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Synthetic fuels in TIMES models – a review and recommendations

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Motivations

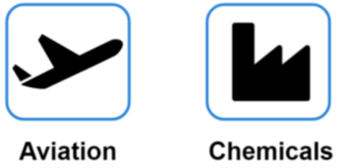
Why is it important to consider synthetic fuel and chemicals in our decarbonisation scenarios?

Residual hydrocarbon demands are bottlenecks for reaching net zero

In ESM’s & IAM’s, petroleum-based hydrocarbons are prevalent in residual emissions
(i) Fuels with high energy density or (ii) products contain carbon

Could invest in synthetic carbon based fuels and chemicals from **sustainable feedstocks**

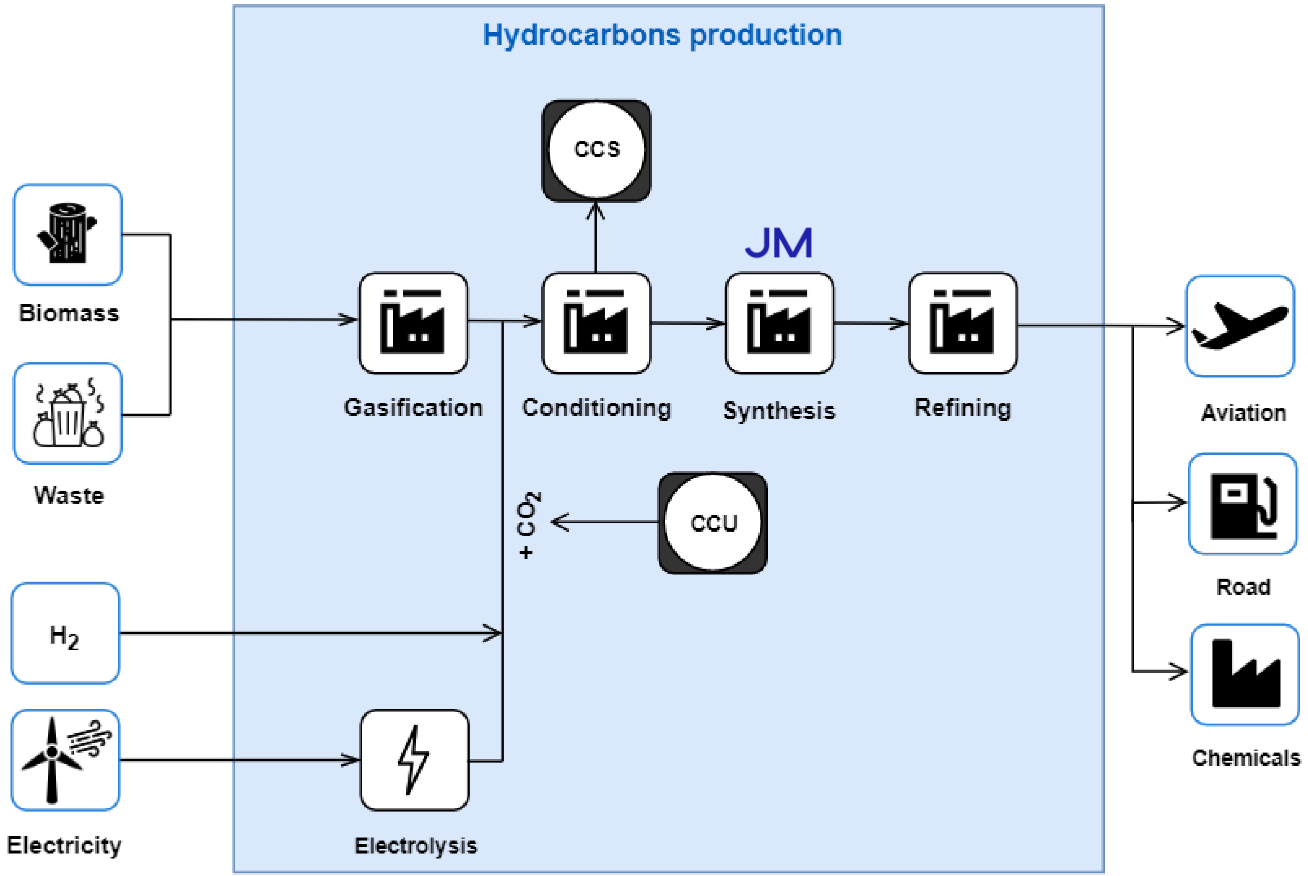
Large low-carbon industrial plants, CAPEX intensive and dependent on feedstock availability



Industrial synthetic fuels production facility at a glance

- Can convert solid (biogenic) or gaseous (H_2 with CO_2) carbon-based energy sources to fuels and chemicals
  - ➢ Synthetic biofuels
  - ➢ E-fuels (or power-to-liquid)
- Industry and the UK government interested in producing SAF using Fischer-Tropsch (JM and BP)
- Opportunities for CCS and CCU

- Successful large scale CtL and GtL applications but **high uncertainties** when using sustainable feedstocks;
  - Resource availability
  - Scale and deployment
  - Practically
  - Chemical structure

