MARGINAL CARBON DIOXIDE PRODUCTION RATES OF THE NORTHWEST POWER SYSTEM

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Contents

SUMMARY

The impact of future carbon dioxide (CO_2) regulation is a significant risk in long-term utility resource planning. Improper accounting for this risk when evaluating resources may result in poor resource decisions and higher costs for the region's ratepayers. This study is an examination of the rate of avoided CO_2 emissions over time under different water and CO_2 price conditions.

In comparison to the opportunity to purchase a similar resource on the market, a resource,[1] such as conservation, that avoids CO_2 emissions, mitigates risk. The opportunity for risk mitigation depends on what the next available megawatt of generating resource is available and how much CO_2 it emits. The *marginal resource* is the least variable cost resource available and needed to meet the next megawatt of load.

In the Northwest, the average marginal CO_2 production rate is substantially higher than the average CO_2 production rate from all electricity generation. This is because hydroelectricity, wind, and solar

[1] Some other examples of resources that have this risk mitigation attribute are conservation, demand response and renewable generation, like wind or solar.

which have low operating costs and no CO_2 emissions are brought on-line before coal-fired or natural gas-fired generating units. However, since the next megawatt of generation avoided would be available from the marginal unit, not an average of all the units online, the emissions of the marginal unit best represents the avoided carbon risk.

INTRODUCTION

During any given hour of the year, there is a diverse mix of generating units supplying power to the regional power system. Some of these units will be hydroelectric, solar, nuclear, or wind generating units that do not emit CO_2 into the atmosphere. At the same time, coal-fired or natural gas-fired generating units that do emit CO_2 into the atmosphere will also be generating power for the region. Each type of generating unit emits CO_2 at a distinct rate. For context, a contemporary natural gas-fired combined cycle unit emits roughly 0.8 to 0.9 pounds (lbs.) of CO_2 per kilowatt-hour. A typical conventional coal-fired steam unit emits roughly 2.1 to 2.4 lbs. of CO_2 per kilowatt-hour. Peaker gas units have a larger range of emissions rates 1.1 to 1.7 lbs. of CO_2 per kilowatt-hour. One way to measure the CO_2 production rate of the Northwest power system is to average the rates of all the generating units operating during a given time period. In this paper, we use the term, average CO_2 production rate, to refer to an average across all resources operating during a given time period. Another way to measure the CO_2 production rate of a power system is to determine the CO_2 emissions rate of the last resource (or marginal resource) brought on-line to supply power during a given time period. In wholesale power markets for energy, generating resources have typically been brought online in the order of their operating costs. In other words, resources with low operating costs utilized before resources with higher costs. In general, hydroelectric, nuclear and wind generating units will be brought on-line before coal-fired or natural gas-fired generating units. Some units that traditionally would have been considered marginal are brought online to provide operating or contingency reserves in addition to energy.

Even though calculating the marginal unit is now more complex due to consideration of reserve requirements, the CO_2 emissions of the marginal resource still seems to be a reasonable proxy of the emissions that can be avoided by adding energy-efficiency measures to the system. This paper estimates the Pacific Northwest power system's marginal resource, and its CO_2 production rate, during each hour for four separate years: 2016, 2021, 2026, and 2031 under 80 different hydro conditions. Because there are typically 8,760 hours during a year, the results are summarized by providing average marginal CO_2 production rates for each year (or each month, in some cases). In this paper, we use the term average marginal CO_2 production rate to refer to an average across only the marginal resources operating during a given time period.

METHODOLOGY

The methodology for determining the regional power system's marginal resource, and thus the marginal carbon emission rate, is similar to the 2008 Council study[2]. In this paper, we will examine two regional strategies, corresponding with the Existing Policy and Social Cost of Carbon scenarios from the Seventh Power Plan[3], in the following years: 2016, 2021, 2026, and 2031. All 80 hydro conditions[4] considered in the Seventh Power Plan will be tested for each scenario.

Council staff uses AURORAxmp® Electric Market Model (AURORAxmp) to develop its wholesale electricity price forecasts. This model simulates hourly supply and demand to determine a marginal resource and market-clearing price for every hour of the simulation period for each of the load-resource zones in the model. The Council's configuration of AURORAxmp uses 16 load-resource zones to represent the entire Western Electricity Coordinating Council (WECC) power system. Four of these zones represent the Pacific Northwest regional power system. Therefore, for each hour of a simulation period for each scenario under a particular hydro condition, AURORAxmp identifies four different marginal resources for the Pacific Northwest, one in each zone.

