SUPPLY CHAIN ANALYSIS

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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.

NARA Goals

NARA's goals are to:

1. **Sustainable Biojet:** Develop a framework for a sustainable biojet fuel industry in the PNW 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 for wood-to-biofuel supply chain analysis
5. **Bioenergy Literacy:** Improve bioenergy literacy to develop a future workforce and enhance stakeholder engagement, participation, and understanding

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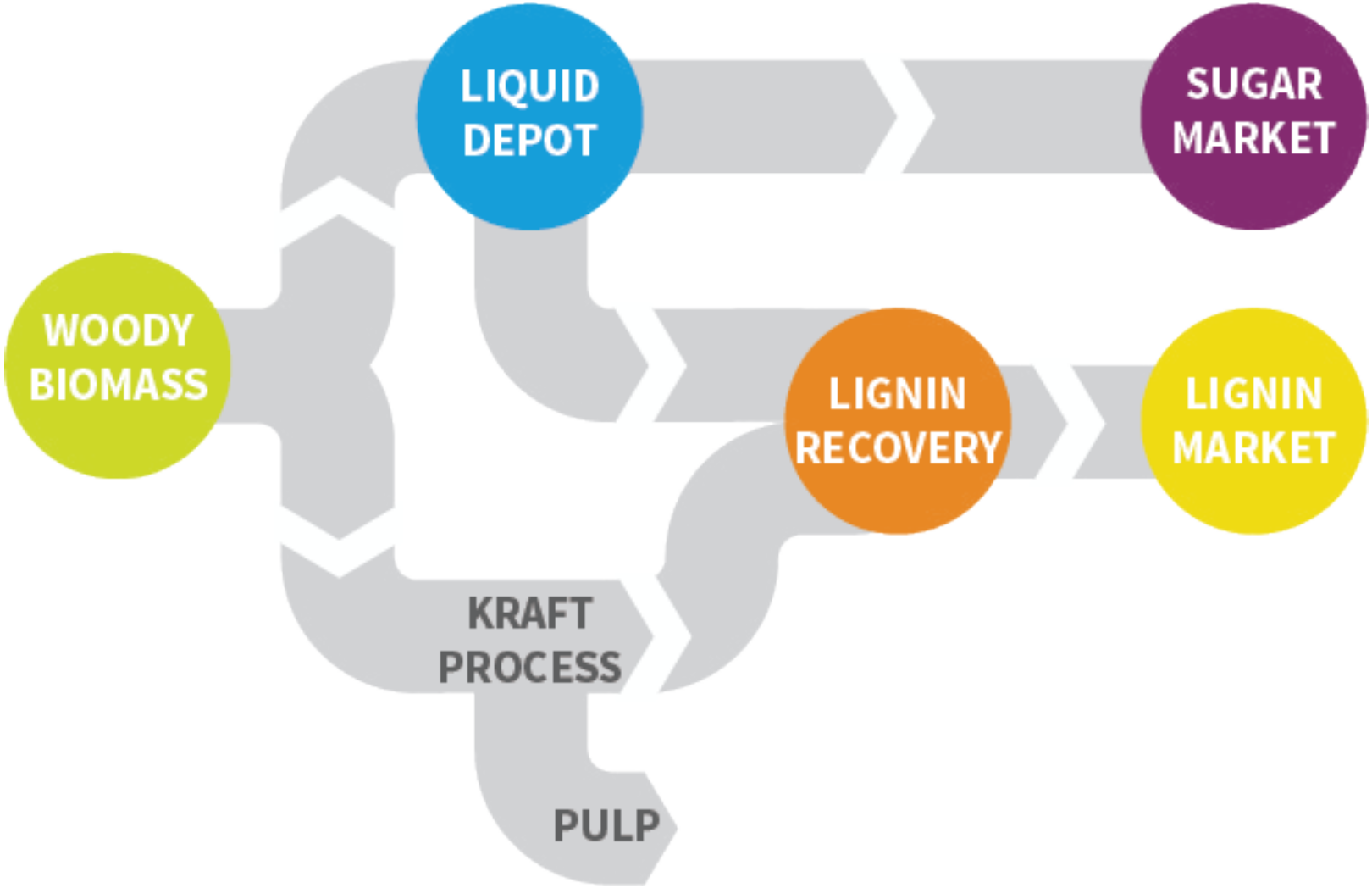
IDX Supply Chain Analysis



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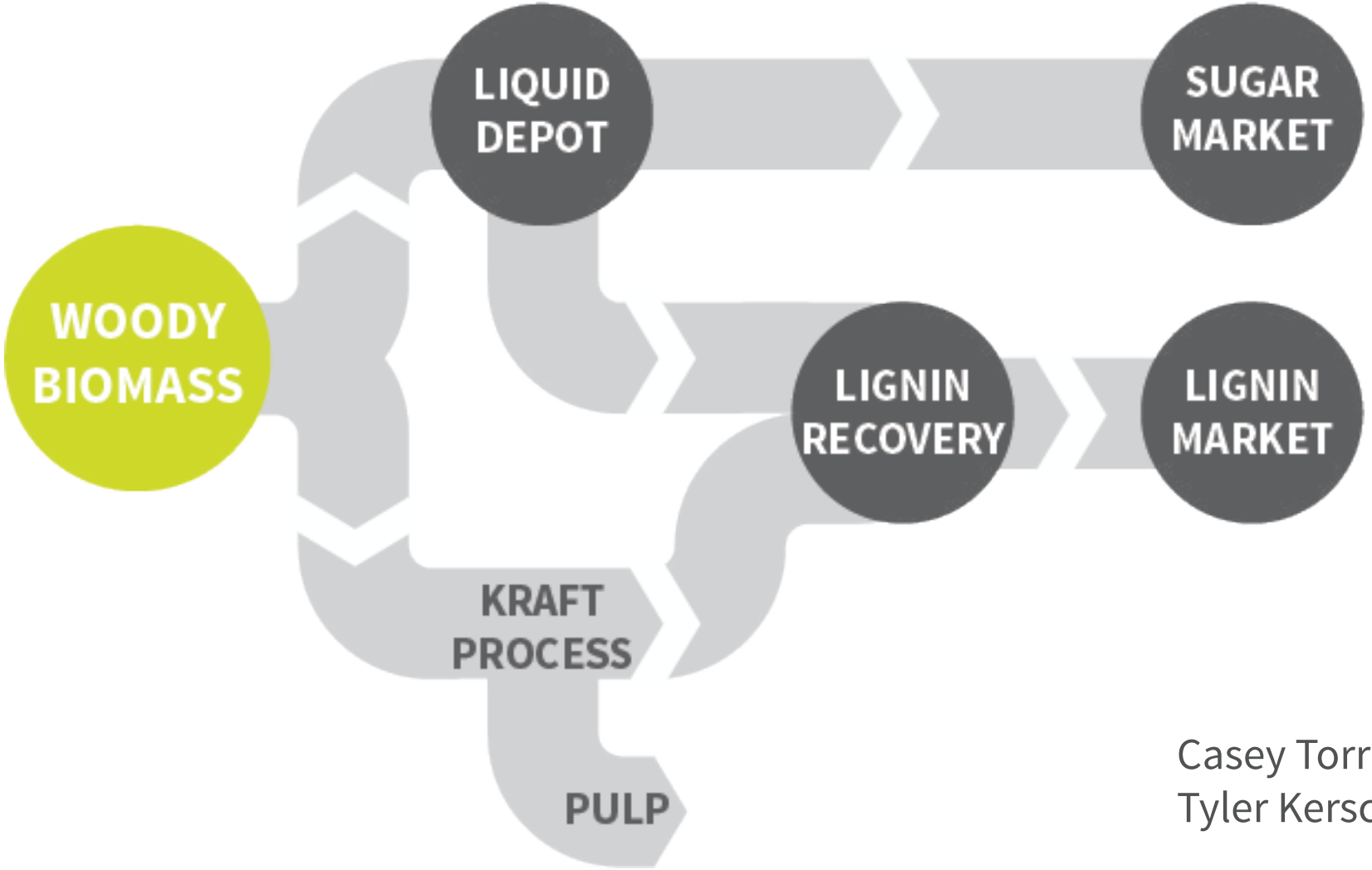
Woody Biomass



Casey Torres
Tyler Kerschener

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Woody Biomass

WHAT IS BIOMASS

- Organic material that is available on a renewable basis
- Forest residuals include limbs, tree tops, stumps, and other debris from logging or thinning operations
- Residuals are typically put in slash piles and burned

Washinton State DNR. Biomass as a renewable energy source. 03/23/11.

US Forest Service. Team helps businesses see benefits of using woody biomass. 07/ 06/11.

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Woody Biomass

RATIONALE FOR USE

- Forest residuals an underutilized renewable resource

- A step closer to energy independence

- Planes are not easily electrified, future market demand a safe bet

WSU News. Alaska Airlines plans biofuel test flight in WSU partnership. 06/03/15.

Holistic Vanity. Plane flying home. 12/17/09.

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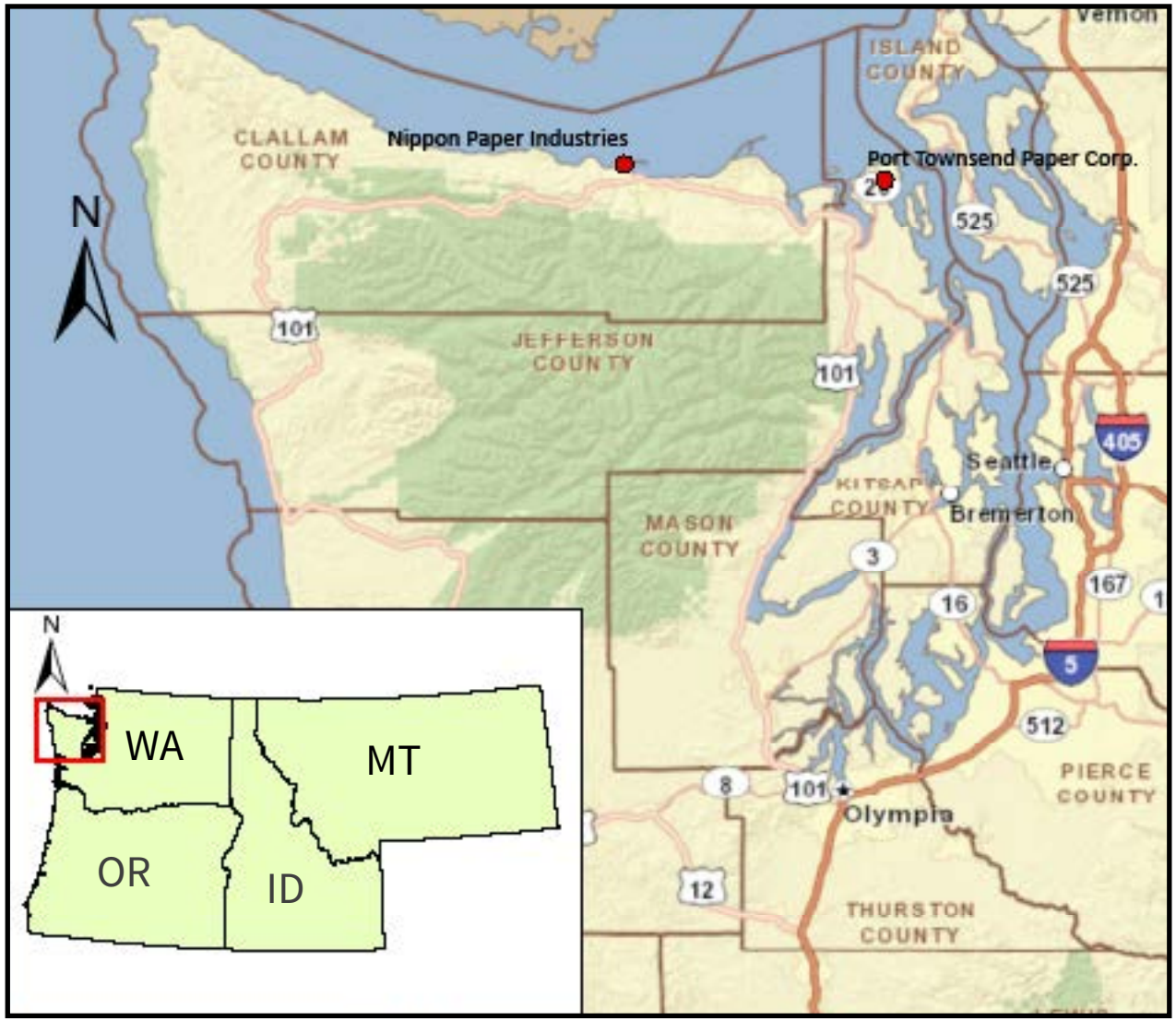
Woody Biomass

