# California Low Carbon Fuel System

## Salient Features
## &
## Comparison of Storage Protocol with EPA Class VI Regulations

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Forum on Carbon Capture Utilization and Storage in Kansas
Lawrence, KS
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# Outline

- LCFS – Salient features
- Comparison of LCFS and EPA Class VI geologic storage regulations
- Potential $CO_2$ uses and markets in future

## California Air Resource Board

# Low Carbon Fuel System (LCFS)

- **Market based system** to reduce carbon footprint of transportation fuels

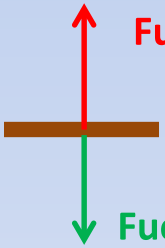
- **Fuel distributors** are required to ensure that their products sold in California meet targets for greenhouse gases (GHG) emissions by either producing low Carbon Intensity **(CI)** fuels or purchasing credits from producers/distributors of lower CI fuels sold in CA

- **Technology neutral:** CI can be lowered by using biofuels, renewables, implementing efficiencies, etc

# LCFS - Key Concepts

- **Carbon Intensity (CI)** of a fuel = grams of $CO_2$ equivalent emitted through the production and transportation life cycle per MegaJoule of energy delivered by the fuel **(gCO2/MJ)**

- **Annual CI Target set by CARB**



**Fuel with CI > Target CI generates deficit**

**Recent gasoline CI = 92**

**Fuel with CI < Target CI generates credit**

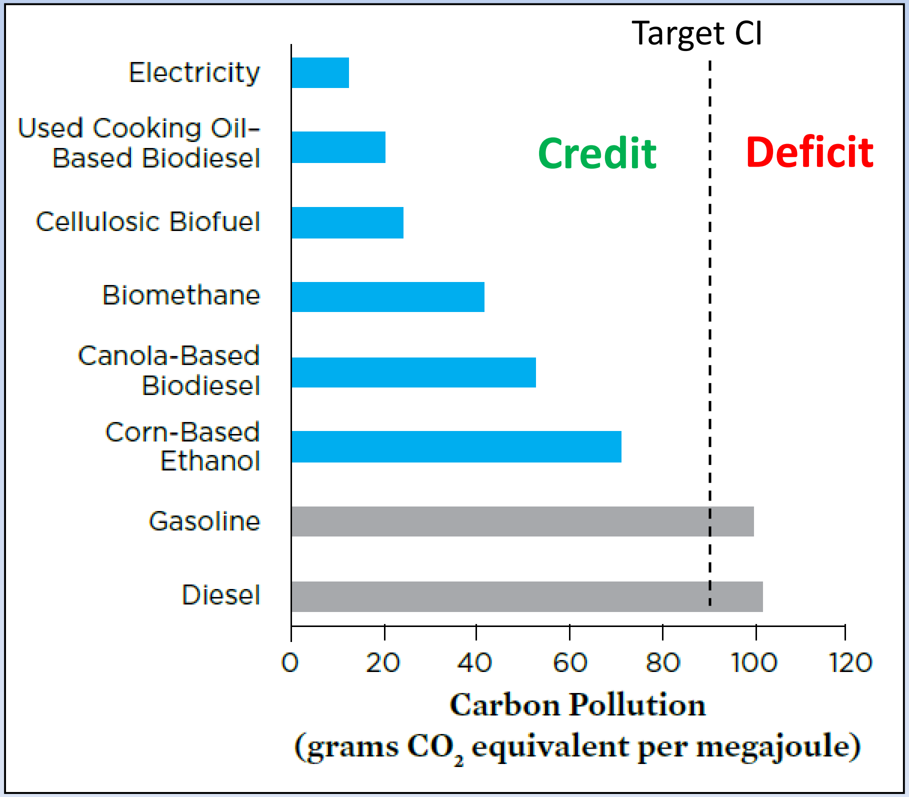
- Separate CI targets for “Reference Fuels” - gasoline, diesel, and jet fuel

- Applies to fuels sold in CA but origin of fuel can be anywhere

- Each producer has to get the approval for the CI of their fuel

- A fuel supplier with CI less than Target CI does not need to participate but can choose to opt-in to avail credits

# Example CI for Representative Fuels



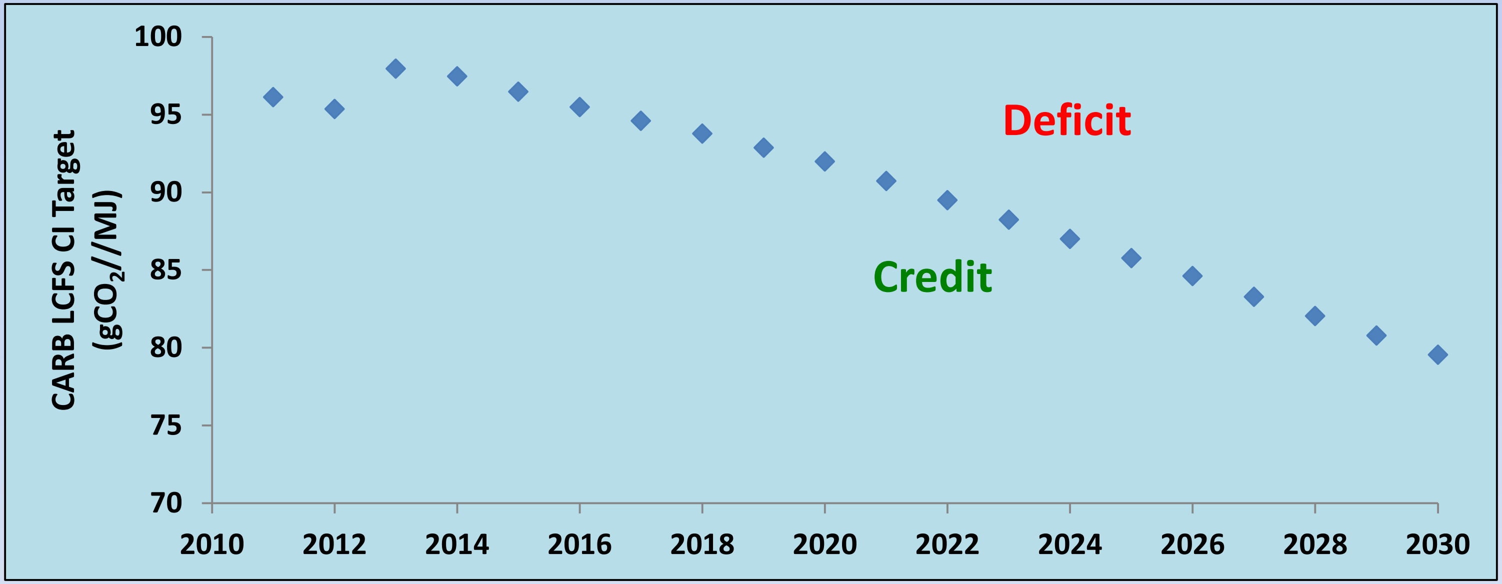
- **CI score not the whole story:**
  - In the long run, fuels with low production/distribution costs per CI will dominate

# LCFS provides strong incentive for emergence of new low CI fuels

- An existing project using Renewable Natural Gas (RNG) generated from anaerobic digestion of dairy manure has an assigned CI value of -250

