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

Development and Analyses of a Thermal Management System (TMS) for a Hybrid-Electric Aircraft – FUTPRINT 50

12th EASN Conference, Barcelona

Felipe Reyes Barbosa, Ricardo Gandolfi, Walter Affonso Jr., Ricardo Jose Nunes dos Reis, Michele Fernandino Westin, Carlos Roberto Ilário da Silva, Higor Feltrin Teza, Timoleon Kipouros, Panagiotis Laskaridis, Hossein Balaghi Enalou, Maria Coutinho, David Bento, Alain Souza, Frederico Afonso, Fernando Lau, Afzal Suleman

FUTPRINT50

EMBRAER

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European Commission

TMS: A Joint Effort

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TÉCNICO LISBOA

Cranfield University

Previous Works

Thermal Management challenges for HEA – FUTPRINT 50

10th EASN Conference (2020) [1]

Most pressing challenges identified;

Potential technologies and their TRL identified: skin heat exchangers, PCM, fuel tank as heat sink.

System Architectures For Thermal Managment of Hybrid-Electric Aircraft – FUTPRINT50

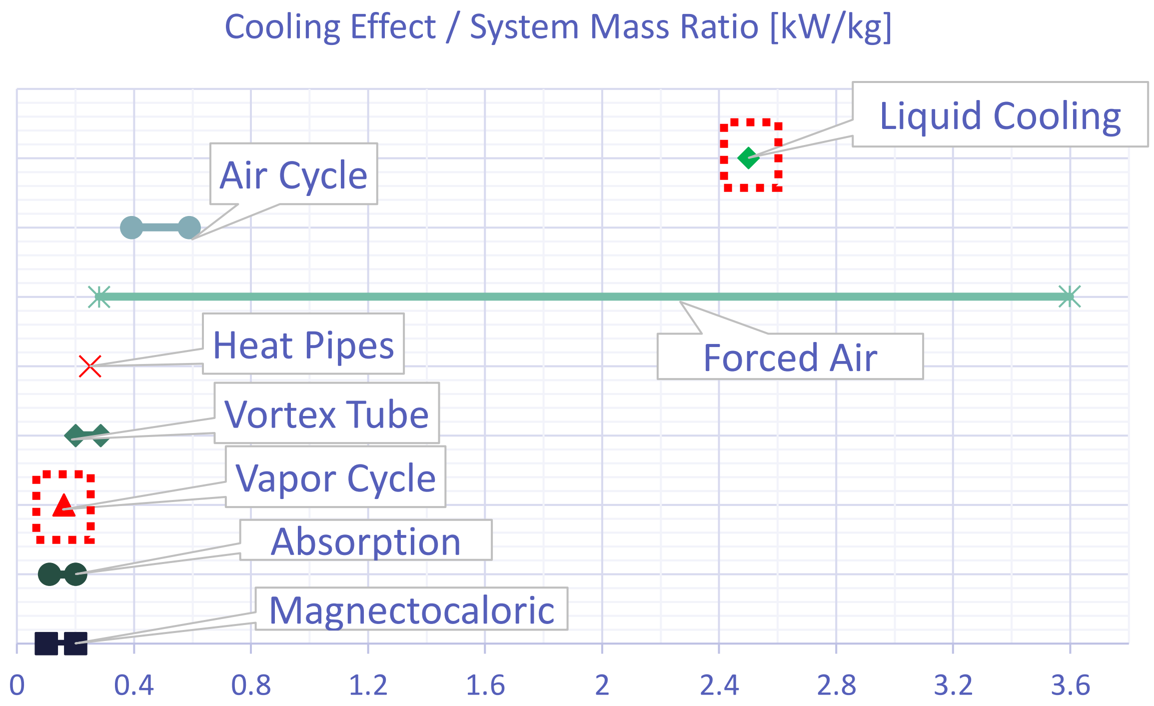
11th EASN Conference (2021) [2]

Comparison of cooling capacities of different cycles/components as function of air flow, electrical consumption and mass;

