Electric Commuter Transport Concept Enabled by Combustion Engine Range Extender

Georgi Atanasov, Jasper van Wensveen, Fabian Peter, Thomas Zill

DLR

Bauhaus Luftfahrt
Neue Wege.

Outlines

Background and Objectives.

Conceptual-Level Aircraft Sizing of a Hybrid-Electric 19-Seater

Results and Assessment

Conclusions and Outlook

Background and Objectives

A collaborative project between the DLR and Bauhaus Luftfahrt:
→ Re-introduction of small regional aircraft with up to 19 passengers.

Approach:
→ 19-seater market analysis
→ 19-seater aircraft data base for support
→ Assessment of feasible concepts

Objectives of this study:
→ A conceptual aircraft design that answers the market analysis results

Design Goals

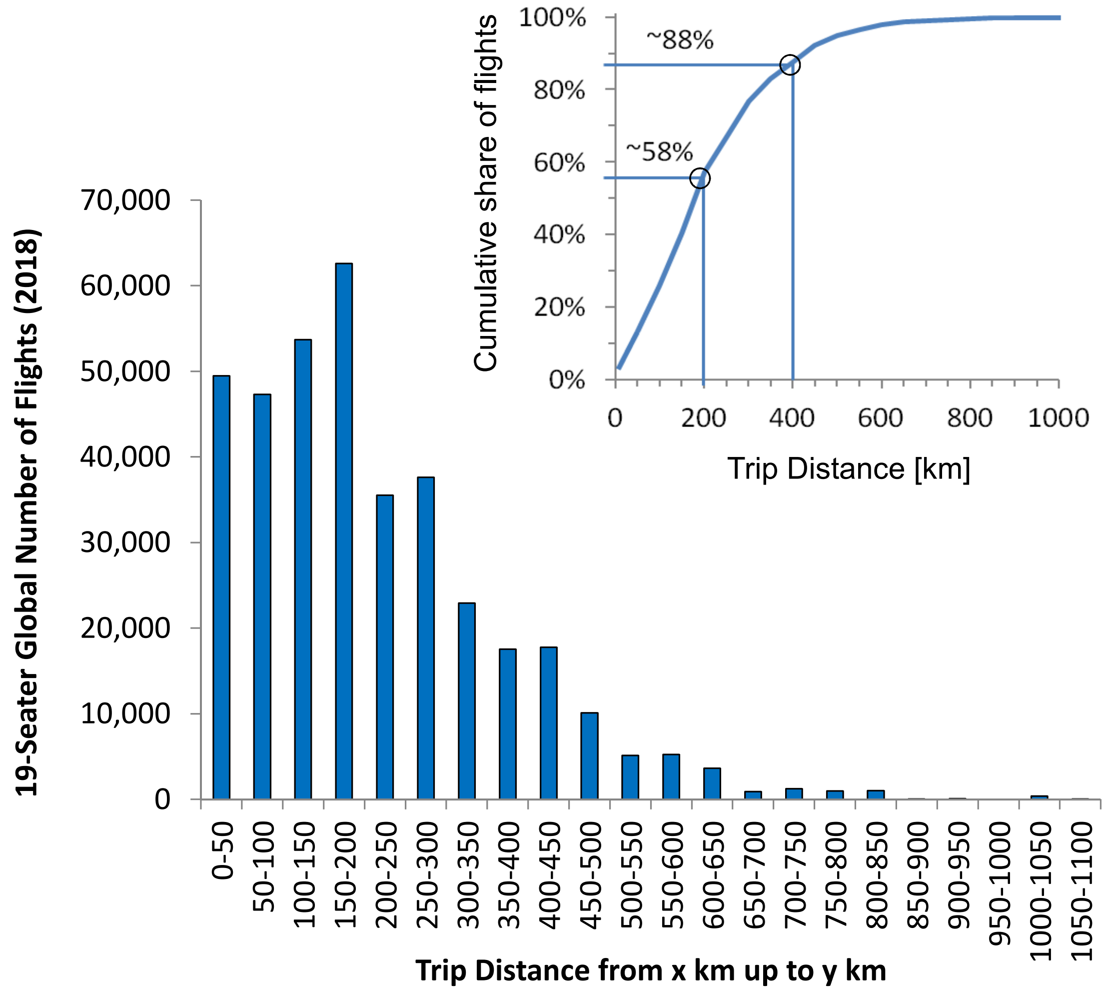
Market research data:

- Extremely short utilization distances of 19-seater aircraft

→ Market suitable for fully electric flight

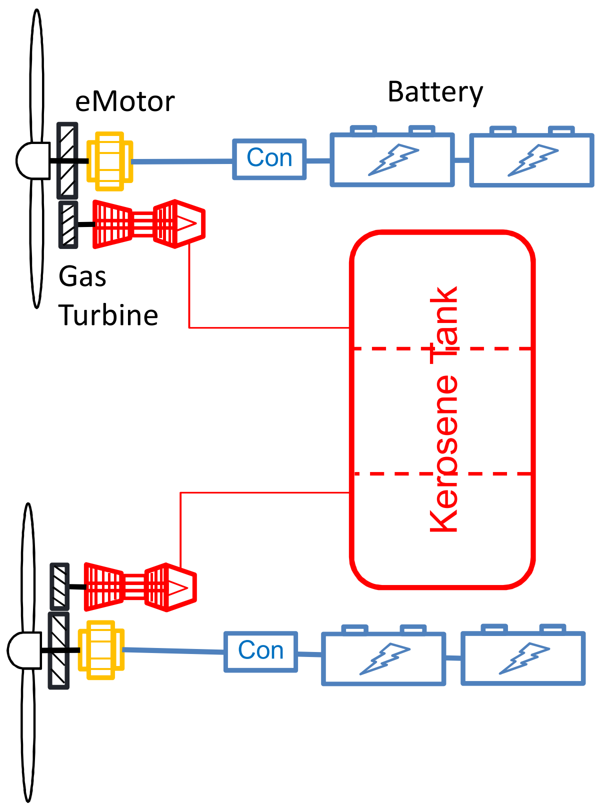
Design aim:

- 19-seater aircraft with fully electric flight capability.
- State-of-the-art electric components at prototype level.
- Certification under CS 23
- Competitive payload-range characteristics

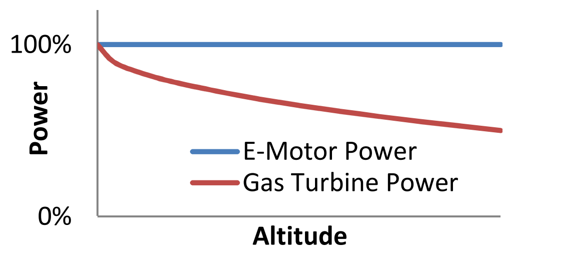


Propulsion Architecture

- Classical twin propeller configuration:
  - Low-risk, dependable conceptual-level results.
- E-Motors:
  - Sized for take-off & all-electric operation.
- Range extender:
  - In parallel to e-motors, with a coupling / decoupling device.
  - For full IFR mission reserves with kerosene.
  - For range flexibility with kerosene.
  - Sized for loiter speeds @ 10000ft.
- Batteries:
  - Sized for all-electric operation.
  - Must not consider mission reserves.



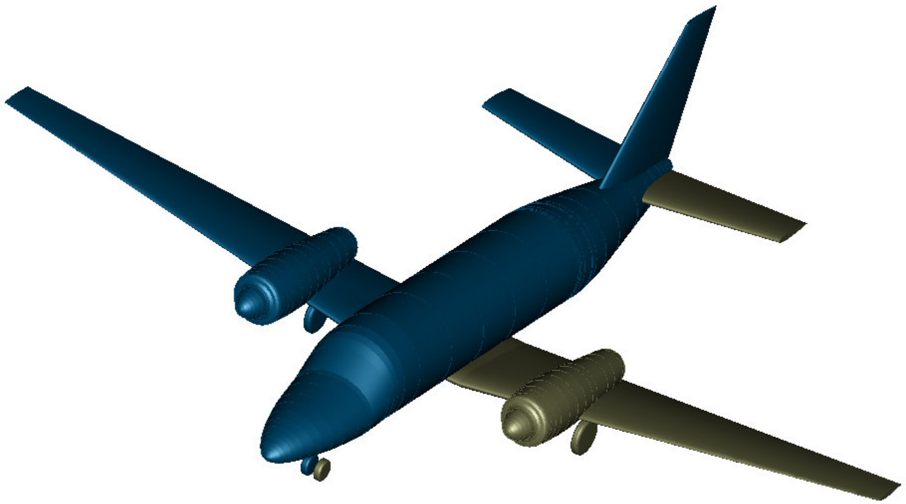
Configurational Aspects

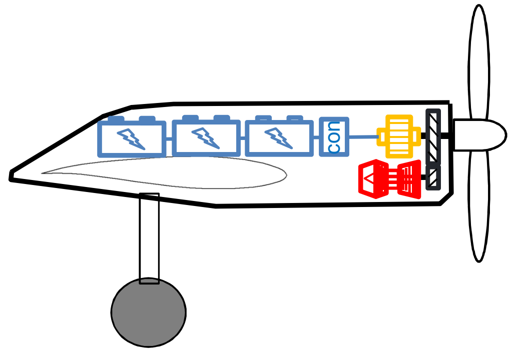


Pressurized cabin complementing the e-motors‘ lack of power lapse.

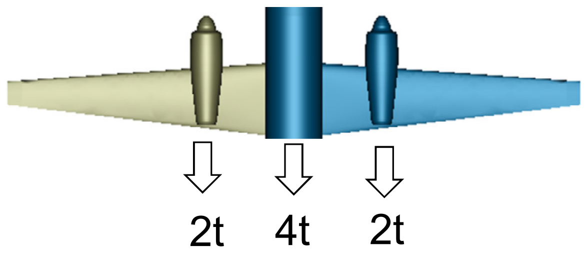
Landing gear to wing root due to space allocation

Designation - E19





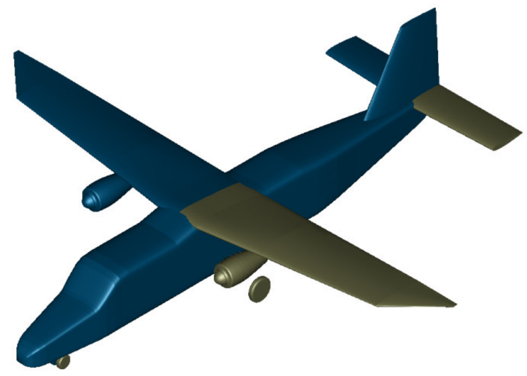
Propulsion mass directly supported by the landing gear



