Technology Strategy for SAF (Sustainable Aviation Fuel) in NEDO

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Future of SAF (sustainable aviation fuel)

In 2050
- Global SAF demand is from 294 M-m^3 to 425 M-m^3.
- In Japan, 23 M-m^3 is necessary.

In 2030
- In Japan, 2.0 M-m^3 is necessary.

In 2020
- Global SAF supply is 0.063 M-m^3, 0.03% of aviation fuel supply.
- SAF production cost is from 2.0 USD/L to 16.0 USD/L.
- Conventional aviation fuel cost is almost 1.0 USD/L.

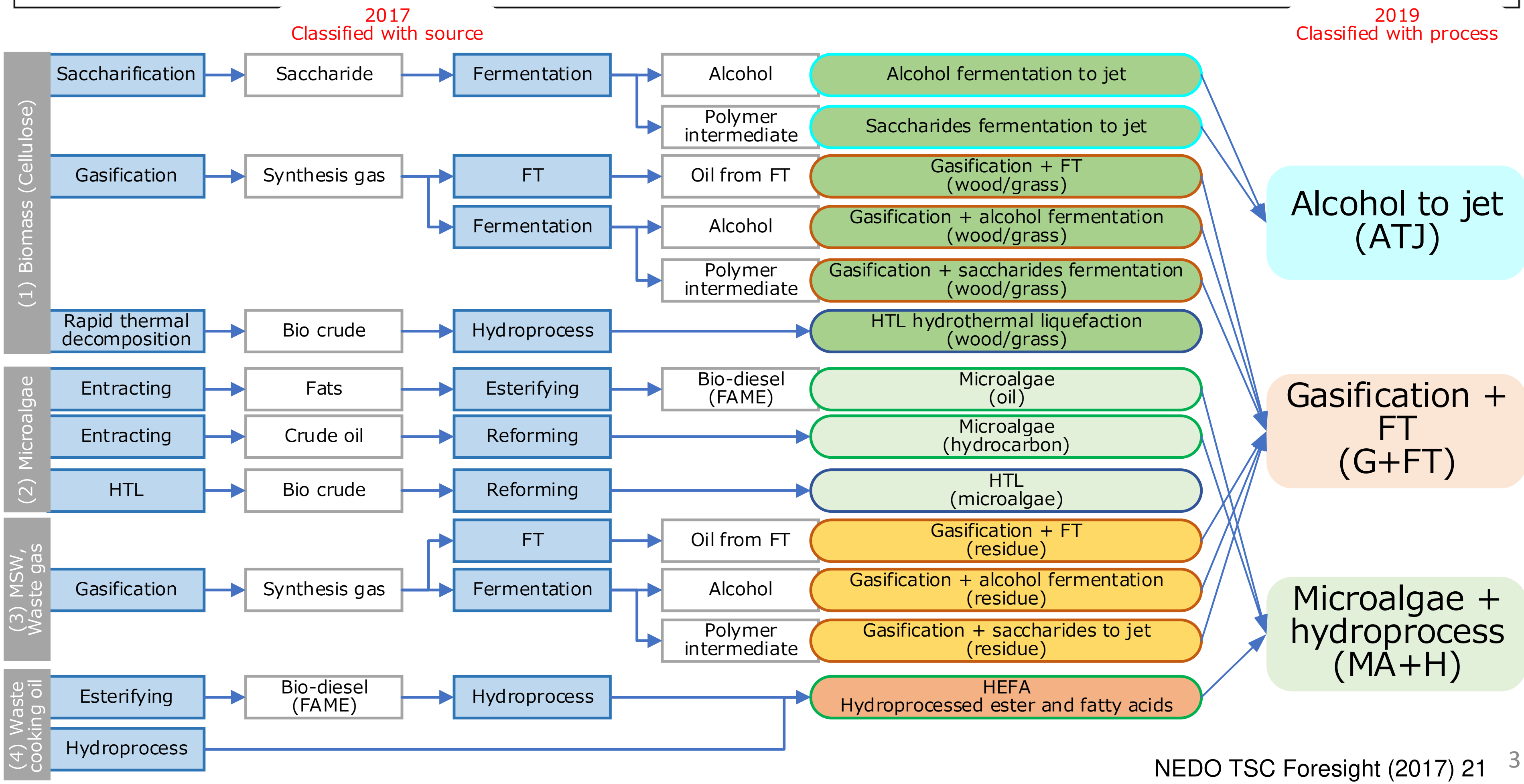
Definitions
SAF = a fuel loaded in air plain.
neat SAF (nSAF) = An aviation fuel produced from non-fossil fuel.