RNG, CI = -250

# LCFS Annual CI a moving Target

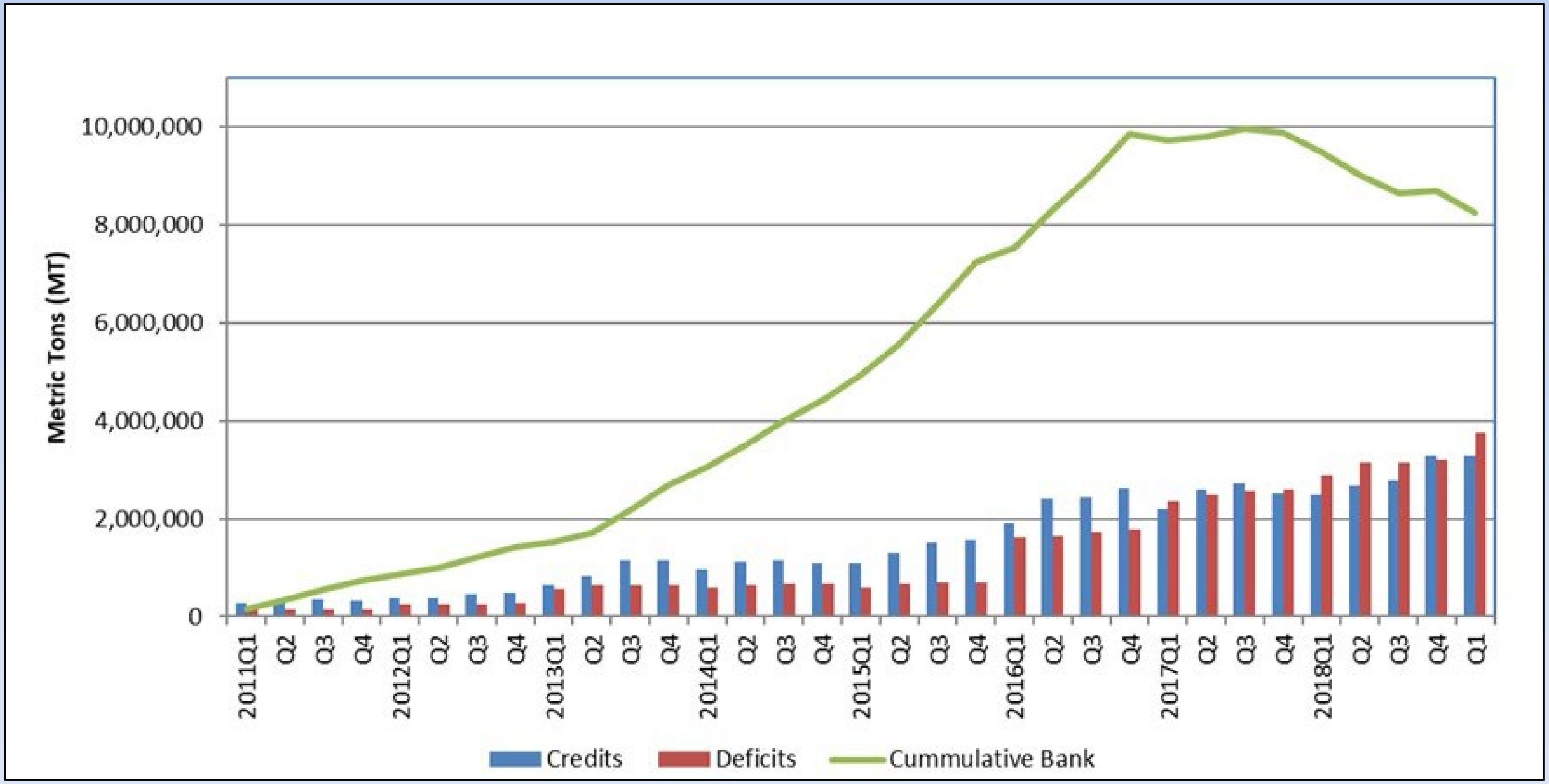


- As more and more low CI fuels enters the market, CARB will lower the Target CI
- Aggressive Target CI may make future credit generation challenging with existing technology and fuel source

# Historical LCFS Credit Pricing

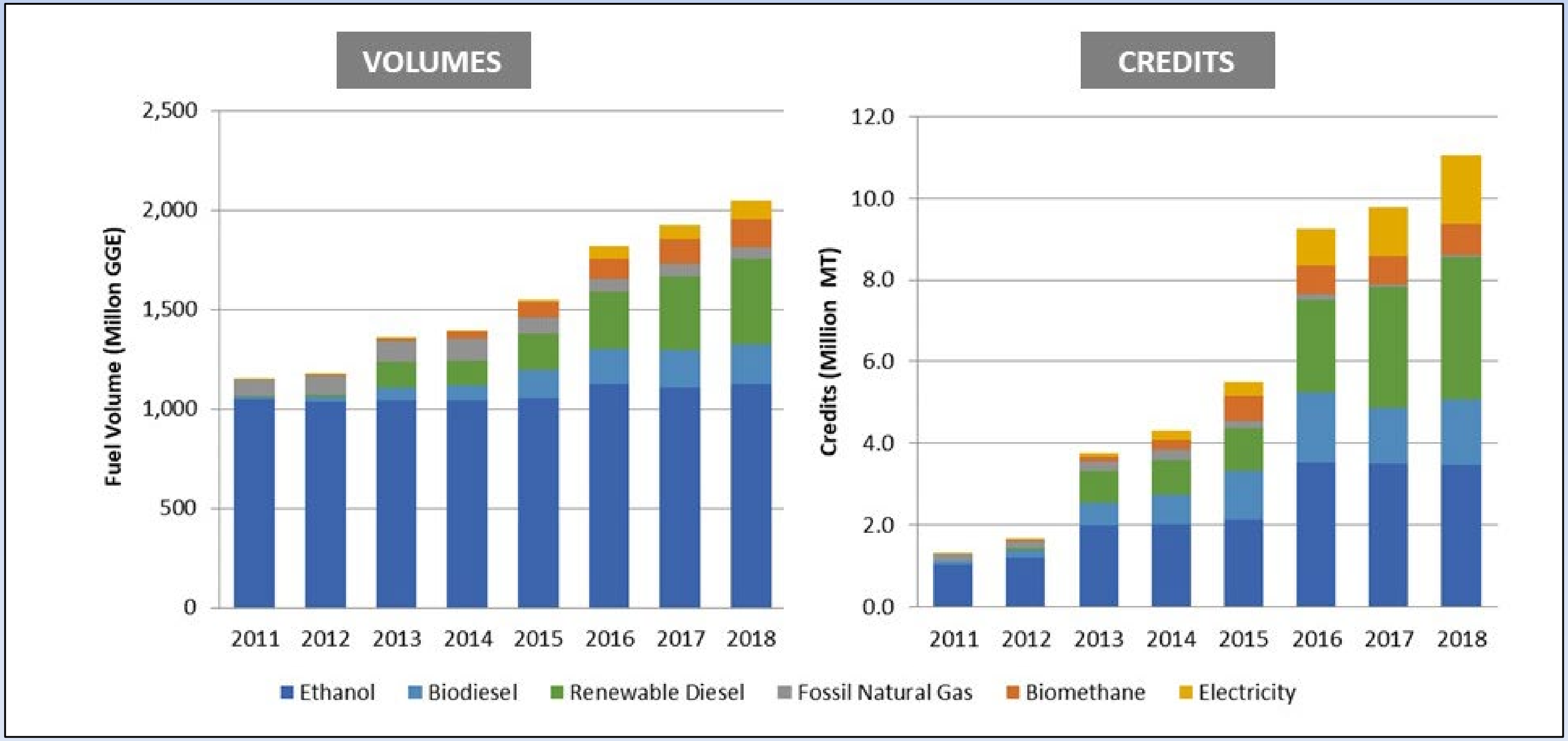
- 1 LCFS credit = 1 MT of CO2 equivalent reduced
- Capped at $200//ton (2016 equivalent)
- Credits never expire
- Credits prices can rise despite good balance between credit and deficits due to hoarding in anticipation of a future rise