Favourable mass distribution for the wing in flight

Conceptual Design Model Calibration

Aircraft Sizing Model Based on Do228

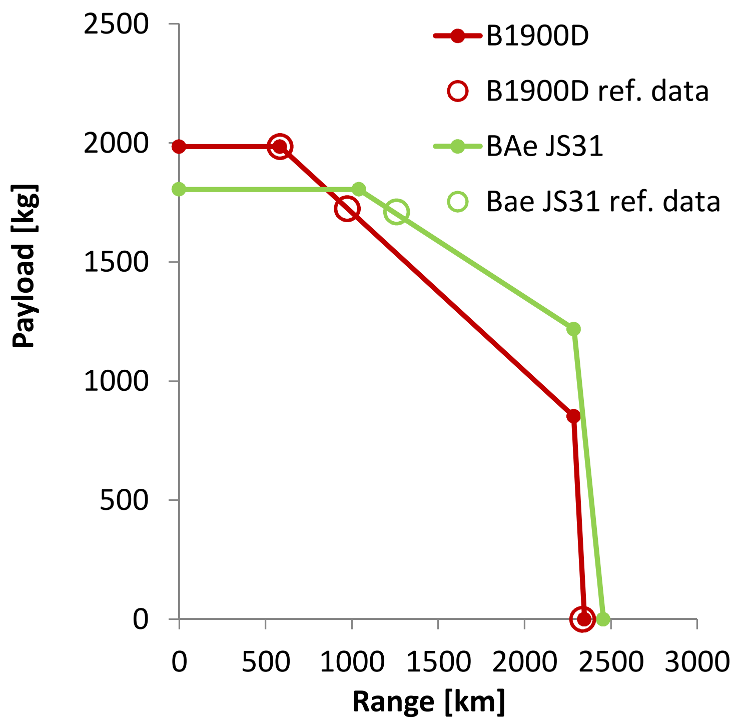


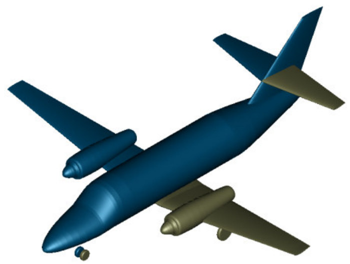
- Refined troughout previous studies
- Dependable for similar configurations

→ Used as a base for this study

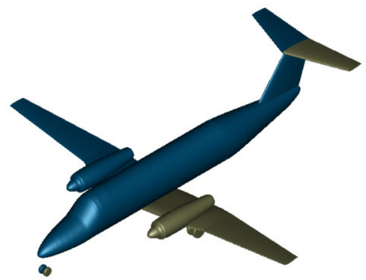
Uncertainty: E19 configuration is different

Model Validation and Calibration on Similar to E19 Configurations





BAe Jetstream 31



B1900D

Top-Level Aircraft Requirements (TLARs) & Assumptions

TLAR	Value	Unit	Remarks
MTOM Limit	8618	Kg	CS23 Limit
Max Payload	1805	Kg	Same as BAe JS31
Min Cruise Altitude	10000	Ft	
Ceiling Altitude	25000	Ft	Same as BAe JS31
Diversion Mission	100	Nm	For IFR flight rules
Approach Speed	109	Kts	Similar to BAe JS31
Takeoff Field Length	1440	m	Same as BAe JS31

Same technology as the Bae JS31:

- Airframe structure
- Systems
- Gas turbine
- Furnishings & Operator Items

Allowances

Segment	Time [min]	Energy [kWh]
Taxi out	3.0	0.8
Take-off	1.1	24.7
Approach & Landing	2.0	6.1
Taxi in	3.0	0.8
Total	9.1	32.4

Sizing Results

Sizing Model Results	Value	Unit
Max. Takeoff Mass (MTOM)	**8618**	**kg**
Design Fuel (IFR Reserves Only)	192	kg
Maxi. Zero-Fuel Mass	**8426**	**kg**
Max. Payload	1805	kg
Operating Empty Mass (OEM)	**6621**	**kg**
Operator's Items	475	kg
Manufacturer's Empty Mass	**6146**	**kg**
Furnishings	270	kg
Systems	650	kg
Propellers + Range Ext. (incl Systems)	388	kg
Airframe Structure	2446	kg
El. Power Train Budget	**2329**	**kg**

State of the Art Technology Assumptions @ Prototype Level

El. Power Train	Tot. Mass [kg]	Tot. Power [kW]	Eff. [-]
E-Motors	253	1251	95.0%
Controllers	12	1321	98.0%
Cooling	44	89	-
Power Distr.	66	1321	99.7%
Battery	2018	1352	-

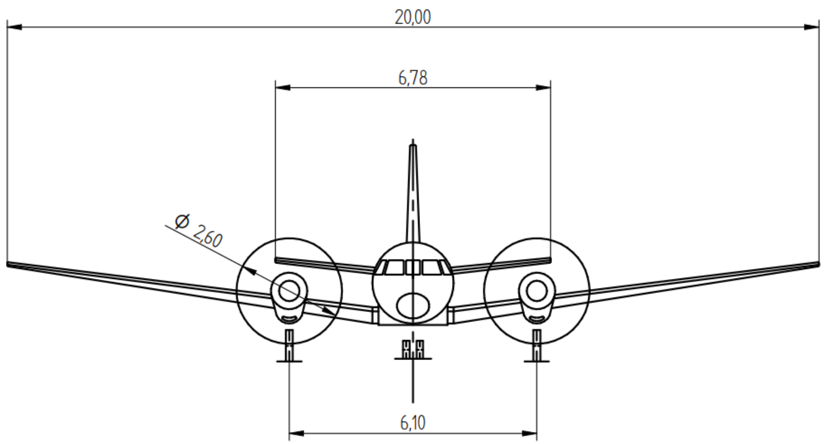
- E-Motors: 5kW/kg @ 1680rpm
- Controllers: 115kW/kg (Siemens)
- Cooling: 1 kW/kg (losses)