STUDY AREA



MAP BY TYLER KERSCHNER

SCALE 1 IN = 320 MILES

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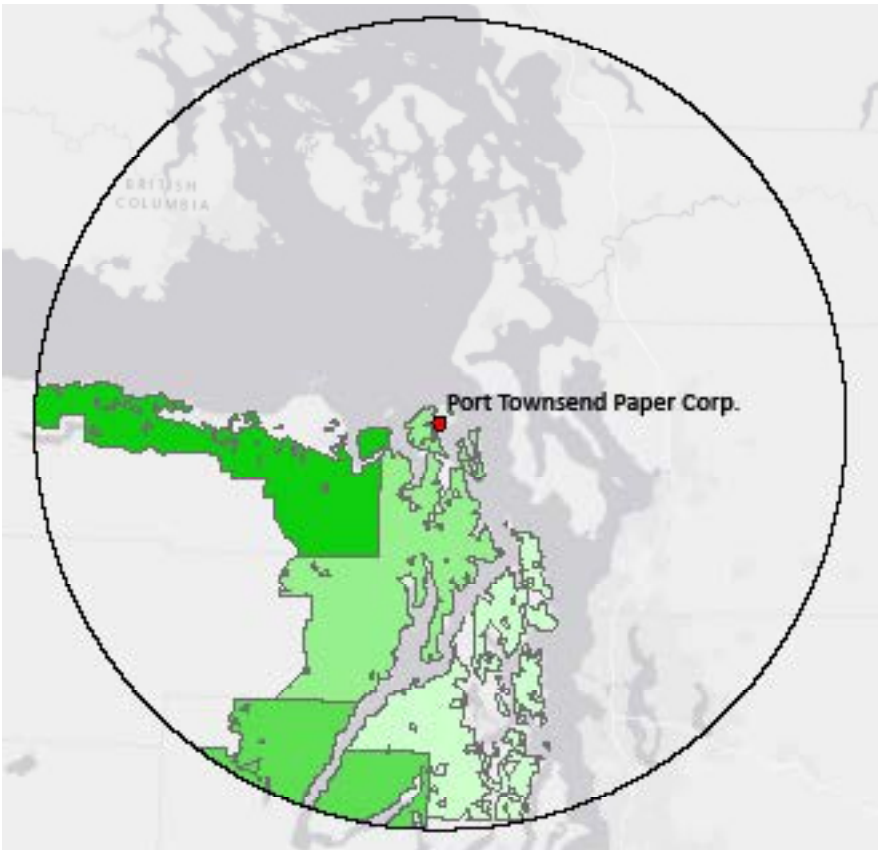
Woody Biomass

PORT TOWNSEND PAPER CORP. VOLUMES

BDT-BONE DRY TON

10 MILE RADIUS 6,000 BDT

30 MILE RADIUS 55,000 BDT



50 MILE RADIUS 112,000 BDT

SCALE 1 IN = 25 MILES

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MAPS BY TYLER KERSCHNER USING NARA TPO FOREST DENSITY DATA

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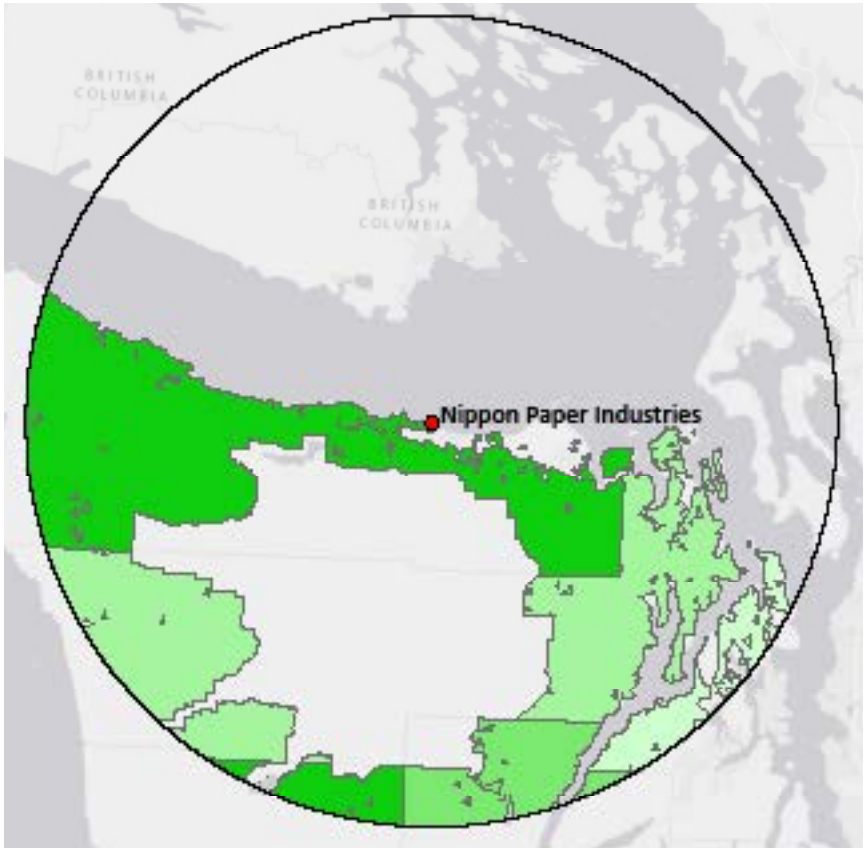
Woody Biomass

NIPPON PAPER INDUSTRIES VOLUMES

10 MILE RADIUS 11,000 BDT

30 MILE RADIUS 62,000 BDT



50 MILE RADIUS 224,000 BDT

SCALE 1 IN = 25 MILES

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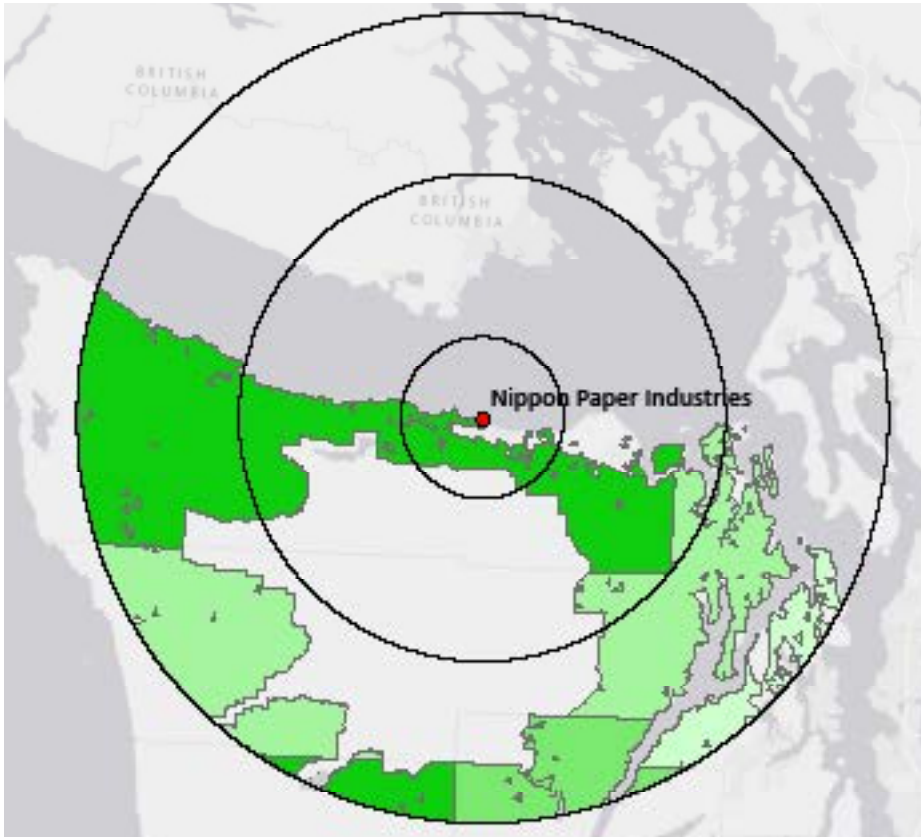
Woody Biomass

COST DATA

10 MILE RADIUS	
150CY TRUCK	$32.25/BDT
120CY TRUCK	$34.25/BDT
100CY TRUCK	$36.00/BDT

30 MILE RADIUS	
150CY TRUCK	$40.50/BDT
120CY TRUCK	$45.25/BDT
100CY TRUCK	$49.25/BDT

50 MILE RADIUS	
150CY TRUCK	$48.75/BDT
120CY TRUCK	$56.50/BDT
100CY TRUCK	$62.50/BDT



Data found using USFS Transportation Costing Model
Image from University Of Washington. Woody Biomass. 04/20/10.

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SCALE 1 IN = 25 MILES

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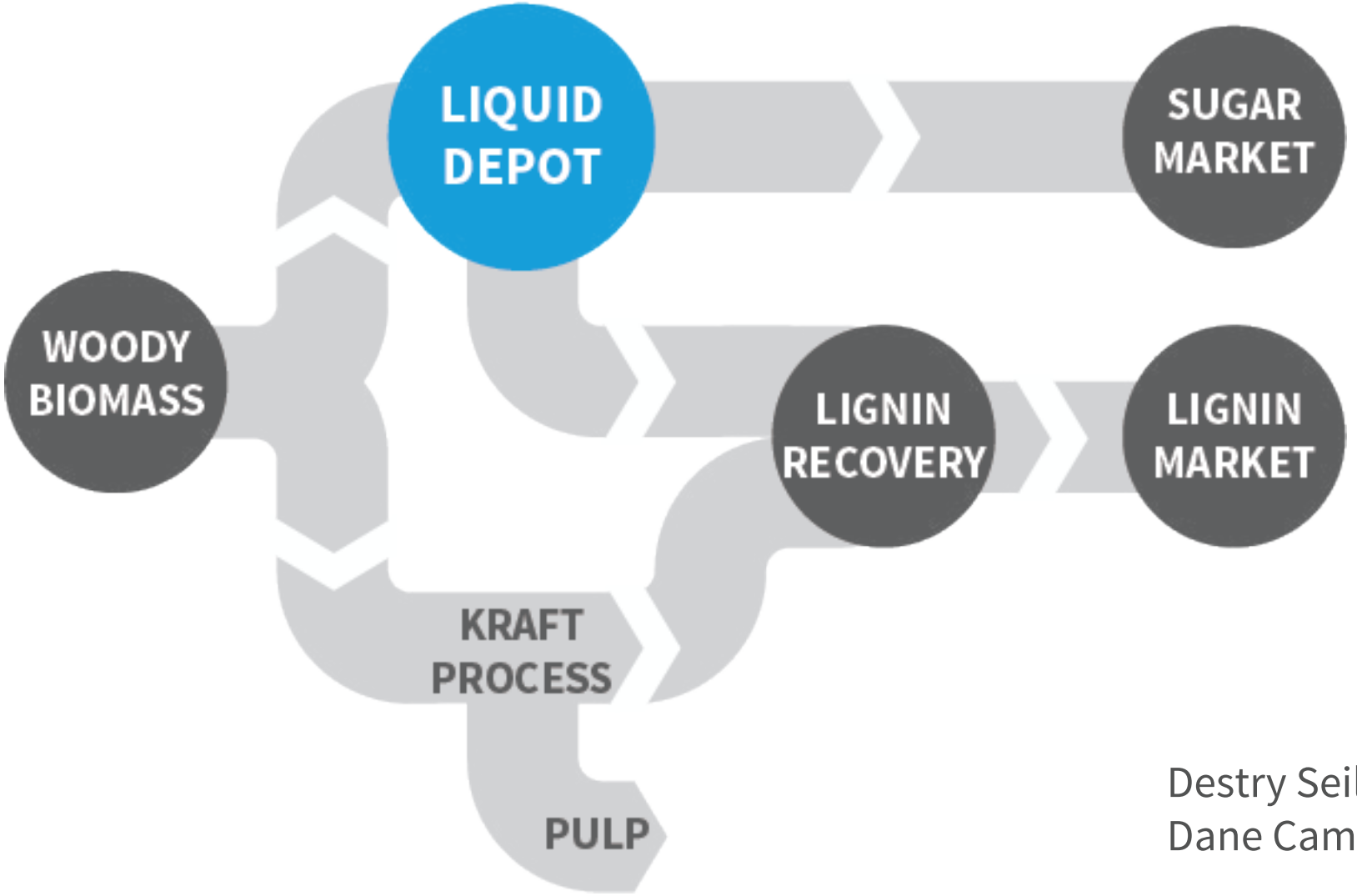
USDA

