National Institute of Food and Agriculture

The Agriculture and Food Research Initiative Regional Bioenergy Feedstock Systems Coordinated Agricultural Projects (CAPs):

An integrated approach to understanding regional feedstock supply, quality and cost

Presented to the ABLC Feedstocks Conference

Miami, FL June 8, 2016

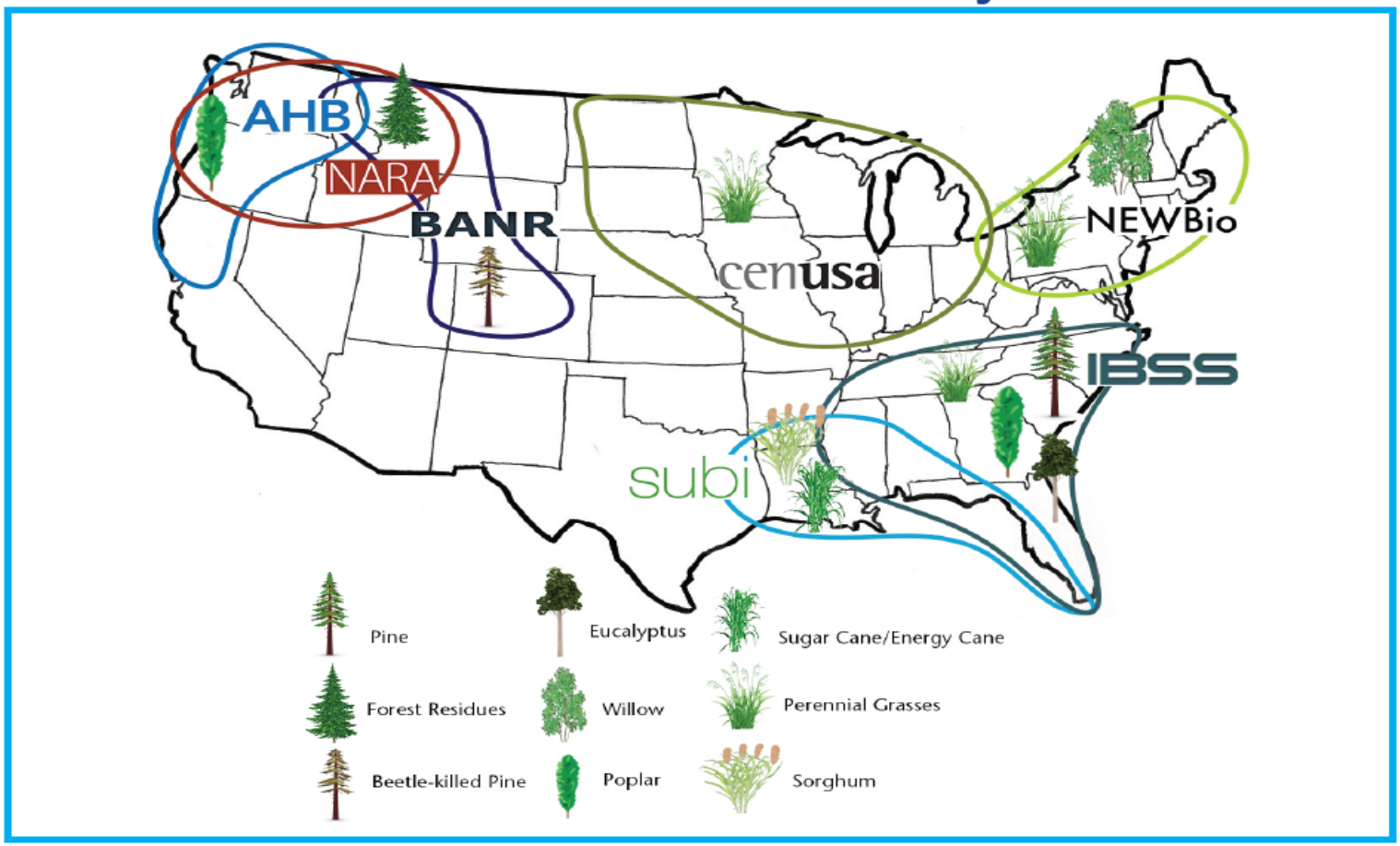
Sustainable Bioenergy and Biobased Product Portfolio Vision

Facilitate the development of sustainable regional production systems for biofuels, biopower, industrial chemicals, and biobased products through partnerships and collaboration, to create and preserve jobs, increase rural economic vitality, enhance food production systems, create ecosystems services, and reduce use of fossil carbon.

AFRI - Coordinated Agricultural Projects

- **Regional Biomass Feedstock Systems**
  - Focus on five non-food feedstocks (2010-2013):
    - ✓ Woody biomass;
    - ✓ Energy cane;
    - ✓ Perennial grasses;
    - ✓ Energy sorghum; and
    - ✓ Oilseed crops
- **Transdisciplinary systems approach to reduce risk**
  - Focus on feedstock development, production, and delivery
  - Must partner with feedstock users & well-align with appropriate conversion technologies and industry for bioproduct production
  - Integrate research and development, education, outreach, demonstration
  - Analyze economic, environmental, and social sustainability
  - Involve communities upfront for their guidance

AFRI Biofuel Feedstocks and Project Locations



Where are the Feedstocks?

