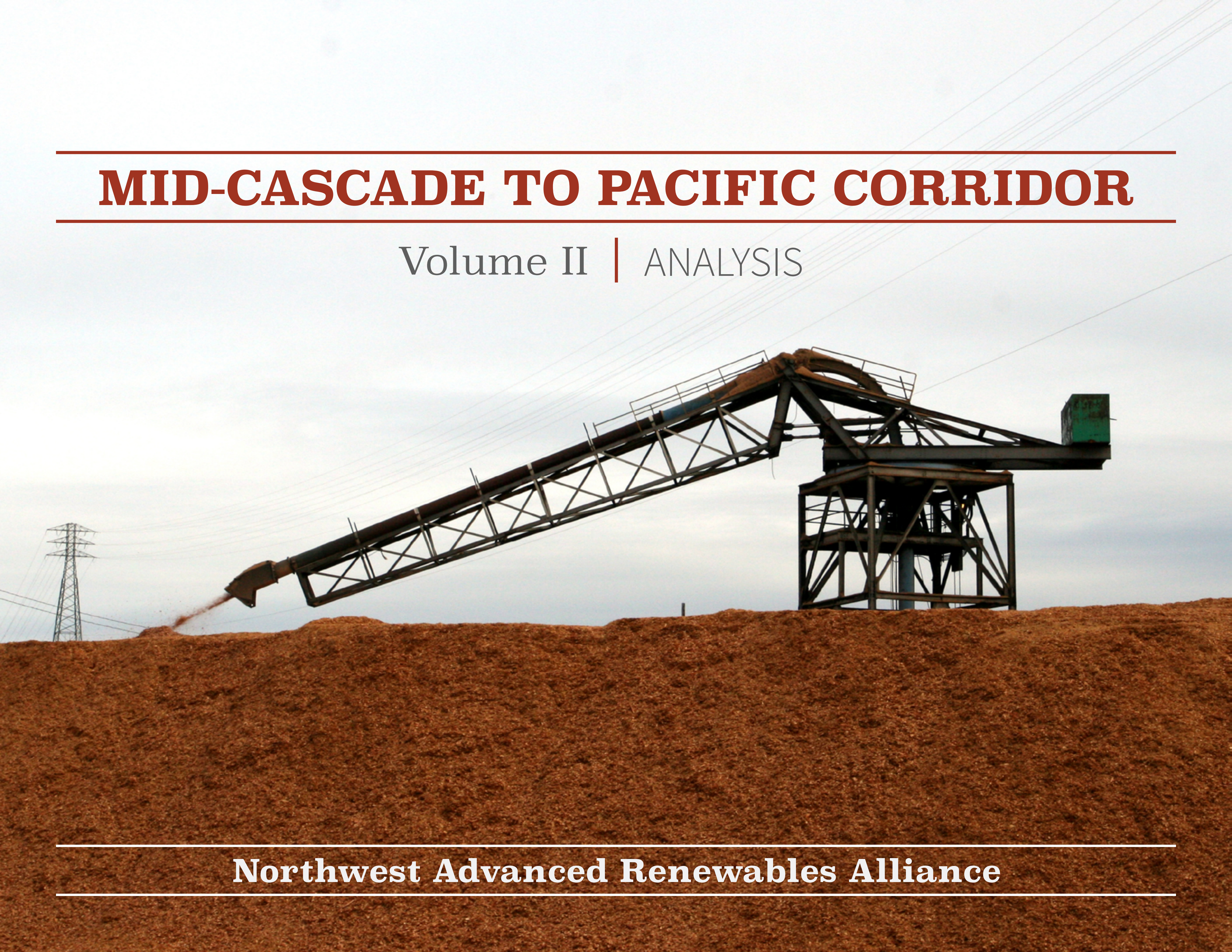
MID-CASCADE TO PACIFIC CORRIDOR

Volume II | ANALYSIS



Northwest Advanced Renewables Alliance

TABLE OF CONTENTS

This project is part of the Northwest Advanced Renewables Alliance (NARA), supported by the Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-304 from the USDA National Institute of Food and Agriculture.

NARA is led by Washington State University and supported by the Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30416 from the USDA National Institute of Food and Agriculture.

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

AFRI	Agriculture and Food Research Initiative program
AHB	Advanced Hardwood Biofuels Northwest
BDT	Bone Dry Tons
Brownfield	Abandoned or underutilized site with real or perceived contamination
CAPS	Coordinated Agricultural Projects
CAAM	Community Asset Assessment Model
C&D	Construction and Demolition Debris
CIA	Community Impact Analysis
CY	Cubic Yard
Greyfield	Vacant or underutilized site with no contamination
IDX	Integrated Design Experience
IO	Input-Output Analysis
LCA	Life Cycle Assessment
MRF	Material Recycling Facility
MSW	Municipal Solid Waste
N&E	New and emerging
NARA	Northwest Advanced Renewables Alliance
NIFA	USDA National Institute of Food and Agriculture
OSU	Oregon State University
RFA	Resource Flow Analysis
RWW	Recycled Wood Waste
SLA	Site Location Analysis
TEA	Techno-Economic Analysis
UI	University of Idaho
USFS	United States Forest Service
MC2P	Mid-Cascades to Pacific Corridor
WSU	Washington State University

AUTHORS

Tamara Laninga
Karl Olsen
Michele Vachon
Michael Wolcott

EDITORS

Charles Burke
Tamara Laninga
Jacob Smith
Michele Vachon

LAYOUT & DESIGN

Jacob Smith
Michele Vachon

Northwest Advanced Renewables Alliance

Mid-Cascade to Pacific Corridor

2.1.0 NARA OVERVIEW

NARA
Northwest Advanced Renewables Alliance

The Northwest Advanced Renewables Alliance (NARA) was initiated in 2011. It is one of seven regional bioenergy Coordinated Agricultural Projects (CAPs) within the Sustainable Bioenergy challenge area funded by the USDA National Institute of Food and Agriculture (NIFA) in its Agriculture and Food Research Initiative (AFRI) program. CAPs in Sustainable Bioenergy are charged to:

> facilitate the establishment of regional systems for the sustainable production of bioenergy and biobased products that: contribute significantly to reducing the National dependence on foreign oil; have net positive social, environmental, and rural economic impacts; and are integrated with existing agricultural systems (USDA NIFA 2010).

This charge is being addressed through collaborative research, education and workforce development, as well as technology transfer through outreach.

NARA is focused on developing feasibility studies and a supporting environment for the sustainable production of biobased products derived from woody biomass feedstock, specifically softwood forest residuals, in Washington, Oregon, Idaho and Montana. The USDA defines woody biomass as the trees and woody plants, including limbs, tops, needles, leaves, and other woody parts, grown in a forest, woodland, or rangeland environment, that are the by-products of forest management (USDA 2008). In addition to focusing on post-harvest forest residuals, NARA is also examining construction and demolition (C&D) wood waste (indifferent to species) as a potential feedstock. In this document the term woody biomass is used to cover softwood forest residuals and C&D wood waste.

2.1.1 ECONOMIC ANALYSIS

In cooperation with NARA members from private industry (e.g. Gevo, Catchlight Energy and Weyerhaeuser), the project has produced an initial techno-economic analysis (TEA) that outlines an integrated bio-refinery operation producing isobutanol and biojet from forest residuals. Assuming bio-refinery construction from scratch (greenfield development) and consumption of 770,000 bone dry tons (BDT) of forest residuals per year, we estimate that about 60 million gallons of biojet would be produced each year from each conversion facility. Based on this scenario, the cost to produce biojet from forest residuals could be two to three times the current market price of petroleum based jet fuel. As overall process refinements are achieved and the price of petroleum derived fuels increase, the price difference should narrow.

2.1.2 CHALLENGE

One way to improve biofuel production economics is to develop an efficient supply chain. Our challenge is to assess regional assets that can be used to improve supply chain efficiencies and result in significant cost reductions. These assets include strategically located industrial facilities in regions with high biomass potential that could host biomass depots, pretreatment processes, fermentation, or alcohol-to-jet refining. These assets could host either a large central bio-refinery or specific components of a distributed production model. In the distributed production approach, existing facilities could produce intermediate products (i.e. refined and sorted biomass, wood-based sugars, isobutanol) that is then concentrated in centralized facilities. At the same time, these distributed operations could help maintain economic scale for other core processes, such as fermentation and conversion of alcohol to biojet fuel at a large bio-refinery. Finally, permitting and related costs might be reduced significantly if bio-refineries are located on previously industrialized sites, either greyfields or brownfields. Greyfields are abandoned or underutilized industrial and commercial facilities available for reuse; however, brownfields may be complicated by environmental contamination. Both types of sites have existing infrastructure present that may expedite the construction of a biofuels operation or may reduce the initial capital construction costs if existing infrastructure can be adapted for biofuels production.

2.1.3 GOALS AND OBJECTIVES

NARA' s primary challenge is to envision and facilitate an environmentally, economically, and socially sustainable wood-based biofuels and co-products industry in the Pacific Northwest. NARA's basic task is to develop, with regional stakeholders, a viable integrated pathway for commercially producing a bio-based aviation fuel (biojet) (Figure 2.1.1).

NARA'S GOALS ARE TO DEVELOP:

1) SUSTAINABLE BIOJET: Develop a sustainable biojet fuel industry in the Pacific Northwest that uses residual woody biomass as feedstock.
2) VALUE-ADDED POLYMER AND CARBON PRODUCTS FROM LIGNIN: Create valuable co-products made from lignin, an industrial byproduct of the woody biomass-to-biojet process
3) RURAL ECONOMIC DEVELOPMENT: Sustain and enhance rural economic development
4) REGIONAL SUPPLY CHAIN COALITIONS: Facilitate and promote supply chain coalitions within the NARA region
5) BIOENERGY LITERACY: Improve bioenergy literacy to develop a future workforce and enhance stakeholder understanding

Since 2011, NARA has analyzed regional supply chains in three areas:

1) CLEARWATER BASIN in North Central Idaho, 2011/2012
2) WESTERN MONTANA CORRIDOR (WMC), 2012/2013
3) MID-CASCADE TO PACIFIC (MC2P), 2013/2014

NARA IS ORGANIZED INTO FIVE TEAMS (FIGURE 2.1.1):

1) THE FEEDSTOCK TEAM takes a multi-pronged approach to the development and sustainable production of feedstocks from wood materials, including forest harvest residues and municipal solid wood waste.
2) THE CONVERSION TEAM works to provide a wood-derived replacement for aviation biofuel and other petroleum-derived chemicals that is economically and technologically feasible. The underlying concept is to harvest low-market-value materials and convert them to high-value products.
3) THE SUSTAINABILITY MEASUREMENTS TEAM evaluates and assesses environmental, social, and economic viability of the wood to biofuels supply chain. The life cycle assessment and community impact analysis groups are conducting much of these analyses.
4) THE OUTREACH TEAM transfers research-based science and technology of converting wood biomass into biofuels and co-products to stakeholders and engages regional stakeholders to facilitate coalitions for the development of a viable regional infrastructure.
5) THE EDUCATION TEAM engages citizens, meets future workforce needs, enhances science literacy in biofuels, and helps people understand how they are going to fit into the new energy economy. The Integrated Design Experience (IDX) group is part of the larger Education team that conducts the regional supply chain analysis. IDX educates undergraduate and graduate students in the context of engaged and participatory learning.

For more information visit the NARA website: nararenewables.org

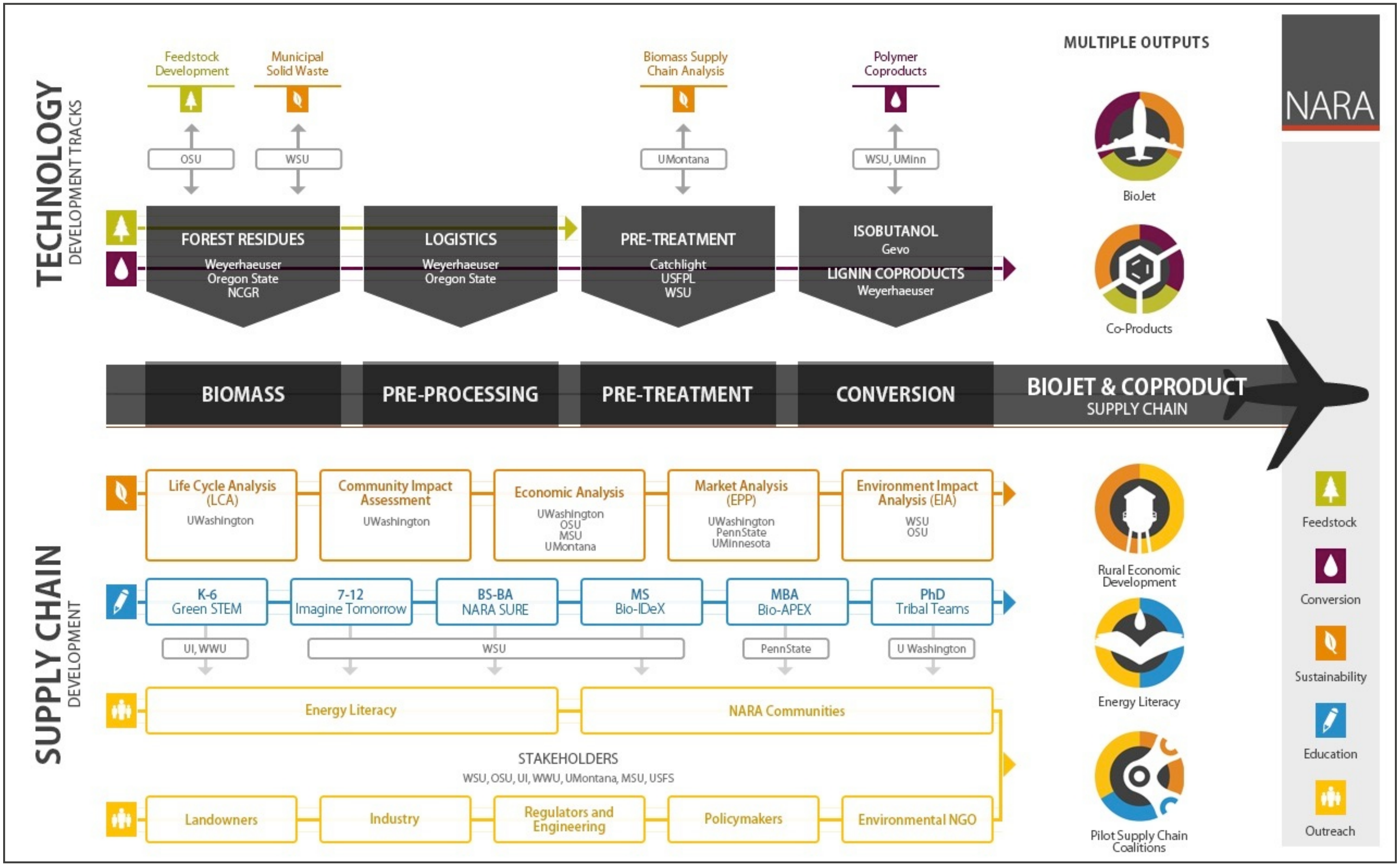


Figure 2.1.1. NARA Structure and Goals

2.1.4 PRIOR SUPPLY CHAIN ANALYSIS STUDIES

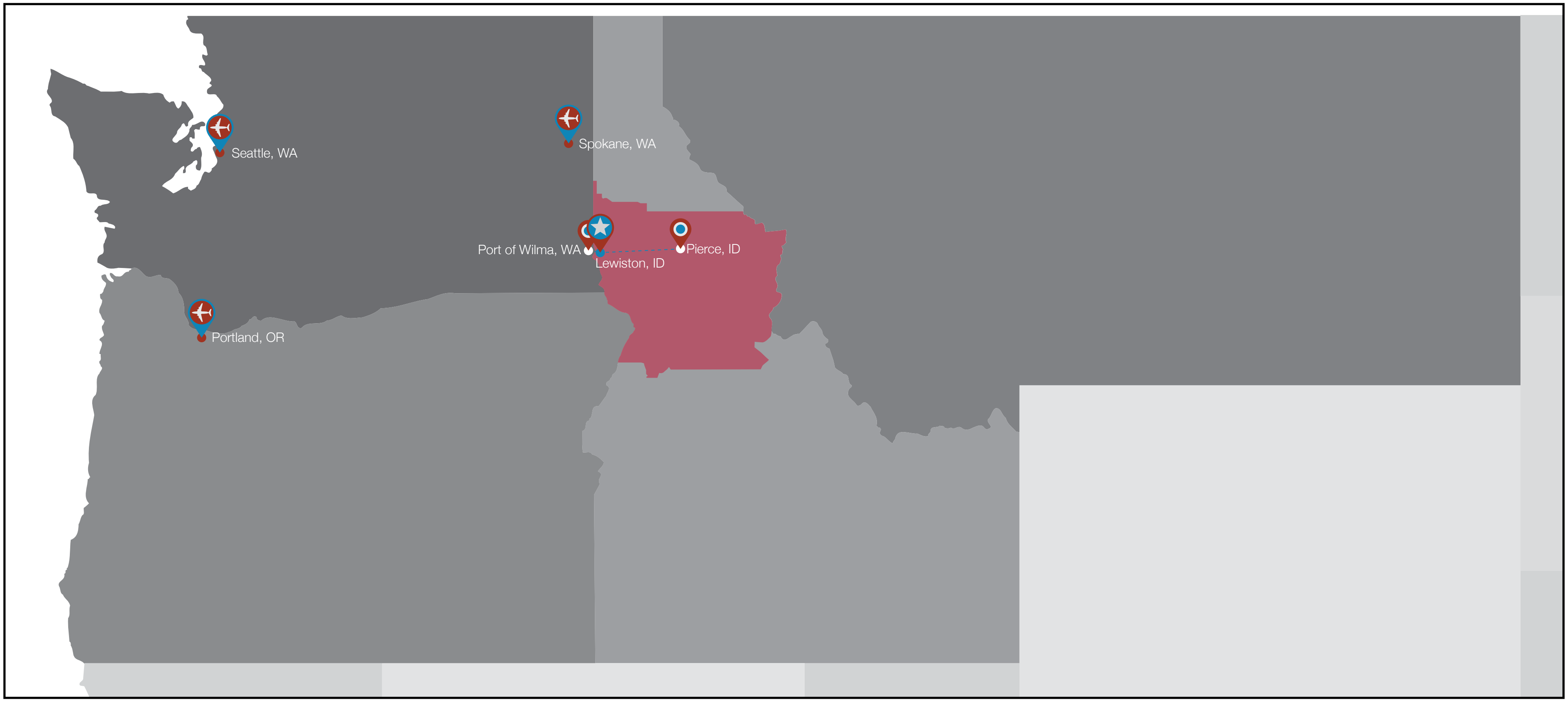


Figure 2.1.2. Clearwater Basin, Idaho, Pilot Supply Chain

CLEARWATER BASIN SUMMARY

Our analysis in the Clearwater Basin started by identifying supply chain assets and the region's resources (biomass availability), key nodes (potential sites for solids depots and conversion sites), and linkages - transportation (highways, railroads, and ports). Forest biomass estimates in the seven counties of the Clearwater Basin ranged from 679,000 BDT at $25/BDT to 738,000 BDT at $40/BDT. Based on the regional assessment, specific sites were identified for further development. These sites are a solids depot at the former Jaype Plywood Mill near Pierce, ID; a conversion facility at the Lewiston, ID pulp and paper mill; and a transportation hub at the Port of Wilma in Whitman County WA (Figure 2.1.2). Using a 50-mile radius, and accounting for land ownership (specifically federal forests), the biomass availability for the Jaype site within a 50-mile radius was estimated to be about 175,000 BDT. Site assessments and schematic site designs were completed for each site. Plans were developed for a chipping and pelletizing facility at the Jaype site; a retrofit of the Lewiston pulp and paper mill as a conversion facility; and a reorganization of the Port of Wilma site as a multi-modal transportation hub.

