COMMUNITY ECONOMIC IMPACT ANALYSIS OF HYPOTHETICAL NARA WOODY BIOMASS JET FUEL REFINERIES IN THE PACIFIC NORTHWEST

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Any opinions, findings, conclusions, or recommendations expressed in this publication are those of the author(s) and do not necessarily reflect the view of the U.S. Department of Agriculture.

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LIST OF ACRONYMS

BDT	Bone Dry Tons
CAPEX	Capital Expenditures
CIA	Community Impact Analysis
GDP	Gross Domestic Product
I/O	Input-Output Analysis
ID	Idaho
IPK	Iso-Paraffinic Kerosene
IMPLAN	Impact Analysis for Planning (software)
MMBF	Million Board Feet
MT	Montana
NARA	Northwest Advanced Renewables Alliance
OPEX	Operation Expenses
OR	Oregon
C2P	Cascades to Pacific region
PNW	Pacific Northwest
RINs	Renewable Identification Numbers
SAM	Social Accounting Matrix
WA	Washington
WMC	Western Montana Corridor
$MM	Million dollar

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EXECUTIVE SUMMARY

The Northwest Advanced Renewables Alliance (NARA) is focused on developing environmentally, socially and economically viable biofuel solutions for the Pacific Northwest (PNW). There is a plan to establish biorefinery facilities in the Cascades-to-Pacific (C2P) and the Western Montana Corridor (WMC). Bringing new industry would tremendously contribute to the local economy. Though, socio-economic structures of the two regions are noticeably different. C2P region has large and prosperous urban areas especially along Interstate-5, and its total value-added accounts for 3.2% of US GDP. Yet, there are many forest dependent rural counties especially on the Pacific Coast and Cascade Mountains and their economic performance remains weak. On the other hand, the area of WMC accounts for 2.4% of the US land, but its total value-added represents only 0.4% of the US GDP in 2014. Large parts of WMC are sparsely populated mountainous areas and alleviating rural poverty by providing living-wage jobs is one of the urgent issues. The introduction of biorefinery facilities is expected to bring considerable economic impacts for both C2P and WMC. It is critically important to quantify the community economic impacts in order to use it as a base of decision-making.

This study used regional input-output analysis (I/O) to measure the economic impacts of the introduction of the biorefinery facilities in C2P and WMC. I/O is a tool to measure the economic impacts. The total economic impacts are the sum of direct, indirect and induced impacts within the region. The direct effect is that a hypothetical biorefinery plant reacts to meet the increased demand. As the biorefinery plant increases the outputs, there will be an increase in demand on the suppliers and so on down the supply chain, which is the indirect effect. As the direct and indirect effects create new jobs, they will spend on local goods and services, which is the induced effect of household. The study used three data source to estimate the economic impacts of the regions: 1) regional economic transaction data, 2) forest residual supply data and 3) operational expenses projection of the hypothetical biorefinery facilities.

In C2P, the economic impacts of the hypothetical biorefinery plant were estimated based on the projected operational expenses. The annual revenue of the plant is projected to be $318 million by selling jet fuel, activated carbon and lignosulfonates. This new demand results in $657-$694 million in industrial output including $230-$297 million in value-added through direct, indirect and induced effects. And, this creates 1,905-2,166 jobs in C2P region. The plant is projected to consume 846,059 BDT of forest residuals as feedstock. As a case study, we assume that the plant was located at Longview WA and they would pay $67.05 per BDT at gate for forest residuals. This scenario results in $76 million in total output creating 630 new jobs through the economic ripple effects in nearby counties. Some forest dependent counties substantially benefit from the feedstock collection projects. For example, Wahkiakum County WA and Pacific County WA increase their county output by 2.7% and 0.6%, respectively. In addition, this plant requires $1.04 billion of capital investment. The construction of the plant brings substantial economic impacts: Cowlitz County WA generates between $114 and $797 million annual output creating between 987 and 3,951 annual jobs during the construction phase. Though, these economic impacts dissipate soon after the construction is completed.

In WMC, hypothetical biorefinery facilities utilize depots in a supply chain to procure and preprocess feedstock because of the low biomass availability. As a case study, we assume the centralized biorefinery plant with a large depot located at Spokane WA and two small depots locate at Princeton ID and Laclede ID. In order to estimate the economic impacts of these integrated biorefinery facilities, the combined multipliers of the paper mill sector, sawmill sector, commercial-logging sector and transportation sector were used. The biorefinery facilities in WMC are projected to generate $71 million by selling jet fuel and wood pellets. This will result in $156 million in industrial outputs through the total economic impacts, of which $60 million is value-added. This creates 777 additional jobs in the region. The operation of feedstock collection in WMC has smaller scale than one in C2P, though, this can contribute to rural nearby counties. Ferry County WA increases the total output by 0.5% and the employment by 0.7%. Shoshone ID, Benewah ID, Pend Oreille WA, Clearwater ID and Stevens WA increase their outputs by about 0.2-0.3%.

The results show that the operations of the hypothetical biorefinery facilities in C2P and WMC can bring substantial economic impacts. Forest residual collection especially benefits the forest dependent rural counties in PNW where the local economy has been suppressed for decades. Understanding the community impacts that new biorefinery industry contributes to regional industrial outputs, value-added and employment is a critical step in formulating effective natural resource and social policy. The results of this study provides a strong justification to support for the introduction of biorefinery facilities to PNW.

INTRODUCTION

The subprime mortgage crisis started around 2006, abruptly ending the housing boom in the US, and US entered the Great Recession from December 2007 to June 2009. With tightening credit, an oversupply of foreclosed homes, and a collapse in speculative housing investment, the housing starts plunged from 2.07 million units in 2005 to 0.55 million units in 2009 (US Census Bureau, 2016). Since housing market consumes the majority of US softwood lumber, the production of the softwood lumber in the US decreased from 40,457 MMBF in 2005 to 23,280 MMBF in 2009 (WWPA, 2009). Simultaneously, the lumber price plunged due to the low demand. For example, the average price of green Douglas-fir (#2 & Better 2X4 8' Portland rate) declined from $345 in 2005 to $151 in 2009 (Random Length, 2012). PNW (ID, MT, OR, and WA) holds an abundance of quality forest resources and produces about 37% of nation's softwood lumber in 2009, and thus forest dependent communities in PNW hit hard by the housing crisis (Keegan et al., 2011).

Housing starts have recovered slowly, but steadily since then: the housing starts increased to 1.11 million units in 2015 (US Census Bureau, 2016). However, the recovery from the Great Recession has been largely confined to some large urban areas in PNW, and others still feel economic stress. People in small town and rural communities are less likely to start new business than they have been in the past (EIG, 2016), which jeopardizes the economic future of the rural communities.

The hypothetical biorefinery facilities in WMC and C2P will use local labor, forest residuals, and other variable inputs to produce jet fuel and co-products. The facilities likely bring great economic impacts to the region since they can create more related business and create new jobs in the region. Since the biorefinery facilities consume local forest residuals as feedstock, introduction of the plants especially benefit the forest dependent communities in PNW. Though, policymakers need reasonable economic information on which to base decisions. Consequently, this study will quantify the community economic impacts (CIA) of the hypothetical biorefinery projects in the region.

Many studies have examined the economic impacts of woody-based biomass energy utilization by applying input-output analysis (I/O). I/O is a tool to measure direct, indirect and induced economic impacts (Leontief, 1936, Miller and Blair, 2009). For example, Gan and Smith (2007) estimated the economic impacts of woody biomass for electricity generation in East Texas. The economic impacts of woody biomass utilization for bioenergy in Mississippi were examined by using I/O model (Perez-Verdin et al., 2008, Joshi et al., 2012). The economic impacts of the potential biomass collection by introducing new conversion technology in Washington State were estimated by applying I/O model (Sasatani, 2016). As an ongoing project, I/O model is applying to assessing the socioeconomic impacts of crop adoption for hybrid poplar-based biofuel development in California (Bandaru et al., 2015). This study will also use I/O model framework to estimate the economic impacts derived by the introduction of biorefinery plants in PNW.

TASK 1: COMMUNITY ECONOMIC IMPACT ASSESSMENT

Task Objective

NARA envisions and facilitates an environmentally, economically, and socially sustainable wood-based biofuels and co-products (hereafter "biorefinery") industry in PNW. This study focuses on the macroeconomic aspects of the NARA project. The goal of this particular research is to quantitatively assess the economic impacts associated with the introduction of hypothetical biorefinery facilities within C2P and WMC regions. The biorefinery facilities consume local forest residuals as feedstock. Forest residuals are byproducts of timber harvests and thinning activities. Selecting potential facility locations will determine the transportation logistics of feedstock, and thus it influence the economic impacts to communities (Polagye et al., 2007). Accordingly, we will also explore how the feedstock collection economically impacts the smaller communities (i.e., county). Applying I/O model, economic impacts derived by the hypothetical biorefinery facilities and their feedstock collection activities were estimated.

Methodology

Data

The study utilized three major data sources. Inter-industrial economic transaction and social accounting matrix (SAM) data were obtained from IMPLAN (MIG Inc. 2016). The data of forest residual availability by county were provided by Natalie Martinkus and Gregory Latta. Projected operation expenses (OPEX) and capital expenditures (CAPEX) data for the biorefinery facilities in WMC and C2P were provided by Tom Spink, Gevan Marrs (techno-economic analysis team; TEA) and Kristin Brandt. Cellulosic biorefineries usually face challenges due to technologies and finance associated with the operation (Martinkus, 2016), but this study used the point-projection by experts under the most likely scenario. In other words, this study does not consider any risk, uncertainty and disturbance associated with the business operation.

Input-output model (I/O)

The introduction of a new bioenergy sector in the C2P and WMC creates economic activity. It benefits the hypothetical biorefinery facility itself as well as its suppliers, related industries, household and whole community within the region. To quantitatively measure the economic impacts from the introduction of the facilities, regional I/O tables were developed. The analysis of expenditures together with the use of I/O allows to measure how the direct economic effects ripple through the economy to generate additional indirect and induced impacts.

An I/O is constructed from observed data for a particular economic region. The economic activity in the region is separated into a number of aggregated industries/sectors, such as commercial logging sector, sawmill sector, and truck transportation sector. The necessary data for I/O is the transaction relationships from each of the producers/sellers to each of the purchasers/buyers, which is called interindustry flows. In addition, the sales to or purchases from exogenous institutions, such as households, government and foreign trade, are also included. I/O assumes that the total output from industry is equal to the sum of final and intermediate demands for its product (Leontief, 1936). Assume that the economy can be categorized into n sectors;

$$x_i = \sum_{j=1}^{n} z_{ij} + f_i \ ,$$

where x_i is the total output of sector i; z_{ij} is the values of the interindustry transactions from sector i to sector j; f_i is the total final demand for sector i's product. As describing the above equation in matrix form;

$$X = Zi + F \ ,$$

where X is the vector of the total output; Z is the matrix of interindustry transaction; i is a column vector of 1's; F is the vector of the final demand. The technical coefficient, $a_{ij}=z_{ij}/x_j$, is the amount of output from sector i required for producing one unit of output in sector j. Then,

$$X = AX + F \ ,$$

where the A matrix is the matrix of the technical coefficients. Manipulating the above equation leads to:

$$X = (I - A)^{-1}F \ ,$$

where I is the identity matrix. The matrix $(I-A)^{-1}$ is known as Leontief inverse matrix, a multiplier matrix of the I/O. Assuming the constant returns of scale and technique of production and the fixed coefficient of production (i.e., linear assumption), then the above equation can rewrite as:

$$\Delta X = (I - A)^{-1}\Delta F \ ,$$

where Δ represents the marginal changes. Consequently, once the marginal changes in the final demand are projected, I/O can estimate the changes in the total output of the region (Miller and Blair, 2009). Since I/O assumes that the cross-sectional economic structure is rigidly fixed and the relationship is linear per se, this equation can apply to not only total industrial output but also employment and value-added.

There are two types of multipliers used in this study: type I and type SAM multipliers (Miller and Blair, 2009). The type I multiplier accounts for both direct and indirect effects of an economic activity. The direct effects are the biorefinery's reaction to meet the increased demand. As the biorefinery increases the output, there will be an increase in demand on its suppliers and so on down the supply chain, which is the indirect effect. In order to calculate the type I multiplier (A matrix), all interindustry transactions[1] are included. The type SAM multipliers incorporates social accounting matrix information to capture the inter-institutional transfers. Thus, the type SAM multiplier accounts for direct, indirect and induced effects of economic activity. As a result of the direct and indirect effects, the level of household income in the region will increase as a result of increased employment and dividends, and a proportion of these will be immediately spent on local goods and services, which is the induced effect of household. It is important to note that the induced effect in this study includes the re-spent by household, but excluded the re-spent by local or federal government. Thus, the SAM multiplier formulation internalizes employee compensation, proprietors' income and households[2]. This means money to the domestic trade, foreign trade and federal, state and local governments are regarded as economic leakages from the region.

