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RE: PG&E Comments on Public Workshop to Discuss Greenhouse Gas Emission Standards for the Fuel Cell Net Energy Metering Program

Pacific Gas and Electric Company (PG&E) appreciates the opportunity to provide feedback on methodologies the Air Resources Board (ARB) should consider for establishing greenhouse gas (GHG) emission reduction standards for fuel cell "customer-generators" participating in Net Energy Metering Service for Fuel Cell Customer-Generators (NEMFC), as required by Assembly Bill 1637 (Low, Statutes of 2016).

PG&E appreciates ARB staff's ongoing efforts to engage stakeholders, including through the May 30, 2017 workshop. PG&E recognizes that this topic is complex and disagreement in how to structure this methodology will exist. However, it is critical to *accurately* assess the marginal resource mix and displacement assumptions, including a realistic appraisal of the renewable resources currently on the margin and likely future scenarios.

In the following sections PG&E offers input on the methodologies proposed by ARB staff at the May 30th workshop and recommends two alternative options.

I. ARB PROPOSED METHODOLOGIES

The ARB's proposed methodologies as described in staff's presentation resulted in two different GHG standards:

- 400 kg CO2e/MWh, using displacement of combined cycle gas turbine (CCGT) power plants as the marginal resource, and;
- 300 kg CO2e/MWh, using displacement of CCGT generation with a 25% renewable energy adjustment (Renewable Portfolio Standard (RPS) target of 25% by January 1, 2017)

While these methodologies are logical and have the benefit of being simple, each of these approaches will result in less than accurate calculations of the GHG emissions factor for marginal resources because they assume the displaced resource for fuel cells would be either a CCGT or a combination of a CCGT and 25% renewables mix. They do not correctly reflect the marginal emissions in California, including the seasonal and diurnal patterns; and ARB's first proposed standard will significantly overestimate the GHG emissions on the margin, especially when averaged over the expected life of a fuel cell resource.

PG&E appreciates staff's proposed methodologies as an appropriate starting point for discussion but believes that they could be improved upon with a more data-driven approach that includes other important considerations. When deciding an accurate methodology for calculating GHG emissions, it is important to establish a standard that allows for forecasting while also taking into account the growth and effects of renewables on the grid.

II. PG&E PROPOSED ALTERNATIVE METHODOLOGIES

In order to set GHG emissions standards that are based on a more accurate and realistic marginal resource mix, PG&E proposes either of the following two methodologies in lieu of ARB's proposed approaches:

(1) E3's 2016 Avoided Cost Calculator (ACC) model (preferably with one modification); or,

(2) PG&E's 2017 General Rate Cast (GRC) Phase II Price Model.

These public, alternate methodologies use inputs not considered in ARB's proposed methodologies such as load and generation quantities, electric and natural gas prices, variable operations and maintenance cost, and the price of GHGs. To account for the fact that average marginal emissions are expected to decline with time, the emissions standard should use an expected emissions factor calculated as of five years after the installation date (e.g. 2022, for fuel cells installed in 2017). If the emissions standard instead uses a factor calculated as of the installation date, a fuel cell that had the same GHG emissions as the grid in 2017 would be displacing *lower-emitting* resources in later years (as the RPS targets increase), and would counter, rather than enhance the state's goals.

More stakeholders may be familiar with E3's 2016 ACC model (produced in the Integrated Distributed Energy Resources (IDER) proceeding at the California Public Utilities Commission) than with PG&E's 2017 Price Model (produced in its 2017 GRC Phase II proceeding). These alternate methodologies diverge in only minor ways and either would result in a similar GHG emissions factor calculation that is more accurate to that produced by ARB's proposed methodologies. These models are explained in more detail in Attachment A, including the benefits and shortcomings of each.

PG&E's believes ARB should consider both models equally viable when determining the adoption of an appropriate methodology going forward. However, PG&E currently recommends its 2017 GRC Phase II Price Model because it more accurately estimates marginal heat rates than the ACC model which tends to overestimate heat rates (as seen in Figures 1-3 in Attachment A). PG&E's model is also calibrated against actual market results. If the ACC model is modified to address the over-estimation issue, then

PG&E supports use of the ACC model in this regulation as it may be more widely accepted by all stakeholders.