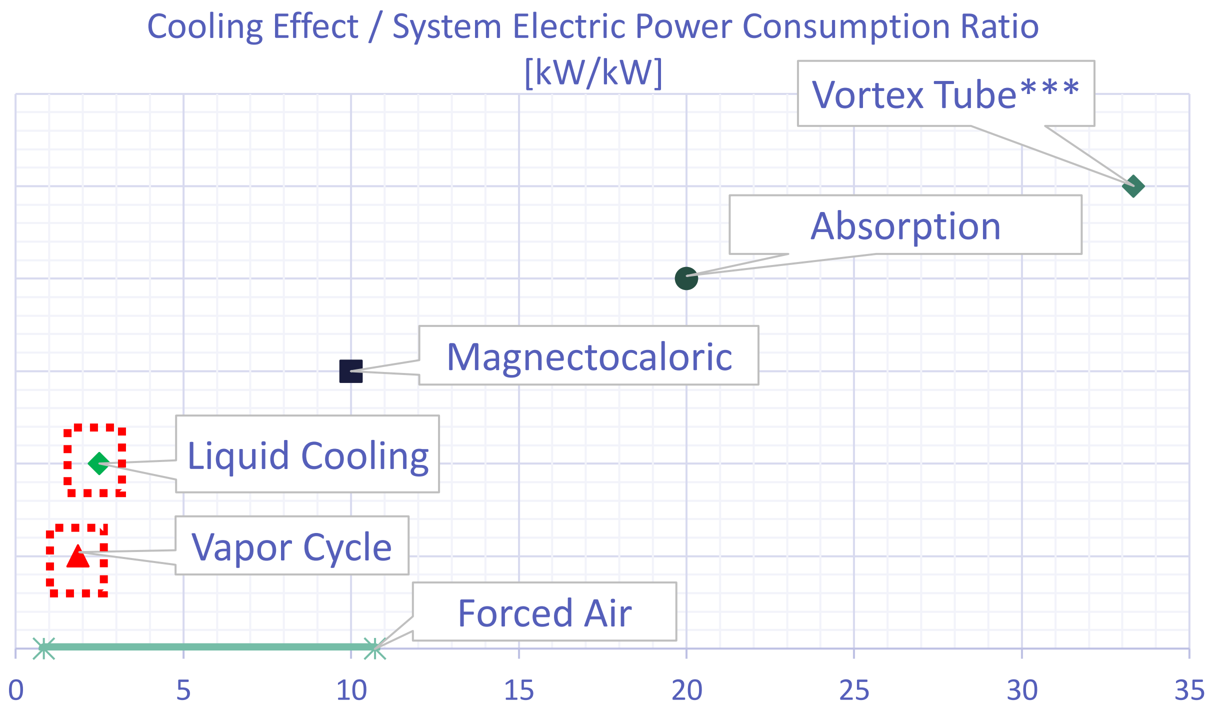
Conceptual architectures presented and discussed.

12th EASN Conference:
TMS architecture development;
TMS results.