Liquid Depot



Destry Seiler
Dane Camenzind

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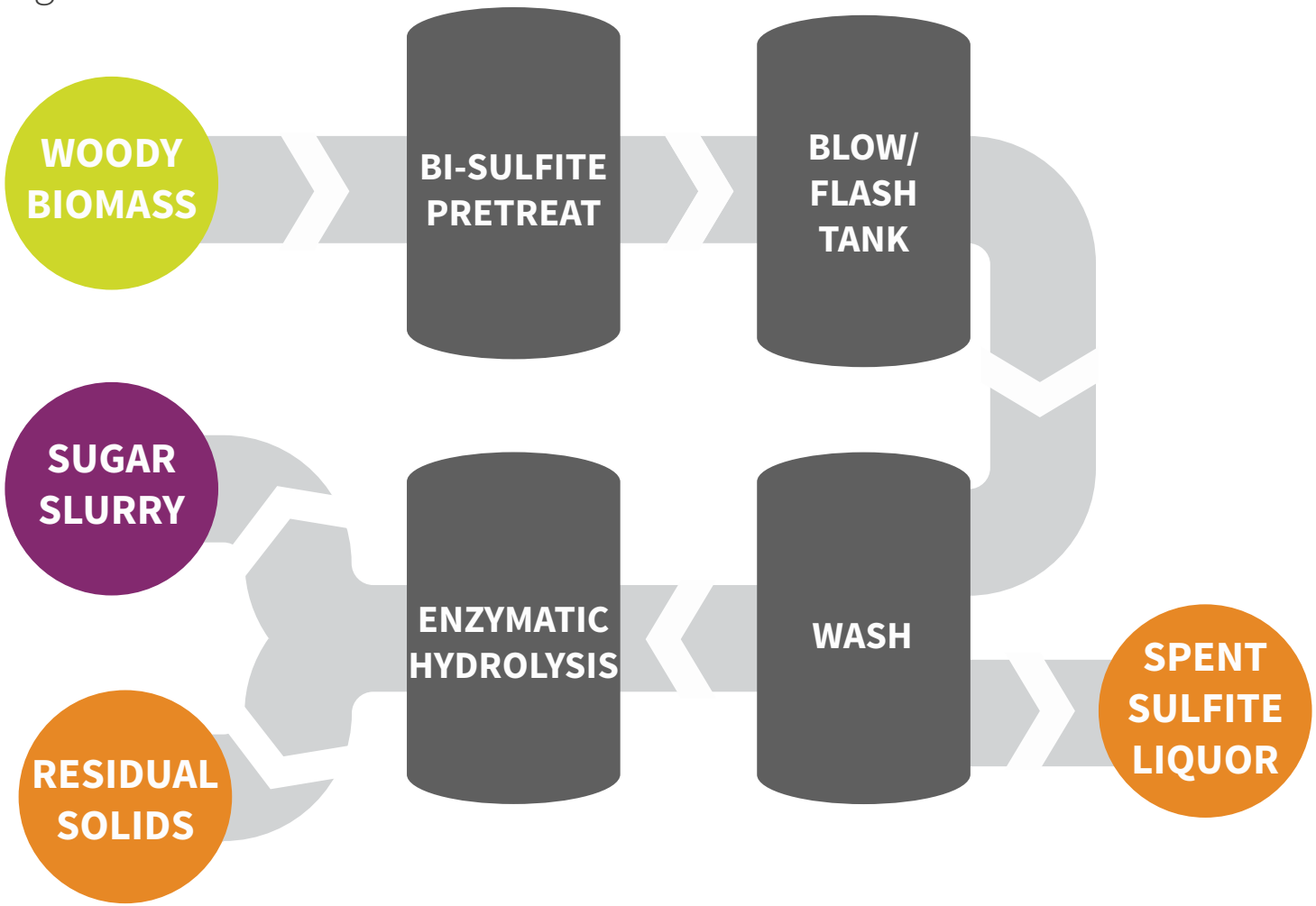
Liquid Depot

Flow Diagram



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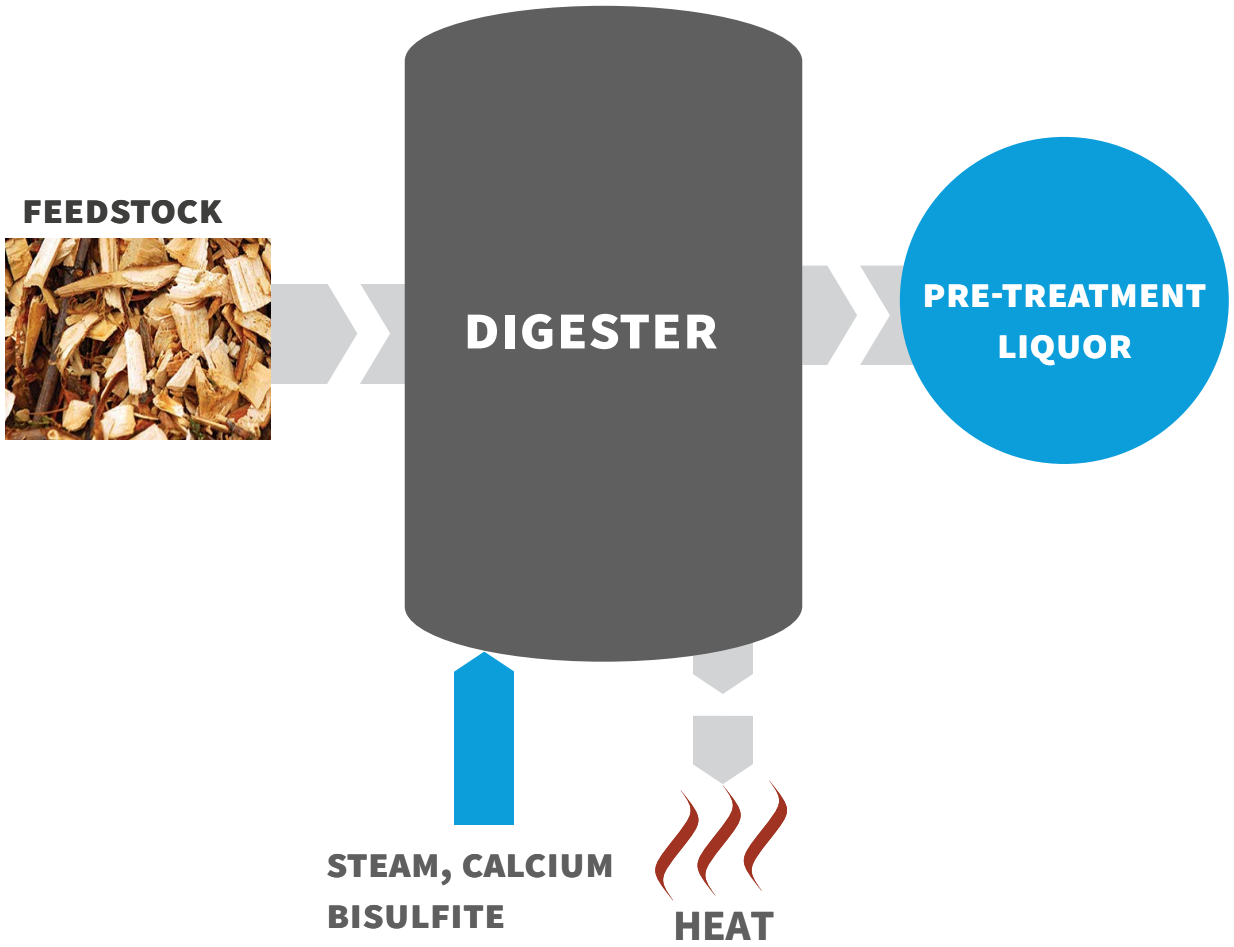
Liquid Depot

MILD-BISULFITE PROTOCOL



- Has a general water to feedstock ratio of 4:1
- Optimal temperature at 145 degrees Celcius
- Optimal pressure at 315 kPa
- Cook time ranging from 180-240 minutes

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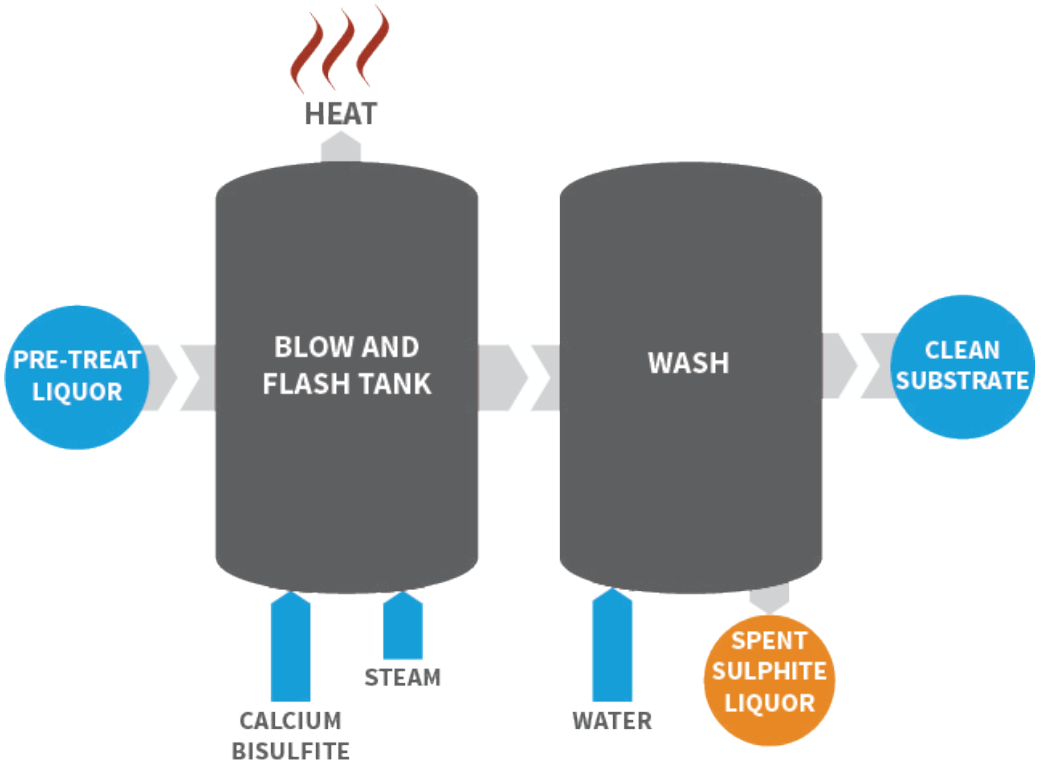
Liquid Depot

BLOWING/SCRUBBING

- Temperature and pressure of the Pre-Treatment Liquor is reduced
- Steam created in the phase change can be recycled as a heat source in other areas of the facility

WASHING

- Separates spent sulfite liquor from clean substrate
- changes pH to levels suitable for enzymes



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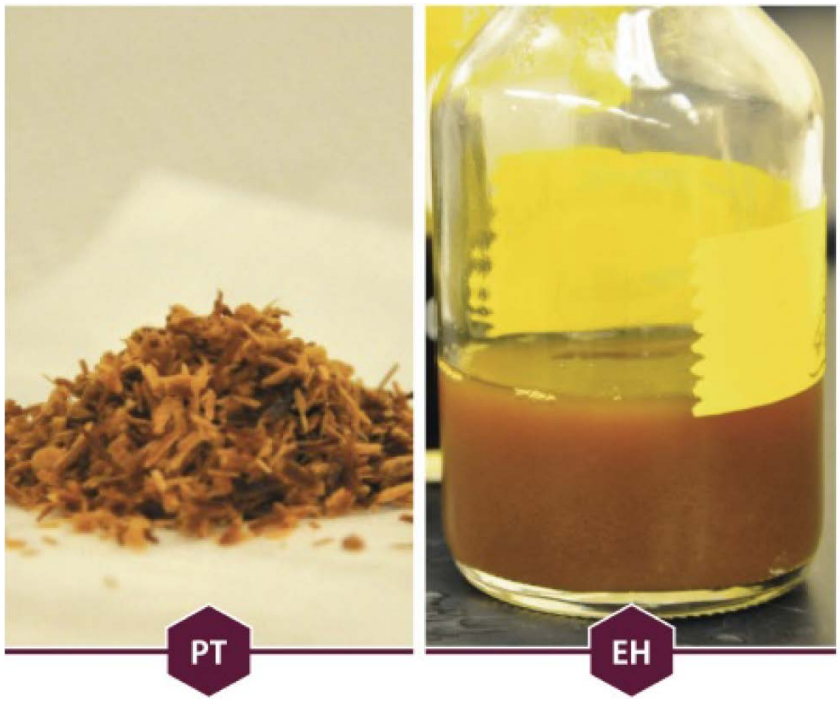
Liquid Depot

