

LOW CARBON FUEL STANDARD  
ANNUAL UPDATES TO LOOKUP TABLE PATHWAYS

**California Average Grid Electricity Used as a  
Transportation Fuel in California  
AND  
Electricity Supplied under the Smart Charging or  
Smart Electrolysis Provision**



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## I. Summary

This document provides the proposed carbon intensity (CI) values and a detailed description of the 2019 annual update to two Lookup Table pathways for electricity under the Low Carbon Fuel Standard (LCFS). Section 95488.5(d) of the LCFS regulation<sup>1</sup> directs the Executive Officer to update the CI annually for these Lookup Table pathways using the methodology described in Section E of the Lookup Table Pathways Technical Support Documentation.<sup>2</sup> Upon certification, the updated pathway CI values are expected to be available for reporting transactions that occur during the first quarter (Q1) of 2019. The proposed CI values are shown in Table 1 and 2.

**Table 1. Proposed CI Values for 2019 Annual Update to Electricity Lookup Table Pathways**

Fuel Pathway Code	Fuel Pathway Description	CI gCO <sub>2</sub> e/MJ
ELCG	California average grid electricity used as a transportation fuel in California (subject to annual updates)	81.49
ELCT	Electricity supplied under the smart charging or smart electrolysis provision (subject to annual updates)	See Table 2 below

**Table 2. Proposed CI Values (gCO<sub>2</sub>e/MJ) for Smart Charging or Smart Electrolysis in 2019**

Hourly Window	Q1	Q2	Q3	Q4
12:01 AM – 1:00 AM	75.66	75.72	76.99	79.59
1:01 AM – 2:00 AM	75.66	75.55	75.49	77.26
2:01 AM – 3:00 AM	75.66	74.67	75.43	76.35
3:01 AM – 4:00 AM	75.66	75.82	75.41	76.23
4:01 AM – 5:00 AM	75.66	75.66	75.37	77.13
5:01 AM – 6:00 AM	77.60	79.66	75.77	84.42
6:01 AM – 7:00 AM	93.84	92.07	83.26	104.09
7:01 AM – 8:00 AM	99.37	81.99	80.03	102.97
8:01 AM – 9:00 AM	79.26	2.11	76.80	84.23
9:01 AM – 10:00 AM	64.58	1.54	77.66	78.70
10:01 AM – 11:00 AM	50.09	2.30	79.08	77.79
11:01 AM – 12:00 PM	48.91	43.59	80.98	78.14
12:01 PM – 1:00 PM	48.39	46.24	85.00	79.29
1:01 PM – 2:00 PM	48.98	47.86	90.61	80.21

<sup>1</sup> All citations to the LCFS Regulation are found in Title 17, California Code of Regulations (CCR), sections 95480-95503

<sup>2</sup> CA-GREET3.0 Lookup Table Pathways Technical Support Documentation. August 13, 2018. California Air Resources Board. Available at: <http://www.arb.ca.gov/fuels/lcfs/ca-greet/ca-greet.htm>

2:01 PM – 3:00 PM	49.00	50.94	95.76	81.58
3:01 PM – 4:00 PM	50.18	55.16	100.69	88.65
4:01 PM – 5:00 PM	62.54	22.98	107.77	109.47
5:01 PM – 6:00 PM	102.11	42.29	114.43	131.19
6:01 PM – 7:00 PM	118.61	105.26	127.44	133.23
7:01 PM – 8:00 PM	114.82	131.73	135.38	127.69
8:01 PM – 9:00 PM	104.76	131.36	122.10	118.72
9:01 PM – 10:00 PM	87.49	106.80	103.03	105.39
10:01 PM – 11:00 PM	77.33	81.49	87.39	92.91
11:01 PM – 12:00 AM	75.67	76.59	79.28	82.27

These updates are designed to reflect the decreasing CI of California grid electricity driven by rapidly increasing contributions from renewables in the California electricity mix (Figure 1) due to mandates driven by the Renewable Portfolio Standard (RPS), the inclusion of Cap-and-Trade carbon pricing in dispatch models, as well as other structural or systemic changes.

