



Europe-Japan Symposium Electrical Technologies for the Aviation of the Future

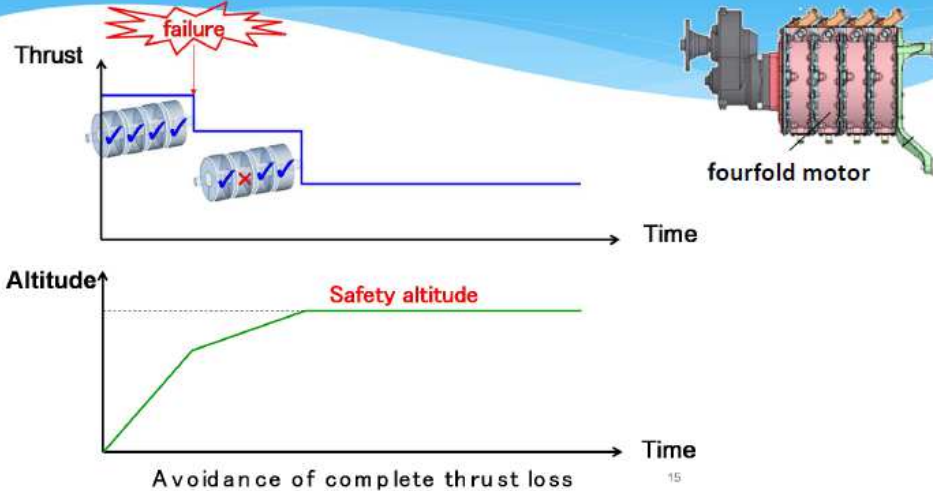
Tokyo, Japan
26th and 27th of March 2015

Summary Session

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Characteristic features of the electric propulsion system(1/2)

社会連携講座 東京大学 IHI
将来航空推進システム技術創成
Advanced Aeropropulsion Laboratory



<http://www.aero.jaxa.jp/publication/event/pdf/event140918/poster07.pdf>
18

High-power density electric motor for propulsion(1/2)

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Advanced Aeropropulsion Laboratory

Tip-drive motor concepts

specific power motor is essential:

$$\text{Power Density} \left[\frac{kW}{kg} \right] \propto H_t \times B_n \times \cancel{M}$$

Masson, P. J., Nam, T., Marvis, D., Brown, G., Kim, H. D., Waters, M. and Hall, D.,
in More-Electric Aircraft: A Potential Application for HTS Superconductors,
Superconductivity Conference, 2008.

High rotation speed is not applicable for large scale motor

◆ Superconducting motor

Adaptation of MgB₂

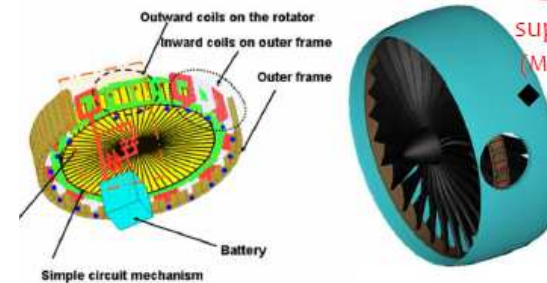
T_{cr}=39[K]

Cryogenic fuel has potential for superconducting medium and coolant.

(Maintaining superconductivity is crucial and important)

◆ Tip drive motor

1. Driving coils (point of action) on the outer shell
2. No need of iron core (Large current variation; Relax physical limits) -> Small (relative) resistance loss
3. Energy recovery via LC circuit



US-Patent#7423405 Electromagnetic Rotating Machine by Okai, K. et al.

Other tip-drive motor concepts for aviation

Magnetically Levitated Ducted Fan Being Developed as a Propulsor Option for Electric Flight (NASA)