Regional Study Areas

This study explores two regions in PNW; C2P and WMC. C2P and WMC are completely different in terms of the socio-economic structure.

C2P

C2P in this study includes the 38 counties from the Pacific Ocean to the mid-Cascade Mountains in Oregon and Washington as shown in Figure CIA-1.1. The region is from Whatcom County WA on the northern tip to Curry, Josephine and Jackson County OR on the southern tip. Large urban areas, such as Seattle/Tacoma/Everett/Bellevue, Portland/Vancouver/Hillsboro, Salem, Eugene, Olympia, Medford and Bellingham, locate along I-5 corridor, and most of the population is concentrated there. Though, there are many forest dependent communities especially in Pacific Coast and on the Cascade Mountains.

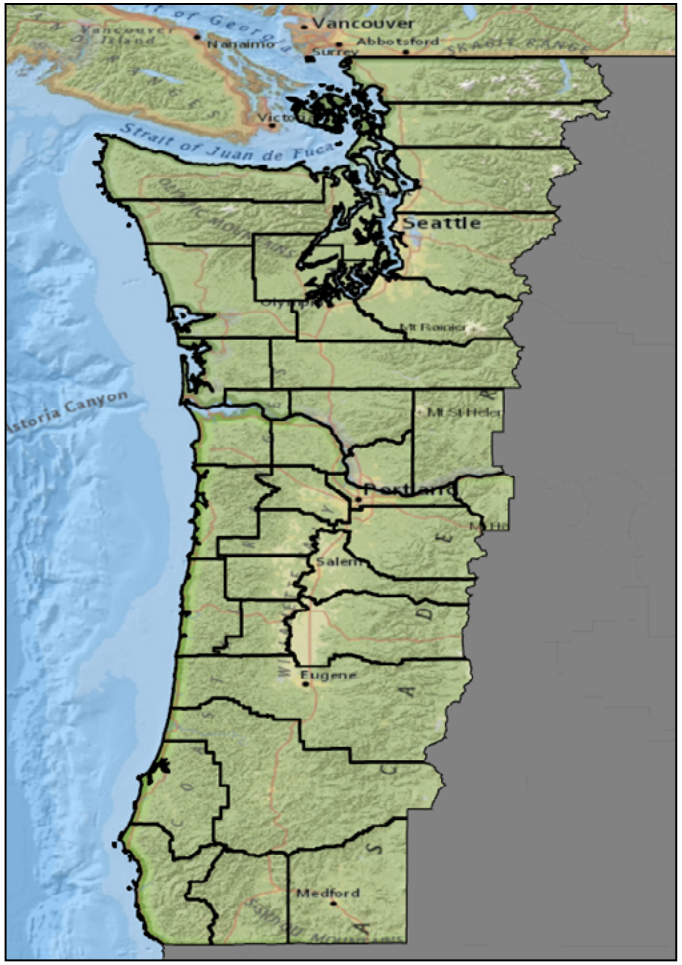

Figure CIA-1.1. A map of C2P region

[1] IMPLAN uses 526 different industry sectors in 2014 data.

[2] IMPLAN uses 9 different household income categories in 2014 data.

Table CIA-1.1 presents the descriptive data of 38 counties in C2P. In 2014, C2P region held about 9 million people and hired 5.3 million employments, which is 2.9% of the nation's employment. The total output[3] of the region was about $1 trillion, which is 3.1% of US total output. The region's top industries in terms of output are aircraft industry (7.8% of the total output), real estate industry (4.7%), semiconductor industry (4.6%), wholesale industry (4.6%), renting industry (4.2%) and software industry (3.9%). Sawmill industry is ranked 56th accounting for 0.4% of the total output in the region. The total value-added in the region was about $557 billion, which accounts for 3.2% of the nation's GDP. The average compensation per employee was $54,128: Washington State has about 25% higher average compensation per employee ($58,703) than Oregon State ($46,885). The counties that host large urban areas and strong companies, such as King, Multnomah, Washington, Snohomish and Pierce, are extremely prosperous. These top five counties account for 70.6%, and top eight counties (plus Clackamas, Clark and Whatcom) account for about 80% of the region's economic output. On the other hand, many rural counties have been economically struggling, and how to make jobs in these areas is one of the critical challenges to resolve.

Table CIA-1.1. Population, employment, and value-added by county in C2P in 2014

County	State	Population (persons)	Employment (persons)	Output (MM$)	Value-added (MM$)	Wages/Emp ($)	Pop'n (%)	Output (%)
King	WA	2,079,967	1,636,594	361,628	220,327	69,263	23.1%	36.6%
Multnomah	OR	776,712	615,647	97,602	55,923	52,105	8.6%	9.9%
Washington	OR	562,998	317,531	91,666	58,064	68,104	6.3%	9.3%
Snohomish	WA	759,583	348,500	86,482	40,007	57,545	8.5%	8.7%
Pierce	WA	831,928	397,531	60,314	36,426	50,886	9.3%	6.1%
Clackamas	OR	394,972	227,068	33,159	17,590	39,625	4.4%	3.4%
Clark	WA	451,008	197,819	32,362	16,564	43,431	5.0%	3.3%
Whatcom	WA	208,351	113,963	25,844	9,830	40,766	2.3%	2.6%
Lane	OR	358,337	192,018	25,722	13,336	39,143	4.0%	2.6%
Marion	OR	326,110	179,805	23,112	12,723	42,402	3.6%	2.3%
Thurston	WA	265,851	133,744	16,800	10,442	46,239	3.0%	1.7%
Kitsap	WA	254,183	121,811	15,981	10,632	50,949	2.8%	1.6%
Skagit	WA	120,365	63,020	15,286	5,551	42,242	1.3%	1.5%
Jackson	OR	210,287	116,339	14,639	7,197	34,296	2.3%	1.5%
Cowlitz	WA	102,133	45,157	9,631	3,965	45,610	1.1%	1.0%
Linn	OR	119,356	52,913	9,134	3,871	40,764	1.3%	0.9%
Yamhill	OR	101,758	47,050	7,094	3,076	36,472	1.1%	0.7%
Benton	OR	86,316	53,954	6,977	4,063	43,115	1.0%	0.7%
Douglas	OR	106,972	49,248	6,238	3,114	35,976	1.2%	0.6%
Lewis	WA	75,128	31,616	4,894	2,454	37,273	0.8%	0.5%
Josephine	OR	83,599	37,582	4,307	2,081	28,632	0.9%	0.4%
Island	WA	79,275	33,495	4,127	2,562	40,262	0.9%	0.4%
Grays Harbor	WA	70,818	29,169	3,929	1,981	37,641	0.8%	0.4%
Clallam	WA	72,715	33,414	3,859	2,057	32,445	0.8%	0.4%
Coos	OR	62,475	29,299	3,590	1,825	35,352	0.7%	0.4%
Clatsop	OR	37,474	23,767	3,318	1,499	33,820	0.4%	0.3%
Polk	OR	77,916	26,376	3,259	1,512	32,675	0.9%	0.3%
Lincoln	OR	46,406	24,659	3,083	1,500	31,690	0.5%	0.3%
Mason	WA	60,711	19,721	2,655	1,313	35,349	0.7%	0.3%
Columbia	OR	49,459	16,015	2,341	1,029	29,762	0.6%	0.2%
Hood River	OR	22,885	16,542	2,123	977	34,083	0.3%	0.2%
Tillamook	OR	25,342	13,075	1,953	764	30,498	0.3%	0.2%
Jefferson	WA	30,228	13,577	1,659	783	27,271	0.3%	0.2%
Pacific	WA	20,561	9,450	1,245	619	30,462	0.2%	0.1%
San Juan	WA	16,015	10,626	1,150	569	21,429	0.2%	0.1%
Curry	OR	22,335	10,154	1,099	540	26,585	0.2%	0.1%
Skamania	WA	11,340	2,928	491	233	32,651	0.1%	0.0%
Wahkiakum	WA	4,067	1,481	165	76	22,181	0.0%	0.0%
Subtotal	**WA**	**5,514,227**	**3,243,618**	**648,504**	**366,390**	**58,703**	**61.4%**	**65.6%**
Subtotal	**OR**	**3,471,709**	**2,049,039**	**340,418**	**190,683**	**46,885**	**38.6%**	**34.4%**
Grand Total	**C2P**	**8,985,936**	**5,292,658**	**988,922**	**557,073**	**54,128**	**100%**	**100%**

WMC

WMC encompasses the western half of Montana and parts of northern Idaho and northeastern Washington, including the 37 counties as shown in Figure CIA-1.2. The region is bounded by Spokane County WA and Pend Oreille County WA on the west to Yellowstone County MT on the east. Lemhi County ID forms the southwest corner and Toole County MT forms the northeast corner. The area of WMC accounts for 2.4% of the whole US land.

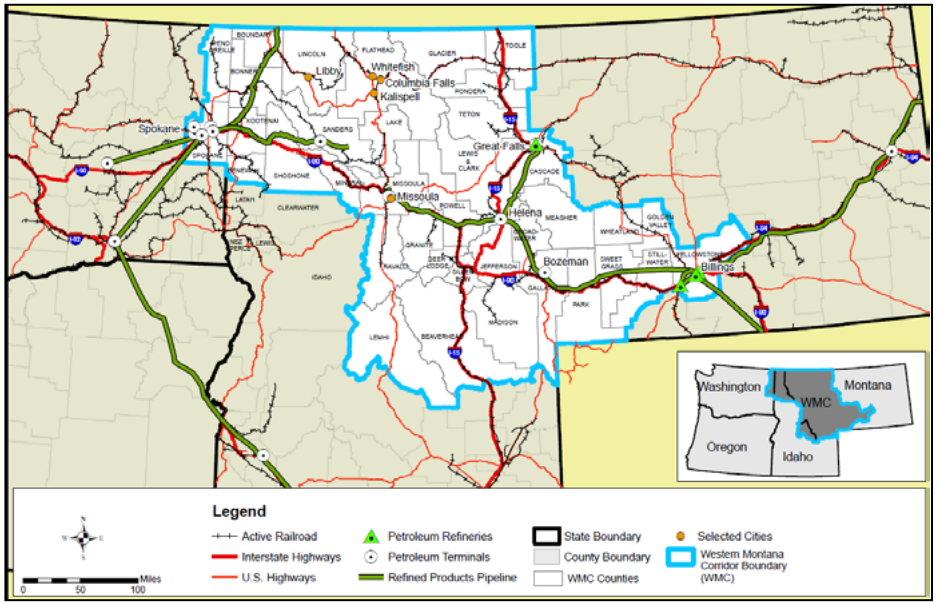

Figure CIA-1.2. WMC Map

[3] Industrial output is the sum of the value-added across all sectors in the economy plus intermediate demand from industrial uses.

Table CIA-1.2 presents the general description of WMC region in 2014. Total population was about 1.6 million, which accounts for 0.5% of the US population. The total employment was 944,407 and industrial output is nearly $136 billion. Gross regional product was $66.3 billion, which accounts only 0.4% of US GDP in 2014. The average household income was $97,805 and the average compensation per employee was $37,978, substantially lower than those numbers in C2P. Spokane County WA is the largest economy representing about 30% of population and industrial output within the WMC region. There are some smaller urban areas, such as Billings, Missoula and Great Falls; though, the majority of counties are rural mountainous areas in WMC. Top 7 counties (Spokane, Yellowstone, Kootenai, Missoula, Gallatin, Cascade and Flathead) account for 73.7% of the population and 78.1% of the industrial output in WMC.

