California Environmental Protection Agency

Air Resources Board

Low Carbon Fuel Standard Re-Adoption:

Natural Gas Carbon Intensity and other CA-GREET Model Adjustments

April 3, 2015

Agenda

- Review of the public process to date
- Comparison of CA-GREET 1.8b and estimated CA-GREET 2.0 carbon intensity values
- Discussion of natural gas and biomethane issues
- Discussion of other carbon intensity values
- Updates to the illustrative compliance scenario
- Next Steps

Public Process To Date

- Proposed CA-GREET update was continuously vetted during the rulemaking process
  - Initially proposed in March 2014 LCFS Concept Paper
  - Discussed in the following workshops:
    - March 11, 2014
    - April 4, 2014
      - Announced that CA-GREET 2.0 would be based on the *publicly available* GREET 1 2013 model from Argonne Laboratory
    - May 30, 2014
      - Presented two-tiered framework for pathway applications
    - August 22, 2014
      - Presented some preliminary CI comparisons
    - November 13, 2014
      - Addressed misunderstandings evident in stakeholder feedback; requested input on new regulatory proposals

Public Process To Date (Cont.)

- On October 10, 2014, we posted
  - The first release of the full CA-GREET 2.0 model (though GREET 1 2013 was always available), and
  - A comprehensive table of all the parameter decisions reached to date
- In conjunction with today's workshop we've posted:
  - Updated versions of CA-GREET 2.0 Tier 1 and Tier 2 calculators
  - A table comparing CA-GREET 1.8b and 2.0 CIs
  - A revised illustrative scenario
  - An updated denaturant calculator

CA-GREET 1.8b versus 2.0 CI Comparisons

Basis of comparison:

- Proposed regulation does not include an extensive lookup table of generic CA-GREET 2.0 values
  - Emphasis in the proposed regulation is on producer-specific values derived using the Tier 1 and Tier 2 versions of CA-GREET 2.0
  - CA-GREET 1.8b and 2.0 CIs are not straightforward to compare
- To improve clarity, the next two slides compare existing CA-GREET 1.8b CIs with our best estimates of corresponding values calculated with the proposed CA-GREET 2.0.
- These example CA-GREET 2.0 CIs are not part of the regulation—***only representative estimates for purposes of this workshop***

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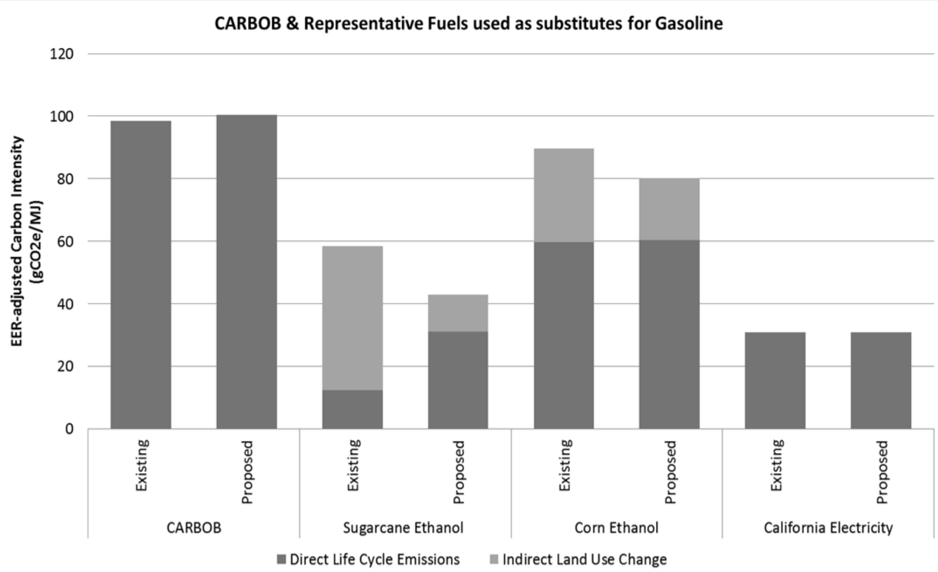
CA-GREET 1.8b versus 2.0 Comparisons



