LNG: Can it Power Aviation?

Feijia Yin / F.yin@tudelft.nl, Dr. Arvind G. Rao / A.GangoliRao@tudelft.nl
Faculty of Aerospace Engineering, Delft University of Technology

Why alternative fuels?

The motivation of implementing alternative fuels to power aviation is multi-fold. The main reasons are presented in Figure 1.

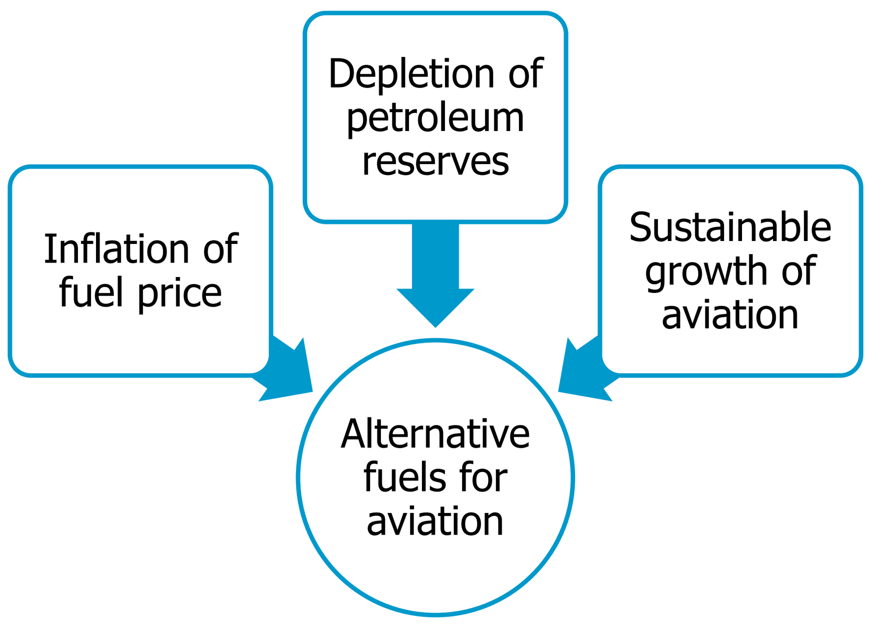

Figure 1: Motivation of alternative fuels for aviation.

Alternative fuel candidates (long range commercial aircraft)

There are various criteria to select alternative fuels for aircraft:

- It should have good energy density, comparable to existing jet fuel.
- It must be scalable.
- It must be cost efficient.
- It should be utilized without dramatic modification of current jet fuel infrastructure.
- It should be environmental friendly.
- It should not affect the food chain.

Based on all the criteria, the prediction of future fuel scenario for long range commercial aircraft is presented in Figure 2.

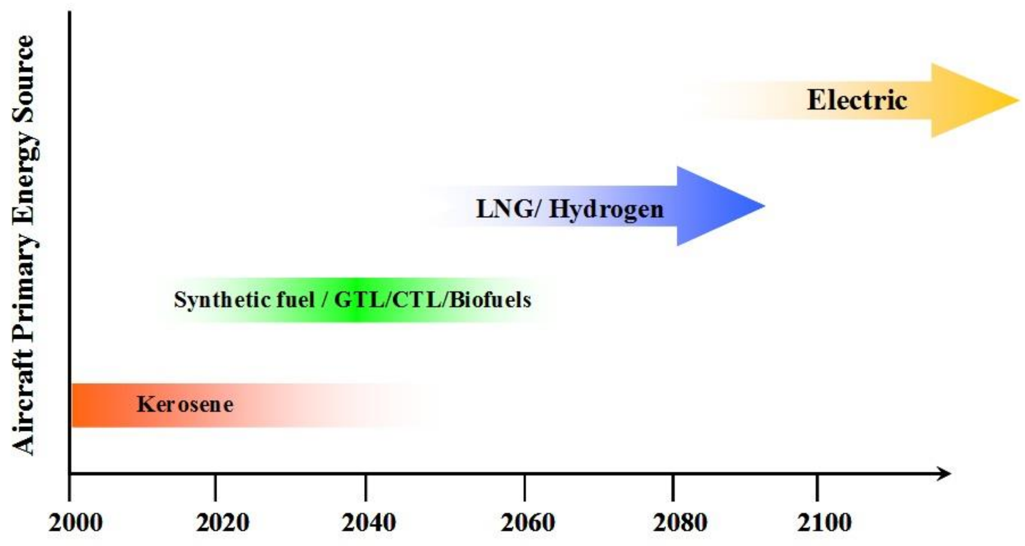

Figure 2: Future fuel scenario for long range commercial aircraft [1].