III. CONCLUSION

PG&E strongly suggests that the GHG standards for NEMFC should be based on the methodology that provides the most accurate and realistic assessment of the marginal resource mix to be displaced. PG&E urges ARB to consider both the E3 model and PG&E's model as more accurate options and is available to meet with staff to discuss both models in detail. We look forward to collaborating with all stakeholders in this process.

Please feel free to contact me if you have any questions or concerns.

Sincerely,

/s/

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Attachment A: Description of PG&E's Proposed Alternative Methodologies

1. E3's 2016 ACC Model

   A. Explanation of the model: The 2016 version of the Avoided Cost Calculator is a spreadsheet-based model used in the IDER proceeding to calculate marginal costs and GHG emissions.[1] The model uses 2015 Day-Ahead (DA) and Real-Time (RT) prices in the California Independent System Operator (CAISO) market to develop an 8760 pattern of marginal effective heat rates (in units of million British Thermal Units (MMBtu) per megawatt hour (MWh)),[2] which when multiplied by the marginal emissions rate of a gas-fired resource in tons per MMBtu yields marginal GHG emissions in t/MWh (metric tons per MWh). With the caveat listed in the next section PG&E considers this historical snapshot to be an accurate measure of the 2015 marginal GHG emissions rates, and the calculation could be easily updated to incorporate data from 2016 using the sources identified in the model.

      For future periods, the ACC model relies on E3's RPS Calculator[3] to compute changes to the marginal heat rates through 2020. For years after 2020, the ACC model assumes that the 8760 "shape" of heat rates and therefore emissions will remain constant, while costs escalate according to forward curves or, when those are not available, inflation.

      The model adjusts the marginal heat rate when prices are either very high or very low, as explained on page 35 of the 2016 Avoided Cost Methodology (see Footnote 1). First, the maximum heat rate is capped at a value of 12,500 Btu/kWh (i.e. any heat rate above 12,500 is reset to 12,500). Second, any negative heat rate (which results from a price less than the variable operations and maintenance (VOM) cost) is set to zero for the purpose of calculating marginal GHG emissions, while any heat rate between 0 and 6,900 is set to 6,900.

   B. Benefits of the model: The ACC model has some significant benefits compared to choosing an annual emissions rate based on an assumed marginal combined cycle generator, with or without an adjustment for RPS penetration:

      i. It produces a defensible marginal GHG emissions rate by hour for historical periods, and can be updated with new data annually.

      ii. It is based on publicly available data, and the models are all publicly available Excel spreadsheets that can be run by virtually any stakeholder.

[1] Available at https://www.ethree.com/public_proceedings/distributed-energy-resources-der-avoided-cost-proceedings/
[2] The marginal effective heat rate is defined as (P – VOM)/(G + GHG), where P is the DA price in $/MWh, VOM is the variable operations and maintenance (O&M) cost in $/MWh, G is the gas price in $/MMBtu, and GHG is the cost of California Carbon Allowances (in $/t) times the conversion factor 0.053 t/MMBtu.
[3] Available at http://www.cpuc.ca.gov/RPS_Calculator/

iii. The model produces defensible forecasts of marginal emissions rates for future years through 2020.

iv. The ACC model is the CPUC's official avoided cost model used for all distributed energy resource cost-effectiveness analysis. Therefore, using the ACC model would provide for consistency with how the CPUC values distributed energy resources.

C. Shortcomings of the model: The ACC model does have some shortcomings relative to its use by ARB for this regulation, which are unlikely to be addressed formally until 2018:

i. The adjustment of historical heat rates when they are between 0 and 6,900 may bias the emissions rates upwards, in that marginal heat rates of combined cycle generators are actually as low as 2,500, close to their minimum generation level.[4] This bias is likely to grow larger with time, as more renewable generation increases the number of hours in which fossil generation is at or close to its minimum levels and prices in the DA market are close to (but above) zero.[5] PG&E therefore recommends that the minimum heat rate be set to 2,500 in the model.

ii. Both historical and forecasted heat rates (and therefore calculated GHG emissions) do not correct for hydrologic conditions in the historical year. All forecasted heat rates based on the extremely dry year 2015 will therefore be biased even higher, while forecasts based on the extremely wet historical year 2017 will be biased low..

iii. The forecast part of the model is not calibrated against actual market results.

