Low Carbon Fuel Standard Overview and Status

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Global Transportation Projections

• Global transportation service demand will grow substantially over the next century
  • Passenger transportation will shift to faster modes – in continuation of a trend already witnessed in many countries
  • Passenger transportation will shift to larger personal cars and light trucks
• Energy intensity (EI) of passenger travel and freight transportation will rise for developing countries and remain flat globally
• Total energy consumption by the global transportation sector grows from 91 EJ in 2005 to 310 EJ in 2100, increases GHG emissions from 6.9 to 19.2 MMT CO$_2$e with no climate policy, or 222 EJ and 8.3 MMT CO$_2$e with climate abatement.
(1) Global transportation service demand will grow substantially over the next century.

**Passenger Travel Demand**

- **PKT**: 2005: 55 Trillion, 2100: 165 Trillion
- **PKTpc**: Same as average level in OECD countries

**Freight Transportation Demand**

- **TKT**: 2005: 90 Trillion, 2100: 290 Trillion

**TOTAL**

- **PKT**: 2005: 55 Trillion, 2100: 165 Trillion
- **TKT**: 2005: 90 Trillion, 2100: 290 Trillion

**KM / person / year**

- 2005: 8,000
- 2100: 19,000

Same as average level in OECD countries
(2a) Passenger transportation will shift to faster modes – in continuation of a trend already witnessed in many countries (1/2)

Historical evolution of passenger transportation (PKT; ~1950 – ~2005)
(2a) Passenger transportation will shift to faster modes – in continuation of a trend already witnessed in many countries (2/2)
(2b) ... and to larger personal cars and light trucks

Share of various size classes within the LDV sector (2005 – 2050)
(3) As a result, the energy intensity of passenger travel will rise for developing countries and remain flat globally

1. Technological progress
2. Penetration of BEVs and FCEVs

1. Lower share of public modes – buses and trains
2. Higher share of aviation and LDVs
3. Upsizing of LDVs

 Globally, EI stabilizes at 0.9 MJ/PKT
Similarly in freight transportation, rising share of road (trucking) will increase the overall energy intensity.

Note: This includes international shipping.
Summary of trends (passenger only)

Global transportation demand will rise to the levels observed in the developed countries

- **2005:** 8,000 PKT/person/year
- **2050:** 12,000
- **2100:** 19,000

Aviation and private cars will have the dominant market share

- **2005:** 51%
- **2050:** 65%
- **2100:** 78%

Global average EI in 2100 will be only marginally lower than 2005 level despite large tech. improvements

- **2005:** 1.00 MJ/PKT
- **2050:** 0.85
- **2100:** 0.85
Transportation Sector is Almost Entirely Based on Crude Today

2005 Transportation
Total GHG = 6.9 MMt CO2e
WTW $\eta = 14.0\%$
478 gCO2/PJ useful energy

Long-Term Shifts in Lifecycle Energy Efficiency and Carbon Intensity. S Yeh, GS Mishra, G Morrison, J Teter, R Quiceno… - Environmental science & technology, 2013
Without Policy, Share of Carbon Intensive Liquid Fuels is increasing

- Annual global oil & gas capital expenditure to pass $1-trillion mark in 2012
- Our projected cumulative transportation fuel use 2005-2100 is on the order of 5,000 EJ.
- 18,000 Gbbl (shown on the figures) is ~110,000 EJ.

Brandt, Adam R., and Alexander E. Farrell. 2007
Urgency in Addressing Transportation Energy Challenges

- Climate Change
  - 40%+ of California GHG emissions are from transportation

- “Economic” Security
  - High and volatile prices negatively affect business and consumers and cause large economic losses

- Air pollution

- Our economy depends on a functional and (ultimately) sustainable transportation system
California: A portfolio approach will give us the best chance of meeting stringent goals for a sustainable transportation future.

