Transportation Fundamentals:
The Low Carbon Fuel Standard

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Who We Are:

Graduate Degree Programs
- Transportation Technology & Policy

Research Centers
- Sustainable Transportation Energy Pathways
- Plug-in Hybrid & Electric Vehicle Research Center
- Energy Futures Program
- China Center for Energy and Transportation
- Sustainable Freight Center

Partner Programs
- National Center for Sustainable Transportation (NCST)
- UC Institute of Transportation Studies
- UC Pavement Research Center
- Policy Institute for Energy, Environment and the Economy

Energy Systems
- California Lighting Technology Center
- Western Cooling Efficiency Center
- Center on Water-Energy Efficiency
- Program on International Energy Technologies
Policy Institute for Energy, Environment and the Economy

Numerous Faculty Partners, including:

Professor Dan Sperling, Civil and Environmental Engineering
Professor Jim Bushnell, Economics
Professor Alissa Kendall, Civil and Environmental Engineering

Staff

- Austin Brown, Ph.D.
  Endowment Director
  530.752.1256
  abrown@ucdavis.edu

- Colin Murphy
  Deputy Director
  530.752.1256
crmurphy@ucdavis.edu

- Mollie Cohen D’Agostin
  Policy Director, 3 Revolutions Future Mobility Program
  530.752.1256
  d’agostin@ucdavis.edu

- Kelly Fleming
  Energy and Transportation Policy Analyst
  530.752.1256
  kfleming@ucdavis.edu

- Hannah Safford
  Researcher
  hsafford@ucdavis.edu

- Amber Marcia, Ph.D.
  Policy Fellow
  209.335.3328
  amaria@ucdavis.edu

- Julie Ekstrom
  Climate Change Program, California Department of Water Resources
  530.752.1256
  jeekstrom@ucdavis.edu

- Julie Witcover
  Assistant Project Scientist
  jwitcover@ucdavis.edu

- Gordon Anderson
  Legal Fellow
  ganderso@ucdavis.edu

- Sam Fulier
  Graduate Student Researcher
  sfulier@ucdavis.edu

- Tiffany Hoang
  Graduate Student Researcher
  thhoang@ucdavis.edu

- Corine Temayo
  Student Assistant
  ctemayo@ucdavis.edu
Introduction

• Alternative Fuels
• Life Cycle Analysis
• Why an LCFS?
• LCFS Structure
• Recent History
• LCFS + Other Policies
• Re-adoption & New Provisions

Key Term:

**Carbon Intensity (CI):** Emissions of greenhouse gases per unit of energy. Measured in grams of CO$_2$ equivalent per megajoule of fuel (g CO$_2$e/MJ)

CO$_2$ equivalent: Greenhouse gases other than CO$_2$ are converted to an equivalent amount of CO$_2$

1 MJ of energy is about as much as is contained in 2 tablespoons of gasoline, or a 100 kg object that falls from 100 meters up.

Gasoline & Diesel CI both around 100 g CO$_2$e/MJ
Transportation, Fuels and Life Cycle Analysis
Transportation is Major Emitter

Transportation accounts for 41% of state GHG emissions.

This rises to over 50% if you include the emissions from oil refineries from production of transportation fuels.

Key Targets
• 40% Reduction by 2030 (SB 32)
• Carbon neutrality by 2045 (Executive Order B-55-18)

Can’t meet these targets without significant progress in transportation.
Alternative Fuels – Liquids*

**Conventional Ethanol**
- Typically made from corn in U.S. (60-90 gCO$_2$/MJ CI)
- Made from sugarcane in Brazil (50-70 gCO$_2$/MJ CI)
- Typically blended into conventional gasoline at 10% rate
- Many but not all cars are “flex fuel,” they can burn any amount of ethanol up to 85%

**Renewable Diesel**
- Typically 35-60 gCO$_2$/MJ CI
- Made from things like vegetable oil, used cooking oil or food processing waste
- Processed in facility similar to oil refinery
- Chemically equivalent to diesel, no engine modifications needed

**Advanced or “Cellulosic” Biofuels**
- Made from waste, agricultural residue or other non-food materials
- Can be ethanol, synthetic “drop-in” fuels, or other forms
- Technology is new, only a handful of plants operational
- Typically 30-50 CI

**Biodiesel**
- Typically 30-50 gCO$_2$/MJ CI
- Made from things like vegetable oil, used cooking oil or food processing waste
- Simpler, lower-energy process to make than renewable diesel
- Requires engine modification to burn more than 20% blend; 5-10% blends common

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*all CIs are LCFS ratings
Alternative Fuels – Non-Liquids*

**Hydrogen**
- Typically 50-80 gCO$_2$e/MJ CI
- Converted to electricity by a fuel cell
- Stored in high-pressure tanks
- Commonly produced from natural gas
- May be produced from electricity and water in future (0-20 gCO$_2$e/MJ CI)