2. PG&E's 2017 GRC Phase II Marginal Cost Model

A. Explanation of the model: PG&E's 2017 GRC marginal cost model (the PG&E GRC cost model) is a spreadsheet-based model used in PG&E's GRC Phase II proceeding (as well as other Time of Use (TOU)-related proceedings, such as the TOU Periods Order Instituting Rulemaking (OIR) and the Matinee Energy Pricing Pilot) to calculate marginal costs.[6] The model fits an Effective Market Heat Rate (EMHR) curve to a weighted average of historical 2010-2016 DA and RT

[4] See slides 16-18 in the February 13, 2007 CAISO presentation on Modification of Incremental Heat Rate Calculation, available at http://www.caiso.com/1b83/1b837e306f1d0.pdf

[5] For example, in the first three months of 2017, the calculated heat rate using DA prices at the PG&E Default Load Aggregation Point (DLAP) assuming a VOM of $0.50 was between 0 and 6,900 in 1161 out of 2160 hours, or 54% of the time. The ACC model would assign a marginal heat rate of 6,900 for each of those hours, which is an overestimate.

[6] Detailed description is in Chapter 2 testimony in Exhibit PG&E-9, Vol 1, available by searching for GRC Phase II Testimony from PG&E filed on 12/02/16 at https://pgera.azurewebsites.net/Regulation/search

prices in the CAISO market, with the EMHR assumed to depend on Adjusted Net Load,[7] modified to account for ramp rate and start-up costs. This model's definition of EMHR is identical to the definition used in the ACC model, except that it uses a higher VOM cost derived from the 2009 California Energy Commission (CEC) Cost of Generation Report. While the PG&E GRC cost model was not designed to calculate marginal GHG emissions, it can easily be modified to do so by adding a single column to each of the historical and forecast tabs, multiplying the EMHR by the afore-mentioned conversion factor of 0.053 t/MMBtu (with a floor of zero and optionally a cap corresponding to the same 12,500 heat rate cap as the ACC model). Thus the PG&E GRC cost model will yield similar estimates of historical GHG emission rates to those of the ACC model, except between heat rates of 0 and 6,900 in which range PG&E considers the GRC model to be more accurate. Also similar to the ACC model, the PG&E GRC cost model's inputs can be easily updated to incorporate data from 2016 using the sources identified in the model.

For future periods, the PG&E GRC cost model relies on *annual* forecasts from the RPS Calculator, but 8760 *shapes* for load and generation from the 2014 Long-Term Procurement Planning (LTPP) proceeding to compute marginal heat rates through 2024. For years after 2024, PG&E would make the same assumption as does the ACC model after 2020, namely that the 8760 "shape" of heat rates and therefore emissions will remain constant, while costs escalate according to forward curves or, when those are not available, inflation.

B. Benefits of the model: The PG&E GRC cost model also has some significant benefits compared to ARB's proposed methodologies, many of which it shares with the ACC model:

   i. It produces a defensible marginal GHG emissions rate by hour for historical periods, and can be updated with new data annually.

   ii. It is based on publicly available data, and the models are all publicly available Excel spreadsheets that can be run by virtually any stakeholder.

   iii. The model produces defensible forecasts of marginal emissions rates for future years through 2024 (i.e., four years further out than the ACC model).

   iv. The calculations for historical and forecast periods use the same underlying model, so they are self-consistent.

   v. The model is calibrated against actual market results in the CAISO, and is very robust as evidenced by out-of-sample tests.

C. Shortcomings of the model: The PG&E GRC cost model also has some shortcomings:

[7] Adjusted Net Load is equal to gross (or metered) load, less utility-scale renewables (wind and solar, geothermal, biomass/biogas and small hydro), nuclear, and a smoothed function of large hydro generation. It represents the amount of load that must be met by thermal resources plus unspecified imports.

i. The model is not as well socialized as the ACC model, and therefore more stakeholders would have a steeper learning curve to run it. However, it is notable that both the Office of Ratepayer Advocates (ORA) and Solar Energy Industries Association (SEIA) have accepted the model's forecasts of marginal energy costs in testimony in the GRC Phase II proceeding.

ii. The PG&E GRC cost model was developed by PG&E. E3 is a consulting company that maintains many models, including the ACC model and the RPS Calculator, which are used in public regulatory proceedings and has a more robust support system in place to respond to questions and maintenance needs.