ENZYMATIC HYDROLYSIS



- Converts Lignocellulose into glucose using enzymes
- Produces two streams, sugar slurry and residual solids
- Conducted in relatively mild conditions

Nara Supply Chain, https://nararenewables.org/docs/one-pager/supplychain.pdf

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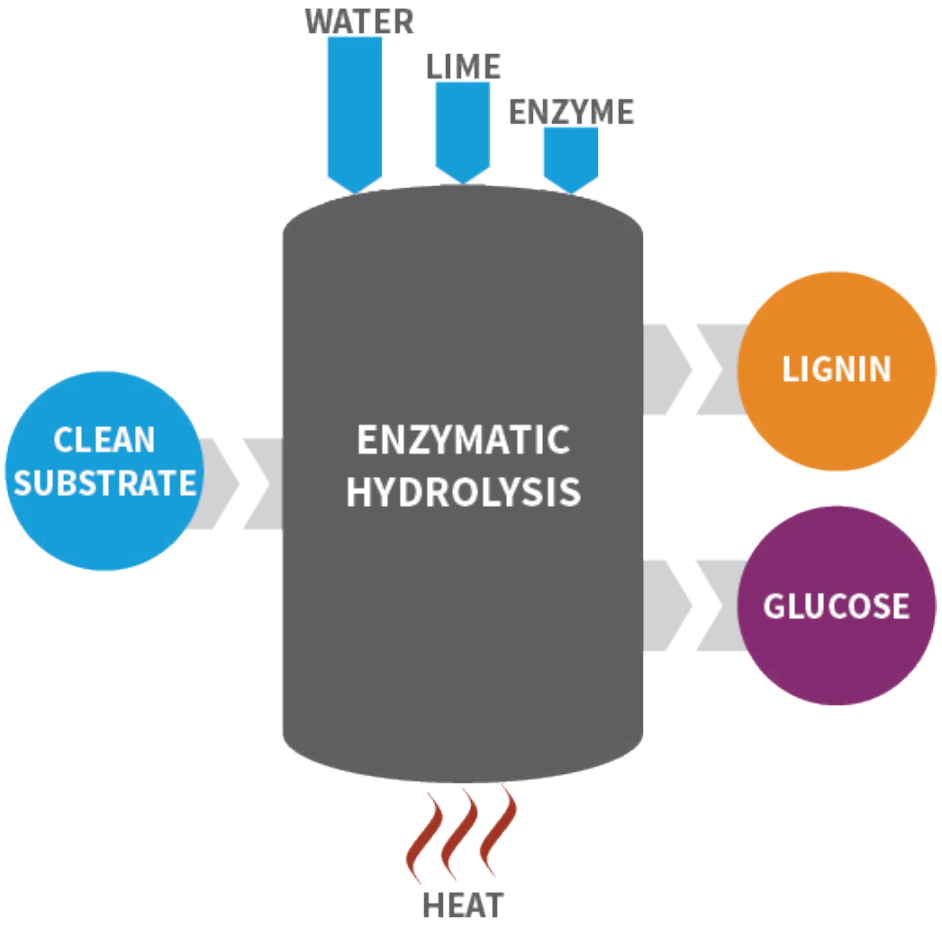
Liquid Depot

ENZYMATIC HYDROLYSIS

- Lime is added to clean substrate to adjust pH
- Three types of cellulase enzymes are added to clean substrate
- Temperature is raised to approximately 120° F
- Process takes 24 to 72 hours



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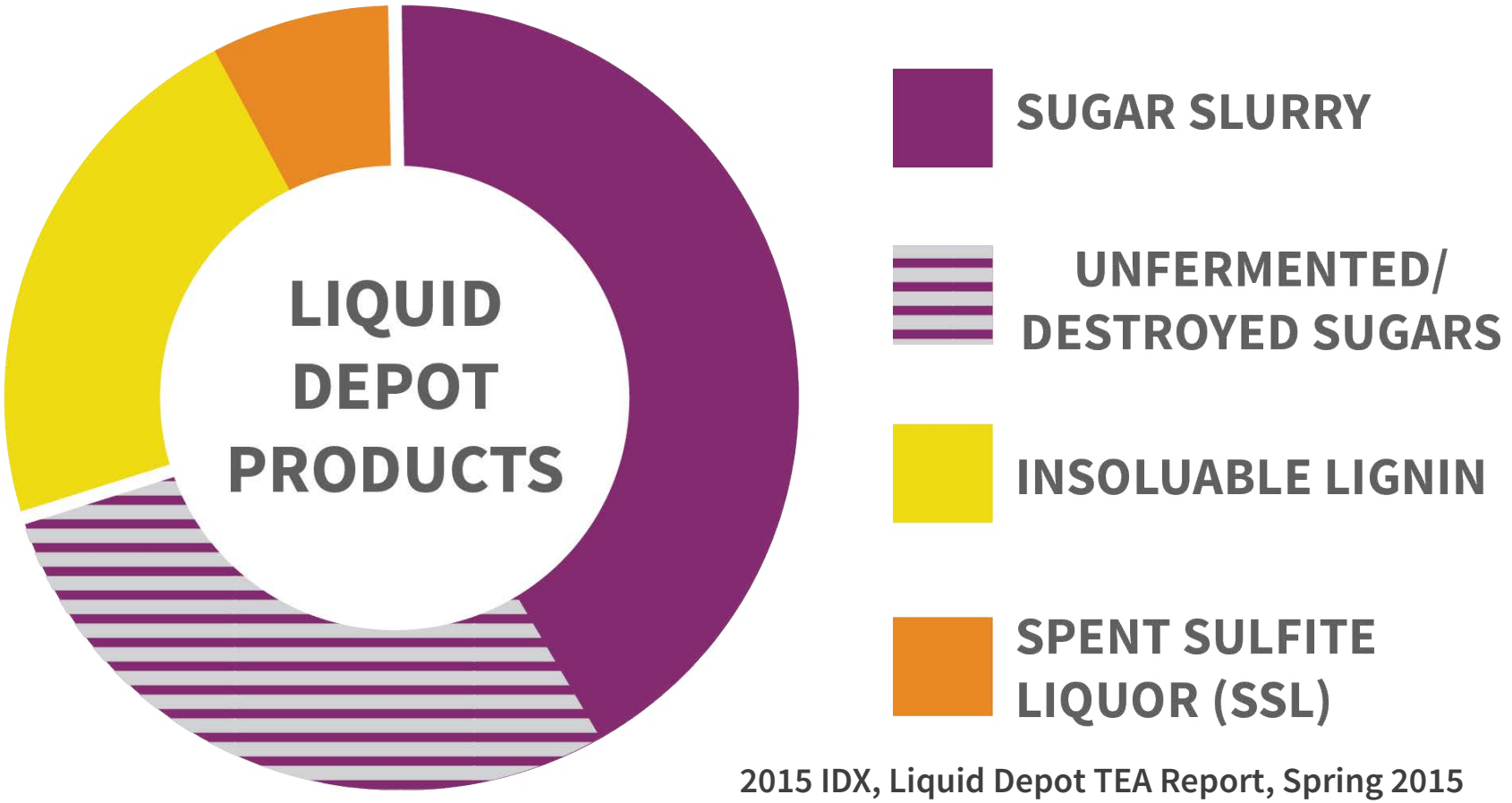
Liquid Depot

CONCLUSION



2015 IDX, Liquid Depot TEA Report, Spring 2015

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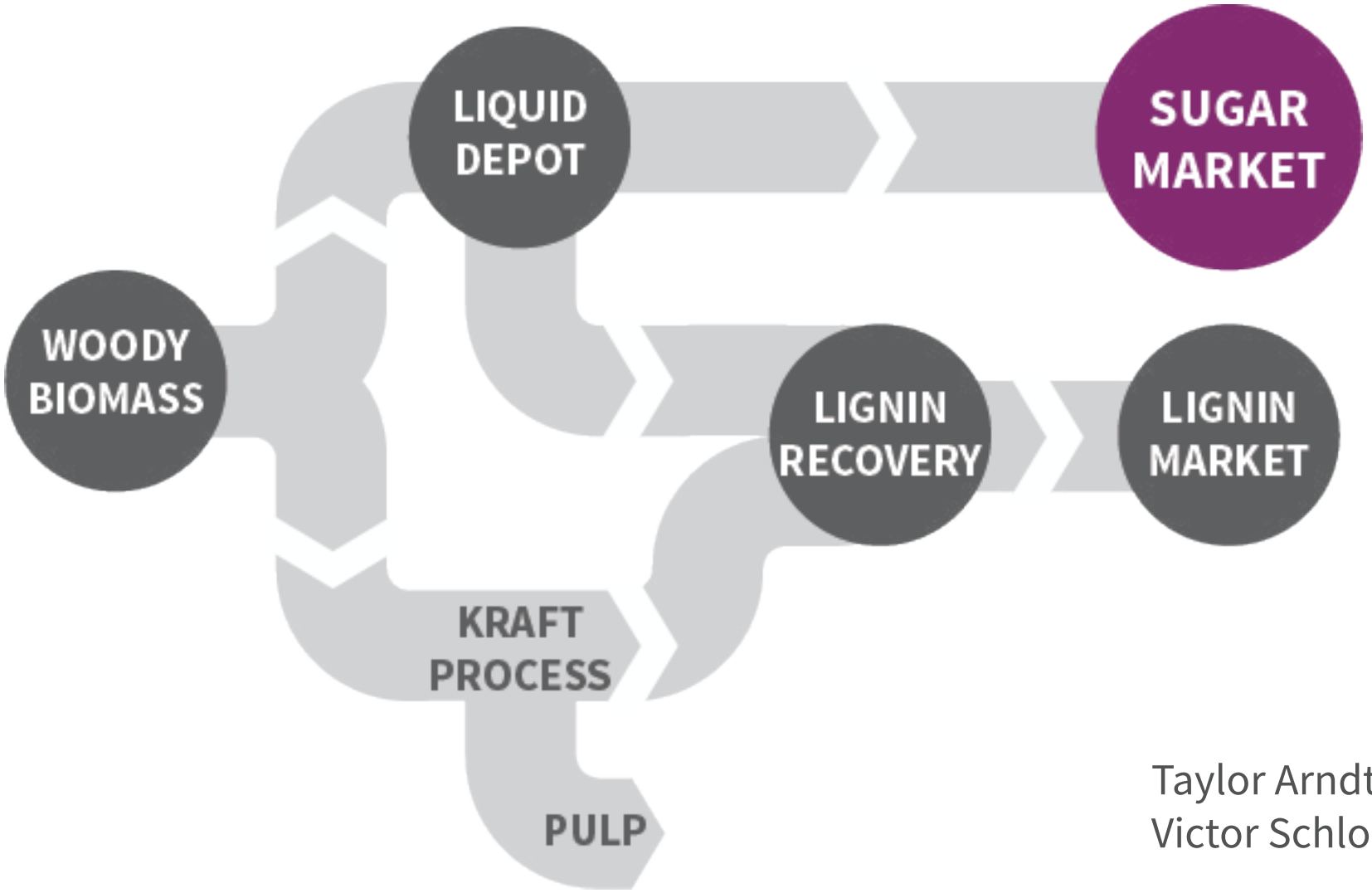
Sugar Slurry Market



Taylor Arndt
Victor Schlonga

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Sugar Slurry Market

SLURRY COMPOSITION

WHAT IS IN OUR SUGAR SLURRY?

- Cellulose
  - Glucose
- Hemicellulose
  - Glucose
  - Xylose
  - Galctose
  - Mannose
  - Arabinose

WHAT IS IN COMMON SUGAR SOURCES?

- Sugarcane: Sucrose
- Sugar beats: Sucrose
- Honey: Glucose and Fructose
- High-fructose Corn Syrup: Glucose and Fructose

WHY DOES IT MATTER?

