CINTRAFOR NEWS

Center for International Trade in Forest Products

Winter 2014

SOFTWOOD EXPORT COUNCIL

PRESS RELEASE December 25, 2013

American Softwoods Japan Office

The Wood Use Points Program (WUPP) is a program initiated by the Forestry Agency (FA) in Japan to provide a subsidy of as much as ¥600,000 equivalent points when a home owner uses more than 50% of a "local wood" species for structural components and/or uses certain amounts of "local wood" species for non-structural interior or exterior decorations. All of the "local wood" species initially included in the WUPP were Japanese domestic timber species, including sugi, hinoki and Japanese larch.

On December 17th, the U.S. Douglas-fir timber species was approved as a new "local wood" species by the National Land Afforestation Promotion Organization (NLAPO), to the Corporation to Establish the Fund for the WUPP program. Consequently, US Douglas-fir lumber and plywood for interior and exterior decorative end-use applications will be considered as "local wood" within the Wood Use Points Program following the official announcement by the Head Office of WUPP that U.S. Douglas-fir has been approved. However, before U.S. Douglas-fir lumber can be used in structural applications, applications must be submitted to all 47 prefectures requesting that they add US Douglas-fir as a "local wood" species for each construction method (e.g., post and beam and 2x4) that is included in the Wood Use Points program in each prefecture. At this point, initial indications are that the prefectural approval process will be completed sometime in March 2014.

The application materials to designate US Douglas-fir as a "local wood" species within the WUPP were prepared by Dr. Ivan Eastin (Professor and Director of the University of Washington's Center for International Trade in Forest Products, CINTRAFOR) and Dr. Daisuke Sasatani (Auburn University). The American Softwoods Japan Office submitted the application to the NLAPO. The third committee meeting was held on December 17th, and the application was approved by the committee members. Many Japanese and foreign companies/organizations have applied for the "local wood" designation and this was the third committee meeting to review the foreign applications since the WUPP program was launched. US Douglas-fir was the first, and only, foreign wood species to be approved as a "local wood" species under WUPP.

"Local wood" species must satisfy two conditions in order to be included within the WUPP: 1) the resource inventory of the timber species must be increasing in the country where it grows and 2) the consumption of the "local wood" species must have a significant economic ripple effect within Japanese rural agriculture, forestry and fisheries communities. The official forest resource inventory data compiled by the US Forest Service showed that the volume of Douglas-fir growing in US forests has increased about 30% over the last 35 years. Thus the US Douglas-fir timber resource in the U.S. was shown to satisfy the first condition of the WUPP. Regarding the second condition, there are a number of Douglas-fir sawmills in Japan, with industrial clusters existing in the Setouchi and Northern Kanto areas. The U.S. application document explains how the processing of US Douglas-fir contributes to the local economy where the major Japanese Douglas-fir sawmills are located, thereby satisfying the second condition of the WUPP. Not only do the Douglas-fir sawmills in Japan provide economic benefits within the local communities but the related industries, including distributors, secondary manufacturers, ports, and markets for by-products also provide economic benefits within these local communities.

Thus, it can be seen that the Douglas-fir forest resource is well managed in the US and provides substantial economic benefits in rural agriculture, forestry and fishing communities within Japan. In Japan, Douglas-fir has a long tradition of being used as structural lumber, non-structural lumber, plywood, flooring, and other types of building materials. Japanese builders and carpenters especially favor using Douglas-fir lumber in horizontal structural applications in traditional post and beam homes, including as beams, girders and purlins because of the high strength of Douglas-fir. Douglas-fir is also favored because of its dimensional stability, durability and stable supply.

Now that U.S. Douglas-fir has been approved as a new "local wood" species it is expected that more houses will be eligible for the Wood Use Points Program and that many more home builders and home owners in Japan can now receive subsidies under the WUPP.

The American Softwoods Japan Office would like to encourage Japanese builders and architects to use more U.S. Douglas-fir wood products and remind them that, at this time, the "local wood" species designation for Douglas-fir wood products has only been granted for Douglas-fir timber harvested in the U.S..

If you have any questions, please contact Tomoko Igarashi at American Softwoods Japan Office.
Tel: 03-3501-2131 Fax: 03-3501-2138
www.americansoftwoods.jp

CINTRAFOR News is available on the web: **http://www.cintrafor.org**

In This Issue:

Director's Notes

University of Washington
School of Environmental & Forest Sciences
Box 352100
Seattle, Washington 98195-2100
Phone: 206-543-8684
Fax: 206-685-0790
www.cintrafor.org

The Center for International Trade in Forest Products addresses opportunities and problems related to the international trade of wood and fiber products. Emphasizing forest economics and policy impacts, international marketing, technology developments, and value-added forest products, CINTRAFOR's work results in a variety of publications, professional gatherings, and consultations with public policy makers, industry representatives, and community members.

Located in the Pacific Northwest, CINTRAFOR is administered through the School of Environmental & Forest Sciences at the University of Washington under the guidance of an Executive Board representing both large and small companies, agencies, and academics. It is supported by state, federal, and private grants. The Center's interdisciplinary research is carried out by university faculty and graduate students, internal staff, and through cooperative arrangements with professional groups and individuals.

CINTRAFOR Succeeds in Gaining the "Local Wood" Designation for Douglas-fir in Japan

On April 1st, 2013 the Forestry Agency announced the start of the Wood-Use Point Program (WUPP). The WUPP awards 300,000 points (equivalent to 300,000 yen or about $3,000) to builders or home buyers who use at least 50% domestic (or local) structural wood when building a new home. They can qualify for an additional 300,000 points if they use a specified amount of local wood in non-structural applications as well. The LDP government approved ¥41 billion (US$432 million) for the WUPP and the program could apply to135,000 homes (approximately 28% of total annual wooden housing starts based on 2012 data). The Wood Use Points will be awarded in addition to any relevant subsidies which may be offered at the prefectural level (currently 43 of 47 prefectures offer their own subsidies for using domestic wood to build homes). By combining WUPP with existing prefectural subsidies, Japanese authorities have developed a program that strongly favors the use of domestic wood species over imported species and places US wood at a competitive disadvantage.

In May, 2013 CINTRAFOR at the request of the US Embassy and the Softwood Export Council undertook a project designed to have US Douglas-fir recognized as a domestic "local wood" species under WUPP. Douglas-fir was selected for this project based on the fact that it represents over 90% of US log and lumber exports to Japan. In order to be successful in our submission, we needed to be able to demonstrate that US Douglas-fir was legally harvested, that the timber inventory was increasing over time and that it contributed to the economic development of rural mountain and fishing communities in Japan. On December 25th, the Japanese government announced that they would recognize US Douglas-fir as a domestic "local wood" species and Douglas-fir wood products could be included within the Wood Use Point Program. This determination was significant because while there were a large number of foreign species submitted for consideration, US Douglas-fir was the only foreign species designated for inclusion within the Wood Use Point Program. Failure to gain the "local wood" designation for U.S. Douglas-fir would have sharply reduced the demand for Douglas-fir products in Japan. In fact, a recent CINTRAFOR trade analysis estimates that the WUPP could have cost US forest products exporters as much as $36 million over the duration of the WUPP subsidy program. CINTRAFOR continues to work with the US Embassy and the Softwood Export Council to ensure that US Douglas-fir is integrated smoothly into the Wood Use Points Program, especially at the prefectural level.