Table CIA-1.2. Employment, value-added and industrial output by county in the WMC region in 2014

County	State	Populations (persons)	Employments (persons)	Output (MM$)	Value-Added (MM$)	Wage/Emp. ($)	Pop'n (%)	Output (%)
Spokane	WA	484,318	269,064	37,734	20,848	44,169	30.4%	27.8%
Yellowstone	MT	155,634	106,462	24,472	9,334	43,621	9.8%	18.0%
Kootenai	ID	147,326	77,491	10,281	4,846	32,643	9.2%	7.6%
Missoula	MT	112,684	78,781	9,114	4,912	35,854	7.1%	6.7%
Gallatin	MT	97,308	72,350	8,625	4,547	34,099	6.1%	6.4%
Cascade	MT	82,344	51,328	7,890	3,547	39,825	5.2%	5.8%
Flathead	MT	94,924	60,526	7,803	3,807	33,114	6.0%	5.8%
Lewis & Clark	MT	65,856	46,616	5,388	3,123	42,113	4.1%	4.0%
Silver Bow	MT	34,680	20,438	3,290	1,696	40,523	2.2%	2.4%
Bonner	ID	41,585	21,961	2,929	1,241	27,106	2.6%	2.2%
Ravalli	MT	41,030	19,314	2,118	960	25,369	2.6%	1.6%
Lake	MT	29,099	13,440	1,470	680	27,453	1.8%	1.1%
Stillwater	MT	9,290	5,439	1,458	644	48,357	0.6%	1.1%
Park	MT	15,880	9,564	984	463	23,884	1.0%	0.7%
Lincoln	MT	19,125	8,519	963	461	27,567	1.2%	0.7%
Beaverhead	MT	9,345	5,667	874	429	30,403	0.6%	0.6%
Glacier	MT	13,696	6,218	865	410	36,281	0.9%	0.6%
Shoshone	ID	12,390	6,385	809	419	39,078	0.8%	0.6%
Boundary	ID	10,979	5,424	711	300	30,046	0.7%	0.5%
Pend Oreille	WA	12,985	4,280	677	322	39,254	0.8%	0.5%
Jefferson	MT	11,558	5,229	665	285	21,602	0.7%	0.5%
Madison	MT	7,820	5,821	664	340	26,864	0.5%	0.5%
Sweet Grass	MT	3,665	2,763	647	274	38,243	0.2%	0.5%
Benewah	ID	9,118	4,821	633	288	33,432	0.6%	0.5%
Toole	MT	5,150	3,281	602	302	38,208	0.3%	0.4%
Sanders	MT	11,364	2,755	593	249	23,037	0.7%	0.4%
Teton	MT	6,064	3,667	543	217	23,767	0.4%	0.4%
Lemhi	ID	7,726	4,038	443	211	24,199	0.5%	0.3%
Deer Lodge	MT	9,150	4,329	436	232	34,204	0.6%	0.3%
Pondera	MT	6,219	2,887	418	196	28,222	0.4%	0.3%
Powell	MT	6,909	3,679	411	218	33,263	0.4%	0.3%
Broadwater	MT	5,667	2,141	290	124	26,150	0.4%	0.2%
Mineral	MT	4,257	1,883	214	85	24,671	0.3%	0.2%
Granite	MT	3,209	1,775	191	84	19,856	0.2%	0.1%
Wheatland	MT	2,102	1,210	167	72	19,993	0.1%	0.1%
Meagher	MT	1,853	1,189	137	55	17,546	0.1%	0.1%
Golden Valley	MT	852	687	77	29	12,259	0.1%	0.1%
Total		**1,593,161**	**941,419**	**$135,586**	**$66,250**	**$37,994**	**100%**	**100%**

Impact Estimate Procedures

Because of the data availability, different estimation procedures were applied to measure CIA of the establishment of hypothetical biorefinery facilities in C2P and WMC.

C2P

The CIA of the hypothetical biorefinery project in C2P is estimated in three different phases: 1) biorefinery operation, 2) feedstock collection and 3) construction of the biorefinery plant. The main CIA is to estimate the economic impacts of the annual operation of the hypothetical biorefinery plant. In order to estimate the economic impacts of the plant, a new "biorefinery industry sector" was developed according to the operational projection of the plant by TEA, and it was inserted in the regional-level I/O table (aggregated 38 counties). The base year of the analysis was 2014 and the original interindustry transaction data from all 526 industries provided by IMPLAN were used to calculate the economic impacts. The economic impacts from the forest residual collection is already internalized in 1), but which counties and how much they would benefit from the hypothetical biorefinery at the certain location are worthy to explore. Accordingly, CIA of feedstock collection at a specific location was estimated by using county-level I/O model. Feedstock collection for the plant and its CIA will vary up to where the plant locates. As a case study, we assumed that the hypothetical biorefinery will be built at Longview, WA. Finally, the CIA during the construction phase is also estimated. This CIA is also location specific, so we used the same assumption as a case study—the hypothetical biorefinery will be built at Longview, WA. According to the CAPEX (capital expenditure) projected by TEA, the construction will be completed in 3 years. The economic impacts of the construction would be huge; though, this will dissipates in very short period of time.

Operation of the Biorefinery Plant in C2P

The presumption of this analysis is a hypothetical biorefinery plant (integrating pretreatment facility co-locating with an IPK production plant) is built in Longview WA[4] and its annual operation precisely follows the OPEX (operation expenses) projected by TEA team (NARA TEA Version 13.43; Marrs et al. 2016). In order to conservatively estimate the economic impacts, this study excludes the potential bio-fuel premium[5]. Table CIA-1.3 shows the income statement of the plant on the

[4] As using regional transaction data of C2P, economic impacts analysis of a hypothetical biorefinery should not be influenced by the location of the plant. Even though the plant was built in a different location within C2P, the economic impacts should be identical, ceteris paribus.

[5] Operational projection by TEA shows two scenarios. One is that the purchasers of IPK are willing to pay bio-fuel premium, so internal rate of return of the plant can reach 10%. The other scenario is that purchasers take IPK with the market price.

OPEX. It is projected that the annual revenues of the plant are $318.1 million and the operating costs are $248.2 million, so the operating earnings are $69.9 million. Operating costs are further broken down to department costs ($178.8 million), labor costs ($15.9 million), maintenance costs ($31.8 million), insurance ($5 million) and property tax ($16.5 million).

Table CIA-1.3. Summary of Income Statement of the hypothetical biorefinery plant in C2P

Total Revenues	**$ 318,085,673**
Operating Costs	**$ 248,170,591**
Department Costs	$ 178,794,522
Baghouse Bags	$ 89,201
Labor	$ 15,936,500
Maintenance	$ 31,845,403
Insurance	$ 5,000,000
Property Tax	$ 16,504,965
Operating Earnings	**$ 69,915,082**

In order to use the information into I/O framework, the items were disaggregated as shown in Table CIA-1.4. The plant obtains revenues from three products. The hypothetical plant manufactures 35.7 million gallons of iso-paraffinic kerosene (IPK), 196,224 dry tons of lignosulfonates and 66,192 dry tons of activated carbon. In addition, the plant can earn by selling 57,182,444 cellulosic renewable identification numbers (RINs) associated with IPK[6]. The assumed market price of IPK is $2.56/gallon, of lignosulfonate is $200/dry ton, and of activated carbon is $1,500/dry ton. Also, the assumed price of RINs is $1.54 per cellulosic RIN or $2.464 per gallon of IPK. Accordingly, the hypothetical plant is projected to earn $91.5 million from IPK, $88.1 million from RINs, $39.2 million from lignosulfonates and $99.3 million from activated carbon.

On the other hand, the cost will be broken down to feedstock, hog fuel, utilities, chemical and others. The plant will consume 846,059 bone dry tons (BDT) of feedstock and it is assumed $62.6 per BDT at gate. Among $178.8 million of the total department costs, the portion of feedstock is 29.6%, of hog fuel is 6.3%, of utility is 22.8% and of chemical products is 37.6%. Employee compensation and property tax are the cost on the income statement, but these are the part of the value-added of SAM. It is projected to hire 173 employees, and thus the productivity per employee is $1.84 million. TEA assumes the plant building is 100% equity finance and there are depreciation and losses forward recorded on cash flow statement for early stage of the operation (Marrs, 2015). The bonus profit may go to proprietors (i.e., equity owners); though, this is very uncertain. In order not to outlook the uncertain issue, this study focuses the normal operation after the eligibility of the depreciation ends. At that time, the taxable income becomes $69.9 million, and the projected income tax at 35% is $24.5 million. The remainder $45.4 million should be distributed to equity holders as proprietors' income.

Table CIA-1.4. Break down income statement of the biorefinery plant in C2P

Total Revenues	**$318,085,673**		
IPK		$91,491,910	
RINs		$88,060,963	
Lignosulfonates		$39,244,800	
Activated Carbon		$99,288,000	
Total Costs	**$215,729,126**		
Total Department Costs		$178,794,522	
Feedstock			$52,963,293
Hog Fuel			$11,340,000
Utilities			$40,838,260
Chemical			$67,163,969
Others			$ 6,489,000
Baghouse Bags		$ 89,201	
Maintenance		$ 31,845,403	
Insurance		$ 5,000,000	
Value-added	**$102,356,547**		
Employee Compensation		$15,936,500	
Property Tax		$16,504,965	
Income Tax		$24,470,279	
Proprietors Income		$45,444,803	

The previous Table CIA-1.4 was further broken down in order to develop the new "biorefinery industry sector" inserting the current I/O table. Each item on the OPEX was closely investigated with Tom Spink. We determined how much materials/services are from or to 1) suppliers in C2P region, 2) suppliers in other parts of the US (domestic trade), and 3) foreign suppliers (foreign imports/exports). This process is important because purchasing items from other regions (i.e., domestic trade and foreign trade) are considered as the economic leakage in I/O framework.

Table CIA-1.5 presents the items which the biorefinery would sell to. All IPK will sell to the regional petroleum refineries, and then blended biojet fuel will be distributed to regional airports, such as Seattle-Tacoma International Airport and Portland International Airport. RINs are traded publicly like other commodity future contracts. Thus, it is safe to assume all of them are domestically traded out of the region. Lignosulfonates are used as plasticizers in making concrete and plasterboard. There is some demand within C2P region as well as other areas in the US. In addition, there is some strong foreign demand, especially in Asian countries.

[6] Calculated IPK equivalence value is 1.6 cellulosic RINs/gal IPK.

Thus, we project that 35% of lignosulfonates will sell locally, 25% will ship to other parts of the US, and 40% will export to other countries. Activated carbon in this project is planned to sell for the power plants to remove mercury from power plant flue gas. Coal-fired power plants are not common in C2P region, and thus we project 95% of the activated carbon will be shipped to other parts of the US. In conclusion, it is projected that the hypothetical biorefinery plant earns $91.5 million from local petroleum refinery industry, $13.7 million from local ready-mix concrete manufacturing industry, $5.0 million from local electric power generation (fossil fuel) industry, $192.2 million from domestic trade, and $15.7 million from foreign exports.

Table CIA-1.5. Items to sell by the biorefinery plant

Item	Total Value ($1000)	Industry to Sell	Value ($1000)	C2P	Domestic Trade	Foreign Exports
IPK	91,492	Petroleum refineries	91,492	100%		
RINs	88,061	Domestic trade	88,061		100%	
lignosulfonates	39,245	Mix concrete manuf.	13,736	35%		
		Domestic trade	9,811		25%	
		Foreign trade (exports)	15,698			40%
Activated Carbon	99,288	Electric power: fossil fuel	4,964	5%		
		Domestic trade	94,324		95%	

Table CIA-1.6 presents the items which the biorefinery would purchase from. All feedstock and hog fuel are from the C2P region. Utility services, such as electricity, natural gas, water, and landfill are locally supplied. Some chemical products, such as sulfur, lime, sulfur dioxide, and nitrogen gas are locally available. However, some items are not available in the region. For example, glucose is from other parts of the US, but about 3% of the price they pay would go to truck transportation sector within the region. How to determine the suppliers should be a strategic consideration for the management, but this list will give a good base line scenario for the hypothetical biorefinery plant at this moment. Perhaps in reality, they might purchase products from intermediators (i.e., wholesalers) more often rather than purchase products directly from the manufacturers. Accordingly, the scenario shown here should be very conservative end of the projection. The interindustry sales by a new biorefinery sector was developed from Table CIA-1.5 and Table CIA-1.6. These were inserted into the existing I/O matrix and then calculated multipliers.