They are here. Where's the value proposition?

Understanding feedstock supply quantity, logistics, quality characteristics, and cost to stand up an integrated value chain

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A new vista for Green Fuels, Chemicals, & Environmentally Preferred Products

Michael Wolcott

Regents Professor

Project Co-Director

Ralph Cavalieri

Associate Vice-President for Alternative Energy

Project Director

Washington State University

USDA

NARA Team

Alaska Airlines
ANDRITZ
Biomass ad Infinitum LLC
Catchlight Energy
CLH
Cosmo Specialty Fibers Inc.
Facing the Future
Forest Business Network LLC
Gevan Marrs LLC
Gevo, Inc.
ICM
Montana State University
National Center for Genome Research
National Renewable Energy Laboratory
Oregon State University
Penn State University
Salish Kootenai College
South Hampton Resources Inc.
Steadfast Management Inc.
Thomas Spink Inc.
University of Idaho
University of Minnesota
University of Montana
University of Utah
University of Washington
University of Wisconsin-Extension
USDA Forest Products Laboratory
USDA Forest Service
Washington State University
Western Washington University
Greenwood Resources
Weyerhaeuser

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NARA: Feedstock to Fuels

FRP

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.

1000 kg BONE DRY WOODY BIOMASS +

T

TRANSPORTATION

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

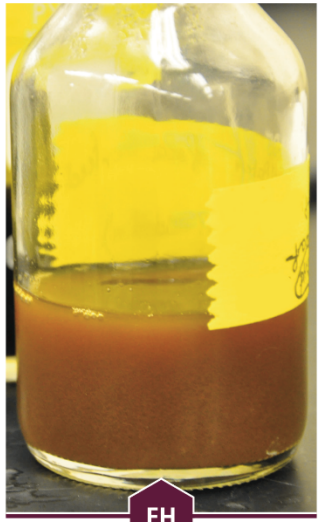
DIESEL +

PT

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.

HEAT, WATER, & CHEMICALS =



EH

ENZYMATIC HYDROLYSIS

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

~300 kg LIGNIN AND

F

FERMENTATION

Specialized yeast convert the monosaccharides into isobutanol.

~260 LITERS ISOBUTANOL OR

BCP

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.

~190 LITERS BIOJET

Completing 5 of 5 years

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Keys to NARA

- ***Innovation and Integration***
  - Robust project management
  - Feedstock Logistics
  - Pre-processing (mild bisulfite, milled wood)
  - Sustainability Analysis (TEA)
  - Novel conversion technologies
    - Isobutanol to AJF, lignosulfonates, activated carbon
  - Workforce development
  - Community and landowner engagement

Why it matters…

- Rural economic development
  - New jobs in rural communities
  - Protected jobs in the pulp industry through diversification
  - Alternative income for landowners
- Products from non-petroleum renewable feedstocks
- Ecosystem services

Biorefinery Approach

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Isobutanol to Jet Fuel Demonstration

Demonstration unit at South Hampton Resources, Silsbee, TX is fully functional

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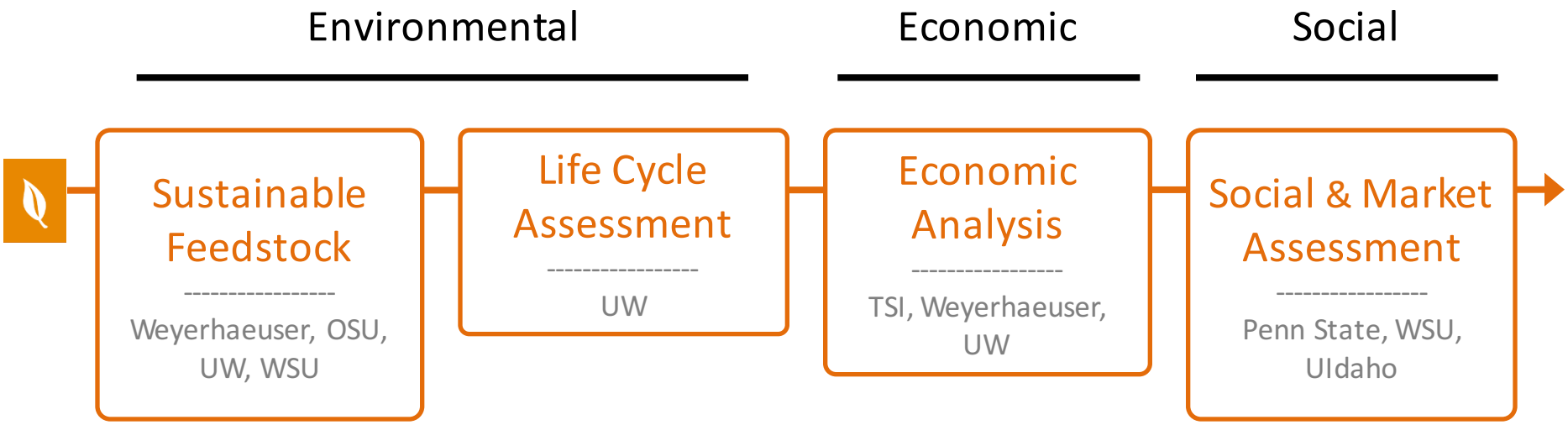
Sustainability Assessment