Update on CINTRAFOR Graduate Students, Visiting Scholars and Peace Corps Masters International (PCMI) Graduate Students

It has been a busy fall quarter for CINTRAFOR with the arrival of many new graduate students and the departure of several students as well as the departure of our PCMI students on their Peace Corps assignments. Currently CINTRAFOR is home to 8 graduate students, including 2 doctoral students and 6 master's students. We also welcomed the arrival of 6 new PCMI students this fall as well as the arrival of 3 visiting doctoral students from around the world.

Peace Corps Masters International Program: The PCMI students from last year received their country assignments from Peace Corps last spring and they departed for their countries of service this fall. **Beth** and **Kevin Dillon** were assigned to the Philippines, **Maggie Wilder** was assigned to Ethiopia while **Mikhael Kazzi**, **Corey Dolbeare**, **Gwen Stacy** and **Alia Kroos** were all sent to Senegal. The current group of PCMI students, **Tabatha Rood**, **Ian Hash**, **Jake Dunton**, **Michael Tomco**, **Zak Williams** and **Jordan Bunch**, is anxiously awaiting their country assignments. **Zak** just recently accepted a placement offer to the Philippines where he will be assigned as a Coastal Resource Management Extension Worker. Finally, we welcome the return of **Cynthia Harbison** who just completed her Peace Corps service in Cameroon and has returned to Seattle to finish writing her PCMI research report.

CINTRAFOR Graduate Students: CINTRAFOR welcomed the arrival of four new graduate students into the program this year. **Cindy Chen** is originally from Beijing, China, but has spent most of her life flying between the U.S. and China. She received her BSc and MSc degrees from the University of California, Irvine in Social Ecology and developed an interest for Environmental Sciences during her studies. After receiving her Masters' degree, she spent two years at the Research Center for Eco-Environmental Sciences in Beijing where she participated in a wide range of research projects studying the impacts of environmental pollution and water scarcity on public health. **Clarence Smith** is an enrolled member of the Blackfeet Nation in Montana. He is a single father with 2 beautiful daughters who received dual BSc degrees in International Business and International Relations at Fort Lewis College in Colorado. While

Director's Notes continued on page 3

Director's Notes continued from page 2

in school he started a consulting company called "4word" which focuses on Native American men in areas like fatherhood, communication skills, diversity, and leadership. **Cody Sifford** is a member of the Navajo Nation and was raised in rural Eastern Montana. He received his BSc degree from Salish Kootenai College in Environmental Science with a terrestrial emphasis. He interned for several years with NASA doing GIS and remote sensing climate research. **BJ Birdinground** is a Crow Tribal Citizen from the Crow Reservation located in Eastern Montana. BJ received his BSc in Environmental Science and Terrestrial Land Resources with a minor in Liberal Arts from Salish Kootenai College on the Flathead Reservation in Western Montana. He spent the last four summers working as an intern with Professor Dan Schwartz at UW's Chemical Engineering Department involved in a research project focused on using a new blanket technology to produce biochar/biofuel from forest residuals.

Visiting International Doctoral Fellows: CINTRAFOR is fortunate to have the opportunity to host three doctoral students from Universities around the world. The Fellows program permits students pursuing degrees at foreign universities to participate in full-time supervised research and work-based learning experiences at the University of Washington. **Francesca Pierobon** is a doctoral student visiting from the University of Padua in Italy. Francesca is working with CINTRAFOR as a member of the research team engaged in conducting a life cycle assessment of biofuel derived from forest residuals left over following timber harvest operations. **Sajad Ghanbari** is a doctoral student visiting from the University of Teheran in Iran who is working with CINTRAFOR as a member of a research team looking at the social, cultural, economic and environmental aspects of non-timber forest product use within Native American tribal groups in the Pacific Northwest. **Tang Shuai** is a doctoral student visiting from the Beijing Forestry University in China. Tang is working with CINTRAFOR to learn more about modeling global trade of forest products and in particular he is interested in understanding the CINTRAFOR Global Trade Model.

CINTRAFOR Graduates: CINTRAFOR recently had three students graduate from our program. **Daisuke Sasatani** completed his doctoral research and successfully defended his dissertation entitled: "Business Strategies of North American Sawmills: Flexibility, Exports and Performance". Daisuke is currently a post-doctoral researcher at Auburn University working on the marketing of trade of southern yellow pine. **Yoshihiko Aga** successfully completed his master's research and thesis entitled: "Market Integration of Domestic Wood and Imported Wood in Japan: Implication for Policy Implementation". Yoshi came to CINTRAFOR as a MAFF (Ministry of Agriculture, Forestry and Fisheries) Fellow and he has returned to MAFF where he has taken up a position as Associate Director of the New Business and Intellectual Property Division, Food Industry Affairs Bureau within MAFF. Finally, **Peter Gill** completed his Peace Corps service in Senegal and returned to CINTRAFOR and successfully defended his PCMI research entitled: "Working with local people to identify tree services, deforestation trends, and strategies to combat deforestation: A case study from Senegal's Peanut Basin". Peter is currently in Nepal where he is working with an environmental NGO.

Environmental assessments of woody biomass based jet-fuel

By *Indroneil Ganguly, Ivan L. Eastin, Tait Bowers, Mike Huisenga and Francecsa Pierobon*

Typical forest harvest operations in the Pacific Northwest of the US leave a considerable volume of unused woody biomass in the forest in the form of treetops and branches. Despite the environmental benefits of using these residuals, the economic feasibility of extracting them from the forest is limited due to low market demand and high collection and transportation costs. Most of the unused woody biomass is collected, piled and burned in the forest while some is simply left on the forest floor to decompose. To address the market failure of more fully utilizing woody residues, the Northwest Advanced Renewables Alliance (NARA) research project is exploring the economic and environmental feasibility of converting residual woody biomass into bio-jet fuel.

To estimate the overall environmental impact associated with converting woody biomass into bio-jet fuel, as well as any net reduction in emissions to the atmosphere associated with avoiding the use of fossil fuel, a detailed preliminary Life Cycle Assessment (LCA) has been performed by the CINTRAFOR research team. Life Cycle Assessment (LCA) is a method to assess the environmental impacts of a product or activity (a system of products) over its entire life cycle. The LCA results for the bio-jet-fuel are critical in demonstrating that bio-jet fuel produced from forest residuals meets the greenhouse gas (GHG) reduction target specified in the US Energy Independence Act of 2007. The US Energy Information Administration (EIA) requires that the overall GHG emissions of cellulosic biofuel produce 60% lower carbon emissions[1] relative to jet fuel produced from fossil fuel in order to be eligible for public procurement.

It should be noted that based on the ISO guidelines and EPA recommendations, the 'biogenic' CO_2 emissions are considered carbon neutral and are not reported in the LCA analysis. The role of forests in the biogenic carbon cycle is the core concept behind the neutrality of carbon embedded within woody biomass. The biogenic carbon cycle

[1] **H.R.6:** http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf, Argyropoulos 2010: http://www.eia.gov/conference/2010/session2/paul.pdf

Woody biomass jetfuel continued on page 4

Woody biomass jetfuel continued from page 3

within the forestry context implies that forest vegetation removes carbon from the atmosphere through photosynthesis and emits it back into the atmosphere through natural processes such as forest fires and decay. When woody biomass is used to produce bioenergy (e.g., bio-jet fuel), it releases this stored carbon, resulting in no net increase in the atmosphere. In contrast, burning fossil fuel (e.g., coal, oil, and natural gas) releases carbon that was trapped beneath the surface of the earth into the atmosphere, resulting in a net increase in carbon emissions.