Choice of Thermodynamic Cycle

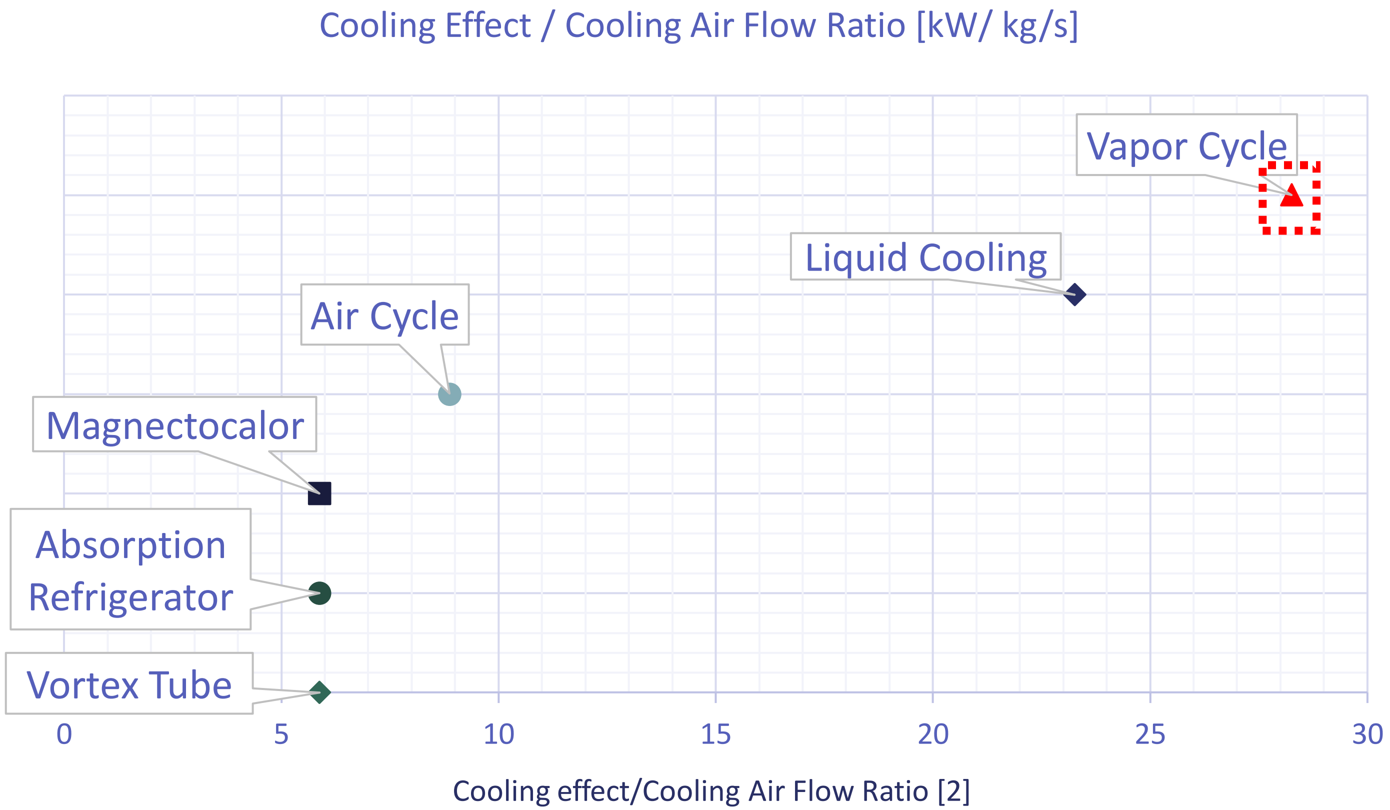


Cooling effect/System Mass Ratio [2]



Cooling effect/System Electric Power Consumption Ratio [2]

Choice of Thermodynamic Cycle



Electrical Components: Temperatures and Efficiencies

Basic Information for Modelling			
Component	Temperature	Efficiency	Cooling Methods [3]
Batteries	25°C (nominal) [3]	92-96% [3]	Convection, cold plate, dielectric oil immersion, tab cooling [5]
Inverters/Converters	-20 to +75°C [6]	97-99% [6]	Convection, cold plate, cryogenic
Electric Motors	-30 to +130°C [3]*	95-99% [3]	Liquid, cryogenic