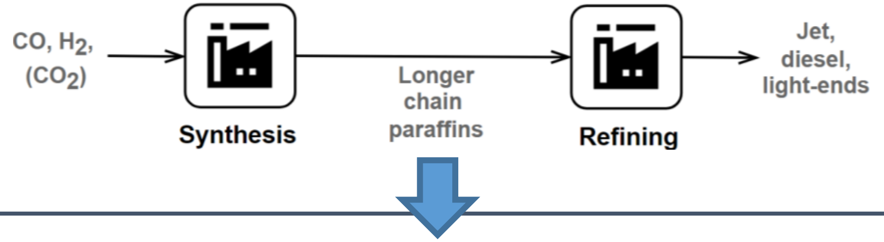


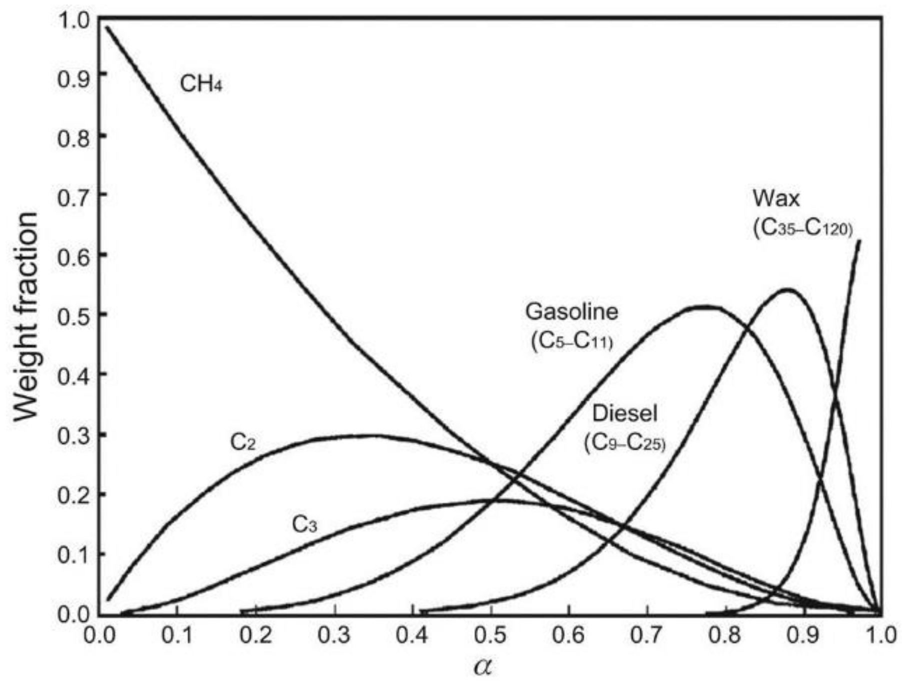
This diagram represents syngas pathways. Other opportunities that can convert biogenic resources into hydrocarbons are not reflected here (i.e. anaerobic digestion, fermentation, pyrolysis or hydrothermal liquefaction)

Product distribution

- Co-production is unavoidable and product slate depends on the process sequence and the conditions of the synthesis reactor (i.e. Fischer-Tropsch)
- Technology providers for refining technologies claim jet slate could be optimised to ~70%
- Co-products consist of high quality paraffins and can be sold to provide value elsewhere in the energy system

Important to look deeper into product slate to understand what is feasible





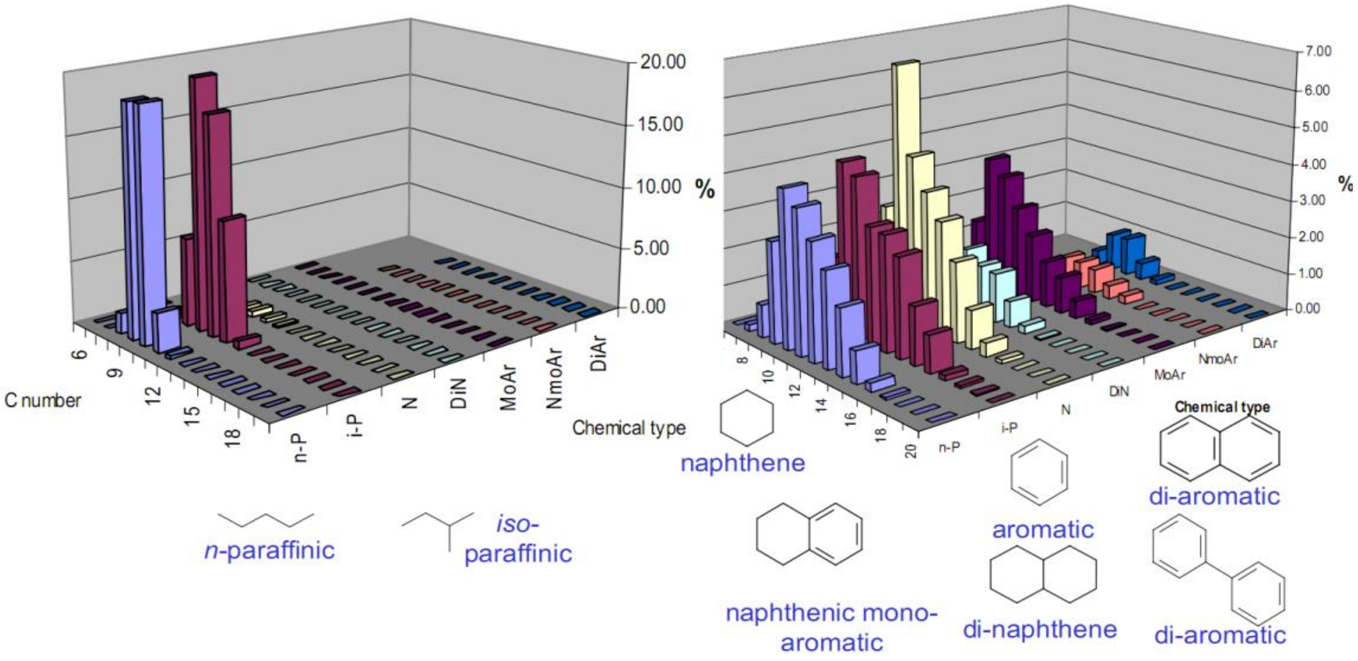
Product distribution as a function of chain length (α) described by the Anderson–Schulz–Flory (ASF) distribution (de Klerk and Maitlis, 2013)

