Appendix F:
Estimated Carbon Intensity Values for the Crude Lookup Table

Proposed Amendments to the Low Carbon Fuel Standard Regulations

Release Date: December 19, 2023

Estimating Carbon Intensity Values for the Crude Lookup Table

A. Proposed Crude Lookup Table CI Values for Individual Crudes

All carbon intensity values were calculated using the Oil Production Greenhouse Gas Emissions Estimator v3.0b[1]. The model user guide and technical documentation provides a description of the model. Versions of the Oil Production Greenhouse Gas Emissions Estimator (OPGEE) have been presented for stakeholder review at eleven CARB workshops[2] and reviewed and/or used in several reports and journal publications.[3,4,5,6,7,8,9] In estimating the carbon intensity for crude oil production and transport to the refinery, OPGEE uses, as model inputs, detailed field-level data such as production method and surface processing equipment, reservoir properties, crude oil and associated gas properties, production and injection volumes, and transport data such as modes of transport and distances from the field to the refinery. In those instances where this level of detail is not known, OPGEE fills in missing data with simple defaults and smart defaults. Smart defaults are used for lesser-known parameters that can be correlated to frequently known parameters. Examples of smart defaults in OPGEE are the estimation of water-oil-ratio and gas-to-oil ratio using field age and crude density as correlation parameters and the estimation of flaring rate using location of crude production together with satellite data.

Detailed model inputs used to estimate the lookup table carbon intensity values shown in Table 9 of the proposed regulation language (Appendix A) are contained in an Excel file.[10] In order to duplicate these carbon intensity values, model inputs for each crude source can be

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[1]Brandt, A.R., Masnadi, M.S, Rutherford, J.S., El-Houjeiri, Vafi, K., H.M., Langfitt Q., Duffy, J., Sleep, S., Pacheco, D., Dadashi, Z., Orellana, A., MacLean, H., McNally, S., Englander, J., & Bergerson, J., *Oil Production Greenhouse Gas Emissions Estimator OPGEE v.3.0b.* (Updated on May 14, 2022). *https://eao.stanford.edu/research-project/opgee-oil-production-greenhouse-gas-emissions-estimator*

[2] Workshops held on March 19, 2012; July 12, 2012; March 5, 2013; March 11, 2014; July 10, 2014; April 4, 2017; August 7, 2017; August 10, 2021, October 14, 2020; April 26, 2022, and February 22, 2023. Source: California Air Resources Board, *Oil & Natural Gas: Meetings & Workshops*. (Accessed on November 8, 2023). *https://ww2.arb.ca.gov/our-work/programs/oil-and-natural-gas-production-processing-and-storage/workshops-meetings*

[3] El-Houjeiri, H.M., Brandt, A.R., & Duffy, J.E., *Open source LCA Tool for Estimating Greenhouse Gas Emissions from Crude Oil Production Using Field Characteristics*. Environmental Science & Technology. May 1, 2013. *https://pubs.acs.org/doi/10.1021/es304570m*

[4] El-Houjeiri, H.M., & Brandt, A.R., *Exploring the variation of GHG emissions from conventional oil production using an engineering-based LCA model*. American Center for Life Cycle Assessment (ACLCA) LCA XII Conference. Tacoma, WA. September 27, 2012.

[5] IHS Inc., *Special Report: Comparing GHG intensity of the oil sands and the average US crude oil*. May 2014.

[6] The International Council on Clean Transportation, *Upstream Emissions of Fossil Fuel Feedstocks for Transport Fuels Consumed in the European Union*. 2014. https://theicct.org/publication/upstream-emissions-of-fossil-fuel-feedstocks-consumed-in-the-european-union/

[7] (S&T)[2] Consultants Inc., *OPGEE analysis and comparison to GHGenius*. Prepared for Natural Resources Canada. August 19, 2013.

