Sustainable Aviation Fuels

State of the Industry

key trends for 2019 and beyond

Jim Lane, The Digest, March 2019

nuu
MEDIA

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ABLC

The Early Stage
The Bioeconomy's Venture Spotlight

BiofuelsDigest
The world's most widely read biofuels daily

BIOCHANNEL.TV

Biotechnology Commercializer

Nuucelerator


the bioeconomy
Uh, what is it, exactly?

The $2.7 trillion bioeconomy

As big as France, growing faster than China

The Bioeconomy Landscape

Applications

Fuels

Drop-in Red Rock Biofuels, Ensyn, AltAir Fuels

Novel REG, gevo, Green Plains, LanzaTech

Chemicals & Materials

Drop-in genomatica, verdezyne, INTREXON

Novel AMYRIS, GF Biochemicals, Bolt Threads

Nutrition

Drop-in Sapphire Energy, Fermentalg

Novel terravia, Impossible, evolva, CALYSTA

Platforms

Deployment

Infrastructure Green Plains Partners, protec fuel, Propel Fueling Change.

Software/Hardware AGERpoint, Edeniq, Amphora

Raw materials

Crop development nexsteppe, AGRISOMA

Precision Ag / Deployment Genera Energy, PrecisionHawk, Aerial Intelligence, PacificAg

Bioconversion & manufacturing

Biocatalytic CLARIANT, DuPont, provivi, greenlight Biosciences

Thermocatalytic GRI, uop A Honeywell Company

Building Blocks

Genetics & Genomics

Development Arzeda., Matrix Genetics, Caribou Biosciences

Enhancement zymergen, AMYRIS, ginkgobioworks

Systems & Devices

Agricultural Pivot Bio, ConsumerPhysics

Industrial ZeaChem, SwRI, ABPDU Advanced Biofuels Process Demonstration Unit

Partners

Deployment TESORO, vinmar, BASF We create chemistry

Investment Spruce Capital Partners LLC, Chemtex, WM Waste Management

The SAF Landscape

Producers

Fats. Oils, greases

Technology developers
ARA, JM, UOP A Honeywell Company

Project developers
Valero, REG, world energy, Darling, Phillips 66, Neste, eni

Alcohol-to-Jet

Technology developers
LanzaTech, LanzaJet, Vertimass, praj

Project developers
ArcelorMittal, gevo, BYOGY Renewables

Woods & other residues

Technology developers
GRI, Velocys, Licella, evolva

Project developers
Ensyn, Cellana, SG Preston, Fulcrum Bioenergy, Red Rock Biofuels, USA Bioenergy

Platforms

Finance & Deployment

Distributors
GoodFuels, SkyNRG, World Fuel Services, Shell, Air BP

Finance & Advocates
CAAFI, Faegre Baker Daniels, Stern Brothers, Munich RE, Global BioFuture Solutions, New Energy Risk

Raw materials

Feedstock development
provivi, hexas biomass, WM Waste Management, Agrisoma

Precision Ag / Deployment
Genera Energy, PrecisionHawk, Aerial Intelligence, PacificAg

Partners

Airlines
FedEx, KLM, virgin atlantic, United, Alaska, British Airways

Airports
Schiphol Amsterdam Airport, Port of Seattle, Stockholm Arlanda Airport, jetBlue, LAX Los Angeles World Airports, SFO

Building Blocks

Genetics & Genomics

Development
Inscripta, Arzeda., Matrix Genetics, greenlight Biosciences, Caribou Biosciences

Enhancement
zymergen, Amyris, ginkgobioworks

Systems & Devices

Agricultural
PrecisionHawk, Crop Enhancement, ConsumerPhysics, FarmersEdge

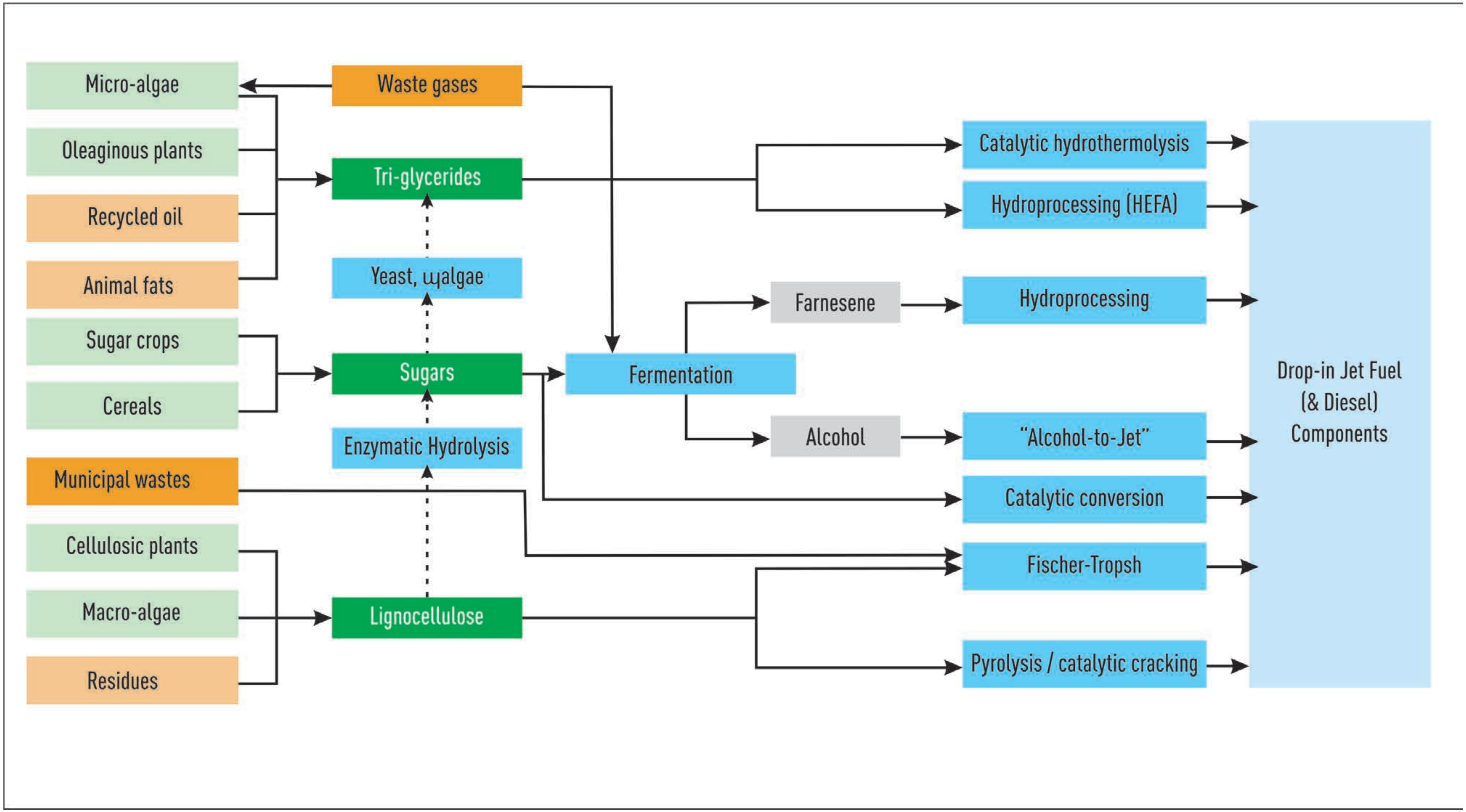
Industrial
NREL National Renewable Energy Laboratory, SwRI, ABPDU Advanced Biofuels Process Demonstration Unit, Bio Base Europe

Bioconversion & manufacturing

Biocatalytic
Clariant, novozymes, POET, DSM Advanced Biofuels, Fluid-Quip, Synata Bio