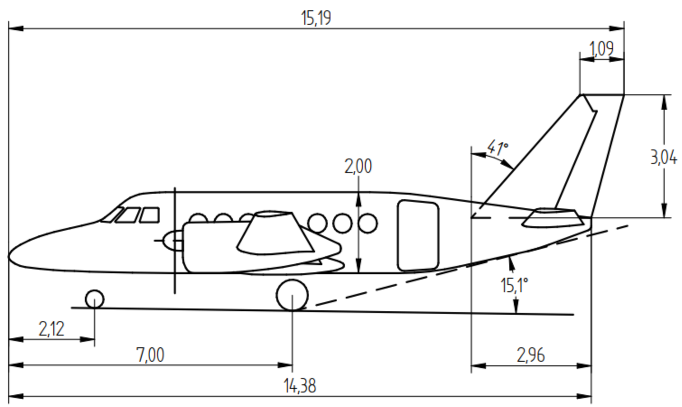
Battery Pack

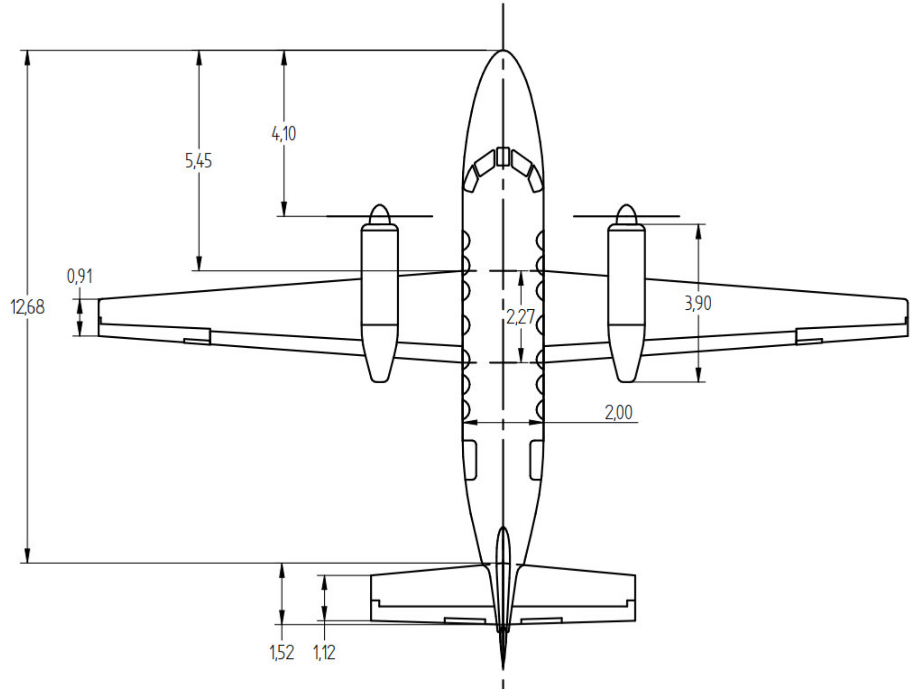
- 230 Wh/kg
- 690 W/kg
- 90% State of Charge (start of Mission)
- 20% State of Charge (end of Mission)

