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# LCFS Draft Report and California GREET Analysis Comments

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# LCFS Summary of Comments

| Item | Report | Comment | Old Value | Suggested Value | New WTT gCO2e/MJ |
|---|---|---|---|---|---|
| California Average Electricity WTT Result | Electricity http://www.arb.ca.gov/fuels/lcfs/042308lcfs_elec.pdf | **The heating content of coal is incorrect in the Fuel_Specs sheet**, resulting too high electricity CO2 content.<br>→ This change would impact all fuel pathways that use California Average Electricity in the ca_greet1.7v98. | **15,421,670 BTU/ton** (ca_greet1.7v98 Fuel_Specs Sheet) | **19,546,300 BTU/ton** (GREET Default). This is the same as the California GREET 1.8 model. | 128.8gCO2e/MJ for Electricity |
| Liquid Hydrogen from Natural Gas WTT Result | North America Hydrogen http://www.arb.ca.gov/fuels/lcfs/072908lcfs_hydrogen.pdf | **The efficiency of hydrogen liquefaction is incorrectly calculated in the Fuel_Prod_TS sheet**, resulting in too high electricity use for liquefaction, and too high CO2 content for hydrogen. | **62.5% Efficiency** (based on 12.5kWh electricity per kg of hydrogen liquefied) (ca_greet1.7v98 Fuel_Prod_TS sheet) | **72.7% Efficiency** (based on 12.5kWh electricity per kg of hydrogen liquefied) or GREET1.8 Default.<br>(Actual process may be more efficient - ARB should request data from Air Products and Chemicals Inc) | 129.2gCO2e/MJ for Liquid Hydrogen |
| Fuel Cell Vehicle Energy Economy Ratio | The Draft Regulation for the California Low Carbon Fuel Standard http://www.arb.ca.gov/fuels/lcfs/101008lcfsreg_draft.pdf Appendix A3 p40 | **The EER of Fuel Cell Vehicles is too low.**<br>1) It is based on vehicles that are not "2010" intent.<br>2) The fuel economy listed is adjusted, combined.<br>FCX Clarity is a MIDSIZE Sedan, designed to be a fuel cell vehicle, and should be used to set the EER. | **2.2** | **EER of FCV should be 3.0**<br>FCX Clarity Unadjusted Combined Fuel Economy = 85.8mpkg=87.9mpgge<br>Midsize sedan 2010 CAFÉ average Unadjusted combined fuel economy = 29.0mpg.<br>87.9/29.0=3.03 | |
| Electric Vehicle Energy Economy Ratio | The Draft Regulation for the California Low Carbon Fuel Standard http://www.arb.ca.gov/fuels/lcfs/101008lcfsreg_draft.pdf Appendix A3 p40 | **The EER of EVs is too high.**<br>1) It is based on very small, limited utility vehicles (2 seat, short range, no trunk space, etc)<br>2) The fuel economy listed is unadjusted UDDS, or even press release material, not EPA tested values.<br>3) The fuel economy figures cited for some of the vehicles do not include charger efficiency, which is typically about 85%. | **4.1** | **EER of EV should be 3.5**<br>Include the charger efficiency of 85%. 4.07*85%=3.5.<br>US DOE GREET uses 3.5.<br>CEC(2007) uses 3.6.<br>RAV4 EV compared to RAV4 Gasoline version = 3.5 | |

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# Other General Comments

- ARB needs to reconsider the reports that were done with the greet1.7ca_v98 model.
  - Any report that uses California Average Mix grid electricity will be incorrect
- ARB should post an as-modified, documented GREET model for each of the reports. Every report lists several modifications to the base model. It is almost impossible to independently check the report or the accuracy of the model.
- All changes to GREET should be documented and explained.
- We only reviewed a few reports, and not as thoroughly as possible. All LCFS reports and GREET modifications should be independently verified and agreed to by another agency (UCDavis, UCBerkely, etc) before becoming the basis for policy decisions.
- ARB should a do a Compressed Hydrogen report.
  - The assumption of liquid hydrogen delivery is inconsistent with the expected predominant methods of hydrogen delivery in the near, mid, and long term.
    - Delivery of compressed hydrogen to vehicles from on-site SMR (such as Burbank), on-site SMR from Renewable Bio-Methane (Fountain Valley), on-site Electrolysis from Renewables (Shell West Los Angeles, CSULA, SMUD, AQMD), etc will form the majority of delivered hydrogen in the future.
- When considering an EER table, consistency in reference data is very important
  - GREET uses midsize vehicle as a base
  - Make sure the source and nature of the fuel economy data is explicitly known and directly comparable
    - Ie) unadjusted hot UDDS, unadjusted combined, etc. Make sure the test mode is known
    - Unadjusted combined is best for comparison
    - Do not use press release or otherwise unverified data
  - Make sure the EV fuel economy data is the plug-to-wheels fuel economy
    - Chargers are approximately 85% efficient.
    - Some EVs also have large charging losses due to battery cooling and conditioning during charging, and this needs to be captured in the plug-to-wheels efficiency.
  - Use the harmonic average rather than an arithmetic average to calculate fuel economy with appropriate city/highway ratios (55% of driving city, 45% highway).

