LCFS Draft Report and California GREET Analysis Comments

(Based on 2Dec08 LCFS Draft)

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LCFS Summary of Comments

Item	Report	Comment	Old Value	Suggested Value	New WTT gCO2e/MJ
Baseline UAFCI for Hydrogen	LCFS Draft Report and North America Hydrogen http://www.arb.ca.gov/fuels/lcfs/072908lcfs_hydrogen.pdf	**The baseline UAFCI for hydrogen should be based on hydrogen produced at the station site by On-Site SMR (including biofeedstocks).** **Liquid hydrogen is not expected to be the primary means of hydrogen distribution.** **Rather, compressed hydrogen produced at the station site by on-site SMR is expected to be the primary mode of hydrogen production and distribution to vehicles in the near to mid future. See attached National Academies of Sciences information.** **ARB Should make a Compressed Hydrogen report based on North American Natural Gas, from On-Site Steam Methane Reforming. This document should set the baseline hydrogen UAFCI.** Important decisions will be made based on ARB scenarios using the baseline values, so it is very important to use the most correct values as the basis of those scenarios.	**153.0g/CO2e/MJ** based on liquid hydrogen production and distribution.	**95.8gCO2e/MJ**, based on the deletion of the hydrogen liquefaction energy and the trucking of liquid hydrogen and the inclusion of hydrogen compression.	**95.8gCO2e/MJ** for Compressed Hydrogen produced from steam methane reforming at the station site.

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LCFS Summary of Comments

Item	Report	Comment	Old Value	Suggested Value	New WTT gCO2e/MJ
Electric Vehicle and PHEV Energy Economy Ratio	The Draft Regulation for the California Low Carbon Fuel Standard http://www.arb.ca.gov/fuels/lcfs/1208lcfsreg_draft.pdf Appendix A p49, p51	**The EER of EV and PHEV in EV Mode is too high.** 1) The EER table is not based on real data from comparable test modes. ARB should use the best, real available data to make the EER table for PHEV. -Argonne National Labs has test data for PHEVs, based on Prius conversions. Also note that charge efficiency of 86% is optimistic – ANL measures 75% to 80% efficiency in actual testing. 2) The VOLT calculation is based on UDDS testing only, not HWY testing. Therefore it cannot be directly compared against other vehicles that are tested. UDDS is lower speed, and with more stops than HWY, so UDDS data will show much higher fuel economy than HWY testing. To establish an accurate image of the fuel economy, both tests should be used to set the EER. 3) The VOLT calculation is based on comparison to V6 Malibu fuel economy – this is probably not an appropriate comparison. VOLT is expected to be a compact car, the Malibu is mid-size.	**4.0**	**3.5 or less.** 1) Real data should be used to make the EER table. PHEV data for fuel economy and charging efficiency of Prius conversions is available from Argonne National Labs. 2) It is important to consider both tests – City and Highway to determine the average fuel economy of a vehicle. 3) If ARB would like to use the VOLT to base the EER table, a comparable 4cyl Compact vehicle should be used (like a COBALT)	

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Comment #1:
The baseline UAFCI for hydrogen should be based on hydrogen produced at the station site by on-site SMR

LCFS Draft Value: 153.3gCO_2e/MJ of Hydrogen (Based on Liquid Hydrogen)