http://nararenewables.org/clearwater-basin/clearwater_basin_atlas.pdf

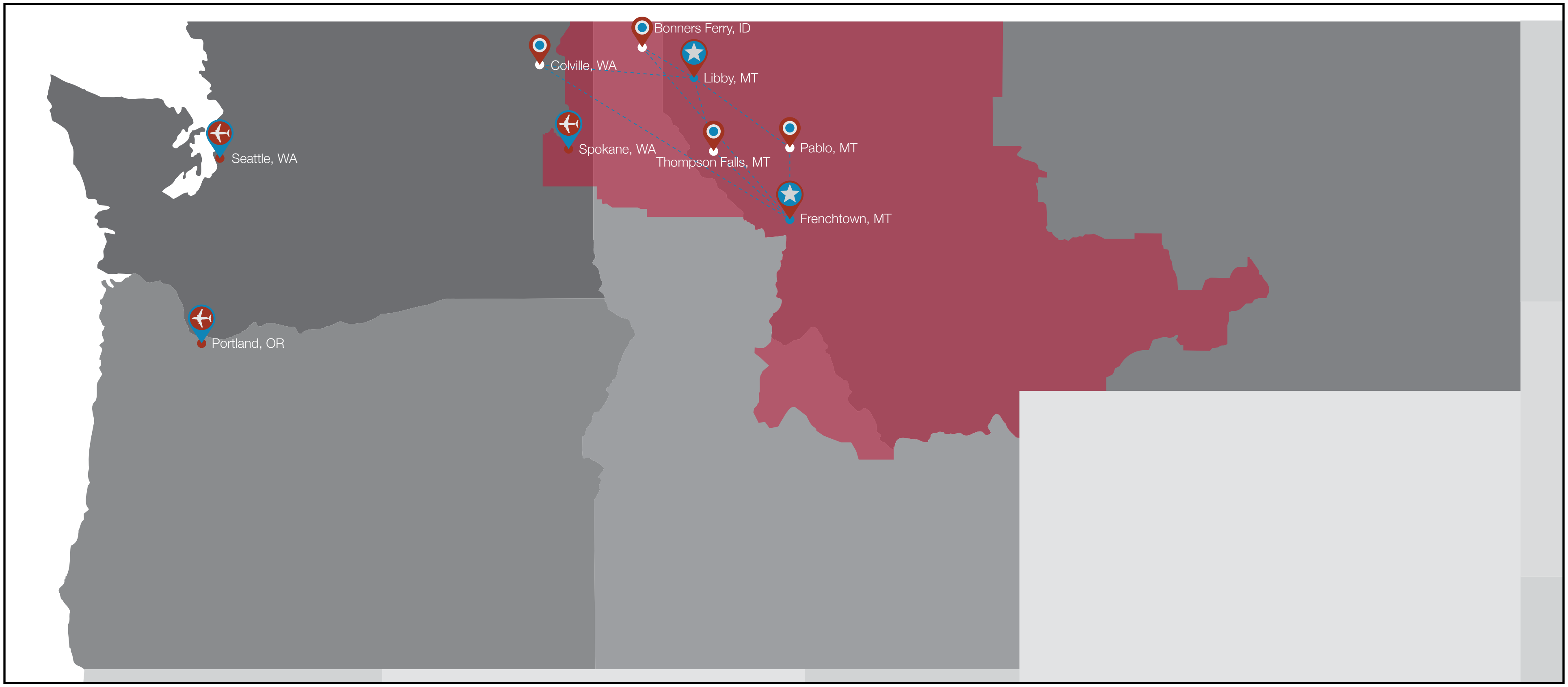


Figure 2.1.3. Western Montana Corridor (Northeast WA, Northern ID, and Western MT)

WESTERN MONTANA CORRIDOR (WMC) SUMMARY

The WMC analysis collected regional asset data including natural, physical, civic, financial, and policy resources necessary for analyzing a wood-based biofuels supply chain. Biofuel supply chains, with conversion facilities at Libby and Frenchtown, MT, were analyzed in detail (Figure 2.1.3). In the WMC, analysis of forest residuals found biomass to be dispersed, making it harder to direct haul the feedstock to a conversion facility. A dispersed depot model was developed, where solid depots were identified throughout the WMC to increase feedstock supply to potential conversion sites. The role of existing supply chain assets, including both functioning and idle mill sites, is essential in decreasing capital expenditure requirements for an advanced biofuels process.

Identified depot sites were classified into three categories: 1) active mills with a co-located depot; 2) idle mills with infrastructure; and 3) decommissioned mills with little or no infrastructure. These were further classified into brownfields and greyfields, which are abandoned or underutilized industrial and commercial facilities available for reuse; brownfields may be complicated by environmental contamination. Other factors considered included location within or outside of city boundaries and proximity to conversion sites. At each site, assets were inventoried, opportunities and constraints identified, and site master plans developed. The sites included: conversion plants in Libby and Frenchtown, and four depot sites located near Colville, WA (active/greyfield); Bonners Ferry, ID (idle/greyfield); Thompson Falls, MT (decommissioned/greyfield); and Pablo, MT (idle/brownfield). Assuming a $40/BDT hauling cost for biomass, two scenarios are shown for a proposed conversion facility at Libby, MT. Figure 2.1.4 shows the road-only scenario. In this case, only 71,000 BDT is accessible for a conversion site at Libby, with 65,000 BDT coming from private lands, and 6,000 from state lands. Furthermore, if additional costs were included, such as removal, rehandling and chipping, the cost estimate is closer to $65/BDT. The analysis shows the necessity of a distributed depot/conversion model, relying on mixed transportation modes (Figure 2.1.5). A similar 400,000 BDT amount was found for a proposed conversion facility at Frenchtown, MT.

http://nararenewables.org/westernmontanacorridor/

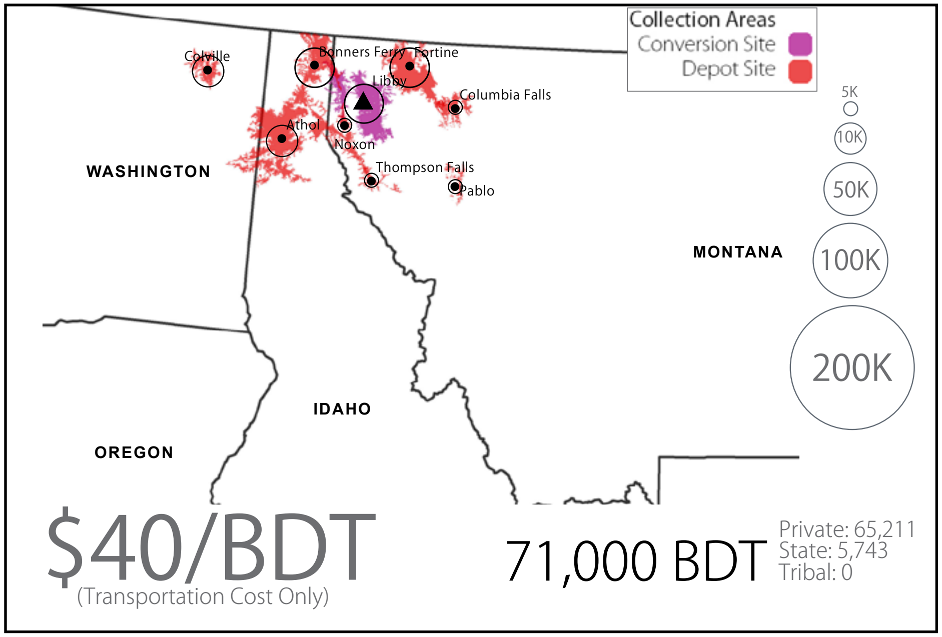


Figure 2.1.4 Libby Conversion Facility and Depot Sites using Road Network, $40/BDT

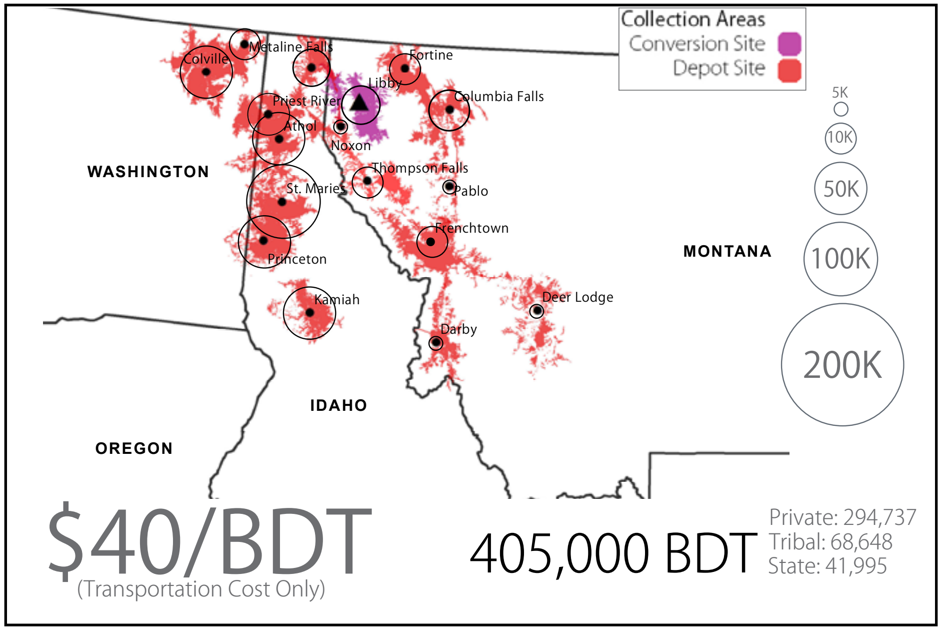


Figure 2.1.5 Libby Conversion Facility and Depot Sites using Rail Network, $40/BDT

2.2.0 INTEGRATED DESIGN EXPERIENCE (IDX)

IDX is an year long studio course where students, and faculty, along with NARA stakeholders, analyze regional assets and identify sites for the emerging wood-based biofuels industry in the Pacific Northwest. As part of the NARA Education Team, IDX serves a dual role of educating and training the future workforce in sustainable biofuels, and assisting communities with identifying and realizing the opportunities available to them for participating in the biomass to biofuels supply chain.

IDX draws a talented group of undergraduate and graduate students from Washington State University and the University of Idaho who are interested in providing innovative solutions to complex, contemporary challenges. Faculty with expertise in engineering, design, planning, and economics facilitate IDX, which attracts students seeking degrees in engineering (civil, mechanical, environmental), architecture, landscape architecture, bioregional planning, law, environmental science, accounting and several other disciplines.

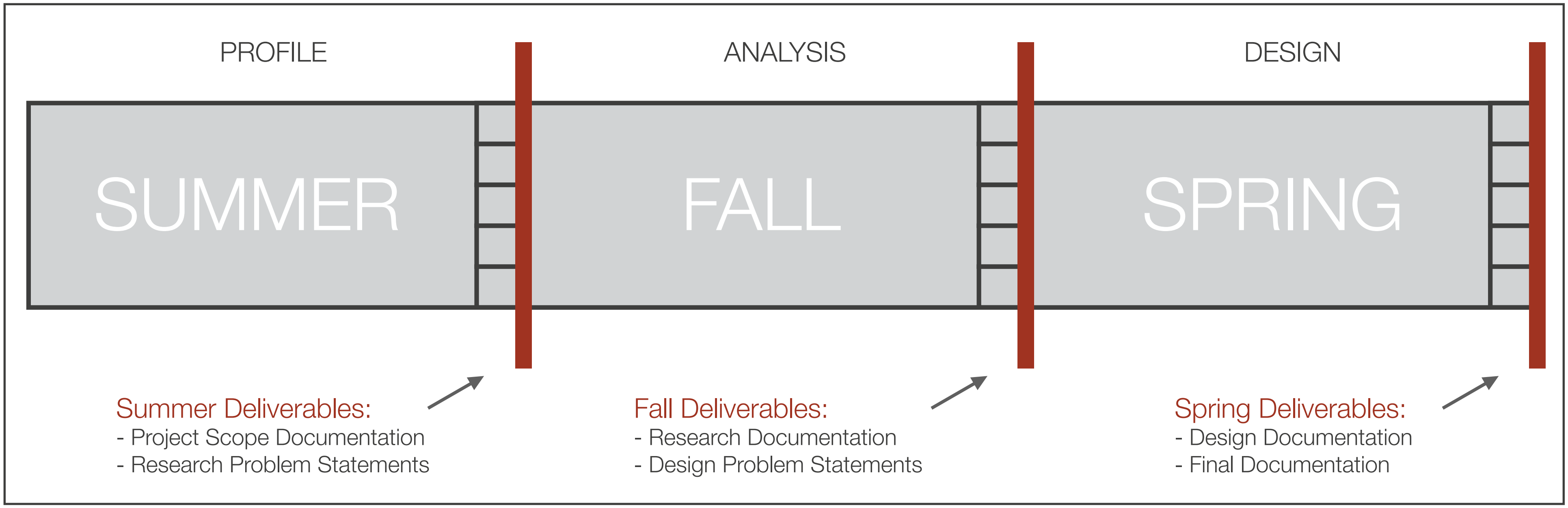
To view IDX class presentations visit https://www.youtube.com/watch?v=8q-usW6AVq0

2.2.1 GOALS AND OBJECTIVES

To produce biojet fuel and co-products from low-value woody biomass at a competitive price, strategies for reducing capital and operational expenditures need to be developed. The preliminary techno-economic analysis (TEA) conducted by NARA emphasizes that transportation and processing costs contribute significantly to the overall price of biojet fuel made from forest residuals. The TEA is presented in NARA Cumulative Report available at this link: http://nararenewables.org/2013-report/docs/. To reduce these costs, a reliable and cost-effective supply chain network is necessary. Pilot supply chain analyses are a key component within NARA's goal to establish supply chain coalitions.

NARA, through the IDX and the Outreach team, works with regional stakeholders to identify and evaluate available assets associated with potential sites suitable to participate in the wood-based biofuels supply chain. The activities associated with converting woody biomass into biojet fuel involve feedstock harvesting, transport, mechanical refinement, pretreatment, chemical conversion, bio-refining, fuel-blending, and biojet delivery to markets. To convert woody biomass into liquid biojet fuel, we consider four types of facilities where different operations within the supply chain occur. The four facility types are solid depots, liquid depots, integrated biorefineries and a distillation and distribution operation. Site selection analysis includes the following steps:

1) EVALUATE potential depot and biorefinery sites in the MC2P region using geographic information systems (GIS) layering based on site selection criteria
2) DESIGN supply chain scenarios for the MC2P region
3) REFINE the MC2P supply chain using resource flow analysis and site programming
4) EXAMINE the possibility of liquid depots producing sugars rather than wood chips, thereby increasing the ability to transport materials longer distances



Summer Deliverables:
- Project Scope Documentation
- Research Problem Statements

Fall Deliverables:
- Research Documentation
- Design Problem Statements

Spring Deliverables:
- Design Documentation
- Final Documentation

Figure 2.2.1 NARA IDX Studio Project Phases

2.3.0 MC2P REGION SUPPLY CHAIN OVERVIEW

MID-CASCADES TO PACIFIC (MC2P) SUPPLY CHAIN

The Mid Cascade to Pacific (MC2P) region encompasses the western half of Oregon and Washington and is highlighted in Figure 2.3.1. The region contains twenty counties, with 19 counties in Northwest Oregon and seven of the counties located in southwest Washington. These counties are situated west of the Cascade Mountain Range and along the I-5 Corridor, a major transportation network linking Portland, OR to Seattle, WA. The MC2P region is divided by the Columbia River, and rich in natural resources, especially woody biomass. The MC2P region was selected for study because if its high concentrations of woody residuals, and it has enough biomass feedstock to support more than one integrated biorefinery (IBR) processing approximately 770,000 BDT per year.

To examine the MC2P region for suitable wood-based biofuels production facilities, IDX first identified assets integral to developing a regional supply chain. These assets are listed in the MC2P Volume 1 Profile document. The second stage involved site analysis. The MC2P Volume 2 Analysis document (currently being viewed) describes the analysis undertaken to select sites in the MC2P region where specific activities such as preprocessing of forest residuals into wood chips or converting chips into isobutanol, along the supply chain occur. In the third stage, conceptual master plans and building designs for solids depots, liquids depots and integrated biorefineries were developed. These findings are presented in Volume 3, the MC2P Design Document.