# History of LCFS Credits and Deficit Generated

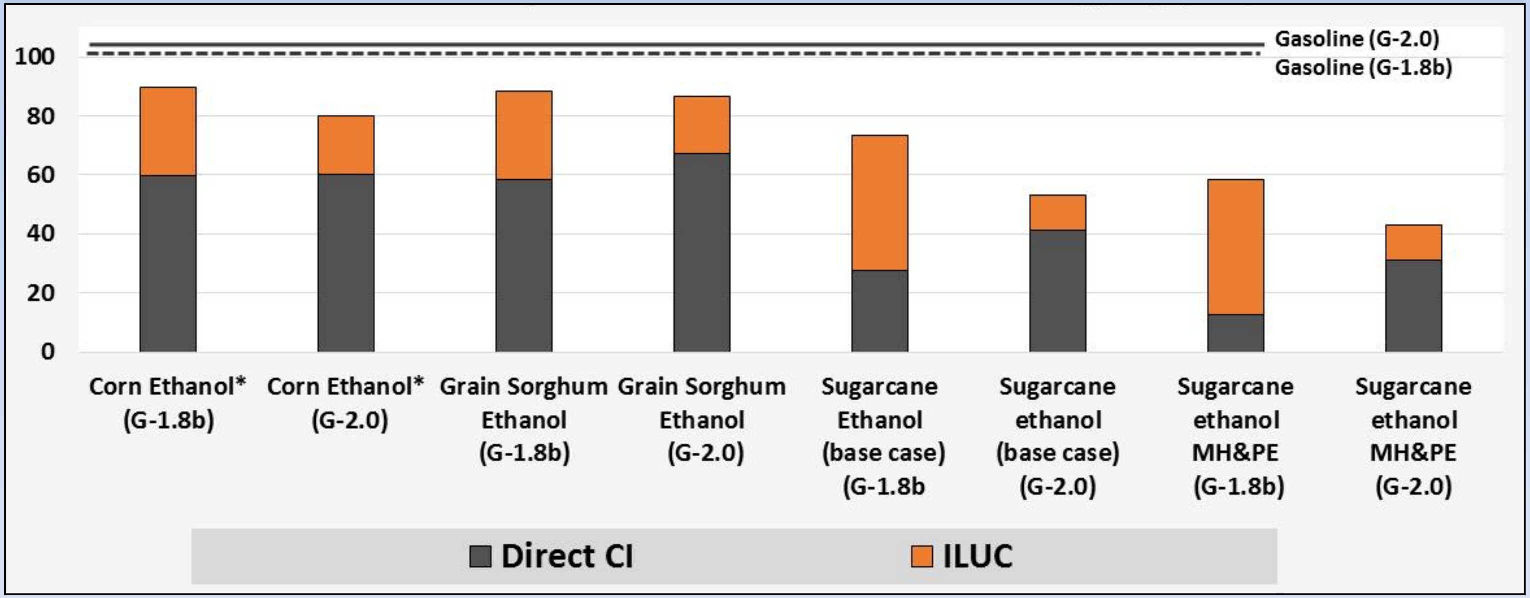


- **Strong demand for credits recently**

# Credits Generated by Source Type

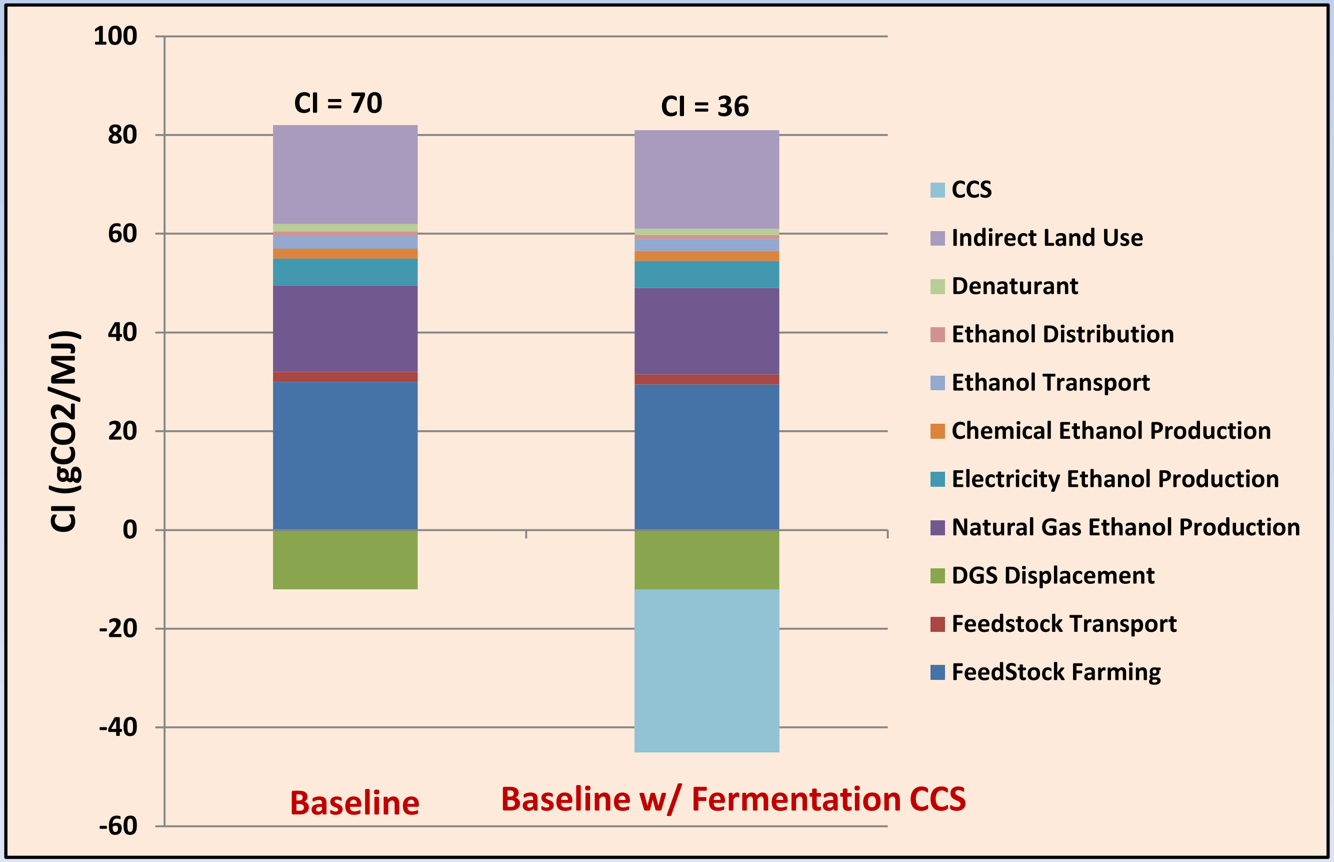


# CI of Ethanol Based on Source and Geographic Locations



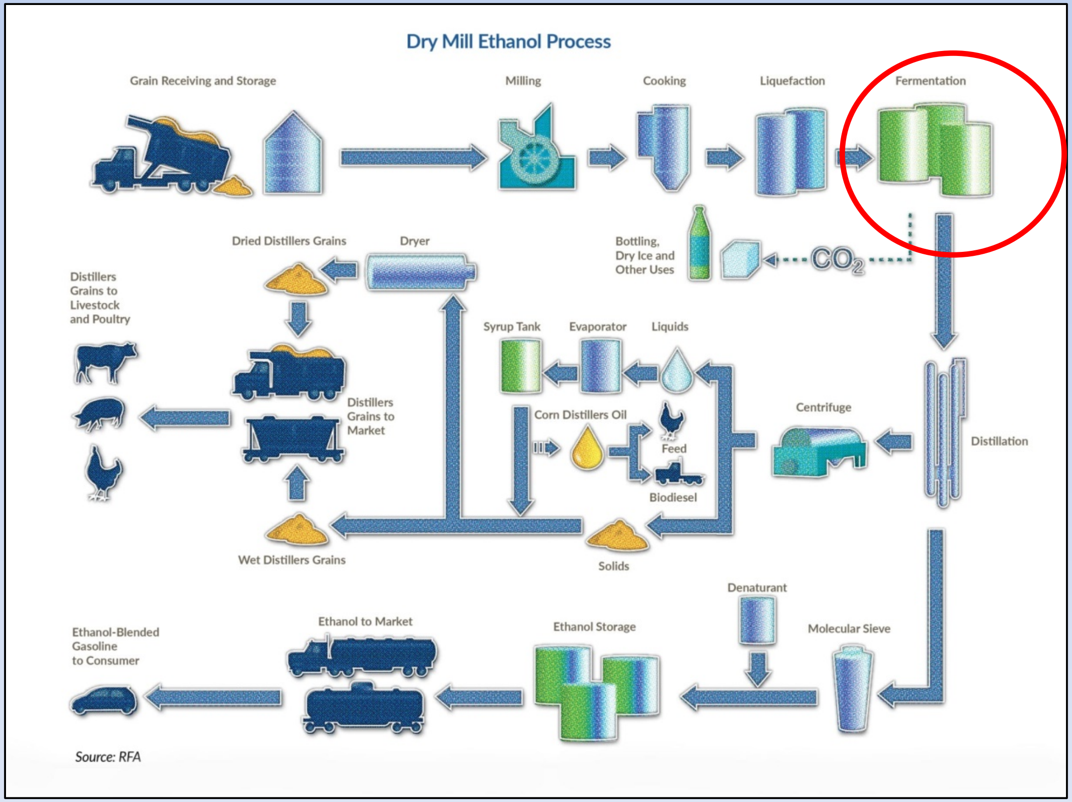
- InDirect Land Use Change (ILUC) a major contributor to biofuel CI
  - Controversial and contested - if abandoned could give a huge boost to ethanol

# Representative Carbon Intensity (CI) Components for an Efficient Kansas Ethanol Plant



- CI Reduction of 33 with fermentation Carbon Capture and Onsite Storage
- At $150/ton LCFS credit → $0.45/gal (roughly equals transportation cost to CA)

# Additional opportunities for lowering CI at ethanol plants

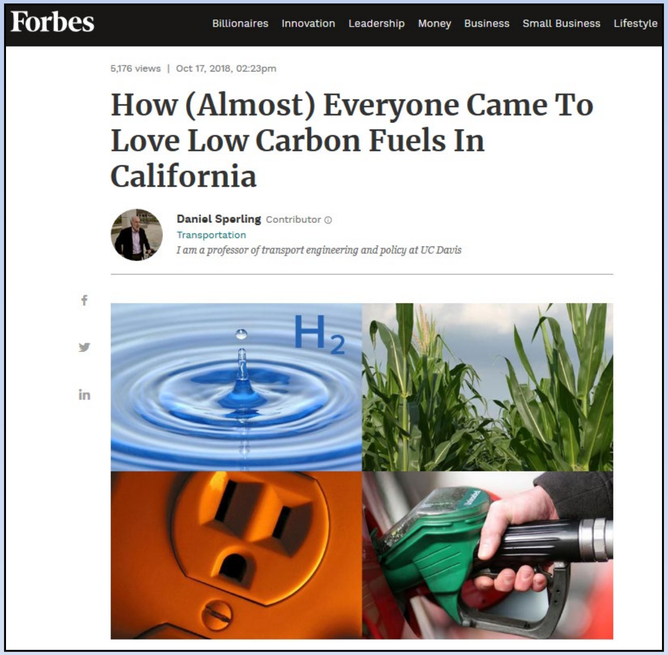


Source: RFA

Present focus on capturing and sequestering $CO_2$ from fermentation

- Potential for further reduction of CI associated with steam, cooling, and power generation