Within short term, drop-in fuels including synthetic fuel, Gas To Liquid (GTL), etc. are candidates. However, from an environmental point of view, cleaner fuels such as Biofuels, Liquid Natural Gas (LNG), Liquid Hydrogen (LH2) or even electric are more attractive (Figure 3).

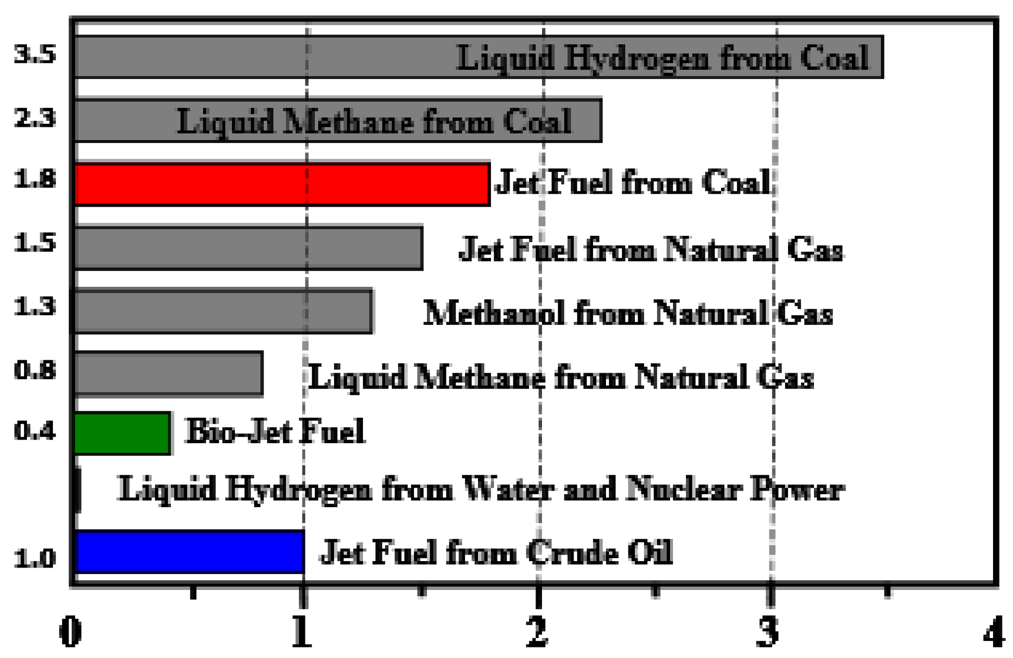

Figure 3: Relative life cycle CO_2 emission for various fuels compared to jet fuel [2].

Opportunity of LNG aircraft

The characteristics of cryogenic fuels (LNG and LH2) are listed in table 1. Figure 4 depicts the relative volume comparison of LNG and LH2 with respect to kerosene for given energy. Although significant reduction of CO_2 emissions by LH2, low boiling point makes the storage a formidable challenge. Moreover, larger storing space requirements penalise the aerodynamics in a conventional aircraft.

Table 1: Characteristics of various alternative fuels.

	Kerosene	LH2	LNG
LHV [MJ/kg]	42.8	120	50
Boiling point at 1 atm [°C]	167-266	-252.3	-161
Specific density at boiling point [kg/m3]	790-808	71	423

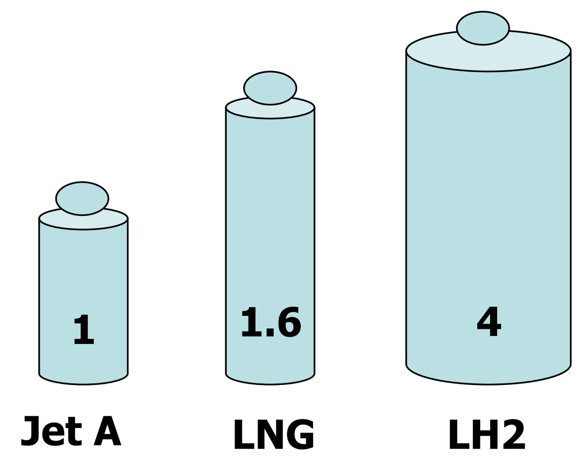

Figure 4: Relative volume for given energy.