→ Effective: 160 Wh/kg

E19 Geometry Overview

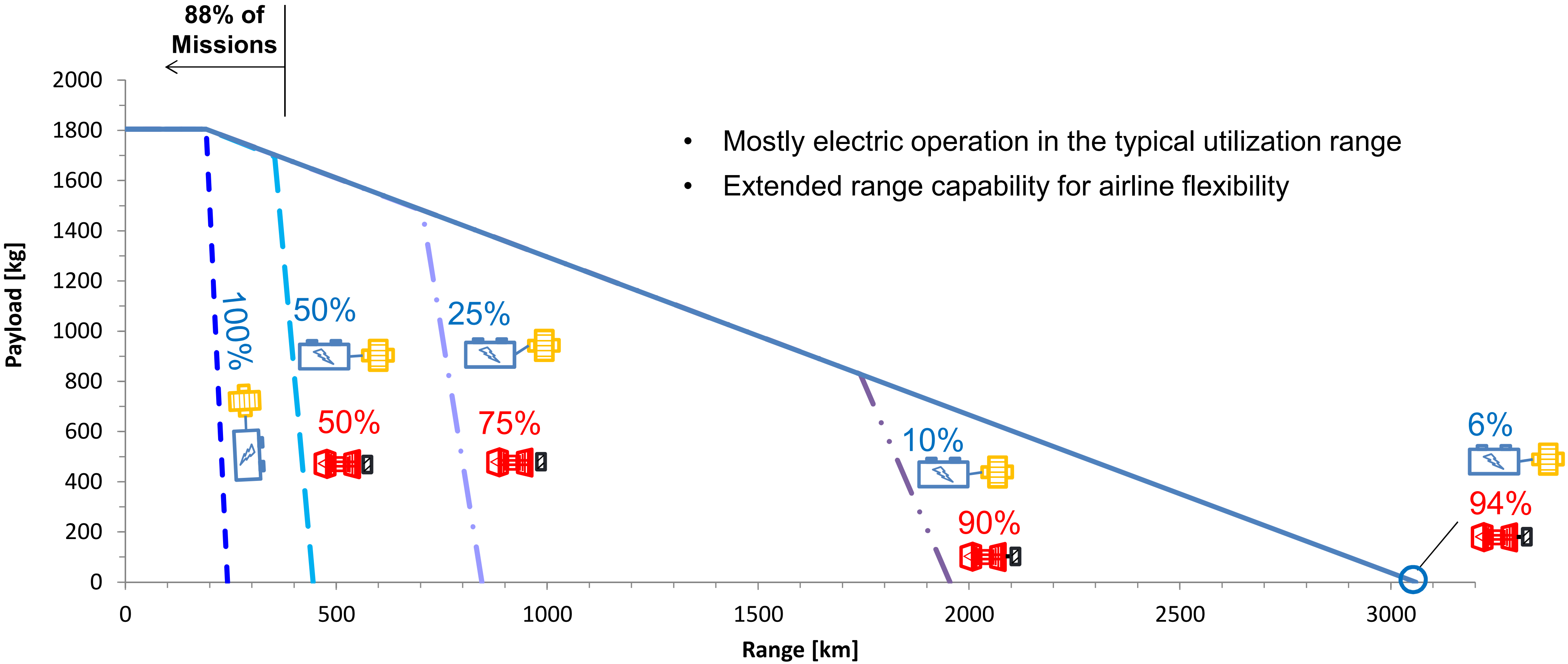






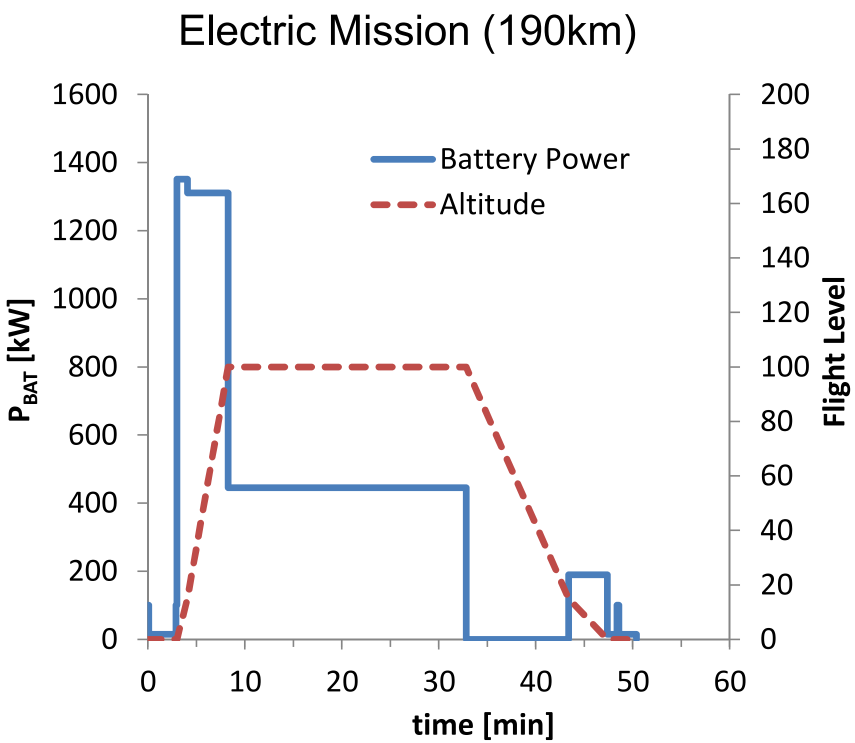
Parameter	Wing	HTP	VTP
Area [m2]	33.2	8.2	6.1
Aspect Ratio [-]	12.0	5.2	1.5
MAC [m]	1.77	1.27	2.17
¼-Chord Sweep [°]	1.8	3.0	36.0
Rel. thickness [-]	16% / 12%	13% / 12%	13% / 12%