Forest-to-Pump Bio-Jet Fuel LCA: Assumptions and Processes

This paper presents the results of a framework 'cradle-to-gate' life-cycle of woody biomass-based bio-jet fuel using TRACI (Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts) indicator factors. In this paper 'cradle' is defined as beginning with natural forest regeneration of young trees and 'gate' is defined as the bio-jet fuel stored at a jet fuel storage facility, ready to be delivered to the pumps. To facilitate this preliminary analysis, it was assumed that the US Dept of Energy/ National Renewable Energy Laboratory(NREL) corn stover to ethanol process model (Humbird et al., 2011)[2] could be adapted and used to convert forestry residues to fermentable sugars. The Gevo, Inc. patented GIFT® (Gevo's proprietary integrated fermentation technology platform) and Alcohol to Jet (ATJ) processes are then used to convert the sugar stream into iso-paraffinic kerosene (IPK), which is the bio-jet fuel. Gevo, Inc. is one of the key corporate partners associated the NARA biofuels project. Gevo's isobutanol has successfully cleared registration with the U.S. EPA as a fuel additive. Further, Gevo has demonstrated that, Isobutanol, a four-carbon alcohol, can be converted to a mix of predominantly C12/C16 hydrocarbons, which meet or exceed the requirements of ASTM D7566-10a for hydroprocessed synthesized paraffinic kerosene (SPK), a blendstock used in jet fuel (US patent no. US8373012, dated Feb, 12, 2013). The resultant forest to pump LCA estimates the life cycle environmental performance of this integrated process of collecting and producing IPK from forestry residuals. To evaluate the various logistical/ procedural pathways, this paper explores a range of biomass transportation scenarios and incorporates (takes credit for) the avoided environmental emissions associated with avoiding the piling and burning of the woody biomass in the forest into the LCA calculations.

The analysis presented in this paper assumes an integrated biomass conversion facility, where the biomass storage, extraction of sugar from woody biomass and conversion of sugar into bio-jet-fuel,

[2] Process Design and Economics for Biochemical Conversion of Lignocellulosic Biomass to Ethanol; http://www.nrel.gov/docs/fy11osti/47764.pdf

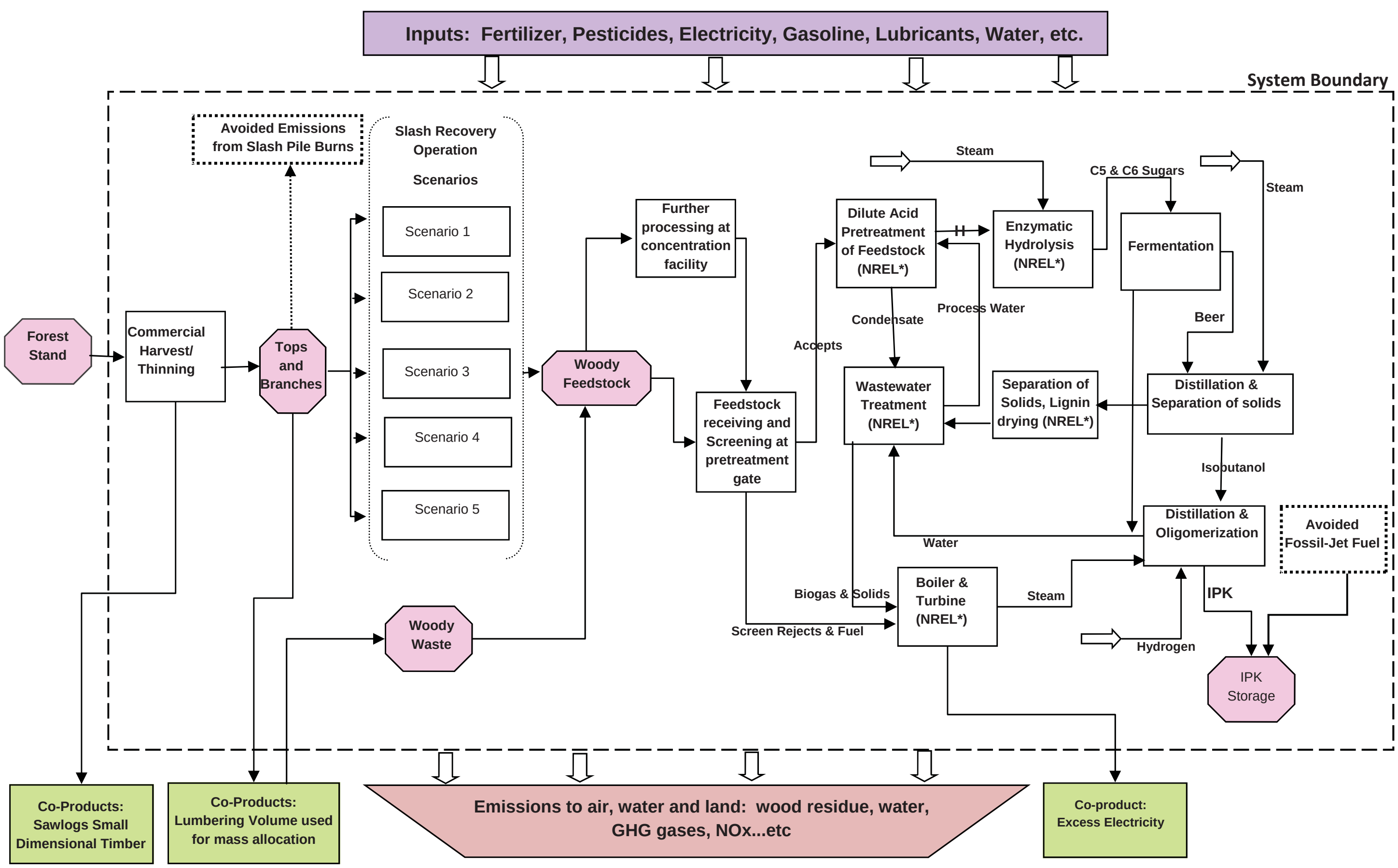

Figure 1: Overall scope for LCA of the woody biomass to bio-jet fuel process.

Woody biomass jetfuel continued on page 5

Woody biomass jetfuel continued from page 4

are all undertaken at the same location. The environmental impact of the complete process is analyzed in terms of the global warming, acidification, smog formation, and ozone depleting potentials, as per the TRACI standards (as recommended by the EPA). As per ISO guidelines for environmental impact assessment of biofuels, this paper will report the 100 year impact assessment numbers for each of the aforementioned impact categories (ISO 2006).

A simplified diagram of the system boundaries associated with the biofuel process is depicted in Figure 1. As shown in the figure, the overall system boundary for developing the LCA of the bio-jet-fuel consists of the following components: (i) woody biomass collection and processing within the forest including delivery to the pretreatment facility; (ii) conversion of the woody biomass to isobutanol and delivery to the bio-jet fuel production facility; (iii) conversion of isobutanol to jet fuel including transportation to the end-user; and (iv) conversion of the by-products derived from the isobutanol and jet-fuel production processes into useful co-products. The individual components of the flow chart presented in Figure 1 are explained in greater detail in the following sections.

