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The Way to Net-Zero Ethanol

Fuel Ethanol Laboratory Conference

October 6, 2021

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Our History: Building the Clean Energy Economy

History

Since 2009; Des Moines, Iowa; Growing to 40 employees; focused on fuels decarbonizing the transportation sector

Vision

To be a global leader in developing solutions for a sustainable world

Mission

To help build out a clean energy economy by providing in-depth knowledge of low carbon regulations, technologies and markets

Future

Transportation, farming, power, industry, buildings

Values

Our people are the ambassadors of our brand. The trust they build with clients is the foundation of our success.

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Our approach

We are consistent across all service areas

1. Fuel agnostic
2. Technology agnostic
3. National and International
4. Market-driven
5. Low-carbon
6. We don’t participate in the value of products or credits

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The Importance of Net-Zero Ethanol

In a world demanding net-zero, the way forward for ethanol is to take advantage of its carbon sinks

1. Sustainable Agriculture
2. Soil Carbon Sequestration
3. Carbon Capture and Sequestration

https://tinyurl.com/nzethanol

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Starting Point: RFA's Commitments

RFA members' July 27, 2021, commitments:

1. 70% reduction by 2030
2. Net-zero life-cycle GHG emissions

https://ethanolrfa.org/wp-content/uploads/2021/07/RFA-Net-Zero-Commitment-Letter-to-President-Biden-.pdf

CATEGORY	CARBON INTENSITY (gCO_2e/MJ)
Fuel Production	29.6
Agriculture	26.0
Land Use Change	3.9
Fuel and Feedstock Transport	3.1
Denaturant	1.3
Tailpipe	0.3
Co-product Credit	-12.8
Total	**51.4**

Source: Scully et al 20 21 *Environ. Res. Lett.,* Carbon intensity of corn ethanol. https://onlinelibrary.wiley.com/doi/10.1002/bbb.2225

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Pathways to Net-Zero Ethanol

MARKET READINESS	LOW CI INPUTS*	SUSTAINABLE MANAGEMENT PRACTICES BY CORN GROWERS	RENEWABLE PROCESS ENERGY	CARBON CAPTURE AND STORAGE BY ETHANOL PRODUCERS
Currently Available	Corn starch, kernel fiber	No till, cover crops, soil carbon sequestration	Biomass, RNG, wind, solar, chp including both electric and process heat demand	Carbon capture and sequestration, enhanced oil recovery including pipeline, truck, rail
Emerging		Biochar, low-CI fertilizer	Pyrolysis, H2	

Greenhouse Gases Impact

GAS NAME (FORMULA)	100-YEAR GLOBAL WARMING POTENTIAL*	TECHNOLOGIES
Carbon dioxide (CO_2)	1	CCS
		EOR
		Biomass heat
		Landfill gas
		Solar
		Wind
		Efficiency
		Wet or mod DGS
		Fertilizer
Methane (CH_4)	34	Dairy manure
		Swine manure
		Landfill avoidance
Nitrous oxide (N_2O)	298	Cover crops
		No till
		Fertilizer

*IPCC 2013 (AR5)

Components of Ethanol Carbon Intensity

- Starch Ethanol CI = 51.4 + (32) for CCS + (19.2) in Fuel Production CI = Net Zero Ethanol

- The (19.2) can be accomplished via combination of RNG, biomass, wind, solar, biochar (*i.e., liquid fuel battery storage)*

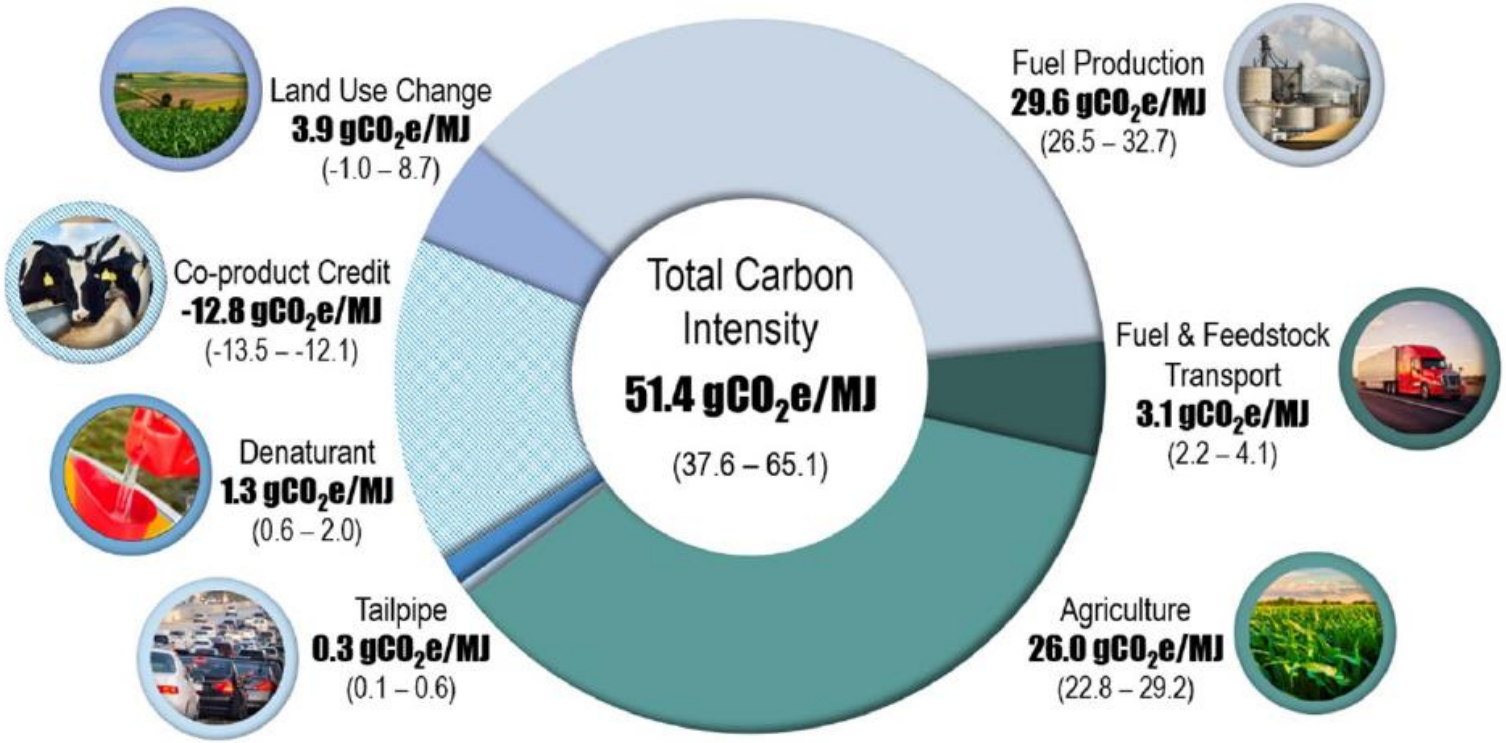

Figure 5. GHG emission categories and total CI of corn ethanol.

