WESTERN MONTANA CORRIDOR

SUSTAINABILITY
Life Cycle Assessment

Northwest Advanced Renewables Alliance

4.2 LIFE CYCLE ASSESSMENT

4.2.1 Methodology

Life cycle assessment (LCA) identifies the environmental impacts of a product or activity over its entire life cycle. NARA performed a comprehensive LCA of the WMC region to accurately estimate the environmental footprint of a woody biomass based biojet fuel supply chain in this region.

LCA is a computational tool that transcends disciplinary boundaries and can be used to evaluate the environmental sustainability of a biojet fuel industry, especially within a particular region. LCA examines the supply chain from the forest to delivery of the biojet fuel to the market. LCAs are categorized into the following modules: woody biomass collection and processing within the forest including delivery to depot facilities; conversion of the forest residues to isobutanol and delivery to the biojet fuel production facility; conversion of isobutanol to jet fuel including transportation to the end user;and conversion of the byproducts derived from the isobutanol and jet-fuel production processes into useful co-products.

In order to accurately estimate the environmental footprint of a woody biomass based biojet fuel supply chain, an integration of knowledge and research from the fields of forestry, logistics, energy economics and chemical engineering is crucial. In the analyses we explored factors that drive the differences in estimates of the new emissions of biofuels relative to fossil fuels and examine variations in key assumptions that have been identified as sources of debate regarding the accuracy of biofuel LCAs.

The results of the LCA will help forest managers and biofuel processing facilities to evaluate biomass recovery options as they pertain to the environmental impacts of the gathering and processing of forest residuals after harvest and conversion into biojet fuel. The environmental impacts will be measured utilizing L CA following the protocols set up by the environmental management standard ISO 14044 (International Organization for Standards 2006a and 2006b). By evaluating the process of extracting and processing forest residuals into biojet fuel, managers can evaluate if there is a need for increased efficiency of the operations, and if the viability and availability of the feedstock are enough to meet economic thresholds for actual use as an alternative fuel source.

4.2.2 Preliminary Findings

This section presents the preliminary results of a life-cycle assessment (LCA) for woody biomass based biojet fuel. The LCA team has evaluated multiple logistical/procedural pathways for biomass transportation scenarios. The following results present the findings of the dominant, or most likely, scenario; and incorporate the avoided environmental costs associated with piling and burning forest residuals (e.g., slash) left in the forest.

Various pretreatment options are currently being evaluated for their technical, economic and environmental feasibility. The LCA results presented here assume an integrated model (similar to the NREL process), where the biomass preconversion, pretreatment and fuel conversion processes are all undertaken at the same location. Two sets of results are presented in the following sections. The first section presents the LCA results of woody biomass collection and delivery at the preconversion facility. The environmental indicators reported for this set of results include global warming, acidification, smog, and ozone depleting potentials. The second set of results represents the complete LCA from 'Wood to Wing'. However, due to the uncertainty associated with the pretreatment and logistics and the sensitivity of the data, only three indicators are presented, namely, global warming, ozone depletion and fossil fuel reduction potentials. Please note: These are not final LCA results for the region. Various pretreatment and feedstock logistics options are currently being evaluated for their technical, economic and environmental feasibility. Final results will be available once these pathways are finalized.

AVOIDED ENVIRONMENTAL BURDENS OF SLASH PILE BURNING:

The results of a comparative LCA analysis of the avoided environmental costs and impacts of using woody biomass residuals for biojet fuel instead of slash pile burning are noteworthy. Forest residuals in the WMC region, which are typically left in the forest after harvest, are burned to avoid fuel accumulation on the forest floor. Compared to the alternative of burning the left over slash piles from harvesting, the environmental impacts of extracting and hauling these residuals to market can be measured by the amount of carbon (CO_2) emitted into the atmosphere. Emissions generated for both scenarios were calculated to provide additional credence for the utilization of leftover residuals instead of burning the slash piles that emit unfiltered smoke and ash. Environmental burdens were measured in terms of global warming, acidification, smog, and ozone depleting potentials. The results reveal that the avoided greenhouse gas (ghg) emissions from slash pile burning balances out the overall ghg emissions from woody feedstock collection and transportation under the assumed scenario. Moreover, there is a net reduction in the environmental impact resulting from extraction of residuals for the biojet fuel project by avoiding slash pile burning for the following indicators: smog formation, acidification, and respiratory effects. A summary of the results are presented in Table 4.2.1.