Normally, SAF is a mixture of nSAF and conventional Jet fuel (e.g. Jet A from crude oil) with 1:1 in weight ratio.
As nSAF amount is not enough, a Jet fuel mixed with few percent of nSAF is called SAF in the market.

第1回 持続可能な航空燃料(SAF)の導入促進に向けた官民協議会, ANRE (2022)

History of the technology strategy in NEDO

- 13 technologies were selected in 2017.
- The three technologies, 1) Alcohol to Jet (ATJ), 2) Gasification+ Fischer-Tropsch (G+FT), 3) Microalgae+Hydroprocess (MA+H), were selected in 2019.



NEDO TSC Foresight (2017) 21

How to find the pros in the price?

For "carbon neutral" production and enough supply, the followings are approximated to find the dominant cost.

- The production rate [m^3-nSAF/plant/year] is varied from 1,000 (1k) to 1,000,000 (1M).
- Any utility (electricity and steam) in the plant is from the raw material.
- Number of labor is calculated with Japanese standard.

The index are as follows.

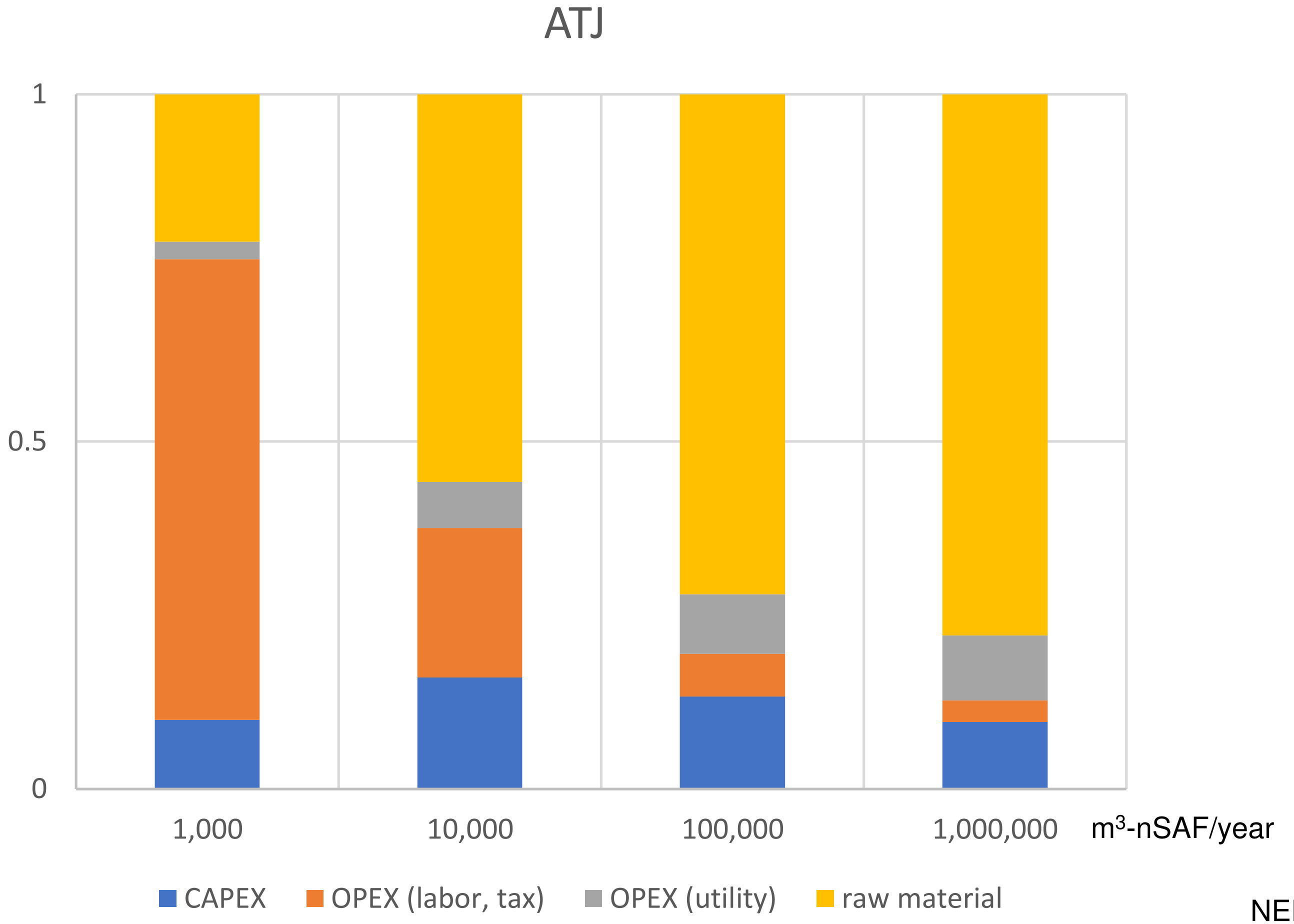
1. CAPEX of 30 years plant lifetime
2. OPEX (labor): Japanese standard in 2023
3. OPEX (utility)
4. Raw material cost

