Draft Prepared by Bryan Neff, California Energy Commission, for Discussion at the July 14, 2014 Staff Workshop on Combined Heat and Power

ESTIMATING FUEL DISPLACEMENT FOR CALIFORNIA ELECTRICITY REDUCTIONS: SUMMARY OF STAFF'S PROPOSED METHOD

Introduction

California's energy strategy is guided by the "loading order," which first calls for reducing electricity demand with energy efficiency and demand response programs, then meeting remaining generation needs first with renewable and distributed resources, and finally with clean fossil-fuelled generation. With the exception of fossil-fuelled generation, these resources are called preferred resources. As preferred resources have become increasingly important in California's electricity system, so has the need to evaluate the programs that support them. A primary metric used in evaluating preferred resource programs is greenhouse gas emissions reduction.

Most methods for calculating emissions reduction vary substantially in their approach and assumptions. These methods have been developed to fit a specific program or purpose. While these methods are sufficient for individual programs, the differences in approaches and assumptions makes program comparison difficult.

California Energy Commission staff is working on a staff paper to propose a common method for estimating the amount of generation fuel displaced from avoided use of grid electricity over the next 15 years. This preliminary summary of that paper identifies California's average dispatchable grid resources and their associated fuel efficiency, presents a method for calculating grid electricity displacement, and illustrates how this numerical representation can be applied to help evaluate four of California's preferred resources: energy efficiency, demand response, renewable electricity generation, and combined heat and power systems. The draft staff paper will be published following the July 14 workshop discussion for public comment. Staff is specifically seeking input to a series of questions in the conclusion of this draft summary.

Method Overview

For this method to be a common basis for comparing programs, it has to be agnostic to the approaches and methods used by those programs to estimate emission reductions. It relies solely on historic heat rate data and the trend found within that data. For these examples to maintain their policy-neutral nature, any energy reduction has to be applied to a common set of dispatchable resources. The proposed method does not make any specific assumptions about the retirement of existing resources, the addition of new resources (preferred or otherwise), the impact today's preferred resource procurement will have on future procurement, the impact the operation of these new resources will have on existing resource operation, the emphasis on a "flexible" grid (requiring resources that will be tasked with ramping more quickly and more frequently than in the past), and future renewable procurement policy and legislation.

Characterizing Electric Grid Generation Resources

Electric generation resources all have technological and operational characteristics that allow them to be grouped into a limited set of categories. These characteristics provide a general guide for the role they play in the generation portfolio and how they operate as a system to meet demand. To balance supply and demand on a nearly instantaneous basis and accommodate non-dispatchable resources, such as nuclear generation and variable renewable generation, the electricity system needs dispatchable resources that are capable of being cycled up and down to follow load. In California, natural gas-fired generation is the predominant resource used to maintain the supply-demand balance.

Natural gas-fired plants can also be categorized based on the technology that is used and/or the way they are operated. A common way to capture their operational differences is by their capacity factor, which is typically expressed as a percentage determined by dividing the actual electric generation output by the generation that would occur if the generator ran at full output year round. Natural gas-fired plants with low capacity factors that run a minimal amount of time each year to meet peak electric demand are called peaker plants. They have the fastest ramping capabilities and, having the highest incremental cost, are the most costly to run. Natural gas-fired plants with higher capacity factors, primarily combined cycle plants that were originally designed to run as baseload but that have ramping capabilities, are used as load following resources on the grid.

Determining Heat Rates

In general, the amount of fuel displaced by an energy reduction measure or onsite generation depends on the amount and type of generation that it displaces, which in turn determines the amount of greenhouse gas emissions reductions that can be attributed to any particular preferred resource. Greenhouse gas emissions reductions are a function of the amount of carbon in the fuel that is converted to carbon dioxide (CO_2) through combustion. As a result, the fuel efficiency of a generator, commonly expressed as a heat rate, is an important factor in determining the amount of generation and the associated fuel that is being displaced, along with the amount of greenhouse gas emissions reductions that are achieved.

The proposed approach for estimating fuel reduction outlined in the forthcoming staff paper uses generator reporting data from the Quarterly Fuel and Energy Report to provide historic heat rates and extrapolates these to provide statewide marginal average heat rate estimates. Fitting a linear regression to the historical heat rates for load following and peaking resources from 2004 to 2013 yields a projection that takes into account recent electric grid trends. The years from 2001 to 2003 were not included in the regression, as the effect of California's electricity crisis forced atypical power plant operation for those years.