E19 Payload-Range Characteristics

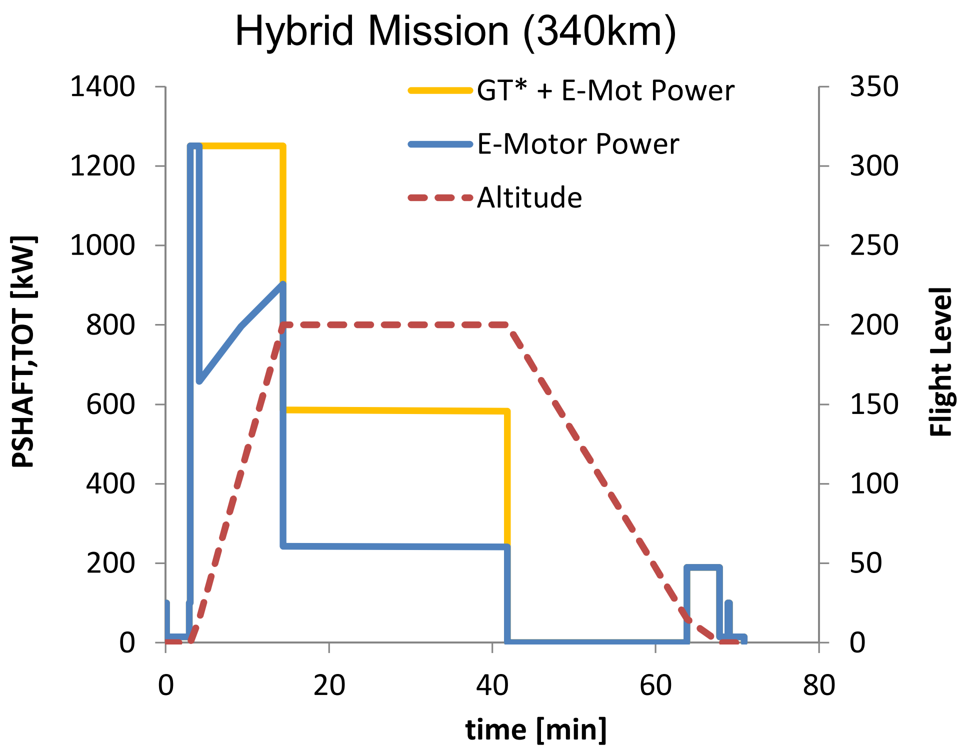


- Mostly electric operation in the typical utilization range
- Extended range capability for airline flexibility

E19 Power Profile

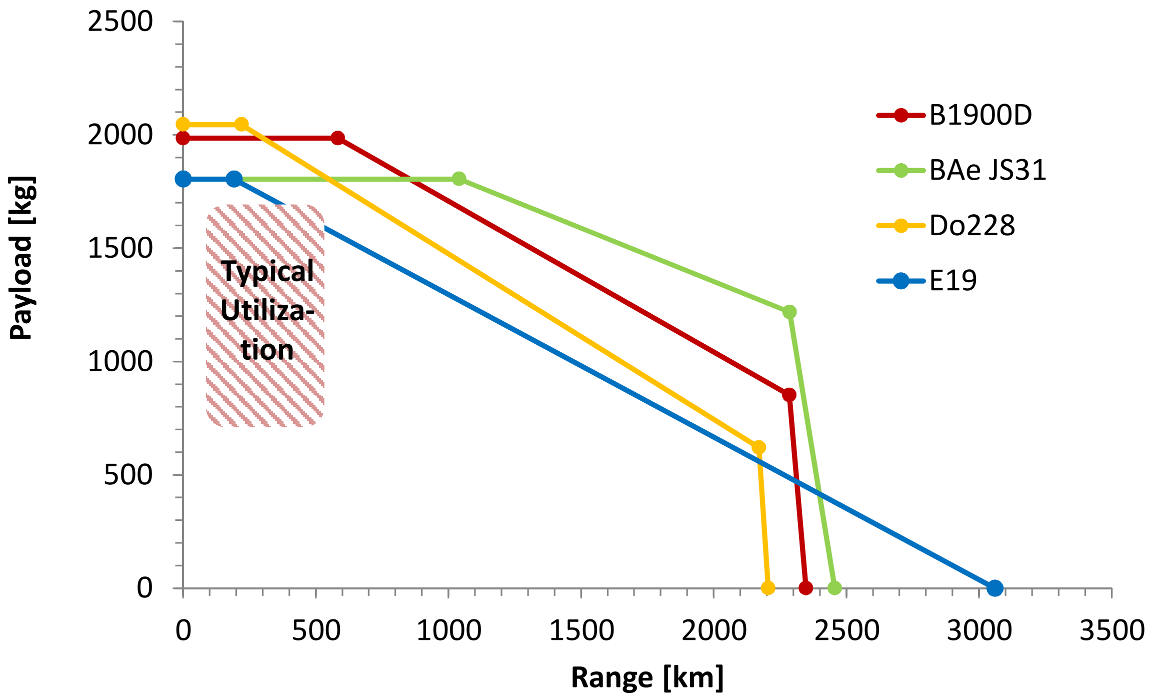


- 10000ft cruise – too short for higher altitude.
- No pressurization offtakes at this altitude.