Table CIA-1.6. Items to purchase by the biorefinery plant

OPEX Category	Item	Item Value	Industry to Sell	Value ($1,000)	C2P Region	Dom. Trade	Foreign Imports
Wood	Feedstock	52,963	Commercial logging	40,172	75.8%		
Wood	Feedstock	52,963	Truck transportation	12,791	24.2%		
Wood	Hog Fuel	11,340	Sawmills	11,340	100%		
Utility	Electricity	26,762	Electric power trans	26,762	100%		
Utility	Natural Gas	8,149	Natural gas distribut.	8,149	100%		
Utility	Landfill	5,490	Waste management	5,490	100%		
Utility	Process Water	437	Water, sewage	437	100%		
Chemical	Sulfur	5,540	Ground mineral	5,540	100%		
Chemical	CaCO3	1,370	Other inorganic chem	685	50%		
Chemical	CaCO3	1,370	Foreign trade	664			48.5%
Chemical	CaCO3	1,370	Truck transportation	21	1.5%		
Chemical	NaOH	530	Other inorganic chem	265	50%		
Chemical	NaOH	530	Domestic trade	257		48.5%	
Chemical	NaOH	530	Truck transportation	8	1.5%		
Chemical	CornSteep Liquor	360	Domestic trade	349		97%	
Chemical	CornSteep Liquor	360	Truck transportation	11	3%		
Chemical	Glucose	18,175	Domestic trade	17,630		97%	
Chemical	Glucose	18,175	Truck transportation	545	3%		
Chemical	NH3	910	Industrial gas manuf.	364	40%		
Chemical	NH3	910	Domestic trade	530		58%	
Chemical	NH3	910	Truck transportation	16	2%		
Chemical	SO2	40	Petrochemical manuf.	40	100%		
Chemical	Lime	1,410	Lime manufacturing	1,410	100%		
Chemical	Ca(OH)2	2,224	Other inorganic chem	2,224	100%		
Chemical	N2	10,880	Industrial gas manuf.	10,880	100%		
Chemical	CO2	250	Petrochemical manuf.	250	100%		
Chemical	Enzyme Royalty	1,000	Domestic trade	1,000		100%	
Chemical	Htec	7,308	Domestic trade	7,308		100%	
Chemical	Other Materials	16,290	Other miscellaneous	4,740	29.1%		
Chemical	Other Materials	16,290	Biological product	2,370	14.6%		
Chemical	Other Materials	16,290	Other organic chem	2,370	14.6%		
Chemical	Other Materials	16,290	Domestic trade	6,321		38.8%	
Chemical	Other Materials	16,290	Truck transportation	489	3%		
Chemical	Ion Exchange etx	523	Domestic trade	507		97%	
Chemical	Ion Exchange etx	523	Truck transportation	16	3%		
Chemical	pH Treatment	105	Other inorganic chem	105	100%		
Chemical	Filter additive	100	Domestic trade	97		97%	
Chemical	Filter additive	100	Truck transportation	3	3%		
Chemical	Floculants	150	Other inorganic chem	75	50%		
Chemical	Floculants	150	Domestic trade	73		48.5%	
Chemical	Floculants	150	Truck transportation	2	1.5%		
Products	Super Sacs Bags	1,574	Plastics packaging	944	60%		
Products	Super Sacs Bags	1,574	Dom/Foreign trade	629		20%	20%
Products	Paper Bags	2,518	Paper bag	2,518	100%		
Products	Baghouse Bags	602	Air purification	361	60%		
Products	Baghouse Bags	602	Dom/Foreign trade	241		20%	20%
Products	Supplies: Guards	10	Investigation security	10	100%		
Others	Miscellaneous	130	Wholesale trade	65	50%		
Others	Miscellaneous	130	Domestic trade	65		50%	
Others	Cooling Tower	700	Other inorganic chem	140	20%		
Others	Cooling Tower	700	Biological product	140	20%		
Others	Cooling Tower	700	Domestic trade	420		60%	
Others	Potable Water	11	Water, sewage	11	100%		
Others	Sanitary Waste Syst.	175	Waste management	175	100%		
Others	Mill Compressed Air	214	Electric power trans	107	50%		
Others	Mill Compressed Air	214	Air and gas compress	107	50%		
Others	Administration Bldg	25	Services to building	25	100%		
Others	Flare Gas System	20	Investigation Security	20	100%		
Others	RO tubes	100	Domestic trade	97		97%	
Others	RO tubes	100	Truck transportation	3	3%		
Others	Mill data software	500	Software publishers	500	100%		

Feedstock Collection in C2P

Feedstock collection can generate extra revenue in forestlands. This activity is especially helpful for the rural forest dependent communities. Yet, how much they can collect forest residuals totally depend on where the biorefinery plant locates because the logistic costs are the bottleneck of the feedstock collection. The hypothetical biorefinery in Longview WA (Cowlitz County) requires 846,059 BDT of feedstock, and it is assumed that they will pay $62.60 per BDT at gate. The forest residual supply to a given facility, considering transportation costs, availability of forest residuals and the cost of feedstock collection, was estimated by Gregory Latta and Natalie Martinkus. Fixed cost is $38.80 per BDT. The variable cost is $0.31 per BDT for every mile from the forest to the facility. As far as the sum of the fixed costs and variable costs are under the gate price (i.e., $62.60), the biomass can be deliverable to the plant. They will consume the biomass from the nearest forests to farther forests. Figure CIA-1.3 shows the feedstock supply to the Longview plant by county. The center circle is Longview. Cowlitz County supplies 154,040 BDT, following by Lewis County (135,632 BDT), Clatsop County (117,459 BDT) and Pacific County (111,715 BDT).

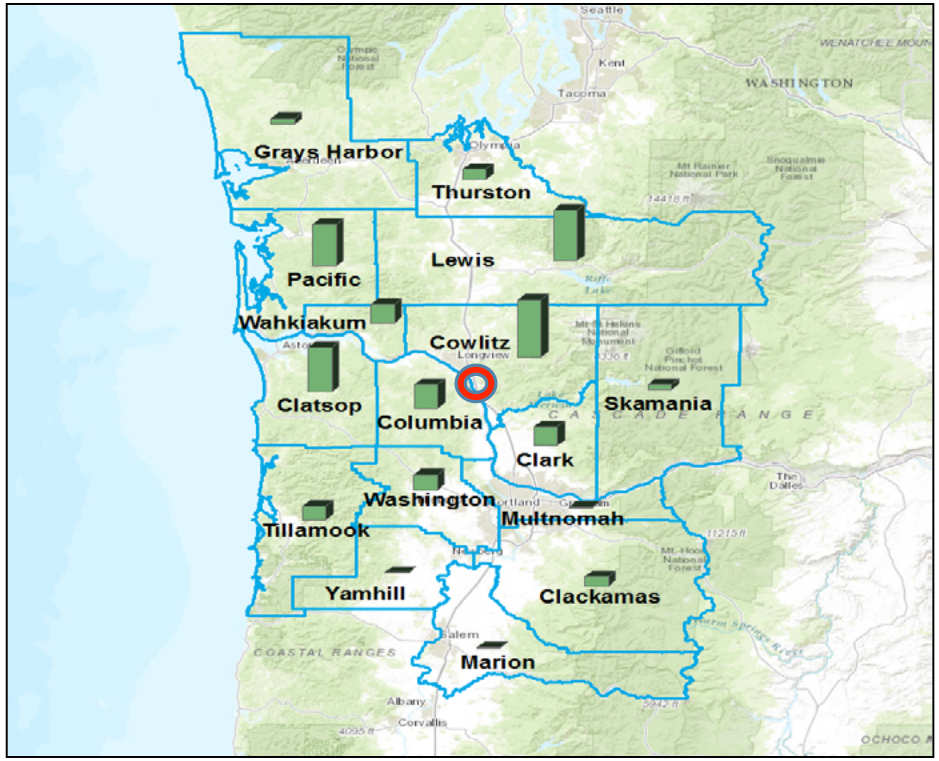

Figure CIA-1.3. Feedstock supply to Longview Plant by County

We assumed that variable costs were distributed to the truck transportation sector. The remainders will stay in commercial logging sector within the county. Table CIA-1.7 shows the detail revenues of the feedstock collection. Cowlitz County is where Longview locates and supplies 18.2% of the required feedstock. Among $9.6 million of the revenue, 14.8% goes to truck industry and 85.2% goes to the commercial logging industry. On the other hand, Grays Harbor County is far away from Longview and supplies only 1.8% of the required feedstock. Among $1.0 million of the revenue, 36.1% goes to truck industry and only 63.9% remains to the logging sector.

Table CIA-1.7. Detailed cost of feedstock collection by county

County	Volume (BDT)	% Supply	Total Revenue ($MM)	Variable Cost ($MM)	Remainders ($MM)
Cowlitz WA	154,040	18.2%	9.643	1.424	8.219
Lewis WA	135,632	16.0%	8.491	2.202	6.288
Clatsop OR	117,459	13.9%	7.353	1.942	5.411
Pacific WA	111,715	13.2%	6.993	2.155	4.838
Columbia OR	64,092	7.6%	4.012	0.514	3.498
Wahkiakum WA	50,853	6.0%	3.183	0.454	2.729
Clark WA	50,076	5.9%	3.135	0.725	2.409
Washington OR	40,728	4.8%	2.550	0.743	1.807
Tillamook OR	35,748	4.2%	2.238	0.766	1.472
Thurston WA	26,592	3.1%	1.665	0.564	1.101
Clackamas OR	24,962	3.0%	1.563	0.569	0.994
Grays Harbor WA	15,385	1.8%	0.963	0.348	0.615
Skamania WA	13,760	1.6%	0.861	0.274	0.587
Multnomah OR	2,707	0.3%	0.169	0.057	0.112
Marion OR	1,440	0.2%	0.090	0.033	0.057
Yamhill OR	871	0.1%	0.055	0.021	0.034
Total	**846,059**	**100%**	**$ 53.0**	**$ 12.8**	**$ 40.2**

All of the variable cost in Table CIA-1.7 cannot stay in the county because truck transportation companies can locate anywhere nearby, say between around Longview areas (Cowlitz County WA and Columbia County OR) and the county where forest residuals are collected. We assigned 50% of the transportation cost remains in the county where forest residuals are harvested, 15% goes to Cowlitz County, 15% goes to Columbia County and 20% goes to all counties along the direct path of truck. Table CIA-1.8 shows how much money will stay in the truck transportation sector and the commercial logging sector of each county. The revenue of commercial logging sector in Table CIA-1.7 and Table CIA-1.8 are identical, but of the truck transportation industry in both tables are different.

Table CIA-1.8. Revenues of truck transportation and logging sectors by county

County	Logging Industry	Truck Industry
Cowlitz WA	$ 8,218,969	$ 4,196,284
Lewis WA	$ 6,288,400	$ 1,318,531
Clatsop OR	$ 5,411,099	$ 970,930
Pacific WA	$ 4,838,395	$ 1,094,855
Columbia OR	$ 3,498,400	$ 2,527,063
Wahkiakum WA	$ 2,729,129	$ 370,809
Clark WA	$ 2,409,287	$ 390,160
Washington OR	$ 1,806,557	$ 454,633
Tillamook OR	$ 1,472,130	$ 382,832
Thurston WA	$ 1,100,564	$ 299,418
Clackamas OR	$ 993,756	$ 286,062
Grays Harbor WA	$ 615,435	$ 173,824
Skamania WA	$ 587,026	$ 137,185
Multnomah OR	$ 111,962	$ 161,560
Marion OR	$ 57,487	$ 16,335
Yamhill OR	$ 33,897	$ 10,320
Total	**$ 40,172,494**	**$ 12,790,799**

Construction of the Plant in C2P

According to the CAPEX, the hypothetical plant will be constructed in 3 years. The fixed capital investment is $1.04 billion excluding the land acquisition fee of $7.8 million. They spend $83.2 million (8%) in the first year, $624.3 million (60%) in the second year and $333.0 million (32%) in the third year. We assume all monies are first absorbed by the construction of new manufacturing structures sector. The CIA of this task used the I/O of Cowlitz County since we assumed the plant would be built in Longview. We also estimated the economic impacts of whole C2P region, so the difference between the total economic impacts of C2P and Cowlitz County represents the economic ripple impacts of other regions inside of C2P.

WMC

The CIA of WMC used operational assumptions developed by Martinkus (2016). Economic impacts are associated from two sources: 1) biorefinery plant operations and 2) feedstock production/collection. Before analyzing the data, regional I/O table aggregating 37 counties was created by using 2014 interindustry data obtained from IMPLAN. In addition, county-level I/O models were created in order to measure the economic impacts of feedstock production/collection activities in each county.

Because of the low productivity of forest biomass in WMC, forest residuals are spatially dispersed. Utilizing biomass depots in a biorefinery supply chain to procure and preprocess feedstock would mitigate supply risk in regions of low biomass availability (Lamers et al., 2015). Accordingly, hypothetical integrated biorefinery facilities, consisting of a central IPK production plant with three wood flour mills (i.e., biomass depots), is proposed in WMC (Martinkus, 2016). In this scenario, 280,000 BDT of forest residuals are delivered to three wood flour mills and 250,000 BDT of micronized wood (i.e., wood flour) is delivered to the central IPK production plant. The scale of the hypothetical biorefinery plant in WMC is about one thirds compared to the plant in C2P in terms of the feedstock consumption. The plant uses saccharification process and produces IPK (5,100,000 gallons) with wood pellets (170,700 BDT) as co-product[7] (Table CIA-1.9). The assumed price of IPK is $2.56 per gallon and of RINs is $1.54 per cellulosic RIN or $2.464 per gallon of IPK, which is same as C2P scenario. Wood pellets are made from micronized wood hydrolyzed residuals and have 9.7% more energy content than usual wood pellet. Thus, the assumed price of the wood pellets is $263.28/BDT ($240 plus 9.7% price premium). Accordingly, it is projected that the hypothetical biorefinery generates $70.6 million of revenues.