*Depends on class, ambient temperature and expected insulation life

The Aircraft Electrical System

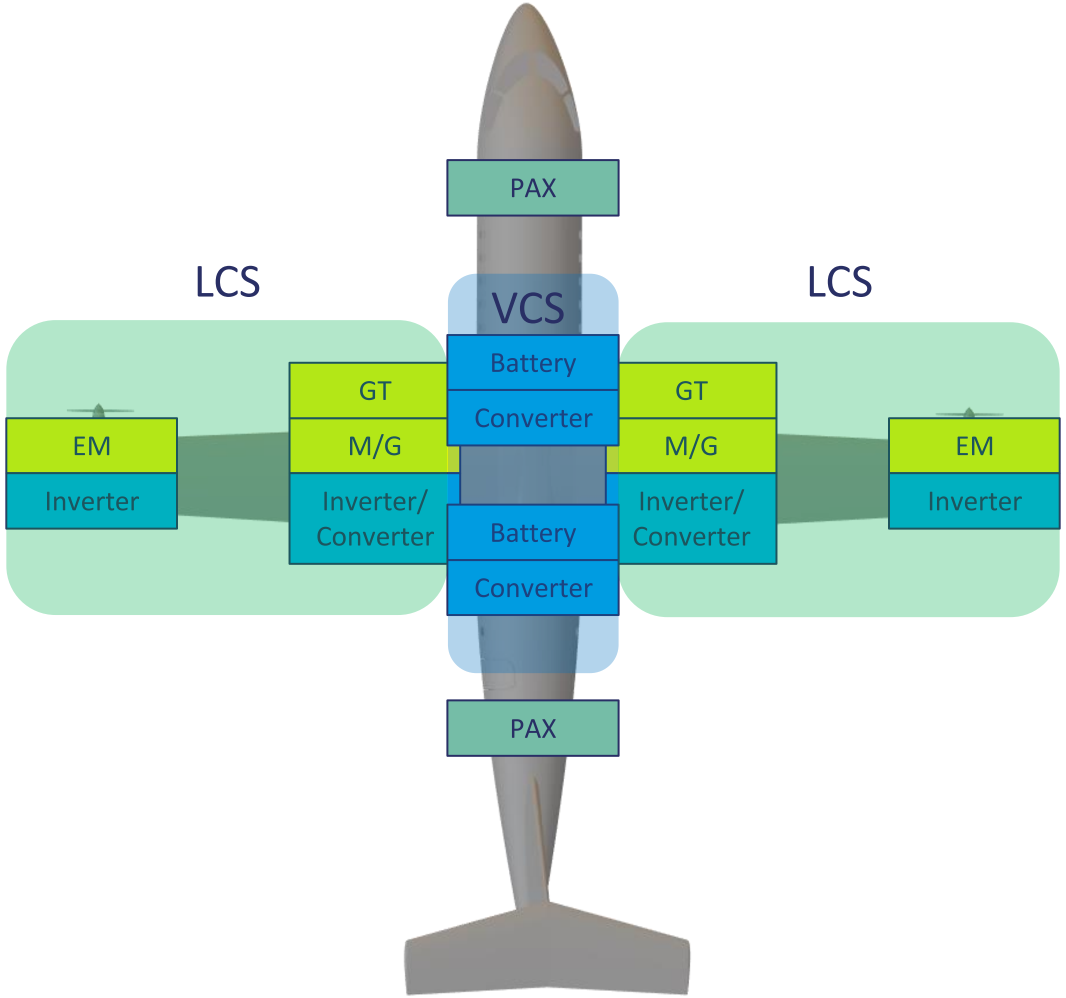
Assumptions:

Thermal management system (TMS) *only* handles the propulsive-electrical system thermal loads;

Parallel-hybrid propulsion: **sustainable aviation fuel (SAF) and batteries**;

Gas turbine engines (GT) may be **boosted by electrical power and/or generate electrical power**. **Electrical motors** may **propel** the aircraft **or harvest** energy – decisions related to energy management strategy (EMS);

