Enabling Lipid-based Fuel Production

Moderator: Steve Csonka (CAAFI)

Opening observations

Panelists:

- Matt Langholtz (DOE, ORNL)
- Roy Scott (USDA, ARS)
- Burt English (UTK, ASCENT)
- John Cusick (The Jacobsen)

COMMERCIAL AVIATION ALTERNATIVE FUELS INITIATIVE

U.S. commercialization activity / intent
HDRD & SAJF from lipids/F.O.G.

- Diamond Green: Norco, LA
- REG: Geismar, LA
- AltAir/World Energy: Paramount, CA
- Diamond Green expansion (160->275->550M gpy)
- AltAir Build out (40 -> 305M gpy)
- Andeavor Dickinson, ND conversion (180+M gpy)
- Phillips 66 / REG: Ferndale, WA
- Rhyze / Phillips 66: Reno/Las Vegas, NV
- SG Preston (duplicate 240M gpy facilities)
- ARA licensing build-out (4+ activities)
- Licensing for additional refinery retrofit(s)
- Refinery co-processing
- Neste, UPM, … potential US pivots

In Production
390 M gpy by YE

In US Development:
Greater than 1.2B gpy
capacity by 2021 !?!

… necessitates serious engagement with purpose grown oilseed & F.O.G. development / expansion

Global HDRD production capacity

The global situation will not provide feedstock capacity relief

* 2018 Global production capacity 4.745M tpy
  * US at 0.750M tpy, or 390M gpy
* Some expect 40% capacity increase by 2020 to 6.7 - 7.5 M tpy

* From whence comes the up to + 2.76 M tpy feedstock?
* Growth of biodiesel remains robust too, creating stiff competition (via favorable economics for corn & soy) for more sustainable HDRD/AJF production

U.S. lipid feedstocks
Potentially enabling of significant production …

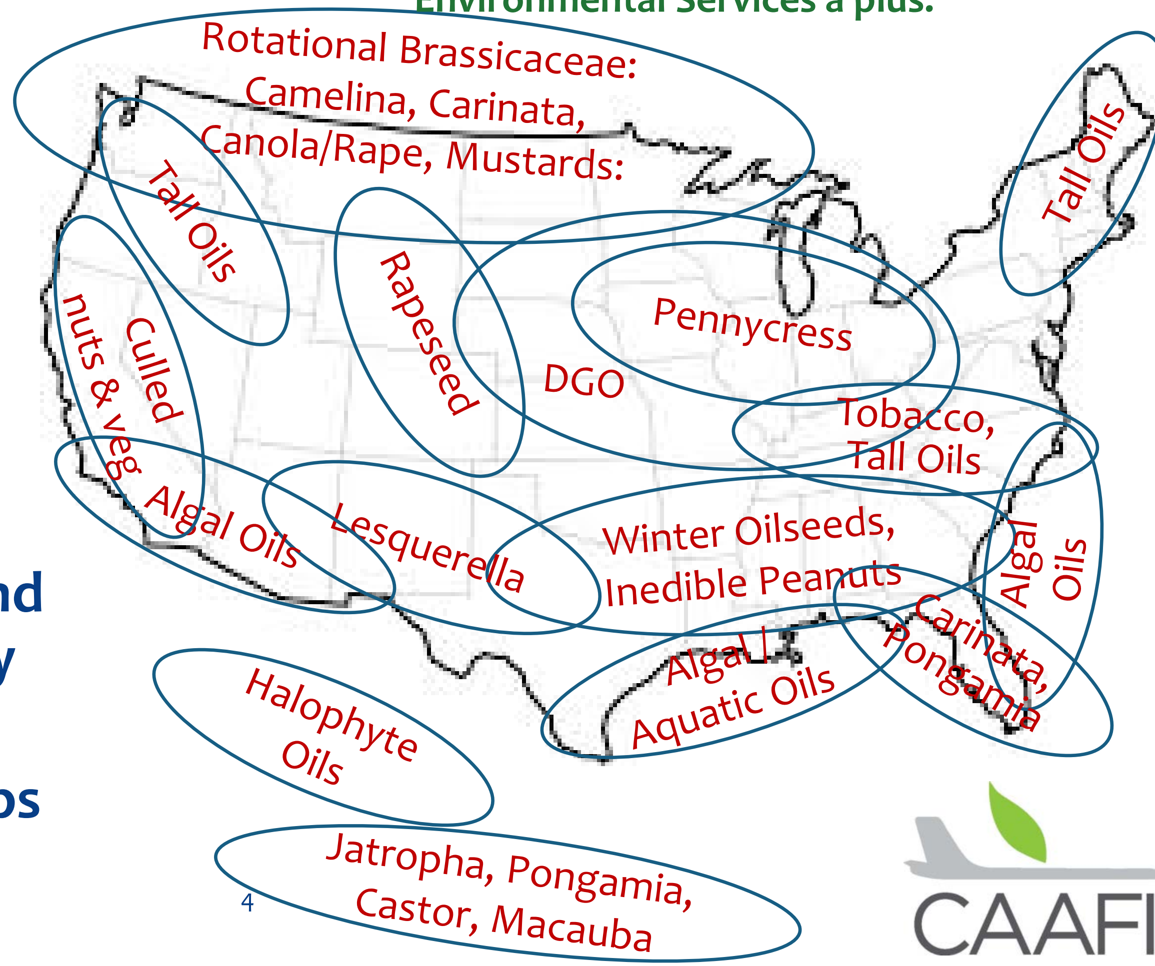
Multiple:
- Conversion processes
- Feedstock developers
- Producers
- Low LUC/ILUC agri-based feedstocks
- Waste F.O.G.
  - White Grease, Poultry Fat, Tallow
  - UCO / Yellow Grease
  - Brown Grease, Biosolids

Easier supply chain scale-up leveraging biodiesel and HDRD production capacity

Lowered H2 cost & availability (from NG) helps

Targeting most sustainable solutions:

Low, or Zero, impact LUC/ILUC & F-v-F solutions; Environmental Services a plus.



Current focus on lipid solutions
Positive attributes

* Straightforward – nature gives us something very nearly fuel
* Significant domain knowledge and infrastructure around grains and oils
  * Handling, storage, processing, transport
  * Rapid energy densification via crush
  * Subsequent fungibility, and ease of working with fluid feedstock
* Main byproduct is protein meal – addresses other key concern – feeding a world of 10B
  * Other co-product markets in chemicals and materials
* Less farmer fear with annuals versus perennial lignocellulosics
* Promise of winter cover oilseeds with minimal LUC/ILUC
* Potential for use of brown greases – relatively untapped market
* Eventual promise of ubiquitous algae production? Microbial lipids?
* Advanced work on oil production from non-traditional plants, or sequestration in lignocellulose

Current focus on lipid solutions
Negative aspects

- Poor growth opportunity from waste feedstocks
- "Only so much viable acreage"
  - LUC/ILUC, biodiversity challenges with wholesale land conversion
  - Only some will be viable on marginal lands (e.g. halophytes)
- Palm-pushback already influencing policy against FOG
  - Also taints all palm, several types of which don't have the negative aspects of concern in SE Asia
- Perceived need for significant hydrogen for conversion
- Purpose-grown lipid feedstocks not ready for primetime

Many folks working to change the paradigm

CoverCress Inc.
The cover crop that pays

AGRISOMA

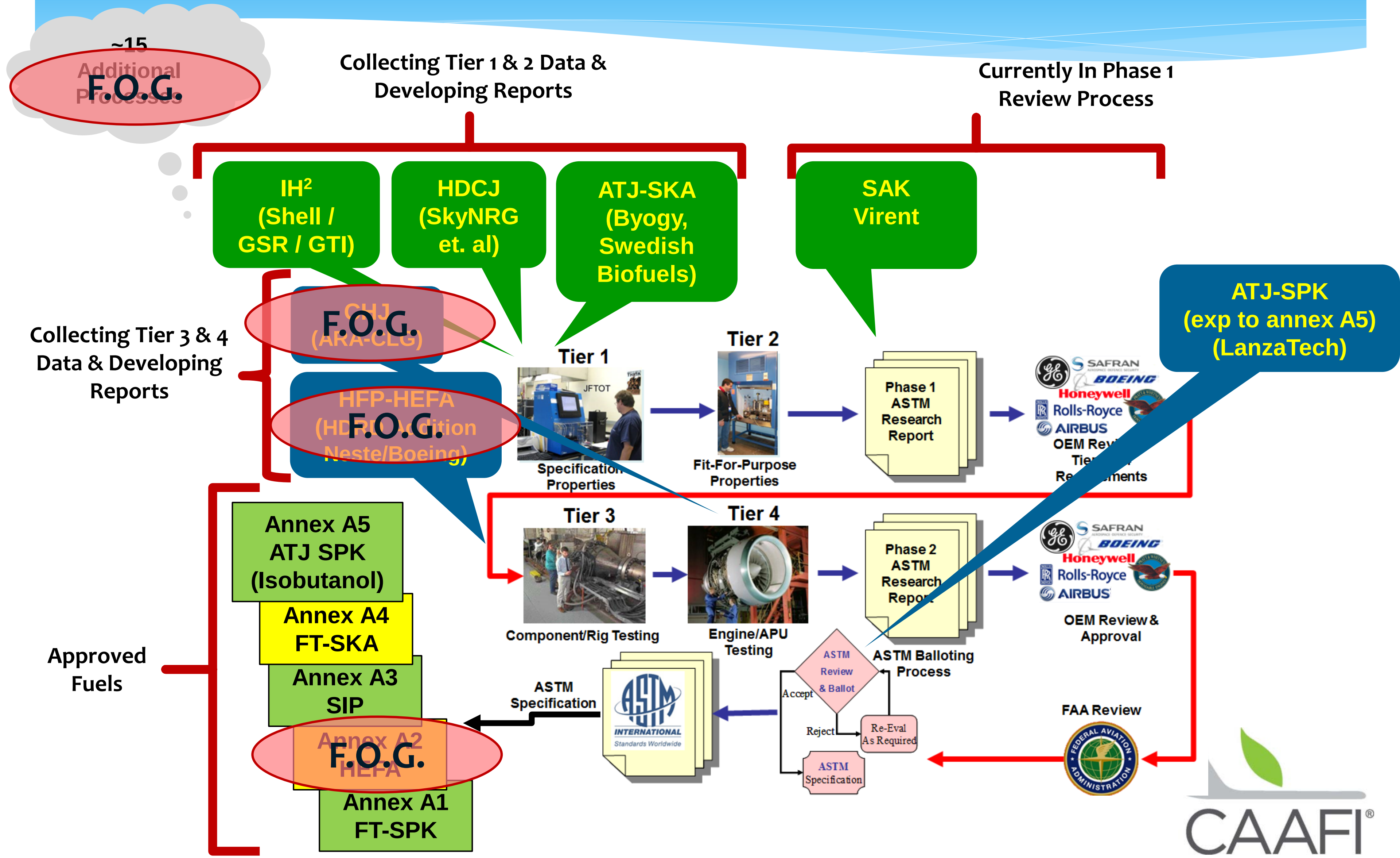
Terviva™

greatplains | the camelina company

USDA United States Department of Agriculture
Agricultural Research Service

- It wasn't so long ago that another oilseed was successfully brought to market and commercial success
  - Canola (the double negative variant of *Brassica napus*)
- Todays skillset in genomics and bio creates new paradigm
- Aided by perceived need to improve farm sustainability (carbon sequestration, erosion prevention, nutrient management, water quality, pollinator health, diversification, …)
- Row crop annuals, bushes, trees, …

Technologies applicable to SAJF



Select additional tech. approaches

D7566	Approach	Feedstock	Notes
	1) IHI: HD HCs	HC oils from other bio-sources	
	2) Forge: LTH	Lipids	Demo plant being built in Ontario
	3) SBI: CGC PICFTR	Lipids - biodiesel	Shell partnership
	4) Tyton: CCL	Lipids	

… 11+ more using various other feedstocks and conversion processes

D1655	Approach	Feedstock	Notes
	1) Co-processing	Lipids	Chevron, BP, Phillips66

* Approved Apr'18. Sets the stage for other entities to follow, by sending various biocrudes to the refineries for finishing:

	2) Co-processing	FT Biocrude	Fulcrum
		Other Biocrude Processes	TBD

CAAFI®

This session

* Designed to address the previous points, and discuss what might be feasible. What does it take to get there? Can we?
  * Matt will discuss DOE's assessment of feedstock availability from the Billion Ton report, including lipids
    * What's in, what's out, what's next?
  * Roy will talk about work being done by ARS to enable additional oilseed crops, especially those with unique application:
    * Winter covers, dual cropping, integrated landscape design
  * Burt will highlight the impact of a single solution in a specific geography
  * John will bring the above together from the perspective of a commercial entity whose expertise is looking at these issues.
* Subsequently, you'll also hear more about lipids in sessions 2.6, 2.8, and 2.9, and 3.9

Lipid-based biomass resources

Matthew Langholtz
Maggie Davis
Rebecca Efroymson
Keith Kline

Oak Ridge National Laboratory

CAAFI Biennial General Meeting
December 5th, 2018
Washington D.C.

