Memo

From: Colin Murphy, NextGen Policy Center
Date: July 5th, 2018
Re: Basis for Estimates of Infrastructure-Based Capacity Credit Estimates

The following explains the basis for estimates cited in NextGen's July 5, 2018 comment to CARB regarding the capacity-based credit pathways based on the provisions described in the June 20 Modified Text

On June 20th, CARB released the Modified Text and Availability of Additional Documents and Information (hereafter the "Modified Text") relating to the open LCFS rulemaking. Pursuant to the Board's instruction in Resolution 18-17, a key element of the Modified Text was the proposed method for generating LCFS credits based on the capacity of installed ZEV fueling infrastructure, as opposed to the energy content and carbon intensity of fuel dispensed. These pathways, for Hydrogen Refueling Infrastructure (HRI) and DC Fast Charging Infrastructure (FCI) represent a significant departure from previous LCFS practices. Given the novel nature of these credits, understanding their impact on the LCFS market is important.

A simple, Excel-based model of expected credit generation was developed to explore the credit-generation behavior of this program under feasible circumstances and to estimate maximum feasible credit generation from these pathways on both an aggregate and a per-station basis. The purpose of this memo is to explain the methods and assumptions used in this model. Given the uncertain nature of energy markets and technological development, the model should not be viewed as predictive of actual market behavior, rather it is meant to characterize the maximum feasible credit generation and inform ongoing discussion on this subject.

The primary question this modeling exercise will consider is how will likely deployment trajectories compare to the proposed limits on pathway approvals and how much revenue each project may be eligible to receive.

The model comprises an excel workbook with a title page and two worksheets, "DC FC Capacity Effect" and "Hydrogen Capacity Effect" for FCI and HRI credits respectively.

Data Sources and Modeling Assumptions

This model attempts to use CARB data and projections, based on the March 6th version of the Illustrative Compliance Scenario Calculator[1] where possible.

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[1] https://www.arb.ca.gov/fuels/lcfs/2018-0306_illustrative_compliance_scenario_calc.xlsx

On both sheets, the the gasoline and diesel CI target schedule is copied from the Illustrative Compliance Scenario calculator, based on the assumption of a 1.25% per year increase in CI target between 2018 and 2030, to a 20% 2030 target. Total deficit generation is copied from Illustrative Compliance Scenario Calculator, based on the 20%, High-Demand, High-ZEV case. The 2.5% credit maximum is calculated below.

For hydrogen and DC fast charging, the projected CI values total energy content of the respective fuels are copied from the Calculation sheet of the Illustrative Compliance Scenario calculator. For electricity, the projected electricity consumption from the April 2018 Cerulogy Report *California' Clean Fuel Future* is also provided, as an alternative, higher-demand case.[2] These numbers are based on the High-Performance scenario from that report and were reported in the Illustrative Compliance Scenario submissions accompanying NextGen's April 23rd comment to the CARB board.[3]

For the most part, the model is not explicitly extended past 2025, since the infrastructure program will stop accepting applications at that point and modeling of advanced technology pathways past 2025 is highly uncertain.

HRI Data, Assumptions and Methods

Lines 15 and 16 present a bounding case - the maximum credits a station could generate assuming 1200 kg capacity and minimal (50kg) hydrogen dispensed per day. This is not meant to be a predictive quantity, but rather an evaluation of whether the HRI pathway could approach its 2.5% of total deficit generation limit given a feasible number of stations.

Below that, three scenarios of interest are presented. A "Success Case" under which hydrogen infrastructure and vehicle deployment support s significant use of hydrogen through 2025 and a Business-as-Usual (BAU) case in which the projected hydrogen consumption from the Illustrative Compliance Scenario is dispensed through a slightly lower number of stations. A Small Station case is also estimated in which the average capacity of stations is half the size of that of the success case and the total hydrogen dispensed is the average of the Success Case and BAU.

Lines 49-69 contain a variety of physical constants, taken from the Illustrative Compliance Scenario Calculator's calculations tab, as well as assumptions, which impact one or more cases.

