**FUTure PRopulsion and INTegration**
towards a hybrid-electric 50-seat regional aircraft

# Foundations towards the future: FUTPRINT50 TLARs, an open approach

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FUTPRINT 50 Consortium

EMBRAER

Universität Stuttgart

ADSE
CONSULTING AND ENGINEERING

FUTPRINT50

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European Commission

# Aviation towards the future: The need for regional hybrid electric aviation



**Aviation** is a key component **for development and resilience.** It is deeply integrated into a worldwide **intermodal transport network.**

**Clean Aviation** to support **sustainable development.**

**Future propulsion and integration: towards a hybrid-electric 50-seat regional aircraft**



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# FUTPRINT50 rationale

Hybrid-Electric
< 50 PAX
EIS 2035/2040

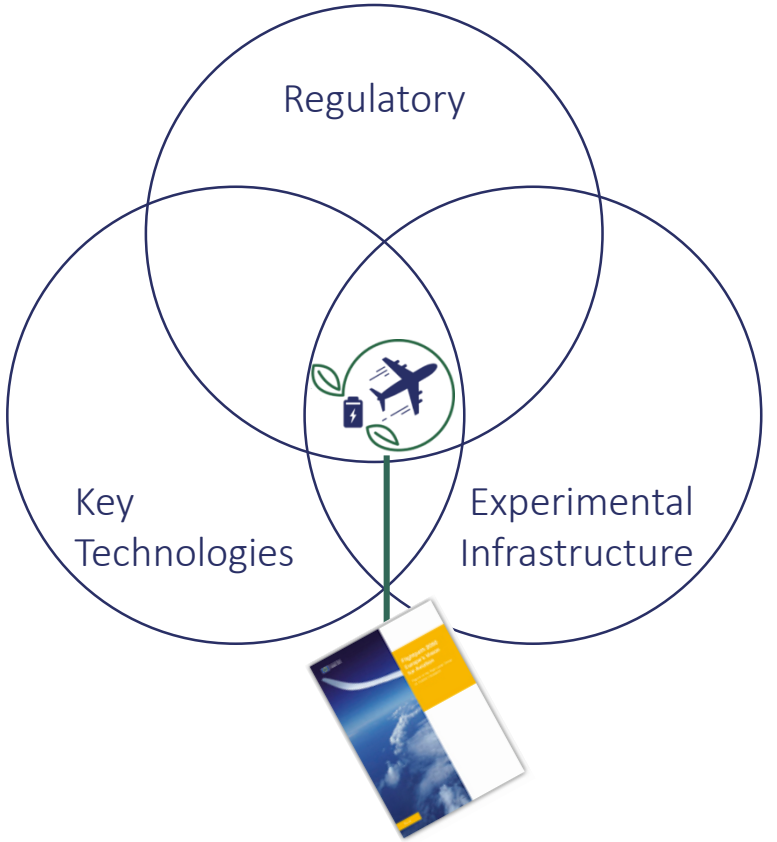
University of Stuttgart Germany | Cranfield University | TU Delft | EMBRAER | ADSE | cea
DASN | Università Niccolò Cusano | ЦАГИ | AC | CIAM | National Research Center | МАИ

Open-source tools & models

In-depth state-of-art
Feasibility study

**New disruptive key technologies:**

- Energy storage
- Energy harvest
- Thermal management



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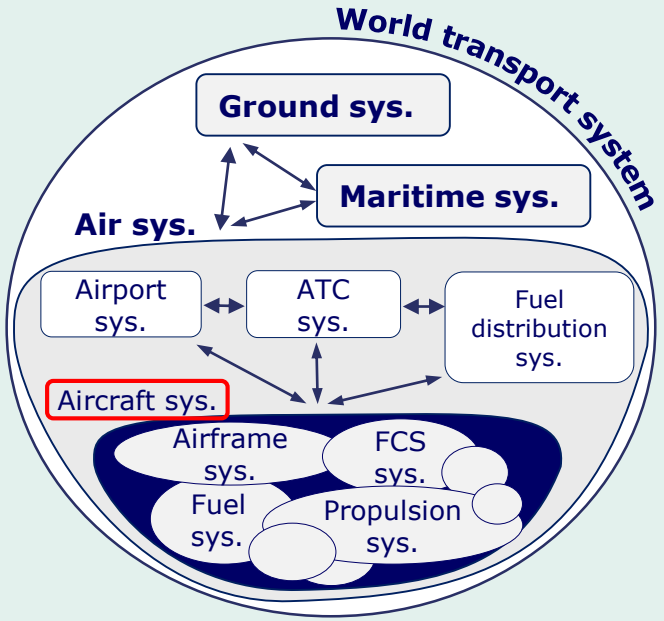
# Creating alignment: Systems Engineering (SE) approach

