# Integration of Electric Aircraft in New Zealand: A Power Systems Study

BY GIACOMO LAMPLOUGH

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## Bio

- Giacomo Lamplough
- Power Systems Engineer at Beca
- University of Auckland (UoA)
- Interested in integration of new technologies and power infrastructure design

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# Acknowledgements

THE UNIVERSITY OF AUCKLAND NEW ZEALAND

Beca

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# Agenda

**Context**

- Recent announcements
- Electric aviation in NZ
- More Electric Aircraft (MEA)

**Scope**

**Modelling/Simulation**

- Aircraft Design
- Charging infrastructure

**Conclusion**

**Questions (5-10 mins)**

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# Next Generation Aircraft

Recent announcement
- Air New Zealand's Memorandum of Understanding (MoU) with Airbus
  - Research hydrogen-based aircraft

Energy technology options
- Battery electric
- Hydrogen fuel cell

Context for the wider, next generation aircraft project
- This presentation focuses on charging requirements


Figure 1 – Air New Zealand and Airbus to research future of hydrogen-powered aircraft in Aotearoa [1]







# Electric Aviation in NZ

- Carbon emissions contribution from the airline industry is an issue

New Zealand is well placed to exploit advances in Electric Aviation
- Scale of its existing regional operations
- Renewable electricity supply

- Trends towards electrification of Aircraft
  - Unknown effect on New Zealand's power grid

- Infrastructure requirements
  - Power Grid
  - Airports

Figure 2 – Alpha Electro - Single engine light sport aircraft for flight training [2]

Figure 3 – ES-19 aircraft (Swedish Company Heart Aerospace) - Sounds Air to fly Electric Aircraft in NZ by 2026 [3]


Figure 4 - New Zealand's first electric aircraft launched at Christchurch airport [4]

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# More Electric Aircraft (MEA)

MEA - utilisation of electrical power to drive non-propulsive aircraft systems [6]

Recent advancements in technology has allowed electrification of many systems
- Elimination of traditional pneumatic systems [7]

Electrification of loads provide [8]:
- Lower maintenance
- Lower weight/volume
- **Higher efficiency**
  - Less carbon emitted

MEA provided incremental steps
- Introducing concept of All-Electric Aircraft


Figure 5 – Air New Zealand's Boeing 787-9 [5]

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# All-Electric Aircraft Design

eVTOL
- Electric Vertical Takeoff and Landing (eVTOL)
- Auckland CBD to Auckland Airport
- Unmanned
- Low capacity
- Short range
- There are hundreds of companies pursuing eVTOL

Figure 6 – Lilium Jet (7-seater) intention to be certified by 2024 [9]

Figure 7 – Volocopter (2-seater) first manned flight [10]

Figure 8 – Joby Aviation S4 [11]

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# All-Electric Aircraft Design

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Figure 6 – Lilium Jet (7-seater) intention to be certified by 2024 [9]

Conventional Aircraft Design

- Regional aircraft
- Longer range
- Higher capacity
- Auckland to Tauranga

Figure 9 – Heart Aerospace All-Electric Regional Aircraft (19-seats) [12]

Figure 7 – Volocopter (2-seater) first manned flight [10]

Figure 8 – Joby Aviation S4 (2-seater) [11]

Figure 10 – Eviation Alice (9-seats) [13]

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# Scope

All Electric Aircraft (AEA)
(19-seater)

Hybrid Electric Aircraft (HEA)
(26-seater)

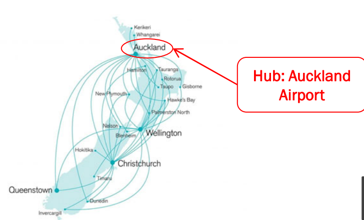


Figure 11 – NZ's Domestic Air Travel Network [14]

By 2030

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# Reference Aircraft

- **Design Reference:** Bombardier Q300 (50-seats)
- **Operational Reference:** Beechcraft 1900D (19-seats)
- **Turnaround Time:** 30 minutes


Figure 12 – Bombardier Q300 (50-seats) basis for AEA and HEA design [15]

Figure 13 – Beechcraft 1900D (19-seats) basis for AEA and HEA network design [16]

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# Weight Distribution of Q300, AEA and HEA