Wood-based biofuels production can occur at one integrated facility, or the activities can be distributed among a number of sites. The facility types NARA is considering are listed below:

1) SOLIDS DEPOT: This facility receives raw slash, forest thinnings, and/or construction and demolition waste biomass and mechanically processes the feedstock for economical transport by rail or highway truck. The processed biomass is received by either a liquids depot, an integrated biorefinery or other potential end user.

2) LIQUIDS DEPOT: This facility receives raw and mechanically processed biomass residuals directly from nearby forests, or in chip or pellet form from a solids depot. Sugar-rich syrup from a liquids depot would then be shipped to an integrated biorefinery or distillation and distribution operation for further refining into biojet fuel or other chemicals.

3) INTEGRATED BIOREFINERY (IBR): This facility is a high-capacity biomass operation that can convert raw biomass or liquid-sugars into biojet fuel.

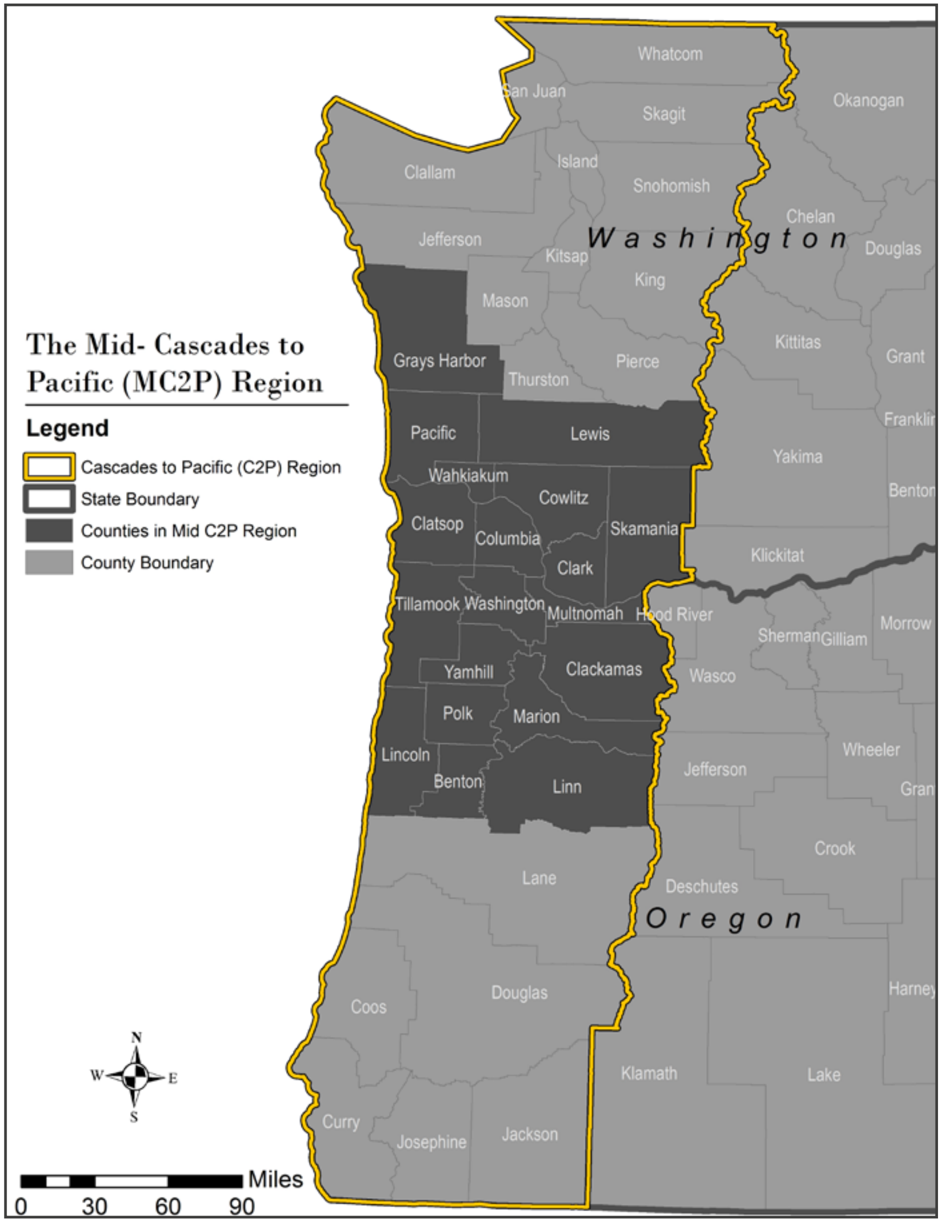


Figure 2.3.1. Mid-Cascades to Pacific Region Study Area

4) DISTILLATION AND DISTRIBUTION (D&D): This facility takes in liquid sugars from a liquids depot and would produce biojet fuel beginning with fermentation through final refining, blending and distribution.

An economically viable woody biomass-to-biojet fuel industry must find a balance between two conflicting objectives when converting a woody material into a liquid biofuel. To reduce transportation costs, multiple solids depots are advantageous so that a large area of the woody biomass, a relatively low energy density material, can be processed. However, with liquid depots and IBRs, the per-unit costs tend to decrease as the plant size increases which means that fewer and larger facilities improve the economics. These conditions suggest that a mix of specialized facilities supporting a centralized IBR is worth consideration in establishing a wood-to-advanced biofuels system.

MC2P SITE PROGRAMMING & RESOURCE FLOWS

Students in the IDX Studio initiated their supply chain analysis by incorporating site programming and resource flow analysis into their site selection criteria. These system modelling tools are used to evaluate potential depot and biorefinery sites along the biojet and co-product supply chain. Site programming is a process that examines everything involved with processing biomass at each node along the supply chain including inputs, outputs, physical parameters of the site, required equipment, site infrastructure, transportation to and from the site, and energy flows. The goal of site programming is to determine the optimal operating parameters required for each type of facility. In conjunction with site programming, a resource flow analysis was performed. A resource flow analysis aims to quantify the flow of resources, measured in mass, within a defined geographical area or industry sector over a set period of time. This analysis can point to opportunities for understanding and managing material consumption. An anticipated outcome from resource flow analysis is that site adaptations and redevelopment opportunities based on existing site attributes and resource availabilities are identified.

The generic resource flow model shown in Figure 2.3.2 illustrates the main resource flows through a defined boundary. Specifically, resources are defined as materials or products. Raw materials are extracted from nature and consumed as they are, or combined with other materials to produce finished products (Linstead & Ekins, 2001, Linstead et al., 2003). The consumption of materials and products creates waste and emissions as by-products. A resource flow analysis can point to opportunities for understanding and managing materials consumption and minimization, aiding in the site selection process.

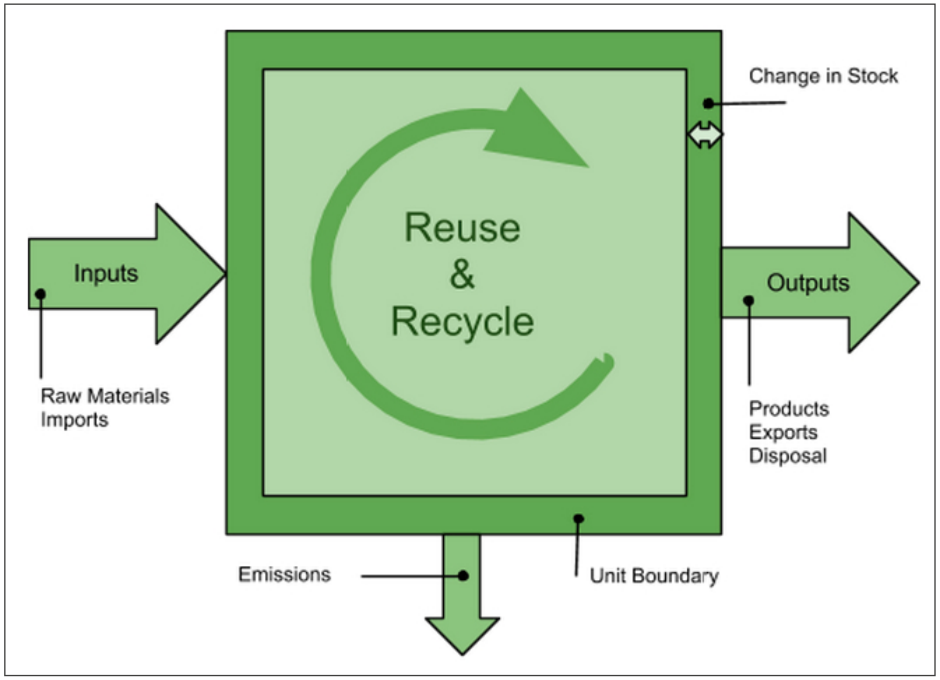


Figure 2.3.2. Generic Resource Flow Diagram

Resource flow analysis also identifies hidden flows, which are materials extracted from nature but not consumed or incorporated into final materials and products (Bringezu and Shutz 2001; Rodrigues and Giljum, 2004). For the MC2P unit boundary, IDX Studio teams quantified a number of flows for each type of industrial operation including:

- Material imports (biomass supplies within 1, 2, and 3-hour drive times), production and exports
- Waste production
- Hidden flows
- Water consumption
- Waste water production
- Air emissions

The site programming and resource flow analysis for a solids depot, liquids depot, integrated biorefinery, and distillation and distribution facility are presented in Figures 2.3.3, 2.3.4, 2.3.5, and 2.3.6, and were useful in further reducing the number of viable industrial sites for solids, liquids and integrated biorefinery operations (See Section 2.4.0).

2.3.1 SOLIDS DEPOT SITE PROGRAMMING & RESOURCE FLOWS

In the NARA supply chain analysis, solids depot operations were analyzed based on receiving and handling 100,000 bone-dry-tons (BDT) of biomass per year. According to the Environmental Protection Agency's volume-to-weight conversion tables, this equates to just over 600,000 cubic yards of loose wood scraps annually. However, according to Dr. Karl Englund, WSU Assistant Research Professor and Extension Specialist for the Composite Materials & Engineering Center and NARA team member, a biomass stockpile capacity of only two weeks is needed at each solid depot operation. This means that just over 23,000 cubic yards of raw biomass is required for a solids depot operation to have sufficient material stored on-site for mechanical processing.

A solids depot operation generally handles the following processes: receives raw materials (biomass) shipped via truck from forest residual locations, mechanically grinds and sorts biomass, transforms biomass into pellets (optional), and transports the processed biomass to a liquids depot or integrated biorefinery. For a solids depot operation, the most important parameters identified in the site programming and resource flow analysis were found to be biomass input and energy flow.

Both the site programming and resource flow analysis revealed that the most significant input at a solids depot is biomass. Biomass is first collected at a landing and then loaded onto trucks for transport to the depot. Because the biomass is often located in remote areas, trucks are the most viable mode of transport for biomass to a solids depot. Once delivered to the solids depot, the biomass is broken down in a tub grinder that reduces the residual woody biomass to roughly three-inch diameter strips. Following the mechanical grinding, the biomass is then chipped into roughly one-inch squares. These chips are the main output produced by a solids depot and can be sent to either a liquids depot or directly to a biorefinery. An optional step is pelletization. Pellets have four desirable qualities: they are compact, flowable, dense and easy to break apart. Pelletization is usually reserved for long-distance transportation or could be sold locally or internationally as a product from a solids depot for home heating.

Ideally all equipment at a solids depot would be powered by electricity. Electrical equipment is generally less expensive to operate and more reliable than its diesel counterparts. Assuming year round operation at forty hours a week, equipment would operate 4,160 hours per year. If a constant inflow of biomass is assumed during these hours, then the solids depot would process roughly 150 cubic yards of loose wood scraps per hour. At this rate, a single Peterson 2750C Electric Grinder would be sufficient for the proposed solids depot and utilize just under 1,600MWh of electrical power per year while only running at half capacity. Processing the ground material through a chipper would then require an additional 972 MWh per year. Figure 2.3.3 shows the site programming and resource flow diagrams of a typical solids depot operation.

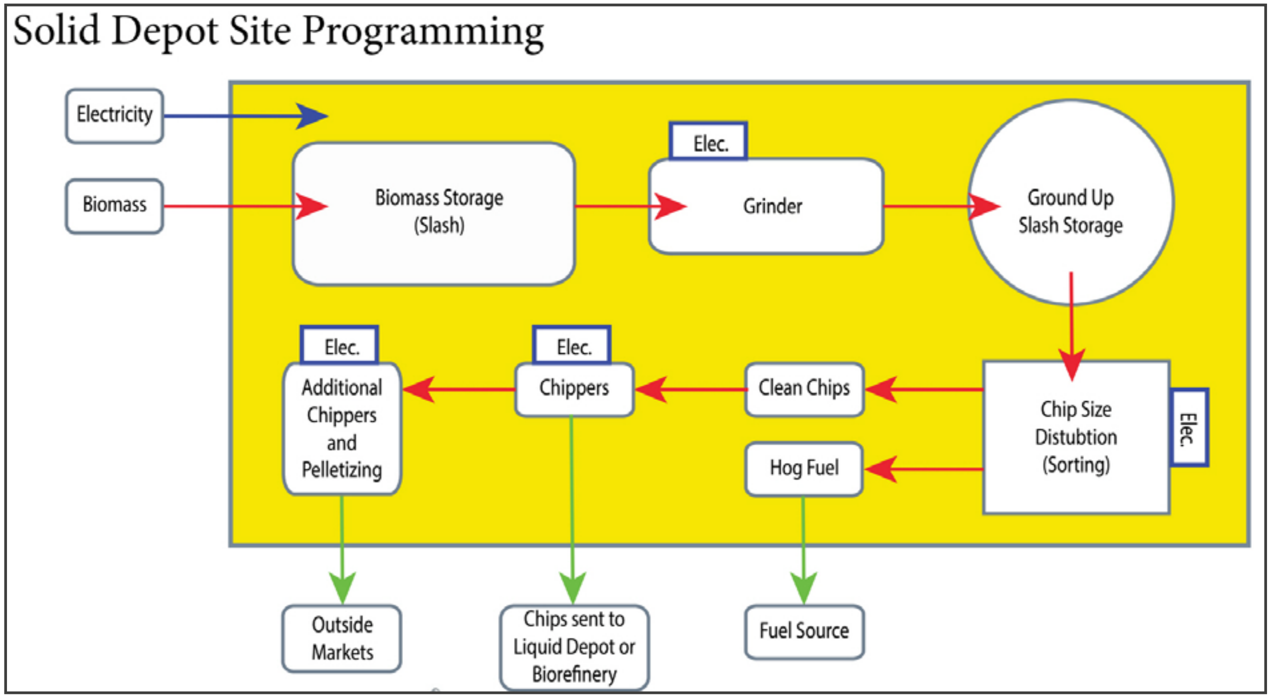


Figure 2.3.3. Solids Depot Site Programming and Resource Flows

2.3.2 LIQUIDS DEPOT SITE PROGRAMMING & RESOURCE FLOWS

Liquids depots, in the site programming and resource flow analysis, were estimated to process 250,000 bone dry tons (BDT) of feedstock per year. Of that volume, 15% is expected to be rejected as low quality from fines, dirt, debris. The rejected feedstock can, however, be used as hog fuel. Figure 2.3.4 shows a typical flow of mass, water and power through a liquids depot. The most important parameters determined in the resource flow analysis are water input, wastewater output, availability of transportation, physical storage capability for biomass and finished product, and energy flows.

A liquids depot typically has four operating processes: input of raw materials (biomass), mechanical processing followed by chemical feedstock pretreatment, enzymatic hydrolysis, and product and by-products separation and recovery. The step by step operations that a liquids depot would employ to identify its operational needs and methods to decrease operational costs are shown in Figure 2.3.4. Estimates of the processing requirements (materials and energy) are tabulated in the Appendix A. This analysis addresses the specific needs of a liquids operation implementing a sulfite pretreatment to overcome recalcitrance of lignocellulose (SPORL) method of pretreatment.

2.3.3 INTEGRATED BIOREFINERY SITE PROGRAMMING & RESOURCE FLOWS

An integrated biorefinery (IBR) is a high-capacity plant that uses either raw forest residuals, mechanically processed woody biomass, or liquid sugars to produce biojet fuel and other products. The target estimate for this operation is 770,000 BDT of biomass per year with an output of around 35 million gallons biojet fuel per year. This calculation is based on a projected 45 gallons of biojet produced per BDT. An IBR typically includes the following unit processes: mechanical pretreatment, chemical pretreatment, enzymatic hydrolysis, fermentation, isobutanol distillation, biojet fuel refining and distillation, and product distribution. While values for all flows are not known, Figure 2.3.5 indicates power and water flows (both out of processing and into wastewater treatment) and shows their relative importance in the overall design of an IBR plant.

The site programming begins with the arrival of forest residuals or liquid feedstock. Three unit processes were placed within the program: input, processing, and output. The input and output portions of the program include material transport into and out of the site and key materials. Processing includes major processes and/or pieces of machinery required. The resource flow diagram in Figure 2.3.5 shows a simplistic flow of mass, water and power through the fully integrated biorefinery design. The information gathered during the resource flow analysis was used to determine the most important parameters at an integrated biorefinery site.

Figure 2.3.5 depicts the most critical parameters in a fully integrated biorefinery model (water and utilities) and shows the developed resource flow for the entire plant operations. By including power, water, chemical inputs, and waste outputs such as wastewater treatment and co-products, complications on how to diagram energy and mass flow arise. For example, typical boiler/turbo-generator units are needed, and this type of equipment has a large energy demand. IBR operations in general will have high industrial power needs. Having a power source available on-site would be cost effective. Also, the wastewater treatment facility will pull wastewater from several steps of the process and should therefore be required for overall plant operations.

2.3.4 DISTILLATION AND DISTRIBUTION FACILITY SITE PROGRAMMING AND RESOURCE FLOWS

The distillation and distribution (D&D) site is an alternative to the fully integrated biorefinery. This type of operation would process only sugars from the liquids depot and thus perform actions beginning with fermentation through final refining and distribution. This type of operation has a much lower demand for power and wastewater treatment due to the lack of any pretreatment processing, and lower acreage demands over an IBR facility. A D&D facility is anticipated to have the same output as a traditional IBR, producing approximately 45 gallons of biojet fuel per BDT of biomass, but this output depends entirely on the sugar output from a liquids depot. The site programming and resource flow in Figure 2.3.6 is for a D&D site. Note that in this diagram, processed water is used only for the distillation and purification steps. The wastewater treatment site is only used for these steps plus fermentation. The boiler/turbogenerator provides power to every processing step.