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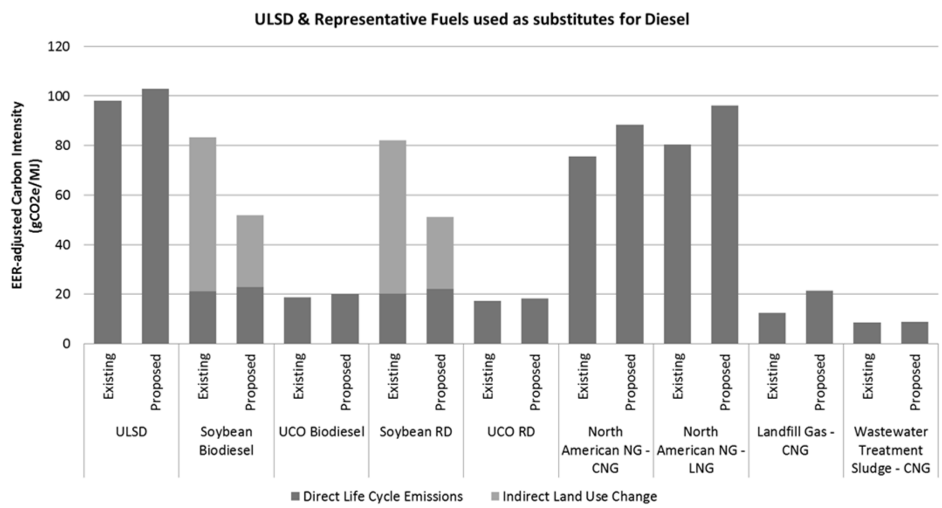
CA-GREET 1.8b versus 2.0 Comparisons



Proposed Changes to be Discussed Today

- Natural Gas
  - Methane leakage rate from well to distribution
  - NG vehicle tailpipe emissions
  - NG pipeline transmission distance
- Updated Brazilian average mix
- N_2O emissions from crop residues
- Heating values of NG
- Canola farming data
- Electricity generation GHG emission factors for non-U.S. sources

Well-to-Tank Methane Leakage from Natural Gas Systems

- Proposed CA-GREET 2.0 values are based on 2014 EPA Inventory and remain consistent with ANL's GREET 2014
- Emerging studies will be reviewed and considered for possible future model updates

Well-to-Tank Methane leakage rates in conventional NG and shale gas pathways

	g CH_4/MMBtu NG throughput		vol. % of CH_4 over NG throughput	
Life Cycle Stage	**Conventional NG**	**Shale gas**	**Conventional NG**	**Shale gas**
Recovery - Completion CH_4 Venting	0.543	12.384	0.0026%	0.06%
Recovery - Workover CH_4 Venting	0.008	2.477	0.000037%	0.01%
Recovery - Liquid Unloading CH_4 Venting	10.357	10.357	0.05%	0.05%
Well Equipment - CH_4 Venting and Leakage	51.345	51.345	0.25%	0.25%
Processing - CH_4 Venting and Leakage	26.710	26.710	0.13%	0.13%
Transmission and Storage - CH_4 Venting and Leakage [per 680 miles]	81.189	81.189	0.39%	0.39%
Distribution - CH_4 Venting and Leakage	63.635	63.635	0.31%	0.31%
Life Cycle Leakage as vol. % of Throughput:			**1.14%**	**1.21%**
Shares of NA NG Supply	77.2%	22.8%		
Overall Contribution to CI	**+ 5.617**		**1.15%**	

Methane Leakage in Landfill Gas Processing

- Model assumes one-step clean-up process with 1% leakage rate adapted from anaerobic digester studies
- No studies specific to landfill gas processing have been identified by staff or stakeholders
- Staff reviewed state[1] and federal[2] rules governing fugitive landfill emissions
  - Concluded state regulations do not translate to a quantifiable feed loss or emission limit. Federal regulations do not apply to processing systems
- In response to stakeholder feedback and due to the uncertainty and lack of data on these operations, staff has agreed to make methane leakage in RNG processing a user-modifiable input

[1] California Air Resources Board (2009). Methane Emissions from Municipal Solid Waste Landfills. 17 CCR § 95464 Gas Collection and Control System Requirement http://www.arb.ca.gov/regact/2009/landfills09/landfillfinalfro.pdf
[2] U.S. EPA (2014). Standards of Performance for New Stationary Sources. 40 CFR 60.753 Operational standards for collection and control systems. https://www.law.cornell.edu/cfr/text/40/60.753

Natural Gas –Tailpipe Emission: Vehicle Shares

Fuel consumption data by vehicle type is used to calculate a weighted average tailpipe emission factor that represents the CA NGV fleet.