**Fossil Natural Gas**
- Typically 80 gCO$_2$e/MJ CI
- Must be compressed (CNG) or liquefied (LNG) to be stored in tanks
- Concern about methane leakage

**Electricity**
- Typically 25-30 gCO$_2$e/MJ CI (grid mix, adj.)
- 0 gCO$_2$e/MJ CI (renewable)
- Electric vehicles 3-5x more efficient than conventional
- Scheduling charging can help minimize impact on the grid

**Renewable Natural Gas**
- Typically 50 to -200 gCO$_2$e/MJ CI
- Made by anaerobic digestion of organic material, like food waste, green waste or animal manure
- Can be cleaned up to be equivalent to natural gas
- Can reduce methane leakage from waste disposal
- Similar methane leakage concerns as fossil

*all CIs are LCFS ratings
Life Cycle Analysis

INPUTS
- Raw Materials
- Energy

PROCESSES
- Raw Materials Acquisition
- Manufacturing
- Operation / Use / Maintenance
- Recycle / Waste Management

OUTPUTS
- Atmospheric emissions
- Waterborne waste
- Solid wastes

Source: Mark Fedkin, Penn State
Life Cycle Analysis - Gasoline

• About 75-80% of carbon is emitted through the vehicle’s tailpipe.
• 15-20% emitted at the refinery, converting crude into gasoline.
• Small amount for transportation, even for crude shipped from overseas.
Life Cycle Analysis - Biofuels

Much more complicated!

Carbon in fuel comes from atmosphere, so less effect on climate change ("biogenic").

Significant emissions from fertilizer, farm equipment, fuel production.

Indirect Land Use Change is critical, problematic and not well understood.
Why an LCFS?

Emissions = Amount of Travel x Vehicle Efficiency x Fuel CI

1. Need a fuel policy than can work on fuels for existing vehicles as well as new, advanced technology ones
2. Must consider life cycle impacts, especially for biofuels
3. Must be compatible with long-term transition to EVs
LCFS – Design and Recent History
LCFS Sets a CI Target, Measures Fuels Against It

Carbon Intensity (gCO₂e/MJ)

- LCFS Credits or Deficits
- LCFS Annual Target
- LCFS Credits
- LCFS Deficits

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Gasoline
Alt Fuel X
Alt Fuel Y
CI Ratings translate into Credits & Deficits

- LCFS target applies to (almost) all in-state transportation fuels
- Fuel volumes receive a lifecycle CI rating
- Fuels generate credits or deficits (tonne CO$_2$e) based on...
  - CI rating “distance” from target
  - Amount of fuel displaced
  - Vehicle efficiency

LCFS sets targets and measures progress based on percent CI reduction. Credits and deficits reflect tons of emissions above or below the target.
LCFS Creates Monetary Incentives to Lower Fuel CI

- If credits & deficits balance, average fuel CI rating hits target
- To comply, distributors of high-carbon fuels must reduce fuel emissions, or buy enough credits to comply
  - incentive to squeeze carbon out anywhere along supply chain
  - innovation
- Credits are tradable, bankable
  - lower compliance costs
  - revenue neutral (not zero cost)
Gasoline & Diesel Have Separate “Pools”

Gasoline & Diesel have different properties, including carbon intensity, so have different nominal targets.

Some fuels can substitute for gasoline, others for diesel. Gasoline and fuels which substitute for it are known as the “Gasoline Pool,” Diesel and substitutes the “Diesel Pool.”

Over time, availability & cost of biodiesel and renewable diesel have meant most credits now come from diesel pool, even though 4 times as much gasoline is sold in CA.
Ethanol Supplies Majority of Compliance Volumes

Ethanol is blended into gasoline at a 10% level to help it burn cleaner and meet federal Renewable Fuel Standard requirements.

- LCFS creates incentive to make ethanol lower carbon

Until targets increased past 2-3%, ethanol in gasoline supplied enough credit for compliance.

Biodiesel and renewable diesel rapidly emerged in mid-2010s.

Source: CARB – LCFS Data Dashboard
Other Fuels Supply Majority of Credits

Ethanol is only moderately lower in carbon than gasoline, so its credit value is limited, despite large volumes.
- Improved ethanol CI ratings have allowed credit generation to grow

Renewable diesel and biodiesel now provide majority of credits

Electricity is a rapidly growing source of credits

Source: CARB – LCFS Data Dashboard
LCFS Built Up Credit Bank, Now Starting to Spend It
This Pattern Is Not a Surprise

Source: California’s Clean Fuel Future
Implications and Looking Ahead
LCFS – Projecting the Next Decade