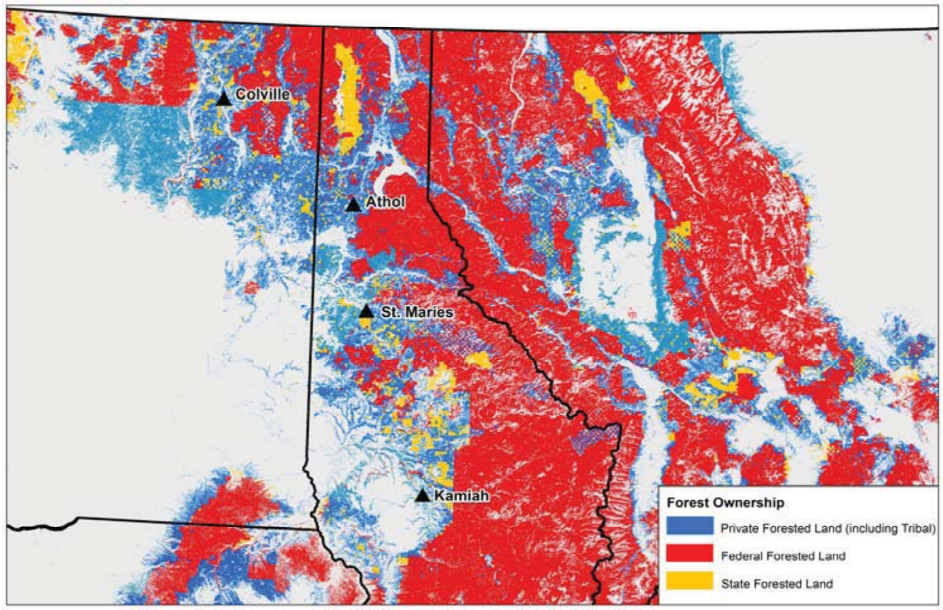

Figure 2: Regional scope of the study *(courtesy of Natalie Martinkus)*

Woody biomass source region

Geographical location, regional vegetation, and topographical characteristics significantly affect the environmental impacts associated with harvesting, collecting and transporting the woody residues from the forest landing to the biomass processing facility. With reference to the Pacific Northwest (PNW), the target region for the NARA project, LCA estimates for woody biomass collected from the interior west region (east of the Cascades) are substantially different from the western Washington/Oregon region. Moreover, within the same sub-region, differences in LCA results might result from differences in forest management intensity and the type of forest management practices associated with different types of forest ownership (e.g., private vs federal vs tribal). This paper assesses the environmental implications of producing bio-fuel within the eastern Washington, northern Idaho, and western Montana region (Figure 2). The analysis also considers the harvest residue collected from private and state forests, indicated by the blue and yellow zones in Figure 2. The biomass resource from federal forests, depicted by the red areas, is not included in this analysis.

Allocation, Avoided Emissions and System Expansions:

<u>Impact allocation associated with residual woody biomass</u>: Based on the forest woody biomass models and empirical results, it is estimated that 61% of the above ground biomass harvested from a mature forest in the interior west region consists of sawlogs and pulp logs with the remaining 39% being composed of branches and tops (residual woody biomass). These residuals represent the feedstock for the NARA biofuel project (Figure 1). However, a significant portion of the residuals ends up being scattered around the forest floor during the harvest and skidding operations. Based on empirical time-motion studies, it is estimated that 65% of the residuals get collected into slash piles at the primary harvest landings. This research assumes that 10% of the biomass in the slash pile is left behind at the landing during the loading, chipping and transporting of the biomass from the landing site to the biomass processing (pretreatment) facility. Based on these conditions, it is estimated that only 58.5% of the total harvest residuals generated during the timber harvest operation is delivered to the pre-treatment facility for conversion into biofuel.

Since residual woody biomass is generated during the harvest operation, and there are multiple products generated from the harvest operation (e.g., sawlogs, pulp logs and residuals), an allocation mechanism needs to be adopted to assign the environmental burdens associated with the production of each of the products. For this project, a 'mass flow' allocation principle was adopted. Since 39% of the above-ground tree biomass is generally left in the forest as harvest residues following a logging operation (either on the forest floor or at harvest landing), a mass equivalent proportion (39%) of the environmental impacts associated with harvest activities is allocated to the bio-jet fuel LCA.

<u>Avoided Emissions from Slash Pile Burning</u>: The harvest residues, primarily consisting of tree tops and branches, are generally collected into slash piles. Unless there is a market for the woody residues, the slash piles must be treated as part of a regional forest fire mitigation mandate. The dominant form of

Woody biomass jetfuel continued on page 6

Woody biomass jetfuel continued from page 5

Table 1A: Benchmark scenario for equipment configuration

Scenario	Harvest System	Loose Residue Shuttle (to secondary landing)	Chipper at Central Landing	Chip transportation to pre-treatment gate
Benchmark	Gentle Slope; Mechanized; (Feller Buncher, Track Skidder)	Modified dump truck (30 CY capacity)	Large Chipper; Direct Loader	Chip van (120 CY capacity)

Table 1B: Benchmark scenario for road-type specific transportation distances

Road type (Avg. miles/hr)		Spur Road (6 miles/hr)	1 ½ lane (20 miles/hr)	Gravel (29 miles/hr)	Highway (55 miles/hr)	Interstate (62 miles/hr)	Total
Benchmark	One way haul miles	2.5	5	10	20	37.5	75

treatment for these slash piles is broadcast burning. Conducting broadcast burns is labor intensive and time consuming, and they substantially increase forest management costs. Moreover, burning these slash piles releases the carbon sequestered in the woody biomass into the air (in the form of CO_2). Removing the harvest residuals from the forest greatly reduces the need for slash pile burning. Based on ISO 14044 (ISO 2006) guidelines, the bio-jet fuel LCA will incorporate the avoided environmental impact of mandatory slash pile burning in the region as a credit.

System Expansions: Based on the NREL model, a closed loop process is assumed for wastewater treatment and the waste lignin is burned in the process boiler and turbine (Figure 1). The waste water treatment process used in this analysis is a closed loop system consisting of anaerobic digestion, aerobic treatment and filtration which completely recycles all of the process water and eliminates the need to discharge waste water outside the system boundaries. Thin stillage is digested to produce biogas, which along with sludge from the anaerobic and aerobic treatment processes, are delivered to the boiler. A grate stoker fired boiler burns the biogas, sludge, screen rejects, lignin and unconverted solids to generate high pressure steam which is sent to a steam turbine. The turbine has three controlled extractions to deliver process steam with excess steam being condensed to produce electricity. A cooling tower supplies cooling water to the condenser and other processes.