Source: Env. Research Letter 16 043001, Scully et al 2021

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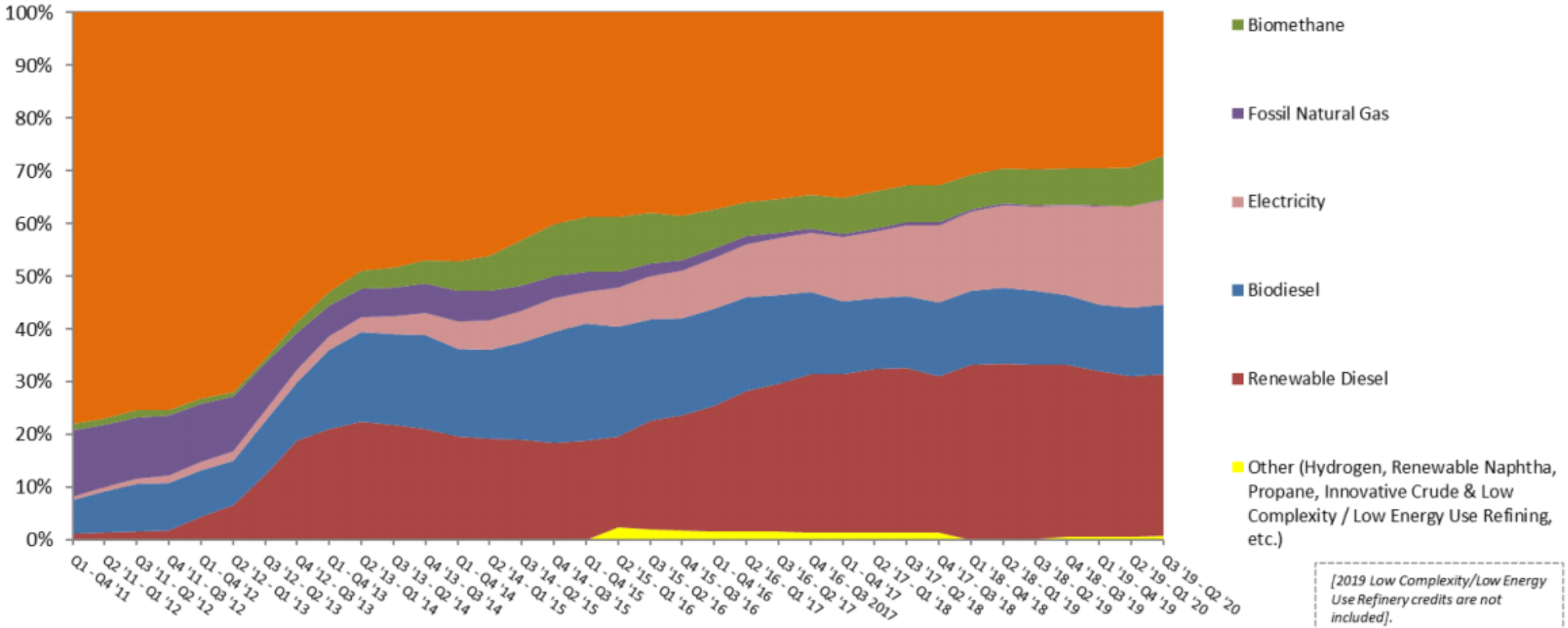
California LCFS Markets
(with iLUC, Farm Practices)

Low-CI Fuels Sell into California

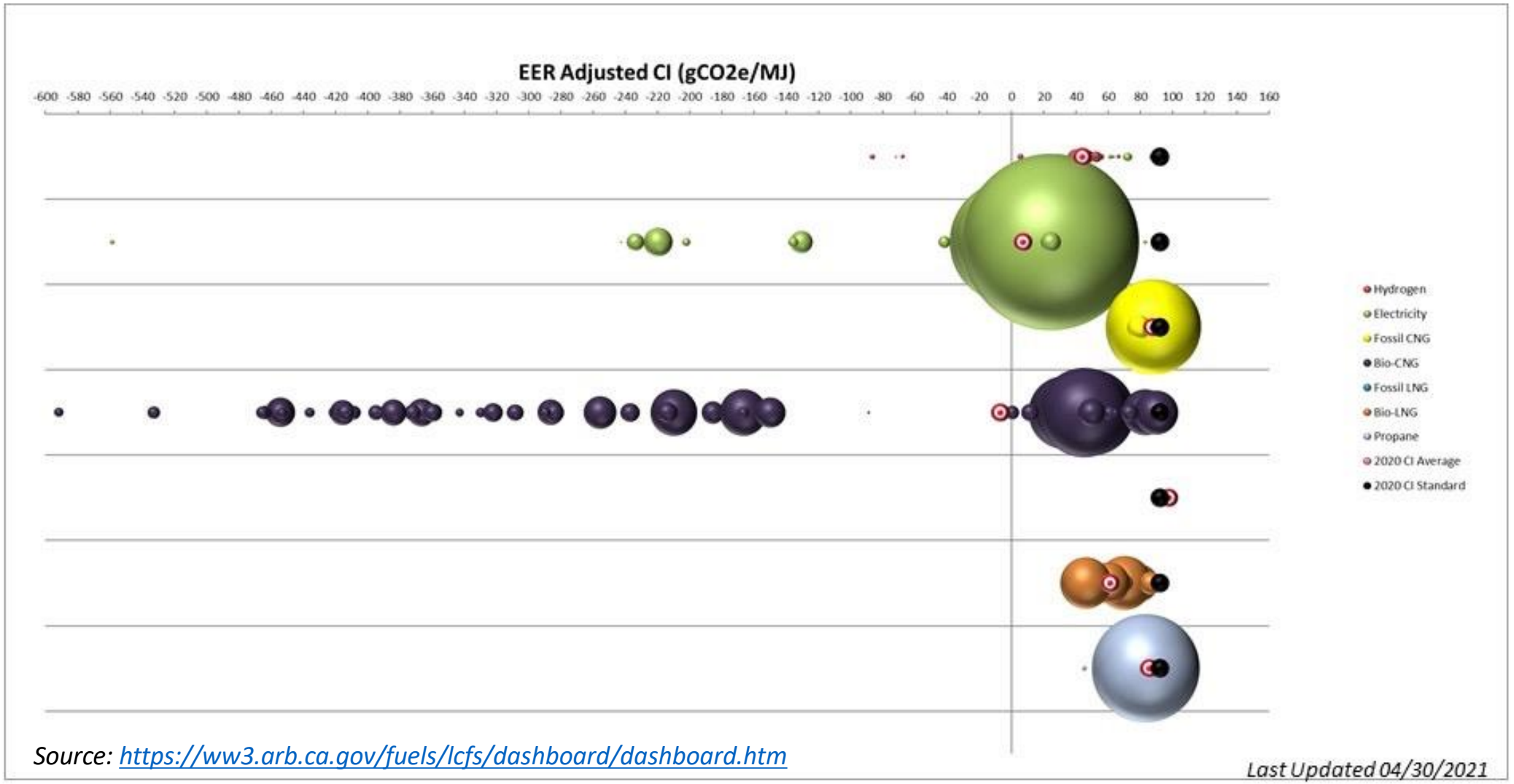
Fig 2. Credit Percentage by Fuel
Q1 2011 - Q2 2020



[2019 Low Complexity/Low Energy Use Refinery credits are not included].