$$\alpha = \left(0.2332 \cdot \left(\frac{y_{CO}}{y_{CO} + y_{H_2}}\right) + 0.633\right) \cdot (1 - 0.0039 \cdot ((T\ (°C) + 273) - 533))$$

Dependent on CO and H_2 composition and reactor operating temperature

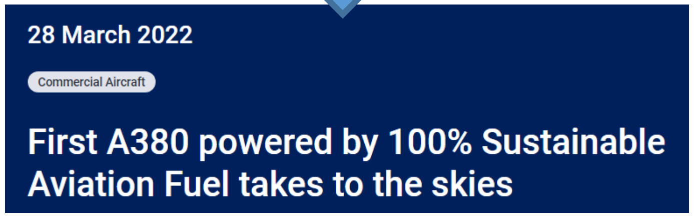
Fuel consumption

Synthetic jet **Jet A-1**



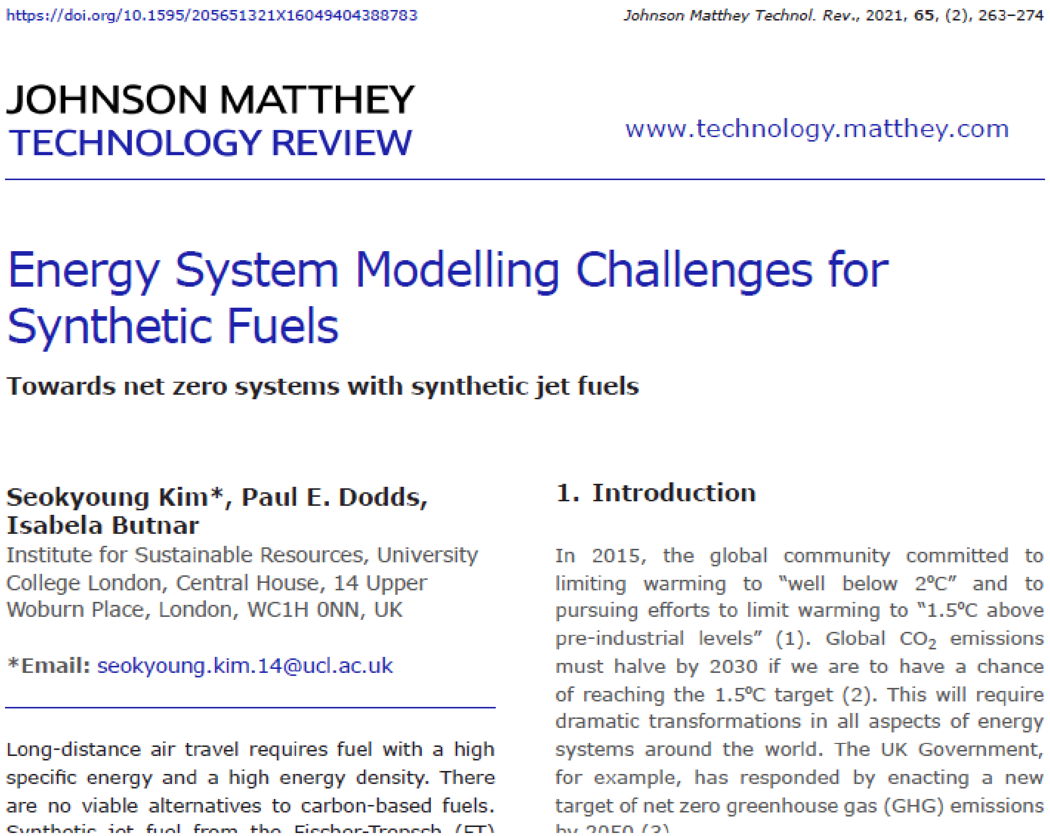
Source: International Civil Aviation Organization (ICAO). (2008). Alternative Fuels for Aviation-Industry Options & Challenges.

- Chemically similar but **not the same**
- Properties and qualities dependent on **hydrocarbon classes** within fuel
- Almost fully compatible except the aromatic content
- Blending rate is limited to 50% today
- There are works going on to improve the blending limit
  - **Airbus** interested in 100% SAF



But still unclear when and the % of the future engines coming online will be able to operate with 100% SAF

How are synthetic jet fuels represented in models?