[8] Vafi, K. & Brandt, A.R., *Uncertainty of Oil Field GHG Emissions Resulting from Information Gaps: A Monte Carlo Approach.* Environmental Science and Technology, 48, 10511-10518. August 10, 2014. *https://pubs.acs.org/doi/10.1021/es502107s*

[9] Vafi, K. and Brandt, A.R., *Reproducibility of LCA Models of Crude Oil Production*. Environmental Science and Technology, 48, 21, 12978-12985. October 3, 2014. *https://pubs.acs.org/doi/10.1021/es501847p*

[10] California Air Resources Board, *MCON Inputs Spreadsheet for Crude Lookup Table (OPGEE 3.0b)*. (Accessed May 2023). *https://ww2.arb.ca.gov/resources/documents/lcfs-crude-oil-life-cycle-assessment*

copied from the Excel file into the corresponding cells on the Inputs sheet of OPGEE and the Run Assessment button clicked. For all California crudes and a few out-of-state crudes, additional cells not on the Inputs sheet must be modified from defaults. These changes are noted on the model inputs spreadsheets for these crudes.

B. Calculation of the 2010 Baseline Crude Average CI Value

The Baseline Crude Average CI is a volume-weighted average of carbon intensity values for crudes supplied to California refineries during the baseline year 2010. Table 1 below shows a breakdown of the sources of crude oil supplied to California refineries during 2010 and the carbon intensity values assigned to these crude sources. All carbon intensity values were calculated using OPGEE v3.0b.

All crude oil produced in and offshore of California is assumed to be refined in California. The volume contributions for California-produced crudes are based on oil production data obtained from the California Department of Conservation.[11] The volume contributions for California federal offshore crudes are based on oil production data obtained from the Bureau of Safety and Environmental Enforcement.[12] The volume contributions of imported crudes are based on oil supply data provided by the California Energy Commission.[13]

Detailed model inputs used to estimate the carbon intensity values are contained in an Excel file.[14] In order to duplicate these carbon intensity values, the "reference year for default flaring intensity" must be set to 2010 (cell M347 of the Secondary Inputs sheet in OPGEE). Model inputs for each crude source can be copied from the Excel file into the corresponding cells on the Inputs sheet in OPGEE and the Run Assessment button clicked. For all California crudes and a few out-of-state crudes, additional cells not on the Input sheet must be modified from defaults. These changes are noted on the model inputs spreadsheets for these crudes.

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[11] Crude production data copied from the California Department of Conservation, *Online Production and Injection Query*. (Accessed February 19, 2018).

[12] Crude production data downloaded from the Bureau of Safety and Environmental Enforcement website, *BSEE Federal OCS Data 2010 and 2012*. (Accessed May 9, 2013).

[13] California Energy Commission, *2010 MCON Import Results 01-28-12 GDS (spreadsheet).*

[14] California Air Resources Board, *MCON Inputs Spreadsheet for 2010 Baseline Crudes (OPGEE 3.0b)*. (Accessed May 2023). *https://ww2.arb.ca.gov/resources/documents/lcfs-crude-oil-life-cycle-assessment*

Table 1: Calculation of Proposed 2010 Baseline Crude Average CI

Country/State	Crude Name	2010 CI (gCO_2/MJ)	2010 Volume (bbl)
	2010 Baseline Crude Average CI	12.61	
Angola	Dalia	10.48	4,669,678
	Girassol	10.65	1,257,982
	Greater Plutonio	12.27	1,116,972
Argentina	Canadon Seco	12.69	1,569,902
	Escalante	11.87	919,027
	Hydra	10.65	379,435
Australia	Pyrenees	7.42	644,757
Brazil	Albacora Leste	7.03	4,399,684
	Frade	6.94	991,259
	Marlim	9.09	13,200,519
	Marlim Sul	8.17	1,780,305
	Ostra	7.87	1,057,309
	Polvo	7.84	986,563
Cameroon	Lokele	25.97	600,239
Canada	Albian Heavy Synthetic	21.6	4,560,973
	Cold Lake	17.18	9,736,048
	Federated	10.73	628,364
	Koch Alberta	10.73	189,694
	Mixed Sweet	10.73	1,871,099
	Suncor Synthetic	26.15	2,733,903
	Syncrude Synthetic	27.89	2,847,112
Colombia	Castilla	12.34	7,991,860
	Vasconia	11.28	2,443,605
Ecuador	Napo	12.09	19,552,878
	Oriente	12.75	45,689,775
Iraq	Basra Light	15.67	46,939,835
Neutral Zone	Eocene	9.43	888,546
	Ratawi	9.87	399,494
Nigeria	Bonny	19.15	473,835
Oman	Oman	15.08	4,026,126
Peru	Loreto	12.68	4,165,476
	Mayna	13.13	890,366
Russia	ESPO	16.13	17,802,032
Saudi Arabia	Arab Extra Light	11.67	24,349,999
	Arab Light	11.59	45,755,141
Trinidad	Calypso	9.01	180,527
Venezuela	Boscan	11.04	178,157
	Petrozuata	20.63	721,236