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# LCFS Electricity Report Error

California Environmental Protection Agency
Air Resources Board

**Detailed California-Modified GREET Pathway for California Average Electricity**

Stationary Source Division
Release Date: April 16, 2008
Version 1.0

http://www.arb.ca.gov/fuels/lcfs/042308lcfs_elec.pdf

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# LCFS Electricity Report Error

- The greet1.7ca_v98 contains an undocumented change to the heating value of coal in the Fuel_Specs sheet.
  - Electricity CO2 result is much higher on the greet1.7ca_v98 model than the ca_greet1.8b model.
  - This change would impact all fuel pathways that use California Average Electricity and the ca_greet1.7v98, so those reports should be corrected.

| | greet1.7ca_v98 | ca_greet1.8b | Greet1.8 Default |
|---|---|---|---|
| Coal Heating Value | 15,421,670 BTU/ton **(This is wrong!)** | 19,546,300 BTU/ton | 19,546,300 BTU/ton |
| Electricity gCO2e/kWh (at the plug) | 592g/kWh using ARB Mix in CA | 464g/kWh using ARB Mix in CA | CA-453g/kWh US-776g/kWh |

- This would result in corrected California Average Electricity of 128.8g/MJ

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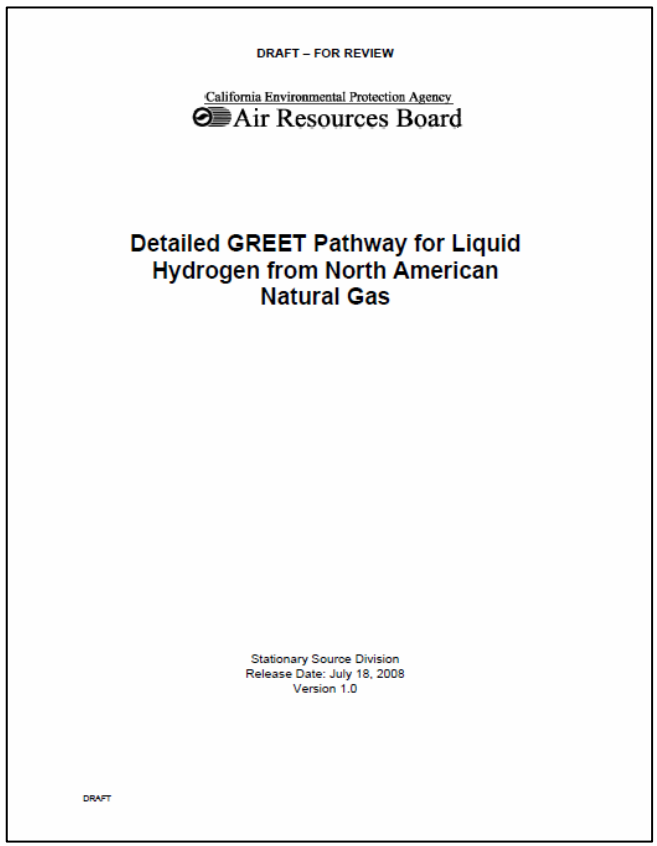
# LCFS Liquid Hydrogen Report Error



DRAFT – FOR REVIEW

California Environmental Protection Agency
Air Resources Board

**Detailed GREET Pathway for Liquid Hydrogen from North American Natural Gas**

Stationary Source Division
Release Date: July 18, 2008
Version 1.0

DRAFT

Based on report from:
http://www.arb.ca.gov/fuels/lcfs/072908lcfs_hydrogen.pdf

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# LCFS Liquid Hydrogen Report Error

- The Liquid Hydrogen Report to determine the carbon content of liquid hydrogen contains an error:
  - The efficiency of hydrogen liquefaction is incorrectly calculated, resulting in extremely high calculated electricity use.
  - The source of the liquefaction energy data (12.5kWh/kg) is not documented.

Definition of Liquefaction Efficiency
(Used in CA_GREET1.7v98Model Fuel_Prod_TS Sheet )

$$\eta = \frac{Electricity}{H2Out}$$

$$\eta = \frac{12.5kWh}{33.3kWh}$$

$$\eta = 62.5\%$$

Electricity to liquefy 1kg of hydrogen (data source not documented)

LHV of 1kg of hydrogen

Incorrect!!

