Quantifying Yields and GHG Emissions from Co-processing in Petroleum Refineries

CRC Workshop on Lifecycle Analysis of Transportation Fuels
October 24-26, 2017

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Outline

- LCFS targets (under consideration) beyond 2020
- LCFS rulemaking timeline
- Background on co-processing
- Objectives of the Work Group
- Quantification of low carbon fuels from co-processing
- Carbon intensity of fuels produced from co-processing
- Future work

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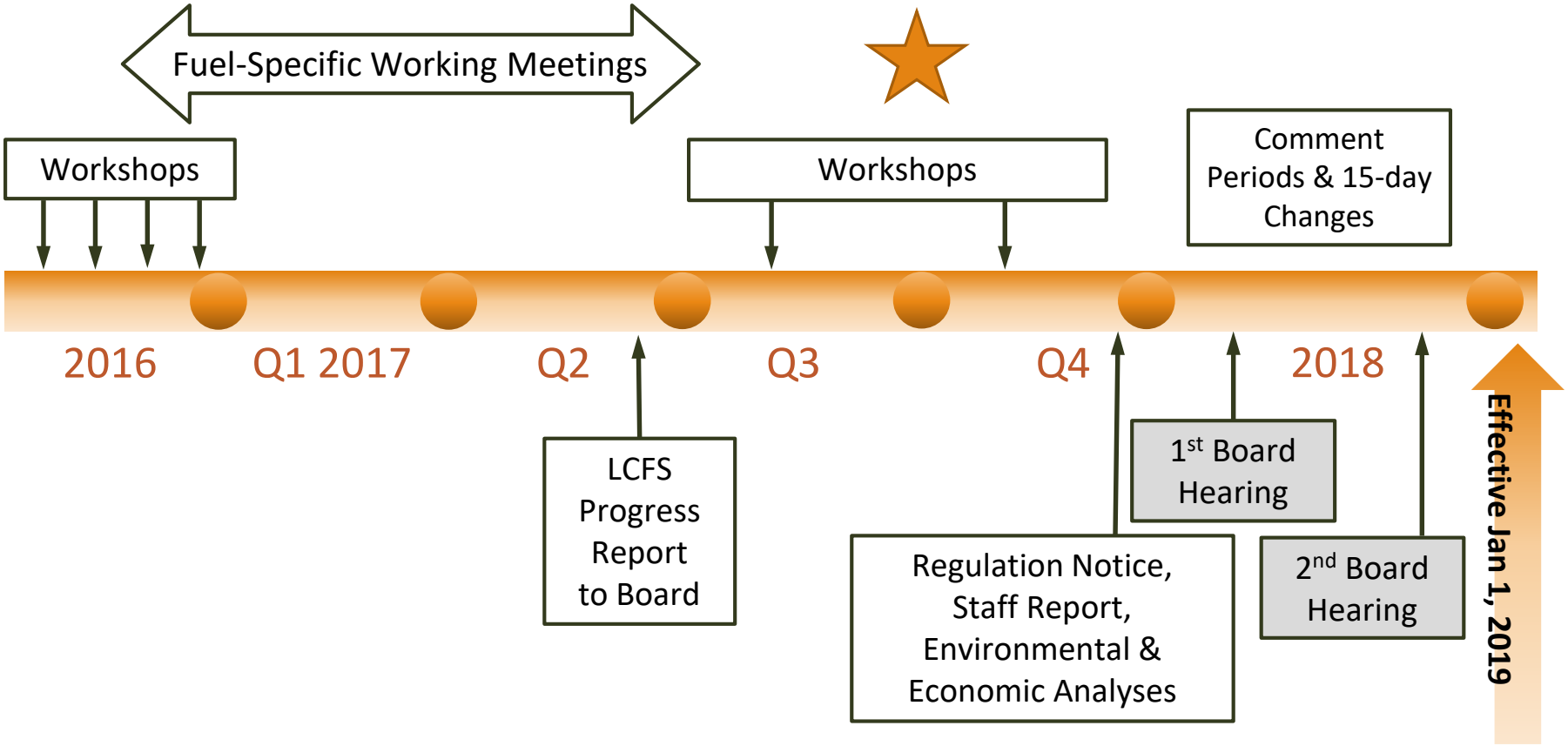
Initial Thinking for Percent CI Reduction for Gasoline, Diesel, and Jet Fuel