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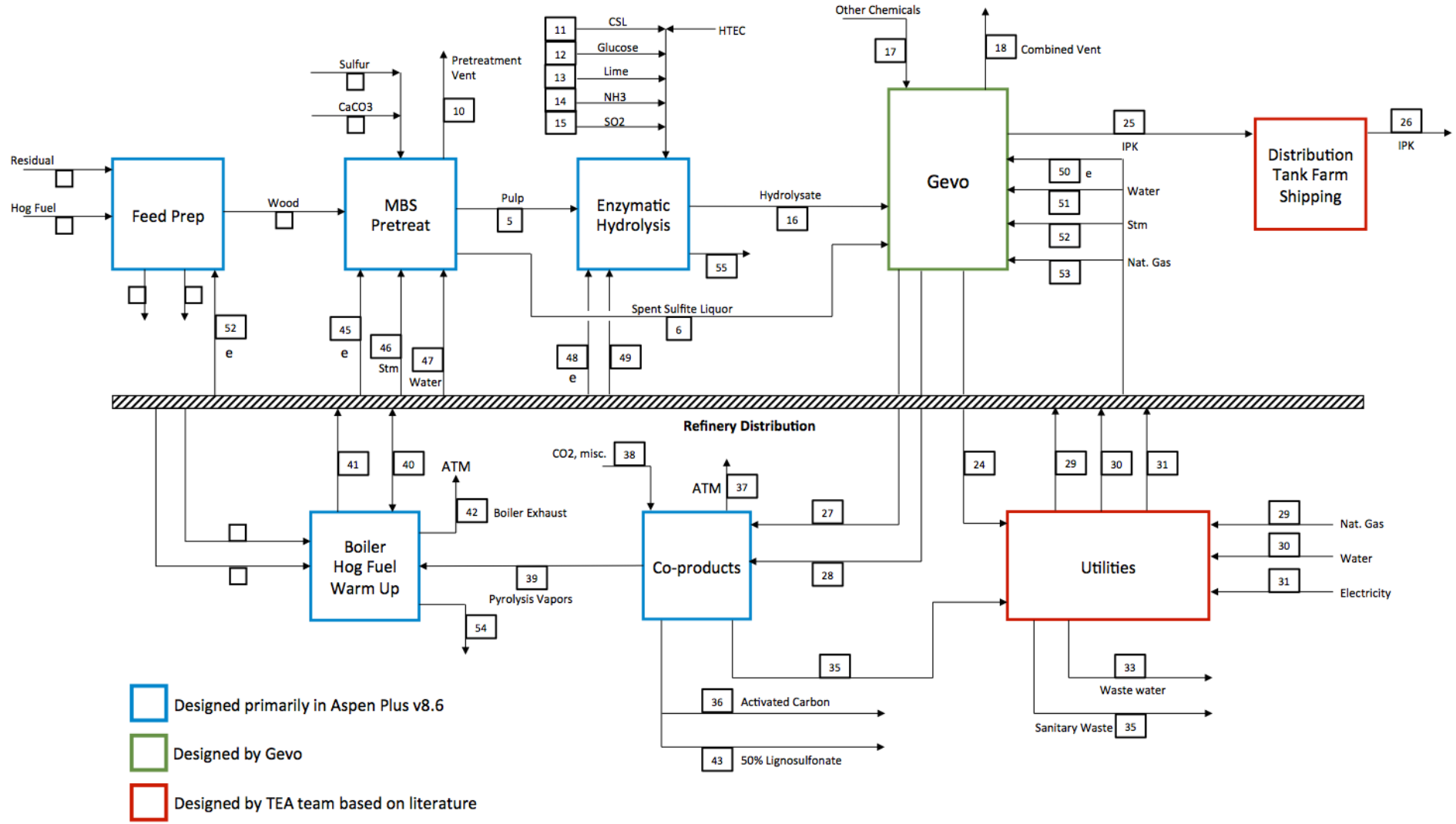
Making Alternative Jet Fuel is Complicated

TAKE HOME LESSONS FROM NARA

NARA ASPEN Process Model



Source: TSI Chemicals & Biomass Products and Processes

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Making Alternative Jet Fuel is Complicated

And Its Even More Complicated to Make Money!