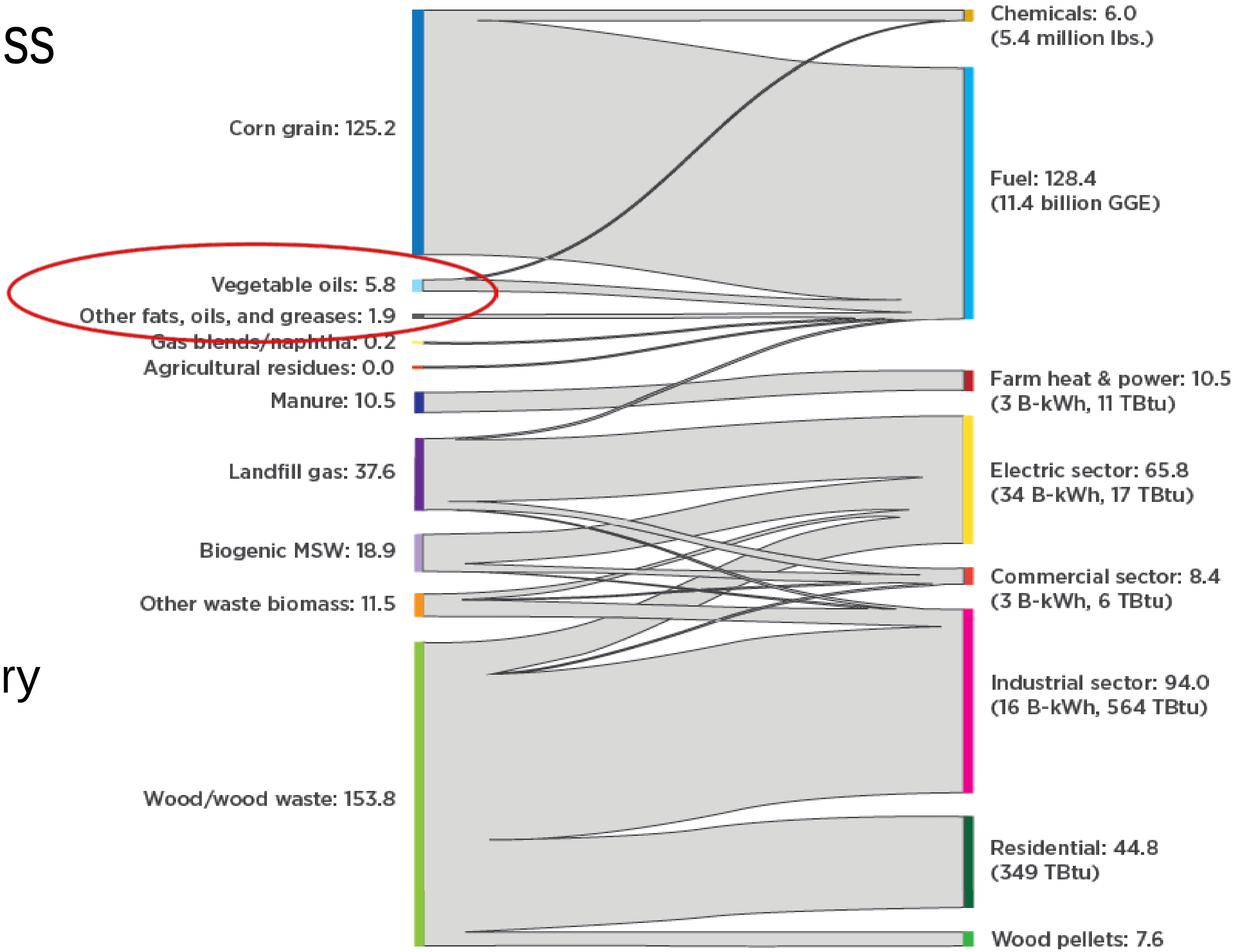
Outline

- 2016 Billion-ton Report
  - Current uses
  - Algae
  - Land area potentially available
- Eucalyptus
- Summary

How Biomass is Currently Used

1 million "bioenergy equivalent" dry ton per day (2014)

Figure 2.5 | Sankey diagram of feedstock, sector consumption, and final product distribution, in million dry tons per year[14]

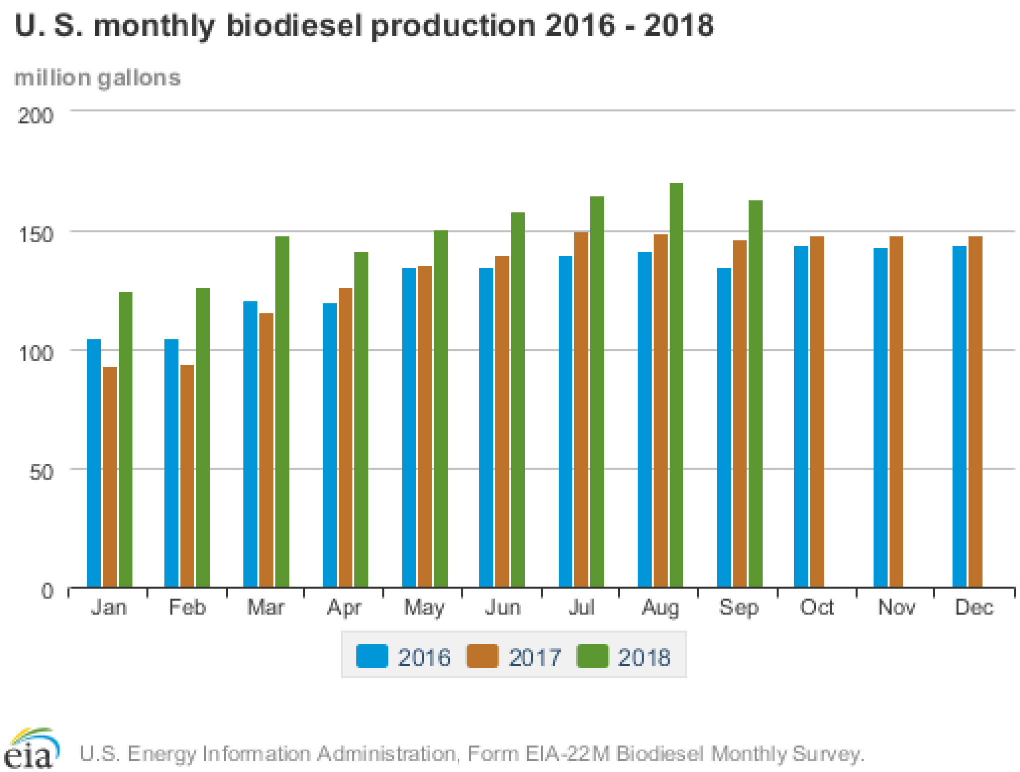


Note: Biomass resources are shown on the left and their allocations are shown on the right. The size of the flow is representative of the amount of biomass allocated to that end use. For this figure, contributions from landfill gas are represented as tons of biomass equivalent by applying a conversion factor of 0.2665 lb/scf.

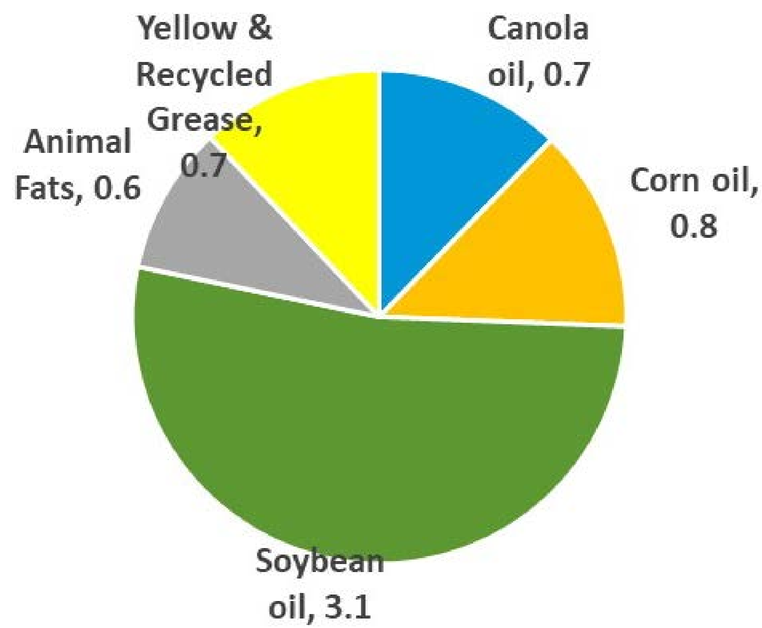
OAK RIDGE National Laboratory

U.S. Biodiesel production, 2016-2018

1.6 billion gallons biodiesel in 2017



5.9 million tons of inputs in 2017



U.S. EIA Monthly Biodiesel Production Report, November 30th 2018, Table 3. Excludes minor fractions of cottonseed oil, palm oil, algae, and other categories.

Oak Ridge National Laboratory

Additional animal fats: 3x the conversion efficiency, but market prices 5-10x higher

Table 5.7 | Animal Fat Production 2012 to 2014 and Current Prices

Fat	2012	2013	2014	Average	2012	2013	2014	Average
	Million tons				$/ton			
Inedible tallow	1.60	1.59	1.50	1.56	874	805	727	802
Edible tallow	0.90	0.89	0.81	0.87	969	858	785	871
Yellow grease/ used cooking oil	0.97	0.99	1.03	1.00	715	660	555	643
White grease	0.65	0.65	0.64	0.65				
Choice white grease	0.58	0.58	0.57	0.58	840	767	645	751
Poultry fat	0.52	0.53	0.54	0.53	784	719	599	701
Lard	0.07	0.07	0.07	0.07	1,160	981	870	1,004
Total	**5.30**	**5.30**	**5.16**	**5.25**				

Source: Data from EIA (2015b).