In order to identify a single Pacific Northwest marginal resource, and marginal CO_2 production rate, for each hour of the simulation period, Council staff conducted additional analysis on the AURORAxmp hourly output databases. The hourly output databases contain statistics summarizing the simulated operation of each generating unit located in the Pacific Northwest[5]. Staff performed a series of filtering steps to arrive at a single marginal resource for each hour. First, staff removed any units considered to be must run resources. Must-run resources generate power regardless of wholesale power market prices. For the Northwest, must-run resources include the following: wind farms, solar plants, municipal solid waste facilities, industrial co-generation facilities, geothermal steam plants, and biogas facilities. Second, for each hour, removing any unit that did not generate electricity in that hour further narrowed the potential marginal units. Finally, from the remaining units, the highest dispatch cost unit was determined to be the region's marginal resource for each hour. This process resulted in a single marginal resource for the Pacific Northwest for each hour of the simulation period.

A sample resource stack[6] in Figure 1 demonstrates stacking the capacity of all the resources in the region by dispatch cost, and determination of the marginal resource by the load obligation of the region within the hour. Note that the region's marginal resource will change not only from season to

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[2] See the "Marginal Carbon Dioxide Production Rates of the Northwest Power System" at https://www.nwcouncil.org/media/29611/2008_08.pdf.

[3] See the Seventh Power Plan.

[4] The hydro conditions represent the result of a GENESYS run using modified streamflows of hydro years 1929 through 2008 to develop hourly boundaries to put into AURORAxmp. These boundaries limit the monthly hydro availability, and the minimum and maximum hourly generation capability of the hydro system in AURORAxmp.

[5] There are 933 generating units in the regional database. That may not correspond to the exact number of power plants, since some plants are broken out by generating unit for modeling convenience.

[6] The gaps in the resource stack indicate that there are no units available at that dispatch cost.

season as the region's water supply, loads, fuel prices, and resource availability varies, but also from hour to hour as demand changes.

