ATTACHMENT E

ESTIMATING CARBON INTENSITY VALUES FOR THE CRUDE LOOKUP TABLE

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New deletions and additions to the originally proposed Appendix I to the Initial Statement of Reasons (published on March 6, 2018) that were made public with the "Notice of Public Availability of Modified Text and Availability of Additional Documents and Information" are shown in ~~strikethrough~~ and <u>underline</u> format, respectively. Additional proposed deletions and additions that are made public with the "Second Notice of Public Availability of Modified Text" are shown in ~~double strikethrough~~ and <u>double underline</u> format, respectively.

Estimating Carbon Intensity Values for the Crude Lookup Table

Proposed Crude Lookup Table CI Values for Individual Crudes

All carbon intensity values were calculated using the Oil Production Greenhouse Gas Emissions Estimator (OPGEE) Version 2.0.[1] A description of the model is provided in the model user guide and technical documentation.[2] Versions of OPGEE have been presented for stakeholder review at six CARB workshops[3] and also reviewed and/or utilized as part of several reports and journal publications.[4,5,6,7,8,9,10] 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

[1] El-Houjeiri, H.M., Vafi, K., Masnadi, M.S., Duffy, J., McNally, S., Sleep, S., Pacheco, D., Dashnadi, Z., Orellana, O., MacLean, H., Englander, J., Bergerson, J and A.R. Brandt. Oil Production Greenhouse Gas Emissions Estimator (OPGEE) Model Version 2.0, ~~March 6~~ June 20, 2018.

[2] El-Houjeiri, H.M., Masnadi, M.S., Vafi, K., Duffy, J., and A.R. Brandt, Oil Production Greenhouse Gas Emissions Estimator (OPGEE) Model Version 2.0, User Guide and Technical Documentation, ~~June 5, 2017~~ June 20, 2018.

[3] Workshops held on March 19, 2012; July 12, 2012; March 5, 2013; March 11, 2014; July 10, 2014, and April 4, 2017. Workshop materials can be accessed at http://www.arb.ca.gov/fuels/lcfs/lcfs_meetings/lcfs_meetings.htm

[4] El-Houjeiri, H.M., Brandt, A.R., Duffy, J.E. (2013) Open source LCA tool for estimating greenhouse gas emissions from crude oil production using field characteristics. *Environmental Science & Technology*. DOI: 10.1021/es304570m

[5] El-Houjeiri, H.M., A.R. Brandt (2012) 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 27th 2012.

[6] IHS Inc. (2014) *Comparing GHG intensity of the oil sands and the average US crude oil*. May 2014.

[7] ICCT (2014) *Upstream Emissions of Fossil Fuel Feedstocks for Transport Fuels Consumed in the European Union.* Authors: Chris Malins, Sebastian Galarza, Anil Baral, Adam Brandt, Hassan El-Houjeiri, Gary Howorth, Tim Grabiel, Drew Kodjak. Washington D.C.: The International Council on Clean Transportation (ICCT).

[8] O'Connor, D. (2013) OPGEE analysis and comparison to GHGenius. Prepared for Natural Resources Canada, August 19th, 2013.

[9] Vafi, K and A.R. Brandt (2014) Uncertainty of Oil Field GHG Emissions Resulting from Information Gaps: A Monte Carlo Approach, *Environmental Science and Technology*, 48, 10511-10518, dx.doi.org/10.1021/es502107s.

[10] Vafi, K and A.R. Brandt (2014) Reproducibility of LCA Models of Crude Oil Production, *Environmental Science and Technology*, Articles ASAP, dx.doi.org/10.1021/es501847p.

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.[11] In order to duplicate these carbon intensity values, model inputs for each crude source can be copied from the Excel file into the corresponding cells on the Inputs sheet of OPGEE and the Run Assessment button clicked. For a few crudes, additional cells not on the bulk assessment sheet must be modified from defaults. These changes are noted on the model inputs spreadsheets for these crudes.

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 the Oil Production Greenhouse Gas Emissions Estimator (OPGEE) Version 2.0.

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.[12] The volume contributions for California federal offshore crudes are based on oil production data obtained from the Bureau of Safety and Environmental Enforcement.[13] The volume contributions of imported crudes are based on oil supply data provided by the California Energy Commission.[14]

Detailed model inputs used to estimate the carbon intensity values are contained in an Excel file.[15] In order to duplicate these carbon intensity values, the "reference year for default flaring intensity" must be set to 2010 (cell M13 of the flaring 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 a few crudes, additional cells not on the bulk assessment sheet must be

[11] MCON Inputs Spreadsheet for Crude Lookup Table, Spreadsheet titled "Lookup_Table_MCON_Inputs_OPGEE_v2.0_(June_20_2018).xlsx."

[12] Crude production data copied from the California Department of Conservation, Online Production and Injection Query, http://opi.consrv.ca.gov/opi/opi.dll, (accessed June 6, 2013).