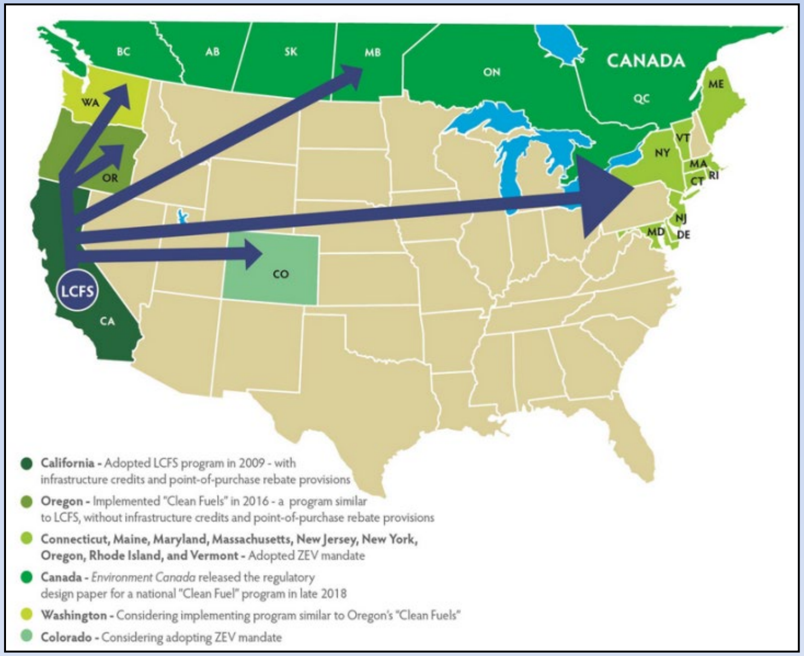
# LCFS Gaining Recognition and Being Followed Worldwide



5,176 views | Oct 17, 2018, 02:23pm

How (Almost) Everyone Came To Love Low Carbon Fuels In California

**Daniel Sperling** Contributor
Transportation
*I am a professor of transport engineering and policy at UC Davis*

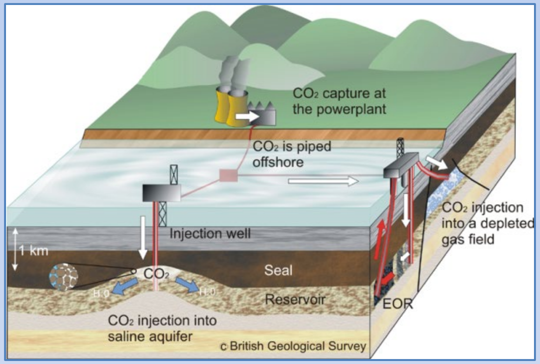


- ● **California** - Adopted LCFS program in 2009 - with infrastructure credits and point-of-purchase rebate provisions
- ● **Oregon** - Implemented "Clean Fuels" in 2016 - a program similar to LCFS, without infrastructure credits and point-of-purchase rebate provisions
- ● **Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, and Vermont** - Adopted ZEV mandate
- ● **Canada** - *Environment Canada* released the regulatory design paper for a national "Clean Fuel" program in late 2018
- ● **Washington** - Considering implementing program similar to Oregon's "Clean Fuels"
- ● **Colorado** - Considering adopting ZEV mandate

