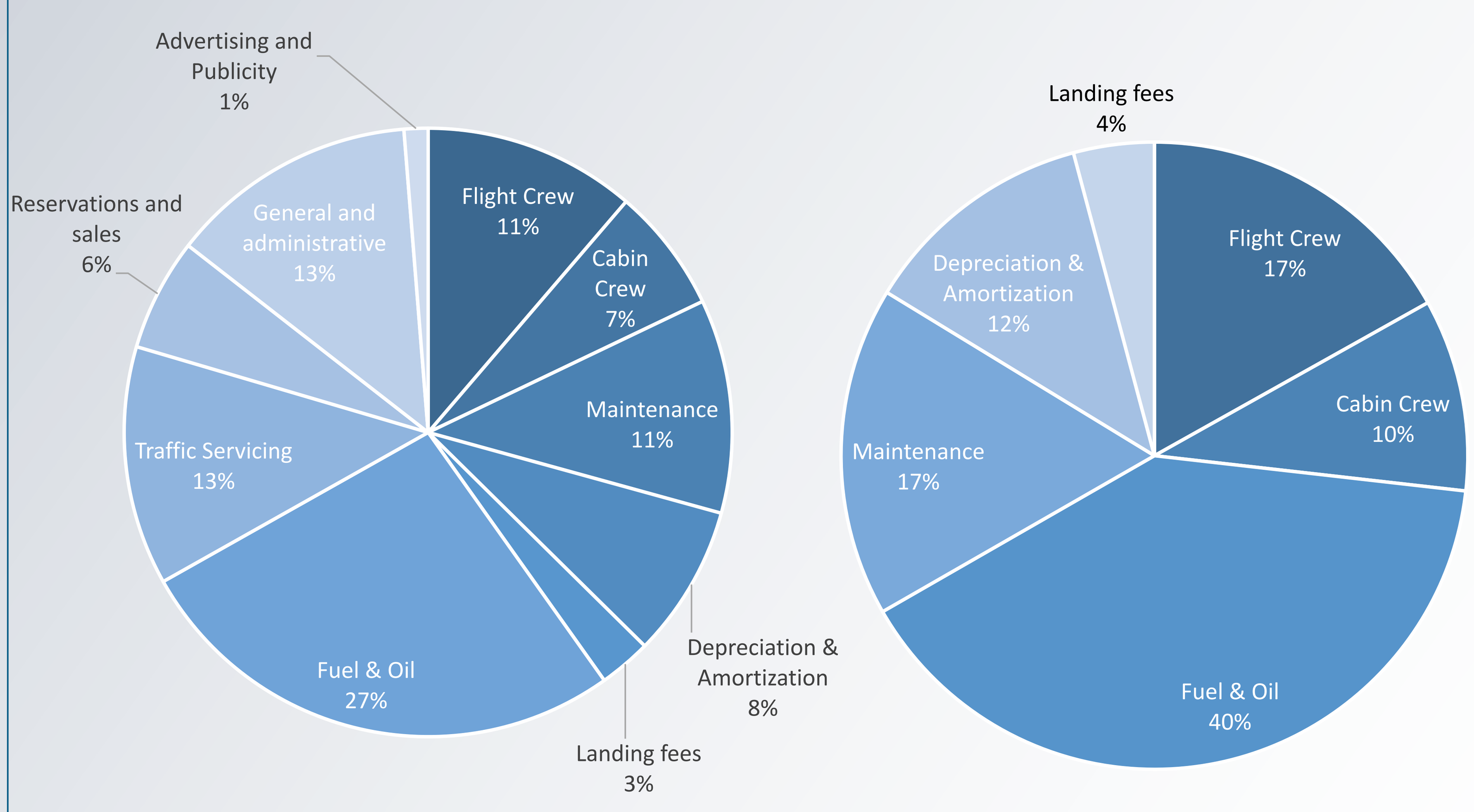
Objective

This study conducts a first-order analysis of the direct operating cost (DOC) of battery electric aircraft. The reference vehicle is a modern similarly sized aircraft (A320NEO).

US Airline Operating Costs (2015)

