Assessment of likely Technology Maturation (ATM) Project

EXECUTIVE SUMMARY

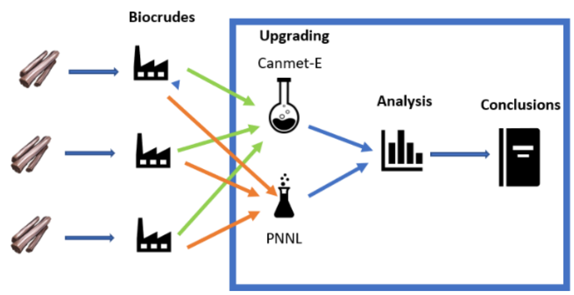
Assessment of likely Technology Maturation Pathways for biojet production from forest residues

Green Aviation Research & Development Network

EXECUTIVE SUMMARY – ATM PROJECT

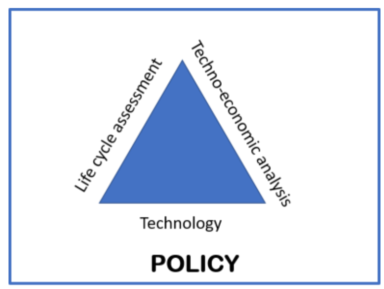
SCOPE OF THE ATM PROJECT

- 3 biocrudes were sourced from 3 different processes (fast pyrolysis, catalytic pyrolysis, hydrothermal liquefaction)
- Two labs carried out the upgrading – Canmet-Energy, PNNL
- Two different hydrotreatment methods were used
- Therefore 6 pathways overall were analysed
- Evaluation included analysis of fuel products, life cycle assessment (LCA) and techno-economic assessment (TEA)
- A provisional supply chain & engineering design for a demonstration scale facility was developed



KEY OBJECTIVES OF THE ATM PROJECT

The key objective of the ATM Project was to demonstrate that thermochemical technologies (fast pyrolysis, catalytic pyrolysis and hydrothermal liquefaction) and upgrading through hydrotreatment was a feasible and suitable method for biojet fuel production. An integrated analysis of technical, techno-economic and life cycle factors was carried out within the current policy framework. A provisional supply chain analysis was carried out in British Columbia to provide supporting data. An engineering concept for a demonstration-scale biocrude production and upgrading facility was developed that considered locations, general equipment requirements and supply chain.



STAKEHOLDERS

BOEING

NORAM

UBC

GARDN Green Aviation Research & Development Network

WESTJET

SkyNRG

BOMBARDIER the evolution of mobility

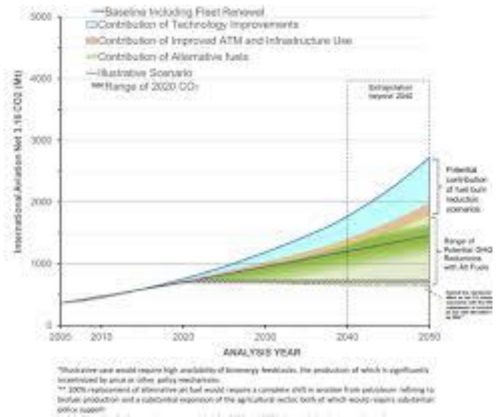
RATIONALE FOR BIOJET FUELS IN THE AVIATION SECTOR

Climate mitigation goals of aviation sector:

- Carbon neutral growth from 2020
- 50% reduction in emissions by 2050

Drop-in biojet fuels are essential for meeting targets and must be functionally equivalent to conventional jet fuel and fully compatible with existing engines and airplanes.

Biojet fuels have to be certified through ASTM and meet strict standards as set out in ASTM D7566. Five technology pathways have been approved under this standard. The technology pathways in this study have not received ASTM certification yet but were analysed against general standards.



Voluntary targets for emission reduction from aviation (https://www.icao.int/environmental-protection/documents/ICAO%20Environmental%20Report%202016.pdf)

RESULTS

Upgrading by Canmet-Energy and PNNL

PNNL used a dedicated hydrotreatment approach where neat biocrude was catalytically deoxygenated.

Canmet-Energy used a co-processing approach, blending the biocrude with furnace fuel oil before hydrotreatment using a proprietary dispersed catalyst.

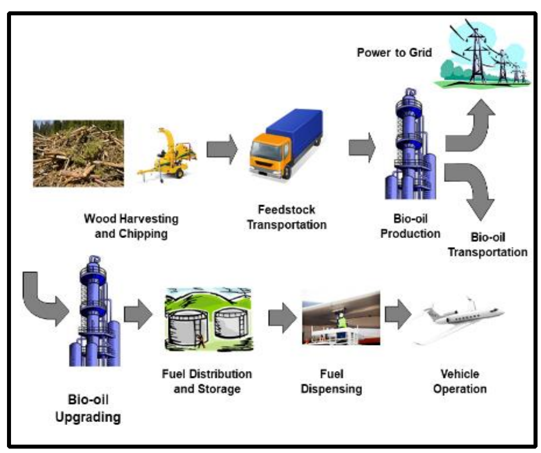
Upgrading of biocrude was demonstrated to be technically feasible down to very low oxygen levels and multiple fuel products were obtained (naphtha, jet fuel, diesel, heavy fuel oil).