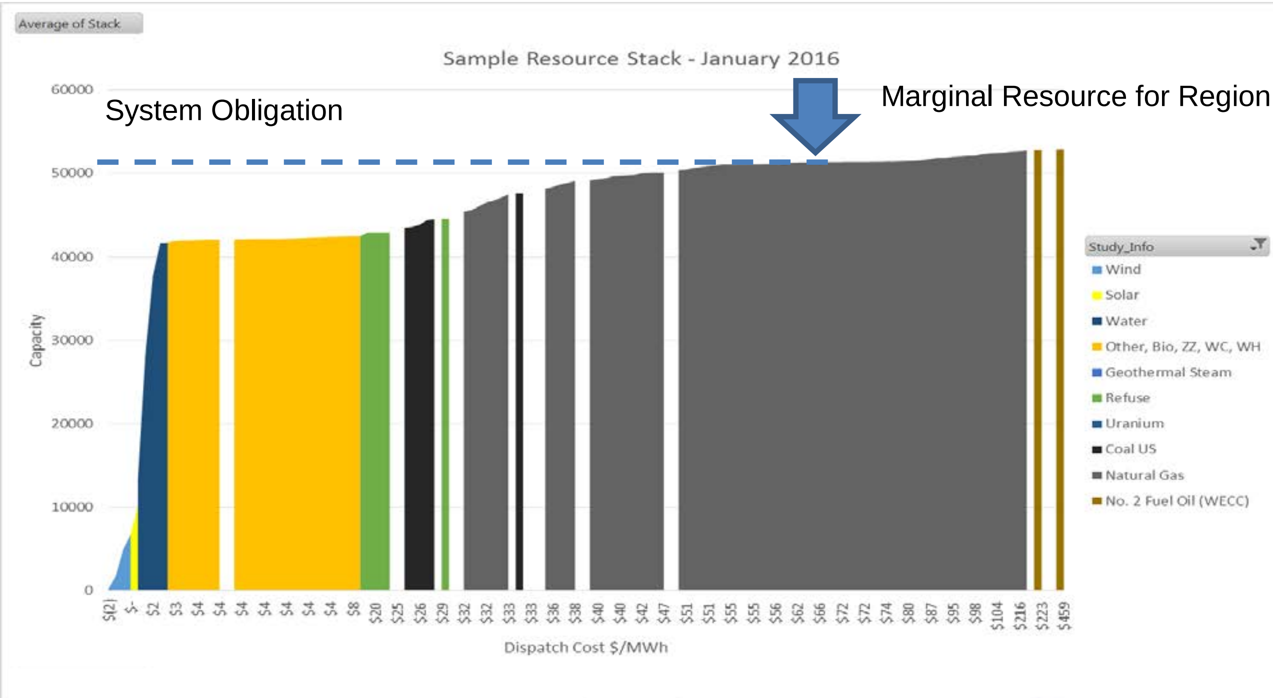

Figure 1: Resource Stacking to Determine the Marginal Unit

RESULTS

Since the Pacific Northwest has a high percentage of negligible or non-carbon emitting resources such as hydroelectric, nuclear, wind and solar generation, the marginal CO_2 production rate is considerably higher than the average CO_2 production rate. Annually, the average electric price and marginal unit dispatch cost are heavily dependent on hydro conditions, but the average regional CO_2 emissions rate and marginal CO_2 emissions rate are both less affected. On a seasonal level, the spring runoff can cause higher marginal emissions, but in general, the emissions tend to be less effected by the hydro level than other factors.

Existing Policy

Monthly Comparison

This comparison examines seasonal changes in emissions rate. While there is some variation in the marginal emissions rate from 1.17 to 1.25 lbs per kWh, there is not a significant pattern associated with seasonality. The average emissions rate shows a little more seasonality as it falls to 0.08 lbs per kWh in spring and raises to 0.25 lbs per kWh in fall. This is to be expected based on the amount of zero emission hydropower produced in spring (lots of hydro) and late summer (less hydro) respectively.