Thermocatalytic
Renmatix, Sweetwater Energy

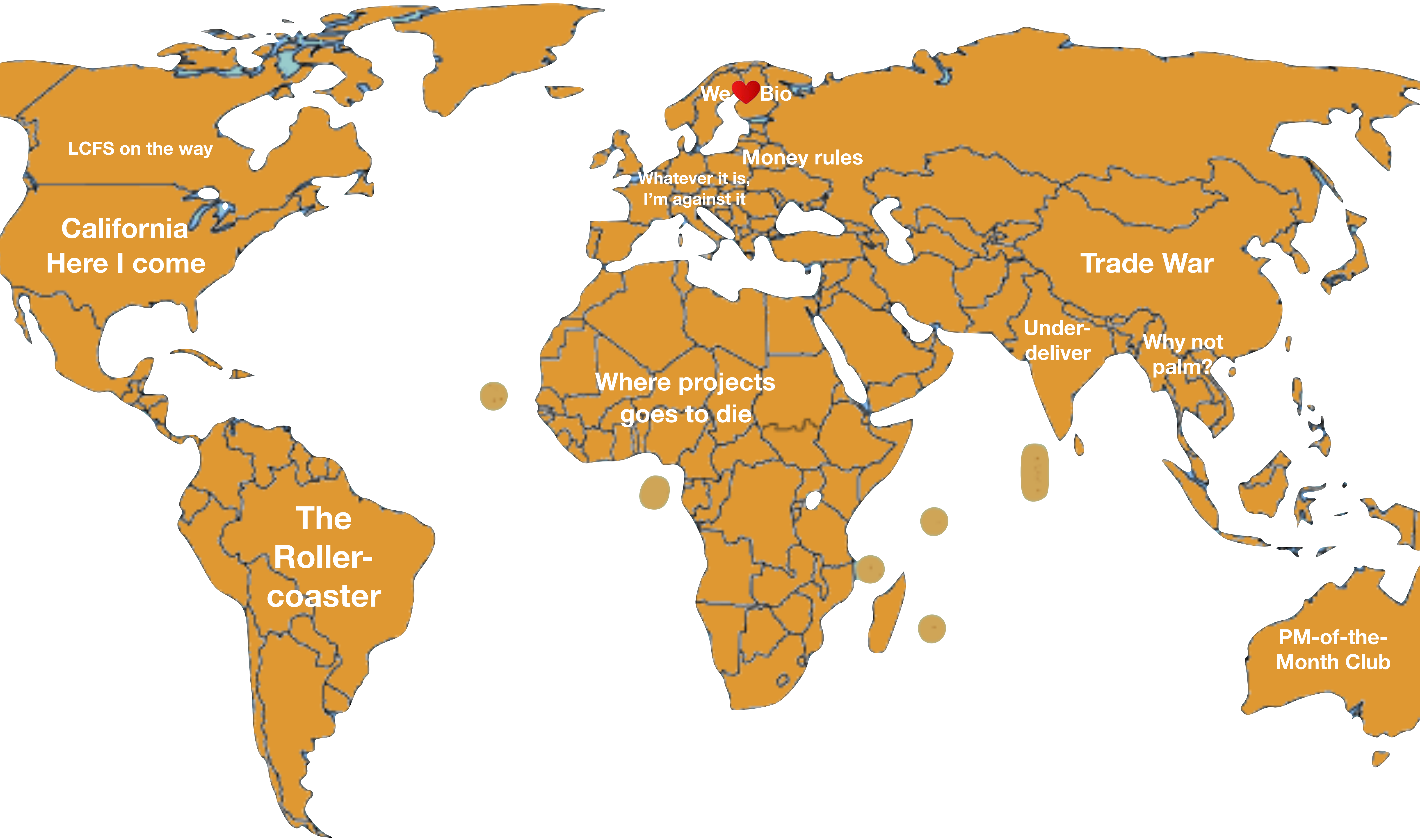
SAF: An array of pathways



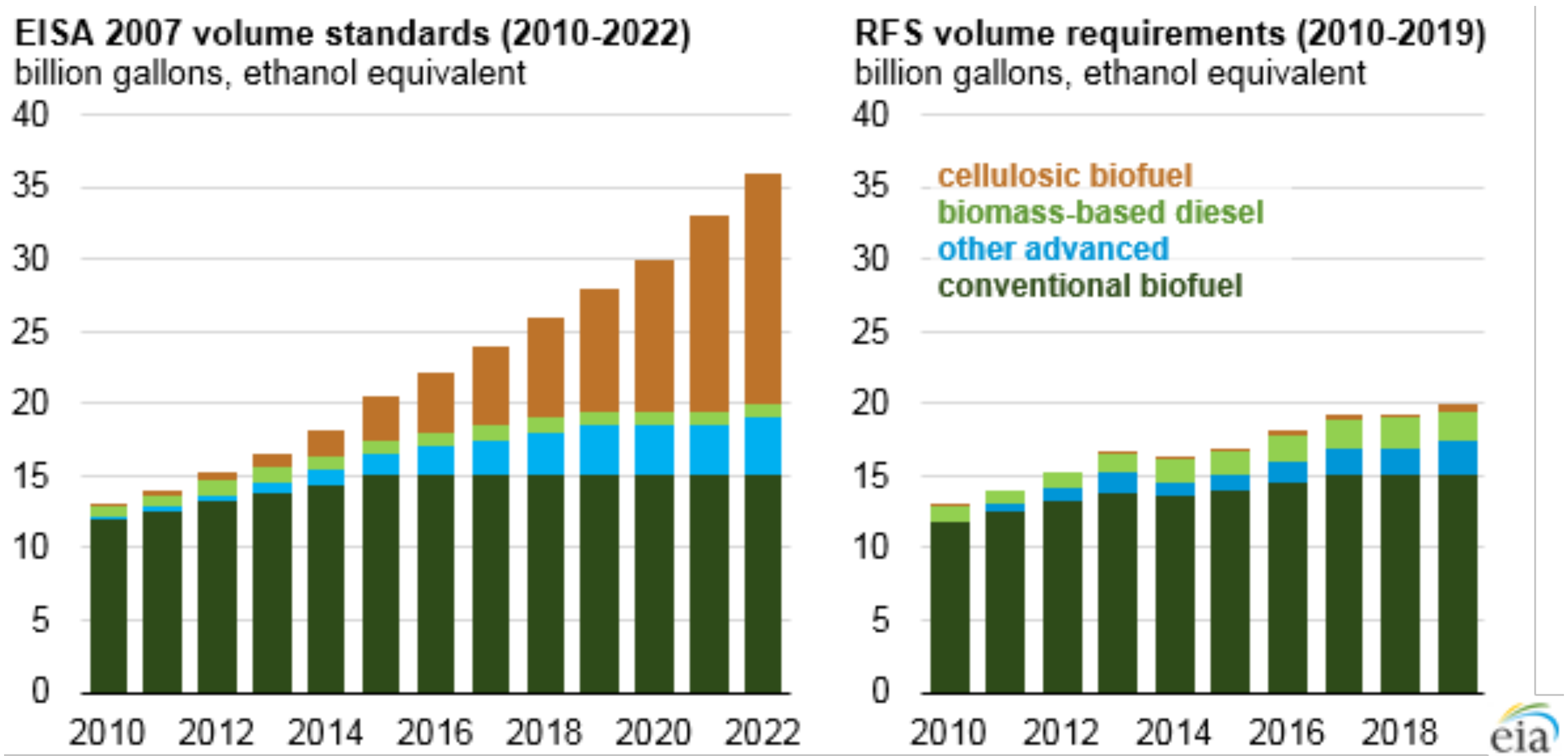
SAF: An array of policies

California LCFS
Vietnam mandate
Peru mandate
Columbia target
EU REDII
Philippines mandate
Taiwan target
Malawi mandate
Malaysia mandate
Paraguay mandate
Sudan mandate
Brazil RenovaBio
Zimbabwe mandate
Jamaica mandate
India mandate
Kenya mandate
Norway mandate
Ethiopia mandate
Angola mandate
China target
Italy mandate
Mauritius target
Argentina mandate
South Africa mandate
Finland mandate
US RFS
Mexico mandate
Canada Clean Fuel Standard
Thailand mandate
Ecuador target
Zambia mandate
Mozambique mandate
Ukraine mandate
Indonesia mandate
Chile mandate
Australian state targets