Country/State	Crude Name	2010 CI (gCO_2/MJ)	2010 Volume (bbl)
	Zuata	20.59	359,793
US Alaska	ANS	9.3	86,382,000
US North Dakota	Bakken	10.85	496,886
US California*	Aliso Canyon	3.26	84,048
	Ant Hill	15.74	43,710
	Antelope Hills	4.57	165,938
	Antelope Hills, North	11.8	303,269
	Arroyo Grande	23.82	416,513
	Asphalto	8.64	332,117
	Bandini	7.67	12,844
	Bardsdale	8.63	68,440
	Barham Ranch	5.5	78,079
	Belgian Anticline	7.64	50,381
	Bellevue	9.22	24,695
	Bellevue, West	8.92	20,092
	Belmont, Offshore	3.77	874,200
	Belridge, North	6.24	2,931,540
	Belridge, South	13.7	26,485,856
	Beverly Hills	5.45	823,937
	Big Mountain	6.86	32,210
	Brea-Olinda	4.44	1,200,090
	Buena Vista	9.44	730,083
	Cabrillo	6.32	37,747
	Canal	5.49	29,355
	Canfield Ranch	5.51	119,099
	Caneros Creek	5.48	32,125
	Cascade	4.29	176,937
	Casmalia	6.55	172,054
	Castaic Hills	5.44	12,873
	Cat Canyon	5.45	336,451
	Cheviot Hills	4.97	51,020
	Cienaga Canyon	6.71	42,637
	Coalinga	25.39	5,637,795
	Coalinga, East	16.72	21,984
	Coles Levee, N	5.47	149,597
	Coles Levee, S	7.9	87,026
	Coyote, East	6.13	227,133
	Cuyama, South	10.94	218,648
	Cymric	18.44	15,475,608
	Deer Creek	4.36	48,601
	Del Valle	6.3	65,358
	Devils Den	4.21	20,188

Country/State	Crude Name	2010 CI (gCO_2/MJ)	2010 Volume (bbl)
	Edison	7.49	757,792
	El Segundo	3.72	20,350
	Elk Hills	8.04	13,941,226
	Elwood, S., Offshore	4.29	870,666
	Fruitvale	11.26	469,295
	Greeley	8.69	132,274
	Hasley Canyon	2.9	45,177
	Helm	5.79	106,799
	Holser	6.45	20,070
	Honor Rancho	3.74	53,687
	Huntington Beach	5	1,826,290
	Hyperion	1.81	10,378
	Inglewood	8.27	2,637,787
	Jacalitos	2.94	131,038
	Jasmin	11.25	101,168
	Kern Front	23.09	2,808,120
	Kern River	9.88	27,376,634
	Kettleman Middle Dome	5.58	33,491
	Kettleman North Dome	7.16	37,245
	Landslide	10.61	34,661
	Las Cienegas	5.64	457,276
	Livermore	1.69	16,035
	Lompoc	17.85	208,503
	Long Beach	5.61	1,455,363
	Long Beach Airport	4.57	11,136
	Los Angeles Downtown	5.34	29,604
	Los Angeles, East	8.74	15,837
	Lost Hills	11.04	11,432,041
	Lost Hills, Northwest	6.55	22,420
	Lynch Canyon	7.16	151,861
	McDonald Anticline	5.59	51,224
	McKittrick	17.69	2,016,851
	Midway-Sunset	21.78	32,407,532
	Montalvo, West	4.88	553,607
	Montebello	10.16	729,238
	Monument Junction	6.44	104,188
	Mount Poso	9.13	542,986
	Mountain View	5.93	132,537
	Newhall-Potrero	5.33	143,065
	Newport, West	3.9	97,190
	Oak Canyon	5.55	29,881
	Oak Park	4.45	20,958