- ➢ Over 20,000 jobs created in California alone
- ➢ 38 million ton reduction in $CO_2$ emissions (over $1B of credit)
- ➢ Big boost for ethanol producers if an equivalent credit based system adopted closer to the Midwest

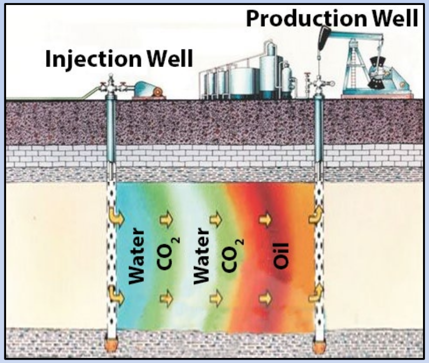
# CI Reduction under LCFS Carbon Capture and Sequestration Protocol

## Saline Storage



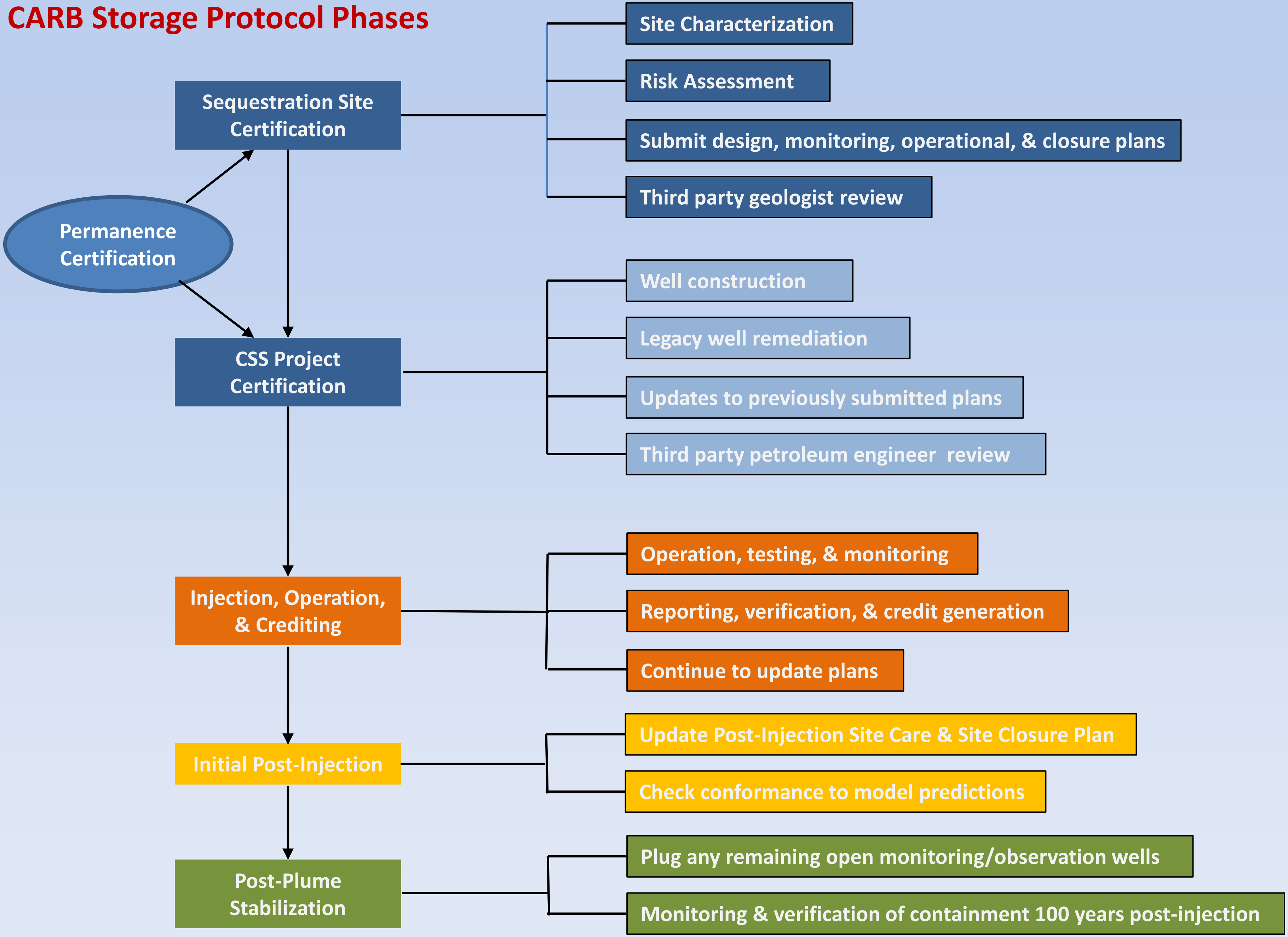
c British Geological Survey

## Enhanced Oil Recovery (EOR)



- Need a state or federal UIC permit in the U.S.
- Class II injection permits are acceptable for $CO_2$-EOR, but the project has to comply with all LCFS storage regulations

# CARB Storage Protocol Phases



Permanence Certification

Sequestration Site Certification

- Site Characterization
- Risk Assessment
- Submit design, monitoring, operational, & closure plans
- Third party geologist review

CSS Project Certification

- Well construction
- Legacy well remediation
- Updates to previously submitted plans
- Third party petroleum engineer review

Injection, Operation, & Crediting

- Operation, testing, & monitoring
- Reporting, verification, & credit generation
- Continue to update plans

Initial Post-Injection

- Update Post-Injection Site Care & Site Closure Plan
- Check conformance to model predictions

Post-Plume Stabilization

- Plug any remaining open monitoring/observation wells
- Monitoring & verification of containment 100 years post-injection

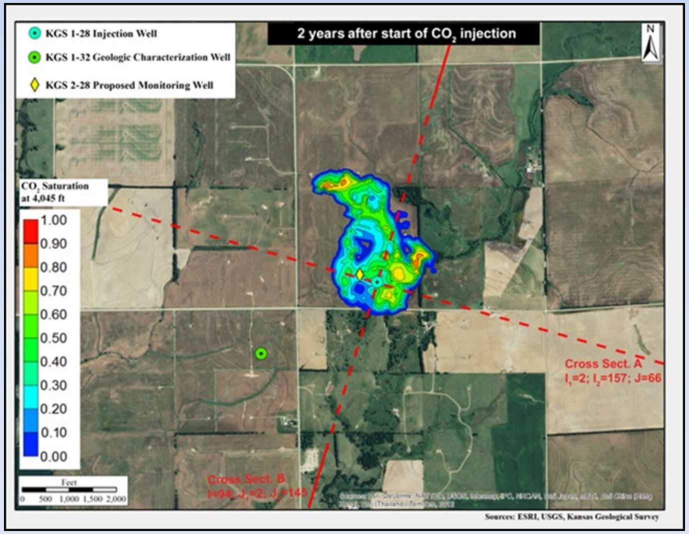
# EPA "Area of Review" versus CARB "Storage Complex"