Once site programming and resources flows were determined for the four site types, regional and site specific assets (e.g., proximity to harvested forests, site acreage, transportation access, etc.) were incorporated into a ranking tool used to further refine potential sites MC2P region that could contribute to the biojet fuels supply chain development. To construct the ranking tool, site assets and characteristics were weighted according to their relative importance to each type of operation. Sites were then compared using a matrix, and an overall score for each site was calculated based on the individual weights assigned to each facility's assets or characteristics. For example, close proximity to regularly harvested forest areas is a higher priority for a solids depot than for an integrated biorefinery, while an industrial site with large acreage is likely critical for an integrated biorefinery or a liquids depot and less important for a solids depot.

Sites were then organized into seven typologies based on regional assets and site characteristics. Table 2.3.1 shows the total number of sites identified in the MC2P region by facility type and category.

Liquid Depot Site Processing

Process with Separation, Steam Plant and Water Treatment Facility

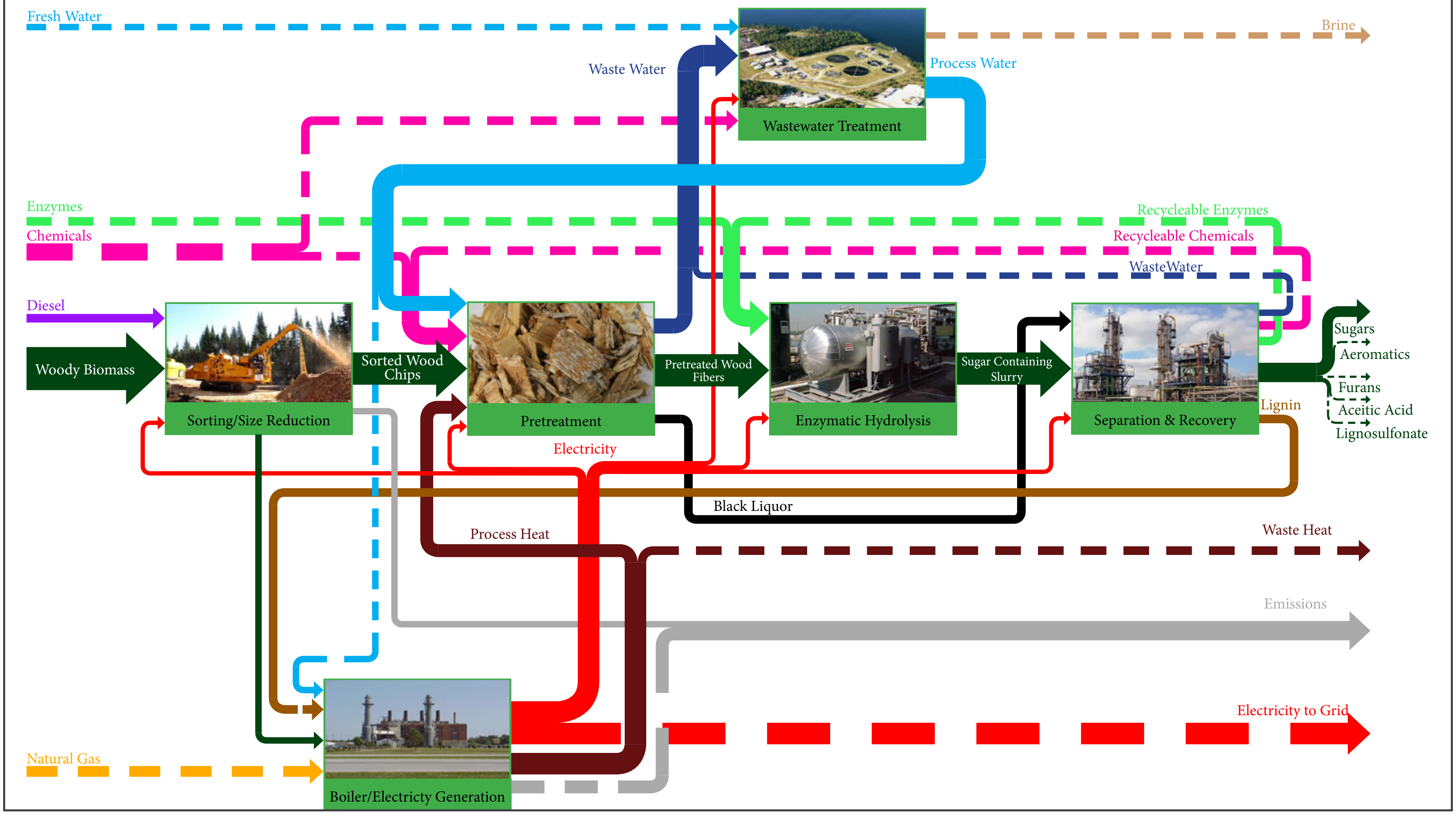


Figure 2.3.4. Liquids Depot Site Programming and Resource Flows

FULLY INTEGRATED RESOURCE FLOW

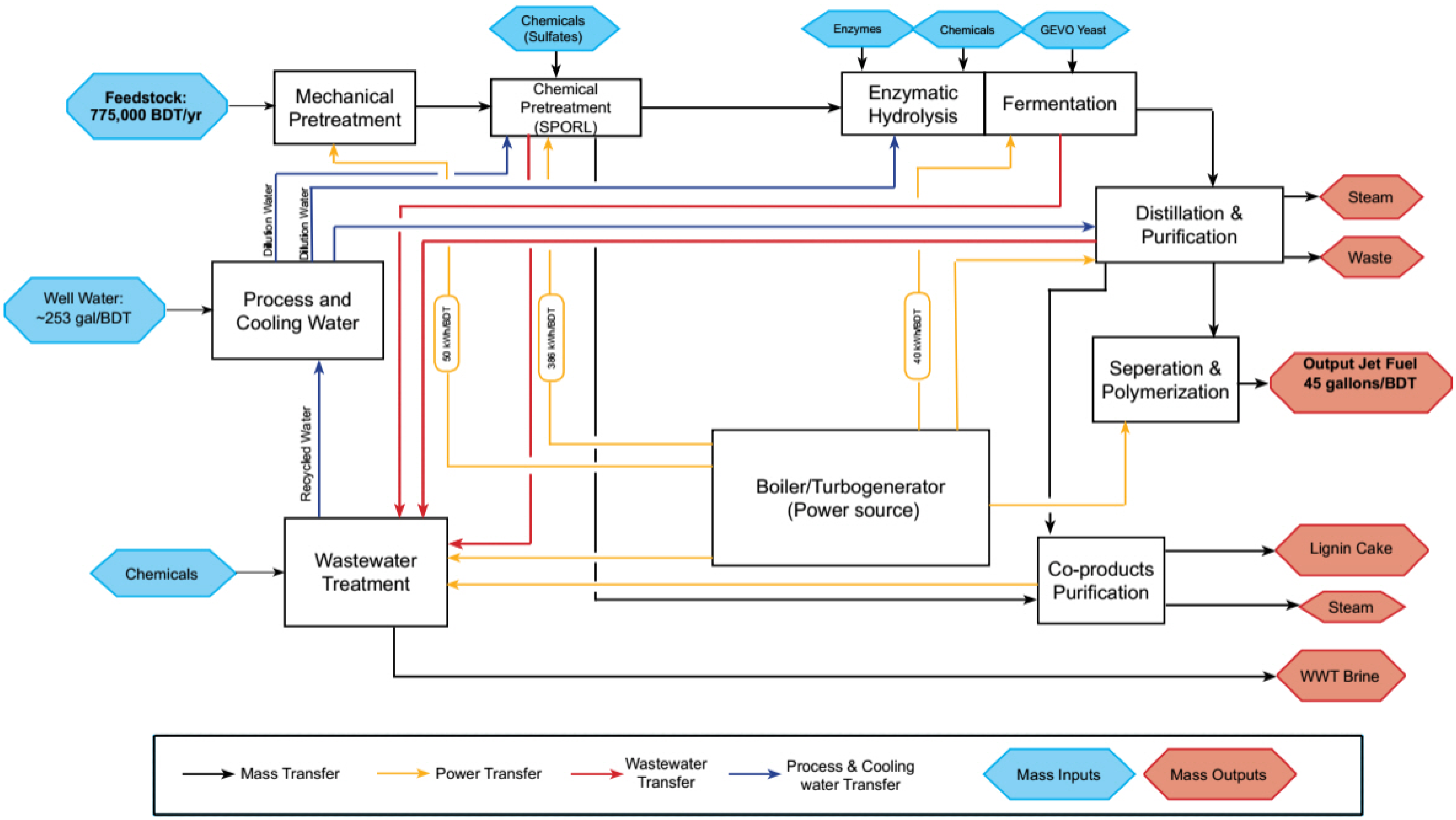


Figure 2.3.5. Integrated Biorefinery Site Programming and Resource Flows

DISTILLATION & DISTRIBUTION RESOURCE FLOW

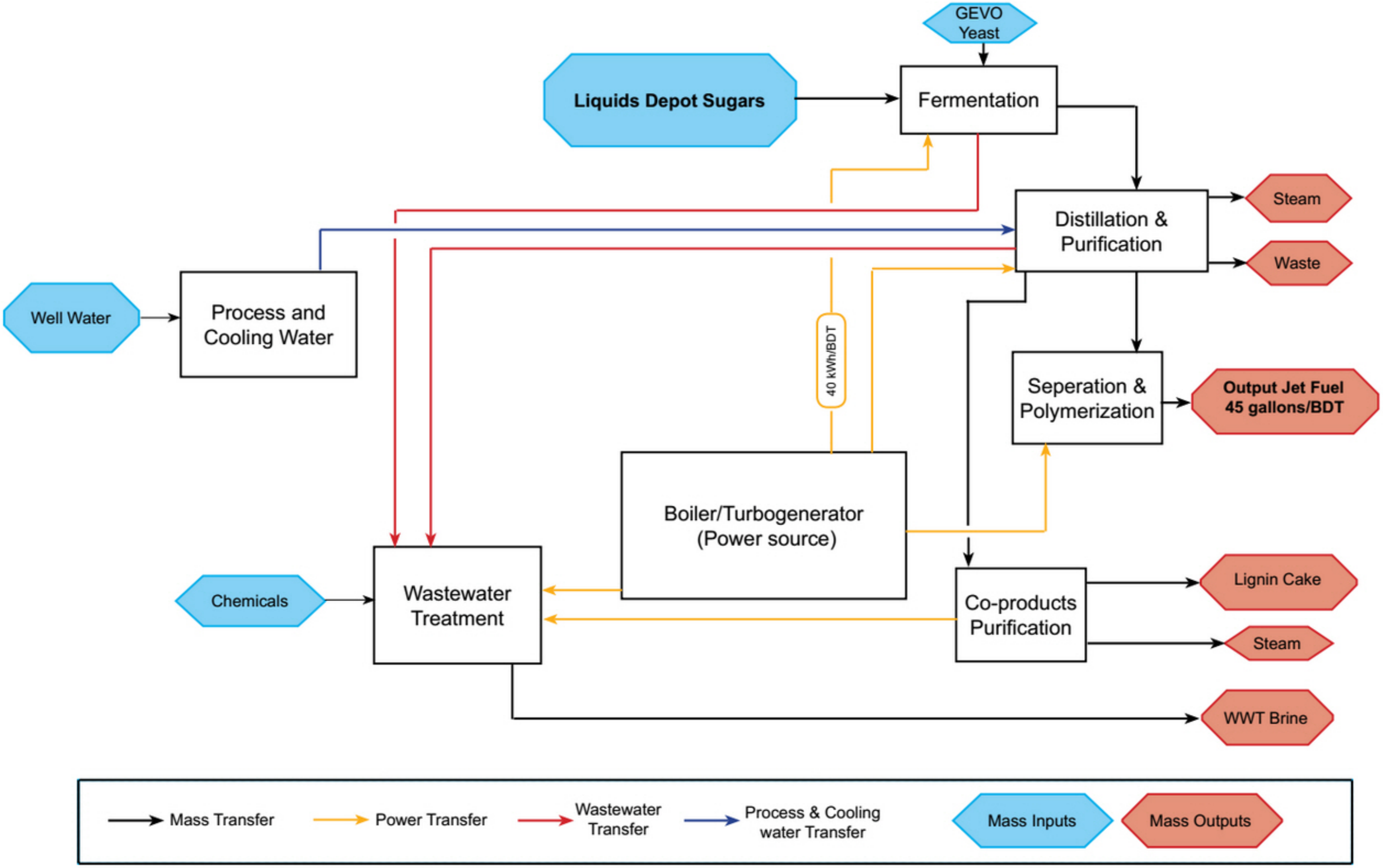


Figure 2.3.6. Distillation and Distribution IBR Site Programming and Resource Flows

2.3.5 SITE SELECTION

Table 2.3.1. Site Typology Categories

Solids Depot (24 Sites)	Liquids Depot (15 Sites)	Integrated Biorefinery (15 Sites)
Saw and/or Chip Mills	Kraft and/or Bi-sulfite Pulp & Paper Mills	Full Integration
Decommissioned Sites/ Surface Mines	Active Sawmills	Distillation/Distribution Only
	Inactive Mills	

Based on the site typology and weighting scheme, the candidate sites were ranked and two sites from among the top scoring candidates were selected for more intensive site study and design. The selected sites contained the highest number of assets and best potential for expansion or redevelopment. An additional consideration for further site analysis was whether site owners were interested in participating in a biofuels industry and willing to be an active participant in the IDX Studio evaluation process. If site owners/operators were not available, their sites were eliminated from future study. The candidate site suggestions in this document are by no means final, as new information about site conditions becomes available, NARA will reassess the opportunities.

Additional considerations used to determining optimal site selection include whether the site fits within the site typologies and could serve as a good case study with findings that are pertinent to several other similar sites and if the site case studies help to further NARA supply chain analysis research.

2.4.0 SITE SELECTION PROCESS

2.4.1 SOLIDS DEPOT

A solids depot would be the smallest facility in the supply chain, both in scale and in number of processes. It would accommodate: A) seasonal and surge storage for raw biomass, and B) mechanical feedstock size reduction (i.e., grinding or chipping). A solids depot would be located at a moderate distance by highway or a somewhat longer distance by rail from its customer liquids depot or IBR and would likely send its wood chip or pellet product by rail hopper car or by highway chip van. This type of plant could use raw forest residuals, forest thinnings, or C&D waste as feedstock.

The site selection criteria for a solids depot are:

- Existing on-site operations (i.e. active or inactive sawmill, chip mill or surface mine)
- Proximity to biomass feedstock
- River port access
- Rail transport link
- Electrical rates

Twenty-four locations were selected and ranked according to the criteria and are shown in Tables 2.4.2 and 2.4.3. Those sites highlighted in blue have been selected for intensive study.

SOLIDS DEPOT ASSET SUMMARY

Many aspects determine whether a site will make an effective solids depot. The most important aspect is proximity to and availability of feedstock. A solids depot operation should be near enough to active logging operations so that transportation costs will be lower. A solid depot should have good transportation routes and also be in proximity to potential liquids depots or an IBR. The MC2P region is littered with active, abandoned sawmills and contains a complicated rail network that provides access to many of the solids depots under consideration. The MC2P region also has two major rivers that divide the region almost in half, North to South and East to West, which could provide a more economically efficient transport option. Twenty-three locations were selected and ranked according to the criteria and are shown in Tables 2.4.2 and 2.4.3. Those sites highlighted in blue have been selected for intensive study.

Table 2.4.1. Solids Depot Site Selection Criteria

	-5	-3	-1	1	3	5
Biomass Residual by Drive Time*	Score (x) less than 35	36 to 40	41 to 45	46 to 50	51 to 55	56 or >
Rail	No feasible rail option	Rail > 5 miles	Rail within 5 miles	Rail within 1 mile	Rail within ½ mile	Rail available onsite
Electrical ($/kWh)	> 0.0838	0.0837-0.0766	0.0765-0.0694	0.0693-0.0621	0.0620-0.0549	< 0.0548
River Access	>5 miles from river	<5 miles from river	Within ½ mile of river	River access, no port facilities	Barge access available with no conveyor	Barge access available on site with conveyor

*Biomass Residuals by Drive Time score explanation

Bone Dry Tons (BDT) available within .5 hour totals are multiplied by 3
BDT available within 1 hour totals are multiplied by 1.5
BDT available within 1.5 hour totals are not multiplied
Final Score (ranging from 35 to over 56) = summation of totals multiplied by respective factors

Table 2.4.2. Active Chip Mill and Sawmill Candidate Solids Depot Facility Operation

Facility Name	County	City	State	Rank
Sierra Pacific Industries	Grays Harbor	Aberdeen	WA	1
Longview Fibre Co/ Kapstone	Cowlitz	Longview	WA	2
Columbia Fiber	Cowlitz	Kalama	WA	3
Stimson Lumber Company	Columbia	Clatskanie	OR	4
Pacific Fibre Products Inc	Cowlitz	Longview	WA	5
RSG Forest Products	Cowlitz	Kalama	WA	7
Dahlstrom Lumber Company	Grays Harbor	Hoquiam	WA	8
Simpson Timber Co.	Cowlitz	Longview	WA	9
Northwest Hardwood Mill	Cowlitz	Longview	WA	10
RSG Forest Products	Columbia	Mist	OR	11
Yankee Forest Products	Columbia	Clatskanie	OR	14
Litter River Inc.	Grays Harbor	Hoquiam	WA	13
Willis Enterprises	Grays Harbor	Hoquiam	WA	14
Weyerhaeuser Co.	Grays Harbor	Aberdeen	WA	15

Table 2.4.3. Surface Mine and Decommissioned Site Candidate Solids Depot Facility Operations

Facility Name	County	City	State	Rank
Former Bradley-Woodward Lumber Company (decommissioned)	Clatsop	Bradwood	OR	1
Neshkaw Sand & Gravel	Grays Harbor		WA	2
Weyerhaeuser Co. (Winter's Pit)	Grays Harbor	Aberdeen	WA	3
Northwest Rock Inc. (Wynoochee East)	Grays Harbor		WA	4
Northwest Rock Inc (Evergreen)	Grays Harbor		WA	5
Northwest Rock Inc (Studer Pit)	Grays Harbor		WA	6
Cowlitz River (Robert J Thompson)	Cowlitz		WA	7
Wallace Rock Product	Lewis		WA	8
Eagle Cliff Northwest LLC (Forest Creek Pit)	Lewis		WA	9

2.4.2 LIQUIDS DEPOT

A liquids depot site could be smaller than an IBR in scale and in its range of manufacturing processes. It would include: A) seasonal and surge storage for raw biomass; B) mechanical feedstock size reduction (i.e., grinding or chipping, pelletizing); C) chemical and thermal pretreatment to further break down the biomass into its cellulose, hemicellulose, and lignin constituents; and D) enzymatic hydrolysis to separate cellulose and hemicellulose into their 5- and 6-carbon sugars. A liquids depot could be located at some distance, perhaps several hundred miles, from its customer IBR, and it could ship its sugar-rich syrup product by tanker truck, rail tank car or through dedicated pipelines. This type of plant could use raw bulk wood residuals or densified biomass, such as chips or pellets, as feedstock, and its syrup output might serve other consumers, such as ethanol or chemical plants. Lignin-based co-products might also be marketed from this type of operation.