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IRR for Integrated Biorefinery - $3.09/gal AJF

Baseline IRR for Greenfield IBR
0.1% < < target of 15-25%

Decrease OpEx = 0
15.9% - barely in target of 15-25%

Decrease CapEx = $104 MM
25% - below liquidation cost of existing plant

Increase Revenue = 100 to 160%
17.8 to 25%

Most Plausible Scenarios
Control Costs
Build Revenue Streams
- require high value products
- biochemical is potential

Sensitivity Analysis for IRR from NARA IBR			
Decrease Opex by 50%, 75%, or 100%			
Capex	Opex	Revenue	IRR
$ 1,441	$ 281	$ 327	0.1%
$ 1,441	$ 140	$ 327	9.4%
$ 1,441	$ 70	$ 327	12.8%
$ 1,441	$ -	$ 327	15.9%
Decrease Capex to 75%, 50%, or 7.2%			
$ 1,441	$ 281	$ 327	0.1%
$ 1,081	$ 281	$ 327	1.4%
$ 721	$ 281	$ 327	3.6%
$ 104	$ 281	$ 327	25.0%
Increase Revenue by 50%, 100%, or 160%			
$ 1,441	$ 281	$ 327	0.1%
$ 1,441	$ 281	$ 491	10.6%
$ 1,441	$ 281	$ 654	17.8%
$ 1,441	$ 281	$ 850	25.0%

Combinations to Achieve Target IRR			
Decrease Capex & Opex by 25% + Increase Revenue 50%			
Capex	Opex	Revenue	IRR
$ 721	$ 211	$ 491	17.7%
Decrease Capex & Opex 25% + Increase Revenue 100%			
$ 721	$ 211	$ 654	25.7%

Making Alternative Jet Fuel is Complicated

And Its Even More Complicated to Make Money!

But its Good for the Environment

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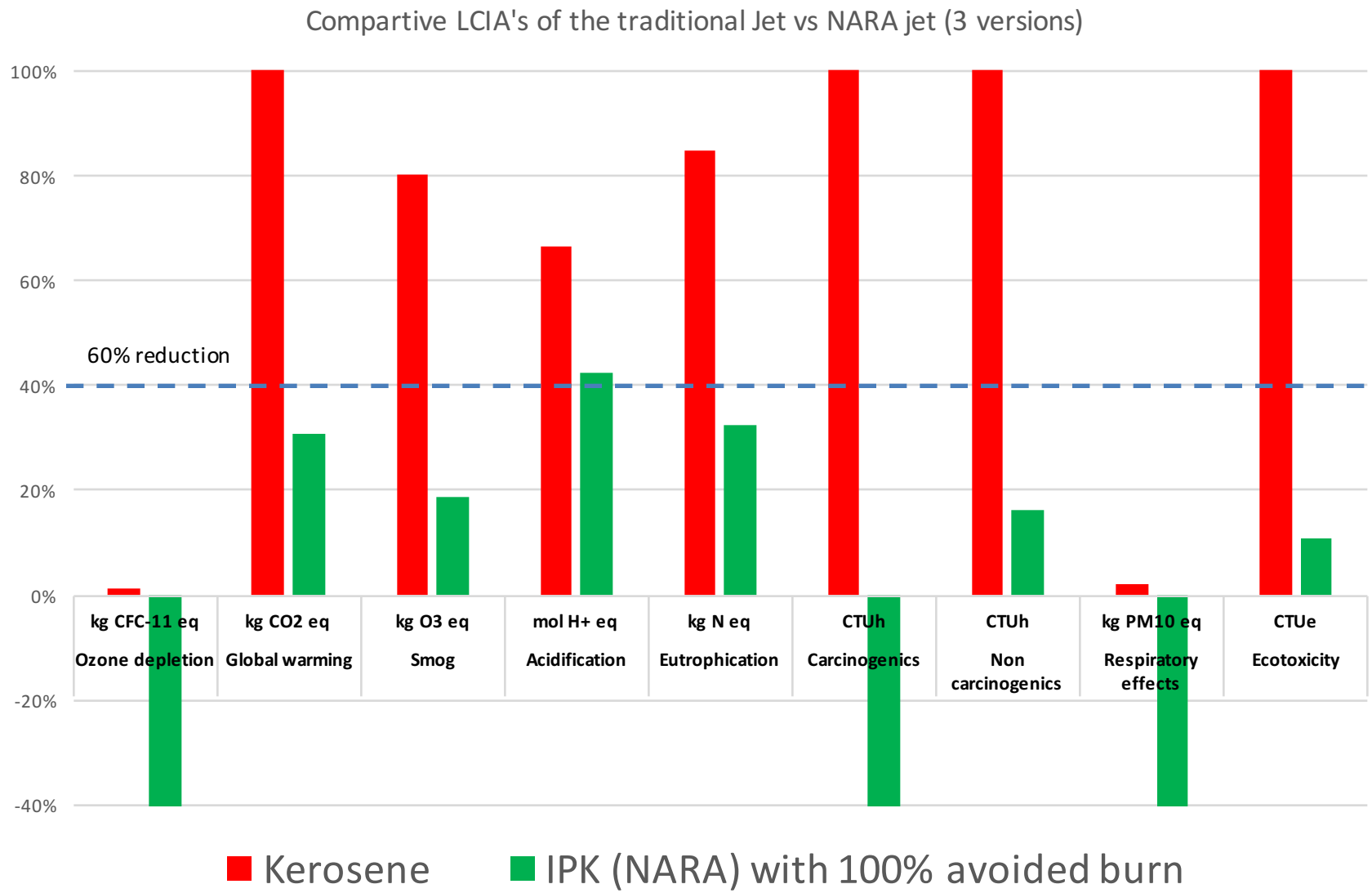
Comparative LCA for NARA Alternative Jet Fuel



Preliminary Results – Do Not Distribute or Cite

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And Its Even More Complicated to Make Money!