Pros in general

ATJ	Alcohol (ethanol) has the conventional market.
	Alcohol from cellulose (future technology) won't compete against food demand.
G+FT	Conventional plant technology is enough.
	Any place could be used for the plant.
MA+H	Higher growth rate could be achieved.
	"Reasonable" CO2 usage is possible.

ATJ (alcohol to Jet)

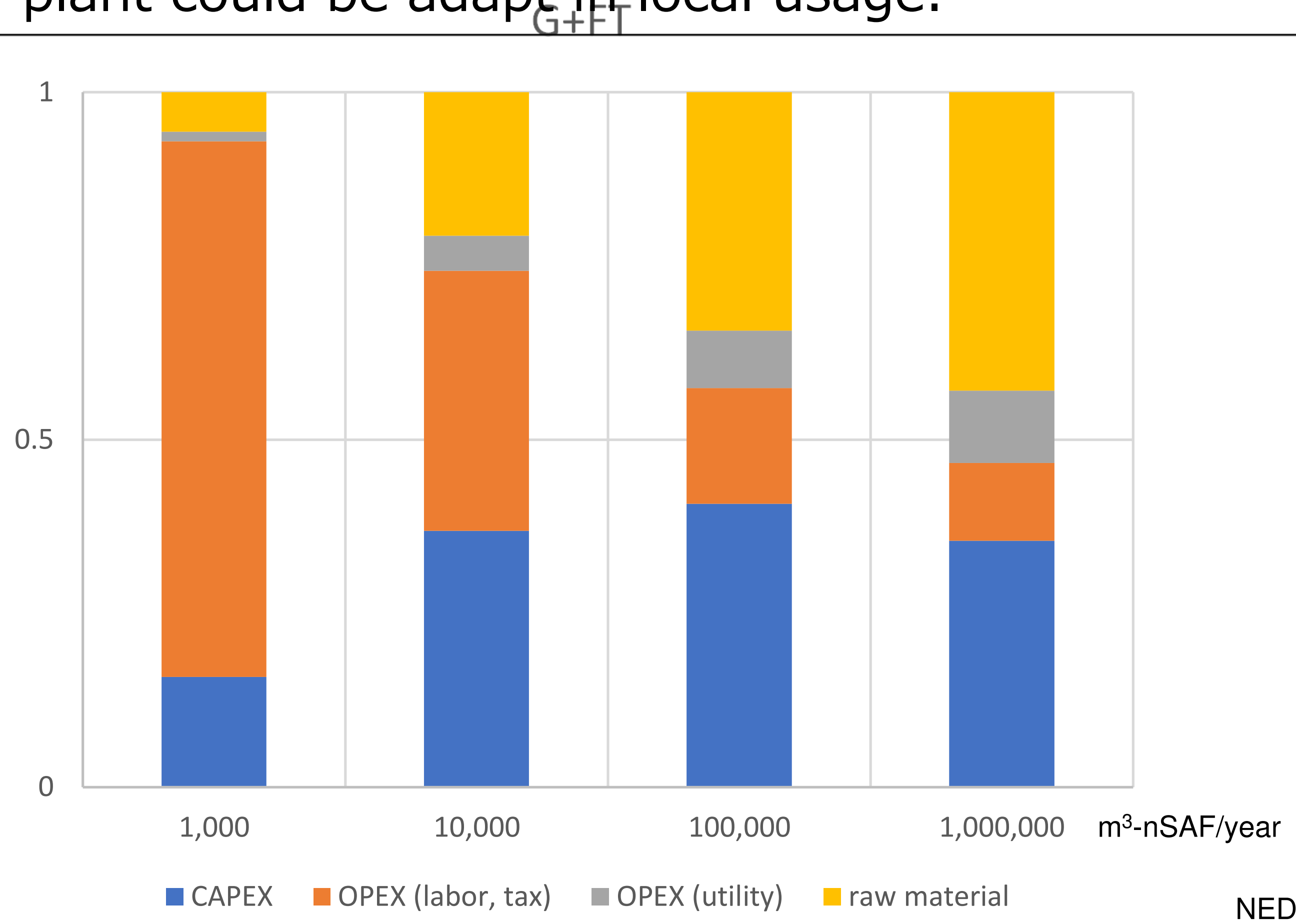
- In large scale, raw material cost is dominant. This means that alcohol should be from cellulose (or waste).
- In small scale, labor OPEX is dominant. This means that "full-automatic" plant could be adapt in local usage.



NEDO TSC (2023)

Gasification+Fischer-Tropsch (G+FT)

- In large scale, raw material cost and CAPEX are dominant. This means that the plant should be placed at the raw material production area and that low price gasifier is necessary.
- In small scale, labor OPEX is dominant. This means that "full-automatic" plant could be adapt in local usage.



Microalgae+hydroprocess, (MA+H)

- 10 times of wood growth rate could be achieved.
- Gene recombination is not necessary.
- “Effective” CO2 supply technology is necessary for ultimate usage of photosynthesis.

Effective land use evaluated with the growth rate

- Wood in Japan 5 ton-dry/ha/year
- Wood in tropical region 30 ton-dry/ha/year
- Sugarcane in Brazil 80 ton-dry/ha/year
- Microalgae in tropical region 100 ton-dry/ha/year (target of NEDO project)

Theoretical maximum of photosynthesis efficiency is 0.124.
Higher heating value (HHV) of microalgae is 22 MJ-HHV/kg-dry.
Solar energy for photosynthesis around equator is 60 TJ/ha/year.