The Carbon Policy Landscape

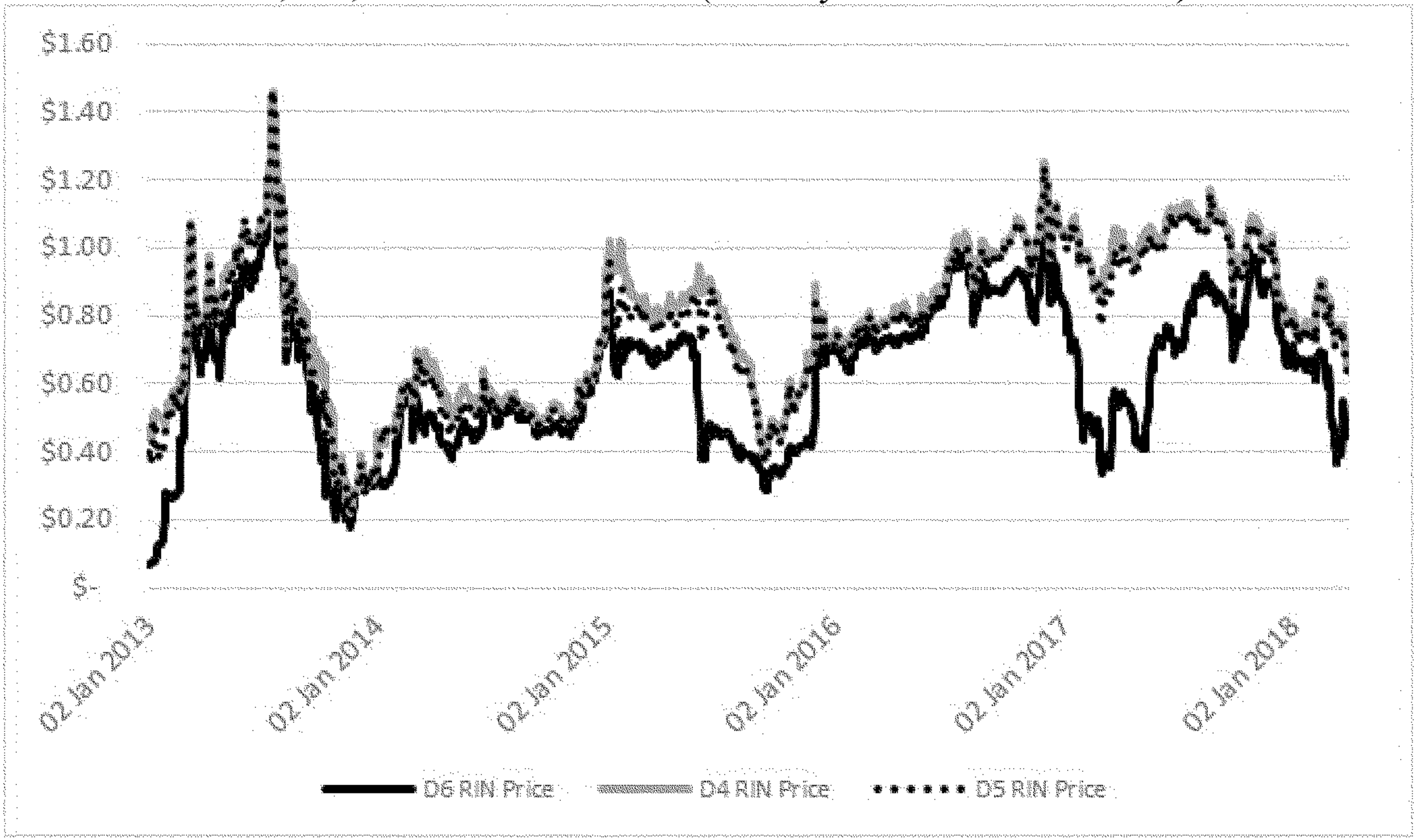


US market biofuels volumes



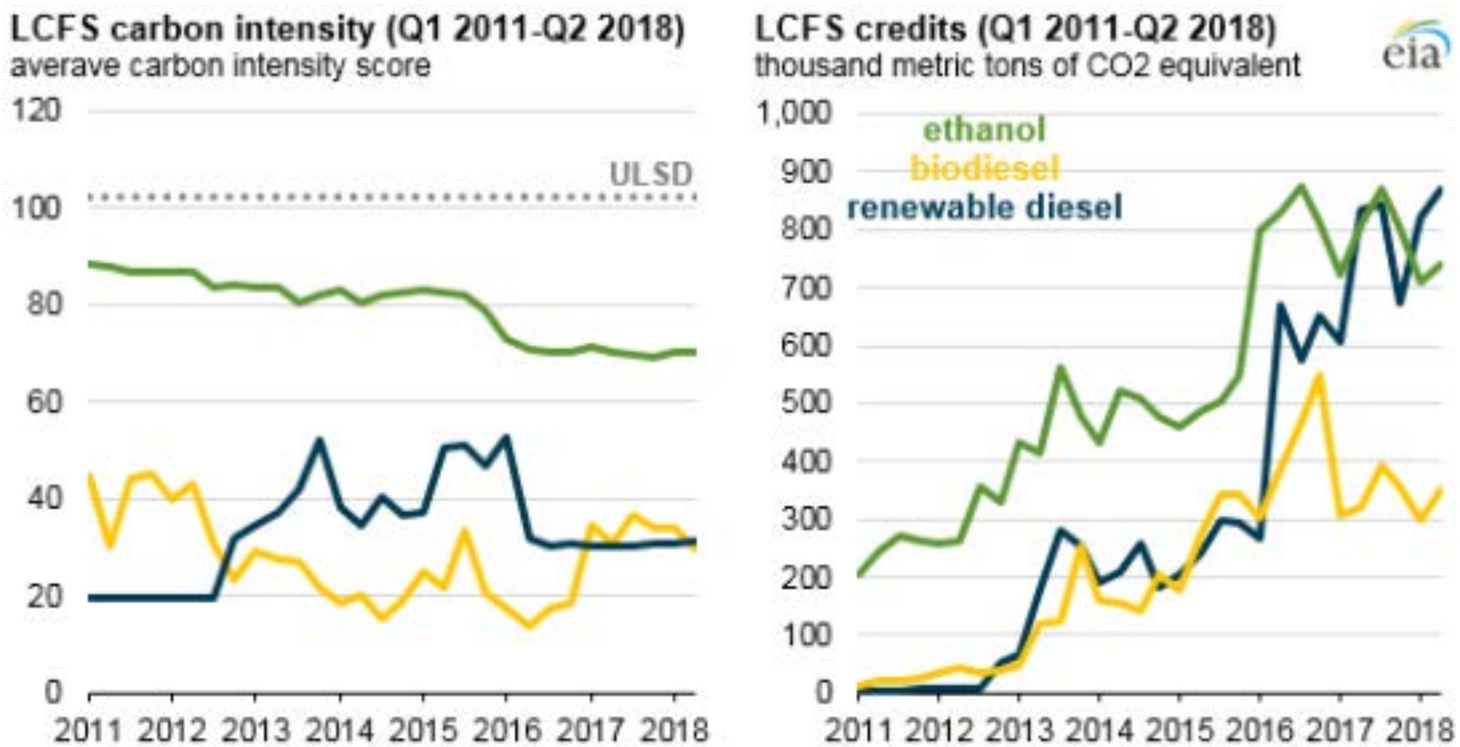
US market carbon prices

Figure VI.B.2-1
D4, D5, and D6 RIN Prices (January 2013 – March 2018)