Year	Percent Reduction	Year	Percent Reduction
2010	Reporting Year		
2011	0.25%	2021	10.0%
2012	0.5%	2022	10.0%
2013	1.0%	2023	11.0%
2014	1.0%	2024	12.0%
2015	1.0%	2025	13.0%
2016	2.0%	2026	14.0%
2017	3.5%	2027	15.0%
2018	5.0%	2028	16.0%
2019	7.5%	2029	17.0%
2020	10.0%	2030	18.0%

Rulemaking Timeline



Background on Co-Processing

- Co-processing refers to simultaneous transformation of biogenic (or low carbon) feedstocks and intermediate petroleum fractions such as vacuum gas oil (VGO) in existing refinery process units to produce a mix of low carbon and conventional fossil fuels
- Pathway for production of low carbon fuels with existing refining, transport and storage infrastructure
- DOE estimates 8 billion gallons of production potential
- Established Technical Work Group composed of subject matter experts and stakeholders

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Core Objectives of the Work Group

- Establish guidelines for quantification of low carbon fuel volumes from co-processing
- Evaluate greenhouse gas emissions of co-processing operations and corresponding carbon intensities of low carbon fuels produced
- Develop guidance to facilitate certification of carbon intensity for co-processed low carbon fuels
- Develop monitoring and verification protocols for co-processed fuels

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Typical Refinery Co-processing

- Vacuum Gas Oil (VGO) in Fluid Catalytic Cracking Units (FCCs) with biogenic feedstocks
- Middle distillates in hydroprocessing units with biogenic feedstocks
- Refinery complexity may dictate specific process units being considered for co-processing
- Typical feedstocks likely to be used include bio-intermediates (e.g., pyrolysis oil), vegetable oil, tallow and used cooking oil

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Framework for Renewable/Low Carbon Fuel Quantification

- Staff will evaluate the applicability of the methods detailed below:
  - Mass balance method
    - Compares mass of inputs and outputs with and without co-processing
  - Carbon mass balance method
    - Assigns renewable carbon content to finished fuels based on the carbon content of low carbon feedstock and the amount of carbon in output streams. Carbon balance prior to co-processing would still be required
- C^{14} analysis
  - Staff is evaluating suitability for quantification of renewable fuel volumes, particularly at low blend percentages

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Low Carbon Fuel Yield Quantification – Mass Balance Based on Observed Yields

- Compare product-specific observed yields in the co-processing (fossil plus low carbon feedstocks) case to yields in the 100% petroleum feedstock (baseline) case

$$LCM_i = CM_i - (M_p \times Y_i)$$

where,

$\mathbf{LCM_i}$	=	Mass of ith low carbon fuel product produced from co-processing
$\boldsymbol{CM_i}$	=	Mass of ith fuel (low carbon + petroleum) produced from co-processing
$\boldsymbol{M_p}$	=	Mass of petroleum feedstock used in co-processing
$\boldsymbol{Y_i}$	=	Specific yield of ith fuel in baseline (kg of ith fuel/ kg of petroleum feedstock)

A detailed illustration is provided in the template for co-processing in hydrotreating units.
https://www.arb.ca.gov/fuels/lcfs/lcfs_meetings/lcfs_meetings.htm

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Low Carbon Fuel Yield Quantification – Carbon Mass Balance

- Determine the carbon content of biogenic feedstocks
- Determine the amount of carbon in CO, CO_2, CH_4, C_3H_8 and other gaseous species
- Estimate carbon correction factor for co-processed feedstock
- Apply renewable carbon correction factor to produced fuels to estimate the amount of low carbon fuels

$$RM_i = \frac{M_{biomass}}{M_{total}} \times CM_i \times \%R_F$$

$\boldsymbol{RM_i}$	=	Mass of i^{th} renewable fuel from co-processing
$\boldsymbol{M_{biomass}}$	=	Mass of biogenic feedstock (dry basis)
$\boldsymbol{M_{total}}$	=	Total mass of feedstock co-processed (petroleum + biogenic)
$\boldsymbol{CM_i}$	=	Mass of i^{th} fuel from co-processing
$\boldsymbol{\%R_F}$	=	Renewable carbon correction factor (%)

