

## Comparison of Greenhouse Gas Emissions from Natural Gas and Diesel Vehicles Underlying Assumptions

- California-specific GREET Model (Modified by Life Cycle Analysis for CA), version 1.8b
- EMFAC (ARB Website) Fuel Economy Values (MJ/Mile): 5.49 (CNG/LNG LDV), 26.86 (CNG/LNG HDV), 5.38 (Diesel/LCFS Diesel LDV), 25.25 (Diesel/LCFS Diesel HDV)
- AB 1007 (CEC Website) EER Values: LDV (CNG and LNG) = 0.98; HDV (CNG and LNG) = 0.94
- Truck Transport Distance = 50 Mil

## Detailed CNG/LNG CA-GREET GHG Emissions

A California modified GREET model v1.8b (CA-GREET) was used to calculate detailed pathway GHG emissions for several pathways detailed below. The pathways include NG recovered in CA and other locations, transported either as NG or LNG and used in LD and HD vehicles as CNG and LNG. Table 1 below details the stage-wise contributions to each pathway and also provides a total for each pathway, both for LD and HD vehicles.

Table 1. CA-GREET GHG emissions for different CNG and LNG Pathways

	NG in CA	NG in MW to CA	NG in Canada, to CA	LNG to Gulf NG to CA, CNG	LNG to Baja NG to CA, CNG	NG in Can, NG to CA, LNG	LNG to Baja NG to CA LNG	LNG to South Coast as LNG	ULSD
Production	3.7	3.7	3.7	3.7	3.7	3.7	3.7	3.7	6.4
Processing	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	
Transport	0.22	6.27	7.9	7.9	1.39	7.9	1.39	0	2.2
1st Liquefaction	0	0	0	13	13	11.97	13	13	
Shipping (tanker)	0	0	0	4	4	0	4	4	
Compression	2.9	2.9	2.9	2.9	2.9	0		0	
Regasification	0	0	0	1.16	1.16	0	1.16	0	
2nd Liquefaction	0	0	0	0	0	0	11.97	0	
LNG/Diesel Truck Transport	0	0	0	0	0	0.157	0.157	0.157	0.3
Refining	0	0	0	0	0	0	0	0	12.3
LD veh comb	56.3	56.3	56.3	56.3	56.3	57.3	57.3	57.3	75.6
<b>LD Total</b>	<b>67.3</b>	<b>73.4</b>	<b>75.0</b>	<b>93.2</b>	<b>86.7</b>	<b>85.2</b>	<b>96.9</b>	<b>82.4</b>	<b>96.8</b>
HD veh comb	55.3	55.3	55.3	55.3	55.3	56.3	56.3	56.3	74.7
<b>HD total</b>	<b>66.3</b>	<b>72.4</b>	<b>74.0</b>	<b>92.2</b>	<b>85.7</b>	<b>84.2</b>	<b>95.9</b>	<b>81.4</b>	<b>95.9</b>

For NG in CA, staff has published a CNG document which may be downloaded from [http://www.arb.ca.gov/fuels/lcfs/042308lcfs\\_cng.pdf](http://www.arb.ca.gov/fuels/lcfs/042308lcfs_cng.pdf). The value from that document (67.9) is different compared to the one for CA NG here (67.3) (column 2 in Table 1) and is likely due to different tailpipe emission factors for CH<sub>4</sub> and N<sub>2</sub>O and fuel economy values used in the two analyses. Also, GWP factors for N<sub>2</sub>O and CH<sub>4</sub> were 296 and 23 respectively in the published document but has now been updated to be 298 for N<sub>2</sub>O and 25 for CH<sub>4</sub> based on IPCC updates.

The ULSD pathway details can be downloaded from ([http://www.arb.ca.gov/fuels/lcfs/042308lcfs\\_ulsd.pdf](http://www.arb.ca.gov/fuels/lcfs/042308lcfs_ulsd.pdf)). For ULSD, the value in the published document (99.6) is different compared to one in this document (96.8), primarily due to different tailpipe emission factors for CH<sub>4</sub> and N<sub>2</sub>O and fuel economy values used in the two analyses. The values calculated in Table 1 above used various assumptions for transport distances, electricity mix, etc. Details of these are provided in Table 2 below. Note that at this time, the CA-GREET model has not been fully updated for the LNG pathway.