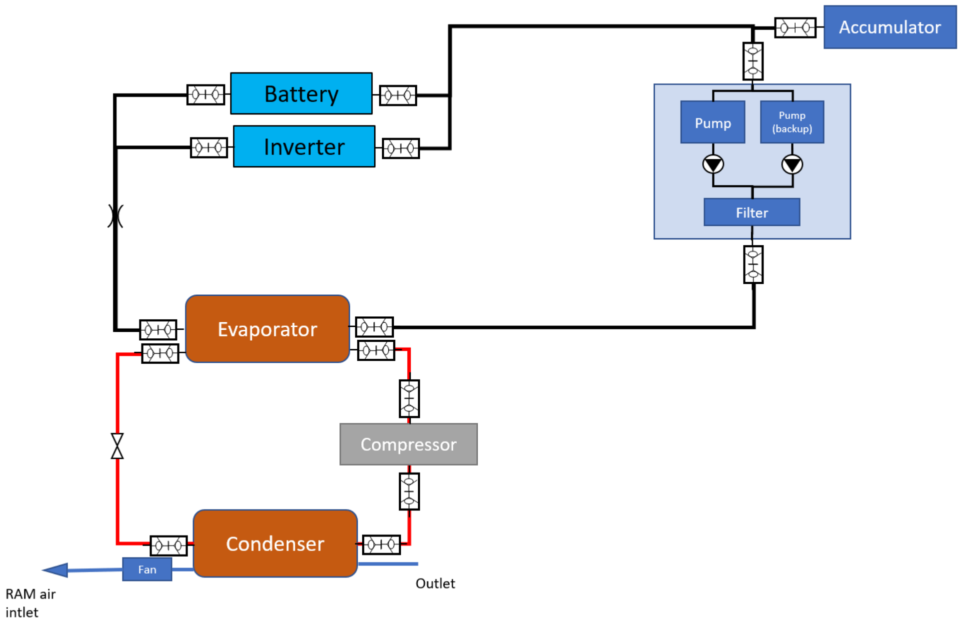
Hybridization factor (power): **10% to 30%.**



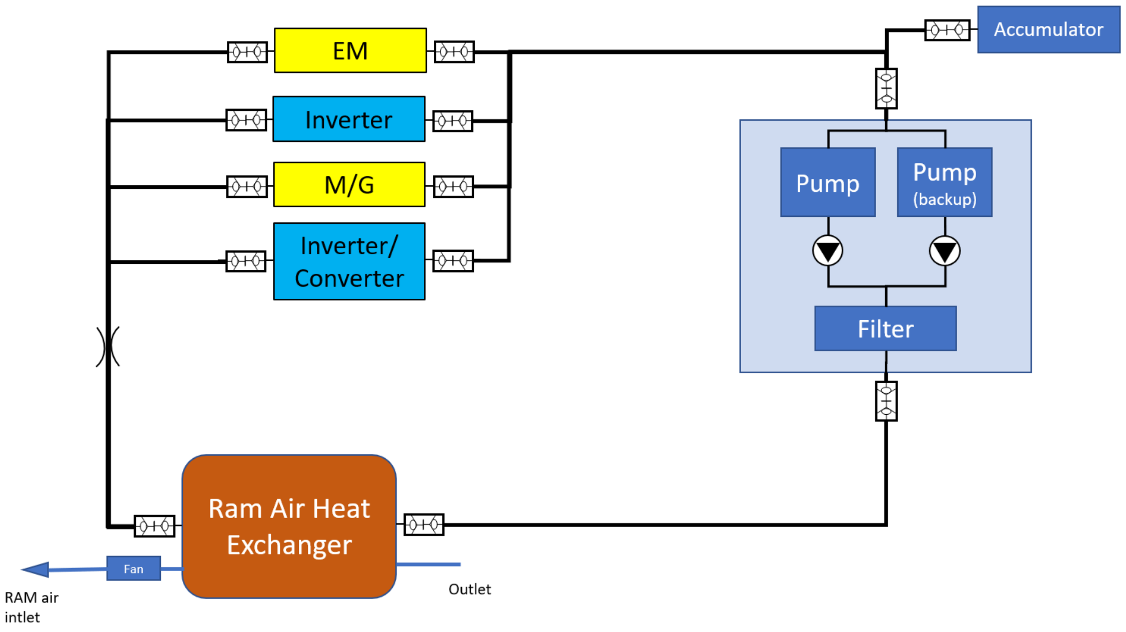
Architectures Families Modelled

"Federalized" TMS: two families of systems (liquid-cooling-based and vapour-compression-based)