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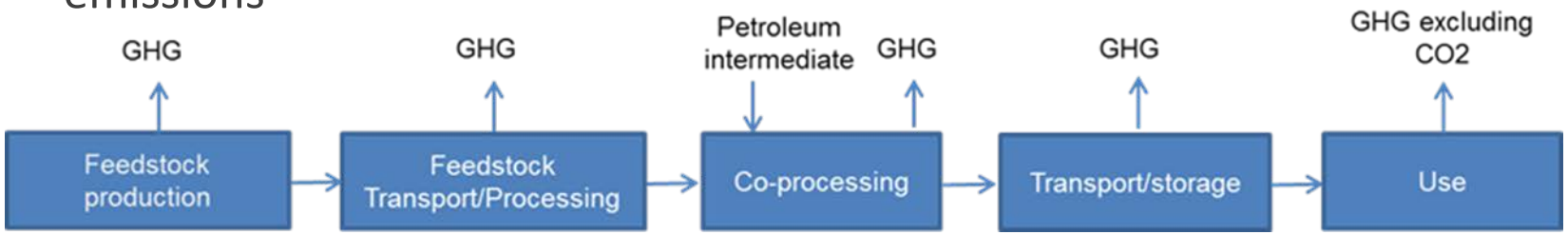
LCA Methodology

- Covers well-to-wheel GHG emissions including direct and indirect emissions



- Except for the co-processing step, GHG accounting methods are similar to typical biofuel pathways
- Work Group discussion focuses on co-processing GHG emissions only

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Framework for Estimating GHG emissions from Co-processing

- Co-processing in FCC units
  - Energy content-based allocation at process unit-level
- Co-processing in hydrotreaters/hydrocrackers
  - Incremental allocation (hybrid approach)

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Process Unit Level Allocation: Co-processing in FCC Units

- Process unit level allocation based on energy content
  - GHG emissions from the co-processing unit attributed proportionally to the fuel product outputs based on energy content of an individual output relative to the total energy content of all outputs
  - Starts with the unit at which low carbon feedstock is introduced, and is carried through subsequent process units used to produce low carbon fuels
  - Detailed calculations and illustration provided in co-processing discussion paper as well as in the template for co-processing in FCC units posted online http://www.arb.ca.gov/fuels/lcfs/lcfs_meetings.htm

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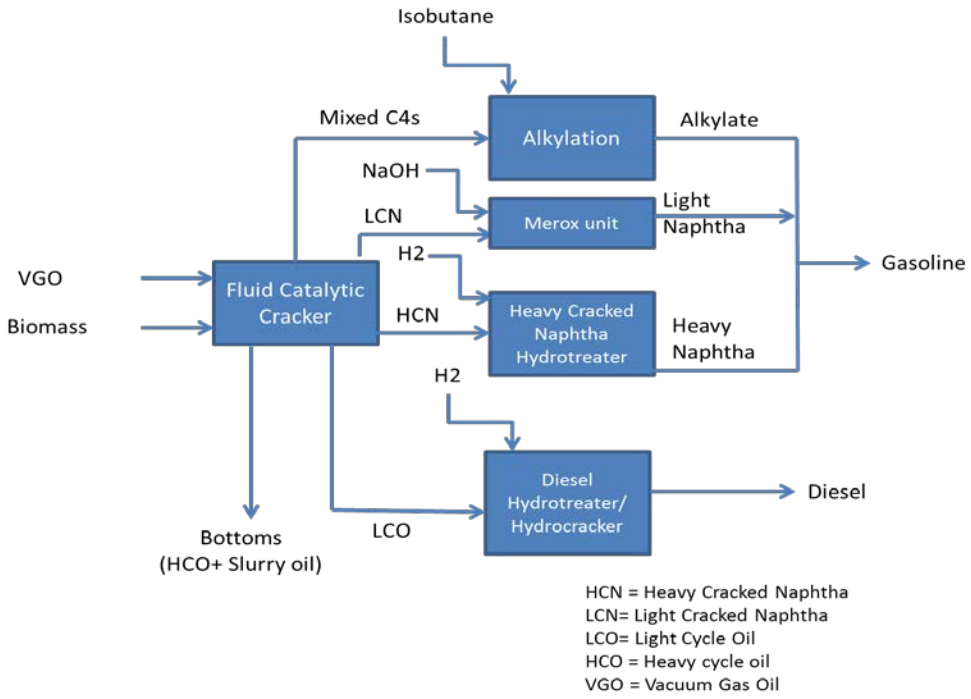
GHG Emissions Quantification: Co-processing in FCC Units

Step by step unit level allocation on the units receiving FCC renewable/low carbon streams