## EPA Area of Review (AoR)

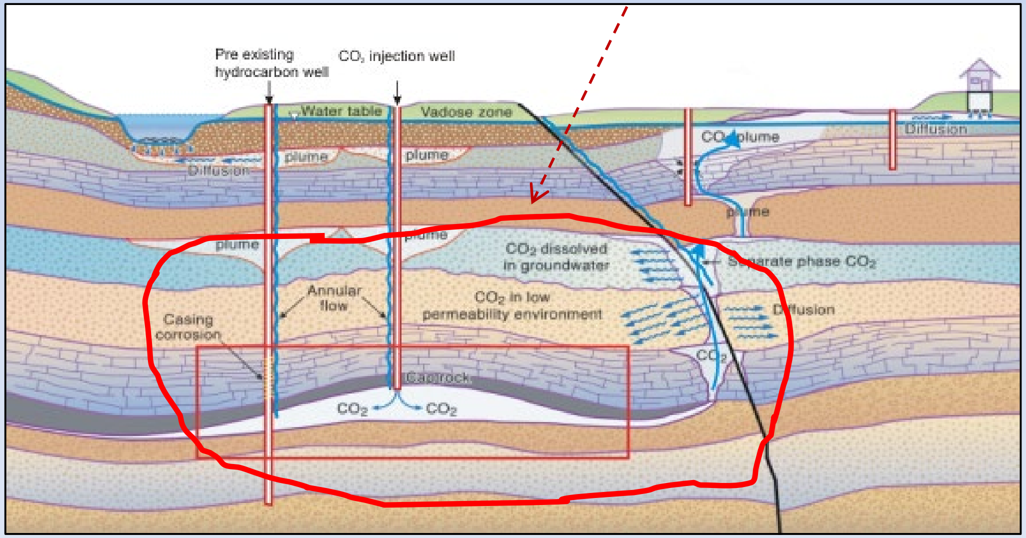
- 2-D Surface Projection

## CARB Storage Complex

- 3-D Subsurface Volume for Containing CO2



Sources: ESRI, USGS, Kansas Geological Survey



# Eligible projects for generating credits under LCFS

| | Industrial Plant | Oil & Gas Field | Direct Air Capture |
|---|---|---|---|
| |  |  |  |
| **Location** | **Anywhere, fuel has to be supplied to CA** | **Anywhere, fuel has to be supplied to CA** | **Anywhere in the world, no need to supply fuel to CA** |
| **Special Restrictions** | **None** | **Must meet minimum CI** | **None** |

# Site based Risk Assessment for $CO_2$ leakage

- Applicant must prepare a list of all potential leakage scenarios and associated $CO_2$ migration pathways, and assign a risk-rank

**Risk Classification for Each Leakage Scenario**

| Probability of Occurrence | Insubstantial | Substantial | Catastrophic |
|---|---|---|---|
| > 5% | Medium risk | **High risk** | **High risk** |
| 1-5% | Low risk | Medium risk | **High risk** |
| < 1% | Low risk | Medium risk | Medium risk |

- **Project cannot be approved if any leakage scenario has a High Risk classification**
  - **CARB allows for mitigation to reduce risk ranking**

- Sites that have a > 90% probability of retaining 99% of the injected $CO_2$ over 100-years are eligible for Permanence Certification

# LCFS CCS Buffer Account

- **Reserve to draw into due to future credit invalidation, deactivated accounts, etc**
- **Operator has to contribute 8 – 16.4% of credits annually to a Buffer Account based on the project's Risk Score**

| Risk Type | Risk Rating Contribution |
|---|---|
| Financial | 0 - 2% |
| Social | 0-3% |
| Management | 1-2% |
| Site | 1-2% |
| Well Integrity | 1-3% |

$$\mathit{CCS\ Project\ Risk\ Rating} = 105\% - [(100\% - \mathit{Risk}_{finacial})\ \mathrm{X}\ (100\% - \mathit{Risk}_{social})\ \mathrm{x}\ [(100\% - \mathit{Risk}_{management})\ \mathrm{X}\ (100\% - \mathit{Risk}_{site})\ \mathrm{x}\ (100\% - \mathit{Risk}_{well\ integrity})\ ]$$

# Comparison of LCFS and EPA Class VI Storage Regulations

| Activity | LCFS Storage Protocol | Class VI Regulation |
|---|---|---|
| Minimum Injection Depth | 2,800 ft | No minimum depth requirement |
| Site Characterization | | |
| Probabilistic Quantification of Leakage Risk | Yes | No |
| Fracture pressure of confining zones | Required from field test | No such testing requirement |
| Layered Confining Zone | Appears to be required | Not required |
| Maximum Injection Pressure | 80% of Fracture Gradient | 90% of Fracture Gradient |
| Lateral Extent of Area to be Protected | Based on the $CO_2$ plume migration | Based on larger of the $CO_2$ plume and “pressure front” |
| Modeling | | |
| Model system response to leakage through faults, fracture, and wellbores | Yes | Not a requirement |
| History Matching Required | Yes | Not a requirement |

| Activity | LCFS Storage Protocol | Class VI Regulation |
|---|---|---|
| **Well Corrective Action** | | |
| Wells Requiring Corrective Action | All wells within the surface projection of the Storage Complex | Only wells that penetrate the upper confining zone |
| Phased Approach for Corrective Action | Not specified | Permitted |
| Methods to Identify Wells Requiring Corrective Action | Site reconnaissance, interviews, physical search, aerial photography, satellite imagery, magnetic ground penetrating radar, electromagnetic survey, and methane detection methods | No firm requirements. State records sufficient for Wellington project |
| **Post Injection Site Care Period** | Minimum of 100-yrs following cessation of injection | Default: 50 yrs<br>ADM – Decatur, IL: 10 yrs<br>KGS – Wellington, KS: 4 yrs |
| **Financial Assurance** | Allows permittee to prepare cost estimates | The face value of liability largely provided by EPA |
| **Independent Third Party Review and Verification of All Work** | Required | Not Required |

| Activity | LCFS Storage Protocol | Class VI Regulation |
|---|---|---|
| **Induced Seismicity** | | |
| Geomechanical and hydrogeologic properties of faults including gouge | Needs to be determined from tests | Can be estimated from literature |
| Calibration of seismic array with check-shots, preferably at depth | Required | Not Required |
| **Monitoring** | | |
| Ecosystem stress monitoring | Required | Not a requirement |
| Indirect Pressure monitoring via satellite and tilt meters/inclinometers | Must be considered | At discretion of EPA UIC Director |
| Minimum of 1-yr baseline data for characterization and history matching | Required | Not a requirement |
| **Well Plugging** | | |
| Well Plugging | • Injection wells to be plugged within 24 months of cessation of injection<br>• Monitoring well to be plugged no sooner than 15 years after plume stabilization, followed by implementation of a Leakage Detection Plan | No minimum plugging timeline |