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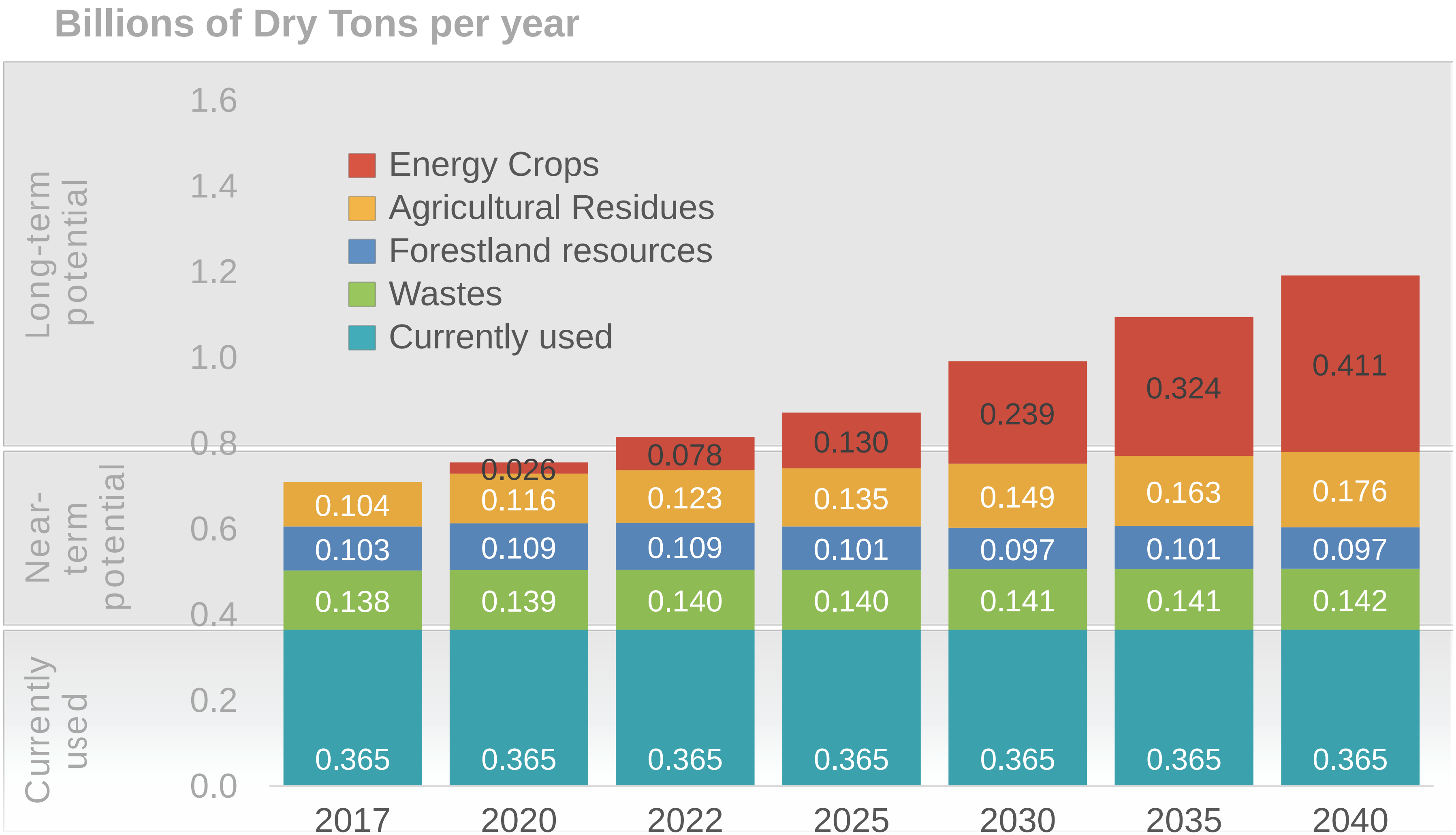
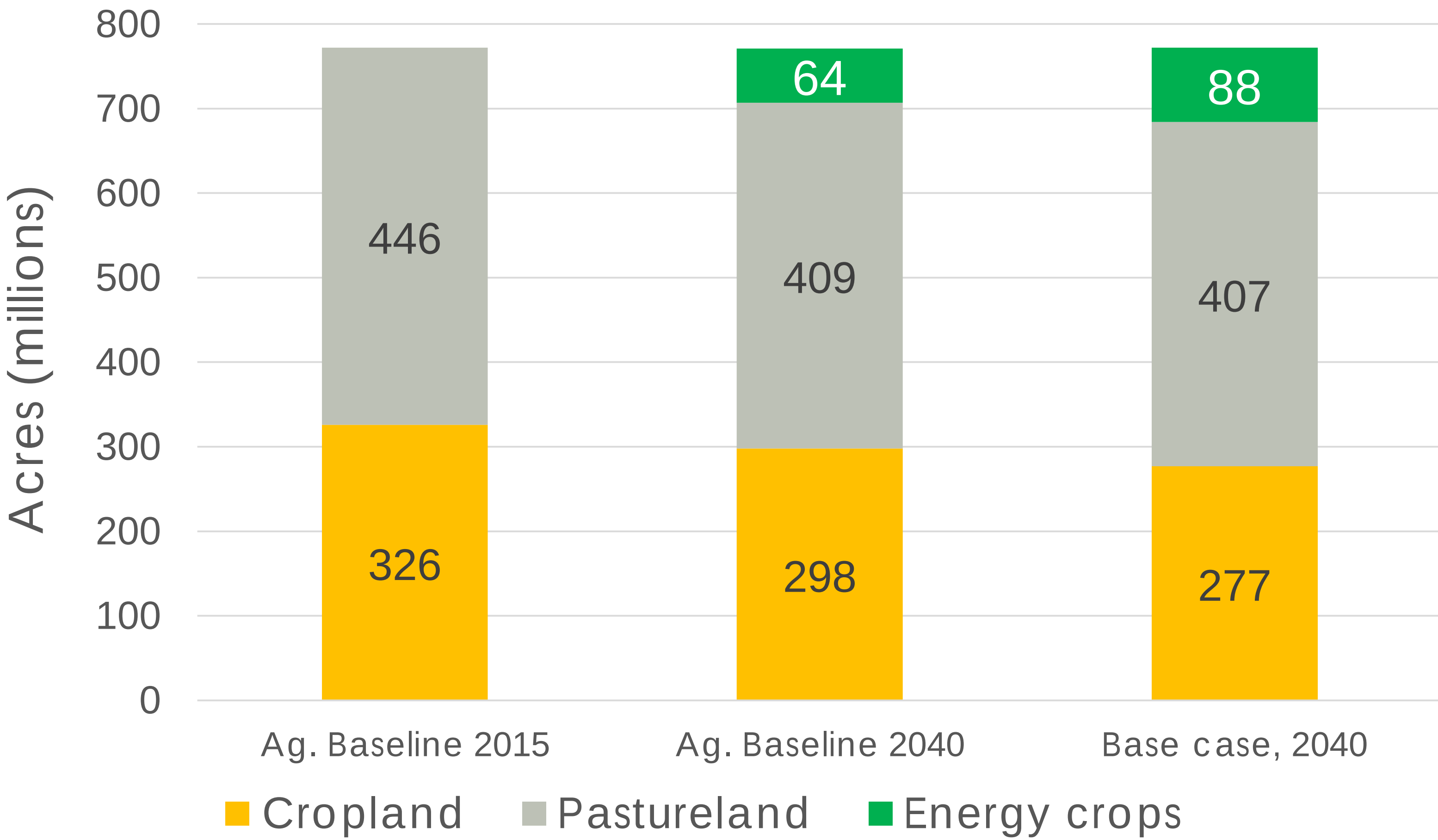
Current and Potential, Base Case at $60/dt



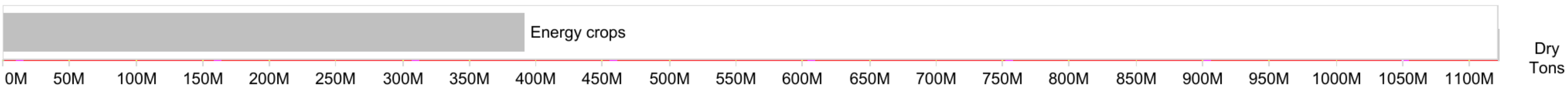
Land allocation, 2016 Billion-ton report Volume 2



Source: Kline et al. 2016 Billion-Ton Report, Volume 2, Chapter 3: Land Allocation and Management: Understanding Land-Use Change Implications under BT16 Scenarios. doi: 10.2172/1338837.

64 million acres of energy crops, base-case, 2040, $60/dt

2040 Agricultural Resources, $60/dt per dry ton or less, roadside.
Agriculture: 1% yield increase (BC1).



Year	Price	Color by
2040	$60/dt	Density (annual dt/sq mile)

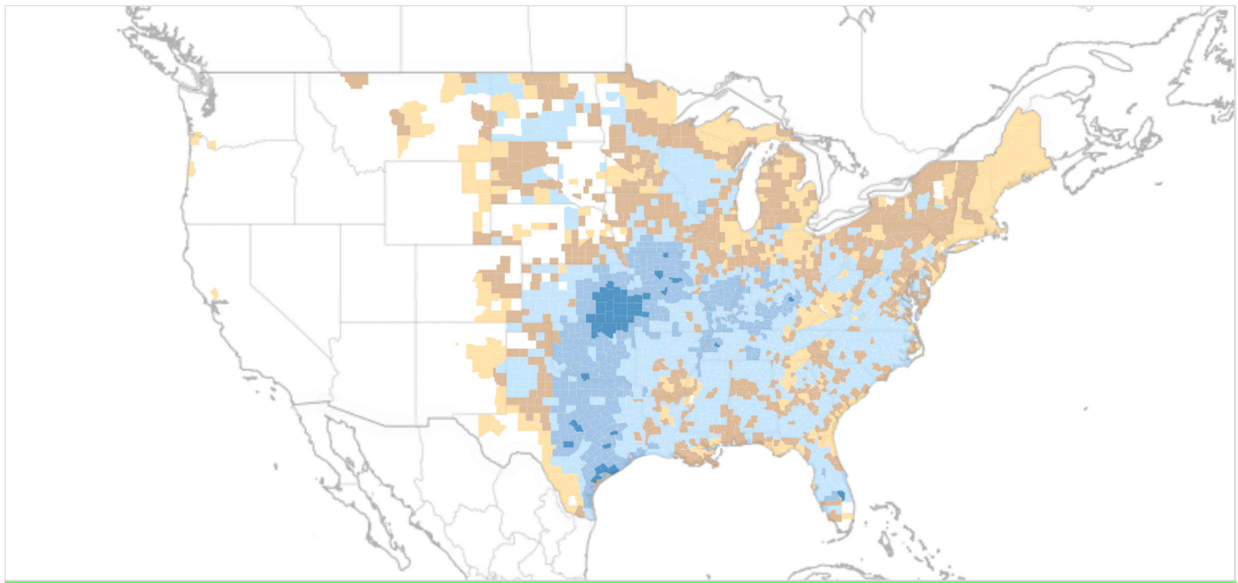
Agriculture Scenario
1% yield increase (BC1)

Feedstocks
Multiple values

- Less than 10 dt/SqMile
- 10-100 dt/SqMile
- 100-500 dt/SqMile
- 500-1,000 dt/SqMile
- Greater than 1,000 dt/SqMile

800,000 dt over a 50 mile radius circle=102 dt/sq mile.

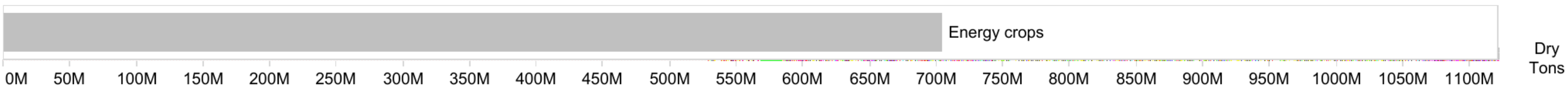
Density (annual dt/sq mile) Potential Agriculture Biomass



Please cite as: U.S. Department of Energy. 2016. 2016 Billion-Ton Report: Advancing Domestic Resources for a Thriving Bioeconomy, Volume 1: Economic Availability of Feedstocks. M. H. Langholtz, B. J. Stokes, and L. M. Eaton (Leads), ORNL/TM-2016/160. Oak Ridge National Laboratory, Oak Ridge, TN. 448p. doi: 10.2172/1271651.