[13] Crude production data downloaded from the Bureau of Safety and Environmental Enforcement web site http://www.data.bsee.gov/homepg/data_center/production/PacificFreeProd.asp, (accessed May 2013 and May 2014).

[14] California Energy Commission, Spreadsheet titled "2010 MCON Import Results 01-28-12 GDS."

[15] MCON Inputs Spreadsheet for 2010 Baseline Crudes, Spreadsheet titled "2010_Baseline_MCON_Inputs_OPGEE_v2.0_(June_20_2018).xlsx."

modified from defaults. These changes are noted on the model inputs spreadsheets for these crudes.

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	~~12.17~~ ~~11.75~~ 11.78	
Angola	Dalia	8.52	4,669,678
	Girassol	9.00	1,257,982
	Greater Plutonio	8.54	1,116,972
Argentina	Canadon Seco	9.23	1,569,902
	Escalante	9.24	919,027
	Hydra	6.94	379,435
Australia	Pyrenees	4.83	644,757
Brazil	Albacora Leste	5.67	4,399,684
	Frade	5.37	991,259
	Marlim	6.44	13,200,519
	Marlim Sul	7.26	1,780,305
	Ostra	5.56	1,057,309
	Polvo	5.48	986,563
Cameroon	Lokele	23.48	600,239
Canada	Albian Heavy Synthetic	~~22.19~~ ~~21.96~~ 22.87	4,560,973
	Cold Lake	~~16.65~~ 16.19	9,736,048
	Federated	7.59	628,364
	Koch Alberta	7.59	189,694
	Mixed Sweet	7.59	1,871,099
	Suncor Synthetic	~~24.97~~ ~~25.61~~ 27.49	2,733,903
	Syncrude Synthetic	~~22.64~~ ~~28.74~~ 31.68	2,847,112
Colombia	Castilla	10.20	7,991,860
	Vasconia	9.55	2,443,605
Ecuador	Napo	9.77	19,552,878
	Oriente	10.95	45,689,775
Iraq	Basra Light	12.93	46,939,835

Neutral Zone	Eocene	7.43	888,546
	Ratawi	9.06	399,494
Nigeria	Bonny	13.64	473,835
Oman	Oman	~~12.60~~ <u>12.34</u>	4,026,126
Peru	Loreto	8.01	4,165,476
	Mayna	9.52	890,366
Russia	ESPO	13.09	17,802,032
Saudi Arabia	Arab Extra Light	9.14	24,349,999
	Arab Light	9.04	45,755,141
Trinidad	Calypso	5.38	180,527
Venezuela	Boscan	9.75	178,157
	Petrozuata	18.78	721,236
	Zuata	18.74	359,793
US Alaska	ANS	12.50	86,382,000
US North Dakota	Bakken	9.63	496,886
US California*	Aliso Canyon	2.74	84,048
	Ant Hill	24.04	43,710
	Antelope Hills	3.05	165,938
	Antelope Hills, North	~~13.07~~ <u>12.34</u>	303,269
	Arroyo Grande	~~27.37~~ <u>25.45</u>	416,513
	Asphalto	7.30	332,117
	Bandini	7.86	12,844
	Bardsdale	5.80	68,440
	Barham Ranch	3.95	78,079
	Belgian Anticline	4.93	50,381
	Bellevue	8.78	24,695
	Bellevue, West	8.93	20,092
	Belmont, Offshore	3.20	874,200
	Belridge, North	~~5.07~~ <u>4.51</u>	2,931,540
	Belridge, South	~~13.98~~ <u>12.68</u>	26,485,856
	Beverly Hills	4.72	823,937
	Big Mountain	4.37	32,210
	Brea-Olinda	3.34	1,200,090
	Buena Vista	~~7.81~~ <u>6.77</u>	730,083
	Cabrillo	4.25	37,747

	Canal	4.46	29,355
	Canfield Ranch	4.17	119,099
	Caneros Creek	3.61	32,125
	Cascade	3.04	176,937
	Casmalia	8.04	172,054
	Castaic Hills	3.52	12,873
	Cat Canyon	4.13	336,451
	Cheviot Hills	3.70	51,020
	Cienaga Canyon	4.85	42,637
	Coalinga	~~27.81~~ 25.79	5,637,795
	Coalinga, East	10.54	21,984
	Coles Levee, N	4.46	149,597
	Coles Levee, S	5.85	87,026
	Coyote, East	5.84	227,133
	Cuyama, South	11.71	218,648
	Cymric	~~20.57~~ 17.40	15,475,608
	Deer Creek	10.28	48,601
	Del Valle	4.93	65,358
	Devils Den	5.59	20,188
	Edison	~~9.46~~ 8.48	757,792
	El Segundo	3.23	20,350
	Elk Hills	6.37	13,941,226
	Elwood, S., Offshore	3.93	870,666
	Fruitvale	~~11.23~~ 9.97	469,295
	Greeley	8.13	132,274
	Hasley Canyon	2.22	45,177
	Helm	4.44	106,799
	Holser	3.64	20,070
	Honor Rancho	3.47	53,687
	Huntington Beach	5.31	1,826,290
	Hyperion	1.88	10,378
	Inglewood	9.29	2,637,787
	Jacalitos	2.61	131,038
	Jasmin	~~15.66~~ 11.75	101,168
	Kern Front	~~25.50~~ 22.56	2,808,120