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Energy System Modelling Challenges for Synthetic Fuels

Towards net zero systems with synthetic jet fuels

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Long-distance air travel requires fuel with a high specific energy and a high energy density. There are no viable alternatives to carbon-based fuels. Synthetic jet fuel from the Fischer-Tropsch (FT)

1. Introduction

In 2015, the global community committed to limiting warming to "well below 2ºC" and to pursuing efforts to limit warming to "1.5ºC above pre-industrial levels" (1). Global CO_2 emissions must halve by 2030 if we are to have a chance of reaching the 1.5ºC target (2). This will require dramatic transformations in all aspects of energy systems around the world. The UK Government, for example, has responded by enacting a new target of net zero greenhouse gas (GHG) emissions by 2050 (3).

doi.org/10.1595/205651321X16049404388783

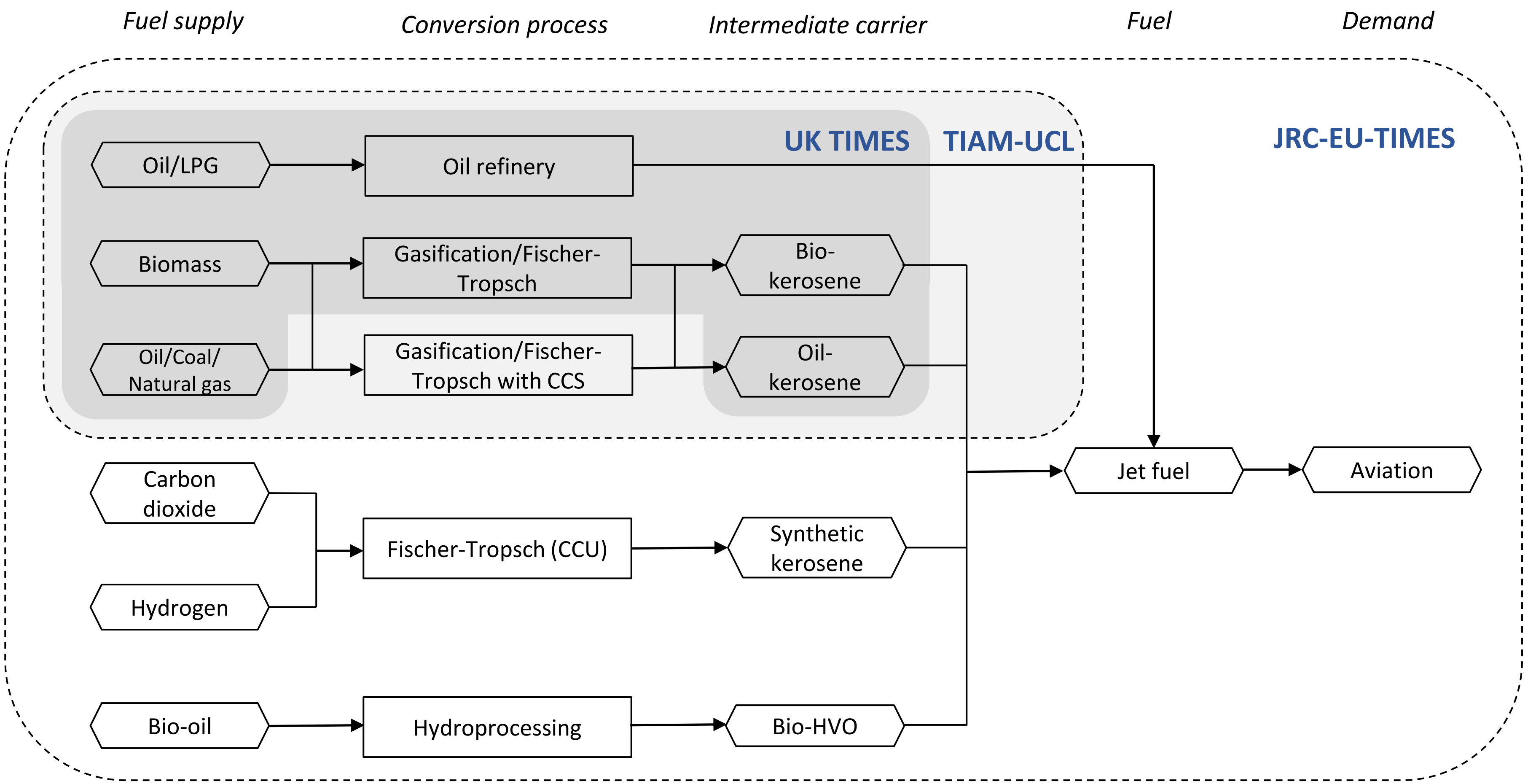
Three TIMES models with different spatial scales

- UK TIMES (UK)
- JRC-EU-TIMES (European)
- TIAM-UCL (global)

Comparison on:

- representations
- model structures
- assumptions
- techno-economic data
- comparable scenario results

