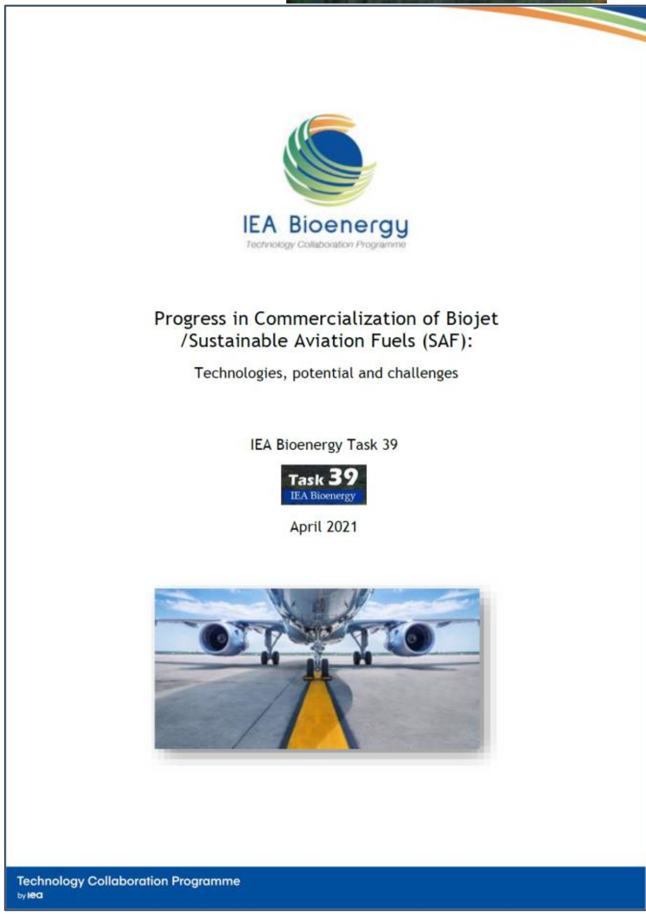
IEA Bioenergy
Technology Collaboration Programme

Task 39
IEA Bioenergy

Progress in Commercialisation of Low Carbon Intensive (CI) Biofuels

(Biojet fuels/Sustainable Aviation Fuels (SAF)

Technologies, potential and challenges


IEA Bioenergy
Technology Collaboration Programme

Progress in Commercialization of Biojet /Sustainable Aviation Fuels (SAF):

Technologies, potential and challenges

IEA Bioenergy Task 39

Task 39
IEA Bioenergy

April 2021

Technology Collaboration Programme
by iea

IEA Bioenergy Workshop, Vienna, October, 2022

Jack.Saddler@ubc.ca

UBC

BC-SMART: (https://www.bc-smart.ca)

The BC-Sustainable Marine, Aviation, Rail and Trucking (BC-SMART) Fuels Consortium

(Developing a decarbonisation strategy for long-distance transport)

BC SMART Low Carbon Fuels Consortium

Some of our BC-SMART Consortium Members

BOEING

Parkland

BRITISH COLUMBIA | Ministry of Energy, Mines and Petroleum Resources

BC Bioenergy Network
PARTNERING FOR A GREENER FUTURE

PORT of vancouver

WEST COAST REDUCTION LTD.

YVR VANCOUVER AIRPORT AUTHORITY

metrovancouver
SERVICES AND SOLUTIONS FOR A LIVABLE REGION

AIR CANADA

seaspan

WESTJET

COPA
Canadian Oilseed Processors Association

HARBOUR AIR SEAPLANES

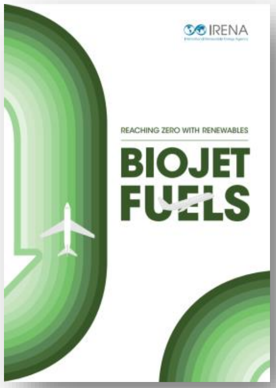
NORAM

UBC

NESTE

SAF/Biojet fuels

- 1.5C Scenario estimates that about 200 billion litres per year of biojet fuel will be required.
  - 2019 production – 140 ML (HEFA/HVO dominated): dramatic increase from 7 ML in 2018.
  - 315 000 flights have used a blend of biojet fuels.
  - Eight pathways have been ASTM approved (7 +coprocessing)
  - Likely to involve around USD 5 billion of investment per year
  - New technologies need to be scaled up
- Currently biojet fuel is 3-6 times more expensive than conventional jet fuel and is likely to be so for some time~$272/bbl (Rotterdam HEFA sustainable aviation fuel, 2020)