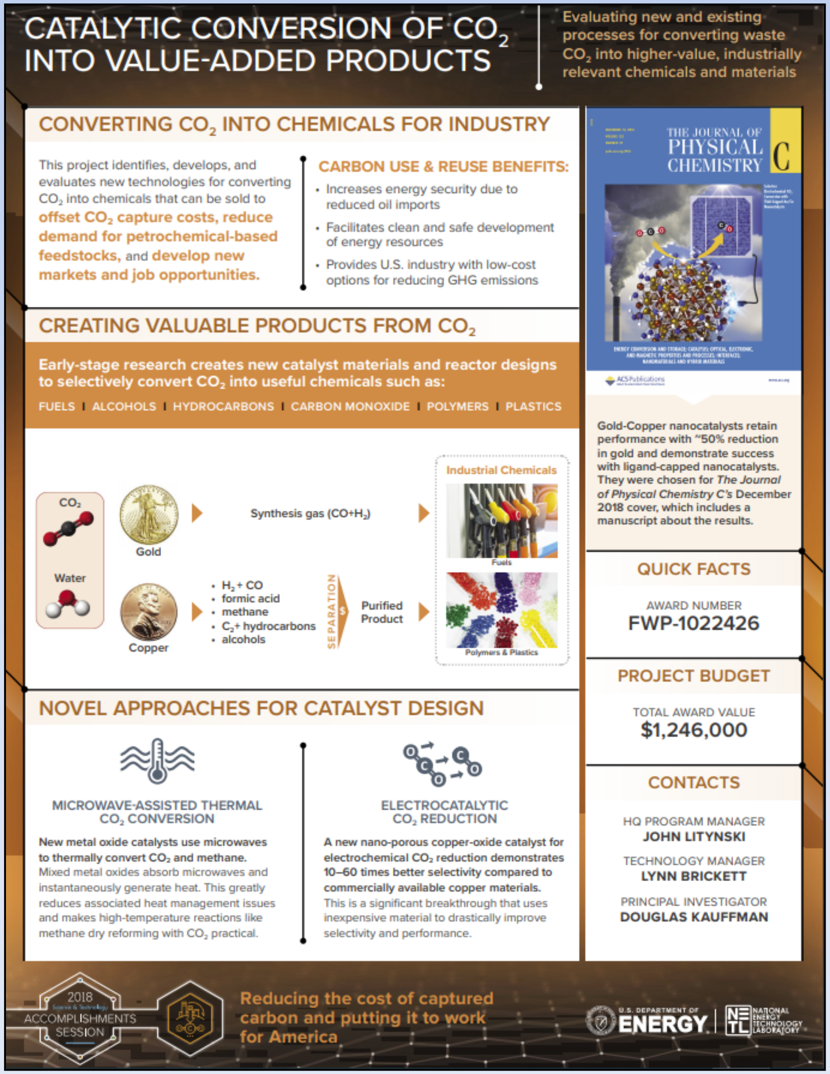
# Permits Timeline

- LCFS Site Certification and Project Certification (CARB target: 6 months for each)

## Timeline for Wellington, KS EPA Class VI Permit

| Date | Activity | Notes |
|---|---|---|
| Aug 2014 | Permit application submitted in new electronic format | |
| Oct 2014 – July 2015 | Spate of earthquakes experienced in KS & OK | First to research & develop methodology to EPA's satisfaction for determining likelihood of earthquake occurrence at $CO_2$ sequestration sites |
| Jan 2015 – Oct 2015 | Reworked hydrogeologic conceptualization to demonstrate absence of drinking water aquifer (USDW) | Successfully demonstrated absence of USDW – first of a kind in KS. Lowered financial obligations by several million dollars |
| Aug 2015 – Mar 2016 | Transportability and conversion problems between proprietary CMG modeling software and EPA's public domain STOMP model | Lack of software utility tools caused eight month delay |
| Mar 2017 | EPA provides written confirmation that all permit requirements fulfilled. Provisional permit can be issued after submitting draft Financial Assurance documents (no need for funding FA) | Wellington permit requirements fulfilled in a little over 2.5 years despite challenges and newness of program |

# Life Beyond LCFS and section 45Q Credits (DOE's Carbon Reuse Program)



## CATALYTIC CONVERSION OF $CO_2$ INTO VALUE-ADDED PRODUCTS

Evaluating new and existing processes for converting waste $CO_2$ into higher-value, industrially relevant chemicals and materials

### CONVERTING $CO_2$ INTO CHEMICALS FOR INDUSTRY

This project identifies, develops, and evaluates new technologies for converting $CO_2$ into chemicals that can be sold to **offset $CO_2$ capture costs, reduce demand for petrochemical-based feedstocks,** and **develop new markets and job opportunities.**

**CARBON USE & REUSE BENEFITS:**

- Increases energy security due to reduced oil imports
- Facilitates clean and safe development of energy resources
- Provides U.S. industry with low-cost options for reducing GHG emissions

THE JOURNAL OF PHYSICAL CHEMISTRY C

Gold-Copper nanocatalysts retain performance with ~50% reduction in gold and demonstrate success with ligand-capped nanocatalysts. They were chosen for *The Journal of Physical Chemistry C's* December 2018 cover, which includes a manuscript about the results.

### CREATING VALUABLE PRODUCTS FROM $CO_2$

**Early-stage research creates new catalyst materials and reactor designs to selectively convert $CO_2$ into useful chemicals such as:**

FUELS | ALCOHOLS | HYDROCARBONS | CARBON MONOXIDE | POLYMERS | PLASTICS

$CO_2$

Water

Gold

Synthesis gas ($CO+H_2$)

Copper

- $H_2$ + CO
- formic acid
- methane
- $C_2$+ hydrocarbons
- alcohols

SEPARATION $

Purified Product

Industrial Chemicals

Fuels

Polymers & Plastics

### QUICK FACTS

AWARD NUMBER
**FWP-1022426**

### PROJECT BUDGET

TOTAL AWARD VALUE
**$1,246,000**

### NOVEL APPROACHES FOR CATALYST DESIGN

**MICROWAVE-ASSISTED THERMAL $CO_2$ CONVERSION**

**New metal oxide catalysts use microwaves to thermally convert $CO_2$ and methane.** Mixed metal oxides absorb microwaves and instantaneously generate heat. This greatly reduces associated heat management issues and makes high-temperature reactions like methane dry reforming with $CO_2$ practical.

**ELECTROCATALYTIC $CO_2$ REDUCTION**

**A new nano-porous copper-oxide catalyst for electrochemical $CO_2$ reduction demonstrates 10–60 times better selectivity compared to commercially available copper materials.** This is a significant breakthrough that uses inexpensive material to drastically improve selectivity and performance.