Volume-Weighted Average CI for Non-Liquid Fuels

2020 Volume-weighted Average Carbon Intensity by Fuel Type for Non-Liquid Fuels

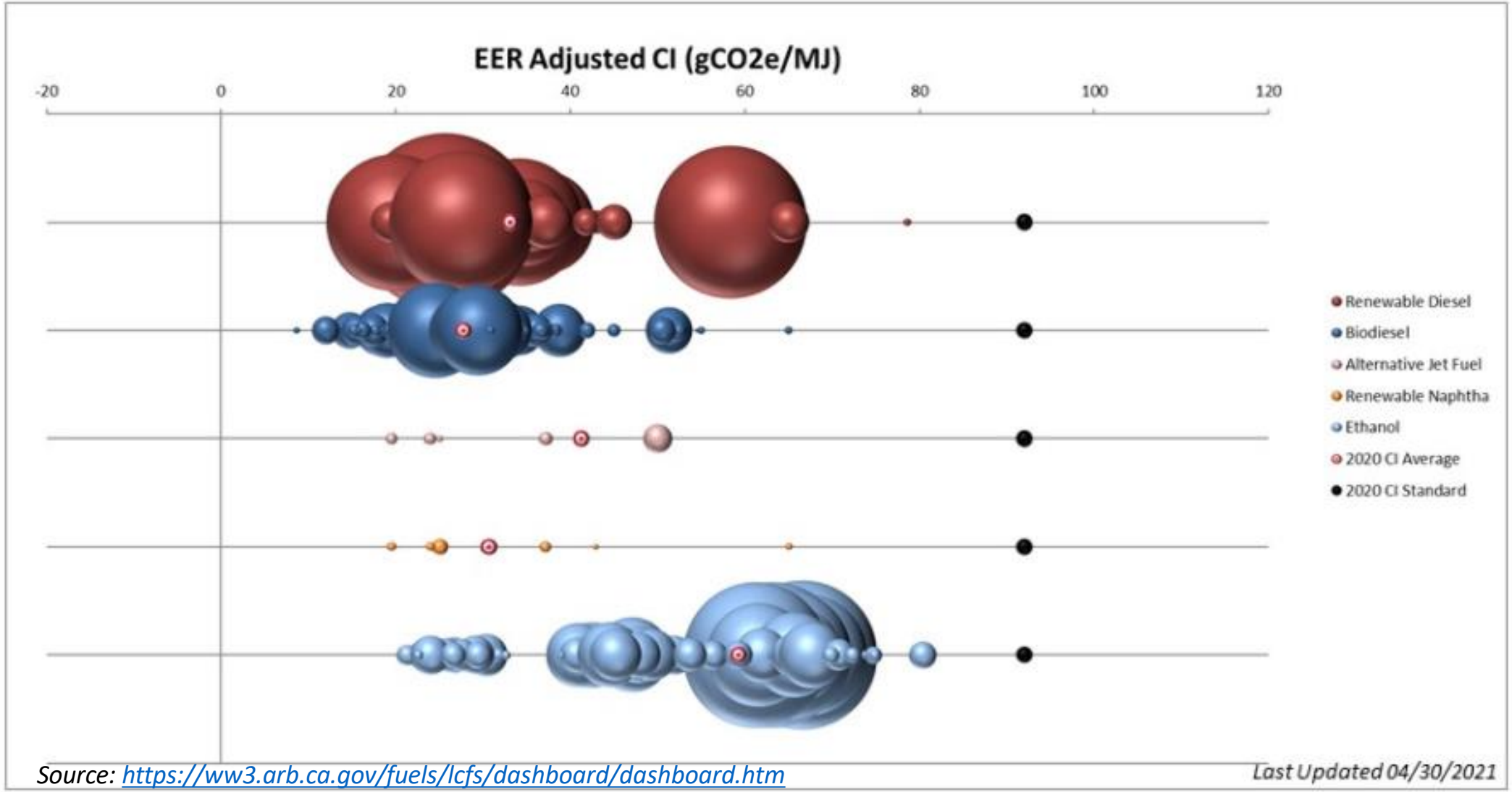


Source: https://ww3.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm

Last Updated 04/30/2021

Volume-Weighted Sales into California

2020 Volume-weighted Average Carbon Intensity by Fuel Type for Liquid Fuels



Source: https://ww3.arb.ca.gov/fuels/lcfs/dashboard/dashboard.htm

Last Updated 04/30/2021

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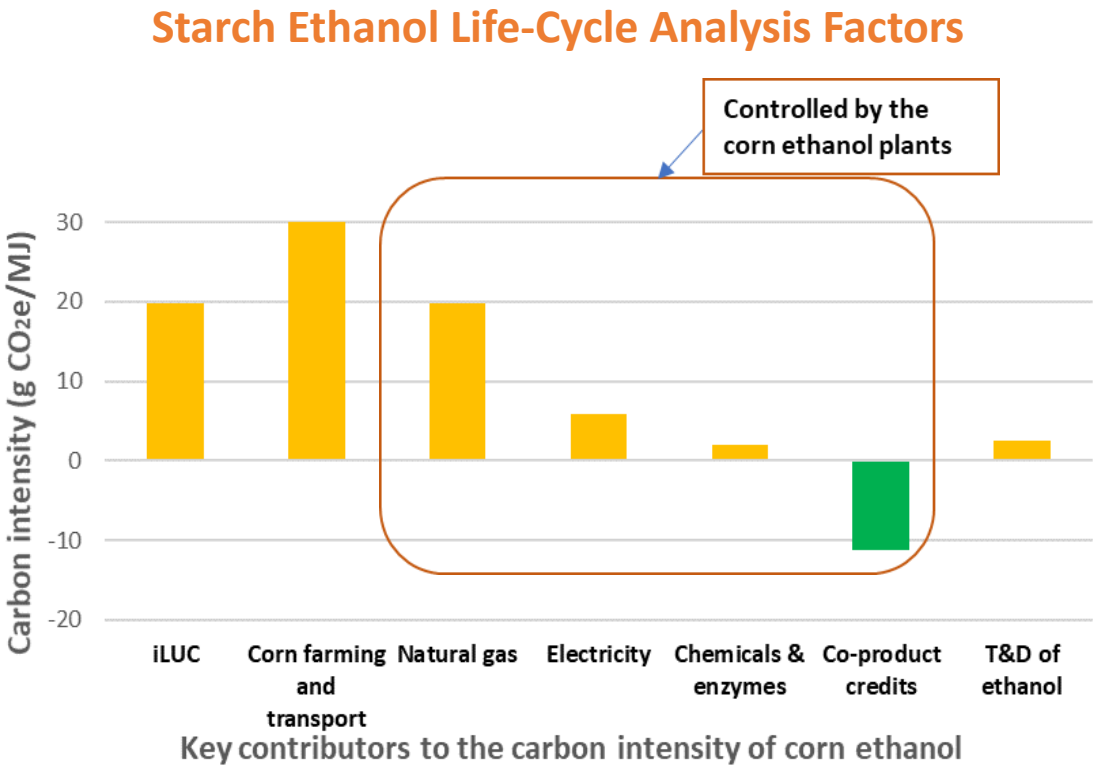
Key Contributors to Ethanol Carbon Intensity

- Indirect land use change (iLUC)
- Corn farming and transportation
  - Fertilizer
  - N_2O emissions from field
  - Fuel used
- Ethanol plant
  - Energy (natural gas, electricity, etc.)
  - Chemicals and enzymes
  - Yields of ethanol and co-products
- Transportation and distribution
- End use as transportation fuel