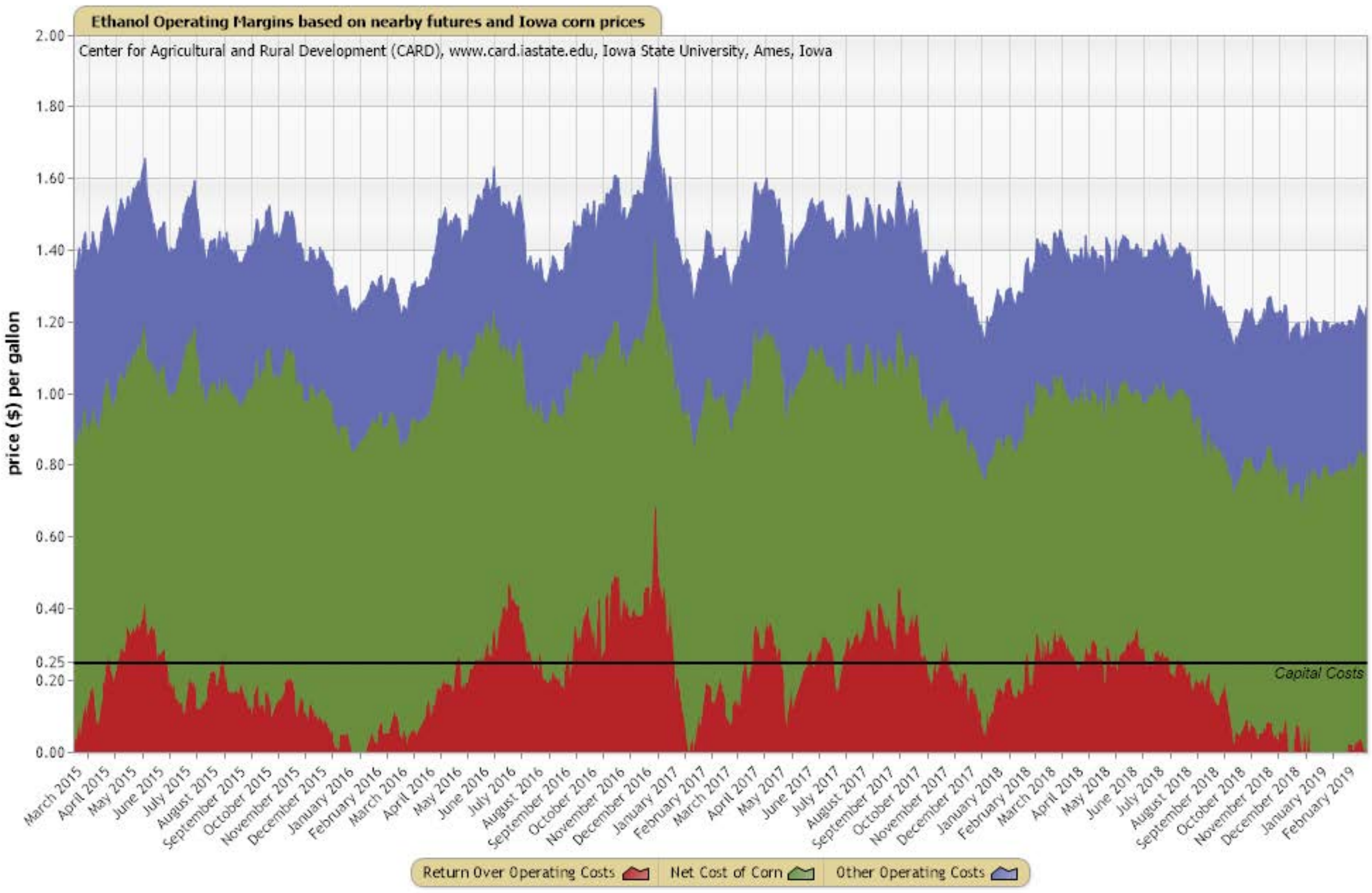


RIN Price Source: Argus Media Group

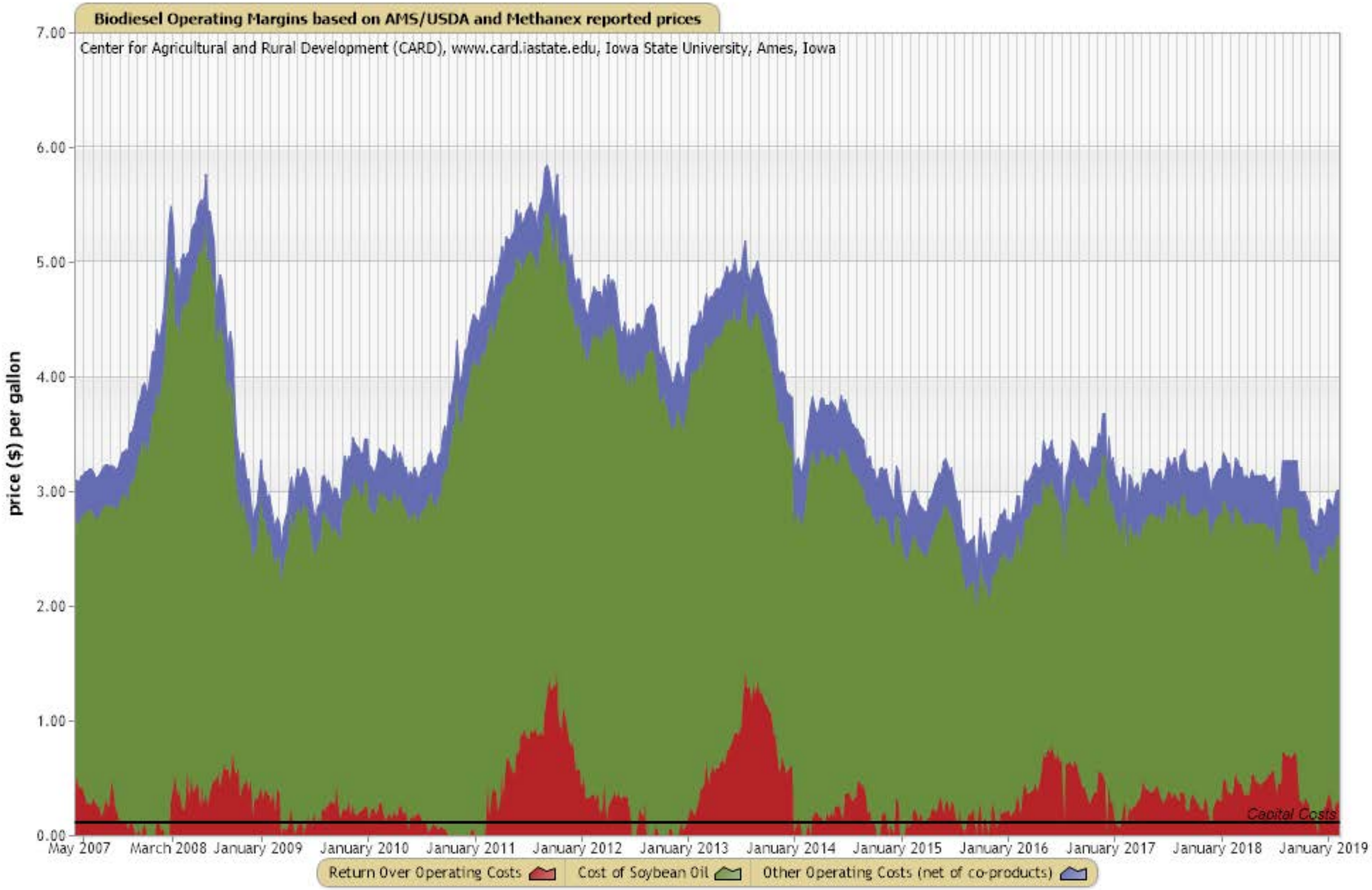
California market carbon data



US market ethanol ROI



US market biodiesel ROI



US market drop-in fuels economics

"NREL determined in 2012 that a 2,000-ton/day wood-based, greenfield plant would have a CAPEX of $232.8 million. The minimum sales price needed to provide overall IRR of 10% on top of 60% financed at 8% was calculated to be **$1.76 per gallon** with wood at $71.97 per dry ton. Feedstock accounted for 55% of the operating cost, and these costs exclude subsidies."

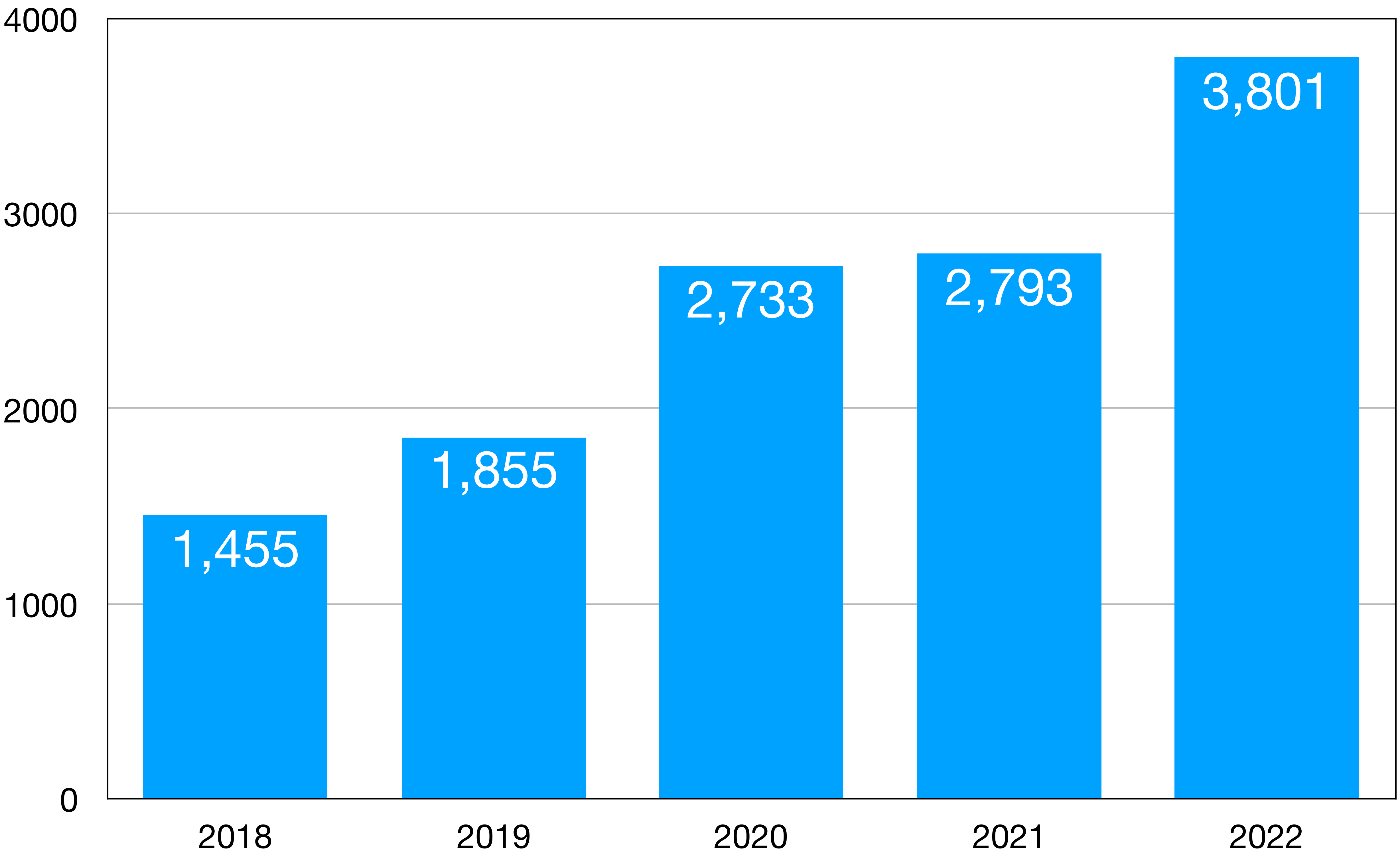
"In California, we are now seeing project flow projecting a sustainable **$7.63 price per gallon for renewable diesel** in the California market, where the Low Carbon Fuel Standard stacks on top of the RIN values from the federal Renewable Fuel Standard. According to those familiar with the project details, the assumed fuel price is $7.63 per gallon at completion of the project. That's striking. The breakdown is as follows:

$2.80 energy value
$2.72 federal RIN value
$2.11 California LCFS value
The anticipated CI of fuel produced by the project "should have a CI of ~10 gCO2e/MJ and receive a LCFS value of >$2.00/gal.," according to project principals."