But its Good for the Environment

And Good For Local Economies

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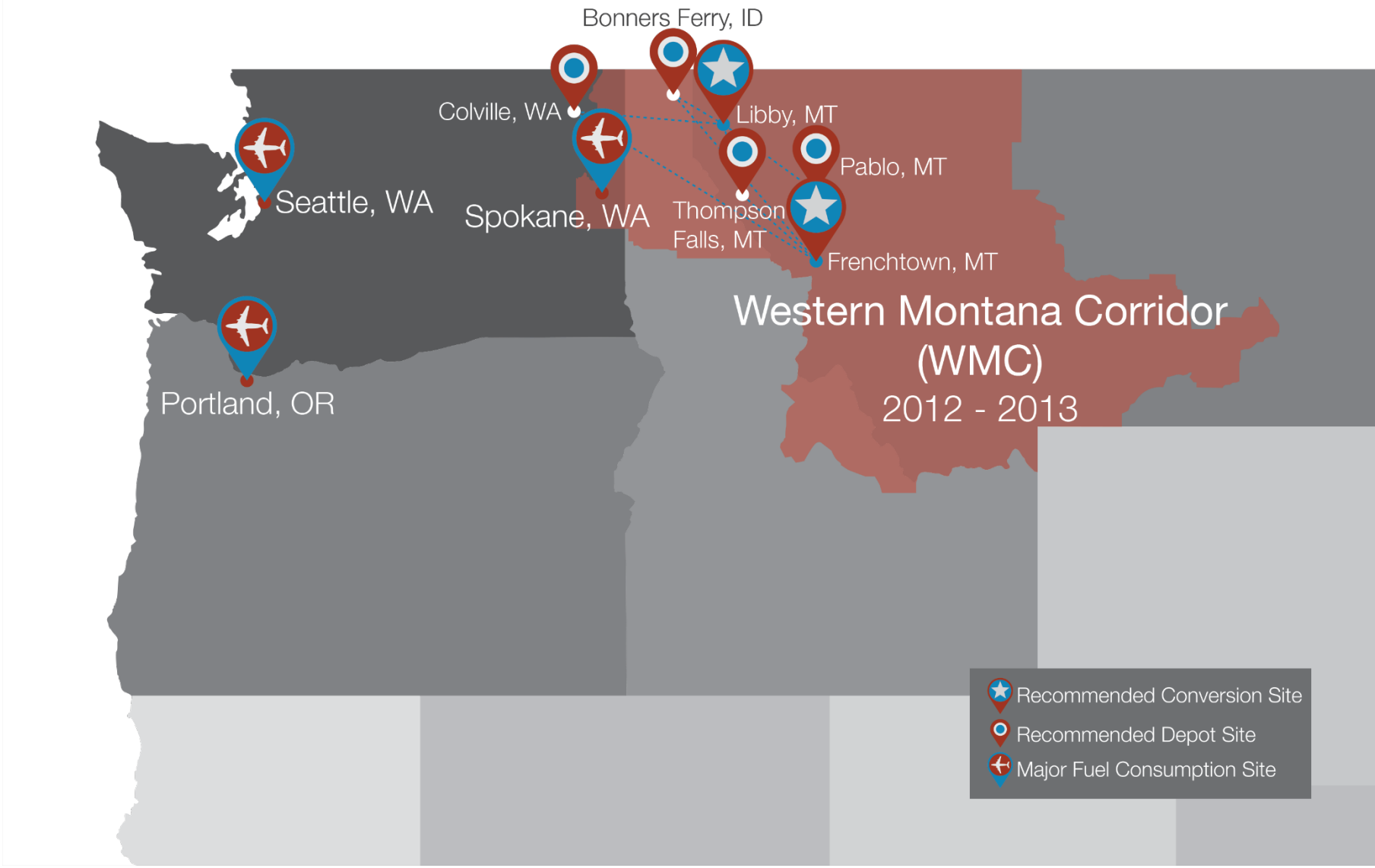
Western Montana Corridor v1.0