- Previous model release used EIA[1] data from 2011
- Propose to use LCFS Reporting Tool data for 2014
  - Combines Light and Medium Duty vehicles
  - Distinguishes compression and spark-ignition engines

LCFS Reporting Tool - Vehicle Category	CNG (Diesel Gallon Equivalents)	% Share (LRT)	% Share (EIA) Previous Model Release	Corresponding GREET vehicle types:
Heavy Duty Vehicles - Compression Ignition Engines	348,193	0.40%	85.50%	Class 8B Heavy-Heavy Duty Trucks and Class 6 Medium-Heavy Duty Trucks
Heavy Duty Vehicles - Spark Ignition Engines	71,672,554	82.80%		Class 8B Heavy-Heavy Duty Trucks and Class 6 Medium-Heavy Duty Trucks
Medium and Light Duty Vehicles - Pickups, Trucks, Vans, SUVs and Passenger cars	14,521,266	16.80%	6.60%	Light Duty Trucks 2 (LDT2)
			5.40%	Light Duty Trucks 1 (LDT1)
			2.40%	Passenger Cars
CNG Total	**86,542,013**			

[1]U.S. Energy Information Administration, "Renewable & Alternative Fuels, Alternative Fuel Vehicle Data" website tool, Accessed October 21, 2014. http://www.eia.gov/renewable/afv/users.cfm (2011 data)

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LCFS Reporting Tool - Vehicle Category	LNG (gallons)	% Share (LRT)	% Share (EIA) Previous Model Release	Corresponding GREET vehicle types:
Heavy Duty Vehicles - Compression Ignition Engines	0	0.00%	99.70%	Class 8B Heavy-Heavy Duty Trucks and Class 6 Medium-Heavy Duty Trucks
Heavy Duty Vehicles - Spark Ignition Engines	55,045,693	100.00%		Class 8B Heavy-Heavy Duty Trucks and Class 6 Medium-Heavy Duty Trucks
Medium and Light Duty Vehicles - Pickups, Trucks, Vans, SUVs and Passenger cars	0	0.00%	0.30%	Light Duty Trucks 2 (LDT2)
			0.00%	Light Duty Trucks 1 (LDT1)
			0.00%	Passenger Cars
LNG Total	**55,045,693**			

[1]U.S. Energy Information Administration, "Renewable & Alternative Fuels, Alternative Fuel Vehicle Data" website tool, Accessed October 21, 2014. http://www.eia.gov/renewable/afv/users.cfm (2011 data)

Natural Gas –Tailpipe Emission: CH_4 and N_2O Factors

Staff expects to update tailpipe EFs as part of the 15-day package; update will be based on Argonne National Lab's forthcoming report on Heavy Duty NGV.

- Currently under industry & academic review
- Expected release of final report in April 2015
- No interim update to CA-GREET TTW emission factors until ANL HDV report publication
- A list of references supplied to ARB from ANL imply a decrease in these factors is likely