Source: Biofuels Digest

Growing r.diesel/jet capacity

(in millions of US gallons in annual production capacity)



Source: Based on announced projects as reported in The Digest.

The Feedstock Landscape

US market feedstock availability forecast

Feedstock	2012	2017	2022	2030
		Million dry tons		
Baseline scenario				
Forest resources currently used	129	182	210	226
Forest biomass & waste resource potential	97	98	100	102
Agricultural resources currently used	85	103	103	103
Agricultural biomass & waste resource potential	162	192	221	265
Energy crops[a]	0	101	282	400
Total currently used	**214**	**284**	**312**	**328**
Total potential resources	**258**	**392**	**602**	**767**
Total – baseline	**473**	**676**	**914**	**1094**
High-yield scenario (2%–4%)				
Forest resources currently used	129	182	210	226
Forest biomass & waste resource potential	97	98	100	102
Agricultural resources currently used	85	103	103	103
Agricultural biomass & waste resource potential[b]	244	310	346	404
Energy crops	0	139–180	410–564	540–799
Total currently used	**214**	**284**	**312**	**328**
Total potential	**340**	**547–588**	**855–1009**	**1046–1305**
Total high-yield (2-4%)	**555**	**831–872**	**1168–1322**	**1374–1633**

Source: DOE Billion Ton Update

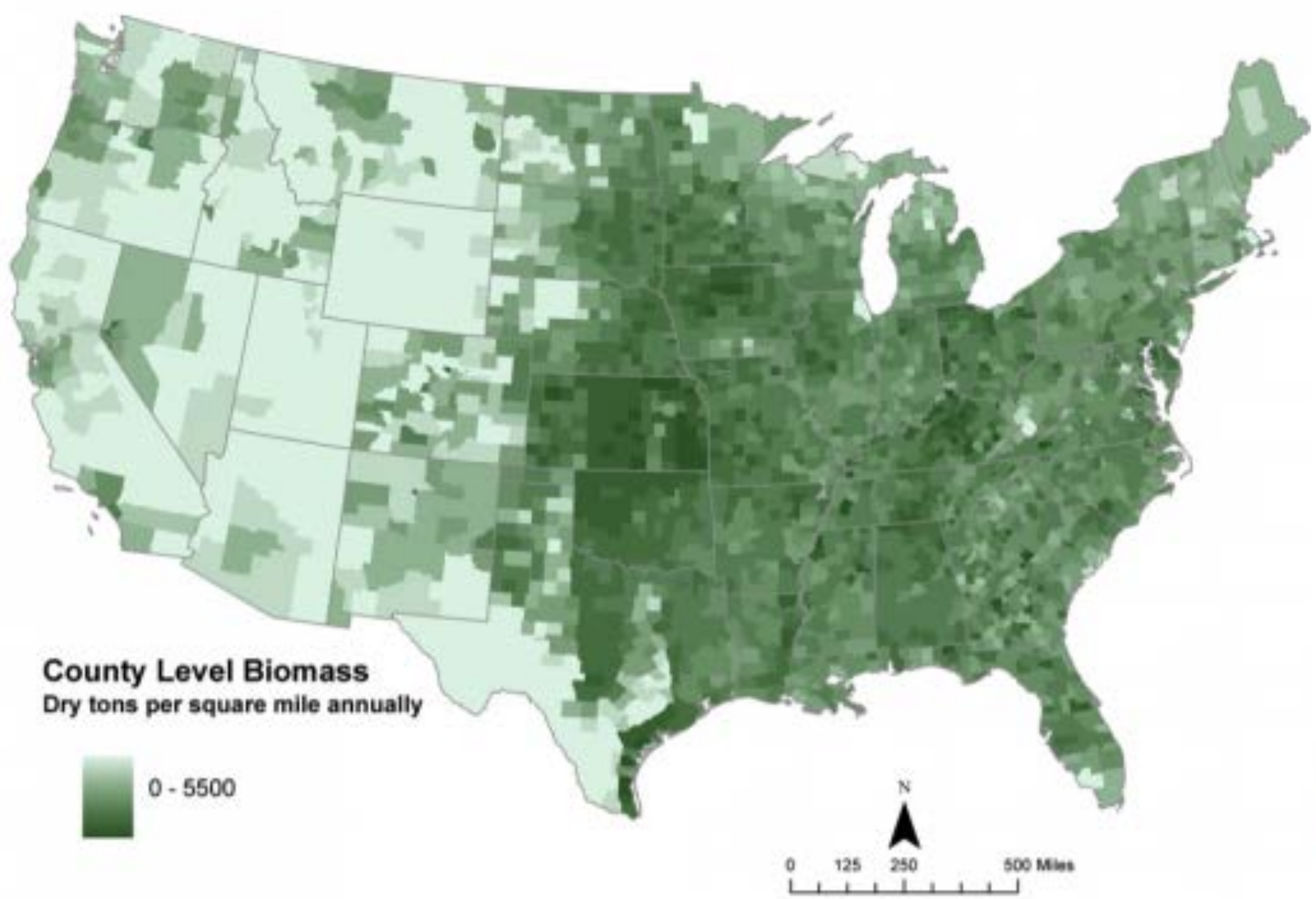
US market feedstock current use analysis

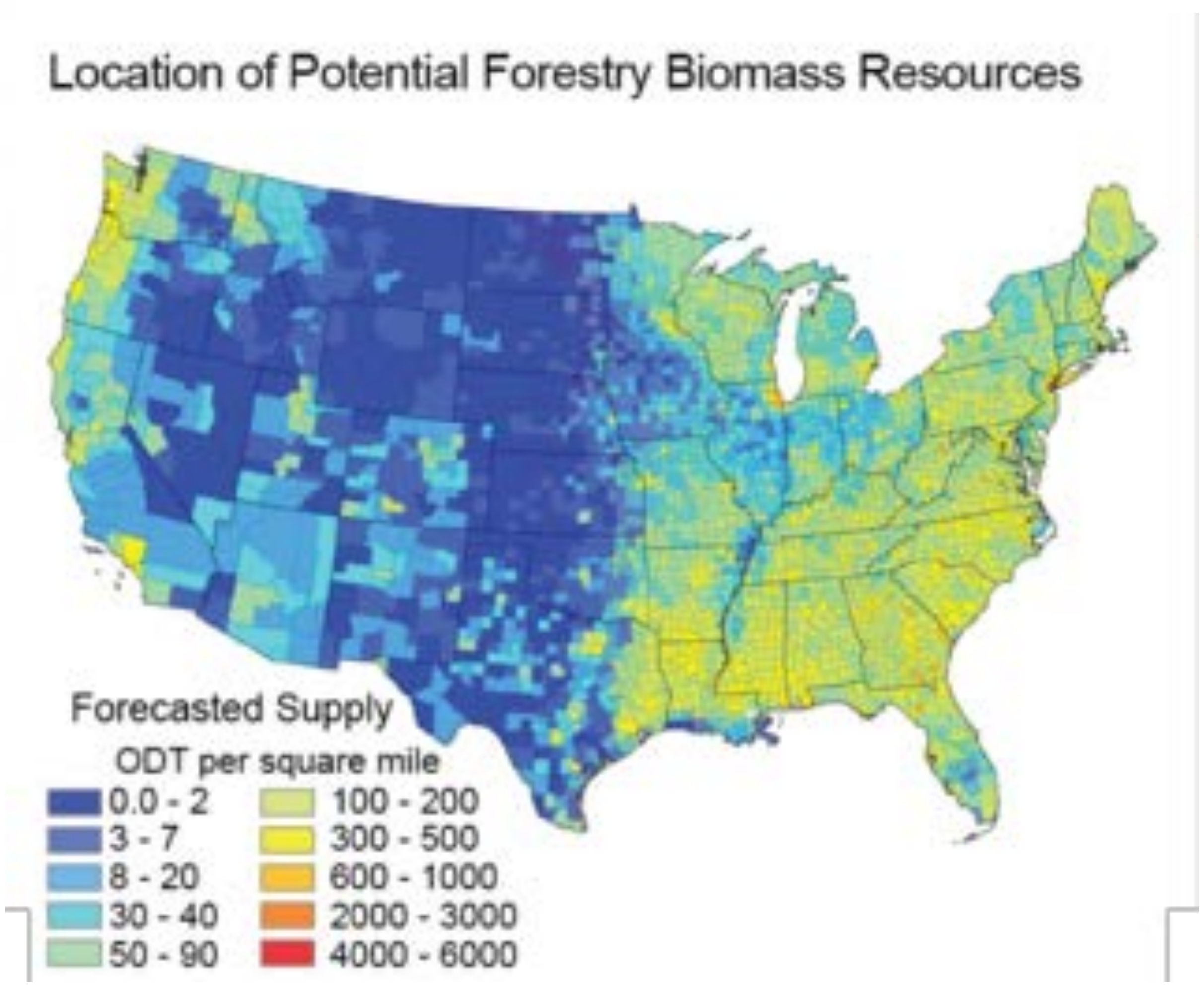
Table 2.1 Projected Consumption of Currently Used Biomass Feedstocks (Million Dry Tons per Year)