NW Biofuels + Co-Products
May 3, 2016 in SeaTac, WA



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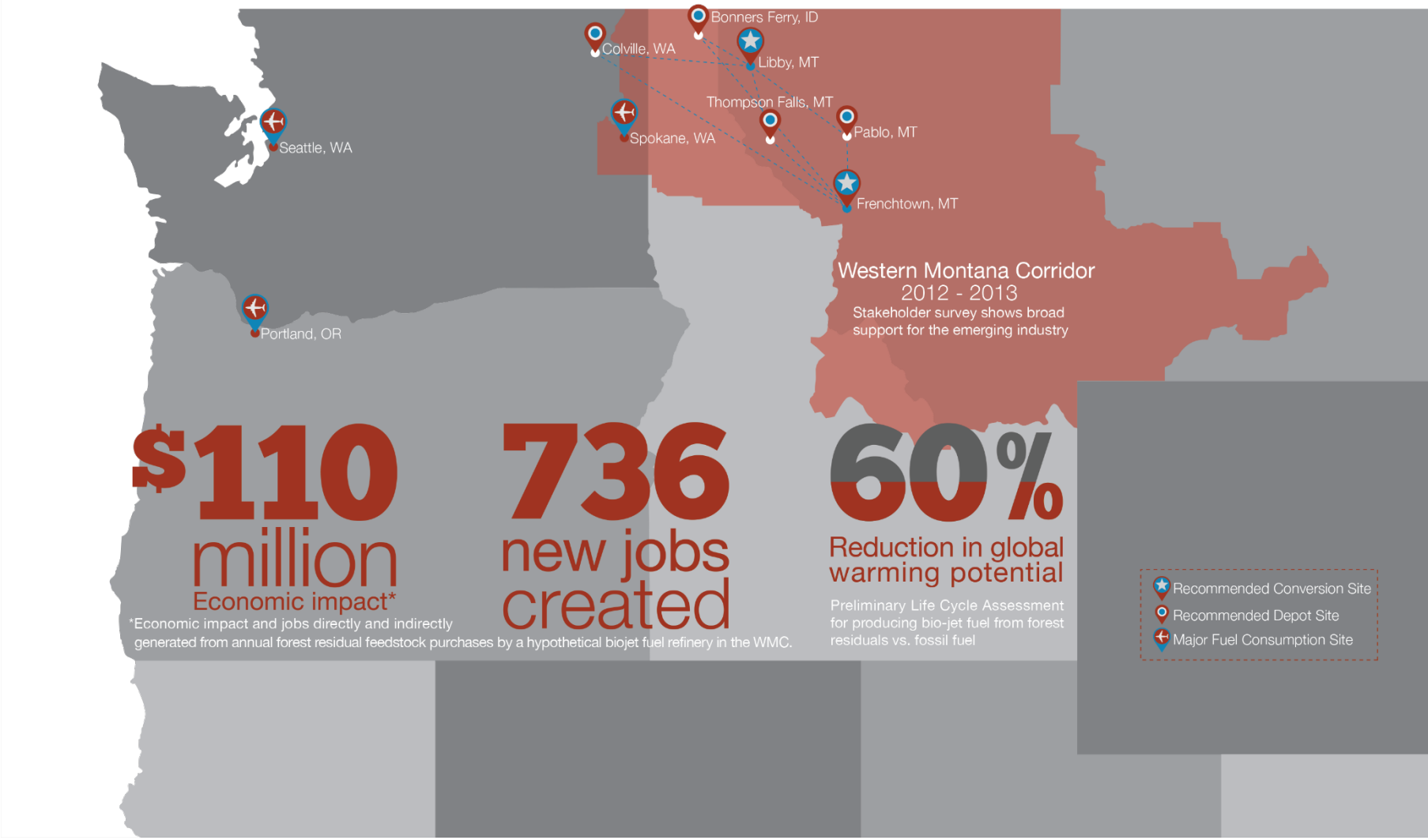
Economic Impact



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Making Alternative Jet Fuel is Complicated