The Success case seeks to define a scenario under which hydrogen deployment achieves ambitious but reasonable targets through 2025. This case assumes that the 200 fueling station target set in Executive Order B-48-18 is achieved and that total hydrogen consumption is 50

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[2] https://nextgenamerica.org/californias-clean-fuel-future/
[3] https://www.arb.ca.gov/lists/com-attach/145-lcfs18-AG4FZlwlUHdQMQRh.zip

million gasoline-equivalent gallons (gge) for transportation in California; this slightly exceeds the trajectory predicted by the 2017 IEPR.[4] The Success Case analysis is intended to evaluate the contribution of the HRI provisions to hydrogen fueling infrastructure deployment under the assumption that California meets its ZEV deployment goals, while assuming that high hydrogen consumption limits total HRI credit generation. Using the IEPR estimate of in-state hydrogen consumption for transport fuel represents a growth trajectory consistent with significant long-term utilization of hydrogen in the transportation space.

The BAU case estimates comparatively less adoption of hydrogen, consistent with the projections in the CARB Illustrative Compliance Scenario, 20% Target, High-ZEV, High Demand case. Under this scenario, total hydrogen demand is less than half of the IEPR estimate. To reflect lower hydrogen demand, a smaller total set of stations was assumed, which included 50 stations through 2019,[5] increasing at a rate of 20 per year. This case meets neither the target set by Executive Order B-48-18 or the growth trajectory for hydrogen estimated by the IEPR.

The small-station case examines a network of smaller stations, 600kg capacity on average, which meets the Executive Order target for the number of stations, but dispenses significantly less aggregate hydrogen, approximately 35 million gge by 2025. This brings the average station size significantly closer to that proposed under current CEC grant programs,[6] though it should be noted that current grant programs and growth projections do not consider the revenue for excess capacity which the HRI provisions would anticipate.

The Success case employs slightly different methodology than the BAU or Small Station case. Under the Success Case, the number of stations is assumed to start at 50 in 2019 and reach 200, by linear growth, by 2025. 2019 hydrogen sales were assumed to be 250 kg per weekday per station. This quantity of dispensed hydrogen per station is almost certainly a significant overestimate, but recent data is unavailable and the intent is to err on the side of underestimating per-station HRI credits. A lower estimate of initial hydrogen consumption would reduce HRI credit generation, especially in the near term. 2025 hydrogen consumption per station was determined by dividing 50 million gge of hydrogen by 200 stations, which yields approximately 800 kg of hydrogen per weekday. This represents approximately ⅔ of the maximum nameplate capacity allowed under the HRI pathway.

For the BAU and small station cases, total hydrogen consumption was assigned to stations to develop per-station estimates. Under BAU, a growth rate of 20 stations per year was assumed, which yielded 170 stations in 2025. Hydrogen consumption was taken from the Illustrative Compliance Scenario calculator and divided by the number of stations to yield the assumed quarterly hydrogen dispensed, per station. The small station case assumed 25 stations per

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[4] https://efiling.energy.ca.gov/getdocument.aspx?tn=223205 Figure 67.
[5] There are 35 retail stations open at present (https://cafcp.org/by_the_numbers) and around 30 currently funded by the CEC (http://www.energy.ca.gov/2017publications/CEC-600-2017-011/CEC-600-2017-011.pdf).
[6] http://www.energy.ca.gov/2017publications/CEC-600-2017-011/CEC-600-2017-011.pdf

year, yielding 200 stations in 2025 and an aggregate hydrogen consumption at the mid-point between the Success Case and BAU. Quarterly hydrogen dispensed per station was then estimated in the same manner as BAU.

For all cases, station uptime was assumed to be 98%, hydrogen CI was assumed to be the default value from the rule, 75 g CO_2e/MJ and the a quarter was assumed to have 91 days. These values, were entered into the equation given in § 95486.2 (a) (5) of the Modified Text, which is copied into the spreadsheet to the right of the numeric data. This yielded quarterly credit generation. The calculations were repeated for each year in sequential columns, with the number of stations, hydrogen dispensed and target gasoline CI changing over time. Estimates of revenue per station were based on an assumed $125 LCFS credit price and 2025 totals are given in column M.