3. Comparison of Market Heat Rates and Modeled Heat Rates for ARB, ACC and PG&E Methodologies

Figures 1 and 2, below, show the historical Effective Market Heat Rate (EMHR) for PG&E's service territory compared to modeled heat rates corresponding to the two ARB proposals, as well as the ACC and PG&E GRC models. In each Figure, the upper dashed line represents the EMHR assuming a low VOM (as used in the ACC model); while the lower dashed line represents the EMHR assuming a higher VOM (as used in the PG&E GRC model). The green solid line represents the modeled *historical* heat rate that would be obtained with the ACC model if its 2015 CAISO data had been replaced by 2016 data, while the solid purple line is the ACC model's *forecast* 2016 heat rate. The solid orange line is the PG&E GRC model's forecast 2016 heat rate. Finally, the dotted purple and green lines represent ARB's two proposals, converted to heat rates by dividing the kg/MWh values by the conversion factor 53 kg/MMBtu.

Table 1 shows the average GHG emissions rate for the methodologies discussed above, for the years 2016 and 2022 (2017 is not included because only the first five months of data are available). Here, ARB High is the ARB methodology assuming a marginal CCGT; ARB Low accounts for the renewable energy adjustment.

Table 1: Average GHG Emissions Rates in 2016 and 2022

Year	ARB High	ARB Low	ACC Backcast	ACC Forecast	PG&E GRC Forecast
2016	400	300	437	502	338
2022	400	254		350	286

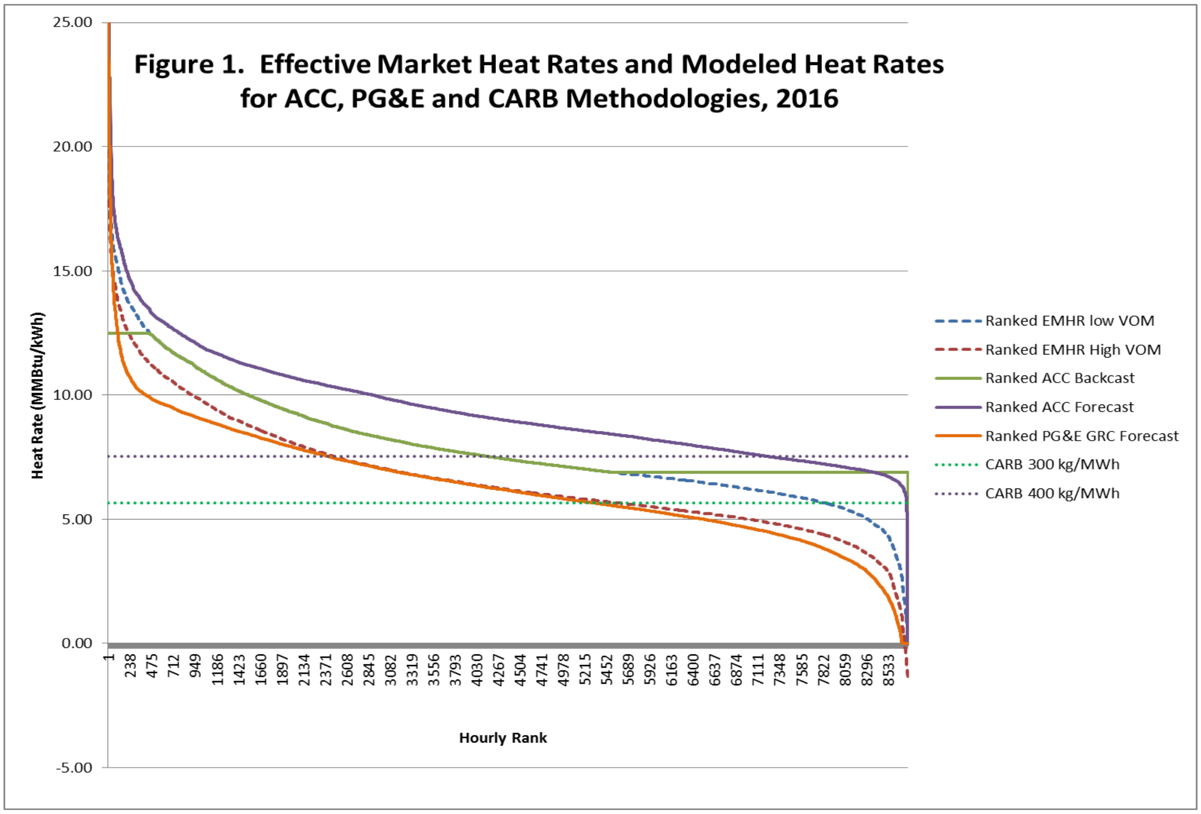

Figure 1. Effective Market Heat Rates and Modeled Heat Rates for ACC, PG&E and CARB Methodologies, 2016