88 million acres of energy crops, high-yield, 2040, $60/dt

2040 Agricultural Resources, $60/dt per dry ton or less, roadside.
Agriculture: 3% yield increase.



Year
2040

Price
$60/dt

Color by
Density (annual dt/sq mile)

Agriculture Scenario
3% yield increase

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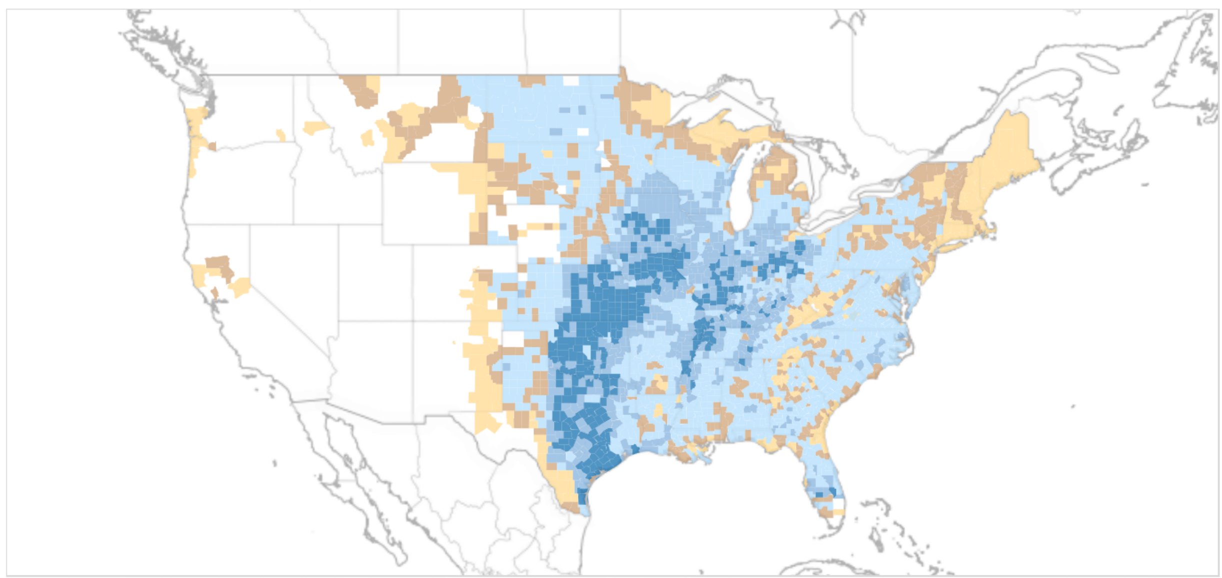

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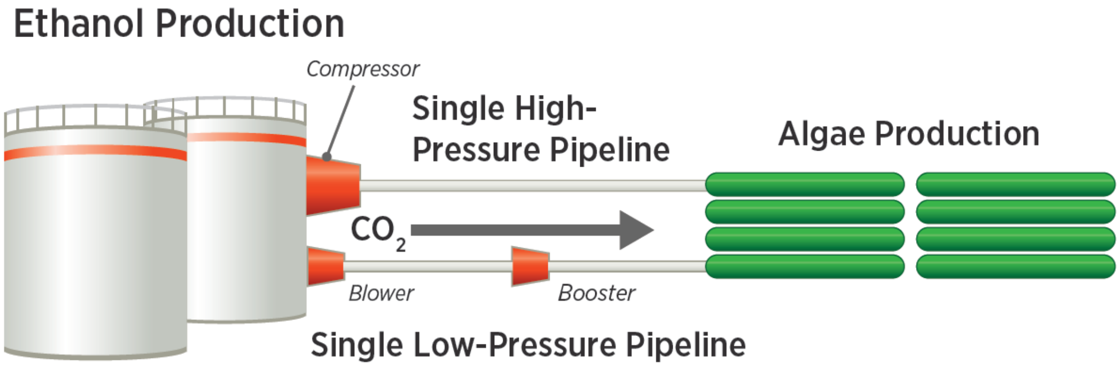
BT16 Chapter 6: Economic availability of biomass from microalgae

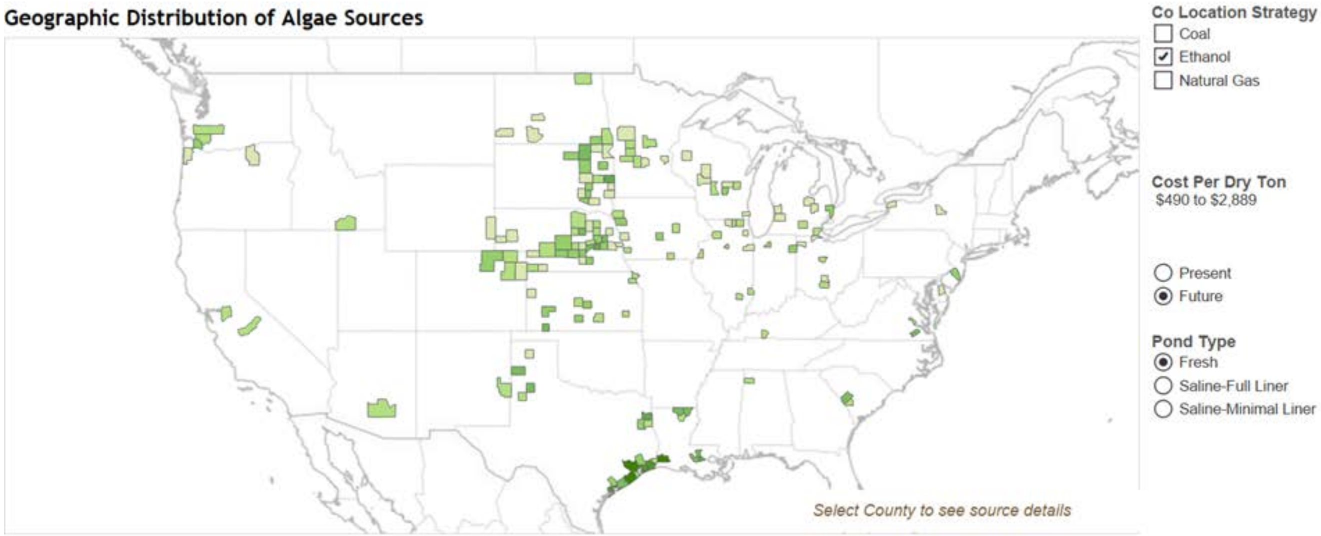
Cost effective distance for CO_2 transport

CO_2 source	Cost-effective distance	
	Current productivity	Future productivity
Coal-fired EGU	3–11 miles	<5 miles
Natural gas-fired EGU	<1 mile	<0.5 miles
Ethanol plant	>20 miles	>20 miles

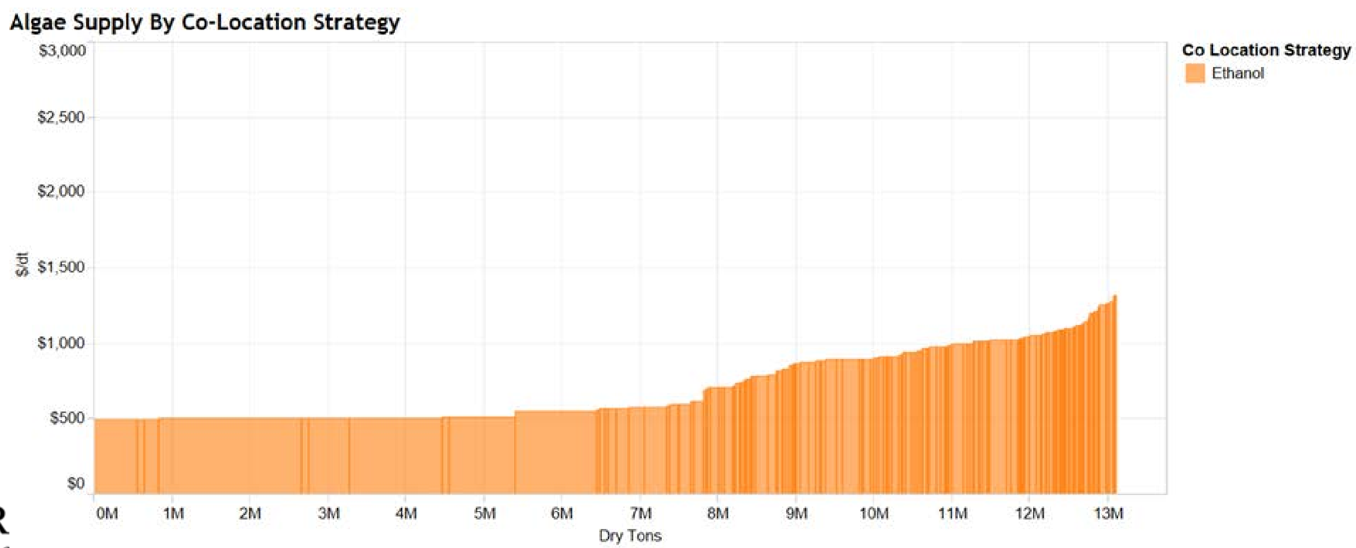
Engineering design based on CO_2 purity



Example result: **future productivity, freshwater, minimally lined ponds, CO_2 from ethanol plants**



Marginal minimum selling price vs supply



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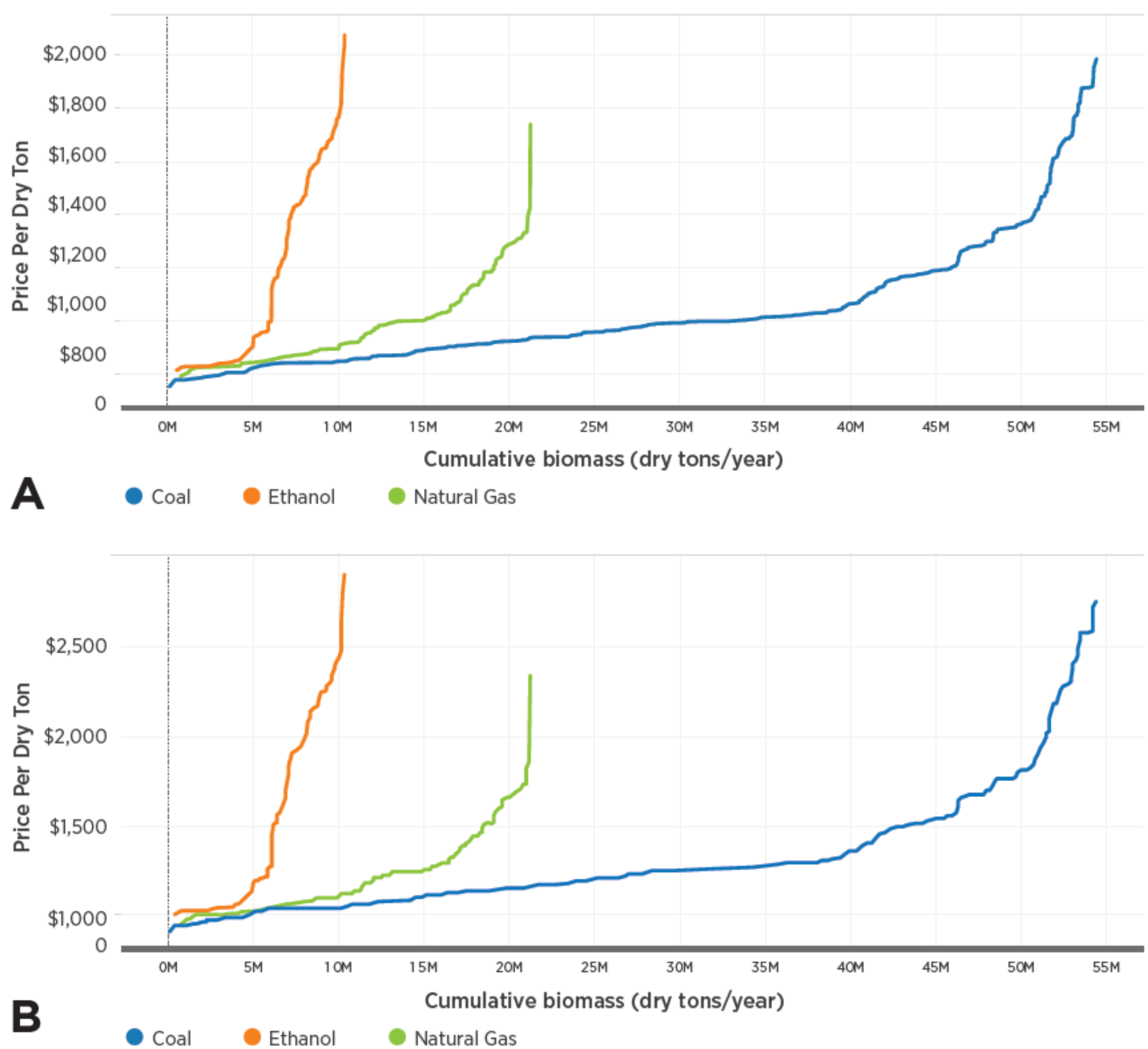
Algae supply curves