July 2021

Available at:
www.irena.orgpublications /

Take-home messages

- Biojet fuels/SAF are essential to reduce emissions from aviation
- Hydrogen and electric planes cannot deliver high reductions and technology still being commercialized
- Current volumes of SAF still very low (~150 MLPY), although many new facilities under construction
- Only one technology is fully commercial for SAF – hydrotreatment of fats and oils (HEFA)
- Gasification plus Fischer-Tropsch; AND Alcohol-to-jet advocated to be the next commercial SAF technologies
- Co-processing in existing refineries; pyrolysis/HTL and Power-to-Liquids will become more significant
- The biggest challenge for commercialization is the high price of SAF!! Policy will be the key driver

Background - Aviation's emission challenges

- Aviation produces 2-3% of global CO_2 emissions
  ~1 billion tons CO_2 per year

- Reasons for urgent action
  - Fastest growing transportation sector – CO2 emissions will double by 2050
  - **VERY** Hard-to-decarbonise sector

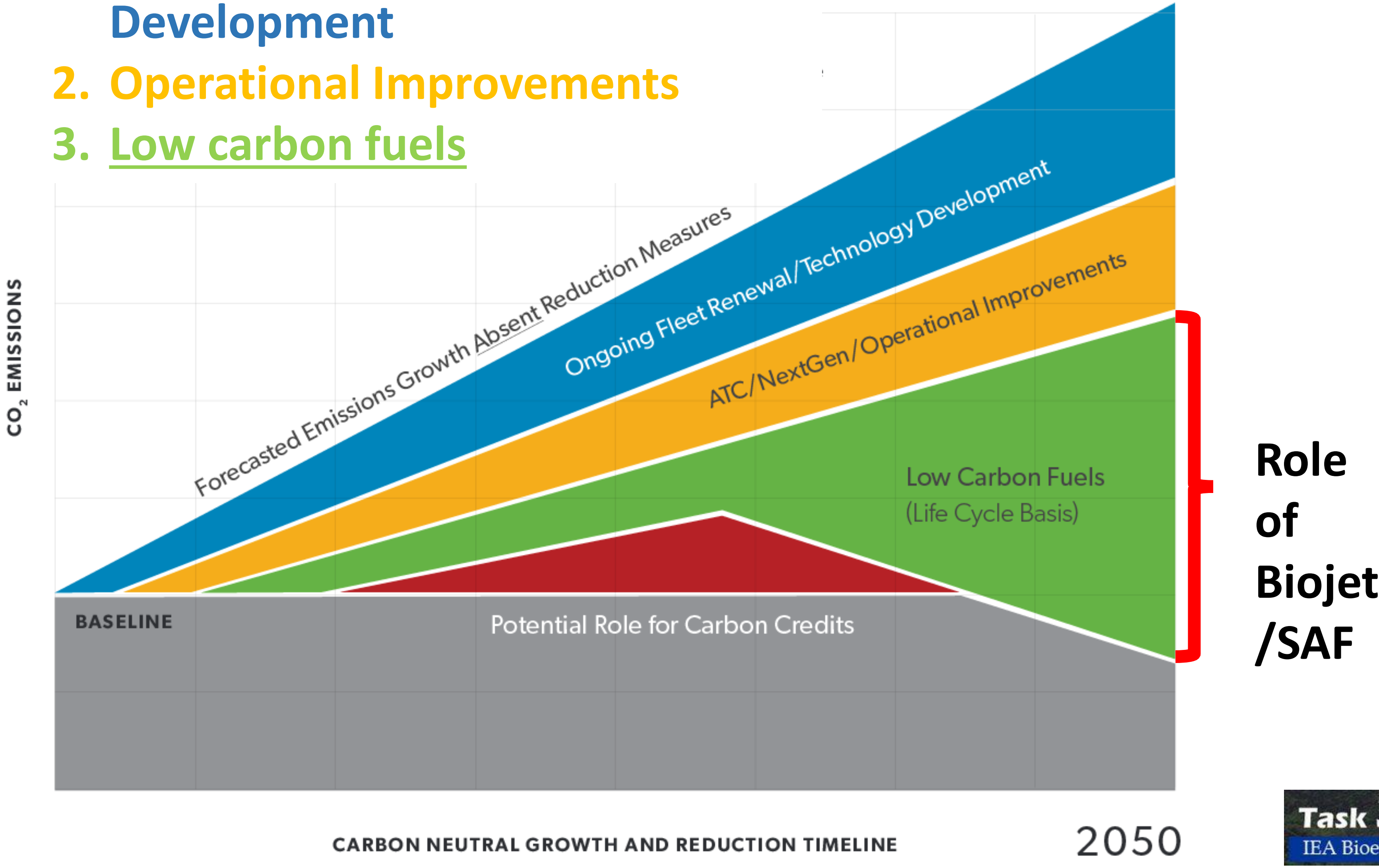
- Industry targets for emission reduction:
  - A cap on net aviation CO_2 emissions from 2020 (**carbon-neutral growth**) – CORSIA (Carbon Offset and Reduction Scheme for International Aviation)
  - A **reduction in net aviation CO_2 emissions of 50%** by 2050, relative to 2005 levels, is the goal!

