The Life Cycle Greenhouse Gas Emissions of Canadian Aviation Biofuels

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Greenhouse Gases: A Global Problem

- Fossil fuels are key sources of energy however, high rates of extraction and use have led to accumulation of greenhouse gases (GHGs) in the air (Fig.1)
- CO_2 is the main GHG from the combustion of fossil fuels which induces higher radiative forcing (CO_2 traps solar radiation as heat in the atmosphere)
- Aviation fuel combustion contributes to 2-3% of global anthropogenic CO_2 emissions (700 million tonnes of CO_2 and increasing, in 2014) [IEA, 2016]

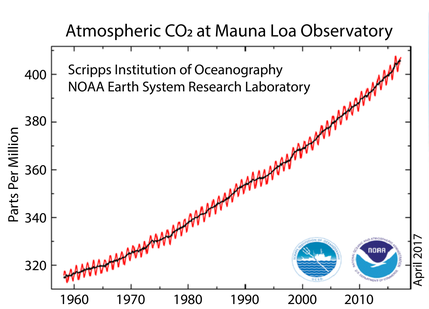

Figure 1. Continuous CO_2 measurements from 1960 to 2017

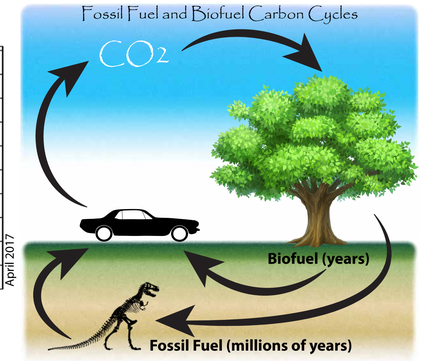

Figure 2. Two pathways for generating and using fuels

- Biofuel use disrupts the accumulation of CO_2 in air because biofuels are made from atmospheric carbon, and not carbon sequestered in fossils (Fig.2)
- Deployment of aviation biofuels (biojet fuel) has been determined to be a key step that can lead to the aviation sector's achievement of carbon neutral growth and overall reduction of GHG emissions [IATA, 2012]

Biofuel Research Objectives

- Understand the potential GHG emission reduction benefits from biojet fuel based on Canadian-grown canola
- Apply a life cycle approach to determine canola biojet fuel's life cycle emissions and how it compares with petroleum jet fuel
- Determine where changes in the canola biojet fuel life cycle can best be made to lead to meaningful reductions in GHG emissions

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Methods

- Apply Life Cycle Assessment (LCA) methodology to define and examine key life cycle processes for canola biojet fuel
- Quantify GHGs emitted (CO_2, CH_4, N_2O) from use of energy resources and materials throughout the life cycle (canola cultivation to fuel use, Fig.3)
- Convert GHG emissions from life cycle processes into GHG equivalent emissions (gCO_2eq) using the radiative forcing of CO_2 as reference, then normalize the emissions to 1 MJ of biojet fuel produced

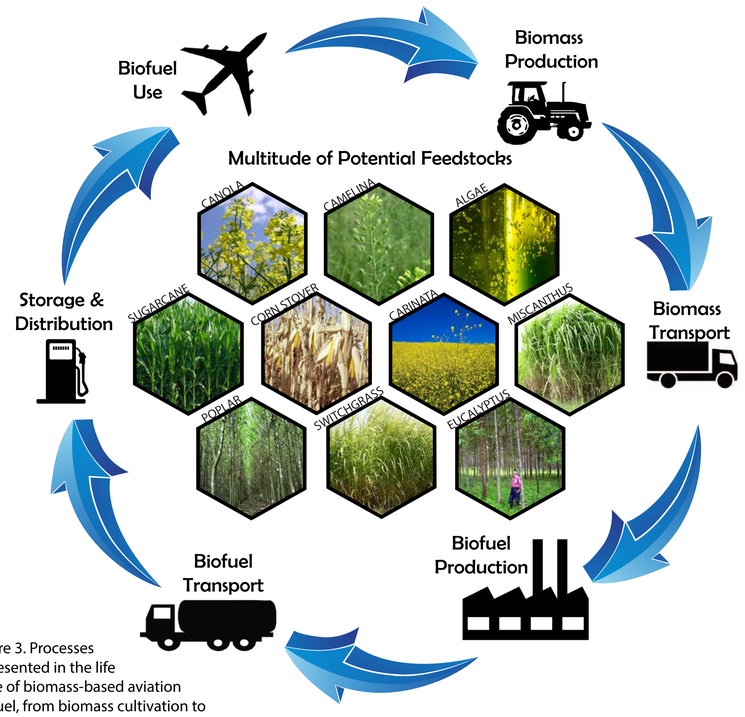


Figure 3. Processes represented in the life cycle of biomass-based aviation biofuel, from biomass cultivation to fuel utilization