Figure 7.31 | Minimum selling price per dry ton vs. cumulative total biomass for each co-location strategy using *Nannochloropsis salina* at present productivities for *(A)* minimally lined ponds and *(B)* fully lined ponds.[7]



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Summary of algae potential co-located with CO_2 sources

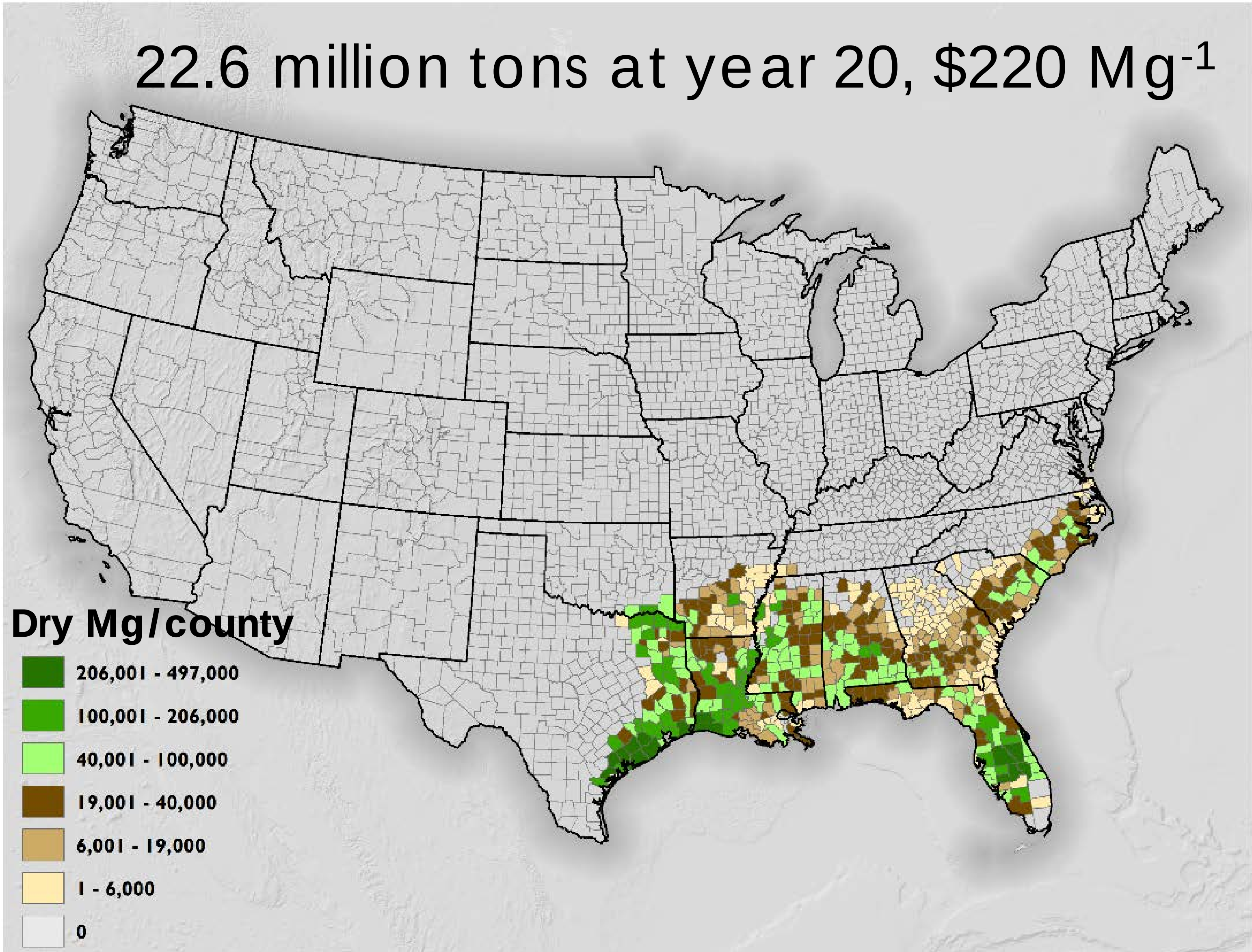
Table ES.2 | Summary of Biomass Potential from Co-Location (million tons/year); *Chlorella sorokiniana* Is the Example Algae Strain Grown in Freshwater Media, and *Nannochloropsis salina* Is the Example Algae Strain Grown in Saline Media[13]

Scenario	Ethanol plant	Coal GU	Natural gas EGU	Total[a]	Range of minimum prices per dry ton[b]
Present productivities, freshwater media	12	19	15	<46	\$719–\$2,030
Present productivities, saline media	10	54	21	<86	\$755–\$2,889
Future productivities, freshwater media	13	10	0	<23	\$490–\$1,327
Future productivities, saline media	11	12	0	<24	\$540–\$2,074

[a] Totals are uncertain, because analyses of different co-location sources were run independently; therefore, some production facilities that are close to multiple CO_2 sources may be double-counted.

[b] For *Nannochloropsis salina*, the range of minimum prices includes both minimally lined ponds and lined ponds. For *Chlorella sorokiniana*, the range of minimum prices includes only minimally lined ponds.

The potential for *Eucalyptus* spp. production for jet fuel additives in the U.S. (in preparation)



Conclusions

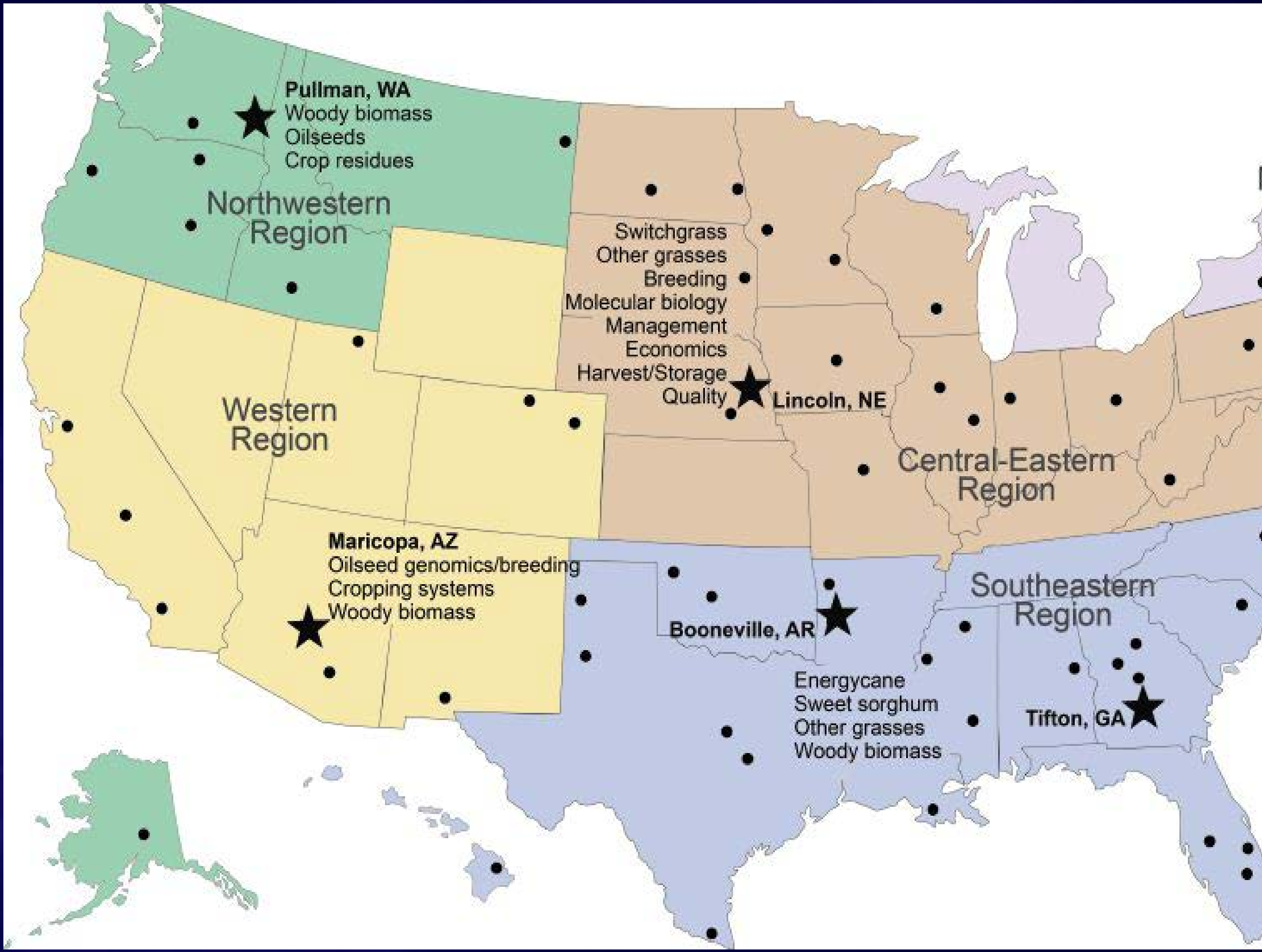
- FOGs contribute to current biodiesel production.
- Oilseed production can increase, subject to price signals (e.g., \$330/ton for soy).
- Algae offers high yields per area/time and co-benefits of CO2 and nutrient waste recycling, but at higher production costs. (e.g. >\$500/ton algae)
- Innovative silvicultural systems can produce terpenes from eucalyptus (e.g., \$100-\$200/ton biomass)

OAK RIDGE National Laboratory

Lipid-based feedstocks and Biorefining Research

Dr. Gene Lester
National Program Leader, Bioprocessing
USDA-Agricultural Research Service

USDA Biomass Research Centers Coordination Hubs and Agency Leadership



‘Liberty’ switchgrass

Grown on marginal, non-food cropping land in central Wisconsin **Liberty** processed into bioethanol, produced 4,960 liters per hectare (**530 gal/ac**). **Corn** grown on nearby high-quality food cropping land (yielding an above-average 200 bu/acre) produced 5,300 liters per hectare (**566 gal/ac**) of bioethanol

Southeastern Region

Grown in marginal lands, **Napier grass** grown in Georgia for **bioethanol** produced 10,300 liters per hectare (**1,101 gal/ac**). Georgia **corn** produced 4,640 liters per hectare (**496 gal/ac**)

Napier grass alongside corn, it's a "pull" crop, attracting insects away from corn while improving soil fertility and preventing erosion.