Model comparisons: UK TIMES, JRC-EU-TIMES and TIAM-UCL



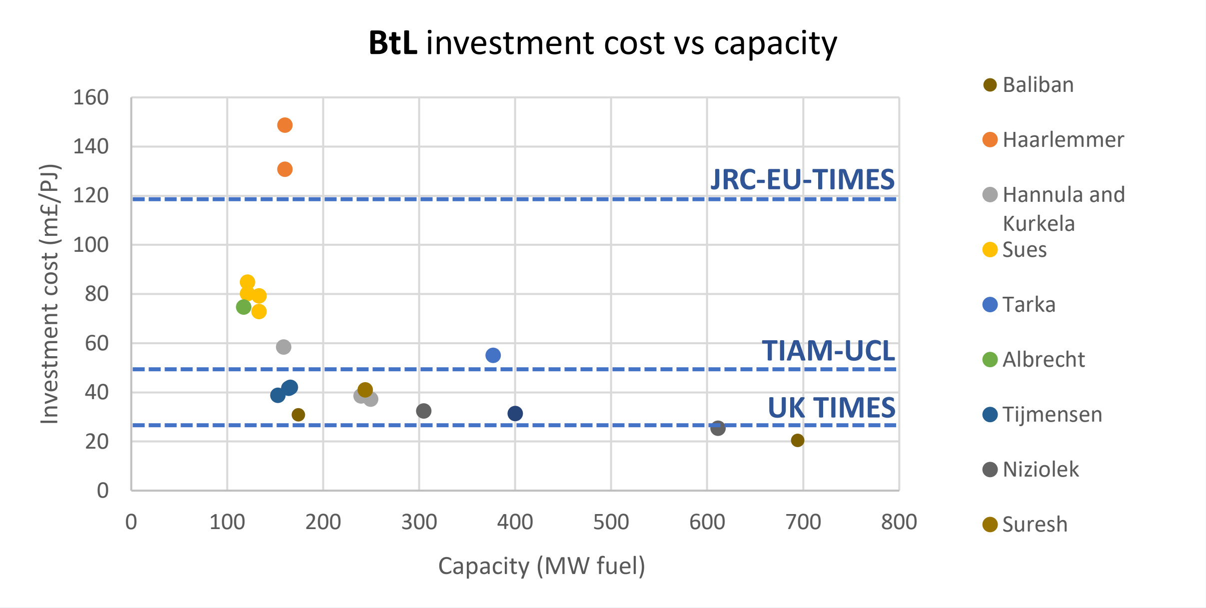
Representations of jet fuel production technologies in the three models
*none of the models entertained the possibility of producing jet fuel from waste

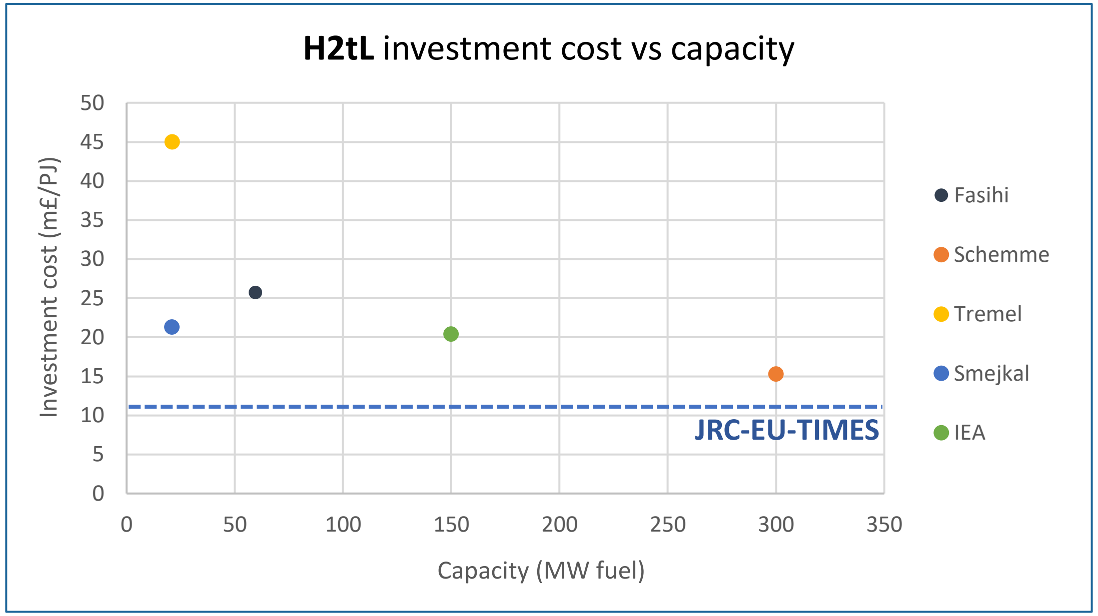
UK TIMES
- Only single FT plant, using biomass to produce 50% diesel and 50% kerosene
- No CCS or CCU

TIAM-UCL
- FT plants with or without CCS using biomass
- No possibility of using captured CO_2 and H_2

JRC-EU-TIMES
- Much broader range of FT technologies
- Assumes diesel and kerosene are interchangeable, mixes together to meet aviation demand