On the other hand, LNG is more attractive for the reasons of:

- Higher volumetric energy density.
- Less storage space than LH2.
- Lower CO2, NOx and soot emissions.
- Lower cost due to availability of Natural Gas.
- Can also be produced by renewable energy.

The successfully experimented TU-155 in 1980s also provides a priceless experience for further development of LNG airplanes. However, 1.6 times larger space requirement than kerosene (not including insulation) causes the same trouble for conventional aircraft in terms of aerodynamic efficiency.

AHEAD Multi-fuel concept

To overcome the volume issue, a novel concept, multi-fuel Blended Wing Body (BWB), is proposed in the EU sponsored AHEAD (Advanced Hybrid Engine for Aircraft Development) project. The schematic of the multi-fuel BWB concept is presented in Figure 5. It is powered by a multi-fuel hybrid engine shown in Figure 6.

The combined LNG and kerosene ease the storage problem. Moreover, the BWB configuration is less sensitive to the enlarged storing space requirements of the cryogenic fuel tanks.

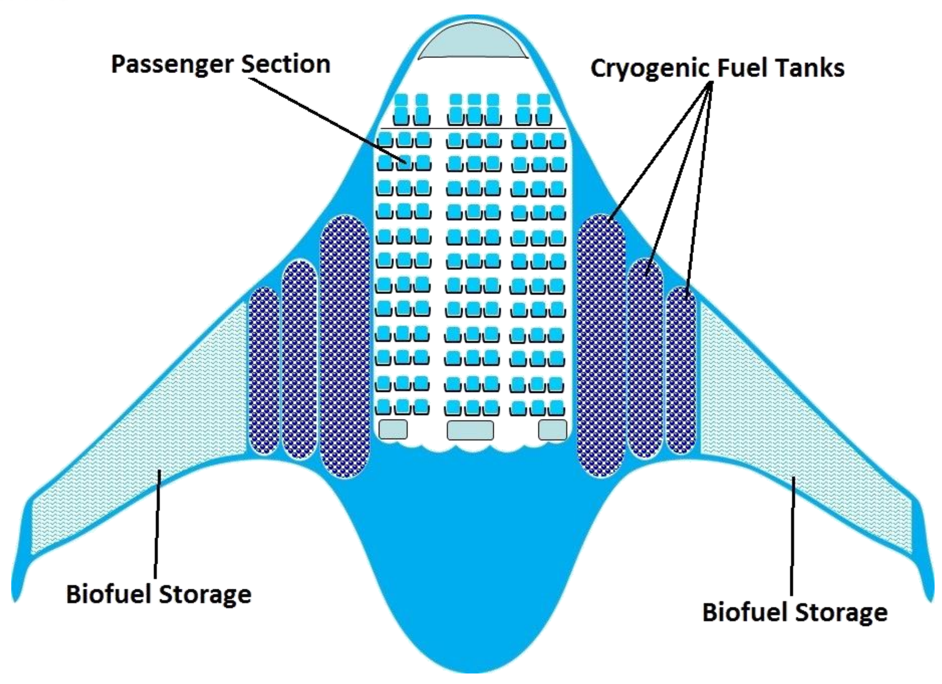

Figure 5: Schematic of the multi-fuel BWB concept

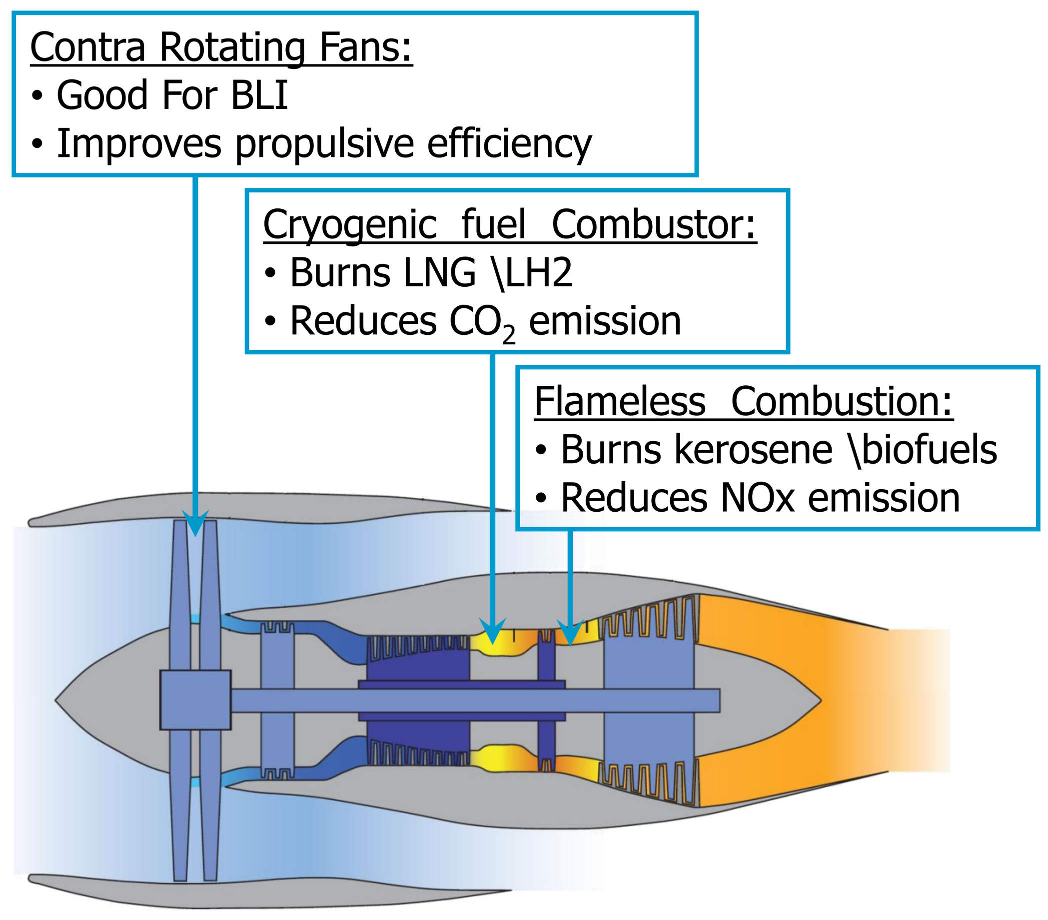

Figure 6: Schematic of the multi-fuel hybrid engine.

Comparison

A comparison is made between the AHEAD hybrid engine and GE90-94B for Boeing 777 in Figure 7. Figure 8 compares the layout of AHEAD BWB to Boeing 777-200ER.

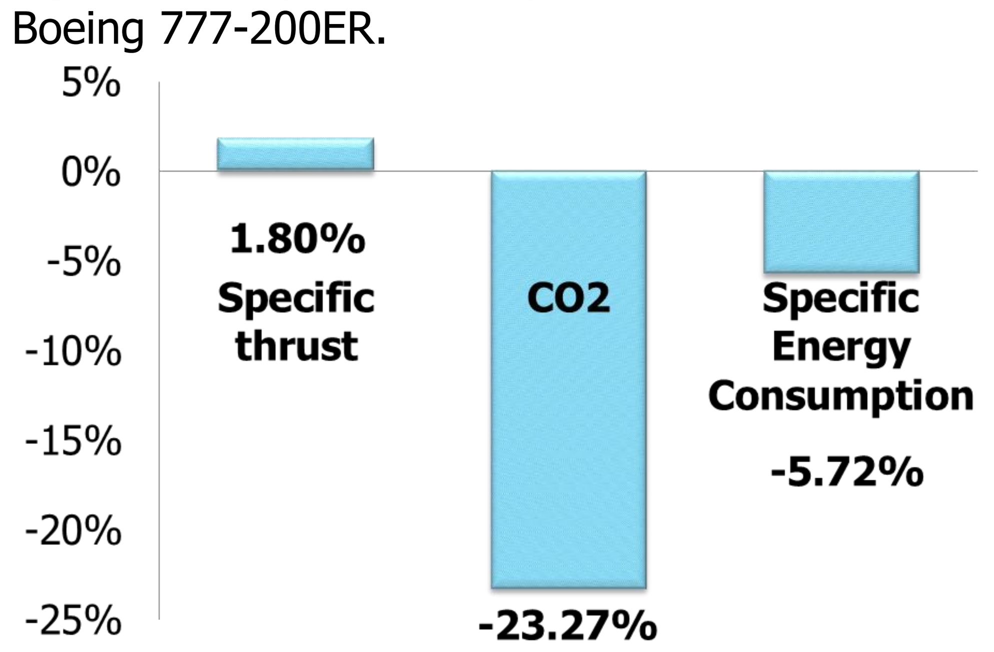

Figure 7: Comparison of the AHEAD hybrid engine to GE90-94B.