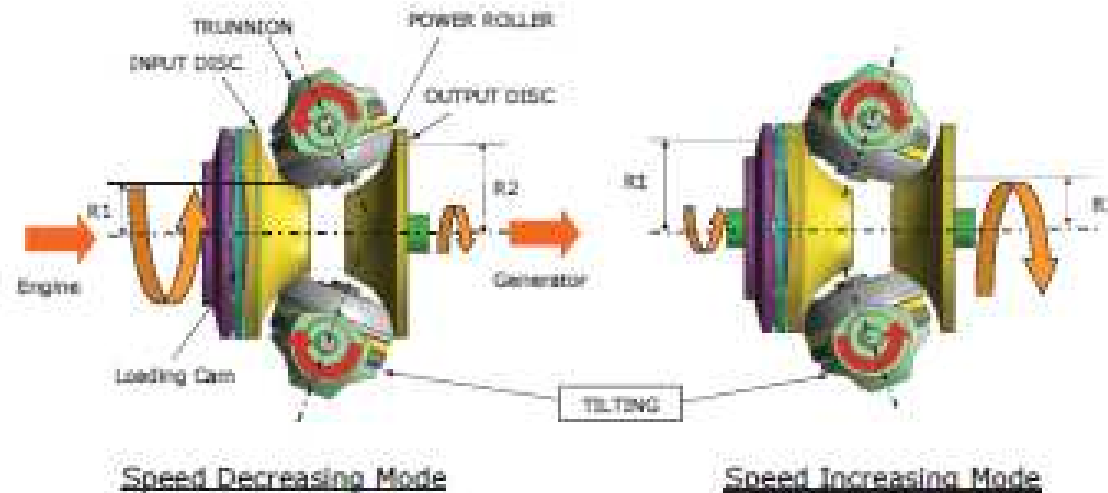
<http://www.grc.nasa.gov/WWW/RT/2003/7000/7720emerson.html>

NASA Tip-Drive motor (to fit around propulsive fan)

NASA-TM-2005-213800

Novel electric machinery configurations for power to mass and safety

Principle of Traction Drive CVT



Typical Configuration of Traction Drive CVT*

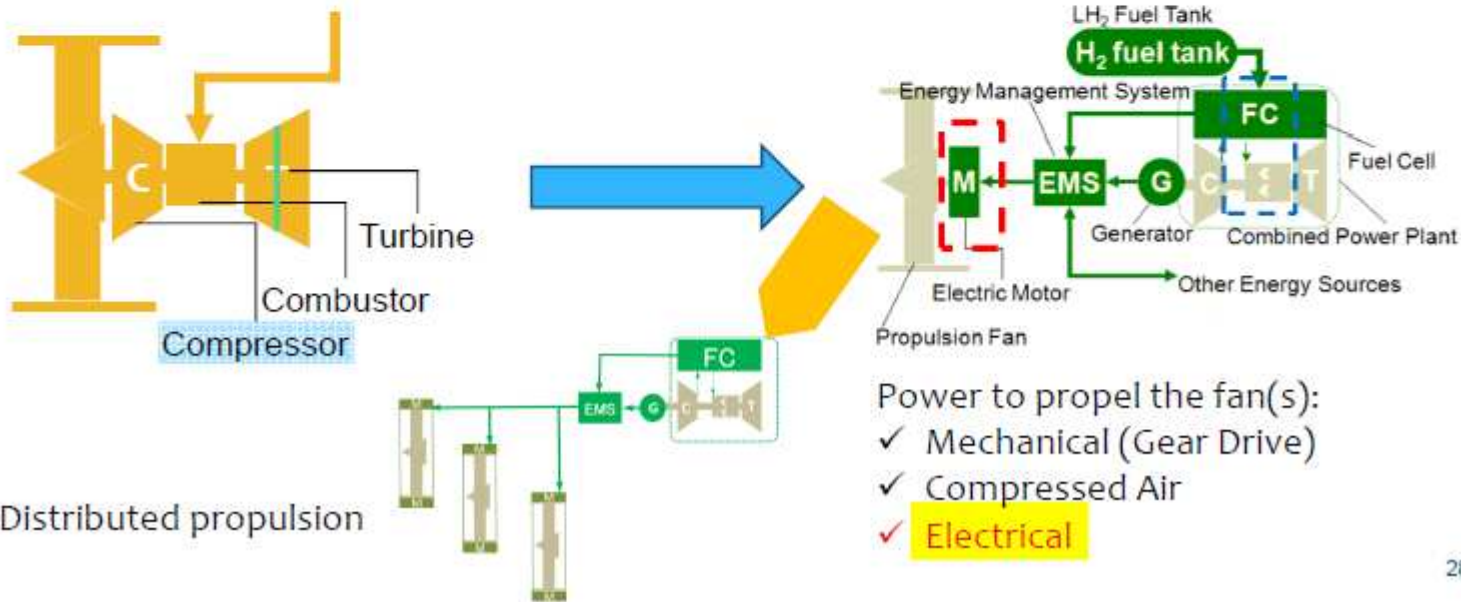
*Continuously Variable Transmission

KHI PROPRIETARY

Optimum fit of electric machinery elements may need advanced gearbox or other rpm adapting technologies