Data comparisons: UK TIMES, JRC-EU-TIMES and TIAM-UCL





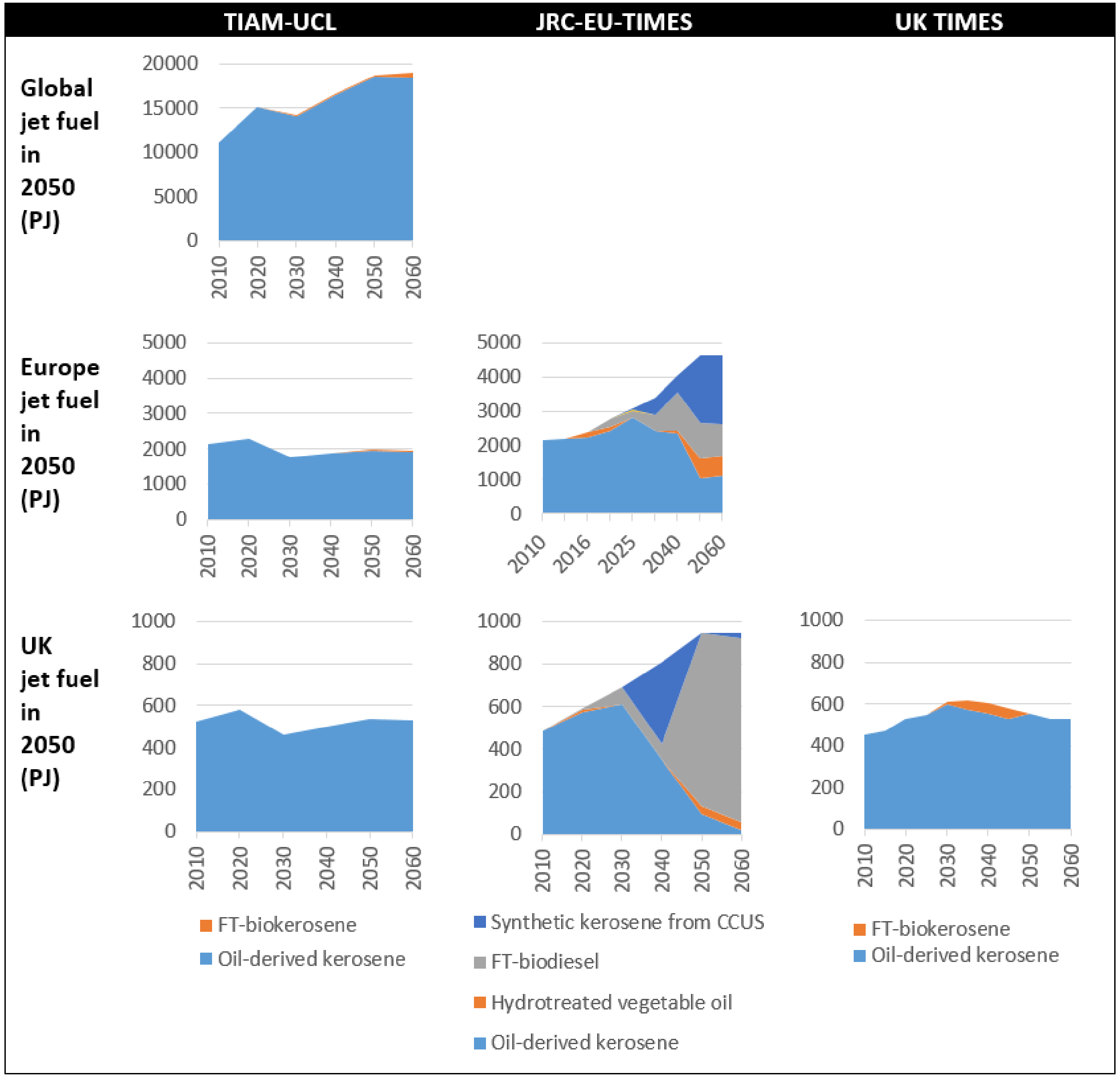
Process efficiencies

	BtL	H_2tL
UK TIMES	0.75	-
JRC-EU-TIMES	0.56	0.78
TIAM-UCL	0.5	-
Literature (median)	0.52	0.70

- Compared investment cost reported in the literature & the values used in the three models
- UK TIMES FT plant that uses biomass has a much lower CAPEX and a substantially higher process efficiency compared to the literature and data used in TIAM-UCL and JRC-EU-TIMES
- JRC-EU-TIMES BtL CAPEX is much higher vs UK TIMES and TIAM-UCL
- H_2tL (e-fuels): JRC-EU-TIMES CAPEX is low and process efficiency is high compared to the literature median

Result comparisons: UK TIMES, JRC-EU-TIMES and TIAM-UCL

- **TIAM-UCL** scenario (<1.5°C) has a limited role for synthetic fuels in aviation worldwide, comprising less than 5% of the total market in 2050
- **UK TIMES** only uses fossil-based jet fuel in 2050, as biomass availability is constricted. Under these assumptions, aviation is a less economic market for biomass (biomass is used for CCS)
- **JRC-EU-TIMES** uses 4 different production routes. Synthetic fuels from H_2 and captured CO_2 provides the largest contributions across Europe. The use of biomass-to-liquid in the UK region is substantial in 2050