The site selection criteria for liquids depot are:

- Status of on-site operations (active pulp & paper mill, active sawmill, idled operation, decommissioned operations)
- Feedstock availability
- Transportation access (rail, highway, barge/seaport)
- Utilities (electricity and natural gas)
- Water availability
- Unemployment rate

Fifteen locations were selected and ranked according to the criteria and are shown in Tables 2.4.4, 2.4.5, and 2.4.6. Those sites highlighted in blue have been selected for intensive study.

Table 2.4.4. Liquids Depot Site Selection Criteria Results

	-5	-3	-1	1	3	5
Forest Residuals (Bone Dry Tons (BDT) per square mile)	No forest residual present.	Non-RFS2 qualifying forest residual.	The majority of all RFS2-qualifying residual within a 30 mile radius has a density less than or equal to 150 BDT/sq mi	The majority of all RFS2-qualifying residual within a 30 mile radius has a density between 150-299 BDT/sq mi	The majority of all RFS2-qualifying residual within a 30 mile radius has a density between 300-449 BDT/sq mi	The majority of all RFS2-qualifying residual within a 30 mile radius has a density greater than 450 BDT/sq mi
C&D Wastesheds (BDT) (2011 data)	No wood reported	< 71,244 BDT	71,245-106,704	106,705-142,164	142,165-177,623	> 177,624
Proximity to Rail	no rail within 10 miles of facility	rail within 10 miles of facility	rail within 5 miles of facility	rail within 1 miles of facility	rail within ½ of facility	rail within facility
Proximity to Roads	>20 miles to highway or interstate	< 20 miles to highway or interstate	< 15 miles to highway or interstate	< 5 miles to highway or < 10 miles to interstate	< 1 mile to highway or < 5 miles to interstate	< 1 mile to interstate
Proximity to Ports	no ports within 5 miles	port within 5 miles	port within 1 mile that can either ship or receive liquid depot materials	port within 1 mile that can receive and ship liquid depot material	port on site that can either ship or receive liquid depot materials	port on site that can receive and ship liquid depot materials
Facility Size	< 30 acres	30-59 acres	60-89 acres	90-119 acres	120-149 acres	< 150
Facility Type				Saw Mill		Pulp Mill
Operational Status	Decommissioned Brownfield	Idle Brownfield	Greenfield	Decommissioned Greyfield	Idle	Active
Electrical Rates ($/kWh)	> 0.0838	0.0837-0.0766	0.0765-0.0694	0.0693-0.0621	0.0620-0.0549	< 0.0548
Natural Gas	not in service zone					in service zone
Rivers	< 80 cfs	80-279 cfs	280-1249 cfs	1250-2224 cfs	2225-3799 cfs	> 3800
Unemployment Rate	< 4.5 %	4.5 - 6 %	6.1 - 7.5 %	7.6-9 %	9.1-10.5 %	> 10.6 %

Table 2.4.5. Pulp and Paper Mill Candidates for Liquid Depot Operations

Facility Name	County	City	State	Rank
Kapstone Pulp & Packaging a/k/a Weyerhaeuser Co.-Longview (Kraft)	Cowlitz	Longview	WA	1
Longview Fibre Co. (Kraft)	Cowlitz	Longview	WA	1
Georgia Pacific-Wauna Paper Mill (Kraft)	Columbia	Clatskanie	OR	2
Cosmo Specialty Fibers* (Bisulfite)	Grays Harbor	Cosmopolis	WA	3

*Cosmo Specialty Fibers is being considered in the IBR; in the analysis, it will be shown how this facility could also be a liquid depot. It is a bisulfite operation which has slightly higher potential to convert woody biomass into isobutanol compared to traditional kraft pulp and paper mill.

Table 2.4.6. Active Sawmill Candidates for Liquid Depot Operations

Facility Name	County	City	State	Rank
Hampton Lumber (Weyerhaeuser-Warrenton Mill)	Clatsop	Warrenton	OR	1
Dahlstrom Lumber	Grays Harbor	Hoquiam	WA	2
Sierra Pacific Industries-Aberdeen Division	Grays Harbor	Aberdeen	WA	3
Mary's River Lumber Company	Grays Harbor	Montesano	WA	3
Stimson Lumber/Stimson Lumber Forest Grove	Washington	Gaston	OR	4
Simpson Lumber Co.	Cowlitz	Longview	WA	5
Banks Lumber	Washington	Banks	OR	6
Northwest Hardwood Mill - Longview	Cowlitz	Longview	WA	7
Stimson Lumber Co.-Clatskanie Sawmill	Columbia	Clatskanie	OR	8
RSG Forest Products-Olympic Forest Products	Columbia	Mist	OR	9
Little River Inc.	Grays Harbor	Hoquiam	WA	10

Table 2.4.7. Inactive Sawmill Candidate Liquid Depot Operations

Facility Name	County	City	State	Rank
Weyerhaeuser Bay City Log Yard	Grays Harbor	Aberdeen	WA	1

LIQUID DEPOT ASSET SUMMARY

The liquids depot operation converts woody biomass to sugar. The most important assets to a liquids depot operations are the proximity to private forest residuals, pulp mill and sawmill locations, and transportation access and options. The most significant input for a liquids depot is woody biomass. Having the facility situated near privately-owned forests that produce forest residuals would require less energy dedicated to biomass transport. Pulp mills are an ideal facility to consider for use as a liquids depot as they could be easily retrofitted, thus minimizing capital costs. Plus operational pulp mills typically have infrastructure already in place, such as roads, railways, or even port access, which makes diverse transportation solutions viable. Transportation options allows a liquids depot to select the most economic mode of transport depending on various operational circumstances. In conjunction with pulp mills, proximity to sawmills also ranked high in the criteria. Sawmills could be a good source of feedstock and provide pretreated biomass feedstock. The most desired assets were evaluated using Geographic Information Systems (GIS) to help identify the preferred locations for liquids depots within the MC2P region. The preferred locations where the greatest number of assets overlapped were located in Columbia County in Oregon, Grays Harbor and Cowlitz counties in Washington.

2.4.3 INTEGRATED BIOREFINERY SITES

An integrated biorefinery (IBR) is a high-capacity plant that can convert biomass from raw slash or other woody residuals to isobutanol or biojet fuel. The IBR includes the following major handling and processing stages: A) seasonal and surge storage for raw biomass; B) mechanical feedstock size reduction (i.e., grinding or chipping); C) chemical and thermal pretreatment to further break down the biomass into its cellulose, hemicellulose, and lignin constituents; D) enzymatic hydrolysis to break down cellulose and hemicellulose into their 5- and 6-carbon primary sugars; E) Primary sugar fermentation to produce isobutanol; F) extraction of isobutanol, likely simultaneous with fermentation; and G) oligomerization of isobutanol to produce the final iso-paraffinic kerosene jetfuel. An IBR would operate most economically by receiving feedstocks directly from nearby forests, chips or pellets from solids depots, or sugar-rich syrup from liquids depots.

The site selection criteria for an integrated biorefinery are:

- Biomass availability
- Existing site acreage
- Rail access
- Barge access
- Aviation facilities
- Cost of living Index
- Electricity rates
- Labor force
- Boiler/Energy plant
- Hydrolysis/Fermentation capability
- Kraft/Bisulfite pretreatment capability
- Wastewater treatment

Fifteen locations were selected and ranked according to the criteria and are shown in Tables 2.4.9 and 2.4.10. Those sites highlighted in blue have been selected for intensive study.

INTEGRATED BIOREFINERY ASSET SUMMARY

The IBR has the potential to be an entirely internalized processing unit for converting raw forest residuals to a final biojet fuel product. However, for the purposes of this analysis, the biorefinery will be considered dependent on receiving mechanically and chemically pretreated material delivered from other facilities. Thus, the integrated biorefinery will be responsible primarily for converting primary sugars to isobutanol and using the isobutanol to produce refined biojet fuel. From this location the biojet fuel will be distributed and all co-products and wastes will be further processed or disposed. Key assets for locating an IBR including existing industrial facilities; proximity to road, rail, pipelines and barge transportation; utility rates; community factors such as the cost of living and other demographics; and the locations of customers such as large airports, aviation companies and military aircraft bases.

Table 2.4.8. IBR Site Selection Criteria

	-5	-3	-1	1	3	5
Biomass Availability (Bone Dry Tons (BDT) per square mile)	No forest residual present.	Non-RFS2 qualifying forest residual.	The majority of all RFS2-qualifying residual within a 30 mile radius has a density less than or equal to 150 BDT/sq mi	The majority of all RFS2-qualifying residual within a 30 mile radius has a density between 150-299 BDT/sq mi	The majority of all RFS2-qualifying residual within a 30 mile radius has a density between 300-449 BDT/sq mi	The majority of all RFS2-qualifying residual within a 30 mile radius has a density greater than 450 BDT/sq mi
Rail Access	No rail access within 10 miles and/or rail is not possible to access due to obstruction.	Rail access within 10 miles and/or rail access is not currently possible but could be added at high cost.	The closest rail is within 5 miles of the site and/or rail could be added at relatively low cost.	The closest rail is within 1 mile of the site and a spur can be added.	The closest rail is within 1/2 mile and a spur can easily be added.	Rail is available on site.
Barge Access	Barge Access is not possible or no rail within 1 mile of a site.	Barge access is possible through rail within 40 miles or barge is within 10 miles but no rail is available within 1 mile of the site.	Barge access is possible through rail within 30 miles. (Rail is within 1 mile of site)	Barge access is possible through rail within 20 miles. (Rail is within 1 mile of site)	Barge access is possible through rail within 10 miles. (Rail is within 1 mile of site)	Port on site.
Pipeline	Site is nowhere near a pipeline, and pipeline use is not possible.	Site is within 50 direct miles to closest petroleum terminal	Site is within 40 direct miles to closest petroleum terminal	Site is within 30 direct miles to closest petroleum terminal	Site is within 20 direct miles to closest petroleum terminal	Site is within 10 direct miles to closest petroleum terminal
Aviation Facilities	No airports exist within 500 miles of the site.	Site is between 400-499 miles away from nearest airport, military base or other consumer of biofuels.	Site is between 300-299 miles from nearest airport, military base or other consumer of biofuels.	Site is between 200-299 miles from nearest airport, military base or other consumer of biofuels.	Site is between 100-199 miles from nearest airport, military base or other consumer of biofuels.	Site is within 100 miles of nearest airport, military base or other consumer of biofuels.
Cost of Living Index	Cost of Living Index is between 94 and 95.6.	Cost of Living Index is between 92.5 and 94.	Cost of Living Index is between 91 and 92.5.	Cost of Living Index is between 89.5 and 91.	Cost of Living Index is between 88 and 89.5.	Cost of Living Index is between 85.9 and 88.
Electricity Rates ($/kWh)	>= 0.0838	0.0837 - 0.0766	0.0765 - 0.0694	0.0693 - 0.0621	0.0620 - 0.0549	<= 0.0548
Labor Force	less than 334,200	334,200 to 353,400	353,400 to 372,600	372,600 to 391,800	391,800 to 411,000	greater than 411,000.
Existing Site Acreage	< 50 Acres	50-100 acres	100-150 acres	150-200 acres	200-250 acres	250+ acres
Wastewater Treatment	not on site					on site
Boiler/Energy Plant	not on site					on site
Hydrolysis/ Fermentation Capability	no					yes
Pretreatment Capability (Kraft or Bisulfite)	no					yes

Table 2.4.9. Fully Integrated Facility Candidates for an Integrated Biorefinery Operation

Facility Name	County	City	State	Rank
Georgia-Pacific Wauna Paper Mill	Columbia	Clatskanie	OR	1
Weyerhaeuser Co. - Longview/North Pacific Paper Company	Cowlitz	Longview	WA	2
Longview Fibre Paper and Packaging Inc.	Cowlitz	Longview	WA	3
Cascade Pacific LLC/Georgia-Pacific	Linn	Halsey	OR	4
International Paper - Albany Paper Mill	Linn	Albany	OR	5
Georgia-Pacific Corp/Camas Paper Mill	Clark	Camas	WA	6
Cosmo Specialty Fibers (CSF)	Grays Harbor	Cosmopolis	WA	7

Table 2.4.10. Distillation and Distribution Candidates for an Integrated Biorefinery Operation

Facility Name	County	City	State	Rank
Boise Cascade - St. Helens/Cascade Tissue Group	Columbia	St. Helens	OR	1
SP Newsprint	Yamhill	Newberg	OR	2
Columbia Pacific Biorefinery	Columbia	Clatskanie	OR	3
Georgia-Pacific West Inc.	Lincoln	Toledo	OR	4
Summit Natural Energy Biorefinery	Washington	Cornelius	OR	5
West Linn Paper Company	Clackamas	West Linn	OR	6
Grays Harbor Paper Company	Grays Harbor	Hoquiam	WA	7
Blue Heron Paper Company	Clackamas	Oregon City	OR	8

*NOTE: NARA did not find a site client for this distillation and distribution IBR scenario.

2.5.0 SUPPLY CHAIN ANALYSIS METHODOLOGY

A supply chain is a system developed to move products or services from supplier to consumer and includes organizations, people, technology, activities, information and resources (Vitasek 2010). Activities along the supply chain transform natural resources, raw materials, and components into a finished product delivered to the end consumer. Forest residuals must go through several processes to be converted into isobutanol and ultimately biojet fuel. These processes include preconversion (chipping the woody biomass into a usable feedstock), conversion (chemically and biologically converting the feedstock into isobutanol), and post conversion (refining into fuel and other co-products). Facilities that can perform these different types of operations are needed throughout the supply chain. Supply chain analysis has been acknowledged as one of the required assessments for stimulating renewable energy development (Council 2011).

The beginning of the biofuels supply chain is the forest. A successful biofuels supply chain requires a region rich in woody biomass, such as the MC2P. To further examine the potential of our candidates sites IDX Studio utilized GIS to examine various supply chain scenarios within the MC2P region. Assuming a hypothetical IBR at Cosmopolis Specialty Fibers, IDX modeled the optimal supply chains for aggregating a minimum of 770,000 BDT/year of residual biomass and comparing and contrasting different combinations of solids depots, liquids depots and integrated biorefinery operations. Figure 2.5.1 illustrates the varied processing steps in the supply chain.

FOREST RESIDUES PREPARATION

Primary feedstock targets include forest residues from logging and thinning operations. We are also considering mill residues and discarded woody material from construction and demolition, in regions where these materials are under utilized.

TRANSPORTATION

Feedstocks are transported from the collection site to a conversion facility. Chipping can take place at the loading or in a preprocessing facility.

PRE-TREATMENT

Wood chips are treated to make the sugar polymers (polysaccharides) accessible to degrading enzymes. These processes allow the lignin to be available for separation.

ENZYMATIC HYDROLYSIS

Specific enzymes are added to hydrolyze (cleave) the polysaccharides and generate simple sugars (monosaccharides).

FERMENTATION

Specialized yeast convert the monosaccharides into isobutanol.

BIOJET & CO-PRODUCTS

Aviation fuels can be generated from the platform molecules derived from wood sugars. Lignin can be used to generate co-products such as epoxies, structural materials and bio-based plastics. As an alternative, lignin can be burned to produce renewable energy.