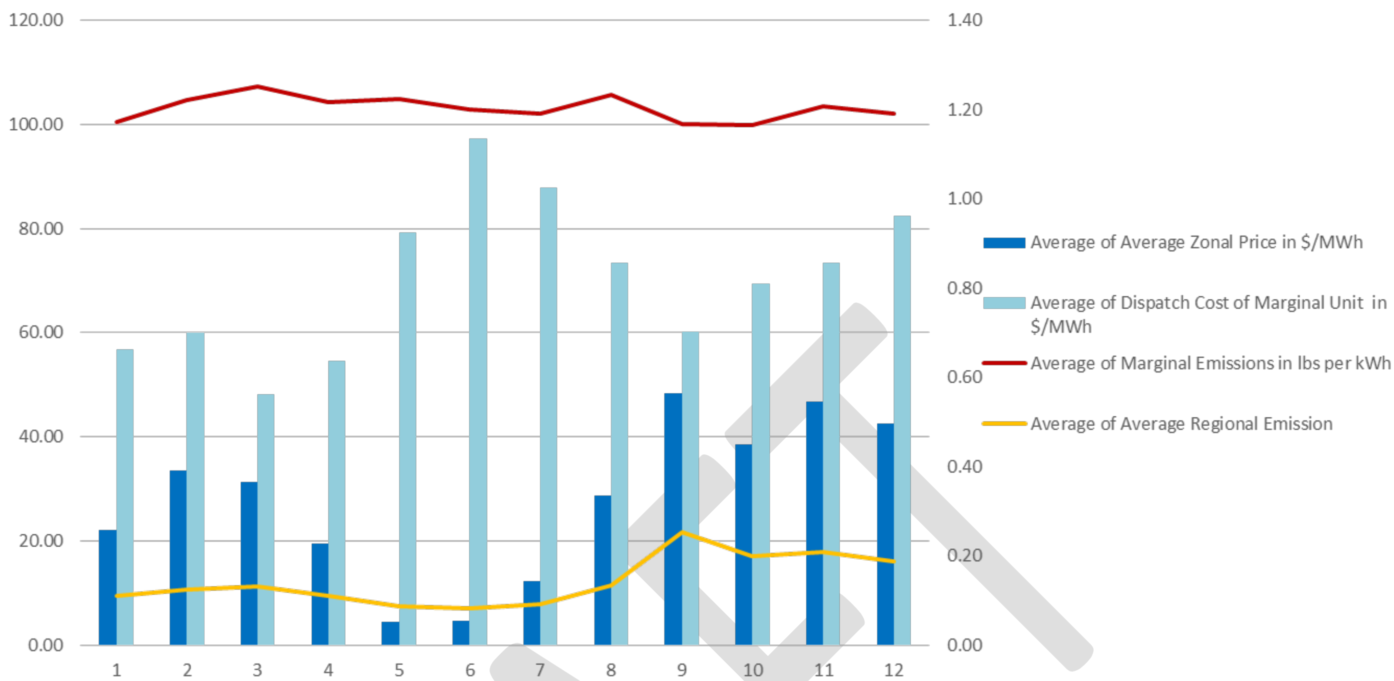

Figure 2: 2016 monthly results

Different Hydro Conditions

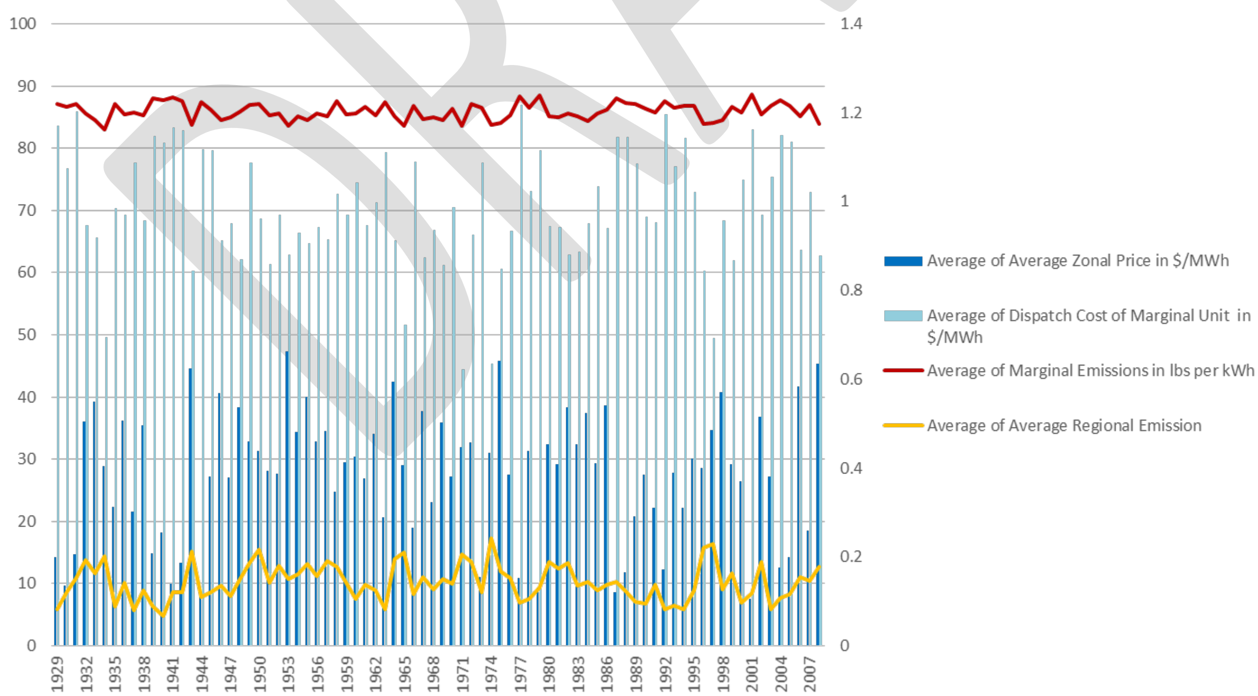

Figure 3: 2016 results across different hydro conditions

Per Figure 3, the marginal regional carbon emissions rates seem to vary by the hydro year, but similarly to the seasonality, the effect does not seem to be associated directly with the amount of hydro. There is significant variance in market price and the dispatch cost of the marginal unit over the hydro years as to be expected, with low average market price, but higher marginal dispatch costs in good hydro years.

Social Cost of Carbon

The Social Cost of Carbon as used in the Seventh Power Plan is used as a proxy for a carbon price in the region. The carbon pricing starts at 45 dollars per ton of CO_2 emitted in 2016 and peaks at just over 66 dollars per ton in 2031.