1. Gao, Z., LaClair, T., Daw, C.S., Smith, D.E., 2013. Fuel Consumption and Cost Savings of Class 8 Heavy-Duty Trucks Powered by Natural Gas. Presented at the Transportation Research Board 92nd Annual Meeting.
2. Carder, D.K., Thiruvengadam, A., Besch, M.C., Gautam, M., 2014. In-Use Emissions Testing and Demonstration of Retrofit Technology for Control of On-Road Heavy-Duty Engines. Prepared for the South Coast Air Quality Management District (Contract No. 11611).
3. Hajbabaei, M., Karavalakis, G., Johnson, K.C., Lee, L., Durbin, T.D., 2013. Impact of Natural Gas Fuel Composition on Criteria, Toxic, and Particle Emissions from Transit Buses Equipped with Lean Burn and Stoichiometric Engines. Energy 62, 425–434. doi:10.1016/j.energy.2013.09.040.
4. Nylund, N.-O., Koponen, K., 2012. Fuel and Technology Alternatives for Buses: Overall Energy Efficiency and Emission Performance. http://www2.vtt.fi/inf/pdf/technology/2012/T46.pdf.
5. Yoon, S., Hu, S., Kado, N.Y., Thiruvengadam, A., Collins, J.F., Gautam, M., Herner, J.D., Ayala, A., 2014. Chemical and Toxicological Properties of Emissions from CNG Transit Buses Equipped with Three-Way Catalysts Compared to Lean-Burn Engines and Oxidation Catalyst Technologies. Atmos. Environ. 83, 220–228. doi:10.1016/j.atmosenv.2013.11.003

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Natural Gas - Pipeline Distances

- In CA-GREET 2.0, pipeline distance is currently a user-input cell for providers of natural gas as a transportation fuel
- This cell contains a "default" value of 1,000 mi. that can be used if no verifiable pathway-specific distance is known
- This "default" was a rough estimate of the average transmission distance to CA fueling stations
- We received comments requesting that we refine this estimate
- We consulted various government and utility sources to ascertain transport distances and volumes. The next slide summarizes the distances we found

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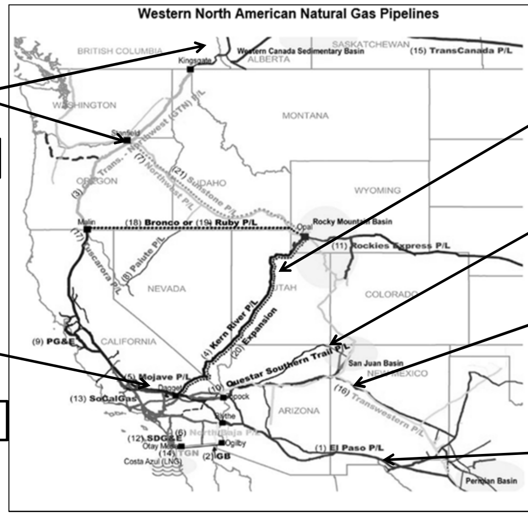
Natural Gas - Pipeline Distances



Natural Gas - Pipeline Distances

- We found that the volume-weighted average transport distance to the CA border is almost 1,300 miles
- To that number must be added the transport distance to CA fueling stations
- Since some uncertainty surrounds this estimate, we propose
  - Sticking with a 1,000-mile default for the current rulemaking, and
  - Working with stakeholders to better refine this parameter for the next CA-GREET update

Electrical Energy Generation Mix

- Marginal mixes are currently used to estimate electricity CIs
- Marginal electricity comes from generation sources that would be built to supply new load
  - Natural gas
  - Renewables
  - Not large hydro and nuclear
  - Marginal mixes are often difficult to define
- We therefore propose using well-defined average mixes (actual on-the-ground generation portfolios)

Electrical Energy Generation Mix

- The impact for users of electricity is generally the inverse of the impact for exporters of electricity (e.g., Brazilian ethanol producers with cogeneration)
  - Many electricity consumers in the U.S. benefit from the average mix: hydroelectric and nuclear generation decrease the CI
  - In Brazil, the average is predominantly hydroelectric and the marginal is predominantly fossil-fuel based
  - Displacing marginal power with cogenerated electricity earns a higher credit

Electrical Energy Generation Mix

- Previously, staff proposed using the average Brazilian 2010 electricity mix from EIA
- Based on comments received we now propose using data from the Brazilian Energy Research Office (Average of 2011-2013 data)

	Current	Updated
Hydro	80%	76.42%
Nuclear	2%	2.6%
Biomass	7%	7%
Coal		1.87%
Petroleum Oil		3.4%
Natural Gas	11%	7.89%
Wind		0.83%

Source: Brazilian Energy Research Office (EPE) of the Ministry of Mines and Energy, Brazilian Annual National Energy Balance. Accessed on 03-FEB-2015. Reports for years 2011, 2012, and 2013 (for prior year data). https://ben.epe.gov.br/default.aspx