ONE BONE DRY **TON** WOODY BIOMASS + DIESEL + HEAT, WATER, & CHEMICALS = **~600** **POUNDS** LIGNIN AND **~60** **GALLONS** ISOBUTANOL OR **~45** **GALLONS** BIOJET

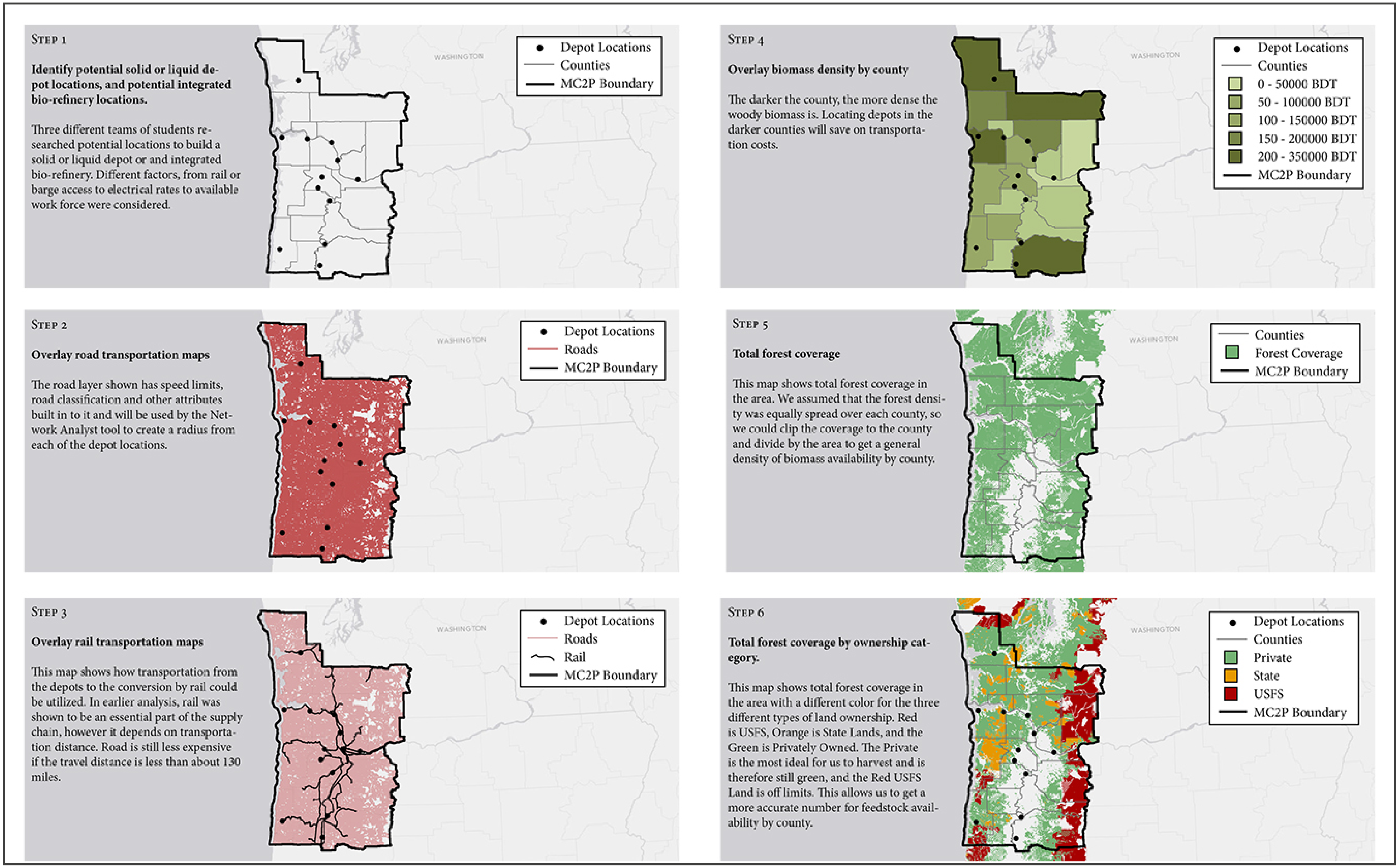
Figure 2.5.1. NARA Supply Chain

2.5.1 STEPS OF ANALYSIS

This section shows the steps taken to undertake the analysis. In order to perform analysis, scenarios were created to take into consideration feedstock availability and transportation distances within the MC2P region. Assumptions made for each type of operation along the supply chain, as well as feedstock availability calculations, are described in the following.

For a solids depot, the following conditions were used in the GIS model:

- Highway and rail access were considered mandatory. That way either trucks or trains could be used to transport the chips or slash to and from depot locations.
- Only existing active saw or chip mill sites were considered. This consideration would reduce capitalization costs as the site would already existing machinery, stormwater permits and electricity access.



Step 1

Identify potential solid or liquid depot locations, and potential integrated bio-refinery locations.

Three different teams of students researched potential locations to build a solid or liquid depot or and integrated bio-refinery. Different factors, from rail or barge access to electrical rates to available work force were considered.

Step 2

Overlay road transportation maps

The road layer shown has speed limits, road classification and other attributes built in to it and will be used by the Network Analyst tool to create a radius from each of the depot locations.

Step 3

Overlay rail transportation maps

This map shows how transportation from the depots to the conversion by rail could be utilized. In earlier analysis, rail was shown to be an essential part of the supply chain, however it depends on transportation distance. Road is still less expensive if the travel distance is less than about 130 miles.

Step 4

Overlay biomass density by county

The darker the county, the more dense the woody biomass is. Locating depots in the darker counties will save on transportation costs.

Step 5

Total forest coverage

This map shows total forest coverage in the area. We assumed that the forest density was equally spread over each county, so we could clip the coverage to the county and divide by the area to get a general density of biomass availability by county.

Step 6

Total forest coverage by ownership category.

This map shows total forest coverage in the area with a different color for the three different types of land ownership. Red is USFS, Orange is State Lands, and the Green is Privately Owned. The Private is the most ideal for us to harvest and is therefore still green, and the Red USFS Land is off limits. This allows us to get a more accurate number for feedstock availability by county.

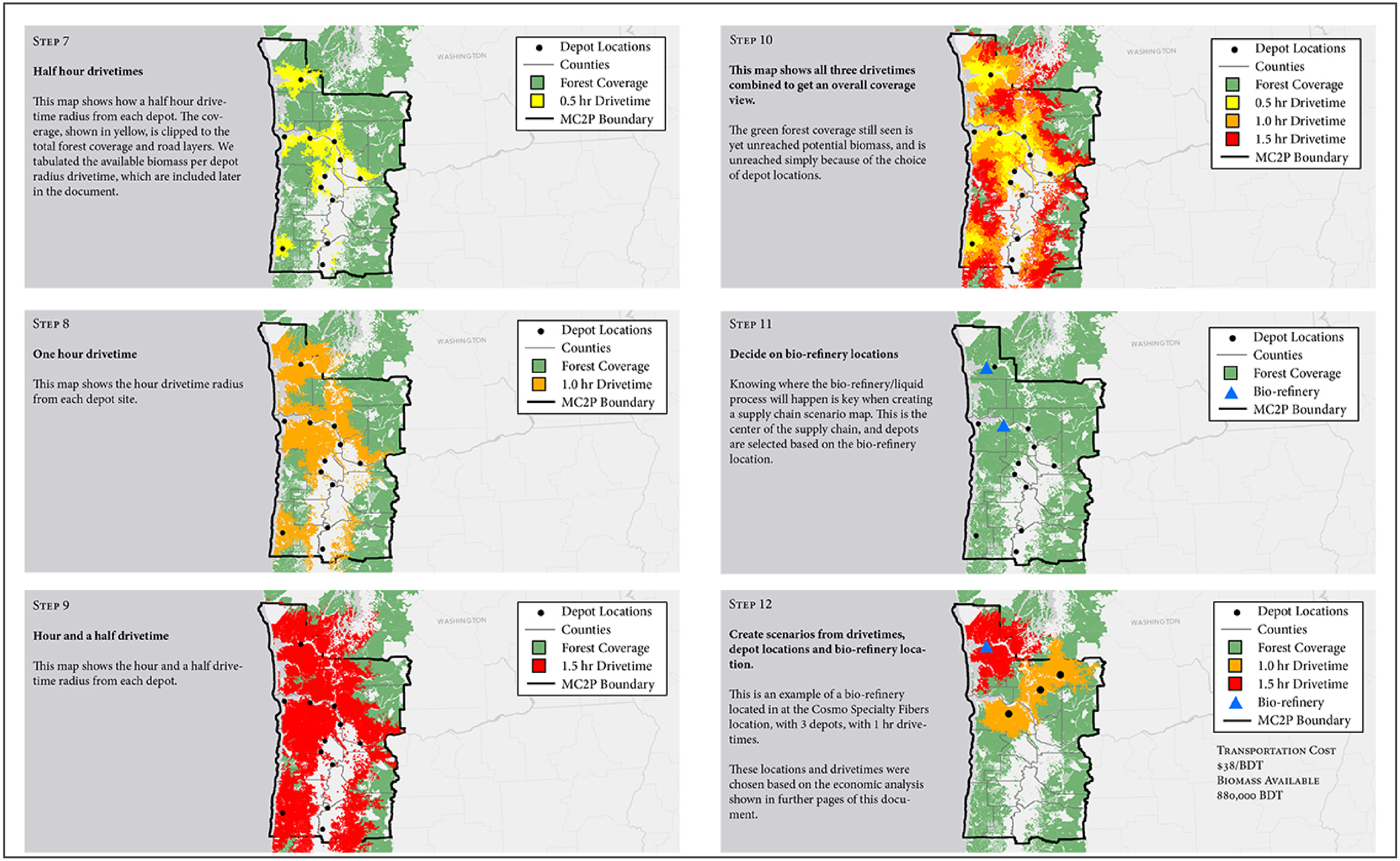
Figure 2.5.2.

- The existing saw or mill site could accommodate the additional operations of converting forest residuals to chemical products.

Based upon additional analysis in GIS, a short-list of 20 solids depots were originally considered; however only three were needed to provide the estimated 770,000 BDT/year demand threshold. The three selected solids depots were chosen to maximize the amount of residual biomass that could be collected, aggregated and transported to our hypothetical IBR site at Cosmo Specialty Fibers.

The following assumptions were made when estimating the available biomass feedstock per drivetime radius:

- Forest residues were selected as the feedstock for the proposed depot or integrated biorefinery.
- The forest residues were assumed to be located at the landing.



STEP 7

Half hour drivetimes

This map shows how a half hour drivetime radius from each depot. The coverage, shown in yellow, is clipped to the total forest coverage and road layers. We tabulated the available biomass per depot radius drivetime, which are included later in the document.

STEP 8

One hour drivetime

This map shows the hour drivetime radius from each depot site.

STEP 9

Hour and a half drivetime

This map shows the hour and a half drivetime radius from each depot.

STEP 10

This map shows all three drivetimes combined to get an overall coverage view.

The green forest coverage still seen is yet unreached potential biomass, and is unreached simply because of the choice of depot locations.

STEP 11

Decide on bio-refinery locations

Knowing where the bio-refinery/liquid process will happen is key when creating a supply chain scenario map. This is the center of the supply chain, and depots are selected based on the bio-refinery location.

STEP 12

Create scenarios from drivetimes, depot locations and bio-refinery location.

This is an example of a bio-refinery located in at the Cosmo Specialty Fibers location, with 3 depots, with 1 hr drivetimes.

These locations and drivetimes were chosen based on the economic analysis shown in further pages of this document.

TRANSPORTATION COST
$38/BDT
BIOMASS AVAILABLE
880,000 BDT

Figure 2.5.3.

- Forest residual feedstock was assumed to be evenly distributed throughout the forest ownership information and availability was only considered from private, tribal or state forest lands. Timber harvest and processing happens year round with no seasonal variability.
- The biorefinery must operate at 770,000 bdt/yr to be economically viable.
- The trucks/trains haul at full capacity.

Using forest residual volume per county estimates (Figure 2.5.2), "drive times" were calculated for each selected depot site. A geodatabase containing all the roads in the MC2P was created in GIS and analyzed using the GIS Network Analyst tool. This tool takes an input of a point file (the depot location) and creates a radius around the proposed depot location that shows the distance traveled given a set time. Radii for 0.5 hr, 1.0 hr, 1.5 hr and 2.0 hrs drive times were calculated and presented in Figure 2.5.3 . The drive time radii were created for each depot site and clipped to the forest coverage map. This forest coverage map, shown in the ArcGIS steps, was clipped by county so that residual volume was only available where forest lands exist. These steps provided volume/forested area/county.

By associating drive time radii to forest coverage, the density of forest residuals by county could be used to determine the volume per drivetime. Supply curves for every depot were plotted to determine the amount of available feedstock for each depot. In addition, best fit curve equations were interpolated using Excel, and the equations are used later to calculate the amount of harvestable feedstock available based on drive times.

Using ArcGIS, six shapefiles were layered to produce the final drivetime maps. Selected depots were layered over the road and rail networks followed by available forest volume. From there, the different types of forest ownership were identified.

Figure 2.5.4 shows the selected depots in the MC2P region. The ArcGIS data show the facilities in Washington that may purchase logs or wood chips. Jean Daniels, Research Forester at the U.S. Forest Service Pacific Northwest Research Station and Todd Morgan of the University of Montana Bureau of Business and Economic Research created the Idaho and Oregon mills shapefiles; they are current as of 2007 and 2008 respectively. The Washington mills shapefile was created by the Washington Department of Natural Resources. It is current as of 2008. The operational status (i.e. inactive, abandoned, idled or closed) and locations of some mills were updated based on website information. The Montana mill GIS file, created by Todd Morgan, was current as of 2009.

Figure 2.5.5 shows the road network in the U.S. and Canada detailing streets, highways, primary roads(with and without limited access) secondary and connecting roads, local and rural roads, trails, roads with special characteristics, access ramps, and ferries. This data set contains road network features such as arterial classification, speed, and direction of travel and addresses.

Figure 2.5.6 shows the rail network system available for processed forest residual transport. The Federal Railroad Administration (FRA) develops and maintains the rail network geospatial data layer. The Research and Innovative Technology Administration's Bureau of Transportation Statistics (RITA/BTS) compiled and formatted the data for release on the National Transportation Atlas Databases (NTAD) 2005. The re-digitized data was created by the GIS section at the Idaho Transportation Department, February, 2006.

Figure 2.5.7 displays the volume of forest residuals per county. The steps used to calculate these volumes were:

1) SEPARATE volumes by ownership class for each year;
2) AVERAGE the volumes by ownership class for 2002 and 2010 (Washington), 2003 and 2008 (Oregon & Montana) and 2001, 2006, 2011 (Idaho). Timber Products Output (TPO) ownership classes include: USFS, Other Public, Private, and Mill. "Other Public - State" volumes were determined by calculating the percent of State-owned forest lands in each county and then multiplying the percentage by the "Other Public" volume to obtain a State volume estimate. These volumes were combined into a shapefile of Washington, Oregon, Idaho and Montana Counties. A separate shapefile was created for each of the four states. The TPO dataset was provided by Todd Morgan at the Bureau for Business and Economic Research (BBER) at the University of Montana Missoula. [10] The logging residue was converted from cubic feet to bone dry tons using the conversion 1CF = 0.0125BDT.

Figure 2.5.8 illustrates forest coverage determined from the USFS dataset.

Figure 2.5.9 shows the final layer which separates forest coverage into the different ownership types. Natalie Martinkus, NARA Education Team lead for GIS, created this shapefile using the following steps:

1) REMOVED all land uses from the National Land Cover Database (2006) CONUS Land Cover tiles for Oregon (http://www.mrlc.gov/nlcd2006.php) that were not forest related and merged tiles together while retaining 41- Deciduous Forest, 42- Evergreen Forest, and 43- Mixed Forest);
2) DOWNLOADED Protected Areas Database_CBI Edition V2 (http://consbio.org/products/projects/pad-us-cbi-editionto obtain land ownership) and clipped PAD ownership by Oregon counties;
3) JOINED land cover with land ownership using the union tool so areas with a forested land cover were joined to associated land ownership; 4) added a "TPO Owner" column sorted into the classes "Other Public - State," "Other Public - Fed," "Private," and "USFS'.

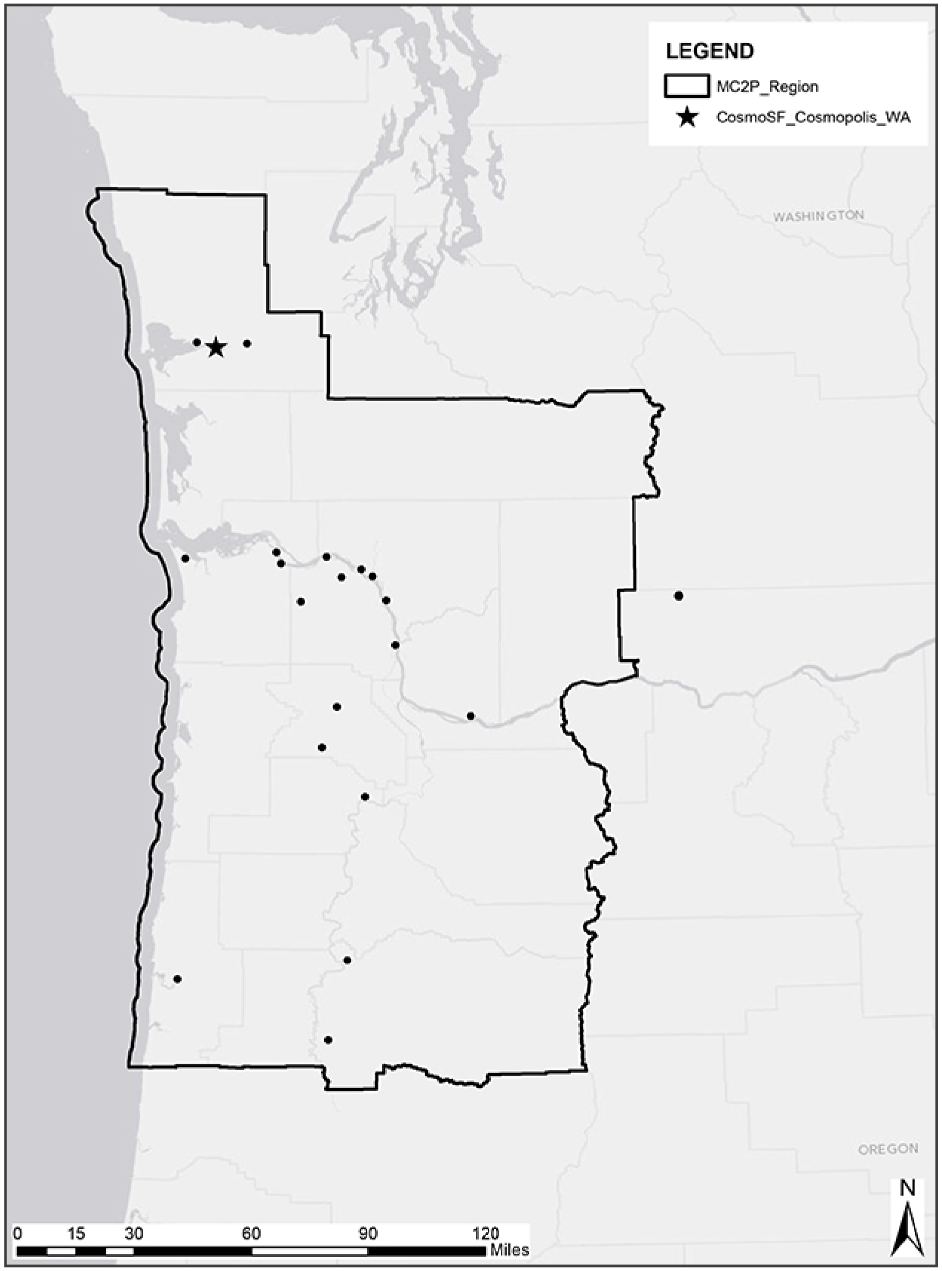


Figure 2.5.4. Shows the proposed Solids Depot locations in the MC2P region in proximity to proposed integrated bio-refinery in Cosmopolis, WA.