Source	Current	2017	2022	2030
Forest				
Fuelwood	38	72	96	106
Mill residue	32	38	39	42
Pulping liquors	45	52	54	58
MSW sources	14	20	20	20
Total forest	**129**	**182**	**209**	**226**
Agriculture				
Ethanol [a]	76 (109)	88 (127)	88 (127)	88 (127)
Biodiesel [b]	2	4	4	4
MSW sources	7	11	11	11
Total agricultural resources currently used	**85 (118)**	**103 (142)**	**103 (142)**	**103 (142)**
Total currently used resources	**214 (247)**	**285 (342)**	**312 (351)**	**329 (368)**

Source: DOE Billion Ton Update

US market feedstock availability analysis



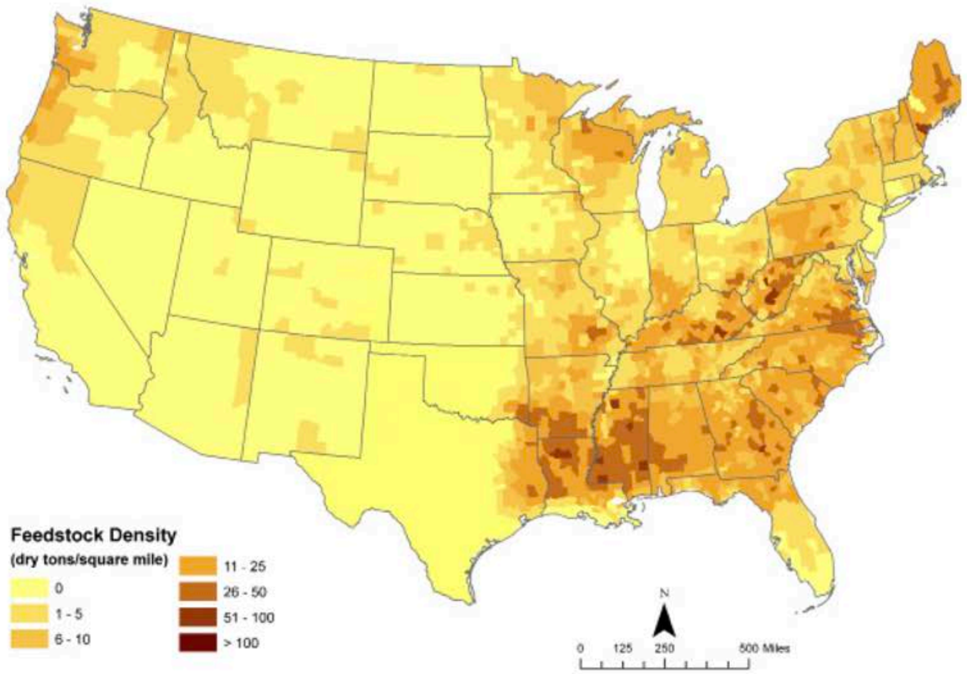


Source: DOE Billion Ton Update

US market feedstock price-geography model

Figure 3.8 Spatial distribution of logging residues at $20 and $40 per dry ton (delivered to roadside)

$20 per dry ton



$40 per dry ton

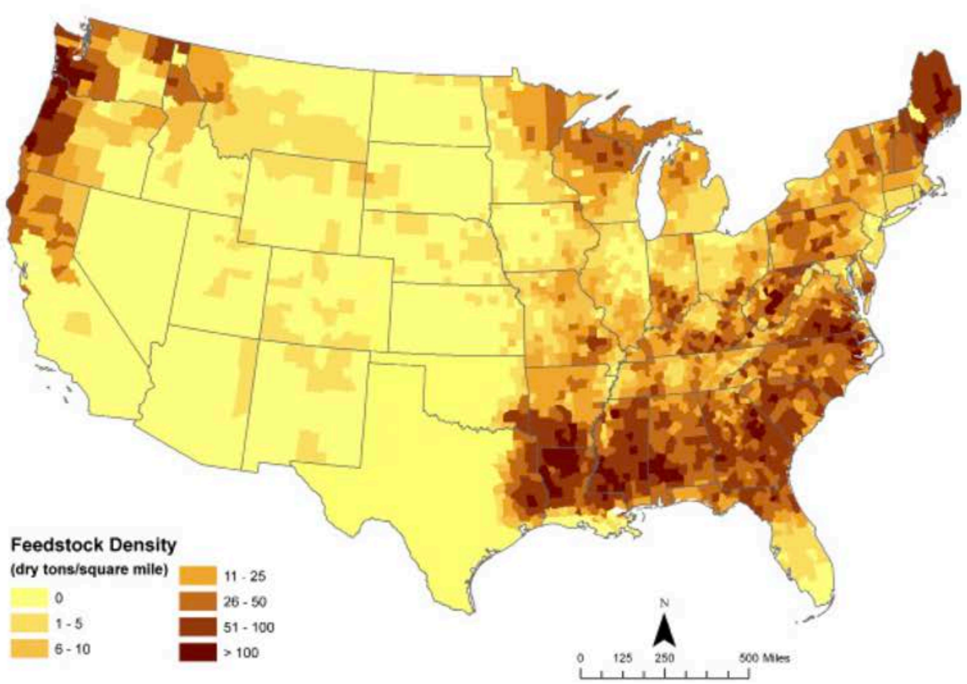


Figure ES.2 Estimated agricultural biomass under baseline assumptions

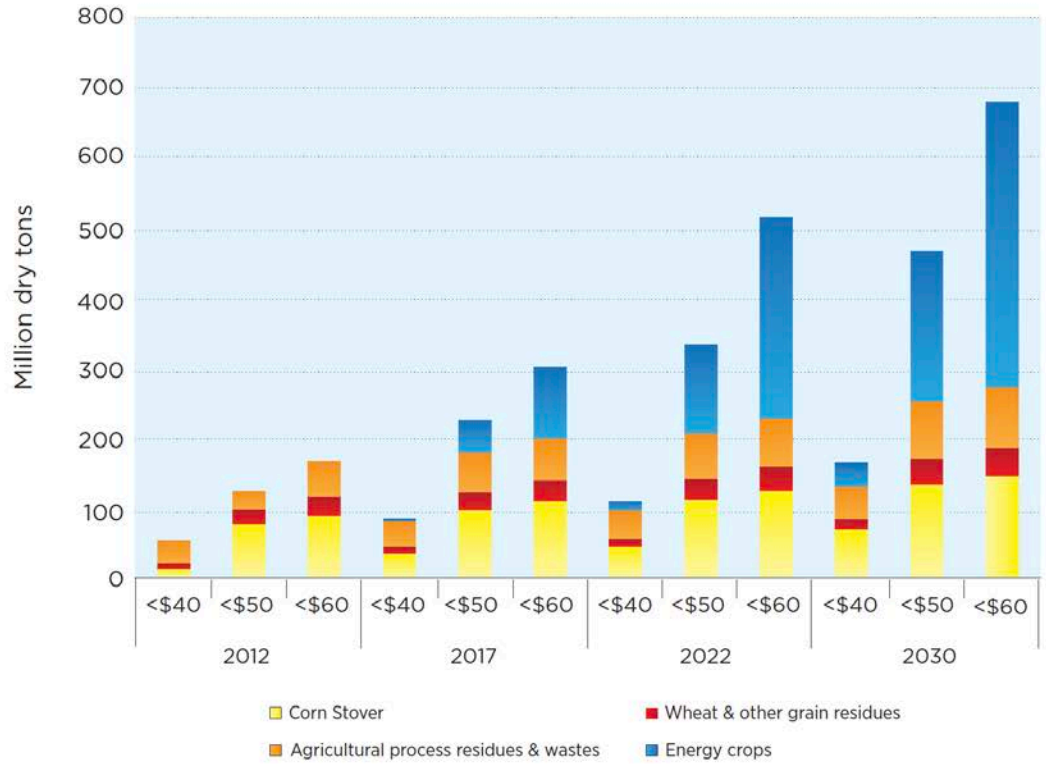
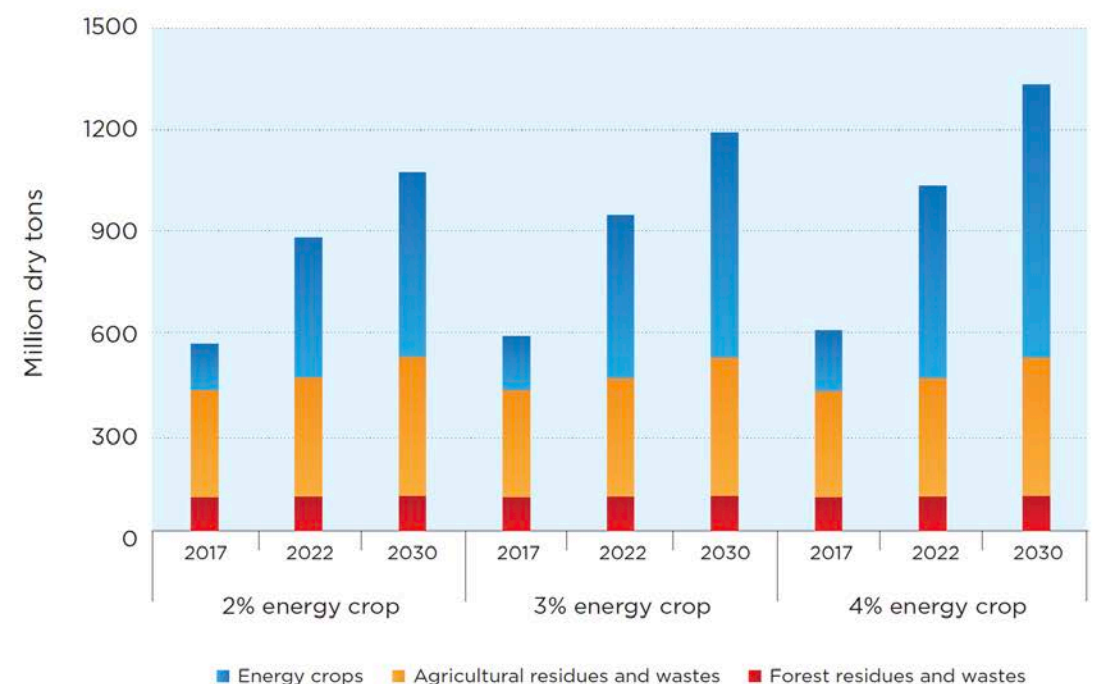