Country/State	Crude Name	2010 CI (gCO_2/MJ)	2010 Volume (bbl)
	Oakridge	4.56	72,368
	Oat Mountain	2.01	112,638
	Ojai	7.94	262,361
	Olive	1.89	18,486
	Orcutt	13.42	1,079,730
	Oxnard	16.02	118,490
	Paloma	7.41	28,244
	Placerita	35.16	744,659
	Playa Del Rey	6.15	45,518
	Pleito	4.45	248,779
	Poso Creek	21.04	2,486,338
	Pyramid Hills	2.43	62,101
	Railroad Gap	8.52	107,341
	Raisin City	7.15	150,266
	Ramona	7.13	62,490
	Richfield	3.52	379,426
	Rincon	5.96	329,735
	Rio Bravo	5.95	231,146
	Rio Viejo	2.82	82,937
	Riverdale	4.65	82,245
	Rose	3.17	207,887
	Rosecrans	6.14	174,688
	Rosecrans, South	5.31	10,748
	Rosedale	6.51	18,437
	Rosedale Ranch	8.81	183,724
	Round Mountain	20.68	2,726,537
	Russell Ranch	8.16	61,164
	Salt Lake	4.14	44,315
	Salt Lake, South	5.33	61,515
	San Ardo	27.63	6,048,571
	San Miguelito	6.51	613,652
	San Vicente	4.04	308,465
	Sansinena	5	152,978
	Santa Clara Avenue	5.87	71,647
	Santa Fe Springs	10.08	649,718
	Santa Maria Valley	5.96	185,697
	Santa Susana	7.28	18,866
	Sargent	7.56	22,844
	Saticoy	6.3	39,377
	Sawtelle	4	181,995
	Seal Beach	5.66	457,276
	Semitropic	5.18	33,742

Country/State	Crude Name	2010 CI (gCO_2/MJ)	2010 Volume (bbl)
	Sespe	7.28	343,375
	Shafter, North	3.88	724,013
	Shiells Canyon	7.32	88,409
	South Mountain	7.06	418,243
	Stockdale	2.83	94,937
	Strand	3.87	12,713
	Tapia	4.72	54,244
	Tapo Canyon, South	4.6	12,438
	Tejon	5.25	471,295
	Tejon Hills	3.45	15,345
	Tejon, North	8.68	37,156
	Temescal	6.55	28,037
	Ten Section	6.68	104,589
	Timber Canyon	8.25	35,660
	Torrance	4.3	363,262
	Torrey Canyon	6.64	73,651
	Union Avenue	3.17	21,600
	Ventura	6.37	4,552,969
	Wheeler Ridge	5.77	64,928
	White Wolf	1.59	11,989
	Whittier	4	107,933
	Wilmington	5.59	13,350,682
	Yowlumne	10.89	238,896
	Zaca	5.3	183,191
US Federal OCS	Beta	3.77	1,564,879
	Carpinteria	6.08	450,083
	Dos Cuadras	6.86	1,158,945
	Hondo	6.84	5,103,155
	Hueneme	5.19	110,313
	Pescado	6.13	3,951,076
	Point Arguello	10.76	1,969,836
	Point Pedernales	6.76	2,134,927
	Sacate	4.85	3,206,868
	Santa Clara	4.93	622,887
	Sockeye	6.34	1,303,256

*All California field producing 10,000 barrels or more during 2010.