## *Hybrid-Electric Aircraft as part of the 'world transport system' defined from a 'life-cycle approach'*

**System of systems**




**Life-cycle approach**


### *Aircraft Mission*

- System of systems
- Life-cycle approach

➔ Seamlessly integrate the aircraft in 'the world'

### *TLARs*

- Stakeholder analysis
- Increase value proposition

➔ Aligning to the stakeholder needs



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# Defining Top Level Aircraft Requirements (TLARs) for FUTPRINT50

***Aims for TLARs***

- *Feasibility of EIS 2035/2040 regional Hybrid Electric Aircraft (HEA)*
- *Providing reference requirements to understand and develop a robust roadmap for HEA, taking into account scalability*

***Methodology***

- *Context drivers (emissions, feasibility, …)*
- *Current regional flights*
- *Future transport networks*

***Focus & Strategy***

- *Focus on replacement*
- *Enabler of future routes and operations*



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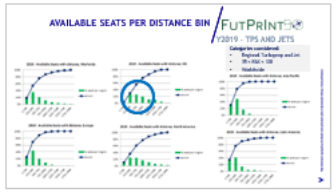
# An overview of current status, trends, needs



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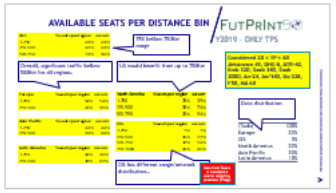

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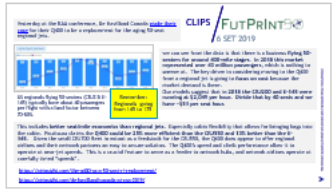

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## 1) Current flights, operations (regional, TP, Jets)


energies

MDPI

Article

**Market and Technological Perspectives for the New Generation of Regional Passenger Aircraft**

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**Abstract:** This article describes the extent to which hybrid aircraft and all-electric aircraft can press a solution for reducing HC, CO, and $NO_x$ emissions and noise in the vicinity of airports, in t category of regional passenger aircraft. The goal of the article is to identify, basing on aircr technical characteristics and market demands, in which sectors of air transport can all-electric hybrid aircraft be most feasibly introduced. Firstly, a simple theoretical model based on a connecti between the aircraft mass and aircraft energy consumption is used to calculate basic techni characteristics and limitations of hybrid and all-electric aircraft. Second, market demands for regio aircraft are presented and discussed, with the intention of recognising the possibilities of replac conventional aircraft with all-electric and hybrid aircraft models in regional air transport in the fu future. Third, quantity of HC, CO, and $NO_x$, $CO_2$ gas emissions of regional aircraft in Europe w calculated to recognise the possible reduction of gas emissions if hybrid and all-electric aircraft wou be implemented.

**Keywords:** all-electric aircraft; hybrid aircraft; fuel-cell aircraft; gas emissions; regional aircraft

1. Introduction

Air passenger transport is rapidly growing. The associated revenue, based on the calculati of passenger kilometres (RPKs), is projected to grow annually, at a rate over of 4%, within the ne 20 years. Although the fastest growth rates are expected in regions with emerging economies, such Pacific Asia, the Middle East, Africa, and Latin America, RPKs in the more mature European market still expected to grow at rate of 3.7% [1]. Likewise, the world fleet is expected to increase by 25,000 un from 2018 to 2037, leading to the total number of 53,600 aircraft at the end of 2037 [2]. On the oth hand, main European airports are expected to reach their full capacity by 2030 [3]. If airports not grow to meet the demand, this can lead to significant economical and other deficits [4]. One the main obstacles preventing the growth of large-airport hubs is the environmental impact of transport to the local environment. Larger European hubs are already inducing flight restrictio such as disallowing take-off and landing during night hours or charging fees for gas emissions Moreover, the Advisory Council for Aeronautical Research in Europe (ACARE) has set a target to redu $NO_x$ emissions in air transport by 80% by the end of 2020 and by 90% by the end of 2050. Likewi the target for noise reduction is 50% by the end of 2020 and 65% by the end of 2050 [5]. Therefo new aircraft designs should focus on solutions that can significantly reduce noise and emissions the new generation of aircraft in the vicinity of airports.

One of the possible solutions would be aircraft electrification. Although electrification of land transport has experienced huge progress in recent years, the same outcome cannot be expected in the aircraft industry. The main reason for this is a low specific energy of batteries, of only 0.1–0.25 kWh/kg [6].