IEA Bioenergy

Task 39 IEA Bioenergy

Measures to reduce emissions

1. Fleet renewal & Technology Development
2. Operational Improvements
3. Low carbon fuels



Sustainable Aviation Fuels (SAF) / Biojet fuels

- Drop-in fuel – *functionally equivalent* to existing petroleum fuels and *compatible* with existing infrastructure
- Fueling infrastructure and planes do not have to be modified
- Biojet/SAF will have the greatest impact on emission reduction!
- Will also impact non-CO_2 climate effects (e.g. contrail production)

SAF production: volumes, future capacity, long-term demand

CURRENT PRODUCTION

- Average of 0.29 MLPY (2013-2015) to 6.45 MLPY (2016-2018)
- In 2019 Neste produced 125 million litres

Source: ICAO Stocktaking 2019

- Announced SAF capacity for Neste by 2023 – 2 BLPY

- **Current jet fuel demand ~360 BLPY**

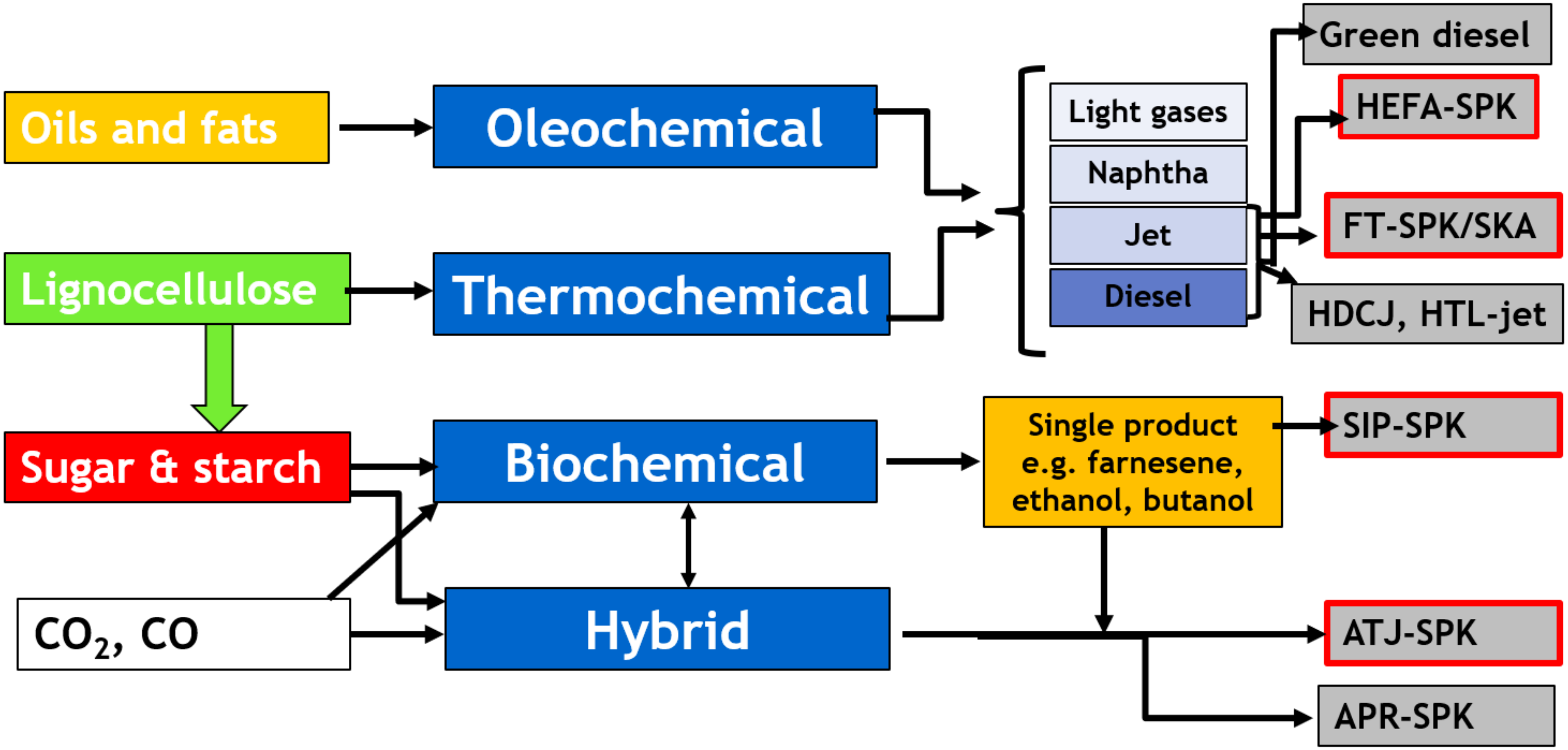
- **Volume of Biojet fuel required by 2050? At least 200 BLPY!!!**

FUTURE PRODUCTION?

Recent commitments and targets from 60 corporations for 10% SAF by 2030

- Amounts to about 30 BLPY

Technologies for drop-in fuel and SAF production (www.Task39.org)



SAF Technologies - status of commercialisation

- HEFA technology (hydrotreatment upgrading of fats, oils and greases) is currently the only fully commercial pathway and will be the main supplier of SAF over the next 10 years

- Commercial scale facilities for Gasification-FischerTropsch and Alcohol-to-Jet are being built and are proceeding towards commercialization

- Lower CI jet fuel via co-processing – e.g. BP, Parkland, Preem, ENI, etc., can be produced now

- Other technologies, such as Power-to-Liquids, will take much-longer to reach commercial scale