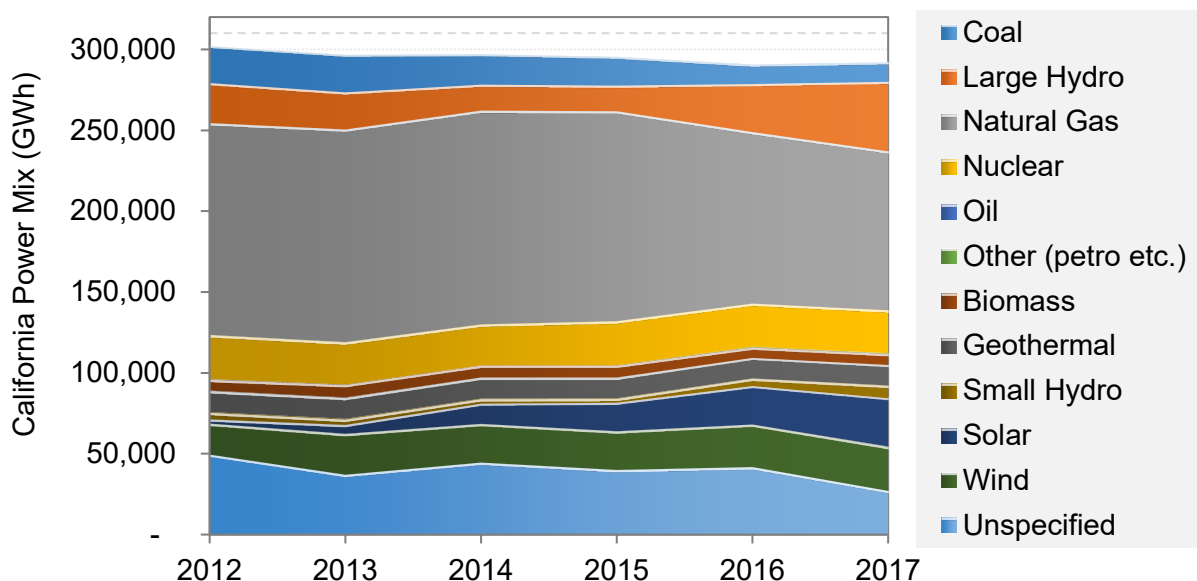


Figure 1. Total System Electric Mix in California in Gigawatt Hours (GWh)<sup>3</sup>

<sup>3</sup> Data source: Total System Electric Generation, 2012-2017. California Energy Commission. [https://www.energy.ca.gov/almanac/electricity\\_data/total\\_system\\_power.html](https://www.energy.ca.gov/almanac/electricity_data/total_system_power.html)

## II. Pathway Details, Assumptions, and Calculations

### 1. California Average Grid Electricity Used as a Transportation Fuel in California

Pursuant to the methodology specified in the Lookup Table Pathways Technical Support Documentation (August 13, 2018), the California average grid electricity pathway is modeled in CA-GREET3.0 using the California Power Mix from the Total System Electric Generation dataset by the California Energy Commission (CEC) for the “Power Generation” stage. The “Feedstock Production” stage is modeled using the U.S. average mix from the U.S. EPA Emissions & Generation Resource Integrated Database (eGRID2014v2); only the “Power Generation” stage of the life cycle is updated using Total System Electric Generation for the 2017 data year. The CEC’s California Power Mix for both 2016 and 2017 data years are compared in Table 1-1. The resulting CI for use in 2019 reporting is calculated, as described below, to be 81.49 (gCO<sub>2</sub>e/MJ).