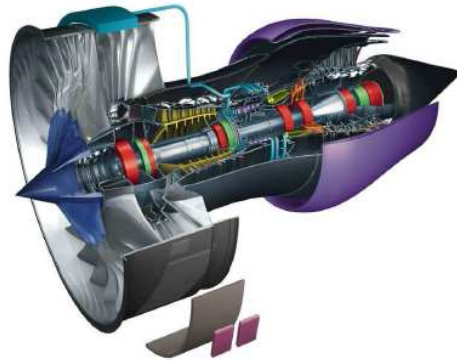
Multiple (electric-)fans powered by (one or small numbers of) core(s)
=> High (effective) bypass-ratio fan engine



New power providing concepts request improvement on component level: e.g. fuel cell

The move to a More Electric Engine Key technology components

10



- Novel Starter Generator
- Electrical Accessories
- Electric Actuators
- Advanced Bearings
- Potential to remove the Accessory Gearbox
- Can be Bled or Bleedless engine



The move to a More Electric Engine The main challenges

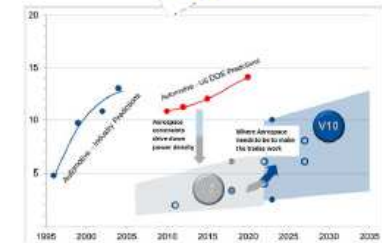
11

Technology

- x1 order of magnitude for Thermal Integration
- X2 order of magnitude for Power Electronics
- X3 order of magnitude for Technology

Risk

- Customer has zero tolerance to programme delay



Higher integrated solutions to drive positive active / passive functional element mass

Challenge – High Power Airworthy Cryogenics 18

- There are no high power (>1 kW available cooling power) aerospace cryocoolers currently in existence
- Aerospace designs typically designed for IR missile sensors and satellite instrument cooling are in the multi-Watt range; Distributed Propulsion with superconducting technology will require multi-kilowatt capacity designs.
- Non-aerospace versions capable of delivering the cooling power required are very heavy and bulky.

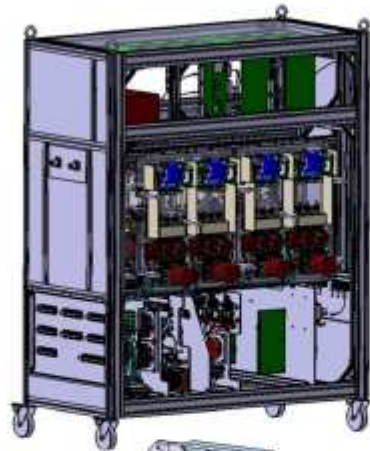
- This design weighs 8 tonnes, and provides 25 kW of cooling power at 77 K
- At 1 MW required input power, the cooler has a specific mass of 8 kg/kW and an overall efficiency of just 2.5 %
- NASA have outlined goals to cut this down to below 3 kg/kW input.



Cooling technologies become more important in ME / hybrid electric architectures especially with HTS

THALES IMPE Road map

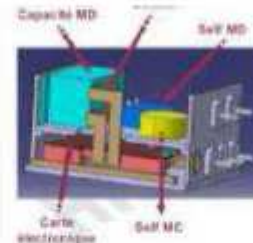
THALES IMPE Bay concept



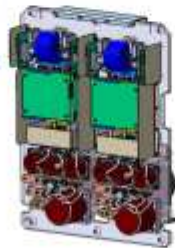
THALES PEM for IMPE Bay (Gen1)



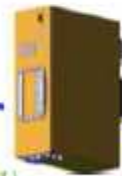
Thales PEM for IMPE Bay (Gen2)



2-3kW/kg
PEM



6kW/kg
PEM(Gen 1)



9-15kW/kg
PEM(Gen 2)



THALES has demonstrated feasibility of IMPE Bay concept
THALES Gen 1 6kW/kg PEM with improved robustness : TRL5 reached in 2015