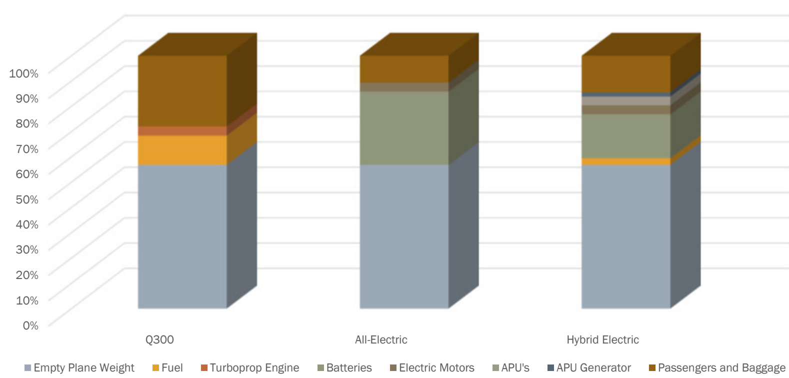


Figure 14 – All Electric Aircraft Weight Distribution

## Outcomes

- Required battery energy density
  - 687 Wh/kg
- Hybrid electric allows increased passenger capacity

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# All Electric and Hybrid Electric Parameters

Table 1 – All Electric and Hybrid Electric Aircraft Parameter Comparison

| Parameter | AEA | HEA |
|---|---|---|
| Max Range (km) | 527 | 527 |
| Max Range with 50% of Battery (km) | 245 | 245 |
| Passenger Count | 19 | 26 |
| Battery Capacity (kWh) | 3883 | 2258 |
| Battery Energy Density (Wh/kg) | 687 | 687 |
| Motor Count | 14 | 14 |
| APU Count | 0 | 2 |
| APU Generator Count | 0 | 2 |

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# Maximum HEA and AEA Range


Figure 15 – Range parameters of AEA and HEA

- Total power consumption per phase of flight simulated in MATLAB/Simulink
- Conservative reserve capacity assumed

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# Charging Requirements

- Operational restrictions
  - Turnaround time < 30 minutes
- Must charge aircraft battery from 50% to 100% in 30 minutes
  - $B_{ESS}$ = Size of Battery (kWh)
  - $T_{bc\_max}$ = Maximum charging duration

$$P_{charger}(kW) = \frac{50\%\ of\ B_{ESS}}{T_{bc\_max}}$$

Equation 1 - Charge Point Rating Equation

Table 2 – Required Charge Point Rating AEA and HEA

| Network Type | Charge Point Rating (MW) |
|---|---|
| AEA | 3.9 |
| HEA | 2.3 |

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# Network Summary

- Match Air New Zealand's FY19 capacity
- HEA design achieves the **same capacity** as the AEA network with fewer aircraft

Table 3 – AEA Network Summary

| Route | Pax | Daily Route Frequency | Required Aircraft |
|---|---|---|---|
| AKL -> KKE | 19 | 10 | 2 |
| AKL -> NPL | 19 | 25 | 4 |
| AKL -> ROT | 19 | 10 | 2 |
| AKL -> TRG | 19 | 25 | 4 |
| AKL -> TUO | 19 | 10 | 2 |
| **Total** | - | - | **14** |

Table 4 – HEA Network Summary

| Route | Pax | Daily Route Frequency | Required Aircraft |
|---|---|---|---|
| AKL -> KKE | 26 | 7 | 1 |
| AKL -> NPL | 26 | 18 | 3 |
| AKL -> ROT | 26 | 7 | 1 |
| AKL -> TRG | 26 | 18 | 3 |
| AKL -> TUO | 26 | 7 | 1 |
| **Total** | - | - | **9** |

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# Auckland Airport Charging Load

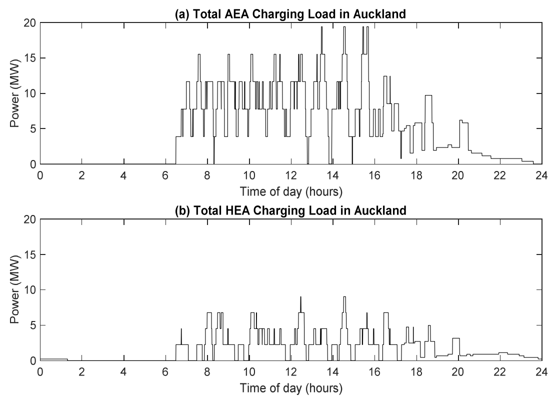


Figure 16 – Total charging load Auckland Airport

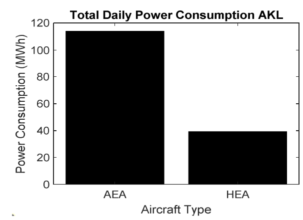


Figure 17 – Total battery power consumption

- Power systems considerations
  - Grid stability
  - Line capacity
- Total power consumption of HEA network is 35% that of AEA
  - Less aircraft required
  - Lower charge point rating
  - Power is offset using alternative fuel source