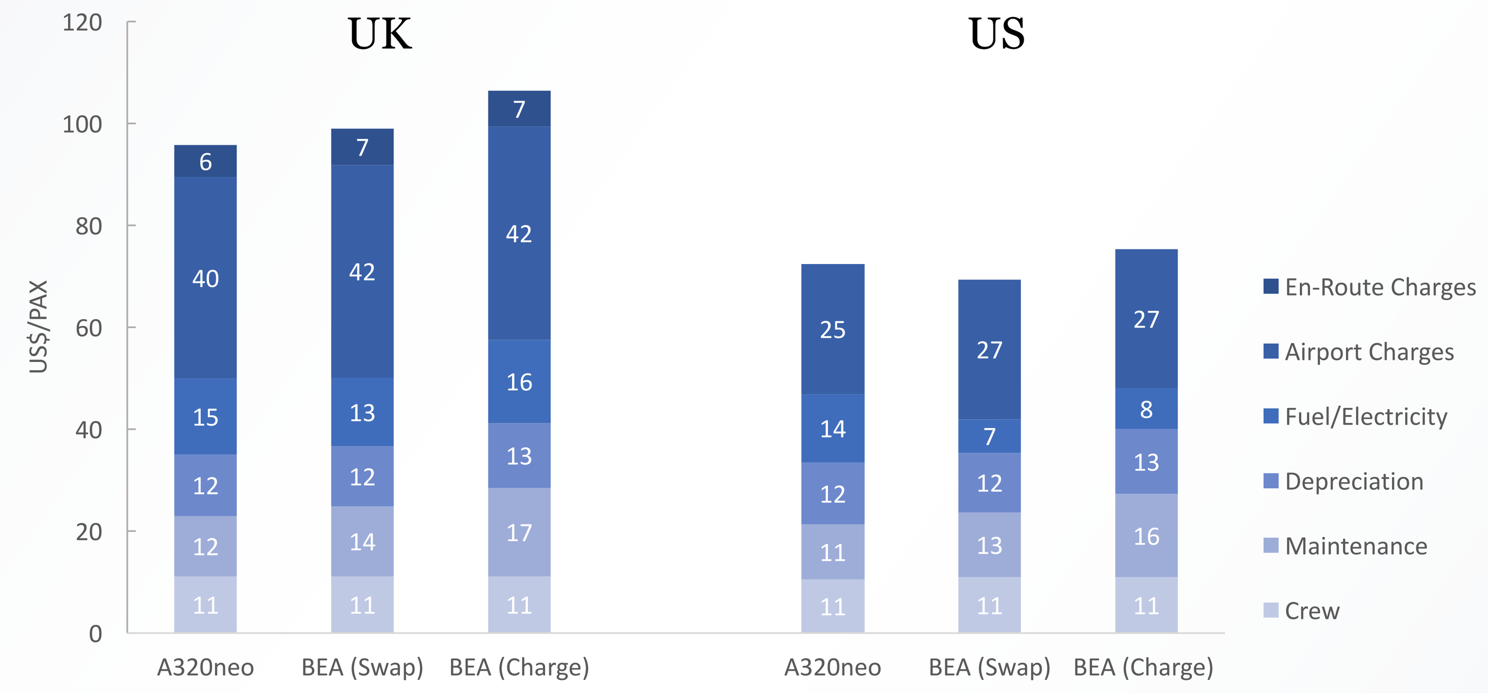


Total Operating Cost — Direct Operating Cost

BTS Form 41 (2015)

- Fuel accounts for nearly 30% of total operating costs and for 40% of direct operating costs (DOC).
- Thus, changes in fuel price can have a strong impact on airline costs, thus affecting fares and demand – battery electric aircraft would be less exposed to fuel price volatility.
- In addition to fuel costs, aircraft electrification will affect capital costs, maintenance costs and en-route/airport charges (around 75% of DOC).

DOC per PAX (830 km mission)



Assumptions

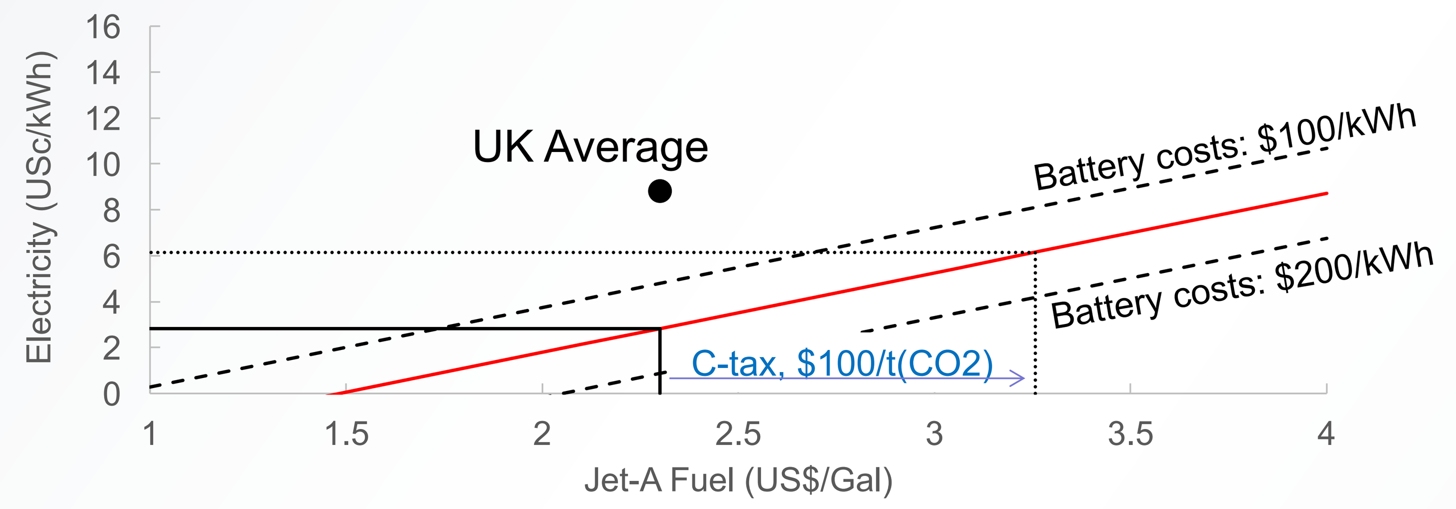
- Battery electric aircraft (BEA) don't require a fuel system, hydraulics, pneumatics, nor an APU; we assume electric propulsor capital costs to be 25% of those of jet engines.
- Electric motors have a smaller number of moving parts; engine maintenance costs are assumed to be 25% of those of jet engines.
- Weighted average airport charges are used for each country.
- Replacement costs of batteries ($150/kWh) are discounted at 5% per annum.
- Energy costs of $2.1/Gal and ¢8.8/kWh in the UK; $2.3/Gal and ¢4.3/kWh in the US.