THALES

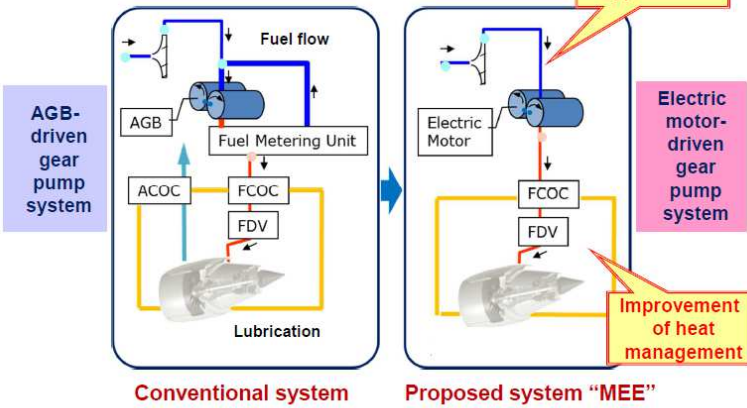
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Power electronics elements have seen enormous progress but need even more progress

Propulsion System Evolution



→ More Electric Engine



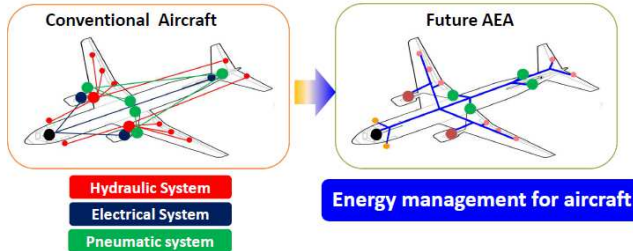
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-11-

➤ Future Aviation by MEAAP



In the aviation industry trends with more electric aircraft and their engine, the Japanese companies collaborate for development of the innovative aircraft energy system with the key technology of electrification towards efficient and eco-friendly aircraft/propulsion.



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-18-

Aircraft & Propulsion Integration

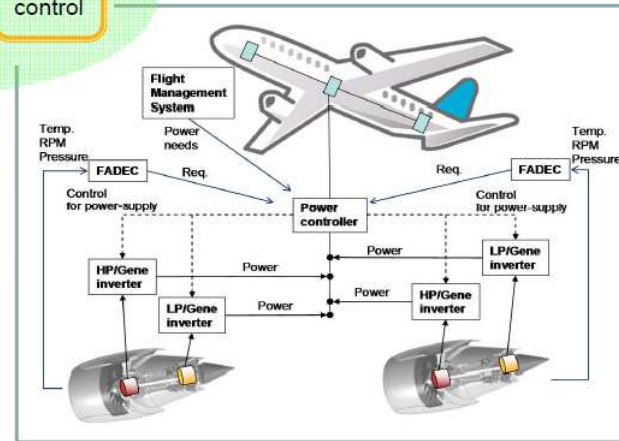


→ Power generating system

Refer to our AIAA and SAE technical papers for more information



Power Generation & Management System



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-15-

Monitoring and Controlling algorithms and corresponding key technologies for optimum use and safety of ME /HE configurations



4. NEDO Projects: PEFC



“Technology Development to reduce platinum usage”

PL: Prof. Inaba (Doshisha Univ.)

Doshisha Univ., Chiba Univ., Osaka Pref. Univ., Kyoto Univ., Toyota Central lab., Tohoku Univ., Shinshu Univ.,
Toshiba Fuel Cell System, Kyusyu Univ., Toray Research Center, Aishin Seiki, Ishifuku

-Development of highly-active core-shell catalysts in order to substantially reduce platinum used in PEFC cathode.

Two-layer structure (precious metal core)



● Pt
● Au
● Pd
● Cu

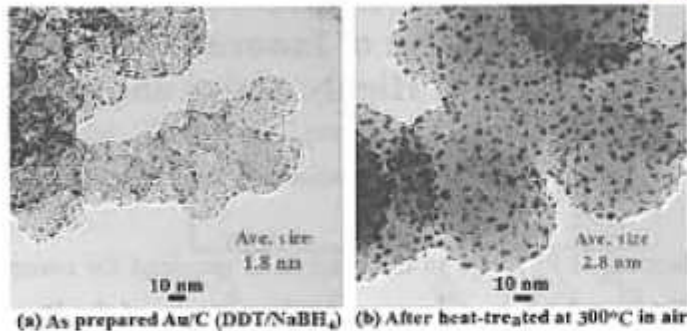


Fig. 2. TEM images of Au/C cores (DDT/NaBH₄).