1st Family: VCS-based

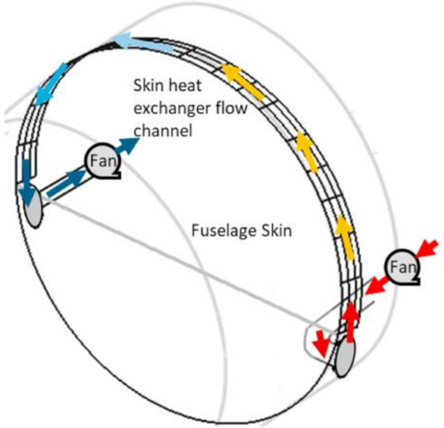


2nd Family: LCS-based



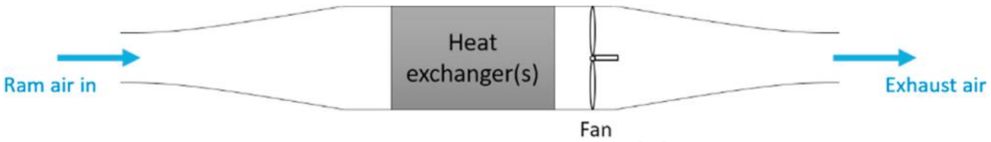
Components Modelled

Skin heat exchanger (SHX): minimize drag, take advantage of existing surface



Skin heat exchanger [3]

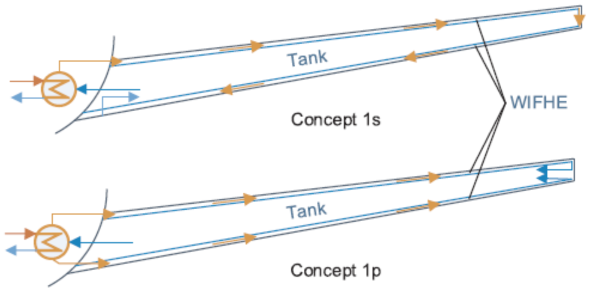
Ram air heat exchanger (HX or RAHX): high maturity. May be associated with Meredith effect [7].



Ram air heat exchanger [3]

Phase change material (PCM): absorb peak/transient heat loads

Fuel tank as heat sink (FT): minimize drag, take advantage of available fluid



Fuel tank as heat sink [4]

Modelling and Simulation

Conceptual Architectures -> Matlab/Simulink -> Splines -> SUAVE

VCS and LCS instant power consumption: f(altitude). Example:

$$W_{VCS} = Q_{batt}\left(0.441 - \frac{0.070}{1 + e^{199.5 - h_{ft}}}\right)$$

Required ram air = f(altitude, Mach);

Mass = f(maximum heat load).