- Use Aspen Plus to develop a biojet fuel production model that can calculate the energy and material requirements of commercial scale biofuel production using promising conversion technologies (Fig.4)

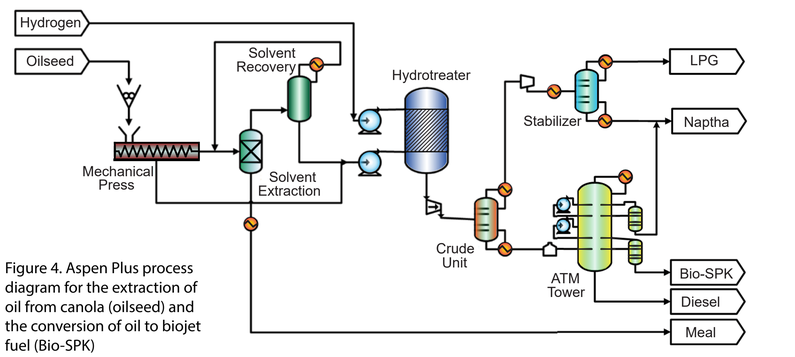
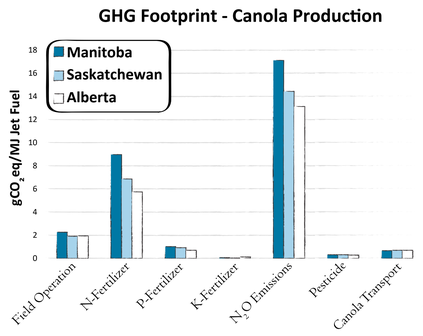
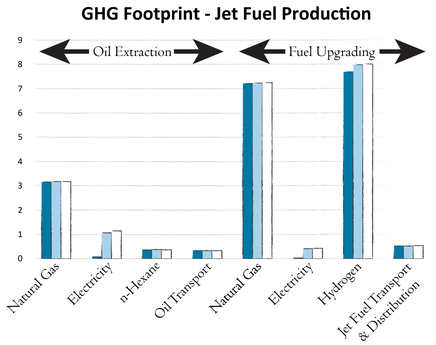


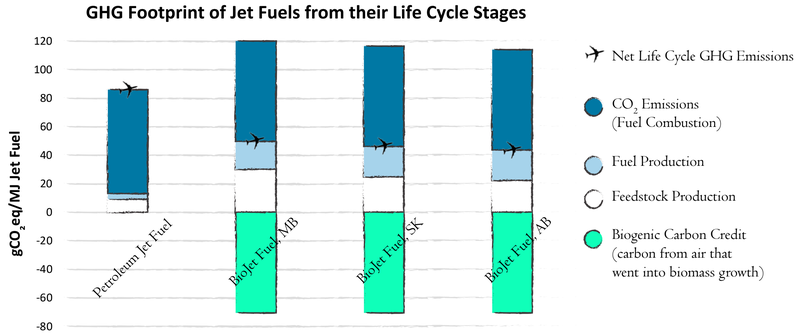
Figure 4. Aspen Plus process diagram for the extraction of oil from canola (oilseed) and the conversion of oil to biojet fuel (Bio-SPK)

Aviation Biofuel Performance

- Three biojet fuel pathways were examined based on differences in canola farming data from Manitoba, Saskatchewan, and Alberta
- Nitrogen fertilizer, natural gas, and hydrogen contributed most to canola biojet fuel's GHG footprint (these are opportunities for emissions reduction)







- GHG emissions from canola production was relatively higher than fuel production: 22 to 30 gCO_2eq/MJ (canola) vs 19 to 21 gCO_2eq/MJ (fuel)
- The carbon content of biojet fuel was fully attributed to carbon sequestered as CO_2 intake during canola cultivation, which neutralizes the positive CO_2 emissions from fuel combustion
- Net life cycle GHG emission of conventional jet fuel was **86 gCO_2eq/MJ** while for canola biojet fuels, the values ranged from **44 to 50 gCO_2eq/MJ**
- Overall, adopting biojet fuel based on Canadian canola has the ***potential to reduce GHG emissions of jet fuels by 42-49%***

Future Research Work

- Conduct sensitivity and Monte Carlo analyses to investigate the range of environmental performance and key canola/fuel production parameters
- Investigate the impacts of induced land use changes, given the transition of non-cultivated lands into dedicated lands for biojet fuel production
- Examine the viability of other biojet fuel pathways based on GHG footprint of Canadian feedstocks and corresponding fuel conversion technologies