- New synthesis method using DDT (C₁₂H₂₅SH)/NaBH₄ resulted in smaller particle size and good dispersibility.

Three-layer structure (non-precious metal core)

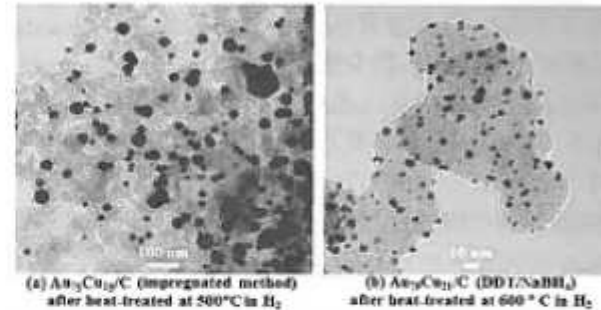
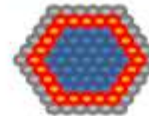
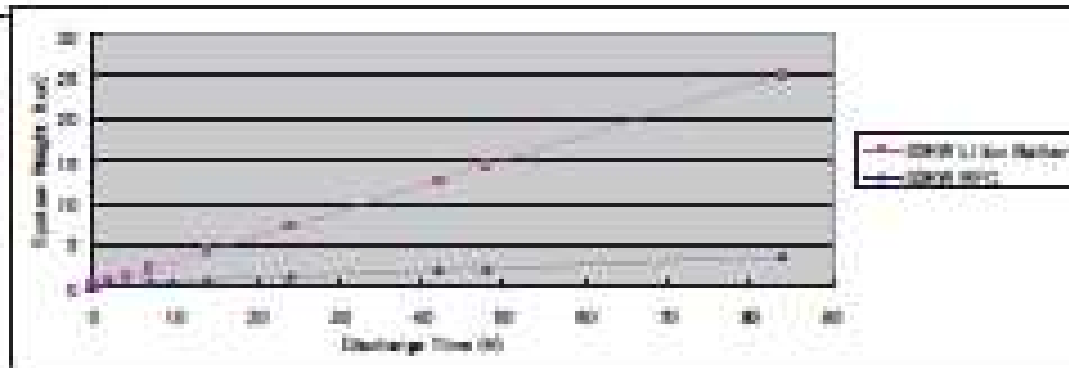
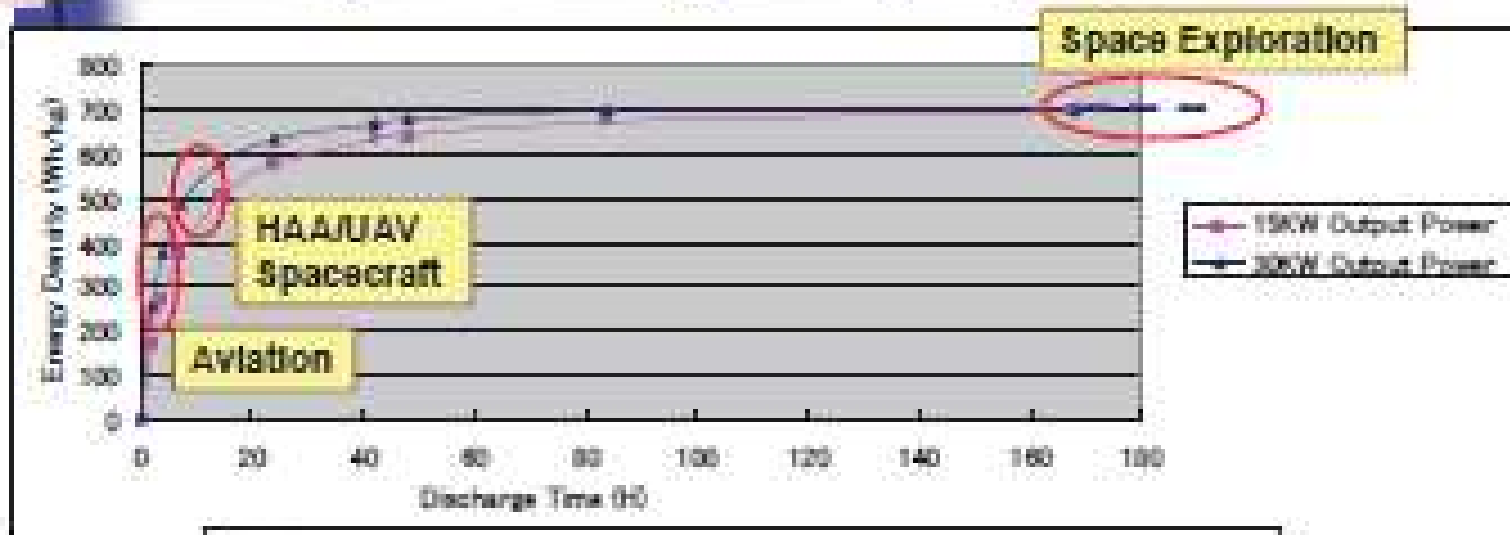