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# Smart Charging Station

- DC microgrid allows:
  - Reduced stress on power grid during times of peak demand
  - Incorporation of renewable energy
  - Integration with traditional power system networks
    - Reliable
    - Economical

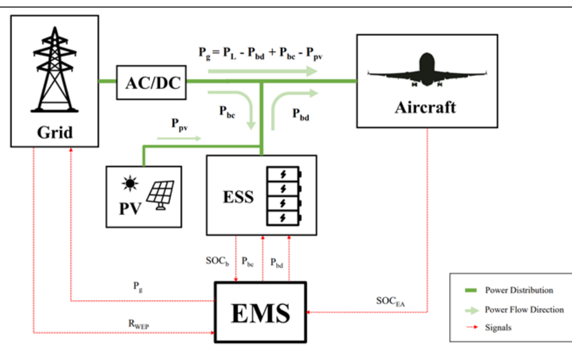


Figure 18 – Smart Charging Station Charging Station adapted from [7]

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# Operation of AEA Smart Charging Station

R(t) = Wholesale Electricity Price (WEP)

SMA = Simple Moving Average

UB = Upper Bound

LB = Lower Bound

*HEA charging station operates identically

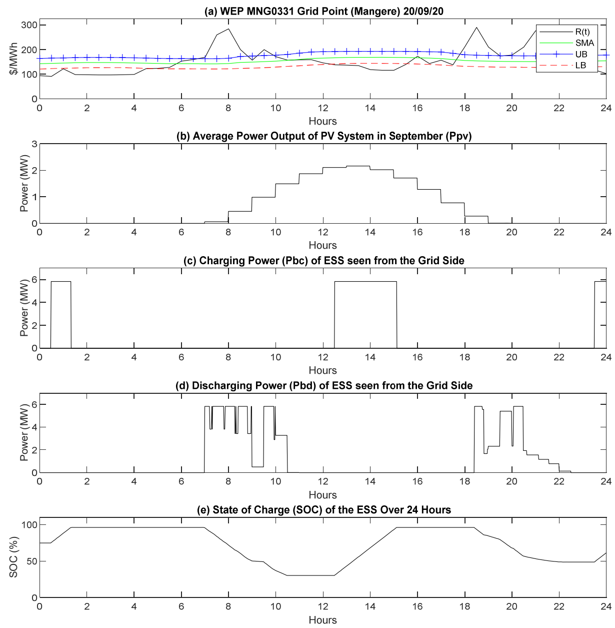


Figure 19 – Smart Charging Station Operation

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# Performance of Smart Charging Station

Morning peak in grid demand (Load Shifting Achieved)

ESS discharging to grid when PL = 0 and preserve cycle

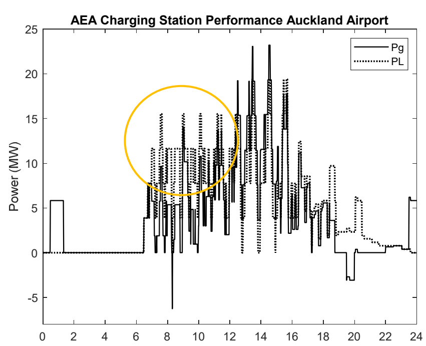


Figure 20 – AEA Charging Station Performance

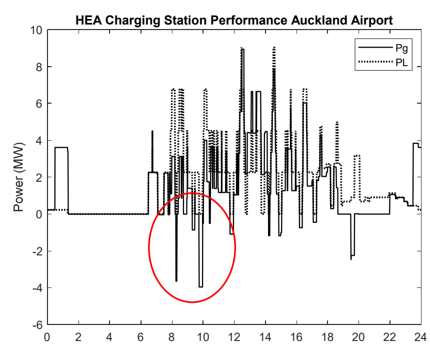


Figure 21 – HEA Charging Station Performance

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# Conclusion

Key Criteria when evaluating AEA and HEA

- Passenger capacity
- Maintenance
- Charge point rating
  - Power infrastructure considerations
    - Grid stability vs Line capacity
      - Doubling of current capacity for AEA
    - Significant investment required
- Carbon emissions
  - Green hydrogen?