**Table 1-1. California Power Mix for data years 2016 and 2017**

	2016 CEC <sup>4</sup>		2017 CEC <sup>5</sup>	
	% Mix	GWh	% Mix	GWh
<b>Residual oil</b>	0.15%	431	0.15%	442
<b>Natural Gas</b>	50.87%	147,817	42.93%	125,332
<b>Coal</b>	4.13%	12,006	4.13%	12,075
<b>Nuclear</b>	9.18%	26,670	9.08%	26,519
<b>Biomass</b>	2.25%	6,553	2.35%	6,874
<b>Hydro</b>	11.87%	34,477	17.41%	50,854
<b>Geothermal</b>	4.38%	12,717	4.35%	12,705
<b>Wind</b>	9.06%	26,321	9.40%	27,442
<b>Solar</b>	8.11%	23,574	10.20%	29,796
<b>Total</b>	100%	290,567	100%	292,039
<b>CI (gCO<sub>2</sub>e/MJ)</b>	93.75		81.49	

As described in the Technical Support Documentation, in order to harmonize the resources reported by CEC with those in CA-GREET3.0, the “Other Petroleum Sources”

<sup>4</sup> 2016 California Total System Electric Generation data from California Energy Commission (CEC) website, accessed 11/2017:

[https://www.energy.ca.gov/almanac/electricity\\_data/system\\_power/2016\\_total\\_system\\_power.html](https://www.energy.ca.gov/almanac/electricity_data/system_power/2016_total_system_power.html)

<sup>5</sup> 2017 California Total System Electric Generation data from California Energy Commission (CEC) website, accessed 11/2018:

[https://www.energy.ca.gov/almanac/electricity\\_data/total\\_system\\_power.html](https://www.energy.ca.gov/almanac/electricity_data/total_system_power.html)

category from CEC's mix was treated as "Residual Oil", while the "Unspecified Sources of Power" category uses "Natural Gas" as a surrogate in CA-GREET3.0. Table 1-1 indicates that although the total power (GWh) generation in 2017 increased slightly (0.5%) from that in 2016, the overall CI of the 2017 mix significantly decreased by 12.26 gCO<sub>2e</sub>/MJ (13%). From the resources breakdown, it is noticeable that such CI reduction in 2017 was mainly due to the decrease in Natural Gas-derived power as well as the increase in other low-emission sources, especially hydroelectric. The year of 2017 marked the 22<sup>nd</sup> wettest year and the 2<sup>nd</sup> wettest winter since 1895 in California. Given that no new hydropower facilities were built, and that the plant efficiency from the existing hydropower facilities did not increase in that year, the growth of the hydroelectric generation in 2017 was mainly caused by the increase in water storage in California and the Northwest power-import region. A published report from the CEC<sup>6</sup> indicates that California "has had to rely upon strong levels of combined-cycle electric generation to offset years when available hydroelectric generation is well below average;" meanwhile, the "cogeneration plants are unable to be displaced by hydroelectric availability due to the steady stream requirements of the thermal hosts." Hydroelectric generation is likely to fluctuate depending on precipitation received in any given generation year, which may affect the carbon intensity of the California grid in future updates. However, CEC's data from the most recent decade indicates that large growth in other renewable power (such as solar and wind) has been gradually offsetting the low hydroelectric generation during dry years.<sup>6</sup>

Table 1-2 details the updated contribution of each power resource in energy input, emission factor and CI. Refer to the Lookup Table Pathways Technical Support Documentation for examples of the calculations in Table 1-2.