Definition of Liquefaction Efficiency
(Used by GREET)

$$\eta = \frac{EnergyOut}{EnergyIn} = \frac{H2Out}{H2In + Electricity}$$

$$\eta = \frac{33.3kWh}{33.3kWh + 12.5kWh}$$

$$\eta = 72.7\%$$

- If the calculation error is corrected and no other changes made, the CO2 content of liquid hydrogen changes from 153.1gCO2e/MJ to 129.2gCO2e/MJ, and the total WTW energy use changes drastically!
- 72.7% is better than GREET default, but ARB should also request data from industry.

See General Comments – why is the focus on liquid hydrogen delivery, when this is not the goal of the industry?

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# Vehicle EERs

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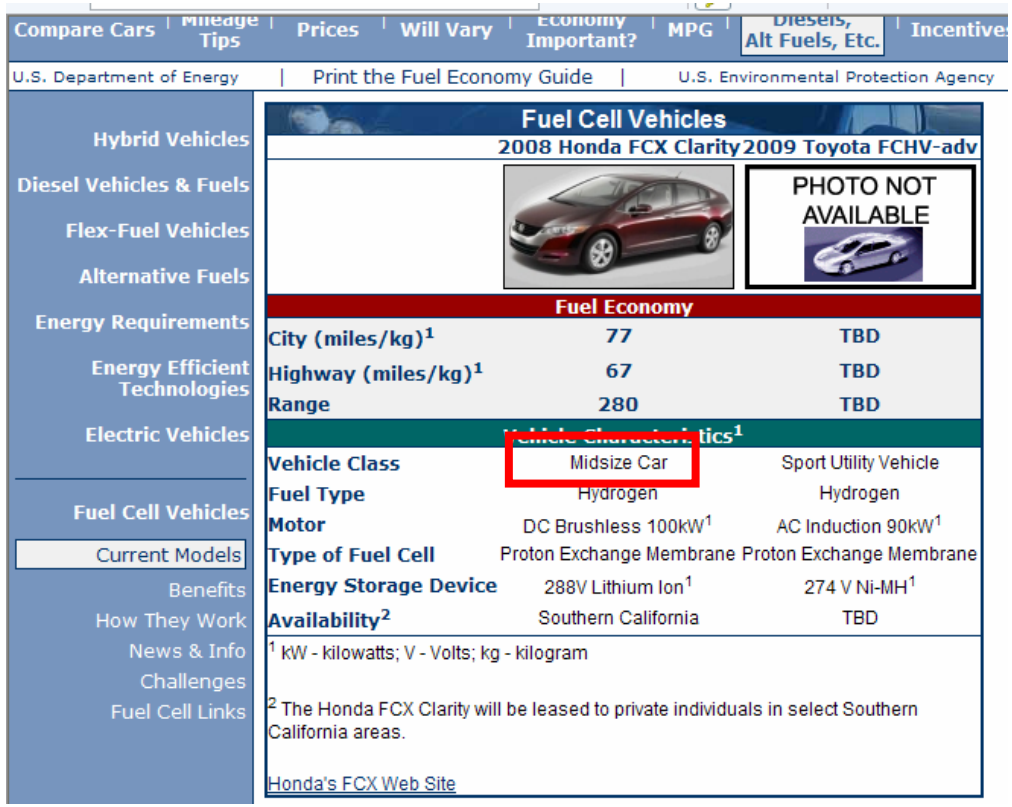
# FCV EER – 2008 FCX Clarity

| 2008 FCX Clarity Fuel Economy Results as Tested By EPA | Miles per kg of hydrogen | | | Miles per gasoline gallon equivalent | | |
|---|---|---|---|---|---|---|
| | City | Hwy | Combined | City | Hwy | Combined |
| Unadjusted (Raw test data) | 86.1 | 85.4 | 85.8 | 88.2 | 87.5 | **87.9** |
| Adjusted (0.78xHWY, 0.9xCity) | 77.49 | 66.6 | 72.2 | 79.4 | 68.3 | 74.0 |
| Label Value | 77 | 67 | 72 | 79 | 68 | 74 |