Timeline depends on:

- Technology Development — Req: 687 Wh/kg
- Infrastructure Development — Line capacity upgrades
- Aircraft Certification — CAANZ – New aircraft can take 12+ month for operational approval

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# Questions?

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# Questions?

What technological readiness level are these aircraft types at?

How did you simulate/model the aircraft?

How did you design the aircraft network?

Why would you choose increase passenger count over range?

When will we actually see electric aircraft in NZ?

How do the Smart Charging stations work?

Green hydrogen…?







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# Future Work

- Hydrogen fuel cell powertrain (aircraft)
- Total Cost of Ownership of Charging Stations
- In Depth System Architecture Modelling of AEA and HEA
- MW Rated Fast Charger
- Battery Thermal Management
- Aircraft Maintenance
- Hybrid Electric Power Consumption

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# Appendix





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# MATLAB/Simulink Simulation

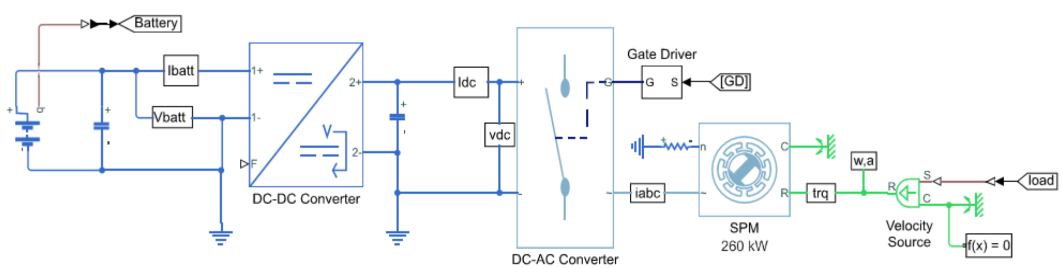


Figure A – All Electric Aircraft Simulink Power Train Model

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# Battery Power Comparison

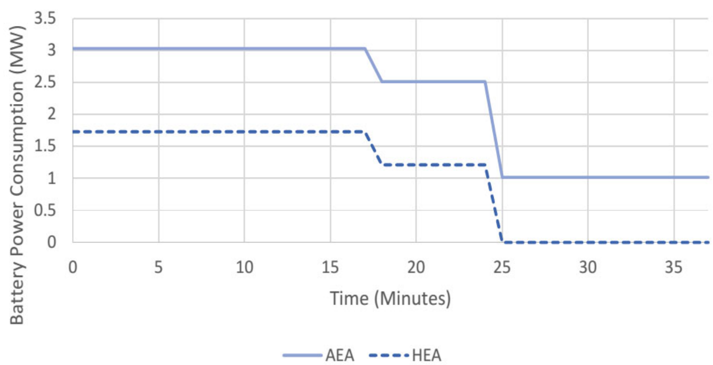


Figure B – All Electric and Hybrid Electric Aircraft Battery Power Consumption

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# Aircraft Network Simulation

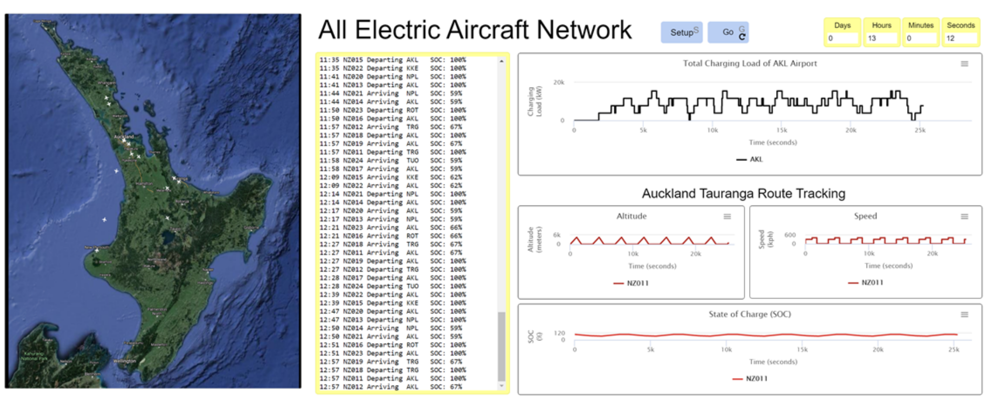


Figure C - Network design based of Air NZ FY19 flight frequencies to measure power consumption in NetLogo

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