Monthly Comparison

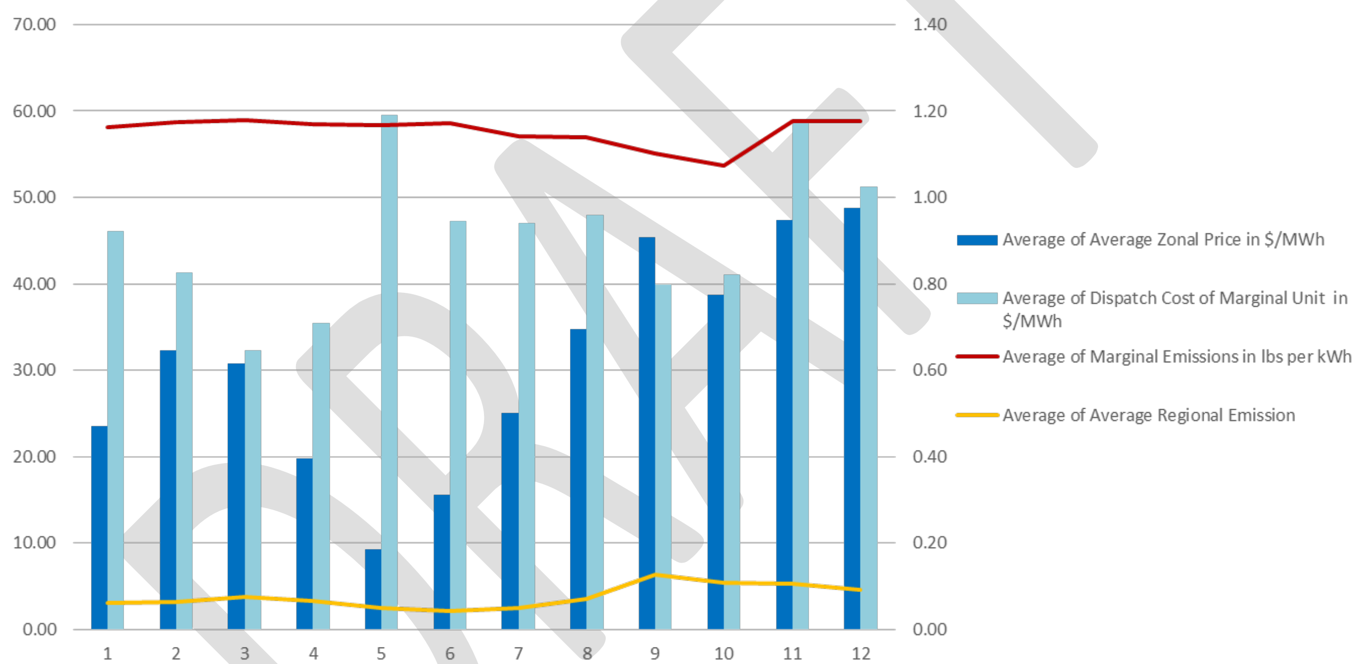

Figure 4: 2016 SCC monthly results

Similar to the seasonal results from the runs without carbon pricing there is some variation in the marginal emissions rate from 1.07 to 1.18 lbs. per kWh, but there does not seem to be significant pattern associated with seasonality. Most notably, the overall marginal and average emissions rates go down when the social cost of carbon is applied to the dispatch cost of emitting plants.

Different Hydro Conditions

When comparing the regional average and marginal carbon emissions rate over 80 historical water conditions between the existing policy and social cost of carbon runs, the average and variability of the emissions rates to hydro condition are reduced in the scenarios with carbon pricing.