Table CIA-1.9. Revenue of a hypothetical biorefinery facility in WMC

Products	Volume	Unit	Price per unit	Revenue
IPK	5,100,000	gallon	2.56	$ 13,056,000
RINs	5,100,000	IPK gallon	2.464	$ 12,566,400
Wood Pellets	170,700	BDT	263.28	$ 44,941,896
Total				**$ 70,564,296**

The location of the plant and depots is critically important since the cost structure changes significantly up to where the facilities are. As a case study, one scenario was chosen from Martinkus (2016). In this scenario, it is assumed that a hypothetical saccharification biorefinery plant and a big depot with an annual demand of 16,800 BDT are co-located in Spokane WA (Spokane County). Additionally, two smaller depots with an annual demand of 56,000 BDT are located in Princeton ID (Latah County) and in Laclede ID (Bonner County). Micronized wood (i.e., wood flour), made from these forest residuals accounting for about 10% losses at the depots, are delivered to the IPK biorefinery plant in Spokane by rail. The gate price of forest residual was fixed to $62.6 per BDT in C2P. On the other hand, the costs of the forest residual collection consist of the fixed costs ($42.8) and variable costs in WMC. Fixed costs include transporting merchantable residuals to a forest landing ($16.5/BDT), grinding the residuals into chips ($22.4/BDT), and loading the chips onto a waiting chip van ($3.9/BDT). The variable costs are the transportation costs from the site to the depot gates. The gate price of forest residuals is the sum of fixed and variable costs, so the gate price varies up to where they collect forest

[7] According to Kristin Brandt and Johnway Gao (personal conversation, 2016), the IPK yield is 20.4 gallon/BDT micronized wood and the pellet yield is 0.6828 BDT/BDT.

residuals. Table CIA-1.10 shows how much forest residuals are collectable from each county under the Spokane-Princeton-Laclede scenario. In total, 109,402 BDT, 167,395 BDT and 3,563 BDT of forest residuals can be collected from WA, ID and MT, respectively[8]. Commercial logging sector of the region earns $12.0 million and truck transportation sector earns $4.0 million. Under this scenario, the overall average gate price of forest residuals is $56.95/BDT: $53.75/BDT at Laclede, $54.43/BDT at Princeton, and $58.85/BDT at Spokane. The maximum gate price to pay at Princeton is $70.23/BDT, at Spokane is $74.48/BDT and at Laclede is $75.06/BDT. Under this scenario, railroad transportation will be used from depots in Princeton and Laclede to the central biorefinery plant in Spokane and the total costs of railroad transportation are $2.38 million from Laclede and $2.44 million from Princeton. Transportation costs of feedstock are high in WMC, which would be the critical bottle neck of the WMC operation.

Table CIA-1.10. Feedstock availability and estimated valuation by location (Spokane-Princeton-Laclede)

		Biomass Volume (BDT)				Fixed	Variable
		Total	Spokane	Princeton	Laclede	($MM)	($MM)
Grand Total		**280,000**	**168,000**	**56,000**	**56,000**	**11.98**	**3.96**
WA	**Subtotal**	**109,042**	**92,710**	**287**	**16,045**	**4.67**	**1.84**
	Asotin	**46**		46		0.00	0.00
	Ferry	**20,023**	20,023			0.86	0.68
	Lincoln	**2,121**	2,121			0.09	0.06
	Okanogan	**314**	314			0.01	0.01
	Pend Oreille	**19,801**	5,259		14,543	0.85	0.21
	Spokane	**27,088**	27,088			1.16	0.20
	Stevens	**39,408**	37,905		1,503	1.69	0.69
	Whitman	**241**		241		0.01	0.00
ID	**Subtotal**	**167,395**	**74,818**	**55,713**	**36,863**	**7.16**	**2.02**
	Benewah	**19,973**	12,739	7,233		0.85	0.28
	Bonner	**30,894**	4,906		25,988	1.32	0.26
	Boundary	**10,876**			10,876	0.47	0.16
	Clearwater	**11,228**		11,228		0.48	0.23
	Idaho	**587**		587		0.03	0.01
	Kootenai	**41,500**	41,500			1.78	0.47
	Latah	**23,085**		23,085		0.99	0.12
	Lewis	**1,698**		1,698		0.07	0.04
	Nez Perce	**1,045**		1,045		0.04	0.02
	Shoshone	**26,508**	15,673	10,835		1.13	0.44
MT	**Subtotal**	**3,563**	**471**		**3,091**	**0.15**	**0.10**
	Lincoln	**2,066**			2,066	0.09	0.04
	Sanders	**1,496**	471		1,025	0.06	0.04

[8] Many counties are outside of the WMC region since Spokane is the western edge of the WMC. Revenues generated in these outside counties should be economic leakage from WMC in a strict sense. Though, CIA of this study included the economic impacts from the forest residual collection activities in these counties because these are indisputable economic contribution for the rural communities in PNW.

Various OPEX scenarios were developed for hypothetical biorefinery facilities in WMC. However, it is not easy to apply the same methodology that we estimated economic impacts of C2P mainly because of two reasons. First reason is that the operational costs vary drastically depending on where the facilities locate in WMC. Thus, it is extremely difficult to estimate the standard operational scenario in WMC. The second reason is that the depth of the supporting industries in WMC are thinner than in the C2P region. Thus, the plant will likely to purchase a large amount of raw materials from outside of the region or from wholesalers. In order to duplicate the methodology we used for C2P, we must predict how much raw materials that the plant will purchase from suppliers within the region and from outside. However, this projection is extremely difficult, if not impossible. In order to overcome these shortfalls, the combined multipliers of existing paper mills and sawmills sectors in WMC were used to substitute.

The technical coefficients (components of A matrix of I/O table) of several sectors were compared in Table CIA-1.11. As a bench mark, the technical coefficients of a hypothetical biorefinery industry in C2P region, which is explained later in this paper, was also shown. Paper mill sector in WMC purchased logs and forest residuals (spent 2.3% of their revenue), sawmill residues (2.0%), utilities (6.3%), transportation (3.7%), products from local wholesalers (6.5%), products from foreign suppliers (12.4%), and products from other regions in the US (31.7%). The value-added (i.e., labor salary, tax and dividends) of the paper mill sector in WMC was 22.6% of their revenue in 2014. Comparing these numbers with paper mill sector in C2P, paper mills in WMC used domestic imports much more and did not directly purchase chemical products from local chemical industry. This suggests C2P region has deeper and diversified related industry for biorefinery plant. Thus, paper mills in C2P can purchase materials within the region rather than from other parts of the US. Also, paper mills in both C2P and WMC rely on wholesalers rather than purchasing products directly from local industry. These facts verify the above arguments. Using existing similar industries to estimate economic impacts can reflect the unique regional economic structures of WMC. In addition, sawmill sector was also used to estimate the economic impacts of the biorefinery facility since the plant will produce wood pellets as co-products. Sawmills in WMC purchased logs and forest residuals (spent 20.9% of their revenue), sawmill residues (10.4%), utilities (2.4%), transportation (4.8%), products from local wholesalers (10.1%), products from foreign suppliers (5.2%), and products from domestic suppliers (10.6%) in 2014. Their value-added was 24.6% of their revenue.

Table CIA-1.11. Comparison of technical coefficients between a hypothetical biorefinery and the paper and chemical sector in WMC

	C2P Biorefinery	Sawmills	Paper Mills	Pulp Mills	Petro Chem.	C2P Paper	C2P Pulp
Logs & For. Res.	12.6%	20.9%	2.3%	3.6%	0.0%	2.4%	3.4%
Sawmill Residues	3.6%	10.4%	2.0%	9.2%	0.0%	2.6%	10.0%
Utilities	12.8%	2.4%	6.3%	5.8%	2.5%	4.3%	3.7%
Build. Maintenance	10.0%	0.9%	1.0%	1.7%	0.2%	0.9%	1.4%
Chemical	**7.7%**	0.0%	**0.1%**	0.2%	0.5%	**1.1%**	1.3%
Transportation	4.3%	4.8%	3.7%	5.3%	2.2%	3.4%	4.6%
Wholesale	**0.0%**	10.1%	**6.5%**	5.8%	2.9%	**7.5%**	6.3%
Foreign Imports	0.2%	5.2%	12.4%	13.0%	8.4%	12.2%	12.1%
Domestic Imports	**11.0%**	10.4%	**31.7%**	27.2%	72.8%	**21.2%**	17.1%
Value-added	32.2%	24.6%	22.6%	13.2%	6.2%	23.8%	19.5%

Now the question is how to assign the numbers to paper mills and sawmills, so we can estimate the economic impacts of the biorefinery. First of all, the hypothetical plant will earn $25.6 million by selling IPK and RINs. Paper mill sector in WMC spent 0.6% of their revenue from paper mill industry in 2014. Accordingly, $25.5 million ($25.6MM/1.006) in final demand is assigned to paper mill sector. Second, the hypothetical plant will earn $44.9 million by selling wood pellets. The paper mill sector already purchased $0.5 million from sawmill sectors if their final demand increased $44.9 million. Also, the sawmill sector in the region spent 10.4% of their revenues from the wood products sector in 2014. Consequently, $40.2 million ([$44.9MM-$0.5MM]/1.104) in final demand is assigned to the sawmill sector. Third, TEA shows the biorefinery will pay $12.0 million to the local commercial logging industry, $4.0 million to the local truck transportation industry, and $4.8 million to the railroad transportation industry. However, already assigned numbers to paper mills and sawmills sectors will result in spending $9.0 million from the commercial logging sectors in WMC. Therefore, we assigned $3.0 million ($12MM-$9MM) for the commercial logging sector, $4.0 million for the truck transportation sector and $4.8 million for the railroad transportation sector. The paper mills in WMC often purchase sawmill residues from Canada, and it is regarded as economic leakage in I/O framework. However, it is assumed that the hypothetical biorefinery facilities use local forest residuals. Thus, the adjustment of feedstock collection above can lead to a reasonable economic impact estimation.

Results

C2P

The total economic impacts from the annual operation of the hypothetical biorefinery plant in Longview are between $656.9 and $694.2 million (Table CIA-1.12). The revenue of the plant is $318.1 million, which is the direct impact of the biorefinery plant. The plant will purchase $179.5 million of goods and service from local suppliers, which is the part of the indirect effect of this final demand (i.e., the revenue of the immediate suppliers). This will generate $78.4 million of further indirect economic impacts in the region (i.e., the revenue of suppliers' suppliers and so on down the supply chain). Calculating induced effects is slightly complex because induced effects are generated from employees' compensation ($15.9 million) and proprietors' income ($45.4 million). Employees of the plant will be locally hired, and thus they will spend money in the region. The induced effects by employees in the region is $80.9 million. On the other hand, proprietors, or the equity holders, can reside anywhere. If some proprietors live in C2P region, they are likely spend money in the region. On the other hand, if the other proprietors do not reside in the region, they do not spend money in the region. Accordingly, the amount of the induced effects by proprietors can fluctuate. If the induced effects by proprietors (i.e., $37.3 million) are fully included, this implies all equity owners reside in the region. In this case the total economic impacts is $694.2 million (maximum economic impacts). If the induced effects by proprietors are completely excluded, this implies all equity owners do not live in C2P and do not spend money in the region. And thus, the total economic impacts is $656.9 million (minimum economic impacts). The real economic impacts should be anywhere between the maximum and minimum. We will use this logic thorough this report.

Forestry sector, such as commercial logging, benefits $47.6 million and wood products sector, such as sawmills, benefit $14.3 million from the hypothetical biorefinery plant. Some sectors benefit mainly from induced effects, such as owner-occupied dwellings sector ($13.9 million), real estate sector ($10.2 million) and hospital and nursing sector ($8.4 million) because the biorefinery plant and suppliers will hire many people in the region.

Table CIA-1.12. Economic Impacts (output base) from the biorefinery's new final demand in C2P

	Sector	Indirect 1 ($MM)	Indirect 2+ ($MM)	Induced w/o proprietors	Induced by proprietors	Total ($MM)
	Total	**$ 179.5**	**$ 78.4**	**$ 80.9**	**$ 37.3**	**$ 694.2**
1	Biorefinery	Direct: $ 318.1				318.1
2	Forestry	40.2	7.3	0.0	0.0	47.6
3	Utilities	35.5	5.6	1.2	0.5	42.8
4	Construction & Maintenance	31.8	1.2	1.2	0.5	34.7
5	Chemical Products	24.6	0.8	0.3	0.1	25.9
6	Truck Transportation	13.9	2.0	0.7	0.3	16.9
7	Retail	0	5.0	6.8	3.2	15.0
8	Wood Products	11.3	2.7	0.1	0.1	14.3
9	Wholesale Trade	0.1	8.1	4.1	1.9	14.2
10	Owner-Occupied Dwellings	0	0	9.5	4.4	13.9
11	Insurance Carriers	5.0	3.9	3.3	1.6	13.8
12	Real Estate	0	2.4	5.4	2.4	10.2
13	Management Services	0	5.1	2.4	1.1	8.6
14	Hospital and Nursing	0	0	5.8	2.6	8.4
15	Nonmetallic Mineral	7.0	1.2	0.1	0.1	8.3
16	Info and Data Processing	0	2.2	4.1	1.8	8.1
17	Petroleum Products	0	5.6	1.4	0.7	7.7
18	Health Care Services	0	0	5.2	2.3	7.5
19	Waste Management Services	5.7	1.0	0.3	0.1	7.0
20	Restaurants and Drinking	0	0.6	4.2	2.0	6.8
	All Others	4.5	23.9	24.6	11.5	64.4

Note: Indirect 1 represents the indirect effects by the immediate suppliers of biorefinery plant. Indirect 2+ represents the indirect effects associated with the higher-order suppliers (i.e., suppliers' suppliers and so on down the supply chain). Thus, the sum of indirect 1 and Indirect 2+ is the total indirect effects of the biorefinery plant.