Feedstock Logistics Scenario

The transportation and in-woods processing/ handling of the woody biomass can significantly influence the overall environmental performance of the NARA bio-jet fuel. Based on forest management practices, topography and existing road networks in the inland west region, a series of woody biomass transportation scenarios are considered in this paper. Emissions generated and total energy used were calculated for each of the feedstock handling and transportation scenarios to identify the optimal solutions that minimized environmental burdens. A benchmark scenario based on the most likely scenario in the region is presented in Tables 1A and 1B. The harvest system and in-woods feedstock handling benchmark scenarios are presented in Table 1A. The distance that the woody biomass must be transported from the harvest site to the processing facility on different types of roads is presented in Table 1B. A ‘gentle slope mechanized harvest’ system consists of a medium sized feller buncher and a track skidder for moving the harvested whole trees to the landing site. Within the benchmark scenario, the loose residues are transported from the primary landing to the secondary landing in a 30 cubic yard (CY) dump truck where they are chipped using a large chipper. In this scenario, the residuals must be transported from

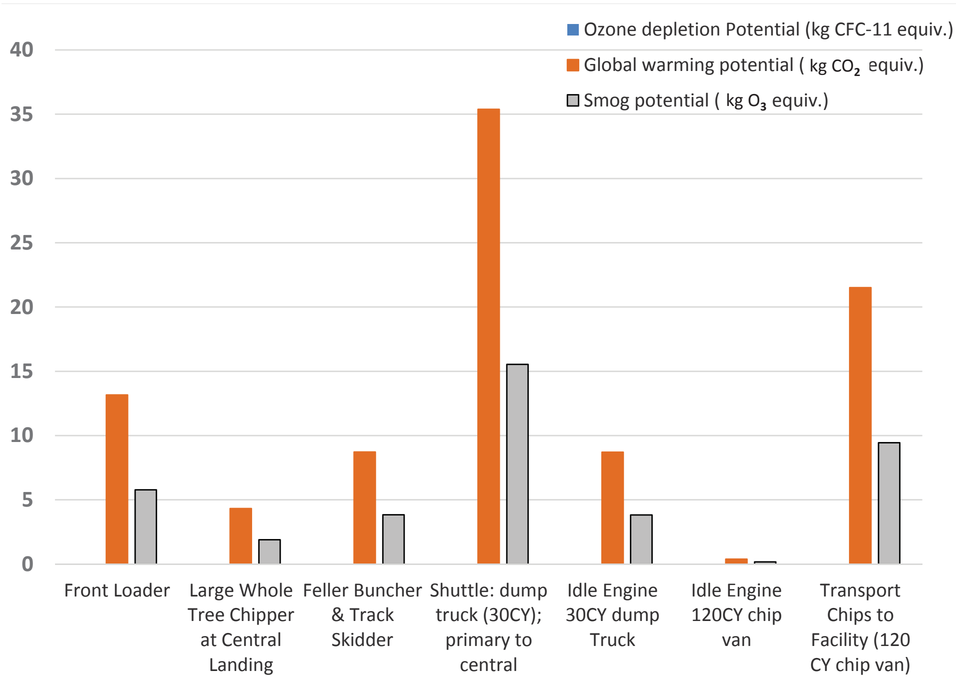

Figure 3: Feedstock logistics LCA contribution analysis

Woody biomass jetfuel continued on page 7

Woody biomass jetfuel continued from page 6

the primary landing to the secondary landing where the chipper and direct loader are located because the 120 CY chip vans cannot navigate the forest spur road. The chipped residues are directly loaded into a 120 CY chip van and transported to the pretreatment facility. Within the benchmark scenario the total distance from the primary landing to the biomass processing facility is 75 miles.

Table 2: Environmental impacts of feedstock logistics and avoided impacts of slash pile burning: benchmark scenario

		Feedstock Logistic System Impact	Avoided Impact	Total Impact
Global Warming Potential	kg CO_2 eq.	92.21	-57.32	34.89
Smog	kg O_3 eq.	40.51	-85.41	-44.90
Acidification Air	mol H+ eq.	72.08	-168.16	-96.09
Respiratory Effects	kg PM10 eq.	0.10	-10.98	-10.88

The results reveal that hauling forest residues over forest roads is the primary contributor to global warming potential (Figure 3). Options that reduce the carbon footprint associated with loose residue collection may be critical in reducing the overall environmental burdens of the process. The results further reveal that strategic forest road development will reduce the global warming potential of feedstock collection over the long run.

Avoided environmental burdens of slash pile burning:

The avoided environmental impacts derived from using residuals to produce bio-jet fuel rather than burning them in slash piles are substantial. By using the residuals to produce biofuel, we can substantially reduce the emissions that are generated from slash pile burning. Compared to the alternative of burning the slash piles, the environmental impacts of extracting and hauling the forest residuals to a processing facility can be substantially reduced.

To demonstrate this, the emissions generated for both scenarios (burning slash piles and extracting the residuals) were calculated. The results show that the avoided greenhouse gas (GHG) emissions from slash pile burning substantially reduce the total GHG emissions from woody feedstock collection and transportation, resulting in a 62.2% reduction of the global warming potential value (Table 2). Similarly, there is a net reduction in the total impact for the other environmental factors (smog formation, acidification, and respiratory effects). It should be noted that the large quantity of biogenic CO_2 emitted during the slash pile burning was not included in the analysis as per ISO and EPA guidelines.

Transportation Logistic Scenarios

Based on the previous LCA contribution analysis of the benchmark logistics scenario, presented in Figure 3, it is evident that shuttling the loose residuals from the primary landing to the secondary landing is the major GWP contributor. Hence, in this section of the analysis, multiple scenarios are developed to test the impact of different transportation logistics on the overall LCA of NARA bio-jet fuel. The alternate equipment scenario (Alt. Equip 1) presented in Table 3A assumes that the forest road between the primary landing and the secondary landing can accommodate a 50 CY roll-off container to shuttle loose residuals between the primary landing and the central landing, rather than the baseline 30 CY dump truck used in the baseline scenario.

The first alternate transportation scenario (Alt. Trans. 1) presented in Table 3B assumes that the primary landing is alongside a 1½ lane road (e.g., 0 miles spur road) where the residual processing equipment (e.g., large chipper and direct loader) and the 120 CY chip vans can be brought in to the primary landing and a centralized secondary landing is not required. The second alternate transportation (Alt. Trans. 2) scenario presented in Table 3B assumes that the distance between the primary landing and secondary landing is 5 miles of spur road. In this scenario, the residuals must be transported from the primary landing to the secondary landing where the chipper and direct loader

Table 3A: Alternate scenario for equipment configuration

Scenario	Harvest System	Loose Residue Shuttle (to secondary landing)	Chipper at Central Landing	Chip transportation to pre-treatment gate
Alt. Equip 1	Same as Benchmark	Roll-off container (50 CY capacity)	Same as Benchmark	Same as Benchmark

Table 3B: Alternate scenario for road-type specific transportation distances

Road type (Avg. road speed)		Spur Road (6 miles/hr)	1 ½ lane (20 miles/hr)	Gravel (29 miles/hr)	Highway (55 miles/hr)	Interstate (62 miles/hr)	Total
Alt Trans 1	One way haul miles	0	5	10	20	40.0	75
Alt Trans 2	One way haul miles	5	5	10	20	35.0	75

Woody biomass jetfuel continued on page 8

Woody biomass jetfuel continued from page 7

Table 3C: Alternate scenario for road-type specific transportation distances

Equipment Scenario	Transportation Scenario	Scenarios No.
Benchmark (30 CY Dump Truck)	Alt Trans 1 (no spur road)	A.1
	Benchmark (2.5 mile spur road)	**B.1**
	Alt Trans 2 (5 mile spur road)	**C.1**
Alt. Equip 1 (50 CY Container)	Alt Trans 1 (no spur road)	A.2
	Benchmark (2.5 mile spur road)	**B.2**
	Alt Trans 2 (5 mile spur road)	**C.2**

are located because the 120 CY chip vans cannot navigate the forest spur road. The total distance from the primary landing to the pretreatment facility for both of the alternate scenarios has been kept constant at 75 miles.