A significant jet fraction was produced in all the pathways from all three biocrudes and all upgrading methods (20.8-36.6%).

The fuel fractions were analysed with a specific focus on the jet fraction. The quality of the jet fractions met most of the general ASTM D7566 specifications and, with further optimization, all standards could likely be met.

Sustainability and Life cycle analysis using GHGenius

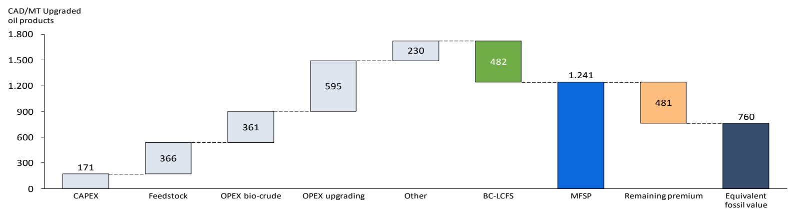
Overall sustainability of biojet fuels is an essential metric. Numerous voluntary certification and regulatory schemes include comprehensive principals and criteria to define, measure and ensure sustainability from the use of biojet fuels.



Potential GHG emission reductions (as CO_2eq) of a biojet fuel is a central component of sustainability and was calculated for each pathway based on the illustrated system boundary. A range of possible emission reductions was demonstrated, with the fast pyrolysis and dedicated hydrotreating pathway producing the highest potential emission reductions of 74% below a fossil fuel baseline. Further optimization of the HTL pathway with dedicated hydrotreating, based on the designed demonstration facility of 200 bbl/day, could deliver emission reductions of 71%. Key factors influencing the potential emission reductions are co-products, hydrogen use and feedstock source (e.g. mill residues vs forest residues), as well as the choice of upgrading method. Avoided emissions from slash burning in BC could have a significant impact on the LCA if included in the calculations.

Techno-economic analysis

A techno-economic analysis of the various pathways showed a minimum fuel selling price (MFSP) between CAD1,724 - CAD3,926 per metric tonne of fuel for the different pathways. The lowest MFSP was obtained with the HTL pathway with single-stage, dedicated hydrotreatment (shown below).

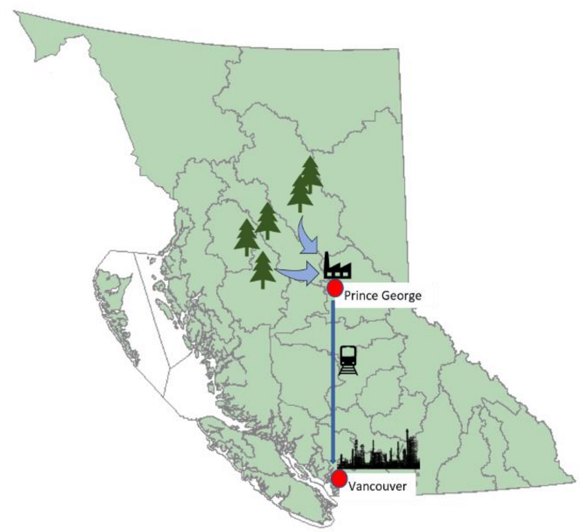


Based on current prices for conventional jet fuel (CAD855,25/MT), a premium of CAD963/MT would be required for the lowest cost biojet. If the credits based on the BC Low Carbon Fuel Regulations are included (CAD482), the premium is reduced to CAD481. As a reference, the current price of renewable diesel (Neste) is $1,775 per tonne. The greatest sensitivities to net present value (NPV) analysis were biocrude CAPEX, feedstock cost and hydrogen cost.

Feedstock availability and cost

Availability in BC was assessed based on current volumes within a 100 km radius of the proposed biocrude facility (200 bpd.

Sufficient feedstock was available at an average cost of CAD80 per oven dry tonne delivered to the biorefinery gate.