These regressions assume the recent trends in technological improvement will continue as newer, more efficient turbines replace some of the current natural gas fleet. This projection of decreasing average heat rate falls below that of currently available technologies by the year 2023, as analyzed in the Energy Commission's *Estimated Cost of New Renewable and Fossil Generation in California Draft Staff Report*.[1] Staff proposes using the heat rate from conventional combustion turbines as a proxy for the average heat rate of peaking resources and the heat rate of conventional combined cycle combustion turbines for the average heat rate of load following resources for years when the regression exceeds the low estimate from the same report. The low heat rate estimates for conventional combustion technology and conventional combined cycle combustion turbines are 9,980 and 7,030 British thermal units/kilowatt-hour (Btu/kWh), respectively. These low heat rates are representative of the reported operation in the Quarterly Fuels and Energy Report data of the most recently installed generation of the same type. These heat rates will be used as a floor for the years 2023 and beyond.

The onsite equivalent heat rates are calculated using a line loss factor of 7.8 percent. Energy is lost during the transmission and distribution of electricity. Accordingly, a megawatt-hour (MWh) of consumption of grid provided energy requires that more than a MWh be generated. A 1 MWh reduction in consumption (due to energy efficiency or demand response) or a 1 MWh of onsite generation (combined heat and power, rooftop solar) reduces the need for grid-provided energy by more than 1 MWh. A line loss factor is needed to account for this additional electricity and the fuel needed to generate it; onsite equivalent represents the reduced efficiency caused by the transmission and distribution of electricity. It is not applied when another grid-connected generator is the source of displacement, as energy from that resource experiences line losses as well.

Combining the results of the regression analysis and this technological heat rate floor yields applicable heat rate estimates for load following and peaking resources, as seen in **Table 1** and **Figure 1.** Peaking resources, although defined as having capacity factors less than 10 percent, only produce 2.5 percent of the total annual energy on average, thus are limited to a maximum of 2.5 percent of the energy displaced annually.

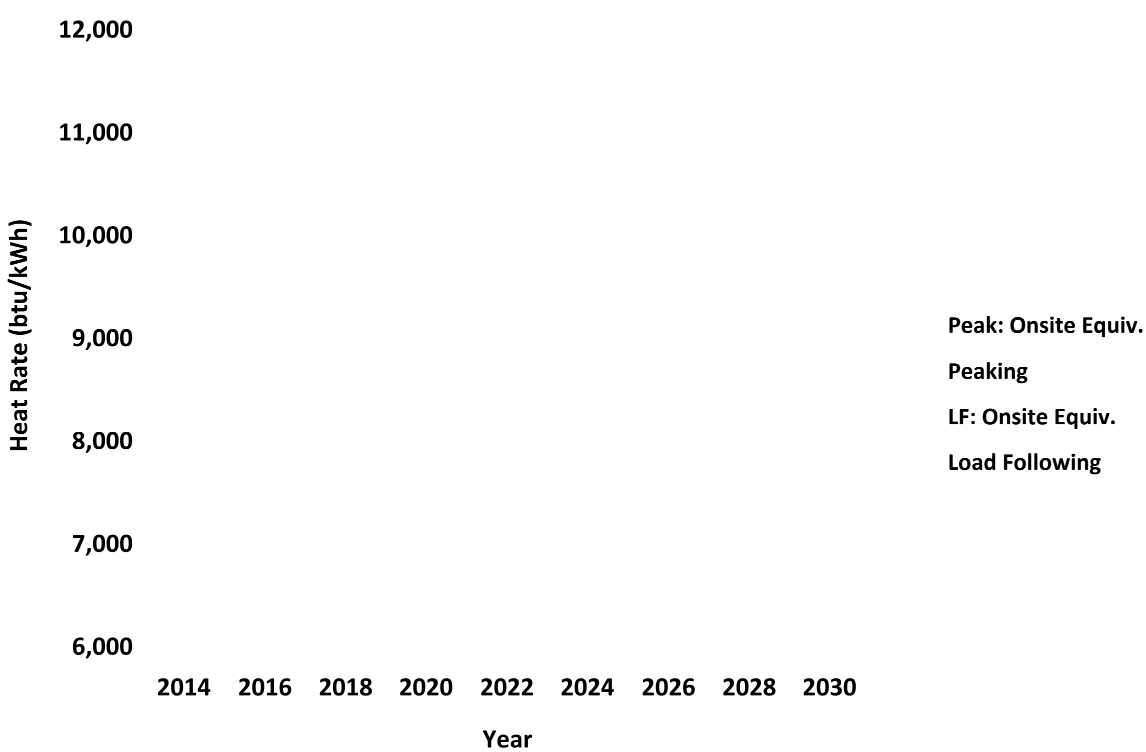
1 See CEC-200-2014-003-SD, May 2014.