Napier grass doubles bioethanol yield/ acre compared to corn grain

Western Region

No-till corn
Miscanthus
Prairiegrass
Canola
Poplar-tree
sugarcane

Northwestern Region

Biomass Crops

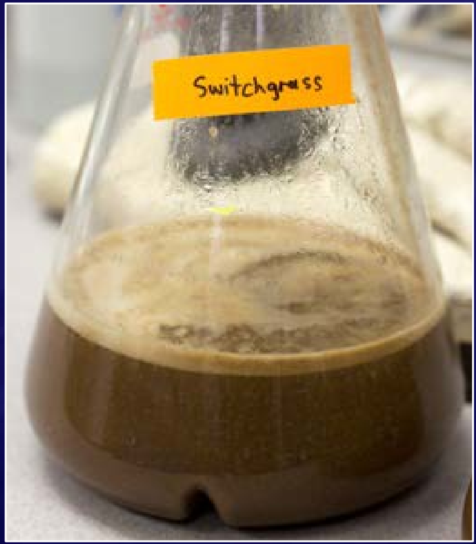
Industrial Oilseeds


USDA-Agricultural Research Service
ARS Regional Research Centers
Western Regional Research Center
Albany, California
Eastern Regional Research Center
Wyndmoor, Pennsylvania
National Center for Agricultural
Utilization Research
Peoria, Illinois
Southern Regional Research Center
New Orleans, Louisiana

Two Ton Per Day Demonstration Unit.

Akwasi Boateng, Charles Mullen, Yaseen Elkasabi

Microbial Oils: Drop-in Fuel oils, Chemicals & Personal Care Products



- Industrial robust yeast

Non-antibiotics Improve Biorefining Productivity

Bacterial infections reduce biorefing productivity.

ARS scientists have developed non-antibiotics (enzymatic and viruses) to destroy problematic bacteria, and eliminate the need to add costly antibiotics.

Novel oily yeast strain makes three times the oil as other strains

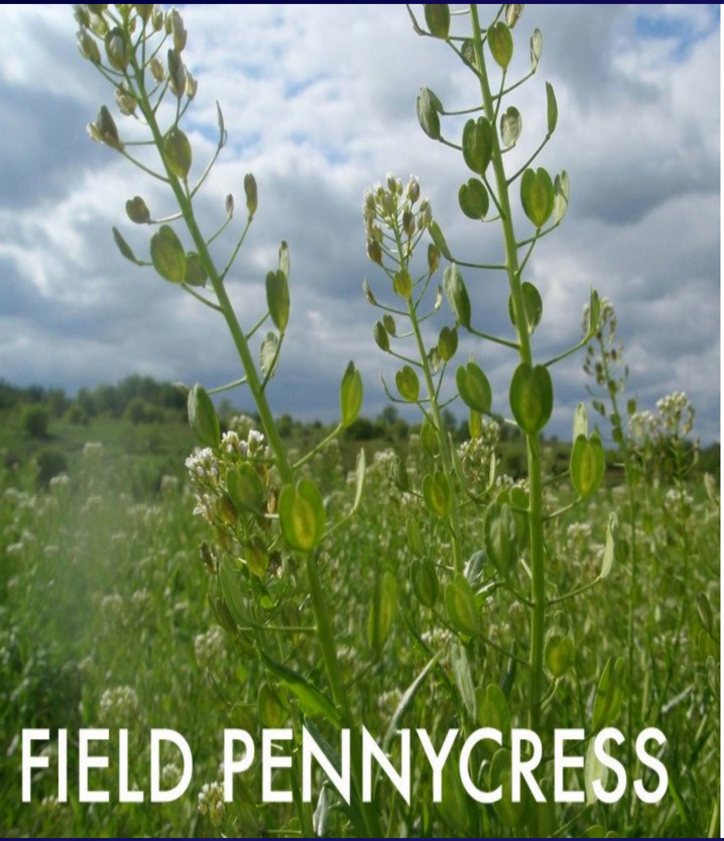
USDA

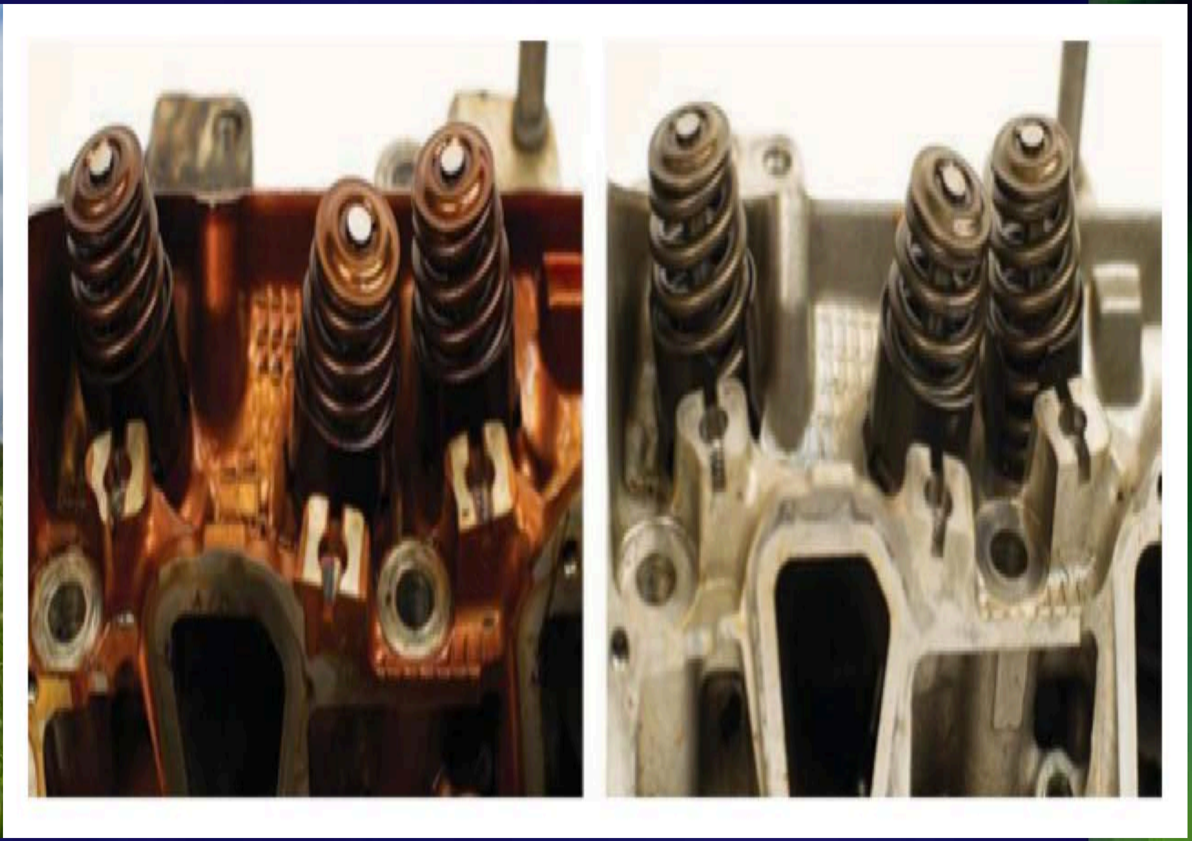
Switchgrass

ARS oily yeast

Supply 20% of U.S. Diesel

Discovery of Estolides from vegetable oil oleic acid





- Las Vegas taxi engine test from a 150,000 mile field trial; estolide motor oil had less varnish, ran cooler and gave greater mileage not attainable with petroleum-based products.

Collaborating with ARS

ARS biorefining is unique because:

- Plant production and Conversion Researchers are integrated in a single agency.
- Biomass production is spread across USA and includes unique genetic material diversifying farming incomes.
- Conversion research includes bio-jet, biodiesel, biochemical, microbial, and thermal conversion routes.
- ARS has the world's collection of microbial bio-conversion organisms.
- Stakeholders include current agricultural producers, processors and bio-product manufactures .
- Complete range of bio-products including those related to feed and food applications.
- USDA BioPreferred® label program offers bio-product companies a way to successfully enter stable, new markets.

Feedstock Viability and Potential Economic Impacts

Project 01

Lead investigators: Tim Rials and Burton C. English
Project manager: Nate Brown

December 5th
Washington, DC

ASCENT
AVIATION SUSTAINABILITY CENTER

Problem / Solution

- **Problem – National Feedstock Analysis**
  - Develop costs of production for the feedstock of interest
  - Economic Evaluation of the feedstock
    - Allow production to compete with existing land uses (POLicY Analysis SYStem (POLYSYS)), national model with county level supply regions
    - Outputs include land use change, change in realized net returns, change in commodity prices, feedstock supply curve,
  - Select a biorefinery type and size (ASCENT Technologies preferred) and allocate CPEX and OPEX to IMPLAN sectors Link POLYSYS output to an Input-output model (IMpact analysis for PLANning model (IMPLAN)) using Analysis By Parts (ABP)
  - Impacts evaluated include:
    - Investment
      - Feedstock Establishment
      - Preprocessing Facility
      - Facility
    - Operating
      - Feedstock maintenance
      - Feedstock Harvest
      - Feedstock storage
      - Feedstock transportation -- ???
      - Preprocessing operating costs
      - Preprocessed transportation costs
      - Biorefinery operating costs
    - Other Cost
      - Employment Compensation and proprietors income
      - Land use change losses
      - RIN receipts (transfer from one region to another)

Solution (National Analysis)

POLYSYS

- USDA Baseline, Pennycress Budget, and Assumed Pennycress Price Paid
- Two Solutions -- Without and With Pennycress

IMPLAN Input

- POLYSYS Output – Pennycress Supply and Location Plus Changes in Direct Land Use, Crop Prices, and Net Returns
- IMPLAN Input – Pennycress Value, Number of Biorefineries, Plus Changes in Proprietor Income (as a result of price received for the crop and for the fuel (RIN)), as a Result of Land Use Change, Construction and Annual Operating, and Annual Cost of Establishing Pennycress

IMPLAN

- Input-Output 2013 National Model with Local Purchase Coefficients
- Analyze Changes as Impacts using Analysis By Parts When Needed

Employment and Economic Activity Metrics

- Annual Operations of Agricultural Pennycress
- Direct Land Use Change
- Change in Commodity Prices
- Annual Operation Impacts of Oil Extraction and Biorefineries
- Proprietary Income Impacts Resulting at Both Farm and Biorefinery

- Investments in Oil Extraction and BioRefinery Facilities

Sample Results

Breakeven Cost

Breakeven Price for Selected Yield		
Yield (lbs.)	Variable Cost ($/lbs.)	Total Specified Cost ($/lbs.)
450	$0.27	$0.35
600	$0.21	$0.26
750	$0.16	$0.21
900	$0.14	$0.17
1050	$0.12	$0.15
1200	$0.10	$0.13
1350	$0.09	$0.12
1500	$0.08	$0.10
1650	$0.07	$0.09

Breakeven Yield

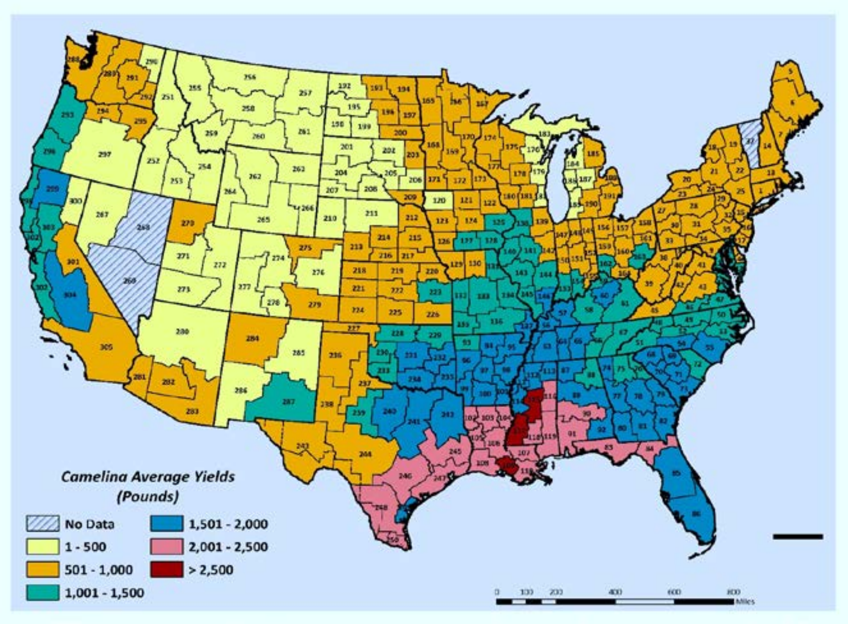
Breakeven Yield for Selected Price		
Price ($/lbs.)	Variable Cost (lbs./acre)	Total Specified Cost (lbs./acre)
$0.18	688	873
$0.20	604	766
$0.23	538	682
$0.25	485	615
$0.28	442	560
$0.30	405	514
$0.33	375	475
$0.35	348	441
$0.38	325	412