### CONTACTS

HQ PROGRAM MANAGER
**JOHN LITYNSKI**

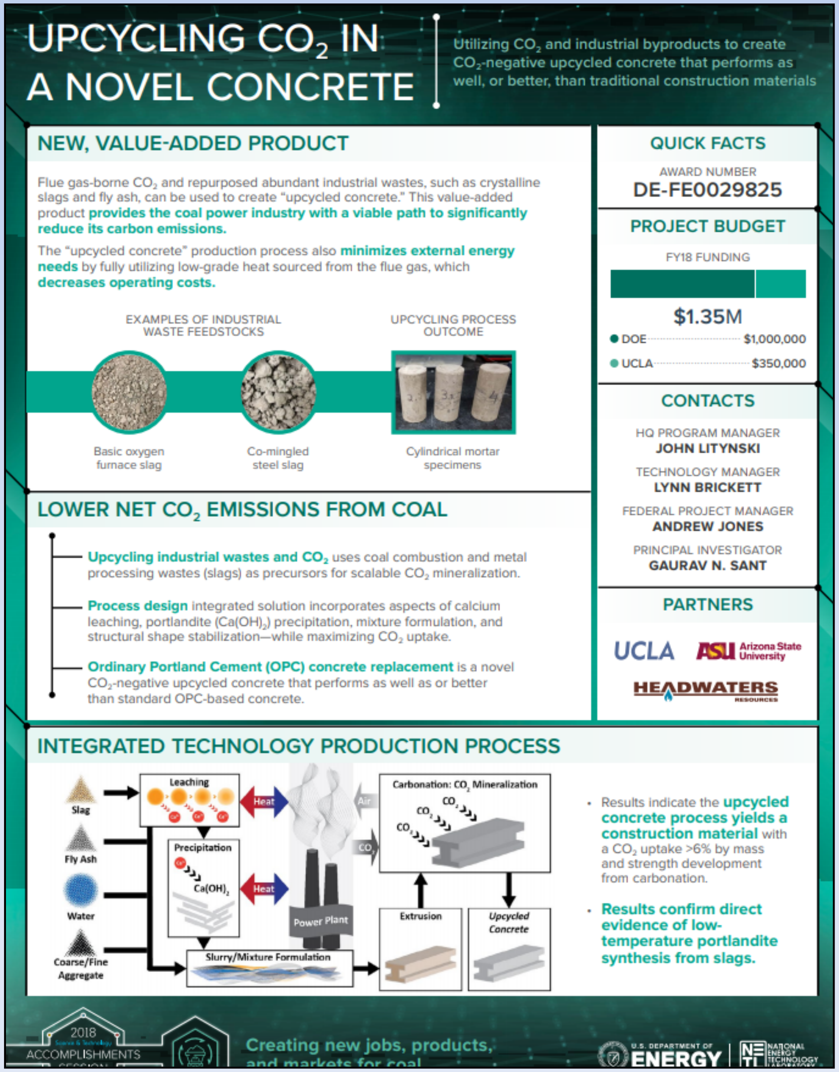
TECHNOLOGY MANAGER
**LYNN BRICKETT**

PRINCIPAL INVESTIGATOR
**DOUGLAS KAUFFMAN**

2018 Science & Technology ACCOMPLISHMENTS SESSION

Reducing the cost of captured carbon and putting it to work for America

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY



## UPCYCLING $CO_2$ IN A NOVEL CONCRETE

Utilizing $CO_2$ and industrial byproducts to create $CO_2$-negative upcycled concrete that performs as well, or better, than traditional construction materials

### NEW, VALUE-ADDED PRODUCT

Flue gas-borne $CO_2$ and repurposed abundant industrial wastes, such as crystalline slags and fly ash, can be used to create "upcycled concrete." This value-added product **provides the coal power industry with a viable path to significantly reduce its carbon emissions.**

The "upcycled concrete" production process also **minimizes external energy needs** by fully utilizing low-grade heat sourced from the flue gas, which **decreases operating costs.**

EXAMPLES OF INDUSTRIAL WASTE FEEDSTOCKS

Basic oxygen furnace slag

Co-mingled steel slag

UPCYCLING PROCESS OUTCOME

Cylindrical mortar specimens

### QUICK FACTS

AWARD NUMBER
**DE-FE0029825**

### PROJECT BUDGET

FY18 FUNDING

**$1.35M**

| | |
|---|---|
| ● DOE | $1,000,000 |
| ● UCLA | $350,000 |

### CONTACTS

HQ PROGRAM MANAGER
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**GAURAV N. SANT**

### LOWER NET $CO_2$ EMISSIONS FROM COAL

- **Upcycling industrial wastes and $CO_2$** uses coal combustion and metal processing wastes (slags) as precursors for scalable $CO_2$ mineralization.
- **Process design** integrated solution incorporates aspects of calcium leaching, portlandite ($Ca(OH)_2$) precipitation, mixture formulation, and structural shape stabilization—while maximizing $CO_2$ uptake.
- **Ordinary Portland Cement (OPC) concrete replacement** is a novel $CO_2$-negative upcycled concrete that performs as well as or better than standard OPC-based concrete.

### PARTNERS

UCLA

ASU Arizona State University

HEADWATERS RESOURCES

### INTEGRATED TECHNOLOGY PRODUCTION PROCESS

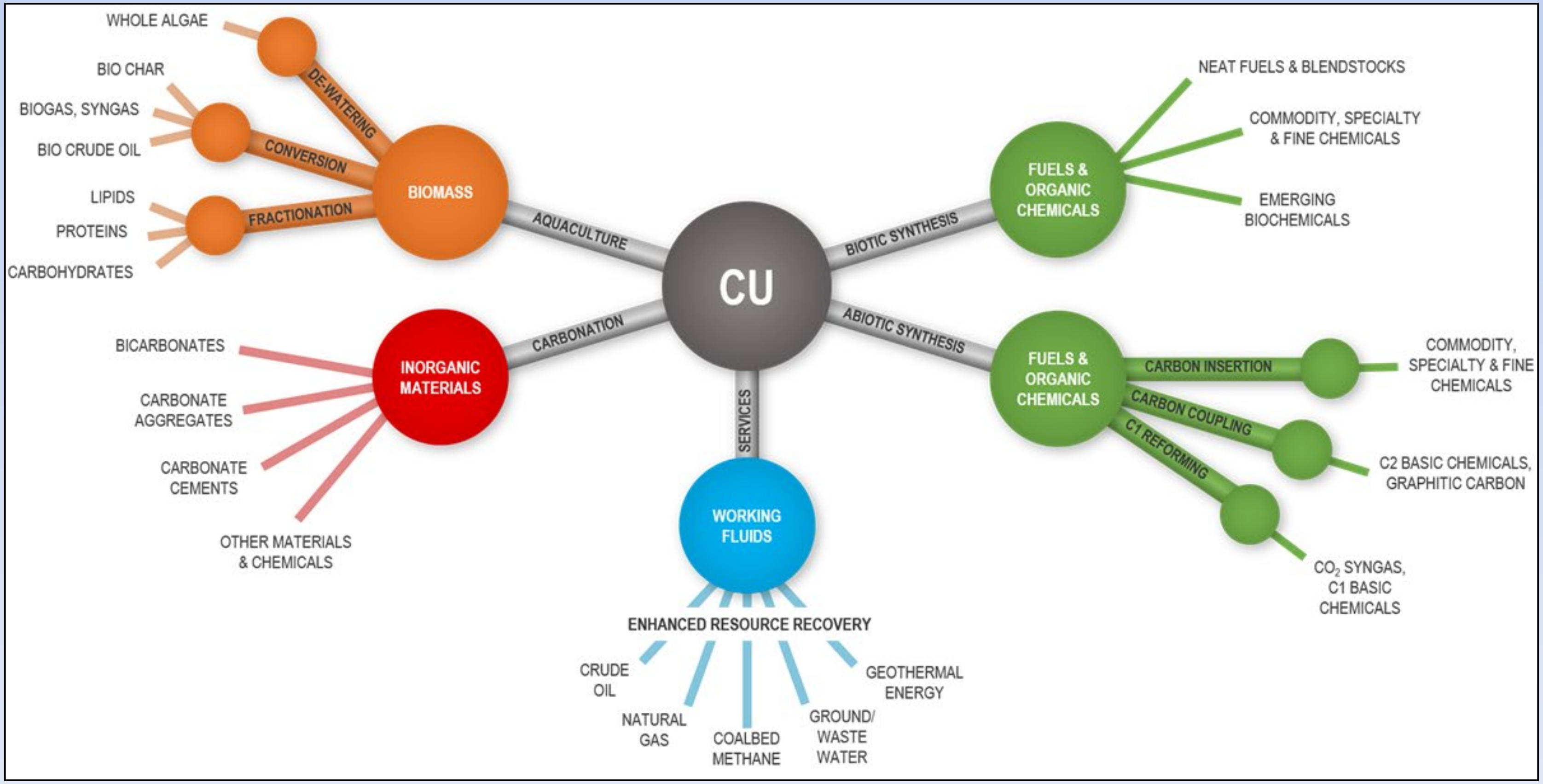
- Results indicate the **upcycled concrete process yields a construction material** with a $CO_2$ uptake >6% by mass and strength development from carbonation.
- **Results confirm direct evidence of low-temperature portlandite synthesis from slags.**

2018 Science & Technology ACCOMPLISHMENTS

Creating new jobs, products, and markets for coal

U.S. DEPARTMENT OF ENERGY | NATIONAL ENERGY TECHNOLOGY LABORATORY

# $CO_2$ expected to be a valuable commodity in the future and not a waste byproduct



- **We are witnessing the emergence of a new field – Carbon Management**

# Remembering Lynn Watney

- Founding and guiding spirit behind CCUS in Kansas
- Eminent geologist and scientist
- Humanitarian and friend to all

1948 - 2019

- **Thank You!**
- **Questions?**