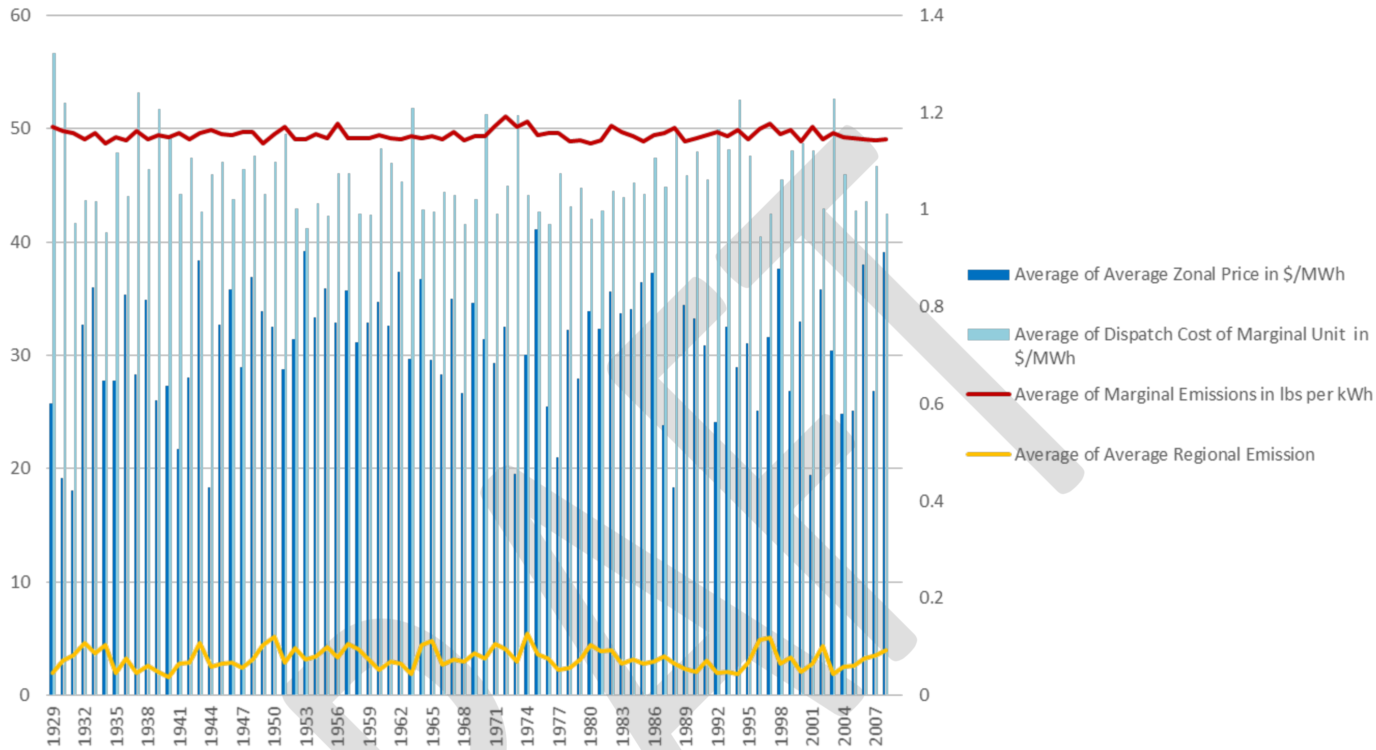

Figure 5: 2016 SCC results across different hydro conditions

Annual Comparison

Per Figure 6, and with the exception of the 2021 scenarios in the existing case, the marginal carbon emissions rate are just under 1.2 lbs per kWh and have minimal variance. As can be seen in Figure 7, the reason for the increased variability in marginal carbon emissions rate throughout the 2021 scenarios is due to coal generation being on the margin just over 34% of the hours. In all the rest of the studies and especially in the studies where a carbon cost was applied, coal is nearly never on the margin. Due to the coal retirements in 2026 and 2031, the variability in the marginal carbon rate is reduced considerably even in the existing policy scenario.