- Climbs higher and faster to improve time performance at the bigger distances

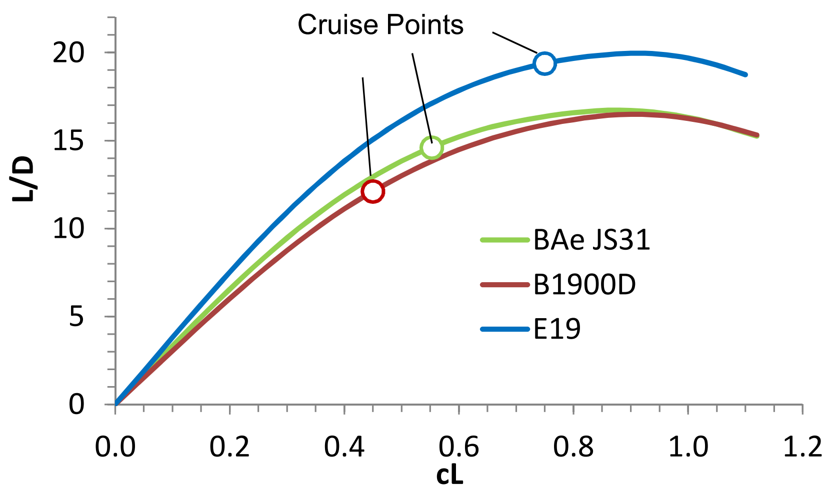
Payload-Range Comparison

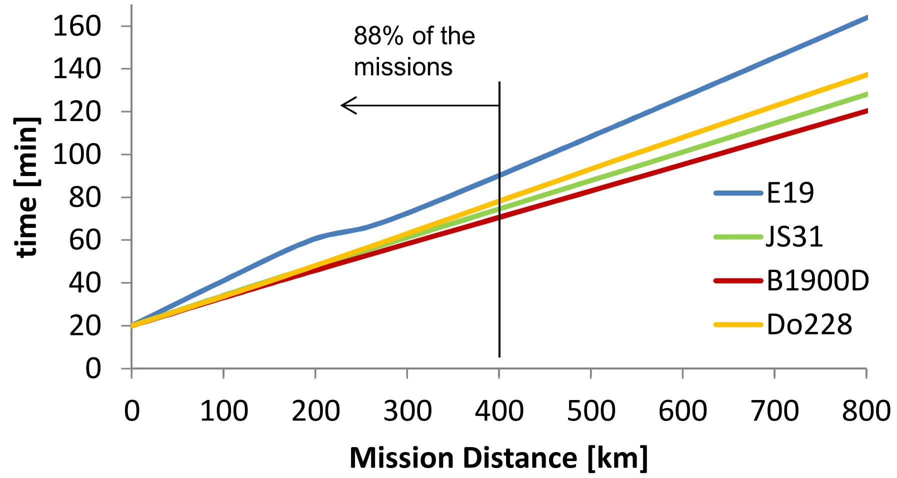


Parameter	Unit	Do228	BAe JS31	B1900D	E19
MTOM	**kg**	**6400**	**6950**	**7766**	**8618**
Sref	m2	32	25.2	28.8	33
Span	m	17	15.9	17.75	20
cL_{cruise}	-	0.3	0.55	0.45	0.75
L/D_{cruise}	**-**	**10.0**	**14.6**	**12.1**	**19.4**
$psfc_{GT,cruise}$	**kg/kWh**	**0.34**	**0.32**	**0.33**	**0.35**