Other Basic Assumptions

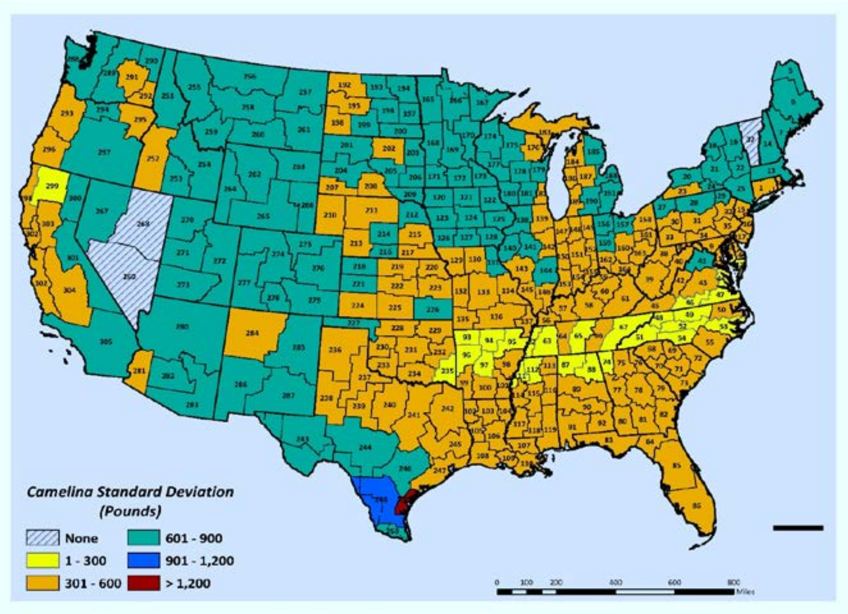
- Potential acreage restricted
  - Maximum cover crop acreage = 0.5*minimum soy/corn acreage in county
- Camelina Price increases from $0.00 to $0.50/pound
- Modeled as a ½ acre corn/camelina and ½ acre soybeans rotation
- Soybeans took a 6.5% yield reduction due to harvest time of camelina.

Yields Generated By EPIC

Camelina as a Cover Crop -- Yield

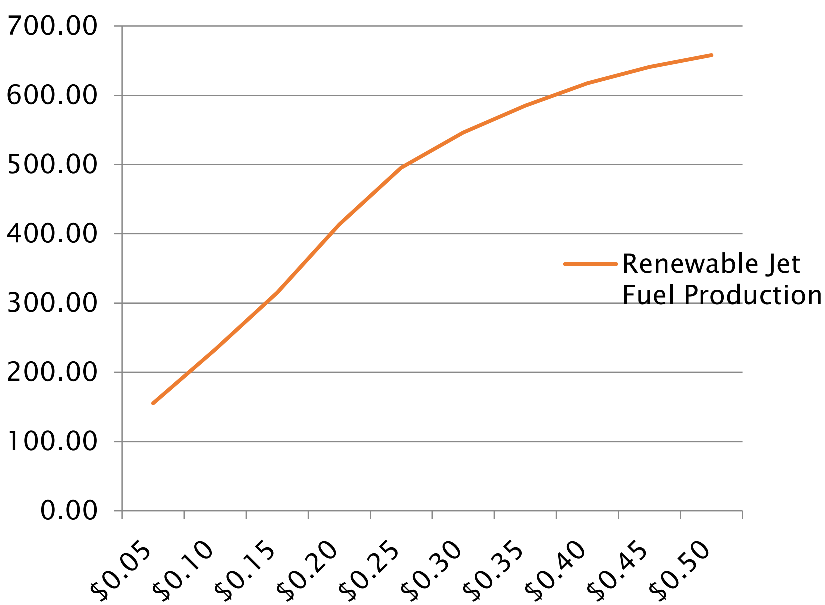


Standard Deviation

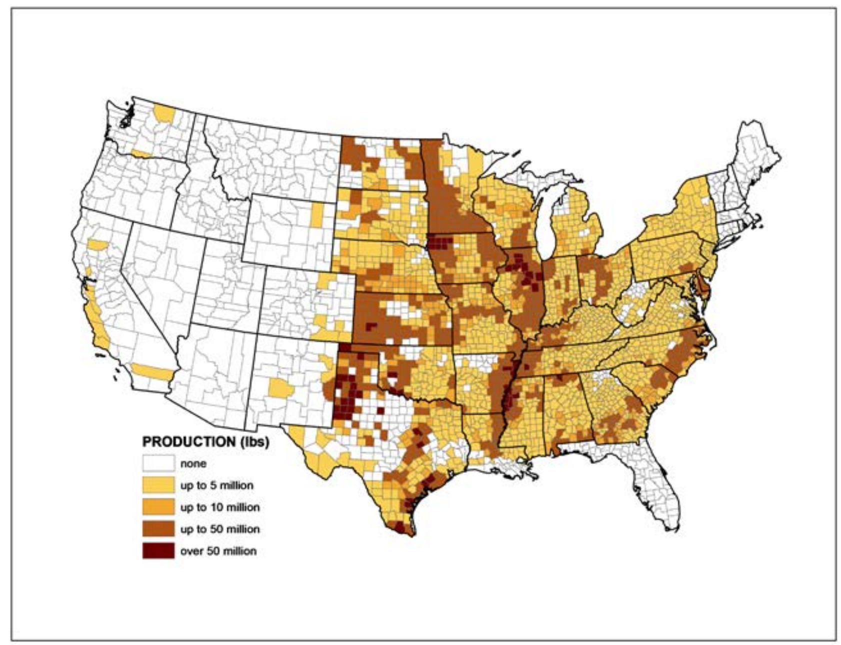


Sample Results – POLYSYS - Camelina

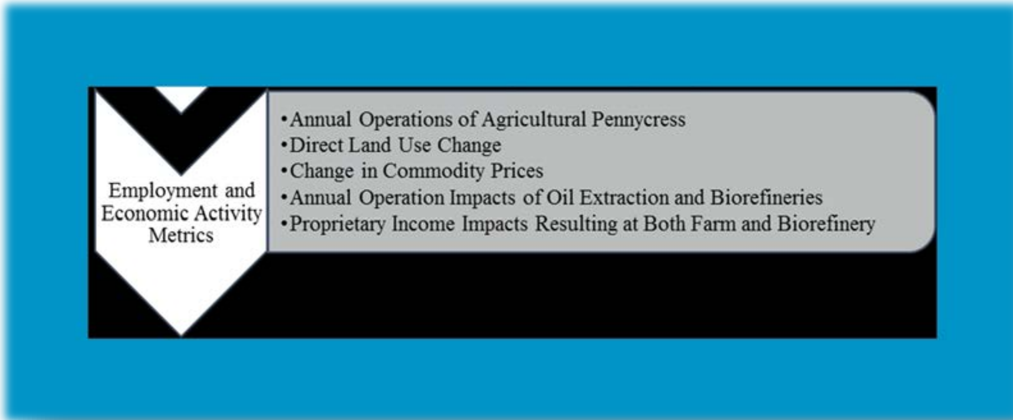
Renewable Jet Fuel Supply (million gallons)



Location



Sample Results – IMPLAN - Pennycress



Impacts as a result to changes in the Agricultural Sector

Impact Type	Employ-ment	Labor Income	Value Added	Economic Activity
Direct	*0*	*4,143.04*	*4,511.51*	*5,045.53*
Indirect	3,999	260.45	430.69	859.58
Induced	37,806	1,967.65	3,457.02	6,273.67
Total	***41,807***	***6,371.14***	***8,399.22***	***12,178.78***

Sample Results – IMPLAN - Pennycress

ASCENT
AVIATION SUSTAINABILITY CENTER

Impacts as a result to changes in the Oil Extraction and Conversion Sector (Million $)

Type of Effect	Employment	Labor Income	Value Added	Output
	Jobs	Million $		
Direct	6,735	$485	$575	$1,151
Indirect	3,450	$243	$403	$859
Induced	6,364	$332	$584	$1,059
Total	16,542	$1,060	$1,562	$3,070

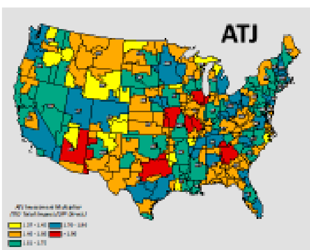
Estimated Total Economic Impacts for the Oil to Jet Fuel Pathway Using Pennycress as a Feedstock and Hydro-Processing as the Conversion

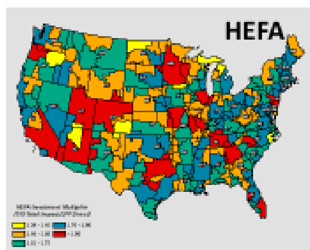
Effect Type	Employment	Labor Income	Value Added	Output
	Jobs	Million $		
Direct	3,442	$6,020	$6,651	$7,754
Indirect	6,723	$470	$845	$1,671
Induced	55,658	$2,897	$5,089	$9,236
Total	65,823	$9,386	$12,586	$18,661

Sample Results – ASCENT Biorefineries

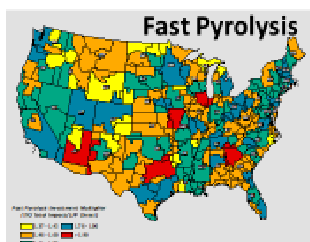
Investment Impacts

Economic Impact Multipliers from Investment (Total Industry Output) for Alternative ASCENT Conversion Technologies



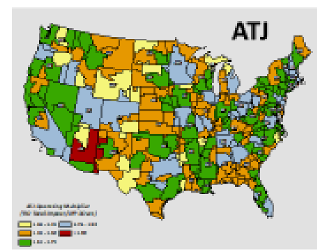


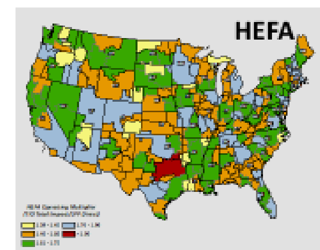
Economic Impacts from investing in a single facility within a Bureau of Economic Analysis region (BEA)
Projections of changes in economic activity as a result of this investment within a BEA region through multiplier effects are projected using Analysis by Parts (ABP) methodology with a U.S. IMPLAN model.



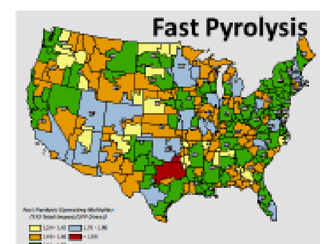
Operation Impacts

Annual Economic Impact Multipliers (TIO) Based on the Operation of Alternative ASCENT Conversion Technologies





Economic Impacts from the annual operation of a single facility within a Bureau of Economic Analysis region (BEA)
Projections of changes in economic activity as a result of annual operation expenditures within a BEA region through multiplier effects are projected using Analysis by Parts (ABP) methodology with a U.S. IMPLAN model.