In both Figures, the 400kg/MWh value clearly overestimates marginal heat rates using either of the VOM values, while the ACC forecast curves also overestimate marginal heat rates, especially for 2016. The PG&E GRC forecast tracks the high-VOM EMHR fairly closely. While PG&E has not had the opportunity to modify the ACC model by reducing the minimum heat rate from 6,900 to 2,500 (or from 6.9 to 2.5 in these Figures), we note that such a modification would bring the ACC model results closer to the market heat rate curves at the right side of the figures, yielding lower and, PG&E believes, more accurate heat rate and therefore marginal emissions rates.

Finally, Figure 3 shows just the modeled EMHR for the ARB, ACC and PG&E methodologies for the year 2022. For this Figure, the lower ARB estimate is reduced to (400*0.635) = 254 kg/MWh to account for the 36.5% RPS mandate as of 2022. For 2022 there is no historical data to compare to; PG&E merely notes that the current ACC model (i.e., with a 6,900 minimum heat rate) yields significantly higher heat rates than either the PG&E GRC model or the lower ARB methodology.

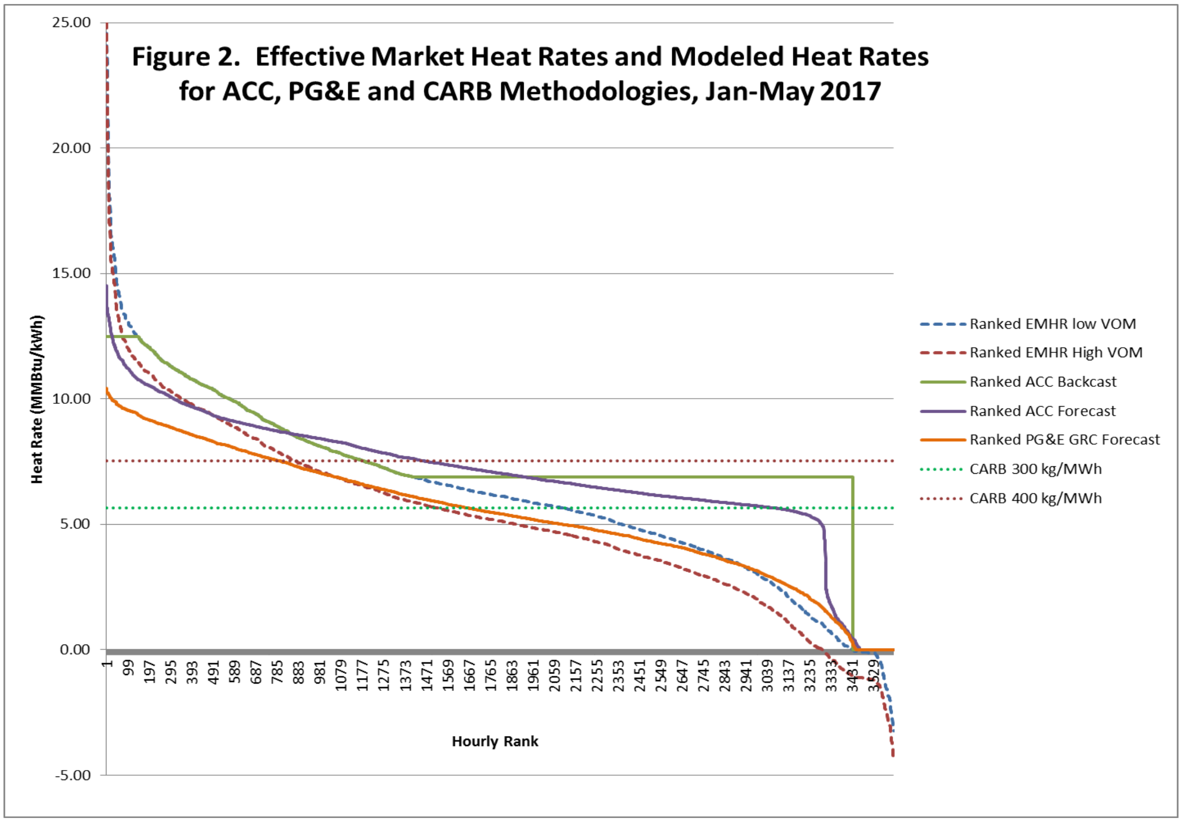
Figure 2. Effective Market Heat Rates and Modeled Heat Rates for ACC, PG&E and CARB Methodologies, Jan-May 2017
Heat Rate (MMBtu/kWh)
Hourly Rank
Ranked EMHR low VOM
Ranked EMHR High VOM
Ranked ACC Backcast
Ranked ACC Forecast
Ranked PG&E GRC Forecast
CARB 300 kg/MWh
CARB 400 kg/MWh