FCI Data and Modeling Assumptions

The FCI credit assumptions evaluate two estimates of DC Fast Charging (DCFC) utilization, one from the CARB Illustrative Compliance Scenario calculator, under the 20% Target, High-Demand, High-ZEV case, and the other from the High Performance scenario reported in *California's Clean Fuel Future.* Both report electricity used in light-duty and heavy-duty vehicles, with the value from *California's Clean Fuel Future* reflecting attainment of Executive Order B-48-18, achieving 5 million electric vehicles sold by 2030; it therefore projects significantly higher electricity consumption than the Illustrative Compliance Scenario value.

Only a small fraction of total electricity used in transportation is supplied to electric vehicles through DCFCs, since at present, the overwhelming majority of charging occurs overnight at a residence or workplace using lower-power charging equipment. RMI and EVGo estimate that at present, 3% of total EV charging occurs at DCFCs, but project this to rise to at least 20% by 2027. This rate of growth represents a substantial change in EV behavior, so must be highlighted as an area of uncertainty. Lower growth rates for DCFC utilization would increase the amount of credits earned per charger, especially in later years.

Less data exists to support assumptions regarding heavy-duty charging behavior, no reasonable estimate was found during the literature review for this modeling exercise. Given the larger battery capacities of heavy-duty vehicles, it is reasonable to assume a significantly greater utilization of >50kW chargers, which is the cut-off for DCFC. The assumed utilization of DCFC for HD vehicles is 40% and it should be noted that both CARB and Cerulogy project substantially less aggregate electricity demand for the heavy-duty sector than light-duty, so the effect of this assumption on average credit generation is quite small.

As with the Hydrogen page, assumptions and constants are provided on lines 48-60. Constants are generally taken from the Illustrated Compliance Scenario calculator.

The FCI proposal in the modified text indicates that unlike HRI pathways, existing DCFCs will not be eligible for FCI credits. This means that the growth trajectory of both number of stations and total charging must exclude existing stations and the charging which occurs there. Per the Department of Energy's Alternative Fuels Data Center, there are approximately 1800 DCFCs in California, at present. It is assumed that 200 new DCFCs would be installed in 2019 and subsequently, a linear trajectory would emerge which would achieve the target in Executive Order B-48-18 of 10,000 DCFCs, statewide, less the 1800 existing DCFCs which were assumed to remain in operation. Projections of DCFC utilization after 2019 were reduced by 90% of the 2019 value, to represent the charging which occurred at pre-2019 vintage stations. Given the very low aggregate pre-2020 electricity demand in both CARB and Cerulogy modeling, the effect of these corrections is relatively small.

Unlike the HRI calculation, both scenarios follow the same method. Total DCFC charging at stations eligible for FCI credit is taken from line 18 (for the CARB case) or 20 (for the Cerulogy case) and divided by four times the number of stations to yield the quarterly charging per-station. For all cases, station uptime was assumed to be 98% and the a quarter was assumed to have 91 days. Electricity CI decreases over time as the renewable energy supplies an increasing fraction of total demand. In order to avoid introducing differing CIs as a confounding factor, the CARB electricity CI from the Illustrative compliance scenario was used for both cases, reported on lines 10 and 11.

All values were input into the equation specified in § 95486.2 (c) (5) of the Modified Text, which is copied into the spreadsheet to the right of the numeric data, this yielded quarterly FCI credit generation per station. Each year was sequentially calculated in its own column and 2020-2025 totals are given in column M.

Results

The proposed HRI and FCI credit pathways offer a substantial incentive for the construction of such infrastructure. The scenarios described in this model represent feasible credit generation under an outcome which achieves, or at least approaches, meeting the targets set in Executive B-48-18.