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<sup>6</sup> Nyberg, M. 2016. Thermal efficiency of gas-fired generation in California: 2015 update. Staff Report. California Energy Commission. ECE-200-2016-002. Available at: <https://www.energy.ca.gov/2016publications/CEC-200-2016-002/CEC-200-2016-002.pdf>

**Table 1-2. Summary of CI for California Average Grid Electricity Used as a Transportation Fuel in California \***

	Electricity Resources Mix	Energy Inputs, Btu/MMBtu	Feedstock Production		Power Generation	
			Emission Factor, gCO <sub>2</sub> e/MMBtu	Contribution to CI, gCO <sub>2</sub> e/MMBtu	Emission Factor, gCO <sub>2</sub> e/MMBtu	Contribution to CI, gCO <sub>2</sub> e/MMBtu
<b>Residual Oil</b>	0.15%	4,767	14,820	70.65	253,578	406.81
<b>Natural Gas</b>	42.93% **	954,186	13,824	13,191	123,600	56,750
<b>Coal</b>	4.13%	127,294	5,515	702	279,776	12,800
<b>Biomass</b>	2.35%	111,211	2,242	249	8,713	219
<b>Nuclear</b>	9.08%	97,112	3,625	352	0	0
<b>Hydro</b>	17.41%	186,265	0	0	0	0
<b>Geothermal</b>	4.35%	46,513	0	0	26,669	1,240
<b>Wind</b>	9.40%	100,510	0	0	0	0
<b>Solar PV</b>	10.20%	109,065	0	0	0	0
<b>Subtotal</b>	100%			14,565		71,416
<b>Tailpipe Emissions</b>				0		0
<b>Total CI, gCO<sub>2</sub>e/MMBtu</b>			<b>85,981</b>			
<b>Total CI, gCO<sub>2</sub>e/MJ</b>			<b>81.49</b>			

\* Values may not sum to the total due to rounding.

\*\* In the CA-GREET3.0 model, all undefined energy resources are assumed to be from natural gas. This value represents the sum of the reported natural gas used in the electricity mix (33.67%) and the undefined energy categories (9.25%), as the total share of natural gas (42.93%) in the CA Electricity Resources Mix.

## 2. California Average Grid Electricity Supplied under the Smart Charging or Smart Electrolysis Provision

### 2.1. Description of smart charging or smart electrolysis CI values:

The carbon intensity values for smart charging or smart electrolysis provisions are calculated based on the marginal emission rates determined using the Avoided Cost Calculator (May 2018)<sup>7</sup> developed by the California Public Utilities Commission. A set of algorithmically neutral carbon intensity values are determined for each hour of the day, for the four quarters of the year, to represent the average marginal emission rates for EV charging or electrolytic hydrogen production that takes place during these times. Shifting EV charging or electrolysis could result in additional emission reductions as compared to Average Grid Electricity CI during the periods when the marginal emission reductions are low.

### 2.2. Calculation of normalized average marginal emission rates for California Average Grid Electricity:

For calculation of marginal emission rates in the Avoided Cost Calculator, natural gas is assumed to be the marginal fuel for electricity generation in California in all hours and the hourly emissions rate of the marginal generator is calculated based on the day-ahead market price curve. The relation between market prices and higher emissions rates is intuitive, higher market prices enable lower-efficiency generators to operate, resulting in increased rates of emissions at the margin. This relationship holds for a reasonable range of prices but breaks down when prices are extremely high or low. For this reason, the avoided cost methodology bounds the maximum and minimum emissions rates based on the range of heat rates of gas turbine technologies. Additionally, if the implied heat rate is calculated to be at or below zero, it is then assumed that the system is in a period of over generation and therefore the marginal emission rate is correspondingly zero as well.

The Avoided Cost Calculator estimates marginal emission rates for utilities in Northern and Southern California, which are based on the normalized hourly day-ahead heat rate profiles for CAISO NP-15 and SP-15 regions. Statewide average marginal emission rates for 2019, weighted by load, are calculated based on the load profile of large load serving entities (LSE) in the two geographical areas, Pacific Gas and Electric (PG&E) in Northern California and Southern California Edison (SCE) and San Diego Gas and Electric (SDG&E) in Southern California. Based on the CAISO OASIS data<sup>8</sup> for all three utilities from January 1, 2017 through December 31, 2017, approximately 45% of the

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<sup>7</sup> Available from the California Public Utilities Commission at:  
<http://www.cpuc.ca.gov/General.aspx?id=5267>

<sup>8</sup> <http://oasis.caiso.com/mrioasis/logon.do> -- CAISO Demand Forecast -- Actual



annual average hourly load is served in Northern California and 55% is served in Southern California, as shown in Table 2-1.