International Electricity Emission Factors

- Foreign fuel pathways currently use U.S. average electricity emission factors to calculate CI
- Staff proposes that foreign producers provide GHG emission factors from one of the following sources for use in CA-GREET 2.0:

1. Verifiable national or regional emission factors from the country's Energy Ministry or equivalent

2. If data from the first source is unavailable, use data from UNFCC National Inventory Submissions
http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8108.php

3. If data from neither of these sources is available, use data from either:

- The International Energy Agency Electricity Statistics
http://www.iea.org/statistics/topics/electricity
- U.S. Energy Information Administration Voluntary Reporting
www.eia.gov/survey/form/eia_1605/emission_factors.html

Correction to fuel properties of Natural Gas

- Updated lower heating value (LHV) and density of natural gas and methane (at 32°F and 1 atm)
- Table 3 in the regulation will be changed to reflect the CA-GREET 2.0 value
- Change aligns CA-GREET with ANL's GREET fuel properties at reference conditions
- Natural gas and pure methane properties are fixed values which are specified in the Regulation and cannot be changed in the model
- Impact to carbon intensity shown in table to the right:

	CA-GREET1.8b	**CA-GREET2.0**	Units
Natural Gas			
LHV	930 (0.98)	983 (1.04)	Btu/ft^3 (MJ/ft^3)
Density	20.4	22.0	g/ft^3
Pure Methane			
LHV	N/A	962 (1.02)	Btu/ft^3 (MJ/ft^3)
Density	N/A	20.3	g/ft^3

	gCO2e/MJ
CARBOB	-0.05
ULSD	-0.06
Natural Gas	-0.37
Hydrogen	-0.55

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Soil N_2O

- Disaggregated N_2O from two sources of Nitrogen (N) in response to stakeholder feedback
  - N Fertilizer (no change from 1.325%)
  - N-content of biomass crop residue (reduced to 1.225%)
- Using the 2006 IPCC GHG Inventory Guide[1]
  - Tier 1 default emission factors for N_2O as a % of N in N-fertilizer and crop residues.
  - Determined using Equations 11.1, 11.6, and Table 11.3
- Applied to crop residues for all feedstocks.

Soil N_2O emissions from N-fertilizer and Crop Residues (gCO2e/MJ)

	Corn Ethanol	Sugarcane	Sorghum	Corn Stover
EF_{CR}=1.325%	15.45	7.48	18.35	0
EF_{CR}=1.225%	15.15	7.2	18.04	0.58
change:	-0.29	-0.28	-0.31	+0.58

[1] IPCC 2006 N_2O emissions from managed soils, and CO_2 emissions from lime and urea application 2006 IPCC Guidelines for National Greenhouse Gas Inventories vol 4 (Hayama: IGES) chapter 11 http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/4_Volume4/V4_11_Ch11_N2O&CO2.pdf

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Canola Farming Data

- Current GREET model uses Canola farming data from outside of North American
- Staff proposes to use the latest values from the Canadian Canola Council
- Based on a survey of more than 1,000 canola growers in North America
- Results are compared with current values in the next slide

Canola Farming Data (cont.)

Parameters	GREET1 2013 values	Canadian Canola Council survey values	Proposed values for CA-GREET2.0
Farming			
Diesel	1,006,720 Btu/dry MT	13.55 liters/dry MT	459,791 Btu/dry MT
Electricity	0	3.40 kWh/dry MT	11,601 Btu/dry MT
NG	0	1.03 MJ/dry MT	976 Btu/dry MT
Agrochemical Inputs			
Nitrogen	53.8 kg/dry MT	50.24 kg/dry MT	50.72 kg/dry MT
P_2O_5	15.42 kg/dry MT	14.39 kg/dry MT	14.31 kg/dry MT
K_2O	14.11 kg/dry MT	2.68 kg/dry MT	2.93 kg/dry MT
Lime	0	0	0
Pesticide	0	0.289 kg/dry MT	0.289 kg/dry MT
Herbicides	0.75 kg/dry MT	0.373 kg/dry MT	0.373 kg/dry MT
N_2O *from fertilizer*	1.325%	0.998 %	1.325%
N_2O *from residue*	1.225%	0.898%	1.225%