Economic output above measures the value of all sales of goods and services. It is the sum of the final purchases and intermediate inputs; therefore, output results in the double counting of intermediate purchases. Value-added focuses on additional value of goods and services produced as subtracting intermediate inputs (e.g., cost of manufacturing) from gross output (e.g., revenue). Hence, value-added is like a profit for the society (people and the government). Value-added includes employee compensation, proprietor income, other property type income and tax on production and imports. The total sum of value-added at the national level is known as a gross domestic product (GDP).

Table CIA-1.13 shows the economic impacts of the hypothetical biorefinery in terms of value-added. The total value-added generated in the region will be between $230.3 and $297.3 million. The value-added derived from direct impacts is $102.4 million including $15.9 million of employee compensation, $16.5 million of property tax and $24.5 million of income tax (after depreciation ends). The remainder $45.4 million will likely become proprietors' income; though, the managers and owners of the plant can allocate this differently depending on their business strategy. Thus, it is safe to say the value-added from the direct impacts of the biorefinery plant is between $57.0 and $102.4 million. The value-added associated with the indirect effects is $126.5 million, and, the value-added associated with the induced effects are between $46.8 (without proprietors income) and $68.4 million (with proprietors income). The value-added of forestry sector ($33.3 million), utilities sector ($22.3 million), construction and maintenance sector ($15.6 million), and retail sector ($10.3 million) exceeds $10 million.

Table CIA-1.13. Value-added creation by the biorefinery plant in C2P (unit: $MM)

Ranking	Sector	Indirect	Induced w/o Employees	Induced by Proprietors	Total
	Total	**$ 126.5**	**$ 46.8**	**$ 21.6**	**$ 297.3**
1	Biorefinery	Direct: $57.0 – $102.4			102.4
2	Forestry	33.0	0.0	0.0	33.0
3	Utilities	21.4	0.7	0.3	22.3
4	Construction & Maintenance	14.8	0.5	0.2	15.6
5	Retail	3.4	4.7	2.2	10.3
6	Wholesale Trade	5.3	2.7	1.2	9.2
7	Owner-Occupied Dwellings	0.0	6.3	2.9	9.2
8	Real Estate	1.8	4.2	1.8	7.9
9	Truck Transportation	7.1	0.3	0.1	7.5
10	Insurance Carriers	4.4	1.6	0.8	6.7
11	Chemical Products	6.1	0.1	0.0	6.2
12	Management Service	3.2	1.5	0.7	5.4
13	Hospital and Nursing	0.0	3.6	1.6	5.2
14	Health Care Services	0.0	3.5	1.6	5.0
15	Other Service except Gov.	1.0	2.5	1.2	4.6
16	Wood Products	4.4	0.0	0.0	4.4
17	Restaurants and Drinking	0.3	2.5	1.1	4.0
18	Waste Management Services	3.4	0.1	0.1	3.6
19	Administrative Services	1.4	1.2	0.6	3.2
20	Banking Services	0.8	1.3	0.6	2.8
	All others	14.8	9.5	4.5	28.8

As industries gain revenues, they will hire more people. How economic impacts in the region result in the job growth is described in Table CIA-1.14. The biorefinery plant is projected to hire 173 employees. Indirect economic impacts result in 1,171 new jobs and induced economic impacts result in between 561 and 821 new jobs. In total, the economic ripple effects of the biorefinery operation create between 1,905 and 2,166 new jobs in the region. Forestry sector creates the most number of jobs, 373. Construction and maintenance creates 200 new jobs, retail sector creates 197 new jobs, restaurants and drinking places creates 114 new jobs, and truck transportation creates 103 new jobs. These are led by both the indirect and induced economic effects.

Table CIA-1.14. Job creation by the biorefinery plant in C2P

Ranking	Sector	Indirect	Induced w/o proprietors	Induced by proprietors	Total
	Total	**1,171**	**561**	**260**	**2,166**
1	Forestry	372	1	0	373
2	Construction & Maintenance	190	7	3	200
3	Retail	56	84	39	197
4	Biorefinery	Direct: 173			173
5	Restaurants and Drinking	10	71	33	114
6	Truck Transportation	97	4	2	103
7	Hospital and Nursing	0	64	29	94
8	Other Service except Gov.	11	54	25	90
9	Insurance Carriers	50	12	6	69
10	Administrative Services	29	26	12	68
11	Health Care Services	0	43	19	62
12	Wholesale Trade	33	17	8	58
13	Management Services	30	17	8	55
14	Wood Products	46	1	0	47
15	Real Estate	11	24	11	45
16	Chemical Products	32	0	0	32
17	Waste Management Services	29	1	1	31
18	Utilities	30	1	0	31
19	Farms	21	5	2	28
20	Education	0	18	9	28
	All others	123	111	52	287

The interindustry sales by a new biorefinery sector were inserted into the I/O table and the modified I/O table can account for the demand by the hypothetical biorefinery industry. In order not to inflate or deflate the total demand of other products in the region, we assume the purchasers switch suppliers from outside region to the biorefinery plant. For example, local petroleum refineries industry will purchase $91.5 million of IPK from the plant, but simultaneously they will reduce $91.5 million purchase from "domestic trade" suppliers. To inverse the new I/O matrix, the multipliers of the biorefinery industry were obtained. Table CIA-1.15 shows the results. Say, if the biorefinery industry in C2P increased $1 of revenue, indirect effects increase the output of suppliers by $0.81. Then, induced effects further increase the output in the region by between $0.17 (excluding proprietors' income of biorefinery) and $0.28 (including proprietors' income of biorefinery). Hence, the total output of the region increase between 1.98 and 2.09 times (i.e., Type SAM multipliers) as the biorefinery industry increases their revenue, ceteris paribus. With regard to the job, the biorefinery industry is assumed to hire one more person if their revenue increases $1.89 million. This will create about 7 new jobs through supply chain of the biorefinery industry, such as commercial logging, sawmills, maintenance and repair of building, truck transportation, and utilities sectors. In addition, induced effects will create between 2.4 and 3.8 new jobs in the region. Theoretically, one new additional job at the biorefinery plant will create between 10.4 and 11.8 new jobs in C2P region, ceteris paribus.

Table CIA-1.15. Multipliers of the new biorefinery industry in C2P

	Direct	Indirect	Induced		Total
Output Base	1	0.81	0.17	min	**1.98**
			0.28	max	**2.09**
Job Base	1	6.97	2.41	min	**10.38**
			3.82	max	**11.79**

At the early stage of the biorefinery operation, they can record depreciation. Since the capital expenditures of the plant are huge, the amount of the annual depreciation is very large as well. Consequently, it is projected that the operating income of the plant will show financial loss, and they even don't have to pay income tax for the early stage. However, net cash flow should be still positive, so they will likely to allocate the excess money to equity holders. If equity holders live in the region and spend proportional amounts of the dividends, this will further increase the induced impacts. Though, these are based on subtle financial decisions. In order to ignore these complex issues, the estimated economic impacts here used the annual operation after the depreciation period ends. It means the estimated economic impacts in this study are based on the conservative edge of the projected TEA.

Feedstock Collection

Applying county level I/O on the depot model, Table CIA-1.16 shows the economic impacts of feedstock collection in terms of output. It is important to note that this section is already internalized in the economic impacts of the biorefinery plant. This section just emphasizes the details of the feedstock collection in order to see how each county can benefit from the biorefinery plant. The direct impacts of commercial logging sector and truck transportation sector are associated with the revenues the biorefinery plant pays. These further generate indirect and induced effects. Cowlitz County WA gains $19.1 million economic impacts due to the feedstock collection activity, followed by Lewis County WA ($11.1 million), Clatsop County OR ($9.0 million), Columbia County OR ($7.8 million) and Pacific County WA (8.2 million).

Table CIA-1.16. Economic impacts of feedstock collection by county when the plant locates at Longview WA

	Total ($MM)	Commercial Logging			Truck Transportation		
		Direct	Indirect	Induced	Direct	Indirect	Induced
Cowlitz WA	**19.1**	8.2	1.3	3.2	4.2	1.2	1.0
Lewis WA	**11.1**	6.3	0.9	2.1	1.3	0.3	0.3
Clatsop OR	**9.0**	5.4	0.4	1.8	1.0	0.3	0.2
Columbia OR	**7.8**	4.8	0.3	1.1	1.1	0.3	0.2
Pacific WA	**8.2**	3.5	0.4	0.7	2.5	0.6	0.4
Wahkiakum WA	**4.4**	2.7	0.7	0.4	0.4	0.1	0.0
Clark WA	**3.9**	2.4	0.2	0.8	0.4	0.1	0.1
Washington OR	**3.4**	1.8	0.3	0.6	0.5	0.1	0.1
Tillamook OR	**2.5**	1.5	0.2	0.3	0.4	0.1	0.1
Thurston WA	**2.2**	1.1	0.2	0.5	0.3	0.1	0.1
Clackamas OR	**2.0**	1.0	0.2	0.3	0.3	0.1	0.1
Grays Harbor WA	**1.1**	0.6	0.1	0.2	0.2	0.0	0.0
Skamania WA	**0.9**	0.6	0.0	0.1	0.1	0.0	0.0
Multnomah OR	**0.5**	0.1	0.0	0.1	0.2	0.1	0.0
Marion OR	**0.1**	0.1	0.0	0.0	0.0	0.0	0.0
Yamhill OR	**0.1**	0.0	0.0	0.0	0.0	0.0	0.0
Total	**76.3**	**40.2**	**5.3**	**12.0**	**12.8**	**3.4**	**2.6**

Figure CIA-1.4 visualizes the total economic impacts derived from the transportation sector (pink) and the commercial logging sector (green) on the map. Apparently, the economic impacts decrease with the distance from the plant locates.

Table CIA-1.17 presents the number of jobs created by the feedstock collection activities in each county. Direct impacts create jobs in logging and truck transportation sectors in each county. Other jobs are created by indirect and induced effects of the new demand by logging and truck sectors. Cowlitz County WA creates 139 new jobs including 55 logging jobs and 28 truck transportation jobs, followed by Lewis County WA (95 jobs), Clatsop County OR (72 new jobs), Pacific County WA (69 jobs), Columbia County OR (67 jobs) and Wahkiakum County WA (45 jobs).

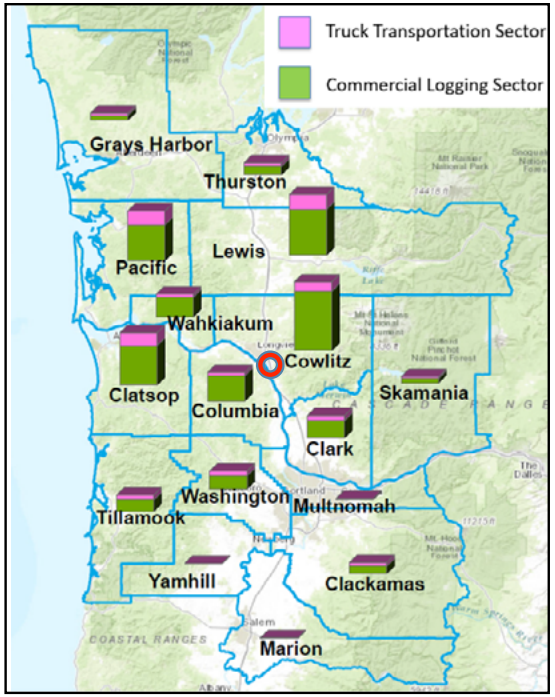

Figure CIA-1.4. Map of economic impacts of feedstock collection of two sectors

Table CIA-1.17. Job creation by feedstock collection activities by county

	Total	Logging	Truck	Others
Cowlitz WA	**139**	55	28	57
Lewis WA	**95**	51	8	35
Clatsop OR	**72**	39	7	27
Pacific WA	**69**	45	8	16
Columbia OR	**67**	27	16	25
Wahkiakum WA	**45**	31	3	11
Clark WA	**30**	19	2	9
Washington OR	**31**	18	3	10
Tillamook OR	**26**	17	3	6
Thurston WA	**17**	8	2	7
Clackamas OR	**17**	9	2	7
Grays Harbor WA	**10**	6	1	3
Skamania WA	**7**	5	1	2
Multnomah OR	**2**	0	1	1
Marion OR	**1**	0	0	0
Yamhill OR	**1**	0	0	0
Total	**630**	**330**	**84**	**216**

Table CIA-1.18 presents the economic contribution of each county in terms of output. The feedstock collection activities in Wahkiakum County WA increase the output of its logging sector by 26.2% and of truck transportation sector by 72.0%. The total output created by the feedstock collection results in 2.7% of the county's total output. This is critical for a rural county like Wahkiakum. The feedstock collection increases 0.6% of Pacific County's output, 0.4% of Columbia County's output and 0.3% of Lewis County's output. Skamania County's commercial logging industry increases its output more than double (+125%) because the great majority of the county's forestlands are national forests, and commercial logging industry there is very small.