Combining the benchmark scenario with the alternate equipment configuration and the alternate transportation scenarios allows us to test a total of five feedstock logistic scenarios (Table 3C). The first alternate transportation (Alt. Trans. 1) scenario does not require transporting the forest residuals on a spur road, and therefore the alternate equipment scenario (point A.1, Figure 4) provided the same environmental impact as the benchmark scenario (point A.2).

After factoring in the avoided environmental burdens of slash pile burning, the total carbon footprint of the baseline scenario using a 30 cubic yard container

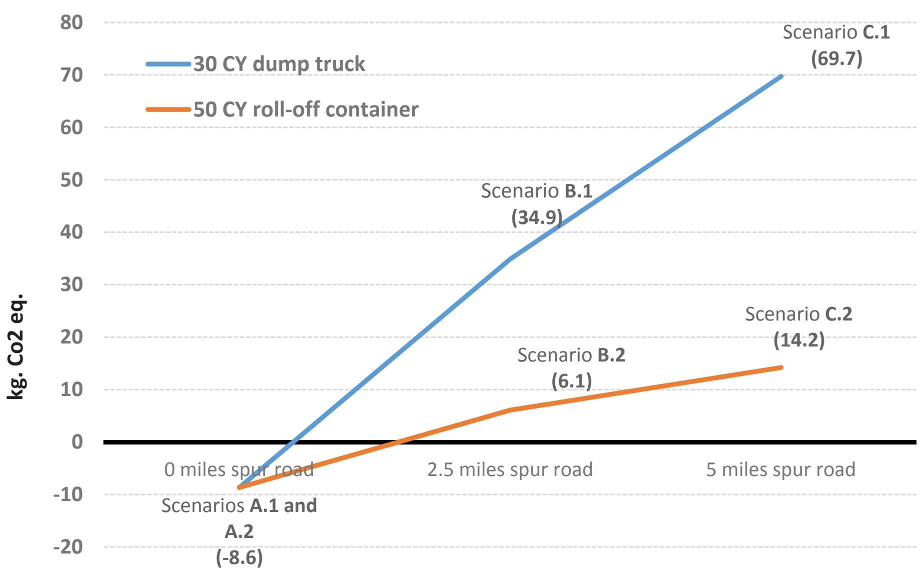

Figure 4: Global Warming Potential for alternate logistic scenarios

(point B.1 in Figure 4) was 34.9 kilograms of CO_2 per bone dry ton of woody biomass delivered to the pre-treatment facility. The environmental impact associated with scenarios A.1 and A.2, where the primary landing is located along a 1½ lane road and no spur road transportation is required, was negative for both scenarios (points A.1 and A.2). Using the larger 50 cubic yard container to haul the residuals 2.5 miles and 5 miles along a forest spur road (points B.2 and C.2, respectively) substantially reduced the global warming impacts relative to using the 30 CY dump truck.

Evironmental Impacts Associated with Biomass Conversion and Biofuel Refinery

A life cycle assessment was also conducted for a potential process to produce bio-jet fuel from forest residuals using a biochemical conversion process developed by the Department of Energy and the National Renewable Energy Laboratory (NREL) to produce a fermentable sugar stream from lignocellulosic biomass. The fermentable sugars are then converted to isobutanol (iBuOH) using a proprietary fermentation process. The isobutanol is then dehydrated to produce isobutene which undergoes an oligomerization process to produce bio-jet fuel (iso-paraffinic kerosene, IPK).

Since the NREL model uses corn stover as the feedstock, the NREL process model mass and energy balance were modified to simulate the use of forest residuals as the feedstock. To do this simulation, the high-level process area inputs and outputs were extracted from the NREL model and applied to the integrated NARA bio-jet fuel process. It may be noted that the NRELs dilute acid pre-treatment of bio-feedstock is only being used as a surrogate model in the NARA process. (Note. This feedstock change has not been vetted in a laboratory. Lab scale experiments of other pre-treatment options are being researched within NARA research team.)

Process cooling, steam and electrical power loads for distillation, separation of solids and oligomerization processes were then added in, so that the total biorefinery (and supporting auxiliary systems) loads would more accurately reflect the differences in feedstock, the different products of fermentation and the differences in the back-end chemistry. Modifications were made to the process areas as needed to account for differences in polysaccharide and lignin content between the two feedstocks.

The flow diagram for the integrated NARA forest residuals-to-IPK process is shown in Figure 1. The flow diagram shows that the feedstock is unloaded, screened and stored in metering bins for delivery to the pretreatment process. It is estimated that approximately 91% of the feedstock material will pass through the screen and be delivered to the pretreatment chamber, while 9% will be rejected and be used as fuel in the boiler. The feedstock is treated with a dilute sulfuric acid catalyst at a high temperature for a short period of time to liberate the hemicellulose (C6) sugars and break down the lignocellulosic material in preparation for enzymatic hydrolysis. The lignocellulosic material is then mixed with a cellulase enzyme and hydrolyzed to produce a fully saccharified sugar stream ready for fermentation.

Woody biomass jetfuel continued on page 9

Woody biomass jetfuel continued from page 8

Fermentation is performed using proprietary biocatalyst and isobutanol recovery process. Beer produced during the fermentation process is distilled using steam to produce isobutanol which is then dehydrated with a catalyst to form isobutene. The isobutene is oligomerized using another catalyst and then in the final step fully saturated with hydrogen to produce the bio-jet fuel (IPK) which is sent to a co-located storage facility.

A high level mass and energy (M&E) balance was developed by coupling the NREL Aspen simulation outputs, which are publicly available, with the Aspen simulation results for the two NARA biofuel conversion processes. The M&E balances were combined to create a total M&E balance for the integrated biorefinery. Finally, a heat balance for the combined heat and power (CHP) plant was developed in Thermoflex to simulate the production of electricity and process steam, cooling water, and electricity from the biomass materials which are available for energy conversion. These three models are not directly linked, so the high level results were combined in an Excel spreadsheet and there may be additional opportunities for heat integration and energy savings that are not reflected in the current energy balance.

The combined biorefinery simulations were totaled and normalized on the basis of one bone-dry ton (BDT) of woody biomass delivered to the biomass processing facility as feedstock input converted IPK. The model produced excess electricity which was sent to the local electricity grid and an energy credit was allocated to the IPK process. The model assumed that 6.857 kg of bone dried woody biomass produced 1kg of IPK.

The LCA specified that the process chemicals and cellulase enzyme were purchased from ancillary industries and the environmental impacts associated with the production of each of these chemicals were incorporated in the LCA analysis. On the infrastructure side, depreciation was modeled within the LCA for the fermentation plant, the (CHP), wastewater treatment, chemical production and IPK storage.

Finally, in the analysis it was assumed that the combustion of the biomass materials resulted in criteria pollutants being emitted into the atmosphere, including particulate matter, NO_x, SO_2, VOCs, CO, in addition to biogenic CO_2, ammonia, N_2O and SO_3. However, emissions from the combustion of the various vent gas streams were not estimated. The LCA analysis also assumed that the process recycled 100% of the waste water and there was no discharge of wastewater outside the system boundary. Solid wastes from the biomass conversion process included combustion ash and flue gas desulphurization residual slurry (calcium sulfate).