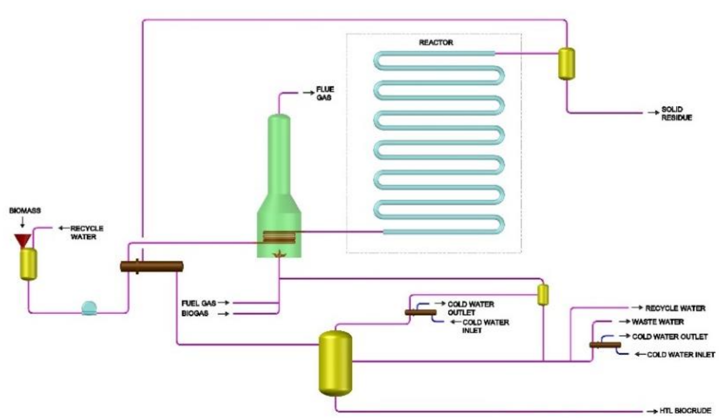
Provisional supply chain

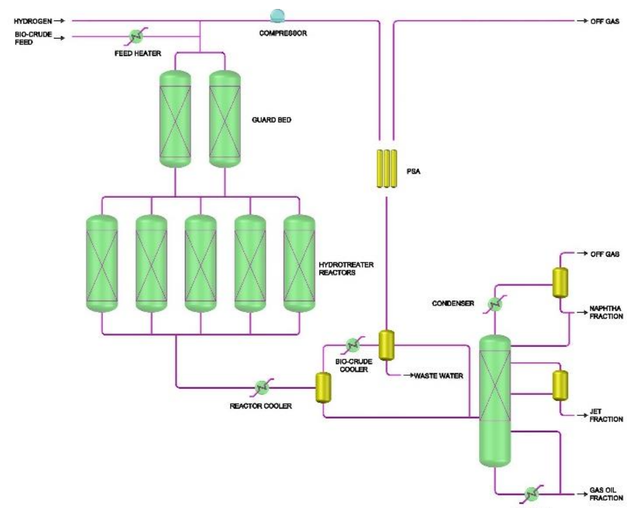
The modelled supply chain is based on forest residue feedstock that is comminuted in the forest and transported by truck to the biocrude facility which is based on sub-critical hydrothermal liquefaction with an associated wastewater treatment plant. The 200 bpd biocrude facility was assumed to be a greenfield development located in Prince George, BC, Canada.

Biocrude is transported by rail to the lower mainland to an upgrading facility which was assumed to be co-located with an existing petroleum refinery in the Lower Mainland region of BC, Canada. Downstream distribution of fuel products was assumed to use the existing refinery distribution channels.

Engineering design for a 200 bbl/day demonstration scale facility

Flow sheets were developed for a 200 bbl/d technology demonstration, including facilities for bio-crude production by subcritical hydrothermal liquefaction (HTL), HTL wastewater treatment by anaerobic and aerobic biological treatment, and bio-crude upgrading by hydrotreatment. The 200 bbl/d technology demonstration plant could produce enough jet fuel for up to 10 medium-haul flights per day as a 10% blend.





POLICIES

British Columbia has a very favourable policy environment for establishing a domestic biojet sector, including a well-developed low carbon fuel standard that has been in operation for many years. Expansion of this policy to include aviation fuel would play an important role in promoting biojet production and consumption, while fuel for international aviation can also be accommodated to incentivize this sector.

NPV showed a strong sensitivity to feedstock price. Therefore forest policies in BC, which could potentially have a significant impact on feedstock cost, were evaluated and modifications to existing policies proposed. The way the current tenure system is structured and the requirement for burning of forest residues in slash piles presents an obstacle to broader use of these residues.

CONCLUSIONS

Biocrudes produced through thermochemical liquefaction technologies, including fast pyrolysis, catalytic pyrolysis and hydrothermal liquefaction can be successfully used to produce a significant volume of biojet fuel. The jet fractions were analysed and demonstrated a high level of compliance with general standards for jet fuel based on ASTM certification. Assessment of potential emission reductions of these pathways through life cycle analysis demonstrated that significant emission reductions were possible with many of the pathways.

Currently, British Columbia has the most advanced policy environment in Canada for the production and consumption of biojet fuels based on a low carbon fuel standard which includes the flexibility of Part 3 agreements. Expansion of these policies to include aviation, in addition to other policies, are likely to have a substantial impact on development of biojet production and consumption.

The ATM Project represents a significant achievement in advancing the knowledge and identifying key challenges of producing biojet fuels through thermochemical liquefaction technologies. To our knowledge, it is the first integrated study that compared technical, life cycle and techno-economic parameters of three types of thermochemical liquefaction technologies and upgrading into finished fuels. The pathways evaluated are still being optimised and do not present a static state of technology and therefore improvements can be expected into the future as development progresses.

BENEFITS OF THE ATM PROJECT FOR CANADA

The aviation industry in Canada has actively pursued increased sustainability through organisations such as GARDN who funded this project. Biojet fuel production and consumption has been at the forefront as the aviation sector recognises the essential role of biojet fuels in decarbonisation of their climate impact. In Canada, airlines such as Westjet, a stakeholder in this project, have engaged in a variety of projects to promote biojet production and consumption as global access to biojet fuels have been limited.

Domestic production of biojet fuels from sustainable feedstocks will benefit Canada and its aviation sector as it will reduce airline emissions and therefore the cost of offsets through the CORSIA scheme. In addition, it will also reduce Canada's emissions in accordance with the UNFCCC Paris agreement, including avoided emissions from slash burning. Development of domestic production will create jobs in the manufacturing sector, but would also have a large impact to reposition the forest sector with extensive job creation as large volumes of residues have to be accessed and processed.

Utilisation of lignocellulosic biomass feedstocks such as forest residues for production of biojet fuel is essential for the long-term supply of biofuels for this sector. Canada is uniquely positioned with extensive sustainable feedstocks and technical skills, as well as existing commercialisation of biocrude production to contribute to biojet fuel volumes.

We acknowledge the contribution of IEA Bioenergy Task 39 in hosting this report on their website and distributing through their communication channels. The report can be downloaded for free from the website at Task39.ieabioenergy.com

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