Table CIA-1.18. Feedstock collection activities' economic contribution for each county

	% of Logging	% of Truck	% of County Output
Wahkiakum WA	26.2%	72.0%	2.65%
Pacific WA	17.9%	20.1%	0.62%
Columbia OR	13.6%	7.0%	0.35%
Clatsop OR	11.9%	3.5%	0.27%
Lewis WA	10.0%	1.6%	0.23%
Cowlitz WA	10.0%	4.2%	0.20%
Skamania WA	125%	12.5%	0.18%
Tillamook OR	3.2%	1.0%	0.13%
Grays Harbor WA	1.0%	0.3%	0.03%
Thurston WA	2.9%	0.2%	0.01%
Clark WA	17.0%	0.1%	0.01%
Clackamas OR	3.0%	0.1%	0.01%
Washington OR	6.5%	0.2%	0.00%
Yamhill OR	0.2%	0.0%	0.00%
Marion OR	0.0%	0.0%	0.00%
Multnomah OR	0.3%	0.0%	0.00%

Economic impacts of forest residual collection under two other scenarios are shown in the Appendix of this report. The first scenario (Table CIA-App.1) assumes the hypothetical plant was established in Cosmopolis (Grays Harbor County, WA). The other scenario (Table CIA-App.2) assumes the plant was established in Springfield (Lane County, OR). Both hypothetical plants require 154,040 BDT of forest residuals. However, the costs of transportation are higher than that of Longview scenario. In order not to inflate the numbers, we assume the biorefinery plants basically pay $62.60 per BDT for forest residuals. If the costs from certain forests exceed $62.60/BDT, the plants will burden the shortage of transportation costs.

Construction of the Biorefinery Plant

The economic impacts of the construction of the biorefinery plant are shown in Table CIA-1.19. In second year, the total economic impacts in terms of output become $1.09 billion in C2P and $797 million of them stay in Cowlitz County WA. This is a large economic impact; though, the number reduces to almost half by third year. The huge economic fluctuation in a small town like Longview may give local government a headache.

Table CIA-1.19. Economic impacts of the biorefinery plant construction in Longview (output base)

Unit: $MM	First Year	Second Year	Third Year
Direct	$ 83.24	$ 624.30	$ 332.96
Indirect Within Cowlitz	$ 8.40	$ 62.89	$ 33.53
Indirect Other C2P	$ 16.34	$ 122.27	$ 65.22
Induced Within Cowlitz	$ 21.99	$ 164.70	$ 87.82
Induced Other C2P	$ 14.89	$ 111.50	$ 59.49
Total Cowlitz County	**$ 113.63**	**$ 797.40**	**$ 429.18**
Total C2P Region	**$ 144.87**	**$ 1,085.66**	**$ 579.02**

With regard to the job creation, the construction sector brings 617 jobs in the first year, 4,628 jobs in the second year and 2,468 jobs in third year (Table CIA-1.20). In addition, indirect effects and induced effects of the construction of the plant create about 18.7% and 41.5% of direct jobs, respectively. In total, 987 jobs are created in first year, 7,408 new jobs in second year and 3,951 new jobs in third year in Cowlitz County WA. Again, the numbers fluctuate in short period of times. This will be a great economic opportunity for the area in terms of the magnitude; though, how to accommodate these temporal workers in Longview area would be a great challenge.

Table CIA-1.20. Job creation by the biorefinery plant construction in Cowlitz County

	1st Year	2nd Year	3rd Year
Direct	617	4,628	2,468
Indirect	115	865	462
Induced	255	1,915	1,021
Total	**987**	**7,408**	**3,951**

WMC

The economic impacts including direct, indirect and induced effects from the hypothetical biorefinery facilities in WMC are shown in Table CIA-1.21. It is assumed that the operation of biorefinery facilities include a saccarification process in the centralized plant and micronizing feedstock at three different wood flour mills. All other operations, such as transportation of feedstock and micronized wood, are done by outside contractors. The assumed revenue of the hypothetical biorefinery is $70.6 million, which is a direct impact of the plant in terms of industrial output. This generates $61.1 million revenue of companies on the supply chain in WMC (i.e., indirect effects in terms of output), including commercial logging and transportation sectors. These further create induced effects of $24.5 million in WMC. Hence, the total economic impact in WMC in terms of output is $156.1 million. These numbers result in $15.7 million of direct impacts, $30.9 million of indirect impacts and $13.3 million of induced impacts in terms of value-added. The introduction of biorefinery facilities increases the gross regional product in WMC by $59.8 million. Also, these can create 174 jobs at the plant (direct impacts), 400 jobs with companies on the supply chain (indirect impacts) and 203 jobs resulted in induced effects. The total economic impacts will create 777 new jobs in the region. Estimation of the value-added and employment of direct effect is comparably rough because the presumption of this methodology is that the economic structure of biorefinery plant is similar to the combinations of the average paper mills and sawmills in the region. The numbers on the OPEX developed by TEA of WMC show a better deductive projection.

Table CIA-1.21. Economic impacts from a hypothetical biorefinery plant in WMC

	Direct	Indirect	Induced	**Total**
Output	$70.6 MM	$61.1 MM	$24.5 MM	**$156.1 MM**
Value-added	($15.7 MM)	$30.9 MM	$13.3 MM	**$ 59.8 MM**
Employment	(174)	400	203	**777**

Since forest residual collection occurs across different counties with varying levels, the new demand from the biorefinery operations will affect local economies according to their potential to supply feedstock. Using Table CIA-1.10 as a case study of feedstock collection, economic impacts were calculated at the county level (Table CIA-1.22). It is important to note that these numbers in Table CIA-1.22 are the part of the indirect impacts of the above Table CIA-1.21. Feedstock collection generates $29.3 million output with 203 new jobs in the WMC and surrounding counties. These numbers include railroad transportation of micronized wood from depots to the centralized plant in Spokane.

The impacts of the feedstock collection for the biorefinery plant in some counties are substantial. Table CIA-1.23 is a breakdown of Table CIA-1.22 by county. Ferry County WA can increase the total output by 0.5% and the employment by 0.7%. Shoshone ID, Benewah ID, Pend Oreille WA, Clearwater ID and Stevens WA can increase the counties' economic activities by about 0.2-0.3%. Apparently, feedstock collection activities are important for rural forest dependent counties in WMC.

Table CIA-1.22. Economic impacts from feedstock collection activities in WMC (Spokane-Princeton-Laclede)

	Direct	Indirect	Induced	**Total**
	Output (Unit: $MM)			
Total	**20.8**	**3.7**	**4.8**	**29.3**
Commercial Logging	12.0	1.9	3.0	**16.9**
Truck Transportation	4.0	1.1	0.6	**5.7**
Rail Transportation	4.8	0.7	1.2	**6.7**
	Employment (Persons)			
Total	**143**	**26**	**34**	**203**
Commercial Logging	107	17	27	**151**
Truck Transportation	28	8	5	**41**
Rail Transportation	8	1	2	**11**

Table CIA-1.23. Economic impacts from feedstock collection by county in WMC (Spokane-Princeton-Laclede)

		Direct Inputs ($MM)			Total Econ Impact in Output		Total Econ Impact in Employment	
		Logging	Truck	Rail	$MM	% of Co.	Persons	% of Co.
(P) Spokane	WA	$ 1.16	$ 0.20	$ 2.41	$ 5.84	0.02%	31.1	0.01%
(D) Bonner	ID	$ 1.32	$ 0.26	$ 1.19	$ 3.73	0.13%	18.6	0.08%
Stevens	WA	$ 1.69	$ 0.69		$ 3.48	0.19%	28.0	0.19%
Kootenai	ID	$ 1.78	$ 0.47		$ 3.33	0.03%	21.8	0.03%
(D) Latah	ID	$ 0.99	$ 0.12	$ 1.22	$ 3.14	0.18%	17.6	0.10%
Shoshone	ID	$ 1.13	$ 0.44		$ 2.24	0.28%	18.7	0.29%
Ferry	WA	$ 0.86	$ 0.68		$ 1.95	0.54%	17.5	0.66%
Benewah	ID	$ 0.85	$ 0.28		$ 1.49	0.23%	13.3	0.28%
Pend Oreille	WA	$ 0.85	$ 0.21		$ 1.35	0.20%	13.3	0.31%
Clearwater	ID	$ 0.48	$ 0.23		$ 0.99	0.20%	7.4	0.17%
Boundary	ID	$ 0.47	$ 0.16		$ 0.82	0.11%	8.0	0.15%
Lincoln	WA	$ 0.09	$ 0.06		$ 0.21	0.03%	2.1	0.04%
Lincoln	MT	$ 0.09	$ 0.04		$ 0.18	0.02%	1.5	0.02%
Sanders	MT	$ 0.06	$ 0.04		$ 0.15	0.04%	1.2	0.05%
Lewis	ID	$ 0.07	$ 0.04		$ 0.15	0.04%	1.2	0.05%
Nez Perce	ID	$ 0.04	$ 0.02		$ 0.09	0.00%	0.7	0.00%
Idaho	ID	$ 0.03	$ 0.01		$ 0.06	0.01%	0.4	0.01%
Okanogan	WA	$ 0.01	$ 0.01		$ 0.04	0.00%	0.3	0.00%
Whitman	WA	$ 0.01	$ 0.00		$ 0.02	0.00%	0.1	0.00%
Asotin	WA	$ 0.00	$ 0.00		$ 0.00	0.00%	0.0	0.00%

Note: (P) represents where the centralized plant and the larger depot locates and (D) represents where the smaller depot locates.

Economic impacts of forest residual collection under two other scenarios are shown in the Appendix section. The first scenario (Table CIA-App.3) assumes a hypothetical centralized plant and a larger depot was established in Lewiston (Nez Perce County, ID) and two smaller depots were established in Princeton (Latah County, ID) and in Athol (Kootenai County, ID). The other scenario (Table CIA-App.4) assumes that a hypothetical centralized plant and a larger depot was established in Frenchtown (Missoula County, MT) and two smaller depots in Post Falls (Kootenai County, ID) and in Moyie Springs (Boundary County, ID). It is assumed both operations require 280,000 BDT of forest residuals and pay fixed and variable costs of the forest

residual collection. They deliver wood flower from depots to the centralized plant by truck. Transportation costs of both scenarios are higher than the main Spokane-Princeton-Laclede scenario. Accordingly, the forest collection activities generate more industrial output and create more jobs under these alternative scenarios. However, the higher costs of feedstock decrease the revenue of the biorefinery facilities, and thus the business operations of two scenarios have higher risk.

Discussion and Conclusions

The hypothetical biorefinery facilities in C2P and WMC regions result in large economic contributions to regional industrial outputs, employment and value-added. In C2P, as the biorefinery plant annually generates $318 million, the whole region will generates $657-$694 million industrial outputs, $230.3-$297.3 million value-added, and 1,905-2,166 jobs through the direct, indirect and induced economic effects. In addition to the biorefinery's operation itself, construction of the plants bring huge economic impacts. For example, building the plant at Longview WA can create between 1,293 and 9,706 new jobs during the construction phase; though, the economic impacts are dissipate in three years. In WMC, the scale of a hypothetical biorefinery plant is smaller than one in C2P due to the low availability of woody biomass. The projected revenue of the hypothetical biorefinery plant with depots is $71 million. This results in $156 million outputs, $60 million value-added and 777 employments in WMC and surrounding counties.

Since the scale of operations and the estimation methods of CIA in two regions are completely different, the comparison of two results needs extra attention. Yet, WMC region can create more jobs per the same unit of IPK production than C2P region. The reason is the difference of wages in two regions. The average compensation per employee in WMC was $37,944, which is about 70% level compared to C2P ($54,128) in 2014.