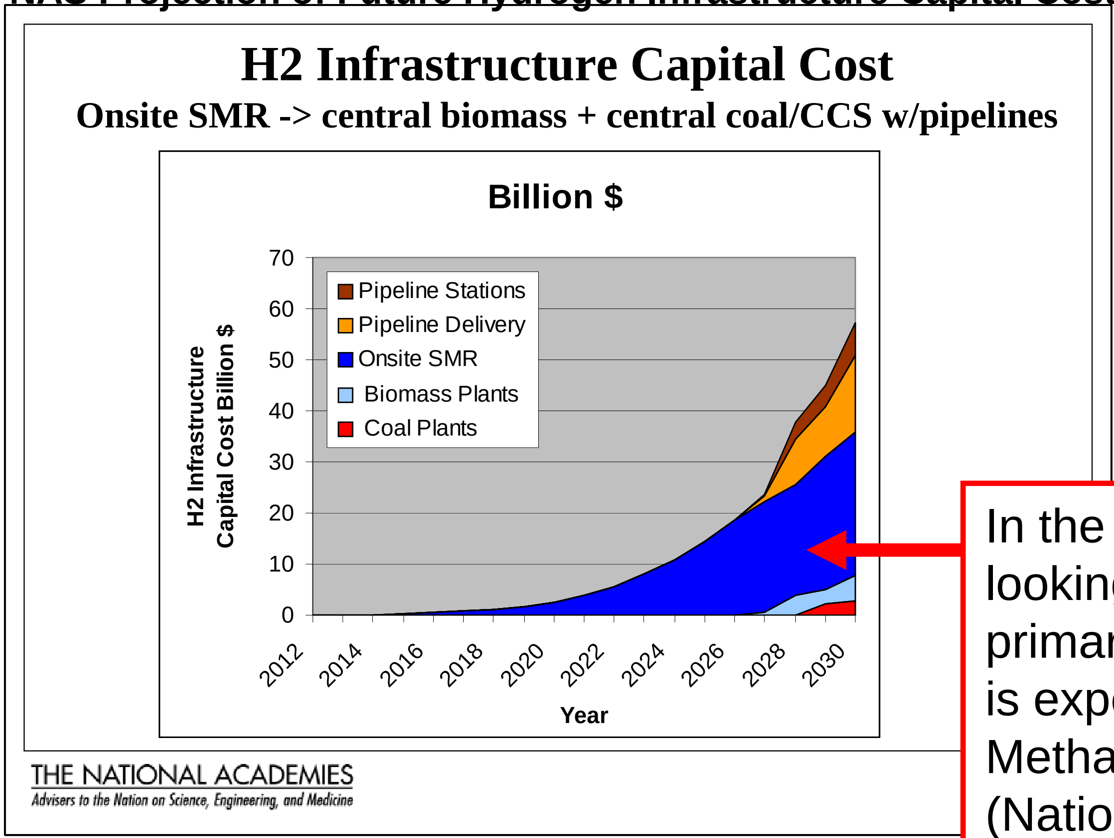
Requested: 95.8gCO_2e/MJ of Hydrogen (Based on Compressed Hydrogen)

Hydrogen Production and Delivery

National Academy of Sciences

- On-Site Steam Methane Reforming should be considered as the primary means of hydrogen production and distribution.
  - The assumption that the primary means of hydrogen distribution will be liquid hydrogen is erroneous.

NAS Projection of Future Hydrogen Infrastructure Capital Cost



Liquid hydrogen was used during the demonstration phase because the equipment was known, inexpensive, and robust, fitting for low volume demonstration facilities. However, it is recognized in the industry that this is probably not best means of providing a large, robust hydrogen infrastructure.

In the time period in which ARB is looking (to 2020 and beyond), the primary means of hydrogen production is expected to be on-site Steam Methane Reforming (Onsite SMR). (National Academy of Sciences 2008)

“Transitions to Alternative Transportation Technologies; a Focus on Hydrogen,” Joan Ogden, 17Nov08

H2 Compression Electricity Use and CO2 Emissions

The electricity used for hydrogen compression can be read directly from the "Hydrogen" sheet in GREET. This is multiplied by the CO2 content of electricity.

Assuming 94% compression efficiency (GREET Default[1])

1000000 BTUx(1/94%-1)

=63830 BTU electricity/MMBTU H2 throughput

=2.13kWh electricity/kgH2

2.13kWhelectricity/kgH2 x 3.6MJ/kWh x 106.7gCO2e/MJelectricity[2] / 120.0MJ/kgH2

=**6.8gCO2e/MJH2** for compression of Hydrogen.
This should be used for the "Distribution and Storage" amount.

1 – GREET Hydrogen Sheet Cell AX57

2 – LCFS Marginal Electrical Generation Emissions (from LCFS Draft Report page 48)

Hydrogen Production and Delivery Energy and Emissions

Table A. Summary of Energy Consumption and GHG Emissions for Liquid Hydrogen

	Energy Required (Btu/mmBtu)	% Energy Contribution	GHG Emissions (gCO_2e/MJ)	%Emissions Contribution
Well to Tank	(Should be re-evaluated)			
Feedstock	73,323	3%	8.1	5%
Hydrogen Production	430,522	16%	80.9	~~53%~~ ← Includes some LH2 boil-off loss. ARB should recalculate this.
Hydrogen Liquefaction	~~1,211,397~~ 0	44%	~~63.6~~ 0	42%
Distribution and Storage	~~9,176~~	0%	~~0.55~~ 6.8	~~0%~~ ← Liquid hydrogen distribution trucks are not needed. Compression of Hydrogen with electric compressors is included instead.
Total (WTT)	**~~1,724,418~~**	**63%**	**~~153.1~~ 95.8**	**100%**
Tank to Wheel				
Carbon/Energy in Fuel	1,000,000	37%	0	0
Vehicle CH_4 and N_2O			**0**	0
Total WTW	**~~2,724,418~~**	**100%**	**~~153.1~~ 95.8**	**100%**

Note: percentages may not add to 100 due to rounding

Table A from "Detailed GREET Pathway for Liquid Hydrogen from North American Natural Gas."