**Figure 5.** Number of passengers for 1–8 (blue), 9–19 (orange), and 20–70 (green) seater aircraft in the European region in 2017.




**Figure 6.** Share in on-demand flights for turboprop (blue) and small jets (orange) for 2017–2018 in the EU [34]. Number of city pairs covered with 1–8 and 9–19 seater aircraft, by distance [34].

## 2) Bibliographic review

- *400 km range for circa 70% TP flights*
- *Some regions require higher ranges (e.g. Russia)*



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# Air travel within the (future) transportation network

## Exploring Future possible scenarios…

| | A | B | C | D | E | F |
|---|---|---|---|---|---|---|
| 1 | Market | car_dist | car_tir | car_time_huma | transit_d | transit_tir |
| 200 | ALB-NYC | 262.448 | 9000 | 2:30:00 | 270.975 | 18899 |
| 201 | ALB-PHL | 399.782 | 13477 | 3:44:37 | 405.74 | 26865 |
| 202 | ALB-WAS | 606.915 | 20587 | 5:43:07 | 616.85 | 33311 |
| 203 | ALB-DTT | 895.966 | 30939 | 8:35:39 | 1155.229 | 63300 |
| 204 | ALB-CHI | 1333.516 | 45264 | 12:34:24 | 1869.23 | 95025 |
| 205 | ALB-MSP | 1960.436 | 65936 | 18:18:56 | 2049.667 | 113756 |
| 206 | ALB-CLT | 1253.544 | 41820 | 11:37:00 | 1229.48 | 81285 |
| 207 | ALB-ATL | 1642.046 | 54625 | 15:10:25 | 1647.776 | 89085 |
| 208 | ALB-FLL | 2268.767 | 73026 | 20:17:06 | 2464.055 | 117981 |
| 209 | CHO-NYC | 559.224 | 20217 | 5:36:57 | 631.686 | 40899 |
| 210 | CHO-WAS | 151.551 | 6159 | 1:42:39 | 329.569 | 26333 |
| 211 | CHO-PH | | | | | |
| 212 | CHI-CH | | | | | |
| 213 | ABX-W | | | | | |

**Understanding other modals**

Using google API for travel times road, transit vs. flight

**Air travel provides**

> Reduced travel time
> Lower infrastructure costs
> Thin network enabler
> Access to remote regions

**Emergence of future operation modes**

> Exploit new technology enablers:
- Increasing autonomy
- Remote tower airports
- Decentralized networks

> Circumvent techn. limitations (e.g., range)


*"90% of travelers within Europe are able to complete their journey, door-to-door within 4 hours. Passengers and freight are able to **transfer seamlessly between transport modes** to reach the final destination smoothly, predictably and on-time." [Flightpath 2050]*



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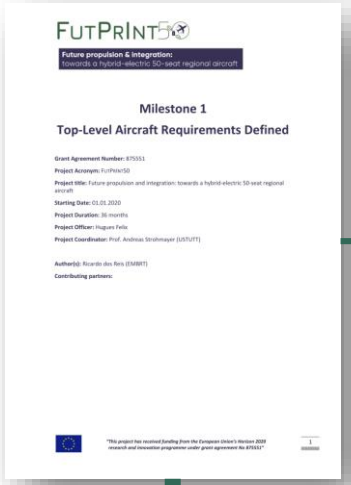
# FUTPRINT50 aircraft class: regional up to 50 pax





**KEY ITEMS**

EIS: 2035/2040
PAX: up to 50
Design range: 400 km
Max. range: 800 km
Cruise speed: 450-550 km/h
Take-off length: 1000 m (+ STOL)
Max. alt: 25 000 ft


**-65 % perceived noise vs. Y2000**

**-75% CO2 / (PAX x km) vs. Y2000**

**-90% NOx / (PAX x km) vs. Y2000**

**A/C taxi : emission free (electric)**
**Design & Manufacture for Recycling**



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# FUTPRINT50 way forward : towards a HEA roadmap

**With collaboration and a common roadmap towards the future of aviation.**

Common roadmap striving for:

- Market,
- technology and
- legal readiness until EIS


**2020** — **2040**

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# Key messages

## Clean Aviation is key for sustainable regional development and resilience!

- EIS 2035/2040 challenging but doable with joint collaboration efforts across the board.
- FUTPRINT50 will develop open reference architectures, models and tools.
- FUTPRINT50 is focusing on energy storage, harvesting and thermal management.
- Replacement as first approach but future operation models might emerge
- Learning to scale: complexity, regulations, integration


Open Collaboration Call:
FUTPRINT50 Academy
www.futprint50.eu



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# THANK YOU!

FUTPRINT50

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