The results of this study show that the forest residual collection activities for the hypothetical plants will substantially help rural forest dependent communities in PNW. When the plant locates at Longview WA in C2P, the plant spends $53 million to the forest residual collection. This generates $76.3 million of industrial outputs and creates 630 new jobs, including 330 logging jobs, 84 truck transportation jobs and 216 other jobs. Forest dependent small counties, such as Wahkiakum County WA and Pacific County WA benefit substantially: they can increase counties' output by 2.7% and 0.6%, respectively. Under the Spokane-Princeton-Laclede scenario in WMC, the hypothetical biorefinery facilities spend $16 million on forest residual collection. This generates $23 million industrial outputs and 192 jobs in WMC and surrounding areas. In addition, micronized wood is processed at depots and the transportation of micronized wood to the centralized plant in Spokane will create further outputs and jobs. However, the location of the plant and depots in WMC plays critical roles to determine which counties can benefit and how much. This will be the consideration for the social assets study of NARA (e.g., Martinkus et al., 2014). I/O model developed in this study was passed to the social asset study team.

This study has examined the economic impacts of the hypothetical biorefinery facilities in C2P in WMC. The results of this I/O provide the basis for understanding the nature and magnitude of the community impacts that the biorefinery plants makes to the economies in two different regions. Results clearly show that creating a biorefinery industry in C2P and WMC will bring substantial economic prosperity to the related industries and livable diversified economy through employment. Feedstock collection is especially beneficial for forest dependent rural counties in PNW where society has been economically struggling for decades. The results of this study provide a strong justification to support for the introduction of a biorefinery industry. Understanding the economic contributions that new biorefinery industry make to regional industrial output, value-added and employment is a critical step in formulating effective natural resource and social policy at the regional level.

Similar to all other economic impact studies using I/O framework, the analysis on this paper has certain limitations. First of all, I/O assumes the linear relationship between outputs of one sector to inputs of others. Thus, the model is based on the constant returns of scale and the constant technique of production. Economies of scale should play a huge role for the plant; though, the underlying production function of I/O is linear. Also, there is always the possibility of factor substitution for the production, but the economic structure of I/O framework is assumed to be fixed. Second, we relied our analysis on the operational projection by TEA. Raw material procurement, allocation of revenue, determination of suppliers, products sales and other business practices substantially influence the numbers in this study. Although TEA team brought the best possible projection, managers and owners of the plant can alter these business practices up to their managerial considerations. Third, the static nature of the model in this study ignores the dynamic business environment. Price and other factors always change in reality, and this fact generates risk and uncertainty surrounding the business. It is important to emphasize that the numbers estimated in this study is based on the 2014 price and the assumptions that we made. Finally, the results do not include any intangible social costs. I/O used the real transaction data. Non-transaction type social externality associated with the project, such as enhancing energy security of the nation, fixing carbon dioxide, reducing wild fire risk, and developing new innovation associated with biomass conversion, are beyond the scope of this study. Lastly, it sounds obvious; though, this study is not meant to support the financial performance of hypothetical biorefinery facilities projected by TEA team of NARA project.

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NARA OUTPUTS

Publications

Sasatani, D. and Eastin, I.L. (2017). Economic impact analysis of a NARA woody biomass jet fuel refinery. *CINTRAFOR Newsletter*, Autumn/Winter, 8-9.

Presentations

Sasatani, D. (2016). Regional economic impacts on the introduction of biorefinery facilities utilizing forest residual in Pacific Northwest. Oral presentation at NARA Final Meeting. Chrystal City, VA. Nov. 17.

Sasatani, D. (2016). An input-output analysis of the potential regional economic impacts of NARA project. Oral presentation at the NARA 2nd Northwest Wood-based Biofuels + Co-Products Conference, SeaTac, WA. May 3-4.

Perez-Garcia, J. (2014). Community impact measurements. Oral presentation at the Year 3 NARA Annual Meeting, Seattle, WA. Sept. 15-17.

NARA OUTCOMES

The results of this study show that the operation of a biomass jet-fuel refinery will bring substantial economic impacts for local communities. Establishing a wood-based biomass jet-fuel refinery in this region would be beneficial to rural economies. This reasonable economic information can be used for the decision making by policymakers. Additionally, the I/O model developed in this study was passed to other NARA teams. For example, the team studied social impacts of a biorefinery adopted our numbers in their model.

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APPENDIX

Alternative Scenarios in C2P

The assumption of below scenarios is that the hypothetical plant requires 846,059 BDT of forest residuals as feedstock. The plant pays $62.60/BDT if the costs of forest residual at gate is less than the price. If the costs of forest residual at gate is more than $62.60, the plant burdens the excess transportation costs.

Table CIA-App.1. C2P economic impacts of feedstock collection if a biorefinery plant was at Cosmopolis (Grays Harbor County, WA)

County	State	Forest Residual Vol. (BDT)	% of Feedstock Supply	Logging Costs ($MM)	Transport. Costs ($MM)	Total Econ. Impacts Output ($MM)	Total Econ. Impacts Jobs (Persons)
*Grays Harbor	WA	233,082	27.5%	$12.44	$8.35	$20.79	258
Pacific	WA	165,801	19.6%	$8.42	$0.98	$9.40	110
Lewis	WA	91,072	10.8%	$3.76	$1.02	$4.79	59
Clatsop	OR	70,653	8.4%	$2.74	$0.95	$3.69	42
Mason	WA	54,644	6.5%	$2.43	$0.50	$2.93	34
Wahkiakum	WA	50,853	6.0%	$2.04	$0.58	$2.61	37
Kitsap	WA	42,344	5.0%	$1.66	$0.55	$2.22	29
Jefferson	WA	41,039	4.9%	$1.64	$0.50	$2.14	33
Thurston	WA	39,525	4.7%	$1.74	$0.37	$2.11	26
Cowlitz	WA	36,792	4.3%	$1.43	$0.48	$1.92	22
Pierce	WA	20,253	2.4%	$0.79	$0.26	$1.05	11
Total		**846,059**	**100%**	**$39.09**	**$14.55**	**$53.65**	**662**

Note: The average cost of forest residuals is $63.41/BDT under this scenario. * represents where the plant locates.

Table CIA-App.2. C2P economic impacts of feedstock collection if a biorefinery plant was at Springfield (Lane County, OR)

County	State	Forest Residual Vol. (BDT)	% of Feedstock Supply	Logging Costs ($MM)	Transport. Costs ($MM)	Total Econ. Impacts Output ($MM)	Total Econ. Impacts Jobs (Persons)
*Lane	OR	222,238	26.3%	$11.59	$9.37	$34.15	254
Douglas	OR	207,033	24.5%	$8.88	$2.20	$15.77	134
Linn	OR	138,084	16.3%	$6.53	$1.07	$11.41	89
Benton	OR	52,766	6.2%	$2.26	$0.52	$4.20	39
Polk	OR	47,548	5.6%	$1.87	$0.61	$3.46	32
Lincoln	OR	45,869	5.4%	$1.78	$0.66	$3.47	26
Coos	OR	37,585	4.4%	$1.46	$0.55	$3.05	25
Marion	OR	33,050	3.9%	$1.28	$0.44	$2.76	20
Yamhill	OR	26,117	3.1%	$1.01	$0.42	$2.05	17
Clackamas	OR	22,914	2.7%	$0.89	$0.37	$1.92	17
Washington	OR	6,424	0.8%	$0.25	$0.11	$0.54	5
Deschutes	OR	3,026	0.4%	$0.12	$0.05	$0.26	3
Jefferson	OR	2,729	0.3%	$0.11	$0.04	$0.20	2
Klamath	OR	677	0.1%	$0.03	$0.01	$0.05	0
Total		**846,059**	**100%**	**$38.05**	**$16.41**	**$83.30**	**664**

Note: The average cost of forest residuals is $64.36/BDT under this scenario. * represents where the plant locates.

Alternative scenarios in WMC

The assumption of below scenarios is that the hypothetical facilities (depots and plant) require 280,000 BDT of forest residuals as feedstock. The plant pays the sum of fixed and variable costs of forest residuals at gate. Wood flour is made from forest residuals in depots and they are delivered to the centralized plant by truck.

Table CIA-App.3. WMC economic impacts of feedstock collection if a biorefinery plant and a larger depot co-located in Lewiston (Nez Perce County, ID) and two smaller depots were in Princeton (Latah County, ID) and in Athol (Kootenai County, ID)

County	State	Forest Residual Vol. (BDT)	% of Feedstock Supply	Logging Costs ($MM)	Transport. Costs ($MM)	Total Econ. Impacts	
						Output ($MM)	Jobs (Persons)
Clearwater	ID	58,923	21.0%	$2.52	$0.73	$4.59	35
Shoshone	ID	49,819	17.8%	$2.13	$0.51	$3.72	31
Benewah	ID	34,916	12.5%	$1.49	$0.19	$2.21	21
(D) Latah	ID	31,603	11.3%	$1.35	$0.86	$3.19	27
(D) Kootenai	ID	27,291	9.7%	$1.17	$0.70	$2.79	19
Wallowa	OR	23,961	8.6%	$1.03	$0.34	$1.96	17
Idaho	ID	17,481	6.2%	$0.75	$0.22	$1.34	11
Bonner	ID	10,923	3.9%	$0.47	$0.03	$0.70	5
Lewis	ID	6,794	2.4%	$0.29	$0.04	$0.43	4
(P) Nez Perce	ID	3,671	1.3%	$0.16	$2.69	$4.50	29
Spokane	WA	3,631	1.3%	$0.16	$0.02	$0.27	3
Columbia	WA	2,926	1.0%	$0.13	$0.03	$0.20	2
Asotin	WA	2,824	1.0%	$0.12	$0.02	$0.21	2
Pend Oreille	WA	2,730	1.0%	$0.12	$0.01	$0.16	2
Union	OR	1,919	0.7%	$0.08	$0.03	$0.15	1
Whitman	WA	588	0.2%	$0.03	$0.00	$0.04	0
Total		**280,000**	**100%**	**$11.98**	**$6.42**	**$26.47**	**209**

Note: The average cost of forest residuals at gate of depots is $65.72/BDT under this scenario. (P) represents where the plant and the larger depot co-locate. (D) represents where the smaller depot locates.

Table CIA-App.4. WMC economic impacts of feedstock collection if a biorefinery plant and a larger depot co-located in Frenchtown (Missoula County, MT) and two smaller depots were in Post Falls (Kootenai County, ID) and in Moyie Springs (Boundary County, ID)

County	State	Forest Residual Vol. (BDT)	% of Feedstock Supply	Logging Costs ($MM)	Transport. Costs ($MM)	Total Econ. Impacts	
						Output ($MM)	Jobs (Persons)
(P) Missoula	MT	33,452	11.9%	$1.43	$4.54	$10.47	75
Sanders	MT	33,313	11.9%	$1.43	$0.34	$2.56	24
Lake	MT	24,355	8.7%	$1.04	$0.22	$1.82	18
Bonner	ID	20,693	7.4%	$0.89	$0.17	$1.48	10
(D) Kootenai	ID	18,367	6.6%	$0.79	$1.19	$2.99	21
Shoshone	ID	17,673	6.3%	$0.76	$0.31	$1.52	13
Powell	MT	16,081	5.7%	$0.69	$0.21	$1.17	13
(D) Boundary	ID	15,113	5.4%	$0.65	$1.86	$3.38	28
Stevens	WA	12,010	4.3%	$0.51	$0.13	$0.95	8
Granite	MT	11,043	3.9%	$0.47	$0.12	$0.77	6
Lincoln	MT	10,540	3.8%	$0.45	$0.10	$0.78	7
Spokane	WA	10,461	3.7%	$0.45	$0.06	$0.81	10
Benewah	ID	9,629	3.4%	$0.41	$0.11	$0.68	6
Clearwater	ID	8,305	3.0%	$0.36	$0.20	$0.78	6
Ravalli	MT	7,293	2.6%	$0.31	$0.07	$0.61	8
Flathead	MT	7,152	2.6%	$0.31	$0.12	$0.70	6
Pend Oreille	WA	6,796	2.4%	$0.29	$0.09	$0.48	5
Latah	ID	4,458	1.6%	$0.19	$0.05	$0.35	3
Idaho	ID	4,270	1.5%	$0.18	$0.08	$0.37	3
Lewis & Clark	MT	2,353	0.8%	$0.10	$0.05	$0.23	2
Mineral	MT	1,854	0.7%	$0.08	$0.01	$0.12	2
Jefferson	MT	1,643	0.6%	$0.07	$0.04	$0.15	1
Silver Bow	MT	1,344	0.5%	$0.06	$0.03	$0.13	1
Lincoln	WA	723	0.3%	$0.03	$0.01	$0.05	1
Broadwater	MT	471	0.2%	$0.02	$0.01	$0.04	0
Cascade	MT	463	0.2%	$0.02	$0.01	$0.05	0
Whitman	WA	147	0.1%	$0.01	$0.00	$0.01	0
Total		**280,000**	**100%**	**$11.98**	**$10.13**	**$33.47**	**277**

Note: The average cost of forest residuals at gate of depots is $78.97/BDT under this scenario. (P) represents where the plant and the larger depot co-locate. (D) represents where the smaller depot is located.