For HRI pathways, a 1200 kg station which dispenses 400 kg of hydrogen per weekday in 2020 would generate approximately 1420 credits per quarter.[7] This means that a station which starts at 250 kg per weekday in 2019 and grows to 800 kg per weekday in 2025 will generate an total of almost 27,000 credits between 2020 and 2025, worth over $3.3 million assuming a constant $125 LCFS credit value. The hydrogen dispensed per station in that example is approximately compatible with the hydrogen fuel trajectory presented in the 2017 IEPR and likely represents the upper bound of feasible outcomes. The BAU case, which projects average per-station hydrogen throughput in a 200 station system of only 336 kg, yields over 38,000 credits, worth

[7] This calculation was confirmed by Jim Duffy by email on June 28th.

over $4.8 million. It is important to note that while the modeling in this exercise runs through 2025, the stations would still be eligible for HRI credits. Even as hydrogen utilization grows, the stations would continue generating HRI credits until they exhausted their 15 year eligibility. 2025 credit generation for a 1200 kg station is 5400 and 1500 credits for the BAU and Success cases, respectively, worth approximately $375,000 for the former and $680,000 for the latter. Likely post-2025 credit generation would substantially add to this total.

HRI credits, as described in the modified text, also provide a significant incentive to expand capacity beyond expected 2020-2035 demand. The following table compares the total 2020-2025 revenue from expected HRI credits under the same assumptions as above, for stations of various sizes.

Total incentive per station 2020-2025 ($ million)

	Case	
Station Capacity (kg)	**BAU**	**Success**
1200	$ 4.8	$ 3.4
1000	$ 3.9	$ 2.4
800	$ 2.9	$ 1.5
600	$ 2.0	$ 0.5

Under the comparatively lower hydrogen utilization of the BAU case, a hypothetical 1200 kg/day station would gain an additional $2.8 million in HRI credit value compared to a 600 kg/day one. A similar incremental advantage to increased capacity is noted under the Success case. It would be assumed that if the incremental cost to increase a proposed station from 600 kg to 1200 kg was less than $2.8 million, doing so would be a no-lose proposition from a station developer's perspective (the revenue would come from LCFS deficit generators and be passed on to gasoline and diesel consumers).

Under the Success Case, the total HRI credit generation averages around 2.63% of total LCFS deficit generation, based on CARB Illustrative Compliance Scenario projections. The program slightly exceeds the 2.5% threshold in years 2020-2024, indicating that a cap mechanism will be required to keep credits below 2.5% of total deficits. Under the BAU case, in which significantly less hydrogen is dispensed, average HRI credit generation is 3.4% of total deficits and the program significantly exceeds the 2.5% cap every year. This indicates that unless stations actually increase the amount of hydrogen dispensed each year, the program could significantly overshoot its intended limits.

The Small Stations case, unsurprisingly, limits total revenue per station as well as aggregate credit generation. This case never exceeds 1.25% of total deficit generation and yields an estimated $1.3 million per station through 2025.

The FCI incentive is substantially smaller on a per-station basis. This is in part due to the smaller size and throughput, on an energy basis, of each station. It should also be noted that the assumption of maximum utilization is set at 6 hours, implicitly setting a maximum utilization of 25%, given that stations must be open 24 hours per day to be eligible. This limitation, along with the 150 kW maximum power, is arbitrary but perhaps necessary to limit the credit generation per station to a tolerable level. Both the CARB and Cerulogy cases start with each 150 kW station generating around 230 credits per year, worth around $28,000. The more rapid growth of EVs in the Cerulogy case erodes FCI credit generation more quickly; the CARB case predicts around 175 credits per charger per year in 2025 compared with 120 in the Cerulogy case.

The incentive to support larger scale is present in the FCI program, though substantially smaller on a per-station basis. This may be considered less undesirable in FCI pathways since higher instantaneous power provides utility to stationh users, even if the total capacity is under-utilized.

Total incentive per station 2020-2025 ($ '000)

	Case	
Station Capacity (kg)	**CARB**	**Cerulogy**
150	$ 153	$ 134
125	$ 123	$ 104
100	$ 93	$ 74
75	$ 63	$ 44