	Kern River	~~11.17~~ <u>10.01</u>	27,376,634
	Kettleman Middle Dome	4.30	33,491
	Kettleman North Dome	5.48	37,245
	Landslide	10.68	34,661
	Las Cienegas	5.10	457,276
	Livermore	2.54	16,035
	Lompoc	33.35	208,503
	Long Beach	6.49	1,455,363
	Long Beach Airport	4.04	11,136
	Los Angeles Downtown	4.61	29,604
	Los Angeles, East	8.53	15,837
	Lost Hills	~~10.87~~ <u>9.67</u>	11,432,041
	Lost Hills, Northwest	4.87	22,420
	Lynch Canyon	~~7.51~~ <u>6.89</u>	151,861
	McDonald Anticline	5.17	51,224
	McKittrick	~~17.30~~ <u>16.00</u>	2,016,851
	Midway-Sunset	~~23.05~~ <u>21.25</u>	32,407,532
	Montalvo, West	2.93	553,607
	Montebello	11.40	729,238
	Monument Junction	4.62	104,188
	Mount Poso	~~15.30~~ <u>10.54</u>	542,986
	Mountain View	~~5.25~~ <u>4.92</u>	132,537
	Newhall-Potrero	3.70	143,065
	Newport, West	3.98	97,190
	Oak Canyon	4.16	29,881
	Oak Park	2.56	20,958
	Oakridge	2.93	72,368
	Oat Mountain	2.03	112,638
	Ojai	4.69	262,361
	Olive	2.01	18,486
	Orcutt	~~13.88~~ <u>11.81</u>	1,079,730
	Oxnard	~~15.92~~ <u>14.96</u>	118,490
	Paloma	4.65	28,244
	Placerita	~~37.37~~ <u>33.52</u>	744,659
	Playa Del Rey	5.59	45,518

	Pleito	3.53	248,779
	Poso Creek	~~23.34~~ <u>19.33</u>	2,486,338
	Pyramid Hills	2.98	62,101
	Railroad Gap	6.93	107,341
	Raisin City	8.01	150,266
	Ramona	4.17	62,490
	Richfield	3.97	379,426
	Rincon	3.88	329,735
	Rio Bravo	5.24	231,146
	Rio Viejo	2.40	82,937
	Riverdale	3.56	82,245
	Rose	2.53	207,887
	Rosecrans	5.55	174,688
	Rosecrans, South	3.68	10,748
	Rosedale	7.38	18,437
	Rosedale Ranch	8.61	183,724
	Round Mountain	~~25.26~~ <u>22.06</u>	2,726,537
	Russell Ranch	8.14	61,164
	Salt Lake	3.16	44,315
	Salt Lake, South	4.31	61,515
	San Ardo	~~28.75~~ <u>25.94</u>	6,048,571
	San Miguelito	4.76	613,652
	San Vicente	2.91	308,465
	Sansinena	3.25	152,978
	Santa Clara Avenue	3.64	71,647
	Santa Fe Springs	12.59	649,718
	Santa Maria Valley	5.04	185,697
	Santa Susana	4.37	18,866
	Sargent	4.83	22,844
	Saticoy	3.86	39,377
	Sawtelle	3.12	181,995
	Seal Beach	5.01	457,276
	Semitropic	4.00	33,742
	Sespe	4.07	343,375
	Shafter, North	3.07	724,013

	Shiells Canyon	4.43	88,409
	South Mountain	3.95	418,243
	Stockdale	2.20	94,937
	Strand	2.74	12,713
	Tapia	5.51	54,244
	Tapo Canyon, South	3.09	12,438
	Tejon	5.83	471,295
	Tejon Hills	6.48	15,345
	Tejon, North	5.82	37,156
	Temescal	3.97	28,037
	Ten Section	6.44	104,589
	Timber Canyon	4.58	35,660
	Torrance	4.82	363,262
	Torrey Canyon	3.75	73,651
	Union Avenue	2.34	21,600
	Ventura	4.66	4,552,969
	Wheeler Ridge	4.55	64,928
	White Wolf	1.85	11,989
	Whittier	2.84	107,933
	Wilmington	6.82	13,350,682
	Yowlumne	11.70	238,896
	Zaca	8.11	183,191
US Federal OCS	Beta	1.52	1,564,879
	Carpinteria	2.98	450,083
	Dos Cuadras	4.13	1,158,945
	Hondo	5.89	5,103,155
	Hueneme	2.80	110,313
	Pescado	5.05	3,951,076
	Point Arguello	13.14	1,969,836
	Point Pedernales	6.18	2,134,927
	Sacate	3.64	3,206,868
	Santa Clara	2.48	622,887
	Sockeye	6.58	1,303,256

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