Steady Progress

Source: California’s Clean Fuel Future
LCFS In-State Activity

17 In-state biofuel production facilities

14 Businesses receive at least $6.5 million annually in LCFS credits.

20 Utilities receive LCFS credits for household charging.

76 On-road electric fleets, 1600+ electric forklifts

12,000+ EV Charging Stations, 500 CNG Stations

Over $3 Billion in total credit value

43 million metric tons of GHG reduction to date

Source: CARB – LCFS Data Dashboard
LCFS is Different than Cap and Trade

<table>
<thead>
<tr>
<th>How It’s Like Cap-and-Trade</th>
<th>How It’s Not</th>
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<tbody>
<tr>
<td>• Provides monetary value for reducing emissions</td>
<td>• Only affects transportation fuels</td>
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<tr>
<td>o More reductions=more $</td>
<td>• Revenue neutral to state</td>
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<td>o Incentive for low carbon tech</td>
<td>o Credit value stays in transportation sector</td>
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<tr>
<td>• Regulated parties can trade compliance credits</td>
<td>o $ transfer from high-carbon to low-carbon fuel providers</td>
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<td>o Reduces compliance costs</td>
<td>• Stronger push-back against dirty fuels</td>
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<td>• Intended to support fuel tech change (vs. near-term least cost CO$_2$ reduction)</td>
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LCFS & Cap and Trade

• Both policies price carbon. Cap and trade prices all the carbon in a fuel. LCFS prices how the fuel performs relative to a target.
  • LCFS credit price is nominally higher than cap and trade allowance price
  • For a given carbon price, cap and trade imposes higher cost per gallon of gas, lower cost per GHG reduction

• Cap and trade doesn’t account for fuel production emissions if they occur out-of-state, or for any emissions associated with land use change
  • LCFS can drive improvements in fuel production efficiency (e.g., for corn ethanol), incentivize feedstocks not reliant on land

• LCFS could lower cap-and-trade allowance prices (e.g., by reducing gasoline/diesel sales)
  • ...like other “complementary” climate policies
  • More likely as LCFS standard declines and cap tightens

• Timing matters! Cap-and-trade finds cheapest reductions – currently in industrial and electricity sectors. LCFS forces start of transportation transition now aiming for 2045-2050 targets.
  • Speed of transportation transition limited by vehicle turnover, new infrastructure build-out rates
LCFS Lawsuits

**Federal.** On grounds of violation of Commerce Clause. Ruling against LCFS; injunction (2011)
- 9th Circuit Court of Appeals issues stay of injunction, upholds constitutionality (2012-2013)
- Supreme Court denies review; remands to lower court regarding *in practice* commerce clause violation (2014)

**State.** On grounds of violation of California Environmental Quality Act and Administrative Procedures Act
- California Court of Appeal rules CEQA and APA violated over analysis of NOx from biodiesel blends (2013); allows LCFS to remain in effect with CI targets frozen until remedied
- CARB re-adopts rule with new analysis meant to remedy (2016)
- Court rejects revised analysis of NOx issues, requires freeze of diesel CI target until remedied (2017)
- CARB updates analysis in LCFS amendment package to remedy (2018); freeze lifted (2019)
LCFS & Electric Vehicles

• EV’s are small fraction of compliance now, but growing rapidly and could be largest source of LCFS credits by 2030 if Executive Order target of 5 million is reached.

• Electricity generates credits when it passes through a charger, at which point it is considered a transportation fuel.
  • 80-85% of EV charging currently happens at home. Utility supplying the home gets the LCFS credits. Utilities required to spend LCFS revenue to support EV deployment.
  • Charger owner gets LCFS credits for non-residential chargers.

• CA grid mix electricity has CI about 90-100 g CO$_2$/MJ, BUT, LCFS accounts for the higher efficiency of EVs through Energy Efficiency Ratio (EER), which means its actual impact is around 30 g/MJ
New Provisions in 2019

- Program extended to 2030 with 20% CI reduction target.
- Significant new provisions for EVs.
  - LCFS support for installation of DC Fast Chargers and Hydrogen fueling stations by giving these stations LCFS credits according to capacity, not use.
  - LCFS Credits for household charging will fund point-of-purchase rebate for EVs
  - EVs can get additional credit for using renewable energy, or charging at off-peak times
- Carbon Capture and Sequestration protocol, fuel producers can get credits for carbon stored underground and appropriately monitored.
- Third-party verification of fuel producers
- Alternative Jet Fuel can now opt-in
For More Information

LCFS Program Website
https://www.arb.ca.gov/fuels/lcfs/lcfs.htm

LCFS Status Report (2018 Update)

California’s Clean Fuel Future

ICF Study of LCFS and Cap-and-Trade Interaction

ICCT Study of Low Carbon Fuel Standards in Pacific Coast Collaborative (California, Oregon, Washington and British Columbia)
https://www.theicct.org/sites/default/files/publications/PacificCoastRegionLCF_Jan2015.pdf
We Are Happy to Answer Questions!

Julie Witcover Ph.D.
jwitcover@ucdavis.edu
policyinstitute.ucdavis.edu

Colin Murphy Ph.D.
cwmurphy@ucdavis.edu
policyinstitute.ucdavis.edu

Twitter: @scianalysis

The Policy Institute now offers rapid response policy analysis – contact kelfleming@ucdavis.edu

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