Table 1: Applicable Heat Rate Estimates

Year	Load Following (LF) (Btu/kWh)	LF: Onsite Equivalent (Btu/kWh)	Peaking (Btu/kWh)	Peak: Onsite Equivalent (Btu/kWh)
2014	7,330	7,950	10,476	11,362
2015	7,295	7,912	10,419	11,300
2016	7,260	7,874	10,361	11,238
2017	7,225	7,836	10,304	11,176
2018	7,190	7,798	10,247	11,113
2019	7,155	7,760	10,189	11,051
2020	7,120	7,722	10,132	10,989
2021	7,085	7,684	10,074	10,927
2022	7,050	7,646	10,017	10,864
2023 to 2030	7,030	7,625	9,980	10,824

Source: Energy Commission, Electricity Analysis Office, Electricity Supply Analysis Division.

Figure 1: Applicable Heat Rate Estimate Curves



Source: Energy Commission, Electricity Analysis Office, Electricity Supply Analysis Division.

Determining the Amount of Fuel Displaced

The proposed method to determine the equivalent avoided fuel from reduced electric grid use is to take the number of kilowatt-hours of avoided grid electricity consumption multiplied by the applicable heat rate.

In general terms, the calculation for both load following and peaking resources is:

(electricity displaced) x (applicable heat rate) = displaced electric grid fuel equivalent

Since this is just an estimate, it is not, nor is it intended to replace, direct measurement of emissions reductions. It is a means to provide uniformity and a common approach to estimation for evaluating different types of resources that reduce or displace the use of grid electricity.

Sample Applications

Staff applied the above methodology using four sample scenarios to illustrate how this estimation may be applied in a given policy, with its own set of assumptions, to yield a numerical result. Each example uses the carbon content conversion metric provided by the United States Energy Information Administration, 117 pounds of carbon dioxide (CO_2) emitted per million British thermal units of natural gas consumed.[2] To simplify the examples, each one uses the applicable heat rate estimates for 2014 from **Table 1**.

Demand Response

Assume a demand response program is implemented that reduces load during the entire time that peaking resources are being used. Also assume that the reduction is a uniform 1 MW (or 1,000 kilowatts) when it occurs. Since this reduction is onsite, the calculation will use the onsite equivalent applicable heat rate. If this load reduction occurred throughout the year, it would be responsible for 8,760 MWh. Applying the peaking energy limit of 2.5 percent yields 219 MWh of peak energy displaced.

For 2014, this calculation would be:

(peak electricity displaced) x (onsite equivalent heat rate for peaking resources) =

219,000 kWh x 11,362 Btu/kWh =

2,488,278,000 Btu

2 See http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11.

Applying the CO_2 conversion factor for natural gas yields a reduction of approximately 291,129 pounds of CO_2.

Energy Efficiency

For this example, assume that the energy efficiency measure alters the operation of an appliance that operates roughly uniformly throughout the year, such as a refrigerator. For ease of calculation, assume that a refrigerator replacement program reduces demand by 2,000 kW. However, since refrigerators only run part of the time, assume that only 10 percent of their compressors will be running at the same time, resulting in a 200 kW reduction throughout the 8,760 hours of the year. This yields a total energy reduction of 1,752,000 kWh. This measure would use the onsite electrical equivalent for both load following and peaking resources. The peaking resources would be limited to 2.5 percent of the energy, calculated to be 43,800 kWh, leaving 1,708,200 kWh of load following energy displacement.

For 2014, this calculation would be:

> (peak electricity displaced) x (onsite equivalent heat rate for peaking resources) +
>
> (load following electricity displaced) x (onsite equivalent heat rate for load following resources) =
>
> (43,800 kWh x 11,362 Btu/kWh) + (1,708,200 kWh x 7,950 Btu/kWh) =
>
> 14,077,845,600 Btu

Applying the CO_2 conversion factor for natural gas yields a reduction of approximately 1,647,108 pounds of CO_2.

Renewable Generation

For this simplified operation of a wind generator, assume a 2.5 MW (2,500 kilowatts) turbine that operates at a 40 percent capacity factor, for a net electricity export of 8,760 MWh (8,760,000 kWh). Also assume that during peak load times, generation was operating at a 20 percent capacity factor, for a total of 109,500 kWh generated on peak.[3]

For 2014, the fuel displacement calculation would be:

> (peak electricity displaced) x (heat rate for peaking resources) +
>
> (load following electricity displaced) x (heat rate for load following resources) =
>
> (109,500 kWh x 10,476 Btu/kWh) + (8,650,500 kWh[4] x 7,330 Btu/kWh) =

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3 8,760 MWh (annual generation at 40 percent capacity) x 2.5 percent (percentage of peak load energy) x 1/2 (half of the non-peak operating capacity) = 109,500 kWh

4 8,760,000 kWh – 109,500 kWh = 8,650,500 kWh

64,555,287,000 Btu

Applying the CO_2 conversion factor for natural gas yields a reduction of approximately 7,552,969 pounds of CO_2.