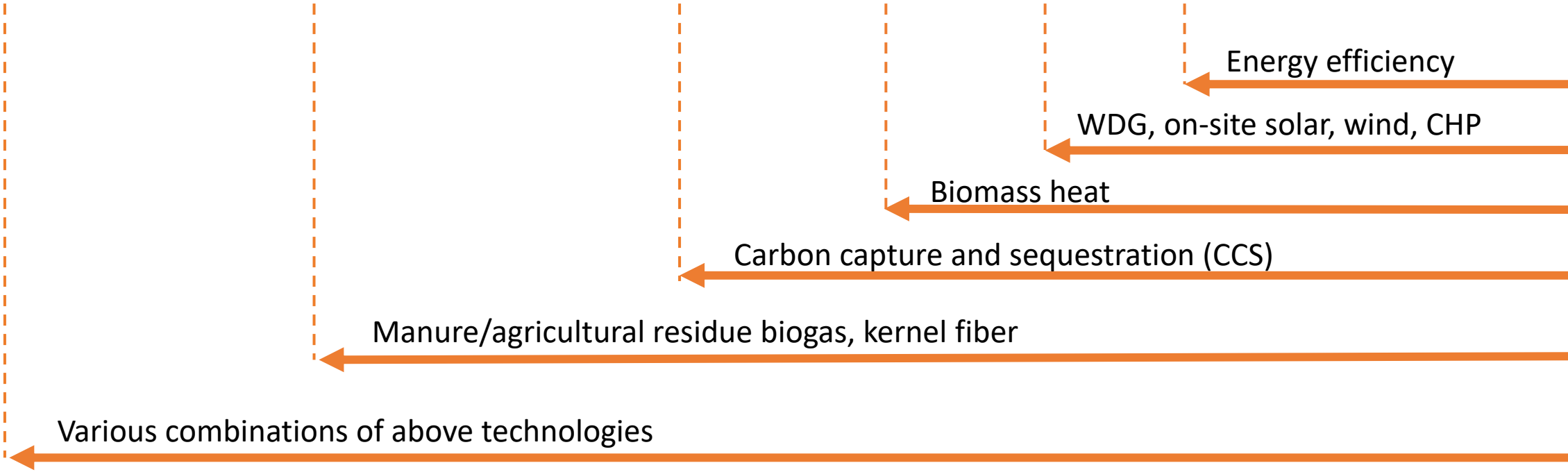


Key Contributors to Ethanol Carbon Intensity

Parameter	Assumed Value	Contribution to CI of EtOH	Potential Reduction Method	Comment
Iluc		20	Better and more accurate modeling	Fixed under current LCFS
Corn farming and transport	Default in CA-GREET	28	No till, less fertilizer, less fuel use	Almost fixed under current LCFS
at Ethanol Plant				
Co-product credit	5 Dry lbs. DGS/Gal	-11	Higher quality co-products	Almost fixed under current LCFS
Natural gas	**24,000 Btu/Gal**	**20**	**Biogas, biomass boiler, CHP, heat recovery**	**Plant-specific**
Electricity	**0.7 Kwh/Gal**	**6**	**On-site renewable power, CHP, higher efficiency**	**Plant-specific**
Chemicals	Industrial typical	2	Advanced enzymes, less chemical use	Plant-specific
T&D of Ethanol	Midwest to California by rail for 1,899 miles	2	Higher transportation efficiency	Plant-specific, not much flexibility
	Total	**67.0**		

Starch/Fiber Ethanol Pathways Under the LCFS

CI Range	0-10	10-20	20-30	30-40	40-50	50-60	60-70	70-80	80+
Feedstock			Waste Wine, Corn Kernel Fiber, Sugar Beets, Stover	Sugarcane, Molasses, Stover, Corn Kernel Fiber, Sorghum	Sugarcane, Molasses, Waste Wheat Slurry, Waste Beverage	Corn, Sorghum	Corn, Sorghum	Corn, Sorghum	Corn, Sorghum



How Nebraska Ethanol Can Benefit

Applicant & Pathway Description	Capacity (MGPY)	Current Certified CI	LCFS Basis Price (79.9-CI)* $0.015-$0.25-$0.15-transload, $	Deltas (California - Chicago	Addl. Gross Profit/gal ethanol	Addl. Gross Profit/year
Nebraska Kernel Fiber Ethanol	4	25.00	$ 0.42	$ 0.43	$ 0.86	$ 3,424,000
Nebraska Kernel Fiber Ethanol w/ CCS	4	(5.00)	$ 0.87	$ 0.43	$ 1.31	$ 5,224,000
Nebraska WDG Ethanol	100	60.00	$ (0.10)	$ 0.43	$ 0.33	$ 33,100,000
Nebraska WDG Ethanol w/ CCS	100	30.00	$ 0.35	$ 0.43	$ 0.78	$ 78,100,000

Notes:

1. Assumed 79.9 OPIS price basis and $0.25 discount per gallon and $0.15 additional shipping cost vs. Chicago
2. Assumed 4% kernel fiber gallons
3. Example is August 11, 2021 OPIS (California price of $2.665 - Chicago price of $2.2325)
4. CCS is assumed to reduce CI by 30 CI points

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Net-Zero Ethanol

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Manure Considerations on Avoided Methane Credits

- Type of manure matters
  - Dairy and swine manures only get methane avoidance credit
  - Beef cattle excluded
- What is the baseline manure management practice?
  - Lagoon scores are best
  - No lagoons = no methane avoidance credit
- How much of the manure goes to lagoons?
  - Can have 40- to 75-point CI impact
- How often are lagoons cleaned out? Agitated?
  - Can have 50- to 100-point CI impact
- How much RNG will be produced?
  - Set amount of methane avoidance credit

Available Tier 1 Simplified Calculators
Biomethane from North American Landfills
Biomethane from Anaerobic Digestion of Wastewater Sludge
Biomethane from Organic Waste
Biomethane from Dairy and Swine Manure