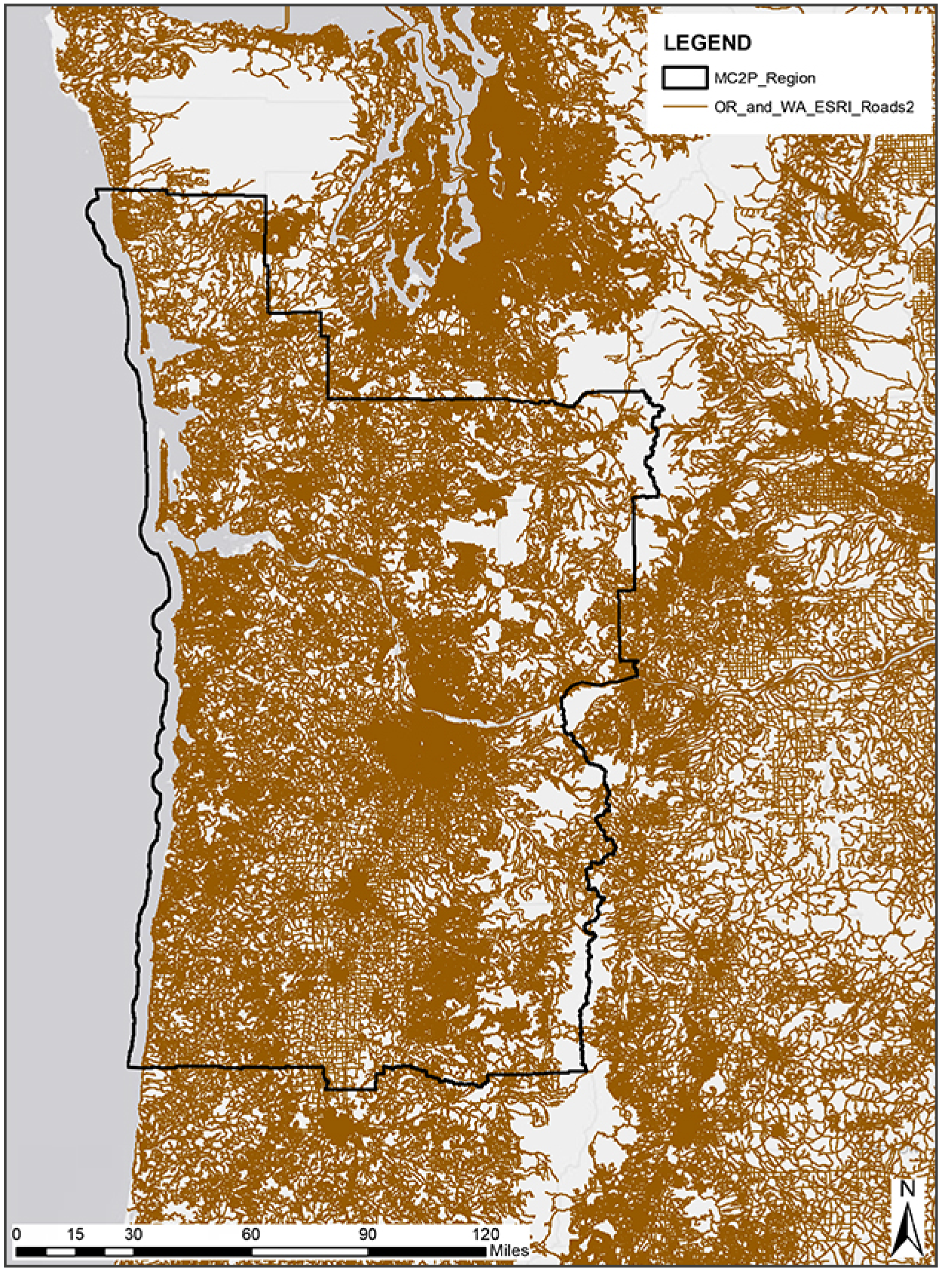


Figure 2.5.5. Shows the road network in the U.S. and portions of Canada detailing streets, highways, primary roads (with and without limited access) secondary and connecting roads, local and rural roads, trails, roads with special characteristics, access ramps, and ferries.

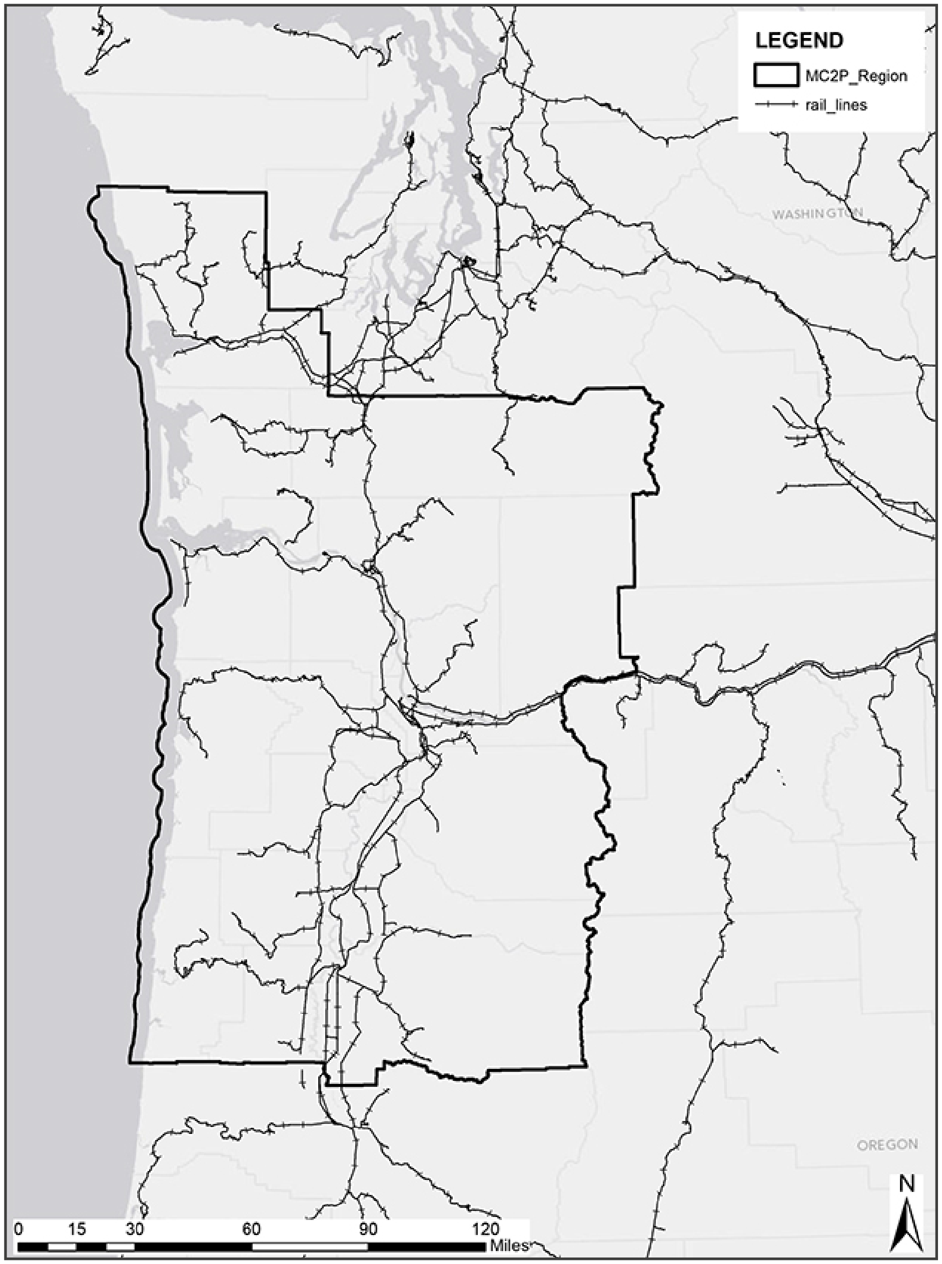


Figure 2.5.6. Rail network system available for processed forest residual transport. Source: Federal Railroad Administration (FRA) geospatial data and the Research and Innovative Technology Administration's Bureau of Transportation Statistics (RITA/BTS); released in 2005.

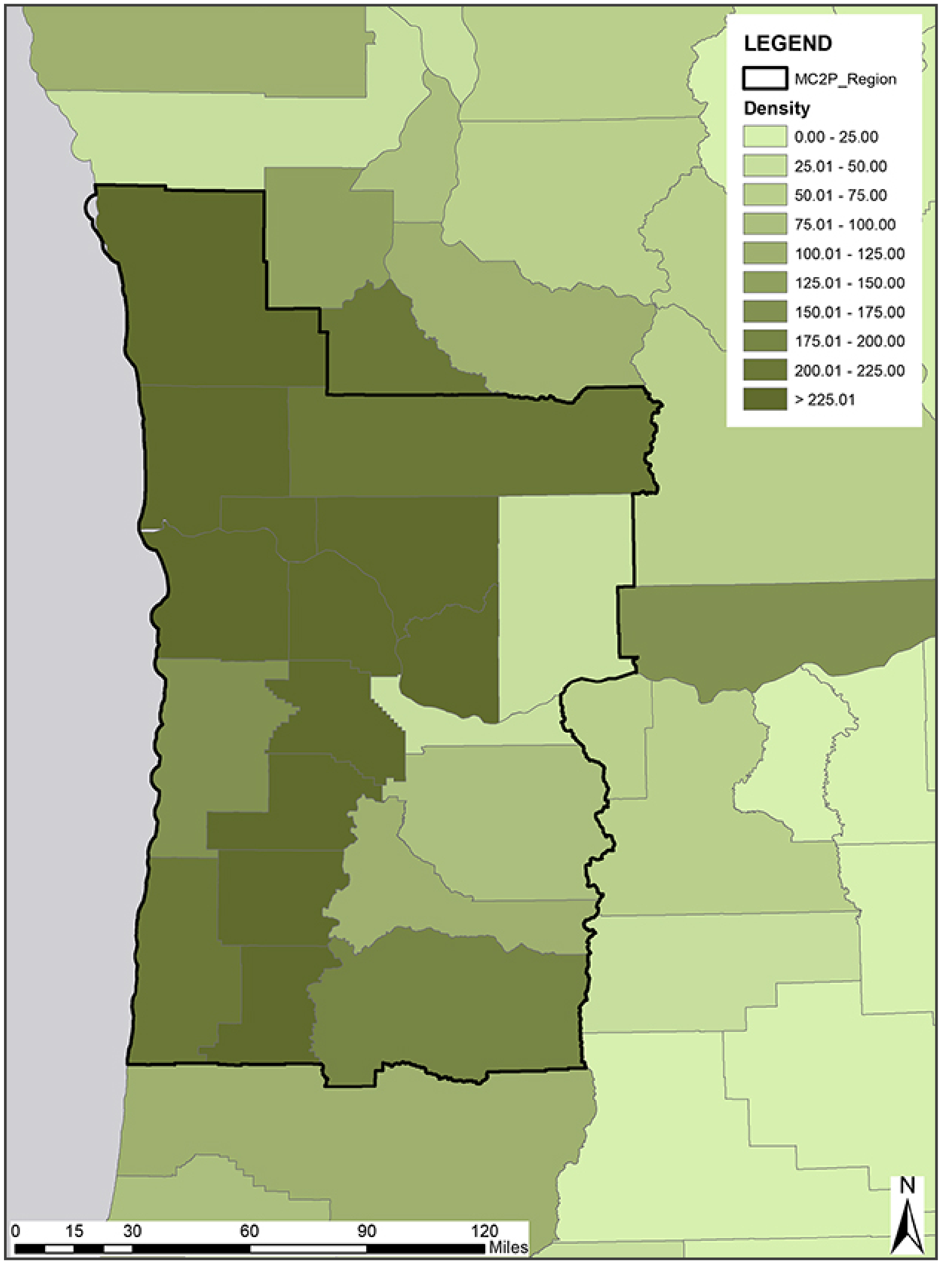


Figure 2.5.7. Volume of forest residuals per county. Source: Bureau for Business and Economic Research (BBER) at the University of Montana Missoula.

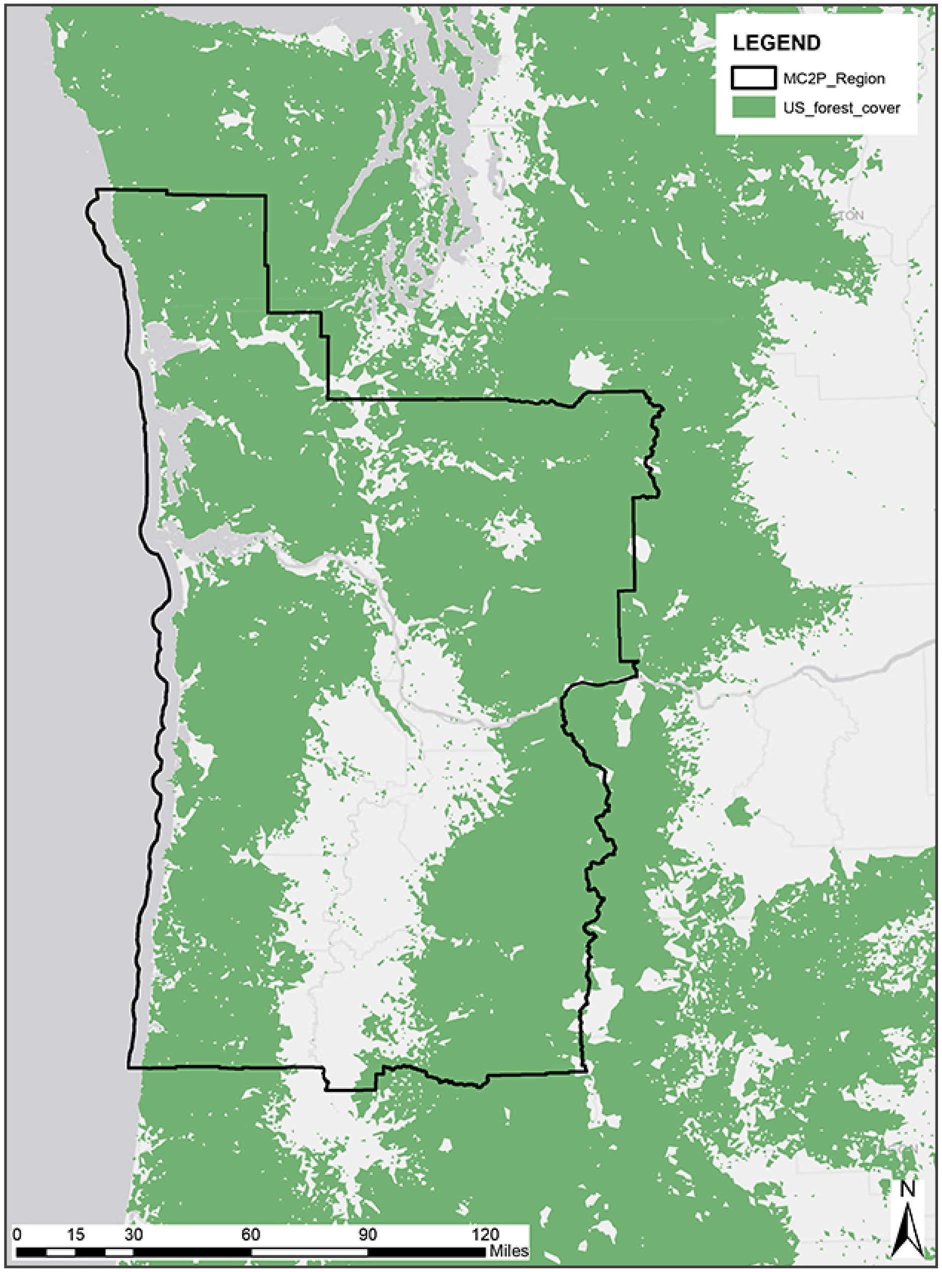


Figure 2.5.8. US Forest Service coverage in the MC2P Region.