COMPARATIVE ANALYSIS: ENVIRONMENTAL IMPLICATIONS

Comparative Analysis: Environmental Implications of NARA Bio-Jet Fuel vs Fossil Based Bio-Jet Fuel Comparable aircraft utilizing biofuels or fossil fuels emit similar levels of carbon dioxide (CO2), which is the primary source of greenhouse gas emissions. However, the primary distinction between biofuels and fossil fuels is the source of carbon stored in the fuel. The environmental footprint associated with burning aviation fuels comes from two primary sources. First, the carbon stored in the aviation fuels is released during combustion. Second, there are significant emissions associated with the extraction, transportation and processing of crude oil into jet fuel.

The use of fossil aviation fuels releases geologic carbon that has been stored for millions of years, and those emissions represent a net addition of CO2 to the atmosphere. The NARA biojet fuel uses wood residue derived from timber harvest operations as the raw material to produce isoparaffinic kerosene (IPK) jet fuel. Trees use atmospheric carbon dioxide to grow and burning biofuels simply releases this sequestered carbon dioxide back into the environment. With a sustainable resource harvest system, where the biomass extracted from the forest is less than the biomass growth during a specified time frame, the net addition of CO2 into the atmosphere is negative. However, the conversion of forest woody residue to biojet fuel requires various inputs from nature (the atmosphere) and industry (the technosphere). Hence, the overall environmental footprint associated with biojet fuel includes all the resources used, emissions and waste generated during the process of biomass growth, collection and conversion into biofuel.

The comprehensive Life Cycle Assessment (LCA) based ‘cradle to grave’ estimation approach used to calculate the overall environmental footprint of these two types of aviation fuels is generally considered to be the most credible. The preliminary results obtained from the ‘forest to pump’ LCA analysis are carried forward to combustion in a jet engine during an intercontinental passenger flight to provide a ‘forest-to-wake’ analysis. These results are compared to the same results obtained from combustion of fossil fuel based jet fuel. The preliminary results of this LCA comparison suggest that the overall global warming potential of the NARA biojet fuel, measured in kilograms of Co 2 emissions, is just 38.4% that of fossil fuel based jet fuel (Table 4.2.2). In addition, the ozone depletion potential of the NARA biojet fuel is approximately 12% that of fossil fuel based jet fuel while the fossil fuel depletion potential is 39.1% of fossil based jet fuel. In other words, our preliminary analysis suggests that there is a 61.6% reduction in the global warming potential, an 88.1% reduction in the ozone depletion potential and a 60.7% reduction in fossil fuel depletion by substituting biojet fuel for fossil fuel based jet fuel. This preliminary result is significant in that it exceeds the mandated 60% emission reduction criterion specified in the US Energy Independence Act guidelines. Table 4.2.2 and figure 4.2.1 show the emissions associated with biojet and fossil based jet fuel in an intercontinental flight.

Table 4.2.1. Preliminary analyses of the emissions reduction associated with biojet fuel used as a substitute for fossil based jet fuel in an intercontinental flight

Impact Category	Unit	System Impact	Avoided Impact	Total Impact
Global Warming	kg CO^2 eq	65.71	-65.7	0.006
Smog	kg O^3 eq	28.8	-89.5	-60.7
Acidification	mol H+ eq	52	-176	-124
Ozone Depletion	kg CFC-11 eq	2.7 IE-09	-3.26E-10	2.3E-09
Respiratory Effects	kg PM 1- eq	0	-11.1	-11.1

Table 4.2.2. Preliminary analysis of the emissions associated with aircraft transportation of one person for 1 kilometer on an intercontinental flight

Impact Category	Unit	Bio-Jet Fuel	Fossil Fuel (Kerosene)
Ozone Depletion	kg CFC-11 eq	1.69E-06	1.42E-05
Global Warming	kg CO^2 eq	32.32	84.22
Fossil Fuel Depletion	MJ Surplus	65.17	165.79