A detailed GREET calculation for hydrogen produced from natural gas on-site at fueling stations should result in GHG emissions of approximately **95.8gCO2e/MJH2**.

95.8gCO2e/MJH2 should be used as the primary value for the UAFCI for hydrogen in LCFS calculations.

Comment #2:
The EER of EV/PHEV is too high.

-Real data should be used, not press release information.
-Complete test data (City + Hwy) is needed for accurate vehicle comparison
-Appropriate comparison vehicles should be used (VOLT is COMPACT, Malibu is MIDSIZE)

LCFS Draft Value:	EV EER=4.0
Change Requested:	EV EER=3.5 or less.

Fuel Economy Measurement – Importance of Comparable Dyno Tests

- The information used for the fuel economy of the EV/PHEV (with the exception of the Rav4 EV) does not come from a known test mode.

LCFS Dec 2, 2008 Draft: Appendix A p51.

Data used to calculate BEV and PHEV mpg values:

AC Propulsion eBox mpg calculation					
Range (miles)	Charge (kWhr)	Charger Efficiency	mile/kWhr	mile/MJ	mpgge
135	35	0.86	3.32	0.92	106.5
PHEV (electricity mode) mpgge calculation					
Range (miles)	Charge (kWhr)	Charger Efficiency	mile/kWhr	mile/MJ	mpgge
40	8	0.86	4.3	1.19	138

Note: Range and Battery Capacity based on estimates for 40 mile range PHEVs.
Charger efficiency of 0.86 is estimated by Tesla motors for the Li ion battery.

This information comes from press releases, not laboratory test data.

Based on press release using UDDS.

Based on press release.

- To directly compare these vehicles against gasoline vehicles, similar test modes should be used to determine the amount of energy that is used in the test and in the recharging of the vehicle.
- EPA has established test modes for electric vehicles, gasoline vehicles, and fuel cell vehicles, and these modes should be used for EV/PHEV in LCFS.
- Argonne National Labs has test data for Toyota Prius PHEV conversions by Energy CS and Hymotion, including AC charging efficiency.
  - An analysis of ANL data shows the EER of Prius PHEV in Charge Depleting Mode is approximately 2.2 (vs Corolla) to 2.7 (vs Camry).

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Fuel Economy Measurement – Importance of Comparable Dyno Tests

ANL Hymotion Prius Test Results

2007-01-0283

Testing and Analysis of Three Plug-in Hybrid Electric Vehicles

Richard W. Carlson, Michael J. Duoba, Theodore P. Bohn, Anantray D. Vyas
Argonne National Laboratory

Table 2: Hymotion Prius, Consecutive UDDS Results

UDDS	#1	#2	#3	#4	#5
Miles Driven (mi)	7.48	7.48	7.48	7.48	7.47
Fuel Used (gal)	0.051	0.037	0.040	0.101	0.113
Electrical Energy Consumed (DC kWh)	0.93	0.96	0.94	0.23	-0.12
Fuel Economy (mpg)	148	200	187	74.3	66.4
Electrical Consumption (DC Wh/mi)	123	128	125	30.6	15.9

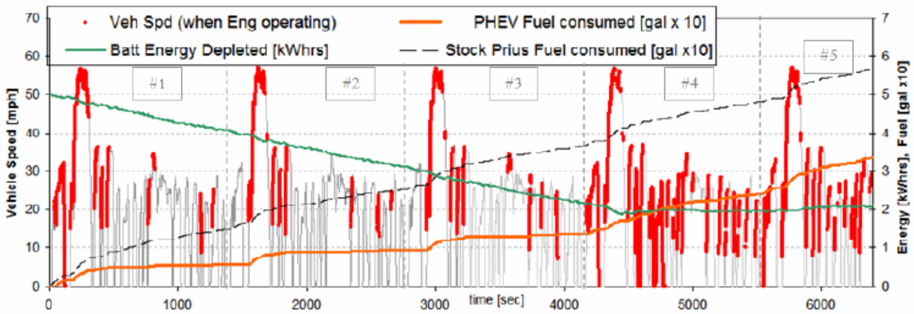

Figure 2: Hymotion Prius Driven on Repeated UDDS Cycles;
Cold Start from 100% SOC to CS Operation

This chart does not show AC kWh used, ANL measured the charging efficiency as 75% for the Hymotion Prius and 80% for the Energy CS Prius.