Repeating this example, except assuming the energy is all used on-site, changes the applicable equivalent heat rates. For 2014, the fuel displacement calculation would be:

(peak electricity displaced) x (onsite equivalent heat rate for peaking resources) +

(load following electricity displaced) x (onsite equivalent heat rate for load following resources) =

(109,500 kWh x 11,362 Btu/kWh + 8,650,500 kWh x 7,950 Btu/kWh) =

70,015,614,000 Btu

Applying the CO_2 conversion factor for natural gas yields a reduction of approximately 8,191,827 pounds of CO_2.

Combined Heat and Power

This example assumes a 5 MW (5000 kW) facility that operates with an 80 percent capacity factor, with the 20 percent down time occurring solely during off-peak hours. To illustrate both onsite and export together in a single example, assume that 50 percent of its power is exported to the grid. There is a potential of 43,800 MWh if this facility generates at 100 percent capacity. Applying the energy limit for peaking resources of 2.5 percent yields 1,095 MWh. This leaves 77.5 percent of energy displaced from load following resources, or 33,945 MWh. This energy is then split evenly between onsite and export, yielding 547.5 MWh for both onsite and export peak electricity displaced and 16,972.5 MWh for both onsite and export load following electricity displaced.

For 2014, the fuel displacement calculation would be:

(onsite peak electricity displaced) x (onsite equivalent heat rate for peaking resources) +

(onsite load following electricity displaced) x (onsite equivalent heat rate for load following resources) +

(export peak electricity displaced) x (heat rate for peaking resources) +

(export load following electricity displaced) x (heat rate for load following resources) =

(547,500 kWh x 11,362 Btu/kWh) + (16,972,500 kWh x 7,950 Btu/kWh) +

(547,500 kWh x 10,476 Btu/kWh) + (16,972,500 kWh x 7,330 Btu/kWh) =

271,296,105,000 Btu

Applying the CO_2 conversion factor for natural gas yields a reduction of approximately 31,741,644 pounds of CO_2.

This calculation only accounts for the displaced grid electricity from this hypothetical CHP generator. Since the operating efficiency of CHP systems and boilers is out of the scope of this paper, this calculation does not take into account how much fuel the CHP unit used, nor the avoided boiler fuel. Real world calculations should take these variables into account.

Summary of Displacement Estimate Examples

Table 2 contains a summary from the examples for avoided energy, displaced fuel equivalent, carbon content, and carbon intensity.[5]

The difference between the two renewable generation examples illustrates the impact line losses have on the calculation. A renewable generator used on-site will have a higher displacement carbon intensity. The difference in displaced carbon intensity in the energy efficiency and the on-site renewable examples is attributable to the ratio of peak to non-peak electricity. For the carbon intensity in the CHP example, the carbon intensity of neither the CHP generator nor the avoided boiler fuel is included.

Table 2: Calculation of Displacement Examples for 2014

Reduction Type	Total Avoided Grid Energy (MWh)	CO_2 Conversion (lbs. CO_2)	Carbon Intensity (CO_2/MWh)
Demand Response	219	291,129	1,329
Energy Efficiency	1,752	1,647,108	940
Renewable (export)	8,760	7,552,969	862
Renewable (on-site)	8,760	8,191,827	935
Combined Heat and Power	35,040	31,741,644	906

Source: Energy Commission, Electricity Analysis Office, Electricity Supply Analysis Division.

Conclusion

Energy Commission staff is seeking public comments and feedback on this proposed method. The Energy Commission requests that parties address the following questions in their written comments:

- Is the Energy Commission staff's approach to estimating fuel displacement reasonable? If not, please explain why.
- Is the Energy Commission staff's approach to the treatment of renewable energy appropriate? If not, please explain.

5 Carbon intensity a ratio of annual carbon displacement over the total avoided grid energy.

- How could the method be applied across programs so that it creates beneficial comparison without interfering with existing program-specific displacement metrics?
- Is the use of annual heat rate values (versus seasonal values) sufficient, given the purpose and scope of the method? If not, please explain and propose an alternative.
- Is the use of a single state-wide heat rate projection appropriate? If not, please explain and propose an alternative.
- Is the use of two heat rate categories (peaking and load following) adequate? If not, please explain and propose an alternative.
- Does the approach sufficiently address the issue of imported electricity? If not, please suggest ways that it could be improved.
- Do you agree with the line loss factor used? If not, please explain and propose an alternative.
- Do you agree with the heat rate floor used? If not, please explain and propose and alternative.