Table 4: Environmental Impacts of converting 1 Bone Dry Ton (BDT) of woody residue into IPK (Forest-to-pump)

		Contribution from		
		Feedstock Delivered to Biomass Facility	**Biomass Conversion and Biofuel Refinery (woody feedstock to IPK storage)**	**Total Impact**
Global Warming	kg CO_2 eq	34.89	190.27	225.16
Smog	kg O_3 eq	-44.90	20.20	-24.7
Acidification Air	mol H+ eq	-96.09	2.45	-93.64
Respiratory Effects	kg PM10 eq	-10.88	0.12	-10.76

The results presented in the Table 4 were developed using the baseline feedstock logistics scenarios presented in Tables 1 and 2. The results show that after accounting for the avoided emissions from burning the feedstock, the net CO_2 emissions for the feedstock process contributes approximately 15% of the overall LCA of bio jet fuel, as presented in the baseline transportation scenario. Notably, the feedstock process has net beneficial impacts on the three highlighted impact categories: smog, acidification air and respiratory effects (denoted by net reduction).

Comparative Analysis: Environmental Implications of NARA Bio-Jet Fuel vs Fossil Based Bio-Jet Fuel

The overall environmental impact associated with the production of bio-jet fuel can be better understood when compared against the emissions associated with fossil based aviation fuel. This section of the paper discusses the LCA emissions associated with transporting 1 metric ton of freight for one kilometer in an intercontinental flight using fossil fuel (kerosene) relative to using bio-jet fuel (iso-paraffinic kerosene, IPK)

Comparable aircraft using bio-jet fuel or fossil jet fuel will emit similar levels of carbon dioxide (CO_2), which is the primary source of greenhouse gas emissions. However, the primary distinction between biofuel and fossil fuel is the source of the carbon stored in the fuel. The environmental footprint associated with burning aviation fuels comes from two primary sources. First, the carbon stored in both aviation fuels is released during combustion. Second, there is a large amount of carbon emissions associated with the extraction, transportation and processing of crude oil into jet fuel relative to bio-jet fuel.

The use of fossil aviation fuels releases geologic carbon that has been stored in the ground, and those emissions represent a net addition of CO_2 to the atmosphere. The NARA bio-jet fuel uses wood residue derived from timber harvest operations to produce iso-paraffinic kerosene (IPK) jet fuel. Trees sequester atmospheric carbon dioxide as they grow and burning biofuels simply releases this sequestered carbon dioxide back into the environment. With a sustainable resource, where the amount of biomass extracted from the forest is less than the total biomass growth over a specified time frame, the net addition of CO_2 into the atmosphere will be negative. However, the conversion of forest residuals to bio-jet fuel requires various inputs from nature (the atmosphere)

Woody biomass jetfuel continued on page 10

Woody biomass jetfuel continued from page 9

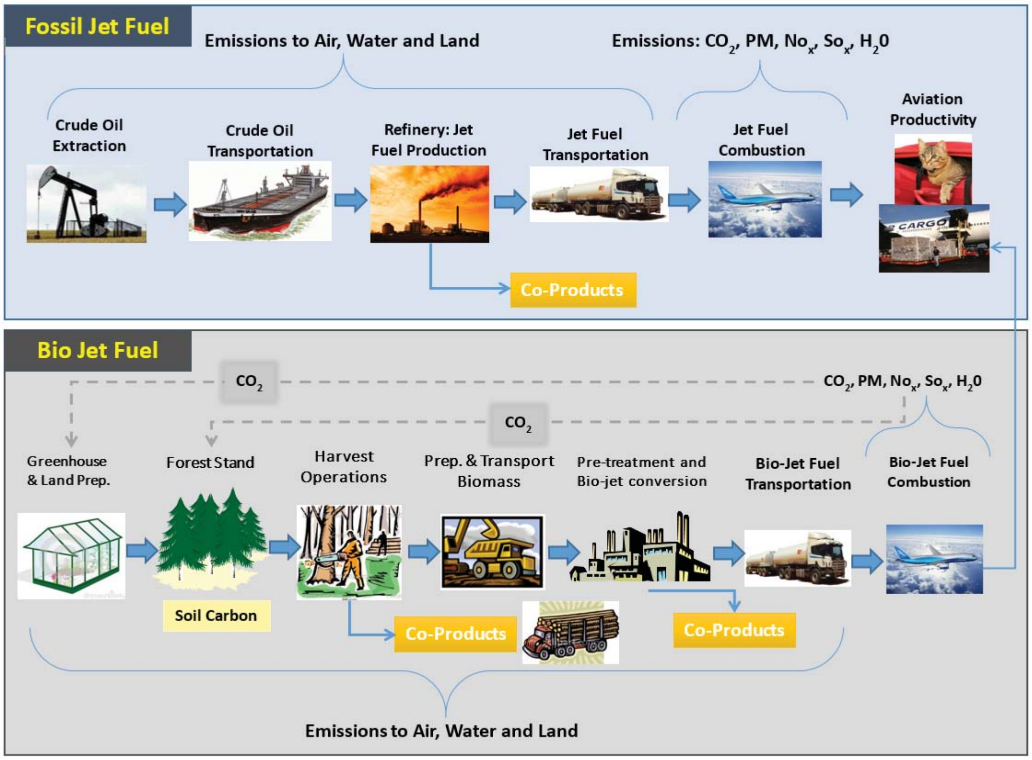

Figure 5. Comparing the LCA's of fossil based jet fuel against bio-jet fuel

and industry (the technosphere). Hence, the overall environmental footprint associated with the production of bio-jet 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 method of comparison. The 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 the combustion of fossil fuel-based jet fuel (Figure 5). The results of the LCA comparison for the 5 logistics scenarios previously described show that the overall global warming potential of the NARA bio-jet fuel, measured in kilograms of CO_2 emissions, ranges from between 30% and 44% of the fossil fuel-based jet fuel (Figure 6). In addition, the ozone depletion potential of the NARA bio-jet fuel ranges between 11% and 65% of that of the fossil fuel-based jet fuel. Hence, our analysis suggests that for the five logistical scenarios considered, a global warming potential reduction of more than 60% was achieved in four of the five cases (bars below the dotted red line in Figure 6). The only scenario where the NARA bio-jet fuel did not meet the 60% reduction requirement was the scenario where the forest residuals were transported 5 miles along forest spur roads. This scenario was included as an extreme case and it is expected that less than 5% of the commercially harvested forests would fit this situation. Moreover, the overall volume of biomass collected from these types of terrains is minimal relative to the forest residuals that are located close to the roadside. Hence, the overall GHG impact of the NARA bio jet-fuel is comfortably within the suggested 60% reduction. This result is significant in that it exceeds the mandated 60% emission reduction criterion specified in the US Energy Independence Act guidelines.

Acknowledgment

This work, as part of the Northwest Advanced Renewables Alliance (NARA), was funded by the Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30416 from the USDA National Institute of Food and Agriculture.