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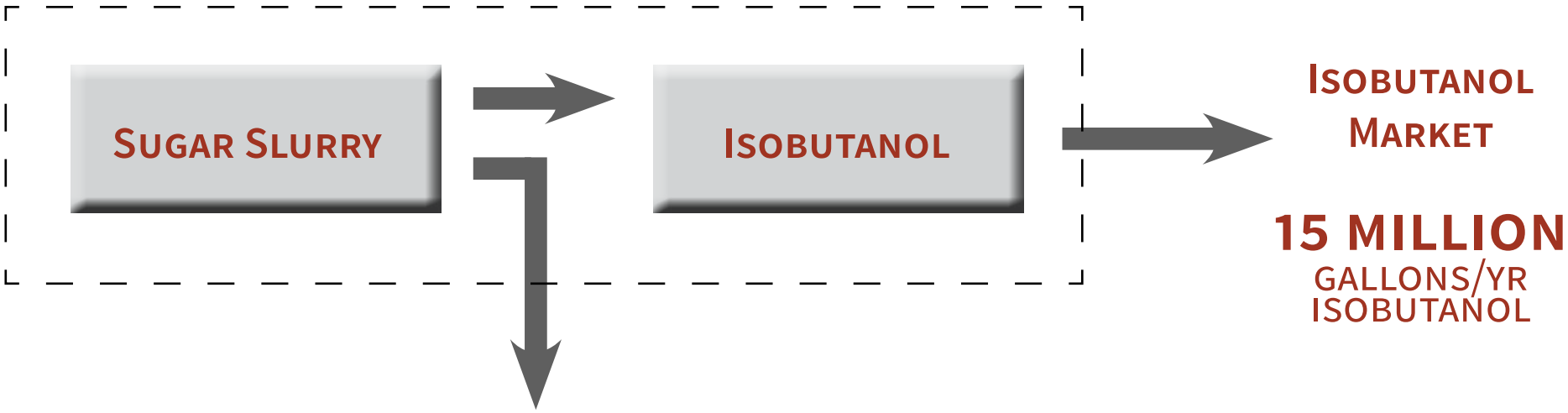
Sugar Slurry Market

SUGAR MARKET OVERVEIW



Market options available for in-house and out-of-house fermentation

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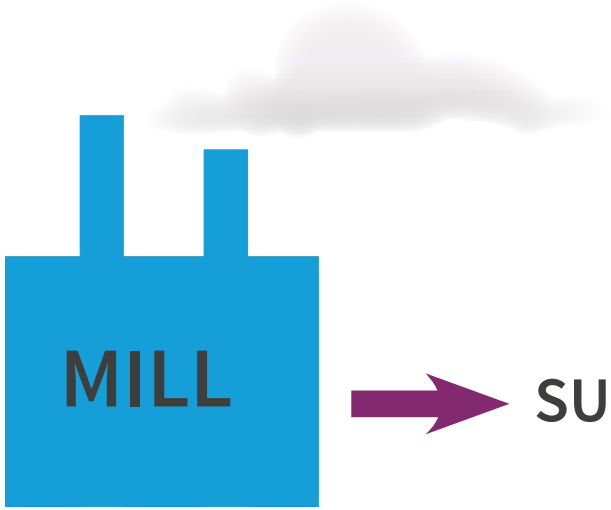
USDA

Sugar Slurry Market

SUGAR MARKET POTENTIAL



SUGAR

BDO (1,4 Butanediol):

Used in many products

BDO Market worth $8.96 Billion by 2019

Livestock feed:

Wood molasses similar to sugar slurry

Isobutanol Producers:

Gevo

Marketsandmarkets. Application (THF, PBT, GBL, PU, and Others) - Global Trends & Forecasts to 2019.April 2015. http://www.marketsandmarkets.com/Market-Reports/1-4-butanediol-market-685.html

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Sugar Slurry Market

ISOBUTANOL MARKET POTENTIAL

Chemical companies have invested in bio-based alternatives:

DOW BASF We create chemistry DUPONT

Revenue Growth			Industry Companies		
2006 to 2015:	$77.9b	→ $89.3b	2006 to 2015:	35	→ 45
2015 to 2020:	$89.3b	→ $106.0b	2015 to 2020:	45	→ 50

IBISWorld. Petrochemical Manufacturing in the US. August 2015. http://clients1.ibisworld.com/reports/us/industry/default.aspx?entid=458

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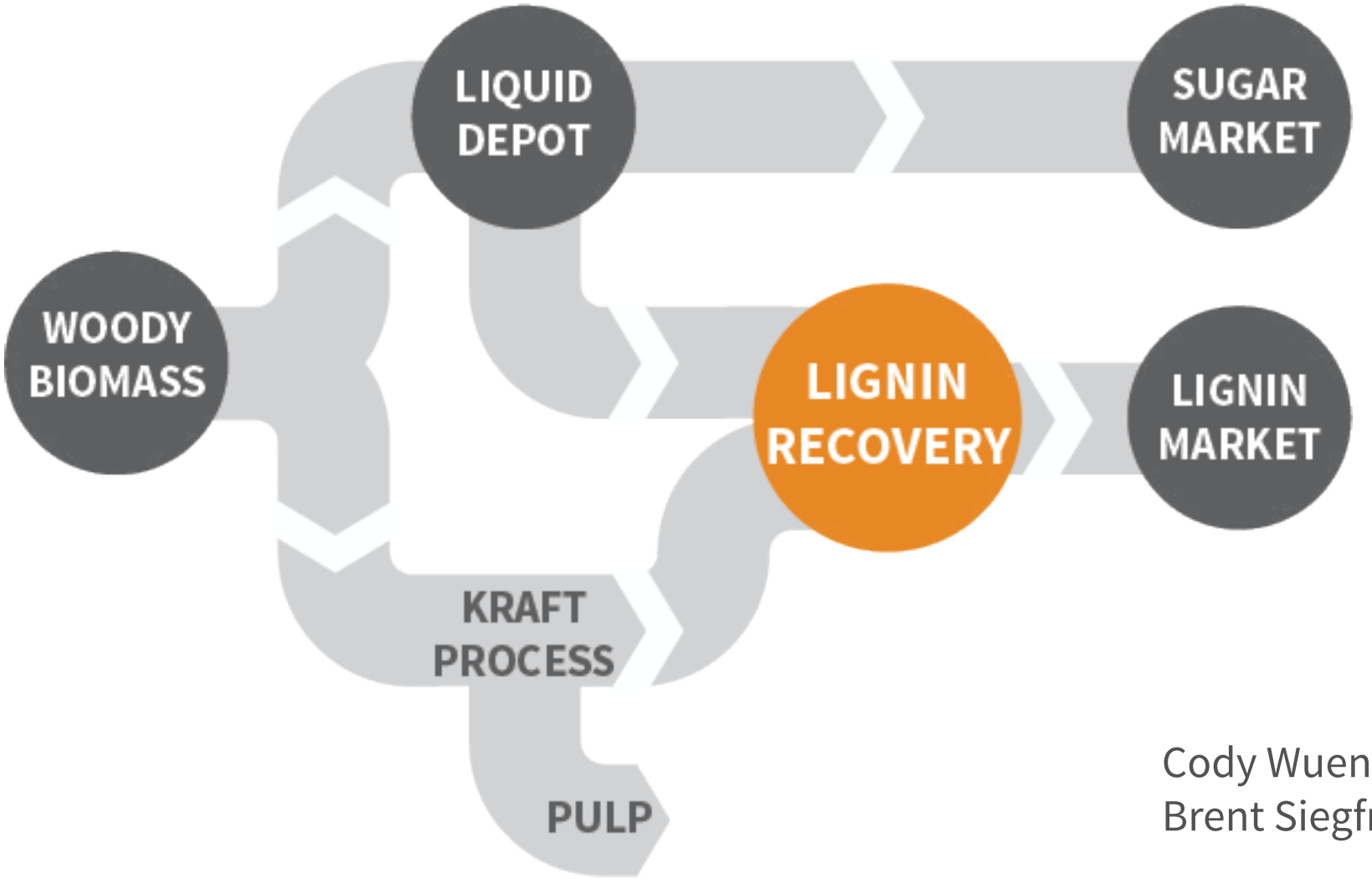
Lignin Recovery



Cody Wuenstney
Brent Siegfried

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Lignin Recovery

LIGNIN

What is Lignin?

Lignin is a constituent of the cell walls of almost all dry land plant cell walls. It is the second most abundant natural polymer in the world, surpassed only by cellulose. Of the polymers found in plant cell walls, lignin is the only one that is not composed of carbohydrate (sugar) monomers.

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Lignin Recovery

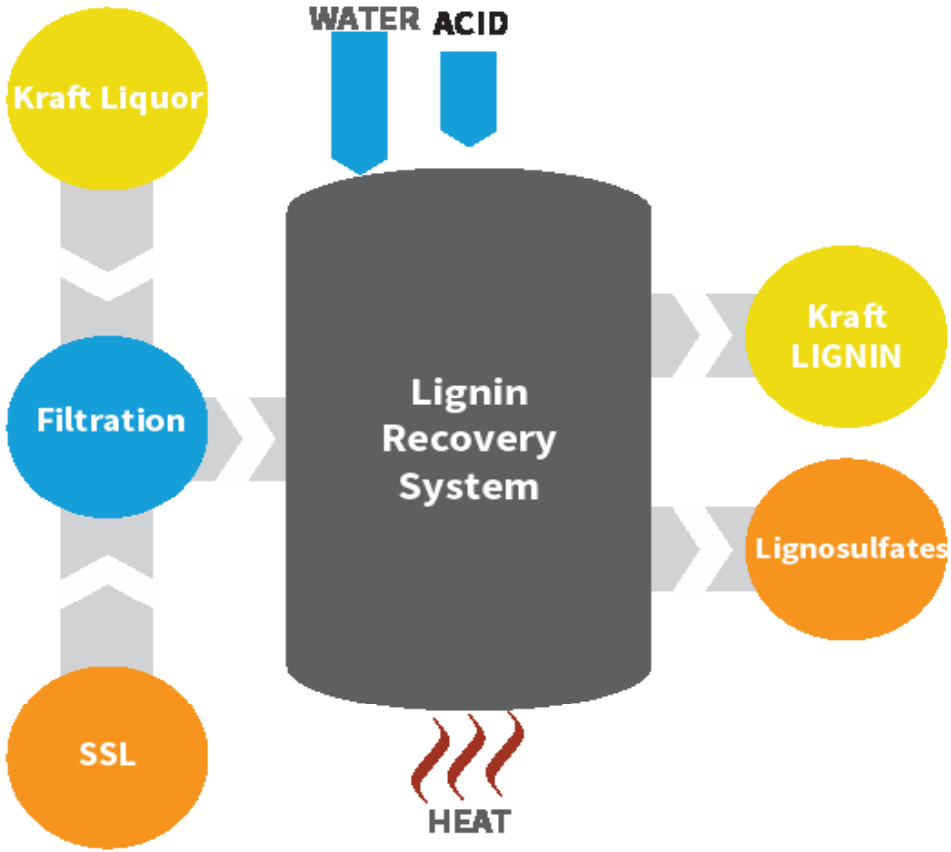
THE TWO LIQUORS

SSL (Spent Sulfite Liqour)

- Sulfite Pulp Plant
- High Sulfite Levels
- Water Soluble
- 42% Lignosulfonates
- High Sugar Levels

Kraft Liquor

- Kraft Pulp Process
- Varying Degrees of Quality
- Acidic
- 40% Lignin
- 15% Solids



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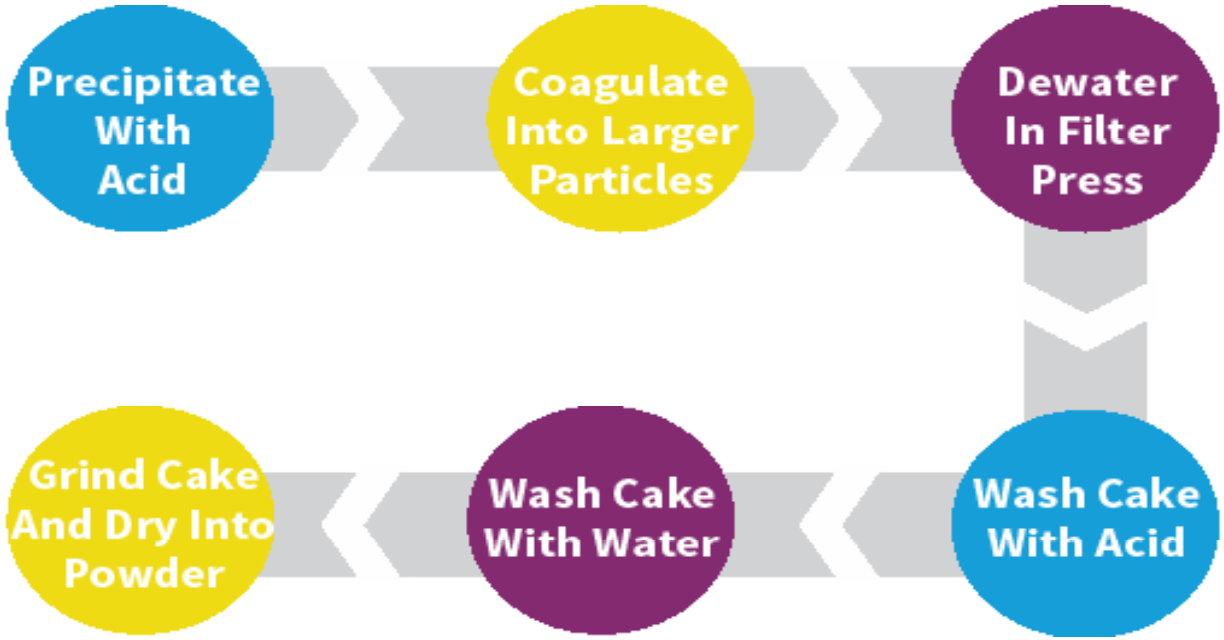
Lignin Recovery
METHODS