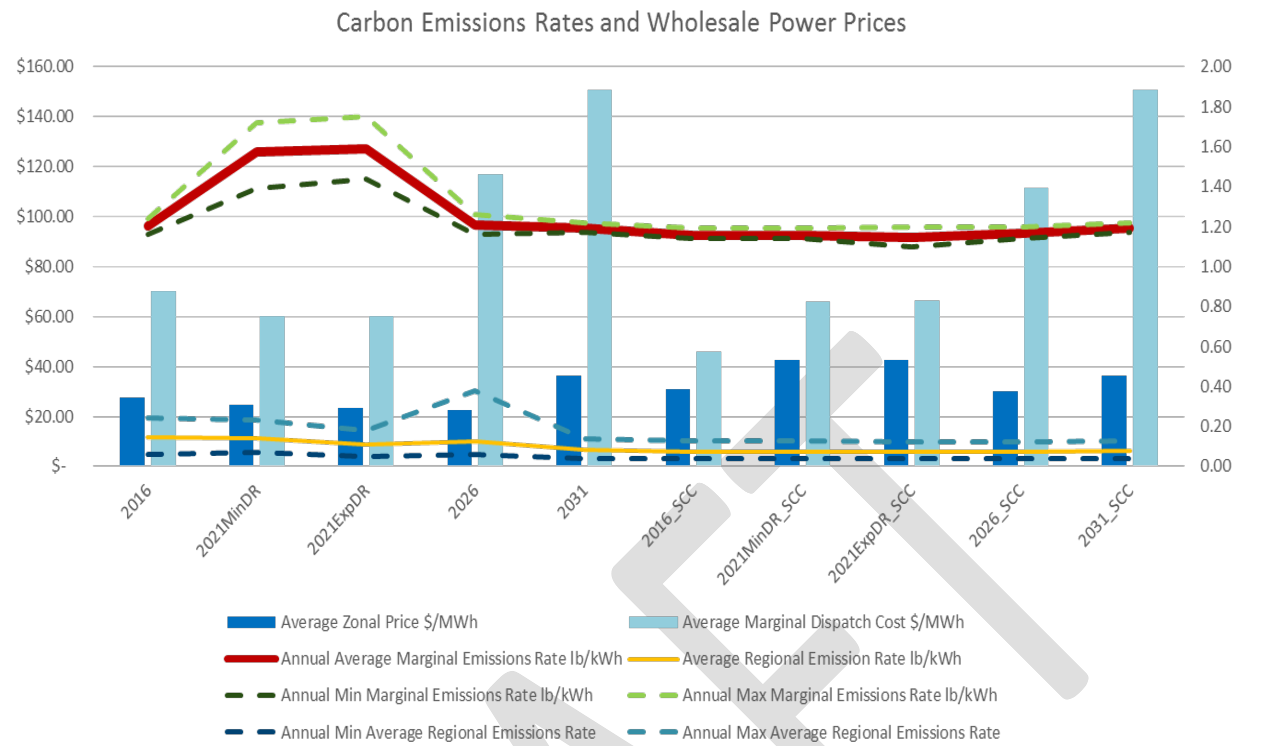

Figure 6: Annual Comparison of Wholesale Power Prices and CO_2 Emissions Rates

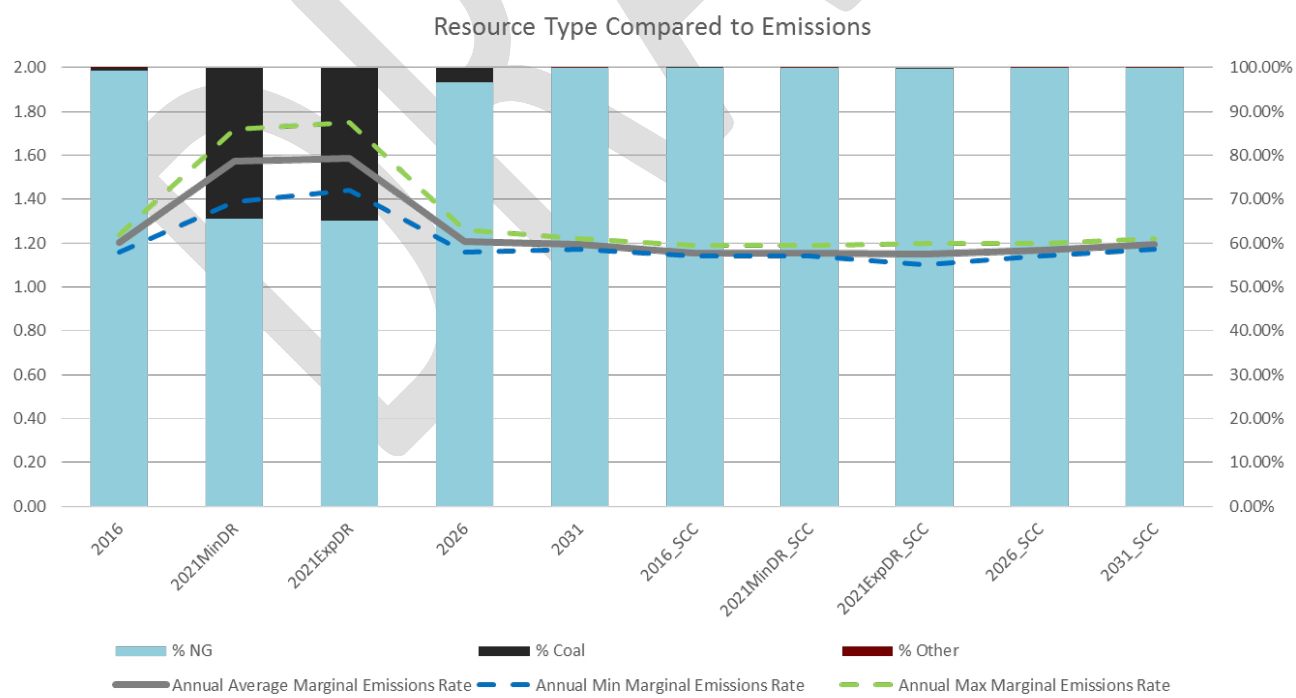

Figure 7: Percent of Resource Type on Margin and Corresponding Emissions Rates

CONCLUSION

This study shows an annual range for the marginal CO_2 emissions rate of 1.16 lbs. per kilowatt-hour and 1.75 lbs. per kilowatt-hour for the existing policy scenario. This a slightly higher rate than reported in the 2008 Council Study. This likely has a lot to do explicit accounting of between 1200 and 1800 megawatts of operating reserve in this study[7]. About half of the load following obligations of the region is served via gas peakers. These peakers are either marginal or just barely sub-marginal in many hours of the study. Further study might be useful to better understand the interaction between operating reserves, marginal units and unit commitment.