Fig. 6. TEM images of AuCu/C cores prepared by the (a) impregnation and (b) DDT/NaBH₄ methods.

17

In addition to Power/Mass and lifetime requirements, driving technologies for lower cost is key.

RFC Potential High Power System Applications - Typical RFC Energy Density Capability -



14

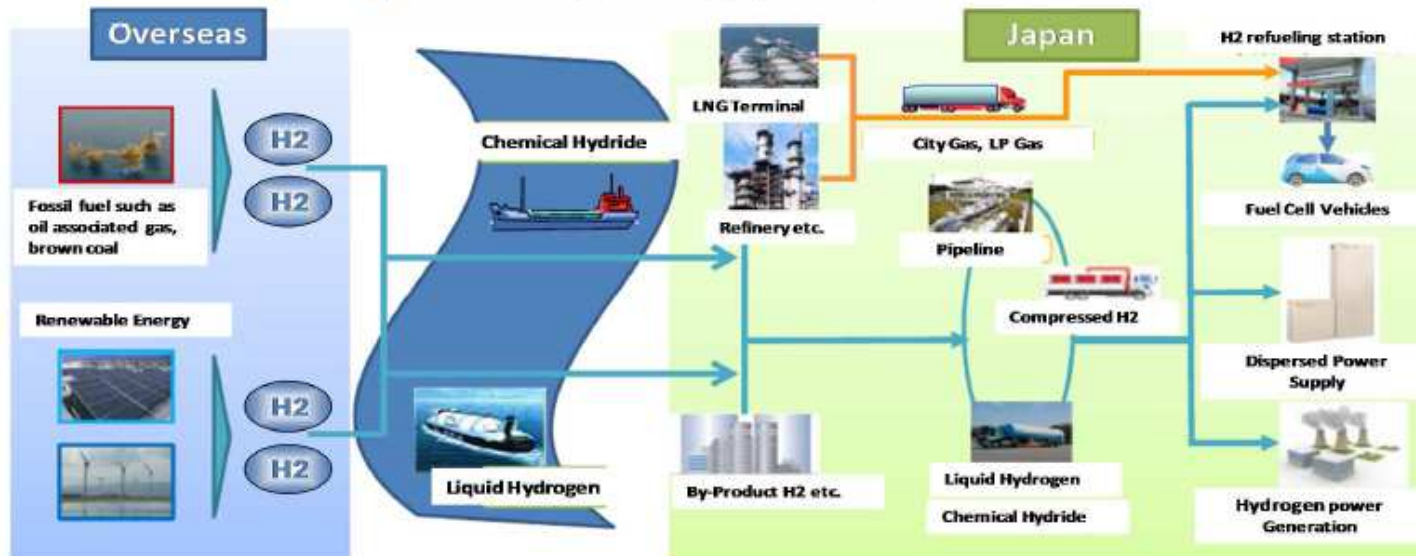
For primary propulsion use: the tank technology and corr.
Energy density is the critical factor.



4.NEDO Project :Energy Carrier Project



Future image of production, storage, transportation and utilization



(Source: Advisory Committee for Natural Resources and Energy, METI)

30

Infrastructure, secured supply chain and cost of H₂ will be the additional crucial factors for a decisions to use it in aviation.

Thank you for your attention!