https://ww3.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm

Dairy and Swine Manure Considerations

Baseline

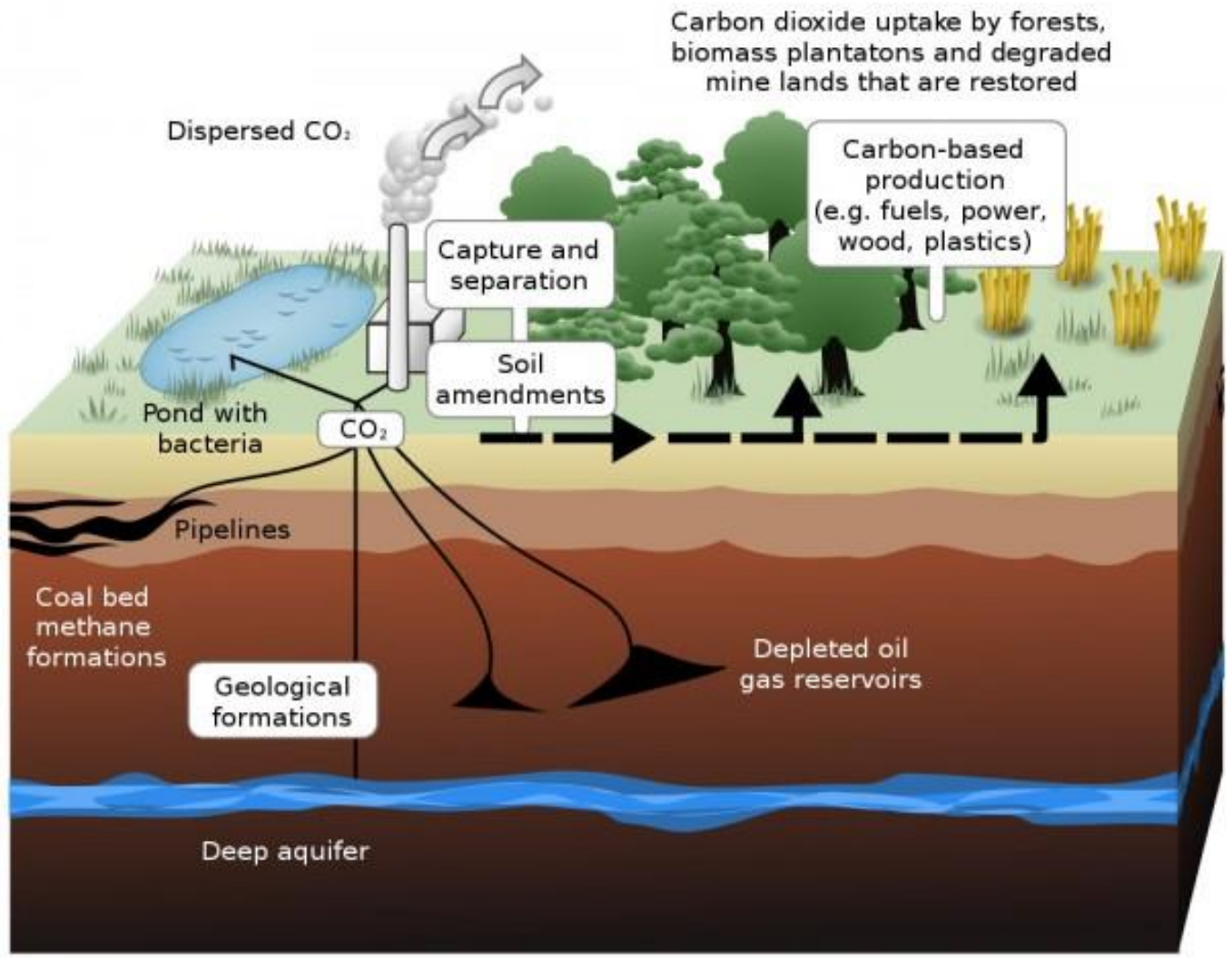
- VS% to lagoon (Solid separation, other manure management systems)
- Lagoon cleanout
- Look back period if multiple manure management systems have been used
- Carryover of manure

Project

- Biogas yield
- VS in effluent to storage lagoon
- Process energy
- Real farm data vs. CARB default data for cows related

What is Carbon Capture and Sequestration (CCS)?

- Carbon is permanently taken from the atmosphere
- For CARB that means 100 years of storage



Source: https://www.climatechangenews.com/

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CCS Projects

Technologies	Announced Projects	Approximate Ethanol CI Reduction, g/MJ	MGPY Ethanol
Carbon Capture and Sequestration	ADM Decatur	TBD	375
	Red Trail	(32)*	60
	Catahoula/Chief Ethanol	TBD	110
	Summit Agriculture Group / Corn LP; Dakota Ethanol; Glacial Lakes Energy; Golden Grain Energy; Granite Falls Energy; Green Plains, Inc.; Heron Lake BioEnergy; Highwater Ethanol; Homeland Energy Solutions; Lincolnway Energy; Little Sioux Corn Processors; Pine Lake Corn Processors; Redfield Energy; Ringneck Energy; Siouxland Energy Cooperative; and Tharaldson Ethanol	TBD	1,700
Enhanced Oil Recovery	Occidental Petroleum / White Energy	(25.56)*	240

** CARB published design-based pathway estimate*

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Agricultural Practices

LCFS Model - Corn farming and transportation burden of 28 to 30 g/MJ

- Farming energy, 3.2+/- g/MJ
- Fertilizers, 12 +/- g/MJ
- N_20 emissions from soil, 14.8 +/- g/MJ
- Plus soil carbon sequestration

Establish lower site-specific farm practices scores and monetize the carbon reduction through the ethanol plant on ethanol shipped to LCFS

Argonne announces average ethanol CI reduced from 58 to 45 g/MJ – Biofpr – September/October 2021

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Site-Specific Farm Practice Challenges

Corn farming and transportation burden of 30 g/MJ

- Establish standards for low-CI farming practices;
  - No till
  - Fertilizer usage
  - Nutrient runoff prevention
  - Carbon sequestration (CCS)

- Establish farm practices verification program for Midwest

- The farm practices verification program must be recognized by voluntary and LCFS programs

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Site-Specific Farm Practices

Based upon USDA Comet Model for Nebraska no till and cover crops

- No till, 0.3-0.6 MT CO2/acre per year
- Cover crops, 0.2-0.4 MT CO2/acre per year
- Combined no till plus cover crops, 0.5-1.0 MT CO2/acre/year

Here we could be tied into a voluntary or transportation market.

EcoEngineers white paper: Midwest soil could be huge carbon reservoir

https://tinyurl.com/carbon-reservoir

Description	Average
No Till Average CS	0.152 MT C/acre/yr
Cover Crops Average CS	0.10 MT C/acre/yr
Total CS as Carbon	0.25 MT C/acre/yr
Total CS as CO2	0.93 MT CO2/acre/yr
Per Acre $35/MT CO2 (BCG 2025)	$32.40 / acre
Per Acre $80/MT CO2 (BCG 2030)	$74.07 / acre
Per Acre $100/MT CO2 (50% LCFS)	$92.59 / acre

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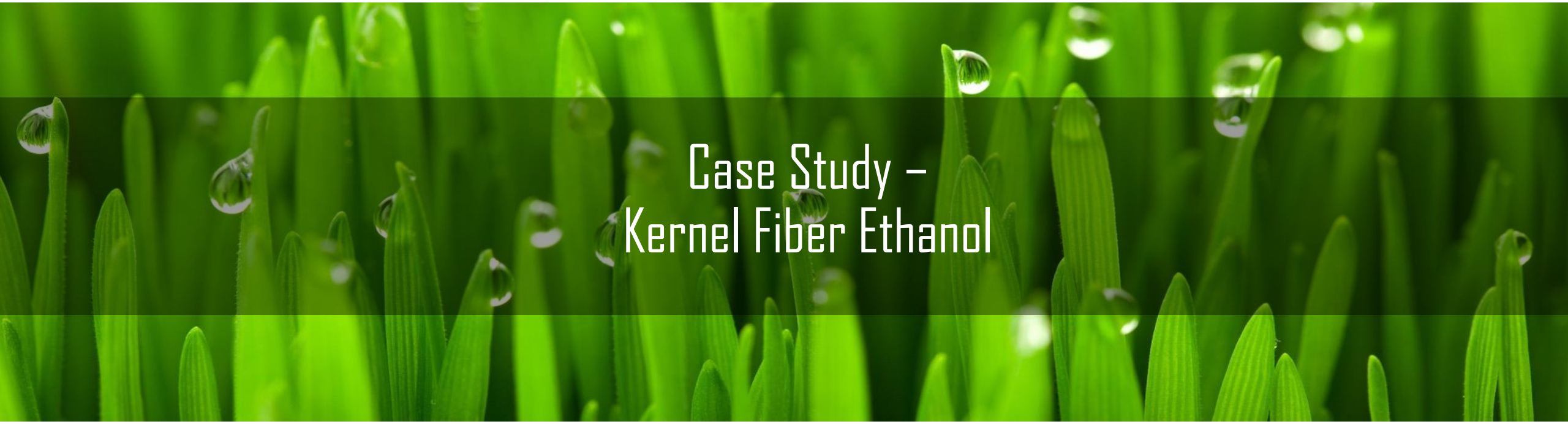