Figure ES.3 Estimated forest and agricultural biomass availability at $60 per dry ton or less under high-yield assumptions

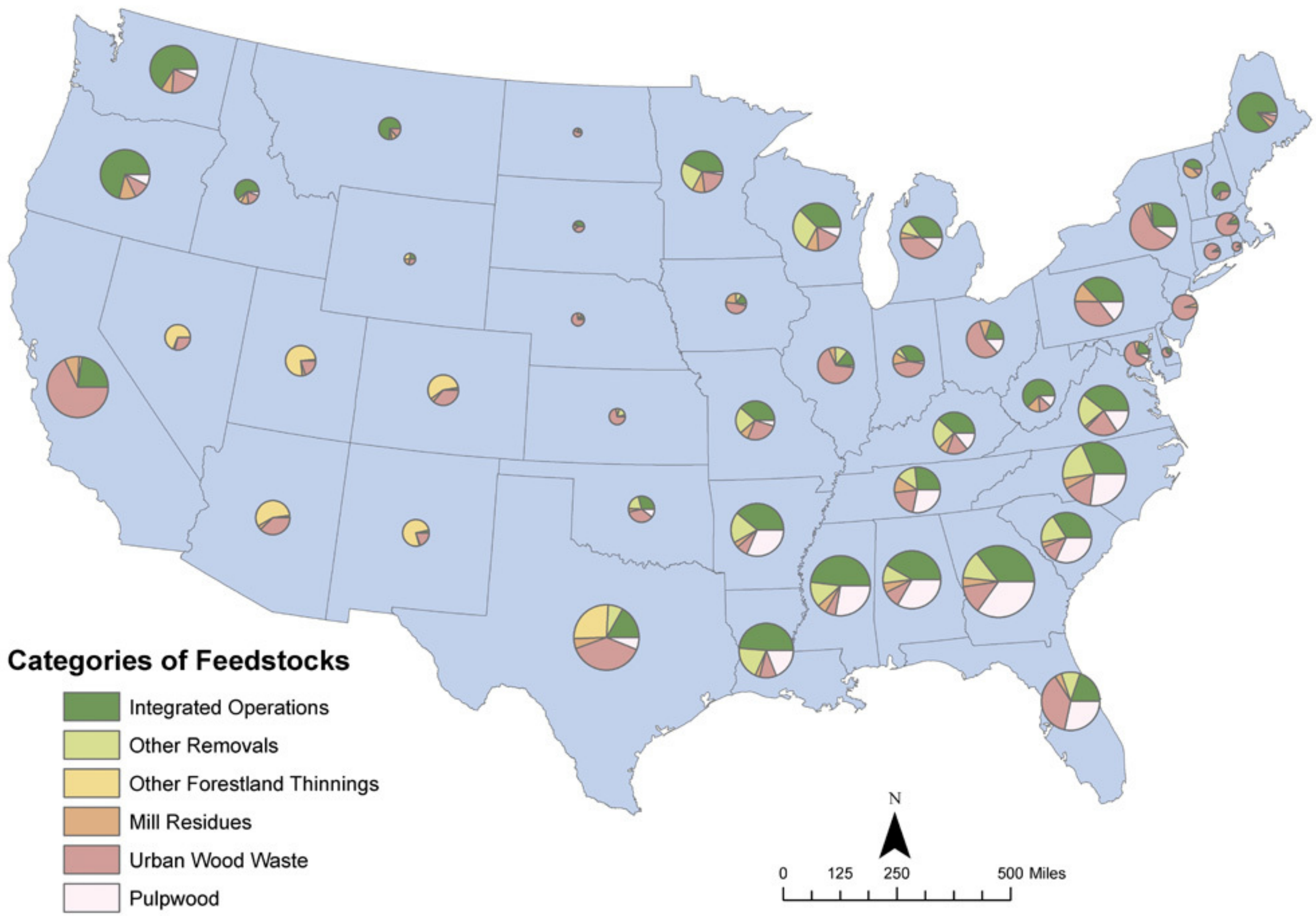


Source: DOE Billion Ton Update

US regional feedstock availability

About 7 million tons of available residue biomass in the Northwest

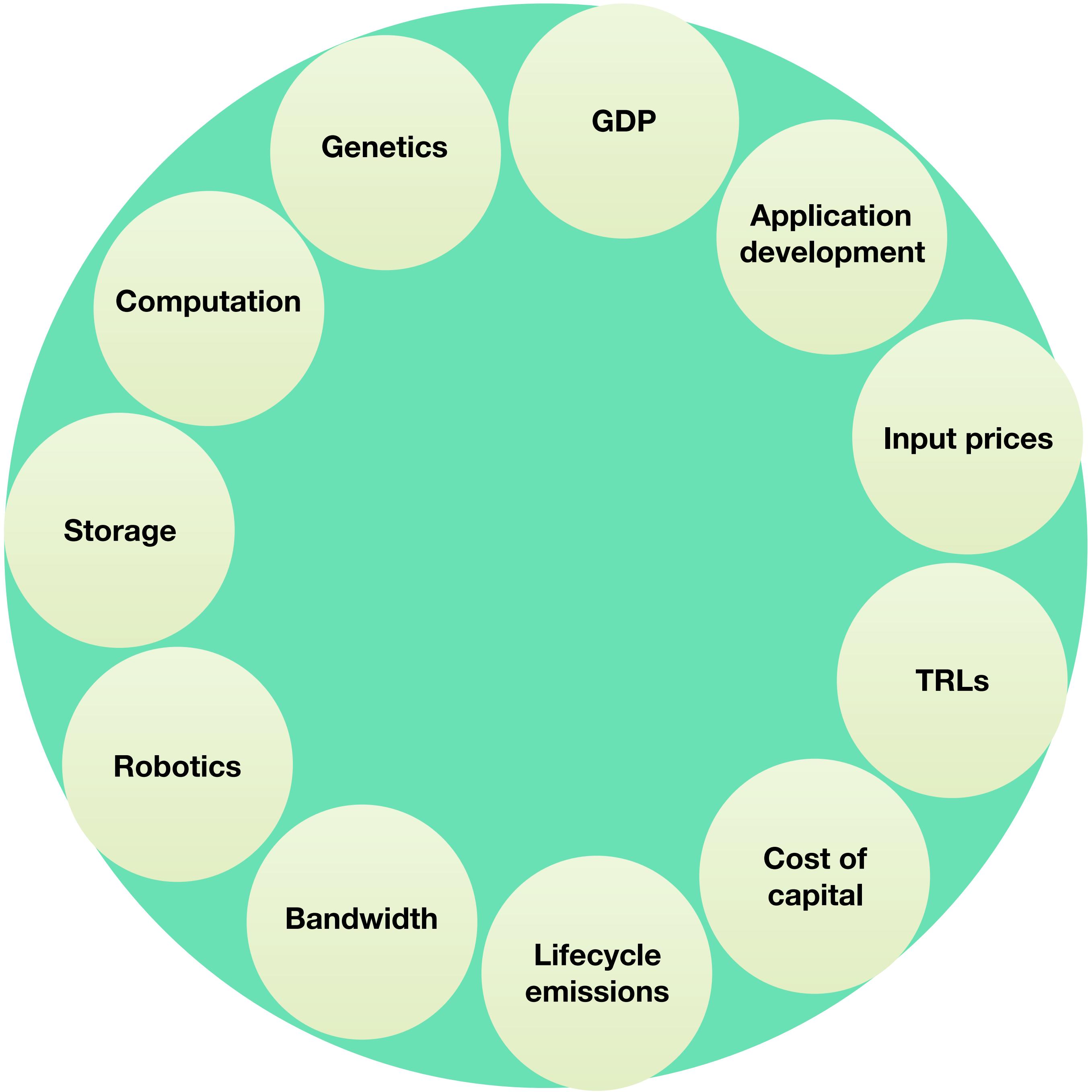
Enough to produce around 500 million gallons of fuel, or support 1 billion gallons of demand in a 50/50 blend.