Given the uncertainties, and the long timelines, it is critical to nurture a portfolio of key technologies toward commercialization and to start now.
Huge Global Investment Needed to Meet Increased Demand for Crude and “Unconventional” Energy Carriers

Increased demand for crude and “unconventional” energy carriers, including CTL, biomass to liquid (BTL), GTL, and electricity and hydrogen from coal and natural gas dampen improvements in technology efficiency and increase lifecycle CI.
Carbon Policy Reduces Total Primary Energy Use and Total GHG Emissions with More Renewables and Higher Efficiencies

RCP4.5 Advanced Tech no CCS (2100)
Total GHG = 8.2 MMt CO2e
Trans sector WTW \( \eta \) =26.3%
Trans sector CI = 141 gCO2/PJ useful energy

Long-Term Shifts in Lifecycle Energy Efficiency and Carbon Intensity. S Yeh, GS Mishra, G Morrison, J Teter, R Quiceno… - Environmental science & technology, 2013
Why Transportation is Unique

• Market failures
  • Inadequate R&D, and pollution externalities

• Unique market conditions and barriers
  • Coordination (network effects) among fuel producers, vehicle manufacturers, and fuel distributors
  • Conservative (inelastic) consumer behavior
  • Large energy security externalities
  • Long time horizons needed for return on fuel infrastructure investments
  • Lack of fuel-on-fuel competition
  • Diffuse nature of the biofuel industries
  • Market power of oil companies.

• Unlike all other sectors, transportation GHG intensity is increasing
  • Investments increasing in high-carbon crude oils, oil sands and even oil shale and gas/coal-to-liquid fuels
Policies Needed for Transport Emissions and Energy Use

- **Vehicle efficiency**
  - CAFE/GHG performance standards

- **Fuel carbon intensity**
  - RFS, LCFS

- **Advanced fuel/vehicle technology**
  - Zero-emission vehicle (ZEV) program
  - Energy infrastructure policies

- **Better VMT management**
  - Pricing of roads and vehicle use, land use mgt, public transport (plus systems mgt, eco-driving)
**Low Carbon Fuel Standard**

- Performance based: GHG intensity reduction target for transport fuels (10% AFCI reduction by 2020)

\[
AFCI(\text{gCO2-}\text{eq/MJ}) = \frac{\sum_{i}^{n} E_i \times CI_i}{\sum_{i}^{n} E_i \times EER_i}
\]

  Total GHG emission

  Total transportation fuels produced/displaced

- Lifecycle measurement for “carbon intensity” of all fuels on an equal basis

- Regulated parties are transport energy suppliers (oil providers, plus others who want to earn credits, such as biofuel, electricity, NG and H₂ providers)

- Harnesses market forces: Allows trading of credits among fuel suppliers, which stimulates investment and continuing innovation in low-carbon fuels

  *The lower GHG-intensity rating, the more carbon credits (and thus economic value) generated*
California LCFS Program

- Adopted April 2009, took effect Jan 2010
- Applies to on-road transport fuels
  - Excludes air and maritime (where California has limited authority)
- Separate targets for gasoline and diesel (10% reduction for each)
  - Allows trading between these two targets
- Default measurements and opt-in procedure for each activity in energy chain
  - Encourages further innovation and investment in low-carbon practices
- Refinements still in progress
  - Rules on “sustainability”
  - Lifecycle calculations for additional energy paths
The LCFS Compliance Schedule

Carbon Intensity (g/MJ)

- Gentle slope in early years
- Backloaded
- Continue Reductions

2010 2015 2020 2025
Fuel Lifecycle – Gasoline

7 g/MJ
Oil Well

1 g/MJ
Refinery

14 g/MJ
Transportation

73 g/MJ
Vehicle

Gasoline
96 g/MJ

Images extracted from Google Earth and attributed to Telemetrics, TeleAtlas and Digital Globe 2009!

Surface mining
In situ

California
Alberta
Fuel Lifecycle – Corn Ethanol

- **Corn Field**: 36 g/MJ
- **Land Use Change**: 30 g/MJ
- **Corn Field**: 2 g/MJ
- **Bio-Refinery**: 38 g/MJ
- **Co-products**: 3 g/MJ
- **Vehicles**
  - Blend with gasoline: -12 g/MJ
  - Transportation: 30 g/MJ
- **Emissions are Offset**: 97 g/MJ

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Compliance Options

A regulated party can:

1) improve energy efficiency or reduce carbon emissions in extracting and processing the fuel,
   • Default vs values provided by regulated parties through method 2A-2B
   • Capture and sequester the carbon emitted during production.