Sulfite Pulping (SSL)

- Ultrafiltration

Kraft Pulping (Kraft Liquor)

- LignoForce
- LignoBoost
- SLRP



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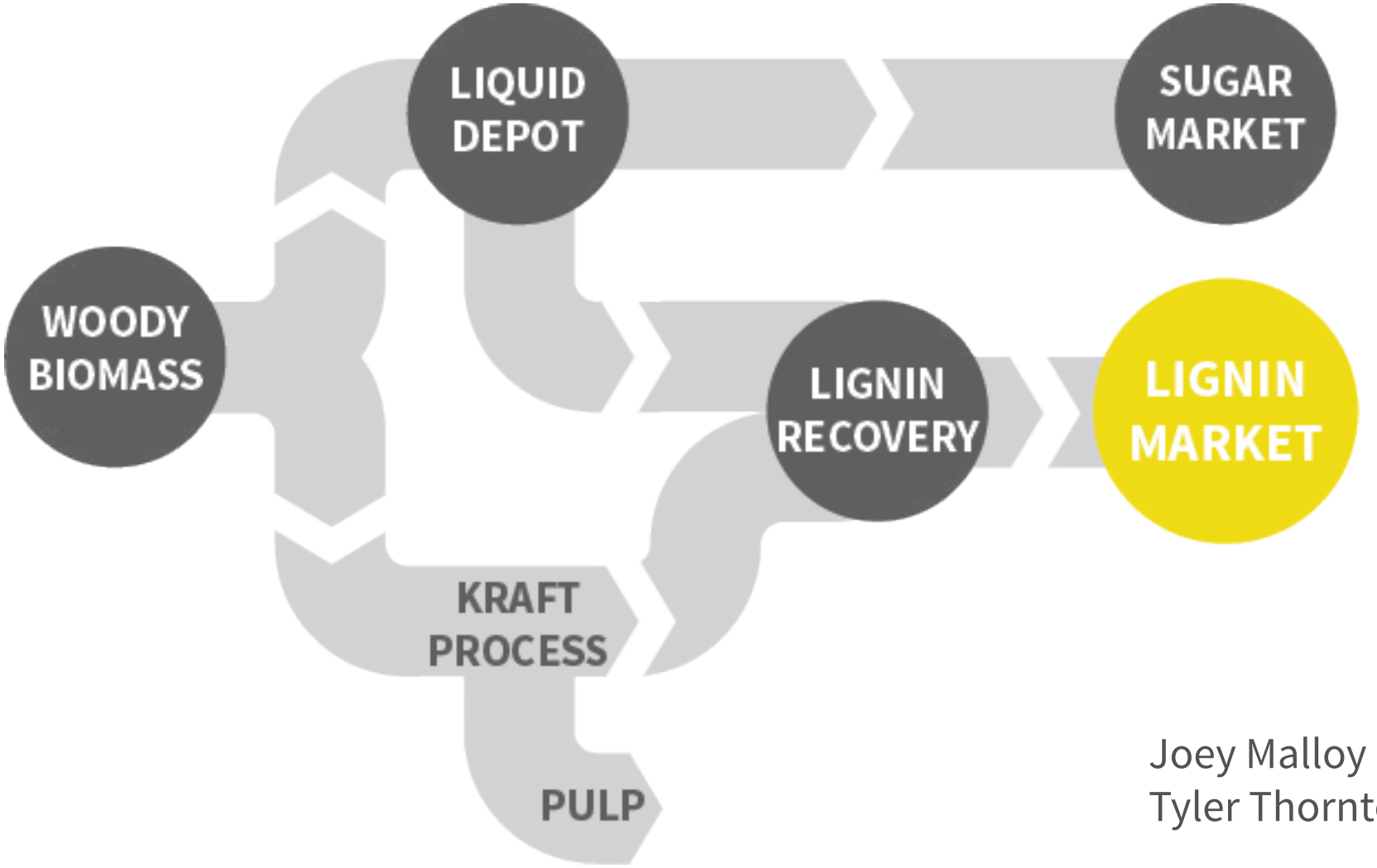
Lignin Market



Joey Malloy
Tyler Thornton

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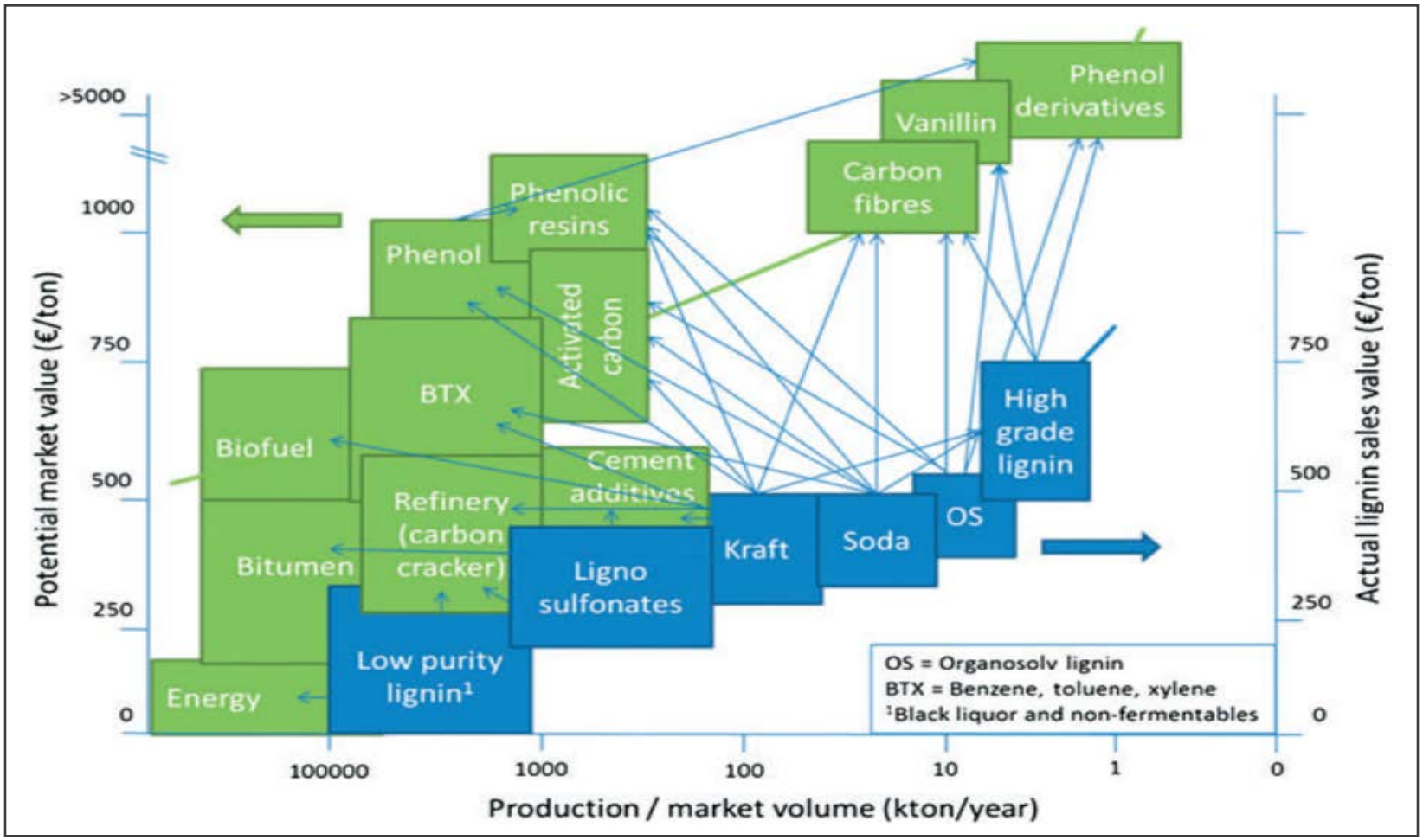
Lignin Market

VOLUME VS. VALUE



Exchange Rate: 1 Euro = $1.13

Paul J. De Wild and Wouter J.J Huijgen. Lignin pyrolysis for profitable lignocellulosic biorefineries. January 14, 2014.

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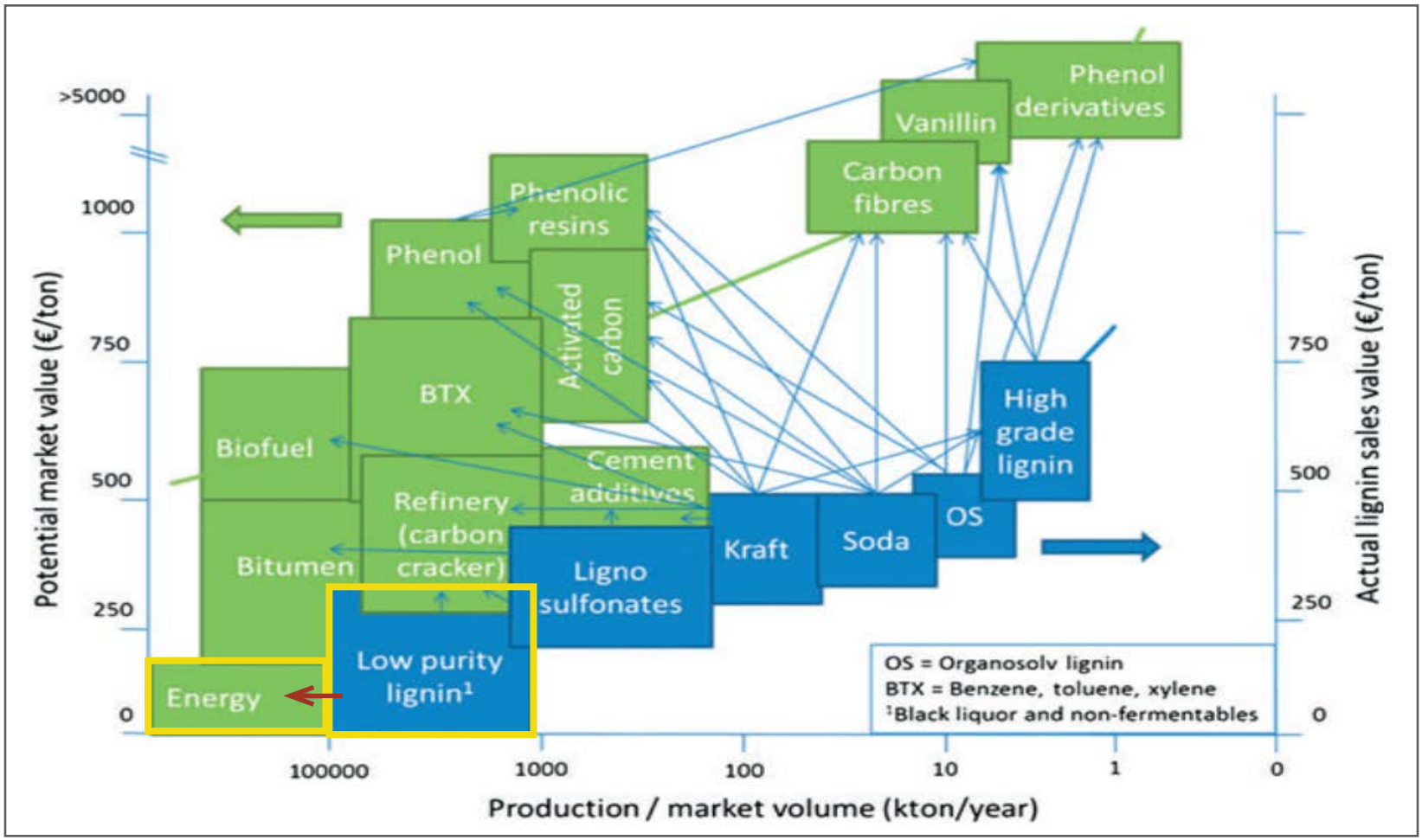