Case Study –
Kernel Fiber Ethanol

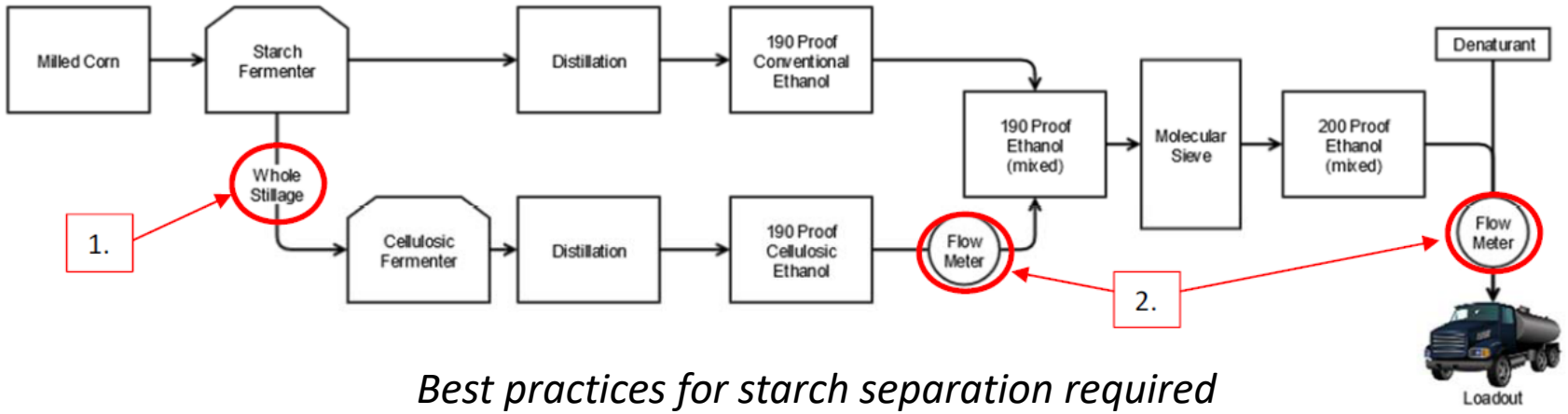
Evaluating Kernel Fiber Ethanol CI - LCFS

- No iLUC (Indirect land use change, 19.8 gCO_2e/MJ for Corn Ethanol)
- No corn farming and transportation burden, 30.1 gCO_2e/MJ
- CI is in the range of 20-40 gCO_2e/MJ
- Adaption of non-baseline methods have increased converted fraction of cellulose vs. early baseline methods (2-5% kernel fiber gallons is common in-situ coprocessing and 7-10% through separate processing)
- ASTM E3181-20 Standard Practice for Determination of the Converted Fraction of Starch and Cellulosic Content From a Fuel Ethanol Production Facility

This presentation is based only upon the LCFS. If the RFS re-opened kernel fiber in 2021 or beyond, the kernel fiber gallon could be worth D3-D6 value now at $1.20 and IRS Producer Tax Credit of $1.01

Separate vs. Simultaneous

Separate Hydrolysis

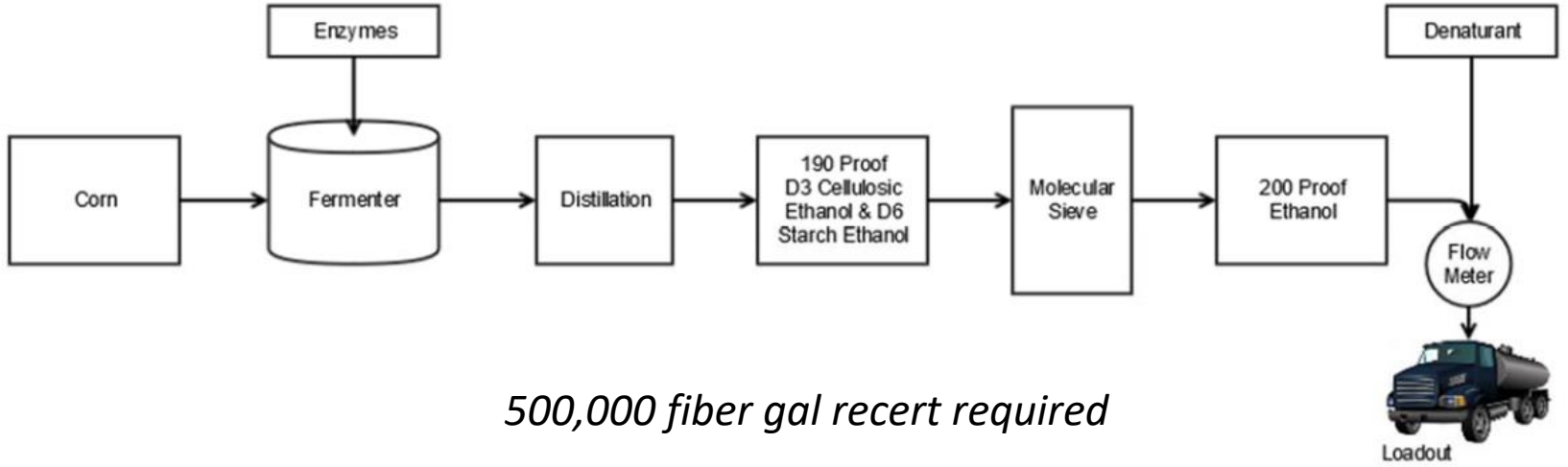


Best practices for starch separation required

RFS Pathways

- QCCP (since 2014)
- ACE D3Max (2020)

In-situ Coprocessing Simultaneous Hydrolysis



500,000 fiber gal recert required

5 RFS Pathways
(up to Dec 2017)
Edeniq 1.0

50 LCFS Pathways
Edeniq 1.0/2.0
Soliton

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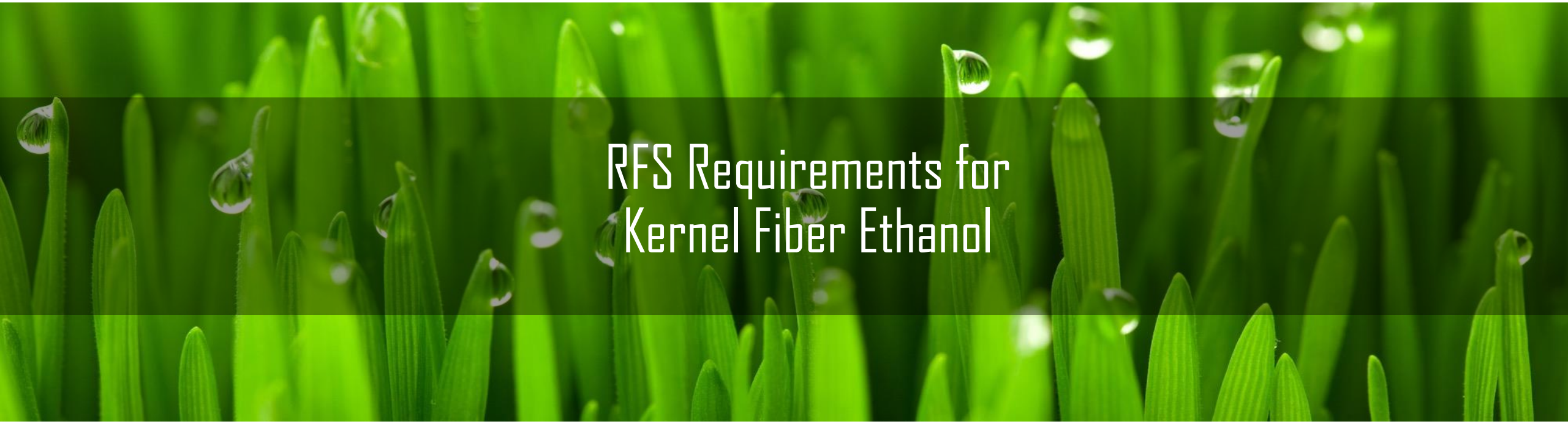