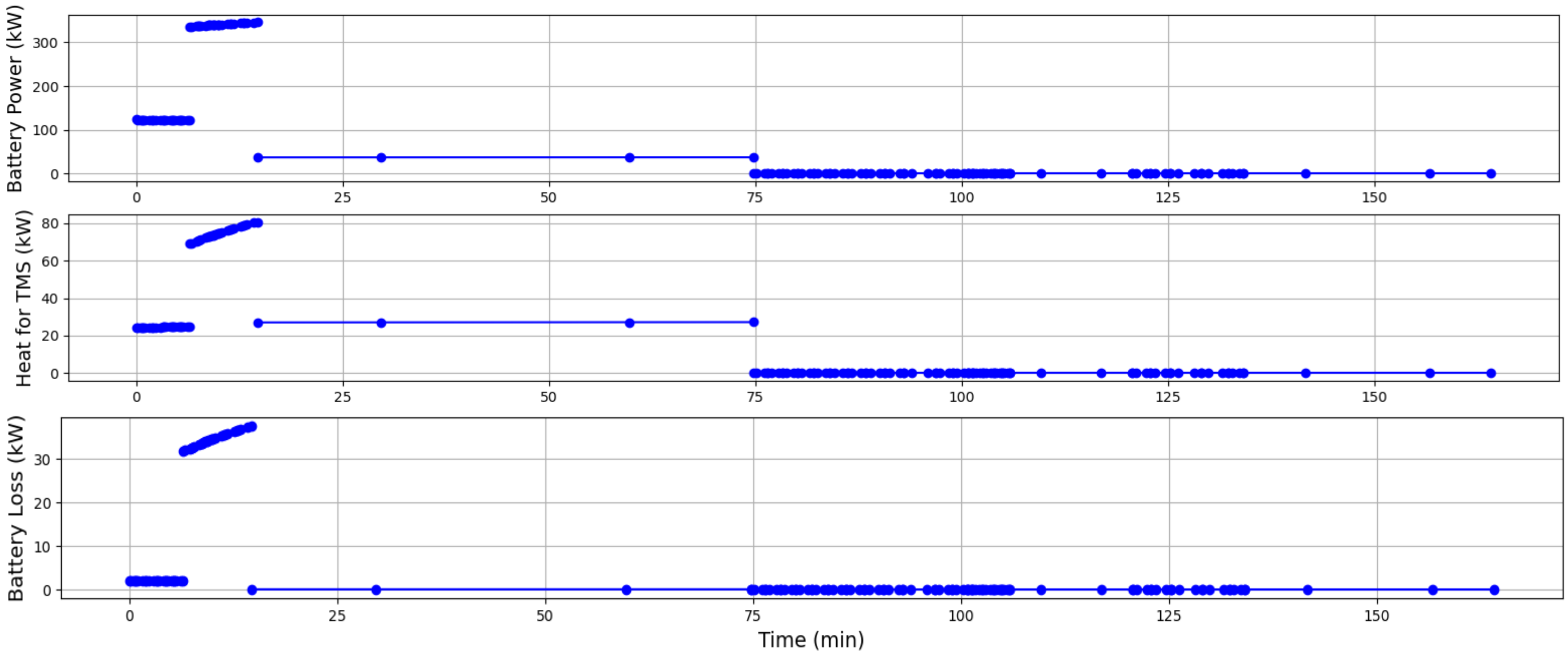
SUAVE Results – 10% Hybridization

TMS is about 2.46% of MTOW and 3.72% of BOW

Main Values	
BOW	13171 kg
MTOW	19841 kg
TMS mass	490 kg*

*Basic redundancy/segregation already considered

SUAVE Results – 10% Hybridization

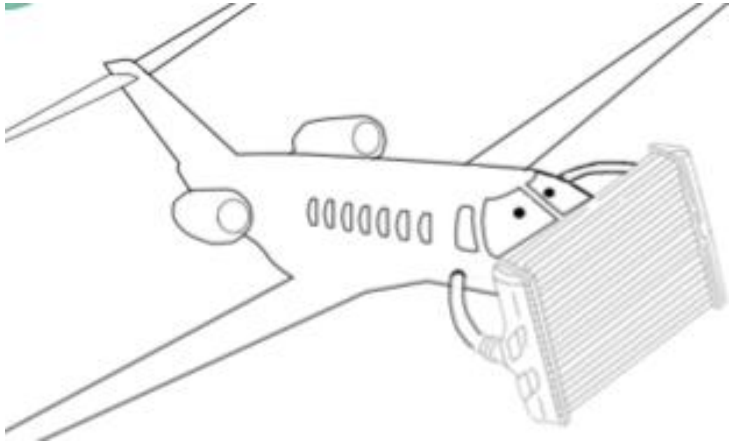


Conclusions

1. TMS adds weight to the aircraft. However, it is necessary for electrification;

2. Fundamental technology is already available, but systems could be improved with new technologies and concepts;

3. TMS also adds drag to the airframe (increased weight and disturbances to airflow). Aircraft designers should take that into consideration.



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THANK YOU!

felipe.reyes@pt.embraer.com

embraer.com & futprint50.eu

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