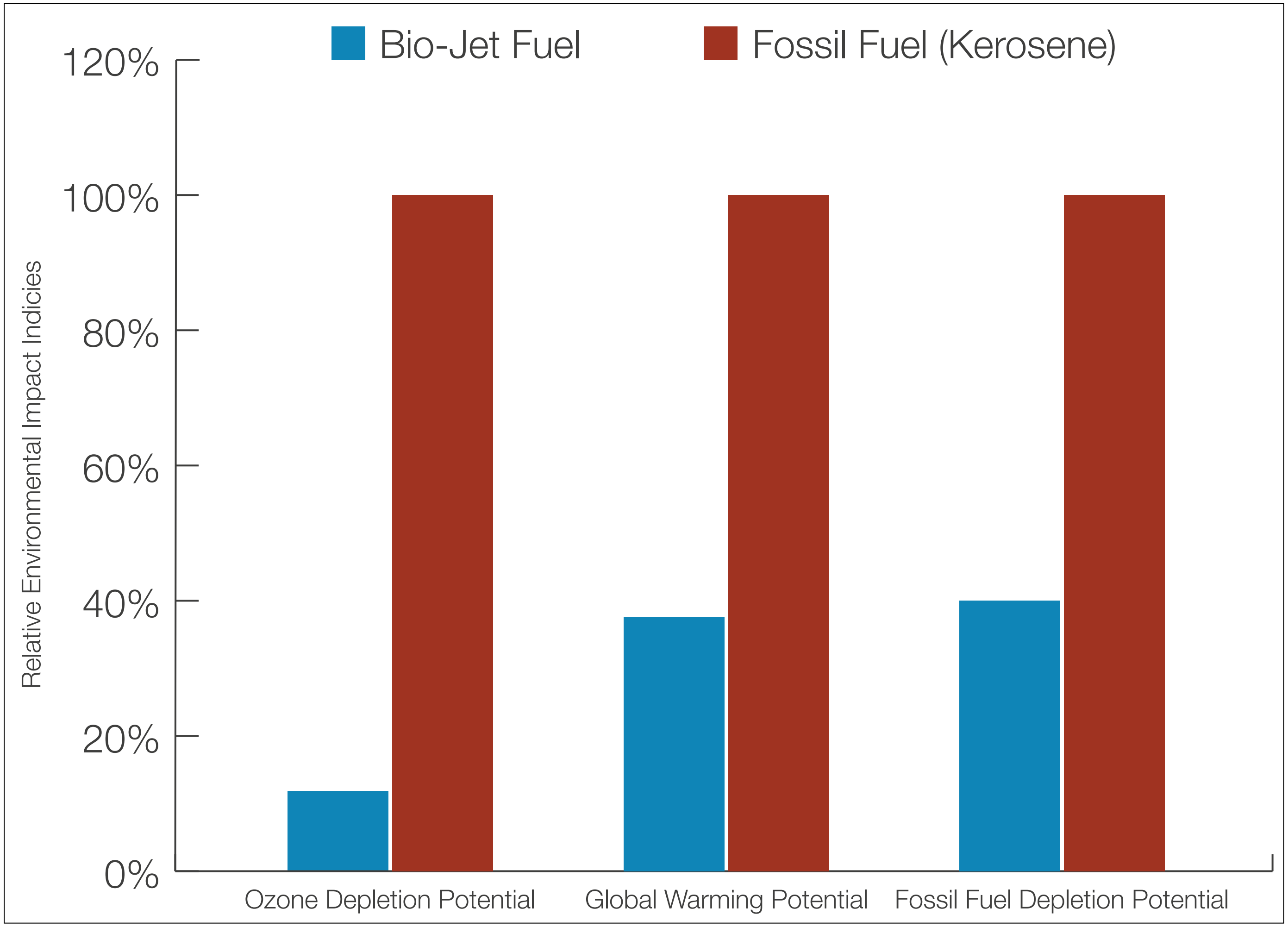

Figure 4.2.1 Preliminary analyses of the emissions reduction associated with biojet fuel used as a substitute for fossil based jet fuel in an intercontinental flight

4.2.3 References

International Organization for Standards (ISO). 2006a. Environmental management life cycle assessment requirements and guidelines. ISO 14044. International Organization for Standardization, Geneva, Switzerland. p20.

International Organization for Standards (ISO). 2006b. Environmental management life cycle assessment requirements and guidelines. ISO 14044. International Organization for Standardization, Geneva, Switzerland. p46.