Denaturant Calculator

- Denaturant calculation in CA-GREET1.8b did not account for the displacement of ethanol by gasoline blendstock
- Calculation of denaturant CI will now be ethanol pathway-specific

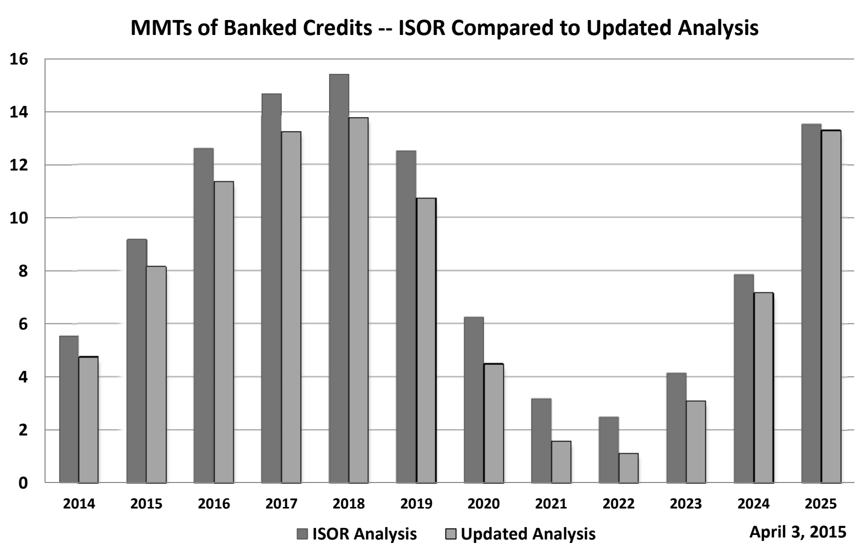
	Existing	Proposed
2010 Average Ethanol Denaturant CI	0.80	1.78

- California Reformulated Gasoline and Ethanol Denaturant Calculator (XLS)[1] provides a more comprehensive and clear explanation of the new approach to accounting for denaturant in ethanol
- Relies on a conservative assumption reflecting the legal requirement that denatured ethanol contains minimum of 94.6% vol. Remainder is assumed to be denaturant for the purposes of estimating emissions, consistent with CA GHG Inventory[2]

[1] Available from: http://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm

[2] California Environmental Protection Agency, Air Resources Board, "2014 Edition of California's 2000-2012 Greenhouse Gas Emissions Inventory Technical Support Document" (May, 2014) http://www.arb.ca.gov/cc/inventory/doc/methods_00-12/ghg_inventory_00-12_technical_support_document.pdf

LCFS Illustrative Compliance Scenario



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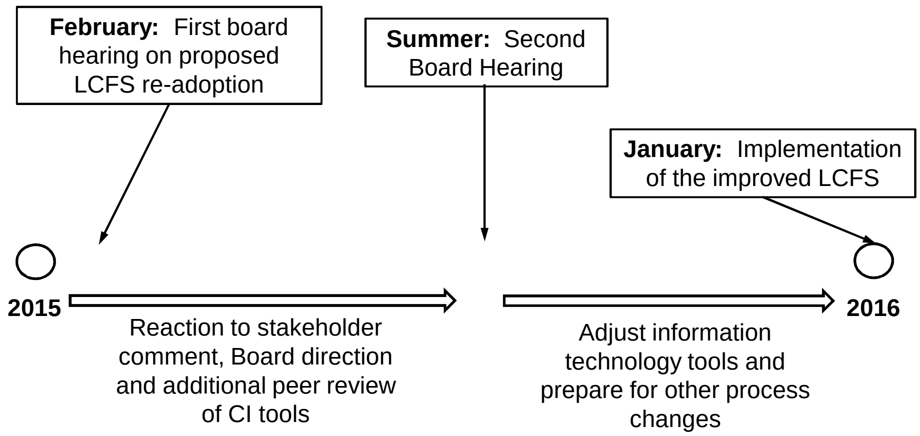
2015-2016 LCFS Timeline



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Thank You