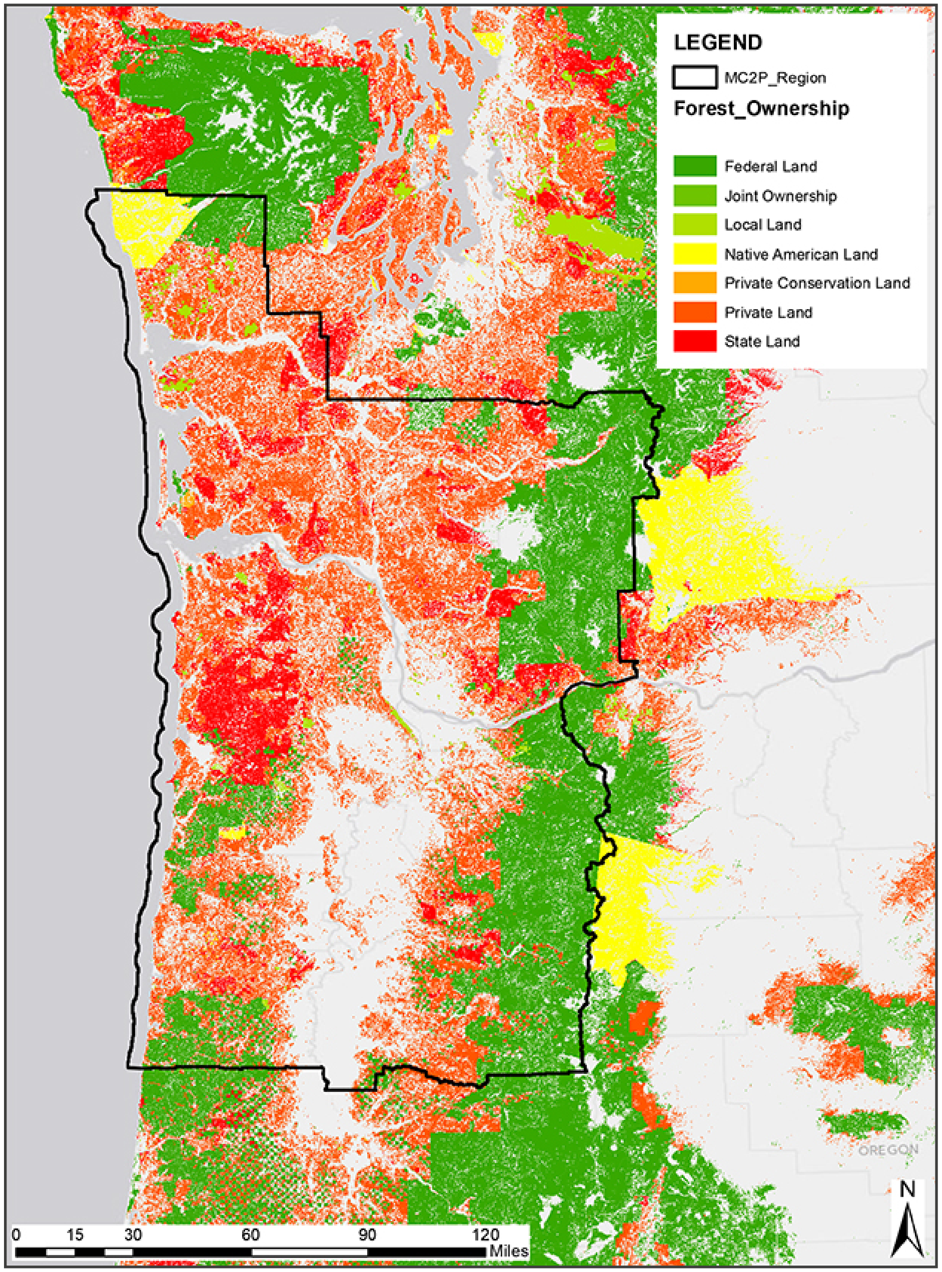


Figure 2.5.9. Combined map of forest ownership in the MC2P Region.

2.5.2 COSMO SPECIALTY FIBERS, COSMOPOLIS, GRAYS HARBOR COUNTY, WA

After an extensive review of potential sites suitable for a fully integrated biorefinery, Cosmo Specialty Fibers emerged as one of the top candidates for an IBR in the MC2P region. This analysis investigates the possibility of adding a biorefinery on site without interfering with their current operations. By using idle equipment and adding necessary infrastructure for biofuel production, additional market opportunities could be realized.

Table 2.5.1. Cosmo Specialty Fibers Site Description

Attribute	Site Details
Existing Facilities	Existing Wastewater Treatment Plant, Digesters equipment, woodchip storage
Electrical Rates	$0.05/Kwh
On-Site Rail Access	Yes
Typology	Integrated Biorefinery
Acreage	250+ acres

DIRECT HAUL SCENARIO FOR COSMO SPECIALTY FIBERS

The first scenario evaluated was the possibility of directly hauling forest residuals straight from the landing to the Cosmopolis Specialty Fibers site. The following assumptions below show the variables used in the evaluation. In Table 2.5.2 you can see that the goal of collecting 770,000 BDT annually is achieved between the 75-minute and 90-minute drive times, costing approximately $40/BDT for transportation costs.

The following assumptions used in the evaluation are:

- Transportation Assumptions
- 1st: Direct Haul (Forest to IBR)
- Roll-on Roll-off Container Trucks
- Capacity: 90 CY (45 CY Container x 2)
- Tree Type: Douglas Fir
- Slash Solid to Volume Ratio: 30%
- Bone Dry Density: 267 lbs/cy

Table 2.5.2. Estimated Cost to Transport Biomass Feedstock with Specific Drive Time Radii from Proposed Sites

Drivetime (Minutes)	Transportation Cost ($/BDT)	Feedstock (BDT)
15	$7	10,000
30	$14	65,000
45	$21	185,000
60	$28	350,000
75	$35	535,000
90	$42	825,000

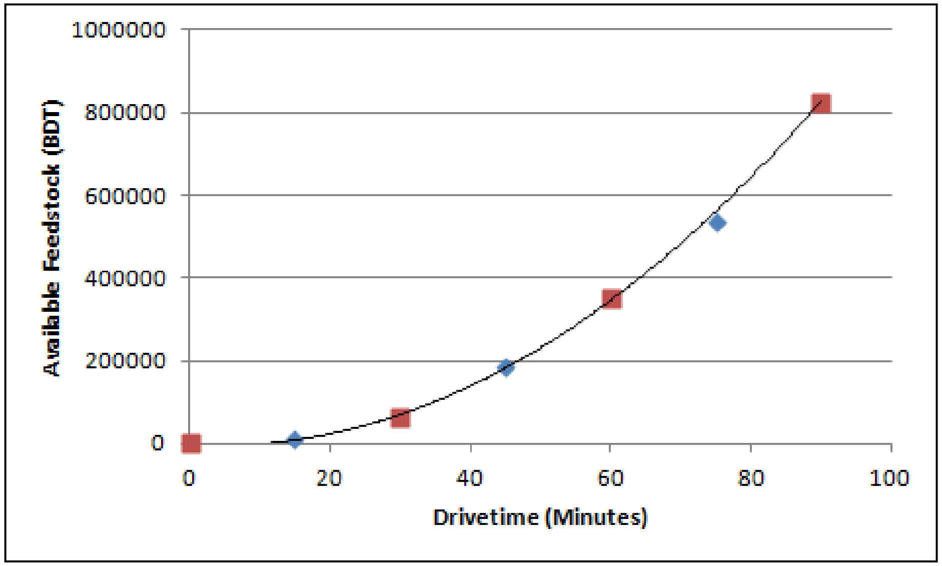


Figure 2.5.10. Available Feedstock per Drivetime for Cosmo Specialty Fibers

MULTIPLE SOLIDS DEPOT SCENARIO TO COSMO SITE

The next scenario evaluated whether transportation costs would decrease at the 770,000 BDT feedstock mark if three solids depots were used to aggregate and mechanically process feedstock for transport to a liquids depot at the Cosmo Specialty Fibers site. For this evaluation, we assumed there would be three solids depots southeast of the Cosmo Specialty Fibers location with the assumptions listed in the Supply Chain section, as well as the cost and anticipated availability of feedstock (Table 2.5.2). For this scenario the cost was found to be similar to the direct haul scenario examined in Section 2.6.2, with the added capital expenditures of construction of the three solids depots.

Based upon the ArcGIS analysis, combined with information from IDX Studio findings, the following list of proposed solids depot sites were identified as having the ability to provide feedstock to the proposed Cosmo Specialty Fibers IBR.

The following locations are potential solids depots suppliers to a liquids depot at the Cosmo Specialty Fibers Location:

1) NORTHWEST FIBER, MORTON, LEWIS, WA
2) WEYERHAEUSER, WARRENTON, CLATSOP, OR
3) RSG FOREST PRODUCTS, KALAMA, COWLITZ, WA

The following assumptions were used in the evaluation of Multiple Solids Depot Supplier Network:

- 1st Scenario: Direct Haul (Forest to Depots)
- Roll-on Roll-off Container Trucks
- Capacity: 90 CY
- Tree type: Douglas Fir
- Slash Moisture Content: 30%
- Bone Dry Density: 267 lbs/cy
- 2nd Scenario: Solids Depot to Liquids Depot/Biorefinery
- Chip Van Transportation: $14/BDT
- Capacity: 148 cy
- Chip Solid to Volume Ratio: 40%
- Bone Dry Density: 356 lbs/cy

The cost estimates to transport biomass from a solids depot to a liquids depot varies depending upon drivetime radius. The cost for biomass transport within a 1-hr radius of the liquids depot is $24/BDT, whereas a 1.5-hour drivetime increases the cost of transportation to $35/BDT.

For the proposed solids depot facilities, sufficient feedstock was found within a 1-hour radius of the proposed liquids facility. Table 2.5.3 shows the BDT of feedstock.

Table 2.5.3. Available Feedstock (BDT) for Proposed Solids Depots

Solids Depot Site	Available Feedstock (BDT) within 1-Hour Radius
Northwest Fiber	95,000
Weyerhaeuser Green Mountain	60,000
RSG Forest Products	260,000
Cosmo Specialty Fibers	385,000

ADDITIONAL SOLIDS DEPOT LOCATIONS

In addition, the Glenwood and Bradwood sites were analyzed as potential solids depot sites along the supply chain. With the same assumptions used for the four previous locations, these two additional solids depots have the potential to ship directly to a liquids depot or integrated biorefinery. Solids depots at the Glenwood and Bradwood sites, could contribute an additional 832,000 BDT of available feedstock; all within a 1.5 hour drive time radius.

For this scenario we found that the cost was about the same as the direct haul scenario above, with the added capital expenditures of setting up the solids depots.

Table 2.5.4. Available Biomass Feedstock for Direct Haul Scenario from Glenwood, WA

Drivetime	Available Feedstock (BDT)
0.5 hour	23,000
1.0 hour	81,000
1.5 hour	150,000

Table 2.5.5. Available Biomass Feedstock for Direct Haul Scenario to Bradwood, OR

Drivetime	Available Feedstock (BDT)
0.5 hour	46,000
1.0 hour	242,000
1.5 hour	578,000

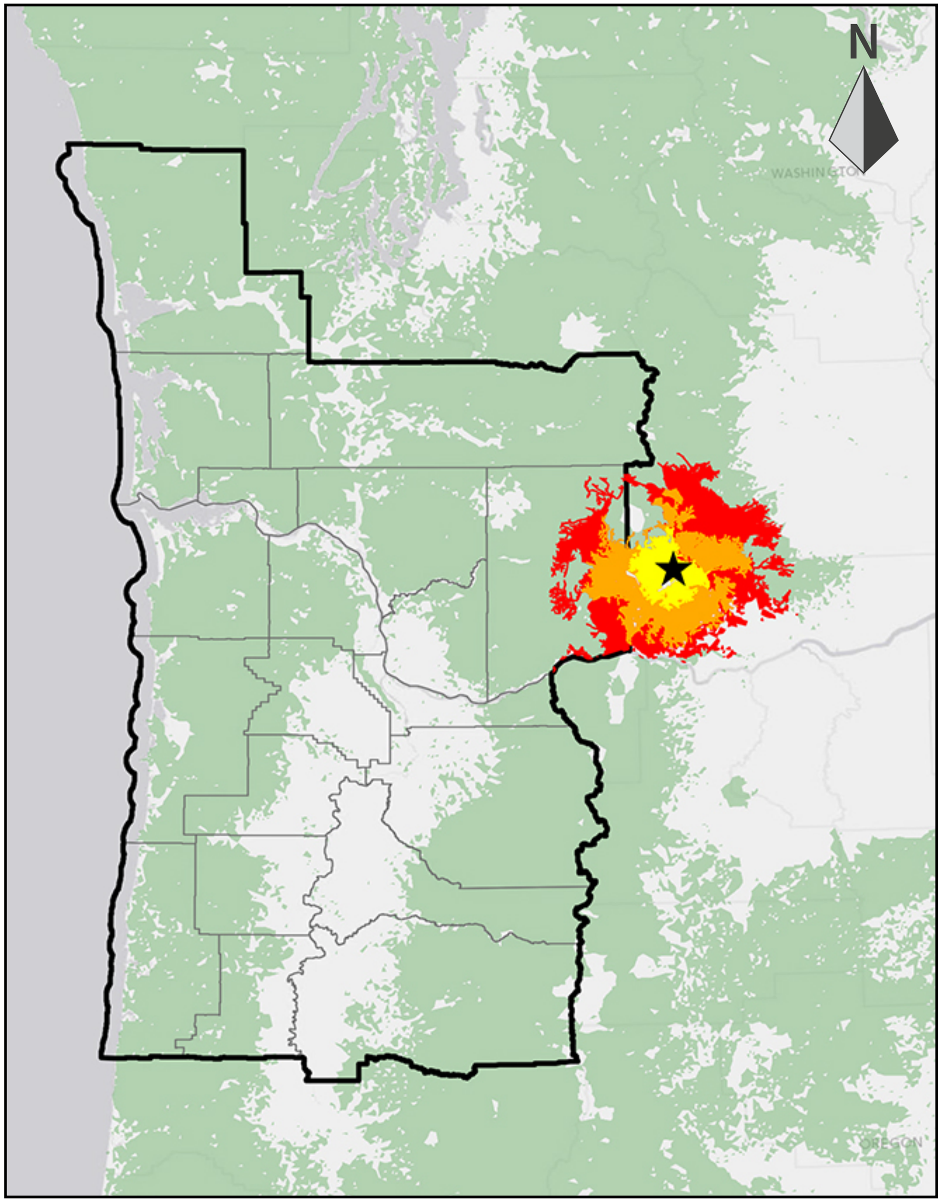


Figure 2.5.11. Available Biomass Feedstock for Direct Haul Scenario from Glenwood, WA

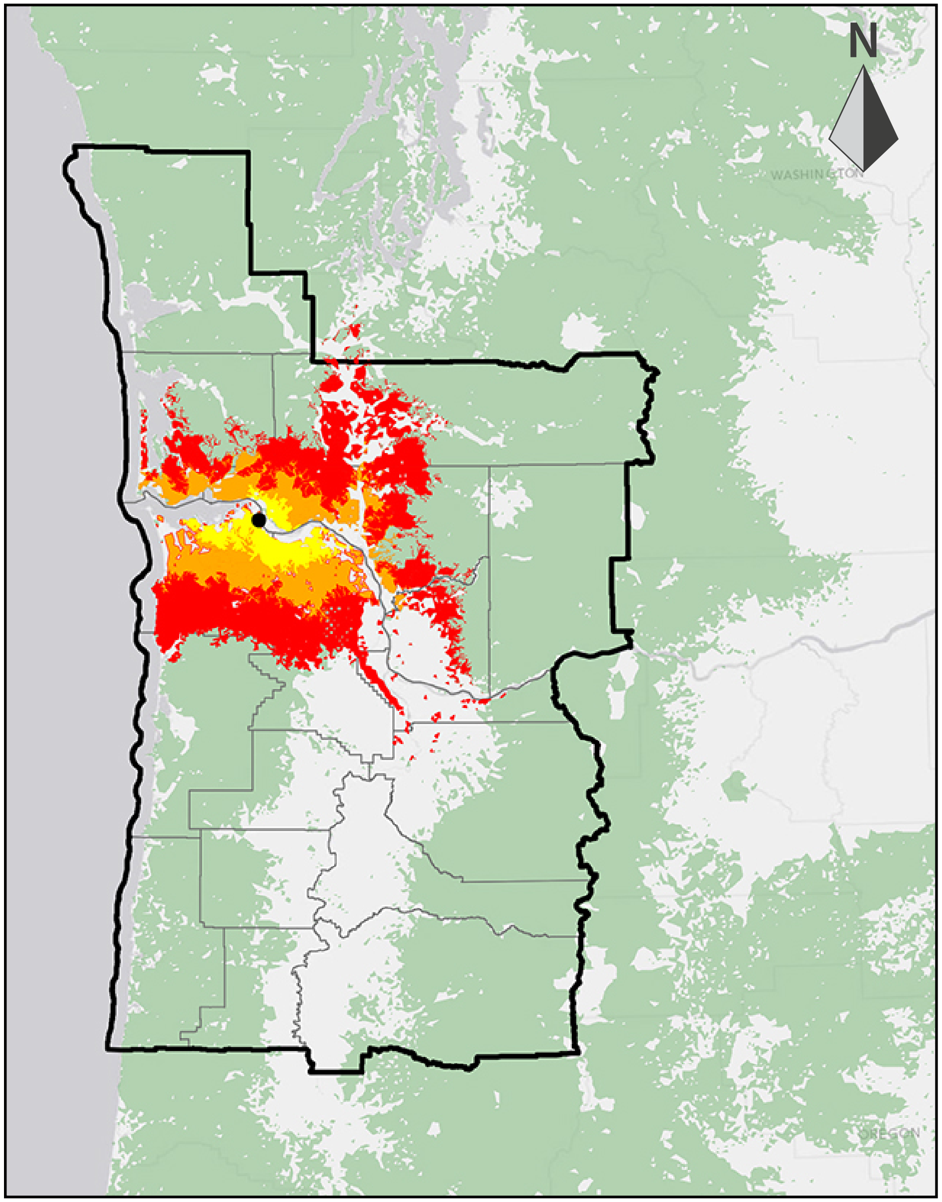


Figure 2.5.12. Available Biomass Feedstock for Direct Haul Scenario from Bradwood, OR

2.6.0 IDX STUDIO SPRING SEMESTER

Fall 2013 IDX Studio activities concluded by identifying one integrated biorefinery, two liquids depots and two solids depots for further analysis and design. The five facilities are listed in Table 2.6.1.

Table 2.6.1. Selected Depot Sites

Solids Depots	Liquids Depots	Integrated Biorefinery
Sierra Pacific Industries Aberdeen, WA	Kapstone Pulp & Packaging Longview, WA	Cosmo Speciality Fibers Cosmopolis, WA
Former Bradley-Woodward Lumber Company Bradwood, OR	Weyerhaeuser Company Bay City Log Yard Aberdeen, WA	

SPRING 2014 IDX STUDIO

Spring 2014 IDX Studio will conduct field trips to the sites to document current conditions, interview site owners and stakeholders regarding current and past operations, and collect detailed site information (i.e. civil engineering survey information, site specific GIS layers, etc.). IDX teams will prepare site inventories, examine major opportunities and constraints for their facility types at each site, and create conceptual master plans and facility plans for each site. The results of Spring 2014 IDX Studio can be found in MC2P Volume III.

PLANNED ACTIVITIES FOR 2014-2015 IDX STUDIO

The lessons learned from the MC2P region will be applied to complete a full supply chain analysis for the NARA four-state region of Washington, Oregon, Idaho and Montana in 2014-2015 IDX Studio academic year.