For more information:
Argonne National Laboratory Transportation Technology Research and Development Center
www.transportation.anl.gov/phev

Contact:
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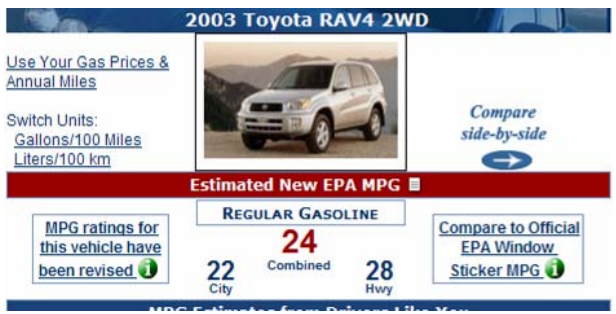
- Argonne National Labs has actual data for PHEV fuel economy and electrical usage.
- ARB could request data and PHEV analysis support from ANL for the purpose of evaluating PHEV EERs.

Fuel Economy Measurement – Importance of Comparable Dyno Tests

- EVs, HEVs, FCVs generally have higher city fuel economy than highway fuel economy (due to regenerative braking). This is opposite of conventional vehicles.
- The EER table in the LCFS Draft Report uses only UDDS data for the GM Volt (and unknown information for the E-Box).
- To compare city-only operation between an EV and a gasoline vehicle yields inaccurate results – it compares the BEST mode of EV vs the WORST mode of gasoline vehicles.
- To accurately compare vehicles, testing should be complete, and compared using the combined fuel economy.

Example from www.FuelEconomy.gov: 2003 Rav4 EV vs Gasoline Vehicle

(This shows Unadjusted Values)



(This shows 5-Cycle Derived Equation values)
Unadjusted values are
City 27.6 HWY 39.4 Combined 32.0 from EPA
http://www.epa.gov/otaq/tcldata.htm)

It makes a big difference to the EER if either City or Highway are not taken into account!

EER Calculation:

Unadjusted City Only → EV City / Gasoline City = 125mpg/22mpg = 4.5 ←

Combined → EV / Gasoline = 112mpg/ 32mpg = 3.5

Complete City/HWY test data is necessary to calculate the EER. UDDS data only is insufficient to compare vehicles.

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Fuel Economy Measurement – Importance of Comparable Vehicles

LCFS Dec 2, 2008 Draft: Appendix A p49.

Draft – For Discussion Only Draft LCFS Regulation

PHEVs	Combined mpg
Chevy Volt (electric mode)	138

Gasoline Vehicle	New City mpg	New HWY mpg	Old City mpg	Old HWY mpg	Unadj. Old City mpg	Unadj. Old HWY mpg	Unadj. Combined mpg	EER
Chevy Malibu 4 cyl. 2.4L S6	22	32	25.0	35.0	27.8	44.9	33.5	
Chevy Malibu 4 cyl. 3.5L 4spd	22	30	25.0	33.0	27.8	42.3	32.9	
Chevy Malibu 6 cyl. 3.6L 4spd	18	29	20.0	32.0	22.2	41.0	28.0	
Chevy Malibu 6 cyl. 3.6L S6	17	26	19.0	28.0	21.1	35.9	25.9	
	19.75	29.25					30.1	4.59

=138/30.1

Note: The 40 mile for range the Volt is calculated over the FTP so the corresponding mpgs for the Malibu is unadjusted.

Average combined mpg BEV and PHEV (electric mode): 118.8

Average EER for BEV and PHEV relative to a conventional gasoline vehicle: 4.0
=average(3.57+3.84+4.59)

Comparing Malibu, VOLT, and Cobalt

	Malibu 4Cyl	Volt	Cobalt
Wheelbase	112.3 in (2852 mm)	105.7 in (2,680 mm)	103.3 in (2624mm)
Length	191.8 in (4872 mm)	177 in (4,500 mm)	180.3 in (4579mm)
Width	70.3 in (1786 mm)	70.8 in (1,800 mm)	67.9 in (1720mm)
Height	57.1 in (1450 mm)	56.3 in (1,430 mm	57.1 in (1450mm)
Raw FTP	27.3	138	31.1
Raw HWY	42.3		46.2
Comb	32	138	36
Volt EER	4.25		3.78

Volt is smaller than Malibu, more similar to Cobalt.

Volt dimensions from http://en.wikipedia.org/wiki/Chevrolet_Volt
Raw Fuel Economy from http://www.epa.gov/otaq/tcldata.htm

1) The GM Volt is expected to be a 4cylinder gasoline vehicle. 6 cylinder vehicles are listed in the LCFS Draft. If only 4Cyl Malibu is considered, EER reduces from 4.6 to 4.25.

2) The VOLT is expected to be a COMPACT vehicle, while the MALIBU is MIDSIZE. An appropriate COMPACT vehicle should be used to make the comparison.

If VOLT is compared to 4cyl Cobalt, EER is 3.78. (This is NOT including any adjustment for lack of Hwy data for VOLT!)

If HWY data is included for the VOLT and E-Box, even 120mpg HWY, the resulting EER will be less than 3.5.

→ EER of PHEV (EV Mode) and EV should be 3.5 or less.