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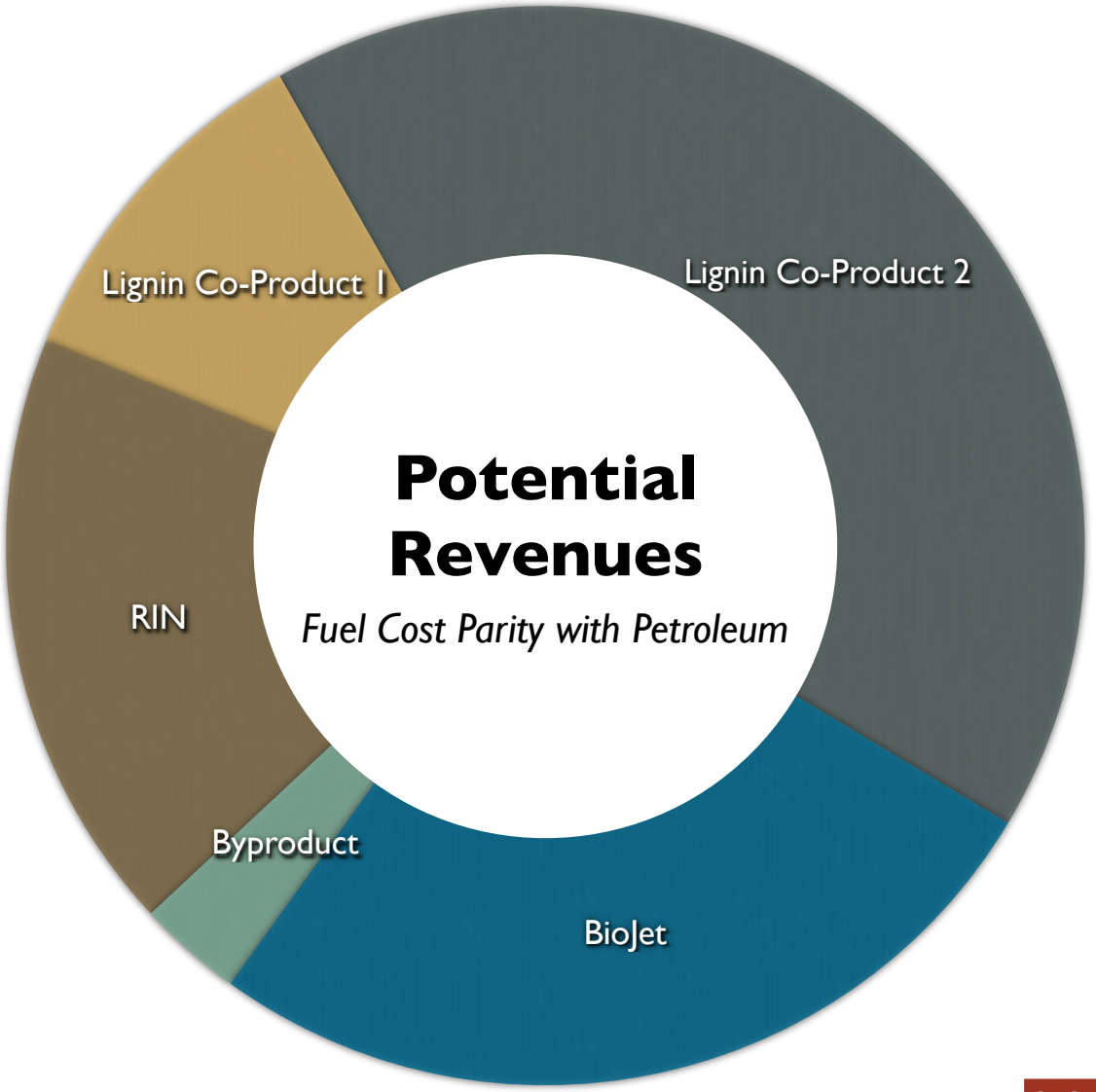
But its Good for the Environment

And Good For Local Economies

Continue the Pathway to Commercial Reality

TAKE HOME LESSONS FROM NARA

Value Chain: Route to Cost Parity for Fuels



Pathway to Commercial Reality

Current Process Design

- Current Status is FEL-1 to FEL-2
- Needs Optimization of Value Chain
- Refinement of Market and Equipment Costs

Consideration for Comparison to Petroleum

- Petroleum fuel production does not account for green house gas production, only costs
- Petroleum fuel allowed to fully depreciate capital including drilling assets
- Petroleum fuels are lowest in value chain that includes petrochemicals

Making Alternative Jet Fuel is Complicated

And Its Even More Complicated to Make Money!

But its Good for the Environment

And Good For Local Economies

Continue on the Pathway to Commercial Reality

Continue to Focus on Supply Chains

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Regional Supply Chain Analyses

Pacific Northwest (PNW)

Supply Chain Analysis

This site provides supply chain data and analysis generated by NARA research for the region identified as the Pacific Northwest, which includes Montana, Idaho, Washington, and Oregon.

Mid-Cascades to Pacific (MC2P)

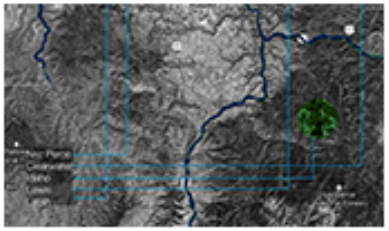
Supply Chain Analysis

This site provides supply chain data and analysis generated by NARA research for the region identified as Mid-Cascades to Pacific, which includes the western sections of Washington and Oregon.

Western Montana Corridor (WMC)

Supply Chain Analysis

This site provides supply chain data and analysis generated by NARA research for the region identified as the Western Montana Corridor, which includes the western section of Montana, Northern Idaho and northeast Washington.



Clearwater Basin

Supply Chain Analysis

This site provides supply chain data and analysis generated by NARA research for the region identified as the Clearwater Basin, located in central Idaho.

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IKIPK

WOOD TO WING

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Conf. Salish and Kootenai
Kevin Jump


Weyerhaeuser Corp
Lane Forest Products


Weyerhaeuser Corp
Lane Forest Products

1K-IPK – Fuel Distribution and Demonstration

Fuel Certification

Alter Jet - ASTM D7566

Blending

Conv Jet – ASTM D1655

Distribution to Wing

Commercial Demonstration Flight

Processing Partners

Gevo Corp

South Hampton Refining

Blending Partner

Alaska Airlines

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Moving from Invention to Commercial Reality

- Forest Residue Collection and Preparation
- Envisioning Integrated Facilities and Siting
- SPORL / MBS Pretreatment
- Alcohol to Jet
- Demonstrating Feasibility with Supply Chain Implementation Partners
- Educating Citizens, Industry, Policy Makers

Advancing Supply Chain Development

THE ROLE OF NARA

Path to Commercialization?