ASTM certification

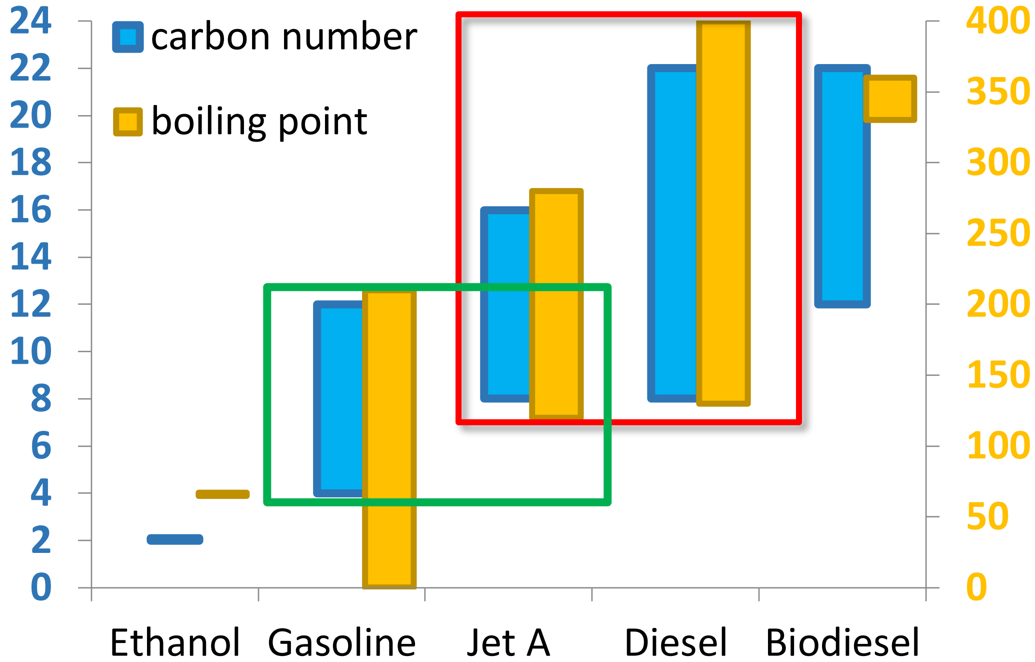
8 Approved pathways

- Fischer-Tropsch SPK & SKA (2009) (50%)
- HEFA SPK (2011) (50%)
- Synthesized Iso-paraffins (SIP) (2014) (10%)
- Alcohol to jet SPK (isobutanol (2016), ethanol (2018)) (50%)
- Catalytic hydro-thermolysis of lipids to jet fuel (50%)
- HC-HEFA-SPK – lipids from *Botryococcus braunii* algae (10%)
- Co-processing of lipids & FT liquids (5%)

- Maximum blends currently limited to 50% (**but why go to 50% as it is expensive**?)
- Several other pathways in progress towards ASTM certification as technology commercialisation is ongoing
- Maximum blends for coprocessing (5%)

Competition between renewable diesel and SAF production

- Production of SAF is more expensive than renewable diesel only
- Jet can be sold as diesel, and this creates competition
- Resolved through POLICY – current policies make renewable diesel more valuable



Distillation cuts based on boiling point, determines product slate

IEA Bioenergy

Task 39 IEA Bioenergy

Price of SAF - challenges and future prospects for price parity

- HEFA SAF currently about 3-6 x the price of conventional jet (~USD$2,000 - $2,300) (Argus media, Greenea)
- Other technologies are not commercial and, consequently, weak techno-economic analyses (TEA) available
- Price based on volume, not VALUE of low carbon intensity
- PRICE considered one of the biggest obstacles to airlines
- SAF will potentially always be more expensive, although significant cost reductions will take place over time

IEA Bioenergy

Task 39 IEA Bioenergy

SAF-specific policies will have the greatest impact on SAF expansion (Key role of LCA assessment!)

- **California/BC LCFS does/hopes to include aviation -** linked to **carbon intensity reduction**
- **US RFS includes SAF**
- Mandates and proposed mandates in Norway, Sweden, Finland
- **ReFuelEU** proposed mandate (volumetric) – 2% in 2025, moving to 5% in 2030, 20% in 2035, 32% in 2040, and 63% in 2050
- **Sustainable Skies Act** (USA) – proposed blenders tax credit; linked to **carbon intensity reduction**
  - $1.50 per gallon up to $2 per gallon for 100% emission reduction
- Voluntary corporate actions & BUYERS ALLIANCES (Sustainable Aviation Buyers Alliance) could create a strong demand signal (irrespective of national policies) (based on SAF certificates)

US Inflation Reduction Act (IRA) provides strong support for SAF (CEM/MI meeting, 22-23 Sept, Pittsburgh)

- **Creates a new tax credit to support the sale and use of SAF**
  - New SAF tax credit starts at $1.25 per gallon for SAF that achieves a 50% GHG reduction when compared to a baseline fossil fuel
  - An additional 1 cent per gallon is available for each percentage point by which the lifecycle GHG emission reduction of the fuel exceeds 50%.
  - The tax credit is capped at $1.75 per gallon

- **Establishes a competitive grant program in support of alternative aviation and fuels and low-emission aviation technology**
  - The program will provide grants to eligible entities to carry out projects located in the U.S. that produce, transport, blend or store SAF.
  - Nearly **$250 million** in funding will be available to support SAF projects under the program.