→ High MTOM is mitigated by improved L/D

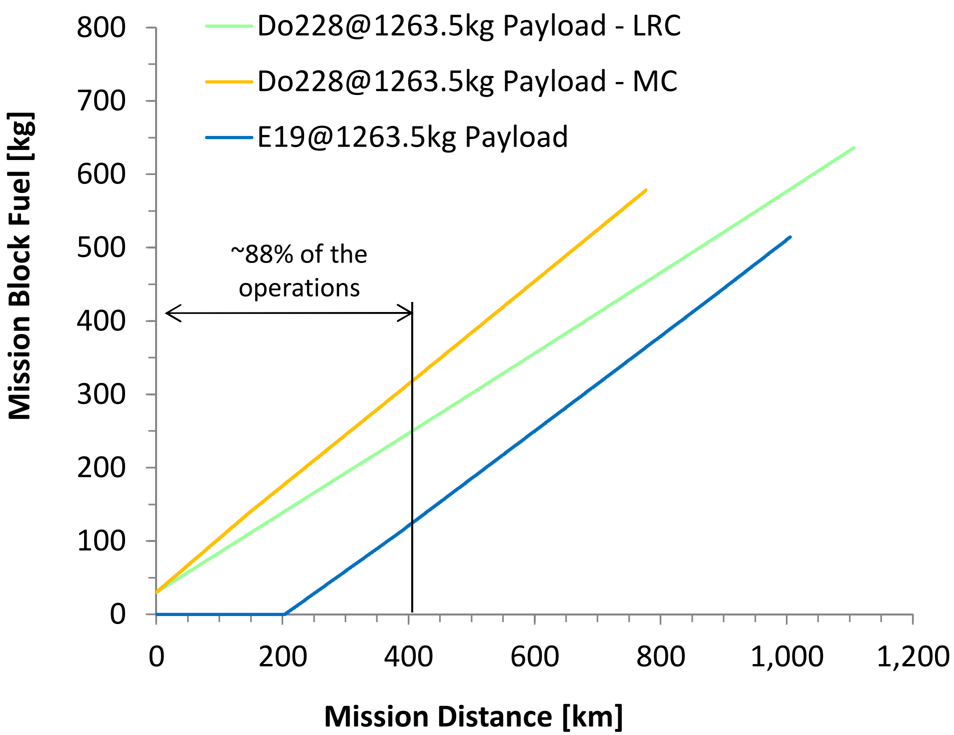
Mission Performance

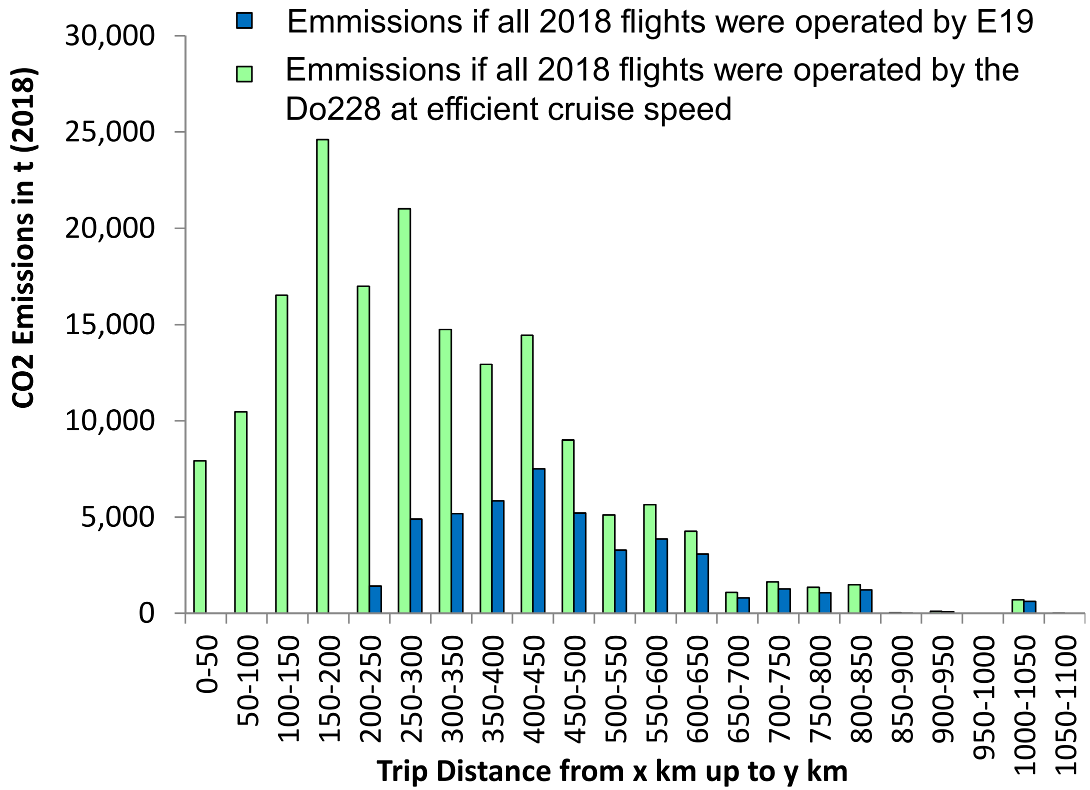




- E19 → velocity traded for efficiency.
- Penalty most prominent at the longer missions.
- Less affected at the typical utilization range.

Sizing Requirements for the Hybrid Chain





- With renewable energy for recharging, ~70% emissions reduction potential at the 19-seater market
- If current electric mix in Germany is used → a potential of ~45% emissions reduction remains

Conclusions

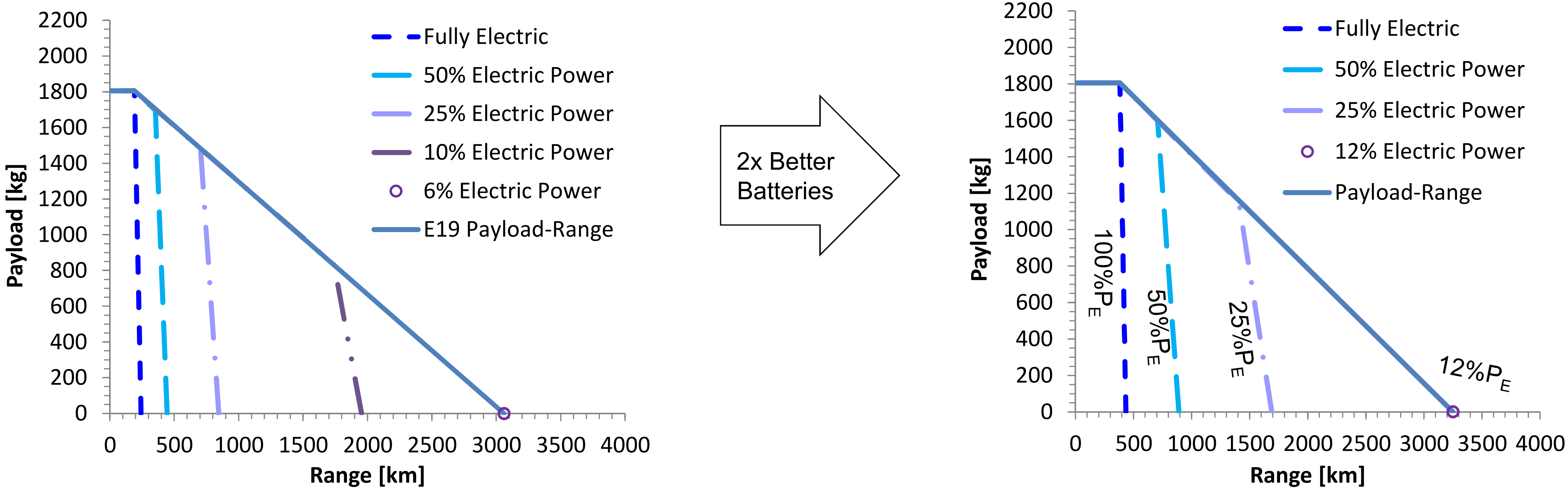
The conceptual design study conclusions:

- State-of-the-art electric power technology is potetially suitable for the 19-seater market.
- **> 70% fuel savings** on average are potentially feasible on this market.
- **> 40% CO2 emission reduction** possible, if battery charging with the German electric mix of today is assumed.

Further efforts needed:

- Operational assessment, including charging during turnaround and life-cycle assessment.

Outlook



- New battery technology could improve performance without redesigning the aircraft.
- The approach is scalable to bigger aircraft for similar range performance.

Thank you for your attention!