RFS Requirements for Kernel Fiber Ethanol

Approved Pathways Under the RFS

Fuel Type	Feedstock Type	Production Process	D-Code
Cellulosic ethanol (60)	Cellulosic biomass – agricultural residues (70)	Cellulosic production process (280)	3
Renewable compressed natural gas, renewable liquefied natural gas, and renewable electricity	Biogas from waste digesters	Any	5
Renewable compressed natural gas, renewable liquefied natural gas, renewable electricity	Biogas from landfills, municipal wastewater treatment facility digesters, agricultural digesters, and separated MSW digesters; and biogas from the cellulosic components of biomass processed in other waste digesters	Any	3

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RFS Pathways 2

Registration Requirements:

- Process diagram; description of the treatment process; description of pre-treatment; third-party engineer verification
- Peer review of non-VCSB laboratory methods
- Initial converted fraction based on a minimum of three batch trials
- Initial converted fraction must be submitted with the registration and remains valid for first 500,000 gallons
- The overall fuel yield including supporting data and a discussion of possible variability
- The cellulosic converted fraction including supporting data and a discussion of variability
- A description of how the cellulosic converted fraction is determined

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Method A Feedstock Energy Equation

$$FE = M(1 - m) \cdot CF \cdot E$$

$$FE_{mf} = (1000 \cdot 0.04)\ (1\text{-}0.15)\ (0.35)\ (7{,}600)$$

$$= 90{,}440$$

$$FE_{st} = (1000 \cdot 0.75)\ (1\text{-}0.15)\ (0.95)\ (7{,}600)$$

$$= 4{,}602{,}750$$

(Simultaneous or in-situ biochemical processing)

$$V_{RIN} = EV \cdot VS \cdot \frac{FE_{D3}}{FE_{D6} + FE_{D3}}$$

$$V_{RIND3} = 1.0 \cdot 64{,}158 \cdot \left(\frac{90{,}440}{4{,}602{,}750 + 90{,}440}\right)$$

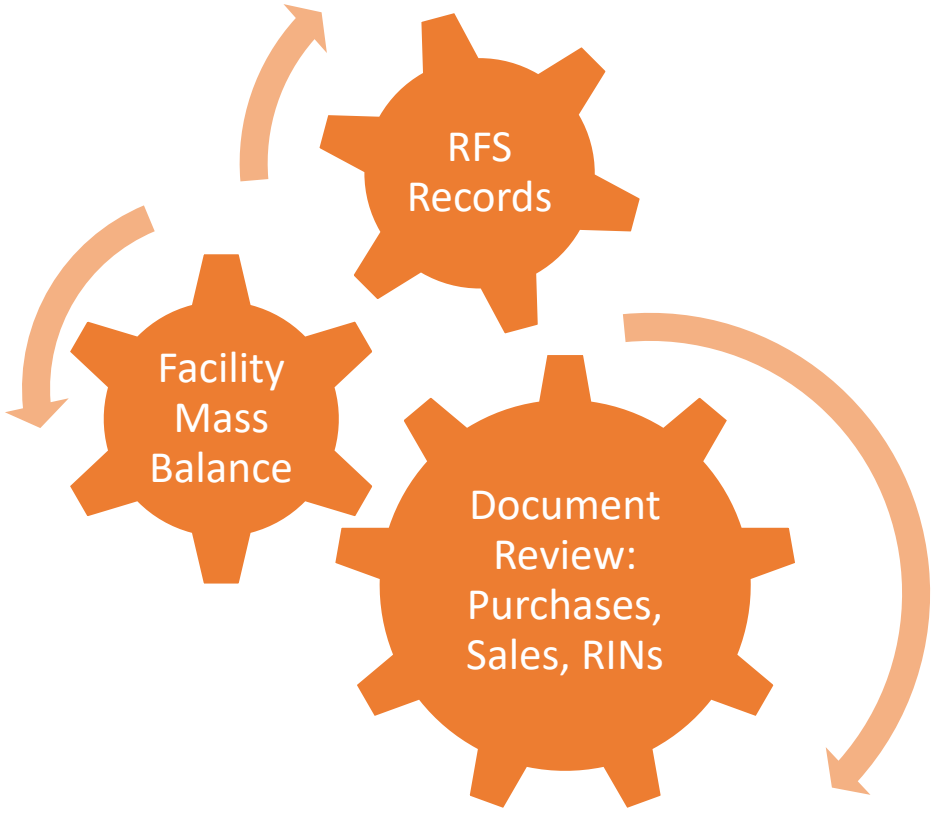
$$V_{RIND3} = 1{,}236 \text{ gallons for D3}$$

Q-RIN Requirements

- The Quality Assurance Program (QAP) is a voluntary audit program for RIN generators
- Put into place after widespread RIN fraud destabilized RIN markets
- Auditors must receive annual approval by the USEPA and meet strict independence criteria

Benefits:

- RINs receive a “Q-RIN” tag in EMTS
- Obligated parties who utilize Q-RINs for their compliance obligation receive an affirmative defense against notices of violation.



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LCFS Requirements for Kernel Fiber Ethanol

LCFS Pathway Types in 2019 and Beyond

Look-up Table Values (§ 95488.5. Table 7-1)	Tier 1 Pathways (Tier 1 Calculators)	Tier 2 Pathways (CA-GREET 3.0)
CARBOB	**Biodiesel**	Tier 1 Fuels using Innovative Method meeting substantiality requirements: ▪ 5% lower if reference above 20 CI ▪ 1 CI lower if reference below 20 CI
Diesel	**Renewable Diesel**	**Wet Mill Ethanol**
CNG	**LNG, CNG from North American NG**	**Plastic to Fuel**
Propane	**Ethanol** ▪ Starch ▪ Fiber ▪ Sugarcane	**Pyrolysis Oil**
Hydrogen	**Biomethane** ▪ N.A. Landfills ▪ Anaerobic Digestion of Wastewater ▪ Organic Waste ▪ Dairy and Swine Manure	**Next Generation Fuels**
Electricity ▪ Grid ▪ 100% Zero-CI ▪ Smart Charging		

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Fuel Pathway Allocation

- **Kernel fiber ethanol**
  - Converted fraction re-calculated within 10 business days of producing 500,000 gallons
  - Changes to testing method must be approved by CARB
  - Physical inventory limits apply
- **Multiple co-products – wet, mod, dry DDG**
  - Associate the produced ethanol in proportion to the “bone dry” co-product stream fraction

* § 95491.(d)(1)(B)

Adding economic technology to your plant location to convert low value fiber to higher value ethanol and higher protein feed