EPA uses 1gge=1.0245kg Hydrogen

- FCX Clarity is the only **midsize** FCV tested by EPA.
- Average **midsize** car Unadjusted CAFÉ fuel economy is about 29.0miles/gallon.
- UNADJUSTED fuel economy is 88.2miles/gge city 87.5 miles/gge hwy = 87.9 miles/gge combined.
- EER of FCV should be 87.9/29.0 = 3.03
- Previous FCVs should not be used to calculate EERs because
  - a) these are very immature relative to today's vehicles
    - Technology was expected to improve greatly from 2003-2005 levels.
  - b) there will be none of these vehicles on the ground in 2010




http://www.fueleconomy.gov/feg/fcv_sbs.shtml

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# EV EER – 2002 RAV4 EV

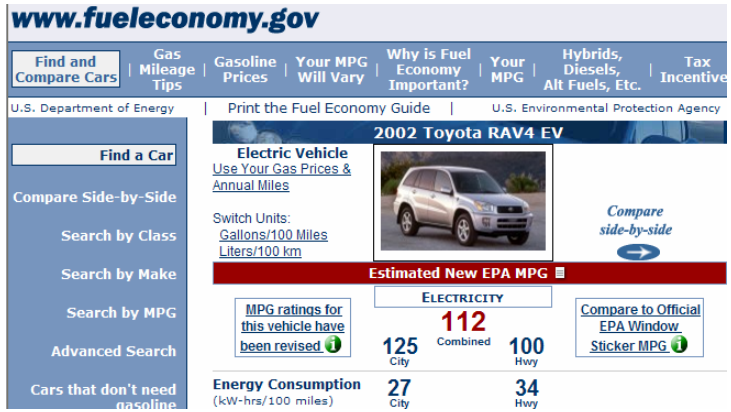
- 2002 Toyota RAV4 EV is similar in size and weight to a midsize car, and was produced in similar gasoline and EV versions.

- Rav4 EV
  - Unadjusted_City_FE=125miles/gge
  - Unadjusted_Hwy_FE=100miles/gge
  - Unadjusted_Combined_FE=112miles/gge
    - This includes the charging loss. EPA runs the vehicle until the battery is empty, and then charges the battery and measures the amount of electricity.

- Rav4 Gasoline (estimates based on adjusted values)
  - Unadjusted_City_FE=25mpg/0.9=27.8mpg
  - Unadjusted_Hwy_FE=31mpg/0.78=39.7mpg
  - Unadjusted_Combined_FE=32.1mpg
    - This is higher than the CAFÉ 28.5mpg vehicle, but both the RAV4 EV and RAV4 Gasoline versions are lower weight as well.

- EER of EV should be 112/32.1=3.49 →3.5

- Also if the charging efficiency is included in the ARB calculations, 4.07x85%=3.5





http://www.fueleconomy.gov/feg/calculatorSelectEngine.jsp?year=2002&make=Toyota&model=RAV4 EV

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# Note on Combined Fuel Economy Calculations and FuelEconomy.gov

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# www.fueleconomy.gov

- The fueleconomy.gov data cannot be compared directly between different vehicles and different model years without some correction. The figures are listed using different adjustment factors.

Fuel Economy Figures Given on fueleconomy.gov are:

| Model Year | EV | FCV | Gasoline Vehicle |
|---|---|---|---|
| 2007 and Before | **Unadjusted**<br>Unadjusted City<br>Unadjusted HWY | **Adjusted**<br>0.9xUnadjusted City<br>0.78xUnadjusted HWY | **Adjusted**<br>0.9xUnadjusted City<br>0.78xUnadjusted HWY |
| 2008 | (none listed) | **Adjusted**<br>0.9xUnadjusted City<br>0.78xUnadjusted HWY | **5 Mode Adjusted**<br>5 Modes<br>Or MPG based equation |
| 2009 | (none listed)<br>(EPA, SAE and CARB are considering what to do) | **EPA is considering now.** | **5 Mode Adjusted**<br>5 Modes<br>Or MPG based equation |

Fuel economy figures are only directly comparable when using the same test modes and adjustment metrics! Otherwise we are comparing apples, oranges, and bananas!

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# Note on Fuel Economy Calculations

For 2007 and prior model years, the values quoted on the fueleconomy.gov site for gasoline vehicles and fuel cell vehicles are “adjusted” values, whereas the numbers for EVs are “unadjusted.” The adjustment is:

*Adjusted_City_FE=0.9 x Unadjusted_City_FE*
*Adjusted_Hwy_FE=0.78 x Unadjusted_HWY_FE*

To make an unadjusted, combined fuel economy number, take the city and highway raw fuel economy scores and **average harmonically**:

$$Unadjusted\_Combined\_FE = \frac{1}{\frac{0.45}{Unadjusted\_HWY\_FE} + \frac{0.55}{Unadjusted\_City\_FE}}$$

$$Adjusted\_Combined\_FE = \frac{1}{\frac{0.45}{0.78 x Unadjusted\_HWY\_FE} + \frac{0.55}{0.9 x Unadjusted\_City\_FE}}$$

(2007 and Prior)

(Note that the “combined fuel economy” in some parts of the draft document is not averaged harmonically (such as the CNG vehicle fuel economy).