2) invest in other lower-carbon fuels so as to offset the emissions from oil, and/or

3) buy credits from other companies that invest in and over-produce low carbon fuels
LCFS vs. RFS

- RFS2 set volumetric mandates for fixed categories of fuels

- LCFS includes all transportation fuels (electricity, NG, H2, etc), including biofuels

- Performance-based standard stimulates innovation in reducing GHG emissions
  - Rewards cellulose at corn-ethanol facilities
  - More incentive to use waste materials
  - More incentive to reduce carbon footprint of oil sands
Regulated parties are required to reduce the carbon intensity of their gasoline and diesel fuels and fuels substitutes sold in California by 10% by 2020.

The average CI requirements for years 2013 to 2020 reflect reductions from revised base year (2010) CI values for CaRFG calculated using the CI for crude oil supplied to California refineries in 2010.

California LCFS will significantly reduce state GHG and petroleum fuel use

- Reduce GHG emissions by 10% and fuel use by 3% relative to 2020 BAU
- Alternative fuels increase from 0.68 billion gasoline gallon equivalent (gge) in 2007 to 2.5-3.73 billion gge in 2020
- Total GHG reduction (WTW) 20-25 million metric tons CO$_2$e.

• Cumulative credits generated a total of 2.835 million metric tons of CO$_2$e.
• A net of excess 1.285 million credits to date, roughly half of compliance obligation in 2013*
• Without any changes (continue with the same fuel mix and CI), it will be possible to be in compliance with the LCFS through 2016

*Assuming the total California gasoline and diesel fuel demand will be 18.1 billion gallons (gasoline gallon equivalent, gge) in 2013, the total number of credits needed to meet the 1% reduction target in 2013 will be approximately 2.55 million metric tons of CO$_2$e credits.
California LCFS Carbon Credits Comes from A Range of Sources

- The shares of credits for different fuel types have remained relatively constant.
  - Ethanol: 78%
  - Fossil/bio LNG/CNG: 12%
  - Bio-/renewable diesel: 9%
  - Electricity: 1%
Biofuels from Waste Comprised Less Than 1% of Biofuel Volumes but Generated 9% of The Total Biofuel Credits
Default (n=129) vs. Opt-in (n=105) Carbon intensity (CI) values of fuel pathways

Bars represent the default values determined by the ARB. Glowing lines represent opt-in values through Methods 2A and 2B. The horizontal line represents the default gasoline (CARBOB) and diesel (ULSD) values (not distinguished at this scale). Numbers under each bar represent the number of default and opt-in CI values for each pathway.

Some opt-in values can be lower than the default values in a particular pathway due to differences in the designed vs. actual technologies used. CI values are adjusted with an energy efficiency ratio (EER) of 3.4 for electricity and 2.5 for hydrogen (gasoline displacement). Corn+ pathway is ethanol produced from a mix of grain-based feedstock including corn, sorghum, and wheat slurry. “Ethanol Other” includes feedstock from other grains (e.g. sorghum) or waste (e.g. waste beverage). “BD/RD Other” includes biodiesel or renewable diesel from other oil seeds or corn oil.
LCFS Credits Trade Volumes and Credit Prices (after 08/2012)

Credit trading volumes:
• 2012: 180,350 credits @ $13.59 (12% of the total credits traded)
• 2013: 40,303 credits @ $27.70
Policy Induced Fuel Shuffling?

- When fuels are moved or “shuffled” from one market to another without any significant change in overall production or fuel characteristics.
  - Lacks a clear definition makes it analytically difficult to determine the extent of the problem
- Corn ethanol exports:
  - favorable production economics and soft demand due to economic recession and the E10 “blend wall”
  - poor sugarcane harvest
- Sugarcane imports: Federal mandates for advanced biofuels have been a key factor
Interactions between LCFS and the Cap-and-Trade program

• California held two C&T auctions resulted in carbon allowance prices of $10.09/MT CO$_2$e (November 2012) and $13/MT CO$_2$e (February 2013)

• Two carbon markets are not currently linked

• Interactions between the two program
  • Refinery emissions are counted under the C&T program as well as the LCFS.
    • 75% of emissions would be freely allocated through 2017, and 50% thereafter.)
  • Distributors of transport fuels (including gasoline, diesel and natural gas providers), currently covered under the LCFS, will be covered under the C&T program after 2015.
  • No quantitative analysis exist examining the interaction between these two programs