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Types of LCFS Reporting

- **LRT reporting**
  - These quarterly reports and annual report are to report the number of gallons and fuel pathways used related to LCFS credits
- **LCFS Verification**
  - LCFS verification will have an option to be completed quarterly or annually, with an annual verification report due August 31 of each year
- **Fuel Pathway Report**
  - Must be completed by all fuel pathway holders starting in 2021 for 2019 and 2020 data
  - Report uses same calculator as original application, but it includes the most recent calendar year of operational CI data (rolling two-year data period)

Monitoring Plan

- **Each entity responsible for obtaining validation and verification must retain a Monitoring Plan**
- Includes:
  - General overview of facility and boundaries
  - Methods, processes, and methodologies used to collect and record data
  - Sources of data and related diagrams
  - Identification of measurement devices
  - Calibration information, and more
- Should be in place when applying for 3.0 pathway

LCFS Verification Requirements

Initial Validation (one time)

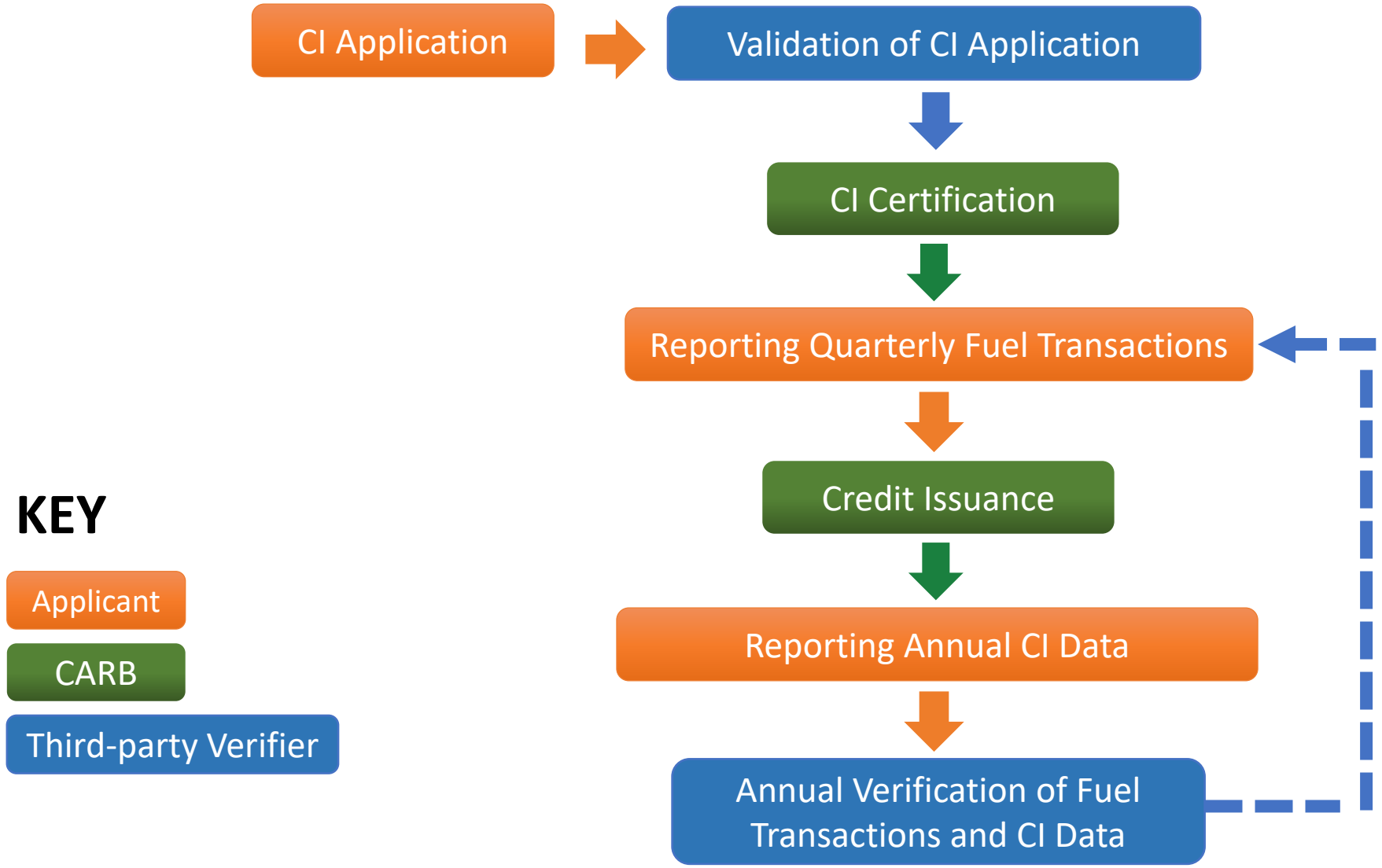
- Site Visit (starting 2020)
- Initial review and statement to certify pathway

Ongoing Verification Services

- Fuel pathway report review
  - Verification of CI score components
- Verification report
  - Verification of data collected and reported
- Site visit
  - Annual visit for verification

(Verification may occur on a quarterly or annual basis)

CARB Overview of Program Structure



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In-situ Kernel Fiber Timetable

Phase	Activity	Schedule (Months)	Calendar Days	Ledger (11K Fiber GPD)
Beta Testing	Beta Testing, Enzyme Trials, Fiber Conversion Testing	Varies	Varies	-
	Determine Enzyme Type/Dosage			
Batch Trials	Start enzyme dosing	1	0	-
	Plant at steadiy state		10	
	First batch sample, pre-conversion		8	
	Batch sampling (3 minimum), pre and post-conversion, including prep and ship			
90-Day Data	Start 90 Day Data, Begin Temporary Pathway (CI=50), Date of last batch sample	3	90	-
	Fiber and Starch Conversion Data from Lab			-
	Calculation of %Kernel Fiber Gallons by Producer			-
	Hit 500K Cellulosic Gallons			500K
	Deadline to Recertify 500K Cellulosic Gallons			Deadline
	Hit 500K Cellulosic Gallons			500K
	90 Day Data Set Complete			-
	Deadline to Recertify 500K Cellulosic Gallons			Deadline
	Submit Data to EcoEngineers		7	-
Pathway Preparation, Validation, CARB Approval	Pathway Application Preparation	3	30	-
	Pathway Application Submission to CARB			-
	Hit 500K Cellulosic Gallons			500K
	CARB Review		15	-
	Deadline to Recertify 500K Cellulosic Gallons			Deadline
	Validation		30-45	-
	Hit 500K Cellulosic Gallons			500K
	CI Certification by CARB, Begin Provisional Pathway (CI = 25 +/-)		15	Deadline

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Kernel Fiber Now™

Kernel Fiber Now™ connects you to our team of professionals who can help connect you to cellulosic ethanol markets:

- 80 million current but expanding from 300 million to 1.5 billion gallon (2-10%) potential ethanol market
- LCFS open and encouraging new kernel fiber pathways
- Non-baseline ASTM E3180-20 count more kernel fiber gallons
- Kernel fiber gallons can be a 40 CI points reduction vs. starch gallons (at 1.6 cents/gallon this could be a total market value adder of $0.50-$0.86/gal)
- If the NIST Standards, NREL Standard Method, and RFS registration of in-situ coprocessing opens up you could add D3-D6 split of $1.30 and potentially IRS Credit of $1.01 (*or you could do this now using separate hydrolysis)*

KERNEL FIBERNOW
THE NEW LOW CARBON FUEL

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