Illustrative FCC Allocation System Boundary

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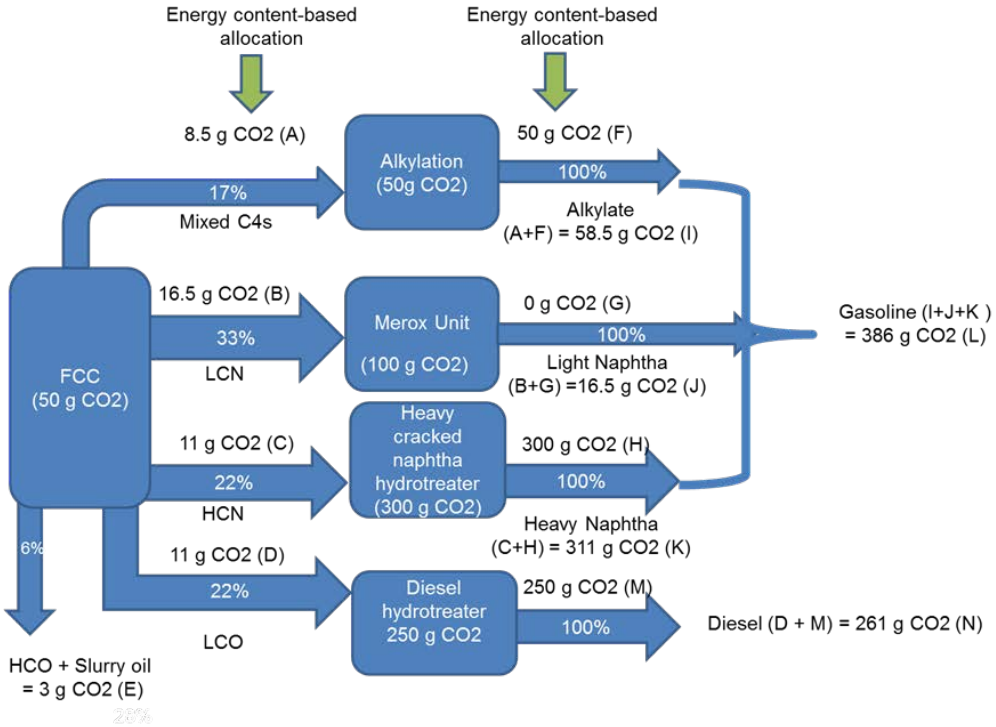
Process Unit Level Allocation



Illustrative Example for an FCC Unit

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Incremental Allocation Approach: Co-processing in Hydrotreating Units

$$GHG_{LCF} = GHG_{cp} - (M_p \times Y_i)$$

where,

GHG_{LCF}	=	GHG emissions associated with low carbon fuel
GHG_{cp}	=	GHG emissions of i^{th} fuel (low carbon + petroleum) produced from co-processing
M_p	=	Mass of middle distillate used in co-processing
Y_i	=	Specific emissions per unit middle distillate processed in the baseline (kg CO_2e/ kg-middle distillate)

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Incremental Allocation: Co-Processing in Hydrotreating Units

- Incremental allocation approach
  - Preferable for co-processing in hydrotreating units because of substantial increase in hydrogen use relative to baseline
  - Calculates GHG emissions by comparing GHG emissions in the co-processing case with the baseline case
  - Simplified example detailed in draft discussion paper
  - Detailed calculations and illustration provided in the template for co-processing in hydrotreating units posted online. http://www.arb.ca.gov/fuels/lcfs/lcfs_meetings.htm

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Guidance for Data Generation for Co-processing in Hydrotreaters or Hydrocrackers

- Draft guidance based on two active applications in the Alternative Fuels Portal
- Provides details of data and other requirements from applicants to quantify low carbon fuel volumes
- Provides details of data and other requirements from applicants to calculate CI for low carbon fuels

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Data Collection/Generation Process

- Establish a baseline prior to initiation of co-processing
  - Collect/measure data on feedstock inputs, product outputs including gaseous components and energy/hydrogen use
- Collect data with co-processing
  - Collect/measure data on feedstock inputs, product outputs including gaseous components and energy/hydrogen use

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Preliminary Thoughts on Monitoring and Verification

Biomass feedstock supply: Monitoring and verification requirements are expected to be similar to renewable diesel/biodiesel pathways

Refining: Documentation of refinery energy use within the co-processing system boundary, feedstock use and fuel production data

Fuel supply: Staff recognizes the need to account for supply of out-of-state co-processed fuels

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Future work

- Additional work group meetings to firm up guidelines on quantification methods and data collection/generation requirements
  - For hydrotreaters/hydrocracker units
  - For FCC units
- Firm up GHG calculation methodologies
- Continue to evaluate C^{14} analysis for its suitability for biogenic carbon quantification
- Develop guidelines for monitoring and verification of low carbon co-processed fuel pathways

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THANK YOU!

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