We have also developed this information for land use change, Employment compensation, feedstock establishment, feedstock maintenance and harvest, transportation, feedstock storage,

How to use this resource

- Which stakeholders can use tool/resource
- How can those stakeholders engage/access tool or resource
  - Information on feedstock quantities is available in the BOX.
  - Information on costs of feedstock needs additional attention for stakeholder use. These costs vary depending on the supply chain
  - Impact factor maps and data behind them can be made available once a manual on how to combine these data is written and reviewed.
  - We are open to discussions, presentations, and other means of communicating our results
  - We can conduct special analyses to meet stakeholder needs
- Schedule/timeline/next steps
  - We will finish the Camelina and Carinota analyses this year pending funding.
  - We will complete the Southeast feedstock analysis for oilseed potential in Tennessee and softwood logging residue potential in Alabama. The logging residue analysis utilizes information from an ongoing DOE project
  - A cash flow analysis and TEA for an ASCENT crushing facility will be available in approximately 6 months

CAAFI Annual Meeting Washington DC 2018

NORTH AMERICAN PROCESSING TREND

- Expectation is for additional Washington State Refiners to announce co-processing and renewable diesel conversion projects such as the US Oil announcement across the year. Multiple projects are believed to be well in motion with completion dates and notably first feedstock movements into Cherry Point starting in the beginning of this year.

- Global feedstock markets will go through unprecedented changes in the coming 5 years as a result of new locational demand into Petroleum Refineries starting in Europe and next the US/Canada.

- The increase in low carbon fuel markets/mandates will drive demand for low "CI", GHG feedstocks for biodiesel renewable diesel, and co-processing

- Increasingly the largest petroleum refiners globally will become direct or in-direct buyers of these feedstocks driven by evolving compliance and processing strategies

PROCESSING OF LIQUID BIOMASS FEEDSTOCKS

Process technology changes will dictate forward demand of these feedstocks. Trend underway is pointing towards existing petroleum refinery gates as the future location of demand. Due to the nature of the compliance burden this pivot will be a logical strategy for most refiners and will push processing from biodiesel – transesterification towards more traditional hydrocracking technology.

Biodiesel → Renewable Diesel and Co-Processing

2005 2020 2035

WASHINGTON PETROLEUM REFINERIES

- **Challenging Refining Market:** Across the past 3-4 years after the short lived relief that $100/bbl Canadian crude oil actually brought, Washington State refiners have been faced to resume hard fought attempts at even razor thin if not negative margin operations.
  - Older WA Refineries matched with increasingly uncertain market conditions making returns on upgrades precarious over the years
  - New, efficient, sophisticated Canadian refineries pumping refined products into Puget Sound via Vancouver to compete into the Pacific Rim.
  - Larger Pacific Rim refiners like Reliance and lower shipping rates have added further pressure on USWC, PNW and even Alaskan refined products markets that once paid steep premiums and were WA state refiners captive markets.

WASHINGTON PETROLEUM REFINERIES

Refinery	Current Owner	Past Owners	Year Constructed	Major Products[2]	Current Capacity
Ferndale	Phillips 66	ConocoPhillips, Tosco, BP, Mobil, General Petroleum	1954	Gasoline, diesel oil, jet fuel, liquid petroleum, residual fuel oil	101,000
Anacortes	Tesoro	Shell Oil	1955	Gasoline, diesel oil, turbine & jet fuel, liquid petroleum gas, residual fuel oil	120,000
Anacortes	Shell Oil	Equilon Enterprises and Texaco	1957	Gasoline, diesel oil, jet fuel, propane, coke, sulfur	145,000
US Oil	US Oil		1957	Gasoline, diesel oil, jet fuel, marine fuel, gas oils, emulsified & road asphalt	40,700
Cherry Point	BP	ARCO	1971	Gasoline, diesel oil, jet fuel, calcinated coke	225,000
Total					631,700

Total operable atmospheric crude oil distillation capacity, barrels per calendar day as of 1 January 2015. Source:[3]

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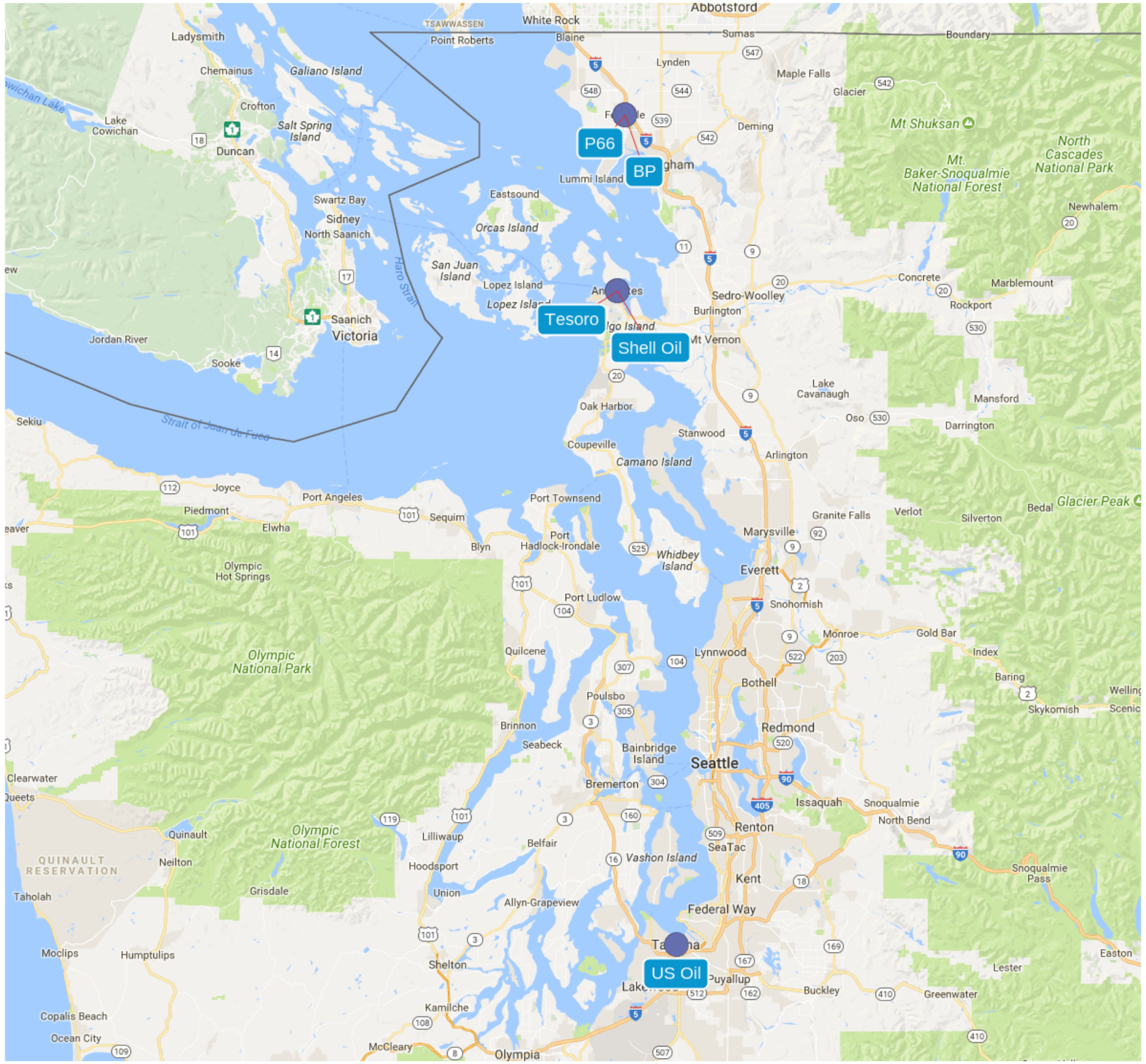
POTENTIAL WASHINGTON REFINERY DEMAND:

	Refinery Capacity Daily	5% Liquid Biomass Daily Feedstock Demand ?
BP Cherry Point	235k US BBLs 9.87 m Gals	11,750 US BBLs 494 k Gals
Shell Anacortes	145 k US BBLs 6.09 m Gals	7,250 US BBLs 305 k Gals
Tesoro Anacortes	120 k US BBLs 5.04 m Gals	6,000 US BBLs 252 k Gals
P66 Ferndale	101 k US BBLS 4.242 m Gals	5,050 US BBLs 217 k Gals
US Oil Tacoma	41 k BBLs 1.722 m Gals	2,050 US BBLs 86,100 Gals



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CALIFORNIA REFINERIES

Demand at 1%:	Daily	Monthly	Yearly
US BBLS	19,906	597,180	7.16m
Gallons	836k	25.08m	300m
MTs	2,786	83,580	1,002,960
Pounds	6.14m	184.2m	2.21b

- Without pretreatment available feedstocks would be RBD Soybean Oil, RBD Canola Oil and Tech Tallow
- Without question feedstock processing infrastructure will need to be built for pretreatment/esterification/refining of crude feedstock into a specification
- The lowest CI feedstocks (aka GHG) will ne overwhelmed thus blended ‘cocktails’ inclusive of VVO will likely become the path of least resistance for the market

GLOBAL MARKET OUTLOOK LOW CI FEEDSTOCKS

- Developing nations have tremendous potential for feedstock output in the coming years, but would require not only tremendous capital investment to build out rendering and collection facilities, but also consumption behaviors would have to change in order to provide the processors with the raw material needed to produce the end product.

- Used Cooking Oil growth has the most likely and immediate growth potential due to a lower entry barrier.

- A transition from biodiesel to renewable diesel will come with growing pains. Low CI sellers are hesitant to commit a large percentage of production into the renewable industry due to uncertainty in policy. Additionally, tight specs create a limited pool from which to draw product. While the US produces approximately 5 billion total pounds of tallow per year, only a limited amount meets stringent specs which are commonly referred to as “Neste spec.” Neste spec is max 50 ppm metal content, most tallow has a spec of > 200 ppm.

GLOBAL MARKET OUTLOOK LOW CI FEEDSTOCKS

- Larger refiners will likely have to seek out multiple suppliers in order to meet their feedstock needs, this becomes more true as the size of the demand increases. Some large tallow producers have been hesitant to commit a large percentage of their book to the renewable sector because of government policy uncertainty. This becomes less of an issue with large refiners, however, because of the lessened credit risk, i.e. a biodiesel plant purely reliant on biodiesel and co product revenues is a greater credit risk in uncertainty than a large refiner that has multiple revenue streams.

- Fat refinement, as seen from Jacob Stern in the US and West Coast Reduction in Canada, is likely going to be employed. Both Stern and WCR offer aggregation and filtration services to produce a refiner spec material.

- For individual plants feedstock pretreatment costs vary, but average around $0.10/gal. This equates to roughly $0.013/lb of feedstock.

- It is extremely important to note that quality is variable, each rendering plant has its own unique footprint. Buyers with the liberal spec requirements or pre-treatment capabilities will be able to secure the most feedstock at the best price.

INCREASED DEMAND OF LIQUID BIOMASS FEEDSTOCKS WILL CONTINUE AS GREATER CAPACITY AND CAPABILITY IS CREATED TO PROCESS THEM

- Strong federal and state/provincial mandates across North America are required for lower carbon transportation fuels.
- Increasingly and based on a number of logical reasons driving these decisions major refiners are presently reviewing their refinery platforms to understand how best to upgrade, retro-fit and/or convert existing infrastructure into renewable diesel and /or co-processing capabilities.
- Trend is in motion: ENI, Total, Repsol, Andeavor, Kern Oil, US Oil
- BP is appearing recently as a potential front runner with projects online at their Cherry Point WA Refinery and recent rumors seemingly confirmed that they are developing a project at the St Croix Refinery with PE firm ArcLight.

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