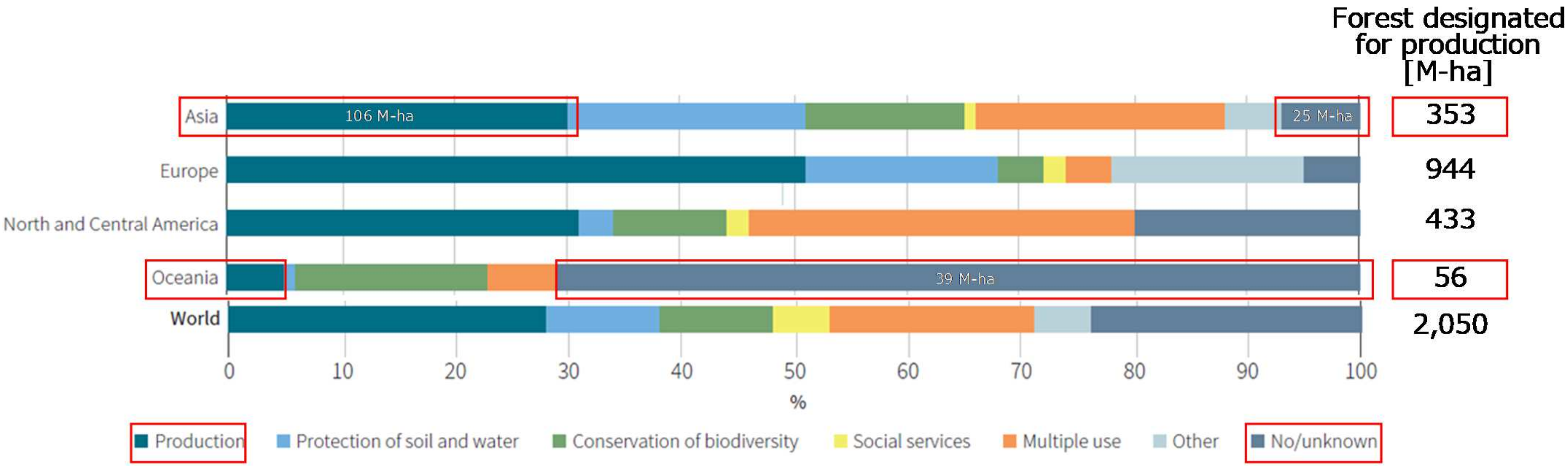
From these approximations, the maximum energy by photosynthesis is 60×0.124 = 7.44 TJ/ha/year.
The maximum microalgae growth rate is 7440/22 = 338 ton-dry/ha/year.

For 400 M-m^3-nSAF, almost 8 M-ha (only 0.2% of Moon surface area) is necessary with the ideal microalgae.

Discussion with T. Hoshino from C4, CHITOSE

How much area can we use for biomass?

- The forest around Pacific ocean (Asia and Oceania) can supply 30% of global nSAF demand from wood.
- Microalgae in NEDO project can supply 100% of global nSAF demand from these forest.



1.0% of production forest in Asia = 1.1 M-ha = 5.5 M-m^3-nSAF = 2 %
50% of unknown forest in Asia = 12.5 M-ha = 62.5 M-m^3-nSAF = 20 %
50% of unknown forest in Oceania = 19.5 M-ha = 97.5 M-m^3-nSAF = 30 %

10 ton-dry/ha/year (wood) is approximated.
0.5 m^3-nSAF/ton-dry = 5 m^3-nSAF/ha/year

FAO, Global Forest Resources Assessment 2020: Main report (2020).

Conclusion

- The three technologies as follows are evaluated.

1. Alcohol to Jet (ATJ) will be a solution with low price alcohol.
2. Gasification and Fischer-Tropsch (G+FT) could be constructed with small capacity in any place.
3. Microalgae and hydroprocess with carbon neutral CO2 (MA+H) has the largest growth rate.

- In case of 1.0 M-m^3/year production rate, as the ratio of raw material cost is large, the plant should be places at the raw material production area.

- Hydrogen and water are also important raw materials in any case. The carbon intensity of them should be evaluated.

- As the plant or the place for the place should be designed to make the carbon intensity [kg-CO2/kg-nSAF] minimum, the supply chain design is important.