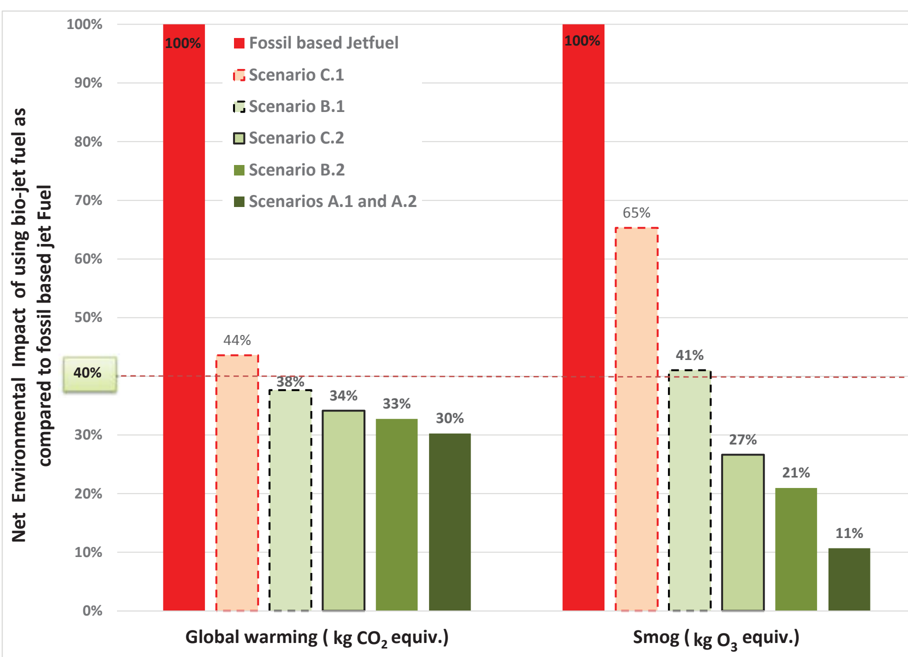

Figure 6. Net reductions in global warming and smog potential associated with bio-jet fuel used as a substitute for fossil-based jet fuel

Selected CINTRAFOR Publications

Phone: 206.543.8684 Fax: 206.685.0790 Web: www.cintrafor.org

WP = Working Papers **SP** = Special Papers* **RE** = Reprints **AV** = Available from Others **FS** = Fact Sheet

*Papers on policy, surveys, proceedings, and other items. Please call or see our website for a complete list of publications and their abstracts.

WP 122 China's Forest Sector: Essays on Production Efficiency, Foreign Investment, and Trade and Illegal Logging
Alicia S T Robbins.. 2012. (96pp) $50.00

WP 121 Impact of Green Bldg Programs on Japanese & Chinese Residential Construction Industries & Market for Importd Wooden Bldg Materials
Ivan Eastin, Daisuke Sasatani, Indroneil Ganguly, Jeff Cao and Mihyun Seol.. 2011. (74pp) $50.00

WP 120 Japanese F-4Star Formaldehyde Rating Process for Value-Added Wood Products
Ivan Eastin and D.E.Mawhinney. 2011. (34pp) $50.00

WP 119 Emerging Power Builders: Japan's Transitional Housing Industry After the Lost Decade
Daisuke Sasatani, Ivan Eastin, Joe Roos. 2010. (104pp) $50.00

WP 118 Exploring the Market Potential of Pacific Silver Fir in the US Residential Decking Market
Indroneil Ganguly, Ivan Eastin, Pablo Crespell, Chris Gaston. 2010. (46pp) $50.00

WP 117 Positioning and Market Analysis of the US Decking Materials Market: A Perceptual Mapping Approach
Indroneil Ganguly, Ivan Eastin, Pablo Crespell, Chris Gaston. 2010. (74pp) $50.00

WP 116 Economic Contribution
Ivan Eastin, Indroneil Ganguly, Daisuke Sasatani, Larry Mason, Bruce Lippke. 2009. (84pp) $50.00

WP 115 A Comparative Assessment of the North American & Japanese 2x4 Residential Construction Systems: Opportunities for US Building Materials. Ivan Eastin and Rose Braden. 2009. (57pp) $50.00

WP 114 Trends in the Japanese Forest Products Market and Implications forAlaskan Forest Products
Joseph Roos, Daisuke Sasatani, Valerie Barber, Ivan Eastin. 2008. (53pp) $50.00

WP 113 The Japanese Market for Laminated Lumber and Glulam Beams: Implications forAlaskan Forest Products
Joseph Roos, Daisuke Sasatani, Valerie Barber, Ivan Eastin. 2008. (23pp) $50.00

WP 112 An Economic Assessment of the Lumber Manufacturing Sector in Western Washington
Jean M. Daniels and John Perez-Garcia. 2008. (69pp) $50.00

WP 111 Review of the Japanese Green Building Program and the Domestic Wood Program
Ivan Eastin. 2008. (52pp) $50.00

WP 110 Forest Certification & its Influence on the Forest Products Industry in China
Yuan Yuan and Ivan Eastin. 2007. (69pp) $50.00

WP 109 A Meta Analysis of Willingness to Pay Studies
Adam Lewis, David Layton and John Perez-Garcia. 2007. (48pp) $50.00

WP 108 Material Substitution Trends in Residential Construction 1995, 1998, 2001 and 2004
Indroneil Ganguly and Ivan Eastin. 2007. (54pp) $50.00

WP 107 China Treated Lumber Market Study
Jeff Cao, Rose Braden, Ivan Eastin and Jeff Morrell. 2007. (56pp) $50.00

WP 106 The Market for Softwood Lumber in Japan: Opportunities for Douglas-fir Structural Lumber for Hirakaku
Ivan Eastin and Craig Larsen. 2007. (48pp) $50.00

WP 105 Overview of the Indian Market for US Wood Products
Indroneil Ganguly and Ivan Eastin. 2007. (82pp) $50.00

A complete list of CINTRAFOR Publications available for sale can be found online at:
http://www.cintrafor.org/publications/workingpapers.shtml

Quantity			Total
	WP 122	$50.00	
	WP 121	$50.00	
	WP 120	$50.00	
	WP 119	$50.00	
	WP 118	$50.00	
	WP 117	$50.00	
	WP116	$50.00	
	WP115	$50.00	
	WP114	$50.00	
	WP113	$50.00	
	WP112	$50.00	
	WP111	$50.00	
	WP110	$50.00	
	WP109	$50.00	
	WP108	$50.00	
	WP107	$50.00	
	WP106	$50.00	
	WP105	$50.00	
	WP104	$50.00	
	WP103	$50.00	

Please attach business card or provide the following information:

PUBLICATIONS ORDER FORM

Name: ____________________

Position: ____________________

Firm/Agency: ____________________

Address: ____________________

City: ____________________ State: ____________________

Zip Code: ____________________ Country: ____________________

Phone (Required): ____________________

Fax: ____________________

Email: ____________________

All payments in US funds. Payment via check or money order only. Must be drawn on a U.S. bank.

Total Publications	
Handling	$5.00
Postage/ $1.00 per item for US	
$2.00 per item for International	
Subtotal	
WA Residents Only 9.5% Tax	
TOTAL ENCLOSED:	

RETURN TO: CINTRAFOR
University of Washington
School of Environmental & Forest Sciences
Box 352100
Seattle, WA 98195-2100 USA

CINTRAFOR
University of Washington
School of Environmental & Forest Sciences
Box 352100
Seattle, WA 98195-2100 USA