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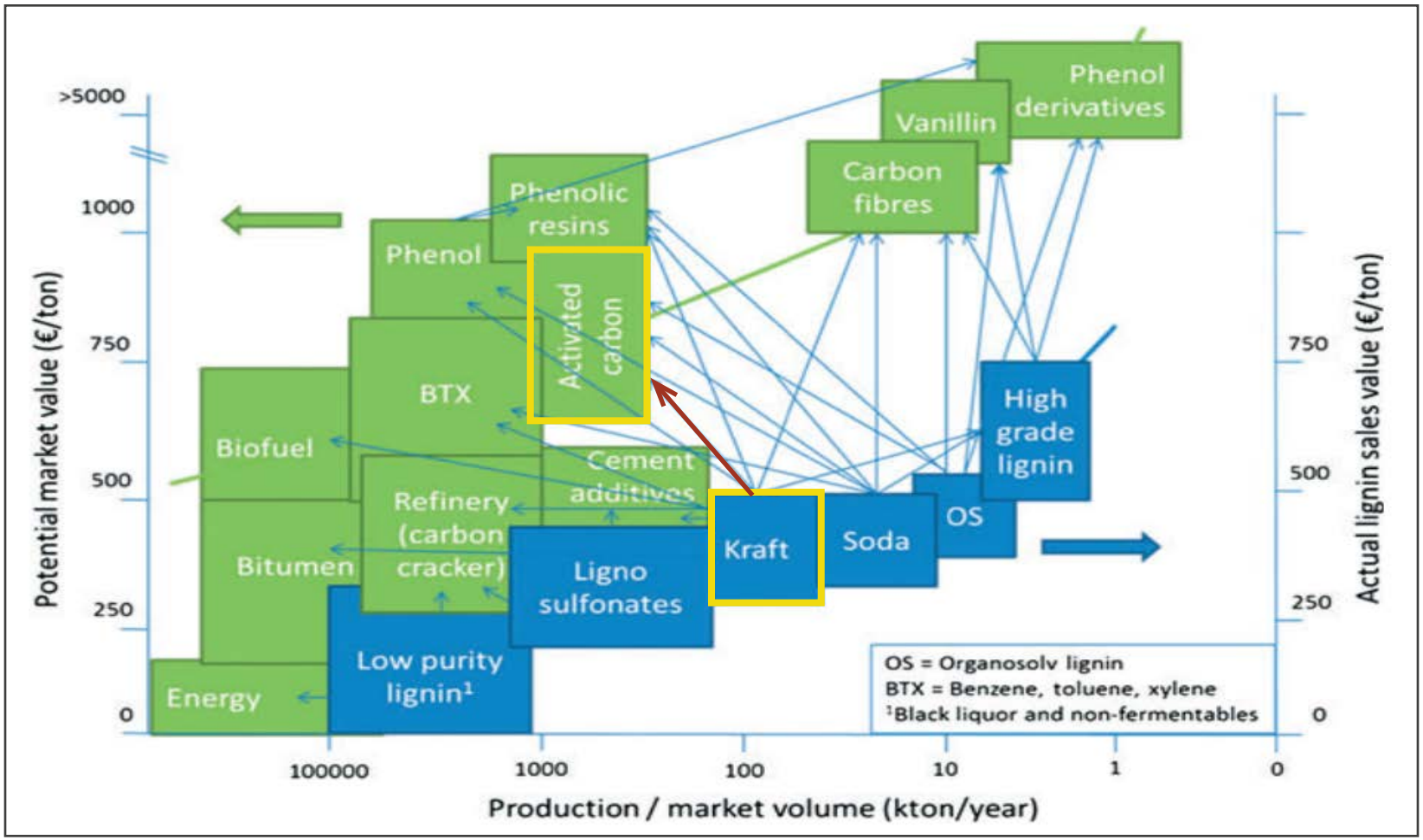

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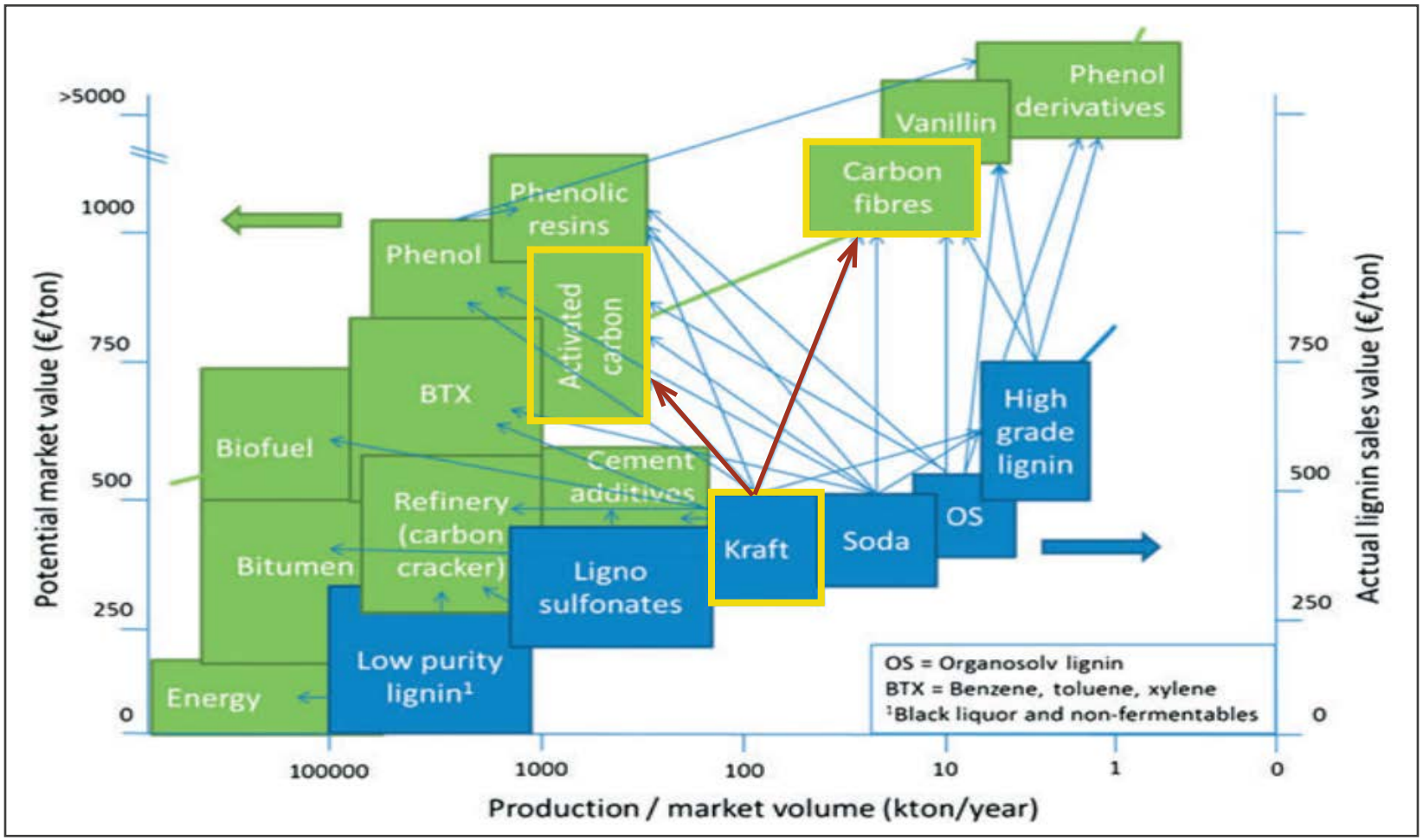

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Lignin Market

LIGNIN SUPPLY OVERVIEW

Potential World production of Biomass is 200 billion tons

- 50 million tons of lignin produced every year

2% of lignin is converted into products

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Lignin Market

AVAILABLE FORMS

High Grade Lignin

Organosolv Lignin

Soda

Kraft Lignin

Lignosulfonates

Low Purity

(Kraft Liquor)

Aromatic Compound

Carbon Fibers

Bioplastics

Resins

Activated Carbon

Sealants

Bio-oil

Bio-gas

Char

Cheap Fuel

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Lignin Market

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Sealants

Bio-oil

Bio-gas

Char

Cheap Fuel

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Lignin Market

INCENTIVE RUNDOWN

Green Alternative

Reduced Carbon Footprint

Still can uses as fuel

Diversify

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Lignin Market

GLOBAL LIGNIN INVESTMENT

Stora Enso

- $36.3-million USD (Finland)

Borregaard

- $8.5-million USD
- with Sappi (South Africa)

CIMV

- $22.7-million USD (France)

Suzano

- $20-million USD (Brazil)

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Lignin Market

NORTH AMERICAN LIGNIN INVESTMENT

Borregaard

- $110-million USD
- JV with Rayonier (Florida)

West Fraser

- $10-million CA, 2014 (Canada)
- $6.1-million CA, 2015 (Canada)

Domtar Corporation

- $36-million USD (Quebec)
- $73.5-million USD (North Carolina)
- (Including lignin-production facility)

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Lignin Market

POTENTIAL NORTHWEST MARKETS

Lignin in Building Materials

- Plywood
- Particle Board
- Oriented Strand Board (OSB)
- Gypsum Board

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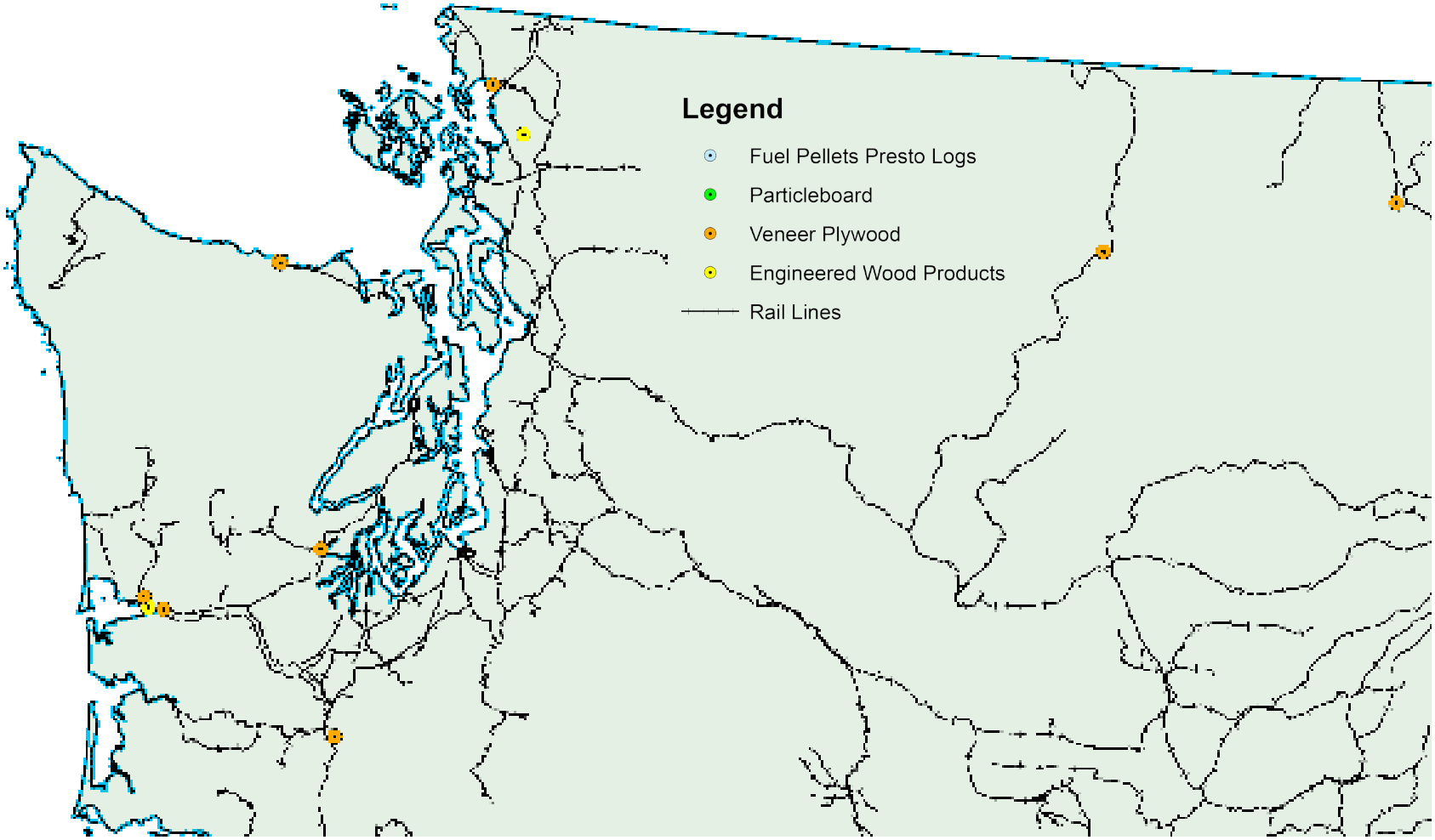
Lignin Market