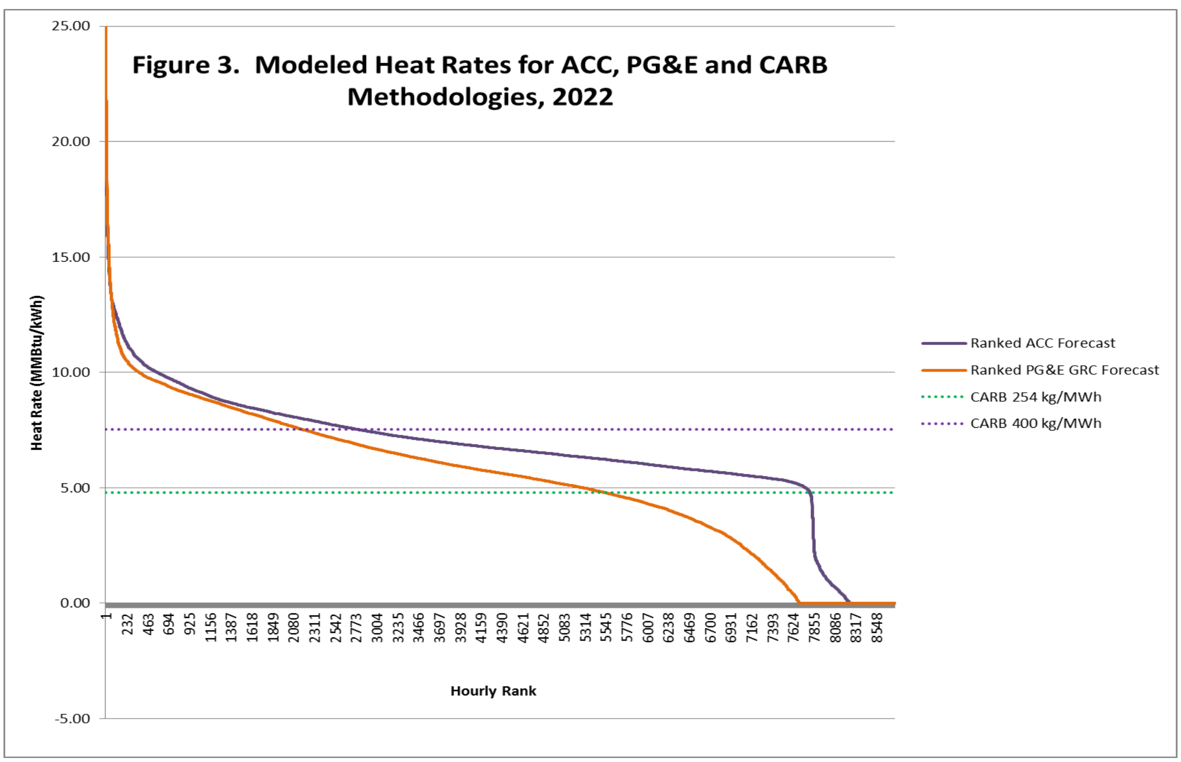
Figure 3. Modeled Heat Rates for ACC, PG&E and CARB Methodologies, 2022
Heat Rate (MMBtu/kWh)
Hourly Rank
Ranked ACC Forecast
Ranked PG&E GRC Forecast
CARB 254 kg/MWh
CARB 400 kg/MWh