Returning to the results of the 2008 study in Figure 8, since the study was considering only average hydro, the subset of the resource stack from whence the marginal units came was significantly smaller than this study. In addition, by adding the different hydro conditions and the explicit reserve obligation, a significant number of peaker gas units were marginal, which accounts for the higher marginal carbon emissions rate and larger range in this study.

[7] AURORAxmp can now explicitly solve considering the economics of reserves and energy. Note that the concept of marginal unit may change over time due to a more sophisticated understanding of reserves and the advent of potential reserve markets.

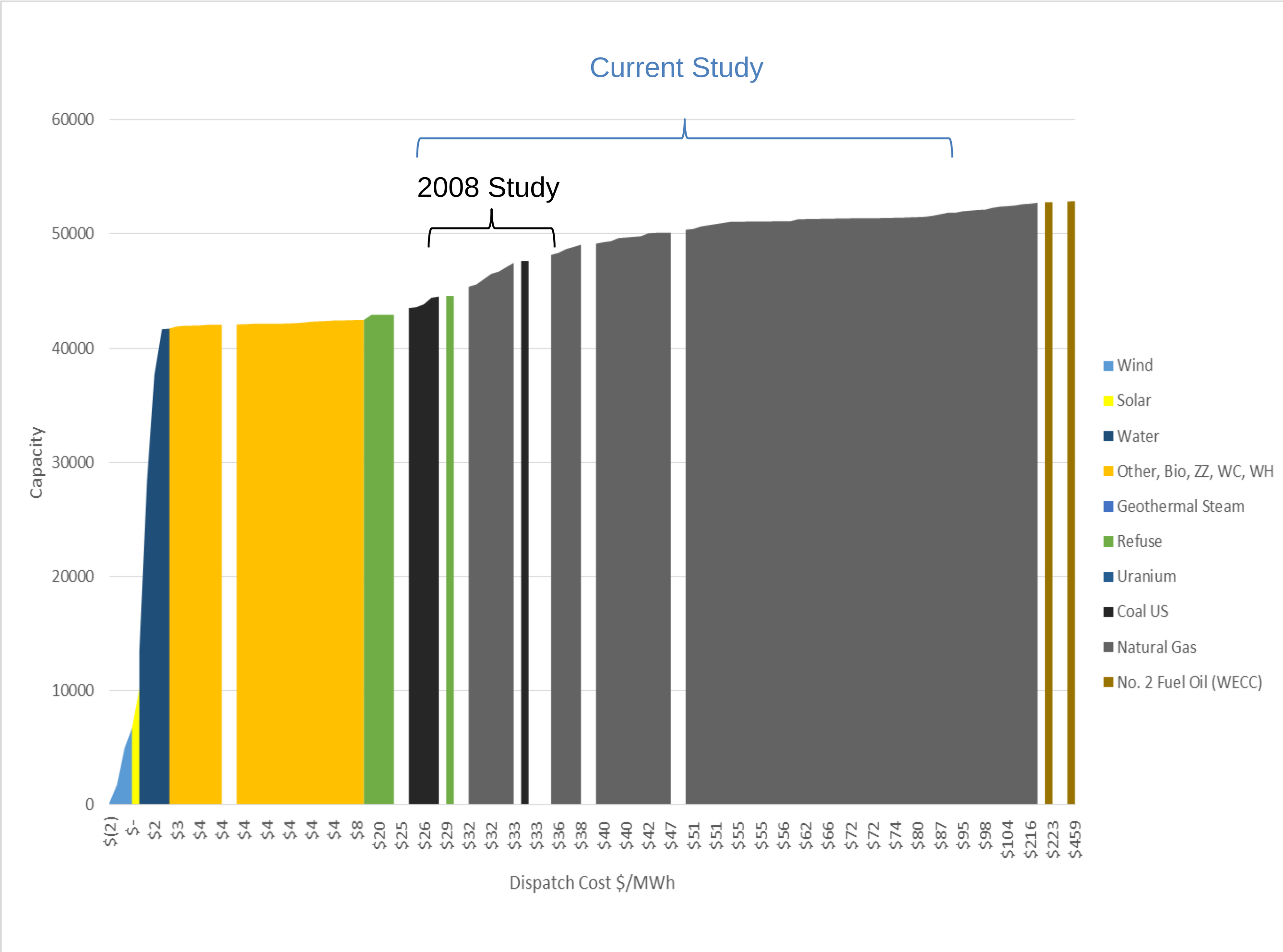

Figure 8: Parts of the Resource Stack: Study Comparison