POTENTIAL OP MARKET LOCATIONS



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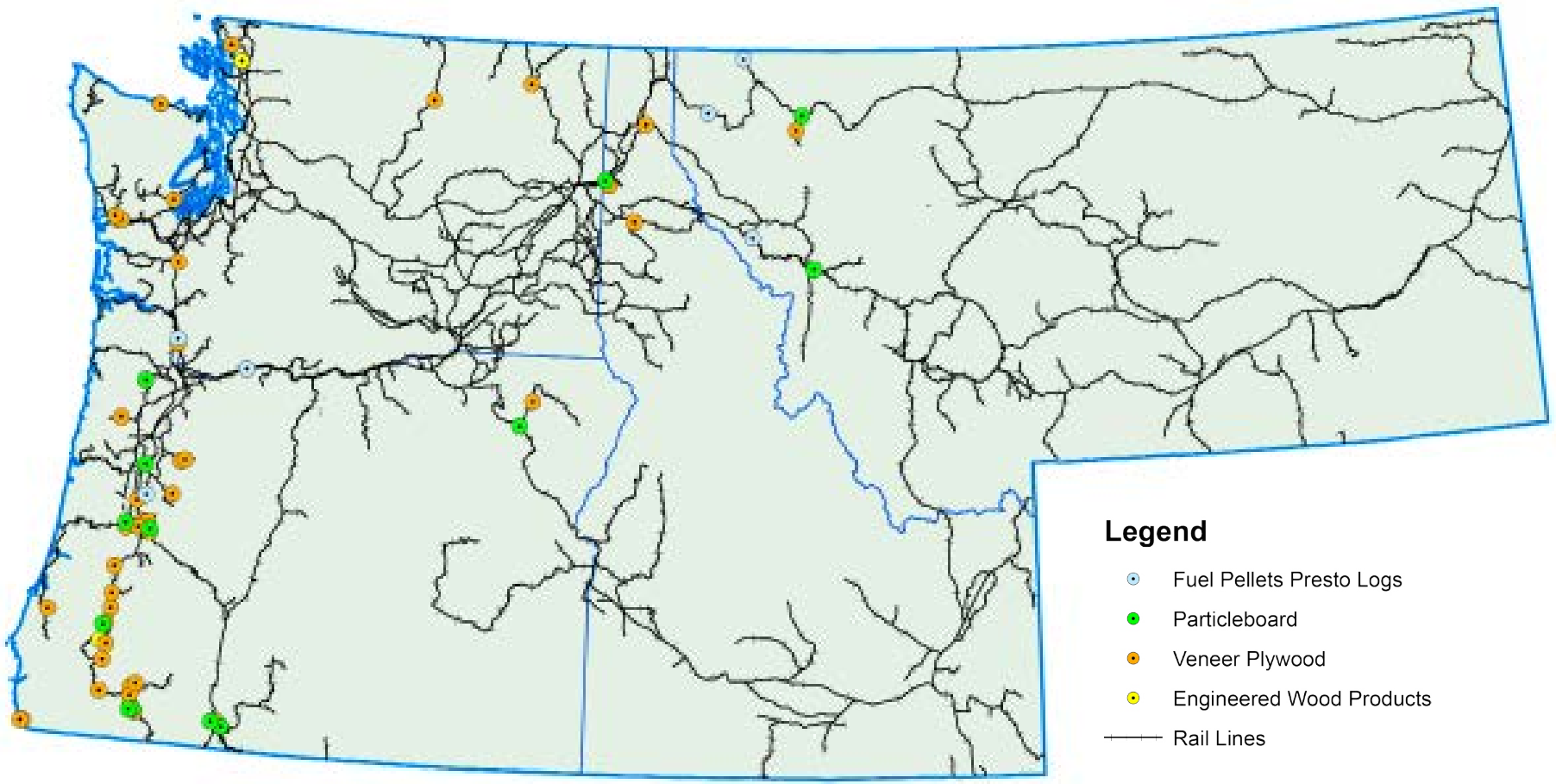
NARA is led by Washington State University and supported by the Agriculture and Food Research Initiative Competitive Grant no. 2011-68005-30416 from the USDA National Institute of Food and Agriculture.

Lignin Market

POTENTIAL 4-STATE MARKET LOCATIONS



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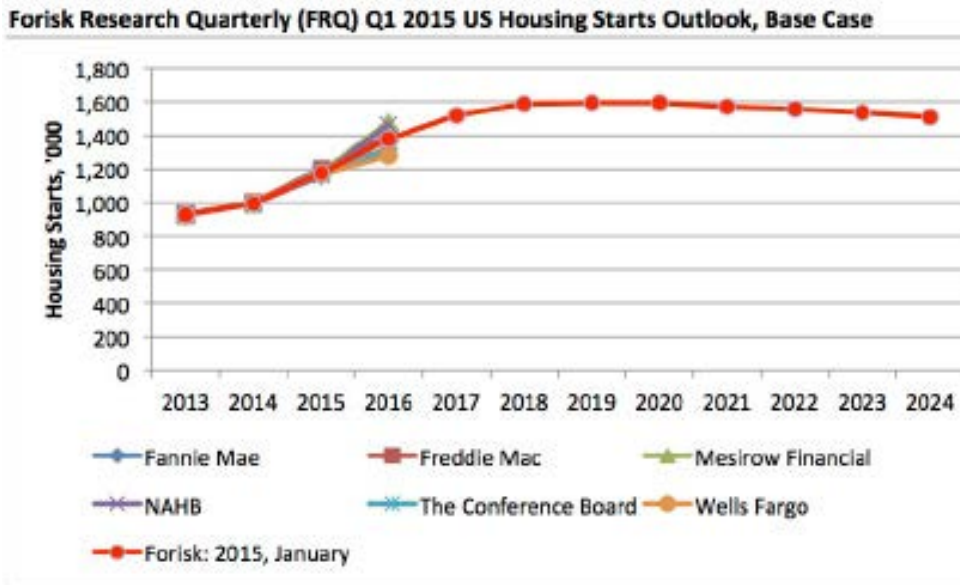
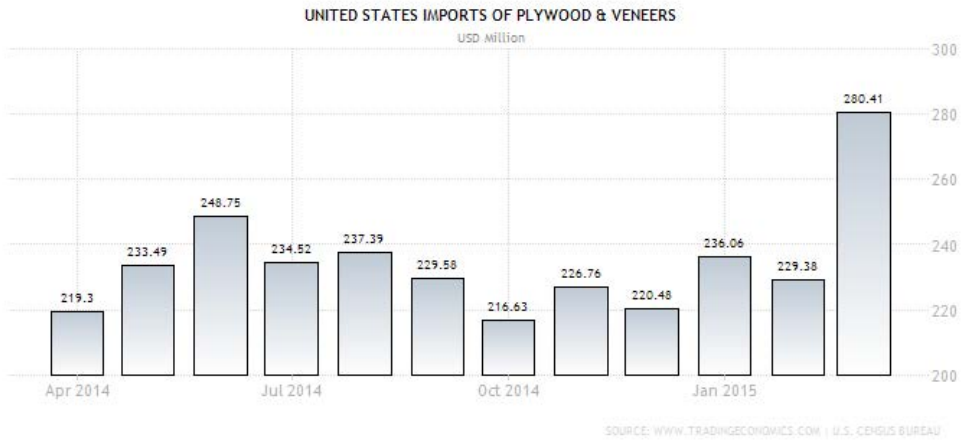
KEY MARKET TRENDS

Housing Market Progress



Plywood Import Trends



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USDA

Lignin Market

CONCLUSION

Exciting Future Growth

Diversify With Available Material

Global Investment

- Government
- Private

Opportunities to lead in the NW

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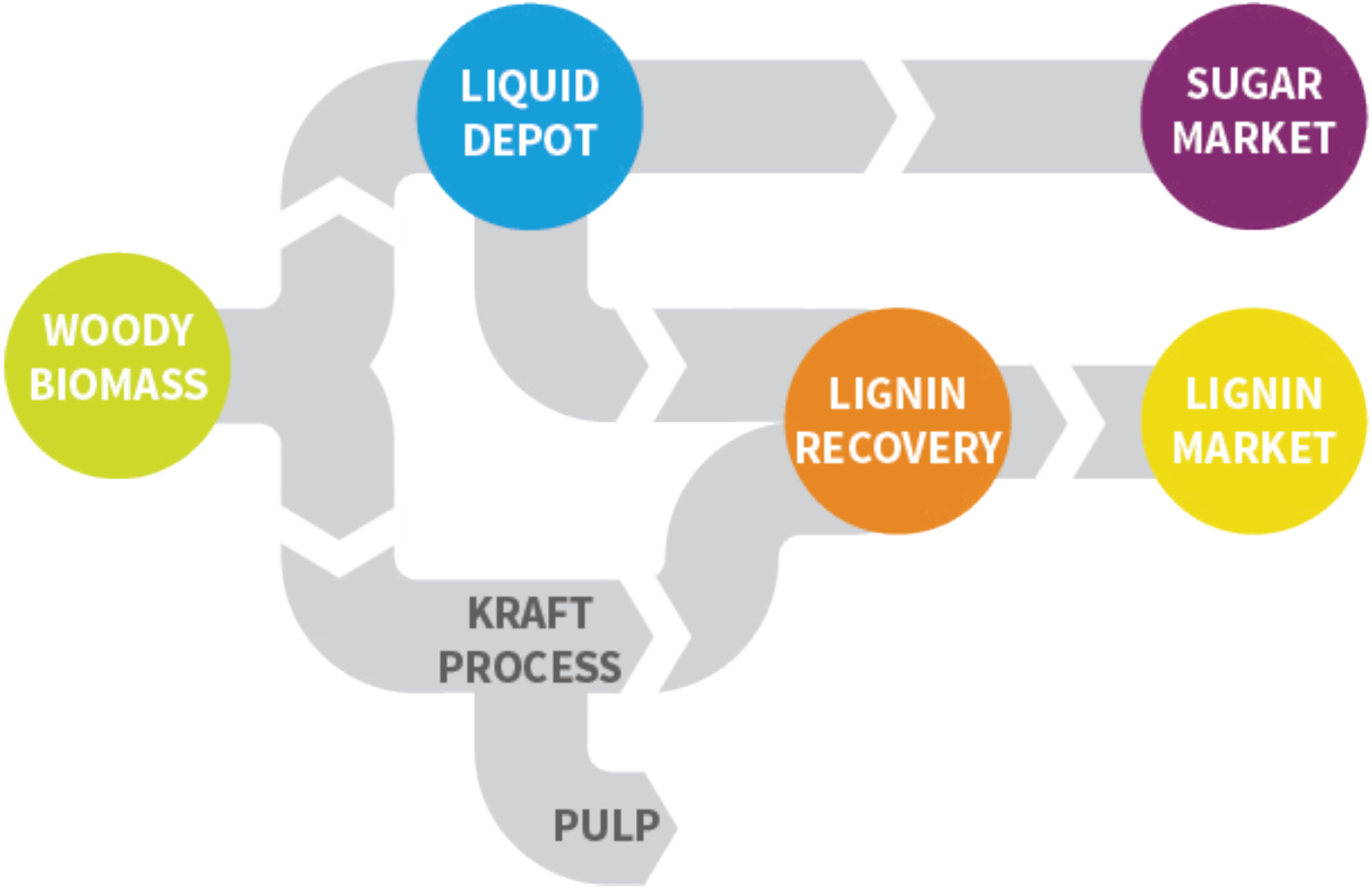
USDA

IDX Supply Chain Analysis



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