IEA Bioenergy

Task 39 IEA Bioenergy

Conclusions

- SAF will be essential if aviation is to decarbonize and **very large volumes** are needed
- Technical challenges remain, but high price difference with conventional jet fuel remains the biggest obstacle
- Policies are essential and there is significant developments on this front in the EU and USA that will have a major impact on SAF development
- However, there is no 'silver bullet' – Thus, commercialization of ALL technologies should be pursued as they can utilize different feedstocks, take advantage of regional differences, "enabling" policies, etc.

IEA Bioenergy

Task 39 IEA Bioenergy

Thanks!

www.BC-SMART.com

Susan van Dyk, Mahmood Ebadian

Task 39
IEA Bioenergy

www.task39.ieabioenergy.com

IEA Bioenergy
Technology Collaboration Programme

www.ieabioenergy.com

HEFA-SPK – CHALLENGES & OPPORTUNITIES

- Feedstock **cost, availability, sustainability and quality**

UCO DDP NWE M+1	EUR per ton	725
UCO CIF ARA Flexi M+1 (bid)	USD per ton	730

9 November 2020

Kerosene = $657/ton

- Limited waste (used cooking oil)
- Crop-based oils – high cost and poor sustainability

Source: Greenea

- With limited investment, every current HEFA (renewable diesel) facility can potentially produce ~15% SAF, significantly expanding volumes
- Further expansion to maximum SAF can be achieved with greater investment (needs policy driver)
- Favourable policies can address competition with renewable diesel to increase SAF value proposition

IEA Bioenergy

Task 39
IEA Bioenergy

Gasification/FT - Challenges & Opportunities

- Slow commercialisation since ASTM certification in 2009
- Challenges with tar formation and feedstock contaminants in the syngas and high cost of cleanup
- Very high capital cost

- Uses waste feedstocks such as MSW, forest and agricultural residues that are available in large quantities
- However, the pathway can produce very low carbon intensity SAF (>80% reduction)

Direct thermochemical liquefaction: (Pyrolysis/HTL) Challenges/Opportunities

- Complexity of biocrudes & variation with type of feedstock
- Upgrading - technical challenges, catalyst inhibition, (e.g., cost and lifespan)
- High hydrogen requirement for upgrading (depending on oxygen content – ~45% in fast pyrolysis bio-oil)
- Significant potential for co-processing in existing refineries to reduce investment costs in upgrading infrastructure
- Can utilise cheap, sustainable feedstocks that are available in large volumes (residues)
- HTL can use a variety of wet feedstocks

IEA Bioenergy

Task 39 IEA Bioenergy

Alcohol-to-jet (ATJ-SPK) - Challenges & Opportunities

- Yields and carbon intensity of alcohol can be a challenge
- Butanol is toxic to the fermentation organism
- Cost of separation of alcohol from fermentation broth
- Already established use of alcohol and intermediates
- Potential for reduced infrastructure cost as ethanol facilities can be repurposed and organisms substituted (e.g., for butanol)
- ASTM certified for isobutanol and ethanol
- Cost and carbon intensity (CI) of the biojet/SAF

Power-to-Liquids - Challenges & Opportunities

- Currently one of the most expensive SAF pathways
- Sufficient and additional renewable energy for hydrogen production is essential to achieve real climate benefits
- Competition for renewable energy – heat, electricity, EVs
- PtL an inefficient way to use electricity – use of electricity for EVs 6x more efficient than e-fuel production
- Very high cost of direct air carbon capture
- Integrated pathway for e-fuel production still at early stage of development, although some parts are commercial