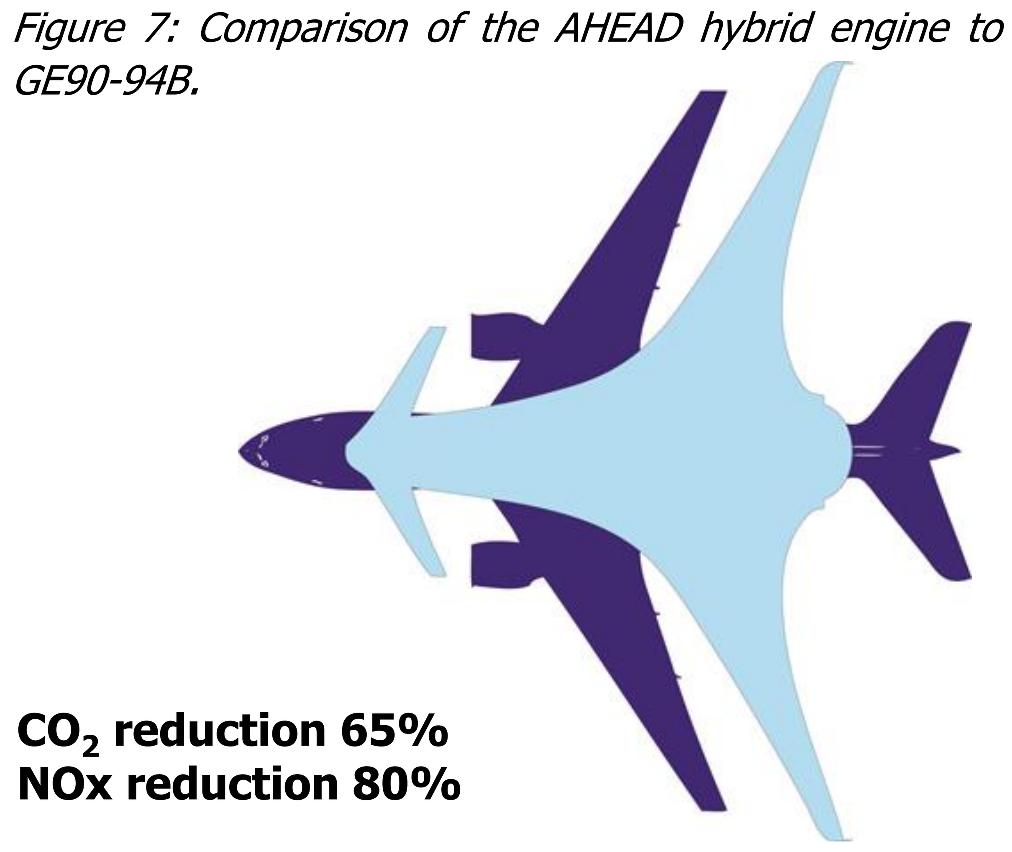

Figure 8: Layout comparison between AHEAD BWB and Boeing 777-200ER.

Discussions

Effort was also made by other scientists and engineers to investigate the feasibility of LNG for aviation, for example, Boeing's "SUGAR freeze" concept, etc.

Although there are pros and cons, the research results so far have indicated that LNG is an outstanding candidate for future aviation. More investigations are required for LNG infrastructure, storage, gas phase leakage, etc.

Acknowledgement

The research leading to these results has received funding from the EU 7th Framework. The authors would like to acknowledge the support of all the partners of this project.

References:
1. Rao, A.G., and van Buijtenen, J.P., "Basic Concepts: Propulsion and Power", Encyclopaedia of Aerospace Engineering, Wiley online library, 2010.
2. Daggett, D. L., Hendricks, R. C., Walther, R., and Corporan, E., "Alternate Fuels for use in Commercial Aircraft", NASA/TM (2008) 2008-214833.

TU Delft Delft University of Technology

Challenge the future

AHEAD ADVANCED HYBRID ENGINES FOR AIRCRAFT DEVELOPMENT

SEVENTH FRAMEWORK PROGRAMME