Table 2. Assumptions and values used

Parameter	Value	Details
Pipeline Transport distance from Gulf to CA (mile)	1764	Assumed distance
Pipeline Transport distance from Canada to CA (mile)	1764	Assumed distance
Pipeline Transport distance from Mid-west to CA (mile)	1400	Assumed distance
Pipeline Transport distance within CA (mile)	50	Assumed distance
Pipeline Transport distance from Baja to CA (mile)	315	Assumed distance
Ocean Tanker distance to Gulf from overseas (mi)	7118	Assumed distance
Ocean Tanker distance to Baja from overseas (mi)	7118	Assumed distance
LNG truck transport within CA (mile)	50	Assumed distance
NG Production and Processing		The GHG emissions for these two steps are assumed to be the same wherever the gas is produced and processed. The values of 3.7 gCO <sub>2</sub> e/MJ for production and 4.2 gCO <sub>2</sub> e/MJ for processing are assumed

		to be the same for all pathways considered here. The basis of these values can be obtained from the CNG document downloadable from <a href="http://www.arb.ca.gov/fuels/lcfs/042308lcfs_cng.pdf">http://www.arb.ca.gov/fuels/lcfs/042308lcfs_cng.pdf</a>
Liquefaction overseas (gCO <sub>2</sub> e/MJ) in Malaysia or other location outside CA	13	91% process efficiency with GREET default using 91% NG as process fuel, balance electricity and diesel. Note that this value is 13 g/CO <sub>2</sub> e/MJ
Liquefaction in CA (gCO <sub>2</sub> e/MJ)	11.97	All electricity with CA average mix. Note that this value is 11.97 gCO <sub>2</sub> e/MJ. Energy use assumed 1.82 kW/gallon. Please refer to the CA-GREET electricity pathway document for details on electricity GHG emissions. ( <a href="http://www.arb.ca.gov/fuels/lcfs/042308lcfs_elec.pdf">http://www.arb.ca.gov/fuels/lcfs/042308lcfs_elec.pdf</a> )
Electricity(gCO <sub>2</sub> e/MJ)	144	For all overseas and outside used U. S. Average. For all processes inside CA, used CA average electricity
CNG LD Fuel economy (MJ/mi)	5.49	For LD, used diesel LD fuel economy and divided by EER (which was assumed to be 0.98)
CNG HD Fuel economy (MJ/mi)	26.86	For HD, used diesel HD fuel economy and divided by EER (which was assumed to be 0.94)
LNG LD Fuel economy (MJ/mi)	5.49	For LD, used diesel LD fuel economy and divided by EER (which was assumed to be 0.98)
LNG HD Fuel economy (MJ/mi)	26.86	For HD, used diesel HD

		fuel economy and divided by EER (which was assumed to be 0.94)
ULSD LD Fuel economy (MJ/mi)	5.38	EMFAC has total gallons used and VMT for LD vehicles. This was used to calculate fuel economy.
ULSD HD Fuel economy (MJ/mi)	25.25	EMFAC has total fuel used and VMT for HD vehicles. This was used to calculate fuel economy.
LD (CNG and LNG) N <sub>2</sub> O emission factor (g/mi)	0.012	Calculated by staff using data from EMFAC
LD (CNG and LNG) CH <sub>4</sub> emission factor (g/mi)	0.146	Considered same as ULSD
HD (CNG and LNG) N <sub>2</sub> O emission factor (g/mi)	0.012	Calculated by staff using data from EMFAC
HD (CNG and LNG) CH <sub>4</sub> emission factor (g/mi)	0.146	Considered same as ULSD
LD (ULSD) N <sub>2</sub> O emission factor (g/mi)	0.016	Used total GHG inventory for N <sub>2</sub> O from ARB website and calculated N <sub>2</sub> O emission factor for LD. ( <a href="http://www.arb.ca.gov/cc/inventory/data/tables/rpt_inventory_IPCC_All_2007-11-19.pdf">http://www.arb.ca.gov/cc/inventory/data/tables/rpt_inventory_IPCC_All_2007-11-19.pdf</a> )
LD (ULSD) CH <sub>4</sub> emission factor (g/mi)	0.146	Some undocumented source
HD (ULSD) N <sub>2</sub> O emission factor (g/mi)	0.045	Used total GHG inventory for N <sub>2</sub> O from ARB website and calculated N <sub>2</sub> O emission factor for LD.
HD (ULSD) CH <sub>4</sub> emission factor (g/mi)	0.146	Used same as for LD ULSD
GWP for N <sub>2</sub> O	298	GREET default
GWP for CH <sub>4</sub>	25	GREET default