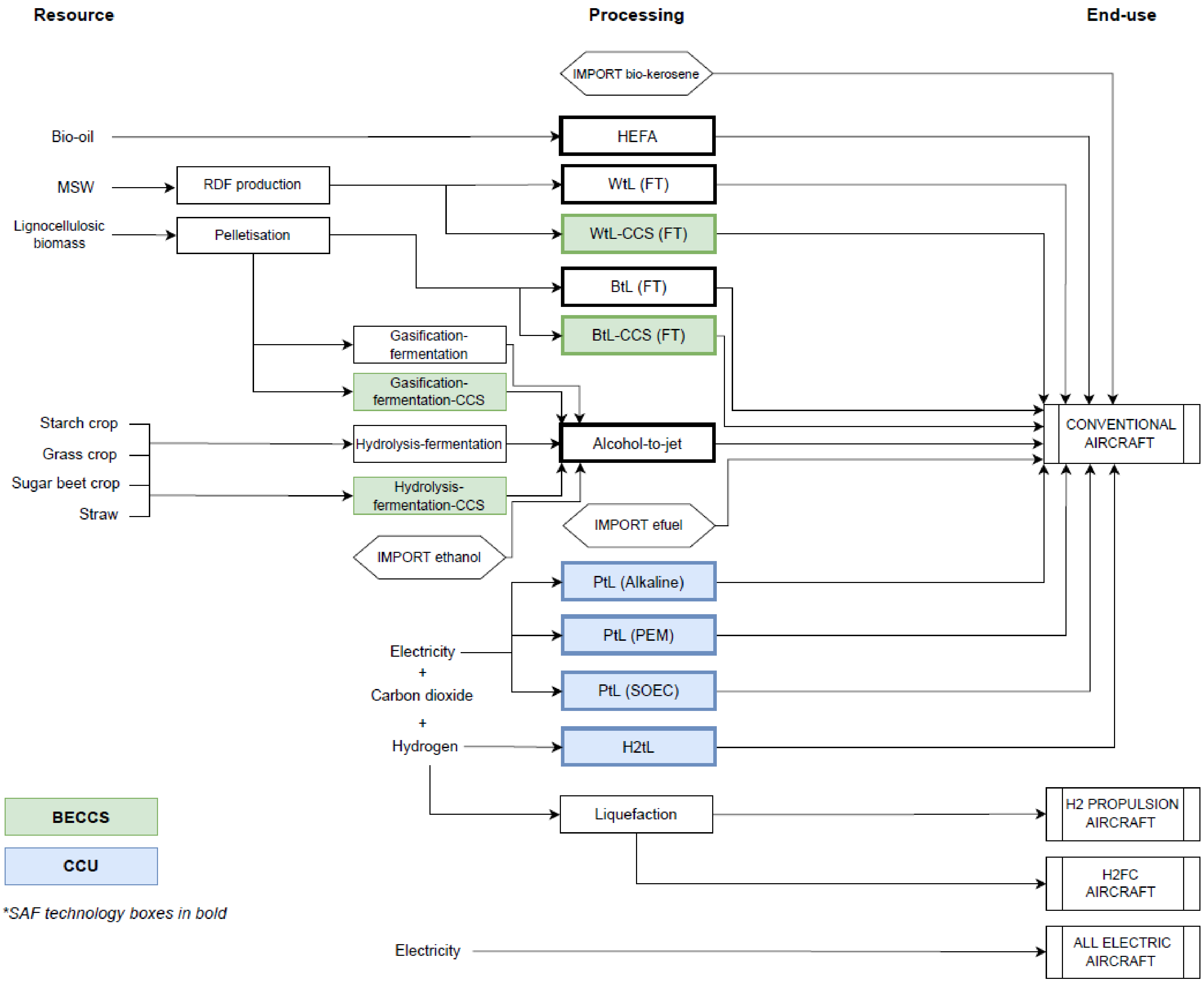
Disaggregated results of technologies used to produce jet fuel, globally, in Europe and in the UK

My views on the best practice for synthetic jet fuels modelling in TIMES

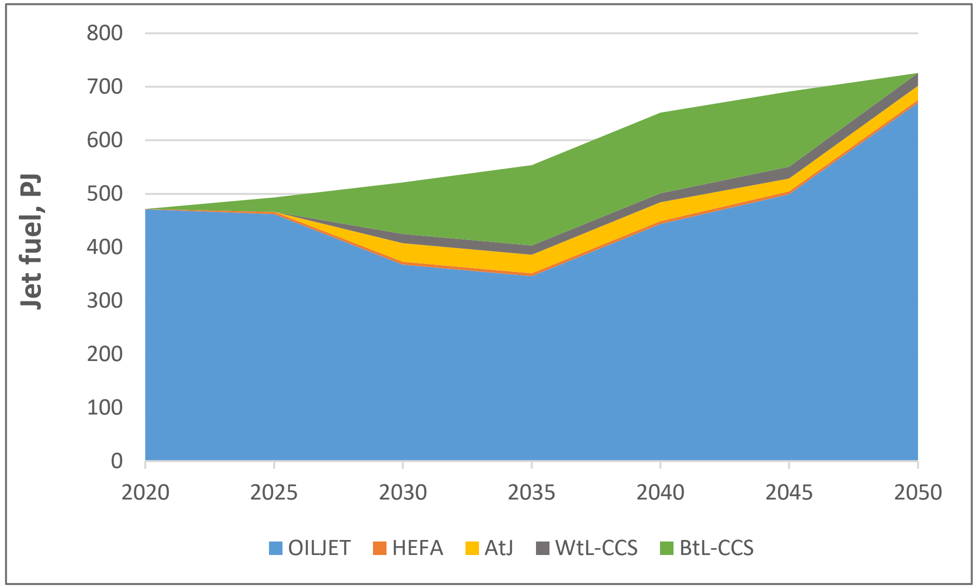
1. Constraints on the production and the consumption of synthetic jet fuels should be reflected
2. Investment cost and plant performance should factor in all process operations
3. Representation of possible pathways should (to a degree) align with the market development (i.e. industry interest)
4. First few projects will not be too big – (i) difficult to accumulate lots of feedstocks and (ii) difficult to raise high amount of capital
5. Fairness on competing technologies (i.e. non-syngas pathways in aviation) for model balance