Results

- Higher max. landing weight increases maintenance costs (tyres, wheels, landing gear) and airport/en-route charges.
- Battery replacements (every 5,000 cycles or 3 years) increase maintenance costs.
- Swapping the batteries could lead to lower DOC, keeping in mind additional set of batteries are needed for operations.

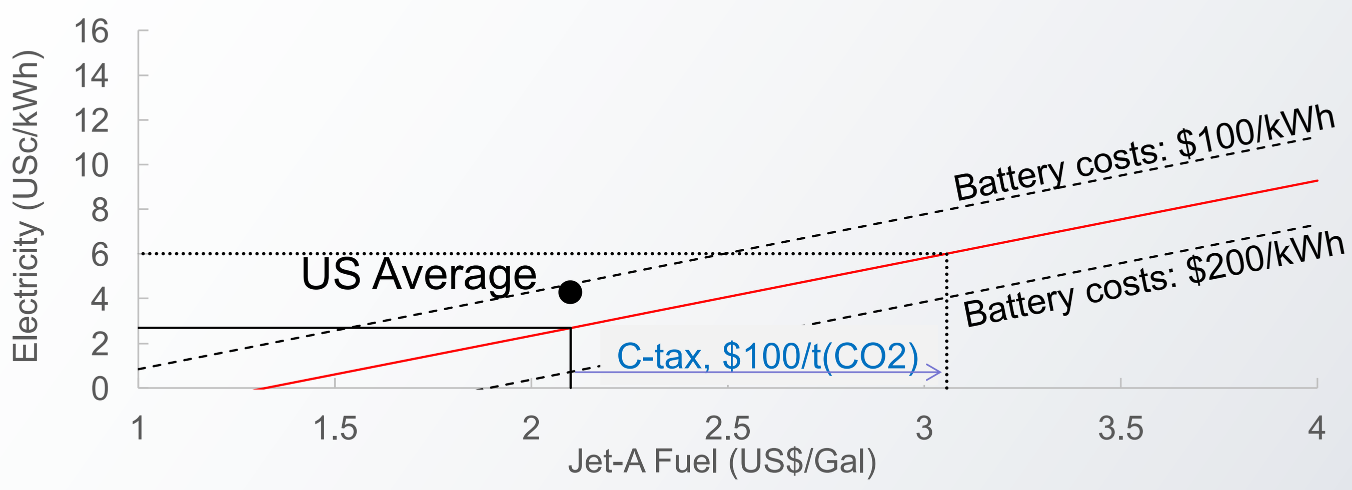
Breakeven Cost Analysis

UK



- The breakeven cost analysis identifies the maximum electricity price for battery electric aircraft to be cost-effective to jet-fuelled aircraft.
- Sensitivity cases for battery prices of $100-200/kWh are represented by dashed lines.
- At current fuel prices, the A320NEO would be more cost-effective than the battery electric aircraft.
- Battery swapping could improve electric aircraft economics.

US



- Lower battery costs significantly improve electric aircraft economics: a $50/kWh reduction increases cost-effectiveness by an additional ¢2/kWh.
- A carbon tax of US$100/tonne($CO_2$) would increase the electricity price ceiling by ¢3/kWh.
- Introducing NOx emissions charges could further improve the cost-effectiveness of battery electric aircraft.

Conclusions & Research Needs

- The cost-effectiveness of battery electric aircraft strongly depends on battery performance and costs, in addition to jet fuel and electricity price. Based on this study, a feasible economic window seems to exist.
- A number of additional factors can improve the cost-effectiveness of battery electric aircraft. These include optimized battery management (including battery swapping and load-levelling the electricity grid), a carbon tax, and emissions charges other than CO_2.
- Better understanding these trade-offs requires a whole-systems model approach.

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