Source: DOE Billion Ton Update


about the risks

Dynamism of global biorefining drivers

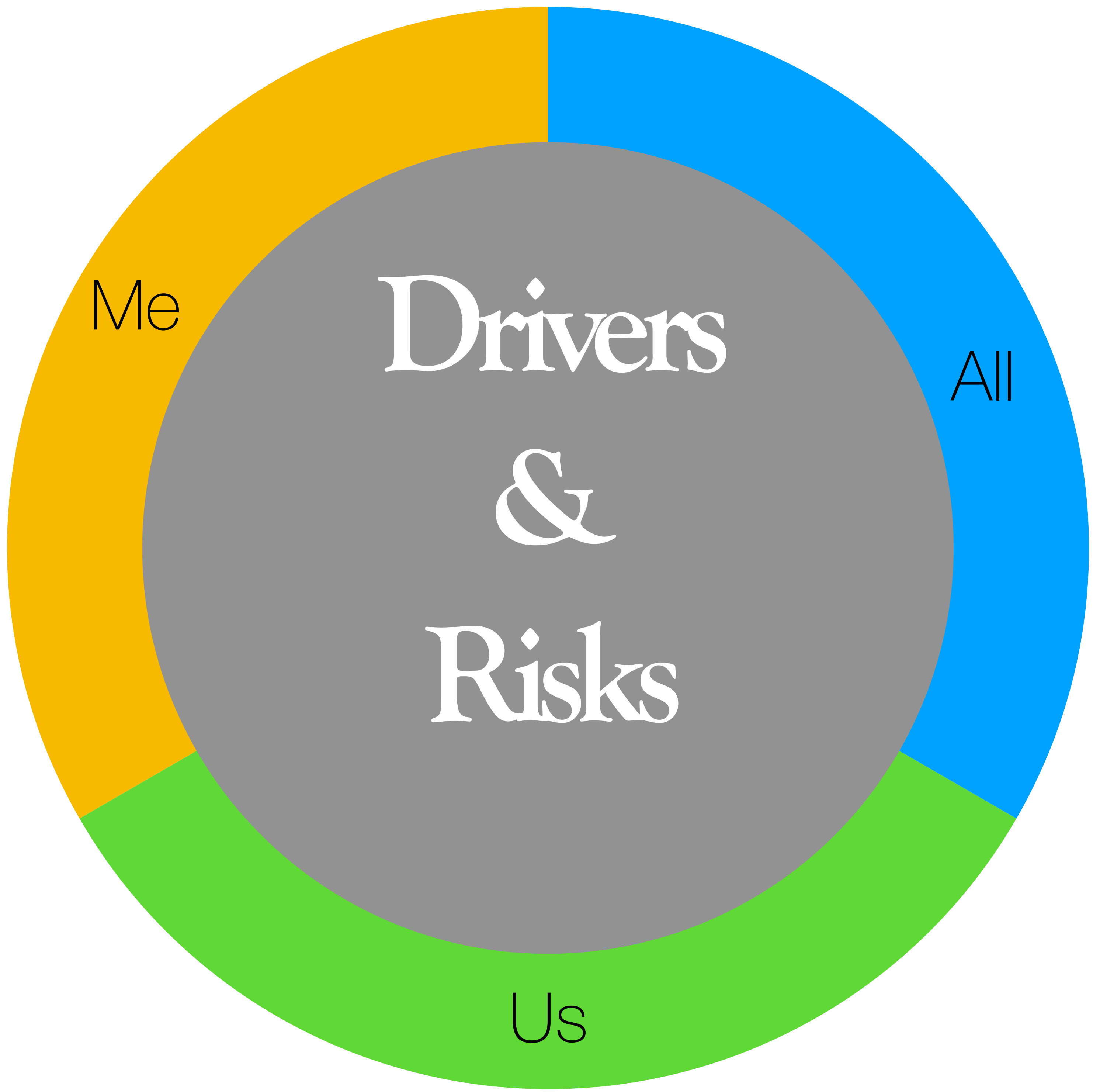


The Disruptive Macros
Dietary change
Currency / trade realignment
Population shift
Privacy vs Bandwidth (blockchain)
Imaging resolution (e.g spyforce)
Shift from text to pictures
Antibiotic resistance
Alterantive currency
Rise of Jihad
Intelligence in the Internet of Things (iIOT)
Trade flow bottlenecking
Political stability
Transparency
Resource scarcity
Commodity prices
Public opiinion
Policy stability
Urban development
Telecommuting
Autonomous systems
Data infrastructure

Dynamism of human drivers & risks

Age
Health
Tolerance
Wealth
Identity
Location
Beliefs
Aspirations
Attitudes
Ideas

Corporate
Financial
Technology
Market
Operational
Construction
Currency
Political
Policy
Country
Privacy
Transparency



Population
Inequity
Climate
Sustainability
Ideas
Inclusiveness
Collaboration
Mobility
Genetics
Robotics
Bandwidth
Storage
Computational
speed

Dynamism of global biorefining scale-up

What's working in highly dynamic development?

- Certification and LCAs
- Motivated feedstock strategic
- SARA
- Rapid response training
- Transparency

- Rate, yield focused
- Not Built Here
- Catalyst first
- Hire experience in dynamic markets
- Think science in the exec suite, markets in the lab

What's working in highly dynamic markets?

- Dynamic priced offtake
- Counter-cyclic carbon price
- Motivated feedstock strategic
- One deep strategic customer engagement who moves fast
- Spin off fixed-fee operational entity
- Transparency
- There are no advantaged processes or molecules, only advantaged moments
- Sell the risk, not the product
- Hedge policy and feedstock risk, not commodity risk

What's working at the company level?

- Lean
- Stable
- Visible, credible
- Flat organization
- Values-driven

- Risk minimizers, not risk takers
- Persistence pays
- Construct, commission, co-own, operate
- Highly collaborative, but decisive
- High degree of cross-training

18 Key projects

Growing r.diesel/jet capacity

Neste Singapore
675 mgy

Neste Finland
200 mgy

Neste Rotterdam
300 mgy

Red Rock Oregon
10mgy

ENI Gela
175 mgy

Diamond Green Norco
675 mgy

USA BioEnergy Arkansas
20 Mgy

REG Geismar
115Mgy

ENI Venice
80 Mgy

Next Renewables Oregon
600 Mgy

World Energy Paramount
300 Mgy

Fulcrum Nevada
10 Mgy

Fulcrum Chicago
40 Mgy

Cielo Canada
20 Mgy

REG/Phillips66 Washington
200 Mgy (est.)

Marathon North Dakota
183 Mgy

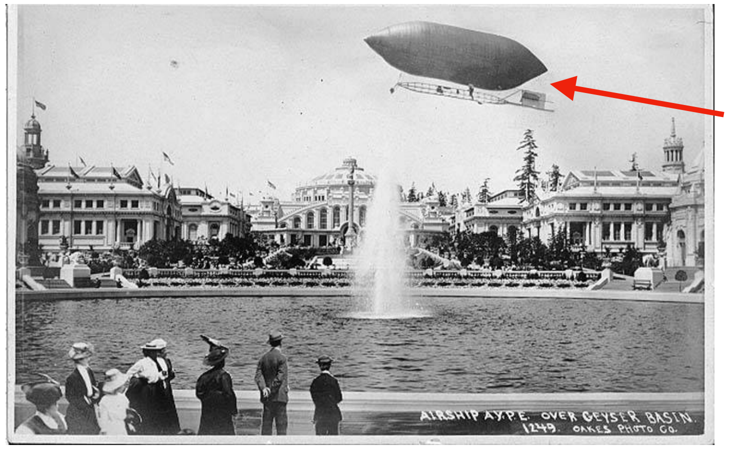
Velocys/BA UK
20 Mgy

Ryze Renewables Nevada
168 Mgy

4 Key drivers

I. Stabilized policy.
II. Mature technologies.
III. Seriousness in tackling transport emissions.
IV. Better risk profiling for project finance markets.

We've been here before.



The airship that hooked William Boeing on aviation was filled with waste hydrogen — a no-cost residue from making fertilizer.

Before aviation, William Boeing was in the wood business.

Yes, boys and girls, my #1 rated children's show was set at a landfill.

Saudi Aramco's founding CEO once sold coal-to-oil conversions on Seattle's docks

ارامكو السعودية
Saudi Aramco

Thought up by a United Airlines CEO

Modern fueling started at Seattle's Pier 32

See you at ABLC!

ABLC2019

April 3-5, 2019 • Washington, DC

Projects, Projects and more projects:
The Advanced Bioeconomy Deploys