- Port of Seattle (Sea-Tac) signed MOU with NARA partners Boeing and Alaska Airlines to bring AJF to Sea-Tac in the next 5-10 years.
  - Commissioned infrastructure and engineering study
- Commercialization roadmap preliminary meeting 5/16 at Sea-Tac brought together NARA, potential industrial partners, Port of Seattle.

If its going to burn....

... it might as well be in a jet engine

John Bailey, OSU NARA Member

What's next?

- Agriculture and Food Research Initiative
  - 2016 RFA is out:
    - Four new regional CAPs
    - Each project $15 M over five years
    - Biofuel, chemical intermediates, biobased products
  - Foundational Research Program
    - Cover Crops for Bioenergy and Biobased Products
- New interagency program with DOE BETO: Feedstock Logistics and Materials Handing

Bill Goldner, Ph.D. wgoldner@nifa.usda.gov

Sustainable Bioproduct Initiative (SUBI) led by Louisiana State University

- In 5th year of funding ($17.5 M total)
- Entire supply chain focus
- Integrated Research, Education, and Extension/Outreach
- Successfully developed cold-tolerant energy cane
- Energy cane and sweet sorghum feedstocks for a full range of higher-value co-products to make the entire system economical
- Commercial partners Virent (aviation fuel) and Optinol (butanol)

Keys to SUBI

- ***Innovation and Integration***
  - Superior energy cane and sweet sorghum genetics
  - Cold tolerant energy cane to move cane production away from the coast
  - Low input production systems
  - Feedstock logistics
  - TEA and Sustainability Analysis
  - Diverse conversion options
    - Chemicals, bioplastics
    - Fuels (butanol, aviation fuel)
  - Workforce development
  - Community and landowner engagement

Why it matters…

- Rural economic development
    - Jobs in an area that sorely needs them
    - Potential for greater farm income than current cropping systems
- Products from non-petroleum renewable feedstocks and accompanying ecosystem services.

Year round feedstock supply

Month	Sorghum	E-cane	Commercial sugar	Other
Jan				
Feb				
Mar				
Apr				Bagasse
May				Bagasse
Jun				Bagasse
Jul				
Aug				
Sept				
Oct				
Nov				
Dec				

Winnsboro Ho 02-113 1st stubble crop (Sept. 2014).

White PVC pole is 10’ long.

Courtesy of Chris Adams.

Sweet Sorghum

- Annual crop
- Contains, a sugar containing juice, starch containing seed heads and fiber
- 90-120 day crop cycle, can be grown across target region
- Gross structure similar to sugarcane
- Can be widely grown across Southern US
- About 6,000 acres required to sustain processing plant for 3 months

Crop Comparison

Energycane	
Harvest time(months)	7
Ag Inputs	none
Planting	perennial
Acres/1000t/day factory	8,000
Growth in non-traditional regions	yes
Dry ton/acre	10-18

Sweet sorghum	
Harvest time(months)	3
Ag Inputs	None*
Planting	annual
Acres/1000t/day factory	6,000
Growth in non-traditional regions	yes
Dry ton/acre	1-9

*fallow with clover

Biofuel Feedstock Production Costs - Louisiana

Feedstock Production Cost	Energy Cane	Sweet Sorghum
	($/dry ton)	*($/dry ton)*
Total Production Costs	$70 - $74	$74 - $90
Land Rent[1]	$14 - $15	$15 - $18
Transportation[2]	$12 - $24	$13 - $27

[1] Rent charged at 1/6 crop share.

[2] Hauling cost example range = $3 to $6 per wet ton.

[3] Costs per dry ton estimated using average dry matter content of 24.3% for energy cane and 22.4% for sweet sorghum

SUBI Pilot Plant at Audubon Sugar Research Center

Process Outline

Sustainable Production

Feedstock development

Sustainability

Harvest

analyze

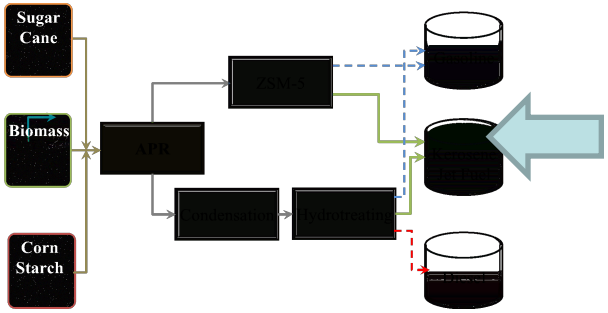
Deliver

Technology development

Process

Economic feasibility

Intermediate Product



Conversion to Fuel

Value to Consumer

Syrup Mills

Technology development

Biomass