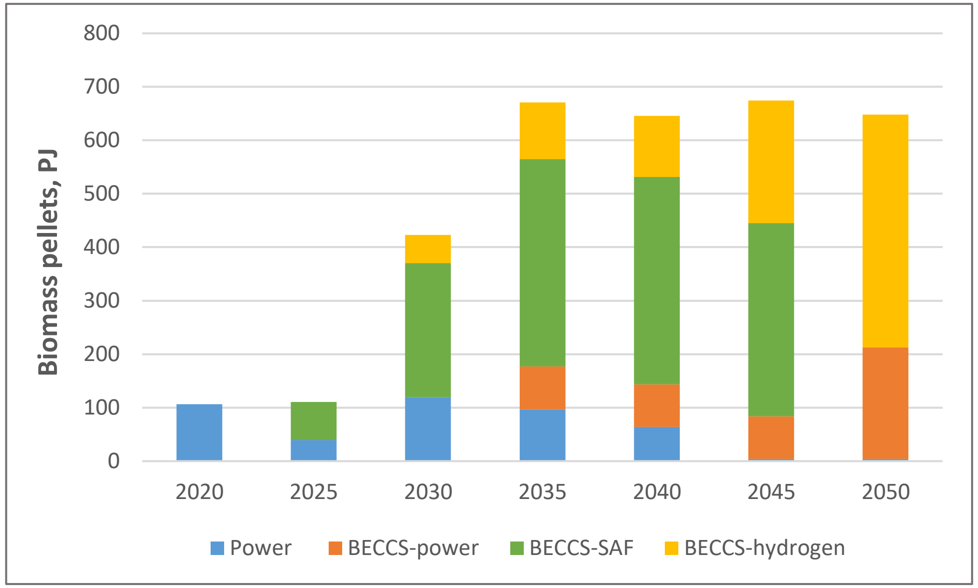
Improvements to the representation of sustainable aviation fuels pathways in UK TIMES

- A set of jet fuel production pathways
- Representing the possibilities for BECCS and CCU where possible



UK TIMES net zero scenario



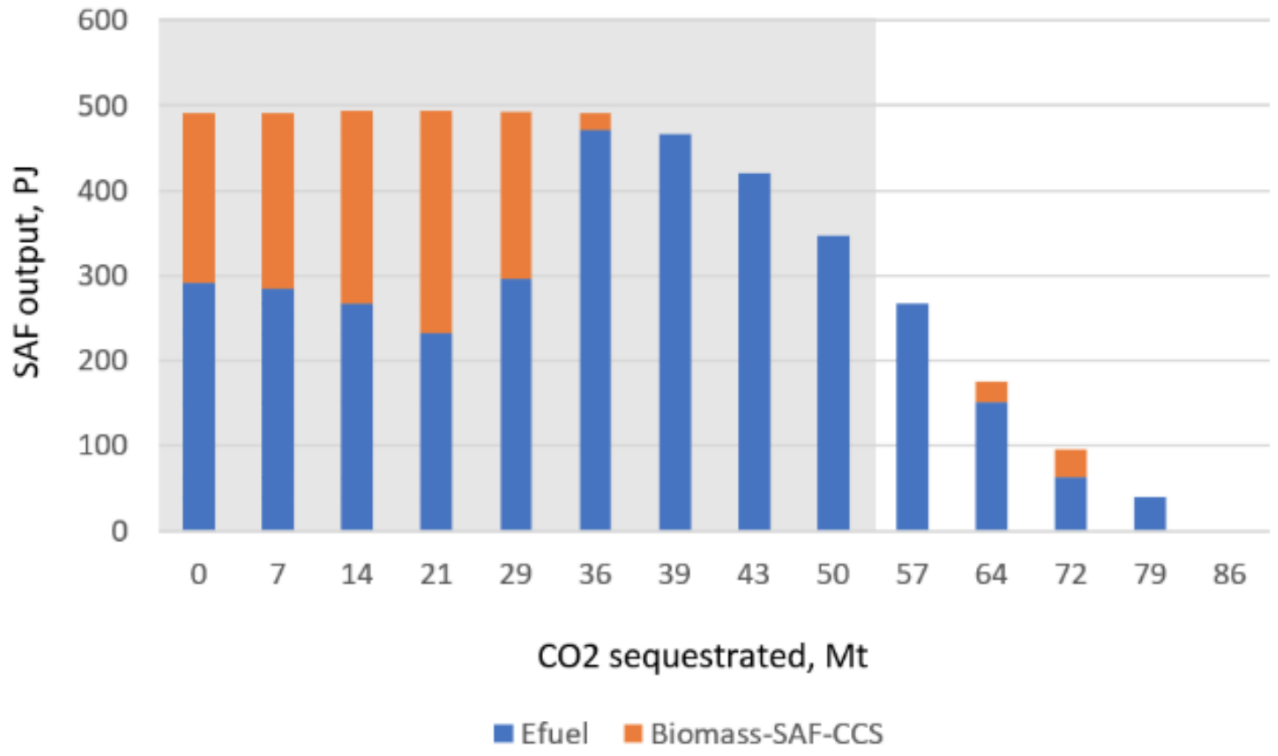


Highlights

- Synthetic jet fuels have a limited role in the UK's energy system in 2050
- Jet fuels from biogenic resources have a transitionary role from 2025 to 2045
- In 2050, biomass shifts to BECCS for hydrogen and BECCS for power
- The UK has a large storage capacity for CO_2
- More economical to sequestrate than utilise CO_2 and there is no market for CCU

Substantial market share in specific scenarios…

- One of these scenarios is assuming CCS is limited in the UK's energy system
- Both synthetic biofuels and e-fuels have a significant market share when CCS is assumed limited below 86 Mt in 2050.
- This shows that there is a close relationship between CCS, negative emissions and synthetic jet fuels output



UK SAF production in 2050 (PJ yr-1), from net zero scenarios with varying degree of CCS constrained in the UK TIMES energy system model. Grey area cover scenarios that achieve net zero through imported emissions credit

> It is important to understand the competitiveness, the inherent complexities and the uncertainties of synthetic jet fuel production facilities before we lock them into our energy system – UK TIMES modelling show they **could be useful in some future energy systems in the UK**

Thanks!

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