**Table 2-1. The average hourly load of the large load serving entities and their share of the overall load in California in 2017**

Load-Serving Entity	Average Hourly Load (MW) <sup>9</sup>	% of Load
<b>PG&amp;E</b>	11,945	45%
<b>SCE</b>	12,064	46%
<b>SDG&amp;E</b>	2,307	9%
<b>Total</b>	<b>26,316</b>	<b>100%</b>

The resulting statewide average marginal emission rates for California Grid Average Electricity are normalized to the annual average California Grid emissions rate over the year for each hourly window for the four quarters of the year, as shown in Table 2-2.

**Table 2-2. Normalized Marginal Emission Rates for California Grid Average Electricity for 2019**

Hourly Window	Q1	Q2	Q3	Q4
12:01 AM – 1:00 AM	0.9285	0.9292	0.9447	0.9767
1:01 AM – 2:00 AM	0.9285	0.9271	0.9264	0.9481
2:01 AM – 3:00 AM	0.9285	0.9164	0.9257	0.9369
3:01 AM – 4:00 AM	0.9285	0.9304	0.9254	0.9354
4:01 AM – 5:00 AM	0.9285	0.9284	0.9249	0.9465
5:01 AM – 6:00 AM	0.9522	0.9776	0.9298	1.0359
6:01 AM – 7:00 AM	1.1515	1.1298	1.0217	1.2773
7:01 AM – 8:00 AM	1.2194	1.0061	0.9821	1.2635
8:01 AM – 9:00 AM	0.9727	0.0259	0.9425	1.0336
9:01 AM – 10:00 AM	0.7925	0.0189	0.9530	0.9658
10:01 AM – 11:00 AM	0.6147	0.0282	0.9704	0.9546
11:01 AM – 12:00 PM	0.6002	0.5349	0.9938	0.9589
12:01 PM – 1:00 PM	0.5938	0.5674	1.0431	0.9730
1:01 PM – 2:00 PM	0.6011	0.5874	1.1119	0.9843
2:01 PM – 3:00 PM	0.6013	0.6251	1.1751	1.0012
3:01 PM – 4:00 PM	0.6158	0.6769	1.2356	1.0878
4:01 PM – 5:00 PM	0.7675	0.2820	1.3225	1.3434

<sup>9</sup> Average hourly load is calculated by taking the average load for the load served for each hour in the year



5:01 PM – 6:00 PM	1.2531	0.5189	1.4042	1.6099
6:01 PM – 7:00 PM	1.4556	1.2917	1.5639	1.6349
7:01 PM – 8:00 PM	1.4091	1.6165	1.6613	1.5669
8:01 PM – 9:00 PM	1.2856	1.6120	1.4983	1.4569
9:01 PM – 10:00 PM	1.0737	1.3106	1.2644	1.2933
10:01 PM – 11:00 PM	0.9490	1.0000	1.0724	1.1402
11:01 PM – 12:00 AM	0.9286	0.9398	0.9729	1.0096

### 2.3. Calculation of smart charging or smart electrolysis CI values:

The carbon intensity values for smart charging or smart electrolysis for a given time period is determined using the California Average Grid Electricity CI and the normalized marginal emission rates for that period. The calculated California grid average electricity CI for the 2019 reporting period is 81.49 gCO<sub>2</sub>e/MJ. This calculation gives the estimated average carbon intensity for electricity as a result of shifting EV charging or electrolysis to a specific hourly window during a given quarter. The carbon intensity values calculated for smart charging or smart electrolysis pathways in 2019 are shown in Table 2.